



# ANALECTA

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ARCHAEOLOGICA RESSOVIENSIA

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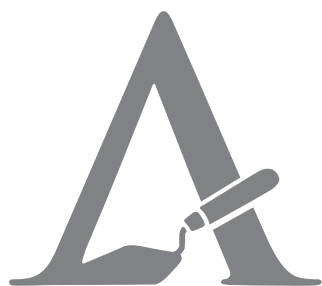


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VOLUME 20 RZESZÓW 2025



Uniwersytet Rzeszowski  
Wydział Humanistyczny  
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Marie-Claire Ries

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## Assessment of the Archaeological Potential of Prehistoric Settlement Areas along the Lake Shores and Wetlands of Carinthia, Southern Austria

### Abstract

Ries M.-C. 2025. Assessment of the Archaeological Potential of Prehistoric Settlement Areas along the Lake Shores and Wetlands of Carinthia, Southern Austria. *Analecta Archaeologica Ressoiviensia* 20, 19–42

The lake district of Carinthia's Klagenfurt Basin in southern Austria offers remarkable potential for advancing interdisciplinary research on prehistoric settlement landscapes. Although Austria's first pile-dwelling site was discovered in 1864 at Lake Keutschacher See today part of the UNESCO World Heritage property "Prehistoric Pile Dwellings around the Alps" – systematic archaeological surveys of Carinthia's more than 1,000 lakes and wetlands have remained scarce. This paper presents a pilot project addressing this long-standing research gap by developing a new anchor point for the identification, documentation, and evaluation of submerged lakeside archaeological heritage and their general archaeological setting.

Combining archival and literature studies with underwater field surveys, sediment coring, and laboratory analyses, the project provides an updated inventory of archaeological structures belonging to the chronological frame of the 5<sup>th</sup> to 3<sup>rd</sup> millennia BC. Activities conducted between 2021 and 2024 in collaboration with local museums, municipalities, students, and volunteers have provided new insights into settlement dynamics, technological innovation, and human–environment interactions during the Neolithic and Copper Age. The Kapuzinerinsel pile-dwelling site in Lake Wörthersee serves as an example of a new discovery demonstrating how targeted potential assessments can bridge persistent gaps in Austria's archaeological record and contribute to improved local heritage protection as well as reinforce connections to neighbouring regions.

Beyond generating new data, the study underscores the broader significance of the Alpe-Adria lakescapes as an important inner-Alpine corridor linking the Italian Peninsula, Southeastern Europe (the Balkans), and the northwestern circum-Alpine lake-dwelling regions. By integrating cultural and natural data, this research promotes sustainable and interdisciplinary approaches that position southern Austria within the wider European archaeological discourse and establish a foundation for future research and management strategies. The project additionally provides new absolute radiocarbon dates that contribute to a better understanding of Carinthia's prehistory.

**Keywords:** prehistoric pile-dwellings, Eneolithic, Copper Age, Austrian archaeology, underwater archaeology

**Received:** 30.10.2025; **Revised:** 27.11.2025; **Accepted:** 01.12.2025

### Introduction: background and project setting

The central aim of this study is to disseminate fundamental knowledge about the largely unexplored prehistoric sites situated within the lakescapes of Carinthia. Results are presented of a recent pilot project conducted mainly between autumn 2023 and spring 2024, funded by the Tyrolean Science Fund and further activities starting from 2021 onwards,

which lead to continuing research directly linked to follow-up underwater archaeological excavation projects. The project was carried out at the Microarchaeological Laboratory at the Department of Archaeologies at the University of Innsbruck. Entitled *Archaeological Potential Assessment of Prehistoric Settlement Areas along the Lake Shores and Wetlands of Carinthia, Austria* (German: *Archäologische Potenzialerfassung an Seeufern und Feuchtgebieten Kärntens* – F45181/10-2022), it constitutes the first systematic

modern attempt to evaluate the archaeological potential of selected lakeshore and wetland areas in this southeastern Austrian region by integrating multiple scales of evidence. Although wetland archaeology has long played a key role in shaping the understanding of European prehistory, Carinthia remains markedly underexplored. Despite the discovery of Austria's first pile-dwelling site at Lake Keutschacher See in 1864 – today part of the UNESCO World Heritage property “Prehistoric Pile Dwellings around the Alps” – systematic archaeological surveys and potential assessments of Carinthia's more than 1,000 lakes and wetlands have never been undertaken (Ruttikay *et al.* 2004). Consequently, significant gaps persist in both archaeological knowledge and modern heritage management, particularly regarding GIS-based mapping, site inventories, and the integration of environmental and archaeological data and the contextualisation to neighbouring regions. Within the limited financial and temporal scope of this pilot project – a five-month study supported by modest funding – the research focused on establishing a framework and collecting baseline data. Despite these constraints, the project demonstrates how focused, small-scale research can yield valuable insights and serve as valuable impetus for future investigations. An interdisciplinary approach was adopted, combining elements of environmental- and field archaeology with microarchaeological techniques to develop a more coherent and modernised picture of prehistoric settlement activity. Methods included archival research, non-invasive field surveys including drone-based imaging and scientific diving, coring transects, semi-quantitative screening of sediment samples for macrobotanical remains, and ceramic analysis. The main objectives were to identify and locate wetland sites, evaluate their state of preservation, and assess their research potential, including vulnerability to environmental and anthropogenic impacts. By contextualising Carinthian wetland sites within a broader European framework, this project aims to contribute to the understanding of prehistoric lakeshore settlements in the Austrian Alpe-Adria region. Carinthia's geographic position – linking southeastern Europe and the southeastern Alpine arc – makes it a crucial yet previously neglected area for studying Neolithic and Copper Age lifeways. The project addresses key research questions concerning the spread and local development of Neolithic to Eneolithic/Copper Age settlement traditions, the emergence of sedentism, and the early exploitation of natural and metallurgical resources.

## Topographical setting and study area

The study area is located on the southeastern fringe of the central Alpine ridge, within Austria's Alpe-Adria region. The primary focus is the Klagenfurt Basin (area of 1,750 km<sup>2</sup>), a prominent inner-alpine valley that encompasses several large, glacially formed lakes. This region features a diverse topography dominated by aquatic landscapes, including lakes, wetlands, peat bogs, and rivers framed by the Karawanks Mountain Range, part of the Southern Limestone Alps, with peaks reaching up to 2,238 metres and the mountain chain forming the border to Slovenia. The Klagenfurt Basin serves as a central geographic entity and resource hub, offering access to significant natural resources, such as lithic raw materials, copper ore deposits, and lead, which have historically shaped human economic activities and the ecology in the area as well as lowlands and fertile soils suited for arable farming and animal husbandry. Carinthia is geographically significant, situated near the tri-border area of Austria, Slovenia, and Italy. This location establishes the region as a critical inner-alpine corridor for prehistoric cultural interaction and exchange, facilitated by fluvial networks such as the southward-flowing main axis of the Drava River. The Drava, flowing eastward through Austria, Slovenia, continental Croatia to Hungary, served as a vital transportation and communication axis linking the Alps to the Carpathian Basin and the Balkans. Originating on the southern foothills of the Karawanks and flowing eastwards along their base, the Sava River constitutes another key communication and trade corridor. Its course further highlights the study area's strategic role within pan-European prehistoric exchange networks linking Carinthia with regions to the southeast of Europe. Furthermore, several mountain passes have evidently been in use since (pre) historical times, including the Wurzen Pass (Korensko Sedlo), Loibl Pass (Loiblpass), Železna Kapla Pass (Hafner Pass/Seeberg Sattel). Those allowed the crossing from southern regions into the northern area of Klagenfurt basin. To the north, the Klagenfurt Basin is bordered by the Hohe Tauern and Gurktaler Alps. Archaeological evidence further suggests frequent transalpine interactions, particularly between Styria and Carinthia, separated by the Packalpe and Koralpe mountain ranges (Bertha 2021). Recent discoveries have revealed that the valleys of Görttschitztal and Lavanttal very likely played equally important roles in the north-south exchange networks of past societies between Styria, across Carinthia, and interlinked to Slovenia. Connections to pile-dwelling regions in the northern Alpine foothills, such as the Salzkammergut area with Lake Attersee,

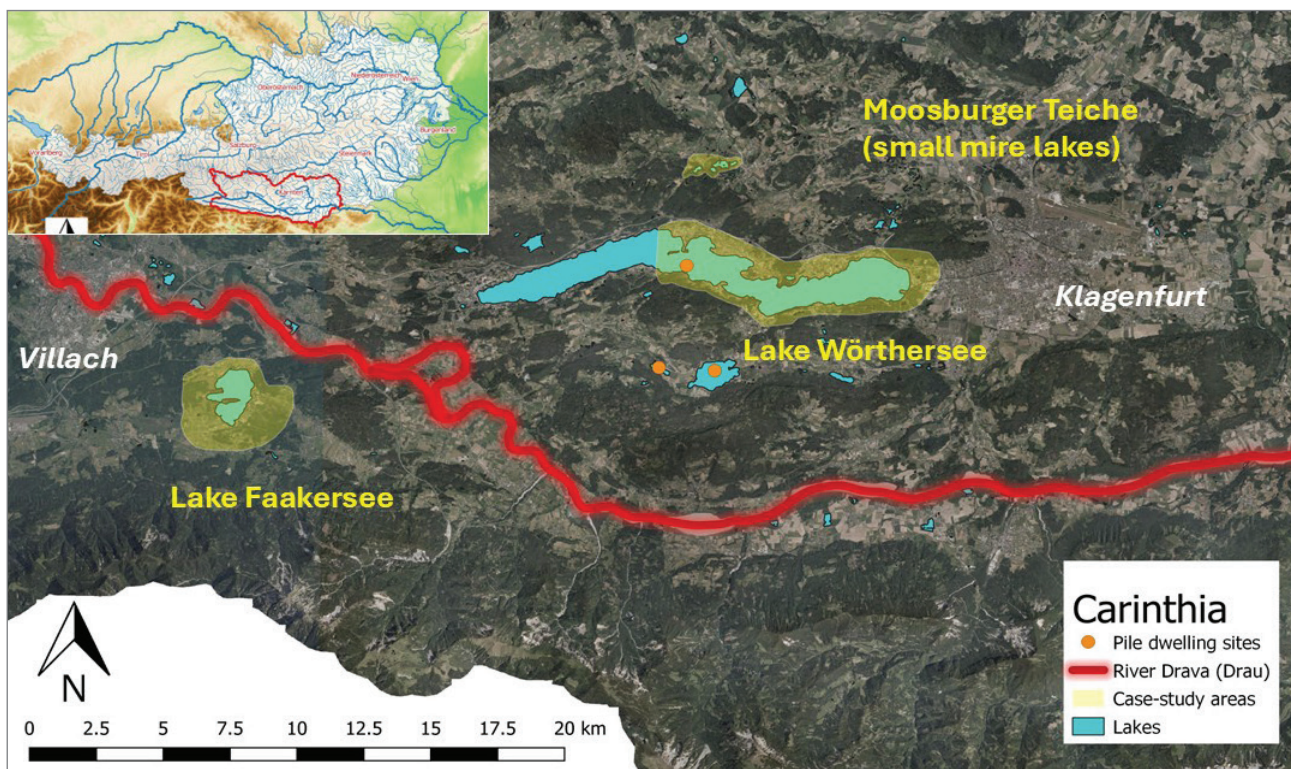


Lake Traunsee, and Lake Mondsee, are also significant (Kowarik *et al.* 2017; 2020).

