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A New Class of Subterranean Dry-Stone Structures: River-Pebble Walls in the Ravne Tunnel Complex, Bosnia-Herzegovina

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Abstract

Dry-stone construction is a globally recognized architectural technique dating back to the Neolithic period and earlier. While surface-level dry-stone features have been extensively studied throughout the Mediterranean and Central Europe, subterranean dry-stone structures built entirely from river pebbles are exceptionally rare and largely undocumented. Over the past two decades, systematic excavation and multidisciplinary analysis in the Visoko Valley of Bosnia-Herzegovina have revealed an extensive network of underground tunnels known as the Ravne Tunnel Complex. Within this labyrinthine system-comprising Ravne, Ravne 3, Ravne 4 and Ravne 6-more than sixty dry-stone walls have been documented as of 2025. These structures were constructed without mortar, often to seal side passages or stabilize cavities and in some cases stretch several meters in length and height.

This article presents the first formal typological, geological and archaeological study of these walls. It integrates stratigraphic observations, radiometric dating (including both U-Th and radiocarbon methods) and detailed mapping. Our findings establish that the Ravne dry-stone walls represent a previously undocumented class of subterranean construction, bearing no parallel in currently published Balkan or global contexts. Radiocarbon dating of charred material found near one of the longest walls indicates human activity in the 4th century CE, confirming a phase of historical reuse. The data presented here offer robust evidence that the Ravne Tunnel Complex features deliberate, anthropogenic subterranean architecture, with significant implications for the understanding of pre-industrial construction practices and regional underground heritage.

Keywords: Dry-stone walls; Subterranean architecture; Ravne tunnels; Visoko; Bosnia-Herzegovina; River pebbles; Radiocarbon dating

Introduction

Dry-stone construction techniques defined by the layering of unbonded stones without the use of mortar represent one of the most enduring and globally widespread forms of architectural practice. From the cyclopean enclosures of Mycenaean Greece to the agricultural terraces of the Western Mediterranean and the precisely interlocked masonry of the Inca highlands, dry-stone structures have fulfilled functional, territorial and symbolic roles across diverse chronological and cultural contexts [1].

These features are typically located above ground, constructed from quarried or angular stones and well documented in both prehistoric and historical periods. In contrast, subterranean dry-stone walls constructed entirely from rounded river pebbles are exceedingly rare and, to date, almost absent from the published archaeological literature [2,3]. No established typology accounts for underground walls built from unworked fluvial cobbles and used primarily to seal or reinforce deep passageways.

Since 2006, a long-term archaeological and geological research initiative has been ongoing in the Visoko Valley of central Bosnia-Herzegovina. Led by the Archaeological Park: BPS Foundation, this initiative has systematically documented a vast network of underground passageways collectively referred to as the Ravne Tunnel Complex, comprising Ravne, Ravne 2, Ravne 3, Ravne 4, Ravne 5 and Ravne 6 [4]. Although dry-stone walls have not been observed in Ravne 2 or Ravne 5, the overall configuration and geospatial alignment of these tunnels suggest a degree of planning, reuse or continuous modification across the wider system **(Figure 1)**.

Figure 1: Geographical context of the study area. The main map displays Bosnia-Herzegovina within the central Balkan Peninsula, highlighting its position relative to neighboring Mediterranean and Southeastern European countries (Source: GISGeography.com). The satellite image inset locates the town of Visoko in central Bosnia, situated within the Dinaric Alps and the Federation of Bosnia and Herzegovina (Source: Google Earth, Landsat/Copernicus; Image date: 13 December 2015). The Visoko Valley hosts the Ravne Tunnel Complex, the primary focus of this study.

Among the most notable archaeological findings in the tunnel networks are over sixty dry-stone walls, discovered to date in Ravne, Ravne 3, Ravne 4 and Ravne 6. These walls are constructed without mortar, using local unsorted river pebbles generally between 10 and 40 cm in diameter and are frequently positioned at the ends of narrow side tunnels or in front of open cavities [5]. Some walls exceed 3 meters in length and over 1 meter in height, composed of up to twelve horizontal courses.

While dry-stone walling traditions are widespread across the Balkan Peninsula, particularly in prehistoric boundary structures, settlement enclosures and medieval hillfort fortifications, the subterranean context of the Ravne examples, along with their construction from undressed river pebbles, sets them apart as a unique architectural phenomenon [6]. No close parallels have been found to date within the regional archaeological literature, nor have comparative subterranean dry-stone structures been systematically recorded elsewhere in Europe.

This article presents the first scholarly synthesis of this phenomenon, focusing on the physical properties, typological features, stratigraphic settings and temporal markers associated with the Ravne tunnel dry-stone walls. Drawing upon geological surveys, LiDAR and GPR data, archaeological excavation reports and radiometric dating including both radiocarbon and Uranium-Thorium analyses we aim to establish these subterranean dry-stone structures as a legitimate and previously undocumented class of anthropogenic architecture within the central Balkan archaeological landscape.

Materials and Methods

The present study focuses on the Visoko Valley, a fluvially incised basin situated in central Bosnia-Herzegovina, approximately 30 km northwest of Sarajevo. Geographically located within the inner Dinaric Alps, the valley is characterized by river terraces, conical elevations and sedimentary layering that facilitated natural voids and the formation of semi-coherent alluvial structures [7]. Since 2006, systematic archaeological, geological and geodetic research has been conducted in the area under the direction of the Archaeological Park: BPS Foundation, leading to the discovery and progressive documentation of an extensive subterranean complex known as the Ravne Tunnel Complex [4].

The complex includes six named tunnel systems-Ravne, Ravne 2, Ravne 3, Ravne 4, Ravne 5 and Ravne 6. While dry-stone structures have only been documented in Ravne, Ravne 3, Ravne 4 and Ravne 6, the inclusion of Ravne 2 and Ravne 5 is warranted due to their structural alignment and relevance to broader spatial analysis.

Documentation of dry-stone walls

From 2010 to 2025, over sixty dry-stone walls were discovered and recorded. These walls were systematically documented in situ during archaeological excavation campaigns led by field archaeologists and geologists of the Foundation. Each wall was assigned a unique field code and its location was measured, photographed and drawn to scale using a combination of manual techniques and digital field tablets for GIS integration.

Morphological data-length, height, course number and construction pattern-were recorded using manual measuring tools, laser distance meters (FERM) and Suunto MC-2 compasses. River cobbles used in construction were visually categorized by lithology (*e.g.,* quartzite, sandstone and metamorphic types), with dimensions ranging from 10 to 40 cm in diameter [7]. No surface working or intentional shaping was detected, suggesting a raw material selection based on fit and stability rather than formal modification.

Wall types were further classified based on position and inferred function: (1) corridor-blocking walls; (2) chamber-sealing walls; (3) structural reinforcement and (4) partial edge walls demarcating thresholds.

