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Rediscovered megalithic engravings in Slovakia: 3D reconstruction and comparative analysis of a forgotten Neolithic site

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The engraved stones uncovered in 1988 in Holíč, western Slovakia, represent a little-known megalithic site of probable prehistoric origin, situated in an underexplored region of Europe. This study presents detailed reconstructions of three engravings using high-resolution lasergrammetry, archival photography and full-scale hand tracing. The motifs consist of a human figure with a tool, a probable animal and concentric circles. Geometric analysis suggests alignment of the engravings with symbolically significant anatomical points. Archaeoastronomical mapping indicates a westward orientation consistent with the summer solstice sunset. While the site lacks stratigraphic context due to post-discovery disturbance, stylistic comparisons link the carvings to Neolithic traditions in France, Italy and Scotland. These findings raise new questions about the eastern extent of Neolithic monumental culture. We advocate for the preservation of the Holíč stones and recommend further interdisciplinary investigation.

In 1988, during the construction of an apartment building in Holíč, a small town in western Slovakia, a group of large stones of unknown origin was discovered at a depth of three metres. Initially considered natural, the largest (measuring 6.8 m) was found with a human skeleton beneath it and unusual engravings on its flat surface. Slovak ethnologist Rudolf Irša was invited to the site, conducting a preliminary investigation later published in *Stones of Forgotten Times*¹. Despite this, construction continued and the stones were relocated multiple times. They now rest near the town castle, arranged artificially in the shape of a sundial (Fig. 1).

In 2004, Charles Tanguy Le Roux (Conservateur général du Patrimoine honoraire), known for his work at the Morbihan megalithic site in Brittany, visited Holíč and produced a detailed report². He classified the engravings into two main types: ‘conchoidal abductions’ (detached flakes from a core stone) used to shape the stones, and ‘décors’. The latter comprised three subtypes: large traces (around 5 cm wide, 0.5–1 cm deep, with flat bottoms), narrow V-profiled traces with zoomorphic and anthropomorphic motifs and nested hoops, and intermediate forms.

At the time of excavation, the stones were found lying horizontally. A simple site map published by Irša¹ indicates that eight of the stones were aligned westward, in the direction of the Morava River. The largest stone was

positioned perpendicularly to this alignment. Le Roux suggested that the layout may once have formed a circular structure. Archival photographs and residual earthworks support this possibility, showing traces of circular earthen mounds (Fig. 2).

The current authors revisited the site in 2022, accompanied by Mr Irša (Fig. 1). At that point, all but one engraving had been significantly weathered. Crucially, material that could have assisted in dating the site, such as two skulls and other human bones, had been lost.

Originally, the excavated site contained more than 40 megaliths and at least two human burials. The skulls and excavation is depicted on the photo from 1988 (Fig. 2). As noted by residents during the 2022 investigation, many of these stones were taken and reused for construction after the discovery. Only 21 stones remain today. The floorplan of current new position—sundial according the design and numbering of Mrs Irša is given along with measurements of the stones (Fig. 1). The original and new position of stones is shown on simple relief map of the city of Holíč, the valley of Morava river and the level profile is shown on a simple section drawing (Fig. 3).

Although megalithic structures are well documented across Western Europe, Slovakia is absent from most megalithic maps^{3–5}.

