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Europe's Oldest Subterranean Structure? New Chronological and Structural Insights from Dry-Stone Wall in the Ravne 3 Tunnel Complex, Visoko, Bosnia-Herzegovina

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Abstract
This study presents groundbreaking archaeological and geochronological findings from the Ravne 3 Tunnel Complex in Visoko, Bosnia-Herzegovina. Through stratigraphic analysis and precise radiometric dating, the article documents the existence of an intentionally constructed dry-stone wall (Wall No. 1) located beneath undisturbed speleothem formations.

UraniumThorium dating of the stalagmite growing atop the wall yields a minimum age of 19,000 ± 1,000 years, while radiocarbon analysis of nearby speleothem layers provides a calibrated date of 26,200 ± 250 years BP. These results suggest that the tunnel system predates the Late Glacial Maximum, making it one of the oldest verified subterranean human structures in Europe.

The presence of architectural continuity, sealed passages, and mineral deposits implies that the tunnels were intentionally constructed and later abandoned or preserved. These findings challenge conventional models of European prehistory and support the hypothesis of advanced construction capabilities in the Upper Paleolithic era.

Keywords: Bosnian Pyramids, Ravne 3 Tunnel Complex, Dry-Stone Wall, Prehistoric Construction, Visoko, Uranium Thorium Dating, Radiocarbon Dating, Speleothem Chronology, Subterranean Archaeology, European Prehistory

Introduction
Subterranean architecture has historically been associated with Neolithic or later periods in Europe, often attributed to ritual, habitation, or defensive purposes. However, recent findings from the Ravne Tunnel Complex in Visoko, Bosnia-Herzegovina, (Figure 1) offer compelling evidence of much earlier human activity potentially extending the known timeline of intentional underground construction in Europe by tens of thousands of years.

A key feature in this reassessment is the discovery of a prehistoric dry-stone wall within the Ravne 3 Tunnel, part of a broader network of artificial passages [1]. (Figure 2-3) This wall is situated beneath intact speleothems, including layered stalagmites, which were sampled for absolute dating using two independent methods.

Uranium-Thorium (U-Th) dating of the overgrowing stalagmites yielded results of approximately 19,000 ± 1,000 years, establishing a minimum age for the wall's construction since the wall had to be in place prior to the formation of these calcite deposits [2]. Separately, radiocarbon dating of a different stalagmite sample within the same tunnel section produced an age of 26,200 years BP, further supporting the hypothesis of pre-LGM (Last Glacial Maximum) activity (2) (Figure 4-9).

These results collectively suggest that both the cavities and dry-stone features predate the Holocene epoch by a considerable margin. The preservation of architectural integrity, including the wall's deliberate alignment and construction using unbonded river pebbles, implies not only human agency but also a degree of engineering awareness previously unattributed to Upper Paleolithic communities in the region [3].

Moreover, the Ravne 3 section forms part of a larger underground network displaying architectural consistency, intentional curvature, stable microclimatic conditions, and notable energetic anomalies raising further questions about its original function [4,5]. These attributes demand a comprehensive reassessment of early human capabilities related to subterranean construction, environmental management, and cognitive planning. This study aims to integrate the latest chronometric, stratigraphic, and architectural data to evaluate the hypothesis that Ravne 3 houses the oldest known man-made subterranean structure in Europe, and to outline its implications for Paleolithic archaeology.

Materials and Methods

Site Overview: Ravne Tunnel Complex

The Ravne Tunnel Complex, located approximately 2.5 kilometers northeast of the Bosnian Pyramid of the Sun in Visoko, is an extensive network of interconnected subterranean passages believed to be artificial in origin. Excavations since 2006 have uncovered hundreds of meters of dry-stone tunnels, ventilation chambers, ceramic megaliths, and subterranean water flows.

The Ravne 3 Tunnel, a recently opened lateral section, features a dry-stone wall partially sealed beneath intact speleothem formations. This location serves as the primary focus of the present study.

Stratigraphic and Architectural Documentation

The dry-stone wall was analyzed for its morphological attributes, spatial orientation, and material composition. The structure consists of rounded river pebbles, stacked in interlocking, unmortared courses, indicative of intentional placement rather than natural accumulation. The wall is situated approximately 4 meters from the current tunnel face and lies directly beneath multi-layered stalagmitic deposits, some exceeding 20 cm in thickness.

