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# Systematic Archaeological Investigation of the Ravne Underground Complex in Bosnia and Herzegovina

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## Abstract

The Ravne underground complex near Visoko, Bosnia and Herzegovina, is among the most extensively investigated subsurface archaeological contexts in Southeastern Europe. Since its identification in 2005, systematic archaeological, geological, and geodetic research has been conducted through annually permitted field campaigns. This article presents a descriptive and methodological synthesis of excavation data from the Ravne underground complex (2005-2025), drawing on stratigraphic excavation, architectural documentation, artefact analysis, and spatial surveying. Investigations have documented interconnected underground passages developed within Quaternary conglomerate deposits, together with recurring features such as shaped corridors, dry-stone constructions, sealed side passages, and intentionally emplaced infill. More than 3300 ceramic fragments, along with lithic, metal, faunal, and organic remains, have been recovered from stratigraphically controlled contexts. Ceramic typology and radiocarbon dating indicate repeated human interaction with the underground space from prehistoric through medieval periods. The study emphasizes empirical documentation and methodological transparency, providing a structured framework for evaluating long-term modification and reuse of subterranean archaeological contexts.

## Keywords

Ravne Underground Complex, Visoko Basin, Anthropogenic Tunnel Backfill, Dry-Stone Tunnel Architecture, Subterranean Stratigraphy, Multi-Period Ceramic Assemblages, Underground Archaeological Methodology

## 1. Introduction

Subterranean archaeological contexts represent a significant yet comparatively

underexplored component of the cultural landscapes of Southeastern Europe. While natural caves, mining galleries, and underground shelters have long been recognized in regional archaeological research, systematically excavated and documented underground passage systems remain relatively rare. The Ravne underground complex, located near Visoko in central Bosnia and Herzegovina, has been the subject of continuous archaeological, geological, and geodetic investigation since 2005. Over two decades of annually permitted fieldwork have produced a substantial body of stratigraphic, architectural, and material data derived from controlled excavation and documentation of interconnected underground passages developed within Quaternary conglomerate deposits. This study presents a descriptive and methodological synthesis of these excavation data, focusing on empirical observations, documentation standards, and contextual relationships rather than interpretive or speculative models.

In Bosnia and Herzegovina, archaeological research has traditionally focused on open-air settlements, fortified hilltops, and medieval urban centers, whereas underground features have largely been treated as natural speleological phenomena or as marginal cultural contexts. This methodological imbalance has contributed to an incomplete understanding of subsurface human activity, especially in regions characterized by complex fluvial and conglomeratic geology.

The scope of this study is limited to the systematic presentation and synthesis of archaeological data generated through controlled excavation and documentation of the Ravne underground complex between 2005 and 2025. Rather than proposing definitive interpretations regarding the origin, function, or cultural attribution of the underground passages, the paper focuses on empirical evidence derived from stratigraphy, architectural features, artefact assemblages, geological observations, and spatial documentation.

The primary objectives are: 1) to consolidate excavation results from multiple tunnel systems into a coherent descriptive framework; 2) to outline the methodological approaches applied to underground excavation, recording, and analysis; 3) to document recurring architectural and stratigraphic patterns observed across the complex; and 4) to establish a transparent empirical basis for future comparative and interpretive research. By emphasizing methodological rigor and contextual integrity, the study aims to contribute reliable primary data to broader discussions of subterranean archaeology in Southeastern Europe while clearly delineating the limits of current evidence.

The Visoko Valley, located approximately 30 km northwest of Sarajevo, is one of the most intensively investigated archaeological landscapes in Southeastern Europe over the last two decades. Since 2005, multidisciplinary research in this area has documented a dense concentration of prehistoric and historic features, including extensive artificially modified underground passages collectively referred to as the Ravne underground complex. These tunnels are excavated within Quaternary conglomerate deposits and exhibit clear evidence of deliberate human intervention, including shaped corridors, junctions, chambers, dry-stone walls, back-

filled sections, and stratified occupation deposits (Osmanagich, 2025a).

The first entrance to the Ravne tunnels was identified in August 2005, following preliminary field reconnaissance earlier that year. References to the tunnels were published shortly thereafter, and systematic archaeological and scientific research commenced in 2006 under the auspices of the Foundation for Archaeological and Scientific Research. Since that time, annual field campaigns have yielded the discovery, documentation, and partial excavation of multiple tunnel systems, including Ravne, KTK, Ravne 2, Ravne 3, Ravne 4, Ravne 5, and Ravne 6.

Unlike natural karst caves, the Ravne tunnels are characterized by consistent passage geometry, intentional sealing of side corridors, and the presence of constructed features within the underground environment. Among the most distinctive elements are dry-stone walls built from rounded river pebbles, ceramic assemblages recovered from sealed contexts, lithic and metal artefacts, and stratigraphic sequences indicating repeated phases of use, modification, and backfilling. Radiometric dating of organic material and speleothems has provided chronological anchors ranging from the mid-Holocene to the historical period, thereby confirming prolonged and episodic human interaction with subterranean spaces (Osmanagich, 2025b).

Recent investigations in Ravne 3 and Ravne 6 have significantly expanded the archaeological dataset, yielding large ceramic assemblages, evidence of organized underground labor, and high-precision geodetic documentation of tunnel morphology. These findings allow for a more rigorous assessment of construction techniques, spatial planning, and functional differentiation within the underground complex, moving beyond speculative interpretations toward a structured archaeological framework (Osmanagich, Hoyle, & Agić, 2023; Šabanija-Softić, 2025).

The present study situates the Ravne underground complex within the broader context of subterranean archaeology in South-East Europe. By synthesizing nearly two decades of archaeological excavation, geological analysis, geodetic surveying, and artefact study, this paper aims to document the development, material culture, and architectural characteristics of the Ravne tunnels while explicitly avoiding interpretive models not supported by stratigraphic and material evidence. Particular emphasis is placed on the systematic nature of the investigations, the regulatory framework under which they were conducted, and the implications of artificially modified underground spaces for regional archaeological research.

## 2. Research History and Methodological Framework

### 2.1. Discovery and Early Investigations (2005-2014)

Archaeological interest in the Ravne underground complex began in 2005, following field reconnaissance in the Visoko Valley that identified anomalous subsurface features within Quaternary conglomerate deposits (**Figure 1**). The first accessible entrance to the Ravne tunnels was documented in August 2005, and preliminary observations were published later that year (Osmanagich, 2005c).


The map shows the location of the Ravne underground archaeological complex in Bosnia and Herzegovina and its regional context in the Western Balkans. The site is located near the town of Visoko, approximately 30 km northwest of Sarajevo.