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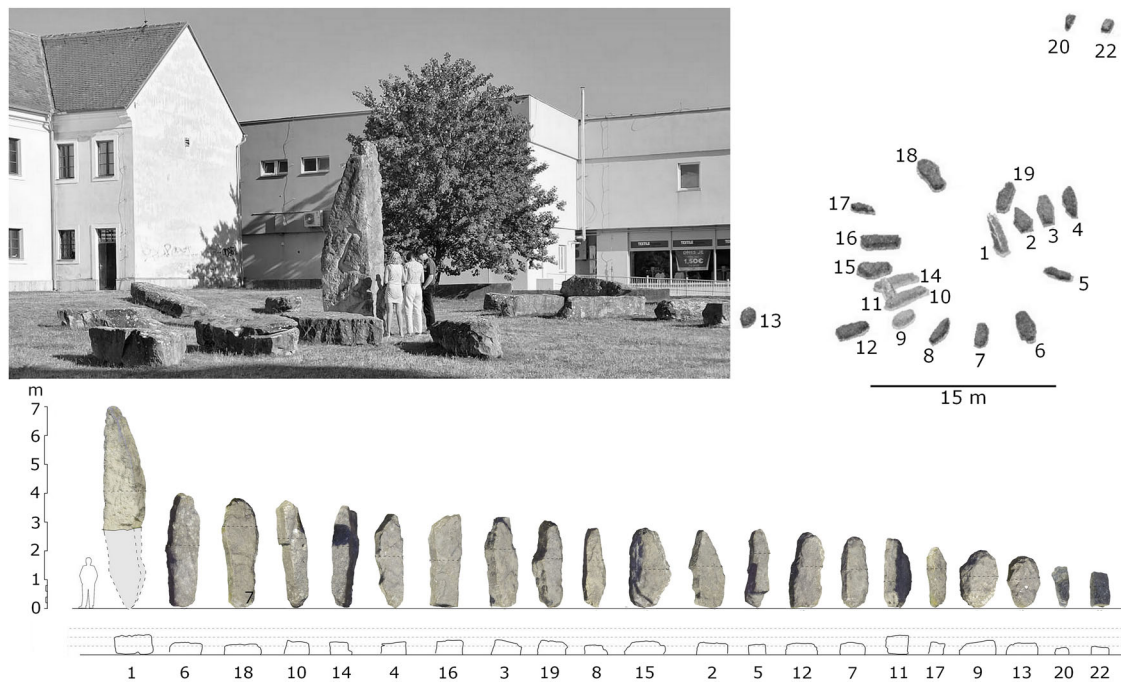


Fig. 1 | The investigation of the site in Holič, Slovakia, in 2022. The stones are artificially arranged in the sundial, with only one stone erected. (Source: photo of the authors and lasergrammetry of stones made by authors: floorplan of the site and row of stones sorted by height).

The Holič stones are not officially designated as a megalithic site and are not protected in any legal and also physical form. When the authors contacted Slovak researchers for more information on the original 1988 find, the stones were dismissed as natural by the workers in the Slovak Academy of Science, despite assessments by Le Roux, Irša and one of the authors, a geologist, confirming human modification. This dismissal may reflect limited expertise in this field. Religious history may also be a factor: as a Catholic country, Slovakia inherited prohibitions against the veneration of ‘pagan stones’, with past Christian emperors ordering their destruction⁶. This Christian approach may cause a lack of interest in cultures that adore natural objects in Slovakia.

Neolithic rondels have been documented in Slovakia⁷, and sandstone artefacts resembling fusiform axes, known in French as haches fusiformes and associated with Neolithic contexts in France, were found within 100 m of the Holič megaliths (Fig. 2)⁸. A clay animal figurine linked to the Lengyel culture was discovered in Holič⁹, showing similarities to Neolithic figurines elsewhere¹⁰. However, no direct dating is possible. Human remains originally excavated with the stones were lost, with only photographs of skulls preserved¹. While Le Roux confirmed the stones as human made², their chronological placement remains uncertain. Comparisons with Neolithic engravings across Europe (Table 1) suggest potential cultural links, though it is plausible the carvings were made after the stones were erected.

In nearby regions, megalithic structures are rare or poorly understood. The Czech Republic has no confirmed examples, though it contains enigmatic sites such as the Petrified Shepherd menhir and the Kounice rows¹¹. Poland has some references to lost or undocumented structures, such as a historical report from Krynica in the Sandecko area describing stone rows leading to a large circle with a central boulder¹². Austria and Hungary lack substantial Neolithic megaliths, making the Holič site particularly significant. The geographically closest prehistoric cultures include Lengyel (5000–4000 BCE), Bell Beaker (2800–1800 BCE), Uněťice (2300–1600 BCE) and the TRB culture (4300–2800 BCE). While TRB sites are known for megaliths, they are generally located in Denmark, northern Germany and Atlantic Europe⁵.

Geographically relatively close, but culturally very far is the Pavlov site, dated to Upper Palaeolithic period, situated only 50 km from the city of Holic. The region itself has a much deeper history than the Neolithic one.