Additionally, recent discoveries of Neolithic finds dating to the 6<sup>th</sup> millennium BC suggest that the inner-Alpine salt mines of the Hallstatt Lake region – long known for their prehistoric salt production – were likely already in use before their booming-phases during the Bronze Age (Figuls *et al.* 2023; Grömer *et al.* 2025). The early exploitation of mineral resources further emphasizes the significance of Carinthia's geographical position as an inner-Alpine corridor playing a key role in transalpine mobility, exchange and resource circulation. Carinthia's karstic landscape, with its numerous caves, springs, and geothermal sources – such as those at Warmbad-Villach near Lake Faaker See – have likely played a key role within a broader prehistoric ritual landscape, further highlighting the region's transalpine archaeological significance. The case of Warmbad-Villach, with its long continuity of settlement, early ritual and economic use of thermal springs, and strategically elevated location, demonstrates the centrality of water-related landscapes in shaping human activity and communication across millennia – an aspect directly relevant to the interpretation of prehistoric sites. Within this context, the

Klagenfurt Basin, particularly its lake district, holds a unique position. Lake Wörthersee, the region's largest lake, exemplifies this environment, extending from Klagenfurt in the east to the city of Velden in the west (Schlamberger 2011). Historical water regulation since the 17<sup>th</sup> century has significantly altered its littoral zones, with currently approximately 77% of the shoreline is now artificially modified and in intense human use (Schulz *et al.* 2008; Daxer *et al.* 2022). These transformations, driven by tourism, leisure activities, and shoreline construction, have had clear and lasting impacts on the archaeological record. Despite these challenges, Carinthia's lakescapes provide analogous potential to well-studied European wetland sites, such as those in the Lake Constance or Lake Zurich regions and very obviously close links to well-investigated regions such as the Ljubljana marshes region, where important well-investigated pile-dwelling sites are located. These similarities underscore the area's potential to contribute valuable insights into prehistoric settlement patterns, resource use, and cross-regional interactions, filling a crucial gap in the understanding of European wetland archaeology.

This study focuses on three distinct research areas (Fig. 1):



**Fig. 1.** The study area, located in Carinthia, southern Austria, within the Alpe-Adria region, comprises three defined potential zones for the study's investigation of pile-dwelling settlements dating from the 5<sup>th</sup> to the 3<sup>rd</sup> millennium BC along the Carinthian lake district (map by M.-C. Ries).

1. **Northeastern Shallow Shoreline Areas of Lake Wörthersee (Eastern Bay, Krumpendorf Area)** – Extending westwards towards the city of Klagenfurt, this main lake basin, with its multiple peninsulas and extensive shallow-water zones, provides a well-defined context for investigating prehistoric lakeside settlements. A particular focus is placed on Kapuzinerinsel, located in the central part of the lake, which occupies a strategic constriction within the basin, forming a natural bottleneck.
2. **Small Mire lakes Moosburger Teiche** – Located approximately 3 km north of Lake Wörthersee, these small mire lakes offer considerable hinterland potential and are analogous to well-studied lacustrine environments comparable to such as Lake Schreckensee (Germany) and Lobsigensee (Switzerland).
3. **Lake Faakersee** – Situated south of the Drava River and only 9 km from the present-day Slovenian border, this smaller lake occupied a strategically important position during prehistoric times within the transalpine research framework, lying between known and partially excavated Eneolithic hilltop settlements (Kanzianiberg and Wauberg). The lake features two prominent peninsulas aligned along key visibility axes between hilltops, further emphasizing its potential role in settlement placement and landscape use. Direct archaeological fieldwork at this site, however, was precluded due to access restrictions imposed by the landowners during the permit application process.

## Materials and methods

The investigation of prehistoric settlement potential along the lakeshores and wetlands of Carinthia employed a multidisciplinary and minimally invasive approach, focusing on creating basic inventories of prehistoric wetland sites – particularly lakeshore settlements dating from the 5<sup>th</sup> to the 3<sup>rd</sup> millennium BC. Archival research in regional museums, including the Kärnten Museum, combined with the collection and evaluation of literature and unpublished records, as well as stray finds and single artefacts, provided essential data for establishing preliminary site inventories and guiding fieldwork strategies. Field investigations, conducted between 2021 and 2024, integrated several complementary methods. SCUBA-assisted scientific diving enabled underwater surveys of the lakebed, identification of submerged structural features. Minimally invasive coring transects were deployed across littoral and wetland zones, often in collaboration with local citizen scientists and students, to sample sedi-

ment sequences targeting potential prehistoric occupation layers. Surface surveys complemented these efforts, and selected excavation units were opened in areas of high archaeological potential, following best-practice approaches for waterlogged sites (Bleicher *et al.* 2024; Reich *et al.* 2025). Aerial drone photography and photogrammetry documented shoreline morphology, submerged features, and site topography. High-resolution orthophotos produced from drone imaging were used for GIS-based mapping via QGIS, supporting spatial analysis and planning of subsequent investigations.

Sediment samples from hand-operated corings were processed at the Microarchaeological Laboratory of the University of Innsbruck using a semi-quantitative microscopic screening technique. Samples, typically less than 200 ml in volume, were fractionated via a “wash-over” procedure using laboratory sieves with mesh sizes of 1 mm and 250 µm. Fine sediments were washed away under a constant water flow, leaving the retained fraction for analysis. Residues were examined under a stereomicroscope at magnifications ranging from 6× to 40× to identify anthropogenic indicators, including charcoal fragments, cultivated plant remains, and other macro-botanical evidence of human activity.

This integrated methodological framework – combining archival research, literature and unpublished records, minimal-invasive coring, targeted excavation, underwater survey, drone photogrammetry, GIS mapping via QGIS, and microarchaeological screening – enabled the creation of reliable data for further collaborative research projects. It allowed a first assessment of site preservation, archaeological potential, and human–environment interactions in selected lakes and wetlands of Carinthia.

## Research history: prehistoric pile-dwellings of Carinthia – a reality check 2024

A current general assessment of the state of archaeological research in Carinthia highlights a clear need for action. To date, a comprehensive baseline inventory of archaeological sites – commonly referred to as the “Archäologische Landesaufnahme” – has not yet been undertaken. As a result, Carinthia remains in a peripheral position compared to many other European regions with long-standing and systematic heritage recording programmes which result in monitoring, supervision and prevention of undocumented destruction of sites during construction activities. The study of prehistoric pile-dwelling settlements in



Carinthia began in the mid-19<sup>th</sup> century during the so-called period of “pile-dwelling fever”. In 1864, the first evidence of prehistoric occupation was recorded on a submerged island plateau in Lake Keutschacher See, inspired by Ferdinand Keller’s discoveries in Switzerland. Subsequent investigations – including the first diving surveys in the 1950s and targeted excavations in the 1990s – produced substantial artefact corpora and led to Austria’s first dendrochronologically dated pile-dwelling settlement, with felling dates of 3947 BCE and 3871 BCE, providing a crucial chronological anchor for Neolithic to Copper Age research in southeastern Austria (Cichocki 2000; 2003; Ruttkay *et al.* 2004). Complementary studies on local material culture by Samonig or Ruttkay established foundational typological references for Carinthian pile-dwelling ceramics (Ruttkay 1996; 1997; Samonig 2003; Ruttkay *et al.* 2004), though these frameworks require methodological revision and integration with new absolute dates from stratified contexts (Ries 2026, in print).

Limited underwater surveys in Lake Wörthersee in the late 1990s and early 2000s identified sites such as Kapuzinerinsel, reported to the Federal Monuments Office Austria (Cichocki and Dworsky 2006). These initiatives were limited in scope and funding, focusing primarily on ad-hoc artefact recovery, including logboats, which highlighted the region’s shortage of expert knowledge and archaeological infrastructure which hindered proper conservation. Furthermore, the lack of definition of archaeological protection zones resulted in significant oversights, leaving large portions of the Wörthersee basin and surrounding paludified wetland areas unassessed and vulnerable to undocumented damage. Similarly, small-scale diving activities in Lake Hafnersee and Lake Faaker See recovered artefacts, but systematic pile-field sampling for dendrochronological dating or Radiocarbon dating was not performed (Hofer 2016; Kowarik *et al.* 2017). Consequently, the designation of the structures in Lake Hafnersee as a “pile-dwelling site” is currently unsupported by clear evidence, lacking both absolute dates and detailed maps, while at Lake Faaker See, recovered objects are no longer traceable and documentation is incomplete, leaving the exact chronological classification, and archaeological definition of these sites uncertain (Hofer 2016).

Since the 2011 UNESCO inscription of the “Prehistoric Pile Dwellings around the Alps”, Austrian research has largely prioritized preservation, erosion monitoring, and public outreach, particularly at Lake Keutschacher See (Pohl *et al.* 2020; Seidl da Fonseca *et al.*

2024). The Kuratorium Pfahlbauten was established as the national entity responsible for the supervision, protection, and management of Austria’s UNESCO pile-dwelling sites. In Carinthia, however, active field-based research has remained notably limited, focusing mainly on annual monitoring, experimental conservation measures, and educational programmes, often directed as child-friendly engagement. As a result, critical scientific questions – including fine-scale chronology, settlement duration and phasing, architectural layout, and integration into the broader circum-Alpine network – have not been systematically addressed, leaving Carinthia’s pile-dwelling archaeology behind both national and international standards of scientific research. Recent initiatives, such as the excavations at Kapuzinerinsel aim to address this imbalance by establishing well-resolved stratigraphies, generating chronological datasets, and complementing traditional fieldwork with interdisciplinary analyses. Such integrated approaches are essential for reconstructing settlement structures, occupation phases, and human–environment interactions, and crucial for contextualizing Carinthia’s prehistoric lake settlements within regional and supraregional frameworks. Only through these systematic investigations can the full research potential of Carinthia’s wetlands be realized, ensuring both the preservation and scholarly utilization of this highly vulnerable and internationally significant cultural heritage.

