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Tematska številka revije *Studia universitatis hereditati* 13 (2) je posvečena Osorju – mestecu na stičišču otokov Cresa in Lošinja v Kvarnerskem zalivu na Hrvaškem. Njegova prostorska lega že sama razkriva niz napetosti in dvojnosti: med dvema otokoma, med kopnim in morjem, med vidno in nevidno dediščino, med zgodovino in mitom. Takšna navidezna samoumevnost Osorjevega pomena je dolgo zakrivala kompleksnost procesov, ki so ga skozi dolga obdobja oblikovali kot dinamičen zgodovinski prostor stalnih okoljskih, družbenih in kulturnih preobrazb.

Dvostranski raziskovalni projekt Osor onkraj mita (N6-0292), ki ga financirata Javna agencija za znanstvenoraziskovalno in inovacijsko dejavnost Republike Slovenije (ARIS) ter Avstrijski znanstveni sklad (FWF) v okviru programa Weave, je nastal iz potrebe po kritičnem premisleku in poglobljenem razumevanju Osorja kot zgodovinskega prostora, kjer dolga kontinuiteta življenja presega zmožnosti ene same discipline ali linearne časovne perspektive. Projekt tako prerašča klasične disciplinarne okvire in se približuje transdisciplinarnemu pristopu, obravnavajoč Osor kot enoten kopenski in morski organizem, v katerem se naravni procesi, materialni ostanki, zgodovinski viri in simbolne krajine povezujejo v integriran analitični okvir. Več kot 3.000 let neprekinjene poselitve zahteva razumevanje prostora v relacijskem, večplastnem kontekstu, kjer se časovne ravni, družbeni procesi in okoljski pogoji medsebojno prepletajo.

The thematic issue of the journal *Studia universitatis hereditati* 13 (2) is dedicated to Osor, a town at the junction of the islands of Cres and Lošinj in the Kvarner Bay in Croatia. Its spatial location alone reveals a series of tensions and dualities: between two islands, between land and sea, between visible and invisible heritage, between history and myth. The apparent self-evidence of Osor's significance has long obscured the complexity of the processes that have shaped it as a dynamic historical space of constant environmental, social, and cultural transformations over long periods of time.

The bilateral research project Osor beyond the myth (N6-0292), funded by the Slovenian Research and Innovation Agency (ARIS) and the Austrian Science Fund (FWF) as part of the Weave program, arose from the need for critical reflection and in-depth understanding of Osor as a historical space where the long continuity of life exceeds the capabilities of a single discipline or linear temporal perspective. The project thus transcends classical disciplinary frameworks and adopts a transdisciplinary approach, treating Osor as a unified terrestrial and marine organism in which natural processes, material remains, historical sources, and symbolic landscapes are linked within an integrated analytical framework. More than 3,000 years of continuous settlement require an understanding of space in a relational, multi-layered context, where temporal levels, social processes, and environmental conditions are intertwined.

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Tematska številka, ki je pred vami, je rezultat tega pristopa. Združuje prispevke, ki se metodološko in vsebinsko naslanjajo na dolgoletno kontinuiteto raziskovanja tega izrazitega mesta. Razprave povezujejo geološke in arheološke raziskave, podvodno in krajinsko arheologijo, analize materialne kulture, bioarheološke podatke ter ponovno kritično ovrednotenje historiografskih in epigrafskih virov. Takšna raznolikost metod ni zgolj seštevek pristopov, temveč produktiven dialog, ki omogoča kontekstualno, primerjalno in sintezno interpretacijo, s čimer Osor obravnava kot zgodovinski palimpsest, kjer se naravni procesi, materialne sledi in človeške prakse prekrivajo ter preoblikujejo skozi čas.

Na tematsko izhodišče prostora in krajine se neposredno navezuje prispevek skupine avtorjev »Potopi prst v morje … Geoarheološki pogled na obalno okolje in pomorsko dostopnost obalnega mesta Osor v severnem Jadran« (Slobodan Miko, Nives Doneus, Dea Brunović, Ozren Hasan, Michael Doneus, Tim Kinnaird, Petra Hus, Filip Šegović, Nikolina Ilijanić, Martina Šparica Miko, Martin Fera), ki analizira geoarheološke značilnosti obalnega prostora, dolgoročne okoljske spremembe in dostopnost pristanišč ter izpostavlja vlogo naravnih procesov pri oblikovanju osorskega morskega prostora in kanala Kavanela skozi holocen.

Perspektivo krajine nadaljuje prispevek skupine avtorjev »Gor in dol po hribu: gradišča in suhozidne ograde na kvarnerskih otokih Cresu in Lošinju v podatkih daljinskega zaznavanja« (Nives Doneus, Martin Fera, Michael Doneus, Dalibor Branković, Vito Benvin), ki se osredotoča na arheološko zaznavanje vidnih in skritih struktur v kraškem agropastoralnem okolju ter opozarja na potencial daljinskega zaznavanja pri razumevanju prazgodovinskih krajin kot celostnih, večplastno organiziranih prostorov.

Prehod od krajine k človeku in njegovim družbenim praksam prinaša prispevek Martine Blečić Kavur »Vzpon železne dobe v Osorju na primeru reprezentativne materialne kulture«, ki se osredotoča na pogrebne kontekste in materialno kulturo začetka železne dobe, osvetlju-

The thematic issue before you is the result of this approach. It brings together contributions that are methodologically and substantively based on many years of continuous research into this remarkable place. The discussions connect geological and archaeological research, underwater and landscape archaeology, analyses of material culture, bioarchaeological data, and a critical re-evaluation of historiographical and epigraphic sources. Such diversity of methods is not merely a sum of approaches, but a productive dialogue that enables contextual, comparative, and synthetic interpretation, treating Osor as a historical palimpsest where natural processes, material traces, and human practices overlap and transform over time.

The thematic starting point of space and landscape is directly linked to the contribution of a group of authors, 'Dip Your Finger in the Sea … Geoarchaeological View on Coastal Setting and Maritime Accessibility of the Coastal Town of Osor, Northern Adriatic' (Slobodan Miko, Nives Doneus, Dea Brunović, Ozren Hasan, Michael Doneus, Tim Kinnaird, Petra Hus, Filip Šegović, Nikolina Ilijanić, Martina Šparica Miko, Martin Fera), which analyses the geoarchaeological characteristics of the coastal area, long-term environmental changes and the accessibility of ports, and highlights the role of natural processes in shaping the Osor marine area and the Kavanela channel throughout the Holocene.

The landscape perspective is continued by the contribution of a group of authors, 'Up and down the Hill: Hillforts and Dry Stonewall Enclosures on the Kvarner Islands of Cres and Lošinj in Remote Sensing Data' (Nives Doneus, Martin Fera, Michael Doneus, Dalibor Branković, Vito Benvin), which focuses on the archaeological perception of visible and hidden structures in the karst agropastoral environment and highlights the potential of remote sensing in understanding prehistoric landscapes as holistic, multi-layered spaces.

The transition from landscape to man and his social practices is brought about by Marti-

je oblikovanje simbolnih prostorov, družbenih identitet in mrež interakcij ter umešča Osor med ključna zgodnježeleznodobna središča vzhodnega Jadrana.

Rimsko obdobje Osorja je v tematski številki osvetljeno z več komplementarnih zornih kotov. Prispevek Irene Lazar »Izbrane steklene najdbe iz Apsorja (Osorja) – odraz bogastva in prestiža« obravnava steklene najdbe kot indikatorje potrošnje, tehnoloških inovacij in vključenosti Osorja v širše trgovske mreže rimskega sveta. Analiza raznolikih provenienc steklenih posod poudarja vlogo Osorja v procesih romanizacije severnega Jadrana.

Umetnostnozgodovinski pogled na rimski Osor ponuja prispevek Katarine Šmid, »Kariatida z Osorja (Apsorus): provincialna reinterpretacija klasičnega motiva«, ki se posveča interpretaciji marmorne kariatide kot primera provincialne apropriacije klasičnih ikonografskih in slogovnih vzorcev. Članek razpravlja o kronologiji, funkciji in simbolnem pomenu skulpture ter jo umešča v širši kontekst avgustejske tradicije in lokalnih interpretativnih praks.

Vprašanje urbanizacije in administrativne vloge Osorja v rimskem obdobju sistematično obravnava prispevek Nives Doneus in Andreje Sironić »Rimska urbanizacija severnojadranskega otoka Cresa: ponovna ocena arheoloških virov iz Osorja, s Cresa in iz Belega«. S kritično presojo epigrafskih, arhitekturnih in arheoloških virov ter z uporabo novih absolutnih datumov članek ponovno ovrednoti dolgoletne razprave ter potrdi Osor kot ključno urbano središče arhipelaga.

Prispevek Zrinke Ettinger Starčić in Igorja Miholjeka »Osorski akvatorij: pregled podvodnih arheoloških raziskav« povzema rezultate večdesetletnih raziskav v osorskem akvatoriju. S povezovanjem starejših in novejših raziskav članek poudarja pomen morskega prostora za razumevanje kontinuitete poselitve, pomorskih dejavnosti in vsakdanjega življenja v Osorju od antike do novega veka.

Tematsko številko zaokroža prispevek Zrinke Mileusnić »Naj Osor znova postane velik:

na Blečić Kavur's contribution 'The Emergence of the Iron Age in Osor through Representative Material Culture', which focuses on burial contexts and material culture at the beginning of the Iron Age, sheds light on the formation of symbolic spaces, social identities, and networks of interaction, and places Osor among the key early Iron Age centers of the eastern Adriatic.

The Roman period of Osor is illuminated from several complementary perspectives in this thematic issue. Irena Lazar's contribution, 'Selected Glass Finds from Apsorus (Osor) – Reflection of Wealth and Prestige', examines selected glass finds as indicators of consumption, technological innovation, and Osor's integration into the wider trade networks of the Roman world. The analysis of the diverse provenance of glass vessels emphasizes the role of Osor in the processes of Romanization of the northern Adriatic.

An art-historical view of Roman Osor is offered by Katarina Šmid's contribution 'The Caryatid from Osor (Apsorus). A Provincial Reinterpretation of a Classical Motif', which focuses on the interpretation of the marble caryatid as an example of provincial appropriation of classical iconographic and stylistic patterns. The article discusses the chronology, function, and symbolic meaning of the sculpture and places it in the broader context of the Augustan tradition and local interpretative practices.

The question of urbanisation and the administrative role of Osor in the Roman period is systematically addressed in the contribution by Nives Doneus and Andreja Sironić, 'The Roman Urbanisation of the Northern Adriatic Island of Cres: Re-Evaluation of Archaeological Sources from Osor, Cres and Beli'. Through a critical assessment of epigraphic, architectural, and archaeological sources and the use of new absolute dates, the article reevaluates long-standing debates and confirms Osor as a key urban center of the archipelago.

The contribution by Zrinka Ettinger Starčić and Igor Miholjek, 'The Osor Aquatorium: An Overview of Underwater Archaeological Re-

dostopna arheologija med otokom in oblakom«, ki obravnava razkorak med izjemno arheološko vrednostjo Osorja in njegovo omejeno sodobno dostopnostjo. S poudarkom na digitalnih dediščinskih orodjih, zlasti konceptu digitalnega dvojnika, članek dostopnost razume kot večdimenzionalen dediščinski izziv ter Osor predstavi kot pilotni primer trajnostnega in vključujočega upravljanja dediščine na majhnih ter oddaljenih najdiščih.

Zbrane razprave ne stremijo k dokončni sintezi zgodovinskih sprememb Osorja, temveč odpirajo številna nova raziskovalna vprašanja in perspektive. Zahvala gre vsem raziskovalcem, ki so prispevali k soustvarjanju te tematske številke in potrdili pomen kritičnega dialoga. Takšno razumevanje Osorja kot zgodovinskega palimpsesta, podprto s transdisciplinarnimi interpretacijami, presega dihotomijo med zgodovino in mitom ter Osor potrjuje kot trajno odprt prostor, kjer se preteklost, pokrajina, človek in domišljija srečujejo v kontinuiranem ustvarjanju pomena.

search', summarizes the results of decades of research in the Osor aquatorium. By linking older and more recent research, the article emphasizes the importance of the marine environment for understanding the continuity of settlement, maritime activities, and everyday life in Osor from antiquity to the modern era.

The thematic issue is rounded off by Zrinka Mileusnić's contribution 'Make Osor Great Again: Accessible Archaeology Between Island and Cloud', which addresses the gap between Osor's exceptional archaeological value and its limited contemporary accessibility. With an emphasis on digital heritage tools, particularly the concept of digital twins, the article understands accessibility as a multidimensional heritage challenge and presents Osor as a pilot case of sustainable and inclusive heritage management at small and remote sites.

The collected discussions do not aim to provide a definitive synthesis of the historical changes in Osor, but rather open up numerous new research questions and perspectives. Thanks go to all the researchers who contributed to the creation of this thematic issue and confirmed the importance of critical dialogue. This understanding of Osor as a historical palimpsest, supported by transdisciplinary interpretations, transcends the dichotomy between history and myth and confirms Osor as a permanently open space where the past, landscape, people, and imagination meet in the continuous creation of meaning.

Dip Your Finger in the Sea... Geoarchaeological View on Coastal Setting and Maritime Accessibility of the Coastal Town of Osor, Northern Adriatic[1]

Potopi prst v morje ... Geoarheološki pogled na obalno okolje in pomorsko dostopnost obalnega mesta Osor v severnem Jadranu

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Abstract

Erosion, sedimentation and rising sea levels can have a significant impact on archaeological research. They have altered the coastline and small-scale topography, both above and below the water's surface. Consequently, the spatial context of historical coastal cities and settlements is lost forever. Osor, an Iron Age and Roman town situated on the island of Cres in the northern Adriatic, exemplifies the methodological challenges posed by coastal archaeological sites.

In such cases, geoarchaeological studies can provide insights into the course of these changes, thus contributing to a better understanding of the past. In the case of Osor, the focus was on how its coastal location and maritime accessibility have changed since prehistoric times. In this context, the presumed locations of the city's ports and the formation of the Osor Channel were investigated. The study reports the results of these investigations and provides evidence that the Osor Channel evolved naturally and that some form of marine communication was feasible during the Bronze Age,rather than being created by means of human intervention during the Iron Age or Roman period. Using the OSL-PD method, Jaz Bay is ruled out as a Roman port, and the possible urban harbour in Bijar Bay is briefly examined.

Keywords: Osor, geoarchaeology, Osor Channel, ALS/ALB, OSL profiling and dating

1 Reseach data will be published in the repository of University of Primorska.

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Izvleček

Erozija, sedimentacija in dvig morske gladine lahko pomembno vplivajo na arheološke raziskave. Ti procesi so preoblikovali obalno linijo in drobno topografijo, tako nad kot pod morsko gladino. Posledično je prostorski kontekst zgodovinskih obalnih mest in naselbin za vedno izgubljen. Osor, železnodobno in rimsko mesto na otoku Cresu v severnem Jadranu, ponazarja metodološke izzive, s katerimi se sooča obalna arheologija.

V takšnih primerih geoarheološke raziskave omogočajo vpogled v potek teh sprememb in prispevajo k boljšemu razumevanju preteklosti. V primeru Osorja je bila pozornost usmerjena v spremembe njegove obalne lege in pomorske dostopnosti od prazgodovine dalje. V tem kontekstu so bile raziskane domnevne lokacije mestnih pristanišč ter nastanek Osorskega kanala. Prispevek predstavlja rezultate teh raziskav in dokazuje, da se je Osorski kanal nastal naravno in da je bila oblika pomorske komunikacije mogoča že v bronasti dobi, ne pa kot posledica človeškega posega v železni dobi ali rimskem obdobju. Z uporabo metode OSL-PD je zaliv Jaz izključen kot rimsko pristanišče, na kratko pa je obravnavano tudi morebitno urbano pristanišče v zalivu Bijar.

Ključne besede: Osor, geoarheologija, Osorski kanal, ALS/ALB, OSL-profiliranje in datiranje

Introduction

During the post-Last Glacial Maximum (LGM) period, the melting of ice sheets caused coastal areas around the world to be inundated, resulting in the formation of the present-day embayments, channels and indentations (Pikelj and Juračić 2013). These changes also shaped the eastern Adriatic, resulting in the formation of the Dalmatian coastline. Marine waters flooded many coastal basins (paleolakes) and paleo-river valleys (Sikora et al. 2014, Brunović et al. 2020; 2024; Hasan et al. 2020; Smrkulj et al. 2024). As the sea level stabilised during the Middle and Late Holocene, deltas or estuaries formed in river mouth regions (Sikora et al. 2014; Felja et al. 2015; Hasan et al. 2020; Smrkulj et al. 2024). These coastal landforms are largely influenced by the region's relative sea-level history, the amount of sediment supplied by their rivers and other coastal processes, such as tides and waves. Human activity in the Late Holocene also had a considerable role in shaping of the coastal environments (Benjamin et al. 2017).

The global rise in sea levels over the last millennium was a relatively slow process (Lambeck et al. 2014). However, rapid, episodic sea-level changes can result from vertical tectonic movements (e.g. Marriner et al. 2017; Benjamin et al. 2017). Measurements of present-day tectonic activity using continuous GPS networks indicate crustal lowering in the Kvarner Gulf area, consistent with tectonic subsidence of 0.63–0.89 mm/year as inferred from Roman fish tanks (Florido et al. 2011). Faivre et al. (2010) concluded that the sea level in the Istrian and Kvarner region was approx. 1.0–1.5 metres lower than it is today during the first and second centuries AD. Vacchi et al. (2016) reviewed the local sea-level rise in the western Mediterranean over the last 10,000 years.

The Croatian proverb 'Dip your finger in the sea and you are connected to the whole world' applies to all coastal and island settlements and to all historical periods. The gradual rise in sea levels therefore has a number of effects on archaeological research (e.g. Benjamin et al. 2017). Erosion, sedimentation and rising sea levels have changed the coastline and the small-scale topography above and below the water. Consequently, the spatial context of historical coastal cities and settlements is lost forever, which makes interpreting the remains of buildings or marine infrastructure challenging. Osor, an Iron Age and Roman town situated on the island of Cres in the northern Adriatic, is an example that illustrates the methodological challenges posed by coastal archaeological sites (fig. 1).

Figure 1: The Wider Location of the Studied Area Surrounding Osor, and the Position of the Marine Core OSOR 2 and the Terrestrial Cores JAZ 1 and 2 (project-owned data, orthophoto and ALS/ALB visualisation, elaborated by Martin Fera, 2025)

Osor is located on a circular land bridge between the islands of Cres and Lošinj, which are separated by the 10-metre-wide Osor Channel (fig. 2). The city wall from the Iron Age and Roman times originally enclosed an area with a diameter of around 300 metres (Doneus et al. 2017). The city is further bounded by the sea to the south, west and north, while a waterlogged karst depression limits the settlement area to the north-east and east. It is widely believed that the Osor Channel is man-made. The possibility that it originated in the Iron Age has frequently been mentioned (e.g. Stražičić 1980, 214). Based on excavation results, Faber (1982, 62) argued that the channel was in use already in Roman times as the city's sewage system was centred on

Figure 2: Osor Channel Between the Islands of Cres (on the Right) and Lošinj (on the Left) (elaborated by Martin Fera, 2023)

the Osor Channel. Recent rescue excavations in Osor (2022–2025) uncovered further evidence of a Roman sewer system which presumably led to the Osor Channel (Baričević 2023). However, no physical connection could be established between the sewer and the channel of Roman Osor.

Already Benndorf (1880) was of the opinion that the location of Osor was chosen for strategic reasons, namely, to control the narrow passage between Cres and Lošinj. This passage comprises the approx. 80-metre-long Osor Channel and the 13-kilometre-long Lošinj Channel to the south. Together, they provide an alternative sailing route between Cres and Lošinj, avoiding the more exposed western shores of both islands. Moreover, in a wider context, Osor can offer the first safe harbour on the route from Istria to Dalmatia after leaving the Istrian Peninsula. Controlling this passage would also allow some degree of control to the communications network from Central Europe to the Eastern Mediterranean. This would enable the inclusion of the city harbour into long-distance maritime routes. Its role as a maritime node since the Iron Age is evident from spectacular finds, including a wide variety of goods from the Pannonian Plain, the Italian peninsula, Macedonia and Greece (e.g. Blečić Kavur 2015; 2021).

Given Osor's strategic importance, it is surprising that hardly any details are known about its coastal setting in ancient times, especially considering Osor's potential as a maritime trading centre. These and a number of other research questions are therefore being addressed as part of the Osor beyond the myth project. Palaeogeographic and paleoenvironmental reconstructions of the submerged coastal areas are particularly important for understanding the archaeological record of Osor's coastal setting. In the context of ongoing investigations, geoarchaeological studies include coring, marine sur-

veys, stratigraphy, reconstruction of the depositional environment, radiocarbon dating, and evaluation of relative changes in sea level.

The Osor project builds on existing results through a series of new geological and archaeological investigations. The landscape-based approach introduced in 2012, which combined airborne laser scanning (ALS) and airborne laser bathymetry (ALB) surveys (Doneus et al. 2015), was crucial in this respect. Consequently, ALS data has provided a significant amount of information on human occupation in the densely overgrown areas of today. Furthermore, ALB has proven to be a valuable tool for rapidly scanning the topography of shallow underwater areas (Doneus et al. 2013).

The results of the geological 'LoLADRIA' project provided another important data set. The southeastern parts of the Lošinj Channel have been investigated at relatively low resolution within the frame of the LoLADRIA project with a focus on the evolution of submerged karst dolines (Brunović et al. 2019). These data provided a starting point for a new study focusing on the geomorphological changes of the coastal area in the shallow, NW part of the Lošinj Channel. The objective of this study was to reconstruct the timeline of Osor and its surrounding areas by combining archaeological findings with geochemical and geophysical data from the sedimentary records of Osor Bay. This multidisciplinary approach enabled the creation of a robust chronology spanning the past 5,000 years, highlighting the significance and temporal changes of various human activities during Osor's existence as a settlement, as well as the impact of rising sea levels.

Case Study Area

Cres belongs, together with the islands of Lošinj, Krk and Rab, to the most northern group of Croatian islands. They are situated in the Kvarner Bay, which is a semi-enclosed basin located between the Istria peninsula and the Vinodol-Velebit coast and encompasses numerous islands oriented parallel to the coastline (Dalmatian type coast) (e.g. Benac et al. 2008a). The Kvarner Bay is part of the northern Adriatic shelf, which is mostly shallow (up to 120 m) and low gradient (0.02°) continental shelf. Lithologically, the main units are Cretaceous carbonates deposited on the Adriatic/Dinaridic carbonate platform (Pamić et al. 1998; Vlahović et al. 2005), overlain by Paleogene carbonates and siliciclastic sediments. Accordingly, ~90% of the eastern Adriatic coast is formed by carbonates, whilst ~6% is formed in Eocene flysch (Pikelj and Juračić 2013). All units were strongly deformed during the Eocene Dinarid (Alpine) orogenesis and eventually uplifted during the latest mountain-building processes (Korbar 2009). Consequently, late orogenic exhumation and Quaternary climate led to the formation of a classical karst region – the Dinaric karst.

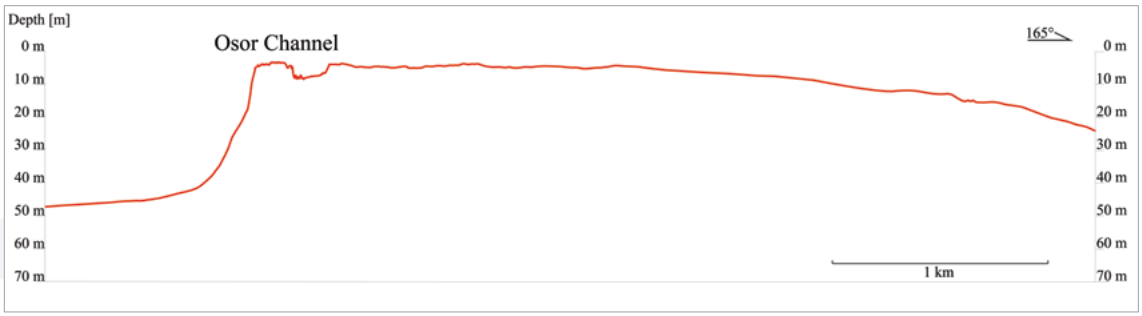

Figure 3: A Generalised Bathymetric Profile of the Osor Channel and the Surrounding Seas Shows the Distinct Sedimentary Environments of the Deep Osor Bay and the Shallow Lošinj Channel (elaborated by Croatian Geological Survey, 2025)

Osor lies at the northern most part of a karstified and tectonic depression (Lošinj Channel), with a sediment infill > 200 m above a Cretaceous basement (Brunović et al. 2024) (fig. 3). The modern-day bathymetry of the Lošinj Channel indicated the existence of several distinct areas within the basin. The shallow northernmost part of the channel extends from the shoreline to a depth of ~40 m with a slope of < 11° that separates this area from the central part of the Lošinj Channel with a maximum water depth of 74 m. The lateral decrease in depth along the basin margins occurs relatively abruptly (Brunović et al. 2024). Marine flooding of the Lošinj Channel occurred during the Holocene, with data from the channel indicating relative tectonic stability or weak subsidence during this period (Brunović et al. 2020; 2024).

Prevalent strata on the islands Lošinj and Cres are carbonate deposits of Cretaceous age (Korbar et al. 2001; Korbar and Husinec 2003, Fuček et al. 2014). The wider area is characterised by 18 lithostratigraphical units of various geological age (Cretaceous, Palaeogene, Quaternary). Several reverse faults were recognized on geological maps of islands Lošinj and Cres (Mamužić 1968; Magaš 1968, Fuček et al. 2014). Osor and its wider surroundings are located within two lithostratigraphic units, which are composed of alternations of dolomites and shallow marine limestones assigned to the Upper Albian-Lower Cenomanian boundary (Sis unit) and Cenomanian pelagic limestones (Belej unit) (Fuček et al. 2014). Town of Osor was built on the karstified limestones of the Belej lithostraigraphic unit (Fuček et al. 2014).

Methodology

Surveys

Airborne Laser Survey (ALS/ALB)

Airborne laser scanning (ALS, based on LiDAR technology) is an active remote sensing method in which the Earth's surface is measured directly from the air using infrared or green laser pulses. It allows large areas to be mapped relatively quickly using a dense point cloud. After the points are classified, products, primarily digital terrain models, can be derived. These show the terrain, and all traces of human activity preserved in relief. In the last decade, ALS has greatly improved large-scale archaeological research in the Mediterranean (e.g. Vinci et al. 2024). Of special interest is also the use of green laser scanners with small footprints for airborne laser bathymetry (ALB). They have the capability to penetrate clear water and consequently measure the underwater topography in high detail resulting in DSMs/DTMs with 0.5 m raster width combining the topography of underwater, terrestrial surfaces as well as the intertidal zone (Doneus et al. 2015; Doneus et al. 2013).

ALB data acquisition was conducted on 29th of March 2012 between 10:54 and 11:33 local time at low tide and at calm wind and water conditions. A RIEGL VQ-820-G was operated at an effective measurement rate of 200 kHz and a 60° scan angle. The flying height of 450 m resulted in footprints of 0.45 m diameter on the water surface. The flying strips had an overlap of 70%. Processing was done using the software RiPROCESS, OPALS (Mandlburger et al. 2009), and SCOP++ (Pfeifer et al. 2001) including strip adjustment to remove systematic errors between overlapping strips and robust interpolation with an eccentric and asymmetrical weight function to identify off-surface points (for a detailed description of the process, see Doneus et al. 2020). The average final ground point density is not uniform because it varies depending on the number of overlapping strips in an area, the density of vegetation, steepness of terrain or the presence of deeper water, which does not return echoes. Typical values are between 3 (dense maquis vegetation) and 20 points per square meter. The remaining point cloud was interpolated to a digital feature model (DFM – Pingel et al. 2015) with a raster width of 0.5 m using linear prediction (equivalent to ordinary Kriging, see Doneus et al. 2020) and imported into a GIS environment for further visualisation. The penetration depth, which depends on the type of la-

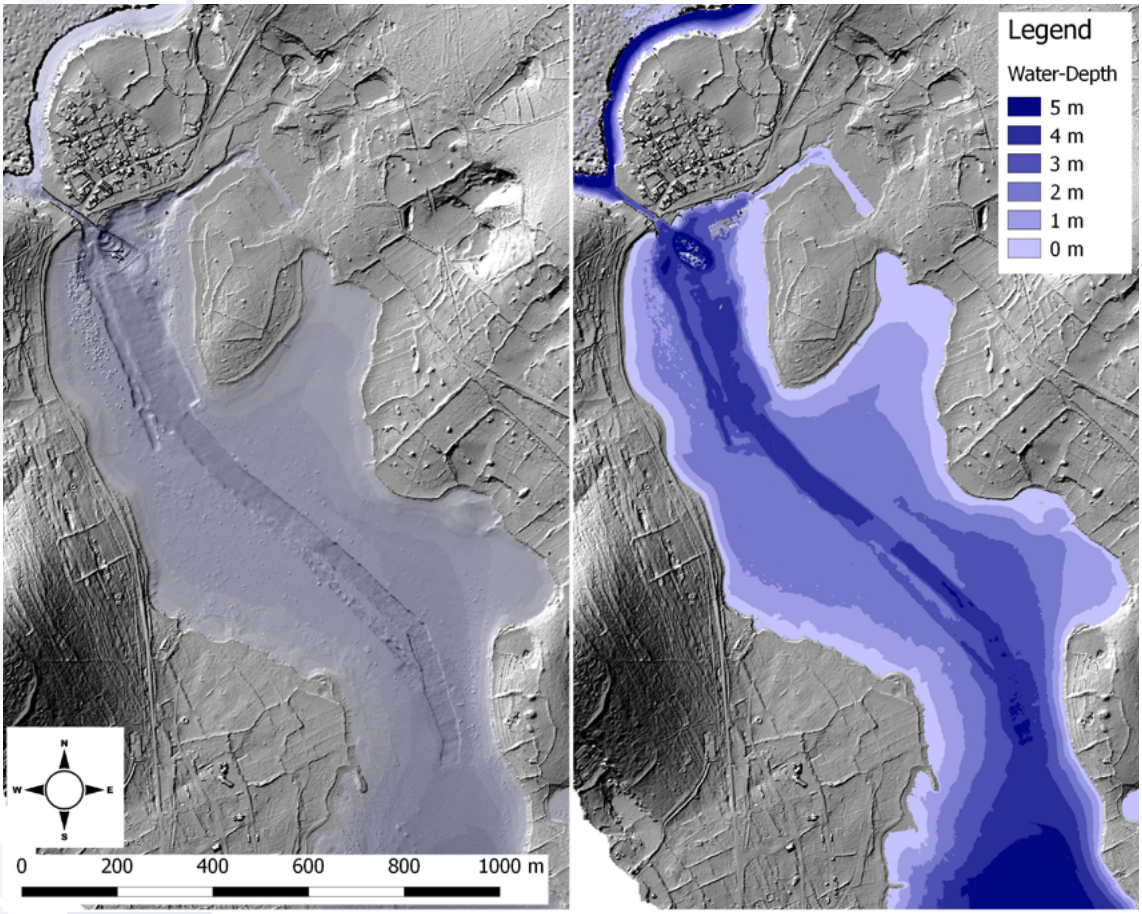

Figure 4: Digital Terrain Model (Combination of Slope and Hillshade) Derived from ALS/ALB Data (elaborated by Doneus et al. 2017). Left: Underwater areas depicted in transparent blue colour. Right: Map of water depth in the Osor and Lošinj Channel

ser scanner and especially on water clarity was up to 10 meters below the water surface. This is sufficient for interpreting coastal settlements and identifying potential submerged archaeological structures (fig. 4).

Knowledge about the detailed underwater relief is of crucial importance for research into Osor, as it provides the maritime context necessary for assessing its coastal setting. Although the ALB-derived digital model only shows the current underwater relief, it clearly illustrates the challenges posed by maritime traffic due to the extremely shallow water depths. Today, small boats can navigate the Lošinj Channel due to dredging, which was probably carried out by the Italian government in the 1920s or 1930s and is still visible in the ALB data (fig. 4).

Multibeam and Sub-Bottom Sonar Survey

Multibeam (MBES) bathymetry data were obtained during the survey of Osor Bay and Lošinj Channel using a WASSP S3 MBES (Furuno ENL, Auckland, New Zealand), which was side-mounted on the MB Dide Rak. The vessel was moving at a speed of approx. 3.5 knots. The MBES operational frequency was 160 kHz, producing 224 beams in a 120-degree angle swath. The vessel positional data were provided using a Hemisphere V103 GPS GNSS antenna with SBAS motion corrections. The pitch, roll and

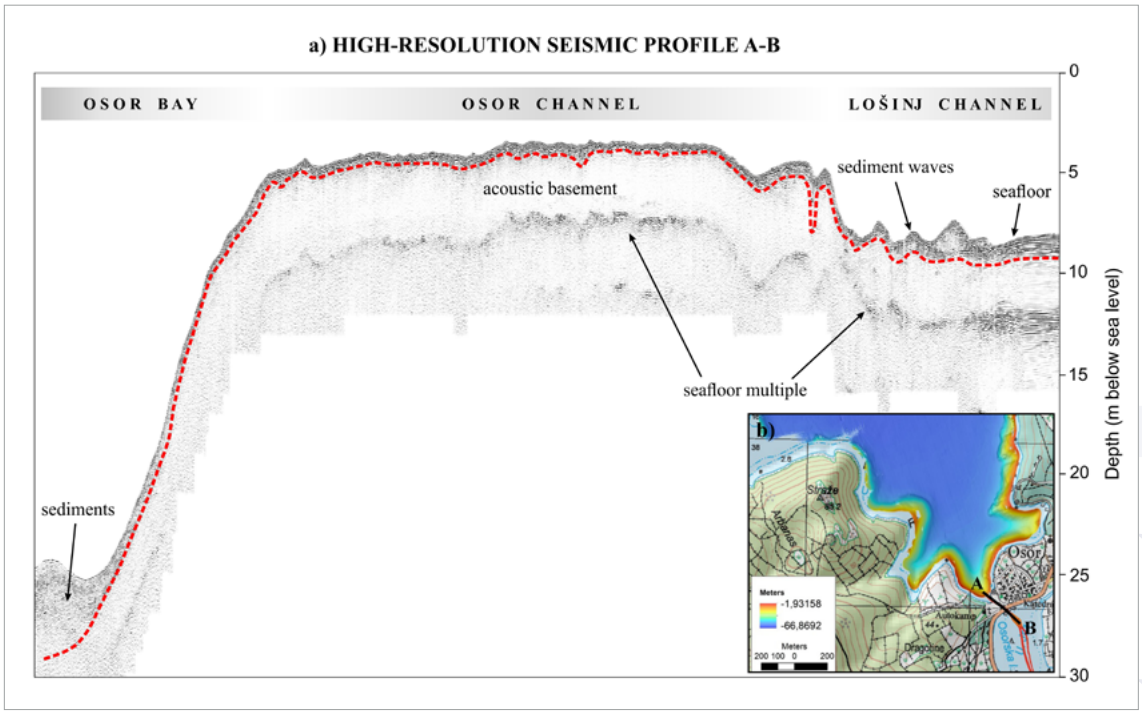

Figure 5: a) High-Resolution Seismic Profile Acquired in the Osor Channel Connecting Osor Bay and Lošinj Channel Using Sub-Bottom Profiler (SBP) (red line marks the transition to acoustic basement through which penetration of the acoustic signal is Limited); b) Location of the Recorded Profile (elaborated by Croatian Geological Survey, 2025)

heave motions were corrected with a WASSP Sensorbox (Furuno ENL, Auckland, New Zealand) inertial measuring unit (IMU). WASSP CDX software (version 3.9, Furuno ENL, Auckland, New Zealand) was used for the device control as well as for recording the MBES data, whereas the postprocessing of the data was performed with BeamworX Autoclean v2020.2 software. The MBES bathymetry and data were processed in BeamworX as a 0.5 m pixel ASCII grid for further analysis in ArcGIS with a Spatial Analyst extension (version 10.2.1, ESRI Inc., Redlands, CA, USA). First, we created a 0.5 m-cell-size digital terrain model (DTM) using an MBES bathymetry grid.

High-resolution seismic data were acquired with a parametric sub-bottom profiler Innomar SES-2000 light. The sub-bottom profiler operates at two low frequencies (6 and 10 kHz) to obtain the high frequency. The device was mounted on a small vessel moving at a speed of 3.5 knots. Seismic profiles were transformed from Innomar native format into SEGY format via SESConvert and integrated into GeoSuite Allworks software (v2021 R2) for processing and interpretation.

Surveys of the Osor Channel

To this end, a number of surveys have been carried out to determine the channel's location and depth in past times. Unfortunately, all efforts to make new observations, particularly with regard to the Osor Channel in Roman times, were unsuccessful.

Large-scale geophysical surveys were conducted in Osor in both 2023 and 2024, and the results are currently being prepared for publication. The two sides of the channel were surveyed in order to identify any old channel banks (fig. 6a). However, this was unsuccessful as the chan-

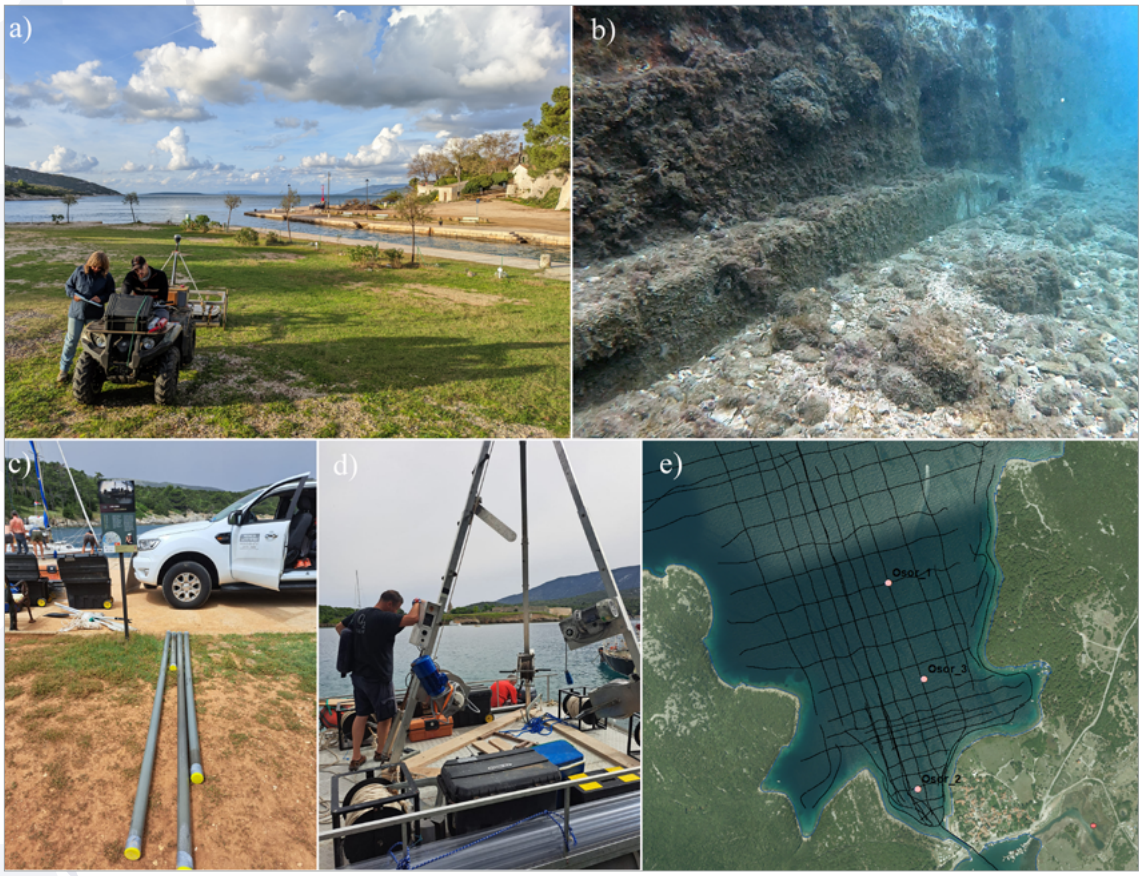

Figure 6: Surveys of the Osor Channel: a) Geophysical survey of both sides of the channel: b) Underwater survey; c)–d) Cores were retrieved using a Niederreiter Piston Corer (UWITEC, Austria) and platform in Osor Bay; e) Coring locations for the three cores (a) elaborated by Martin Fera, 2025; b) elaborated by Croatian Conservation Institute, 2023; c–e) elaborated by Croatian Geological Survey, 2024)

nel had been rebuilt many times over the centuries, and the area between the city wall and the channel had been completely filled in during the last 100 years.

Osor has been at the centre of infrastructural modernisation since the summer of 2022. Construction work was accompanied by large-scale rescue excavations, including underwater excavations at the south end of the Osor Channel. This opportunity was used to conduct a video documentation of the channel ground (fig. 6b), which clearly shows the modern mortared sides of the channel.

The high-resolution seismic profile acquired in the Osor Channel using a sub-bottom profiler (SBP) shows several metres of sediment on either side of the channel (see fig. 3, fig. 5, and figs. 6c–e). However, the seismic profile through the Osor Channel shows no penetration into the subsurface due to the tightly packed layer of sediment and stones of different sizes at the bottom of the channel. This was also confirmed during the underwater excavation (fig. 6b).

Geoarchaeological Research

Coring and Lithological Description

Three sediment cores (OSOR 1–3) were recovered from Osor Bay (fig. 1) at depths between 30 and 40 m below the present sea level. The cores were retrieved using a Niederreiter piston corer

Figure 7: Coring in Jaz Bay With an Eijkelkamp Percussion Drilling Set – Hammer Cobra TT, Cores JAZ 1 and 2 (elaborated by Nives Doneus, 2024)

(UWITEC, Austria) placed on the coring platform with a tripod. Cores were cut in the laboratory of the Croatian Geological Survey into 1.4 m-long segments and split longitudinally. One half of each core was archived, while the other half's surface was smoothed and photographed.

Two cores were also taken from the Jaz Bay tidal inlet, (JAZ 1 and 2, fig. 1 and fig. 7) with an Eijkelkamp percussion drilling set – hammer Cobra TT. The water depth during coring varied from 0 to 20 cm depending on the tidal oscillations. The core JAZ 2 was dated using the optically stimulated luminescence profiling and dating (OSL-PD) method.

The cores were subsampled for particle size analysis (PSA); total carbon (TC), total organic carbon (TOC), total inorganic carbon (TIC) and total nitrogen (TN) concentration measurements. The results for cores OSOR 2 and JAZ 2 are discussed in this paper.

Grain-size Distribution

A Shimadzu (Kyoto, Japan) SALD-2300 laser diffraction particle size analyser was used to analyse the particle size distribution in sediment core samples. The instrument measures particle diameters between 0.017 and 2500 μm. First, the organic matter was removed from 0.1–0.2 g of the sample with hydrogen peroxide (H_2O_2) (Allen and Thornley 2004). Since most of the samples in this karst environment are predominantly composed of carbonate material, they were not pretreated with hydrochloric acid (HCl). Fossil shells were manually removed from the samples. Sodium hexametaphosphate ($(NaPO_3)6$) was added to allow dispersion and prevent particle aggregation. We used the GRADISTAT 8 software (Blott and Pye 2001) for statistical data processing. For the sediment classification, the Folk and Ward (1957) method was applied.

Organic Carbon and Nitrogen

To measure organic carbon (TOC), total nitrogen (TN), total inorganic/carbonate carbon (TIC), and insoluble residuum (IR), a Thermo Fisher Scientific (Waltham, MA, USA) Flash 2000 NC Analyzer was used. Two grams of bulk sediment were freeze-dried and ground. The samples were packed into tin capsules for the analysis of total carbon (TC) and TN. To measure TOC, the carbonate component was removed by HCl. The TIC was calculated as the difference between TC and TOC. The C/N ratio was calculated by dividing the TOC and TN. Insol-

uble residuum was calculated as the mass difference between the sample treated with HCl and the untreated mass of sediment. The amount of insoluble matter in the sediment was used as a robust measure of the noncarbonate mineral matter in the sediment samples. The analytical precision of this method was controlled by repeated measurements of the individual samples and the standard reference material, Soil NC Reference Material (%N = 0.21 and %C = 2.29).

Chronology ^{14}C AMS (Osor Bay)

The chronology of the core OSOR 2 drilled in vicinity of the town of Osor at a depth of 30 m was investigated through the AMS radiocarbon dating method (^{14}C). Dating was performed on three well-preserved mollusc shells. AMS radiocarbon dating (^{14}C) was performed at Beta Analytics Laboratory (Miami). Due to the small number of dates, an age–depth model was not reconstructed. Ages are reported as calibrated calendar years before the present (cal yr BP; present =1950 CE).

Optically Stimulated Luminescence Profiling and Dating (OSL-PD)

The OSL-PD method applied here employs a two-stage approach to the luminescence investigation (Kinnaird et al. 2025; Srivastava et al. 2023): in the first stage, the luminescence properties of the bulk sediment in the core was evaluated using portable OSL equipment (Munyikwa et al. 2020). A relative luminescence stratigraphy was constructed and used to identify positions down-core for dating purposes. This was used to identify the most promising positions in the core

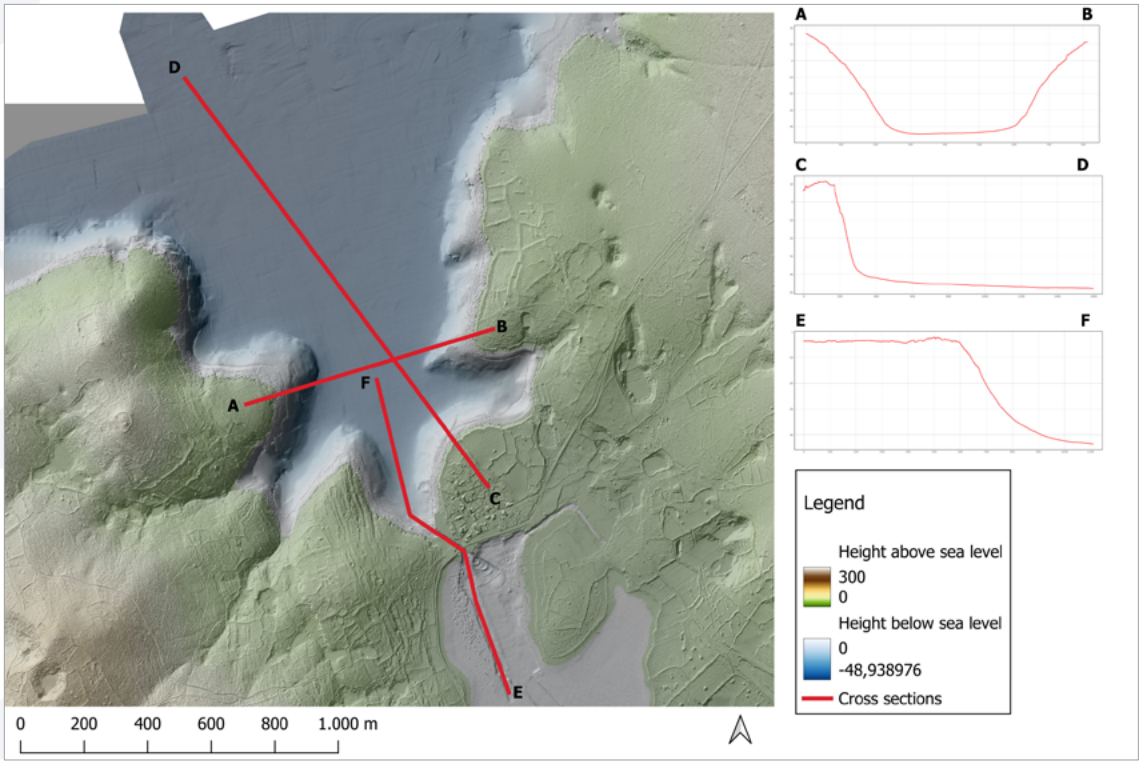

Figure 8: Combination of Terrain Models From Bathymetric LiDAR and Multibeam Sonar Data Delivered a Seamless Terrain Model of the Topography Onshore and Offshore, Allowing the Construction of Bathymetric Profiles, Which Clearly Show the Underwater Topography and the Steep Drop From Osor Towards Istria (elaborated by Michael Doneus, 2024)

for dating purposes, deemed to be either side of the terrestrial–marine boundary.

Its adaptability makes the OSL-PD method a highly valuable tool for dating discrete landscape features and terrestrial and marine sediments recovered in cores. It provides sediment chronologies that can be used to interpret the environmental archives contained in soils. The method was recently successfully tested in the karst landscape surrounding Osor, yielding a date range of 200 ± 100 AD for the municipal land survey of the Roman town (Doneus et al. 2024).

Two cores were taken in March 2024 from the Jaz Bay (fig. 1). While the HGI core (JAZ 2) is still undergoing sediment analysis, the second core (JAZ 1) has been used for OSL-PD dating, focusing on coastal changes outside Osor.

Results

Osor Bay

The Morphology of Osor Bay and the Lošinj Channel

For the needs of the current project, the ALB was fused with the multibeam sonar (MBES) data. Analysis of the ALB- and multibeam-based DTMs revealed a mean height difference of 5 cm in the small overlapping areas. Nevertheless, this was sufficient to integrate the point clouds using the previously mentioned OPALS software, creating a continuous relief extending from the shoreline to a depth of around 50 m below the sea level.

The bathymetric data of Osor Bay shows steep slopes down to 40 m, followed by a relatively flat seafloor that gradually deepens to 50 m below sea level (fig. 8, profile C-D). This flat morphology extends to the Istrian peninsula with very small variation between 49 and 52 m depth. The morphology to the south of Osor, which marks the northernmost part of Lošinj Channel, is a karstified extension of Cres and Lošinj islands with submerged dolines filled with up to 10 m of marine and terrestrial sediments (Brunović et al. 2019; 2020; 2024). The sea floor is a gently inclined shallow shelf disturbed by dredging to allow boat transport. Osor Bay and Lošinj Channel are connected with a 2.6 m deep modern channel.

Lithology and Sediment Texture

The sediment sequence of OSOR 2 core exhibits coarsening-upwards trend, with a transition from coarse silt to sand at a depth of 185 cm, with a slight fining upwards trend at depths between 10 and 30 cm. Additionally, the colour of the sediments changes abruptly from grey to dark brown (185 cm) and to a brownish grey at a depth of 70 cm. The sedimentary succession of OSOR 2 is composed of three sections based on colour variability (from the base of the core to 185 cm, the dark brown section from 185 cm to 70 cm and a grey-light brown section from 70 to the core top). On a macroscopic scale, it is not possible to recognize a distinct layering, the core is homogenous in its structure.

The sediments can be predominantly classified as silty sand and sandy silt (Folk and Ward 1957) (table 1). The mean particle sizes range from fine silt to coarse sand (4.5–575.6 mm). The distribution of the particle size in the core sediments is shown in table 1. and figure 8.

Table 1: Basic Statistical Parameters for Grain Size Distribution in the Sedimentary Succession of Core OSOR 2 (elaborated by Croatian Geological Survey, 2025)

	Number of samples	Mean	Minimum	Maximum	Std.Dev.
% CLAY	36	2.18	0.09	10.63	2.30
% SILT	36	47.08	14.04	89.35	15.56
% SAND	36	50.74	0.02	85.62	17.71

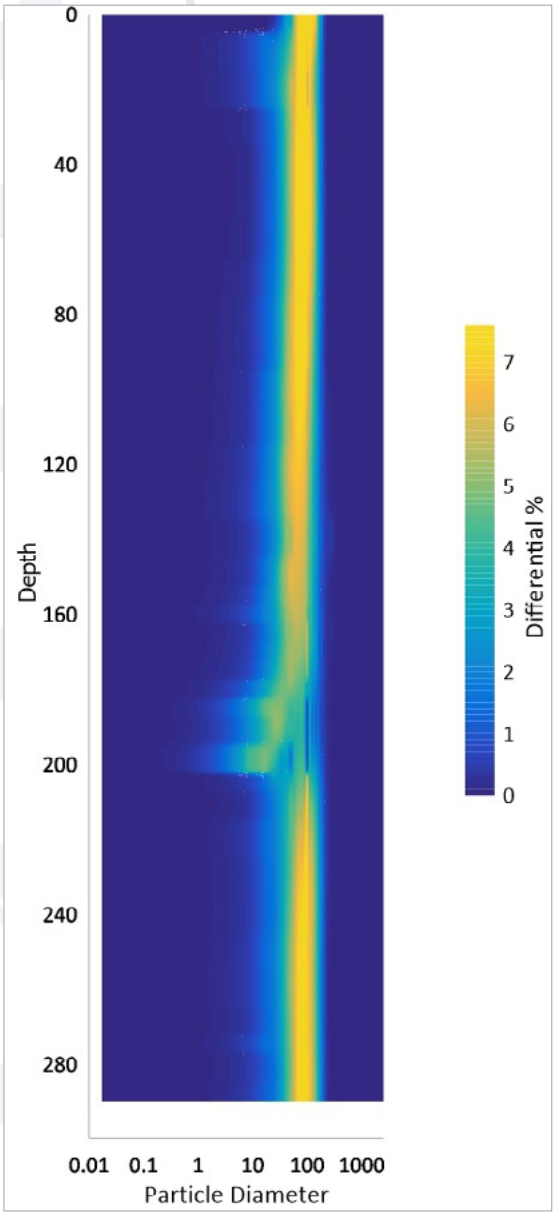

Figure 9: Particle Size Distribution (particle diameter in mm) in Core OSOR 2 (elaborated by Croatian Geological Survey, 2025)

The sand content varies from 0.03 to 85.62% (average 50.74%) and the silt from 14.4 to 89.35% (average 47.08%), while the clay content ranges from 0.09 to 10.63% (average 2.18%) (table 1). In the silt fraction, coarse silts prevail. The gravel fraction is comprised of marine molluscs and lithogenic limestone grains, which were removed before the PSA by laser diffraction. The most abrupt change in the grain-size distribution is noted in the sediments at depths of 185 and 200 cm (fig. 9). This sedimentary succession is characterized by silt and clay fractions and the absence of sand. The oldest sediments below this abrupt change show a uniform grain size distribution with approx. 60% of sand and 40% silt. These silty sands indicate high hydrodynamics as the core is located close to shore (shoreface) while the finer fractions were transported to the more proximal environments (to be proved in cores OSOR 1 and OSOR 3).