Stratigraphic sequencing was conducted using photogrammetry, 3D scanning, and manual field recording, enabling the creation of a high-resolution model of the wall-speleothem relationship. Special attention was given to identifying contact points between anthropogenic and speleogenic features to support chronological interpretation.

Absolute Dating Techniques

Two independent dating methods were employed to establish a terminus ante quem for the wall's construction

- Uranium-Thorium (U-Th) dating was applied to intact stalagmites overgrowing the upper stone layers. Samples were analyzed at the Gliwice Radiocarbon and U-Series Laboratory (Poland). Results indicated a minimum age of 19,000 ± 1,000 years BP, placing the wall's construction during or before the late Upper Paleolithic period [2].
- Radiocarbon (^{14}C) dating was also conducted on calcitic stalagmite layers associated with the same stratigraphic level, using accelerator mass spectrometry (AMS) techniques. A sample returned a calibrated age of approximately 26,200 years BP, affirming that speleothem development—and by implication, the cessation of wall activity occurred well before the onset of the Holocene [2]. Both sets of results are consistent with long-term microclimatic stability in the tunnel, as evidenced by the well-preserved speleothems.

Structural and Material Analysis

A selection of stones from the wall was subjected to petrographic analysis using thin-section microscopy and X-ray fluorescence (XRF). These analyses confirmed the use of locally sourced river cobbles, primarily composed of quartzite, sandstone, and schist. The consistent lithology and standardized dimensions suggest intentional selection and transport, reinforcing the hypothesis of human construction.

The architecture exhibits signs of load distribution awareness, including battering (slight inward slope) and lateral support from surrounding fill. The dry-stone style observed in Ravne 3 is consistent with other parts of the Ravne Tunnel Complex but displays unique depth and preservation relative to stratigraphic position.

Environmental Parameters

Ambient temperature, humidity, and air ionization levels were monitored throughout the Ravne 3 corridor using standard field equipment. Conditions remained remarkably constant (temperature ~12.5°C, RH ~95%), consistent with prior studies suggesting that the tunnel complex was engineered or selected to optimize microclimatic stability [3,4,5]. These factors likely contributed to the preservation of both speleothems and dry-stone structures.

Results

Stratigraphic Context and Wall Construction

Excavations within the Ravne 3 tunnel corridor revealed a dry-stone wall approximately 80 cm in height and extending over 2.3 meters in visible length, composed of uniformly shaped river cobbles arranged without the use of mortar. The wall was found partially embedded within a matrix of fine silty clay and speleothem deposits. The base layer of the wall was securely anchored into the natural tunnel floor, while the upper courses showed compression from overlying stalagmitic flowstone.

Photographic documentation and 3D scanning confirmed that speleothems developed in direct superposition above the upper stone layer, demonstrating a clear post-construction chronology. The uniformity of the speleothem layer atop the structure rules out later intrusive building activity and affirms its stratigraphic integrity.

Radiometric Dating Results

Two independent dating methods provided consistent, corroborated estimates for the age of overlying speleothems

- Uranium-Thorium (U-Th) analysis yielded a calibrated age of 19,000 ± 1,000 years Before Present, from a stalagmite adhering directly to the top surface of the wall stones [2]. This establishes a firm lower limit, indicating that the wall must have been constructed prior to 19,000 years BP.
- A separate radiocarbon analysis of speleothem calcite (not associated with organic material) conducted on a stalagmite sample returned a date of approximately 26,200 years BP [2]. This result, while older than the U-Th data, further strengthens the case that the tunnel cavity and its anthropogenic modifications predate the late glacial maximum.

These two results suggest that cavity formation and human structural activity occurred well into the Upper Paleolithic period, making the Ravne 3 dry-stone wall potentially one of the oldest subterranean architectural features currently known in Europe.

Morphology and Intentional Design

The Ravne 3 wall exhibits clear indicators of intentional design

- The stones were sorted by size, with larger stones placed at the base and smaller ones above.
- A concave curvature facing the tunnel entrance was noted, suggestive of a retaining function or symbolic demarcation.
- The wall's alignment is consistent with previously mapped dry-stone structures in other sections of the Ravne Tunnel Complex, suggesting shared construction principles or cultural continuity.