### **Settlement landscapes of Eneolithic Carinthia: cultural context and archaeological insights**

Understanding the prehistoric pile-dwelling phenomenon in Carinthia requires contextualization within the broader framework of Neolithic to Eneolithic/Copper Age settlement dynamics across southern Austria. Despite decades of research, the regional development remains poorly understood, with significant chronological and spatial gaps indicating an urgent need for modern archaeological reassessment (Ries 2026, in print). The lakeshore settlements of Carinthia cannot be interpreted in isolation; rather, they must be seen as integral components of a wider network of contemporaneous terrestrial sites that collectively shaped the landscape between the 5<sup>th</sup> and 3<sup>rd</sup> millennia BC. Without such contextual integration, interpretations of lakeside habitation patterns remain fragmentary and one-dimensional. A comprehensive reassessment of known Neolithic and Eneolithic sites in Carinthia is therefore essential. The last systematic



attempt to visualize regional settlement distributions was undertaken by Guido Vahlkampff (1995). Since then, numerous excavations and surveys – such as those at Knappenberg and Wauberg – have enriched the archaeological record, highlighting the need to update existing models, including the chronological framework based on radiocarbon dating (Gleirscher 2006; 2008; Ebner-Baur 2017; Bertha and Tiefengraber 2020).

Of the 22 known sites, only two have been radiocarbon dated, while the remaining sites are classified solely based on traditional typochronological frameworks focused on the study of pottery (Fig. 2). These classifications rely on partly outdated typochronological frameworks. To date, only two datasets of radiocarbon dates have been published – one for Lake Keutschacher See and one for the Kapuzinerinsel site, the latter of which is presented in this contribution (Fig. 2, 3).

Preliminary observations suggest that settlement locations in Carinthia follow a distinct spatial logic. All identified sites are situated on elevated, hilltop points, offering strategic advantages for defence, visibility, and control over surrounding areas (Fig. 4). Moreover, the distances between individual sites are relatively short – often less than 10 km, and in some cases below 5 km – implying possible contemporaneity and suggesting the existence of close communication and exchange networks between settlement sites. Notably, all settlements are located near fluvial systems or waterways, indicating a deliberate choice of locations that allowed for both terrestrial and/or aquatic connectivity (Fig. 3, 5).

The conspicuous absence of lowland settlements may reflect specific environmental or cultural preferences, but it is more likely linked to preservation issues and large gaps within the current archaeological record. This gap underscores a methodological shortcoming in Austrian research and highlights the need for comprehensive reassessments of existing site inventories and the application of large-scale, non-invasive prospection to reconstruct prehistoric settlement networks and integrate lakeshore and inland sites into a holistic understanding of habitation dynamics in southern Austria.

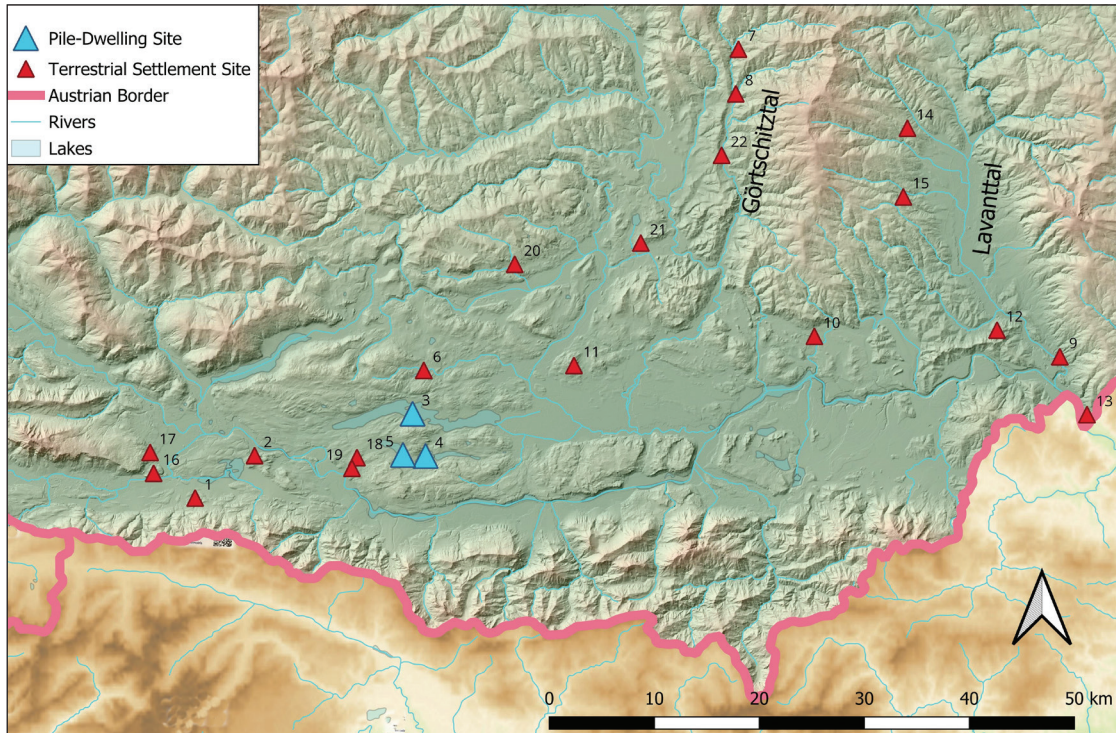
The Neolithic to Eneolithic settlement record of Carinthia remains highly fragmentary and has not yet been systematically reassessed using modern day archaeological approaches. Current data provides only isolated, snapshot-like glimpses into early farming communities, while fundamental questions concerning settlement dynamics, site dimensions and layout,

architectural traditions, and socio-economic organization remain largely unanswered. Among the few known inland sites, the eponymous site of Kanzianiberg – located a few kilometres north of the Slovenian border near Lake Faaker See – represents a key reference point (Dolenz 1938; Pedrotti 1990; Gleirscher 2006). Finds recovered during early excavations and surface collections in the 1930s, later studied by Pedrotti in the 1990s, indicate strong cultural connections with northern Italy and the Pannonian Basin (Pedrotti 1990). Additional small-scale investigations at nearby hilltop sites, such as Wauberg between Lake Faaker See and the Drava River, have yielded evidence of occupation during Eneolithic times (Bertha and Tiefengraber 2020). Microarchaeological analyses of sediments from this context identified fish remains, providing clear evidence for the economic exploitation of adjacent aquatic environments and the systematic use of waterscapes as subsistence resources (Ries 2022c). The visual and topographic relationships between these hilltop and lakeshore sites underline their integration within a shared settlement and communication network oriented along fluvial and lacustrine landscapes. Another open question concerns the role of certain settlements within early metallurgical networks. Several Carinthian sites, including Fuchsofen/Klein St. Paul, Wauberg, Kanzianiberg, Keutschacher See, and Kapuzinerinsel, have yielded evidence of copper metallurgy, such as casting moulds and copper artefacts. However, the exact function of these sites within regional resource exploitation as hubs for technological innovations and economical exchange remains unclear and has not yet been satisfactorily addressed by archaeological research (Gleirscher 2007; Frank and Pernicka 2012). Access to copper ores and the exploitation of metallurgical resources likely influenced settlement choice and may have been a driving factor in the development of regional settlement systems. Despite these insights, the archaeological record remains incomplete in large parts – particularly concerning absolute chronology and settlement morphology. The absence of lowland sites contrasts sharply with settlement patterns in adjacent regions such as the Carpathian Basin, continental Slovenia and Croatia where large extended sites have been investigated extensively during the last decades (Velušček 2017; Čataj 2020). This discrepancy raises the question of whether it reflects genuinely different settlement preferences in the region or merely results from research bias and the absence of systematic archaeological surveys in Carinthia, which very likely hampers the current understanding of regional settlement patterns in

	Neolithic to Eneolithic settlement sites in Carinthia	Available Absolute (Radiocarbon) Dates	Bibliographic Reference
1	Kanzianiberg, Finkenstein	no	Pedrotti 1990; Dolenz 1938
2	Wauberg	no	Bertha and Tiefengraber 2020
3	Kapuzinerinsel/Wörthersee (pile-dwelling)	yes	Ries 2022a; Ries 2026
4	Keutschach /Keutschacher See (pile-dwelling)	yes	Cichocky 1994; Samonig 2003; Ruttkay <i>et al.</i> 2004
5	Hafnersee (pile-dwelling)	no	Pohl 2017; Kowarik <i>et al.</i> 2017
6	Moosburg	no	Ries 2026; Vahlkampf 1995; Kohla 1960
7	Knappenberg/Görtschitztal	no	Ebner-Baur 2017
8	Kirchberg bei Klein St. Paul/Görtschitztal	no	Tiefengraber (unpublished)
9	Kulm bei Ettendorf/Lavanttal	no	Vahlkampf 1995
10	Steinkögelen bei Völkermarkt Haimburg	no	Vahlkampf 1995
11	Maria Saaler Berg/Zollfeld	no	Vahlkampf 1995
12	Rabenstein bei St. Paul im Lavanttal	no	Carneiro 2004; Tiefengraber 2004
13	Rabenstein bei Lavamünd	no	Vahlkampf 1995
14	Forst-Strappelkogel bei Wolfsberg	no	Vahlkampf 1995
15	Reisberg Wolfsberg	no	Vahlkampf 1995
16	Villach/Federaun	no	Steinegger pers. communication
17	Villach/Tscheltschnigkogel	no	Gleirscher 2006
18	Kathreinkogel/Schiefeling am See	no	Vahlkampf 1995
19	Gradišče/St. Egyden a.d. Drau	no	Vahlkampf 1995
20	Ottlienkogel/Glantschach	no	Vahlkampf 1995
21	Odwinskogel (Otwinskogel)/St. Georgen am Längsee	no	Vahlkampf 1995
22	Weitersdorf/Klein St. Paul, Fuchsofen/Görtschitztal	no	Gleirscher 2008

Fig. 2. Tabular overview of recorded Neolithic/Eneolithic settlements in the Carinthia region, listing site name, location, chronological/dating status and principal literature references (compiled from published and archival sources; the inventory may be incomplete; edited by M.-C. Ries).