**Figure 1.** Geographic location of the Ravne Underground Complex, Visoko, Bosnia and Herzegovina.

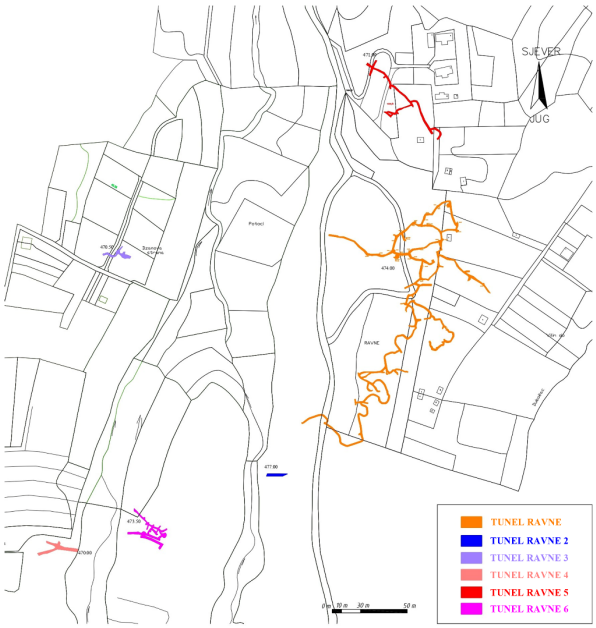
In November 2005, the Foundation for Archaeological and Scientific Research was established to coordinate systematic exploration, documentation, and excavation of the underground features. Formal archaeological fieldwork commenced in April 2006 under the supervision of licensed archaeologists, in cooperation with local museums and heritage institutions. Initial campaigns focused on clearing entrance areas, stabilizing passages, and documenting tunnel morphology, while adhering to minimal intervention principles.

Between 2006 and 2014, research activities concentrated primarily on the main Ravne tunnel system and the KTK tunnel (**Figure 2**). This phase involved extensive manual removal of backfill material, installation of temporary wooden supports in unstable sections, and the first geodetic surveys of accessible corridors (**Figure 3**).

Several external specialists participated during this early phase, contributing expertise in archaeology, geology, speleology, and surveying. These investigations established a foundational understanding of the Ravne tunnels as artificially modified underground spaces rather than purely natural cavities and highlighted the need for improved stratigraphic control and standardized excavation protocols in deeper sections (Moon, 2014).

## 2.2. Expansion and Systematization of Research (2015-2025)

From 2015 onward, research entered a more structured phase, marked by the discovery of additional tunnel systems—Ravne 2, Ravne 3, Ravne 4, Ravne 5, and Ravne 6 (**Figure 4**)—each documented through stratigraphic excavation and geodetic survey (Osmanagich, Hoyle, & Agić, 2023).

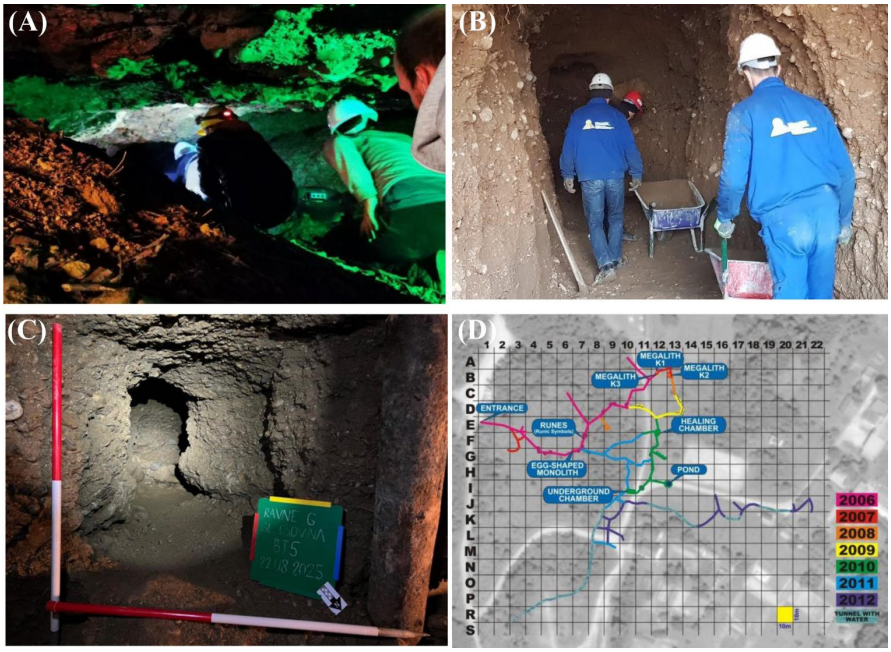



Individual tunnel systems (Ravne, Ravne 2 - Ravne 6) are distinguished by color. The plan is based on geodetic survey and excavation mapping conducted between 2006 and 2025. The total length of cleared and documented tunnels exceeds 3 km. Scale bar in meters.

**Figure 2.** Plan view of the Ravne underground tunnel complex showing the spatial distribution of mapped passages beneath the Ravne Valley (Visoko, Bosnia and Herzegovina).


(A) Collection of organic material samples from tunnel wall sediments for laboratory analysis, conducted by Foundation field archaeologist Andrew Lawler (United Kingdom) in 2007. (B) Manual clearing of tunnel infill and installation of temporary wooden supports by the Foundation's mining team during the initial excavation phase in summer 2006. (C) Geodetic surveying of underground passages using total station equipment, conducted in 2010 to document tunnel geometry and spatial relationships prior to further clearance and mapping.

**Figure 3.** Early archaeological and technical documentation of the Ravne underground complex (2006-2010).




(A) Initial prospection and identification of the Ravne 4 tunnel during exploratory investigations in 2019. (B) Systematic clearing and manual excavation of the Ravne 5 tunnel, documenting removal of anthropogenic infill (2024). (C) Archaeological documentation and stratigraphic work in the Ravne 6 tunnel, including controlled excavation and contextual recording (2025). (D) Chronological map of cleared sections within the Ravne tunnel, illustrating the progressive extension of documented passages between 2006 and 2012.

**Figure 4.** Chronological expansion and archaeological investigation of the Ravne underground complex (2019-2025).

Excavation strategies during this phase adhered strictly to annual permitting procedures defined by cantonal and federal heritage regulations. Each field season was preceded by the submission of a formal research proposal detailing objectives, personnel, equipment, and methodologies, followed by approval from the competent Ministry of Culture, consultation with the Federal Institute for the Protection of Cultural Heritage, and contractual cooperation with the designated local museum. Annual reports documenting results and findings were submitted upon completion of each campaign.

Methodologically, this phase emphasized stratigraphic excavation of tunnel fills, precise artefact provenance, and systematic documentation of architectural features. Particular attention was given to dry-stone walls, junctions, and sealed passages, which were treated as primary archaeological features rather than secondary obstructions. (Osmanagich, 2025d). Geodetic surveying using total stations was conducted to integrate newly cleared sections into an expanding spatial database, enabling accurate mapping of tunnel orientation, depth, and interconnectivity.

The most significant archaeological assemblages recovered during this period derive from Ravne 3 and Ravne 6. Excavations in these tunnels yielded large quantities of ceramic fragments—collectively exceeding 3300 pieces—ranging in date

from the Neolithic to the late medieval period, as well as metal objects, faunal remains, and charcoal concentrations. These finds were recovered from stratified contexts associated with tunnel floors, sealed side passages, and areas adjacent to dry-stone constructions (Osmanagich, Hoyle, & Agić, 2023).

### 2.3. Analytical Approach and Documentation Standards

Across both research phases, a multidisciplinary analytical framework was applied. Geological assessments focused on conglomerate composition, natural fracture patterns, and sediment sources to distinguish anthropogenic modification from natural processes. Archaeological analyses prioritized the integrity of context, stratigraphic relationships, and the comparative typology of artefacts, particularly ceramics.

All excavation units were documented through scaled photography, written context sheets, and measured drawings. Artefacts were catalogued according to standardized inventory systems and, where appropriate, subjected to specialist analysis. Radiocarbon dating of organic materials and uranium-series dating of speleothem growth were employed to establish chronological parameters for tunnel use and modification.