Geodetic and spatial mapping

Spatial documentation was undertaken by two licensed geodetic firms based in Visoko: Geoprom (Eng. Tarik Sokolović) and Survey Wizard (Eng. Tarik Harbaš). The mapping process employed Trimble 5700 GPS receivers, Topcon GTS-105N Total Stations, Nikon AK19 prisms and digital clinometers to ensure high-precision positioning. Field data were post-processed using AutoCAD and QGIS, creating orthorectified 2D tunnel maps and three-dimensional wall placement models [5].

Drawings and technical renderings were directed and prepared by Richard Hoyle, the Foundation's lead field geologist, whose scale-accurate plans and profile sections serve as the basis for figures included in this article.

LiDAR and GPR surveys

In 2015, the Foundation contracted Airborne Technologies GmbH (Austria) to conduct a full LiDAR survey of the Visoko Valley (Contract No. 04-23/2015). The resulting 3D terrain model allowed researchers to detect anomalous geomorphic features and to analyze altitudinal symmetry between opposing tunnel entrances. These data confirmed that the Ravne and Ravne 3 entrances lie at nearly identical elevation and on the same latitude, separated by approximately 200 meters across a northwest-trending valley [4] **(Figure 2 and Figure 3)**.

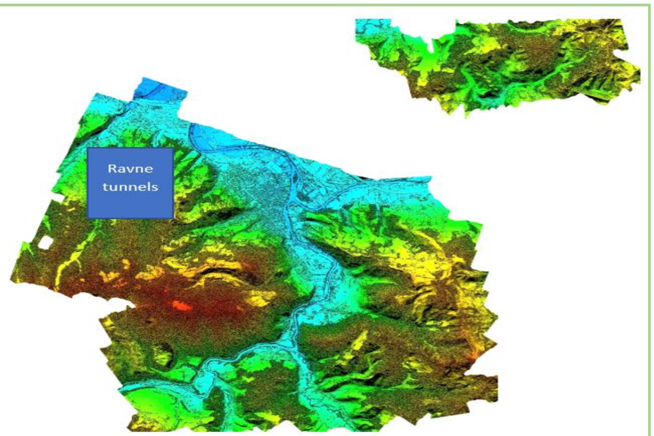

Figure 2: A LiDAR (Light Detection and Ranging) scan map of the Visoko Valley, Bosnia-Herzegovina. Ravne Tunnel Complex is located in the upper left quadrant of the map, outlined here with a blue square for orientation [8].

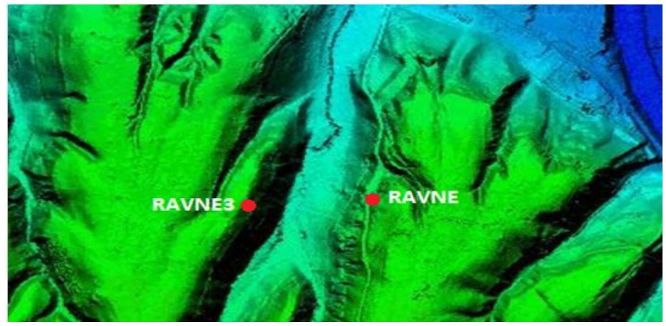

Figure 3: LiDAR terrain model showing the northwest-oriented valley with marked entrances to Ravne and Ravne 3 tunnels [4].

In July 2023, Ground Penetrating Radar (GPR) investigations were carried out by Czech geophysical firm RTGPR using a 50 MHz antenna. The GPR scans, performed along surface transects above the Ravne tunnel system, revealed subsurface cavities and stratified anomalies, interpreted as blocked or yet-to-be-excavated tunnel segments. Signal reflectance suggested the presence of compact material interfaces consistent with the location of some already-documented walls. Data interpretation, however, was limited by the presence of natural alluvial deposits and surface vegetation **(Figure 4 and Figure 5)**.

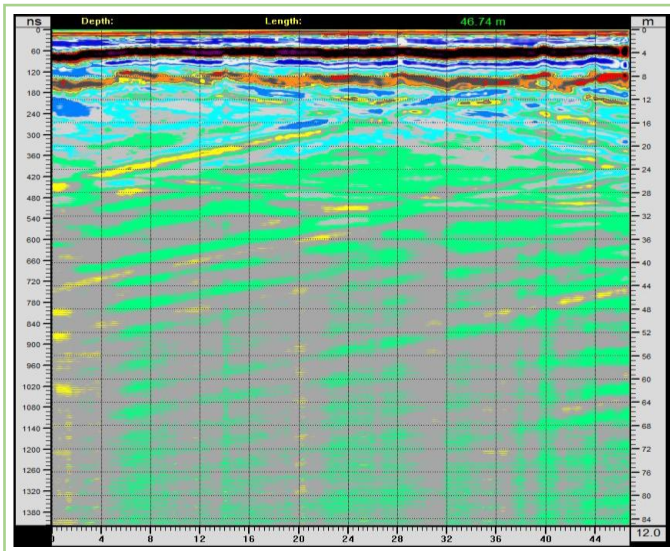

Figure 4: The radar profile spans approximately 46.74 meters in length with depth penetration reaching 12 meters. The upper 3 meters display dense and high-amplitude reflections consistent with conglomerate and compacted overburden. Below this, distinct hyperbolic anomalies and disrupted layers between 10-30 meters horizontally and 4-7 meters in depth indicate possible subterranean cavities, consistent with artificial tunnel voids or wall-closed chambers within the Ravne Complex [9].

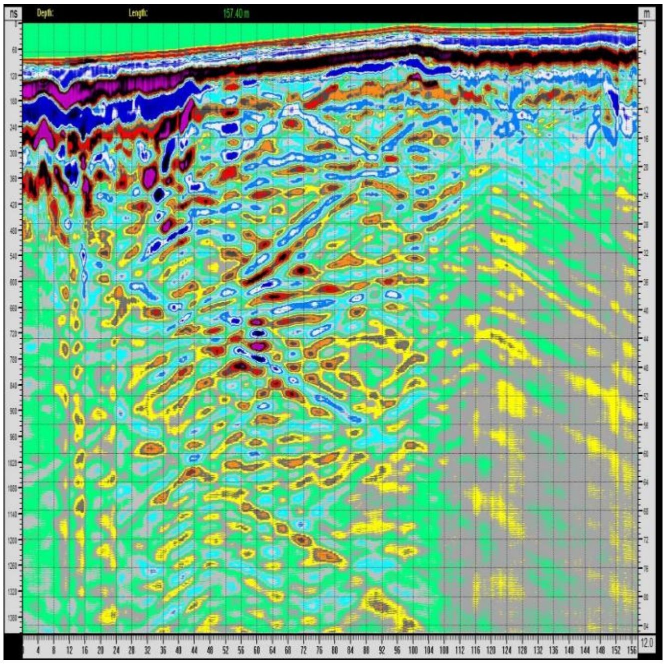

Figure 5: The radargram covers a longitudinal profile of 157.4 meters. It reveals multiple horizontal and sub-horizontal anomalies, including reflectors at approximately 4 to 10 meters depth, some of which suggest potential linear cavities or voids consistent with tunnel-like features. The uppermost layers display strong reflections indicative of shallow compaction and gravelly or conglomeratic strata. The central region of the scan shows intermittent diffractions and amplitude attenuation patterns suggestive of subsurface heterogeneity and possibly constructed voids. These results support the hypothesis of structured subterranean features along this transect [9].