Organic Carbon and Nitrogen

Organic carbon content (TOC) is generally below 1.0% and TN below 0.1% in the basal section of the sedimentary succession up to the depth of 190 cm. This section is characterised by the uniform low content of TOC and TN and was delineated as geochemical Zone 1 (table 2, fig. 10). Zone two shows a gradual increase in (TOC) peaking at the 70 cm to 6.7% (Zone 3) and then abruptly dropping below 3% (zone 3) to the top of the core. Nitrogen concentrations peaked in the interval between 155 and 100 cm, and do not follow the distribution of TOC, although the general distribution shows the highest TN in Zone 2 and a small increase in concentrations in the topmost samples of zone 3. The difference in the distribution of N in Zone 2 enabled us to divide Zone 2 into Subzone 21 (from 190 to 120 cm) and Subzone 22 (from 120 to 190 cm).

Table 2: Mean Values of TOC and TN Concentrations, Inorganic Carbon (TIC) and Insoluble Residuum (%) and Subdivision of Core OSOR 2 into Geochemical Zones (elaborated by Croatian Geological Survey, 2025)

	Mean			
Zone	N%	insoluble res.%	TOC%	INC%
1	0.06	32.73	0.28	8.39
2	0.20	32.80	2.87	8.11
3	0.14	30.13	3.04	8.22
Average	0.14	32.17	2.02	8.23

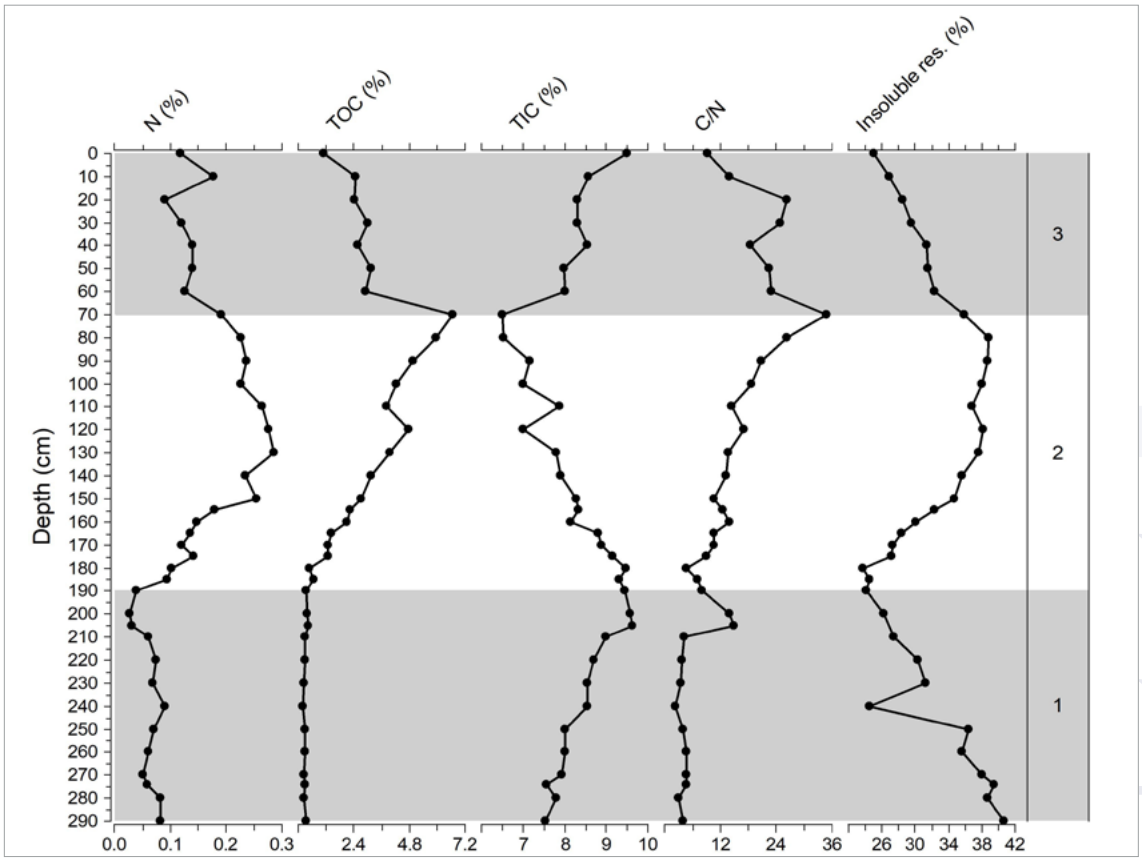

Figure 10: Geochemical Zones (1–3) and Subzones (21 and 22) of Core OSOR 2 and Depth Profiles of TOC and TN Concentrations, Inorganic Carbon (TIC) and C/N Weight Ratios and Insoluble Residuum (%) (elaborated by Croatian Geological Survey, 2025)

Insoluble residuum follows the distribution of TIC (carbonate) with an upward decline in concentrations from the base of Zone 3 to the boundary of Zone 2. In Zone 2 the carbonate (TIC) content continues to decrease with the increase of organic carbon accumulation. The amount of TIC rises abruptly in Zone 3 and continues to rise to the top of the core, while the insoluble residuum follows an opposite trend in this zone (fig. 9). Smear slide inspection of the sediments showed that the organic carbon concentrations are related to the contents of silt-sized charcoal in the sediment. These higher TOC values are associated with increased charcoal deposition possibly sourced from human activities in Osor. The molar ratio C/N < 10 suggests that organic carbon (TOC) in Zone 1 is marine organic matter, while sediments in Zones 2 and 3 contain a mixed source of both marine and terrestrial organic carbon. The sedimentary succession at a depth of 70 cm shows a ratio of 24, which indicates that most of the organic carbon is of terrestrial origin. Zone 3 shows a gradual shift upwards towards the marine organic matter source C/N < 10 (fig. 10)

Core Chronology

Radiocarbon measurements on three mollusc shells revealed that sediment core OSOR 2 spans at least 5.5 calibrated ka BP (table 1). ^{14}C analysis of the mollusc shells from the part of the core where a distinct change in colour (from grey to

Table 3: Radiocarbon Ages for the Osor Bay (core OSOR 2) Sedimentary Succession (elaborated by Croatian Geological Survey, 2025)

Depth (cm)	Lab.code	Material	Conventional age (BP)	$d^{13}C$	Calibrated Age (BP)	Calibrated Age (BC)	Prob. (%)
70–71	Beta-703103	Marine Shell	2210 +/- 30 BP	+1.1 o/oo	1680–1366 cal BP	270–584 cal AD	95.4
122–124	Beta-703104	Marine Shell	2740 +/- 30 BP	+1.6 o/oo	2318–1996 cal BP	369–47 cal BC	95.4
195–197	Beta-703105	Marine Shell	5410 +/- 30 BP	+2.5 o/oo	5621–5313 cal BP	3672–3364 cal BC	95.4

brown) and grain size occurred (195–197 cm) yielded ages of approx. between 5621–5313 cal BP (3672–3364 cal BC). The brown sedimentary succession gradually transitions to grey at the depth of 70 cm which was dated at 1680–366 cal BP (270–584 cal AD). Based on the chronology, the sedimentation rate is estimated to be 0.3 mm/year.

Jaz Bay

Lithology and Sediment Texture

The description of the core, taken for OSL-PD, includes the following units: unit 1, between 3.5–8 cm depth in core, a greyish brown silt with some clay and sand; unit 2, 8–21 cm depth, a light brownish grey coarse sand with some silt and clay; unit 3, 21–37 cm depth, a light grey very coarse sand, almost entirely shell and shell fragments; unit 4, 37–75 cm depth, dark grey clayey silt; unit 5, 78.5–82.5 cm depth, dark grey clayely silt, with shell fragments; unit 6, 82.5–102 cm depth, light yellowish brown middle- to coarse-grained sand, almost entirely shells and shell fragments; unit 7, 102–151 cm depth, dark grey clayey silt, some iron straining, shells and shell fragments; unit 8, 151–164 cm depth, light olive brown clayey silt; unit 9, 164–251 cm depth light olive brown clayey silt, iron oxide particles and nodules, possible greying, very few shells; unit 10, 235.5–284 cm depth, yellowish bown clayey silt, lots of iron oxide and manganese particles and nodules, some calcium carbonate nodules, very few shell fragments; and unit 11, 284–304 cm depth, light yellowish brown clayey silt, lots of iron oxide and manganese particles and nodules, some calcium carbonate nodules, very few shell fragments. Units 1 to 7 are marine; units 8 to 11, terrestrial.

Table 4: Effective Environmental Dose Rates Following Water Correction (elaborated by Kinnaird et al. 2025). [a]Effective Beta dose rate combining water content corrections with inverse grain size attenuation factors obtained by Mejdahl (1979) for K, U, and Th; [b]weighted combination of estimates from ICP-MS, ICP-OES and uDOSE

Lab code	Position	Water content / %	Cosmic dose / mGy a^{-1}	Effective dose rates, wet / mGy a-1		
				Beta[a,b]	Gamma[b]	Total[b]
1529_5	Core 2/5 OSL1	24 ± 7	0.15 ± 0.02	0.89 ± 0.07	0.76 ± 0.05	1.80 ± 0.09
1530_4	Core 3/4 OSL2	24 ± 7	0.15 ± 0.01	1.71 ± 0.13	1.49 ± 0.11	3.36 ± 0.17

Table 5: Burial Doses, Total Effective Environmental Dose Rates and Corresponding Depositional Ages for CERSA1529 and 1530 (elaborated by Kinnaird et al. 2025)

Lab code	Paleodose / Gy	Aliquots / n	Dose rate / mGy a-1	Age /ka	Calender years
1529_5	3.35 ± 0.04	24 (24)	1.80 ± 0.09	1.86 ± 0.10	AD 170 ± 100
1530_4	23.08 ± 0.17	20 (20)	3.35 ± 0.17	6.89 ± 0.44	-

Core JAZ 2 Chronology

Through units 1 to 7, 23 to 140 cm depth in core, signal intensities progess with depth from 8.73 x 10^3 to 1.53 x 10^4 counts, spiking to 4.88 x 10^4 counts at the base of unit 7, at 142 cm depth in core (table 4). OSL intensities are more heterogenous through unit 8, fluctuating around 7.90–7.41 x 10^4 counts. Across the unit 8–9 boundary, there is a step-change in intensities from < 7.4 x 10^4 to > 1.5 x105 counts, coinciding with the transition from marine to terrestrial sediments. The aim was to date marine transgression, so samples were taken either side of this bounday at 142 cm depth in core (base of marine sequence) and 171 cm depth (top of terrestrial sequence). Table 4 and table 5 list the palaeodoses and environmental dose rates for these samples, together with the corresponding depositional ages. Further details are provided in Appendix.

Discussion

Geological Perspective on Osor Bay and Lošinj Channel

The analysis of coastal marine sedimentary records can be used to assess the impact of human intervention over time on the surrounding environments. High-resolution land and bathymetric maps were produced by merging airborne laser scanning (ALS) and high-resolution multibeam sonar data, providing a holistic interpretation of the geomorphology of the town of Osor and its surroundings.

The core OSOR 2 was cored at a depth of 30 m on a gentle shoreface slope close to town of Osor but also close to the artificial channel, that connects Osor Bay with Lošinj Channel. The total sediment succession at the coring location is approx. 3.5 m thick, and the core penetrated 2.9 m of the sediment succession. The location of the core was chosen to allow access to an undisturbed sedimentary succession, which could record events related to the Osor site, but also to detect possible changes in the sediment records related to the construction of the channel and the influx and transport of sediments from Lošinj Channel. The opening of the channel should have had an influence on the sedimentary record in Osor Bay. The shallow south side of the channel, where the modern harbour is located, is unsuitable for the detection of environmental and human-induced changes because of dredging activities over time and the lack of stratification of cultural layers.

Osor Bay Prior to 5.5 cal ky BP (3500 cal BC)

In marine environments, organic carbon (TOC) and C/N are generally considered proxies for the relative contribution of terrestrial vs. marine organic matter and shifts in primary productivity. Ratio of total organic carbon and total nitrogen (C/N) has been largely used discriminate different origins related with sediment organic matter. Generally, the value of C/N ratio for organic matter of marine derived organic matter is less than 7, organic matter of soil has a ratio 8–20, and the ratio that exceeds 20 is characteristic for organic matter of terrigenous origin (Meyers, 1994). A low C/N ratio (<8) is found in the marine sediments in the core OSOR 2 in the sediment succession from the base of the core to a depth of 200 cm, three centimetres below the dated interval at 195–197 cm (5.6–5.3 ky cal BP / 3672–3364 cal BC). The sediment geochemistry and lithology (changes in grain size) indicate stable consistent hydrodynamics and the increase of carbonate content and decrease of insoluble residuum suggesting a low contribution of terrigenous soil input/washout from the land surface. The concentration of organic carbon and the C/N ratio correspond to those in the Holocene marine sediments of Lošinj Channel (TOC < 1.5% and C/N < 10) (Brunović et al. 2020).

The base of the core did not reach the carbonate bedrock and according to the relative sea level data from Brunović et al. (2020) for Lošinj Channel the shoreline, 30 m below the present sea level was attained at approx. 9.0 cal ky BP. This would indicate that the sediments

at the base of the core were deposited in relatively shallow water in proximity to the coast. Although human occupation on island of Cres is continuous since the Mesolithic (Forenbaher and Miracle 2005), the geochemical and sedimentary record of core OSOR 2 does not imply any detectable environmental change that could be linked with human activities.

Insoluble residuum follows the distribution of TIC (carbonate) with an upward decline in concentrations from the base of Zone 3 to the boundary of Zone 2, this could be due to sea-level rise and deepening of the bay and reduced availability of soil mineral matter from the shores (the shore becomes more distal from the marine accumulation site).

Environmental Change in the Osor Bay Marine Sediments from Aprox. 5.5 cal ka BP (3500 BC) to 1.5 cal BP (270–584 AD)

The sediment core record in the interval between 200–185 cm shows an abrupt change in sediment texture with a significant decrease in grain size to dominantly silt and a shift from primary marine production of organic matter (C/N <10) to an erosion/terrestrial input (C/N >12) (fig. 10 and fig. 11). The sudden influx of terrestrial organic matter input and change of sediment texture could be an indication of land clearance at a magnitude that it has been recorded in the sediment succession. The overall increasing and changing shifts of TOC concentrations and C/N ratios towards the top of core OSOR 2 are

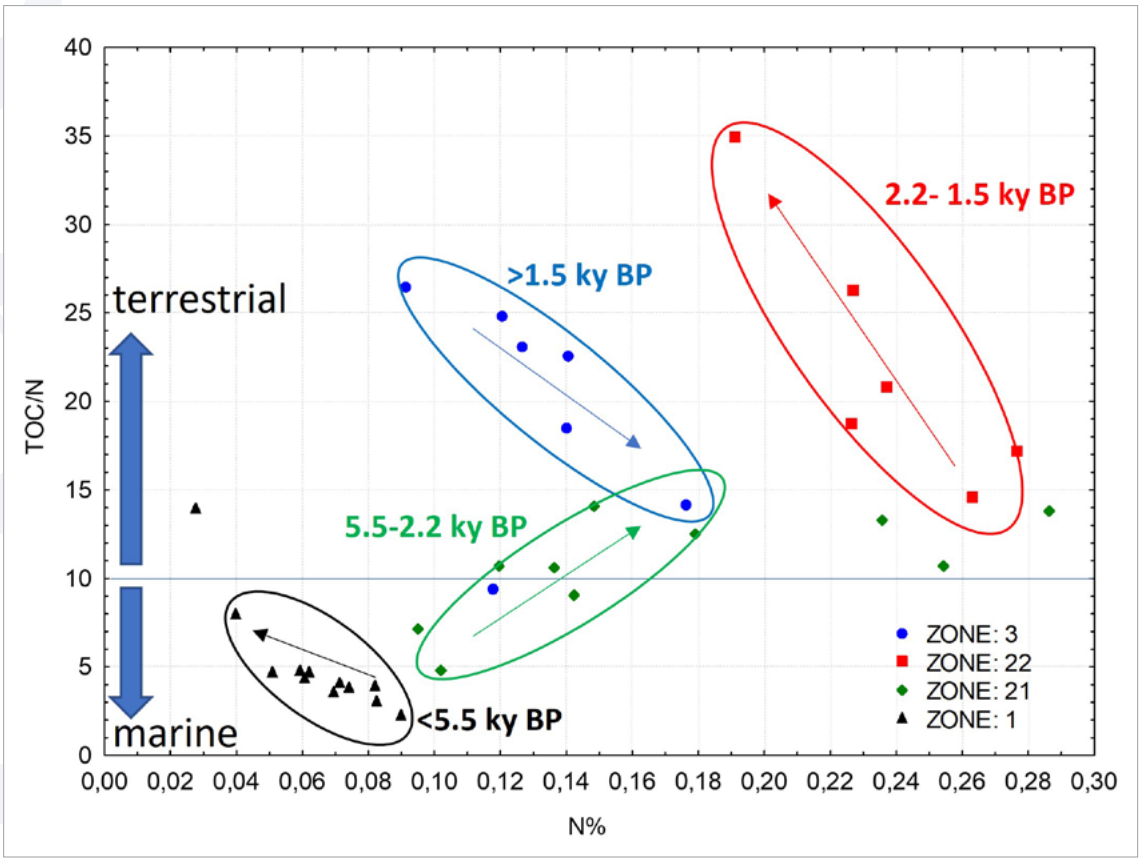

Figure 11: Changes in the Sources of Organic Carbon in the OSOR 2 Core Through Time (elaborated by Croatian Geological Survey, 2025). The arrows within the ellipse indicate general trends of change in organic Carbon and Nitrogen.

best visualised on the diagram in figure 9. The distribution is complex and differs within Zone 2. Subzone 21 exhibits a trend of gradual increase of terrestrial organic carbon into the bay from 5.5 cal ka BP to 2.2 cal ka BP (3500–200 cal BC). The positive correlation between TOC and N is typical of natural environments and terrestrial plants. In Zone 22 (from 2.2 cal ka BP to 1.5 cal ka BP) this correlation does not exist: organic carbon is increasing, and nitrogen is decreasing. This is probably a consequence of the large input of charcoal from human activities in Osor. Carbon and nitrogen associations suggest that anthropogenic activity in the Osor area was gradually intensifying through Subzone 21 and then intensified in amount and peaked after 2.2 cal ka BP. During this period (Subzone 22), the altered C/N signature is possibly a consequence of more advanced technologies of firing used compared to the period of Subzone 21 or a change in source of organic matter.

Environmental Changes in Osor Bay Marine Sediments After 270–584 cal AD

The geochemical record of Osor Bay marine sediments dramatically and abruptly changes after 70 cm (1.7–1.4 cal ky BP/270–584 cal AD), the source of organic carbon is different than in Subzone 22, with a trend indicating a gradual demise of dominantly terrestrial derived organic carbon towards primary marine production of organic matter (fig. 11). The change in CN ratio indicates a progressive change in sources of organic matter and increased deposition of inorganic carbon (carbonates; fig. 10). The lower C/N ratio is most probably a consequence of several factors including decreased vegetation cover and loss of woodland surrounding Osor. The depositional environment through this period was less influenced by anthropogenic activities although higher nutrient loading can be detected in the youngest sediments indicated by an increase in nitrogen content (fig. 10 and fig. 11). Resolving the complex system of anthropogenic influence of Osor in the future would be through an evaluation of the contribution from each source and to pinpoint human signatures on nutrient inputs to the coastal area. However, although multiple organic matter sources have been identified in natural coastal sediments, widely used mixing models have only two end-members, terrestrial and marine sediments (Ogrinc et al. 2005). Future research should focus on d15N content of the core OSOR 2 which could be used to track agricultural and urban point sources. In summary, terrigenous material has lower values for d15N and d13C than estuarine and marine organic matter (Ogrinc et al. 2005). The geochemical change through the OSOR 2 core reflect a complex history of environmental change generally caused by the anthropogenic influence of Osor.

Osor Channel and the Town's Maritime Accessibility from Archaeological Perspective

The dating of the opening of the Osor Channel for maritime use is an important issue in all archaeological disputes concerning the maritime accessibility of Osor. As mentioned in the introduction, it is widely accepted that the channel was created by humans during the Iron Age or Roman period. However, the results obtained during the last two years of research contradict this archaeology-based interpretation.

Sediment core OSOR 2 has the potential to serve as a possible sedimentary record for determining the timing of the opening of the Osor Channel. However, geochemical and sedimentological analyses have not yet succeeded in establishing this event's precise timing. Material transported by currents from the Lošinj Channel shelf area could carry specific fossils (ostracods and foraminifera) or plant remains from the marshes on the southern side of the channel. Once the correct proxy has been identified, it may be possible to precisely date the opening of the Osor Channel.

Current state of research and the gradual increase in terrestrial organic carbon and the initial initial ^{14}C data imply that an increased contribution, potentially due to human activities such as deforestation, may have begun as early as 5621–5313 cal BP (3672–3364 cal BC). It is also plausi-

ble that material from the Lošinj Channel shelf (wetland) was transported by currents towards Osor Bay. This suggests that marine communication through what is now the Osor Channel was feasible during the Bronze Age. More precise dating and geochemical proxies will enable the establishment of marine communication through the strait to be determined more accurately. Given the steady rise in the sea level, which was reconstructed at around −3 m for ca. 4600 BC (Brunović et al. 2019), this seems like a natural process. Current results cannot determine whether human intervention played a role in the formation of the Osor Channel. The sedimentary record (Subzone 21) partly coincides with the period of hillforts of the eastern Adriatic Bronze Age approx. 2200–900 cal BC (Blečić Kavur 2014), a topic covered in another article in this volume.

A further increase in terrestrial organic carbon in marine sediments, peaking between Iron Age and Late Antiquity (forthcoming publication, see also chapter 5.1.2), can be attributed to the growth of the city, agriculture activities as well as to the maintenance of the Osor Channel. From Roman times onwards, when quay walls and other maritime infrastructure elements were introduced to the northern Adriatic region (e.g. Koncani Uhač 2023), it is likely that the Osor Channel was also maintained accordingly. If a bridge was built between Cres and Lošinj, the waterway's banks had to be reinforced. However, no evidence of a Roman bridge has been found to date. A permanently installed bridge may have functioned similarly to those in the Middle Ages and the early modern period. Illustrated sources, like the one from 1500–1530 (http://www.arhiv.hr/portals/0/_DigitalniArhiv/GrafikeHrvatskihMjesta/Osor1.htm), show a permanent bridge with a narrow central section that could be raised to allow (sailing) boats to pass underneath.

It also seems impossible to determine the exact location of the channel in Roman times, as its position in relation to the Roman city wall is no longer traceable. The topography between the present-day Osor Channel and the city wall has changed significantly due to extensive filling in modern times. This is particularly evident when the first cadastral map of Osor from 1821 (Sušanj Protić 2015, fig. 11) is compared with the present-day one. Furthermore, strong currents require the channel to be repaired repeatedly, resulting in the loss of older traces. For example, during the construction works in 1894, the remains of an older 'riva antica' were found (Stato di Trieste n. d.). The southern end of the Osor Channel is particularly susceptible to erosion and requires regular repairs, as evidenced by the wooden pillars (dating in progress) detected during underwater excavations.

As the exact location of the Roman channel remains unknown, its depth cannot be determined. Today, the depth of the Osor Channel allows ships with a draft of up to 1.5 metres to pass through (Peljar 2012, 61). Hrvatski hidrografski institut (2003) states that the channel is 2.4 metres deep. However, ALB and underwater measurements show that the depth is actually around 3–3.5 m (the difference in measurements of up to 60 cm can be attributed to the ebb and flow of the tide). The shallow depth of the Osor Channel has obstructed shipping at least since the Late Middle Ages. According to Sušanj Protić (2015), the city's layout was reduced in size during the Venetian period. This appears to be partly linked to restrictions on maritime traffic, as the Osor Channel was too shallow for large Venetian ships due to natural sedimentation processes and a lack of maintenance (Klen 1957, 316–7). Ultimately, the Venetian government resolved this issue by relocating the island's administrative centre from Osor to Cres.

It is reasonable to assume that the bottom of the channel is limited by bedrock. This is evident from the seismic measurements taken prior to construction and underwater work commencing at the southern end of the channel (MOHO d.o.o. 2023). These measurements indicate that the bedrock lies 4–6 metres below the current sea level. The size of Roman ships has been reconstructed based on shipwrecks. For the

Roman Portus, it is estimated that ships with a draught of between 1.9 and 7 metres could frequent the harbour (Boetto 2010, table 1). Given the shallow bottom of the Osor Channel and the lower sea level of 1–1.5 m in Roman times (Vacchi et al. 2016; Marriner et al. 2014), large-draught vessels may have been restricted on the maritime route next to Osor. Stražičić (1995, 78–9) suggested that using the tidal current or the higher sea level during high tide, or unloading ships before crossing the canal, could have partially mitigated this issue. However, as it is not possible to ascertain whether shipping was feasible down to the bedrock in Roman times, any further calculations regarding maritime traffic are purely speculative.

The steep decline in terrestrial organic carbon in marine sediments after the Roman times makes a monocausal explanation unlikely. Such an approach would be inaccurate as both natural and human influences may have played a part in the history of the Osor Channel. From a historical perspective, there are numerous human-induced processes that could have contributed to lower sedimentation rates in the Osor Bay. Following two centuries of prosperity and continuous peace, Late Antiquity was marked by a series of radical changes. For example, large-scale agricultural production in southern Istria is believed to have ceased from Late Antiquity period onwards, with communities then cultivating a variety of products for personal consumption or sale within the region (Levak 2013). How the upheavals of the Late Antique period affected small regions like the Kvarner Islands in terms of land use and trade, and more specifically the maintenance of the Osor Channel, remains unclear.

Another possibility is the natural or deliberate closure of the Osor Channel to shipping. This would also explain the lower rate of sediment accumulation resulting from the short- or long-term destruction of the channel. In addition, a climatic influence cannot be ruled out and should be considered when analysing the data. The so-called Late Antique Little Ice Age (LALIA from 536 to 660 AD) is considered to have been a period of turmoil in Europe, which caused human migrations and pandemics. The exact causes of the climate cooling are still not determined exactly but a possible cause could be a series of volcanic eruptions between 536 and 547 AD (Büntgen et al. 2016). The activities that were producing the specific organic carbon footprint in Osor during the period of Subzone 22 abruptly stopped after the Late Antique Little Ice Age. In order to confirm this, higher resolution dating in the transition from Subzone 22 to Zone 3 is needed.

Harbours and Anchoring in Jaz and Bijar Bay

Like many other parts of the Croatian coast, the Kvarner Bay is a challenging sailing passage on the route between Italy and Greece. The near-coastal Velebit massif is the area from which the notorious cold northeasterly wind (Croat. bura) originates, with gusts reaching almost 200 km/h. The 16th century insult 'damn the Kvarner having let you pass' (Kozličić 2006, 84) vividly describes the region. The region is also influenced by microtidal conditions with an average amplitude of ~30 cm but the influence of atmospheric pressure patterns together with predominant winds enables the sea level to rise to 1.6 m above mean sea level (Benac et al. 2008b). This illustrates the need for safe ports along the route between Istria and Dalmatia, and Osor was potentially one of them.

Most theories actually argued for two harbours, one in the north located in the bay of Bijar (Faber 1980; Ettinger Starčić 2012) and one south of the city walls in the bay of Jaz, now infilled (Faber 1980; Stražičić 1995). While the theory of a harbour in Bijar seems to be supported by underwater finds, no archaeological proof, like firm evidence of port facilities, could be found for the Jaz Bay to date. A geophysical survey of the coastal area between the Jaz Bay and the Lošinj Channel in spring 2024 discovered building remains (forthcoming publication), but it is currently unclear whether these

are of Roman origin. However, the OSL-PD investigation provided some insight on marine transgression in Jaz Bay: the base of unit 7 (dark grey clayey silt, some iron straining, shells and shell fragments) marks inundation by the sea, as these are the first marine sediments preserved in core. These sit unconformably on unit 8, representing an erosional contact. Unit 8 is light olive-brown clayey silt, deposited in a terrestrial setting. By AD 170 ± 100, the marine transgression had reached the low-lying land to the south and east of Osor town. Unit 7's base is erosional and cut into terrestrial sediments with a depositional age of 6.89 ± 0.44 ka, meaning that only the last transgression can be dated.

In essence, the Jaz area was part of the coastal land up to AD 170 ± 100 when rising sea levels led to saltwater advancing inland. For this reason, today's Jaz Bay can be ruled out as the site of a (Roman) city harbour. After Roman times, as far as can be currently determined, the rise of the sea level, the natural sedimentation and erosion processes, as well as the anthropogenic interventions play the most important role in further changes of the Jaz Bay (Stražičić 1995, 74–88). Regarding the potential medieval saltworks in the Jaz area, the drill core sample offers limited insight as it was likely taken from outside the presumed location of the saltworks. The oldest historical sources date back to the time of the Venetian Republic. Despite the inaccuracies inherent in historical maps, they depict the Jaz area as a bay (e.g. Pavić 2000, fig. 6). The wetland contributed to the spread of malaria, leading to its gradual filling in by the 19th century. Stražičić (1995, fig. 3) suggests this occurred after 1821. Subsequently, dredged sediments from the Lošinj Channel were deposited there, and the creation of the L-shaped channel designed for fish farming through the middle of Jaz Bay was the last modern intervention (fig. 1 and fig. 4). No archaeological finds have been discovered in the L-shaped channel in the bay (Ettinger Starčić 2012).

The suggestion by Faber (1980, fig. 4) that a section of the ancient harbour in Bijar was located in the waterlogged karst depression to the north-east and east of the city (fig. 4) can also be dismissed. The related question of whether Osor was ever located on an artificial island created by channels between Bijar and Jaz (Faber 1980, fig. 4) also does not seem to be correct, as the results of previous small-scale geoarchaeological research seem to contradict that theory (Draganits et al. 2019). Firstly, the waterlogged karst depression contains fresh water, not salt water, and is therefore unaffected by changes in sea level. Secondly, the study showed that the depression was almost completely filled with sediment around 6000 years ago, and consequently cannot represent the harbour of Roman Osor, particularly given the lower sea levels of the past. An additional core was taken in the karst depression in spring 2024 to corroborate the 2019 results, and sediment analysis is ongoing.

Additionally, the Roman walls and (late) Roman graves were located at the edge of the depression in the area proposed by Faber (1980, fig. 4) as the northern harbour. The graves and building structures were excavated in the 1990s (Majnarić Pandžić 1992, 270) next to the abandoned monastery from 15th century (Lemessi 1980, 148). While the archaeological excavation has never been published and the material been lost, some excavation documents remain in the Osor Archaeological Collection. Thus, in addition to precise geological dating, the archaeological evidence indicates that Osor was not naturally an island and that there was at no time a seawater link between Bijar and Jaz Bay.

Therefore, the only possible location for a city harbour is Bijar Bay. Evidence of anchoring has been found in the form of scattered ceramic material at the bottom of the bay (Ettinger-Starčić 2012). Although no remains of the harbour structure have been found, the Roman walls mentioned above in the area of the monastery may be the first indication of harbour infrastructure outside the city walls. The 12 mooring bollards that stretch along Bijar Bay and are carved from limestone have already been mapped

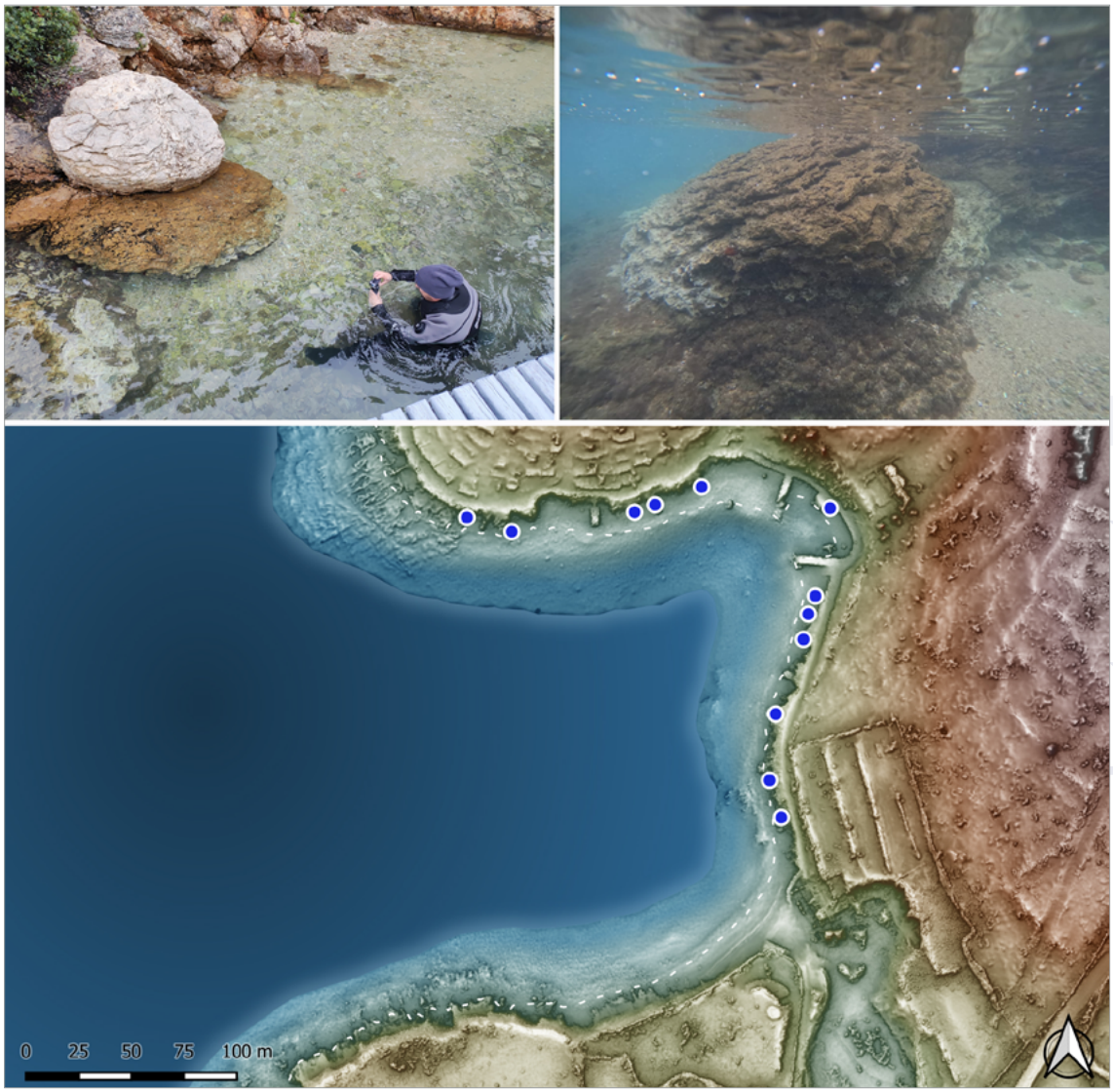

Figure 12: Documentation of the Boat Moorings in the Bijar Bay and a Comparison of Their Location and a Hypothetical Roman Sea Level (–1.5 m) Marked by a White Dashed Line (elaborated by Martin Fera, 2025, and Neno Starčić, 2024)

by Faber (1980). They were re-recorded and documented during fieldwork (fig. 12). A comparison of the location of the bollards and the Roman sea level shows that they were indeed suitable for securing ships in Roman times. However, this does not necessarily mean that they were carved at that time, as local diver Neno Starčić sums up: 'People have been using the same places to anchor for centuries.'

Conclusion

The Osor beyond the myth project emerged from the necessity to reinterpret the history of this regional trading port. Although the main focus is archaeology, it has become clear in recent decades that archaeology alone is incapable of capturing all the factors that have shaped the place's history. Given its location as a coastal city,

it was particularly important to investigate the natural (topographic) conditions alongside other archaeological questions.

Although the precise timing remains uncertain in the moment, the gradual increase in terrestrial organic carbon and the initial ^{14}C data suggest that an increased contribution, possibly resulting from human activities such as deforestation, may have started as early as 5621–5313 cal BP (3672–3364 cal BC). It is also plausible that material from the Lošinj Channel wetland was transported by currents towards Osor Bay. This suggests that marine communication through present-day Osor Channel was feasible during the Bronze Age. More precise dating and geochemical proxies will allow marine communication through the strait to be determined more accurately. There is a gradual increase in the amount of terrestrial organic carbon entering the bay from 5.5 to 2.2 cal ka BP (3500–200 BC), resulting from the significant input of charcoal caused by human activities in Osor. After 1.7 - 1.4 cal ka BP (270– 584 cal AD), the source of the organic carbon changes dramatically and abruptly. This indicates a gradual decline in the dominance of terrestrial-derived organic carbon in favour of primary marine production of organic matter.

The results presented in this paper provide deeper insights into questions concerning the coastal area and the maritime accessibility of Osor. While some of the new findings were expected, others came as a complete surprise. The results should encourage further archaeological investigations in the region and demonstrate the value of taking an interdisciplinary approach.

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Summary

Sea-level variability during the Late Pleistocene and Holocene profoundly shaped the Mediterranean region. During the Last Glacial Maximum, sea level was approx. 120–134 metres below its present position. The subsequent post-glacial rise led to the inundation of extensive coastal areas formerly inhabited by human populations, resulting in the submergence of numerous coastal archaeological sites that remain concealed beneath the sea surface today. Consequently, submerged landscapes have been the focus of many geoarchaeological investigations. However, until recently, the eastern Adriatic coast has remained relatively understudied in this respect.

This study focuses on the submerged landscapes surrounding Osor, an Iron Age and Roman town located on the northern Adriatic island of Cres. The Osor beyond the myth project arose from the need to reinterpret the history of this regional trading port. Given Osor's coastal setting, particular emphasis was placed on reconstructing natural (topographic) conditions alongside broader archaeological questions. The results presented here offer new insights into Holocene relative sea-level rise, past environmental changes, and the coastal configuration and maritime accessibility of Osor.

A central research question concerns the construction of the Osor Channel, traditionally believed to have been excavated for maritime purposes. This narrow waterway, separating the islands of Lošinj and Cres, played a key role in maritime trade routes linking Istria and Dalmatia. Geoarchaeological investigations in the Osor area included geophysical surveys, sediment coring, and detailed geochemical and grain-size analyses of sediment cores. Radiocarbon and optically stimulated luminescence (OSL) dating were employed to establish a chronological framework. Integrated airborne laser scanning and multibeam sonar bathymetric data provided detailed insights into the submerged geomorphology of the area surrounding Osor.

A 2.9 m-thick sediment succession (core OSOR 2), recovered from Osor Bay, enabled the reconstruction of Holocene palaeoenvironmental changes driven by both natural processes in the wider region and anthropogenic activities in Osor. The OSOR 2 core did not yield unequivocal evidence of human intervention associated with the construction of the channel that would resolve the debate concerning its archaeological construction date. Instead, preliminary results suggest that the connection between Osor Bay and the Lošinj Channel via the Osor Channel was likely established during the Bronze Age, implying that natural processes played a substantial role in its formation. Furthermore, the results indicate that the Jaz area remained part of the coastal land until AD 170 ± 100, when rising sea levels caused marine waters to advance inland. On this basis, present-day Jaz Bay can be excluded as a (Roman) city harbour.

Povzetek

Spremembe morske gladine v poznem pleistocenu in holocenu so pomembno oblikovale sredozemski prostor. Med zadnjim ledenim maksimumom je bila morska gladina približno 120–134 metrov nižja kot danes. Poznejši postglacialni dvig morske gladine je povzročil poplavljanje obsežnih obalnih območij, ki so jih naseljevale človeške skupnosti, kar je vodilo do potopitve številnih obalnih arheoloških najdišč, ki so še danes skrita pod morsko gladino. Posledično so potopljene krajine predmet številnih geoarheoloških raziskav, vendar je bila vzhodna obala Jadranskega morja do nedavnega v tem pogledu razmeroma slabo raziskana.

V tej raziskavi obravnavamo potopljene krajine v okolici Osorja, železnodobnega in rimskega mesta v severnem Jadranu, na otoku Cresu. Projekt Osor onkraj mita je nastal iz potrebe po ponovni interpretaciji zgodovine tega regionalnega trgovskega pristanišča. Zaradi obalne lege mesta je bila poleg drugih arheoloških vprašanj posebna pozornost namenjena tudi rekonstrukciji naravnih (topografskih) razmer. Predstavljeni rezultati prinašajo nova spoznanja o relativnem dvigu morske gladine v holocenu, okoljskih spremembah v preteklosti ter obalni konfiguraciji in pomorski dostopnosti Osorja.

Ena osrednjih raziskovalnih tem se nanaša na nastanek Osorskega kanala, za katerega se tradicionalno domneva, da je bil izkopan za pomorske namene. Ta ozek morski prehod med otokoma Lošinj in Cres je imel ključno vlogo v pomorskih trgovskih poteh med Istro ter Dalmacijo. Geoarheološke raziskave na območju Osorja so vključevale geofizikalne raziskave, vrtanje sedimentnih jeder ter podrobne geokemične in granulometrične analize sedimentov. Za vzpostavitev kronološkega okvira dogodkov so bile uporabljene radiokarbonske in OSL-datacije. Združeni podatki letalskega laserskega skeniranja in večsnopne sonarno-batimetrske meritve so omogočili vpogled v potopljeno geomorfologijo območja okoli Osorja.

Sedimentno zaporedje debeline 2,9 m (jedro OSOR 2), odvzeto v Osorskem zalivu, je omogočilo rekonstrukcijo holocenskih paleookoljskih sprememb, povezanih z naravnimi procesi v širšem prostoru in s človeškimi dejavnostmi v Osorju. Jedro OSOR 2 ni zagotovilo nedvoumnih dokazov o človeških posegih, povezanih z izgradnjo kanala, ki bi omogočili razrešitev razprave o njegovi arheološki starosti. Nasprotno pa preliminarni rezultati kažejo, da je bila povezava med Osorskim zalivom in Lošinjskim kanalom preko Osorskega kanala verjetno vzpostavljena že v času bronaste dobe, kar nakazuje pomembno vlogo naravnih procesov pri njegovem nastanku. Poleg tega rezultati kažejo, da je območje Jaz ostalo del obalnega kopna vse do okoli leta 170 ± 100 n. št., ko je zaradi naraščanja morske gladine prišlo do vdora morske vode v notranjost. Na tej podlagi je današnji zaliv Jaz mogoče izključiti kot (rimsko) mestno pristanišče.

Up and Down the Hill: Hillforts and Dry Stone Wall Enclosures on the Kvarner Islands of Cres and Lošinj in Remote Sensing Data[1]

Gor in dol po hribu: gradišča in suhozidne ograde na kvarnerskih otokih Cresu in Lošinju v podatkih daljinskega zaznavanja

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Abstract

The Cres-Lošinj archipelago is a region characterised by numerous topographically prominent settlements. In the past, systematic research on this subject has been limited, mainly due to the difficulty of accessing the area because of dense vegetation. This study aims to address this gap by providing an overview of 85 locations where hillfort settlements and other types of enclosures have been systematically examined. It is based on a systematic analysis of ALS data covering approximately 500 km² of the archipelago over several months.

The current state of knowledge offers little opportunity for traditional archaeological evaluation, which relies on the typological and chronological characteristics of ceramic materials or on formal analogies between settlement features. Therefore, the discussion in this study focuses primarily on the potential of archaeological remote sensing for studying topographically prominent settlements in agro-pastoral karst landscapes. ALS interpretations of individual sites have been made available to experts to facilitate further discussion of the archipelago's dry stonewalled landscapes in general and of hillforts in particular.

Keywords: ALS, Cres/Lošinj, hillforts, dry stone walls, agro-pastoral remains

Izvleček

Cresko-lošinjski arhipelag je območje, značilno po številnih topografsko izrazitih naseljih. Doslej so bile sistematične raziskave tega območja omejene predvsem zaradi težkega dostopa, ki ga povzroča gosta vegetacija. Namen pričujoče raziskave je zapolniti to raziskovalno vrzel s pregledom 85 lokacij, kjer so bila sistematično preučena naselja na gradiščih in druge vrste naselbinskih ograj. Temelji na sistematični analizi ALS-podatkov, ki zajemajo približno 500 km² arhipelaga in pokrivajo večmesečno obdobje .

Trenutno znanje ponuja malo možnosti za tradicionalno arheološko vrednotenje, ki temelji na tipoloških in kronoloških značilnostih keramičnih materialov ali na formalnih analogijah med naselbinskimi elementi. Zato se razprava osredotoča predvsem na potencial arheološkega daljinskega zaznavanja pri

1 Reseach data will be published in the repository of University of Primorska.

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preučevanju topografsko izrazitih naselij v agropastoralnih kraških krajih. ALS-interpretacije posameznih najdišč so bile dane na voljo strokovnjakom, da bi olajšale nadaljnjo razpravo o suhozidnih krajih arhipelaga nasploh in o gradiščih posebej.
Ključne besede: ALS, Cres/Lošinj, gradišča, suhozidi, agropastoralni ostanki

Introduction

The Cres/Lošinj archipelago is home to the remains of numerous topographically prominent settlements, hillforts and different types of agro-pastoral enclosures. These are concealed not only by vegetation, but also by evidence of more recent human activity, such as agriculture and military installations. They have been the subject of limited research since their first mention in scientific publications over 100 years ago. This research has been primarily concerned with locating prehistoric dry stone fortification walls visible to the naked eye. Given the karst topography, dense ground vegetation and limited visibility of archaeological remains, not to mention the lack of technical resources available, researching hillforts was highly challenging. However, this situation has changed slightly because of advances in airborne laser scanning technology (ALS or LiDAR). It is currently the only successful method available for identifying the remains of dry stone walls and fortifications in areas covered by dense vegetation. This is primarily because ALS is a remote sensing technique that is not subject to the same rigorous limitations as other prospection methods, enabling the exploration of areas that would otherwise be inaccessible. The limited use of ALS in recent years is due to the fact that, prior to 2024, such investigations in Croatia could only be carried out using project data (e.g. Tončinić et al. 2023; Popović et al. 2021; Doneus et al. 2015). However, this situation is set to change after 2024, as a complete ALS survey of Croatia has recently been made publicly available upon request. As part of the 'Multisensor Aerial Survey of the Republic of Croatia' project, a digital terrain model (DTM) with a grid width resolution of 1 m is provided. This nationwide data offers a fresh perspective also on the islands of Cres-Lošinj archipelago.

This paper addresses the following research question: How might new technologies change our view, compared to previous studies, of hillforts on the islands of Cres and Lošinj? To answer this question, we systematically examined 500 km² of ALS-generated terrain models of the archipelago for traces of hillforts and subsequently compared our results with the current state of research. Due to the size of the study area, archaeological interpretation has focused on hillforts, with the mapping of prehistoric burial mounds being left aside.

Methodologically, this study is part of a consistent archaeological approach involving large-scale prospection for the study of the history of the archipelago. The current project, Osor beyond the myth, examines the role of Osor in maritime routes and Roman urban architecture within the city walls, as well as the city's landscape context and land use patterns. The use of large-scale prospection has therefore also benefited research into hillfort settlements.

Having introduced the case study area and the current state of research, we will present the methodology employed to identify and map relevant archaeological remains. The following discussion provides a comparison of the new results with those of earlier archaeological research. Finally, it examines the potential of archaeological remote sensing for studying topographically prominent settlements in agro-pastoral karst landscapes. To this end, it is necessary to address the fact that the dry stone wall enclosures visible in the ALS data are not necessarily equivalent to the (prehistoric) hilltop settlements.

Case Study Area

The Cres-Lošinj archipelago comprises two large islands and several smaller inhabited and uninhabited islets (fig. 1). Together with the islands of Krk and Rab, they belong to the northernmost group of Croatian islands, situated in the Kvarner Bay. They are typical of the Dinaric karst landscape and are characterised by open pastures, slope terraces, sinkholes, karst valleys and agricultural plots surrounded by dry stone walls (Andlar et al. 2018). The karstic limestone, especially on Cres and Lošinj, is densely covered with typical Mediterranean vegetation, consisting mainly of dense, rigid, mostly evergreen shrubbery (macchia) – anthropogenic secondary vegetation (fig. 1).

Cres and Lošinj are two of the most mountainous islands in Croatia. While the southern parts of both islands have mild relief and a rugged coastline, the western side of Lošinj below the 589-metre-high Osoršćica mountain and the northern parts of Cres, with terrain heights of more than 500 metres above sea level, are extremely steep. The northwest-southeast orientation of the two main islands, together with the high terrain, acts as a divide for weather and winds. The east coasts of Cres and Lošinj are particularly exposed to stormy northeasterly winds (Croatian: bura), while the west coasts of the two islands are affected by strong southeasterly winds (Croatian: jugo).

The prehistoric hillfort settlements on Cres and Lošinj are part of the Bronze and Iron Age settlement pattern along the eastern Adriatic coast. Hellmuth Kramberger (2024) links Bronze Age hillforts in Istria to a turbulent pe-

Figure 1: Views of the Cres and Lošinj Archipelago: a) The Brdo site (54) illustrates a modern development on a presumed prehistoric site (elaborated by Filip Vukoja, 2019); b) Abandoned agropastoral remains surrounded by macchia (elaborated by Michael Doneus, 2023); c) Aerial view on Osor and densely overgrown part of Lošinj Island (elaborated by Michael Doneus, 2010)

riod in the 2nd millennium BC. During this time, climate fluctuations and natural disasters caused population shifts, resulting in new types of fortified settlements in protected locations. The widespread presence of prehistoric, fortified settlements on Cres-Lošinj archipelago was first noted at the beginning of the 20th century, when Marchesetti (1903) documented and listed more than 400 hillforts in Istria and the Kvarner Bay region. His work from 1924 is dedicated to the Kvarner Islands (Marchesetti 1924).

Since then, the state of preservation and visibility of dry stone walls – which formed hillfort settlement features, topographically distinctive enclosures, or were used as a part of agro-pastoral activities – has changed in many locations. The large-scale abandonment of agro-pastoral use, especially after the Second World War, has led to complete coverage by scrub or bushland in many areas (fig. 1b and fig. 1c). Some enclosures or presumed hillforts are not visible in the relief due to intensive agricultural terracing or military installations (e.g. Piccolo Calvario, Umpiljak and M. Telegrafo on the island of Lošinj).

Archaeological research into hillforts has focused so far on unsystematic surveys and small-scale excavations (Marchesetti 1924; Mirosavljević 1955; 1956; 1959; 1960; 1974). A detailed summary of this research can be found in publications of Blečić Kavur (2014, 25–41; 2015, 25–38). Works summarising the distribution of hillforts across the entire Cres-Lošinj archipelago essentially reported the same information without verifying their distribution in the field (e.g. Ćus-Rukonić et al. 2013; Ćus-Rukonić 1982, 9–13; 2005). The difficult terrain combined with dense vegetation probably also played a role here. Stražičić 's work (1981, 106–13) provided a good overview for the time, offering his thoughts on the functions of hillforts. Recent research is still limited to unsystematic surveys, either carried out for professional interest (Branković and Benvin 2024) or in response to large-scale construction projects (Fidon and Eko invest 2021). The dating of the paleosoil with pottery fragments next to the hillfort above Vrana lake (Hrib (34)) to 1900 cal BC (Ilijanić et al. 2024) is a rare example of geological research that archaeology can profit from.

Another approach to studying hillforts is the use of GIS analysis. Čučković (2017) argues for a link between seafaring and the Bronze Age settlements on the island of Lošinj due to the numerous hillforts, which, in his opinion, are unlikely to have been built for agricultural purposes due to the limited amount of available agricultural land. A comparison with Istria could suggest that most of the hillforts are likely to date in the Bronze Age (Čučković 2017, 532).

Overall, research into prehistoric hillforts within the Cres-Lošinj archipelago is insufficient. While some studies have been conducted on other islands in the Kvarner Basin (e.g. Konestra and Nowacki 2020), a general comparison with prehistoric karst research on the nearby mainland illustrates the advances that have been made in the study of prehistoric settlements and landscapes in general (e.g. Bernardini et al. 2013; Vinci and Bernardini 2017; Bernardini et al. 2020; Lozić and Štular 2024; Mlekuž Vrhovnik and Fabec 2024).

Methodological Approach

In a region where no new systematic research on hillfort settlements has been conducted for decades, the first step is to compile basic documentation. This was achieved through a systematic interpretation of ALS data. Operated from an aircraft, this remote sensing technique can cover large areas in a relatively short time, providing dense 3D point clouds that represent the terrain of the scanned area, as well as all vegetation and objects located thereon (Vinci et al. 2024). Based on a classification of the individual points, digital terrain models (DTM) and digital feature models (DFM) can be derived through appropriate selection (Pingel et al. 2015; Štular et al. 2021), especially in the latter case revealing the terrain and all modern and archaeological structures that are still visible in relief.

The nationwide ALS-derived digital terrain model (DTM) for Croatia, mentioned above,

came in the form of an ASCII grid with a raster size of 1 m and was visualised using the Relief Visualisation Toolbox (RVT) (Kokalj et al. 2019; Kokalj and Somrak 2019). The 'archaeological combined cVAT' visualisation technique was used, blending hillshading from three directions with slope, positive openness and sky-view factor.

In order to interpret and enhance this ALS-based terrain model, we drew on two complementary data streams. Firstly, the published records of known hillforts and fortified settlements across the archipelago were georeferenced to create a point layer containing basic chronological and research history metadata. Secondly, we conducted a systematic screening of the RVT-enhanced DTM itself, mapping the topographic signatures of preserved remains and identifying enclosed sites that had not previously been documented. Together, these steps form the basis of the archaeological interpretation.