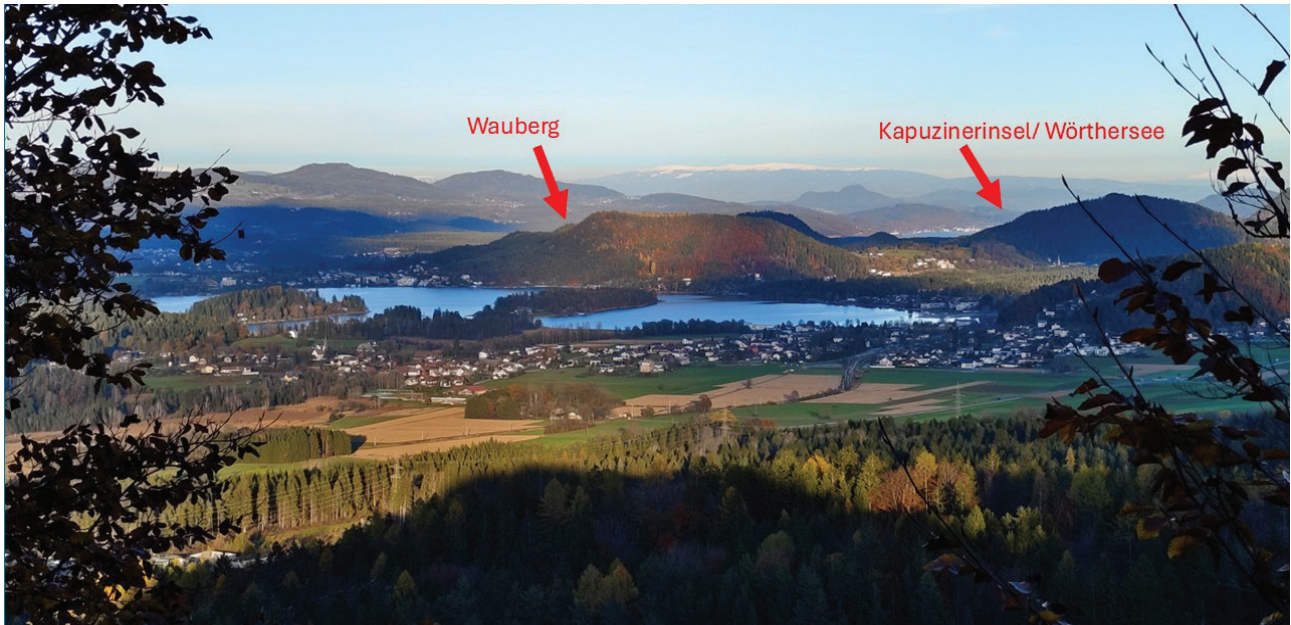
**Fig. 3.** Map of the current state of settlement distribution in Carinthia 5<sup>th</sup> to 3<sup>rd</sup> millennium BC based on Vahlkampff (1995), with subsequent additions and updates.

1. Kanzianiberg, 2. Wauberg, 3. Kapuzinerinsel/Wörthersee, 4. Keutschacher See (UNESCO-site), 5. Hafnersee,
6. Moosburg, 7. Knappenberg, 8. Kirchberg bei Klein St. Paul, 9. Kulm bei Ettendorf, 10. Steinkögel bei Völkermarkt Haimburg, 11. Maria Saaler Berg/Zollfeld, 12. Rabenstein bei St. Paul im Lavanttal, 13. Rabenstein bei Lavamünd,
14. Forst-Strappelkogel bei Wolfsberg, 15. Reisberg Wolfsberg, 16. Federaun/Villach, 17. Tscheltschnigkogel/Villach,
18. Kathreinkogel/Schiefing, 19. Gradišče/St. Egyden a.d. Drau, 20. Ottilienkogel/Glantschach, 21. Odwinskogel (Otwinskogel)/St. Georgen am Längsee, 22. Weitersdorf/Klein St. Paul Fuchskogel, Fuchsofen/Görtschitztal (map by M.-C. Ries).



**Fig. 4.** Drone image. Eastward view of the Kanzianiberg, an exemplary Carinthian hilltop-site, showing the steep edge of its western limestone plateaus, the location where archaeological remains were discovered. The Kanzianiberg is a key landmark site that has profoundly influenced our understanding of Carinthian prehistory. Located at the northern foothills of the Karawanks' Mountains, it yielded rich Neolithic to Eneolithic assemblages during excavations in the 1930s (photo by M.-C. Ries).





**Fig. 5.** View from the northern plateau of Kanzianiberg over Lake Faaker See towards the northeast, illustrating the spatial proximity between Kanzianiberg, Wauberg, and potential lowland or lakeshore settlements within the prehistoric settlement landscape of Carinthia (photo by M.-C. Ries).

the archaeological record. When viewed at a broader scale, scattered surface finds and excavations suggest a denser and more complex settlement landscape than previously assumed, a hitherto scientifically unexamined period potentially reflecting an early phase of cultural expansion, prosperity and intensified human presence in Austria's southern Alpine sphere.

Moreover Carinthia – with its numerous lake and wetland archives that remain largely untapped – offers major potential for palaeoecological research. High-resolution pollen analyses can provide detailed insights into past vegetation dynamics and anthropogenic landscape transformations on a broader spatio-temporal scale. Revising existing pollen records and conducting modern, archaeology-focused high-resolution palynological studies could identify the earliest agricultural activities by Neolithic communities, reflected in *Cerealia*-type pollen, *Plantago lanceolata*, or increased microcharcoal records, providing an informative proxy for early farming practices. Some records, such as from Millstättersee or Höfleinmoor at Sattnitz northeast of Lake Wörthersee, might suggest Mesolithic to Neolithic human impact through reduced primary forest and increased light-demanding woodland taxa such as hazel (Fritz 2000; 2007). Although no corresponding archaeological sites have been documented, it is plausible that Mesolithic communities were already influencing Carinthia's environment, as lithic stray finds from Pyramidenkogel or alpine sites suggest (Leitner

1984; 1990; Jernej 2012; Posch *et al.* 2023). Integrating high-resolution palaeoecology with archaeology provides a powerful approach to reconstruct land-use changes, the emergence of sedentary communities, local settlement dynamics, and the onset of farming practices, thereby helping to address major gaps in our understanding of the development and evolution of prehistoric societies in Carinthia. Further research should also target inner-alpine basins and valleys with fluvial axes, such as the Lavanttal and Görtscitztal, which link the Drava valley and Klagenfurt Basin to Slovenia in the south and to large inner-alpine valleys of Styria in the north (Bertha 2021). These corridors served as natural routes of communication, cultural interaction, and exchange, connecting the northeastern Alpine forelands of Styria with the Judenburg Basin (Aichfeld/Mur Valley) and further towards southeastern Europe. Given the close geographical and cultural ties to the Balkans, it is appropriate to contextualize Carinthian assemblages of prehistoric material culture within a Eneolithic/Copper Age periodization framework, as suggested by Wolfram Schier (2014). Existing periodisation models, notably those proposed by Elisabeth Ruttkay and Bertram Samonig, require critical revision in light of new evidence, as parts of their work are outdated (Ruttkay 1994; 1996; 1997; Bertha and Tiefengraber 2020; Bertha 2021; Ries 2026, in print). The so-called Kanzianiberg–Lasinja Group, traditionally assigned to the Late or Final Neolithic, should

be reconsidered within a broader supra-regional Copper Age framework. The presence of imported copper artefacts, comparable to examples from the Balkans, points to Carinthia's integration into extensive exchange networks of raw materials, technological innovations, and cultural traditions during the 5<sup>th</sup> to 3<sup>rd</sup> millennia BC.

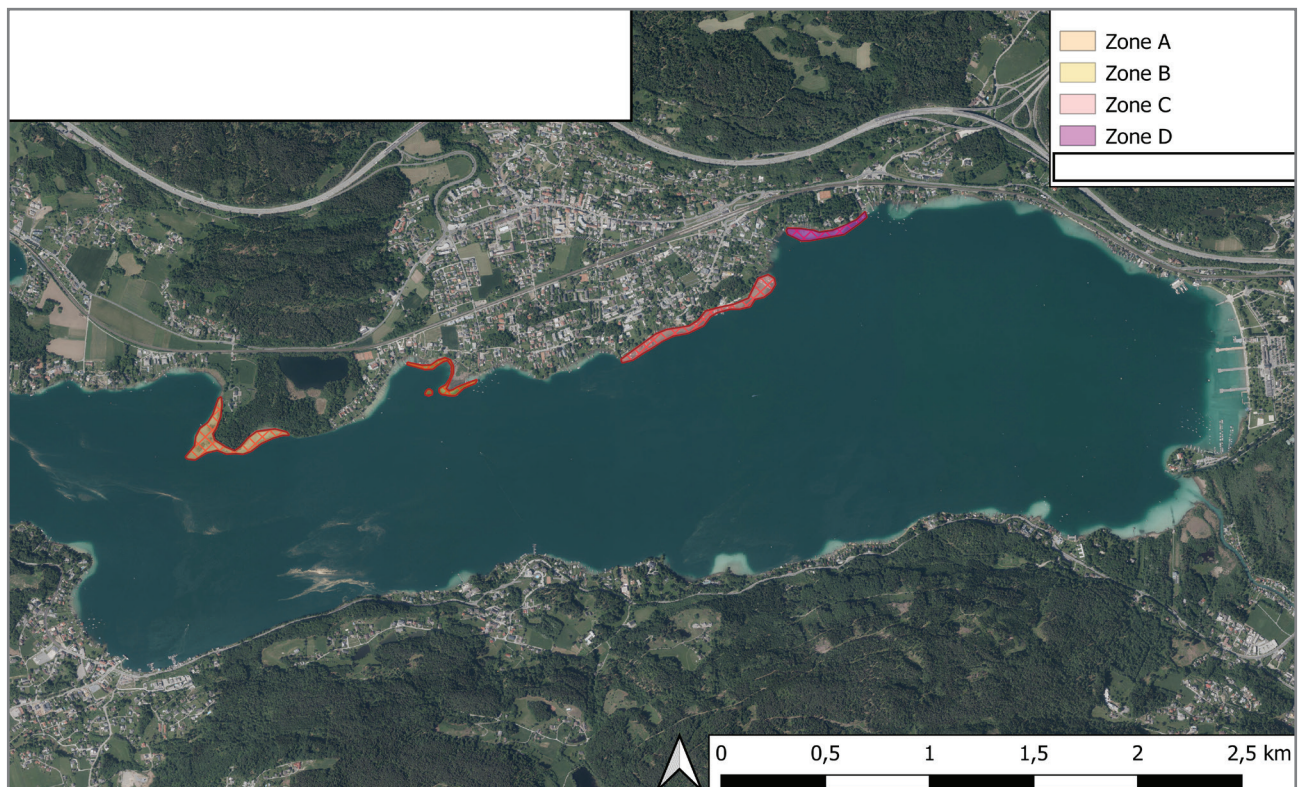
Comparable evidence from neighbouring Styria and Slovenia provides important reference points. Sites such as Wildoner Schlossberg in Styria demonstrate the existence of sedentary farming communities from the Middle Neolithic onwards, while scattered Starčevo and LBK sherds from eastern Styria and the Ljubljansko barje region possibly attest even much earlier cultural interactions across the Alpe-Adria corridor (Tiefengraber 2015a; 2015b; 2015c; 2018; Velušček 2017). Achieving a comparable state of research for Carinthia – through systematic palaeo-ecological sampling, targeted excavation, and absolute dating – remains essential for understanding the regional trajectory of Neolithisation, the transition to the Eneolithic, and its cultural and environmental context, including the crucial role of waterways in facilitating the expansion and movement of prehistoric communities.