Stratigraphy, radiometric dating and compliance

Fieldwork was conducted under official annual permits issued by the Ministry of Culture of Zenica-Doboj Canton, with collaborative oversight by the Visoko Heritage Museum and approval from the Federal Institute for the Protection of Cultural Heritage (Sarajevo). Stratigraphic profiles of tunnel sections containing dry-stone walls were drawn using conventional sectioning techniques and select walls were photographed prior to, during and after partial exposure.

Associated materials included ceramic sherds, iron tools, bronze ornaments and carbonized wood fragments [4]. Radiocarbon dating of charred organic material adjacent to one of the most extensive dry-stone walls-measuring 4.8 m in length-was performed by the TÜBİTAK Marmara Research Center (Gebze, Turkey). Results dated the feature to the 4th century CE, suggesting reuse or secondary occupation of the tunnel space during Late Antiquity [10].

Separately, Uranium-Thorium dating of speleothems taken from sealed segments of Ravne 3 was performed by the Institute of Geology (Czech Academy of Sciences) in partnership with the Polish Academy of Sciences, yielding calibrated ages of up to 5,900 years BP for stalagmite basal layers [4].

All field records, images, geodetic files and radiometric reports are held in the internal archive of the Archaeological Park: BPS Foundation and are available for verification and future research collaboration.

Geological and Geodetic Context

The Visoko Valley lies within the tectonically active Inner Dinarides, a fold-and-thrust belt characterized by complex Neogene sedimentation and Quaternary fluvial processes. The Ravne Tunnel Complex is situated in a fluvially incised sub-basin flanked by Holocene terraces and composed of two major geological units: a younger conglomerate layer, informally referred to as the "Ravne Conglomerate Formation," and an underlying sequence of Miocene marl and interbedded sandstone [11].

Stratigraphy and subsurface context

Geological cross-sections across the Ravne Valley demonstrate a clear angular unconformity between the horizontally bedded Ravne Conglomerate and the northwest-dipping Miocene sediments [7]. The conglomerate is composed of unsorted, rounded quartzite, limestone and metamorphic cobbles within a fine-grained, clay-rich matrix. In contrast, the underlying marl shows uniform bedding, increased compaction and occasional inclusions of fine sandstone and calcareous nodules **(Figure 6)**.

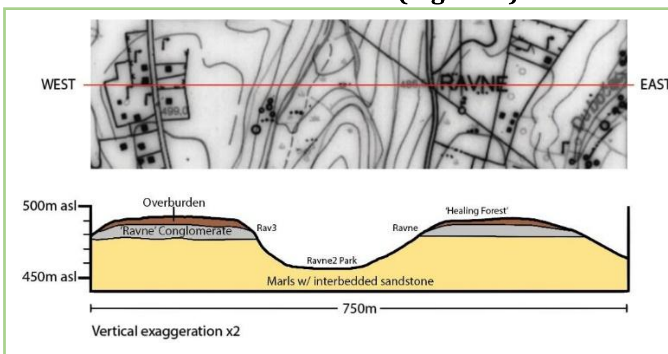

Figure 6: Geological cross-section of the Ravne Valley showing relative positions of Ravne and Ravne 3 tunnel entrances and underlying formations. This east-west geological cross-section illustrates the stratigraphic relationship between the Ravne Conglomerate Formation and the older Miocene marl-sandstone sequence [4].

In the Ravne and Ravne 3 tunnels, dry-stone walls are frequently situated along transitional zones between these formations-either resting directly on marl floors or embedded in conglomerate walls. Their consistent placement suggests deliberate exploitation of pre-existing voids or erosional pockets, potentially guided by differences in sediment cohesion and permeability [4,5].

No indications of collapse, slumping or tectonic displacement have been observed in the vicinity of the walls, reinforcing the interpretation that tunnel voids were artificially created and that the walls were constructed to block, reinforce or delimit passageways. The infilling material located behind most walls closely resembles the local conglomerate in composition but lacks bedding or compaction, supporting the hypothesis of anthropogenic backfilling [4].

Topographic relationships and elevation models

One of the most significant geodetic findings is the near-identical elevation and latitude of the Ravne and Ravne 3 tunnel entrances, both situated around 435 meters above sea level. The entrances are approximately 200 meters apart, located on opposite flanks of a narrow northwest-oriented valley [4,5]. This alignment was confirmed through high-precision Total Station measurements, LiDAR-based digital terrain models and Trimble GPS surveys carried out between 2015 and 2023 **(Figure 7)**.

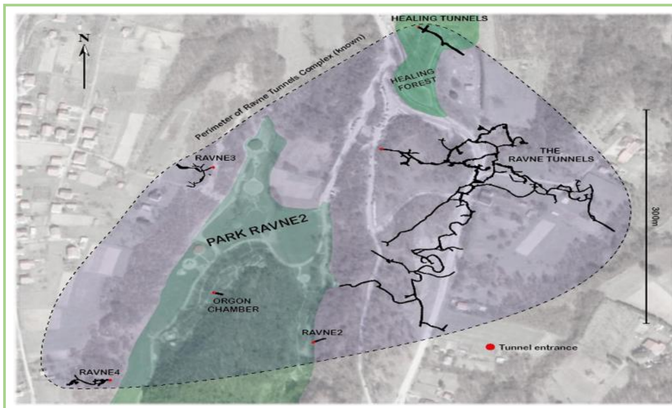

Figure 7: Mapped extent of the Ravne Tunnel Complex in Visoko, Bosnia-Herzegovina, showing interconnected sections explored and maintained between 2005 and 2025. This map displays five currently accessible tunnel systems: Ravne (the main network, with 2.6 km cleared), Ravne 2, Ravne 3, Ravne 4 and Ravne 5 (also referred to as the “Healing Tunnels”). Tunnel entrances are marked with red dots. The dashed line indicates the approximate known perimeter of the entire complex, based on geodetic and geological analyses.

A topographic map produced from LiDAR data by Airborne Technologies GmbH (Austria) under Contract No. 04-23/2015 shows consistent slope gradients across the valley, with no major topographic barriers between Ravne and Ravne 3 [11]. This observation supports the hypothesis that the tunnels may have once been part of an interconnected subterranean system-either physically linked in the past or spatially planned as part of a larger underground architectural framework.