This methodological framework provides the basis for interpreting the Ravne underground complex as a long-term, artificially modified subterranean system shaped by repeated human activity. The following sections examine the geological context, architectural characteristics, and material culture of the tunnels in greater detail, drawing on evidence generated through nearly two decades of systematic research.

## 3. Legal, Institutional, and Methodological Framework

Archaeological research within the Ravne Underground Complex has been conducted under a formal legal and institutional framework established in accordance with Bosnia and Herzegovina's cultural heritage legislation. Since the initiation of systematic fieldwork in 2006, all excavation and documentation activities have been carried out by the Archaeological Park: Bosnian Pyramid of the Sun Foundation, an organization registered with the state Ministry of Justice for archaeological and scientific research.

Each annual research campaign has been preceded by the submission of a detailed project proposal to the competent Cantonal Ministry of Culture. These submissions include a defined research program, a list of qualified personnel, excavation methodology, equipment inventory, and a summary of results from the previous field season. Approval is issued only after a favorable assessment by the Federal Institute for the Protection of Cultural Heritage and the conclusion of a formal cooperation agreement with the designated local museum authority. This permitting procedure has been followed consistently throughout the research period.

Fieldwork is conducted under the supervision of licensed archaeologists, with

support from specialists in geology, geodesy, and conservation as required. Excavation strategies prioritize stratigraphic integrity and controlled removal of tunnel fill, with particular care given to sections containing architectural features or sealed deposits (Figures 3-5). Mechanical excavation is not employed within the tunnels; all clearing and excavation activities are performed manually to preserve contextual relationships.


(A) Cleared section of the Ravne tunnel, showing a stabilized passage excavated through conglomerate material. (B) Interior view of the KTK tunnel, documenting a distinct subterranean corridor investigated as part of the broader Ravne underground network. (C) Clearing operations at the Ravne 2 tunnel entrance, illustrating manual removal of infill during systematic excavation. (D) Archaeological excavation in progress within the Ravne 3 tunnel, with field archaeologists documenting stratigraphy and material remains under controlled conditions.

Figure 5. Archaeological excavation contexts within the Ravne underground complex.

Documentation standards applied at Ravne conform to established archaeological practice. Excavation units are recorded using written context sheets, scaled photography, measured drawings, and geodetic coordinates. Artefacts are catalogued according to standardized inventory systems, with find numbers linked to stratigraphic units and spatial data. Where appropriate, materials are sampled for laboratory analysis, including radiocarbon dating of organic remains and mineralogical assessment of sediments.

Geodetic surveying plays a central role in documenting the spatial organization of the underground complex. Total station instruments have been used since 2006 to record tunnel geometry, junctions, depth variation, and orientation (Figure 3 and Figure 5). These measurements are integrated into cumulative plan views that

enable comparison across tunnel systems and excavation phases, providing a reliable spatial framework for archaeological interpretation.

An important methodological consideration at Ravne is the distinction between natural geological features and anthropogenic modification. Geological assessments are conducted in parallel with archaeological excavation to identify natural fracture planes, sediment sources, and depositional processes (Osmanagich, Hoyle, & Agić, 2023). This integrated approach ensures that architectural features such as dry-stone walls, passage shaping, and infill deposits are evaluated within their broader geomorphological context.

The consistent application of this legal, institutional, and methodological framework over nearly two decades has produced a large and well-documented dataset. It provides a reliable basis for analyzing the Ravne Underground Complex as an artificially modified subterranean system shaped by repeated human activity, rather than as an isolated or anomalous feature.

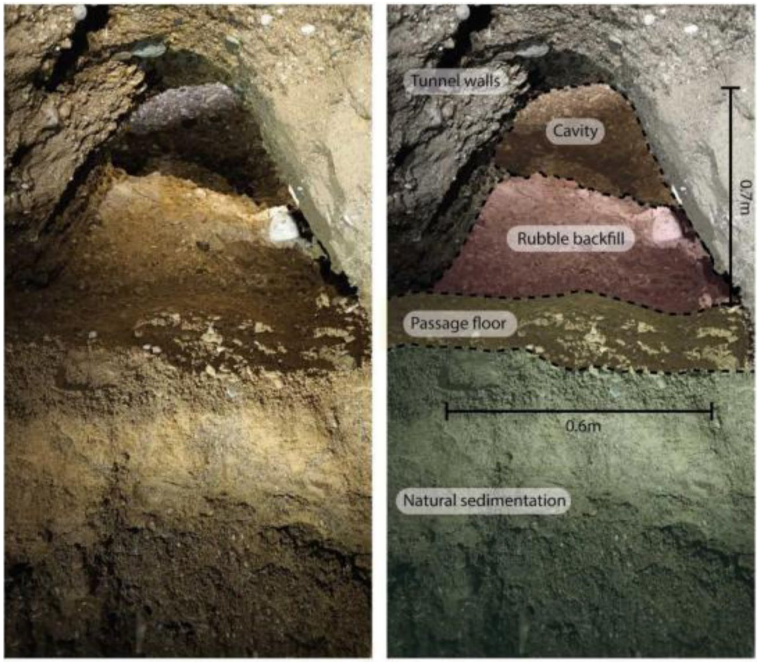
## 4. Geological Context and Tunnel Construction Characteristics

### 4.1 Geological Setting and Host Conglomerate Properties

The Ravne Underground Complex is developed within Upper Miocene conglomerates and sandstones that dominate the Visoko Basin. This lithological setting consists primarily of rounded river pebbles and cobbles cemented within a sandy–clayey matrix, locally referred to as Ravne conglomerate (**Figure 6** and **Figure 7**). The material exhibits moderate cohesion, allowing stable void formation during excavation, while remaining sufficiently soft to permit manual shaping with simple tools. Comparable conglomerate formations are documented elsewhere in the Bosna River catchment, though no comparable subsurface networks are known from the region.

Geological observations from excavation campaigns indicate that the tunnel walls exhibit consistent profiles, with smooth surfaces and relatively uniform cross-sections. In several areas, the tunnels exhibit flattened floors and gently arched ceilings, producing a morphology that differs from that of irregular karstic cavities or natural fissures. The absence of solutional features typical of karst systems—such as scalloping, vertical chimneys, or phreatic tube forms—supports the interpretation that the passages were artificially excavated rather than naturally formed. (Courty et al., 1989; Goldberg & Macphail, 2006).

Stratigraphic exposure within collapsed or partially infilled tunnel sections reveals a clear distinction between compact natural sedimentation layers and heterogeneous backfill material (**Figure 6**). At multiple locations, particularly in Ravne 3 and Ravne 6, unconsolidated fill composed of mixed pebble sizes, a sandy matrix, and cultural material overlies compact geological strata. This fill differs markedly from the surrounding undisturbed conglomerate, suggesting deliberate infilling rather than gradual natural deposition.




Left: original photograph documenting exposed sediment layers following controlled excavation. Right: annotated interpretation of the same section, distinguishing tunnel walls, upper cavity, anthropogenic rubble backfill, original passage floor, and underlying natural sedimentation. The clear separation between natural deposits and intentionally introduced fill material demonstrates deliberate closure and later reopening of the passage. Scale indicated in meters.