The data was collected and managed in a spatial database using the desktop GIS-software QGIS (ver. 3.40.5) in the form of a GeoPackage. The geometries were organised within a relational database scheme, with an entry in the point layer for each site entity (n=85), as well as related line features for the archaeological interpretation of visible structures. Additionally, a polygon representing the maximum extent was generated to provide general information on the size of the structures. To ensure clear identification, the site names are based on the Croatian base map (HOK), although many of the hills have different local names to those used on official maps.

Additional parameters were recorded as attributes for each entity, based on the established scheme of the 'Atlas of Hillforts of Britain and Ireland' (Lock and Ralston 2022). The Atlas of Hillforts applied three main inclusion criteria: (1) a locally dominant topographic position, (2) enclosing works that were sufficiently substantial (e.g. multivallate ramparts or ditches with a width of at least ~4 m), and (3) a minimum internal area (commonly set at around 0.2 ha). This criteria were simplified and adapted for the use in the northern Adriatic. We treated enclosed sites as a morphological continuum, incorporating enclosures of every size and type where an exclusive modern agricultural or pastoral use could be ruled out based on their form and/or relative stratigraphy. The degree of certainty was categorised as one of three levels, based on the literature and the visible structures in the digital terrain model (DTM). The topographic position was categorised into different classes: knoll/hillock, hilltop, hillslope, plateau/cliff-edge, ridge and inland promontory. A short qualitative description categorises the sites into three size classes and describes any fortification features.

Some hillforts, mainly on the island of Lošinj, have been surveyed in recent years (Branković and Benvin 2024). Several sites, particularly those near Osor, were surveyed also during the autumn and winter of 2024/25.

Results

A total of 85 locations were systematically reviewed. Detailed terrain models revealed 35 locations where simple dry stone wall enclosures or settlement fortifications had already been identified as archaeological sites. As expected, the terrain models provided a clearer picture of the shape, structure and complexity of these remains. However, no visible archaeological traces were evident in the ALS data at the other 22 presumed sites. Furthermore, 28 new locations of enclosures and settlements were added to the catalogue.

The results are summarised in table 1. The table compiles ALS results and publications by Marchesetti (1924), Mirosavljević (1955; 1956; 1959; 1960; 1974), Stražičić (1981), Miletić (2002), Šiljeg (2006), Starac (2011), Čučković (2017), Ilijanić et al. (2024) and Branković and Benvin (2024). For ease of reading, table 1 primarily cites works by Stražičić and Čučković. The second publication contains detailed references, which do not need to be repeated here (Čučković 2017, 21).

In table 1 slightly stricter criteria were used for the interpretation of the dry stone wall remains

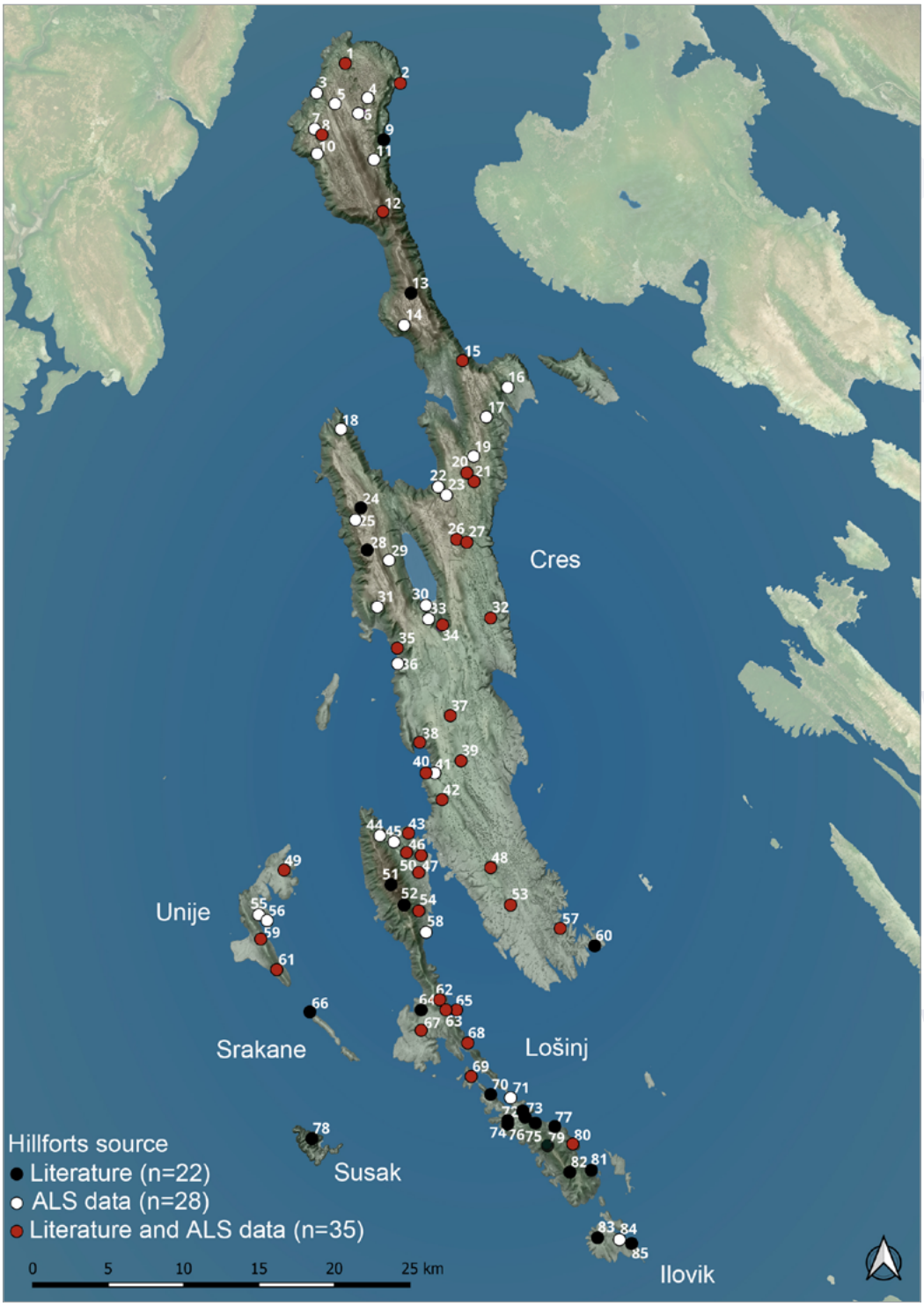

Figure 2: An Overview of the Mapped Hillfort Settlements and Enclosures Classified by Source (background data: DTM HR (https://dgu.gov.hr/); elaborated by Martin Fera, 2025)

(settlement, enclosure) than in previous studies. The result is illustrated in figure 2. The locations/sites were grouped into three categories: sites documented only in regional publications; sites mapped only using high-resolution ALS data; and sites reported in literature with visible dry stone wall remains in the remote sensing data. Sites that did not meet the criteria of at least two of these categories (e.g. ALS structures and datable finds from trial excavations/unsystematic surveys) were marked with a question mark. This applies to the majority of the hilltop settlements recorded by Marchesetti (1924). In elevated areas with no clear defensive structures other than simple enclosures, the distinction between agro-pastoral use and archaeologically defined fortified settlements was not always clear. Therefore, simple enclosures for which no datable finds were available were generally designated as 'enclosures'. However, where the features in the ALS data were extremely distinct and/or datable finds mentioned in the literature, the enclosures were defined fortified settlements. The term 'settlement' is used in the broadest sense to refer to human habitation in permanent dry stone walled structures, without discussing the function of the individual locations. For this discussion, we believe that systematic research including meaningful dating is needed, as it can be assumed that the same hills could have fulfilled different functions over time. Therefore, the list of 85 locations is not equivalent to the same number of (prehistoric) hillforts; it merely comprises locations where hillfort settlements and other types of enclosure were systematically reviewed.

There is an obvious discrepancy between the locations of the hillfort settlements mentioned in the literature and those revealed by the analysis of ALS data, as only 35 have visible structures in the DTM; for the remaining 22 locations, this was not the case. Of the sites mentioned in the literature, only 50% showed clear fortification structures in the DTM.

There are various reasons for this outcome. Firstly, it is challenging to identify the actual location, layout and purpose of enclosed settlements without systematic use of prospection methods and excavations. Secondly, the presumed hillforts could be hidden beneath the modern settlements, as in the case of Beli (9). Thirdly, some of the settlements referred to by Marchesetti (1924) are now partially or wholly occupied by military installations (see, for instance, the levelled plateau on M. Telegrafo (76)) or obscured by subsequent land use (for instance 11, 15, 19, 54, 58, 73 or 80). Other presumed hillforts, such as Jablanac on the island of Cres – where, according to Ćus-Rukonić et al. (2013, 11), a 'signaling and monitoring station' is expected to be situated – were not included in the list at all due to a lack of supporting evidence.

In terms of geographical distribution, more than half of the presumed hillfort and enclosure sites (46 out of 85) are located on the island of Cres. Another 28 sites are found on the island of Lošinj, and a further 12 are located on smaller islands. A clear concentration can be seen on Cres in the topographically higher regions in the north, as well as around Lake Vrana. In contrast, the southern half of Cres, including Punta Križa, has a sparse distribution. The highest density of sites is found on the narrow, rugged island of Lošinj.

The classification of the topographical location paints a diverse picture: only slightly more than half are designated as hilltop locations (fig. 3). The rest are located on small hills, mountain

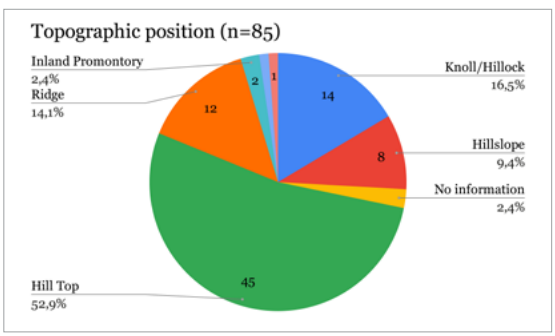

Figure 3: Pie Chart Listing the Actual Topographic Position of the Documented Sites (elaborated by Martin Fera, 2025)

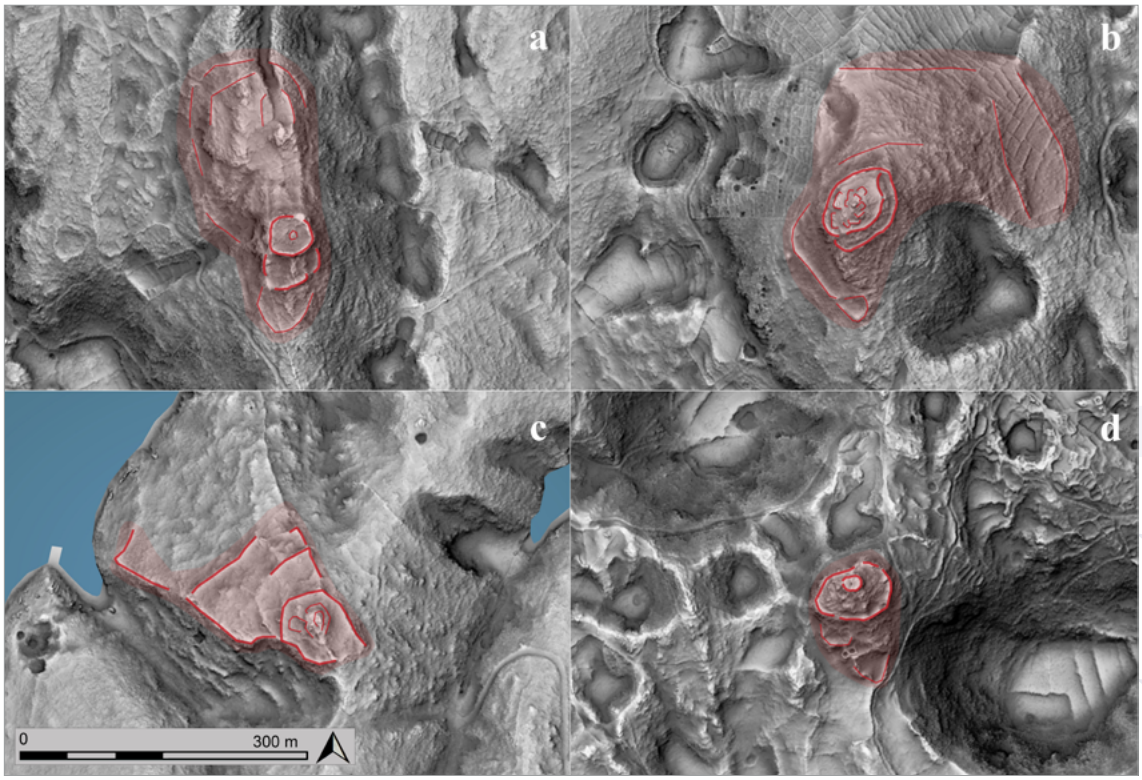

Figure 4: Multi-Zonally Organised Prehistoric Fortifications: a) Pukonjina (21), b) Pelginja (20), c) Gradac (57) and d) Važminec (4) (background data: DTM HR (https://dgu.gov.hr/); elaborated by Martin Fera, 2025)

ridges, plateau edges or steep slopes. The extent, construction and complexity of the ramparts, and the structure and use of the enclosed areas, also vary considerably. Documented interior or surrounding features are generally limited to central mounds, built (platform) or agricultural terraces or, in a few cases, ecclesiastical ruins dating from after the prehistoric occupation or modern settlement use (fig. 1a)

Most enclosures are relatively small (up to 5 ha) to medium (5 to 15 ha) in size defined by one or more low ramparts, banks, or dry stone walls. Extensive, multi-zonally organised prehistoric fortifications can be recognised in some cases, some of them including elevated round structures or mounds (fig. 4). Other hillforts are situated on plateaus bordering the cliff edge, surrounded by a single enclosure (fig. 5). Of all these examples (16, 22, 25, 29 and 34), only the preliminary dating of the paleosoil containing pottery fragments next to the hillfort Hrib (34) to 1900 cal BC provides a chronological reference (Ilijanić et al. 2024).

Three hillforts (Petričina (2), Porozina (3) and Sv. Lovre (47) (similar to Kuši (40)) (fig. 6) have entirely different layouts to those described above. They are similar in size, being two to three times larger than other hilltop settlements and have a uniform shape. This is defined by two enclosures, one of which encloses the central settlement area and the other the entire site. A prime example is the hillfort of Sv. Lovre (47), which is over 400 metres long and has three separate terraces. In the central part, numerous dry stone dwellings are still preserved. Unfortunately, past surveys have only revealed a few pieces of prehistoric pottery (Branković and Benvin 2024, 92). On its northern side, the settlement is overlaid by several mortared dwellings, including a church dedicated to Sv. Lovre and a possible hermitage, which Jurković (2008, 19) counts to the 11th and 12th centuries.

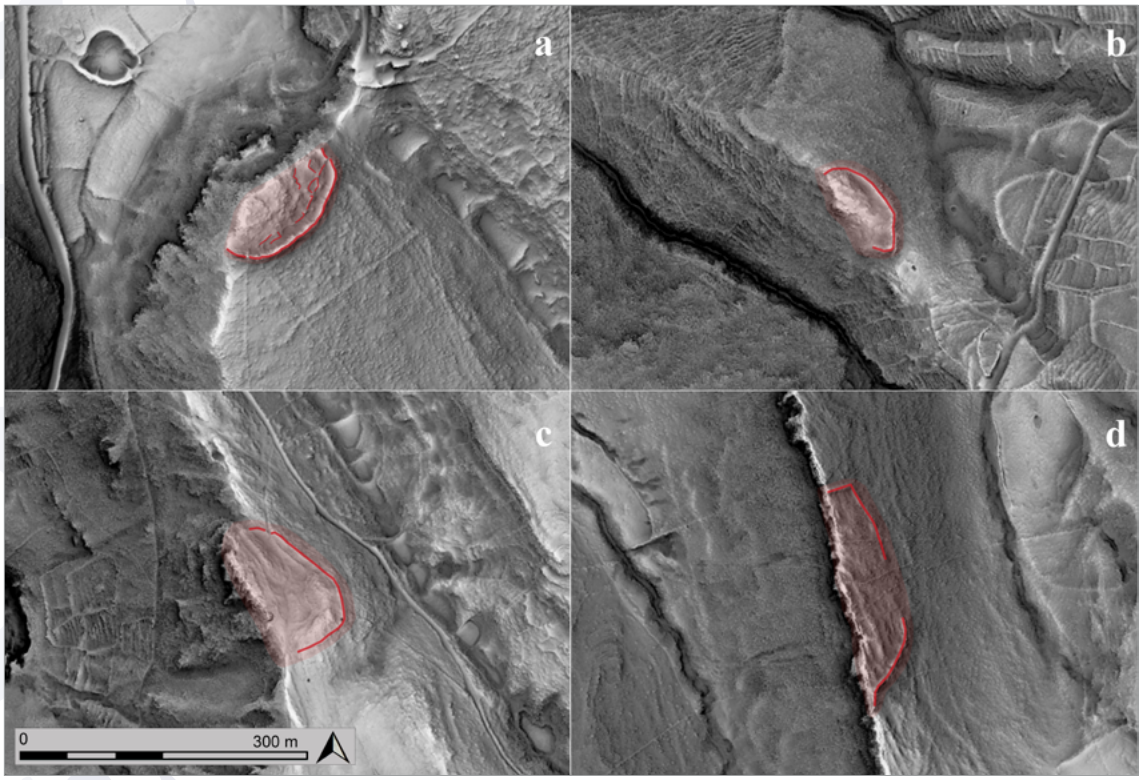

Figure 5: Plateau/Cliff-Edge or Ridge: a) Mravinci (16); b) Draga Buč (22); c) Brajdice (25); d) Hrib (34) (background data: DTM HR (https://dgu.gov.hr/); elaborated by Martin Fera, 2025)

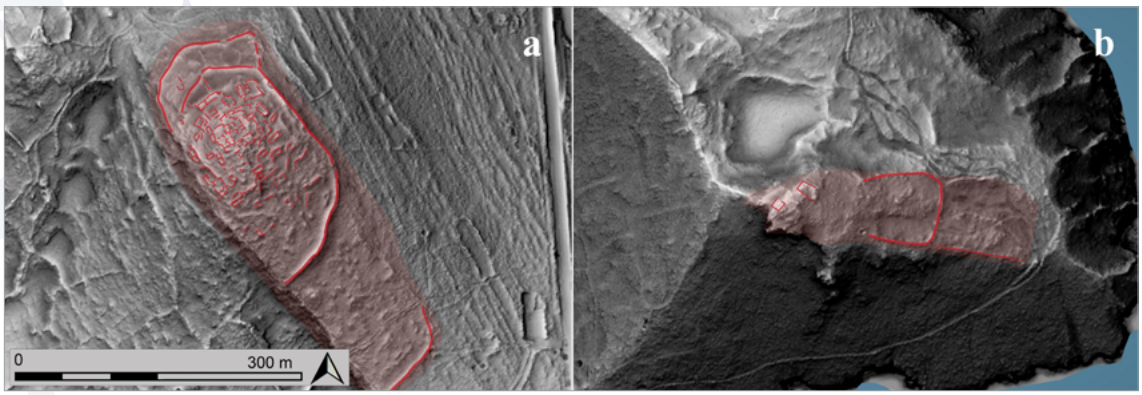

Figure 6: Large, Oval Hilltop Settlements with Partially Preserved Building Structures in the Central Area: a) Sv. Lovre (47); b) Petričina (2) (background data: DTM HR (https://dgu.gov.hr/); elaborated by Martin Fera, 2025)

Discussion

Integrating large-scale ALS surveys into the study of hillforts has generated a substantial amount of data. A detailed discussion of each site would therefore exceed the scope of this publication. However, in order to verify the results presented here and stimulate further research in the region, a basic interpretation of each documented hillfort and/or enclosure is provided in the Appendix.

The discussion offers a brief evaluation of the new results and compares them with those of previous studies. It also considers the potential of archaeological remote sensing for studying topographically prominent settlements in agro-pastoral karst landscapes. To this end, it is necessary to address the fact that the dry stone wall enclosures visible in the ALS data are not necessarily equivalent to the (prehistoric) hillfort settlements.

The Hillforts of the Cres-Lošinj Archipelago

The standard practice of documenting visible ramparts, which has been employed since the earliest studies of fortified hilltop settlements (e.g. Marchesetti 1924), must nowadays be modified and extended. This is most easily demonstrated by comparing the hillfort plans in Mirosavljević's publication (1974) with the results of this study (fig. 7). Given the difficult ground conditions and technical resources available in the late 1960s, it is evident that his documentation of the settlement features was – from today's perspective – only partially successful. The settlement of Vela Straža (48) located on the Punta Križa Peninsula, for example, appears completely different in the ALS data than on well-known maps (fig. 7a). The settlement's unusual shape may have been caused by the area's agricultural use, meaning the original layout is no longer visible. Further minor errors in the original plan are also visible, such as the dry stone wall surrounding the sinkhole, which was mistakenly attributed to the hillfort at the time. Similar results are revealed by the other comparisons shown in fig. 7.

Evaluating the 500 km² area provided new insights into the distribution, shape and location of the hillforts. However, the dating of the indi-

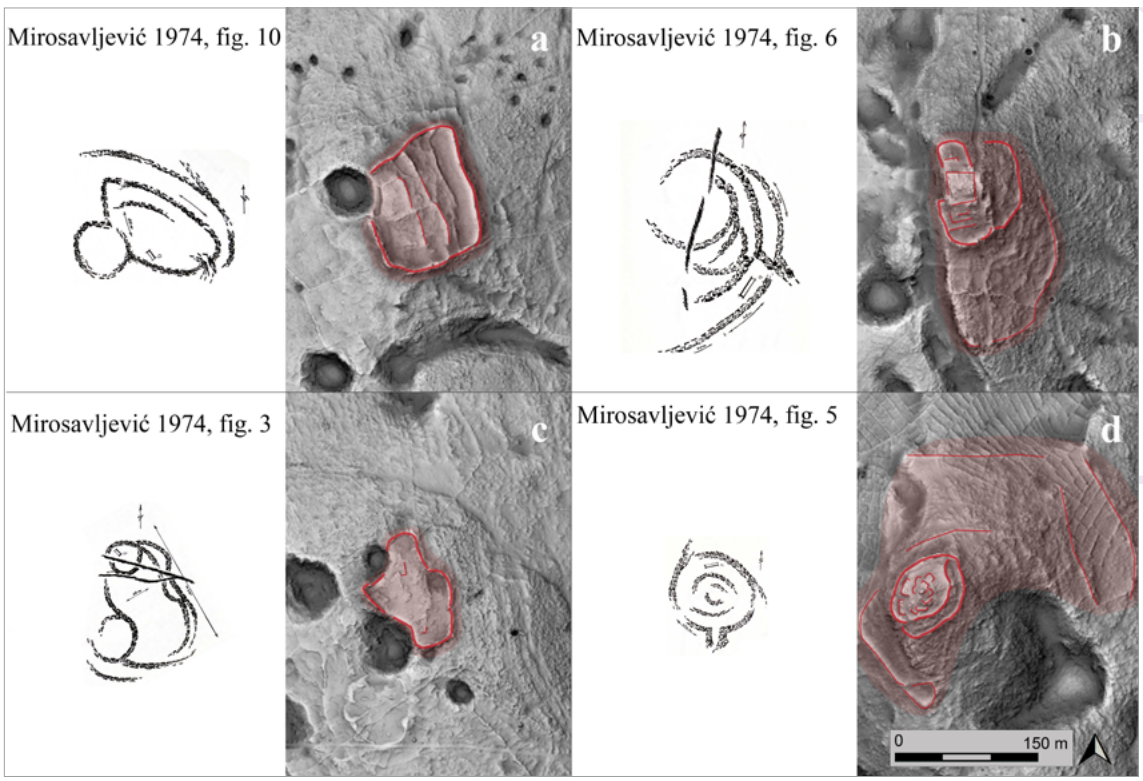

Figure 7: A Comparison of the Ground Plans (in Approximate Scale) From Mirosavljević's Work (1974) With Those Obtained Through the Analysis of ALS Data: a) Vela straža (48); b) Skulka (26); c) Jelovica (32) and d) Pelginja (20) (background data: DTM HR (https://dgu.gov.hr/); elaborated by Martin Fera, 2025)

vidual sites still requires further research. Questions of prehistoric material culture on the archipelago have been addressed in detail mainly in context of research of Osor (Blečić Kavur 2014; 2015; Blečić Kavur and Kavur 2024, 2025). After Čučković (2017, 532) the presence of prehistoric pottery fragments on hillforts mostly indicates a Bronze Age settlement horizon. However, this assessment must be confirmed by future research, given that systematic research on Bronze and Iron Age pottery is still lacking. In this context the question arises not only as to the location of Iron Age settlements, but also as to the extent to which sites – now referred to as prehistoric hillfort settlements – contain settlement traces from more recent historical periods. As all research builds upon the work of Marchesetti (1924), his views are widely accepted, particularly in compilations on the research history into the archipelago (e.g. Ćus-Rukonić 1982; Ćus-Rukonić et al. 2013). As he was primarily interested in prehistoric hillforts, he included all topographically prominent enclosures in his list, creating the impression that these were entirely prehistoric or Bronze Age settlements. At the same time Marchesetti noted later finds on the hillforts although without the distinction between Roman and Late Antique times. Consequently, descriptions of Roman or Late Antique settlement patterns in the archipelago (e.g. Ćus-Rukonić 1982) are of little help in reconstructing settlement processes after the Iron Age. Archaeological material from the Roman or Late Antiquity period has been noted so far at only few sites (15, 57, 60–62). This figure will probably increase after further research on the archipelago. For the Late Antique hillfort of Beli (9), see the contribution on Roman urbanisation in this volume.

Hillforts in the Area of Osor

Systematic research is also required into the hillfort settlements in the area around Osor. As the only known example of a lowland prehistoric settlement to date, Osor is strategically located on a circular land bridge between the islands of Cres and Lošinj. On its western edge the city is bordered by a narrow channel that also separates the islands of Cres and Lošinj. Current geoarchaeological research on the Osor Channel indicates the transport of sediments by currents between Cres and Lošinj as early as 5621–5313 cal BP (3672–3364 cal BC) (see Miko et al. 2025). This indicates that the narrow strip of land between Cres and Lošinj had already been submerged by the Bronze Age, leading to the separation of both islands by the sea. This change in the landscape and the creation of the new maritime route may be related to prehistoric trade in and around Osor. Grave and settlement finds from the Bronze Age (Blečić Kavur 2014; 2015; Blečić Kavur and Kavur 2013; 2025) demonstrate the area's earliest archaeological traces, prior to the establishment of the Iron Age and Roman town. The richest archaeological finds from this period come from the city's necropolis and valuable insights into the inhabitants of Osor (Mihovilić 2013; Blečić Kavur 2015; 2021; 2025; Blečić Kavur and Kavur 2013; 2024). After Blečić Kavur and Kavur (2025) the material culture confirms the role of Osor as an economic centre of the Kvarner region and the wider northern Adriatic during the last two millennia of the prehistoric era.

The presumed concentration of hillforts near Osor was considered an indication of Osor's leading role in the Iron Age (e.g. Stražičić 1995, 76; Ćus-Rukonić et al. 2013, 11). This reasoning is easy to understand. In two-dimensional maps, which have been used for archaeological overviews for over a century (fig. 8), Osor appears to be surrounded by hilltop settlements (Stražičić 1981, fig. 29; 1995, fig. 2). However, to better understand the apparently high number of hillforts around Osor, it is necessary to view them not as dots on a map, but to compare their location with the prevailing relief. The dense distribution of hillforts is not limited to the north-eastern tip of Lošinj Island but extends across the entire island (fig. 2). This is due to the numerous locations suitable for topographically prominent settlements arising from the rugged terrain

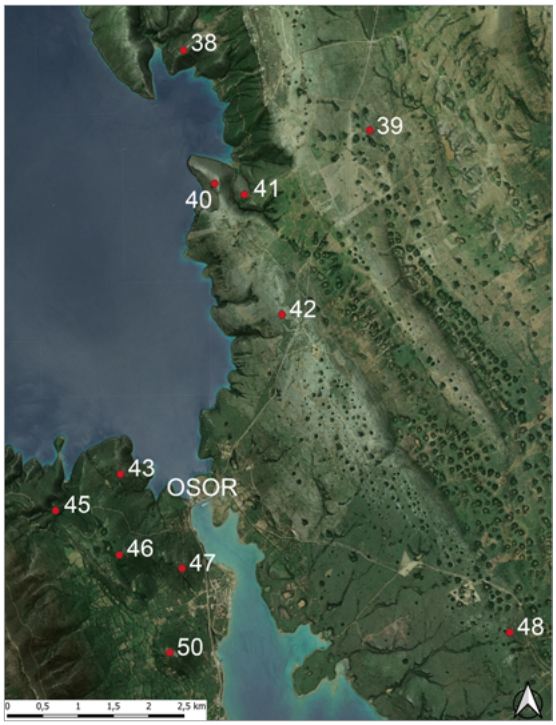

Figure 8: Gračišće Ustrine (38), Sv. Mihovil (39), Kuši (40), Ognjarice (41), Peščenji (42), Bog (43), Kalćić (45), Bijela glava (46), Sv. Lovre (47), Vela Straža (48) and Halmac (50) (background data: [Credit Nimbo by KERMAP]; contains modified Copernicus Sentinel data 2023; elaborated by Martin Fera, 2025)

and the mountain ridge running parallel to the coastline.

Given that none of the eleven hilltop settlements near Osor have been systematically investigated, there is scope for a great deal of speculation, which cannot replace systematic archaeological research on the subject. The available sources currently suggest that prehistoric pottery fragments were found at most of the eleven hilltop settlements (38, 39, 40, 42, 43 and 50) (Mirosavljević 1974; Starac 2011). However, this is not sufficient to determine which hillforts were inhabited during which time periods, whether there was a clear process of settlement and abandonment or how the topographically prominent locations were used at other times. No trace of the hillfort of Konopičje, which is mentioned by Ćus-Rukonić et al. (2013, 11), has been found in the ALS data. The location has been defined as a burial site in a recent publication (Blečić Kavur and Kavur 2024, 26–8).

From Hillforts to Landscapes

Geographically, the archipelago belongs to the typical Dinaric karst landscape (Fuerst-Bjeliš et al. 2024). This is characterised by dry stone walls that serve various settlement and agro-pastoral purposes, such as enclosing slope terraces, sinkholes, and agricultural land (Kremenić et al. 2021; Andlar et al. 2018). To adequately address the specific archaeological remains amidst this complexity, archaeological methods capable of handling extensive and complex data sets are required. This primarily involves landscape archaeology, which covers a wide range of topics (e.g. Doneus and Doneus Forthcoming). A key aspect of landscape archaeology is providing a comprehensive, diachronic, large-scale description of the location, extent, character, and chronological sequence of material remains. Archaeological prospection is the first step in this process, as it establishes the spatial context of archaeological finds, features and sites. In this sense, the purpose of remote sensing methods, or archaeological prospection in general, is not to identify specific archaeological remains. Its strength lies in its ability to comprehensively document all visible remains, regardless of their age or the research topic, since the relevance of the remains can only be determined through subsequent data interpretation.

The same applies to research into hillfort settlements, which can be considered part of the archipelago's dry stone wall heritage. Archaeological interpretation of ALS data alone, or in combination with unsystematic surveys, does not always allow distinction to be made between hillforts and enclosures of different origins (see also Mlekuž Vrhovnik and Fabec 2024, 89) (fig. 9). They are located in different positions and heights, vary in size and shape, and may have been altered by different uses to become what we see today in the data (e.g. fig 7a).

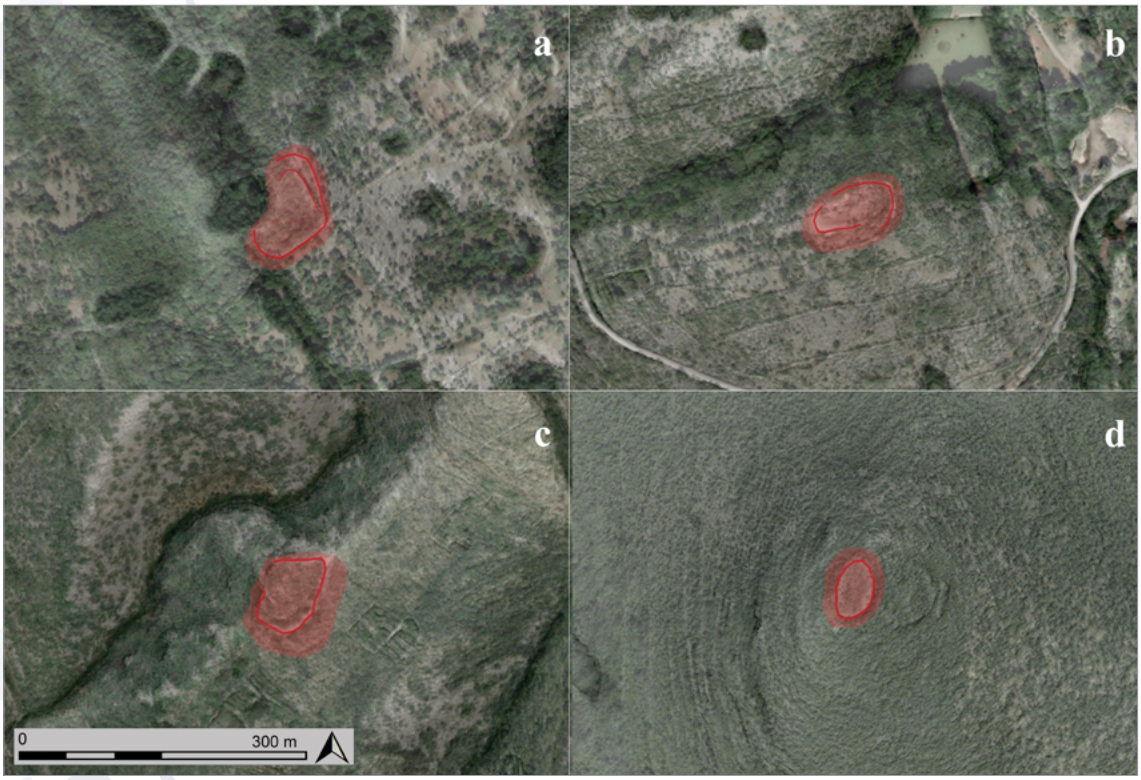

Figure 9: Examples of Different Enclosures: Novograjca (5), Telcar (10), Banestrovica (31) and Malondarski (49) (background data: DTM HR (https://dgu.gov.hr/); Bing Satellite Imagery © Microsoft; elaborated by Martin Fera, 2025)

A closely related field to archaeological prospection is the study of prehistoric landscapes. Large-scale data interpretation provides an opportunity to shift the focus from individual prehistoric enclosures and fortifications to the surrounding landscape (e.g. Cowley et al. 2019). The karst landscapes surrounding the eastern Adriatic coast have been repeatedly in the focus of archaeological remote sensing, providing archaeological research also with insights into prehistoric agro-pastoral landscape features (Vinci and Bernardini 2017; Bernardini et al. 2020; Lozić and Štular 2024; Mlekuž Vrhovnik and Fabec 2024). In addition, the figures 4 and 7 demonstrate that the karst landscape of the Cres-Lošinj archipelago has preserved more than just fortifications of prehistoric hillforts. They show multi-fortified settlements and highlight the need for large-scale interpretation to document not only nearby burial mounds, but also nearby the remains of prehistoric land use.

It is challenging to identify prehistoric land use based on dry stone wall systems, particularly in complex karst landscapes, as these systems are subject to change and are often exposed to decay, rebuilding and reshaping. Nevertheless, the remains of dry stone walled landscapes can provide chronological and typological indicators similar to finds and excavation features. Airborne laser scanning provides the necessary methodological toolkit for obtaining the relative stratigraphic sequence of dry stone walls directly from the ALS data. Mapping and interpretation of a small area on the Punta Križa Peninsula, extending from Osor to the southern end of the island of Cres, has highlighted the advantages of diachronic interpretative mapping (Doneus et al. 2022). The area in question has a

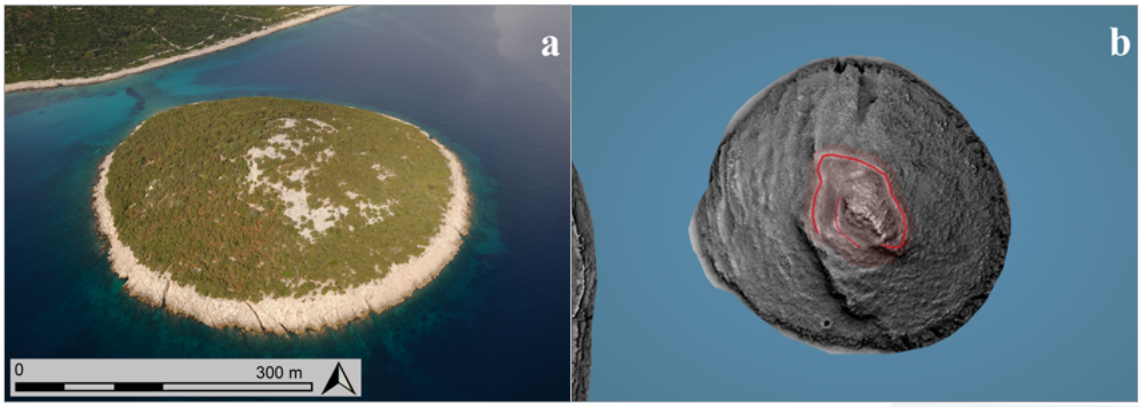

Figure 10: Site and Island of Veli Osir (65): a) Aerial photograph; b) ALS-based data interpretation (aerial photograph by Michael Doneus, 2012; background data: DTM HR (https://dgu.gov.hr/); elaborated by Martin Fera, 2025)

very dynamic landscape of dry stone walls and contains at least five phases of agricultural use, reflecting the complexity of the island's economy in past centuries. The oldest stratigraphic feature is a bank belonging to a Roman land survey, dating to 200 + 100 AD (Doneus et al. 2024).

Absolute dating of the dry stone walls, which were used as boundary markers in Roman land surveying, was carried out using optically stimulated luminescence profiling and dating (OSL-PD). The method measures the last time buried deposits were exposed to light (Kinnaird et al. 2025). In the first stage, the luminescence properties of the sediment in the core are evaluated using portable OSL equipment (Munyikwa et al. 2020). A relative luminescence stratigraphy is then constructed and used to identify down-core positions for dating purposes. This stratigraphy is subsequently employed to determine the most promising locations within the core for dating. The OSL dating method is highly versatile and has been successfully employed in various research projects, including those investigating Mediterranean terraces (Kinnaird et al. 2017; 2025; Srivastava et al. 2023; Turner et al. 2021), prehistoric field patterns (Vervust et al. 2020), individual sites (Kinnaird et al. 2019), and the reconstruction of coastal landscapes (for Osor see the geoarchaeology article in this volume). The successful application of the OSL-PD method in the karst landscape of Cres-Lošinj makes it possible to combine ALS data to create relative stratigraphic sequences and use the OSL-PD method to date (prehistoric) hillforts and/or past land use on the archipelago.

Another potential use of the OSL-PD method is to date terrestrial and marine sediments. The potential hillfort on the small island of Veli Osir (65) appears to be a suitable candidate for this method (fig. 10). Due to its current location, it is hardly recognisable as an elevated settlement as the island has low relief (53 m). Nevertheless, the surrounding area and the seabed are worth exploring. Given the continuous rise in the sea level, reconstructed to approximately -3 metres for around 4600 BC (Brunović et al. 2019) and based on the current maximum water depth of 5 metres between the islands of Lošinj and Veli Osir it can be assumed that the visible elevation in aerial photograph on figure 11a represents the remains of a submerged prehistoric path to the settlement. Although submerged prehistoric sites have played a minor role in Adriatic Sea research (for Punta Križa see Parica 2023, 124–7), sites like Veli Osir, provided that surface finds confirm its use in prehistoric times, offer the opportunity to break new ground in the study of prehistoric settlements.

Conclusion

A systematic investigation of detailed terrain models confirmed 35 locations where simple dry stone wall enclosures or settlement fortifications had previously been recognised as archaeological sites. No visible archaeological traces were evident in the ALS data at the other 22 presumed sites. However, 28 new locations of enclosures and settlements were added to the catalogue.

Although high-resolution ALS-derived digital terrain models markedly improve our capacity to detect anthropogenic landforms beneath dense vegetation, the threshold of feature recognition remains constrained: subtle morphological anomalies may be filtered out or masked by processing algorithms, and their archaeological significance cannot be addressed reliably without systematic ground assessment. Furthermore, the interpretation process has shown that in some cases, the distinction between simple pastoral or agricultural enclosures and those with a fortified character is difficult to make based solely on ALS data. In addition, well-known hillforts exhibit a variety of overlapping functions throughout their lifespan. Combining modern remote sensing with older field research gives the project breadth but also highlights discrepancies that can only be resolved through large-scale systematic research.

One key point that could significantly advance future research is that investigating ALS-based terrain models shifts the focus from sites to landscapes. Combined with appropriate dating methods, such as OSL-PD method, this allows the archaeology of the landscapes around and between hillforts to be investigated, leading to new research questions and perspectives.

Table 1: List of Documented Hillforts and Enclosures. The Source column refers to the background information for single locations: a) DTM HR, b) Stražičić 1981, c) Čučković 2017, d) Ilijanić et al. 2024, e) Miletić 2002, f) Starac 2011, g) Šiljeg 2006.

Nr.	Name	Interpretation	Archaeological finds	E UTM 33N	N UTM 33N	Source
1	Gornja Glava	Settlement (?)	?	446668	4 948886	a, b
2	Petričina	Settlement (?)	?	450311	4 948256	a, b
3	Porozina	Settlement (?)	?	444845	4 948065	a
4	Važminec	Settlement (?)	?	448149	4 947161	a
5	Novograjca	Enclosure	?	446081	4 946972	a
6	Palvana	Enclosure	?	447793	4 946873	a
7	Višnjin	Enclosure	?	444733	4 946041	a
8	Halm	Settlement	Prehistory	445053	4 944772	a, c
9	Beli	Settlement	Prehistory (?), Late Antique (?) - modern times	449276	4 944745	b
10	Telcar	Enclosure	?	444822	4 944377	a
11	Kalci	Settlement (?)	?	448632	4 944084	a
12	Sis	Settlement (?)	?	449197	4 943643	a, c
13	Velo Gračišće	No structures		451021	4 943112	b
14	Zakenj	Settlement (?)	?	450599	4 942941	a
15	Sv. Bartolomej	Settlement	Prehistory/Roman/Late Antiquity/Early Middle Ages	454483	4 942419	a, c
16	Mravinci	Settlement (?)	?	457396	4 941994	a
17	Melzicar	Settlement (?)	?	456060	4 940397	a

Nr.	Name	Interpretation	Archaeological finds	E UTM 33N	N UTM 33N	Source
18	Sv. Marija	Settlement (?)	?	446372	4 938399	a
19	Draga	Settlement (?)	?	455161	4 937776	a
20	Pelginja	Settlement	Prehistory	454690	4 937702	a, c
21	Pukonjina	Settlement	?	455194	4 937677	a, c
22	Draga Buč	Settlement (?)	?	452835	4 937502	a
23	Trnket	Settlement (?)	?	453422	4 936418	a
24	Vrh sela	Enclosure (?)	?	447748	4 935523	b
25	Brajdice	Settlement (?)	?	447457	4 934794	a
26	Skulka	Siedlung	Prehistory	454034	4 934260	a, c
27	Krasa	Settlement (?)	?	454772	4 933298	a, c
28	Helm	Settlement (?)	?	448212	4 932101	c
29	Heljčić	Settlement (?)	?	449645	4 931888	a
30	Punta Zaglavac	Settlement (?)	?	452076	4 931022	a
31	Banestrovica	Enclosure	?	448743	4 930772	a
32	Jelovica	Settlement	Prehistory	456346	4 930401	a, c
33	Dolec	Enclosure	?	452206	4 930380	a
34	Hrib	Settlement	Prehistory	453000	4 930156	a, d
35	Sv. Kristofor	Settlement	Prehistory	450143	4 930002	a, c
36	Orlec	Enclosure	?	450285	4 929920	a
37	Gračišće, Belej	Settlement (?)	?	453629	4 929199	a, b
38	Gračišće, Ustrine	Settlement	Prehistory	451687	4 928795	a, b
39	Sv. Mihovil	Settlement	Prehistory	454322	4 928749	a, g
40	Kuši	Settlement	Prehistory (?)	452128	4 927132	a, g
41	Ognjarice	Settlement (?)	?	452551	4 926962	a
42	Peščenji	Settlement (?)	Prehistory	453081	4 922643	a, b
43	Bog/Straže	Settlement	Prehistory	450793	4 922523	a, c
44	Osoršćica	Enclosure	?	449044	4 922142	a
45	Kalćić	Enclosure	?	449876	4 948886	a
46	Bijela glava	Settlement (?)	?	450776	4 948256	a, c
47	Sv. Lovre	Settlement (?)	Prehistory (?)	451666	4 948065	a, c
48	Vela straža, Cres	Settlement	Prehistory	456302	4 947161	a, c
49	Malondarski	Enclosure	?	442578	4 946972	a, c
50	Halmac	Settlement	Prehistory	451493	4 946873	a, c
51	Pogled	Settlement (?)	?	449695	4 946041	c
52	Laće	Settlement (?)	?	450509	4 944772	c
53	Maslovnik	Settlement	Prehistory	457640	4 944745	a, c
54	Brdo	Settlement (?)	?	451538	4 944377	a, c
55	Vela straža, Unije	Enclosure	?	440954	4 944084	a

Nr.	Name	Interpretation	Archaeological finds	E UTM 33N	N UTM 33N	Source
56	Maračol	Settlement (?)	?	441516	4 943643	a
57	Gradac	Settlement	Prehistory/Roman/Late Antique	460999	4 943112	a, b
58	Jakov	Enclosure	?	452025	4 942941	a
59	Sičin	Settlement	Prehistory	441158	4 942419	a, e
60	Sv. Damjan	Settlement	Roman/Late Antique	463204	4 941994	f
61	Turan	Settlement	Prehistory/Roman/Late Antique (?)	442181	4 940397	a, e
62	Polanža	Settlement	Prehistory, Roman/Late Antique	452622	4 938399	a, c
63	Čunski	Settlement	Prehistory	453259	4 937776	a, c
64	Grušina	Settlement (?)	?	451694	4 937702	c
65	Veli Osir	Settlement (?)	?	453945	4 937677	a, c
66	Vela straža, Vele Srakane	Settlement	?	444381	4 937502	c
67	Stan	Settlement (?)	?	451793	4 936418	a, c
68	Krbošćak	Settlement (?)	?	454759	4 935523	a, c
69	Koludarc	Settlement (?)	Prehistory (?)	455037	4 933298	a, c
70	Vela straža, Lošinj	Settlement (?)	?	456318	4 932101	c
71	Malin	Enclosure	?	457730	4 931888	a
72	Kaštel	Settlement (?)	?	458255	4 931022	c
73	Vršak	No structures		458571	4 930772	c
74	Piccolo Calvario	Settlement (?)	?	457424	4 930380	c
75	Umpiljak	Settlement (?)	?	459160	4 930156	c
76	M. Telegrafo	Settlement (?)	?	457371	4 930002	c
77	Stražica	Settlement (?)	?	460534	4 929920	c
78	Garbe	Settlement (?)	?	444472	4 929199	c
79	Sv. Ivan	Settlement (?)	?	460034	4 928795	c
80	Bulbin	Settlement	Prehistory	461780	4 928749	a, c
81	Mulmon	Settlement	Prehistory	462909	4 927132	c
82	Pogled	Settlement (?)	?	461564	4 926962	c
83	Križine	Settlement (?)	Prehistory (?)	463367	4 922643	c
84	Mala straža, Ilovik	Settlement (?)	?	464841	4 922523	a
85	Velika straža, Ilovik	No structures		465581	4 922142	c

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Summary

The landscape of the Cres–Lošinj archipelago is characterised by the remains of numerous topographically prominent settlements, hillforts, and various types of agro-pastoral enclosures. Both vegetation and more recent human activity contribute to the concealment of these sites. Since their first mention in scientific publications over a century ago, research has been limited, primarily focusing on locating prehistoric dry stone fortification walls. The karst topography, dense ground vegetation, and limited visibility of archaeological remains have made the study of hillforts particularly challenging. This situation has changed with advances in airborne laser scanning (ALS or LiDAR) technology. A comprehensive ALS survey of Croatia has recently been made publicly available, offering a new perspective on the islands of the Cres–Lošinj archipelago.

This study addresses how archaeological remote sensing can alter our understanding of hillforts on Cres and Lošinj. We approached this by systematically examining ALS-derived terrain models covering 500 km² of the archipelago for traces of hillforts and comparing the results with the current state of research.

In total, 85 locations were systematically reviewed. Detailed terrain models confirmed 35 locations where simple dry stone enclosures or settlement fortifications had previously been identified as archaeological sites. As expected, the terrain models provided a clearer picture of the shape, structure, and complexity of these remains. No visible archaeological traces were apparent in the ALS data at the other 22 presumed sites. Additionally, 28 new locations of enclosures and settlements were added to the catalogue. There is a clear discrepancy between the locations of hillfort settlements reported in the literature and those revealed by ALS analysis; only 50% of the literature sites exhibited clear fortification structures in the DTM.

While high-resolution ALS-derived digital terrain models have substantially improved our ability to detect anthropogenic landforms, research into prehistoric material culture remains fragmented. An exception is the ongoing research at Osor, but it remains insufficient for establishing a relative chronological framework for hillforts across the entire archipelago. Consequently, there is little scope for the traditional archaeological evaluation of newly documented hillforts and enclosures based on the typological or chronological characteristics of ceramic materials or on formal analogies between settlement features.

Accordingly, the discussion focuses primarily on the potential of archaeological remote sensing for studying topographically prominent settlements in agro-pastoral karst landscapes. It highlights that the dry stone enclosures visible in the ALS data do not necessarily correspond to (prehistoric) hillfort settlements. At the same time, ALS allows for a shift in focus from individual enclosures to prehistoric landscapes, which can include extensive, multi-zonally organised fortifications across the Cres–Lošinj archipelago.

The bird's-eye perspective also facilitates the planning of targeted field research. However, this does not eliminate the need for challenging on-site investigations. As large-scale excavations have become rare and many dry stone walls yield no finds, the OSL-PD method offers an alternative, providing absolute chronological data where other evidence is lacking. The complexity of the archipelago's agro-pastoral karst landscape, including (prehistoric) hillforts and enclosures, may be seen as a challenge but also represents a compelling archaeological opportunity. Accordingly, archaeological interpretations of all catalogue sites are provided as part of this publication to support further discussion of the archipelago's dry stone walled landscapes in general, and of hillforts in particular.

Povzetek

Krajino arhipelaga Cres-Lošinj zaznamujejo ostanki številnih topografsko izrazitih naselij, gradišč in različnih vrst agropastoralnih ograj. Gostota vegetacije in kasnejše človekove dejavnosti prispevajo k prikritju teh najdišč. Od njihove prve omembe v znanstvenih publikacijah pred več kot sto leti so bile raziskave omejene predvsem na lociranje prazgodovinskih suhozidnih obrambnih zidov. Kraška

topografija, gosto rastlinje in omejena vidljivost arheoloških ostankov so predstavljali velik izziv pri preučevanju gradišč. Ta situacija se je spremenila z napredkom tehnologije daljinskega zaznavanja z letalskim laserskim skeniranjem (ALS ali LiDAR). Nedavno je postala javno dostopna celovita ALS-preglednica za Hrvaško, ki ponuja povsem nov pogled na otoke arhipelaga Cres-Lošinj.

Prispevek obravnava vprašanje, kako lahko arheološko daljinsko zaznavanje spremeni naše dojemanje gradišč na otokih Cres in Lošinj. To smo raziskali s sistematičnim pregledom 500 km² terena arhipelaga na osnovi ALS-modelov za sledi gradin in kasnejšo primerjavo rezultatov z obstoječim stanjem raziskav.

Sistematično je bilo pregledanih skupno 85 lokacij. Podrobni terenski modeli so potrdili 35 lokacij, kjer so bile že identificirane preproste suhozidne ograje ali naselbinske utrdbe kot arheološka najdišča. Kot pričakovano so modeli terena omogočili jasnejšo predstavo o obliki, strukturi in kompleksnosti teh ostankov. Na preostalih 22 predvidenih lokacijah v ALS-podatkih niso bili zaznani arheološki sledovi. Poleg tega je bilo v katalog dodanih 28 novih lokacij ograj in naselij. Obstaja očitna razlika med lokacijami gradišč, omenjenimi v literaturi, in tistimi, ki jih razkrivajo ALS-podatki; le 50 % lokacij v literaturi je v DTM pokazalo jasne obrambne strukture.

Čeprav digitalni terenski modeli visoke ločljivosti, pridobljeni z ALS, bistveno izboljšujejo zaznavanje antropogenih oblik v pokrajini, raziskave prazgodovinske materialne kulture ostajajo fragmentirane. Izjema je tekoče raziskovanje v Osorju, vendar to še vedno ni dovolj za vzpostavitev relativne kronološke sheme gradin po celotnem arhipelagu. Posledično je malo prostora za tradicionalno arheološko ovrednotenje novoodkritih gradišč in ograj na osnovi tipoloških ali kronoloških značilnosti keramičnih materialov ali formalnih analogij naselbinskih elementov.

Zato se razprava osredotoča predvsem na potencial arheološkega daljinskega zaznavanja pri preučevanju topografsko izrazitih naselij v agropastoralnih kraških krajih. Pri tem je treba upoštevati, da suhozidne ograje, vidne v ALS-podatkih, ne predstavljajo nujno (prazgodovinskih) gradišč. Hkrati ALS omogoča premik fokusa z individualnih ograj na prazgodovinske krajine, ki lahko vključujejo obsežne, večsistemsko organizirane obrambne strukture po celotnem arhipelagu Cres–Lošinj.