Role of geodesy in feature interpretation

Geodetic documentation of the dry-stone walls was carried out by Geoprom (Eng. Tarik Sokolović) and Survey Wizard (Eng. Tarik Harbaš), both based in Visoko. Measurements were performed using Topcon GTS-105N Total Stations, Trimble 5700 GPS receivers and Nikon AK19 retroreflector prisms. All datasets were post-processed in AutoCAD and QGIS, producing vectorized 2D and 3D models of the Ravne tunnel passages and feature locations [5] **(Figure 8)**.

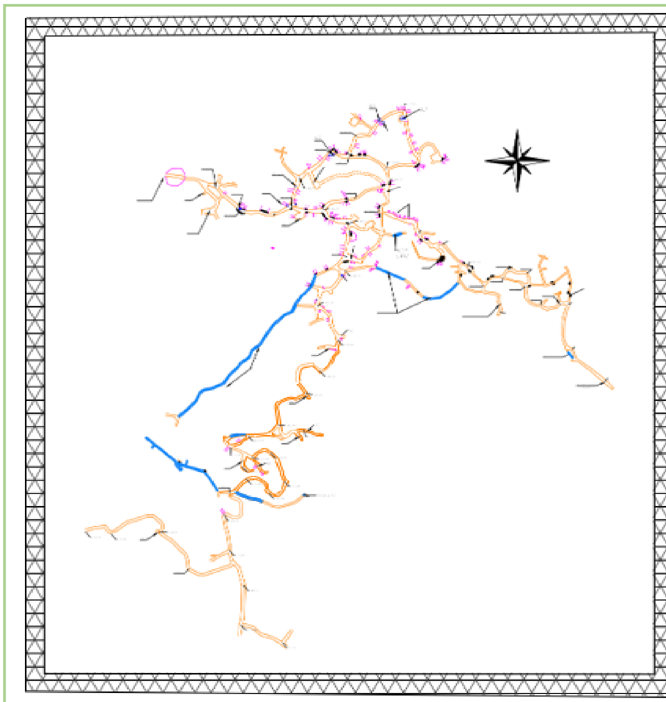

Figure 8: Detailed topographic map of the Ravne Tunnel Network (as of 2024), showing cleared passageways, chambers and blocked segments. This plan view illustrates the primary passage network (orange), side branches, water channels (blue)and obstructed zones. Key chambers and intersections are labeled, while restored areas and archaeological checkpoints are marked in magenta. The total length of surveyed and cleared tunnels exceeds 2.6 km, extending in a southeast-northwest orientation beneath the Ravne Valley [4].

The walls themselves demonstrate notable horizontal consistency, often following the tunnel axis and appearing at fixed intervals relative to entrance points and major chamber intersections. This regularity suggests more than ad hoc construction; rather, it points to an integrated design logic underlying the placement of architectural interventions within the tunnel system.

Furthermore, the elevation profiles of the tunnels show that most walls occur within a vertical b and of 2.5 meters, typically placed at floor level or slightly recessed into the conglomerate walls. This finding reinforces the interpretation that the tunnels were purposefully engineered spaces, with the dry-stone walls serving to compartmentalize, stabilize or conceal certain passage sections [3,6] **(Figure 9 and Figure 10)**.

Figure 9: Tunnel intersection within the Ravne Tunnel Complex, view from main corridor toward side passages (2025). This image shows a characteristic branching point inside the Ravne tunnels, highlighting the construction geometry of intersecting passages with rounded arch-like profiles. The tunnel walls and ceiling are composed of compacted river pebble conglomerate, which remains structurally intact without artificial reinforcement. Lighting elements visible in the background mark the preserved route for visitors [12].

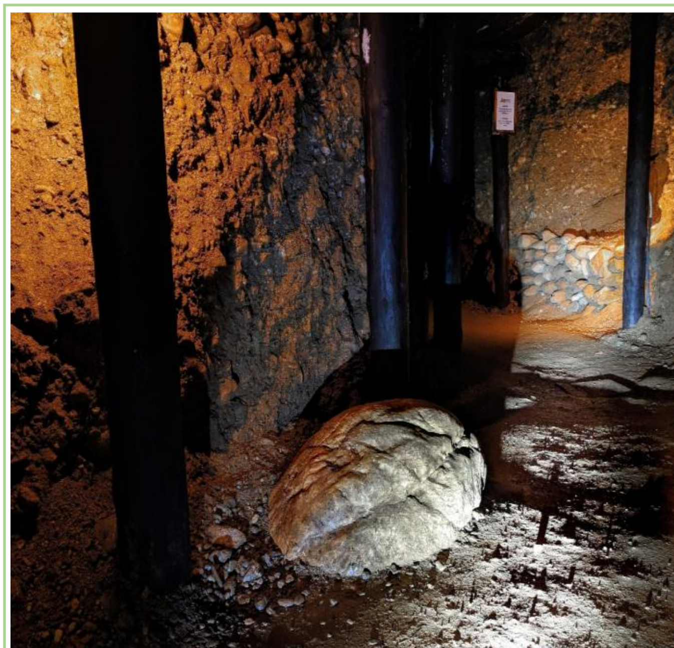

Figure 10: Tunnel segment 35 meters from the entrance to the Ravne Tunnel Complex, showing modern wooden supports and first visible dry-stone wall. This photograph captures an early section of the main Ravne tunnel where vertical wooden supports were installed by the Foundation for visitor safety. In the background, a dry-stone wall constructed from rounded river pebbles can be seen, closing off a side passage-part of a recurring architectural pattern throughout the complex. A large stone monolith is visible in the foreground, situated within the original tunnel profile [4].

Typology and Architectural Characteristics of the Dry-Stone Walls

Over sixty dry-stone walls have been documented within the Ravne Tunnel Complex, including tunnels Ravne, Ravne 3, Ravne 4 and Ravne 6, making this one of the most extensive occurrences of subterranean dry-stone construction in the central Balkans. The walls vary in length, height, construction method and contextual function, but all share key architectural features that distinguish them from above-ground examples found in traditional dry-stone typologies [1,3].

Construction materials and technique

All walls are built from rounded river pebbles and cobbles, collected from local Quaternary alluvial deposits. These include quartzite, sandstone and metamorphic stones, typically ranging in size from 10 to 40 cm in diameter [7]. No signs of chiseling, squaring or shaping were observed;

instead, wall builders selected stones based on natural geometry and interlocking potential **(Figure 11)**.

Figure 11: Dry-stone wall in the Ravne Tunnel Complex, one of over sixty discovered so far. This photo documents a typical example of the dry-stone walling technique found throughout the Ravne tunnel system. Rounded river pebbles were carefully stacked without mortar to block side passages, behind which unconsolidated fill material is typically encountered.