Notably, no collapsed ceiling material or signs of natural rockfall were detected in direct association with the wall, further distinguishing it from random geological formations.

Speleothem Preservation and Microclimate

The overlying speleothem layers were found to be dense, laminated, and well-preserved, exhibiting characteristic stalagmitic banding and calcite purity. This quality of preservation is consistent with the tunnel's stable temperature (~12.5°C) and high humidity (~95%), both of which are conducive to long-term speleogenetic development. Ionization levels, while not directly measured in this study, are known from adjacent sections to be elevated, supporting hypotheses that the tunnel environment was deliberately selected or engineered for its preservation qualities [1,3].

Discussion

Reassessing the Chronology of Subterranean Architecture in Europe

Radiometric analyses of the Ravne 3 Tunnel's dry-stone wall specifically, uranium-thorium dating indicating a minimum age of 19,000 ± 1,000 years BP and radiocarbon dating of overlying stalagmitic material yielding 26,200 years BP place the structure firmly within the Upper Paleolithic period [2,3]. These results predate the known emergence of underground construction in Europe, traditionally associated with Neolithic and later societies.

For instance, the Menga dolmen in Spain, a massive subterranean megalithic tomb dated to the 5th millennium BCE, is considered one of the earliest known examples of underground architectural planning in Neolithic Europe [6]. Similarly, a 5,000-year-old paved cellar recently excavated in Denmark provides additional evidence of complex subterranean construction during the late Neolithic [7]. However, the chronological evidence from Ravne 3 extends this timeline significantly, suggesting that intentional subterranean engineering occurred during a period typically defined by hunter-gatherer subsistence and symbolic cave art rather than built environments.

Paleolithic Cave Art and Symbolic Behavior

Evidence from across Europe demonstrates that early humans possessed the capacity for symbolic thinking and visual representation long before the Neolithic revolution. The El Castillo Cave in Spain contains red disk paintings dated to at least 40,800 years ago using uraniumseries dating techniques [8]. In Chauvet Cave, France, charcoal-based animal drawings have been radiocarbon dated to between 32,000 and 30,000 years ago, making them among the oldest known examples of representational art [9].

Recent uranium-thorium dating of cave art in La Pasiega, Maltravieso, and Ardales caves in Spain has pushed the earliest known symbolic art back to over 64,000 years ago before the arrival of anatomically modern humans in Western Europe thereby implicating Neanderthals as the creators [10]. This discovery alters the long-standing narrative about the cognitive and cultural capacities of Paleolithic populations, both Neanderthal and early Homo sapiens.

Implications for Understanding Upper Paleolithic Societies

The Ravne 3 dry-stone wall, constructed and subsequently sealed beneath layers of calcite and speleothem, implies purposeful activity within a subterranean context, demonstrating social coordination and advanced spatial awareness during the Upper Paleolithic. Unlike natural cave dwellings, which were passively occupied, the engineered nature of the Ravne wall its placement, dry-stone technique, and burial beneath calcified layers indicates long-term intention, maintenance, and environmental adaptation [1-3].

The wall's discovery contributes to a growing body of evidence that early societies demonstrated complex planning and possibly ritualized behavior. The co-occurrence of underground engineering with symbolic cave art suggests that the Paleolithic period may have involved a broader spectrum of cultural activity than previously acknowledged. Rather than marking the beginning of complex social behavior in the Neolithic, the findings from Ravne 3 and other contemporaneous sites imply a gradual evolution of symbolic and architectural knowledge [6-11].

Conclusion

The discovery of a dry-stone wall sealed beneath calcite layers and stalagmites in the Ravne 3 Tunnel Complex, Visoko, Bosnia-Herzegovina, marks a pivotal contribution to the study of early human engineering. Radiometric dating results from both U-Th analysis (19,000 ± 1,000 years BP) and radiocarbon analysis (26,200 BP) of overlying speleothems challenge existing models of subterranean construction in prehistoric Europe [1–3].

This structure clearly anthropogenic in design predates known examples of Neolithic subterranean architecture by many millennia. When considered alongside the symbolic cave art traditions from Chauvet, El Castillo, and La Pasiega [6–8], the wall in Ravne 3 offers compelling evidence of intentional activity, spatial planning, and possibly ritualized behavior during the Upper Paleolithic. Such activity reflects a level of cognitive and cultural complexity not previously attributed to this era's populations.