Pogled iz zraka olajša in poenostavi načrtovanje ciljanih raziskav v prihodnosti, vendar ne nadomešča zahtevnega terenskega dela. Ker so obsežna izkopavanja redka in številni suhozidi ne dajejo najdb, je metoda OSL-PD alternativa, ki lahko v takih primerih zagotovi absolutno kronološko določitev. Kompleksnost agropastoralne kraške krajine arhipelaga, vključno s (prazgodovinskimi) gradišči in ograjami, je lahko izziv, hkrati pa predstavlja zanimivo arheološko priložnost za nadaljnje raziskovanje. Zato so v pričujočo objavo vključene arheološke interpretacije vseh lokacij iz kataloga, da bi torej olajšale nadaljnjo razpravo o suhozidnih krajih arhipelaga nasploh in o gradiščih posebej.

The Emergence of the Iron Age in Osor Through Representative Material Culture

Vzpon železne dobe v Osorju na primeru reprezentativne materialne kulture

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Abstract

Situated at a strategically important position within the Cres–Lošinj archipelago, Osor developed during later prehistory into a (proto)urban settlement and became one of the key centres of the Kvarner region and the northern Adriatic. This research is based on a typological-stylistic, and comparative analysis of published and previously unpublished attire and jewellery finds from three cemeteries, considering their archaeological context and funerary practices. Special emphasis is placed on the types of artefacts identified and their integration into patterns of Iron Age social practices in the Adriatic and wider European regions. The analysis draws on data from archival, systematic, and rescue archaeological investigations, as well as the results of recent absolute dating and bioarchaeological studies.

The aim of the paper is to expand the concept of Osor's archaeology of death through an analysis of representative material culture from closed grave assemblages dating to the initial phase of the Early Iron Age, and to examine its role in the construction of social structures, identities, and networks of interaction. The results indicate internal social differentiation and regional and supra-regional cultural connections, thereby confirming Osor's role as an important node of interaction between the 10th and 8th centuries BCE.

Keywords: Osor, Early Iron Age, burials, material culture, social structure and cultural contacts

Izvleček

Osor, umeščen na strateško pomembno točko creško-lošinjskega otočja, se v mlajši prazgodovini razvije v (proto)urbano naselbino in eno glavnih središč Kvarnerja ter severnega Jadrana. Raziskava temelji na tipološko-stilski in primerjalni analizi objavljenih ter doslej neobjavljenih najdb noše in nakita s treh grobišč ob upoštevanju njihovega arheološkega konteksta ter pogrebnih ritualov. Posebna pozornost je namenjena vrstam najdenih predmetov in njihovemu umeščanju v vzorce železnodobnih družbenih praks jadranskega in širšega evropskega prostora. Uporabljeni so podatki iz arhivskih, sistematičnih in zaščitnih arheoloških raziskav ter rezultati novih absolutnih datacij in bioarheoloških analiz. Cilj prispevka je razširiti koncept osorske arheologije smrti z analizo reprezentativne materialne kulture iz zaprtih grobnih celot začetne faze starejše železne dobe ter ovrednotiti njeno vlogo pri oblikovanju družbenih struktur, identitet in kulturnih stikov. Rezultati kažejo na notranjo družbeno diferenciacijo ter regionalne in nadregionalne kulturne povezave, kar potrjuje vlogo Osorja kot pomembnega vozlišča interakcij v obdobju od 10. do 8. stoletja pr. n. št.

Ključne besede: Osor, starejša železna doba, pokopi, materialna kultura, družbena struktura in kulturni kontakti

Introduction

Osor, situated at a highly sensitive point connecting the Cres–Lošinj archipelago (fig. 1), had already emerged during later prehistory as one of the key centres of the Kvarner region and the wider northern Adriatic area (Blečić Kavur 2014; 2015). Its importance arose primarily from its geographical and ecological position, as well as from the ways in which local communities actively shaped and exploited

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the environment for economic, social, and cultural purposes. Geographical and geological advantages, together with control over major maritime communication routes, enabled Osor to develop strong socio-economic potential, comparable to that of mainland and other insular centres. In this context, the island setting itself – despite its inherent constraints – did not represent an obstacle, but rather a framework within which Osor progressively developed through networks of social and cultural relations, as well as sustained in long-term a population within its landscape throughout later prehistory (Blečić Kavur and Kavur 2025).

Previous discussions on the archaeology of death and excavations at Osor focused on a comprehensive analysis of burial methods and practices during the Bronze and Iron Ages, as the largest assemblage of preserved material derives from burials and graves (Blečić Kavur 2015). As a result of archival research and new systematic and rescue excavations Čaušević-Bully et al. 2017; Los 2018; Bully et al. 2024; Baričević et al. 2025), a substantial body of new data has been obtained concerning the topography and typology of graves. These data have been fully evaluated and interpreted in their mutual interconnections, revealing burial grounds distributed across several different locations both within and beyond the urban perimeter of Osor (fig. 1).

The three necropolises presented here – at Kavanela–Preko mosta, near the church of Sv. Marija (St Mary), and at the monastery of Sv. Petar (St Peter) – attest to a relatively sizeable population already during the Late Bronze Age and the early phase of the Iron Age, as well as to the community's need to bury their dead in different, yet strategically significant, locations (fig.

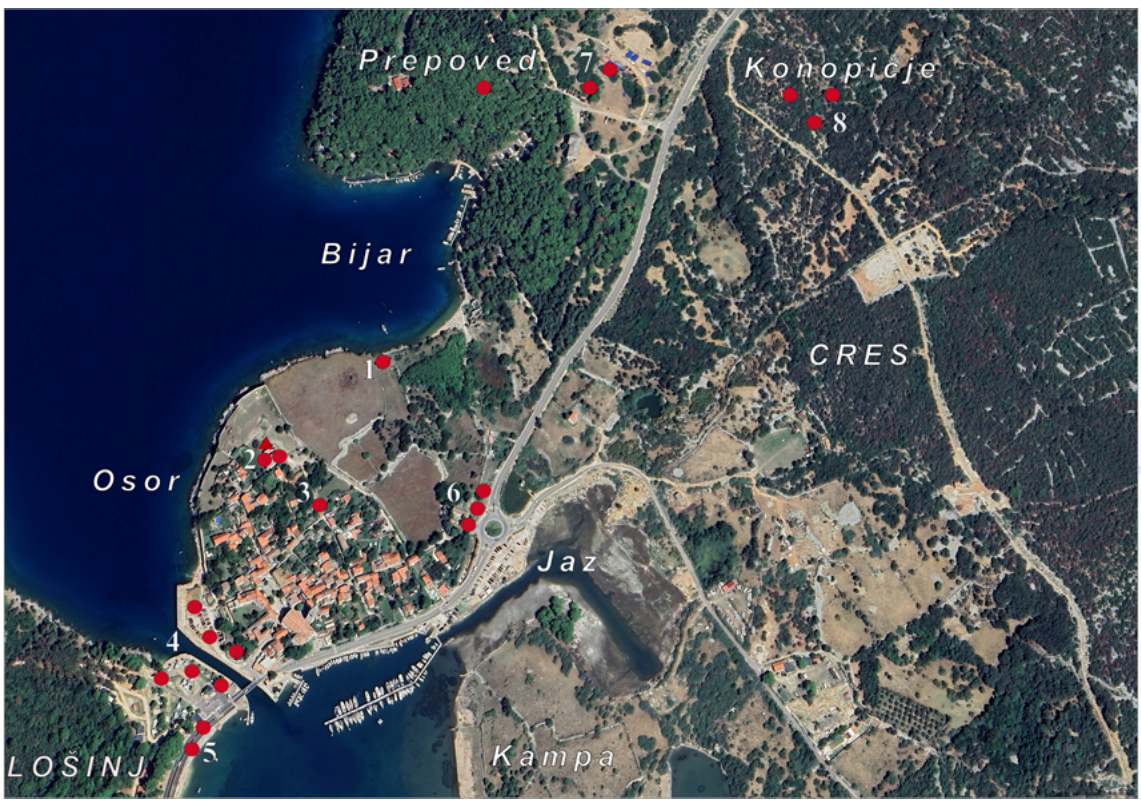


Figure 1: Topography of Osor Graves and Burials: 1 Sv. Katarina, 2 Sv. Petar, 3 Osor, 4 Kavanela, 5 Preko mosta, 6 Sv. Marija, 7 Mala Prepoved, 8 Konopičje (Blečić Kavur and Kavur 2024, fig. 1)

1). According to the current state of research, the most commonly accepted burial practice involved interment in flat graves or burials beneath tumuli (burial mounds). Inhumation predominated, while cremation was considerably rarer, reflecting specific cultural or ideological meanings as well as chronological distinctions. In the case of inhumation burials, the deceased were placed in a crouched or seated position within stone chests, from which the richer graves derive, containing a greater number and diversity of grave goods (Blečić Kavur 2021; Blečić Kavur and Kavur 2024).

This study broadens the concept of so-called Osor archaeology of death by analysing representative material culture contextualised in relation to individual graves and necropolises from the initial phase of the Early Iron Age. By comparing and evaluating both published and previously unpublished artefacts within a typological–stylistic and comparative framework, the study draws on data from archival, systematic, and rescue archaeological investigations, as well as new absolute dates and bioarchaeological studies. The aim is to reinterpret material culture within newly defined closed assemblages and a more precise chronological framework, considering it as an indicator of social structures and identities, networks of interaction, and cultural connections within broader regional and historical patterns from the 10th to the 8th centuries BCE.

Material Culture in Time and Space

To understand and reconstruct the ways of life of communities inhabiting the Osor area during the dynamic periods of later prehistory, material culture forms the foundation of all research. The first comprehensive overview of the assemblage was provided by Glogović (1982b; 1989), who identified Osor as one of the most important sites of this period in the Kvarner region. This was followed by specialised studies, syntheses, and overviews (e.g. Glogović 1982a; 1988; 2003; Blečić Kavur 2010; 2012; 2014; 2015; 2017; 2020; 2021), which expanded knowledge of individual valuable or distinctive artefacts and, consequently, broadened perspectives on the internal dynamics of the community, its economic practices, presumed social stratification, and symbolic and identity-related patterns.

Due to the lack of documentation from earlier excavations and the questionable circumstances of discovery, scholarly focus was until recently largely directed towards typological and stylistic analyses and the possible chronological determination of a substantial number of metal objects. These objects mostly originated from destroyed graves or from the ritual pyre of the western necropolis at Kavanela (Glogović 1982a; 1982b; 1989; 2003; Ćus-Rukonić 1981; Blečić Kavur 2010; 2014, 25–7; 2015, 25–8; 2020), and to a lesser extent from other topographical locations within and beyond the urban area (Mladin 1960; Mihovilić 2013; Blečić Kavur and Kavur 2013; 2024; 2025).

Outside the City Walls

As described above, burial outside the perimeter of the present-day settlement – and presumably also outside the Iron Age settlement – certainly took place at three deliberately chosen locations (fig. 1). Two necropolises were situated on the landward sides along the main approaches to the settlement. The larger was located along the south-western side of the fortifications, on the approach to and on the Kavanela isthmus from the Lošinj side. The second was established along the eastern extension of the fortifications, near the present-day cemetery and the church of Sv. Marija, marking the approach to the settlement from the Cres side (Blečić Kavur and Kavur 2024, 20–8).

Kavanela

At the so-called western necropolis, divided by the Osor isthmus of Kavanela, the first and most extensive investigations of the prehistoric and Roman necropolis – extending as far as the chapel of Sv. Stjepan (St Stephen) – began in the 19th century (fig. 1). The beginning of the Ear-

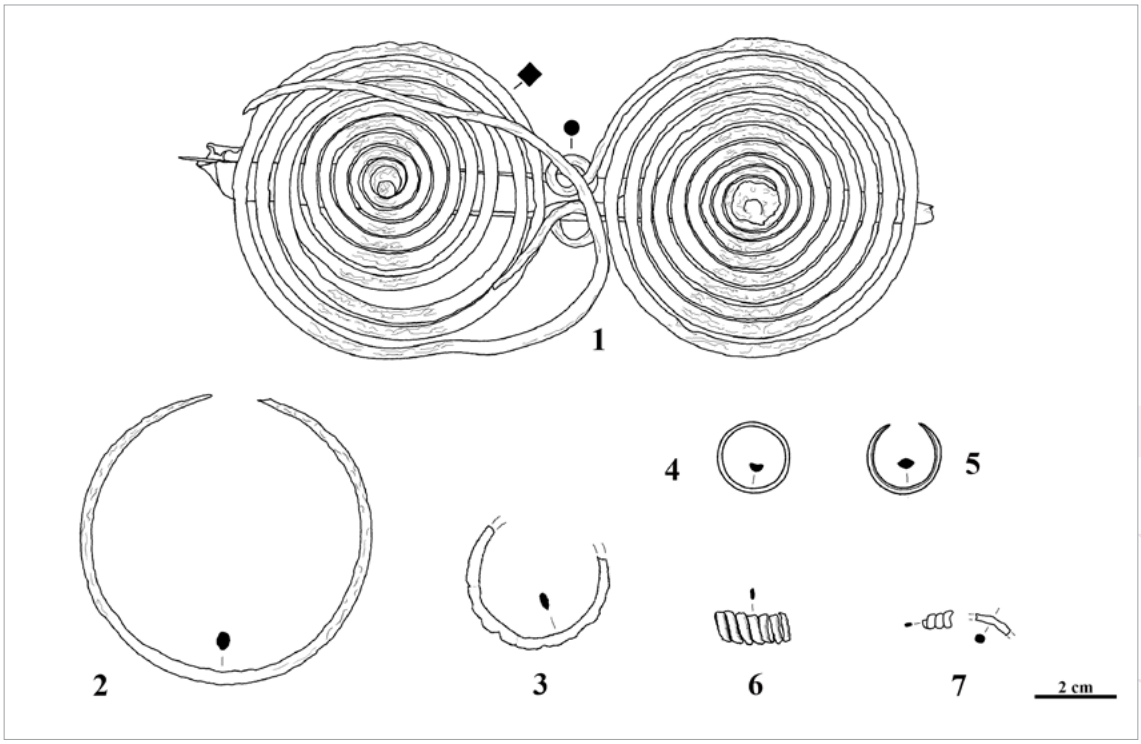


Figure 2: Preko Mosta, Inventory From a Grave 8 (drawings by Valeria Medić, 2018)

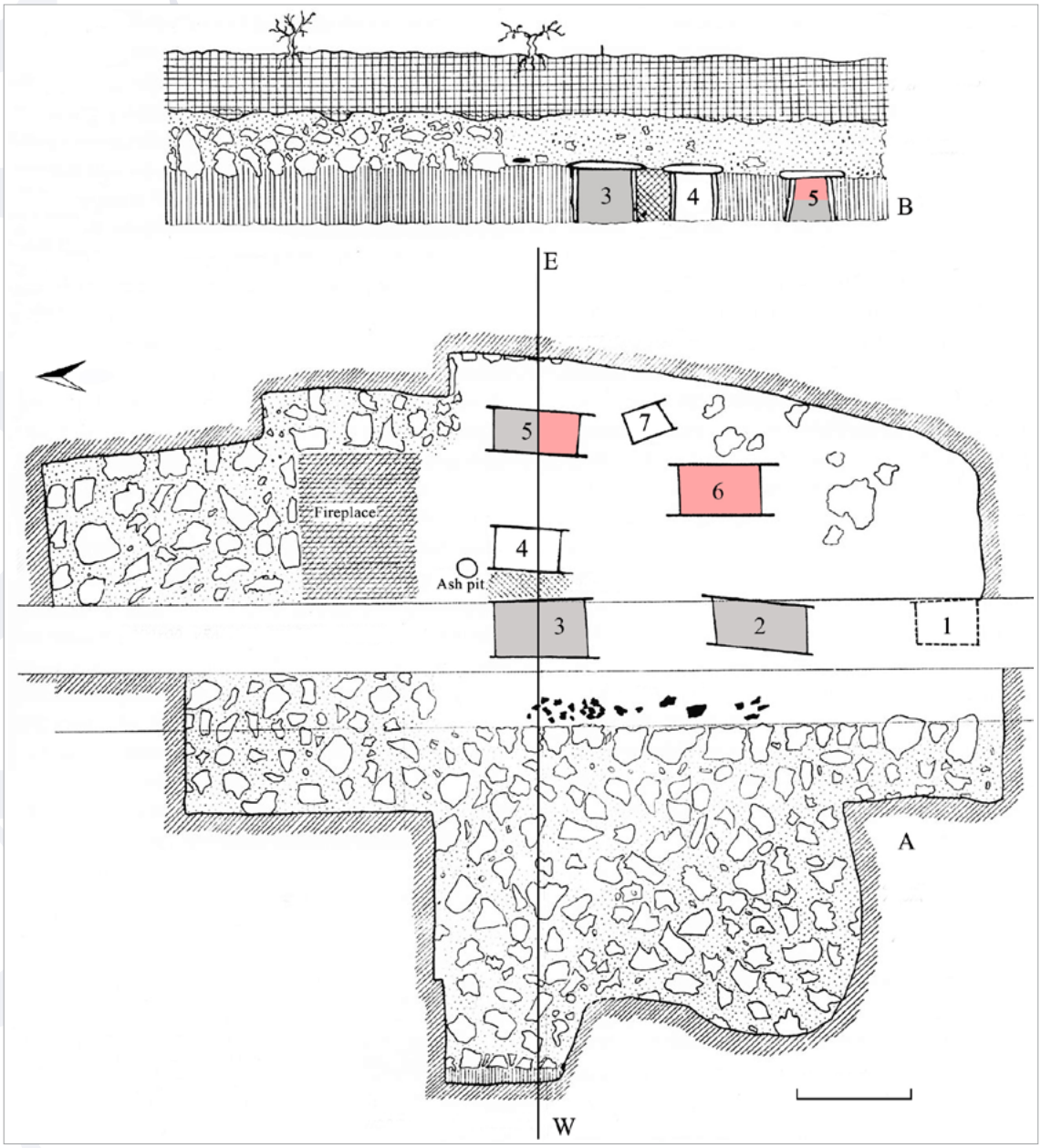
ly Iron Age could be defined solely on the basis of the collected attire and jewellery items, which have since been evaluated, placed within a broader cultural and chronological context, and published (cf. Glogović 1982a; 1982b; 1988; 1989; 2003; Blečić Kavur 2010; 2012; 2014; 2015; 2017; 2020; 2021). More recent investigations in the Kavanela area along the fortifications did not document new graves; however, these were recorded further south on the Lošinj side, along the stretch from the Preko mosta site to Nerezine (fig. 1) (Janeš et al. 2025).

Preko mosta

The recently excavated graves from the southern Preko mosta site on the island of Lošinj complement the wider cemetery area at Kavanela (fig 1; 2). Most of the interments date to the Roman period, with only three Iron Age graves investigated, indicating that the prehistoric necropolis reached its southernmost extent at this location. Skeletal remains were documented in small burial pits carved directly into the bedrock (Los 2018, 12–4; Burmaz et al. 2025). In this context, grave 8 is the most significant, as it contained an Adriatic-type spectacle fibula with decorative round plates on a spiral, accompanied by ring jewellery and spiral wires (fig. 2). Although the circumstances of discovery at the site allow for more precise dating, and the collected skeletal material is extremely degraded (Los 2018, 12), the grave can be typologically associated with the Early Iron Age tradition, that is, within the 9th–8th centuries BCE.

Sv. Marija

The first direct evidence of the discovery of material culture and burial assemblages was confirmed by the investigation of the tumulus at the cemetery church of Sv. Marija in 1959 (fig. 1; 3) (Mladin 1960; Glogović 1989, 6, fig. 3, pl. 3; Blečić Kavur 2010, 134–5, fig. 93; cf. Teržan 2013, fig. 3). Seven graves containing eight inhumations in crouched or seated positions with-



Figue 3: Sv. Marija, Plan of the Graves in the Tumulus: grey – men's, red – women's, white – children's graves (Blečić Kavur and Kavur 2024, fig. 6)

in stone chests were discovered in the tumulus. Several assemblages provided valuable contextual data, enabling the formulation of a hypothesis regarding a family tumulus with kinship ties among the interred individuals (Mladin 1960, 214; cf. Teržan 2013, 246)!

Mladin reports that grave 1, destroyed during the infrastructural works (fig. 3), contained two small cast bronze bracelets and an amber bead, and thus attributed the grave to a child burial (fig. 4, 1–2) (Mladin 1960, 221)! Grave 2 yielded the only pin from this burial mound

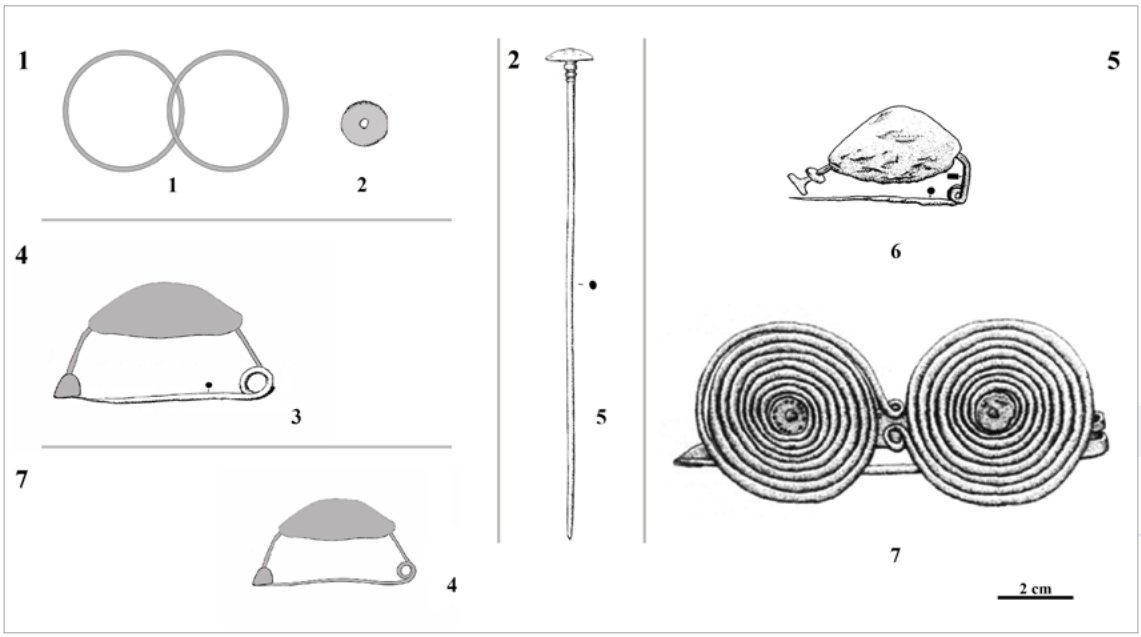


Figure 4: Sv. Marija, Inventory From Graves 1, 2, 4, 5, and 7 (Glogović 2003, pl. 30, 204; 36, 265; adapted by M. Blečić Kavur, 2025)

and was assigned to a male individual (fig. 3; 4, 5) (Mladin 1960, 221, pl. 11, 4; Glogović 1989, pl. 6, 1; Blečić Kavur 2010, pl. 39, 537). Based on its typological characteristics, the pin was grouped with those having a large and slightly conical head, representing a complete exception in the eastern part of the northern Adriatic, yet closely related to pins from northern Italic and pre-Alpine areas of the second half of the 9th century BCE (Škvor Jernejčič 2014, fig. 5).

Fibulae were recorded in four graves. Those, most likely bow-shaped fibulae with amber bead on the bow, from graves 4 and 7 have been lost (fig. 3; 4, 3–4), while the most significant examples are from assemblages 5 and 6. Grave 5 is the only known example to date of a so-called secondary burial recorded in Osor burial practices (fig. 3; 4, 6–7) (Mladin 1960, 221–2; Blečić Kavur and Kavur 2024, 22–6). In this grave, a male individual was primarily interred, and a female individual was placed in a secondary position. A larger Adriatic-type spectacle fibula was found beneath the head of the female, while the bow-shaped fibula with amber bead on the bow was placed beside her left shoulder (Mladin 1960, pl. 8, 2; 10, 2; Glogović 2003, pl. 30, 204; 36, 265; Blečić Kavur 2010, pl. 39, 539–40).

The richest assemblage was documented in grave 6 (fig. 3; 5). In addition to the spectacle fibula and four bow-shaped fibulae with amber bead on the bow, it contained an Osor-type fibula, numerous amber beads, rare glass beads from a necklace, four tubular bronze-sheet bracelets with additional rings, four rings, two looped buttons, and a biconical ceramic spindle whorl (Mladin 1960, 222; Blečić Kavur 2010, pl. 40; Teržan 2013, pl. 1).

In its immediate vicinity, grave 7 was also found (fig. 3), containing the burial of a younger individual or child, accompanied by a bow-shaped fibula with amber bead on the bow (fig. 4, 4). Mladin associated this grave more closely with the female individual in grave 6, suggesting a possible kinship link between them (Mladin 1960, 214–5, 222, pl. IIA; cf. Blečić Kavur and Kavur 2024, 25)!

The spectacle fibula from grave 6 is damaged, although the discs were made from wire of

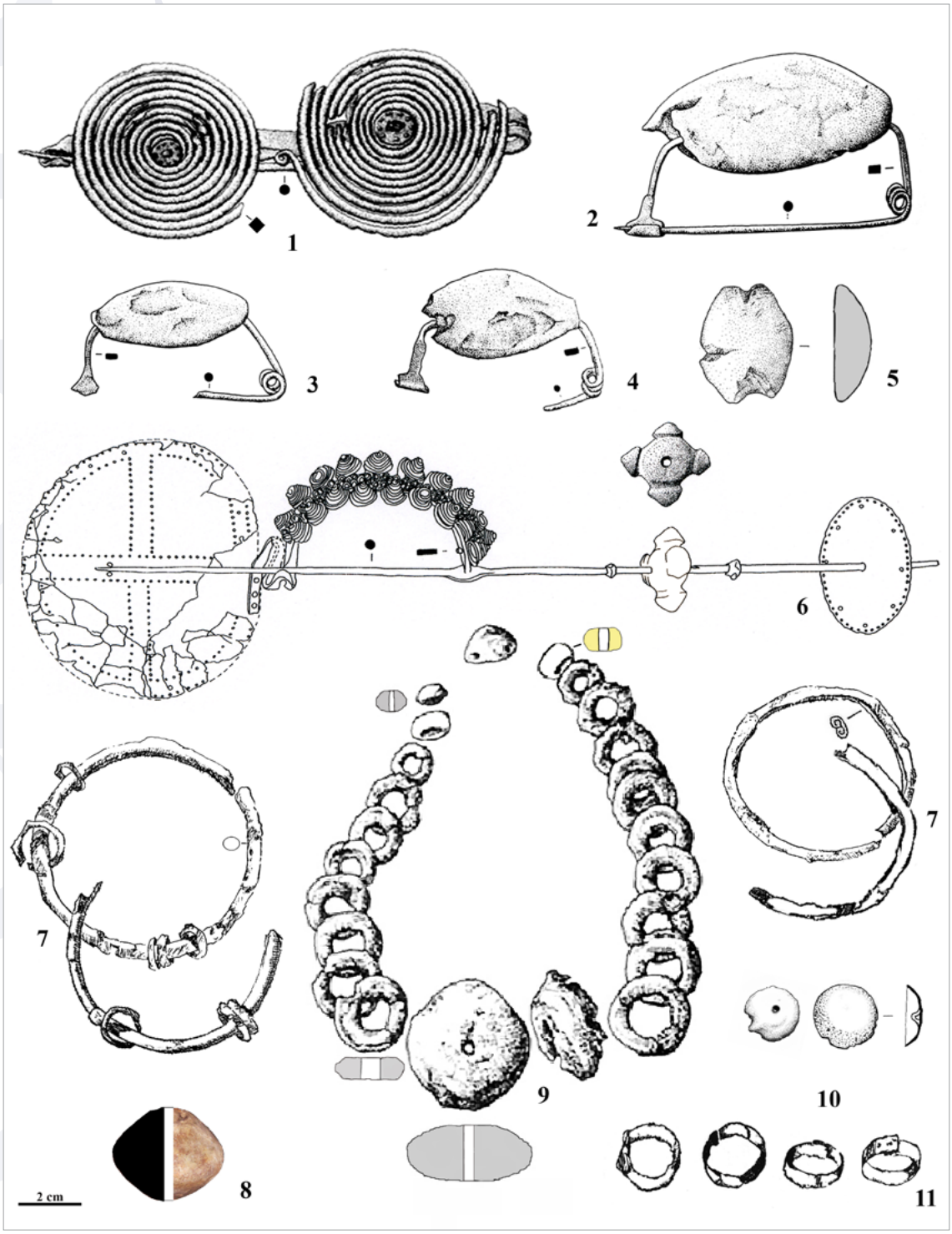


Figure 5: Sv. Marija, Inventory From Grave 6 (Mladin 1960, pl. 8, 1, 5; 9; 10; 11, 2–3; 12; 13; Buršić-Matijašić 1990, pl. 2, 1–3, 6–7; 3, 5–6; Glogović 2003, pl. 27, 177; 36, 257–9; 39, 294; 44, 341; adapted by Martina Blečić Kavur, 2025)

square cross-section, with a small central loop of the circular cross-section (fig. 5, 1). It is classified as an Adriatic type, or Type B according to Lo Schiavo (1970, 443, pl. 30, 3–4; cf. Kilian 1985, 250), and as the Nin type according to Pabst (2012, 80–2, fig. 21; 24). This was a dominant item of attire, with the closest parallels recorded at the Kavanela cemetery, where as many as 11 or 12 fibulae, either complete or in fragments, have been documented (Glogović 2003, pl. 26, 171, 173–4; 27, 176, 178; Blečić Kavur 2010, pl. 43, 573–8). Additional finds are known from the islands of Krk and Rab (Glogović 2003, pl. 26, 172; 31, 214; Blečić Kavur 2010, pl. 28, 403; 31, 428; 35, 497), as well as from sites in northern and central Dalmatia, while they are entirely absent in Istria and the nearby inland (Glogović 2003, 25–30). All of these fibulae are of larger dimensions; the wires of the discs converge in a small central loop, and the straight bar and pin are attached to the discs with rivets, usually covered by a thin decorated bronze plate (Blečić Kavur 2010, pl. 39, 539; 40, 541; 42, 568–72; 43, 579).

As with other cultural groups of the Adriatic basin, where the circumstances of discovery are well documented, spectacle fibulae in the Osor community were associated with female and/or child burials, with their size possibly playing a role (Glogović 1989, 24; cf. Pabst 2012, 177). They were often found together with other types of fibulae, particularly bow-shaped fibulae with amber on the bow, as well as two-part bow fibulae with a disc on the foot of the Osor type, fragments of which are well known from earlier excavations at Kavanela (Glogović 2003, 29–30; Blečić Kavur 2010, pl. 44, 586–96).

Alongside the spectacle fibulae, both graves 5 and 6 also contained bow-shaped fibulae with amber beads on the bow (fig. 4, 6; 5, 2–5). With a total of seven examples, this was the most numerous type investigated at this cemetery, and they had also been recorded during earlier excavations at Kavanela (Ćus-Rukonić 1981, pl. 1, 2–3; Glogović 2003, 36, 38, 41, pl. 36, 256–9, 274; 39, 294; Blečić Kavur 2010, pl. 45, 598–602). These are simple, single-looped bow fibulae of rectangular construction, most of which belong to Type 63a with a larger bead, while only one Osor example – from Kavanela – was assigned to Type 63b with a smaller, flatter bead, according to the typological classification of Palavestra (1993, 64, 213; 2006, 46, fig. 17). The closest parallel is a fibula from destroyed graves at Vidasa na polju near Novalja on the island of Pag (Glogović 2003, 36, pl. 37, 274), while they are more commonly found in the Liburnian area at the Zaton and Nin necropolises (Lo Schiavo 1970, 431, 482, pl. 26, 2, 5; Batović 1965, fig. 15, 9–15; 1968, pl. 10, 1; 11, 1–2; 12; 1976, 63, C6; Hiller 1991, 94–97). Further very close parallels are found in the graves of Este and Ca' Morte, Verucchio, and Bologna, where they marked the second phase (Boiardi and von Eles 1994, 36, pl. 8, 16–17; Gentili 1994, pl. 18; Negroni Catacchio 2009, 201, fig. 4, 6), as well as the contemporaneous phase of the Piceni culture (Negroni Catacchio 2003, 465–7; Trachsel 2004, fig. 135, 18). These fibulae belong to a long-lasting form within the Adriatic area, and it is considered that they were in use from the 9th to the 6th centuries BCE (Glogović 2003, 41).

The described grave 6 also contained an elaborate two-part Osor-type fibula (fig. 5, 6) (Mladin 1960, 221–2, pl. 11; Glogović 2003, pl. 44, 341; Blečić Kavur 2010, 145, fig. 93; 94, 1; 95; pl. 40, 542–6). This is the first and richest association of carefully selected jewellery and status elements of attire found in Osor graves. Extensive studies have been published on these fibulae (Glogović 1982a; 1989, 25–8; 2003, 43–5; Hiller 1991, 53–6; Blečić Kavur 2010, 134–51; cf. Kukoč 2013; Teržan 2013; 2021). They are particularly significant as one of the few types named after an eponymous site in the Kvarner region, as proposed by Lo Schiavo (1970, 434, pl. 27, 1). Although they originate from only three sites – Osor, Krk, and Punat – with other examples known from the narrower Liburnian area, the highest concentration is in the Kvarner region, represented in two variants: the Osor variant (I) and the Krk variant (II) (Blečić Kavur 2010, 134–51), which differ in the shape of the bow, the pin, and the decorative elements (fig. 6).

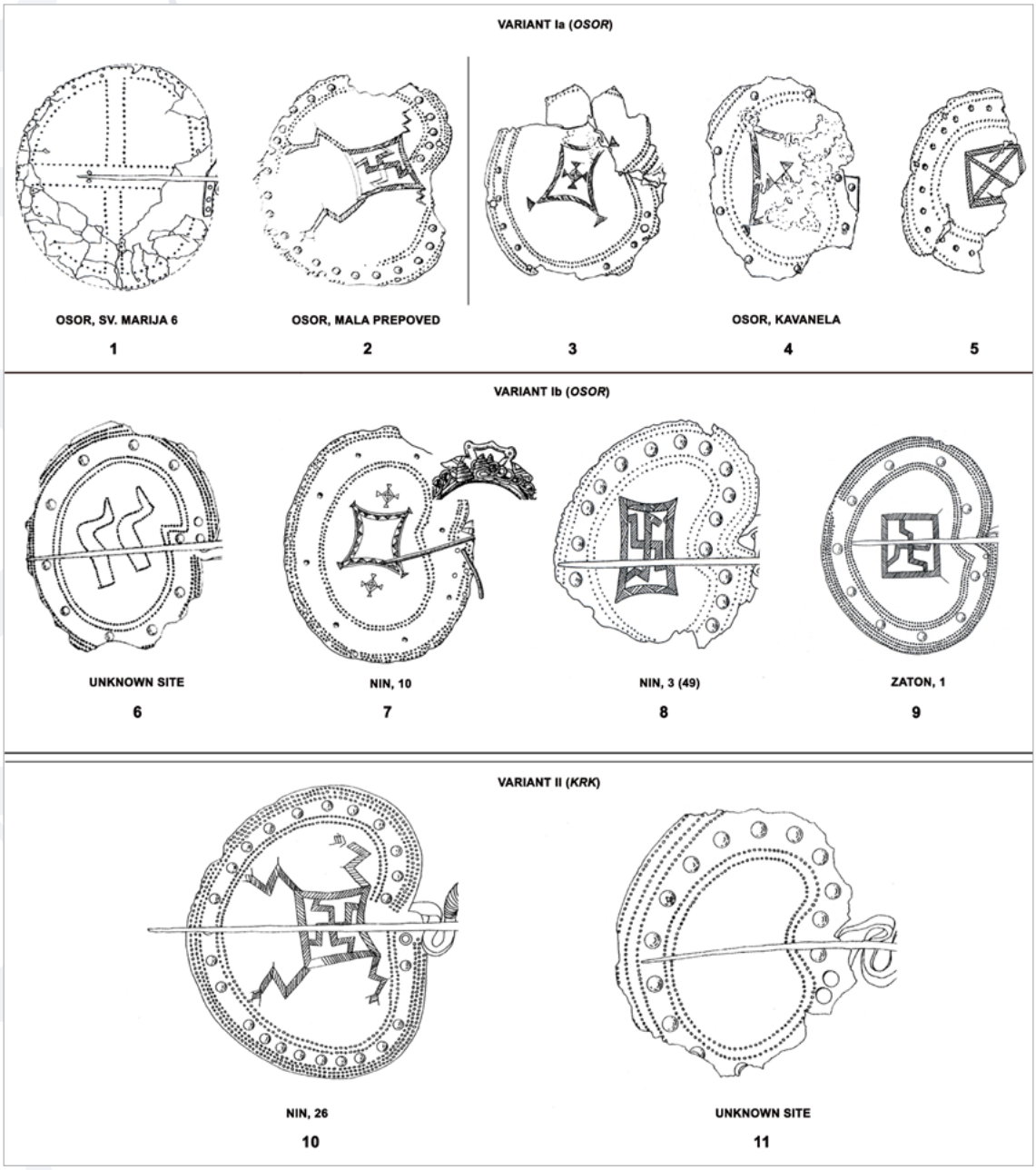


Figure 6: Decorated discs of Osor-type fibulae, including variants and subvariants, from Kvarner and Dalmatian sites (Glogović 2003, pl. 43–46; adapted by Martina Blečić Kavur, 2025)

From Osor, only examples of the Osor type and variant are known, that is, the larger, composite bow fibulae (fig. 6, 1–5). They consist of a long pin, either twisted or wrapped with wire, with a foot in the form of a disc and a bow that is elevated and subsequently attached to the pin. The bow is further decorated with inserted wire coiled in spirals and twisted loops, and sometimes with an added amber bead and a bronze circular disc at the end of

the pin (Blečić Kavur 2010, pl. 40, 546; 41, 553; 44, 585).

The origin of this fibula can be reliably traced to italic *fibulae a disco* (Merhart 1942, fig. 1, pl. 2; Trachsel 2004, 198–218, fig. 127; 134), which are closely related to single-piece Picene examples (Lucentini 1999, 258, fig. 478; 2007, 104, fig. 6). However, as all Kvarner and northern Dalmatian fibulae are two-part (fig. 6), with amber beads added to the long pin, this fibula has been defined as characteristic luxury jewellery of the second phase of the Liburnian culture (Batović 1987, 350, pl. 37, 13; 38, 21), as well as of the Kvarner cultural group (Blečić Kavur 2010, 140, fig. 279; 2021, 537–8), with widespread use throughout the 8th century BCE (Kukoč 2013). In this way, a distinct local expression in attire was manifested, while typical jewellery elements from the wider Adriatic basin were adopted, highlighting the possibility of regional production specifically in the Kvarner area and northern Dalmatia.

Fibulae from Osor (Mladin 1960, 219, 222, pl. 13; Glogović 1982a, 74–84, pl. 2–4; 1982b, 36, fig. 2, 4–6; 1989, pl. 22, 3–7; 23, 5), Nin (Batović 1968, pl. 10, 2; 1976, fig. 13, 4; Hiller 1991, 53–6, pl. 8, 97; 27, 300; 30, 343; Majnarić-Pandžić 1998, fig. 134), and Zaton (Batović 1965, fig. 14, 1; Hiller 1991, pl. 49, 517; Glogović 2003, 43–4, pl. 43–6), which belong to the eponymous type and variant, are morphologically very similar. They are distinguished by ornamentation, i.e., the iconographic content of exclusively geometric motifs on the foot disc, of which only the fibula from the tumulus at Sv. Marija stands out with a completely different concept (fig. 5, 6; 6, 1). Even the shape of the amber bead on the pin was not entirely identical, as Liburnian fibulae have round beads, whereas Osor examples have polygonal beads (Blečić Kavur 2010, pl. 40, 546; 41, 553; 44, 586–95). Despite the description, Palavestra does not differentiate between these two bead types, but classifies them under Type 69, associated with the fibula (Palavestra 1993, 58–9, 63, 219).[1] The incised decorative and symbolic-semantic programme on the discs of the Osor examples is varied and non-uniform, and in detail does not correspond to Liburnian specimens (fig. 6). On Osor fibulae, the most common motif is a square, with either concave or straight sides, often combined with a so-called *patee* or Mantuan cross, of which two examples from Kavanela have been preserved. In fact, these two motifs appear in much smaller numbers and in different compositions on fibulae from Nin (graves 10, 3/49) (fig. 6, 7–8).

A motif characteristic of the Liburnian area is the swastika, depicted in various forms or combined with the schematised frog motif on the Krk (II) variant fibula, as seen in Nin grave 26 (fig. 6, 10) (Batović 1976, fig. 13; 1987, pl. 37, 13; Glogović 2003, 45). This motif also appears on the Osor variant fibula from the grave at Mala Prepoved (fig. 7, 1), but aside from the type of fibula, it differs in execution. In addition to the swastika, the bird motif is absent from the iconographic programme of the Osor examples, whereas it dominates, rendered in various ways, on Liburnian fibulae. The cross and St Andrew's cross motifs are so far known only from Osor and, like the polygonal beads and the round disc on the pin, represent its distinctiveness (fig. 6). Glogović associated the cross motif on the Osor fibula more closely with related fibulae from the Terni necropolis, highlighting a possible stronger Italic influence on the workshop producing the Osor examples, which probably operated in Osor itself (Glogović 1989, 27; 2003, 45; Blečić Kavur 2010, 140; 2021, 537–8).

The spectacle fibulae, bow-shaped fibulae with amber bead on the bow, and Osor-type fibulae from graves 5 and 6 thus provided the only basis for determining the upper chronological limit of their appearance in both Osor and the wider Kvarner region. Accordingly, the female individual from grave 5, and the younger individuals from graves 4 and 7, were placed with-

1 Chronologically and geographically, the closest parallels to the polygonal beads are from the Casa di Ricovero in Este (Chieco Bianchi and Calzavara Capuis 1985, pl. 298, 235e).

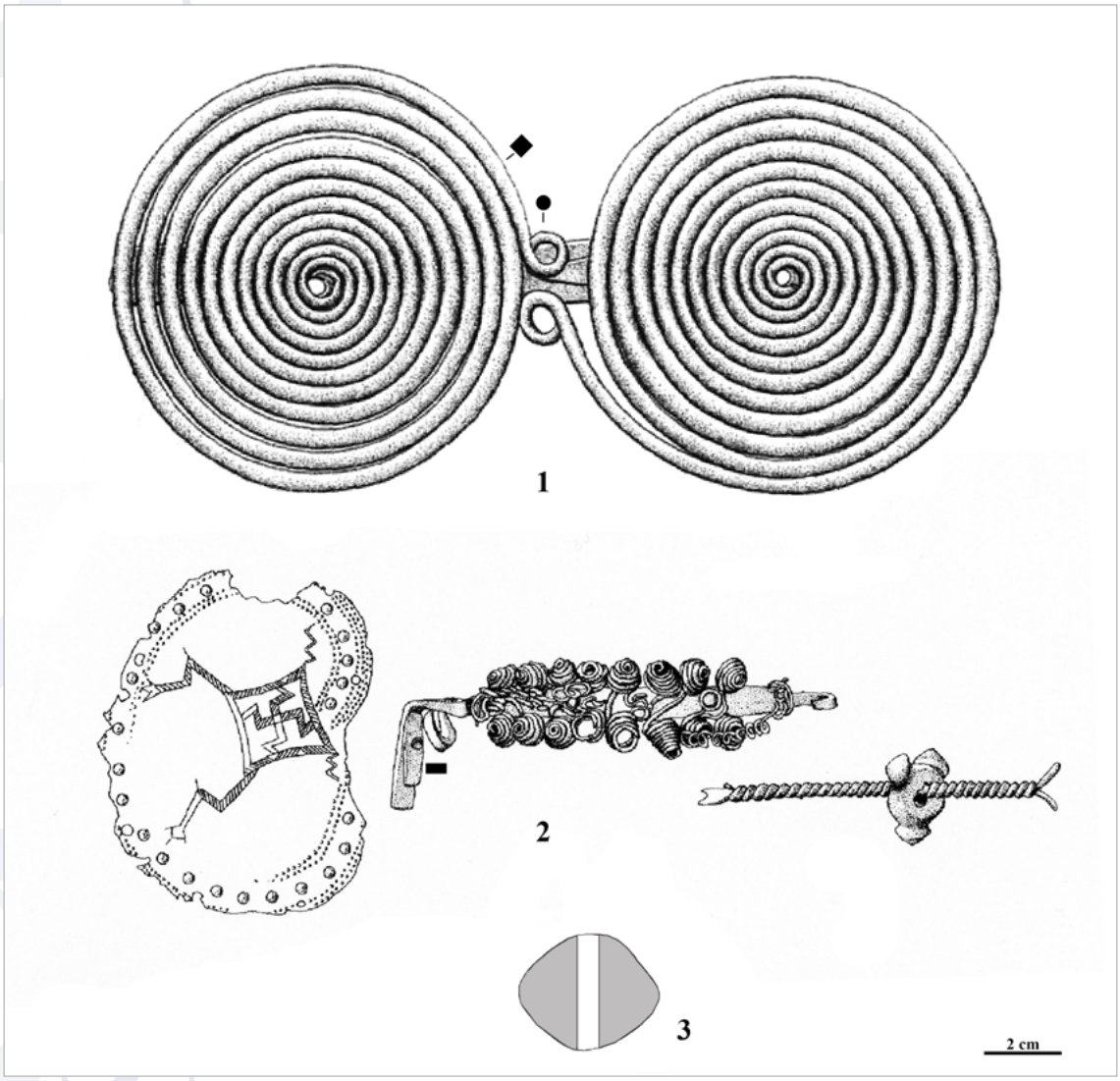


Figure 7: Mala Prepoved, Selection From a Grave (Glogović 2003, pl. 26, 175; 45, 342; Blečić Kavur 2021, fig. 2, 5)

in the same chronological horizon as the female from grave 6, i.e., in the second half of the 9th century and the beginning of the 8th century BCE, equivalent to phase 2 of the Kvarner group (Glogović 2003, 45; Blečić Kavur 2010, 127–30). This corresponds to the contemporaneous chronological span in Italic contexts of central and southern Italy, where single-part bow fibulae with a disc on the foot do not appear after the 9th century BCE, i.e., after the initial *Primo Ferro* 2 phase. Exceptions are found only in contexts dated to the early 8th century BCE (Pacciarelli 2001, 54, fig. 30; Tamburini-Müller 2006, 39, pl. 2, 3.4–3.6; 64, 36; Lucentini 2007, 104, fig. 6c).

The proposed chronological framework for the use of the described jewellery assemblage, established through typological-stylistic and comparative analysis, is further supported by the absolute dating results of skeletal remains from three individuals to the final decades of the 9th

century BCE.[2] Bioarchaeological analysis determined that graves 2 and 3 contained two older male individuals, while a younger individual aged between 9 and 11 years was buried in grave 4. The skeletal remains from grave 6 undoubtedly belonged to an adult (Novak 2025; Novak et al. 2025), who, based on the associated grave goods, is identified as female. A large quantity of various animal bone fragments was recovered from all the described graves.

Grave 6 also contained other jewellery, including two pairs of tubular bronze bracelets similar to those from Kavanela (Glogović 1989, pl. 37, 6; Blečić Kavur 2010, pl. 50, 793–802) and Sv. Petar (fig. 11, 4), simple bronze rings and smaller hoops, as well as an amber bead necklace composed of beads of various shapes with two yellow glass beads (Buršić-Matijašić 1990, pl. 2, 1–3, 6–7; 3, 5–6). Small blue glass beads, two bronze buttons with small loops and a biconical ceramic spindle whorl were also included in the grave assemblage (fig. 5).

The presence of the spindle whorl is particularly significant (fig. 5, 8), as in rich female graves of the Etruscan necropolises of Tarquinia and Vulci, where a higher number of single- part disc-on-foot fibulae with geometric decoration are found, spindle whorls and/or bobbins are almost invariably present. These have been interpreted as indicators of social status, economic position, and the privileged role of women as bearers and custodians of household production, particularly spinning and weaving (Torelli 1997, 59–73; Pacciarelli 2001, 244, 247; cf. Gleba 2009). In this context, grave 6 can also be understood as a local variant of the same codified scheme: a complex attire with multiple sets of fibulae and jewellery, complemented by a ceramic spindle whorl for spinning. While the association of women with weaving is typically a binary interpretation, reflecting stereotypical assumptions about gender roles in the past (cf. Arnold 2016), the assemblage of objects and the iconography of the fundamental symbols present on Osor fibulae do not merely represent decoration, but conceptualise time and its cyclical nature – endless, like the very act of weaving (Torelli 1997, 59–62; Primas 2007, 306–11; cf. Gleba 2009).

Mala Prepoved

The largest known Adriatic-type spectacle fibula from Osor was identified among the 'collection' of Kavanela material during a review at the Archaeological Museum of Istria in Pula. According to field documentation and the report by Baćić, it was associated with a distinct crouched skeletal burial in a stone chest excavated in a tumulus at Mala Prepoved (fig. 1; 7, 1) (Baćić 1963, 1–2; 1967, 3–4; Blečić Kavur and Kavur 2024, 26). The grave assemblage also included a very large two-part Osor-type fibula (Glogović 2003, pl. 26, 175; 45, 342; Blečić Kavur 2010, pl. 43, 579; 44, 585), a ceramic spindle whorl (fig. 7, 2–3), and small fragments of coarse pottery around the grave – an ensemble of objects which, in reduced form, corresponded to that of grave 6 at the more southerly Sv. Marija. This not only confirms burial at a location above the cove at Bijar but also affirms the combination of these two indicative items as markers of particularly prominent female individuals. Although the osteological material has not survived, the burial likely belonged to a female individual, as indicated not only by the characteristic fibulae but also by the ceramic spindle whorl. As the only element relating to spinning and weaving, it most probably reflected the role and status of the deceased within her (narrower or wider) Iron Age community.

Within the City Wall

Evidence for burials within the settlement perimeter has existed since the earliest excavations in the 19th century, but only more recent research has provided direct confirmation. Individual graves have been identified from the chapel of Sv. Katarina to the monastery of Sv.

2 The dates are FTMC-OG28-1 2576±33 BP, FTMC-OG28-2 2561±32 BP and FTMC-OG28-3 2628±32 BP (Novak 2025).

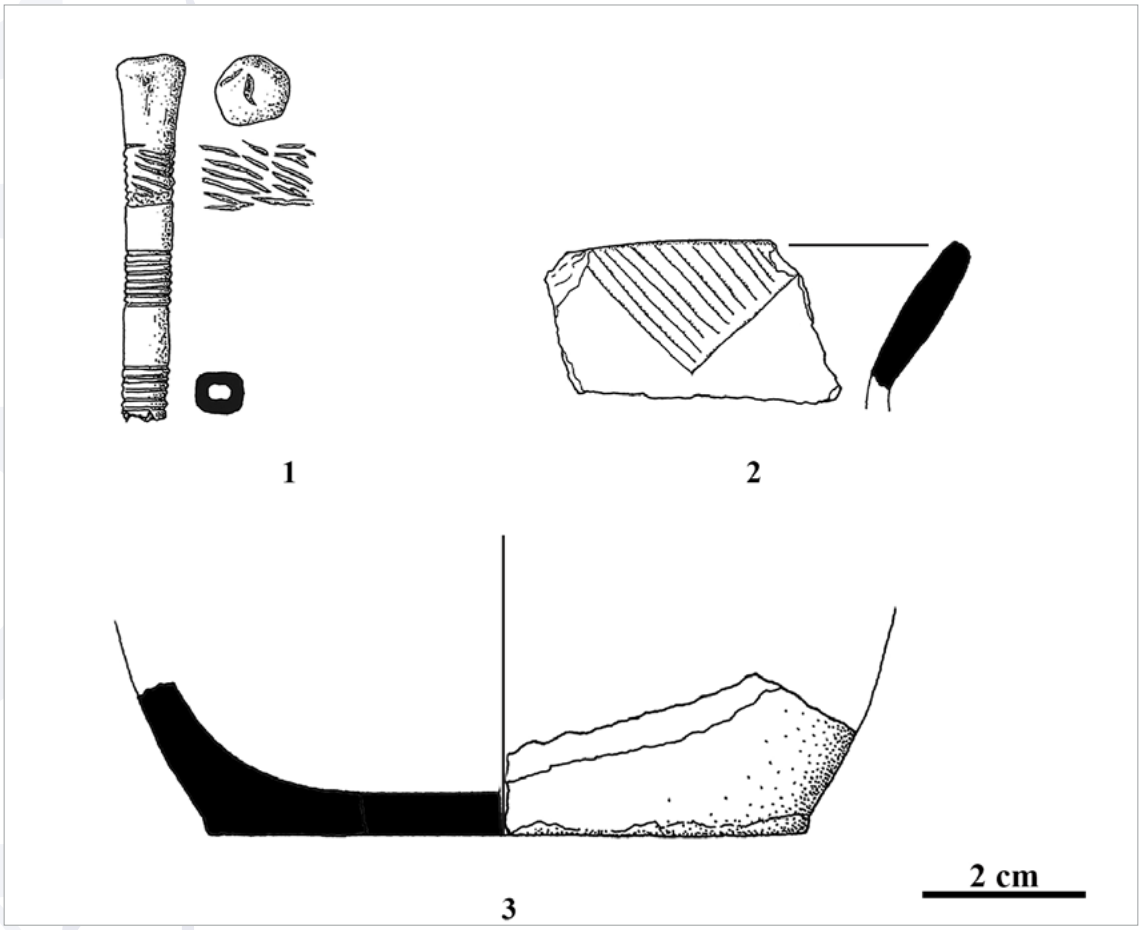


Figure 8: Sv. Katarina, Inventory From a Grave (Mihovilić 2013, fig. 4, 1–3; adapted by Martina Blečić Kavur, 2025)

Petar and at its foothill (fig. 1). In total, nine graves, representing different burial methods and rites, significantly contribute to the understanding of funerary strategies within the living space of Iron Age Osor (Blečić Kavur and Kavur 2024, 17).