**Figure 6.** Stratigraphic profile of a cleared tunnel section in the Ravne underground complex.

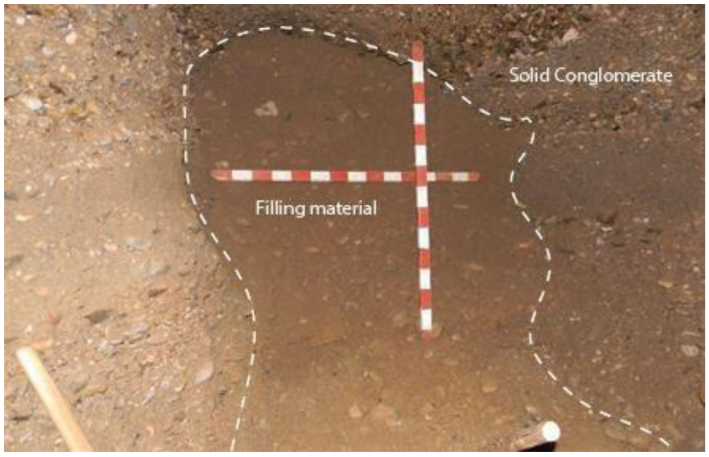



**Figure 7.** Stratigraphic exposure within the Ravne underground complex showing a sharp boundary between consolidated Ravne conglomerate (right) and unconsolidated anthropogenic tunnel infill (center and left). The infill consists of poorly sorted, loose sediment with mixed pebble sizes and no cementation, in contrast to the surrounding lithified conglomerate. Photo documentation from Ravne 3 excavation.

Dry-stone wall structures, constructed from selected river pebbles without mortar, are repeatedly encountered within the tunnel system (**Figure 8**). These walls

vary in thickness and height but share consistent construction techniques, including the placement of horizontal stone courses and the careful selection of stones. In some cases, walls are bonded directly against tunnel walls, while in others they span the entire width of a passage. Geological analysis indicates that these features are not products of sediment collapse or pressure fracturing but represent intentional architectural interventions.


(A) Dry-stone wall segment within the Ravne tunnel, positioned between temporary wooden supports installed during early excavation phases. (B) Dry-stone wall sealing a side passage in the Ravne 3 tunnel, associated with compacted infill and calcified shelf stone. (C) Dry-stone wall structure documented in the Ravne 4 tunnel, composed of stacked river cobbles without binding material. (D) Dry-stone wall feature recorded in the Ravne 6 tunnel during systematic archaeological documentation (2025), with scale and context markers visible.

**Figure 8.** Dry-stone wall constructions within the Ravne underground complex.

Calcification phenomena are observed in limited sections of the tunnels, particularly where moisture movement is present. Thin carbonate crusts occur on exposed stone surfaces, including some dry-stone structures. Their presence indicates prolonged periods of stability following construction or modification phases. Importantly, calcification patterns frequently overlie rather than underlie structural features, implying that wall construction predates at least part of the mineral deposition sequence (**Figure 6** and **Figure 7**).

The geological setting also provides insight into excavation logistics (Cigna & Burri, 2000; Moyes, 2012). The conglomerate's composition allows stone removal without large-scale fracturing, reducing the likelihood of catastrophic collapse. At the same time, the presence of larger embedded cobbles would have required selective extraction and shaping, as evidenced by in situ tool marks and worked sur-

faces. These characteristics suggest a practical understanding of local geology by those who excavated the tunnels.

Taken together, geological and structural evidence support the interpretation that the Ravne tunnels were excavated and modified within a geologically favorable formation, using techniques adapted to the properties of the Ravne conglomerate. The recurring architectural elements—consistent passage dimensions, deliberate backfilling, and dry-stone construction—indicate planned subterranean activity rather than opportunistic use of natural cavities.

### 4.2. Sedimentological Characteristics of Anthropogenic Backfill

Stratigraphic excavation within the Ravne underground complex reveals recurrent deposits of unconsolidated material that are sedimentologically distinct from the surrounding host conglomerate (**Figure 6** and **Figure 7**). The Ravne conglomerate is a lithified polymictic deposit composed of rounded river pebbles firmly cemented within a sandy-clayey matrix, exhibiting high cohesion and resistance to hand excavation. Individual clasts cannot be removed without fracturing the surrounding matrix.

In contrast, tunnel infill deposits are weakly compacted to unconsolidated, poorly sorted, and composed of mixed pebble sizes embedded within a loose sandy matrix. Pebbles are easily dislodged by hand and display no cementation. Stratigraphic profiles show sharp, irregular but clearly defined interfaces between consolidated conglomerate and overlying or intruding infill, indicating discrete episodes of secondary deposition rather than gradual in situ weathering or collapse.

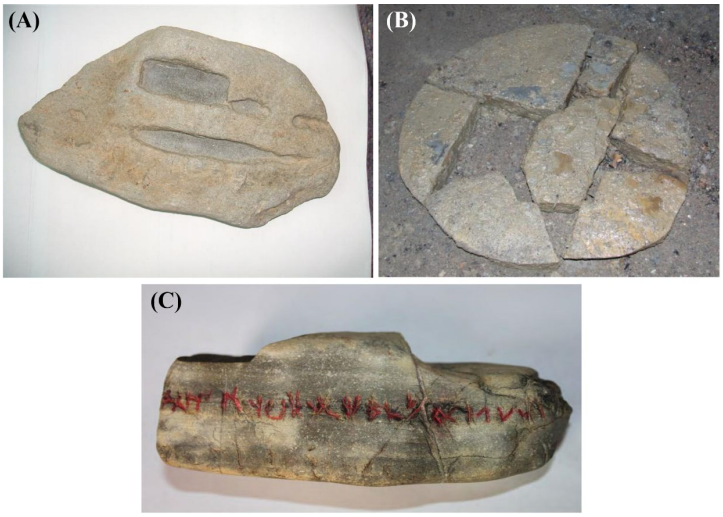
Natural sediment inputs, such as localized pebble fall or fine-grained weathering residues, occur only in limited volumes adjacent to tunnel walls and ceilings and do not form laterally extensive deposits. By contrast, anthropogenic infill frequently incorporates cultural material, including ceramic fragments, charcoal, and faunal remains, further distinguishing it from natural debris flow or collapse deposits. (**Figures 9-12**)

These sedimentological characteristics provide a consistent basis for identifying deliberate backfilling events associated with tunnel modification, closure, and reuse.

Such sharply defined sedimentological contrasts are widely used in geoarchaeology to distinguish secondary anthropogenic deposits from primary geological formations (Goldberg & Macphail, 2006).

## 5. Archaeological Material and Cultural Evidence

Archaeological excavation within the Ravne Underground Complex has produced a substantial and diverse body of material culture recovered from stratigraphically controlled contexts. Artefacts originate primarily from tunnel infill deposits, sealed side passages, and areas immediately adjacent to dry-stone wall structures (**Figures 8-12**). Their distribution and depositional settings provide direct evidence of repeated human interaction with the subsurface environment over an extended period.