Walls were assembled without mortar or binding agent, using a technique involving the careful placement of stones in alternating horizontal courses, with minor infill stones stabilizing voids. Larger stones often form the base, while mid-sized cobbles dominate upper sections. The highest documented wall reaches 1.25 m in height and 3.00 m in width, constructed in 12 courses and incorporates two flat slabs and cobble corner supports [4,5].

In Ravne 3, walls are often recessed into the conglomerate or anchored at the boundary between conglomerate ceilings and marl floors. Many are built to seal passages, stabilize cavities or brace chamber walls. Their overall construction quality is consistent and robust, especially in cases where multiple rows of interlocked cobbles and larger anchoring stones are observed **(Figure 12-figure 14)**.

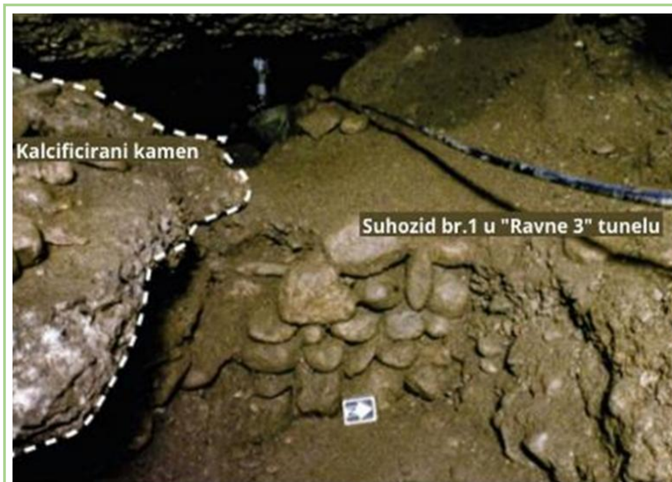

Figure 12: First dry-stone wall ('suhozid') discovered in the 'Ravne 3' tunnel. This dry-stone structure composed of stacked river pebbles, was uncovered in 2019 during systematic excavation led by field archaeologist MA Amna Agić. The wall appears embedded in compact tunnel fill, with a calcified stone mass visible to the left. The discovery provided the first physical confirmation of intentional closure features within Ravne 3 [4].

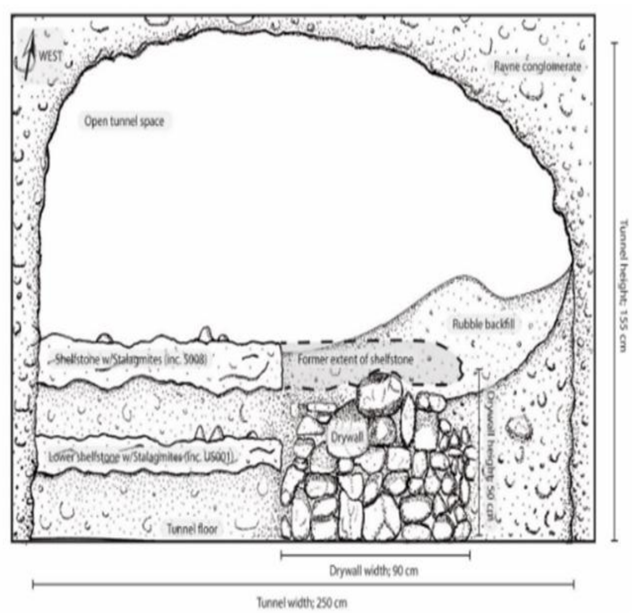

Figure 13: Architectural profile of Dry-stone Wall 1 in the Ravne 3 tunnel. Detailed cross-sectional drawing of the first dry-stone wall discovered in the Ravne 3 tunnel, showing its position relative to the open tunnel space, infill and surrounding Ravne Conglomerate. The structure is built from stacked river pebbles and sealed behind a rubble backfill, interpreted as intentional tunnel closure. Drawing by field geologist Richard Hoyle, 2019 [4].

Figure 14: Photograph of the second dry-stone wall discovered in the Ravne 3 tunnel complex, composed of stacked river pebbles. This structure corresponds to the wall shown in the technical drawing. The wall is embedded within the Ravne Conglomerate and partially covered by surrounding fill. The presence of rounded pebbles and intentional placement indicates deliberate human construction [4].

Wall categories

Based on spatial placement, structural function and wall orientation, the walls can be grouped into four provisional categories:

Corridor-sealing walls

These walls terminate tunnel branches and are often positioned in narrow side corridors. In most cases, they block access to voids filled with unconsolidated material. This suggests their function was to seal off hazardous, unstable or previously used segments.

Chamber-retaining walls

These walls are built in broader chambers to retain loose fill or delimit transition zones. In Ravne 3, one such wall measuring 4.8 meters in length and up to 80 cm in height was constructed with 7-9 stone courses and found to contain carbonized wood in adjacent fill-radiocarbon dated to the 4th century CE [13].

Reinforcement walls

Identified in Ravne and Ravne 6, these walls are located along longitudinal axes, parallel to tunnel walls. They appear to provide structural reinforcement to weakened side walls or cavity edges. Unlike sealing walls, they often feature interleaved stones extending laterally beyond the primary face.

Threshold and niche walls

Shorter, partial walls were documented marking changes in tunnel elevation or chamber entry. These appear to denote thresholds, possibly for symbolic, functional or architectural reasons. Some exhibit integration with adjacent dry-laid steps or floor transitions **(Figure 15-Figure 20)**.

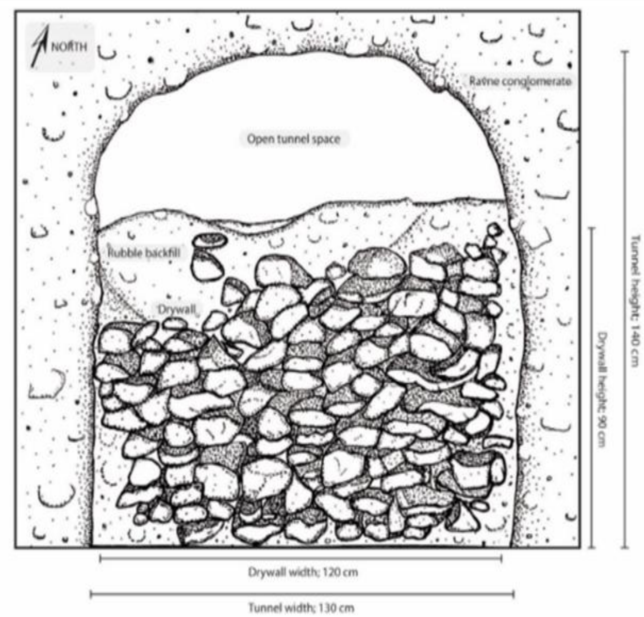

Figure 15: Second documented dry-stone wall in the Ravne 3 tunnel complex, shown in a detailed cross-sectional drawing. The illustration presents a wall constructed from water-worn river pebbles, built to a height of 90 cm within a tunnel approximately 140 cm tall and 130 cm wide. Behind the wall lies unconsolidated rubble backfill.