Moreover, the site contributes to a growing body of research suggesting that Paleolithic humans and potentially even earlier hominin groups engaged in deliberate environmental modifications, not merely for shelter or subsistence, but potentially for symbolic, functional, or social purposes. This expands our understanding of prehistoric lifeways and demands a reconsideration of the linear progression model that situates "advanced" engineering and planning exclusively in post-Neolithic contexts [4,5,9].

Future multidisciplinary research including micromorphological analysis, paleoenvironmental reconstruction, and comparative architectural studies is essential to confirm these preliminary interpretations. Nevertheless, the Ravne 3 dry stone wall stands as Europe's most ancient known engineered subterranean feature to date, offering a rare glimpse into the technical and cultural capacities of Paleolithic societies.

Statements

Funding

This study was fully supported by the **Archaeological Park:** Bosnian Pyramid of the Sun Foundation, a non-profit organization. No external grants from public, commercial, or nongovernmental sources were received.

Conflicts of Interest

The author declares no conflicts of interest.

Ethical Approval and Research Permits

All archaeological work was conducted under legal permits issued by the Ministry of Culture of Zenica-Doboj Canton, Bosnia-Herzegovina. The project was carried out by the Archaeological **Park:** Bosnian Pyramid of the Sun Foundation, operating as a registered NGO with full approval from the Ministry of Justice of Bosnia-Herzegovina. Artifact preservation and classification were conducted in collaboration with the Visoko City Museum, which serves as the official custodian of recovered materials.

Data Availability

Data supporting the findings of this study including dating reports, stratigraphic logs, and tunnel schematics are available upon reasonable request and are archived at the Foundation's scientific office in Visoko

Acknowledgment

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The author is particularly grateful to the field technicians, geologists, and tunnel mapping teams for their meticulous documentation and data collection, as well as to the laboratory personnel involved in chronometric testing and sample analysis. The tireless commitment of all those working on-site under often demanding conditions has contributed significantly to the discoveries presented in this study.

List of Figures

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.

Source: Osmanagich S (2025) A New Class of Subterranean Dry-Stone Structures: River-Pebble Walls in the Ravne Tunnel Complex, Bosnia-Herzegovina. Journal of Environment and Biological Science, J Environ Biol Sci. Vol.1 No.1: 05.

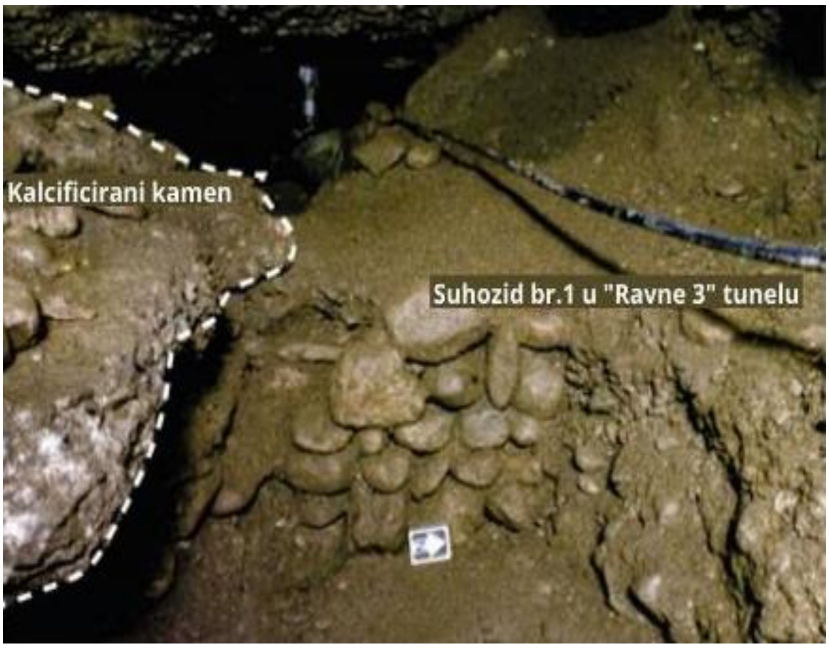

Figure 2: First dry-stone wall discovered in the 'Ravne 3' tunnel.