Sv. Katarina

In 1962, a skeletal burial in a crouched position was excavated at this location (fig. 1; 8), the only one confirmed so far on the northern approach to Osor. Grave goods included pottery fragments and a bone handle of an awl (Mihovilić 2013; Blečić Kavur and Kavur 2024, 17[3]). The handle was made from the metatarsal bone of a sheep or goat, square in cross-section at the base and round at the upper part, decorated with incised fields consisting of two pairs of multiple parallel lines running around the bone and a single field of shorter lines incised obliquely at the proximal part (fig. 8, 1). Handles decorated in this manner are rare finds. However, in the nearby area, smooth but undecorated examples have been found at Nesactium and the Lim hillfort (Mihovilić 2013, 219), as well as further north in grave 22 of the St Barbara necropolis at Elleri (Montagnari Kokelj 1997, pl. 25, 22). Many more and better parallels are found in the northern Italic cultural sphere, already from the Terramare and Peschiera horizons (Provenzano

3 In the cited publication, the grave was mistakenly attributed to the Early Bronze Age; this is corrected here.

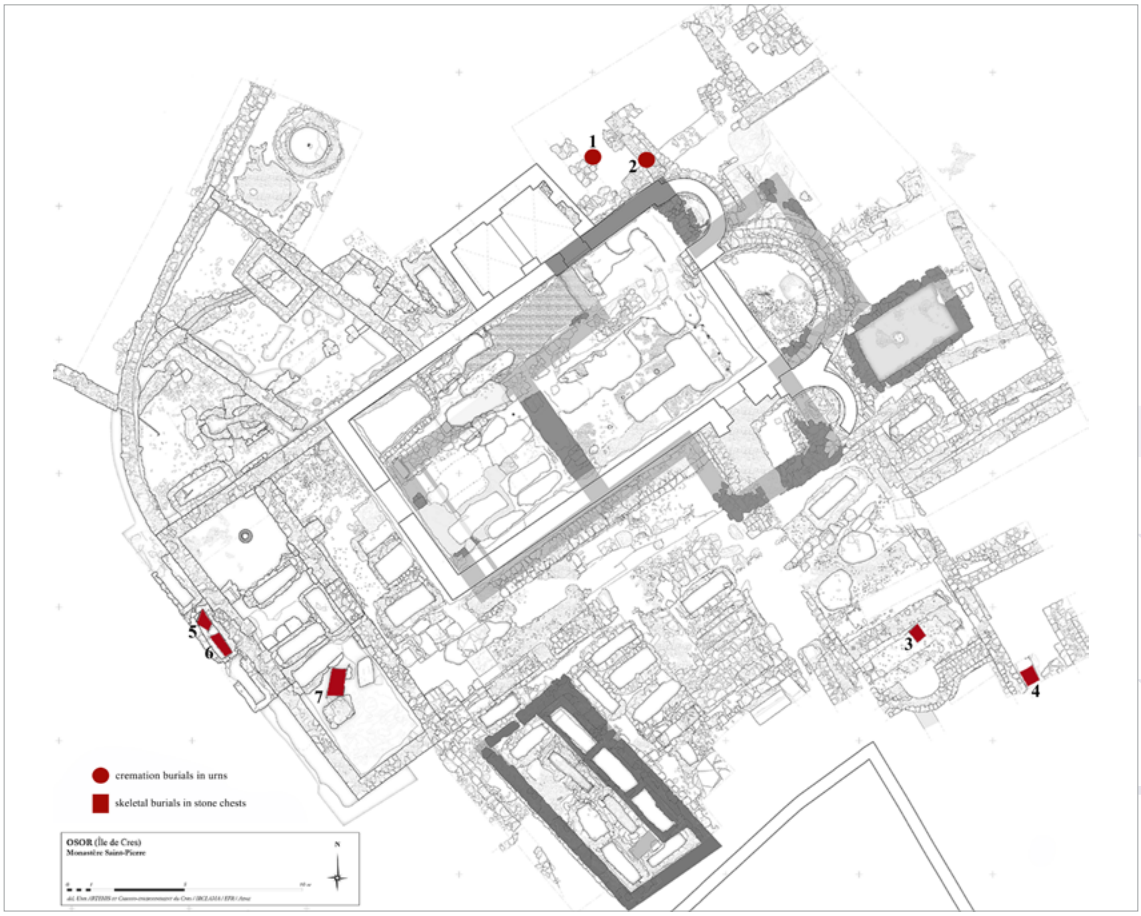


Figure 9: Floor Plan of the Monastic Complex at Sv. Petar with Marked Iron Age Grave Locations (Blečić Kavur and Kavur 2024, fig. 2)

Figure 10: Sv. Petar, Ceramic Amphora Used as an Urn in Grave 1 (Blečić Kavur and Kavur 2013, figs. 2–3)

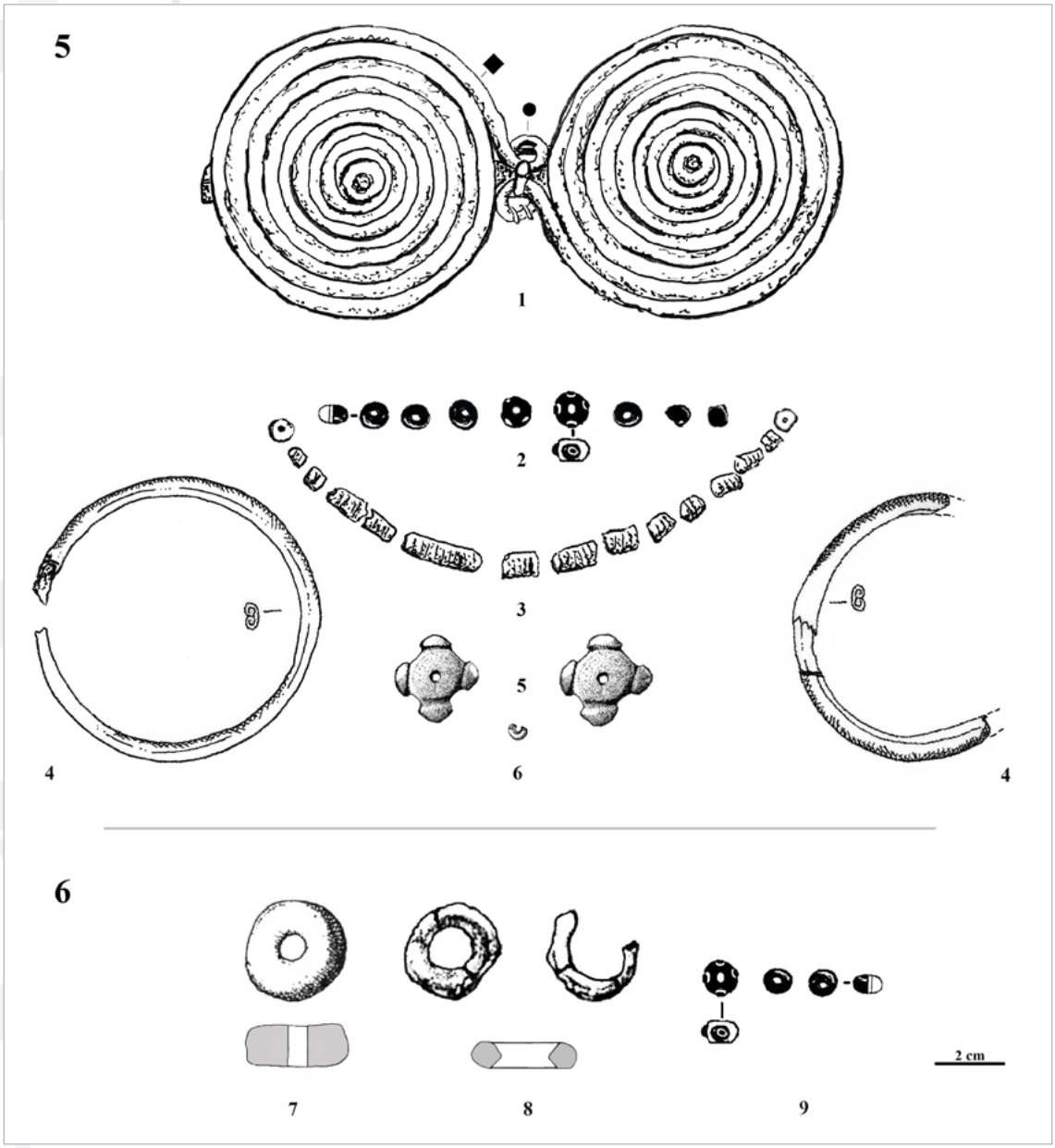


Figure 11: Sv. Petar, Inventory From Graves 5 and 6 (Blečić Kavur and Kavur 2025, fig. 7; drawings by Monika Petrović and Martina Blečić Kavur, 2025)

1997). Although an undecorated wooden example was found in graves in the Bezdanjača cave in Lika (Drechsler-Bižić 1983, 253, pl. 37, 4), a more recent discovery from the more southerly Donja Cerovačka cave is also relevant. This is a polished, well-preserved, geometrically linear decorated bone handle made from the same raw material, containing a bronze awl, which has been absolutely dated to the 11th century BCE (Tresić Pavičić 2020, fig. 20; Tresić Pavičić and Kudelić 2025, 277).

Awls, as multifunctional tools, were common grave goods throughout Europe from the Eneolithic and Early Bronze Age up to the Late Iron Age. Given the context, their symbolic role in graves remains uncertain (Willroth 1997; cf. Tecco Hvala 2012, 341). Although the grave was dated to the 7th century BCE based on a pottery rim fragment with incised triangular decoration, both the decoration and the rim profile are difficult to determine precisely and to link closely with Timavo-type vessels, as proposed by Mihovilić, since these typically have a much more flared, almost S-shaped profile. It is more likely that this burial, like comparable examples from Istrian or northern Italian sites, belongs to an older tradition and should be placed within the broader chronological span of burials from the 11th/10th to the 9th century BCE, i.e., in phase I.C/II of the Kvarner group.

Sv. Petar

In the second half of the 10th and the early 9th century BCE, i.e., at the transition from the Late Bronze Age to the Early Iron Age, the first (6.115) of two urn burials was identified during excavations in 2009 within the foundation structures of the Benedictine monastic complex outside the church of Sv. Petar (fig. 1; 9; 10) (Marić et al. 2010, 277–9, figs. 2–5). The urn was compared morphologically and stylistically with amphorae from phase II of the Ruše cultural group, within the continental circle of the Late Urnfield Culture spanning 950–900 BCE,[4] and was thus dated to phase I.C of the Kvarner chronological sequence marking the transition to the Iron Age. This amphora represents the first find of its type and burial rite at Osor.Alongside the recording of other burials of the same type within the foundations of medieval architecture, the presence of a small cremation cemetery at this highest topographical position in Osor was reasonably inferred (Blečić Kavur 2014, 110–11, fig. 64; 2021, 542–3; Blečić Kavur and Kavur 2013; 2024, 17–19, figs. 2–3). Although this burial rite had long characterised the neighbouring Istrian area during the Early Iron Age (Mihovilić 2014), it was also observed among Liburnian, Piceni, and Japodian communities at the transition of the last prehistoric millennia (cf. Kukoč 2010; 2011).

The next burial, grave 5 (5.184), was excavated in 2016 in the southern nave of the forecourt of the church of Sv. Petar (fig. 9; 11) (Bully et al. 2017, fig. 20; Čaušević-Bully et al. 2017, fig. 14). The burial of an adult female aged between 25 and 30 years (Patterson et al. 2022), was in a semi-crouched position, enclosed by large unworked stone blocks and oriented northwest–southeast. With a variety of jewellery and attire accessories – including an Adriatic-type spectacle fibula, double-section bracelets, three amber beads in two variants, eight blue glass beads in two variants, and twelve fragments of ribbed bone beads – this grave represents the richest burial at this burial ground (fig. 11, 1–6) (Blečić Kavur 2021, fig. 6; Blečić Kavur and Kavur 2024, figs. 2–3; 2025, fig. 7). Particular attention should be given to two polygonal amber beads, as they are a morphologically distinctive type for the Osor area, having adorned the pins of large fibulae of the Osor type, such as those from grave 6 at Sv. Marija (fig. 5, 6) or from Mala Prepoved (fig. 7, 2). This confirms their use as components of necklaces or pendants, and as amulets in pectoral jewellery, which were also decorated with glass and bone beads. The assemblage thus represents a typical set of dress items of the local community. Based on typological and chronological parameters, the assemblage can be reliably dated to the second half of the 9th century BCE, with a possible continuation into the early 8th century BCE, that is, Phase II of the Kvarner cultural group (Blečić Kavur 2021, 543; Blečić Kavur and Kavur 2024, 19).

Grave 6 (5.185), located nearby, falls within the same chronological framework and contains round and flat biconical amber beads, as well as blue glass beads of various sizes (fig. 9; 11,

4 The date is US6 1016 – Poz-34654, 2735±35BP (Blečić Kavur and Kavur 2013, 354, fig. 5).

7–9) (Bully et al. 2017, fig. 21; Čaušević-Bully et al. 2017, fig. 15). Bioarchaeological analysis identified the burial as that of an adult female (Novak and Carić 2019; Patterson et al. 2022). Unlike the graves in the tumulus at Sv. Marija, no animal bones were found in these graves.

Osor

During extensive rescue excavations in 2022–2023 in the so-called Zone C (fig. 1), another individual Iron Age grave with an inhumation but without grave architecture was investigated. The grave contained a damaged Adriatic-type spectacle fibula and several amber beads (Baričević et al. 2025). Bioarchaeological analyses confirmed that the burial was of an adult female (Novak et al. 2025).[5] Given its location, it cannot be ruled out that this grave should be considered in the context of the northern graves at Sv. Petar, to which it is connected not only chronologically but also spatially, possibly forming part of a larger cemetery extending across this broader, highest north-western urban grid of Iron Age Osor (Blečić Kavur and Kavur 2024, 20).

Conclusion

This multi-layered reinterpretation of Osor burials from the 10th to the 8th century BCE is based on the integration of archaeological data, material culture studies, bioarchaeological research, and radiocarbon dating. For the first time, Osor graves and their associated finds have been considered as interconnected, spatially and chronologically differentiated units, significantly expanding the concept of the so-called Osor archaeology of death. The results show that, from the Late Bronze Age and the early phases of the Iron Age, Osor developed a complex funerary landscape characterised by the parallel use of different spaces and burial practices, including the less common cremations and the more frequent inhumations, either on flat ground or under tumuli. The presence of heterogeneous burial practices within the urban area indicates a flexible relationship between the worlds of the living and the dead, in which ancestral memory remained permanently integrated into the daily life of the community. Such diversity reflects not only chronological changes but also the longevity and complexity of the social and identity choices of these people (Blečić Kavur and Kavur 2024; 2025).

New absolute dating data have enabled the precise chronological anchoring of burial units at Sv. Petar and Sv. Marija to the 10th and 9th centuries BCE, fully corroborating the results of typological, stylistic and comparative analyses of attire and ornaments. This makes Osor one of the few sites on the eastern Adriatic coast where prominent graves from the initial phase of the Early Iron Age can be reliably linked to absolute dates, thereby defining more precisely both the period of use and the deposition of specific items.

The sex of individuals in the presented graves has been confirmed through conventional bioarchaeological methods (Novak and Carić 2019; Novak 2025; Patterson et al. 2022; Novak et al. 2025). This is important for interpreting social structure, as it demonstrates that certain items were specifically associated with adult women as bearers of symbolic capital, status and tradition. Where bioarchaeological analyses did not yield results, the possible sex of the individual was, when feasible, inferred based on the typological and chronological classification of characteristic items. Such attributions relate to socially and visually constructed gender identities rather than necessarily to biological sex (cf. Arnold and Wicker 2001).

The prominent graves at the churches of Sv. Marija and Sv. Petar, as well as at the Mala Prepoved site (fig. 1; 5; 7; 11) – similar to those that, judging by the material culture, were certainly also present at Kavanela – indicate a structured practice of burying prominent individuals with clearly defined funerary ceremonies. They primarily attest to the existence of social groups responsible for performing these rites, while also reflecting the hierarchy within the broader com-

5 The analyses were carried out at the Institute for Anthropological Research in Zagreb.

munity, further manifested in the diverse composition of grave goods.

The most common element of female dress among the deceased was the Adriatic-type spectacle fibula, followed by the bow-shaped fibula with an amber bead on the bow, documented in various combinations. Based on these, four basic categories of attire can be distinguished: 1) graves without fibulae, containing amber and glass beads or other forms of jewellery (Sv. Marija grave 1; Sv. Petar grave 6); 2) graves with a single fibula alongside bronze and/or amber jewellery (Sv. Marija graves 4, 7; Sv. Petar grave 5; Preko mosta grave 8, Osor grave Zone C); 3) graves with two fibulae and additional jewellery (Sv. Marija grave 5; Mala Prepoved); 4) complex attire comprising of multiple fibulae, jewellery, and other grave goods, represented solely by grave 6 at Sv. Marija. In the case of child burials, the inclusion of amber and glass beads, as well as a single fibula, was generally assumed, whereas male graves were mostly found either without grave goods or with only a pin (Sv. Marija, grave 2). Other elements are not currently attested in the examined sample.

The association of spectacle fibulae with bow-shaped fibulae with amber bead on the bow, as well as with Osor-type fibulae, in various burial contexts, reflects a rich inventory often accompanied by ceramic spindle whorls. Their presence goes beyond sexual differentiation and indicates concepts of social role, identity, and bodily ideology (Arnold 2016; Rebay-Salisbury 2016, 78–80). Interpreted in this way, the assemblage of objects fits within a broader European socio-cultural discourse concerning women with significant agency in household production, exerting continuous influence and bearing multiple symbolic meanings, including within the religious order (cf. Huth and Kondziella 2017). The motifs of rotation, interlacing, and cyclicality – visible in the iconography of the fibulae and in the practices of spinning and weaving – acquire a clear semantic dimension.

The Iron Age community of Osor was not merely a passive recipient of external influences; rather, it was an active participant in trans-Adriatic networks of interaction, within which foreign forms and ideas were selectively adopted and creatively reinterpreted. Standardised elements, technical features of advanced metallurgical craftsmanship, and the repetition of certain morphological solutions indicate the activity of workshops embedded within a wider communicative space, as well as the production of objects with distinct local characteristics, such as Osor-type fibulae, bracelets, pendants, and others. Geochemical and isotopic analyses of the fibulae demonstrate regional homogenisation of tin exchange and the mixing of metals of European and Asian origin, most likely associated with intensive bronze recycling (Powell et al. 2026).[6] Evidence for potential metallurgical activity at Osor itself will be provided directly by finds of ceramic casting spoons and ceramic furnace nozzles from the settlement, while geochemical analyses of sedimentary archives have confirmed intensive anthropogenic impact from around 1500 BCE (Miko et al. 2025). Numerous amber beads, particularly the distinctive polygonal ones, as well as larger fragments of raw amber of Baltic provenance (Blečić Kavur 2021, 538, fig. 3; Wojewódka 2024), further support the hypothesis of local processing activities, which were most likely complemented by the working of bone, glass, and other utilitarian objects.

Of particular interpretative value are the relationships between imported and locally produced material culture, which in the Osor graves are evident through deliberate and recurring combinations of jewellery types. Luxury and/or prestige items set the standard in line with the values of the wider cultural sphere's social concept. However, beyond the adoption of foreign forms during the 10th and 9th centuries BCE – such as certain types of pins, pendants, or ceramic vessels – there is clear evidence of selec-

6 Samples for tin isotope analyses were taken from 11 spectacle fibulae, 4 Osor-type fibulae, *sanguisuga*-shaped fibulae, bracelets, pins, and *Caput Adriae*-type phalerae from Kavanela, Preko mosta, Sv. Marija, and Sv. Petar.

tive appropriation and active reinterpretation in the second half of the 9th and early 8th centuries BCE, whereby imported items and formal concepts were integrated into the local aesthetic and symbolic system. Such combinations – for example, the pairing of typologically distinct fibulae, amber, and glass – indicate the existence of prescribed visual codes and socially recognisable dress compositions. These did not merely reflect economic activity or material value but also the social control of the symbolic meanings of jewellery, particularly in the context of female identity and status.

In the Osor graves, however, ceramic vessels are absent, although their fragments are found around the graves at all necropolises. This clearly reflects the rites performed during and after the burials, including post-mortem vessel-breaking ceremonies, as observed in the graves at Sv. Marija, Sv. Katarina, and Mala Prepoved, as well as the deliberate destruction – or ritualisation – of objects at the ceremonial cremation sites on Kavanela, which were undoubtedly accompanied by funerary festivities (Mladin 1960; Blečić Kavur and Kavur 2024, 21).

In synthesis, the new data significantly enhance our understanding of Osor's archaeology of death and its representative material culture, portraying the Osor community as a developed and hierarchically organised society with clearly defined practices and traditions. The results of integrated interdisciplinary approaches, which continue to be applied, enable Osor's graves to be understood not merely as a collection of valuable finds, nor the material culture simply as a passive or one-dimensional reflection of daily life, but as an active and inclusive medium of identity, ideology, and social memory. Through this perspective, contacts and connections with the Adriatic and broader European spheres – particularly in the procurement of diverse raw materials – become apparent. Within this framework, Osor is confirmed as a principal island centre and an interpretative model of a regional hub, both in vertical and horizontal connections across the Kvarner, as well as diagonally between Histrian Nesactium and Liburnian Nin. Its archaeological heritage is therefore crucial for understanding regional and supra-regional social and cultural processes in the Adriatic landscape during the rise of the last prehistoric millennium.

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Catalogue of Graves

Preko Mosta

During infrastructure works in 2018, part of the necropolis on the Lošinj side of Kavanela was excavated.

Grave 8: Extremely poorly preserved small bones and cranial remains were placed on an earthen substrate covering a small-levelled plateau of bedrock. Near the grave, two small amorphous ceramic fragments were found.

1 Spectacle fibula made of bronze wire with a square cross-section. The discs consist of 10 spiral coils and are connected by a small central loop with a circular cross-section. They are riveted to a straight rectangular bar. A circular plate with punched concentric decoration is at the centre of the left disc.

Dimensions: L. 17.2 cm; disc diam. 7.7 cm. Inv. no.: AZO 2963

2 Larger bronze ring, probably a bracelet, pointed at one end and of oval cross-section.

Dimensions: diam. 7 cm. Inv. no.: AZO 2964

3 Fragments of flat bronze ring, lenticular in cross-section.

Dimensions: diam. 3.2 cm. Inv. no.: AZO 2958

4 Bronze ring, semicircular in cross-section.

Dimensions: diam. 1.5 cm. Inv. no.: AZO 2966

5 Fragment of bronze ring, lenticular in cross-section.

Dimensions: diam. 1.5 cm. Inv. no.: AZO 2965

6 Spirally wound bronze wire – *salteleone*, rectangular in cross-section.

Dimensions: L. 1.7 cm; diam. 0.7 cm. Inv. no.: AZO 2942

7 Fragments of bronze wire, circular in cross-section and spirally coiled.

Dimensions: L. 2 cm. Inv. no.: AZO 2942

Bibliography: unpublished.

Mala Prepoved

In 1963, a stone chest constructed from limestone slabs was excavated within the tumulus. It contained the inhumation of an individual in a crouched position, accompanied by attire and jewellery items, as well as fragmented pottery.

8. Spectacle fibula made of bronze wire with a square cross-section. The discs consist of 11 spiral coils and are connected by a small central loop with a circular cross-section. They are riveted to a straight rectangular bar, which transitions into the pin with two coils.

Dimensions: L. 22.9 cm; disc diam. 11 cm. Inv. no.: AMI P/10156.

9 Bronze, two-part, bow fibula of the Osor type, partially preserved in three fragments. Composite construction: semicircular bow of rectangular cross-section with 16 spirally wound conical elements and looped wire decoration. The foot is preserved as part of the catchplate with a disc attachment. The disc is flat, circular to heart-shaped, largely complete except for edge damage, and decorated along the rim with parallel punched dots enclosing circles. The centre features a concave-sided square with an incised inverted swastika motif; each corner is further decorated with applied 'leg' motifs (upper corners W-shaped, lower corners elongated, frog-like forms). Large pin of circular cross-section, wire-wrapped, with a polygonal amber bead featuring triangular protrusions.

Dimensions: bow L. 11.6 cm; pin L. 9.5 cm. Inv. no.: AMI P/2585, 6977.

Bibliography: Baćić (1963), Glogović (2003, pl. 26, 175; 45, 342), Blečić Kavur (2021, fig. 2, 5).

Sv. Marija

The tumulus was excavated in 1959. The grave was destroyed at the beginning of the excavation; it reportedly contained a child burial in a crouched position, with the head to the north.

10 *Two bracelets* – destroyed during excavation.

11 *Amber bead* – destroyed during excavation.

Bibliography: Mladin (1960, 221), Teržan (2013, pl. 2, 1).

Grave 2: Stone chest constructed of five limestone slabs, containing an inhumation of an adult male in a crouched position, oriented north–south.

12 Bronze pin with a large slightly conical head and three ribs of varying size on the neck.

Dimensions: L. 13 cm. Inv. no.: AMI P/7016.

Bibliography: Mladin (1960, 221), Glogović (1989, pl. 6, 2), Blečić Kavur (2010, pl. 39, 537), Teržan (2013, pl. 2, 3).

Grave 3: Stone chest constructed of five limestone slabs, containing an inhumation of an adult male in a crouched position, oriented north–south. No grave goods.

Bibliography: Mladin (1960, 221).

Grave 4: Stone chest constructed of five limestone slabs, containing an inhumation of a child in a crouched position, oriented north–south.

13 Fragment of a bronze pin with coiled wire from a bow fibula with amber bead on the bow, which disintegrated during excavation.

Dimensions: L. 6.2 cm. Inv. no.: AMI P/7035.

Bibliography: Mladin (1960, 221), Teržan (2013, pl. 2, 2).

Grave 5: Stone chest constructed of five limestone slabs with a double burial: a primary male and a secondary female individual. The secondary burial was placed in a crouched position, oriented north–south.

14 Spectacle fibula made of bronze wire with square-section. The discs consist of 9 spiral coils, connected by a small central loop with a circular cross-section. They are riveted to a straight rectangular bar. Circular plates with punched concentric decoration are at the centre of the discs.

Dimensions: L. 11.5 cm; disc diam. 4.8 cm. Inv. no.: AMI P/7023.

15 Bow-shaped fibula with an amber bead on the bow. The square cross-section bow ends in a two-coil spring, which transitions into a circular cross-section pin; the foot is triangular and hammered. A large oval amber bead is on the bow, and a bronze disc of rectangular cross-section is above the foot.

Dimensions: L. 5 cm; amber bead L. 3.5 cm. Inv. no.: AMI P/7018.

Bibliography: Mladin (1960, 221–2), Glogović (2003, pl. 30, 204; 36: 256), Blečić Kavur (2010, T. 39, 539–40), Teržan (2013, pl. 2, 4–5).

Grave 6: Stone chest constructed of five limestone slabs, containing the inhumation of an adult individual in a crouched position, oriented north–south. The grave also contained bones of a small child and animals.

16 Spectacle fibula made of bronze wire with a square cross-section. The discs consist of 9 damaged spiral coils and are connected by a small central loop with a circular cross-section. They are riveted to a straight rectangular bar. Central circular plates with punched decoration are at the centre of the discs.

Dimensions: L. 16.4 cm; disc diam. 5.6 cm. Inv. no.: AMI P/7024.

17–19 Three bow-shaped fibulae with amber beads on the bow. Bows of rectangular cross-section with 2–3 coil springs and circular cross-section pins; triangular feet, partly damaged. Oval amber beads, one partially damaged; one fibula incomplete and one missing.

Dimensions: L. 6.5–9.1 cm; amber bead L. 4.8–8 cm. Inv. nos.: AMI P/7017, 7020, 7021 (*lost*).

20 Flattened oval amber bead with longitudinal perforation, from a bow-shaped fibula.

Dimensions: L. 3.9 cm. Inv. no.: AMI P/7019.

21 Bronze two-part bow fibula of the Osor type, partially preserved. The bow is semicircular, with a rectangular cross-section, featuring 19 spirally wound conical elements and added looped wire. The bow tapers at the end and is flattened into a twisted wire, which is threaded and secured to

the pin. The foot is partially preserved on the mount, with a connector to the disc, from which most of the reduced cross motif remains. The pin is large, circular in cross-section, with an oval bronze disc at its end, a polygonal amber bead with triangular protrusions, and a flattened part with a circular hole for the bow wire. Decoration on the disc consists of punched small circles.

Dimensions: L. 44 cm; foot disc diam. 12.6 cm; bow disc diam. 6 cm. Inv. no.: AMI P/7040.

22 Necklace of 18 amber ring beads (rhombic cross-section), one small and one large circular bead, and two yellow glass beads.

Dimensions: bead diam. 0.8–3.2 cm. Inv. no.: AMI P/7016.

23 Tubular bronze bracelets, deformed and corroded; two complete, two fragmentary, some with small rings (4 items).

Dimensions: 1. bracelet diam. 7.2 cm; 2. bracelet diam. 7 cm. Inv. nos.: AMI P/7027, 7028.

24 Small bronze buttons with loops (2 items).

Dimensions: diam. 1.6–2.2 cm. Inv. nos.: AMI P/7036, 7037.

25 Rings of thin bronze sheet, riveted or open, partially preserved (4 items).

Dimensions: diam. 1.1 cm. Inv. nos.: AMI P/7029, 7032.

26 Large biconical ceramic spindle whorl.

Inv. no.: AMI P.

27 Blue glass beads – *lost*.

Bibliography: Baćić (1959), Mladin (1960, 222), Brušić-Matijašić (1990, 66–7, pl. 2, 1–3, 6–7; 3, 5–6), Glogović (1982a, pl. 2, 5; 1989, pl. 6, 1; 2, 2, 4–7; 23, 5; 2003, pl. 27, 177; 36, 257–9; 39, 294; 44, 341), Blečić Kavur (2010, pl. 40; 41, 547–54), Teržan (2013, pl. 1).

Grave 7: Stone chest constructed of five limestone slabs with the inhumation of a child (possibly a newborn) in a crouched position, oriented northwest–southeast.

28 Fragment of bow and amber bead from a bow-shaped fibula with amber bead on the bow.

Dimensions: L. 4 cm. Inv. no.: AMI P/7022 – *lost*.

Bibliography: Mladin (1960, 222), Teržan (2013, pl. 2, 6).

Sv. Katarina

A grave containing an inhumation of an individual in a crouched position was excavated in 1962 along the northern edge of the settlement, towards Bijar.

29 Polished bone awl-handle, square in cross-section at the median part and circular at the distal. Decorated with two fields of seven parallel incised lines; the distal part is decorated with a field of oblique incisions.

Dimensions: L. 8.3 cm; diam. 1 cm. Inv. no.: AMI P/15792.

30 Fragment of a flat base of a pot or large vessel, coarse fabric.

Dimensions: 7.2 cm. Inv. no.: AMI P.

31 Fragment of a slightly everted rim of a large vessel with hatched triangle decoration, coarse fabric.

Dimensions: L. 6.9 cm. Inv. no.: AMI P.

Bibliography: Mihovilić (2013, figs. 2–3; 4, 1–3).

Sv. Petar

Grave 1 (6.115): A pit with a cremation burial in an urn was excavated in 2009 within the foundation structures of a wall complex behind the apse of the Church of St Peter. The pit was cut into a clayey–earthen layer to a depth of approximately 30 cm and set directly on bedrock. The upper part of the urn contained a layer of gravel, indicating the presence of an organic lid. A large quantity of cremated bones from a single adult individual was recovered.

32 Biconical urn with a tall conical neck and a pronounced transition from the rounded shoulder to the neck. The neck bears an incised decoration of two thin parallel lines. Slightly drawn-out, flat ring foot; markedly everted and thickened rim. One preserved vertical handle at the junction of the shoulder and lower neck. Medium-grained fabric with inclusions of quartzitic sand, grog, and calcium carbonate; exterior smoothed and burnished, interior uneven. Fire-affected and eroded surface, predominantly greyish-brown with orange-brown and black areas.

Dimensions: H. 27 cm; shoulder diam. 29 cm; foot diam. 8 cm. Inv. no.: AZO 1874.

Bibliography: Marić et al. (2010, 277–79, figs. 2–5), Blečić Kavur and Kavur (2013, figs. 3–4), Blečić Kavur (2014, 110–1, fig. 64).

Grave 3 (4.323): Excavated in 2013 in the area of Building B, Space IVg. The inhumation was placed in a small, square stone chest (55×42 cm), constructed of four thin limestone slabs and partly set into a clayey substrate. The northern slab extended approximately 20 cm beyond the edge of the chest. The dimensions of the chest and the few scattered skeletal remains indicate a child burial.

33 Three small amber beads. Inv. no.: AZO.

Bibliography: Čaušević-Bully et al. (2014, 8, fig. 4), Marić et al. (2014, 463, fig. 2).

Grave 5 (5.184): The grave was excavated in 2016 at the bottom of a medieval stone tomb (5.186), near the façade of the vestibule. A younger female individual was buried in a semi-crouched position, surrounded by large unworked stone blocks and oriented northwest to southeast.

34 Spectacle fibula made of bronze wire with a square cross-section. The discs consist of 9 spiral coils and are connected by a small central loop with a circular cross-section, to which wires are attached. They are riveted to a straight rectangular bar that transitions into the pin with two coils. Central circular plates with punched decoration are at the centre of the discs.

Dimensions: L. 18.4 cm; disc diam. 8.1 cm. Inv. no.: AZO 3003

35 Bronze bracelets of double bent cross-section. One fully preserved, the other fragmented (2 items).

Dimensions: diam. 8.4 cm; fragment L. 4.6 cm. Inv. nos.: AZO 3004, 3005

36 Two well-preserved amber polygonal beads, with circular bodies and four triangular protrusions, and one circular flat bead.

Dimensions: polygonal beads L. 2.2–2.4 cm; diam. of circular bead 1 cm. Inv. nos.: AZO 3585, 3586

37 Blue glass beads, two with a horizontal white inlay along the body, and two 'eye' beads also bordered with white stripes.

Dimensions: diam. of eye beads 0.9 cm; diam. of inlay beads 0.8 cm. Inv. nos.: AZO 3587, 3588

38 Cylindrical and ribbed bone beads, total 13 pieces.

Dimensions: L. 0.6–2.2 cm; diam. 0.7 cm. Inv. no.: AZO 3589

Bibliography: Bully et al. (2017, fig. 20), Čaušević-Bully et al. (2017, fig. 14), Blečić Kavur (2021, 543, fig. 6), Blečić Kavur and Kavur (2024, 19, figs. 2–3; 2025, fig. 7).

Grave 6 (5.185): Excavated in 2016 in the immediate vicinity, i.e., southeast of grave 5 near the façade of the vestibule. Stone chest constructed of three partially preserved limestone slabs, containing the burial of a female individual in a crouched position.

39 Three amber beads: one round and oval in cross-section, and two flat rhomboid beads, all heavily damaged.

Dimensions: diam. of round bead 2.3 cm; diam. of flat beads 2.5 cm. Inv. no.: AZO 2511, 2512, 2513

40 Three blue glass beads: two round and one larger 'eye' bead with white inlays.

Dimensions: diam. of eye bead 1.7 cm; diam. of round beads 0.4 cm. Inv. no.: AZO 3590, 3591

Bibliography: Bully et al. (2017, fig. 21), Čaušević-Bully et al. (2017, fig. 15), Blečić Kavur (2021, 543, fig. 6), Blečić Kavur and Kavur (2024, 19, figs. 2–3).

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Summary

The paper presents an interdisciplinary analysis of burial assemblages from the Osor area, dating to the transition from the Late Bronze Age to the early phases of the Early Iron Age (10th–8th centuries BCE). The study reassesses social structures, identities, and networks of interaction in the northern Adriatic region. The research combines typological–stylistic analysis of representative material culture with contextual, bioarchaeological, and chronological data, with particular emphasis on newly identified closed grave assemblages as methodologically reliable units of archaeological interpretation. The analysis draws on both published and previously unpublished assemblages of attire and jewellery from several burial grounds with different spatial and functional roles (Kavanela–Preko mosta, Sv. Marija, Mala Prepoved), as well as from burials within the urban area of Osor (Sv. Katarina, Sv. Peter, Osor – Zone C) (fig. 1; 3; 9). The material is examined through 40 catalogue entries grouped into 11 defined grave assemblages, with consistent differentiation between primary and secondary burials, degrees of preservation, and possible post-depositional disturbances. This contextual approach avoids isolated typological interpretation and supports a socially informed understanding of funerary practices.

The typological–stylistic analysis of fibulae, jewellery, and associated objects is conducted through comparison with regional and supra-regional parallels from the Adriatic and Italic spheres. Relative chronological results are evaluated against radiocarbon dating, providing a secure chronological framework for individual grave assemblages and placing Osor among the limited number of eastern Adriatic sites with reliably absolutely dated Early Iron Age burials.

The analysis of material culture focuses on identifying standardised visual codes of dress. Combinations of Adriatic spectacle fibulae, bow fibulae with amber beads on the bow, two-part Osor-type fibulae, and jewellery of amber, glass, and bronze are interpreted as structured social markers. Variations in the frequency and complexity of these assemblages are considered indicators of status and social role, particularly in female burials. The presence of ceramic spindle whorls and the decoration of Osor-type fibulae in the richer graves are discussed within a framework of symbolic economy related to labour, cyclicality, and social reproduction. Bioarchaeological data are incorporated into the interpretation to limit methodological bias arising from attributing social roles solely on the basis of artefact typology.

The interpretative framework assumes that material culture functions as a medium of social communication. In this context, geochemical and isotopic analyses of metals and amber indicate regional homogenisation of raw materials, intensive bronze recycling, and Osor's involvement in long-distance exchange networks, while also suggesting local production and craft practices. The selective adoption and transformation of external forms, particularly in the development of Osor-type fibulae, are understood as processes of local reinterpretation within broader trans-Adriatic interaction spheres. Taken together, these approaches position Osor as a regional centre whose funerary practices and material culture reflect sustained visual conventions, social differentiation, and long-term cultural interaction during the formative phases of the Early Iron Age.

Povzetek

Prispevek predstavlja interdisciplinarno analizo grobnih celot z območja Osorja, ki segajo v prehod iz pozne bronaste dobe v zgodnje faze starejše železne dobe (10.–8. st. pr. n. št.). Namen raziskave je na novo ovrednotiti družbene strukture, identitete in mreže interakcij v severnojadranskem prostoru. Raziskava združuje tipološko-stilsko analizo reprezentativne materialne kulture s kontekstualnimi, z bioarheološkimi in s kronološkimi podatki, pri čemer je poseben poudarek na novoodkritih zaprtih grobnih celotah kot metodološko najzaneslji-

vejših enotah arheološke interpretacije. Analiza temelji na objavljenih in doslej neobjavljenih sklopih noše ter nakita iz več grobišč z različno prostorsko in funkcionalno vlogo (Kavanela – Preko mosta, Sv. Marija, Mala Prepoved) ter iz grobišč in grobov znotraj urbanega prostora Osorja (Sv. Katarina, Sv. Peter, Osor – cona C) (sl. 1, 3, 9). Predmeti so obravnavani v 40 kataloških enotah in v okviru 11 opredeljenih grobnih celot, pri čemer se dosledno razlikuje med primarnimi in sekundarnimi pokopi, stopnjo ohranjenosti ter morebitnimi postdepozicijskimi motnjami. Tak kontekstualni pristop preprečuje izolirano tipološko interpretacijo in omogoča družbeno utemeljeno razumevanje pogrebnih praks.

Tipološko-stilska analiza fibul, nakita in spremljajočih predmetov je bila izvedena s primerjavo z regionalnimi in nadregionalnimi vzporednicami iz jadranskega ter italskega prostora. Relativnokronološki rezultati so bili preverjeni z radiokarbonskimi datacijami, kar zagotavlja trdno kronološko umeščenost posameznih grobnih celot in Osor umešča med redka najdišča vzhodnega Jadrana z zanesljivo absolutno datiranimi grobovi zgodnje starejše železne dobe.

Analiza materialne kulture je usmerjena v prepoznavanje standardiziranih vizualnih kodov noše. Kombinacije jadranskih očalastih fibul, ločnih fibul z jantarno jagodo na loku, dvodelnih fibul tipa Osor ter nakita iz jantarja, stekla in brona so interpretirane kot strukturirani družbeni simboli. Razlike v pogostosti in kompleksnosti teh sklopov se razumejo kot pokazatelji statusa ter družbene vloge, zlasti v ženskih pokopih. Prisotnost keramičnih vretenc in dekoracije na fibulah tipa Osor v najbogatejših grobovih se dodatno razlaga v okviru simbolne ekonomije, povezane z delom, s cikličnostjo in z družbeno reprodukcijo. Bioarheološki podatki so vključeni v interpretativni proces z namenom zmanjšanja metodološke pristranskosti pri pripisovanju družbenih vlog zgolj na podlagi tipologije predmetov.

Interpretativni okvir izhaja iz predpostavke, da materialna kultura deluje kot aktiven medij družbene komunikacije. V tem kontekstu geokemične in izotopske analize kovin ter jantarja kažejo na regionalno homogenizacijo surovin, intenzivno reciklažo brona in vključenost Osorja v daljnosežne trgovske mreže, hkrati pa tudi na obstoj lokalne proizvodnje in obrtnih praks. Selektivno prevzemanje in preoblikovanje zunanjih oblik, zlasti pri razvoju fibul tipa Osor, se razume kot zavesten proces lokalne reinterpretacije znotraj širših transjadranskih interakcijskih sfer. S sintezo navedenih metodoloških pristopov prispevek Osor potrjuje kot dinamično regionalno središče, katerega pogrebne prakse in materialna kultura odražajo stabilne vizualne reprezentacije, izrazito družbeno diferenciacijo in dolgotrajne kulturne interakcije v času oblikovanja starejše železne dobe.

Selected Glass Finds from Apsorus (Osor) – Reflection of Wealth and Prestige
Izbrane steklene najdbe iz Apsorja (Osorja) – odraz bogastva in prestiža

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Abstract
The article focuses on selected glass finds from Osor. The exact provenance of the finds is unknown; most likely, they were discovered in a Roman necropolis of Apsorus. Among the excavated materials, early products of Roman glassmaking, dated to the 1st century AD, stand out and illustrate the remarkable diversity of glassmaking technological practices of the period. Some of them were still made in moulds, others by mould-blowing, but we should also mention the earliest blown products. Imports of these products in Roman towns and cities along the Adriatic reflect the economic strength of the population and an extensive trade network expanding from northern Italy to the Eastern Mediterranean.
Keywords: Osor, Roman glass, moulds and mould-blowing, trade, import

Izvleček
Članek se osredotoča na izbrane najdbe stekla iz Osorja. Podatki o izvoru najdb niso ohranjeni, najverjetneje pa so bile odkrite v rimski nekropoli Apsorja (Apsorus). Med gradivom izstopajo zgodnjerimski izdelki, nastali v 1. stoletju, in ilustrirajo izredno raznolikost rimskega steklarstva ter tehnoloških praks tistega časa. Nekateri so bili še izdelani v kalupih, drugi so bili pihani v kalup, med njimi pa so tudi zgodnji pihani izdelki. Uvozi tega posodja v prvih rimskih mestih in naseljih vzdolž Jadrana odražajo ekonomsko moč prebivalstva in razvejano trgovsko mrežo, ki se je raztezala od severne Italije do vzhodnega Sredozemlja.
Ključne besede: Osor, rimsko steklo, kalupi in pihanje v kalup, trgovina, uvoz

Osor – Apsorus

The arrival of the Romans in the 2nd century BCE undoubtedly marked the beginning of a new era for Osor. Together with other areas of Kvarner, Osor boldly crossed the threshold of history and began another rich epoch of its splendid past (Blečić Kavur 2015, 231–3). Archaeological sources, no matter how stingy and/or truncated, support the assumption of cultural and economic completion of the longest chapter of Osor prehistory. Then Osor, along with other areas of Kvarner, boldly crossed the threshold of history and began another extremely rich epoch of their magnificent past. Material culture indicates an important role of Osor in the Romanisation of the northern Adriatic. During Roman rule, Osor (Apsorus) was granted the status of a *municipium* and developed into a Roman city (Starac 2000, 79; Faber 1980; 1982).

Although the exact date of the establishment of the autonomous city remains questionable, analyses of material culture can help uncover aspects of town life and its inhabitants, as well as reflect their social status (Kurilić 1999; Šašel Kos 2017; Šmid 2025).

In this article, we will focus on selected glassware finds from the Archaeological Collection Osor, Lošinj Museum (Fadić 1982). The exact provenance of the finds is unknown; most likely, they were discovered in a Roman necropolis west of the Apsorus (Fadić 1982, 111). Marchesetti also confirms this possibility in his publication (1924, 141). Excavations in this necropolis began

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in 1874 by the local priest Bolmarčić. Unfortunately, the excavations were carried out without proper archaeological methods, so it is not surprising that no burial complexes have been preserved. They were continued in 1881 and 1894, but unfortunately, no archaeological documentation has been preserved, nor has all the excavated material been left on Cres (Blečić Kavur 2015, 25–8). That is why the study of the material can focus more or less on typology and comparison.

Among the excavated material exhibited in the museum, early products of Roman glassmaking stand out. Some of them were still made in moulds, others by mould-blowing, but we should also mention a few early blown products.

Why are we focusing on glass, and what do these finds reflect?

In the 1st and 2nd centuries BC, the Hellenistic states of the Mediterranean were conquered by the Romans and incorporated into the Roman State as provinces. This led to cultural and social influences and exchanges, as well as intense development and several innovations in various Roman crafts, including glassmaking. Glass-working developed in the Roman State based on knowledge from the Hellenistic centres and provided the impetus for the creation and development of an independent Roman glass industry, which flourished from the Augustan era until the end of the Roman Empire.

No period better illustrates the remarkable diversity of technological practices of this early period than the Augustan era and subsequent decades. Glass finds from archaeological contexts of this period show a great variety and range in form, colour, decoration and production techniques. Multicoloured mould-made mosaic vessels became quite rare. Monochrome transparent glass vessels, made in moulds, and later also decolourised vessels, were increasingly produced.

Imports of these products in newly created towns and cities along the Adriatic reflect the economic strength of the population. The presence of glass material made using various glassmaking techniques, as evident in the glass finds from Osor, suggests that the settlement had a wide trade network and a population with the corresponding economic power at that time. Most of the early glass vessels were imported from the newly founded glass workshops of central Italy, but some pieces may also have come from workshops in the Eastern Mediterranean.

The Mould-Made Glasses

The group of mosaic vessels is represented by a ribbed bowl (form Isings 3 (Isings 1957); AR 2; Lazar 2.1.4), unfortunately destroyed and disfigured, as it was most probably placed on a pyre with a deceased (fig. 1a). The bowl was made of cobalt blue and white opaque glass plaques with a marble pattern.

A mould-made ribbed bowl was produced by sagging a glass disc over a preheated mould; this is the most characteristic and widespread form of early Roman glassmaking, achieving exceptional popularity and widespread use, probably due to its practicality. It is known in both the western and eastern parts of the empire. Differences in size, rib design, and glass are a result of the numerous workshops where ribbed bowls were produced. Judging by settlement finds, the bowl was a widely used item in Roman households, as can be concluded from the finds in civil and military contexts at numerous European sites.

Numerous sites, such as Emona and Polhov Gradec in Slovenia (Petru 1972; Plesničar Gec 1972; Lazar 2003 – fig. 1b), and Zadar in Croatia (Eterovič Borzić and Štefanac 2021, 43, cat no. 50), indicate that it was also frequently placed in graves as a vessel or even used as an urn. Its usefulness and popularity are the reasons why it remained in use throughout the entire 1st century and beyond, when glass blowing had already been introduced. Its popularity is therefore the reason why it remained in use throughout the 1st century and beyond, when glass blowing had already completely prevailed over other manufacturing techniques.

From numerous comparisons, we would mention only a few examples. In the settlement

Figure 1: Remains of a Ribbed Bowl (a) Destroyed in a fire (pyre?) and completely preserved (photo by Monika Petrović, 2025)

of Augusta Raurica (Augst in Switzerland), mosaic ribbed bowls are characteristic of the first half of the 1st century, the period between 20 and 50 AD (Fünfschilling 2015, 263, 265). A ribbed bowl made of mosaic glass with a marbled pattern of dark blue and white glass from Celje (Roman Celeia; Lazar 2023, 418) and the one from the northern necropolis of Emona (violet and white glass of the same pattern) can be identified as type AR 2.1. (Fünfschilling 2015, 261). They are also known from Salona, Tilurium (Buljević 2016, 30, pl. 1, 10–1), and Burnum mili-

Figure 2: Completeley Preserved Ribbed Bowl from Slovenj Gradec Necropolis (after Lazar 2003, fig. 9a)

tary camp in Croatia (Jadrić 2011, pl. 4, 2–4), the early layers of Emona (Gaspari 2010, 110, fig. 64) and Romula (Lazar 2025, 55), as well as from the necropolis in Polhov Gradec (Lazar 2003, 37, fig. 9a) and Emona graves (Petru 1972, pl. 21, 17; Plesničar Gec 1983, pl. 3, 12).

The group of monochrome, translucent coloured glasses from the early imperial period is represented by two mould-made vessels, a plate and a bowl (fig. 2; 4), made of translucent deep green glass. D. F. Grose defined six families of mould-made vessels within the group of the early Roman glass (Grose 1989, 244–61). Monochrome translucent coloured fine ware, and monochrome opaque coloured fine ware, were defined as Family III – Roman cast monochrome vessels (Grose 1989, 254). Due to the angular and carinated ceramic-like profiles, the group was also known as the so-called *glass with ceramic profiles,* as it was defined by Berger (1960, 24–30) in his study of the glass from Vindonissa.

This group of coloured fine wares was made by mould pressing (Lierke 2009) and is characterised by angular lathe-turned forms (fig. 3), strong colours and very high standards of craftsmanship. Some of the colours, like emerald green, are the inventions of the newly established Roman glass industry (Grose 1991, 2). The angular forms reveal the influence of the contemporary metalware of the Julio-Claudian era (Grose 1989, 254). The distribution of these products is Western; the majority of the examples were discovered on Italian and other European archaeological sites. That's why this group is understood as a distinctive product of the early Roman glass industry in the west, and the Italian production centre is assumed. These glasses first appeared in the first quarter of the 1st century AD, perhaps continuing to about AD 60 (Grose 1989; 1991; 2017). Only a generation or two after its appearance, the coloured fine ware obviously fell from fashion.

The plate and bowl from Osor (figs. 2–4) are made of deep green glass, typical of these products. The most widespread colours are dark green in various shades, dark and cobalt blue and peacock blue, the result of the different minerals used to colour the glass. Emerald green and peacock blue are colours developed by the Ro-

Figure 3: Detail from the Interior of the Plate with a Circle and a Dot in the Centre, a Remnant of Working on a Lathe (photo by Monika Petrović, 2025)

Figure 4: Bowlwiith Carinated Walls Made of Deep Green Glass (photo by Monika Petrović, 2025)

man glass industry and used almost exclusively for this group of glassware.

The plate (pl. 1, 1) with carinated walls can be compared with the finds from Slovenia as form 1.1.4. (Lazar 2025, 56, fig. 29). The bowl with carinated walls (pl. 1, 2) represents form Isings 2 or form 2.1.11. known from Romula in Slovenia (Lazar 2025, 58, fig. 30), where this group of glasses is represented with numerous forms and examples.

The comparisons from well-dated sites are known from Magdalensberg (Czurda-Ruth 1979, 65–91), where fragments presumably date before 45 AD when the site was abandoned, with few examples attributed to the late Augustan level (1979, 70–1). In Vindonissa, finds are concentrated in Tiberian and early Claudian contexts, some continuing into the Neronian period (Berger 1960, 24–30). Some fragments are also known from Salona (Buljević 2016, 64).

At Cosa, dated examples come from five deposits (Grose 2017, 81). The earliest is deposit IV (before 25–15 BC) associated with the Augustan reoccupation of the town. They can represent some of the earliest products of the Roman glass industry, or they were imported from the eastern Mediterranean (Grose 2017, 81–2). Deposits V and VI are dated to the period of cca 25–15 BC to cca 40–45 AD, carinated bowls, pyxides and a bowl with an out-turned rim are represented in these strata (Grose 2017, 81, pl. 8, 134, 136–7, 139; 9, 154). Vessels presented in deposits VII and VIII (before cca 50–55 AD) prove the production of these glass vessels until the mid-1st century or even later, but not after the last quarter of the 1stcentury (Grose 2017, 82).

In the second half of the 1st century, demand and taste for fine glassware dramatically changed. Intense colours were forgotten, and the desire for something new and different arose – a group of elegant tableware made of colourless glass appeared on the market, often decorated with cut faceted decoration, which further emphasised the quality of glass and of the glassmaker's work. Therefore, in the Flavian period, the coloured fine ware was replaced by a new group of tableware, made of decolourised glass.

In the Osor Museum collection, the new group of tableware is represented with a shallow footed bowl with a wide, overhanging rim (fig. 5). The bowl is completely preserved, undecorated and made of high-quality decolourised glass (pl. 1, 3). Its form can be compared to the finds from Slovenia (Lazar 2003, 42; 2025, 68, cat. no

Figure 5: Footed Bowl Made of Decolourised Glass (photo by Monika Petrović, 2025)

425, 426) and represents the undecorated version of form 2.1.8 (Lazar 2003, 43).

Small and large bowls made of decolourised glass without decoration appear in considerable numbers and variations in form, for example, at Augst (*Augusta Raurica* in Switzerland (Fünfschilling 2015, 108, form AR16.2; nos. 5254–260) as well as in *Romula* in Slovenia (Lazar 2025, 69). This is a large group of vessels with low ring foot, rarely with a high foot, most often without decoration or with individual shallow ridges on the body. Rim can be made or shaped in very different ways. It is often wide and flared, profiled, and with an overhanging rim.