Figure 16: Dry-stone wall with central boulder element in the Ravne tunnel complex. This dry-stone wall segment, documented during 2023 excavations in the Ravne Tunnel Complex, exhibits a distinctive construction around a centrally placed large boulder. Measuring approximately 95 cm in height and 180 cm in width, the wall features seven courses of carefully laid river pebbles without mortar. The placement of the boulder appears deliberate, possibly serving as a stabilizing core or carrying symbolic meaning.

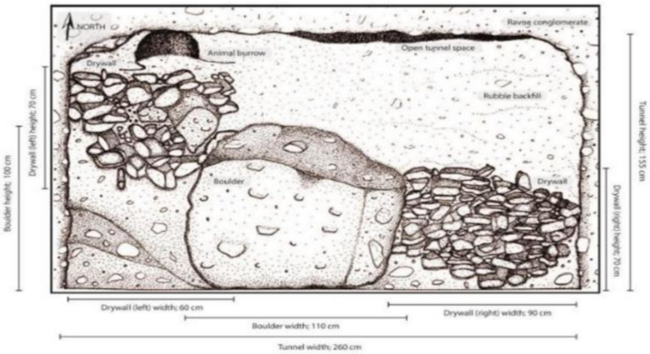

Figure 17: Profile drawing of dry-stone wall no. 3 discovered in the Ravne 3 tunnel complex in 2020. This cross-section shows two separate dry-stone walls constructed from rounded river pebbles and separated by a large natural boulder. The drawing also indicates a visible animal burrow above the left-hand wall and the rubble backfill behind the right-hand wall, all enclosed within the Ravne Conglomerate matrix. The dimensions of each component are marked, confirming the constructed nature and structural coherence of the wall units.

Figure 18: Continuous dry-stone structure in Ravne 3 tunnel identified as a single wall segment. This photograph documents a major discovery within the Ravne 3 tunnel complex. During the 2024 excavation campaign, removal of loose fill material adjacent to Section A revealed that two previously recorded dry-stone walls-Wall 2 and Wall 3-are in fact connected, forming a single, extended structural feature. The wall measures approximately 480 cm in length and stands 60-80 cm high, composed of seven to nine courses of river pebbles laid without mortar. It blocks access to a large cavity and appears to stabilize surrounding loose fill. The wall orientation is northwest-southeast and it is located 45 meters from the entrance of Ravne 3.

In the immediate vicinity of the wall, excavators recovered a concentration of charred wood fragments, suggesting the presence of a former fire-use area. A radiocarbon sample of this material was submitted to the TÜBİTAK Marmara Research Center (Turkey) and returned a calibrated date in the 4th century CE, placing the use of this space in the Late Antiquity period (ca. 3rd-5th century CE).

Figure 19: Large dry-stone wall in Ravne tunnel with slab and cobbled features. This dry-stone wall measures approximately 125 cm in height and 300 cm in width, making it one of the most expansive examples recorded within the Ravne Tunnel system. Constructed in twelve courses, the wall exhibits a high degree of stability and intentionality in its design. A series of horizontally embedded flat stone slabs are prominently featured in the midsection, possibly to enhance structural cohesion. Uniquely, the wall terminates at both ends with large rounded cobbles, a feature not previously observed in this form.

Figure 20: Dry-stone walls along the southwest-trending 'water tunnel' in the Ravne complex. The most substantial and architecturally striking dry-stone walls identified across the entire Ravne Tunnels Complex are located along and adjacent to the southwest-oriented corridor known as the “Water Tunnel.” In contrast to drywalls blocking side tunnels or chambers elsewhere, many of these structures appear to function as side reinforcements, built directly along the passage flanks without clear evidence of blocked branches behind. Their construction suggests an advanced method of tunnel stabilization or reconfiguration.

Distribution and consistency

Walls are not randomly distributed but tend to occur at predictable intervals, often between 30 and 50 meters from tunnel entrances or at the convergence of branches. This patterned placement supports the view that tunnel construction and subsequent walling followed a strategic plan-whether for ritual, navigational or structural reasons remains speculative, but the consistency suggests intent rather than ad hoc behavior.

In Ravne 3, three previously presumed separate walls were later shown to be segments of a single 4.8-meter-long construction, indicating more extensive architectural continuity than initially assumed [5]. This wall, designated “Wall 2,” remains one of the best-documented features and has been the focus of recent chronological and material analysis.

Walls in the southwest sector of the Ravne tunnels, particularly near the “Water Tunnel,” represent some of the most substantial examples, built flush against tunnel walls and with no visible passages behind them. These may represent dead-end terminations, chamber buttresses or markers for yet-unexplored features beyond the visible matrix.

Stratigraphy and Dating Evidence

The archaeological layers associated with the dry-stone walls in the Ravne Tunnel Complex provide key evidence for understanding the chronology of the site and the functional phases of its construction and use. In particular, stratigraphic documentation from Ravne 3 and Ravne tunnels has yielded the most comprehensive material dataset. These include wall construction layers, infilled cavities and organic remains such as carbonized wood, all of which support the anthropogenic origin of the structures.

Stratigraphic context

The walls are generally embedded within horizontally bedded conglomerate or rest upon underlying marl floors, often adjacent to infill material of loose, unsorted pebbles and compacted clay. Excavation records show that walls were frequently constructed at the end of short branches or side tunnels, with infill material sealed behind them. In some cases, the walls appear to retain material inside larger cavities, while in others, they block narrow corridors leading into previously open spaces.

Stratigraphic trench A302 in Ravne 3, excavated by the Foundation’s archaeological team under the supervision of field archaeologist MA Amna Agić, revealed a series of horizontal layers consisting of sandy conglomerate, marl clay and charcoal-rich lenses. These sediments correspond with human activity and material deposition over extended periods and formed the basis for sample selection for radiometric analysis.

In multiple instances, the walls themselves were partially embedded within the surrounding fill-suggesting deliberate construction into existing passages that were later abandoned or repurposed. No evidence of collapse, natural blockage or hydrological sedimentation was found in association with the walls, reinforcing the interpretation that these features were intentionally placed.

Radiocarbon dating

Radiocarbon analysis of carbonized wood was performed on a sample recovered immediately adjacent to Wall 2 in Ravne 3, the largest documented wall in that tunnel. The sample was submitted to the TÜBİTAK Marmara Research Center in Gebze, Turkey, in early 2024. The analysis dated the charcoal to the 4th century CE, placing human presence or reuse of the tunnels within the Late Antiquity period [13].