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.

Source: Osmanagich S (2025) A New Class of Subterranean Dry-Stone Structures: River-Pebble Walls in the Ravne Tunnel Complex, Bosnia-Herzegovina. Journal of Environment and Biological Science, J Environ Biol Sci. Vol.1 No.1: 05.

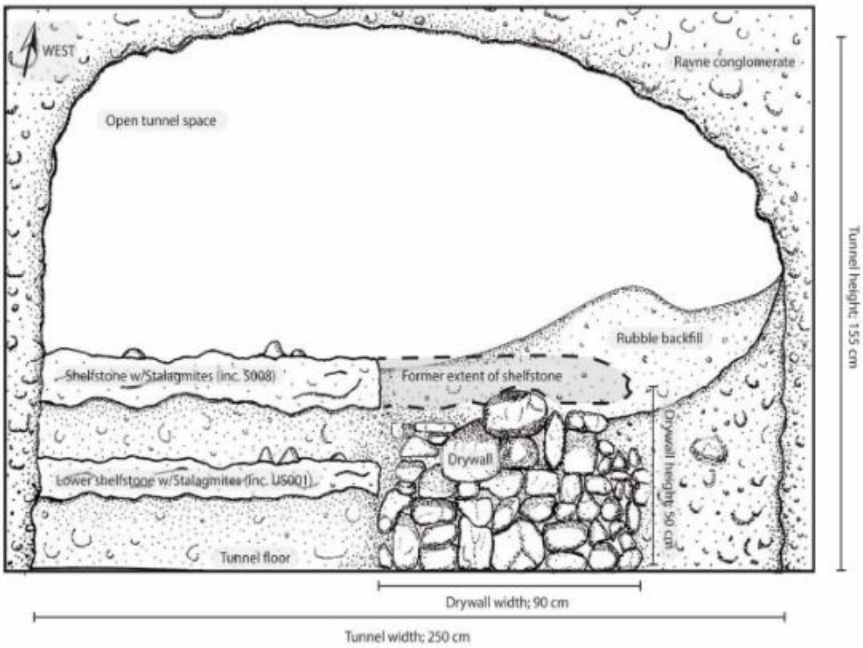

Figure 3: Architectural profile of Dry-stone Wall 1 in the Ravne 3 tunnel

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.

Source: Osmanagich S (2025) A New Class of Subterranean Dry-Stone Structures: River-Pebble Walls in the Ravne Tunnel Complex, Bosnia-Herzegovina. Journal of Environment and Biological Science, J Environ Biol Sci. Vol.1 No.1: 05.

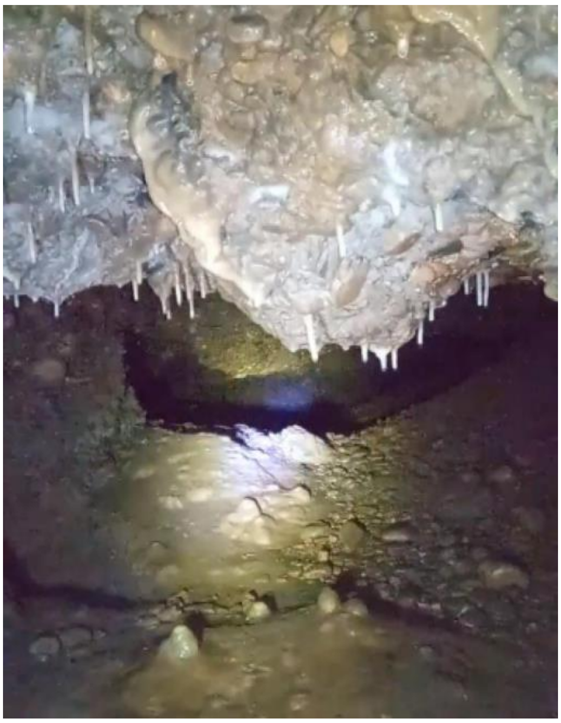

Figure 4: Stalactites and stalagmites in an undisturbed section of the Ravne 3 tunnel.

This image shows an active speleothem formation zone within the Ravne 3 tunnel system. Stalactites can be seen descending from the conglomerate ceiling, while stalagmites are visible rising from the compact tunnel floor, indicating prolonged periods of water percolation and calcite deposition. Such formations develop slowly over centuries or millennia in stable underground microclimates, providing important clues to the long-term undisturbed nature of the environment.