A varied selection of the rims of these products is presented in a monograph on Roman glass from Augst (Fünfschilling 2015, 108, fig. 141). At the site of Romula, a Roman road and customs station in Pannonia (SE Slovenia), a considerable amount of decolourised undecorated tableware was also excavated (Lazar 2025, 69, fig. 42a). These types of bowls are dated to the late 1st and 2nd centuries (Fünfschilling 2015, 278–79).

Mould-Blown Glass

Mould-blowing was the last newly discovered glassmaking technique. Products blown in single and multi-part moulds are represented among the Roman glass material from the 1st to the 5th centuries. However, it is the 1st century in which the greatest range of forms and variety of these vessels can be identified. The predominant products of this period are those of the so-called Syro-Roman workshop circle or production centres. A detailed study of mould-blown wares, about their origins, designs or moulds, to the masters of these wares, was contributed by Marianne E. Stern (Stern 1995), and later complemented by studies of individual craftsmen, such as Ennion (Israeli 2011; Lightfoot 2014).

According to studies by Jennifer Price (Price 1991) and Marianne E. Stern (Stern 1995), 1st-century mould-blown wares can be classified into three groups:

1. Late Tiberian to Early Claudian, i.e. 35–45 (cylindrical beakers signed by *Ennion*, beakers with inscriptions (so-called motto beakers), hemispherical ribbed bowls) (see Fünfschilling 2015, fig. 146, 1–7).
2. The Claudian-Neronian period or between 45–61 (hemispherical ribbed bowls, circus cups, various cups with floral and similar decoration) (see Fünfschilling 2015, fig. 146, 9–13).
3. Group of the Late Neronian and Flavian period or between 61–75 (jug and polygonal bottle with Ennion signature, ribbed bowls, conical beakers with various decoration, head-shaped bottles) (see Fünfschilling 2015, fig. 148, 1–8).

Figure 6: Finely Ribbed Shallow Bowl Made of Translucent Glass with a Bluish Tinge, Mould-Blown (photo by Nadir Mavrović, 2025)

Based on recent finds from August, Sylvia Fünfschilling (2015) concludes that this division is more or less artificial; in archaeological layers, finds from Groups 1 and 2 are represented simultaneously, from the end of the reign of Tiberius until the early years of Nero's reign (Fünfschilling 2015, 113). The forms of all three groups can also be traced together in archaeological contexts; e.g., circus cups and ribbed bowls are represented throughout the second half of the 1st century. The proposed division was an attempt to arrange the known products chronologically within the group as a whole. Today, the archaeological contexts do not fully support the proposed timespan and division, according to Sylvia Fünfschilling (Fünfschilling 2015, 113).

The technique of mould-blowing flourishes from the mid-first century to the Flavian period, with a slightly different development in the west than in the eastern part of the empire. Given the representation of particular forms, like mould-blown bottles with various decorations, the cradle of this technique is probably somewhere in the Middle East (Stern 1995, 66); however, almost nothing is known about the location of the production centres.

Several products were imported from the Eastern workshops, produced in various bright colours such as green, blue, violet, amber, etc. The products are not very numerous, which is why the finds are even more important. On several sites across the Empire, we may observe that mould-blown vessels of the 1st century were a rarity, and available predominantly to well-to-do clients. They are seldom found in graves; probably, they were considered too precious.

Among the Osor finds, we should mention at least three examples of different forms, which are excellent representatives of mould-blown series from the 1st century.

The first one is a shallow, finely ribbed bowl (pl. 1, 4) made of high-quality clear glass with a slight bluish tinge (fig. 6). It was possibly blown into a one-part mould. On the inside of the bottom, we can see a vestigial omphalos, while on the underside, two concentric ridges. The group of mould-blown shallow bowls is considerably smaller than that of deeper specimens, as shown by an overview of these finds in the Gallia Narbonensis region, where this vessel form is the most common among all mould-blown products (Fontaine and Roussel-Ode 2010, fig. 9). Jennifer Price notes that shallow bowls are noticeably

Figure 7: Truncated Conical Beaker with Almond Boss Decoration (photo by Monika Petrović, 2025)

Figure 8: Base of a Beaker Wwith Rosette Decoration (photo by Monika Petrović, 2025)

more common in the context of Mediterranean sites than in the western part of the empire (Price 1991, 72). Many of them are decorated with concentric ridges on the outside of the bottom, while the omphalos inside, at the bottom of the vessel, is less common. Comparisons for the latter can only be found at certain sites, such as Marseille, Apt, the Gulf of Fos, Avignon, and Peyrestortes (Fontaine and Roussel-Ode 2010, 188, fig. 9, 58, 59, 60, 67). Among other comparisons, it is worth mentioning the finds from the Relja necropolis in Zadar (1989, grave 797; 2005, grave 329; Eterović Borzić and Štefanac 2021, 32, cat. no. 18, 149, cat. no. 469), the Black Sea region (Pontykapeion; Kunina 1997, 276, no. 121), southern Spain, Italy (Price 1991, 64) and the nearby Aquileia (Calvi 1968, 101, pl. 16, 1). In France, they are dated to the second quarter of the 1st century (Fontaine and Roussel-Ode 2010, 189), while in Augst they are present in the middle and second half of the 1st century (Fünfschilling 2015, 292).

The second well-preserved find is a truncated conical beaker (pl. 1, 5) with knobbed or almond decoration over the body (fig. 7). This form is sometimes also known as the Hercules beaker[1] and is known in many series. The principal decoration consists of alternating rows of oval knobs or bosses pointing downward. They were made of bluish, naturally coloured or decolourised glass, but finds of beakers made of coloured glass are also known. They were blown into a four-part mould joined to a disk-shaped base section, but beakers blown only in two vertical sections are also known (Stern 1995, 103–4). Decoration on the body occurs in many variations. Knobs can be plain and simple, as seen on the Osor beaker, or three-tiered and alternating with small circular bosses; sometimes the bosses are also framed with linear patterns.

Most of these vessels were probably drinking vessels, and, having in mind their decoration, they should probably be associated with Hercules and associated celebrations or worship.

1 The decoration on the beaker is said to be reminiscent of Hercules' club; exceptionally, there are small bottles made in the shape of Hercules' club (Ernesto Wolf Collection; Stern 1995, 105, fig. 70)

Figure 9: Fragment of a Mould-Blown Cylindrical Beaker with Vegetal Decoration (photo by Monika Petrović, 2025)

A wide variety of these beakers was published from France (Fontaine and Roussel-Ode 2010, 184). The published finds are made of coloured and naturally coloured glass, with various types of decoration (Fontaine and Roussel-Ode 2010, fig. 5, 6). The beaker from Osor is similar to finds from Zaton in Zadar (Gluščević 1986, 256, pl. 1, 2), the Gulf of Fos (no. 44 and Ruscino, no. 49), comparisons are also known from Rome, Augst and Aquileia (Fontaine and Roussel-Ode 2010, 184), Pompeii and Herculaneum (Stern 1995, 104). Several beakers with more elaborate boss decoration and the addition of theatrical masks are known from Liburnian sites in Croatia, such as Asseria (Fadić 2005, 78, 86, figs. 1–3).

They were in use from the mid- to the second half of the 1st century, but less is known about when the form went out of use.

The third find is a fragment of a cylindrical beaker or cup with vegetal decoration (pl. 1, 6). On the wall and rim, we can recognise the line where the two parts of the mould were put together (fig. 9). The fragment is too small to define its form, but most probably, it was a drinking vessel, produced in the Claudian-Neronian period, like other cups with floral or similar decoration (Price 1991, 68). A possible comparison to its form and vegetal decoration is a completely preserved cup from Emona grave no. 5 (1280), dated to the second half of the 1st century (Petru 1972, 116, pl. 118, 3; Lazar 2004, 55, no. 23).

It is also worth mentioning two mould-blown base fragments of balsamaria. They were made of a yellowish glass and blown in the form of a grape (Fadić 1982, 117, fig. 1, fig. 33, and fig. 34). Due to their small size (body height 2.8 and 1.5 cm), we may assume they belonged to a form Isings 78e. These small vessels, mostly without handles, were produced in the 1st century, with the first products appearing in the second half of the 1st century (Moirin and Arveiller 2010, 215; Goethert-Polaschek 1977). The vessels were most often blown from naturally coloured, yellow or blue glass, but also from opaque white glass. Their size did not exceed 10 cm in height. They can be found in settlement contexts and also as grave goods; among other places, they are known from sites in Italy (Pompeii, Aquileia), Spain, France, and Germany (Moirin and Arveiller 2010, 221–4).

Early Blown Glass

The mould-made techniques went out of use in the first decades of the 1st century AD (except for ribbed bowls), and costly products were replaced with new ones.

The discovery of free blowing in the 1st century BC caused gradual changes in glassmaking. The discovery of glass blowing caused the rapid spread of cheaper and more available free-blown products, and in the course of the 1st century AD, glass became, more or less, a commodity for all.

The Zarte Rippenschalen were one of the earliest free-blown products known in all the provinces of the Empire. Marianne E. Stern placed them among the so-called vessels exploring the blow-pipe, i. e., among the products made in the period from 30 BC to 50 AD (2001, 43).

The bowls are mostly hemispherical, around 5 to 6 cm in height, and the rim is cracked-off, unworked or lightly ground. During the working process, the glassblower wound the thin glass thread around the paraison and then created the ribs, before the bowl was inflated to its final shape. The threads became thin, in some places almost invisible; the ribs did not expand because pinching cooled the glass during forming (Stern 2001, 82).

The use of these bowls is still questionable. According to some researchers, the unworked rim should speak against being a drinking vessel, but for serving food or even washing hands at dinner. However, some bowls were very probably used (also) as drinking vessels. From sites in Croatia and Slovenia, a wide range of these finds from settlements and necropolises, varied in size, colour, and decoration (Croatia: Jadrić 2011, 364 and note 21, pl. 5, 1– 4; Slovenia: Lazar 2004, 61, no. 42, 43), could perhaps confirm their use as drinking vessels.

The finds of these bowls are widespread in all the provinces of the Empire, but predominantly concentrated in northern Italy, the SE Alpine area, Dalmatia and the Ticino area. They were most probably made in the western part of the Roman Empire. Several bowls found in the Eastern Mediterranean are monochrome, like the completely preserved bowl from Osor. We can't confirm if this is a regional variant or perhaps a local product.

The earliest dating of these finds is known from Cosa in Italy, where finds come from the strata dated to the last decades of the 1st century BC, even earlier than the Magdalensberg and Morgantina finds, which are dated to the first decades of the 1st century AD (Grose 2017, 123).

Concluding Remarks

With the selected 1st-century AD glass finds, we presented the varied assemblage of glass products discovered in Osor. The products represent all glass-making techniques developed and used by Roman glassmakers. It is a rare opportunity to have such a varied group of glass products on one site and study them. We can mention a similar example from Slovenia, the Roman road and customs station *Romula* in Pannonia, where we had an opportunity to compare 1st-century finds from a settlement and necropolis (Tomaž et al. 2024; Tomaž et al. 2025).

What can this selected group of high-quality glassware tell us about the Roman town of Osor? Without a doubt, its population included a group of wealthy people, both Romans and locals, who were well aware of what was available on the glassware market and what the most prestigious products were. They were well informed about what was popular in the period and where or by whom these items were available. These residents had the wealth and economic power to buy these products or have them made to order. With their quality and uniqueness, they could show off the prestige, taste and personal economic power to their dinner guests. The rich and varied glass material, imported from Italic and Mediterranean workshops, shows that Osor played an important role in the process of Romanisation of the northern Adriatic.

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Catalogue

Mould-made glass

1. Melted fragments of a ribbed bowl made of mosaic glass, blue and white marbled pattern.

   Form: Is 3; Lazar 2.1.4.

   Publication: unpublished.

2. Plate with carinated walls and a low ring-foot made of dark green glass, mould-made, with a circle on the inside of the base, remnants of attachment to a lathe.

   Dim.: diam. 18 cm, height 2.7 cm, inv. no. 176, 210.

   Form: Trier 7; Lazar 1.1.4.

   Publication: Fadić (1982, 120, sl. 3, 44).

3. Bowl with carinated walls and a low ring-foot, made of dark green glass, mould-made.

   Dim.: diam. 13.5 cm, height 5.5 cm, inv. no. 160, 594.

   Form: AR 6.2; Lazar 2.1.11.

   Publication: Fadić (1982, 122, sl. 3, 47).

4. Bowl with an outplayed wall and overhanging rim on a low ring-foot made of decolourised glass, mould-made and finished on a lathe.

   Dim.: diam. 13.3 cm, height 4.1 cm, inv. no. 159, 593.

   Form: var. AR 16.2; Lazar var. 2.1.8.

   Publication: Fadić (1982, 122, sl. 3, 46).

Mould-blown glass

1. Finely ribbed bowl made of naturally coloured glass with a bluish tinge, mould-blown, possibly blown in one-part mould. On the inside of the bottom, a vestigial omphalos, on the underside, two concentric ridges.

   Dim.: rim diam. 12.4 cm, base diam. 5.5 cm, height: 4.5cm.

   Form: Stern 1995, Type 2; AR 30.1; Lazar 2.2.1.

   Publication: unpublished.

2. Truncated conical beaker with almond boss decoration on the walls, on the base a stylised flower with six petals, mould-blown, naturally coloured glass.

   Dim: rim diam. 6.4 cm, height 11.5 cm, inv. no. 602.

   Form: AR 33.1; Lazar 3.1.1.

   Publication: Fadić (1982, 124, sl. 3, 53).

3. Fragment of a rim and a wall of the beaker with vegetal decoration and visible vertical seam, yellowish glass, mould-blown.

   Dim.: 4 x 3.6 cm; inv. no. 863.

   Form: var. AR 31.

   Publication: Fadić (1982, 124, sl. 3, 54).

Free blown glass

1. Globular ribbed bowl with cut-off rim made of naturally coloured glass with a bluish tinge (zarte Rippenschale).

   Dim: height 6.8 cm, inv. no. 158, 592.

   Form: Is 17; Lazar 2.3.1.

   Publication: Fadić (1982, 117, sl. 3, 48).

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Summary

The arrival of the Romans in the 2nd century BCE marked the beginning of a completely new era for Osor. Together with other areas of Kvarner, Osor began another rich epoch of its splendid past. Material culture indicates that it played an important role in the Romanisation of the northern Adriatic. Osor (Apsorus) was granted the status of a *municipium* and developed into a Roman city. The article focuses on selected glassware finds from the Archaeological Collection Osor, Lošinj Museum. The exact provenance of the finds is not known; most probably, they were discovered in a Roman necropolis west of the Apsorus. Among the excavated material exhibited in the museum, early products of Roman glassmaking stand out.

Why are we focusing on glass, and what do these finds reflect?

In the 1st and 2nd centuries BC, the Hellenistic states of the Mediterranean were conquered by the Romans and incorporated into the Roman State. This opened cultural and social influences and exchanges, as well as intense development and several innovations in various Roman crafts, including glassmaking. No period better illustrates the remarkable diversity of technological practices of this early period than the Augustan era and subsequent decades. Glass finds show a great variety and range in form, colour, decoration and production techniques.

Imports of these products in newly created towns and cities along the Adriatic reflect the economic strength of the population. The presence of glass material made using various glassmaking techniques, as evident in the glass material from Osor, suggests that the settlement had a wide trade network. Most of the early glass ves-

sels were imported from the newly founded glass workshops of central Italy, but some pieces may also have come from the workshops of the Eastern Mediterranean.

The mould-made glasses are represented by a blue and white mosaic ribbed bowl, unfortunately destroyed and disfigured, as it was most probably placed on a pyre with a deceased. The group of coloured fine wares (a plate and a bowl with carinated walls made of deep green glass) was made by mould pressing and is characterised by angular lathe-turned forms, strong colours and very high standards of craftsmanship. Some of the colours, like emerald green, are the inventions of the newly established Roman glass industry, and the angular forms reveal the influence of the contemporary metalware of the Julio-Claudian era.

In the second half of the 1st century, demand and taste for fine glassware dramatically changed. Intense colours were forgotten, and a group of elegant tableware made of colourless glass appeared on the market, often decorated with cut faceted decoration. In the Osor Museum collection, the new group of tableware is represented with a shallow footed bowl with a wide, overhanging rim.

Mould-blowing was the last newly discovered glassmaking technique. Products blown in single and multi-part moulds are represented among the Roman glass material from the 1st to the 5th centuries. However, it is the 1st century in which the greatest range of forms and variety of these vessels can be identified. A finely ribbed shallow bowl, a truncated conical beaker with almond decoration and a fragment of a cup with vegetal decoration represent this group of glass.

The discovery of free-blowing in the 1st century BC caused gradual changes in glassmaking, and society was faced with a rapid spread of cheaper free-blown products. In the course of the 1st century AD, glass became, more or less, a commodity for all. The Zarte Rippenschalen were one of the earliest free-blown products known in all the provinces of the Empire.

The rich and varied glass material, imported from Italic and Mediterranean workshops, shows that Osor played an important role in the process of Romanisation of the northern Adriatic.

Povzetek

Prihod Rimljanov v 2. stoletju pr. n. št. je za Osor pomenil začetek nove dobe. Skupaj z drugimi območji Kvarnerja je začel novo bogato obdobje svoje sijajne preteklosti. Materialna kultura kaže, da je imel pomembno vlogo pri romanizaciji severnega Jadrana. Osor (Apsorus) je dobil status municipija in se razvil v rimsko mesto. Članek se osredotoča na izbrane najdbe stekla iz Arheološke zbirke Osor Lošinjskega muzeja. Natančen izvor najdb ni znan; najverjetneje so bile odkrite v rimski nekropoli zahodno od Apsorja. Med izkopanim materialom, razstavljenim v muzeju, posebej izstopajo zgodnji izdelki rimskega steklarstva.

Zakaj se osredotočamo na steklo in kaj odražajo te najdbe?

V 1. in 2. stoletju pr. n. št. so Rimljani osvojili helenistične države Sredozemlja in jih vključili v rimsko državo. To je omogočilo kulturne in družbene vplive ter izmenjave, intenziven razvoj in številne inovacije v različnih rimskih obrteh, vključno s steklarstvom. Nobeno obdobje ne ponazarja izjemne raznolikosti tehnoloških praks tega zgodnjega obdobja bolje kot avgustejska doba in naslednja desetletja. Steklene najdbe kažejo veliko raznolikost in razpon v obliki, barvi, okrasih ter proizvodnih tehnikah.

Uvoz teh izdelkov v novonastala mesta ob Jadranu odraža gospodarsko moč prebivalstva. Prisotnost steklenih izdelkov, ki so bili izdelani z uporabo različnih steklarskih tehnik izdelave, kot priča stekleni material iz Osorja, kaže, da je imelo naselje razvejano trgovsko mrežo. Večina zgodnjih steklenih posod je bila uvožena iz novoustanovljenih steklarskih delavnic v osrednji Italiji, vendar so nekateri kosi morda prišli tudi iz delavnic vzhodnega Sredozemlja.

V kalupih narejeno posodje zastopa modro-bela rebrasta skodelica iz mozaičnega stekla, žal močno poškodovana v ognju, saj je bila najverjetneje položena na pogrebno grmado skupaj s pokojnikom. Fino namizno posodje iz obarvanega enobarvnega stekla intenzivnih barv (krožnik in skodelica) je bilo izdelano z oblikovanjem v kalupih, njegova značilnost pa so ostre linije, dodelane na stružnici, intenzivne barve in visoka kakovost izdelave ter obrtnega znanja. Nekatere barve, kot npr. smaragdno zelena, so izum novoosnovane

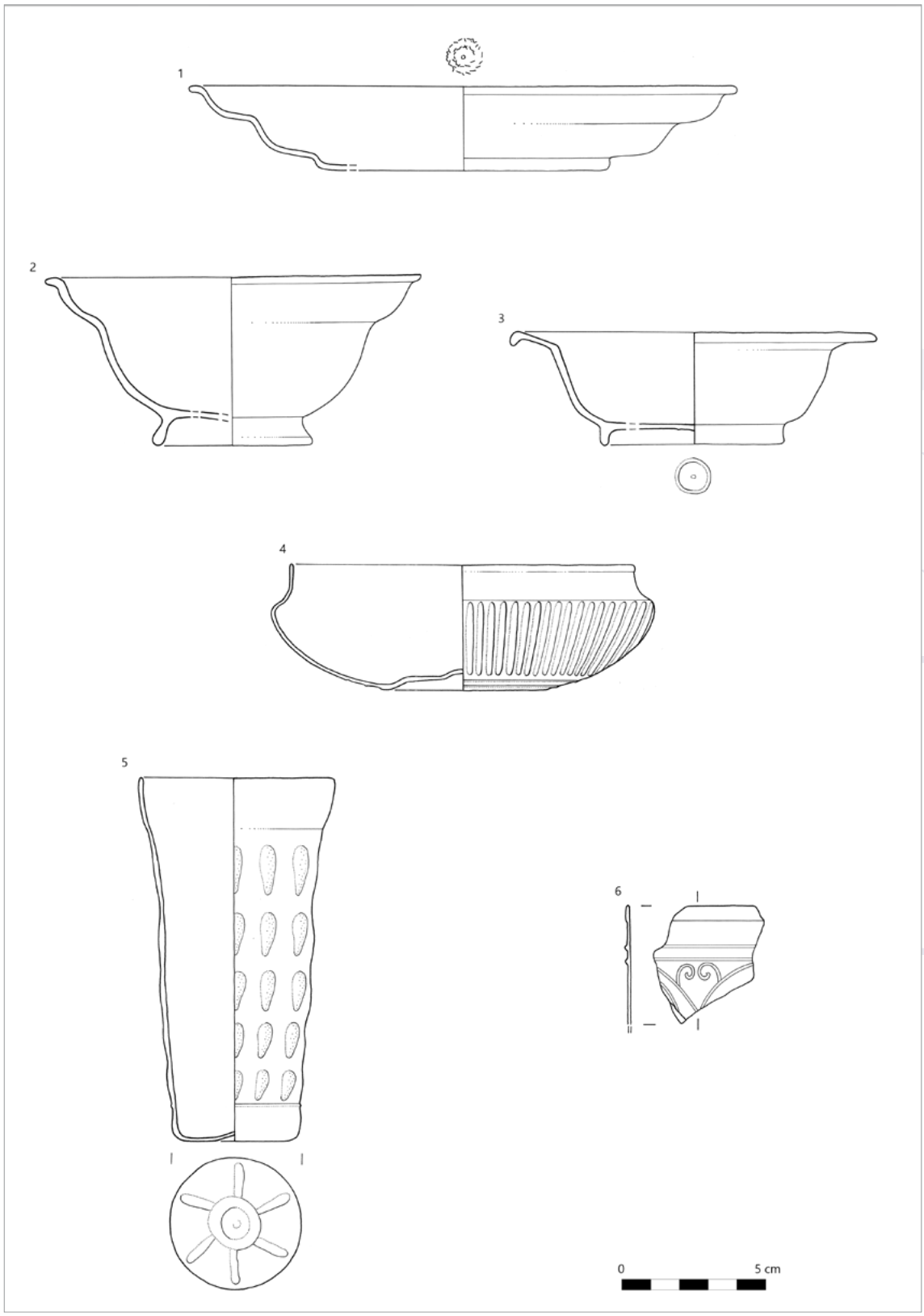
rimske steklarske industrije, ostre linije pa odražajo tudi vpliv sočasnega kovinskega izdelka iz julijsko-klavdijske dobe.

V drugi polovici 1. stoletja sta se povpraševanje in okus za fino stekleno posodje dramatično spremenila. Intenzivne barve so bile pozabljene, na trgu se je pojavila skupina elegantnega namiznega posodja iz brezbarvnega stekla, pogosto okrašena z vrezanim fasetiranim okrasom. V zbirki Lošinjskega muzeja je nova skupina namiznega posodja zastopana s plitvo skodelico na prstanasti nogi s širokim ustjem z navzdol zapognjenim robom.

Pihanje v kalup je bila zadnja novoodkrita tehnika izdelave stekla. Izdelki, pihani v enodelnih in večdelnih kalupih, so zastopani med rimskim steklenim materialom od 1. do 5. stoletja. Vendar je v 1. stoletju mogoče opaziti največjo raznolikost oblik in okrasja teh posod. To skupino stekla predstavljajo plitva skodelica s fino narebrenim ostenjem, visoka konična čaša z mandljevim okrasom in odlomek čaše z rastlinskim okrasom.

Odkritje tehnike prostega pihanja v 1. stoletju pr. n. št. je povzročilo postopne spremembe v proizvodnji stekla, družba pa se je soočila s hitrim širjenjem cenejših izdelkov, izdelanih s tehniko prostega pihanja. V 1. stoletju n. št. je steklo postalo bolj ali manj blago za vse. Male kroglaste skodelice z rebri (t. i. *Zarte Rippenschalen*) so bile eden najzgodnejših pihanih izdelkov, ki so bili razširjeni v vseh provincah cesarstva.

Bogati in raznoliki stekleni izdelki, uvoženi iz italskih in sredozemskih delavnic, odražajo, da je Osor igral pomembno vlogo v procesu romanizacije severnega Jadrana.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The Caryatid from Osor (Apsorus): A Provincial Reinterpretation of a Classical Motif
Kariatida z Osorja (Apsorus): provincialna reinterpretacija klasičnega motiva

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Abstract
The study examines the marble female statue from Osor (Apsorus; now in the Museo Archeologico Nazionale di Venezia, inv. no. 162-A), traditionally referred to as Medea, Caryatid, or Muse-Caryatid. The figure is dressed in a *chiton* and *diplex,* it was carved with an unfinished back, suggesting placement against a wall. Stylistic and iconographic analysis of its posture and drapery associate it more closely with the Tralles/Cherchell type of caryatides than with the Erechtheion prototypes, thereby underscoring its primarily decorative rather than structural purpose. The statue's archaizing hairstyle and drapery, together with other sculptural finds from Apsorus, suggest an Early Imperial date of production, most likely within the Augustan or Julio-Claudian period. The absence of a clear archaeological context precludes certainty about its original function, but its decorative role – possibly within a public building or elite residence – appears most plausible. The statue exemplifies the transmission and adaptation of classical models in provincial Roman art, reflecting Apsorus's cultural engagement with modern metropolitan artistic trends.
Keywords: Apsorus, Caryatid, Grimani collection, Dalmatia, Augustan era

Izvleček
Prispevek obravnava marmorni ženski kip iz Osorja (Apsorus; danes Museo Archeologico Nazionale di Venezia, inv. št. 162-A), ki je bil tradicionalno poimenovan Medeja, Kariatida ali Muza-Kariatida. Figura je oblečena v hiton in *diplex,* njen hrbet je neobdelan, kar nakazuje, da je bila prvotno postavljena ob steno. Slogovna in ikonografska analiza tako v drži kot v draperiji kip povezujeta s kariatidami tipa Tralles/Cherchell ter ne s prototipi iz Erehtejona, kar poudarja njegovo dekorativno in ne nosilno funkcijo. Tako arhaizirajoča pričeska kot oblačilo in preostale kiparske najdbe nakazujejo njegov nastanek v zgodnjem cesarstvu, verjetno v avgustejski ali širše julijsko-klavdijski dobi. Zaradi pomanjkanja jasnega arheološkega konteksta prvotni namen kipa ni z gotovostjo določljiv, vendar se zdi njegova dekorativna vloga – morda kot okras neke javne stavbe ali razkošne zasebne vile – najverjetnejša. Kip obenem ponazarja prenos in prilagoditev klasičnih vzorov v provincialni rimski umetnosti ter odraža kulturno vpetost Apsora v sočasne umetnostne tokove metropole.
Ključne besede: Apsorus, kariatida, zbirka Grimani, Dalmacija, avgustejska doba

Introduction

The deteriorated marble female statue (Museo Archeologico Nazionale di Venezia, inv. no. 162-A; fig. 1),[1] commonly referred to as Medea (Faber 1982, 74), Muse (Dütschke 1882, 46, no. 115; Favaretto 2002, 91), Caryatid (Anti 1930, 29, no. 5; Polacco and Traversari 1988, 19, no. 3; De Paoli 2006–2007, 428) or Muse-Caryatid (De Paoli 2006–2007, 446), was excavated in Osor (it. Ossero)[2] and

1 Dütschke (1882, 46, no. 115); Anti (1930, 29, no. 5); Polacco and Traversari (1988, 19, no. 3, with the list of the earlier literature); De Paoli (2006–2007, 428); Harl and Harl (2025, 19809).

2 The earlier literature suggests that the object was excavated prior to 1587 (e.g. Valentinelli 1863, 12, no. 51; Dütschke 1882, 46, no. 115; Anti 1930, 29, no. 5; Polacco and Traversari 1988, 19, no. 3, who wrongly indicate that it was donated to Giovanni Grimani); however, since Antonio Grimani died in 1523, the find must have occurred significantly earlier.

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Figure 1: Caryatid from Apsorus (Museo archeologico nazionale di Venezia, Musei archeologici nazionali di Venezia e della Laguna, inv. no. 162-A, su concessione del Ministero della Cultura; photo: Singer, Neg. D-DAI-Rom 68.4933)

subsequently donated by its inhabitants to Antonio Grimani (1434–1523), who later became the Doge of Venice (1521–1523; Favaretto 1993, 24; De Paoli 2006–2007, 446, n. 79). In 1494, Grimani was appointed Capitano Generale da Mar, but in 1499, he suffered a severe defeat in the naval battle of Zonchio, leading to his exile on the island of Cres (it. Cherso).[3] Upon his return to Venice in 1509, the statue became part of his extensive collection of antiquities and was placed in Palazzo Grimani, positioned in a niche at the right corner of the courtyard, near the entrance (De Paoli 2006–2007, 428; De Paoli 2021, 48, n. 16).

The son and heir of Antonio Grimani, Cardinal Domenico Grimani (1461–1523), survived his father by only a few months. Upon his death, the collection was bequeathed to the family. Eventually, his nephew, Giovanni Grimani (1506–1593), who was appointed Patriarch of Aquileia in 1545 and was himself an avid collector of classical art, inherited the entire collection of his late brothers, Marco, Marino, and Vettore. He also reacquired portions of the Greek and Roman artefacts that had been previously sold. In 1587, Giovanni Grimani donated his extensive collection of ancient sculptures to the *Serenissima (*Dütschke 1882, 46, no. 115; Anti 1930, 29, no. 5; De Paoli 2006–2007, 446, n. 79; Ferrara and Bergamo Rossi 2021, 20), where it is now housed as part of the Grimani Collection.[4]

The statue was discovered headless, and during the Renaissance, a head from another statue (Museo Archeologico Nazionale di Venezia, inv. no. 162-B) was added. In the early 20th century, this head was replaced with a plaster cast taken from its museum counterpart, the Muse Melpomene (inv. no. 161; Anti 1930, 29, no. 5; Polacco and Traversari 1988, 19, no. 3).

The Caryatid from Apsorus

The female statue from Apsorus stands 2.28 meters high (including the added head; Polacco and Traversari 1988, 19, no. 3) and is dressed in a *chiton* and *diplex*. The lower portions of her arms are missing; however, the positioning of

3 According to Marcella De Paoli, he remained in Osor on the island of Cres until his return to Venice (De Paoli 2021, 48, n. 16), whereas Irene Favaretto (1993, 15; 2002, 84) argues that he left it after two years and sought refuge in Rome.

4 On collection: Favaretto (2002, 84–93), De Paoli (2006–2007).

Figure 2: Caryatid from Tralles, *Istanbul Archaeological Museum*, inv. no. 1189 (D-DAI-IST-671)

Figure 3: Caryatid, Le Musée public national de Cherchell, inv. no. S 89 (photo: Amel Bouder)

the upper arms indicates that the right arm was raised while the left was lowered. Its back is unfinished, suggesting that it was originally positioned against a wall. However, the figure lacks defining attributes, making a precise identification difficult – especially considering that, in the provinces, the iconography of deities and other mythological figures was not always directly copied from the prototypes. Instead, posture, movement, or attributes were often subject to minor or significant modifications and deviations (cf. lately Witschel 1995, 251, n. 22; Dorka Moreno et al. 2021, 5–9). Of particular interest is the arrangement of the locks in her braids, which fall over her breasts. This archaic hairstyle closely resembles the rigid, stylized hair of the *korai* in archaic Greek art and was also employed for the renowned caryatides on the porch of the Erechtheion in Athens, that were erected around 415 BC.[5] In addition to serving as structural supports in place of simpler columns, their role evolved to become primarily aesthetic and non-structural (Polacco and Traversari 1988, 20). Centuries later, this hairstyle was adopted by the caryatides in Rome, used as decorative elements in the Forum Augusti, which exerted a significant influence on provincial art.[6]

5 On *korai* in Erechtheion *inter alios:* Lauter (1976, 12–40), Schmidt (1982, 79–84), Jenkins (2006, 125–8). On dating see esp. Lauter (1976, 16–7), Vickers (2014, 123–31). On their hairstyle: Schwab and Rose (2015, 1–4).

6 A number of studies have addressed the caryatides from the Forum of Augustus and their role within the broader architectural and ideological programme: cf. e.g. Zanker (1968, 11–3), Hölscher (2007, 119–20), La Rocca (2011, 993–1010), Lo Monaco (2021, 34–6).

However, quite early was noted that rather than directly following the type that derives from the figures of the Erechtheion-porch, the statue from Apsorus more closely resembles the caryatides of the Tralles/Cherchell type, whose prototype was likely conceived around the mid-3rd century BC or slightly later (Özgan 1995, 131–2).[7] This resemblance is particularly evident in its posture – one arm lowered and the other raised (the positioning of the arms is in preserved examples either the same or mirrored) – as well as in the arrangement of the braids, and the garment, as all are wearing chiton and diplex. In addition to the best-preserved replicas from Tralles (fig. 2) and Caesarea in Mauretania (fig. 3), this type is also attested by two heads in Athens (National Archaeological Museum, inv. nos. 1682 and 1683; Schmidt 1982, 92–5; Özgan 1995, 125, n. 785), both of which feature holes at the top, as well as by now-lost head originally from Tralles that was previously housed in the Evangelical School in Izmir (Mendel 1914, 259; Schmidt 1982, 93–4; Özgan 1995, 125, n. 786). The heads from Athens date to the Hadrianic era, while the one from Tralles is attributed to the late 2nd century BC or early 1st century BC (Özgan 1995, 126).

The best-preserved example of this type is the Caryatid from Tralles (Istanbul Archaeological Museum, inv. no. 1189; Collignon 1903, 13–29; Mendel 1914, 257–60, no. 541; Schmidt 1982, 92–3; Özgan 1995, 125–33, no. 70). According to unverifiable tradition, it originates from the theatre of Tralles (Mendel 1914, 259; Fittschen 1979, 236; Schmidt 1982, 94). Initially dated to the Augustan era, it was later reassigned to the Claudian era due to stylistic differences compared to the replica from Caesarea.[8] The caryatid holds the brim of her *chiton* with her lowered right arm, while a *modius* rests atop her head. By analogy with relief depictions of caryatides at the corners of Attic sarcophagi (Fittschen 1979, 236, n. 22; Polacco and Traversari 1988, 21) and considering her posture, she may have originally decoratively 'supported' the epistyle with her raised hand, as no holes are present in the *modius*. Her back is completely, though *a prima vista* more crudely than the front side, carved, suggesting that the figure was not affixed to an architectural structure but was instead a freestanding sculpture placed in front of a wall (Schmidt 1982, 92).

The statue from Apsorus appears to bear a closer affinity to the caryatid from Caesarea (Cherchell, Le Musée public national de Cherchell, inv. no. S 89; Collignon 1903, 15–6; Mendel 1914, 259; Fittschen 1979, 236–38; Schmidt 1982, 92–3; Özgan 1995, 126–7; Kreilinger and Atif Hamza 2019, 47–8; Harl and Harl 2020, 24448) than to one from Tralles. The Caesarea figure is dated to the reign of the client kings, approximately the 20s BC (Özgan 1995, 126–7) or between circa 25 BC and 40 AD (Kreilinger and Atif Hamza 2019, 48). Although the statue is fragmentary – missing both the arms and the head – certain formal characteristics allow for a comparative analysis. The treatment of the drapery, particularly the arrangement of folds and the pronounced brim of the garment, is consistent with the Tralles example. *Per analogiam*, the brim was likely held by the figure's lowered arm. The back of the Caesarea figure is roughly carved, suggesting that it may have served a similar architectural function as the caryatid from Tralles (Schmidt 1982, 92–3; Kreilinger and Atif Hamza 2019, 47–8). Additional contextual evidence for the statue's placement is provided by the discovery of fragmentarily preserved Gorgoneion at the same site (Cherchell, Le Musée public national de Cherchell, inv. no. S 195). Given their size and the elaboration of the reverse side, these pieces were likely decorative elements belonging to the architectural ornamentation of a large building. It is therefore highly plausible that both the caryatid and the Gorgoneion formed components of a coherent

7 For a detailed discussion of its dating and the current state of research, see Özgan (1995, 128–32).

8 On the question of dating, see Özgan (1995, 126–8).

Figure 4: Melpomene (Museo archeologico nazionale di Venezia, Musei archeologici nazionali di Venezia e della Laguna, inv. no. 161, su concessione del Ministero della Cultura; photo: Singer, Neg. D-DAI-Rom 68.4934)

decorative program, possibly conceived in emulation of the sculptural scheme of the Forum of Augustus[9] – a model extensively replicated throughout the Roman provinces.[10]

Quite early was scholarly attention drawn to a group of related statues that exhibit notable affinities with the Apsorus figure (Benndorf 1866, 230; Dütschke 1880, 324; Bulle 1894, 153), namely the examples in Mantua (Palazzo Ducale, inv. no. 6674; Labus 1837, 258–9; Dütschke 1880, 323–5, no. 720; Collignon 1903, 22–4), the Hermitage (inv. no. ГР-3097; fig. 5),[11] and Melpomene in Venice (Museo Archeologico Nazionale di Venezia, inv. no. 161; fig. 4),[12] the last of which was even erroneously believed to originate from Apsorus (Harl and Harl 2025, 19809). All of them share the material (marble), posture (standing frontal, one arm raised, another one lowered), the approximate measurements, the garments (*chiton* and *diplex*), archaistic hairstyle, the folding of the drapery and unfinished back.[13]

Due to the resemblances Maxime Collignon classified these figures as a sub-group within the Tralles/Cherchell type,[14] proposing that Roman copyists had reinterpreted the original caryatides as representations of the Muses – an interpretation he applied to all of these examples.[15] Nevertheless, they diverge from the Tralles/Cherchell types in two significant respects: the style of the drapery, which reflects influences from the Greek Classical tradition, and the function of the lowered arm, which does not

9 Cf. reconstruction in Kreilinger and Atif Hamza (2019, 47–8).

10 Cf. Boschung (2003, 6–7, n. 27, with the cited examples), La Rocca (2011).

11 Collignon (1903, 24–5, n. 3), Waldhauer (1936, 26–8, no. 260), Schmidt (1982, 95). Its provenance remains uncertain; it was presumably brought from Athens to Venice, where it was sold in 1851 (cf. Waldhauer 1936, 26, n. 2).

12 On statue, see: Dütschke (1882, 47–8, no. 120), Anti (1930, 29, no. 6), Lancha (1994, 995, no. 193), Polacco and Traversari (1988, 18, no. 2, with the list of the literature), De Paoli (2004, 71, no. II. 24) Harl and Harl (2025, 19809). In earlier scholarship, it was classified as a Greek – most likely Attic – work (cf. Dütschke (1882, 47, no. 120), Anti (1930, 29, no. 6)), but it is now generally considered to be of a Roman production, possibly from the Hadrianic period, executed in the Archaic style (De Paoli 2004, 71, no. II. 24).

13 Despite the similarities it was highly stressed that there is no proof that they were originally displayed together, neither that they originate from the same finding (Polacco and Traversari 1988, 20–1).

14 On the dependence on Tralles/Cherchell type see the list of the literature in Polacco and Traversari (1988, 20). On the type: Schmidt (1982, 92–5).

15 Collignon (1903, 22, 26), Waldhauer (1936, 27). They were also grouped together by other scholars: Mendel (1914, 259), Waldhauer (1936, 27), Schmidt (1982, 95). Evamaria Schmidt (1982, 95) held them for the Antonine copies.

Figure 5: Caryatid, St. Petersburg, *The State Hermitage Museum,* inv. no. ГР-3097 (©The State Hermitage Museum)

appear to have held the brim of the garment but more likely supported an attribute.[16] The statues do not feature holes in the head (Schmidt 1982, 95), and unlike the Tralles and Cherchell figures their backs are left uncarved and without elaboration – strongly indicating that they were intended to be placed against a wall rather than viewed in the round, and that they did not play the supportive, but rather decorative role (Schmidt 1982, 95, n. 548).

The best-preserved example of this group is the Antonine (Lancha 1994, 995, no. 193) statue housed in the Hermitage Museum, which retains both arms. Although both attributes, the scroll in the raised and the codex in the lowered hand are modern additions (Waldhauer 1936, 26; Schmidt 1982, 95), the preservation of the limbs allows for a more comprehensive understanding of the original pose. The hairstyle suggests that the figure did not originally wear a *modius.* Furthermore, a single hole in the calotte of the skull likely served for attachment to an architectural element – possibly the epistyle – indicating that the statue was positioned in front of a building and fulfilled a purely decorative function (Waldhauer 1936, 26; Schmidt 1982, 95). This arrangement may well parallel the architectural placement hypothesized for the caryatides from Tralles and Caesarea.

In the absence of attributes, the precise identification of the statue from Osor remains uncertain. Its archaizing hairstyle clearly evokes the visual language of the caryatides, yet the interpretation as a Muse-Caryatid remains also possible in light of a comparable example of the Muse of Tragedy in Venice. Nevertheless, it must be noted that the addition of attributes could potentially support an alternative identification, as the combination of *chiton* and *diplex* is far from being a standard costume for depictions of the Muses, neither the hairstyle, resembling the hairstyle of caryatides,[17] and that only one statue from that sub-group (Museo Arche-

16 Oskar Waldhauer concluded that the lowered arm in each figure once held an attribute associated with a specific Muse, and that the statues were originally positioned in front of a building, thereby relinquishing their original architectural, supportive function (Waldhauer 1936, 27).

17 In *Lexicon iconographicum mythologiae classicae,* only the above discussed figure of Melpomene in Venice is wearing this particular garment and has such a hairstyle (Faedo 1994, 993–1011; Lancha 1994, 1013–25).

ologico Nazionale di Venezia, inv. no. 161) with certainty has the attribute, associated with the Muses. This ambiguity leaves open the possibility that the figure may have originally represented another mythological character, identified by the unpreserved attribute, and reinterpreted within the caryatid tradition.

Hypothetical Setting

The archaeological context and precise findspot of the Apsorus statue are unknown, making it impossible to determine its original function with certainty. Based on the discovery of marble portrait heads believed to represent members of the Julio-Claudian dynasty, along with a dedication to Jupiter and an inscription referencing a priest of Minerva, scholars have envisaged the existence of a Capitolium (Faber 1982, 74; Matijašić 1989–1990, 261). Within this framework, Aleksandra Faber proposed that the so-called 'Medea' might actually represent Juno, and that the statue could have originally stood in the Capitolium (Faber 1982, 74). However, this interpretation is difficult to reconcile with the unfinished treatment of the statue's back, which suggests it was intended to be viewed only from the front.

Regrettably, the architectural remains from Apsorus are extremely limited and provide no proper information regarding the statue's original placement. Given that iconographic schemes comparable to caryatides were often employed for statues displayed in public buildings without a structural function – such as thermae or theatres – or served as decorative elements in elite domestic settings (Witschel 1995, 250; Zanker 2015, 110), it is most plausible that the caryatid from Apsorus likewise belonged to such a context.

The variation in the position of the arms among the statues of the caryatides Tralles/Cherchell type – some with the right arm raised (Mantua, Osor, Hermitage), others lowered (Tralles, Cherchell, Venice) – suggests, in my view, that these figures were designed to be installed in complementary pairs or even groups in architectural juxtapositions.[18] This interpretation is further supported by reconstruction of the original placement of the Caesarea figure.[19] In this light, the female figure from Apsorus may have stood to the left of a large architectural structure, perhaps symbolically 'supporting' the epistyle with her elevated right arm.

Nevertheless, considering the well-documented integration of the imperial cult within the province of Dalmatia (cf. Cambi 1998; Buzov 2015) that is in Apsorus evidenced by the discovery of three marble portrait heads and a fragmentary torso of the members of the Julio-Claudian dynasty (Cambi 1982; Cambi 1998, 46–7), it is plausible to suggest that the female statue was originally part of an architectural context inspired by the decorative program of the Forum of Augustus, a model widely emulated throughout the western provinces as a means of expressing loyalty and devotion to the emperor (cf. La Rocca 2011, 1004). However, in the absence of additional evidence, this interpretation must remain hypothetical.

The Dating

For both statues located in Venice Renato Polacco and Gustavo Traversari suggested that they may have been produced in Hadrianic era.[20] In the absence of archaeological context or distinctive iconographic attributes that might narrow the chronology, the dating of the Apsorus statue can only be hypothesized in relation to other finds from the site and the broader historical development of the settlement (cf. Zaninović 2005, 16–8; Blečić 2007, 200; Jadrić-Kučan 2011, 143–6; Blečić Kavur 2015, 18–21). Notably, the majority of the Roman stone monuments unearthed in Osor date to the 1st century AD (Cambi 1982,

18 For such an arrangement and some examples of it see Zanker (2015, 110–1).

19 See reconstruction in Kreilinger and Atif Hamza (2019, 48).

20 *Sono da ritenere due modesti lavori decorativi di gusto arcaizzante, creati nel II sec.d.C., forse in epoca adrianea, piuttosto che in epoca antoniniana come altri hanno supposto* (Polacco and Traversari 1988, 21).

95–92). Among these, three marble portrait heads depicting members of the Julio-Claudian dynasty are of particular significance,[21] as they attest to the imperial cult[22] and reflect the existence of a thriving sculptural tradition in Osor during the Early Imperial period. On this basis, it is reasonable to propose a similar dating for the statue in question.

Furthermore, such a chronology is supported by broader cultural trends of the Augustan period, during which archaic and archaistic figures were frequently interpreted as symbols of sanctity, antiquity, and long civic continuity of the settlement (Zanker 1988, 243–5; Fullerton 1990, 197–206; Witschel 1995, 250). These associations would have reinforced both the image of Apsorus as a long-established and culturally vibrant settlement, and its alignment with contemporary artistic currents in the Early Imperial Rome. Given Apsorus' evident openness to the artistic and ideological influences of major urban centers,[23] the statue's creation within this early imperial context appears highly plausible.

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21 Especially remarkable is a portrait of Augustus of the Alcudia type (Arheološka zbirka Osor, inv. no. AZO 409), a portrait type, conceived in the 30s BC, which remains unaffected by the later Prima Porta variant developed after the Senate conferred the title Augustus upon Octavian in 27 BC (Zanker 1973, 44; Smith 1996, 37; Cambi 2000, 31; Jadrić-Kučan 2011, 144).

22 The statuary group may have been erected during one of the extended stays of Drusus Minor and his wife in the province of Dalmatia. He resided there from the winter of AD 17–18, departed to participate in the campaigns against the Germanic tribes in Germania, and returned following the sudden death of Germanicus and his funeral in AD 19. Drusus remained in Dalmatia until assuming his second consulship in May AD 20 (Cambi 2000, 39; Jadrić-Kučan 2011, 144–5; Jadrić-Kučan 2018, 253).

23 In addition to the previously mentioned marble heads of members of the familia Caesaris, a relief of Spinario was also found in Osor (Arheološka zbirka Osor, inv. no. AZO 842), which represents the adaptation of the well-known Hellenistic genre figure (see lately Šmid 2024–2025).

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Summary

The paper explores the so-called Caryatid from Osor (Apsorus), a marble female statue now preserved in the Museo Archeologico Nazionale di Venezia (inv. no. 162-A) and belonging to the Venetian Grimani Collection. Although discovered headless, it was later fitted with a head from another statue, subsequently replaced in the 20th century by a plaster cast.

Standing 2.28 meters high and dressed in a chiton and diplex, the statue's unfinished back suggests that it was conceived to stand against a wall rather than as a freestanding figure. Its hairstyle – featuring braids falling symmetrically over the chest – recalls archaic *korai* and, by extension, the caryatides of the Erechtheion, but its stylistic and iconographic features align more closely with the caryatides Tralles/Cherchell type, whose pro-

totype probably dates around mid-3rd century BC. The composition, with one arm raised and the other lowered, and the garment find parallels especially in the subtype of Tralles/Cherchell type, in examples in Mantua (Palazzo Ducale, inv. no. 6674), the Hermitage (inv. no. ГР-3097), and Venice (Museo Archeologico Nazionale di Venezia, inv. no. 161).

Its unfinished back and absence of a *modius* or other architectural support argue against a functional role as a bearing figure and instead support its use as decorative sculpture, placed in front of walls or niches, possibly within a public building, theatre, or a luxurious private villa, where such statues symbolized erudition and artistic cultivation. Given the limited archaeological evidence from Osor, the statue's function remains hypothetical.

Chronologically, the Osor statue most plausibly dates to the early Imperial period, around the first century AD, coinciding with a broader revival of archaic forms under Augustan classicism, in which archaic and archaistic motifs were reinterpreted as symbols of religious piety and civic longevity. The adoption of such forms in provincial contexts, like that of Apsorus, underscores its integration into the artistic and ideological orbit of Roman Empire, demonstrating both familiarity with metropolitan models and the local capacities for reinterpretation.

Povzetek

Prispevek obravnava t. i. kariatido iz Osorja (Apsorus), marmornat ženski kip, ki je danes shranjen v Museo Archeologico Nazionale di Venezia (inv. št. 162-A) in je del beneške zbirke Grimani. Čeprav je bil kip odkrit brez glave, so mu pozneje dodali glavo drugega kipa, ki je bila v 20. stoletju nadomeščena z mavčnim odlitkom.

Figura v višino meri 2,28 metra in je oblečena v *chiton* in *diplex;* neobdelan hrbet nakazuje, da je bil kip zasnovan za postavitev ob steno in ne kot samostojna figura. Njegova pričeska – kite, ki simetrično padajo čez prsi – spominja na pričesko arhaičnih kor in s tem posledično tudi na kariatide z Erehtejona, vendar se slogovne in ikonografske značilnosti bolj ujemajo s tipom kariatid Tralles/Cherchell, čigar prototip verjetno sega v sredino 3. stoletja pr. Kr. Kompozicija, z eno roko dvignjeno in drugo spuščeno, ter oblačilo najdeta posebej dobre vzporednice v podtipu Tralles/Cherchell, v primerkih v Mantovi (Palazzo Ducale, inv. št. 6674), Ermitažu (inv. št. ГР-3097) in Benetkah (Museo Archeologico Nazionale di Venezia, inv. št. 161).

Neobdelan hrbtni del in odsotnost modija ali druge arhitekturne opore govorijo proti funkcionalni vlogi nosilne figure in podpirajo razlago, da je kip služil kot dekorativna skulptura, postavljena pred steno ali v nišo, morda v javni stavbi, gledališču ali razkošni zasebni vili, kjer so takšni kipi simbolizirali izobraženost in umetniško kultiviranost. Glede na omejene arheološke podatke iz Osorja ostaja prvotni namen kipa hipotetičen.

Kronološko kip iz Osorja najverjetneje spada v zgodnje cesarsko obdobje, okoli 1. stoletja po Kr., ko se v okviru avgustejske obnove pojavi širši preporod arhaičnih oblik. Arhaični in arhaizirajoči motivi so bili v tem času interpretirani kot simboli verske pobožnosti in dolge urbane tradicije mest. Prevzem takšnih oblik v provincialnih kontekstih, kot je bil Apsor, poudarja njegovo vključenost v umetnostni in ideološki krog Rimskega imperija ter kaže na poznavanje metropolitanskih vzorcev in hkrati lokalne zmožnosti za reinterpretacijo znanih motivov.

The Roman Urbanisation of the Northern Adriatic Island of Cres: Re-Evaluation of Archaeological Sources from Osor, Cres and Beli

Rimska urbanizacija severnojadranskega otoka Cresa: ponovna ocena arheoloških virov iz Osorja, s Cresa in iz Belega

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Abstract

The article examines the question of Roman urbanisation on the island of Cres during the early imperial period. It seeks to balance the markedly different levels of research conducted at Osor, Cres, and Beli, evaluating them impartially. This re-evaluation is based on the principle that considering inscriptions, architecture, and landscape context together provides a more comprehensive understanding of Roman urban development than treating these categories separately. Adopting this approach has improved understanding of the available archaeological evidence. At the same time, it has revealed that perceptions of the Roman towns on Cres are influenced more by the state of research than most scholars would admit. The contribution of archaeological prospection methods and the dating of historical mortar are also discussed. Due to the very different post-Roman historical trajectories and natural conditions at each site, a wide range of results has been observed.

The findings confirm that Osor was the Roman centre of Cres and that the inscription CIL III 3148 (10131) most likely originates from there. The location of the potential Roman settlement of Crexi remains unknown. No evidence was found to support the existence of an early imperial town at Beli. Instead, the dating of the city wall mortar indicates a settlement phase in late Antiquity.

Keywords: Kvarner Islands, Osor, Cres, Beli, Roman *municipium,* Mortar analysis

Izvleček

Članek obravnava rimsko urbanizacijo otoka Cres v zgodnjem cesarskem obdobju. Poskuša uravnotežiti zelo različno raziskanost Osorja, Cresa in Belega ter jih nepristransko ovrednotiti. To ponovno vrednotenje temelji na načelu, da celovito razumevanje rimske urbanizacije omogoča sočasno upoštevanje napisov, arhitekture in krajinskega konteksta, saj posamezne kategorije same ne dajejo popolne slike. Takšen pristop je izboljšal razumevanje razpoložljivih arheoloških virov. Hkrati je pokazal, da je naše dojemanje rimskih mest na Cresu odvisnejše od stanja raziskav, kot bi si marsikateri raziskovalec želel priznati. Obravnavana sta tudi vloga arheoloških prospekcijskih metod in datiranje zgodovinske malte. Zaradi povsem različnih zgodovinskih procesov po rimskem obdobju in naravnih pogojev na posameznih lokacijah so rezultati zelo različni.