The charcoal was embedded in compact sediment at the base of the wall and showed no signs of post-depositional contamination or migration, suggesting the fire-related activity occurred during or shortly after the wall’s construction. The stratigraphic relationship supports the interpretation that the wall was actively used to seal or enclose a space during this time. Though the precise cultural affiliation remains open to interpretation, it is broadly consistent with regional archaeological patterns of reuse and modification of pre-existing spaces during Roman or post-Roman periods [6].

Uranium-thorium dating of speleothems

Additional chronological data were obtained from speleothems discovered within blocked passageways near dry-stone walls in Ravne 3. A stalagmite (sample S002) located near the sealed cavity behind Wall 1 was sampled in 2019 and analyzed by the Institute of Geology of the Czech Academy of Sciences, in collaboration with the Polish Academy of Sciences.

The U-Th dating revealed a calibrated basal age of 5,900 ± 300 years Before Present, indicating that the formation of the speleothem predated any modern or Late Antique tunnel use. The presence of a well-preserved speleothem in a sealed chamber provides a terminus post quem for tunnel excavation and points to prehistoric or protohistoric phases of tunnel formation.

Stratified artifacts and cultural associations

Ceramic fragments, bronze and iron tools and occasional ornaments were recovered from wall-adjacent fill in Ravne and Ravne 3. Notably, a bronze pendant with a stylized Celtic knot motif and several coarse ware pottery sherds with simple incised decoration, were found near Wall 3. Typological comparisons place these items within the late Roman or early medieval periods, in agreement with the radiocarbon results.

No diagnostic Neolithic ceramics were found directly associated with the walls, although earlier materials are documented in deeper stratigraphic contexts within the broader tunnel complex. This supports the hypothesis that dry-stone wall construction represents a later phase, likely reflecting tunnel reuse or modification after an original (possibly prehistoric) excavation [2,3].

Comparative Analysis of Subterranean Dry-Stone Walls

While dry-stone architecture is widely documented in above-ground and funerary contexts across Europe and the Mediterranean, the presence of intentional dry-stone walling constructed from river cobbles in subterranean, non-funerary environments remains exceptionally rare. The Ravne Tunnel Complex represents, to the best of current knowledge, a unique concentration of such structures, both in terms of quantity and preservation.

Above-ground dry-stone traditions

Traditional dry-stone techniques, such as those seen in Illyrian hillforts, Mediterranean terraces and prehistoric enclosure walls, involve the placement of unworked stones without mortar, relying on friction and gravitational stability [1,14]. In the Balkans, dry-stone fortifications from the Bronze and Iron Ages-such as those at Gradina na Jelici (Serbia), Gornja Tuzla (Bosnia-Herzegovina) and Stari Grad (Croatia)-often employed roughly hewn stones or naturally fractured slabs set into massive exterior walls [6,15].

These constructions are generally built above ground, display monumental scale and served clearly defensive or territorial functions. None of them, however, match the confined architectural environment, internal walling logic or construction materials used in the Ravne tunnels.

Subterranean comparanda

Subterranean dry-stone constructions in prehistoric or early historic contexts are considerably less frequent. Notable comparanda include:

- The Hypogeum of Hal Saflieni (Malta), where wall supports and niches were carved or occasionally reinforced with stone slabs in underground temples dated to the 4th millennium BCE [16].
- The Rock-cut tombs of Mycenae and later Etruscan hypogea, which exhibit minimal use of dry-stone bracing, typically combined with cut bedrock and lintel structures [17].
- The Chavin de Huantar tunnels (Peru), which involve corbelled stone vaults but use more squared and fitted masonry [18].

None of these cases involve rounded river pebbles, nor do they exhibit the serial construction of dozens of short dry-walled segments within passageways, as observed in the Ravne tunnels.

Materials and setting

The use of unmodified alluvial cobbles, arranged into multi-course retaining or sealing walls, reflects a localized building response to readily available material. The high humidity, stable microclimate and clay-bound conglomerate matrix of the Ravne tunnels contributed to the long-term preservation of these structures. This sharply contrasts with Mediterranean and Aegean subterranean examples where worked stone or bedrock carving predominated due to drier conditions and harder lithologies [1,19].

The Ravne walls' distribution across four tunnel systems (Ravne, Ravne 3, Ravne 4, Ravne 6), including several still under excavation, suggests that this was not an isolated tradition but rather a consistent architectural practice.

Interpretive framework

The repetitive placement and coherent construction technique raise the possibility that these walls were not merely functional barriers but also carried symbolic or ritual significance. In this regard, comparisons may be drawn to the cist graves and Neolithic passage tombs of Western Europe, where dry-stone chambers served dual symbolic and practical purposes [20]. However, unlike megalithic tombs, no human remains, grave goods or clear funerary architecture have been discovered in the Ravne complex to date.

An alternative interpretation may view the walls as phase markers, possibly corresponding to periods of access, restriction or reuse. The carbonized material associated with some walls, radiocarbon-dated to Late Antiquity, further suggests a multiphase history involving both prehistoric creation and Roman-era modification [13].

While definitive parallels are lacking, the Ravne dry-stone walls contribute a previously undocumented architectural phenomenon to European subterranean archaeology. Their quantity, consistency and structural logic argue for recognition as a new class of archaeological feature, whose regional and temporal affiliations remain open for further investigation.

Discussion and Interpretation

The discovery of over sixty dry-stone walls constructed from rounded river cobbles within a complex network of subterranean tunnels in Visoko, Bosnia-Herzegovina, presents a series of interpretive challenges and opportunities for Balkan and wider European archaeology. While their material simplicity and spatial modesty contrast sharply with monumental surface architecture, their intentionality, consistency and persistence across multiple tunnel systems indicate deliberate human agency and planned construction over time.

Anthropogenic origin

There is no evidence to suggest that the walls emerged from natural sedimentation, collapse or geogenic accumulation. On the contrary, their symmetrical composition, course alignment and deliberate integration into tunnel morphology are consistent with anthropogenic features. Many of the walls seal passages, brace corridor flanks or retain backfill in chamber recesses, suggesting a functional rationale associated with tunnel use and modification.

Moreover, walls discovered at consistent depths and spatial relationships-such as fixed intervals from entrances or chamber transitions-imply a preconceived spatial logic. This architectural planning argues against ad hoc activity or random blocking and instead supports the notion of an organized construction program, possibly maintained across phases or generations of users.

Temporal layers of use

Radiocarbon dating of charred material associated with Wall 2 in Ravne 3 places at least one phase of tunnel reuse in the 4th century CE, corresponding to the Late Roman or early post-Roman period [13]. This aligns with ceramic and metal artifacts found in proximity to several walls-such as corroded iron nails, coarse medieval pottery and a bronze pendant with a Celtic knot motif-all tentatively dated to the Roman and medieval phases.