Sam Osmanagich. "Archaeological Stratigraphy and Environmental Analysis of the Ravne 3 Tunnel Complex (Visoko, Bosnia-Herzegovina): Evidence from Multi-Period Artifacts, Radiometric Dating, and Energetic Microclimate Data". Acta Scientific Environmental Science 2.1 (2025): 68-96.

Figure 5: Conical stalagmites in Ravne 3 tunnel, with S002 prepared for Uranium-Thorium dating

The upper image shows the conical stalagmites S001 and S002 located on the tunnel floor of Ravne 3, identified for radiometric analysis. In the lower panels, stalagmite S002 is shown in detail: it has been sectioned vertically to extract a clean carbonate sample from the basal layer, necessary for U-Th dating. The laminar growth patterns are clearly visible, indicating continuous calcite deposition. This dating method was employed to help establish a minimum age for undisturbed tunnel sedimentation and ceiling integrity.

Osmanagich, S. "Archaeological Stratigraphy and Environmental Analysis of the Ravne 3 Tunnel Complex (Visoko, Bosnia-Herzegovina): Evidence from Multi-Period Artifacts, Radiometric Dating, and Energetic Microclimate Data". Acta Scientific Environmental Science 2.1 (2025): 68-96.

Figure 6: Stalagmites S001 and S002 Discovered in Tunnel Ravne 3

Two cone-shaped stalagmites (S001 and S002) were found at the same stratigraphic level in Tunnel Ravne 3. These speleothems were sampled for geochronological analysis to help estimate the tunnel's minimum age.

Stalagmite S001 was dated using radiocarbon (C-14) analysis and yielded an apparent age of 26,200 ± 250 years, although this result is likely distorted due to the presence of "dead carbon" from dissolved carbonate ions in the conglomerate bedrock. The base of the stalagmite was not dated, meaning the true age may be greater.

Stalagmite S002 was dated using Uranium-Thorium (U-Th) ICP-MS analysis, yielding a more reliable age of 5,900 ± 300 years, as U-Th dating is unaffected by carbonate contamination in the same way as radiocarbon methods.

Despite their proximity and similar morphology, the large discrepancy in the results highlights methodological differences and challenges with speleothem dating. The U-Th age for S002 serves as a minimum age for the cessation of human activity in that area of the tunnel.

Sam Osmanagich. "Archaeological Stratigraphy and Environmental Analysis of the Ravne 3 Tunnel Complex (Visoko, Bosnia-Herzegovina): Evidence from Multi-Period Artifacts, Radiometric Dating, and Energetic Microclimate Data". Acta Scientific Environmental Science 2.1 (2025): 68-96.

Figure 7: Radiocarbon Analysis of Samples from Tunnel Ravne 3: Laboratory Procedures and Results

This table presents the radiocarbon dating results obtained for multiple samples collected from the Ravne 3 Tunnel Complex in Visoko, Bosnia-Herzegovina. The analyses were conducted by the Laboratory for Radiocarbon Dating, Institute of Environmental Geochemistry, National Academy of Sciences of Ukraine, Kyiv.

Laboratory Methods and Approach

The conventional radiocarbon dating method was employed, based on liquid scintillation counting of benzene samples. The laboratory procedure involved the following steps:

- **Sample Preparation:** Organic and carbonate materials were sought in each sample.
- **Thermal Destruction (Vacuum Pyrolysis):** Samples were subjected to vacuum pyrolysis at 250°C for three hours to release measurable carbon. If residual charred carbon was visually detected, it indicated the presence of organic matter.
- **Chemical Conversion:** In cases of carbonate presence, chemical reactions were applied:
- CO_2 was liberated through acid destruction.
- CO_2 was then reacted with lithium to form lithium carbide. o Lithium carbide was further processed into acetylene and then into benzene ($C + Li \rightarrow Li_2C_2 \rightarrow C_2H_2 \rightarrow C_6H_6$).
- **Measurement:** Radiocarbon content was determined by measuring radioactivity within the benzene samples using liquid scintillation counting.