### Case study: northeastern shallow shoreline areas of Lake Wörthersee (Eastern Bay, Krumpendorf Area)

In winter 2023, a multi-day diving survey was conducted in the shallow littoral zone of Lake Wörthersee near Krumpendorf to identify potential prehistoric pile-dwelling sites (Ries 2024b). Fieldwork was supported by local collaborators, “Wasserrettung Krumpendorf”, who provided infrastructure and equipment. The survey documented numerous anthropogenic features in the shallow-water zone (Fig. 7, 8).

Most were of historical and modern origin, associated primarily with past fishing practices (Fig. 8). Dense pile fields, often combined with underwater stone mounds, correspond to historical fishery installations documented in Carinthian and other circumalpine lakes (Jernej 2023). Stone mound structures are prominently discernible in aerial photographs. Aerial drone images clearly show the underwater stone mounds of Lake Wörthersee such as in investigation zone D additionally revealed underwater mounds (Fig. 7).

Coring and sediment analyses showed that the uppermost layers consisted mainly of minerogenic lake marl and glacially formed clay, with occasional



**Fig. 6.** Map of the littoral zones surveyed at Krumpendorf. Four survey areas (Zones A–D) were defined, with investigations carried out in the shallow-water zone to assess archaeological potential (map by M.-C. Ries).





**Fig. 7.** Aerial view of Lake Wörthersee showing submerged stone mounds, clearly visible in Investigation Zone D. These features represent preserved traces of past fishing activities, providing evidence for historical exploitation of the littoral zone (photo by M.-C. Ries).

deposits of naturally accumulated organic matter, likely representing degraded reed belts. No stratigraphic traces of prehistoric cultural layers – such as subfossil detritus containing charcoal and cultivated plants – were identified. In several cores, glacial clay was found directly at the surface, indicating severe erosional processes, likely accelerated by motorized boating and anthropogenic shoreline modifications (Fig. 9).

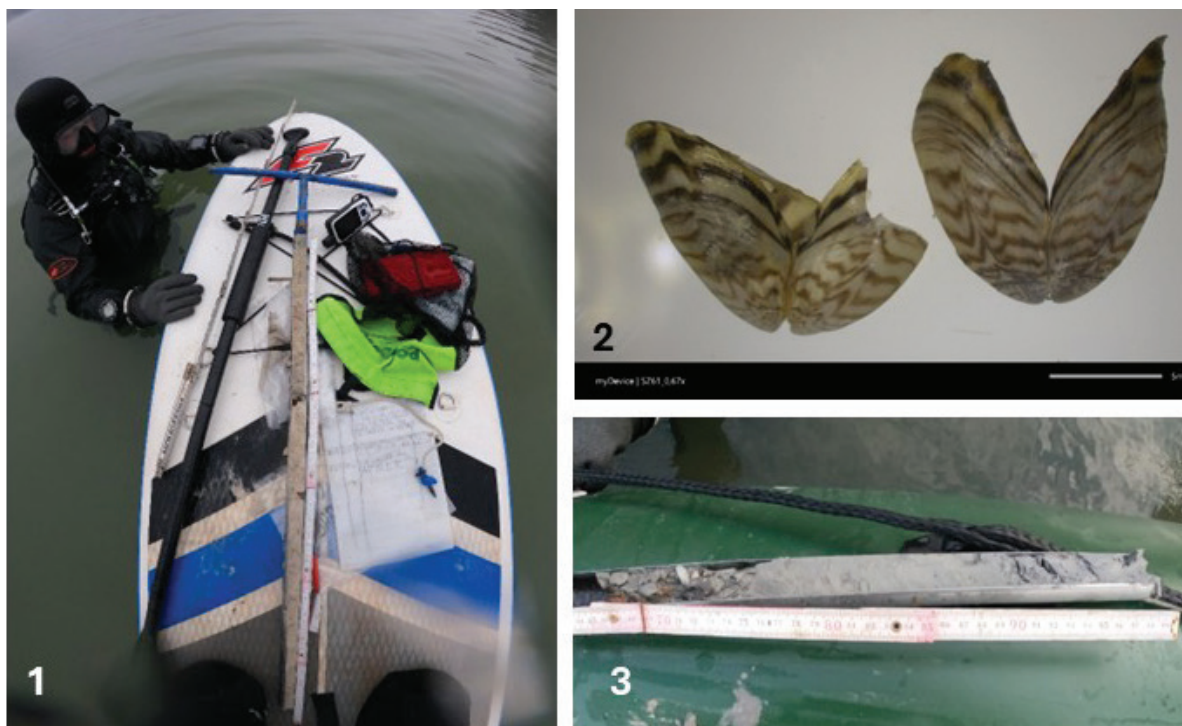
Despite the absence of prehistoric material such as pottery fragments or remains of organic cultural layers from pile-dwelling sites in the four surveyed underwater zones (A–D), stray finds along the Krumpendorf lakeshore evidence the presence of prehistoric people, including a lithic artefacts (silex core) and a fully preserved ceramic vessel assignable to the Epi-Lengyel/Copper Age (late 5<sup>th</sup> to early 4<sup>th</sup> millennium BC) (Ries 2024b). This suggests that adjacent near-shore areas, particularly former submerged littoral zones now silted-up or dry, may still contain undiscovered prehistoric pile-dwelling remains. Previous human interventions, including artificial water-level regulation and shoreline modifications, may not have entirely disturbed or removed such structures, as observed in similar situations at circumalpine lakes (Dieckmann *et al.* 2012; Huber *et al.* 2020).

This implies that the shorelines of Lake Wörthersee likely preserve plenty undiscovered prehistoric pile-dwelling sites, now situated on land due to the change of the water table, which could be revealed through systematic excavation or during construction activities along the shorelines. These dry or paludified palaeo-shoreland areas possess significant archaeological potential and should be carefully monitored and subjected to systematic heritage supervision in planning processes prior to construction activities (Ebersbach *et al.* 2019). Several areas in Krumpendorf retain particular potential for future archaeological investigations. The largely undeveloped Walterskirchen Nature Reserve and zones surrounding the lakeside promenade, marina, “Bad Stich”-area, and local shoreline restaurants have previously yielded Copper Age finds, confirming prehistoric occupation (Ries 2024b; *Fundmeldung Krumpendorf* 1955).

Preservation in the shallow littoral zones is generally poor. Erosion has caused the loss of significant amount of littoral sediment layers which lead to widespread exposure of glacially formed clay and gravel deposits visible in the sediment cores retrieved in 1 m sequences via hand-operated corer (Fig. 9). Microarchaeological analyses confirm extreme erosion and sediment disturbance, while the presence of invasive neozoic fauna



**Fig. 8.** Dense occurrence of modern- to historic wooden pile fields, characterized by small-diameter, well-preserved vertical timber, representing traditional fishery installations (“Fischreis”), often associated with stone mounds either around or near the piles. Example from the shallow-water area in front of the Walterskirchen promontory (photo by M.-C. Ries).



**Fig. 9.** Microarchaeological results document extreme erosional truncation and sediment reworking. Zebra mussels (*Dreissena polymorpha*) occurring to >70 cm depth below surface, demonstrate continued biotic disturbance (2). Core 19.1 comprises only consolidated, fine-grained glacial clay, evidencing full removal of post-glacial stratigraphic units in shoreline areas (3). Diver A. Laskaris during core documentation (1) (photo by M.-C. Ries).



zebra mussels (*Dreissena polymorpha*) up to 70 cm below the surface further illustrates ongoing change of the environment and anthropogenic pressures.

Overall, while accelerated erosion and historical fishing activities dominate the visible archaeological landscape around Krumpendorf, inland and formerly submerged lake zones e.g. palaeo-shorelines may still preserve intact prehistoric pile-dwelling settlements. The Krumpendorf littoral zone thus represents a complex archaeological landscape, only partially surveyed and understood. Given documented erosional dynamics and ongoing human impacts, preventive archaeological monitoring should accompany shoreline constructions, dredging, or restoration. Intensified research in both submerged and former lakeshore zones is essential to advance our knowledge of prehistoric human activity in Carinthia and to prevent the undocumented loss of cultural heritage of outstanding significance.

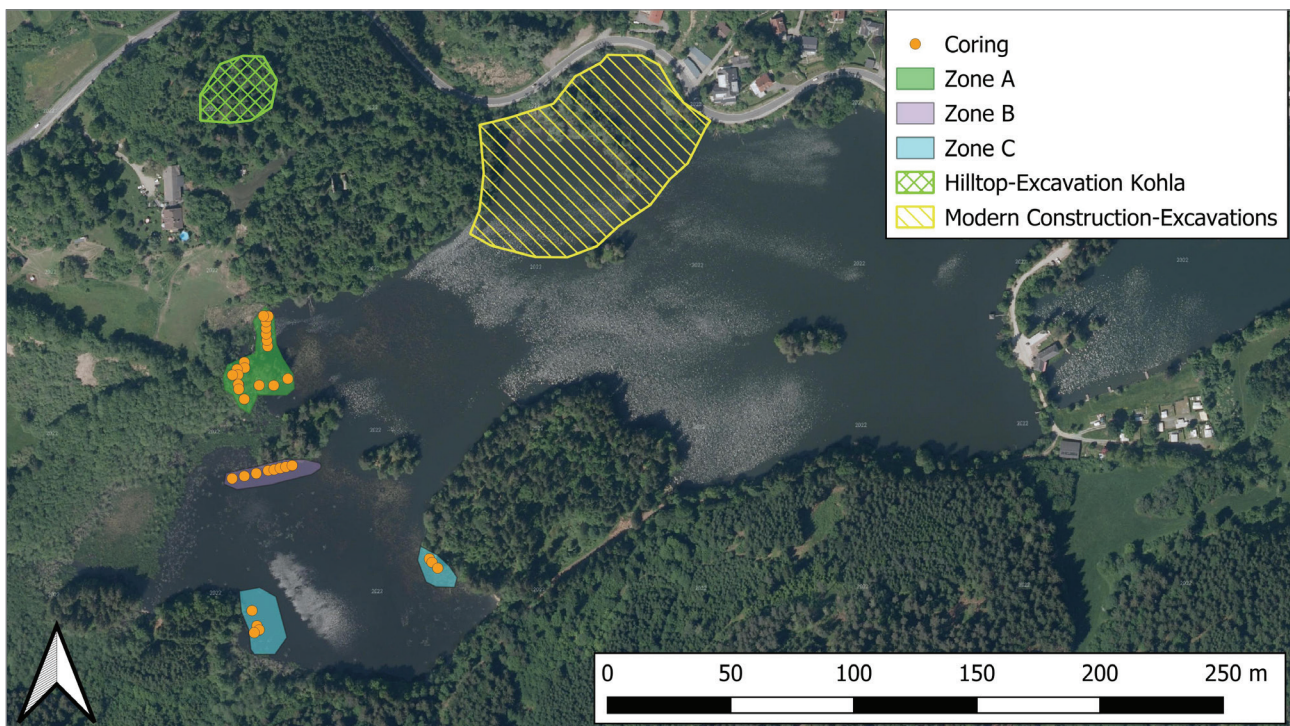
### Case study: small mire lakes Moosburger Teiche

A multi-day coring survey in August 2023 at the Moosburg mire-lakes provided initial insights into a sensitive cultural landscape located in a wetland en-

vironment (Ries 2024c). Conducted as part of a University Innsbruck field practicum, the survey covered three transects (A–C) and revealed local sedimentation processes and anthropogenic influence, including abundant charcoal fragments and burnt clay in selected cores (Fig. 10, 11). No diagnostic features of prehistoric pile-dwellings, such as post alignments or cultural layers, were identified.