However, Uranium-Thorium dating of nearby speleothems provides basal ages of approximately 5,900 years Before Present, indicating that cavity formation and tunnel use may predate the late Iron Age by millennia. This supports a stratified occupation model, wherein tunnel excavation and wall construction occurred in multiple episodes, possibly with long intervening phases of abandonment or shifting purpose.

This temporal range raises critical questions: Were the walls part of the original architectural scheme or later additions to an already ancient infrastructure? Could some walls be prehistoric, while others represent Late Antique reoccupation?

Functional hypotheses

The most immediate interpretation of the walls is utilitarian: structural stabilization, containment of loose fill and spatial control. Their placement in front of backfilled voids or cavities supports the hypothesis that they served to regulate tunnel access, possibly after abandonment, for safety or for symbolic closure.

However, repetitive construction in otherwise inaccessible or functionally marginal areas challenges a purely pragmatic explanation. In several cases, walls are located deep within secondary branches, distant from natural entrances or ventilation paths. This distribution opens the possibility that certain walls marked thresholds-symbolic boundaries or ritual demarcations within a socially or spiritually meaningful landscape [16,20].

While no direct ritual artifacts-such as altars, inscriptions or human remains-have been recovered, the repeated appearance of walls in strategic subterranean locations aligns with threshold architecture seen in other contexts, such as Minoan or Iberian cave sanctuaries, where stone partitions-controlled entry and visibility.

Broader significance

From a regional perspective, the Ravne Tunnel Complex provides the only known concentration of subterranean dry-stone walls constructed from unmodified river cobbles in Southeastern Europe. Their form, placement and construction distinguish them from known megalithic or mortuary walling and they challenge prevailing typologies of prehistoric and Roman subterranean structures.

This phenomenon may represent a local innovation, reflecting adaptation to specific environmental conditions and available resources in the Visoko Basin. Alternatively, it could preserve a now-lost architectural tradition, whose analogs were either erased, misclassified or remain undiscovered across the Balkans and beyond.

While the lack of definitive cultural indicators hinders precise attribution, the sheer number and integrity of the walls, combined with their spatial coherence, strongly support recognition of this feature class as a distinct archaeological phenomenon, deserving of further comparative, stratigraphic and material analysis.

Conclusions

The dry-stone walls discovered within the Ravne Tunnel Complex in Visoko, Bosnia-Herzegovina, constitute a previously undocumented form of subterranean architecture in the central Balkans. Their defining characteristics-use of unmodified river cobbles, lack of mortar, multi-course construction and repeated placement across four independent tunnel systems-establish their intentional human origin and elevate them from anecdotal features to a cohesive architectural phenomenon.

While similarities exist with surface-level dry-stone traditions in the Mediterranean and prehistoric Europe, the subterranean context and construction logic of the Ravne walls are unique. The systematic presence of walls in Ravne, Ravne 3, Ravne 4 and Ravne 6, often associated with stratified archaeological deposits, suggests their use was functional, spatial and possibly symbolic. Radiocarbon dating of charcoal adjacent to Wall 2 places at least one phase of activity in the 4th century CE, with additional evidence pointing toward earlier prehistoric phases, as indicated by Uranium-Thorium dating of nearby speleothems.

Though the original purpose of the tunnels remains subject to ongoing research, the dry-stone walls provide a clear material signature of human agency, spatial organization and environmental adaptation. Whether serving as structural reinforcements, spatial delimiters or ritual markers, these walls reflect a continuity of underground construction practices that demand broader recognition in Balkan and European archaeology.

Future research, including 3D documentation, comparative typological studies and expanded dating programs, will help to contextualize these walls within broader architectural traditions and to clarify their role in the cultural history of the Visoko Valley.

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Conflict of Interest

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References

1. Iliopoulos A (2014) Dry stone construction: History and technique. Mediterranean Archaeology and Archaeometry 14: 195-204.
2. Kolb M (2011) Monumental architecture and urbanism in bronze age Sicily. American Journal of Archaeology 115: 377-401.
3. Suárez V, Bueno-Ramírez P, Balbín-Behrmann R (2023) Megalithic architecture: Construction techniques and social implications. European Journal of Archaeology 26: 101-123.
4. Osmanagich S, Hoyle R, Agić A, Delibašić H (2023) Ravne 3 Tunnels. Visoko: Archaeological Park: BPS Foundation.
5. Hoyle R (2020) Ravne Tunnels Complex Subterranean Survey. Technical documentation. Visoko: Archaeological Park: BPS Foundation.

6. Trifunović S (2010) Late roman fortifications in the central Balkans. Belgrade: Institute of Archaeology.
7. Šarac B, Ganić M, Muftić D (2005) Geological characteristics of the Visoko Basin. Geologia Bosniaca 25: 33-41.
8. Osmanagich S (2025) Multidisciplinary evaluation of the pyramid-shaped formation near Visoko, Bosnia-Herzegovina: A case for anthropogenic construction. J Biomed Res Environ Sci [Crossref], [Google Scholar]
9. Osmanagich S (2025) Archaeological stratigraphy and environmental analysis of the Ravne 3 tunnel complex. Acta Scientific: Environmental Sciences Journal.
10. Osmanagich S (2025) Establishing deep time: Multi-method dating of archaeological and speleological features in the bosnian valley of the pyramids. Geoinformatics and Geostatistics: An Overview [Crossref], [Google Scholar]
11. Hoyle R (2018/2019) Geoarchaeological Report.
12. Osmanagich S (2025) Ravne tunnels as a regenerative environment: Scientific measurements and human testimonials. Acta Scientific Medical Sciences.
13. TÜBİTAK (2024) Radiocarbon Dating Report of Sample R3-Charcoal-24/01. Marmara Research Center, Gebze, Turkey. Documentation of the Archaeological Park: BPS Foundation.
14. UNESCO (2018) Art of dry-stone walling, knowledge and techniques. Intangible Cultural Heritage of Humanity.
15. Garašanin M (1973) Praistorija na tlu Srbije. Belgrade: Srpska akademija nauka i umetnosti.
16. Trump D (2002) Malta: Prehistory and Temples. London: Midsea Books.
17. Hägg R (1997) Art and Cult in the Bronze Age. In The Role of the Centre, edited by Åström P 71-82.
18. Rick JW (2005) The evolution of authority and power at Chavín de Huántar, Peru. Archaeological Papers of the American Anthropological Association 14: 71-89. [Crossref], [Google Scholar]
19. Miletić B (2007) Neolithic architecture in the Central Balkans. Starinar LVII: 1-21.
20. Bradley R (2007) The Prehistory of Britain and Ireland. Cambridge: Cambridge University Press.