Rezultati potrjujejo, da je bil Osor rimsko središče otoka Cresa in da napis CIL III 3148 (10131) verjetno izvira od tam. Lokacija morebitnega rimskega naselja Crexi ostaja neznana. Ni dokazov, ki bi potrjevali obstoj zgodnjecesarskega mesta Beli. Datiranje malte mestnega obzidja kaže na fazo naselitve v pozni antiki.

Ključne besede: kvarnerski otoki, Osor, Cres, Beli, rimski municipij, analiza malte

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Introduction

The framework that holds together our knowledge of the Roman history of the Cres-Lošinj archipelago is about 250 years old. It was created at a time when the first interest in antiquity was awakened and reflected in travelogues. For Cres and Lošinj, the travel report of Alberto Fortis (1771) reflects this period. It is not only the oldest publication of its kind, but also the first to include archaeological information. It lists epigraphic monuments, including CIL III 3148 (10131), which refers to the construction of the *curia* under the direction of the *duumviri* in the time of Tiberius (AD 14–37). This is the starting point for this paper. According to Fortis (1771, 137), it originates from the small village of Beli (Ital. Caisole) on the northern tip of the island of Cres (fig. 1). A second epigraphic monument (CIL III 3147), important for the regional history, mentions the *aedile* and *duumviri* and was found on the islet of Susak, SW of the island of Lošinj (fig. 1).

The presumed origin of the CIL III 3148 (10131) inscription at Beli has made the site an important reference point in archaeological research into the urbanisation of the Cres-Lošinj archipelago. However, the research is complicated by the absence of written sources mentioning Beli or the island of Susak; instead, the towns of Crexi and Apsorus are mentioned for the archipelago (Plin. Nat. hist. III, 140). Ancient Crexi is often equated with the modern town of Cres or assumed to be located in its vicinity. Apsorus is today's small village of Osor near the southern tip of the island of Cres (fig. 1). Matijašić (1990, 259) puts it in a nutshell when he says that, paradoxically, the only two inscriptions that provide written evidence of the existence of the institutions and magistrates of Apsorus and Crexi were not found in the respective urban centres. The resulting discussion about the number of urban centres founded on the island of Cres and their role in the administrative system has been going on for more than 100 years (summary in Starac 2000, 78–80). The question was not only whether three independent Roman towns actually existed (today's Beli, Cres and Osor), but also their exact locations, given that some researchers have equated the Roman town of Crexi with modern-day Cres, while others believed it was located in the modern village of Beli (e.g. Margetić 1984, 245–7; Wilkes 1969, 196; Alföldy 1965, 73). However, there is general agreement that Roman towns were founded only on the island of Cres, but not on the neighbouring island of Lošinj.

Table 1: Transcription of the Epigraphic Inscription CIL III 3148 (10131). https://edh.ub.uni-heidelberg.de/edh/inschrift/HD057945

Ti(berio) Caesar[e] Aug(usti) f(ilio)
Augusto pon[t(ifici)] max(imo)
C(aius) Aemilius Vols(oni) f(ilius) Ocla(tinus)
L(ucius) Fonteius Q(uinti) f(ilius) Rufus
IIviri porticum
curiam d(ecreto) d(ecurionum) faciundum
curavere id(em)que probav[ere]

Osor has been the focus of the Austrian-Slovenian project Osor beyond the myth since 2023. The project examines Osor's role in maritime prehistoric trade routes, Roman urban architecture within the city walls, but also the city's landscape context and land use under the Roman regime. In this sense, the new project results add to the discussion about traces left by Roman urbanisation on the island of Cres as a whole. This paper therefore addresses the question of whether 'old' archaeological monuments can be re-evaluated in light of the new project results, and whether this process can contribute to the ongoing discussion about the Roman urbanisation of the island of Cres.

The discussion will also draw on the results of a second project that is currently ongoing. Titled 'Mortar analyses of archaeological monuments in the Mediterranean climate regions' (2024–2025), this Croatian-Austrian collaboration focuses on the radiocarbon analysis of historical mortars from the Cres-Lošinj archipelago. As most of the samples are still being an-

alysed, this publication will only include the results relating to the city wall of Beli, as these are directly relevant to the history of Roman urbanisation on the island of Cres.

The paper begins with a brief overview of the case study area. A comprehensive list of all publications dealing with the Cres-Lošinj archipelago is not included. Only publications that are relevant and contain older citations, provide an overview, or deal with a specific topic are mentioned, in order to avoid unnecessary redundancy. This is followed by a presentation of the recent research results from Osor and Beli. The following discussion examines the contradiction between recent research findings and the prevailing view on the Roman cities of the Cres-Lošinj archipelago. This in turn requires a discussion of the reliability of the information surrounding the discovery of the inscription CIL III 3148 (10131). Other inscriptions from the region are not discussed in detail here, as such an analysis would exceed the scope of this work. An overview of the archipelago's inscriptions and their interpretation can be found in Kurilić's work (1999). Most of the inscriptions can also be viewed in the Heidelberg Digital Epigraphic Database (https://edh.ub.uni-heidelberg.de). Finally, the location, dating and the regional roles of the presumed Roman settlements at Osor, Cres and Beli are discussed.

Case Study Area

The Kvarner Islands are the northernmost islands along the coast of modern-day Croatia. They include the islands of Krk, Cres, Lošinj and Rab, as well as numerous smaller islands (fig. 1). A total of five Roman settlements on three Kvarner islands have been mentioned in written sources: Fulfinum (Omišalj) and Curicum (Krk) on Krk; Apsorus (Osor) and Crexi (Cres) on Cres; and Arba (Rab) on Rab (ancient toponyms after Margetić 1979, 330–2). According to Starac (2000, 78–83), epigraphic sources indicate the granting of municipal privileges during the 1st century AD.

The extent of research into the suspected larger Roman settlements in the present-day towns of Osor, Cres and Beli varies greatly (e.g. Ćus-Rukonić 1984) (fig. 2). No excavation results are available for the village and region of Beli, although a summary of archaeological zones in the surrounding area indicates significant archaeological potential (Bradanović 1999). Publications dealing with Roman Beli mainly refer to the Tiberian inscription and paint a picture of a flourishing city from the early imperial peri-

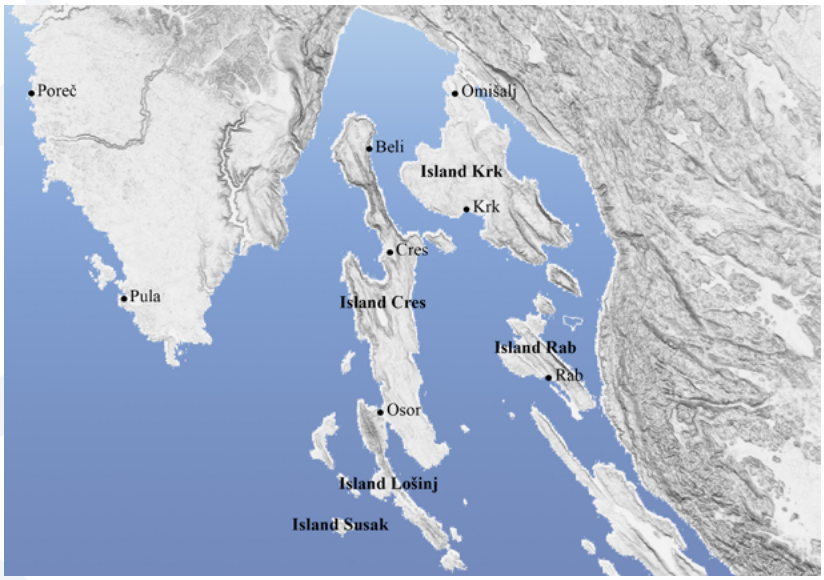

Figure 1: The Cres-Lošinj Archipelago, Including the Places and Geographical Names Mentioned in the Text (Base: SRTM, elaborated by Nives Doneus, 2025)

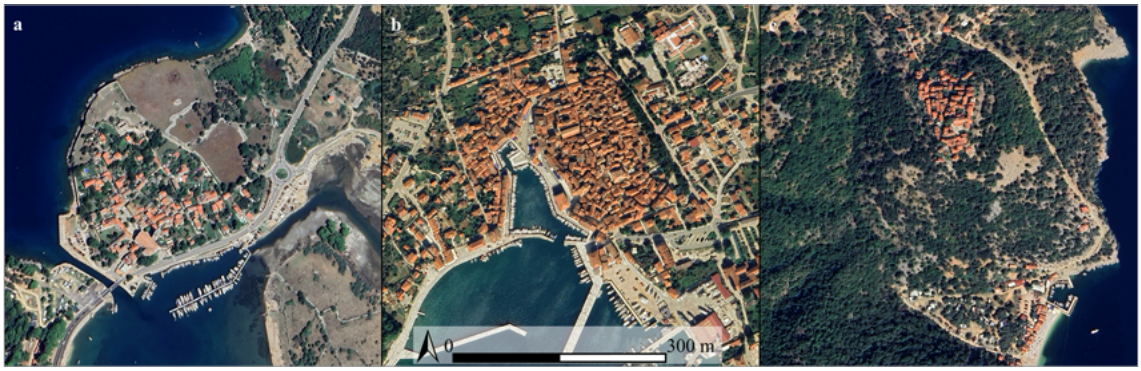

Figure 2: Present-day Settlements of Osor (a), Cres (b) and Beli (c) (Google Earth. Image © 2025 Airbus, elaborated by Nives Doneus, 2025)

od (Mitis 1913a; Imamović 1975, 219–220). Apart from the inscription from the time of Tiberius mentioned above (CIL III 3148 (10131)), only a few other funerary inscriptions from secondary sites in the vicinity of Beli are known and offer concrete evidence of Roman settlement(s) until the middle of the 2nd century (Šarić 1982; Margetić 1984).

The same applies to inscriptions found in the area around the town of Cres. However, the location of Roman Crexi has been debated since research on the archipelago began (Mitis 1913b, 100). The Roman town has either been searched for in the area around the present-day town of Cres (Imamović 1975, 221–3; Ćus-Rukonić 1984, 234–5) or it is believed to lie beneath the modern city (Stražičić 1980, 215; Ćus-Rukonić 2014, 22).

This state of research is in strong contrast to the studies that have been conducted in Osor. The present archaeological data indicate that area of later Osor was inhabited already in the Bronze Age (Blečić Kavur 2021; Blečić Kavur and Kavur 2025) and have acquired its future significance with the largest still visible infrastructure project – the erection of the city walls (Mohorovičić 1953; Faber 1982). In the 2nd century BC, the region passed slowly under the Roman influence (Blečić Kavur 2015, 217–33) and later rule with Osor receiving consequently the status of a *municipium,* as indicated by the available evidence (Starac 2000, 79–81). During the 1950ies, archaeological interest focused on the architectural monuments (Mohorovičić 1953). Excavations along the city wall conducted in the 1970ies revealed its complex stratification and the discovery of submerged moorings NE of the city gave first hints to a possible harbour infrastructure (Faber 1982). In addition to questions of urban layout, architecture and epigraphic monuments (Šarić 1982; Margetić 1984) also the Roman military presence in Osor was discussed, with a focus on the interpretation of a *stela* dedicated to a Roman naval officer (Kurilić 2012; Šašel Kos 2017). Osor was also the focus of large-scale rescue excavations led by the Croatian Conservation Institute between 2022 and 2025 that made a significant contribution to the history of the town, particularly its Roman period (Baričević 2023). The rise of Christianity and the emergence of new sacral architecture in the late Antiquity (e.g. Turković and Maraković 2005) played a significant role in the city and strengthened in this way its regional importance into the Middle Ages (Bully et al. 2024).

Roman origin is assumed for some other villages on the Cres-Lošinj archipelago as well (Imamović 1975). The settlement pattern, on Cres and smaller islands, includes also numerous *villae rusticae* (Ćus-Rukonić 1982; Ćus-Rukonić 2001). These have not yet been the subject of large-scale, systematic research, but remains of Roman rural settlements have been recorded during research into late Antique and early me-

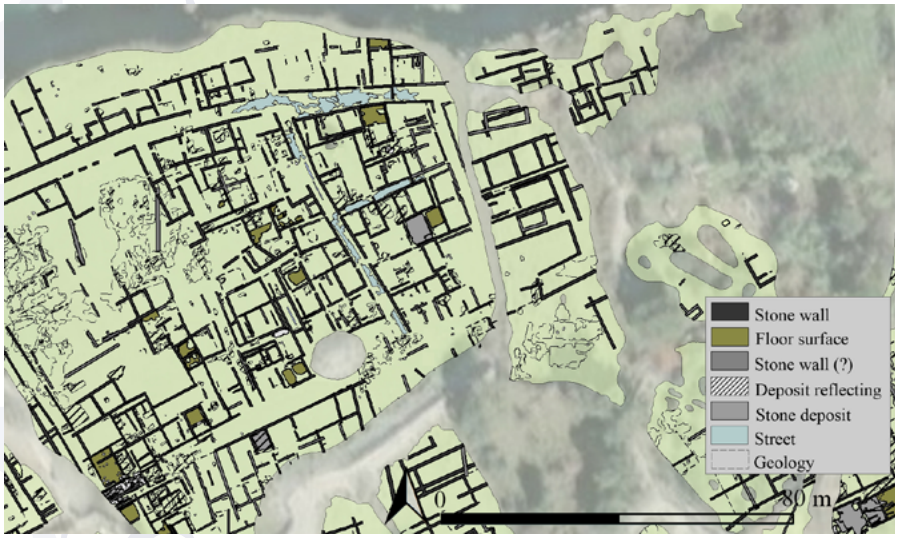

Figure 3: NW Part of the Roman Osor in the Results of the Ground Penetrating Radar Survey 2023–24 Indicating the Layout of the City, Including the Streets and *Insulae* (elaborated by Geosphere Austria, 2024)

dieval architecture (e.g. Bully and Čaušević-Bully 2012).

Recent Research Results

Osor

Research into the landscape of the Osor region has been ongoing since 2012 (Doneus et al. 2015). After large-scale geophysical measurements in 2014/15 (Doneus et al. 2017), Osor was the focus of a second geophysical survey in autumn 2023/spring 2024. The results, which are being prepared for publication, provide an insight into the NW-SE oriented street grid of a small town with a diameter of about 300 m and the *insulae* measuring 1 x 2 *actus* (fig. 3). The *forum* was situated in the SW of the city, and its location was confirmed during archaeological rescue excavations in the main square in 2022–24 (Baričević 2023).

To the west, the city borders the Osor Channel, which separates the islands of Cres and Lošinj, providing a navigable route between Osor Bay and the Lošinj Channel to the south. A separate article in this volume discusses the importance of the Osor Channel for (Roman) shipping, as well as the issues related to coastal changes and the presumed location of city harbours.

In recent years, systematic and large-scale analyses of archaeological remote sensing data have also enabled the stratigraphic information contained within the airborne laser scanning data surrounding Osor to be analysed. Based on the relative chronology of the dry stone walls outside the city limits, evidence of a Roman system of dry stone walls was discovered (Doneus et al. 2022). These features were dated using the OSL profiling and dating method (OSL-PD), which yielded a date range of AD 200 ± 100 (Doneus et al. 2024). Furthermore, there is an obvious spatial connection between the layout of the Roman Osor and land surveying, as the boundary lines of the surveying system are oriented according to the city's location, considering the location of the *forum,* where the *umbilicus* (the intersection of the survey axes) may be assumed.

Overall, these results provide the first clear evidence of municipal land surveying on the Croatian islands.

Beli

Archaeological Prospection

The successful application of archaeological prospection methods in the evaluation of Roman cities hinges on the use of appropriate techniques, as well as on the topographical conditions and the state of preservation of the archaeological structures. For example, Osor is an extremely favourable location for geophysical

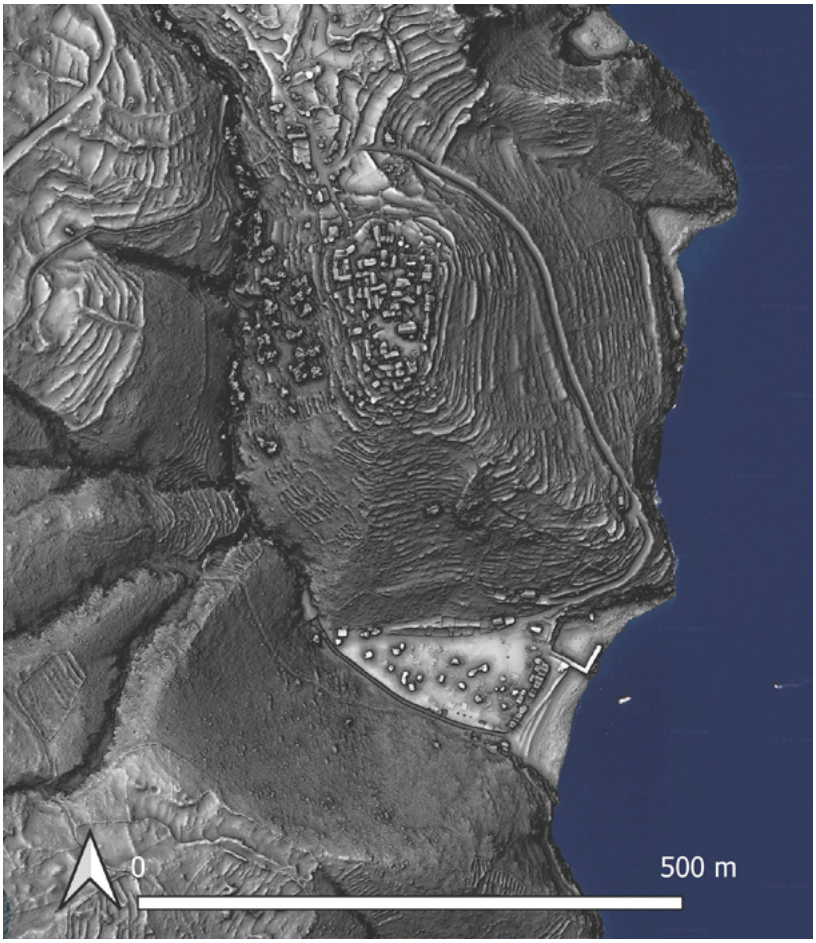

Figure 4: The ALS/ALB Archaeological Combined cVAT Data Visualisation of Beli Reveals the Steep Terrain and Numerous Agro-Pastoral Relics (project-owned ALS/ALB data, visualisation by Michael Doneus, Orthophoto: Google Earth. Image © 2025 Airbus. Elaborated by Nives Doneus, 2025)

prospection due to its accessible, vegetation-free terrain (see fig. 3). In contrast, prospection surveys have contributed little to the understanding of Roman settlement processes in Beli and the surrounding area.

Designed as a hilltop settlement, Beli lies approx. 130 metres above sea level and has a built-up area within the city walls of approx. 170 x 100 metres (fig. 2). Remote sensing project data was acquired by means of airborne laser scanning (ALS) and airborne laser bathymetry (ALB) in 2023, covering among other areas also Beli region (fig. 4). The landscape is characterised by agricultural remains, most of which are no longer in use today. Agricultural plots are located on small, flat areas to the north and west of the village of Beli, while former agricultural terraces stretch from sea level to the city walls. The ALS data revealed no Roman land surveying in the vicinity of Beli (Doneus et al. 2024). In Pod Beli Bay, which is sheltered from the wind and weather by stone breakwaters, ALB data show no discernible submerged structures down to a depth of 10 metres.

The settlement area in Beli is very compact, leaving hardly any unbuilt spaces for modern geophysical surveys. For this reason, geophysical measurements in spring 2024 were only carried out on the church square and at the entrance to the village (fig. 5). Even though the measurements were successful, the results could not provide any new insights into possible Roman or post-Roman building periods, as the measurement areas were too limited.

tained may be unclear, they can provide a means

Figure 5: A Geophysical Survey of the Main Square in Beli with a Handheld Ground-Penetrating Radar System (elaborated by Nives Doneus, 2024)

Mortar Analysis

Research in the Osor region indicates that archaeological remote sensing is especially effective at demonstrating the diversity, extent and complexity of past land use (Doneus et al. 2024). Many of these traces have not been classified as archaeological remains or sites and have received little attention in archaeological research. One reason is certainly the fact that, until recently, archaeological methods could not deal with large-scale land use remains that did not contain any datable finds. However, these are not the only archaeological category difficult to date. Stone structures or buildings, with or without mortar binding, can also pose a challenge when additional dating information is lacking.

Dating building structures with mortar binding is often difficult when using construction techniques as a primary reference. Even if early Roman, late Roman and early medieval walls can be visually distinguished from each other and apparently use different mortar bindings, their respective dating remains only an estimate without the accompanying archaeological material. Although mortar analyses cannot always be applied successfully, and the dates obtained may be unclear, they can provide a means of acquiring chronological information from structures like bridges (Sironić et al. 2022) or aqueducts (Sironić et al. 2019) that otherwise could not be dated.

Radiocarbon dating of mortar is based on the fact that, during hardening, the lime in the mortar absorbs CO_2 from the atmosphere and preserves it in the binder as calcite ($CaCO_3$), thus containing information about the date of formation (Daugbjerg et al. 2020). However, the dating of mortars is not straightforward, since, in addition to the binder calcite, mortars also contain carbonates from other sources, such as aggregate, unburned carbonate rock used for lime production and recrystallised carbonates.

Furthermore, the quality of the mortar compromises the accuracy of the radiocarbon dating. As there is still no universal method for the radiocarbon dating of mortar, physical analysis (petrography and XRD) and chemical analysis (carbonate content, kinetic curve, carbon stable isotope content ($\delta^{13}C$) and relation of radiocarbon content ($a^{14}C$) of CO_2 fractions) must be considered in parallel. To further confirm dates obtained through mortar dating, different approaches involving dating of inclusions, sequen-

Figure 6: Aerial Image of Beli, Showing the Sampling Point for The Mortar Dating (Red Dot), a Relevant Section of the City Wall, and the Mortar Sample in Detail (project-owned aerial image, elaborated by Nives Doneus, 2025)

tial dissolution and extrapolation can be considered (Sironić et al. 2023; Sironić et al. 2024).

As part of the project, one of the mortar samples was taken from the city wall of Beli. Currently, there have been no archaeological investigations of the city wall, which is only partially preserved due to later additions and extensions. It is also only partially visible at ground level due to dense vegetation. The degree of preservation is also difficult to determine based on the above-ground sections, since these are largely of more recent origin. The mortar sample was taken on the east side of the village, on the exterior of the city wall at its lowest point and directly on the limestone rock (fig. 6).

The radiocarbon dating of the Beli sample (Zagreb Radiocarbon Laboratory identification number Z-9011) was performed using the sequential dissolution and extrapolation approach. Since the ^{14}C dating of mortar depends on the quality of the sample, the result of the ^{14}C mortar analysis have to consider the data collected during the preparation of sample pointing to the reliability of the dating, as well as the results from the physical analysis done prior to the sample preparation. The thin-section petrography and XRD analysis proved that the sample did not contain calcite recrystallization or magnesite which could lead to carbon contamination or delayed hardening (see the protocol section).

The principle of the approach of sequential dissolution and data extrapolation is to collect only the carbon form binder and reduce the amount of contamination originating from geogenic carbonate to a minimum. Both binder and geogenic carbonates, besides being chemically the same, have also the same crystal form (calcite). The main difference is their morphology; the binder is softer and reacts quicker with acids forming CO_2. By selecting certain grain fraction (GF) of mortar and sequentially collecting portions of CO_2 produced during reaction of GF with acid, the initial CO_2 fractions mostly contain carbon from binder, while in further CO_2 fractions the binder to geogenic ratio drops. By extrapolating the ^{14}C content of the collected fractions at the initial point (time = 0), the ^{14}C content containing pure binder carbon,

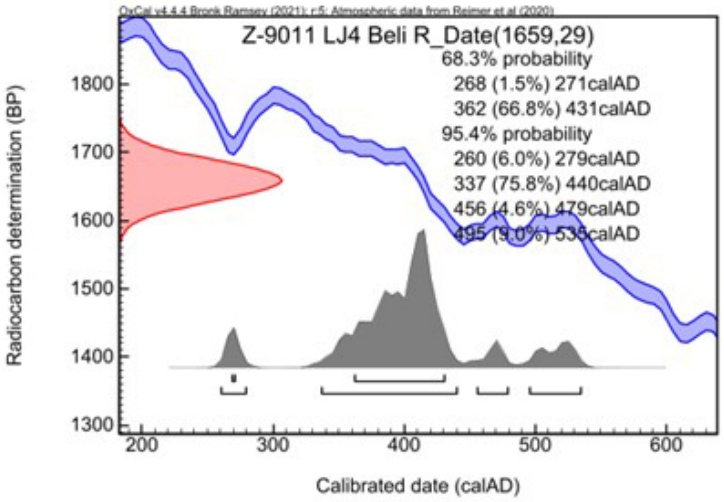

Figure 7: ^{14}C – 1 Calibrated Result of the Extrapolated ^{14}C Value for Sample of Beli (https://c14.arch.ox.ac.uk/oxcal/OxCal.html; elaborated by Andreja Sironić)

and information of the true date of mortar formation, can be calculated.

The Beli sample (Z-9011) had 70.4 % of carbonate content (as $CaCO_3$) and point at which the kinetic curve (velocity of CO_2 production in time during sample reaction with acid) starts to stagnate (pc) is 25%. The carbon content is high confirming that the mortar is non-hydraulic and so reliable for ^{14}C dating. However, pc value is a bit low (at well preserved samples pc is about 60 %) implying possible contamination by geogenic carbon, which could make result too old. To confirm/deny the contamination with geogenic carbon, the $\delta^{13}C$ values are used since they point to origin of carbon, binder carbon has values –20 to –9‰, while geogenic carbon has higher values around 0‰. For the measured CO_2 fractions (tbl. 2) all $\delta^{13}C$ values are low (from –17.5 to –18.0‰) proving that the carbon originates predominantly from binder. The difference between $a^{14}C$ values of the first and the second fractions are low (tbl. 1), and $a^{14}C$ value of the whole amount GF also does not stand out from the first two fractions proving that the selected grain size of mortar is predominantly comprised of the binder. From the a14C values the extrapolated $a^{14}C$ value of 81.3 ± 0.4 pMC and radiocarbon age 1660 ± 30 BP are calculated. From radiocarbon age calibrated dates are obtained (fig. 7).

Table 2: Carbon Isotope Results for CO_2 Fractions and the Whole Amount of Mortar Sample from Beli (Z, A – Zagreb Radiocarbon Laboratory ID numbers, UGAMS – CAIS ID number, $\delta^{13}C$ – uncertainty 0.1 ‰)

Name				Measured values	
Z	A	UGAMS	CO_2 fraction size	$\delta^{13}C$ (‰)	$a^{14}C$ (pMC)
9069	3768	75903	1st fraction, 6 %	–17.5	80.7 ± 0.3
9070	3769	75904	2nd fraction 19 %	–17.8	78.7 ± 0.3
9011	3723	75446	Whole amount GF (100%)	–18.0	75.1 ± 0.2

The calibrated date for this sample spans cal AD 260–535 (95.4 % probability range). The highest probability range for the Beli sample is from cal AD 337–440 placing it in 4th/5th century AD.

Discussion

The results of the current projects demonstrate that previous debates on Roman cities on the island of Cres neglected one crucial aspect: the spatial dimension of Roman urbanisation and the traces it left behind. This is particularly evident in the case of the Roman city of Osor, where excavation and archaeological prospection results paint a historically consistent picture. The loca-

tion, size and layout of the city, as well as the associated land surveying, all lead to the same conclusion: the Iron Age settlement was succeeded by a regional Roman centre following a successful transformation in the early imperial period. Furthermore, a comparison between Beli, Cres and Osor, suggests that, based on current knowledge, only Osor meets the criteria for the construction of a *curia* under the leadership of *duumviri* (CIL III 3148 (10131)) during Tiberius's reign (AD 14–37).

The absence of archaeological sources that would confirm the existence of an early imperial town or settlement in Beli is problematic and must be addressed if we are to improve our understanding of the region's Roman history. Apart from its mention as the location where the Tiberian inscription was found, there is currently no other hint of a small Roman town in the 1st c. AD. This refers not only to the lack of confirmation from archaeological excavations or prospection data, but also to Beli's geographical location, which do not align with those of a typical early imperial trading or coastal town. The dating of the mortar in the town wall at Beli points to late Antiquity. This raises the legitimate question of why, in 1771, Fortis gave the village of Beli as the location of the epigraphic monument CIL III 3148 (10131). Although this question can only be answered hypothetically today, it is nevertheless worth exploring.

Alberto Fortis and His Work

A. Fortis scientific interests and personal opinions were shaped by the context of his time. Therefore, 250 years later, his words should be taken for what they are: personal impressions and narratives from the perspective of a naturalist from the end of the 18th century. As a result, his assessment of the country and its people is sometimes rather harsh, as when he describes the island's inhabitants as 'ugly, poor and lazy' (Fortis 1771, 40). Fortis (1771, 135) also adopts S. Giustiniani's comment from the mid-16th century, according to which many Latin and Greek inscriptions were found in Osor in his time. This report also owed more to the (political) spirit of the time than to reality, as we can now assume that these were not Greek but Glagolitic inscriptions (e.g. Klen 1984).

Archaeological objects like statues or epigraphic monuments were of general interest even before Fortis' voyage in 1770/71. Nicola Dinarizio (Fortis 2014, 305, note 79), Bishop of Osor (1745–1757), created the first epigraphic collection of the archipelago in Osor during his term of office (Fortis 1771, 136). However, by the time of Fortis's travels in 1770/71, N. Dinarizio had already passed away in 1764, so the information about the locations of the epigraphic monuments was most likely based on the notes of Canon and Archdeacon Sovich (CIL III, 399), who had documented the diocesan search for inscriptions. Fortis' report also shows that he did not actually see epigraphic monuments *in situ*, but only as part of the Osor collection. Only the inscription from the island of Susak (CIL III 3147) was observed by him (1771, 121, 242) 'under a miserable hut' (the inscription is now lost, see Ćus-Rukonić 2001, 243). It is therefore possible that the inscription CIL III 3148 (10131) was mistakenly attributed to Beli. While this hypothesis cannot be verified, neither can the information provided by Fortis be regarded as proven archaeological fact.

Roman Beli

Based on information collected in Osor, A. Fortis was the first scientist to conclude that Beli had a significant regional importance in Roman times (Fortis 1771, 40): '[T]he castle of Caput insulae stood proudly during the reign of Tiberius, home to a flourishing Roman civilisation.' T. Mommsen's adoption of the discovery details (CIL III, 1873, Part 1, 399) lent scientific credibility to the circumstances of the discovery, meaning that every subsequent study cited the CIL work and listed Beli as the original finding spot. For regional or North Adriatic archaeological research, Italian-language publications such as those by Ignazio Mitis (1913a) were crucial in establishing the Forits claims as archaeological

facts. Mitis begins his brief historical account of Beli with the words (Mitis 1913a, 12): '[S]tood the magnificent castle of Caput Insulae, seat of a flourishing Roman civilisation at the time of Tiberius.' He adopts the keywords *caput insulae*, Latin for 'head of the island' (Fortis 1771, 137) as a synonym for Beli and uses information about the epigraphic monument from the time of Tiberius without even referencing Fortis by name. However, he admits elsewhere in the publication that he is familiar with his work (Mitis 1913a, 15). Finally, I. Mitis (1913a, 14) provides inaccurate information about the inscription's discovery, stating that it was found in 1775.

This detailed examination of I. Mitis's publication is not intended to highlight errors; it is merely one example of how quickly a historical narrative can develop and become established. In 1925, Silvio Mitis (1925, 77) adopted Ignazio Mitis's information about Beli, thereby introducing the term *caput insulae* to those interested in the younger history of the Cres Island. Consequently, most subsequent academic publications and popular science books have relied on I. Mitis's article and upheld the archaeological assessment of the site as a Roman town (e.g. Fučić 1990, 17). Ćus-Rukonić's comment (1984, 235) in her summary of the history of research on the archipelago, which states that I. Mitis reported on his excavations in Beli and the existence of a *forum* and *curia* in 1913, seems to be a misinterpretation of I. Mitis' reports. In fact, I. Mitis did assume the existence of these buildings in Beli based on the Tiberian inscription but did not provide any physical evidence or excavation results to support these claims.

Admittedly, several epigraphic monuments were found around Beli (Šarić 1982). The authors also do not intend to deny the existence of a Roman population in the region, but rather to point out that, aside from CIL III 3148 (10131) mention, there is no evidence of an early imperial period in Beli. Also from a spatial perspective, the location, shape and size of the settlement provide no indication of a *municipium,* as the basic requirements of a typical small Roman coastal town cannot be met. The area within the city walls, which measures 170 by 100 metres, is only half the size of the municipium Apsorus and, due to to the relief, the typical early imperial city plan seen in Osor cannot be realised here. The remains of the *templum, curia* and *forum* referred to by Ćus-Rukonić (1982, 14) or of building remains by E. Imamović (1975, 223) cannot be confirmed by any archaeological evidence; they most likely merely reiterate the views of I. Mitis in 1913.

The absence of Roman surveying remains outside Beli can be attributed to the challenging terrain and/or the fact that Beli was not a *municipium*. The elevated position on the eastern side of Cres likely provided a defensive advantage and excellent visibility during the early imperial era onwards. However, this exposed location is also the reason for the lack of an adequate harbour. The stormy north-easterly wind (Croat. bura), to which Beli is extremely exposed, needs no explanation for any Croatian coast resident and influences everyday life in Beli to this day (for more on the geography of the island of Cres, see Stražičić 1981). The evidence cited by Imamović (1975, 223–4) or Stražičić (1980, 215) for a Roman harbour in Pod Beli Bay, located below the village, originates from a note by S. Mitis (1927, 91) and could not stood up to thorough scientific review. Also, the so-called Roman bridge of Beli is just part of the region's tradition. The first mention probably dates back to I. Mitis (1913a, 17). Despite a complete lack of scientific evidence to support its Roman origins, it is referenced in archaeological publications regularly (e.g. Imamović 1973).

In the last 100 years no new architectural, epigraphic or other archaeological evidence has come to light in Beli or been brought to the attention of archaeologists. In an area where prehistoric, Roman and younger settlement activities can be expected, this missing archaeological record can only be found by systematic archaeological excavations. Given this state of research, any discussion about the Roman administrative network on the island of Cres (summary in

Starac 2000, 78–80) is obsolete and can only be conducted once more absolute data from Beli are available and the Roman Cres is better defined (see the following chapter). In the moment, the late Antique dating of the mortar sample from the city wall is the first chronological date for a possible Roman presence in Beli. At the same time, we have to see this date for what it is: a successful dating exercise, but one that, without further research, is insufficient to prove the presence of a late Antique settlement. Here, use of further mortar dating and OSL-PD method would help to establish a firm chronological database. For this reason, we refrain from drawing comparisons with late Antique hilltop settlements in the northern Adriatic. However, we strongly hope that these new results will stimulate a fresh debate about Beli and his role in the region. Late Antique coins (Mitis 1913a, 17) and the 239 AD milestone (CIL III 3210, CIL III 10162, CIL XVII 400234) found in the Beli area provide further limited evidence of a late Antique presence at the northern end of the island of Cres.

Roman Cres

Compared to the archaeological results from Osor, it is currently highly challenging to reconstruct the history of the Roman settlement of Crexi. However, references in ancient sources (Plin. Nat. hist. III, 140) and the continued use of the name suggest that a Roman settlement called Crexi may indeed have existed near the present-day town of Cres. Since the beginning of archaeological research on the archipelago, it has been presumed that the Roman city was located in or near the present-day town of Cres, for example on the hill of Sv. Bartolomej or Loveški (e.g. . Čače 1992–93, 17–8). The discussion about the Roman Cres has therefore long been an integral part of the island's archaeology (e.g. Ćus-Rukonić 2014; Margetić 1984; Imamović 1975). However, one issue has not yet been raised: Can or should the written mention of Crexi be taken as evidence of an early Roman town? S. Čače observed as early as 1992–93 (footnote 76) that the term 'Crexi' is almost certainly a demonym rather than a toponym. Only Ptolemy (2.16.8) records Kreksa as an actual place-name.

Archaeological evidence has confirmed Roman settlement activities in and around Cres, including the scattered remains of Roman walls in the town area, graves (Ćus-Rukonić, 2014, 20–2) and a few inscriptions (Šarić 1982). However, when it comes to the question of the early Roman town of Crexi, there is currently insufficient physical evidence to support this view. The most important structural elements of an early imperial *municipium* are still missing: a recognisable Roman city layout, a corresponding city grid with *insulae,* and any indication of a *forum* or other public buildings or spaces. The notion that the CIL III 3148 (10131) inscription regarding the construction of a *curia* refers to Crexi and can therefore be used as evidence of a Roman *forum* in Cres (Ćus-Rukonić 2014, 24) is, with all due respect, merely speculative and not an archaeological fact. The discovery of individual Roman walls seems also to be insufficient for a reconstruction of the Roman street grid and the location of the *cardo* and *decumanus,* as proposed by Ćus-Rukonić (2014, 22, 24).

Although the development of the city in modern times (Borić 2011) has probably erased much of its historical substance, it is striking that there is currently no evidence to support the existence of an early Roman city of Crexi, unlike in other places on the Kvarner Islands. In the towns of Krk, Osor and Rab, various clues have survived despite subsequent settlement occupation. In Osor and Krk, these are physical remains of city walls (e.g. Faber 2000 with older literature); in Krk and Rab, relevant inscriptions were found (e.g. Glavičić 2009; Margetić 1987). Furthermore, Roman Osor has been verified in recent decades during all construction projects within the city walls, which were accompanied by rescue excavations (unpublished reports). Nothing comparable applies to the town of Cres. For this reason, it may be worth considering whether the lack of clear evidence for a Roman *municipium* Crexi actually represents the

archaeological facts, rather than being a reflection the of the current state of research.

Attempts to locate Roman Crexi using remote sensing data (airborne laser scanning and aerial archaeology) also failed to produce satisfactory results. There may be several reasons for this. For successful localisation using archaeological remote sensing, visible or partially preserved building structures are required. An example is the Roman Fulfinum (Omišalj), which was identified by preserved building structures (Čaušević-Bully and Valent 2015). Another factor that makes archaeological remote sensing challenging is the high density of cultivated plots around the town of Cres. While these form exceptional landscape features (Kremenić et al. 2021), they obstruct the visibility of other remains of past land use. Evidence of Roman land surveying only extends as far as just south of Cres (Doneus et al. 2024). If there were any further Roman dry stone walls around Cres, they could not be identified for the same reason. However, the absence of Roman land surveying around the present-day town of Cres may also be related to the challenging terrain or the settlement's lack of a legal basis for land surveying.

Conclusion

If we accept that the Tiberius inscription does not originate from Beli but was mistakenly attributed to it, we must ask where it actually comes from. Currently, all research results point to Roman Osor, supporting the transformation of the idea of Osor as a main Roman town on the island of Cres into an archaeological fact.

One could argue that the current state of research on Beli and Cres does not allow for such a statement. This would be correct if archaeology relied solely on luck and time to find evidence for an academic thesis, rather than employing a variety of methodological approaches. Archaeological finds, including epigraphic inscriptions, constitute only a portion of the sources accessible to archaeologists. Another way to obtain results is through the large-scale interpretation of landscape features. Considering the traces of the Roman era on the archipelago as a whole, including the spatial components of Roman land use, offers a different perspective. After all, the spatial components of systematic Roman settlement expansion also bear witness to history, not just monuments and artefacts. This is the case in Osor: Given its location and size, and the presence of evidence for urban building structures and coherent land surveying, it is currently the only location on the island of Cres that can be considered an imperial Roman city.

The work of regional researchers such as Alberto Fortis remains of particular interest due to its value as a historical document, providing detailed accounts of the researchers' impressions, as well as the natural and historical background. Even if some details are debated today – like the provenance of the epigraphic monument CIL III 3148 (10131) – his work remains a key source of information. Without Fortis, many valuable archaeological relics would have been lost due to the changing political landscape and the two world wars. The field of science continues to benefit from his efforts to this day.

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Mortar analysis protocol

The mortar sample from Beli was pretreated and prepared in form of graphite targets for the accelerator mass spectrometry (AMS) at the Zagreb Radiocarbon Laboratory, Ruđer Bošković Institute, Zagreb, Croatia.

Prior to preparing the sample for radiocarbon analysis, the sample was tested for pH using phenolphthalein to check if it was completely hardened (is not still absorbing atmospheric CO_2). Further pre-analysis included petrography of thin layers to check for recrystallisation, as well as X-ray analysis to check for the presence of magnezite, which could indicate delayed hardening (Daugbjerg et al. 2020). After all the tests returned negative results (no reactivity, no recrystallisation and no magnesite content), the sample preparation was proceeded.

The selected part of mortar was cryogenically treated (heated to 80 °C and cooled to −196 °C by liquid nitrogen, at least 5 times) and gently broken by hammer. The sample was dry sieved to collect 32–63 μm grain size fraction (GF). The amount of carbonate as $CaCO_3$ was analyzed by producing CO_2 from the known amount of sample. From GF a kinetic curve was developed by monitoring the velocity of CO_2 production during reaction with 85 % H_3PO_4. From the kinetic curve the required amount of CO_2 for the first and the second CO_2 fraction was calculated (Sironić et al. 2023). CO_2 fractions were obtained by using an equivalent amount of 2 % HCl. From each CO_2 fraction the graphite was produced and obtained ^{14}C result at the Center for Applied Isotope Studies, University of Georgia, USA (Cherkinsky et al. 2010; Krajcar Bronić et al. 2010; Sironić et al. 2013). One ^{14}C result was also obtained from the whole amount of the GF. Along with each ^{14}C result, the result of the ^{13}C content ($\delta^{13}C$) was obtained. From the shape of the kinetic curve, the content of carbonate in the sample, the shape of ^{14}C amount vs carbon content curve and $\delta^{13}C$ values of each CO_2 analysis it was decided if the extrapolated result for radiocarbon date of mortar is reliable.

The $\delta^{13}C$ values were measured on Isotope Ratio Mass Spectrometer and are expressed in per mill relative to Vienna Pee Dee Belemnite and have uncertainty of 0.1‰. ^{14}C content ($^{14}C/^{13}C$ values) was measured on accelerator mass spectrometer (AMS) at the CAIS. 14C values are normalized to $\delta^{13}C$ of −25‰ and expressed as percent modern carbon ($a^{14}C$) and as age before present (BP) (Stuiver and Polach 1977; Mook and van der Plicht 1999).

Figures

SRTM – Shuttle Radar Topography Mission, NASA EarthData, https://www.earthdata.nasa.gov/data/instruments/srtm

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Summary

The framework that integrates the various aspects of Roman history in the Cres–Lošinj archipelago has existed for around 250 years. When interest in antiquity was just beginning to grow, travel literature was also gaining prominence. Alberto Fortis's 1771 travelogue exemplifies this period for the islands of Cres and Lošinj. It is not only the earliest publication of its kind on the archipelago, but also the first to record crucial archaeological information for the study of the islands' history and culture. This includes epigraphic monuments such as the CIL III 3148 (10131) inscription, which refers to the construction of a curia during the reign of Tiberius. According to Fortis, this inscription originates from the small village of Beli, at the northern tip of Cres.

Debates concerning the number of urban centres on Cres, and their role within the administrative structure, have persisted since Fortis's time. The discussion has focused not only on whether three independent Roman towns existed, but also on their precise locations.

Since 2023, the Austrian–Slovenian project Osor beyond the myth has focused on Osor. The new findings provide insights into the impact of Roman urbanisation across the Cres–Lošinj archipelago, as well as clarifying the debate concerning Roman towns on Cres. This study also draws on results from a second project, a joint Croatian–Austrian initiative investigating the radiocarbon dating of historical mortar from the Cres–Lošinj archipelago. Mortar dating from the city walls of Beli provides direct evidence concerning the history of Roman urbanisation on Cres.

Given well-founded suspicions that the archipelago's most important epigraphic source had been misattributed, the archaeological evidence for the three presumed Roman towns – Osor, Cres, and Beli – was compared. In doing so, it was necessary to consider not only individual epigraphic monuments but also traces of the Roman period across the archipelago as a whole, as only this approach reveals the full significance of Roman presence. In addition to monuments and artefacts, the spatial patterns of systematic Roman settlement expansion testify to this history.

The results confirm that Osor can be identified as the Roman centre of Cres and that the inscription CIL III 3148 (10131) likely originates there. The location of Roman Cres remains unknown. Mortar dating indicates that Beli was settled in Late Antiquity, but no evidence supports the notion that it functioned as a Roman town during the early imperial period.

Povzetek

Okvir, ki združuje različne vidike rimske zgodovine na arhipelagu Cres-Lošinj, obstaja približno 250 let. V času, ko se je zanimanje za antiko šele začelo krepiti, so postali pomembni tudi potopisi. Potopis Alberta Fortisa iz leta 1771 odraža to obdobje v primeru otokov Cres in Lošinj. Gre ne le za najzgodnejšo tovrstno publikacijo o arhipelagu, temveč tudi za prvo, ki navaja ključne arheološke

podatke za preučevanje zgodovine in kulture otokov. Sem sodijo epigrafski spomeniki, kot je napis CIL III 3148 (10131), ki se nanaša na gradnjo kurije v času vladavine Tiberija. Po Fortisu naj bi ta napis izviral iz majhne vasi Beli na severnem delu Cresa.

Debata o številu urbanih središč na Cresu in njihovem pomenu v upravni strukturi poteka že od Fortisovega časa. V ospredju je vprašanje, ali so obstajala tri samostojna rimska mest in kakšna je bila njihova natančna lega.

Od leta 2023 se na Osor osredotoča avstrijsko-slovenski projekt Osor onkraj mita. Novi rezultati osvetljujejo vpliv rimske urbanizacije na celoten arhipelag Cres-Lošinj ter prispevajo k razjasnitvi razprave o rimskih mestih na Cresu. Razprava v prispevku temelji tudi na rezultatih drugega, hrvaško-avstrijskega projekta, ki preučuje radiokarbonsko datiranje zgodovinskega materiala iz malte na arhipelagu. Rezultati za obzidja mesteca Beli ponujajo neposredne dokaze o zgodovini rimske urbanizacije na Cresu.

Glede na utemeljene sume, da je bil najpomembnejši epigrafski vir arhipelaga napačno pripisan, smo primerjali arheološke vire treh domnevnih rimskih mest: Osorja, Cresa in Belega. Pri tem je bilo treba upoštevati ne le posamezne epigrafske spomenike, temveč tudi sledove rimskega obdobja na celotnem arhipelagu, saj lahko le tako razumemo polni pomen rimske prisotnosti. Poleg spomenikov in predmetov materialne kulture o tej zgodovini pričajo tudi prostorski vzorci sistematične rimske poselitve.

Rezultati potrjujejo, da je Osor rimsko središče Cresa in da napis *CIL III 3148* (10131) verjetno izhaja od tam. Lega rimskega Cresa ostaja neznana. Datiranje malte kaže, da je bil Beli poseljen v pozni antiki, vendar ni dokazov, da bi bil v zgodnjem cesarstvu rimsko mesto.

The Osor Aquatorium: An Overview of Underwater Archaeological Research
Osorski akvatorij: pregled podvodnih arheoloških raziskav

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Abstract
In the Kvarner area and the Cres-Lošinj archipelago, Osor is the oldest and most significant island settlement, as well as the best-researched archaeologically. In addition to land-based archaeological surveys and research, ongoing since the late 19th century, the seabed of the entire island area has been systematically surveyed and studied. Particular attention has been given to the Osor seabed, due to the importance and value of the material culture originating from the settlement itself. This article presents all previous research conducted over the past 70 years, chronologically divided into two main periods: the first systematic research during the second half of the 20th century, and more recent systematic and protective research in the early decades of the 21st century. The results of these activities certainly complete the picture of the way and dynamics of life in this island centre throughout different historical periods, especially from the perspective of ancient seafaring, navigation, and Osor's role in established transport and economic communications.
Keywords: Cres-Lošinj, Osor, harbour, maritime trade route, underwater archaeological research

Izvleček
Na območju Kvarnerja in arhipelaga Cres-Lošinj je Osor najstarejše in najpomembnejše otoško naselje ter arheološko najbolje raziskano. Poleg kopenskih arheoloških pregledov in raziskav, ki potekajo že od konca 19. stoletja, je bilo sistematično raziskano tudi morsko dno celotnega območja otoka. Posebna pozornost je bila osorskemu morskem dnu namenjena zaradi pomena in vrednosti materialne kulture, ki izvira iz samega naselja. Članek povzema vse dosedanje raziskave, opravljene v zadnjih 70 letih, kronološko razdeljene v dve glavni obdobji: med prve, sistematične, raziskave v drugi polovici 20. stoletja in novejše, sistematične ter zaščitne, raziskave v zgodnjih desetletjih 21. stoletja. Rezultati teh aktivnosti zagotovo dopolnjujejo sliko načina in dinamike življenja v tem otoškem središču skozi različna zgodovinska obdobja, predvsem z vidika starodavnega pomorstva, navigacije in vloge Osorja v vzpostavljenih transportnih in gospodarskih povezavah.
Ključne besede: Cres-Lošinj, Osor, pristanišče, pomorska trgovska pot, podvodne arheološke raziskave

Introduction

Situated on the narrow isthmus connecting the islands of Cres and Lošinj, Osor is one of the most prominent historical settlements not only within the Cres-Lošinj archipelago but also throughout the entire Kvarner region and the northern Adriatic. It is justifiably considered the 'metropolis' of Kvarner and the safest city on the eastern Adriatic coast in early history (Blečić Kavur 2014; 2015, 15; Blečić Kavur and Kavur 2025).

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Figure 1: Osor, View of the Town and the Old Port (photo: Sara Popović, 2023)

Osor is framed by the Kavanela (Cavanella) channel, which connects the Kvarner Gulf to the north with the Kvarnerić to the south (fig. 1). This sea strait, with its prevailing sea currents and winds, along with suitable coves on both sides, was crucial in shaping Osor into an essential, millennia-old port on the oldest transport routes that connected Northern and Central Europe with the Mediterranean during the late prehistoric period. Despite this wealth of evidence and the efforts of earlier researchers (e.g. Imamović 1979; Faber 1980; Stražičić 1995), direct and concrete evidence of a prehistoric port or infrastructure has not yet been documented. Their existence is only assumed and linked to later Roman structures.

The abundant material culture, mostly unearthed from necropolises, tombs, the settlement itself, and surrounding areas (Blečić Kavur 2015; 2021; 2025; Blečić Kavur and Kavur 2013; 2024a; 2025), testifies to Osor's prominent role on the island and its extensive cultural and economic networks. Additionally, a collection of items from underwater research significantly enhances our knowledge, understanding, and interpretation of life in Osor, particularly during the period of Roman rule (Ettinger Starčić 2012; 2013). At that time, the city flourished, gaining a city charter and becoming a municipium (*Municipium Apsorus*), probably under Augustus or Tiberius (Suić 2003, 64; Vrsalović 2011, 246). It not only maintained but also developed its status as an important port on the sea route from Salona to Aquileia, primarily due to favourable winds and sea currents (Zaninović 2005; cf. Orlić 1986; Jurišić 2000).

The significance and value of Osor's position on shipping routes, as well as the standard of living of its ancient inhabitants, are corroborated by numerous finds of material culture from earlier excavations of necropolises and tombs (Ettinger Starčić and Ćus-Rukonić 2015), as well as the most recent discoveries in the area of Preko mosta and along the road towards Nerezine (Janeš 2022; Perković Gjurašin 2022; cf. Blečić Kavur 2025; Blečić Kavur and Kavur 2024a).

Earlier scholarship held that Osor possessed a fully developed port infrastructure and a refurbished Kavanela canal during this period. It was long maintained that the town had three ports: in Bijar Bay, in the Old Port (Stara luka) by the Kavanela passage, and in Jaz Bay (Imamović 1979; Faber 1980; 1982). Today, however, it is difficult to envisage Jaz Bay as an operational harbour, as it is entirely silted up and buried. Furthermore, the existence of a channel linking it with Bijar Bay has not been scientifically con-

Figure 2: Locations of the Underwater Sites of Osor Mentioned in the Text (Google Earth; elaborated by Martina Blečić Kavur, 2025)

firmed and has, in fact, been convincingly rejected (fig. 2) (Doneus et al. 2015, 773; Miko et al. 2025).

The development and importance of Osor began to decline in the 15th century, when it ceased to be the administrative and episcopal seat of Cres and Lošinj. However, it did not disappear entirely; through various transformations, life at this location has continued to the present day (cf. Sušanj Protić 2015).

The strategic position of Osor, both within the archipelago and on the northern Adriatic shipping route, historically secured it a key role in maritime and economic networks. This has resulted in a rich cultural and architectural heritage that testifies to the civilisations which have shaped it for millennia. This paper presents all underwater archaeological research conducted since the late 1960s, from preliminary surveys and inspection to trial excavations and individual finds. Based on different approaches and methodologies, the research is divided into two periods. This structure allows the collected data to be organised chronologically through the history of the research, highlighting the value of the sites and the wealth of archaeological remains, from the ancient to the modern era.

Underwater Research in the Second Half of the 20th Century

The earliest records of underwater archaeological sites, particularly in the shallow waters along the Croatian coast, date back to the 16th century, with the first mention of an ancient shipwreck appearing in the 18th century. Individual efforts to protect underwater heritage began only in the mid-20th century, and from the 1970s onwards, they became part of a well-organised system (Radić Rossi 2012).

Several valuable finds have been discovered on the nearby seabed. Notably, one of the most important is a shipwreck from the early Imperial epoch near the island of Ilovik, which contained flattened Forlimpopoli-type amphorae and luxurious glass and bronze vessels (Orlić 1986; Ju-

rišić 2000, 65; Radić Rossi 2012, 292; Ettinger Starčić 2013, 26–30).