Given the presence of prehistoric and historic monuments in the area, additional archaeological remains around the Moosburg ponds cannot be excluded. The basin represents a highly sensitive archaeological zone with particular potential for the presence of wetland pile-dwelling settlements and related structures such as prehistoric timber trackways in paludified peat-environments. Follow-up investigations with advanced equipment and adequate funding are required to complete the currently fragmentary research picture.

A modern reassessment of material from earlier excavations on the elevated hilltop along the Moosburg waterbodies (Kohla 1960; 1973; Vahlkampff 1995) is urgently required. Kohla's excavations in the 1950s, conducted on the ridge north of the Mitterteich, documented evidence of a prehistoric settlement



**Fig. 10.** Map of the surveyed zones at Moosburger Teiche. Three survey areas (Zones A–C) were defined, with investigations conducted in shallow, macrophyte-covered waters to assess archaeological potential and identify preserved remains. The study area is situated near the hilltop excavations by Kohla, which yielded settlement evidence attributable to the Epi-Lengyel cultural horizon (map by M.-C. Ries).





**Fig. 11.** A group of archaeology students conducting hand-operated coring and documentation of local stratigraphy in challenging environments at shore-line areas of the Moosburger Teiche Lakes (students: B. Jell and M. Kerschner) (photo by M.-C. Ries).

and provided the primary impetus for the recent field investigations. Although the original excavation yielded limited stratigraphic documentation, the recovered artefacts indicate settlement activity during the Neolithic to Copper Age which can be attributed to the Epi-Lengyel.

For example, fragments of ceramic ladles with perforated handles and biconical vessels with downward-pointing knob-like lugs and incised rim decoration were found. These forms correspond to vessel types known from the Lasinja-culture horizon. The fragment of a clay ladle or spoon with a perforated handle is characteristic of the Lasinja phase. The so-called “Knickwandschale mit abwärtszeigendem Zapfenbuckel” represents a well-defined type within the same cultural complex. Comparable assemblages are well documented at sites in neighbouring regions, such as Slovenia and Styria, supporting a clear cultural affiliation of the Moosburg material with the broader Lasinja cultural sphere (Tiefengraber 2015c; 2018; Velušček 2017; Bertha 2021; Ries 2026, in print).

Among the finds, a miniature vessel stands out due to its clear stylistic and technological links to the material culture of adjacent Southeast European regions like Slovenia, Croatia or Serbia (Kramberger *et al.* 2021). This object is currently the focus of detailed archaeometric analyses, which aim to clarify its content by residue analysis, functional use, and broader cultural significance (Fig. 12).

The ongoing study of this vessel, combined with a systematic re-evaluation of the earlier excavation material, is essential for assessing supraregional con-

nections, and establishing absolute chronological frameworks. Integrating these data with new fieldwork and sediment analyses allows a modern interpretation of the site’s occupational history and its role within the wider prehistoric landscape of the south-eastern Alpine region. These efforts highlight both the scientific potential of the Moosburg site and the necessity of employing state-of-the-art investigations to fully realize its archaeological significance.

The wetland deposits of the Moosburg ponds also represent a valuable environmental-archaeological archive for studying human–environment interactions. Palaeoecological analyses could clarify local settlement dynamics and give insights into the local Neolithisation process. Any future modifications of the pond areas – shoreline redevelopment, restoration of natural habitats, construction, dredging – should be accompanied by systematic archaeological monitoring. Overall, the Moosburg mire-lakes constitute a culturally and environmentally significant landscape with high potential for prehistoric pile-dwelling settlements and for advancing understanding of Neolithic to Copper Age human activity in Carinthia.

### Kapuzinerinsel in Lake Wörthersee

The currently investigated pile-dwelling site of Kapuzinerinsel in Lake Wörthersee represents a major addition to Carinthia’s prehistoric settlement record. Located less than 5 km from the UNESCO World Heritage pile-dwelling-site at Lake Keutschacher See,



**Fig. 12.** Ceramic miniature vessel from Moosburg, originating from the early excavation campaigns. The object shows strong similarities to ceramic forms known from southeastern European regions, suggesting the possibility of a non-local “foreign type” or imported object (photo by M.-C. Ries).

the site provides the first securely dated evidence of Eneolithic occupation in the Wörthersee basin (Ries 2022a; 2022b; 2024a; 2025; 2026, in print).

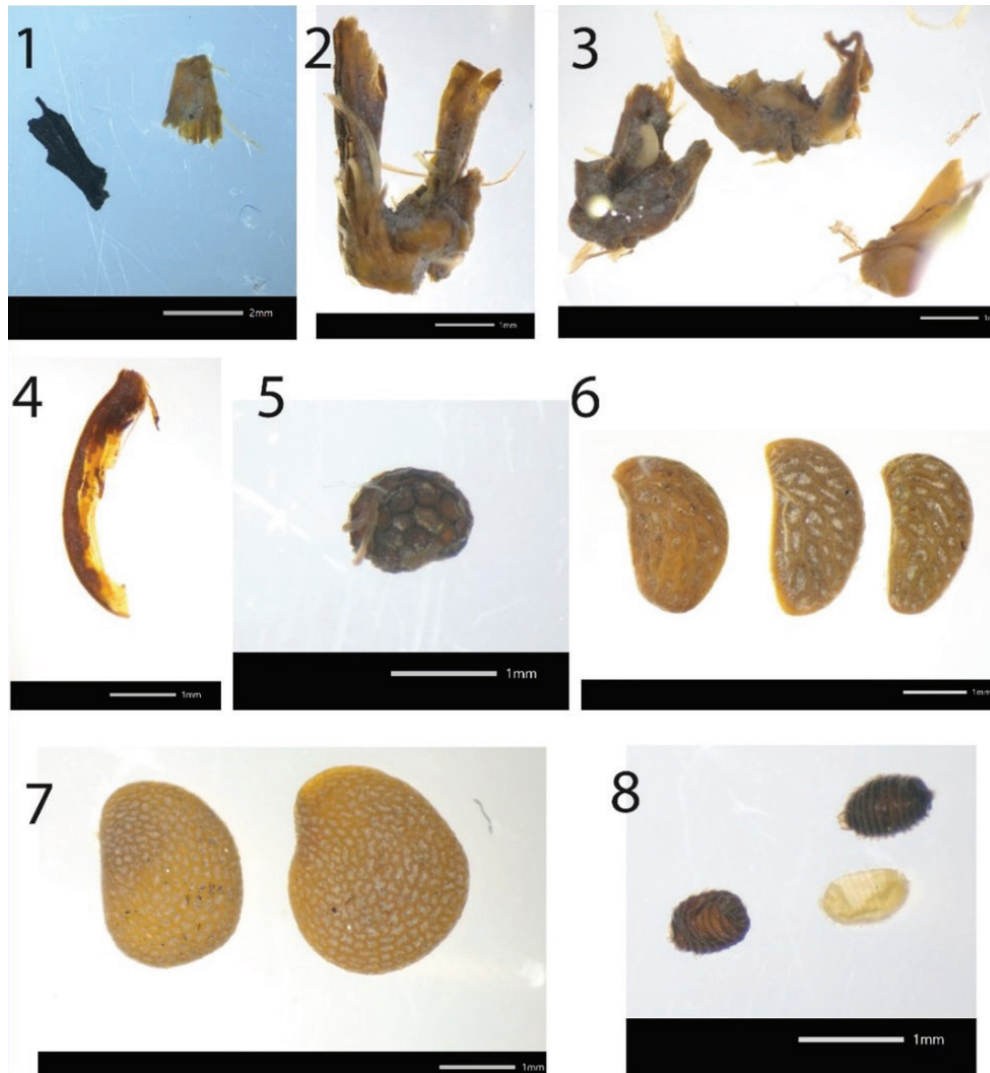
Initial underwater prospection in the winter of 2021, combined diving surveys, hand-operated coring, and systematic sediment sampling (Ries 2022a). These investigations revealed dense pile fields, eroded organic cultural layers, and artefact assemblages including pottery, lithic artefacts, and a rich archaeobotanical and zooarchaeological record. The site occupies a strategic position within a central-lake constriction, likely reflecting its importance in water-orientated regional and supraregional exchange networks.

Already during the first diving surveys, stratigraphic observations and sediment analyses indicated severe erosion and the rapid degradation of submerged archaeological deposits. Subsequent microarchaeological and archaeobotanical screening of waterlogged sediments yielded uncharred cereal chaff, cultivated

crops, and gathered wild plants, pointing to a mixed farming and foraging economy (Fig. 13). Radiocarbon analysis of selected terrestrial macroremains, conducted in 2022, provided the first absolute date for Kapuzinerinsel, placing its occupation in the late 4<sup>th</sup> millennium cal BC ( $3781 \pm 129$  BP; Beta-623764,  $2\sigma$  range). This result establishes Kapuzinerinsel as the oldest known settlement evidence from Lake Wörthersee and underscores its exceptional value for understanding early sedentary lifeways in Carinthia (Fig. 14).

At the same time, evidence of alarming scales of erosion induced by wave activities have already been visible during the 2021 surveys, which have consequently been reported to the Federal Monuments Office Austria (Ries 2022a).

Approximately 3 kg of unstratified pottery stray finds from the shallow-water zone of Kapuzinerinsel, collected over past decades by private individuals, are currently curated in the Kärnten Museum in



**Fig. 13.** Result of microarchaeological screening. Uncharred botanical macro-remains from the cultural layer samples collected during the 2021 survey at Kapuzinerinsel.