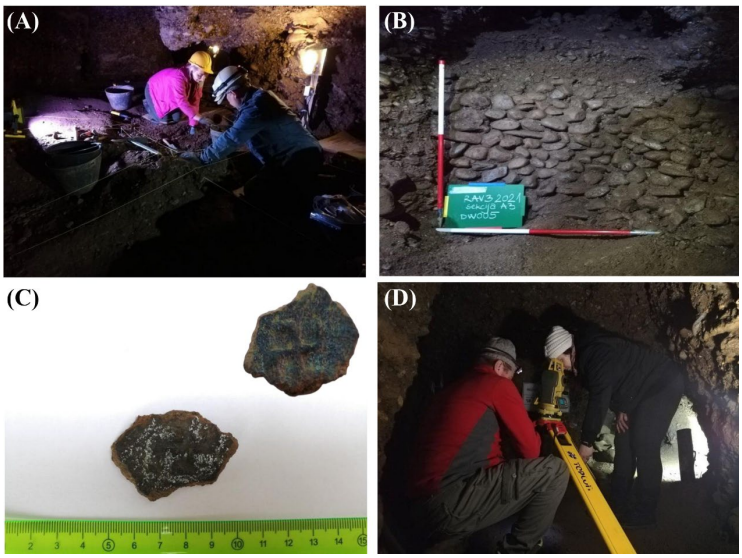



(A) Worked stone object with rectilinear recessed surfaces, recovered from the Ravne tunnels (2008). (B) Fragmented circular stone object composed of fitted segments, documented in the KTK tunnel (2007). (C) Elongated stone artifact bearing incised linear markings highlighted during documentation, recovered from the Ravne tunnel system (2014). All objects are presented as documented finds without functional attribution.

**Figure 9.** Selected lithic finds were documented during the early excavation phases of the Ravne underground complex.


Upper: In situ excavation context within the Ravne 3 tunnel showing the location where ceramic fragments C and D were recovered from tunnel fill approximately 22 m from the main passage, adjacent to speleothem formations. Lower left: Ceramic fragment **C**, a rim sherd exhibiting linear ornamentation, representing the only decorated element identified within this assemblage. Lower center: Ceramic fragment D, a base sherd indicating vessel morphology and manufacturing technique. Lower right: Representative selection of ceramic fragments forming part of the more than 3300 ceramic pieces recovered from the Ravne 3 tunnel system during systematic archaeological investigations.

**Figure 10.** Ceramic artefacts from the Ravne 3 tunnel system (2019-2024).




(A) Archaeological excavation and stratigraphic documentation in a side passage of the Ravne 3 tunnel during the 2021 field season. (B) Longest documented dry-stone wall in the Ravne 3 tunnel, composed of stacked river pebbles and embedded within compact tunnel fill; the ceramic fragment bearing an incised symbol was recovered from this context. (C) Ceramic fragment with incised motif recovered from Ravne 3 and dated to the early medieval period (8th century CE) based on typological assessment. (D) Geodetic surveying and spatial documentation of tunnel geometry using a Total Station (Topcon GTS-211D) during the 2021 survey campaign.

**Figure 11.** Recent archaeological documentation in the Ravne 3 tunnel.

Upper left: elongated wooden artefact interpreted as a wooden arrow (Find R62025-001), recovered from the main tunnel axis at the 32 m mark within stratigraphic unit SJ 001. Lower left: assemblage of animal bone fragments (Find R62025-005) discovered in secondary position within the fill of the newly opened parallel tunnel (R6-PT2). Right: upright wooden artefact interpreted as a totem-like object (Find R62025-003), found in situ at the 45 m mark of the main tunnel axis, adjacent to dry-stone wall S10 and the entrance to side tunnel BT19. All organic finds were documented in situ, sampled, and subjected to radiocarbon ($C^{14}$) analysis, indicating activity in the late medieval period (late 15th-early 16th century).

**Figure 12.** Selected archaeological finds from the Ravne 6 tunnel, 2025 research campaign.

### 5.1. Ceramic Assemblages

Ceramic material constitutes the most abundant artefact category recovered to date. Systematic excavations conducted between 2019 and 2024 yielded more than 3300 ceramic fragments, with the highest concentrations documented in the Ravne 3 tunnel (Figure 10, Figure 11). Additional ceramic material was recovered from Ravne, Ravne 6, and selected passages within Ravne 1.

Several ceramic fragments were recovered from sealed contexts behind dry-stone walls or from compact tunnel-fill layers, showing no evidence of modern disturbance. In Ravne 3, ceramic fragments were found partially embedded in fill deposits adjacent to calcified surfaces and speleothem formations, indicating deposition prior to secondary mineral formation.

A small number of diagnostically significant fragments, including a ceramic sherd bearing an incised swastika motif, are consistent with early medieval material culture documented elsewhere in South-East Europe (Figure 11).

Quantitative assessment of the ceramic assemblage indicates that approximately 5% of the recovered fragments are attributable to Neolithic handmade wares, 12% correspond to Roman-period ceramics, and the remaining approximately 83% derive from medieval production. The medieval assemblage includes both coarse utilitarian wares and finer fabrics, reflecting sustained interaction with the tunnel system during the historic period. Diagnostic rims, bases, and decorated fragments form a minority of the assemblage but provide reliable typological anchors for chronological attribution.

### 5.2. Lithic and Stone Artefacts

Lithic artefacts recovered from the Ravne tunnels include worked and modified stone objects whose precise functions remain uncertain. Early excavation phases documented shaped stone elements interpreted as working surfaces or molds, as well as circular stone objects composed of fitted segments recovered from the KTK tunnel (Figure 9).

Large stone blocks bearing incised markings were recovered from sealed tunnel sections during later excavation campaigns (Figure 9). Their stratigraphic position within closed contexts supports their association with human activity rather than natural geological processes.

### 5.3. Organic and Faunal Remains

Organic material recovered from the underground complex includes charcoal-rich sediment lenses and faunal remains embedded within tunnel fill (Figures 10-12). In Ravne 6, excavation during the 2025 campaign yielded fragmented animal bone assemblages and wooden artefacts recovered from sealed stratigraphic units (Figure 12).

Radiocarbon-dated organic material associated with tunnel infill and dry-stone wall contexts provides chronological constraints on phases of tunnel use and closure (Figure 13, Figure 14).

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Vilnius Radiocarbon
Performed by

# DATING CERTIFICATE

**No. 2025-10-09-FTMC-DT95**

28th October 2025

1. Applicant for analysis: Ms Ajla Šabanija Softić, Foundation "Archaeological park: Bosnian Pyramid of the Sun", Ravne bb, Visoko
2. Material of sample: Wood
3. Date of sample receiving: 2025-10-15
4. Analysis date: 2025-10-28
5. Equipment used for analysis: Single stage accelerator mass spectrometer (SSAMS, NEC, USA), Low-Energy Accelerator (LEA, Ionplus AG, Zürich), Automated Graphitization Equipment AGE-3 (Ionplus AG, Zürich).
6. Method of analysis: Samples were pretreated with an acid-base-acid-bleaching protocol. IAEA C3, IAEA C9, and NIST-OXII were used as reference materials.
7. Results of analysis:

| Sample designation | Lab. code | Radiocarbon age, BP | pMC |
|---|---|---|---|
| R6 - 1 | FTMC-DT95-1 | 415±29 | 94.97±0.34 |
| R6 - 2 | FTMC-DT95-2 | 433±28 | 94.76±0.33 |
| R6 - 3 | FTMC-DT95-3 | 402±29 | 95.13±0.34 |

*The results are given in years before 1950 (radiocarbon age BP). The uncertainty in the age determination is given +/- one standard deviation. All radiocarbon ages are corrected for isotopic fractionation using the measured 13/12C-ratio. The radiocarbon ages must be translated to calibrated radiocarbon years.*

Radiocarbon dating certificate issued by the Accelerator Mass Spectrometry Laboratory, Vilnius, documenting calibrated radiocarbon results for a sample collected from the Ravne tunnel context. The certificate provides an independent chronological reference for material associated with tunnel use and human activity.