However, the most prominent discovery in the island group is undoubtedly the Hellenistic bronze statue of a young athlete (Apoxyomenos), found near the islet of Vele Orjule, next to the island of Lošinj, in 1996 (Ettinger Starčić 2013; Ettinger Starčić and Potrebica 2017). The absence of other finds directly associated with the statue makes it impossible to reliably date it or interpret the circumstances of its arrival on the seabed. Although it is considered the first and only discovery of such a significant artistic monument in Croatian waters (Radić Rossi 2012, 295), it is worth recalling the much earlier collection of individual finds of extremely valuable early Imperial sculpture in Osor itself, specifically in Jaz Bay (figs. 2–3) (e.g., Cambi 1982). For this reason, the seabed around Osor has been recognised as having exceptional potential for future research since the last century.

Despite this, and in contrast to the terrestrial archaeological research conducted in Osor for over 150 years, underwater exploration began remarkably late (Ettinger Starčić and Ćus-Rukonić 2015). The first survey of Osor's waters took place in 1971, conducted by Radmila Matejčić and Velika Ruševljan from the Maritime and History Museum of the Croatian Littoral Rijeka, in collaboration with the Republic Institute for the Protection of Cultural Monuments. Based on information from port authorities and local officials, the aim of the survey was to inspect all reported and known sites in Osor Bay (on the left bank). During that period, the underwater areas of Bijar Bay and the Old Port of Osor, as well as the bays of Radiboj, Pirac, and Golubljaj, and the capes of Maestro, Boko and Osor were surveyed (fig. 2) (Matejčić and Ruševljan 1971, 1–6; Matejčić 1976; Matejčić and Orlić 1982, 164). The surveyed sites were described in detail in a report, but the material culture remained mostly unpublished, except for the amphorae, which were soon systematised typologically and chronologically by Velika Ruševljan (1970).

It was not until 1979 that Dasen Vrsalović, in his doctoral dissertation – which remains a fundamental work on the eastern Adriatic seabed – classified the existing sites into four major categories: shipwrecks, scattered finds, isolated objects, and port facilities and finds alongside ancient architecture (Vrsalović 1979). This was followed by numerous inspection surveys of bays and capes in the waters near Osor. The sites were then mapped and interpreted several times by Marjan Orlić, who believed that such finds indicated the intensity of navigation and seafaring in this important geostrategic and transit area (Matejčić and Orlić 1982; Orlić 1986).

Dasen Vrsalović categorised the shipwreck finds, placing the site at Boko Cape, west of Osor in Osor Bay and along the coast of the island of Lošinj, into the first category (fig. 2). Due to the abundance of fragments of amphorae, pottery, and roof tiles – a typical and common type of cargo – this was classified as a devastated shipwreck. The amphorae were identified as the Apulian type Lamboglia 2 and are dated to the 1st century BCE (Vrsalović 2011, 77; Orlić 1986, 6). As a significant and potential archaeological site, it was also inscribed in the Register of Cultural Goods of the Republic of Croatia (Z-48).

Vrsalović then included the discovery of multiple examples of the same Lamboglia 2 type amphorae and their fragments, which were explored in Radiboj Bay along the Kolo peninsula, on the island of Lošinj (fig. 2), in the category of so-called 'scattered finds'. Given the material culture found, he believed there was a possibility that shipwreck remains existed beneath the surface sand (Vrsalović 2011, 84; Orlić 1986, 6). This site was also entered in the Register of Cultural Goods of the Republic of Croatia as an underwater archaeological site (RRI-0309).

Under the category of isolated objects, several potential sites were listed in Osor Bay along the coast of the island of Lošinj. For example, the discovery of two early Byzantine amphorae of the Dressel 34 type, dating from the 6th century, was recorded near Maestro Cape (fig. 2). Further north, in Pirac Bay, late antique amphorae

Figure 3: Roman Imperial Portrait of Drusus the Younger (photo: Nadir Mavrović, 2017)

from the 4th and 5th centuries were documented, and in Golubljaj Bay, not far from Osor Cape itself, an amphora of North African origin from the 3rd century was found (fig. 2). Near Škojić at Osor Cape, a stone anchor was also recorded (fig. 2) (Vrsalović 2011, 87).

Port facilities and finds alongside ancient architecture were documented at the sites of Bijar Bay, northwest of Osor, and the Old Port of Osor (fig. 2). In Bijar Bay, numerous scattered objects were investigated, particularly pottery from both the ancient and medieval periods, as well as port infrastructure and various construction materials. This identified the location as a highly important site, and it was therefore inscribed in the Register of Cultural Goods of the Republic of Croatia (Z-77). The Old Port of Osor yielded the most finds, especially fragments of amphorae with various typological features, as well as bowls, plates, pots, platters, and lids, dating from antiquity to the 14th/15th century (Matejčić and Orlić 1982, 166–7). A large number of round wooden beams were also found, most likely posts (*palina*) used for mooring ships in the harbour (Vrsalović 2011, 89). Along with the site in Radiboj Bay, the Old Port was designated as one of the most promising areas in the Osor waters, with the intention of further systematic research (fig. 2) (Vrsalović 2011, 89).

The category of isolated or individual objects also includes three partially preserved Roman sculptures, discovered by chance by a trawler fisherman in Jaz Bay. These pieces are identified as Roman Imperial portraits depicting Octavian, Drusus the Younger, and a younger person, all dated to the 1st century BCE (figs. 2–3). These sculptures are considered exceptional examples in the eastern Adriatic coastal region (Cambi 1982, 85–98; 2002, 124).

Underwater Research in the 21st Century

During the late 1980s and 1990s, the attention of archaeologists was focused on other, more significant sites in the Cres-Lošinj seabed. However, after a break of several years, new underwater inspection surveys of the Osor waters were undertaken in 2008. These were conducted as part of the regular project Reconnaissance of Kvarner (2008–2012), led by Igor Miholjek from the Department for Underwater Archaeology of the Croatian Conservation Institute, in collaboration with the Lošinj Museum and the Special Police Diving Centre of the Ministry of the Interior of the Republic of Croatia from Mali Lošinj.

The project's goals were to assess the current state of known archaeological sites, determine their level of devastation, and create new documentation. Furthermore, the project aimed to conduct a comprehensive survey of potentially interesting locations, identify possible new sites, and verify information received from local fishermen, resulting in the investigation of 20 sites (Dugonjić 2010, 212; Ettinger Starčić 2012, 623–4). The project also planned the recovery of finds from endangered sites or those near the shore. All surveyed sites were documented, and the retrieved objects were registered and, after full processing, stored at the Lošinj Museum. Dur-

Figure 4: Osor, Old Port – Details of the Wooden Piles (photo: Robert Mosković, 2008)

Figure 5: Osor, Bijar Bay – Fragment of a Pluteus (photo: Robert Mosković, 2008)

ing this period, two locations in the waters of Osor were surveyed and investigated: Old Port and Bijar Bay (fig. 2).

The location of Osor Port, specifically at the pier near the bridge, has been known since the 1970s due to a reported discovery of a monoxylon (dugout canoe). Given the context and previous research, this area was categorised as containing port facilities and finds associated with ancient architecture. As another monoxylon is already part of the permanent collection at the Osor Archaeological Collection, this report appeared plausible. A test excavation with four trenches was conducted. Although fragments of modern-era pottery and considerable recent waste from boats and the shore were found, the anticipated monoxylon was not documented. However, at the end of the pier, eight

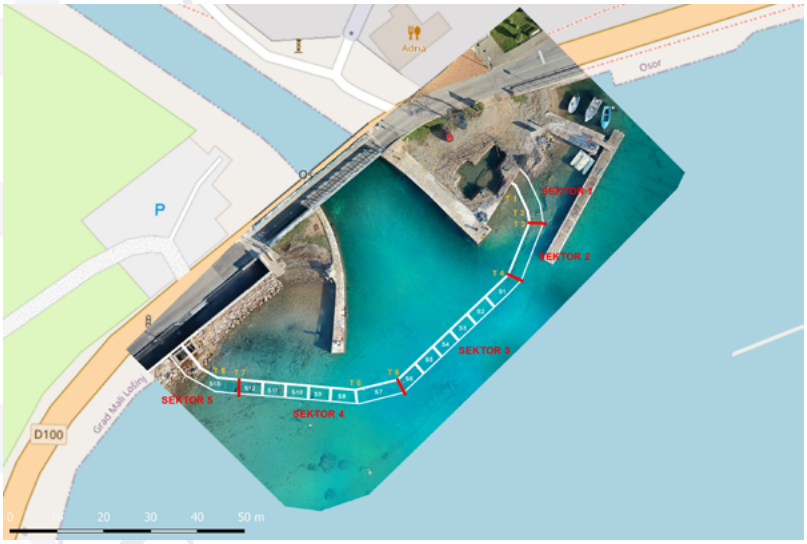

Figure 6: Osor, Old Port – Layout of The Archaeological Excavation with Marked Sectors and Trenches (sectors – red; archaeological trenches – white; reference points – yellow) (made by Sara Popović and Denis Jakopović, 2023)

wooden piles were recorded (fig. 4). These likely date from the Venetian period and were used for mooring ships (Dugonjić 2010, 218–9; Ettinger Starčić 2012, 625).

The entire area to the north, from Osor and its medieval walls to Bijar Bay, was also surveyed, as it had been in the 1970s. The presence of a large quantity of archaeological and building material was confirmed, including fragments of various types of amphorae, pottery, tegulae, imbrices, and stoppers from different periods, ranging from antiquity to the modern era. An exceptional find was a fragment of stone sculpture, dated to the 9th century, which was most likely part of a pluteus (a low stone screen) from an Osor church (fig. 5) (Dugonjić 2010, 218; Ettinger Starčić 2012, 625).

In 2014, another amphora was discovered at the entrance to Osor Bay on the Lošinj side. During a rescue excavation led by Zrinka Ettinger Starčić of the Lošinj Museum, a complete Lamboglia 2-type amphora was found at a depth of 11.7 metres. However, due to the circumstances of its discovery, it was not possible to determine its original site, and the amphora was therefore classified under Vrsalović's category of isolated or individual objects and is now kept in the Osor Archaeological Collection.

The most recent underwater rescue excavations in the waters of Osor took place in 2023, as part of two projects: the Nerezine Linear Construction Agglomeration and the route for a new 110 kV underwater cable from Cres to Lošinj. Two different locations in Osor Port were investigated: the first by the Department for Underwater Archaeology of the Croatian Conservation Institute from Zagreb, and the second by the ARS NAUTICA Institute for Maritime Heritage and the University of Zadar.

At the first location, directly in front of the entrance to the Kavanela channel, a trench was excavated measuring 107 m long, 3 m wide, and up to 4 m deep (fig. 2; 6). The excavation area was divided into five sectors. On the Cres side of the trench (sectors 1 and 2), around ten wooden piles were found in sector 2, which had been used to secure the stone embankment. Along the coast of the island of Lošinj (sectors 4 and 5), approximately thirty wooden piles were discovered in sector 4, which had secured the muddy and sandy Lošinj coastline, in contrast to the rocky Cres side (fig. 6). This difference is due to the stronger sea currents on the Cres side, which prevent as much sediment from being deposited as along the Lošinj stretch. As this is a shipping channel with strong currents, it has been established that the canal is mechanically cleaned and

Figure 7: Osor, Old Port – Archaeological Excavation in Sector 3 (photo: Jerko Macura, 2023)

deepened to a depth of 4 m at regular intervals. Given these conditions and the dredging, more precise cultural layers could not be defined.

During the preparation of the documentation, multiple complementary methods were employed using modern digital technologies. The proposed route plan for the future water supply pipeline, provided by the infrastructure works contractor, was integrated in a GIS environment with airborne laser scanning data. These data also included seabed coverage (courtesy of the Ludwig Boltzmann Institute, Vienna), enabling a more detailed understanding of the seabed topography within the study area. For photographic and graphic documentation, the excavation area was subsequently surveyed from the air using an unmanned aerial vehicle (UAV). A total of 867 aerial photographs and 24 reference points, whose spatial positions were recorded using a total station, were used to generate the model and orthophotographs. Geodetic measurements of the reference points were conducted using GNSS. The same reference points used for georeferencing the aerial model were also employed to reference the models of underwater-recorded archaeological excavation trenches. The 3D model of the archaeological trenches was produced from 2,409 photographs. Photogrammetric 3D models and orthophotographs were generated using dedicated software, while all resulting georeferenced datasets were integrated and overlaid in QGIS, where the graphic documentation was also produced (Popović 2023).

The greatest number of archaeological finds were discovered in sector 3, located just in front of the canal but connected to Osor's infrastructure (fig. 7). In this 320 m² area, over 200 objects were found that could be typologically and stylistically defined and chronologically dated. These included pottery and container from various historical eras, ranging from the Hellenistic period to the Venetian Republic and up to the 19th century.

The pottery is divided into several categories: coarse prehistoric and Hellenistic ceramics, fine Roman ceramics and amphorae, and a small portion of glazed modern-era pottery produced in northern Italy. Other finds include Roman oil lamps, modern-era smoking pipes, and fragments of unidentified objects.

Quantitatively, the largest number of finds comprised amphorae and their parts, especially stoppers, which were made on a wheel and in a mould. These included, for example, necks of the Portorecanati/Unije type, bifid handles of Dressel 2-4 type amphorae, globular ribbed bodies of Late Roman 1 type amphorae, and fragments

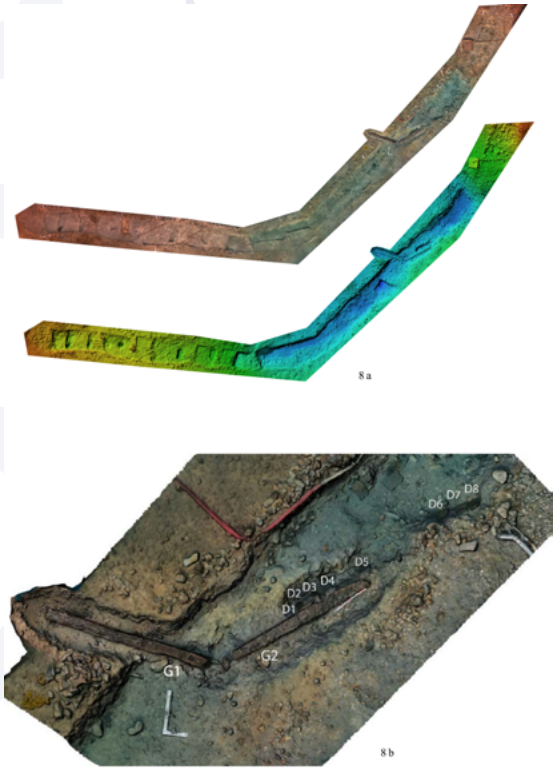

Figure 8: Osor, Old Port – a) DEM Model and Orthophoto of the Archaeological Excavation (made by Jerko Macura; processed by Sara Popović, 2023); b) 3D Model with DesignatIons of Wooden Elements (G – beam; D – wooden planks) (made by Anton Divić, 2023)

of North African and Spatheon-type amphorae (Miholjek 2024).

The largest portion of fine pottery consists of imported Hellenistic ceramics, which can be categorised into several types and styles, including *Gnathia* ware, black-glazed, and Hellenistic relief pottery. All these examples are attributed to tableware for serving and drinking liquids, such as drinking cups, bowls, and plates, and are dated from the late 4th to the 1st century BCE, corresponding to the end of the Iron Age and the beginning of Roman era in Osor (Blečić Kavur and Kavur 2024b; cf. Blečić Kavur 2015).

During the subsequent Augustan and early Tiberian periods, the finest tableware was imported, as in other significant economic and military strongholds of the Roman Empire. Examples of thin-walled pottery and both smooth and relief *terra sigillata* from the early Roman period had already been found in Osor, and recent surveys of the Osor channel have confirmed this. Fragments of bowls, plates, cups, and jugs, some bearing stamps and decorations, were collected. Despite the unclear stratigraphy, this is the first instance of such material culture being found within a defined archaeological context, and it represents the largest number of finds to date from the Osor seabed and its surrounding area (Blečić Kavur and Kavur 2024b).

In addition to these finds, two large wooden beams were discovered during the excavation in Sector 3 (fig. 8). They measured 4 metres in length with a cross-section of 30 × 30 cm and were oriented in the direction of the tide. The beams were reinforced with vertically placed planks and yellow clay, which was not found elsewhere at the site. Given their dimensions, they were very likely installed to direct the sea currents in the canal and to secure the Lošinj side of the coast. Samples from the beams and piles were taken for further analysis to determine the age of the wood, which could provide more information about the periods when these elements were installed and used. Although preserved stratigraphic layers are lacking, the quantity, quality, and diversity of the material culture confirm the long-term, continuous use of this area as a port and its significance within the social dynamics of Osor over the centuries (Miholjek 2024) (figs. 6–8).

The second excavation was carried out southeast of the previous location, in a section approaching the modern-day coast of Jaz Bay. This survey of the future 110 kV Cres-Lošinj underwater cable route was led by Irena Radić Rossi (2023) (fig. 2). Due to the previous data and finds, as described earlier, there were high expectations for this area. However, it yielded significantly poorer results compared to the first location in front of the Osor strait. A surface inspection of the seabed revealed modern waste and scattered finds along the entire route of the future cable and in the bay itself. Fragments of

pottery were observed along the route, broadly dating from antiquity to the modern era.

During the excavation, material culture was only found in two trenches and consisted of small fragments of modern-era pottery. In trench 14, a certain amount of rounded pottery fragments and pebbles were found, suggesting the existence of a beach at some point in time. The majority of the finds were fragments of ceramic and glass vessels from various periods, which hold no significant scientific or artistic value, as they were discarded from the shore or from boats into the shallow sea (Radić Rossi 2023).

Conclusion

Underwater archaeological research and survey in the Osor aquatorium have been conducted for more than 70 years, though not always with the same intensity, purpose, or objectives. The aim of the initial inspection and field surveys was to document as many potential sites as possible and to record them in legal proceedings to protect them from possible deliberate or further devastation. The collected material culture mostly relates to periods from antiquity to the modern era, among which the presumed shipwreck near Radiboj Bay, harbour infrastructure, and individual finds of early imperial sculpture are particularly noteworthy.

In recent decades, archaeological research in the Kvarner area has been carried out systematically, both as part of an inspection project and through protective, smaller-scale interventions on selected routes. Significant archaeological heritage, as well as new circumstances related to changes in the marine environment, have been documented, especially in the area of Osor Old Port. Older data have also been revised, the state of individual locations and sites has been analysed, and perspectives for further research have been defined. Viewed as a whole and in a broader context, this research significantly complements existing knowledge based solely on the results of land-based research. Material evidence of intense maritime activities confirms the important role of Osor in the social and economic development of the region, highlighting its strategic position, prominent maritime and intermediary function, and the continuity of its settlement. The results of the research not only expand the understanding of ancient maritime routes and trade patterns, but also provide relevant insights into the daily lives of sailors and the local population throughout Osor's thousand-year history.

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Summary

Within the Kvarner area and the Cres–Lošinj archipelago, Osor is the oldest and most important island settlement, as well as the most thoroughly investigated archaeological site. Systematic archaeological research has been conducted continuously since the late 19th century, encompassing both terrestrial and underwater surveys across the entire island area. Particular attention has been given to the seabed around Osor due to the significance and value of the material culture associated with the settlement.

This paper summarises all research carried out over the past seventy years, divided into two main periods: the first systematic investigations in the second half of the 20th century, and the more recent systematic and rescue excavations in the early 21st century. Through inspection and field surveys, numerous potential sites were documented and incorporated into protection procedures, to prevent further intentional or unintentional damage. The collected material mainly relates to periods from Antiquity to the Modern Era, with particularly notable finds including a presumed shipwreck site in Radiboj Bay, harbour infrastructure, and Early Imperial sculptures.

In recent decades, archaeological research in the Kvarner area has been conducted systematically, both through large-scale surveys and smaller-scale rescue excavations. Significant archaeological heritage has been documented in the Osor harbour area, along with new evidence of environmental changes in the marine setting. Earlier data have been re-evaluated, the condition of individual sites reassessed, and perspectives for further research defined. In a broader context, these investigations substantially complement previous knowledge based solely on terrestrial research. Material evidence of intensive maritime activity confirms Osor's key role in the social and economic development of the region, highlighting its strategic position, strong maritime and intermediary function, and continuity of settlement. The results not only deepen our understanding of ancient sea routes and trade networks but also provide valuable insights into the everyday life of sailors and local inhabitants throughout Osor's millennia-long history.

Povzetek

Na območju Kvarnerja in znotraj creško-lošinjskega arhipelaga Osor predstavlja najstarejše in najpomembnejše otoško naselje, ki je hkrati najtemeljiteje arheološko raziskano. Sistematične raziskave potekajo neprekinjeno od konca 19. stoletja in

vključujejo kopenske ter podvodne preglede celotnega področja. Posebna pozornost je bila namenjena osorskemu podmorju zaradi izjemnega pomena materialne kulture, povezane z naseljem.

Prispevek povzema vsa dosedanja raziskovanja zadnjih 70 let, razdeljena v dve obdobji: med prva, sistematična, v drugi polovici 20. stoletja ter novejša, zaščitna in dokumentacijska, v 21. stoletju. Z rekognosciranji in s terenskimi pregledi je bilo evidentiranih več potencialnih najdišč, ki so bila vključena v postopke varstva, da bi se preprečile nadaljnje namerne ali nenamerne poškodbe. Gradivo se večinoma nanaša na obdobje od antike do novega veka, med katerim izstopajo brodolomsko najdišče v zalivu Radiboj, pristaniška infrastruktura in najdbe zgodnjecesarskih skulptur.

V zadnjih desetletjih so raziskave prinesle pomembne podatke o osorskem pristanišču, zlasti o arheološki dediščini in spremembah morskega okolja. Revidirani so bili starejši podatki, analizirano stanje na posameznih lokacijah ter opredeljene smernice za nadaljnje raziskave. Celostna obravnava rezultatov bistveno dopolnjuje spoznanja, pridobljena z izključno kopenskimi raziskavami. Dokazi o intenzivnih pomorskih dejavnostih potrjujejo ključno vlogo Osorja v družbenem in gospodarskem razvoju regije, njegov strateški položaj ter kontinuiteto poselitve. Rezultati poglabljajo razumevanje antičnih pomorskih poti in trgovinskih vzorcev ter osvetljujejo vsakdanjik pomorcev in lokalnega prebivalstva skozi tisočletno zgodovino mesta.

Make Osor Great Again: Accessible Archaeology Between Island and Cloud
Naj Osor znova postane velik: dostopna arheologija med otokom in oblakom

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Abstract
Osor, a small settlement, embodies the tension between exceptional archaeological significance and limited contemporary accessibility. Once a key maritime and ecclesiastical centre of the northern Adriatic, it is today marked by demographic decline, infrastructural constraints, and strong tourism seasonality. This article conceptualises accessibility as a multidimensional heritage problem that extends beyond physical access to include interpretation, knowledge circulation, and public engagement. Focusing on digital heritage tools, particularly the concept of a digital twin, it argues that digitally mediated access can transform archaeological research into a distributed educational and cultural infrastructure. Osor is presented as a pilot case for rethinking heritage promotion, interpretation and presentation in small and remote sites, aligning archaeological interpretation with sustainability, innovation, and learning.
Keywords: archaeological heritage, digital heritage, accessibility, digital twin, sustainable tourism

Izvleček
Osor, majhno naselje, ponazarja razkorak med izjemno arheološko vrednostjo in omejeno sodobno dostopnostjo. Nekdanje pomembno pomorsko in cerkveno središče severnega Jadrana danes zaznamujejo demografski upad, infrastrukturne omejitve in izrazita sezonskost turizma. Prispevek obravnava dostopnost kot večplastni dediščinski problem, ki poleg fizičnega dostopa vključuje tudi interpretacijo, diseminacijo znanja in vključevanje javnosti. S poudarkom na digitalnih dediščinskih orodjih, zlasti na konceptu digitalnega dvojnika, pokaže, kako lahko digitalno posredovana dostopnost arheološko znanje preoblikuje v razpršeno izobraževalno in kulturno infrastrukturo. Osor je predstavljen kot pilotni primer za premislek o promociji, interpretaciji in prezentaciji dediščine na majhnih ter oddaljenih najdiščih.
Ključne besede: arheološka dediščina, digitalna dediščina, dostopnost, digitalni dvojnik, trajnostni turizem

Introduction

Osor is a small settlement located at the narrow channel separating the islands of Cres and Lošinj in the northern Adriatic, Croatia. Despite its small area and population, archaeologically and historically it was an important urban site of the eastern Adriatic due to its strategic maritime crossing point that enabled control of navigation routes linking the Kvarner Gulf with the wider Adriatic basin (Doneus et al. 2017, 763–4). In the past, the canal connecting Cres and Lošinj has enabled its development into regional centre of exchange and administration. Today's Osor is far from its historical role and this duality between historical importance and current marginality defines its contemporary state. On the one hand, the town is situated on archaeological remains, ecclesiastical architecture, urban structures, and ritual landscapes. On the other hand, Osor today is characterized by demographic decline, limited economic activity, and strong seasonal

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dependence on tourism concentrated in summer months. As a destination, it remains peripheral in relation to major Croatian tourism hubs, and its heritage visibility outside professional audiences is low. This discrepancy between rich heritage and physical isolation is not unique just to Osor, but it is emphasised due to its insular location and infrastructural issues. Access to Osor is shaped by island mobility infrastructure, seasonal ferry timetables, and climatic factors that affect daily connectivity. These conditions impact the flow of visitors and also the circulation of knowledge, as archaeological research results are largely disseminated through academic publications and exhibitions rather than through integrated public interpretation frameworks.

In this article we will try to show that Osor presents an ideal laboratory for developing new and contemporary models of heritage accessibility that include digital technologies and sustainable tourism principles (Maietti 2023). Instead of proposing activities for the increased physical visitation, we are approaching the issue of accessibility as a multi layered concept that combines physical presence, interpretation, and digital reach. The metaphor used in the title 'between island and cloud' expresses the transition from spatially and informationally limited heritage toward distributed, digitally mediated heritage infrastructures. The concept to 'Make Osor Great Again' is intentionally playful, but analytically serious. It does not propose a return to a historical golden age of urban importance but instead searches for a strategic solution for promotion and use of Osor's archaeological heritage within contemporary cultural, educational, and technological ecosystems. This is grounded in the basic assumptions that archaeological knowledge has limited impact on society if it remains available mostly to specialist circles, that small and remote heritage sites require alternative dissemination models beyond mass tourism and that digital tools enable various forms of heritage access without increasing physical pressure on fragile locations or locations with limited physical accessibility. These assumptions are in line with current European policy frameworks that emphasise sustainability, resilience, and innovation in cultural tourism (Rababeh et al. 2024, 2). They also reflect transformations in heritage studies and practices, where digital mediation is not just a possibility for representation, but it becomes a useful infrastructural layer able to connect research, education, and public engagement (Niccolucci et al. 2022; Hutson et al. 2023; Cassar et al. 2025). Osor has an ideal potential as a pilot site for such an approach based on several factors: the long duration and interdisciplinarity of archaeological research, the clear spatial limits of the historic town, the existence of both material and immaterial heritage assets, and the practical constraints on visitor numbers. These elements make it an exemplary case for testing how archaeological knowledge can be translated into forms of access that are not dependent on physical visit of the site.

Archaeological and Historical Context[1]

Archaeological research shows that Osor's location at the junction of Cres and Lošinj formed the basis for development of long-term strategic importance. Settlement occupation extends from prehistory onward, with increasing complexity during the Bronze and Iron Ages, when maritime exchange intensified across the northern Adriatic (Doneus et al. 2017, 763). Its hinterland and maritime environment formed an integrated landscape. During the Roman period it became a municipium. The construction of the canal separating Cres and Lošinj, whether Roman in origin or later modified, enhanced its position as a maritime gateway. In the early medieval period, Osor had the role of an episcopal seat, with ecclesiastical authority extending across surrounding islands (Pactat et al. 2021, 8). Churches and monastic complexes are material remains that reflect its past role as a religious and political centre (Marić et al. 2014). Vene-

1 For the results of the recent scientific research within the project Osor beyond the myth, consult the remaining articles in this issue.

tian domination and later Habsburg administration reshaped its urban functions, but it is important to note that the gradual shifts in trade routes and geopolitical priorities led to a decline in regional importance. This enables us to interpret Osor as a microcosm of Adriatic history, reflecting transitions from prehistoric networks to Roman imperial structures, from ecclesiastical power to early modern marginalisation. Its urban fabric preserves these layers in compressed form, making the town an exceptional site for interpretation.

Recent archaeological research, especially within the project Osor beyond the myth, has significantly expanded knowledge of Osor's urban and landscape archaeology. New results position Osor not as an isolated town but as the core of a wider archipelagic system involving both terrestrial and maritime components. Material culture from excavations includes ceramics, sculpture, architectural fragments, and everyday objects that reflect both local production and long-distance exchange. These finds are preserved and partially displayed in the Archaeological Collection of Osor. The collection provides an essential interpretive point, linking physical artefacts with urban space and historical narrative. Yet, despite this research richness, public interpretation remains relatively fragmented. Archaeological results are presented through exhibitions, publications, but they lack a unified narrative framework connecting landscape, material culture, and social history. This fragmentation reflects structural issues common to small heritage sites: limited institutional capacity, seasonal staffing, and dependence on tourism seasonal cycles. Besides monuments and artefacts, Osor presents a cultural landscape in which built heritage, natural environment, and ritual practices are intertwined. This landscape dimension is important for understanding Osor's heritage value. Archaeology here is not limited to particular sites but also reflected in spatial relations between town, sea, and hinterland. Therefore, its interpretation can integrate environmental history, mobility, and socio-economic change. It also provides a basis for connecting archaeological interpretation with contemporary challenges such as climate change, sea-level rise, and sustainable land use.

Accessibility as a Heritage Problem

Physical accessibility in Osor is shaped by its insular geography. Although Cres and Lošinj are connected by a bridge, access to the archipelago depends on ferry routes from the mainland and is subject to weather conditions and seasonal fluctuations that affect tourists but also researchers and educators. School groups, for example, face logistical and financial barriers to organising visits, particularly outside the peak tourist season. In general, physical accessibility to archaeological sites is a growing concern, especially for those with disabilities (Cantarellas 2023, 519–22). Historic urban sites often present physical barriers, and archaeological areas can be left as islands of ruins, fenced and inaccessible (Ribeiro et al. 2012, 4149; La Mantia 2024, 156). The transport (in)connectivity, biodiversity, cultural heritage, and carrying capacity are all crucial elements to consider when developing strategic plans for areas with specific characteristics (Cecić 2023, 87–96). Physical accessibility also intersects with infrastructure limitations. Osor does not have accommodation facilities and transport infrastructure to host larger number of visitors. While this protects the integrity of the historic town, it also limits the scale of heritage outreach through traditional tourism models. These conditions generate a paradox: Osor's archaeological and historical value is high, but its practical accessibility is low. The consequence is a communication gap between research production and public promotion. Knowledge circulates within academic networks but has no strategy to reach broader audiences.

Accessibility is not only spatial but also epistemic. Even when visitors reach Osor, interpretation depends heavily on their prior knowledge and on limited material. Archaeological collection and heritage signage provide information, but rely on static display formats that are

not able to fully present and explain the complexity of archaeological processes or historical change, and the upgrade and inclusion of new research insights is slow. This informational problem reflects a wider challenge in archaeology: translating research into acceptable forms to non-specialist publics. Without mediation, archaeological remains appear as fragments detached from everyday experience, so interpretation becomes interface between scientific knowledge and social meaning. Digital interpretation tools, such as AR, 3D reconstructions, and interactive narratives, address this gap by embedding explanation directly into spatial experience (De Bonis et al. 2022, 92–101). They also enable multilingual access, adaptability to different age groups, and integration with educational curricula. The application of virtual reality in the interpretation of cultural heritage is at an exceptionally high level worldwide, while in Croatia, it is still in development (Pleše 2024, 16–7). Simply including scientific information in digital technology is not enough. It is necessary to develop diverse types of digital tools and interpretation levels to make content more accessible and engaging for users, encouraging learning and exploration. Finally, accessibility raises several questions: who controls heritage narratives, who participates in interpretation, and who benefits from tourism. A digitally based accessibility strategy requires institutional integration: shared data standards, cooperative content development, and joint responsibility for maintenance and updating. Such integration aligns with contemporary models of participatory heritage management, where knowledge production and dissemination are collaborative (Čadovska 2012, 23).

Osor shows the contradiction faced by many small heritage towns: exceptional historical depth combined with limited physical reach. Archaeological research depicts the town's importance as a maritime and cultural node in the northern Adriatic, yet these findings remain unevenly translated for the public. Accessibility, therefore, becomes the central analytical problem, as access to place, knowledge, narratives, and learning opportunities. In the following parts of this article we will show that this problem can be addressed through a strategic combination of tourism policy, cultural programming, and digital heritage tools, especially the development of a digital twin of Osor, that can transform and translate archaeological research data into an educational infrastructure capable of extending Osor's reach from the island to the cloud.

Tourism and Policy Frameworks

The development of heritage tourism in Osor must be contextualised within Croatia's broader tourism and cultural policy frameworks, which increasingly prioritise sustainability, diversification, and cultural value. The Sustainable Tourism Development Strategy of the Republic of Croatia to 2030 establishes sustainability as the guiding principle for tourism growth, emphasizing quality over quantity, environmental responsibility, and integration with local communities (Strategija razvoja održivog turizma do 2030. godine 2023). This strategy explicitly identifies cultural heritage as a resource for creating distinctive and resilient destinations, particularly outside major urban and resort centres (Cukrov 2010, 106; Nikolić 2021, 32). The importance of sustainable heritage protection is recognized in international policies (UNESCO, ICOMOS), necessitating national and regional conservation and management plans (Rababeh, et al. 2024, 2). For small heritage towns such as Osor this is particularly relevant. Traditional mass tourism models are neither feasible nor desirable given the town's spatial constraints and fragile archaeological fabric. Instead, the national strategy's emphasis on thematic tourism, digital innovation, and education-based experiences provides a conceptual framework within which Osor can reposition itself as a site of knowledge, learning, and cultural encounter rather than just as a sightseeing destination. The development of archaeological tourism requires the involvement of the local population and educational ac-

tivities for valorisation, as well as their participation in heritage management (Cindrić 2021, 67). The Croatian Tourism Act (Zakon o turizmu 2023) and related policy instruments also stress the importance of destination management and stakeholder coordination, suggesting integrated planning between tourism boards, municipalities, cultural institutions, and civil society. In this sense, Osor's heritage cannot be treated in isolation but must be a part of coordinated governance structures that align tourism promotion with heritage conservation and dissemination of scientific research results.

At the regional scale, the Tourism Development Strategy for Cres and Lošinj (Horwath HTL 2021) articulates a vision of the archipelago as a sustainable, high-quality destination rooted in nature, health tourism, and cultural identity The document highlights the need to reduce seasonality, strengthen thematic products, and improve the interpretation of cultural resources (Čorak 2013, 22; Rudančić and Ćućić 2019, 7–8; Nikolić 2021, 31). Within this, Osor has a role as a historical and archaeological point and not a resort-oriented settlement. Its potential is in complementing beach destinations through heritage-based experiences. The strategy recognises the importance of small towns and villages as carriers of authenticity and local character, suggesting that targeted investment in interpretation and infrastructure can generate added value without large-scale physical development. Efforts in Mali Lošinj demonstrate how sustainability can be translated into tangible advantages, including preserving the environment, fostering the local economy, and safeguarding cultural identity, despite challenges like pronounced seasonality. Regional planning documents further emphasise the role of digital technologies in destination branding and visitor engagement. Digital platforms are identified as tools for storytelling, itinerary planning, and educational outreach, enabling destinations to communicate complex narratives and to reach audiences beyond those physically present (Floričić et al. 2023, 73). For Osor, this orientation aligns directly with the need to overcome insularity through mediated forms of access.

Cultural heritage governance in Croatia operates across multiple institutional levels, involving the Ministry of Culture and Media, regional conservation offices, museums, and local authorities. In Osor, this governance structure intersects with tourism institutions such as the Mali Lošinj Tourist Board and regional destination management bodies. While this multi-level system provides legal protection for monuments and archaeological sites, it can also lead to fragmentation in interpretation and promotion. The challenge is in bridging the heritage protection and tourism use. Archaeological sites are subject to strict conservation rules, which can limit physical access and development. On the other hand, tourism seeks visibility, narrative, and visitor engagement. Digital heritage tools offer a mediating layer between these elements by enabling interpretation without physical intervention in sensitive areas. The integration of digital strategies into tourism governance would be a technical innovation but also an institutional one, as it requires shared data infrastructures, collaborative content production, and long-term maintenance commitments. We must warn that Osor's development as a digitally accessible heritage site depends as much on governance capacity as on technological feasibility.

The Osor Musical Evenings represent a key contemporary practice through which Osor's heritage is reactivated and reinterpreted. By situating classical music performances within spaces, the festival shows possibilities for the adaptive reuse of archaeologically and historically significant structures. In this context, music operates as an intangible heritage practice that animates material remains, producing meanings that extend beyond scholarly interpretation and embed archaeology within lived, ritualised experience (Pleše 2024, 31). Despite its strong cultural and symbolic impact, the festival remains concentrated in the summer season, reflecting broader Adriatic tourism patterns and limiting its contribution to sustainable heritage manage-

ment. Proposals to expand the festival through educational, research-oriented, and interpretive programmes have been emphasised as a means of strengthening Osor's role as a year-round archaeological and cultural site (Čorak 2013, 23). In this sense, the Osor Musical Evenings function not only as a cultural event but as a form of archaeological mediation, contributing to place branding grounded in the past and local legitimacy, which must resonate with the community before achieving wider recognition (Cukrov 2010, 106).

Digital Heritage Tools

Augmented reality and virtual reality have become popular tools in heritage interpretation. Users can visualise lost structures, explore inaccessible areas, and engage with historical narratives in immersive ways (Quattrini et al. 2016, 383; Fazio et al. 2019, 511; De Bonis et al. 2022, 92). In archaeological contexts, AR overlays can superimpose reconstructions onto present-day ruins, and VR environments can simulate entire landscapes and urban spaces across time periods (Kingsland 2023, 63; Rodríguez-Garcia et al. 2024). These technologies are particularly useful for making remote, fragile, or physically inaccessible sites available to a wider audience, including underwater archaeological sites (Haydar et al. 2011, 312; Bruno et al. 2017, 1). In Osor, AR and VR have already been implemented in the form of the Osorski vremeplov, which allows visitors to experience reconstructed views of twelve locations within the historic town through VR headsets (Pleše 2024, 31). This initiative represents an important proof of concept, demonstrating that digital reconstruction can enhance visitor understanding without requiring extensive physical interventions in protected areas. However, current implementations remain site bound. A more systematic approach would integrate AR and VR into a broader interpretive ecosystem, linking them with archaeological databases, educational content, and tourism platforms. Such integration would transform isolated digital experiences into components of a comprehensive digital heritage infrastructure. The increased accessibility and interactivity of these digital displays can strengthen the connection between heritage and individuals, which contributes to long-term preservation efforts (Pleše 2024, 23).

Serious games are designed to combine entertainment with learning, making them very useful for heritage education (Mortara et al. 2014, 319; DaCosta and Kinsell 2022). They can simulate excavationa, trade networks, or settlement dynamics, and allow users to experiment with historical scenarios. This participatory dimension changes and shifts heritage interpretation from passive reception to active exploration, providing immediate feedback (Hulin 2021, 2; García et al. 2024; Thise et al. 2025, 318). They can help disseminate archaeological findings and methodologies, encouraging players to engage with reconstructed historical settings (Kingsland 2023, 63; Murtas and Lombardo 2024, 1). For Osor, serious games could model Bronze and Iron Age settlemens, maritime trade routes, or urban transformations. Players could decide about resource management, defence, or ritual practice, and this way learn about the logics of past communities. Such simulations would not replace scientific interpretation but translate it into experiences. Serious games also support inclusion of younger audiences and using different learning styles. When integrated in education, they help develop heritage literacy, historical empathy, and perception of archaeology (Kilis et al. 2025, 1).

Among participatory digital tools, Minecraft Education Edition has bacome effective platform for heritage interpretation and teaching. Its block-based environment allows users to reconstruct historical sites collaboratively, basedon archaeological evidence and pedagogical objectives (Fernández and Medeiros 2019; Hobbs et al. 2023, 138; Krappala et al. 2024). Heritage projects across Europe have used Minecraft to model castles, towns, and landscapes, integrating history, geography, and environmental studies. In Osor, Minecraft could be used to recreate

the different phases, enabling students to explore spatial organisation, building techniques, and environmental relationships (Mørch et al. 2021). Such reconstructions could be linked to curricular topics in history and geography, integrating Osor in broader narratives of Mediterranean and island societies. The pedagogical potential of Minecraft is its capacity to merge play with structured learning. Teachers can design tasks that require students to interpret archaeological data, compare reconstructions with modern layouts, and reflect on processes of change over time (Cassone et al. 2019, 28; Mørch et al. 2021; Steier and Davidsen 2021, 198; Krappala et al. 2024).

AR, VR, serious games, and Minecraft should not be treated as isolated innovations but as interconnected elements of a digital heritage ecosystem. Each tool is made for different audiences and uses: AR enhances on-site experience, VR enables remote exploration, serious games support experiential learning, and Minecraft fosters collaborative construction of knowledge. For Osor, integration means that all these tools use a common data from archaeological research results, spatial models, and interpretation. This can be conceptualised as a digital twin of Osor's archaeological landscape, serving as the basis for diverse applications. Such a digital twin would ensure consistency across platforms and enable updates as new research emerges.

Digital Twins in Archaeology

The concept of the digital twin originates in engineering and manufacturing, where it denotes a dynamic digital replica of a physical system that is continuously updated through data exchange. In contrast to static 3D models, digital twins are characterised by their capacity to integrate heterogeneous data streams, represent temporal change, and support simulation and scenario testing (Liu and Wang 2024, 1019; Kleijn et al. 2024). When applied to cultural heritage and archaeology the term is referring to multi-layered digital representations of archaeological objects, sites, anfd landscapes that combine geometry, metadata, interpretive narratives, and analytical functions (Niccolucci et al. 2022; Cassar et al. 2025). In archaeological practice, early digital representations focused on photogrammetric or laser-scanned 3D models of artefacts and monuments. These models served for documentation and visualisation but remained isolated from broader interpretive systems. The digital twin extends this approach by including models that links spatial geometry with stratigraphy, material culture, environmental data, and historical interpretation (Parrinello and Picchio 2023). This allows dynamic updating and interactive connection of the digital replica with the physical object (Parsinejad et al. 2021, 72).

Digital twins are understood as infrastructures for archaeological knowledge, rather than merely as visual outputs (Cassar et al. 2025). They integrate excavation records, geophysical survey data, environmental reconstructions, and architectural hypotheses into a single navigable environment. Such environments support public dissemination and scientific analysis (Liu et al. 2024). At the architectural scale, digital twins of individual monuments allow the modelling of construction phases, structural behaviour, and conservation interventions (Hutson et al. 2023). What distinguishes these applications from earlier digital heritage tools is their emphasis on process, as digital twins are designed to be updated as new data becomes available, preserving the research lifecycle within the model itself. Digital twins have also been adopted as tools for public archaeology, expanding access to sites that are remote, fragile, or partially inaccessible. By hosting digital twins on web platforms or integrating them into AR/VR applications, heritage institutions can offer immersive experiences without exposing physical remains to mass visitation (Bertoldi 2021, 1444; Parsinejad et al. 2021, 72; Banfi et al. 2023, 176). These platforms integrate multimedia to enhance visitors' experiences and dissemination (Liu et al. 2024). Such uses align with broader trends in open science and open heritage, where data sharing and public engagement are considered integral to re-

search practice. Digital twins enable a form of distributed heritage presence, where the archaeological site exists simultaneously in situ and online (Niccolucci et al. 2022). This dual existence supports both conservation goals and access to knowledge. However, public-facing digital twins also raise ethical and interpretive questions. Who controls the narrative in the model? How are local perspectives represented? What commercial uses are permitted? These questions show the need for governance frameworks that treat digital twins as cultural assets rather than purely technical tools.

The Digital Twin of Osor

Osor's archaeological richness, spatial compactness, and logistical constraints make it an ideal candidate for the development of a digital twin. The town's historic core can be modelled at high resolution, while its surrounding landscape can be represented through GIS layers and terrain models. Archaeological data from excavations and surveys would provide the empirical basis for reconstruction, while historical sources supply contextual narratives. The central rationale for a digital twin of Osor would be accessibility (Bertoldi 2021, 1444). A digital twin would enable access to Osor's past for audiences who cannot travel to the island, including school groups, international learners, and persons with mobility impairments. It also enables off-season engagement. Furthermore, a digital twin would allow Osor's archaeological data to be mobilised across multiple platforms: AR applications, VR experiences in museums, serious games, and Minecraft Education modules. This way, the digital twin would function as a backbone infrastructure that ensures consistency and scientific integrity across all digital outputs (Niccolucci et al. 2022; Shimoda et al. 2025, 1360). Based on comparative cases, digital twin of Osor should consist of geometric model (3D model of the town and its landscape), chronological layers (separate reconstructions for major periods), data annotations (excavation units, bibliography, radiocarbon dates), uncertainty encoding (excavated remains, hypothetical reconstructions), narrative modules (trade, religion, daily life, and similar).

In educational contexts, the digital twin of Osor would be used as a learning environment (Kilis et al. 2025, 1; Shimoda et al. 2025, 1360). Students would navigate the model, compare historical phases, and engage in tasks. The digital twin supports constructivist pedagogies by allowing learners to manipulate data and test hypotheses. When linked with Minecraft Education, the twin can provide the scientific reference layer for student-built reconstructions. Minecraft worlds can thus be based in archaeological reality, while still allowing creative exploration (Mørch et al. 2021; Krappala et al. 2024). Such an approach aligns with interdisciplinary curricula that integrate history, geography, environmental studies, and digital literacy. Osor would become a case study for understanding island societies, trade networks, and human-environment interaction in the northern Adriatic. On-site AR experiences can draw directly from the twin, overlaying reconstructions onto present-day ruins. VR applications can transport users to different periods of Osor's history (De Bonis et al. 2022, 92). Because all applications draw on the same underlying twin, updates in archaeological interpretation can propagate across platforms. This would ensure to avoid the fragmentation that occurs when each digital product is developed independently. It would also ensure that public representations remain aligned with current and updated scientific research.

Developing and maintaining a digital twin requires long-term institutional collaboration that clearly defines responsibilities for data curation, content updates, and user access. Ideally, this framework would involve collaboration between academic institutions, museums, local authorities, and tourism boards. From a sustainability perspective, the digital twin contributes to conservation by reducing pressure on physical remains. It also supports economic sustainability by generating digital heritage products that can be used in education, tourism, and cultural programming (Maietti 2023).

Conclusion

Osor shares common characteristics with many heritage sites: historical depth combined with limited contemporary reach. Archaeological research has revealed its importance as a maritime and cultural point in the northern Adriatic, yet this knowledge remains limited to the wider public. The proposed case of Osor sows a transformation in archaeological practice: from site-centred preservation toward networked heritage infrastructures. Traditional heritage management has focused on protecting physical remains and regulating visitor access. While these objectives remain neccessary, they must be complemented by strategies that enable the circulation of knowledge and digital twins offer a possibility to develop this kind of system (Liu and Wang 2024, 1019). They include archaeological data within platforms that are accessible, updateable, and pedagogically usable. In doing so, they transform archaeology from localised scientific research into a distributed educational resource. However, digital access should not replace physical experience but enrich it, ensuring that virtual experiences remain connected with material remains.

The Osor case suggests that small heritage towns can act as testbeds for innovative models because their scale enables manageable experimentation. Rather than competing with large urban heritage centres, they can specialise in integrative, research-based digital interpretation. We have tried to offer the solution in redefining access through digital mediation. By integrating tourism strategies and digital heritage tools, Osor can become a site of learning and interpretation. The concept of a digital twin of Osor represents the basis for this kind of approach. As an infrastructure linking research, education, and public engagement, it enables consistency, transparency, and scalability across AR, VR, serious games, and Minecraft-based learning environments (Kilis et al. 2025, 1). It also aligns with sustainability principles by reducing physical pressure on the site. 'Make Osor Great Again' thus becomes a call for smart presence: from island to cloud, from excavation to education, from isolation to connection. In this model, Osor's past is not just preserved but activated as a resource for contemporary understanding, learning and use of the new knowledge for future resilience.

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Summary

This article examines Osor, a small settlement on the islands of Cres and Lošinj, as a case study for rethinking archaeological accessibility in contexts characterised by high heritage value and limited physical reach. Archaeological and historical research has demonstrated that Osor played a strategically important role in the northern Adriatic from prehistory through the Roman and early medieval periods, functioning as a maritime gateway, administrative centre, and episcopal seat. Today, however, Osor is marked by demographic decline, infrastructural constraints, and strong dependence on seasonal tourism, which together limit both visitor access and broader public engagement with archaeological knowledge.

The article approaches accessibility as a multidimensional heritage problem that extends beyond physical access to include the circulation of knowledge, interpretation, education, and participation. While Osor's insular location and fragile archaeological fabric make mass tourism neither feasible nor desirable, these same constraints position the town as an ideal testing ground for alternative, digitally mediated models of heritage access. Archaeological research in Osor is rich and interdisciplinary, yet its results are primarily disseminated through academic channels and fragmented exhibitions, leaving a gap between research production and public interpretation.

Within this framework, the article situates Osor in relation to Croatian national and regional tourism and cultural policy, which increasingly emphasise sustainability, thematic tourism, and digital innovation. Cultural practices such as the Osor Musical Evenings are examined as examples of how intangible heritage can activate archaeological and historical spaces, while also revealing the limitations of seasonally concentrated cultural programming. The analysis shows that heritage-based

development in Osor must prioritise quality, interpretation, and learning rather than visitor volume.

The core proposal of the article is the development of a digital twin of Osor as an infrastructural solution to accessibility. Conceptualised as a dynamic, multi-layered digital representation of the town's archaeological landscape, the digital twin would integrate spatial models, excavation data, historical interpretation, and narrative content. It would function as a backbone for diverse digital applications, including augmented and virtual reality, serious games, and educational platforms such as Minecraft, ensuring scientific consistency and adaptability over time. By enabling access independent of physical presence, the digital twin would extend Osor's archaeological knowledge 'from island to cloud', supporting education, public engagement, and sustainable heritage management without increasing pressure on the site itself.

The article concludes that small and remote heritage towns like Osor can serve as laboratories for innovative heritage models. By integrating archaeological research, digital technologies, and sustainable tourism strategies, Osor demonstrates how archaeological knowledge can be transformed into a distributed cultural and educational resource, reinforcing both heritage protection and contemporary relevance.

Povzetek

Prispevek obravnava Osor, majhno naselje na otokih Cres in Lošinj, kot študijo primera za premislek o dostopnosti arheološke dediščine v okoljih z izjemno dediščinsko vrednostjo in omejenim fizičnim dosegom. Arheološke in zgodovinske raziskave kažejo, da je imel Osor od prazgodovine do rimskega in zgodnjesrednjeveškega obdobja v severnem Jadranu strateško vlogo kot pomorsko vozlišče, upravno središče in škofijski sedež. Danes pa se sooča z demografskim upadom, infrastrukturnimi omejitvami in izrazito sezonsko odvisnostjo od turizma, kar omejuje tako obisk kot širšo javno dostopnost arheološkega znanja.

Prispevek dostopnost obravnava kot večplastni dediščinski problem, ki presega fizični dostop in vključuje kroženje znanja, interpretacijo, izobraževanje ter sodelovanje javnosti. Zaradi otoške lege in občutljive arheološke strukture množični turizem v Osorju ni ne izvedljiv ne zaželen, hkrati pa te omejitve mesto določajo kot idealno okolje za razvoj alternativnih, digitalno posredovanih modelov dostopa. Arheološke raziskave v Osorju so obsežne in interdisciplinarne, vendar so njihovi rezultati večinoma dostopni strokovni javnosti, medtem ko je javna interpretacija razdrobljena in omejena.

V tem kontekstu prispevek Osor umešča v okvir nacionalnih in regionalnih kulturnih ter turističnih politik, ki vse bolj poudarjajo trajnost, tematski turizem in digitalne inovacije. Kulturne prakse, kot so Osorske glasbene večeri, so analizirane kot primeri aktivacije zgodovinskih in arheoloških prostorov skozi nesnovno dediščino, hkrati pa razkrivajo omejitve sezonsko osredotočenega kulturnega dogajanja. Razprava pokaže, da mora dediščinski razvoj Osorja temeljiti na interpretaciji, učenju in kakovosti izkušnje, ne pa na količini obiskovalcev.

Osrednji prispevek, ki ga ponuja članek, je razvoj digitalnega dvojnika Osorja kot infrastrukturne rešitve za vprašanje dostopnosti. Digitalni dvojnik je razumljen kot dinamična, večplastna digitalna predstavitev arheološke krajine, ki povezuje prostorske modele, podatke izkopavanj, zgodovinsko interpretacijo in pripovedne vsebine. Deloval bi kot skupna osnova za različna digitalna orodja, kot so obogatena in navidezna resničnost, resne igre ter izobraževalne platforme, pri čemer bi zagotavljal znanstveno konsistentnost in možnost posodabljanja. S tem bi omogočil dostop do arheološkega znanja neodvisno od fizičnega obiska ter razširil dediščinsko prisotnost Osorja »od otoka do oblaka«.

Prispevek zaključuje, da lahko majhna in oddaljena dediščinska mesta, kot je Osor, delujejo kot laboratoriji za inovativne pristope k upravljanju in posredovanju dediščine. Z integracijo arheoloških raziskav, digitalnih tehnologij in trajnostnih turističnih strategij Osor ponuja model, v katerem arheološko znanje postane razpršen kulturni in izobraževalni vir z dolgoročno družbeno vrednostjo.