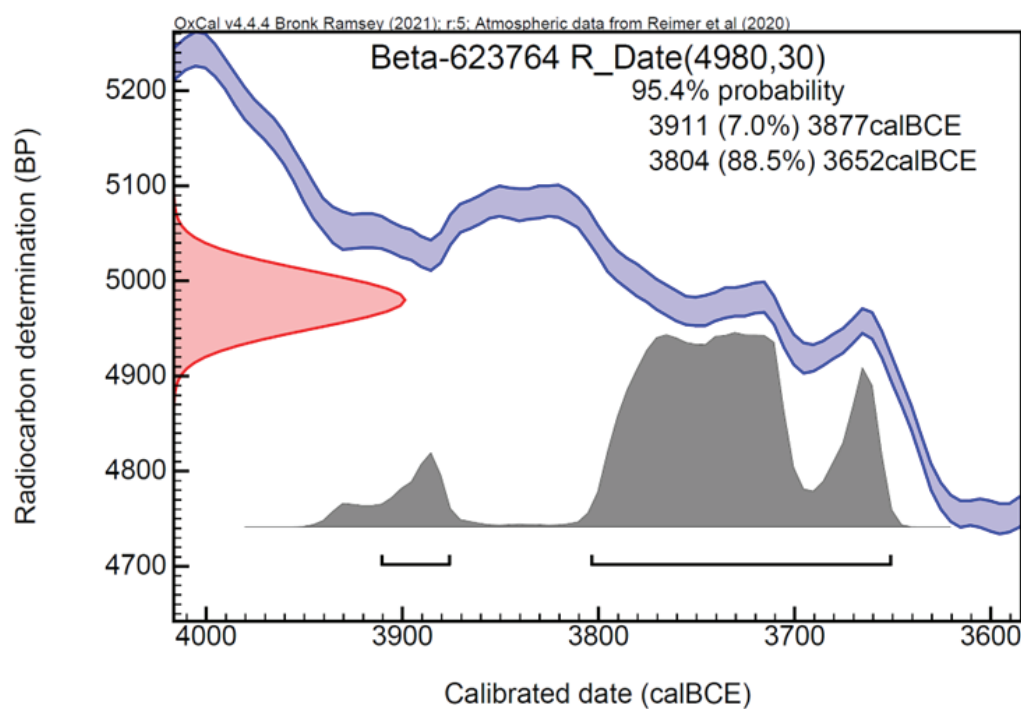
1–3. cereal chaff fragments, 4. flax seeds (*Linum usitatissimum*), 5. poppy (*Papaver somniferum*), 6. raspberry (*Rubus fruticosus*), 7. groundcherry (*Physalis alkekengi*), 8. oogonia of stoneworts (*Characeae*). The majority of archaeobotanical remains are strongly intermixed with reed rhizomes (visible as filamentous brown fibers) (photo by M.-C. Ries).

Klagenfurt. These materials were systematically re-evaluated and included in a typo-chronological study during 2023 (Ries 2026, in print). The assemblage also comprises artefacts recovered after a severe storm in summer 2022, which caused substantial erosion along the island's terrestrial margins. Uprooted trees were mechanically displacing cultural layers and exposing prehistoric material – a striking indicator of the increasing frequency of extreme weather events, possibly linked to climatic change resulting in the loss and destruction of archaeological heritage (Fig. 15).

The historical collections further contain stray finds retrieved from earlier disturbances, offering

fragmentary but valuable insights into the site's phasing and settlement history. On this basis, preliminary working hypotheses for the chronological and cultural sequence have been formulated. The earliest phase is attributed to the Early Copper Age Kanzianiberg–Lasinja I IIa horizon (ca. 4300–3900 BC). It is followed by a distinct Middle Copper Age phase (ca. 3900/3800–3500 BC), associated with furrow incision pottery “Furchenstichkeramik” defined as the local group of Kanzianiberg–Lasinja IIc facies Keutschach (Ruttikay 1996; 1997; Samonig 2003; Ruttikay *et al.* 2004; Ries 2026, in print), and culturally related to pottery groups characterized by furrow-incisions,

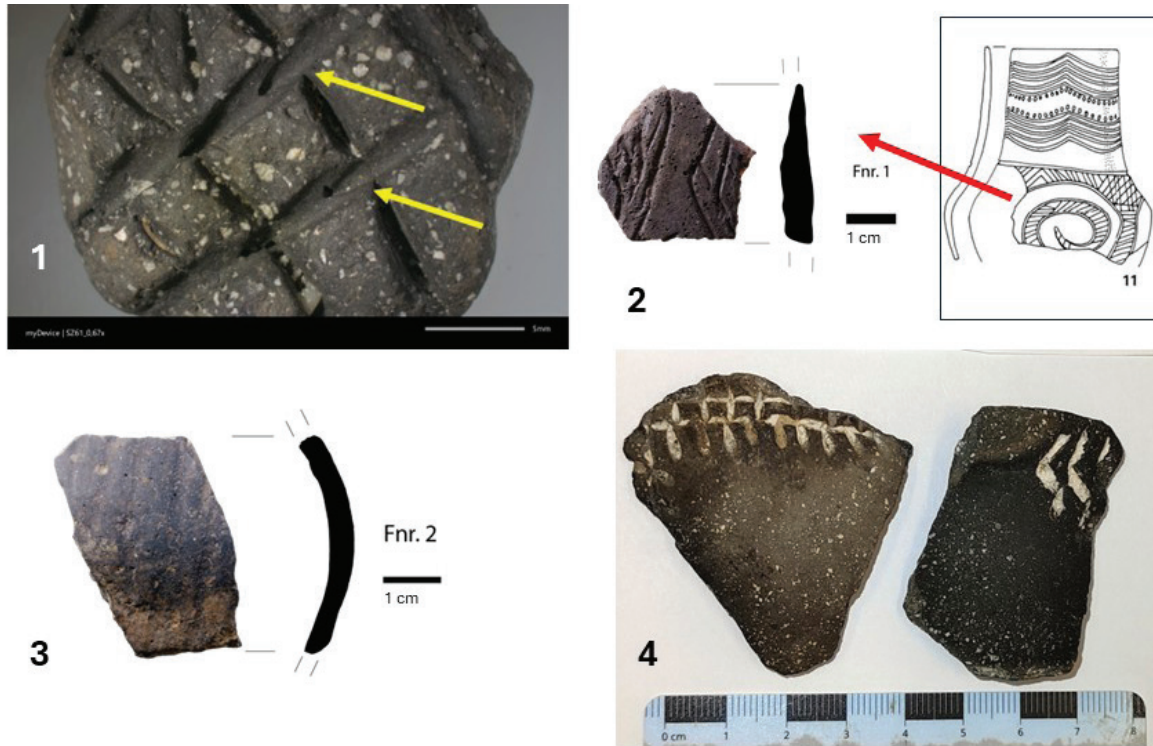




**Fig. 14.** Calibrated Radiocarbon date from terrestrial macrobotanical remains from the archaeological cultural layer at Kapuzinerinsel (image by M.-C. Ries/Beta Analytic).



**Fig. 15.** Archaeological rescue documentation following the summer storm of 2022 reveals substantial damage along the terrestrial part of Kapuzinerinsel, with uprooted trees exposing an estimated 50–70 artefacts per tree crater (photo by R. Jernej).



**Fig. 16.** Pottery fragments from Kapuzinerinsel.

1. hydrodynamically eroded sherd with clearly defined furrow incisions, 2. sherd with crossed bundles of incision lines filling curvilinear motifs, showing strong stylistic parallels to material from Keutschacher See and the Hočevarica site, 3. pottery fragment likely attributable to the Boleráz group of the Baden Culture, 4. sherds from the 2024 underwater excavation campaign, reflecting the stylistic development commonly referred to as the local “Facies Keutschach” from the 1<sup>st</sup> half of the 4<sup>th</sup> millennium BC (photo by M.-C. Ries).

similar observable in the pottery from Mondsee and Retz-Gajary groups (Fig. 16).

The ceramic assemblage includes several fragments of small, finely made jugs produced predominantly in a reducing firing atmosphere and composed of fine clay pastes. Many of these vessels exhibit polished surfaces and are equipped with band handles, while the main feature of these jugs are curvilinear incised motifs. Characteristics of this local ceramic tradition is the use of curvilinear volutes filled with fine incised lines, representing a stylistic expression that seems to be anchored in the Carinthian lake district also at Keutschacher See but shows wider cultural affiliations similarly extending into northeastern Slovenia and western Hungary. This Carinthian stylistic development has been described as the “Facies Keutschach”, particularly recognizable in the white incrustation-paste inlay of the decoration applied to the incised patterns (Samonig 2003; Ruttkay *et al.* 2004; Gleirscher 2014; Ries 2026, in print).

In addition, the assemblage includes “Kerbschnitt” pottery combined with S-shaped, continuous circumferential ornamental bands along the rim, further un-

derlining the site’s role in a broader supra-regional stylistic network and strong links to Lake Keutschacher See. Material recovered during the 2024 field campaign reinforces the interpretation of the site as a nodal point within long-distance exchange networks, connecting the Eastern Alpine lakescapes with contemporaneous sites in the Austrian Salzkammergut area along the northern Alpine foothills or Slovenian sites such as Hočevarica and communities in the Transdanubian region of Hungary (Velušček 2004; 2017). Moreover, a third ceramic phase, previously unrecognised in the regional sequence of pile-dwelling settlements, can most probably be attributed to the Boleráz group of the Baden Culture (from c. 3500 BC onward). This phase is marked by vessels exhibiting shallow diagonal cannelures, closely comparable to Horizon VII at the Wildoner Schlossberg site in Styria and indicates continued occupation and shifting cultural affiliations over time (Tiefengraber 2018, fig. 212; Ries 2026, in print).