**Figure 13.** Radiocarbon dating certificate (Vilnius Laboratory).

## 5.4. Spatial Distribution and Contextual Integrity

Artefacts are rarely encountered on exposed tunnel floors; instead, they are concentrated within sealed passages, behind dry-stone constructions, or embedded within compact fill layers (**Figures 9-12**). This spatial patterning supports the interpretation of deliberate deposition or abandonment episodes linked to tunnel modification.

## 5.5. Archaeological Implications

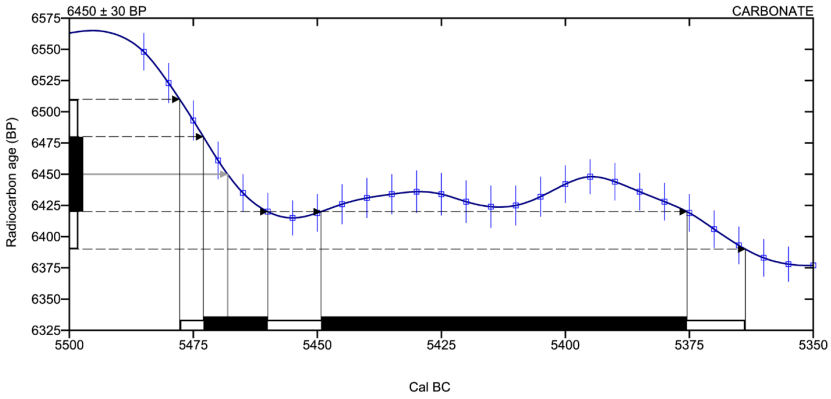
The archaeological material recovered from the Ravne Underground Complex documents sustained and recurrent human engagement with an artificially modified subterranean environment. The diversity of artefact types, their stratigraphic integrity, and their association with architectural features such as dry-stone walls indicate that the tunnels were not used episodically or opportunistically. Instead,

the evidence supports a pattern of planned use, modification, closure, and reopening spanning multiple cultural periods.

**CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS**

(Variables: C13/C12 = -10.5 o/oo : lab. mult = 1)

| | |
|---|---|
| **Laboratory number** | **Beta-388489** |
| **Conventional radiocarbon age** | **6450 ± 30 BP** |
| **2 Sigma calibrated result 95% probability** | **Cal BC 5480 to 5365 (Cal BP 7430 to 7315)** |
| Intercept of radiocarbon age with calibration curve | Cal BC 5470 (Cal BP 7420) |
| 1 Sigma calibrated results 68% probability | Cal BC 5475 to 5460 (Cal BP 7425 to 7410)<br>Cal BC 5450 to 5375 (Cal BP 7400 to 7325) |




**Database used**
INTCAL13

**References**
**Mathematics used for calibration scenario**
A Simplified Approach to Calibrating C14 Dates, Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322
**References to INTCAL13 database**
Reimer PJ et al. IntCal13 and Marine13 radiocarbon age calibration curves 0– 50,000 years cal BP. Radiocarbon 55(4):1869– 1887.

**Beta Analytic Radiocabon Dating Laboratory**
4985 S.W. 74th Court, Miami, Florida 33155 • Tel: (305)667-5167 • Fax: (305)663-0964 • Email: beta@radiocarbon.com
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Radiocarbon calibration report issued by the Beta Analytic Radiocarbon Dating Laboratory (Miami, Florida, USA) for a calcite crystal sample collected from the water section of the Ravne tunnel system. The calibrated age results indicate mid-6th millennium BCE calcite formation based on IntCal13 calibration.

**Figure 14.** Radiocarbon calibration of calcite crystal from the Ravne tunnel (Florida Laboratory).

Taken together, the artefactual evidence distinguishes the Ravne tunnels from natural caves sporadically occupied for shelter (Bosak et al., 2015; Ford & Williams, 2007). The material record, by contrast, reflects an underground system

integrated into broader cultural, economic, and organizational practices of past communities in Bosnia and Herzegovina and the wider Southeastern European region (Bergswik & Dowd, 2018).

## 6. Chronological Framework and Dating Evidence

Establishing a chronological framework for the Ravne underground complex relies on the integration of stratigraphic relationships, artefact typology, radiocarbon dating of organic material, and relative dating derived from mineral deposition. No single method is sufficient on its own; rather, the temporal interpretation emerges from the convergence of multiple independent lines of evidence.

### 6.1. Stratigraphic Relationships and Relative Dating

Stratigraphic observations across the Ravne tunnel systems demonstrate repeated phases of excavation, use, intentional infilling, and later reopening. In several locations—most clearly documented in Ravne 3 and Ravne 6—compact anthropogenic backfill overlies earlier passage floors and architectural features, including dry-stone walls (**Figure 8**). These relationships indicate that wall construction and associated use phases predate at least one episode of deliberate infilling.

Carbonate crusts and localized calcification observed on tunnel walls and dry-stone structures provide additional relative chronological indicators. In multiple instances, mineral accretions overlie stone constructions rather than underlie them, implying a period of structural stability following construction and prior to later disturbance or reopening. Although such deposits cannot provide absolute ages on their own, they constrain the sequence of events within the underground system (**Figure 13**, **Figure 14**).

### 6.2. Ceramic Typology and Cultural Phasing

Ceramic assemblages recovered from stratigraphically controlled contexts constitute a primary source of chronological information. Typological assessment of more than 3300 ceramic fragments indicates a broad temporal range extending from the Neolithic through the late medieval period (**Figure 8**) (Osmanagich, Hoyle, & Agić, 2023). Early handmade wares with coarse fabrics and simple forms are consistent with prehistoric traditions documented in the wider region, whereas later wheel-finished or more refined fragments correspond to historic and medieval production.

Particularly diagnostic finds include a ceramic sherd bearing an incised swastika motif recovered from Ravne 3 (**Figure 11**). The stratigraphic position of this fragment, recovered from sealed tunnel fill adjacent to a dry-stone wall, supports its association with a defined phase of tunnel use rather than later intrusion.

Comparative typology associates this motif with early medieval Slavic material culture, where incised swastika-like symbols are documented on ceramics from sites in the central Balkans and the Pannonian Basin dating to the 6th-9th centuries CE (e.g., Pleterski, 2013; Curta, 2001).

### 6.3. Radiocarbon Dating of Organic Material

Absolute dating of materials from the Ravne underground complex was conducted using radiocarbon ($C^{14}$) analysis of both organic remains associated with tunnel use and secondary mineral deposits related to post-excavation hydrological processes. Two independent laboratories were employed in order to address different chronological questions (**Figure 13**, **Figure 14**).

Organic material from sealed tunnel contexts was analyzed at the Accelerator Mass Spectrometry Laboratory, Center for Physical Sciences and Technology (FTMC), Vilnius, Lithuania (**Figure 13**). Three wood samples recovered from sealed anthropogenic infill deposits in the Ravne 6 tunnel were pretreated using an acid–base–acid protocol and dated using AMS techniques. The samples yielded the following conventional radiocarbon ages: FTMC-DT95-1: 415 ± 29 BP; FTMC-DT95-2: 433 ± 28 BP; FTMC-DT95-3: 402 ± 29 BP. Calibration using the IntCal curve at the 95.4% confidence level (2σ) places these samples within the late fifteenth to early seventeenth centuries CE. These dates provide terminus ante quem constraints for the associated infill deposits and confirm a phase of tunnel use and closure during the late medieval period.