Results Overview

- Samples C2-018 and C2-025 initially showed no datable organic carbon through pyrolysis. However, carbonate acid destruction allowed the production of benzene and successful radiocarbon dating: o Sample C2-018 (sandstone-like material) produced a relatively higher benzene yield.
- Sample C2-025 (pressed clay-like material) produced less benzene.
- Sample C2-024, interpreted as a possible bird bone fragment, contained no measurable organic carbon and could not be dated.
- Stalagmite sample S001 was carefully stratified into layers (A, B, and C). Carbon analysis was conducted separately for external and internal sections: o Layer A and Layers B+C were individually processed and dated. o Additional cross-sections were taken for precision, producing multiple protocol results.

Radiocarbon Dating Results (summarized in Table)

The results indicate a complex chronology for the tunnel, with radiocarbon dates ranging from the late Upper Paleolithic (26,200 years BP) to more recent Holocene periods (ca. 3,000–4,000 years BP). These findings suggest multiple phases of use and environmental changes within the Ravne 3 system.

Source: Osmanagich S (2025) Establishing Deep Time: Multi-Method Dating of Archaeological and Speleological Features in the Bosnian Valley of the Pyramids. Geoinfor Geostat: An Overview 13:3.

Lab No.	Description	Benzene (g)	pMC (%)	Age (years BP)
3729	S001 Layers (B+C)	1.3853	64.5	3520 ± 50
3730	S001 Layers (A)	0.694	72.9	2540 ± 50
3732	S001 Layers (C)	1.2285	61.7	3880 ± 55
3733	S2-018	1.3183	68.3	3070 ± 50
3734	S001 Layers (B) A	1.0192	3.8	26200 ± 250
3735	S2-025	0.149	26.7	10625 ± 300

Замовник (Customer)	Foundation "Archaeological park	”Bosnian Pyramid of the Sun"
Зразок(Sample):	Sample S001 (layer B, top)	(carbonate)
Код лабораторії (lab code)	IHME-3734	
Маса бензолу (benzene mass)	1,0192	грам (g)
Час вимірювання (counting time)	3000	хвилин (minutes)
Швидкість лічення проби (Sample count rate)	0.87	CPM
Фон (імп./хв.) (Background count rate)	0.506	CPM
Ефективність реєстрації (counting efficiency) :	73,51%	Процент (percent)
Радіовуглецева дата (Radiocarbon date)	26200 ± 250	BP
Калібрована дата (Calibrated date)	-	

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Figure 8: Uranium-Thorium Dating of Stalagmites from Ravne 3 Tunnel Complex

This figure presents the results of U-series dating of stalagmite samples collected from the Ravne 3 Tunnel Complex in Visoko, Bosnia-Herzegovina. The analyses were performed using uranium-thorium (U-Th) isotopic dating methods, a technique particularly well suited for dating calcium carbonate formations such as stalagmites.

Laboratory Methods and Facilities

- **Chemical Processing:** After thermal decomposition of organic matter, a ^233U–^236U– ^229Th spike was added to each sample. The samples were then dissolved in nitric acid, and uranium and thorium were chemically separated from the carbonate matrix using chromatographic extraction with TRU-resin.
- **Laboratories Involved**
- U-series Laboratory of the Institute of Geological Sciences, Polish Academy of Sciences (Warsaw, Poland) conducted the chemical separations.
- Institute of Geology of the Czech Academy of Sciences (CAS) (Prague, Czech Republic) conducted the isotopic measurements using a double-focusing sectorfield ICP mass spectrometer (Element 2, Thermo Finnigan MAT).

All measurements were corrected for background radiation and chemical blanks. Standard reference materials and blank samples were run in parallel with the test samples to ensure analytical accuracy.

Dating Results

- Sample US001 (from a lower stalagmite layer) was dated to 19,000 ± 1,000 years BP.
- **Sample S008,** analyzed with the same method, yielded an age of 15,000 ± 1,000 years BP.

- An additional stalagmite sample, S002, yielded a U-Th age of 5,900 ± 200 years BP. This sample had previously been dated using radiocarbon methods, which produced divergent results due to the "dead carbon" effect commonly associated with speleothem samples in carbonate-rich contexts.