Evidence for early copper metallurgy, indicated by a clay crucible fragment containing arsenical copper, is currently under archaeometric analysis. Complementary radiocarbon and dendrochronological



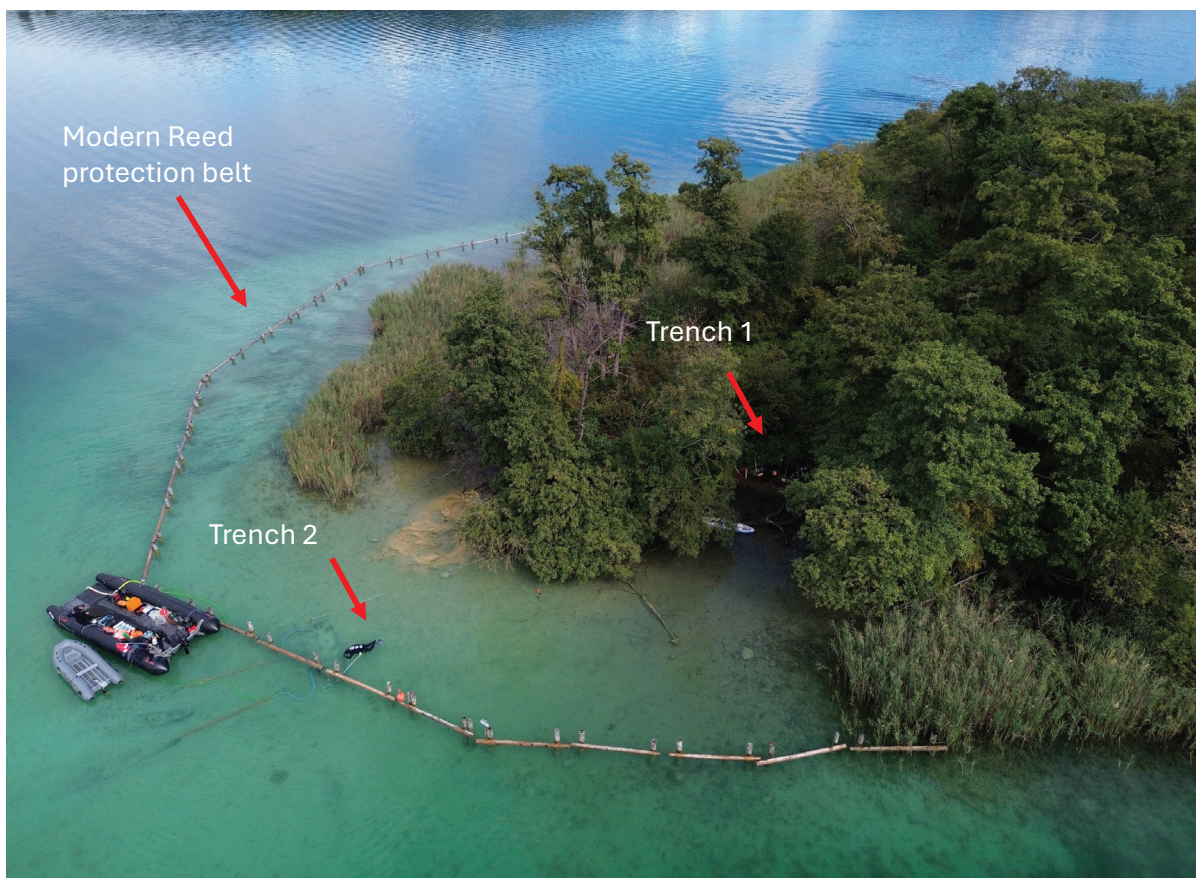
analyses of waterlogged piles which are currently underway are expected to refine the chronological phasing and to reconstruct aspects of settlement layout (Zielke 2025).

Following repeated efforts to secure funding for essential rescue excavations, a small research grant was successfully obtained in 2024. During autumn 2024, a three-week targeted excavation was conducted with the support of the State of Carinthia (Art and Culture) and the Archaeological Research Network Innsbruck (AFIN). Two trenches covering 21 m<sup>2</sup> were opened in submerged and adjacent terrestrial zones (Fig. 17). Excavations revealed multi-phased occupation layers, exceptionally preserved timber structures within dense pile fields, and a diverse artefact assemblage exceeding 33 kg of recovered materials. The majority of ceramics can be attributed to the 4<sup>th</sup> millennium BC, stylistically consistent with the “Facies Keutschach” (Kanzianiberg–Lasinja IIc). Additionally, a fully preserved Iron Age animal-head fibula (5<sup>th</sup> century BC) found within the underwater excavation trench highlights the site’s diachronic significance (Ries 2024).

Lithic material, including silex from at least three optically distinguishable raw material sources, grinding and hammer stones, complement the assemblage. Dendrochronological analyses of more than 100 sampled piles are ongoing to establish absolute dating and reconstruct settlement structures (Zielke 2025).

The underwater and terrestrial excavations at Kapuzinerinsel were conducted according to modern standards for pile-dwelling research, following best-practice methodologies developed in Switzerland for the systematic investigation of waterlogged prehistoric lakeshore settlements. The project involved an international team of nine archaeologists and scientific divers, with technical support from ZAPA (Slovenia) and German Collaborators (State Office for the Preservation of Monuments / Wetland Archaeology, Hemmenhofen and Terramare Archaeological Services). Excavation focused on two trenches: an underwater area measuring 4 × 5 m and a terrestrial area of 2 × 1 m.

A 1 m<sup>2</sup> grid system was implemented to ensure systematic spatial documentation (Fig. 18). Underwater dredges were used to remove sediment in con-



**Fig. 17.** Drone aerial photograph of the Kapuzinerinsel site during the 2024 underwater archaeological excavation, showing Excavation Trench 1 and Excavation Trench 2, as well as the reed protection belt established in 2019 as a nature conservation measure (photo by K. Bauer and M.-C. Ries).



**Fig. 18.** West side of the island showing the reed protection belt and the excavation trench in the shallow water zone, divided into 1 m<sup>2</sup> units for systematic documentation. Scientific diver conducting documentation steps; underwater dredges in use (image by M.-C. Ries).

trolled 1 m<sup>2</sup> units, while all piles were numbered and documented in situ prior to sampling. Emphasis was placed on high-resolution digital documentation, including extensive photography, video recording, and structure-from-motion (SfM) photogrammetry using Agisoft Metashape. This approach generated detailed three-dimensional models of the pile field and surrounding features, ensuring that pile positions and spatial relationships were precisely recorded. Subsequent georeferencing of square-metre photographs provided exact coordinates for each pile, enabling precise spatial analysis and integration into the site's GIS database. The procedure, inspired by modern best-practice examples developed and tested by Swiss pile-dwelling research teams, was applied at the Kapuzinerinsel excavation project to ensure systematic, high-quality documentation and recording of the underwater archaeological features (Bleicher *et al.* 2024; Reich *et al.* 2025). Excavated sediments were collected in fine mesh nets for subsequent wet-sieving on land, allowing recovery of small artefacts and microarchaeological materials. The primary objectives of the campaign included the assessment of site preservation, documentation of pile-field architecture, and targeted wood sampling for dendrochronological analysis. Semi-quantitative feature recording enabled rapid evaluation, while the integration of 3D modelling and careful sediment management maximized the preservation of contextual information. Public outreach was an integral component, with updates disseminated via

social media and national television, highlighting the scientific and cultural significance of the site and the potential of Austrian underwater archaeology.

The final evaluation, detailed analysis, and publication of the Kapuzinerinsel excavations remain pending due to limited financial support and are planned for subsequent years. Preliminary observations suggest the presence of linear structures very likely island-enclosing palisades and the potential existence of remains from several multi-naved houses, representing multiple occupation phases. Excavated areas exhibit high pile densities, with up to nine wooden piles per square metre, reflecting local construction practices and enabling the reconstruction of settlement dynamics as well as past climate conditions through dendrochronological analysis of tree-ring patterns. Initial wood anatomical analyses of pile samples identified a total of 12 different wood genera, providing insights into prehistoric forest management, resource use, and human–environment interactions. Moreover, radiocarbon dating of selected samples is underway, which may allow year-precise absolute dating via wiggle-matching once integrated with the emerging mean oak chronology and individual tree-ring series.

If dendrochronological dating proves successful, as ongoing analyses are expected to show in 2026, Kapuzinerinsel could become only the second dendrochronologically dated pile-dwelling site in Austria, providing high-resolution absolute dating and a unique dataset for Chalcolithic architecture. As



the first underwater pile-dwelling excavation at Lake Wörthersee, it offers substantial potential for transdisciplinary research, enabling the reconstruction of settlement organization, socio-economic dynamics, and subsistence strategies in 4<sup>th</sup>-millennium BC Carinthia.

Kapuzinerinsel must be considered heritage at risk. Despite its exceptional significance as a 6,000-year-old site, current local conditions pose an immediate threat. A reed-protection belt established in 2019 as part of nature conservation measures has altered the site's surroundings, but the settlement remains highly vulnerable (Fig. 17). Intensively used waterskiing and boating tracks less than 50 m from the site generate an alarming scale of wave-induced erosion, destabilizing piles and degrading organic cultural layers. Without additional protective measures, substantial portions of the site will be permanently lost within the next years. Rescue excavation represents the preferred method both to safeguard the site and to document its archaeological value. Only a fraction of the settlement has been systematically investigated. Further rescue excavation, targeted sediment sampling, and archaeobotanical analyses, scheduled for the upcoming years, are urgently required to mitigate erosion, recover sensitive features and finds, and clarify occupation phases, settlement layout, and human–environment interactions. The immediate implementation of protective and monitoring measures is essential to preserve the site's integrity, scientific potential, and its status as a unique record of prehistoric lake-dwelling communities in Austria and the wider context of circum-Alpine pile-dwelling networks.

## Conclusion

The pilot project assessing prehistoric settlement potential along the lakeshores and wetlands of Carinthia has clearly demonstrated the region's exceptional value for interdisciplinary archaeological research. Sites such as Kapuzinerinsel in Lake Wörthersee exemplify the multifaceted and wide-ranging insights that can be gained from combining underwater fieldwork, coring, sediment analysis, microarchaeology, and radiocarbon and dendrochronological dating. The investigations document multi-phased occupation, early agricultural practices, specialized craft production, and evidence of long-distance exchange, situating Carinthia firmly within broader prehistoric networks of the Alpe-Adria region. Moreover, these efforts provide an initial methodological and conceptual impulse for more systematic research across southern Austria's lakes and wetlands, offering a first

step toward addressing long-standing gaps in chronology, settlement layout, and research on human–environment interactions.

Despite these advances, Carinthia's archaeological heritage remains highly vulnerable. hydrodynamic erosion, intensified recreational use, unsupervised shoreline modifications, and incomplete protection measures threaten the survival of key sites. The absence of defined archaeological protection zones along bodies of water, coupled with the fragmentary nature of existing site records, underscores the urgent need for preventive heritage management, rescue excavations, and to invest in archaeological infrastructure and foundational research. Small-scale pilot studies, like those conducted in Moosburg and Krumpendorf, highlight both the scientific potential and the fragility of these landscapes and their active undocumented loss. In conclusion, Carinthia offers unparalleled opportunities to reconstruct prehistoric settlement dynamics, technological innovation, and socio-economic interactions in lake-dwelling contexts. By integrating fieldwork, laboratory analyses, archival research, and heritage management, these initiatives not only provide critical data for regional and supraregional studies but also establish a sustainable framework for protecting one of Austria's significant and endangered prehistoric cultural landscapes. Immediate intervention, systematic excavation, and interdisciplinary research are essential to preserve the archaeology of these unique lakescapes, to fully realize their scientific potential, and to ensure Carinthia's integration into broader European archaeological research agendas.

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