In addition, a calcite crystal sample was collected from an open, water-affected section of the Ravne tunnel system and submitted to the Beta Analytic Radiocarbon Dating Laboratory (Miami, Florida, USA) for conventional radiocarbon analysis (**Figure 14**). The sample originated from secondary calcite deposits precipitated from percolating surface water and forming stalactitic structures on the tunnel ceiling. Laboratory pretreatment confirmed the mineral nature of the sample and excluded organic contamination. Radiocarbon measurement was performed using liquid scintillation counting with isotopic fractionation correction based on $\delta^{13}C$ values, and calibration was conducted using the IntCal13 calibration curve.

The calcite sample (Laboratory ID: Beta-388849) yielded a conventional radiocarbon age of 6450 ± 30 BP, with a calibrated age range (95.4% probability) of 5480 - 5365 cal BC (7430 - 7315 cal BP). Because calcite precipitation requires an exposed cavity surface and active water percolation, this result provides a minimum age for the existence of an open underground void at the sampled location. Consequently, the tunnel segment from which the sample was collected must have been formed and accessible prior to the onset of calcite crystal growth during the mid-6th millennium BCE.

Together, the radiocarbon results indicate that the Ravne underground complex preserves evidence for multiple chronological phases, including prehistoric cavity exposure documented by calcite formation and later medieval use and modification reflected in dated organic materials. These datasets address different formation processes and are therefore complementary rather than contradictory.

### 6.4. Integration of Chronological Evidence

When considered together, stratigraphy, ceramic typology, and radiocarbon dating indicate that the Ravne underground complex was not created or used during

a single chronological episode. Instead, the evidence supports a model of recurrent human activity, involving excavation or modification of passages, periods of use, deliberate closure through backfilling and wall construction, and subsequent reopening.

The presence of artefacts spanning multiple periods within sealed underground contexts distinguishes Ravne from natural caves intermittently visited over time. Rather than random accumulation, the chronological pattern reflects structured and repeated engagement with the subterranean environment. This interpretation is further supported by the spatial organization of dated contexts and their association with architectural features such as dry-stone walls and sealed junctions (**Figure 8**).

It is important to emphasize that the various dating methods applied at Ravne address different formation processes and should not be interpreted as providing a single construction date. Radiocarbon dates obtained from organic material within tunnel infill deposits reflect periods of use, modification, or closure rather than initial excavation events. Conversely, radiocarbon dating of secondary calcite deposits provides minimum ages for the existence of open cavities but does not date human intervention directly. When interpreted within their proper methodological limits, these datasets are complementary and support a multi-phase model involving early cavity exposure, followed by repeated human modification and reuse during later prehistoric and historic periods.

### 6.5. Chronological Implications

The chronological framework established here places the Ravne underground complex within a long-term sequence of human activity in Bosnia and Herzegovina and the wider South-East European region. The evidence demonstrates that artificially modified underground spaces were accessed and managed across different cultural periods, challenging the assumption that such environments played only a marginal role in regional archaeological landscapes.

While additional dating—particularly of speleothem growth and deeper stratigraphic units—will further refine this framework, the current dataset provides a robust temporal foundation for interpreting the Ravne tunnels as a multi-period, intentionally modified subterranean system.

## 7. Discussion

### 7.1. Nature of the Ravne Underground Complex

The combined geological, architectural, stratigraphic, and artefactual evidence supports the interpretation of the Ravne underground complex as an artificially modified subterranean system shaped through repeated phases of human activity rather than as a natural cave network opportunistically used over time. The consistency of passage geometry, the presence of deliberately constructed dry-stone walls, and the patterned distribution of backfill deposits distinguish the Ravne tunnels from natural cavities or karstic systems (**Figure 2**, **Figures 6-8**).

Geological context plays a decisive role in this interpretation. Excavation within mechanically favorable conglomerate deposits permitted controlled shaping of passages without reliance on natural dissolution processes. The absence of diagnostic karst morphologies, combined with uniform tunnel profiles, argues against natural speleogenesis as the primary formation mechanism. Instead, the tunnels reflect intentional excavation and modification adapted to local geological conditions.

### 7.2. Architectural Organization and Underground Planning

Architectural features documented throughout the complex demonstrate a level of organization incompatible with ad hoc or episodic underground use. Dry-stone walls recur across multiple tunnel systems (Ravne, Ravne 3, Ravne 4, Ravne 6) and follow consistent construction principles (**Figure 8**). Their placement—frequently sealing side passages or reinforcing corridor walls—indicates deliberate control of underground space rather than collapse mitigation or random obstruction (Osmanagich, 2025d).

Stratigraphic relationships further support this interpretation. In numerous locations, dry-stone walls are directly associated with heterogeneous anthropogenic fill deposits, indicating intentional closure of passages (**Figures 6-8**). Subsequent reopening episodes are suggested by later disturbance of sealed areas and renewed passage clearance. This pattern reflects a managed underground environment subject to repeated modification rather than a static or abandoned space.

### 7.3. Material Culture and Underground Use

Artefact assemblages recovered from the Ravne underground complex provide insight into the nature and duration of underground use. The dominance of utilitarian ceramics, the scarcity of decorative elements, and the presence of functional lithic and organic artefacts suggest that activities within the tunnels were practical rather than symbolic (**Figures 9-12**). Ceramic typology and radiocarbon dating demonstrate that underground use occurred during multiple cultural periods, including prehistoric and medieval phases.

Importantly, artefacts are rarely recovered from open tunnel floors. Instead, they are concentrated within sealed contexts, embedded in fill layers, or associated with architectural features (**Figures 9-12**). This spatial pattern implies intentional deposition or abandonment during phases of closure rather than casual loss during transit. Such behavior is consistent with structured underground activity involving planned modification and controlled access.

### 7.4. Chronological Patterning and Recurrent Use

The chronological framework established through stratigraphy, ceramic typology, and radiocarbon dating indicates that the Ravne underground complex was neither constructed nor used during a single discrete period. Rather, evidence indicates recurrent use, involving multiple episodes of excavation, occupation, clo-

sure, and reopening over an extended temporal span (Section 6).

This pattern distinguishes Ravne from natural caves, which accumulate material gradually through intermittent visitation. Instead, the chronological and spatial organization of the Ravne tunnels reflects sustained engagement with the underground environment, suggesting that subterranean space formed an integrated component of broader cultural practices over time.

### 7.5. Regional Context and Archaeological Significance

Within the broader archaeological context of South-East Europe, the Ravne underground complex represents an unusual but well-documented example of extensive artificially modified subterranean architecture. While underground features such as mines, storage pits, and ritual caves are known elsewhere in the region (Bognar et al., 2011; Jiménez-Moreno et al., 2009; Bugarski & Radišić, 2016), few sites exhibit the combination of scale, architectural intervention, stratigraphic integrity, and multi-period material culture documented at Ravne.

The Ravne complex, therefore, contributes to a growing body of evidence that underground spaces played a more significant role in past human societies than traditionally acknowledged. Its systematic investigation provides a valuable case study for understanding how subterranean environments were excavated, organized, and reused across different cultural and chronological contexts.