Interpretation

The considerable variation in the ages of stalagmite layers (ranging from ~5,900 to ~19,000 years BP) is attributed to differences in sample depth, layering, and sample selection. For example, deeper stalagmite layers are logically older and less likely to have been disturbed by anthropogenic activity or environmental contaminants. These results collectively support the interpretation that human or environmental influence on tunnel stability and inactivity dates back well into the Upper Paleolithic.

Conclusion

These U-series dating results underscore the need for continued stratified sampling and analysis of the extensive stalagmite formations preserved in Section A and A2 of Ravne 3. The chronological depth indicated by these measurements is of significant importance for understanding the long-term geochronology and potential anthropogenic activity associated with the Ravne tunnel system [11].

Laboratory report: Institute of Geology CAS (Prague, Czech Republic) & Institute of Geological Sciences, Polish Academy of Sciences (Warsaw, Poland).

Source: Osmanagich, S. (2025) Establishing Deep Time: Multi-Method Dating of
Archaeological and Speleological Features in the Bosnian Valley of the Pyramids. Geoinfor Geostat: An Overview 13:3.

U-series dating report

Institute of Geology CAS

Samples quantity: 2

Material: calcite powder

Method description:

Chemical procedure of uranium and thorium separation

After thermal decomposition of organic matter a ^{233}U-^{236}U-^{229}Th spike is added to samples before any further chemical treatment. Sample is dissolved in nitric acid. Uranium and thorium is separated from carbonate matrix using chromatographic method with TRU-resin Chemical procedure has been done in U-series Laboratory of Institute of Geological Sciences, Polish Academy of Sciences (Warsaw, Poland). Internal standard sample and blank sample were prepared simultaneously any series of studied samples.

Measurement

Isotopic composition of U and Th measurement has been performed in Institute of Geology of the CAS, v. v. i. (Prague, Czech Republic). Measurements were performed with a double-focusing sector-field ICP mass analyzer (Element 2, Thermo Finngan MAT). The instrument was operated at a low mass resolution ($m/\Delta m \geq 300$). Measurement results were corrected for counting background and chemical blank.

Results:

Lab. no.	Sample	U cont. [ppm]	^{234}U/^{238}U AR	^{230}Th/^{234}U AR	^{230}Th/^{232}Th AR	Age [ka]	*Corrected age [ka]	**Initial ^{234}U/^{238}U AR
1518	US 001	0.0277±0.0001	1.2743±0.0053	0.2581±0.0053	1.823±0.037	32.38±0.76	19±1	1.289±0.068
1519	S008 (a)	0.0458±0.0002	1.2334±0.0049	0.2308±0.0050	1.696±0.037	28.54±0.71	15±1	1.243±0.083

Calculations use the decay constant of Jaffey et al., 1971 (^{238}U), Cheng et al., 2013 (^{234}U and ^{230}Th) and Holden, 1990 (^{232}Th). Ages do not include uncertainties associated with decay constants.
AR – activity ratio;
* Corrected ages using typical silicate activity ratio ^{230}Th/^{232}Th = 0.83 ± 0.42 derived from the ^{232}Th/^{238}U activity ratio = 1.21 ± 0.6, ^{230}Th/^{238}U activity ratio = 1.0 ± 0.1, and ^{234}U/^{238}U activity ratio = 1.0 ± 0.1 (e.g., Cruz et al., 2005).
** Calculated based on ^{234}U/^{238}U AR corrected for detrital contamination and corrected age.

Cheng H, Edwards RL, Shen C-C, Polyak VJ, Asmerom Y, Woodhead J, Hellstrom J, Wang Y, Kong X, Sp C, Wang X, Alexander EC. 2013. Improvements in 230Th dating, 230Th and 234U half-live values, and U-Th isotopic measurements by multi-collector inductively coupled plasma mass spectrometry. Earth and Planetary Science Letters 371-372: 82-91.
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Figure 9: Continuous Dry-Stone Structure in Ravne 3 Tunnel Identified as a Single Wall Segment

Osmanagich S (2025) Establishing Deep Time: Multi-Method Dating of Archaeological and Speleological Features in the Bosnian Valley of the Pyramids. Geoinfor Geostat: An Overview 13:3 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 Source: Osmanagich S (2025) A New Class of Subterranean Dry-Stone Structures: River-Pebble Walls in the Ravne Tunnel Complex, Bosnia-Herzegovina. J Environ Biol Sci. Vol.1 No.1: 05.

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