### 7.6. Methodological Implications

From a methodological perspective, the Ravne project demonstrates the importance of treating underground contexts as primary archaeological sites rather than as marginal or purely geological phenomena. The integration of stratigraphic excavation, architectural documentation, geodetic surveying, and material analysis has proven essential for disentangling complex formation processes within confined subterranean environments.

The long-term, legally regulated research framework applied at Ravne offers a replicable model for future investigations of underground systems in comparable geological settings. Continued excavation, refined dating, and specialist analyses will further clarify the function and chronology of the Ravne tunnels, but the existing dataset already establishes their significance within regional archaeology.

### 7.7. Limitations and Alternative Explanations

The interpretations presented in this study are constrained by several methodological and contextual limitations inherent to long-term underground excavation. Although stratigraphic excavation, controlled documentation, and multidisciplinary analyses have been systematically applied, access to the Ravne underground complex remains partial, and large portions of the tunnel network have not yet been excavated or exposed. Consequently, interpretations are based on currently accessible sections and may be refined as additional areas are investigated.

Distinguishing anthropogenic modification from complex natural geological

processes is further complicated in conglomeratic formations. While geological assessment indicates that many observed features are inconsistent with known karstic or sedimentary processes, alternative explanations—such as the modification of pre-existing natural voids, episodic enlargement of fissures, or reuse of naturally formed cavities—cannot be entirely excluded on the basis of current evidence alone. Similarly, the presence of artefacts within underground contexts does not, by itself, determine the original purpose or initial formation of the passages, as materials may have been introduced during later phases of reuse, modification, or closure.

Chronological interpretation is also limited by the indirect nature of available dating evidence. Radiocarbon dates derive from organic material associated with use or infill deposits rather than from construction events themselves, providing terminus ante quem constraints rather than absolute construction dates. As such, the timing and sequence of excavation, modification, and reuse phases should be regarded as provisional.

Future research incorporating expanded excavation, additional absolute dating (including speleothem analysis), micromorphological study, and independent comparative assessment will be essential for further evaluating competing hypotheses regarding the formation and use of the Ravne underground complex.

Alternative explanations, including a mining function, must be considered. Documented medieval and early modern mining galleries within the Central Bosnian Metallogenic Belt are typically characterized by narrow, irregular passages following ore veins, frequent evidence of fire-setting, hammer-and-chisel tool marks, and waste rock accumulations directly adjacent to extraction faces. By contrast, the Ravne tunnels exhibit consistent passage geometry, absence of ore extraction fronts, lack of diagnostic mining tool marks, and no associated slag or beneficiation debris. Furthermore, passage orientation does not correlate with known metallogenic structures. While limited reuse of underground spaces for storage or transit cannot be ruled out, the morphological and contextual differences argue against interpreting the Ravne complex as a mining system sensu stricto.

### 7.8. Consideration of Natural Formation Hypotheses

Any interpretation of the Ravne underground complex must consider the possibility that natural geological processes contributed to the initial formation of subsurface voids. In conglomeratic environments, such processes may include the enlargement of pre-existing fissures, localized sediment washout, or limited mechanical erosion along zones of structural weakness.

However, several lines of evidence argue against natural speleogenesis as a sufficient explanation for the Ravne tunnels in their observed form. First, the conglomerate host matrix is highly cemented and does not exhibit dissolution features typical of karst systems. Second, passage geometry remains remarkably consistent across multiple tunnel systems, with flattened floors, arched ceilings, and con-

trolled junctions that contrast with irregular natural cavities. Third, sedimentological analysis demonstrates sharp stratigraphic boundaries between consolidated geological strata and heterogeneous, artefact-bearing backfill deposits, indicating deliberate secondary infilling rather than gradual natural accumulation.

While it remains possible that limited natural voids or fractures predated human activity, the cumulative geological, architectural, and stratigraphic evidence indicates that the Ravne underground complex was substantially modified—if not excavated—through intentional human intervention. Natural processes alone cannot account for the scale, organization, and repeated architectural features documented across the system.

### 7.9. Scope and Interpretive Limits of the Present Study

This study is intentionally limited to the empirical archaeological investigation of the Ravne underground complex as an artificially modified subterranean system. It does not address hypotheses concerning pyramidal structures, surface monumental architecture, or broader landscape interpretations sometimes associated with the Visoko Valley. The analyses presented here are based exclusively on stratigraphic excavation, geological assessment, artefact study, and spatial documentation of underground features.

By maintaining a strict focus on observable data and methodologically verifiable evidence, this paper seeks to contribute to subterranean archaeology independently of speculative or interpretive models not directly supported by the underground archaeological record.

## 8. Conclusion

The systematic archaeological investigation of the Ravne underground complex demonstrates that it represents an artificially modified subterranean system shaped through repeated phases of human activity rather than a naturally formed cave network or an incidental underground feature. Geological, architectural, stratigraphic, and artefactual evidence converge to support this interpretation.

Excavation and documentation across multiple tunnel systems—Ravne, KTK, Ravne 2, Ravne 3, Ravne 4, Ravne 5, and Ravne 6—have revealed consistent passage geometry, deliberate corridor shaping, and the recurrent presence of dry-stone wall structures. These architectural elements, combined with patterned backfill deposits and sealed passages, indicate planned modification and management of underground space rather than ad hoc or opportunistic use.

The archaeological material recovered from stratigraphically controlled contexts provides direct evidence of sustained human engagement with the underground environment. Ceramic assemblages spanning a broad chronological range, lithic and stone artefacts, and organic remains suitable for radiocarbon dating document repeated use and reconfiguration of the tunnels over extended periods. The spatial distribution of artefacts—concentrated within sealed or deliberately infilled contexts—further supports interpretations of intentional deposition linked

to tunnel modification and closure phases.

Chronological evidence derived from stratigraphy, ceramic typology, and radiocarbon dating indicates that the Ravne underground complex was neither created nor utilized during a single cultural episode. Instead, it reflects recurrent use across multiple periods, including prehistoric and medieval phases. This long-term pattern distinguishes Ravne from natural caves that are intermittently visited and underscores its role as a managed subterranean environment integrated into broader cultural practices.

From a regional perspective, the Ravne underground complex is among the most extensively documented artificially modified underground systems in Bosnia and Herzegovina and Southeastern Europe. Its scale, architectural coherence, and stratigraphic integrity provide valuable data for ongoing discussions on the role of subterranean spaces in past societies.

Methodologically, the Ravne project underscores the importance of treating underground contexts as primary archaeological sites that require systematic excavation, rigorous documentation, and interdisciplinary analysis. Continued research, including expanded dating programs and specialist studies, will further refine interpretations of the complex. Nevertheless, the existing evidence establishes Ravne as a significant archaeological site whose investigation enhances understanding of long-term human interaction with subterranean environments.

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## Author Contributions

The author is solely responsible for the conception of the study, field research coordination, data interpretation, and manuscript preparation.

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## Ethical Approval

All archaeological investigations were conducted under permits issued by the competent cantonal and federal heritage authorities of Bosnia and Herzegovina and in cooperation with designated local museum institutions.

## AI Usage Statement

Artificial intelligence tools were used exclusively for linguistic refinement and organizational assistance during manuscript preparation. All research design, data interpretation, and scholarly conclusions are the responsibility of the author.

## Conflicts of Interest

The author declares no conflict of interest.

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