Astronomical alignment is another recurring feature of megalithic sites^{13–15}. For instance, ‘the solar and lunar alignments of the Station Stone rectangle’ at Stonehenge highlight site-specific astronomical calibration¹⁶, p. 157. This has contributed to the development of archaeoastronomy as a distinct research field. The main gates or the entrances to Neolithic structures often point to the full moonrise, moonsets, or solstices and equinoxes of the sun. In this work, the consideration of astronomical orientation was studied as well. In Slovakia, some rondels from Lengyel culture dated to the Neolithic period (5000–4000 BCE) had their gates aligned with a full moon rise, so this event was visible through the opening in the wooden circular structure by the people living inside the circular settlement⁷.

Holič’s name itself may hint at the site’s past significance. In 1331, King Karol Robert and Jan of Luxemburg referred to the area as Alba Ecclesia; Latin for white assembly, gathering, highlands, or church. Yet the first church in Holič was not built until 1397¹⁷. The stones, now grey, were originally white-yellow-beige and situated prominently above the Morava River valley. This elevated visibility may have inspired the designation ‘white temple’.

Given its potential age, symbolic engravings and orientation, the Holič site may represent a missing link in the study of Neolithic monumental culture in Central Europe.

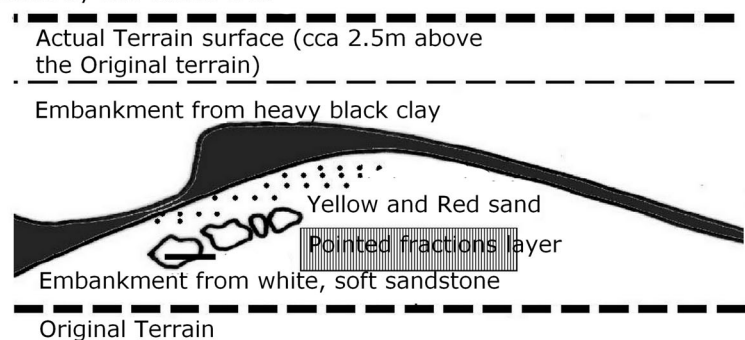
This study contributes to ongoing debates about the origins and distribution of megalithic traditions by providing new empirical data from a region previously underrepresented in such analyses. Despite the loss of key contextual evidence, the engravings offer a rare window into prehistoric expression and symbolism. A comprehensive reconstruction and comparative analysis is therefore urgently needed. Our goal is to document, reconstruct and contextualise the Holič engravings using a combination of lasergrammetry, archival photographs and comparative Neolithic analysis.

This article presents the reconstruction of three engraved stones from Holič, using 3D lasergrammetry, archival photographs and large-scale hand drawings. We compare these engravings with other European Neolithic motifs to assess cultural parallels, investigate possible astronomical orientations and explore their potential symbolic significance.

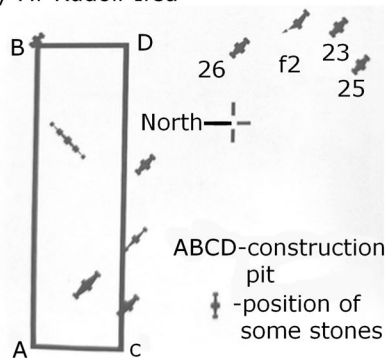
Photos from the excavation in 1988: the megaliths and two human skulls. (archive of Mr Rudolf Irsa)



Photo and simple sketch of Stratigraphic profile by Mrs Rudolf Irsa



The simple plan of the position of the 8 stones found in 1988 by Mr Rudolf Irsa



Fragments of Stone tools, burnt on some parts, made out from different types of stone. These were found directly in the site, layer close to the original terrain. The megaliths were found in the same level.



Sandstone dagger found in the vicinity of the site and the drawing of an animal figurine found in Holic. Both from neolithic period.



Fig. 2 | The photos from the archive of Mr Rudolf Irsa from the excavation in 1988, a simple plan and stratigraphic profile of the site taken from his book 1, the photos of the tools found in the deep layers. A sandstone dagger and animal figure were found in the city of Holic.



RELIEF MAP OF THE CITY OF HOLIČ WITH MARKED SITE OF EXCAVATION OF SANDSTONES AND OTHER IMPORTANT SITES

LEGEND

- ⊗ EXCAVATION OF STONES IN 1988
- CALVARY, PANORAMIC VIEW TO THE VALLEY
- LAPIDARIUM HOLIČ, CURRENT POSITION OF STONES
- ★ MEDIEVAL CASTLE
- ⬠ FINDING OF SANDSTONE DAGGER

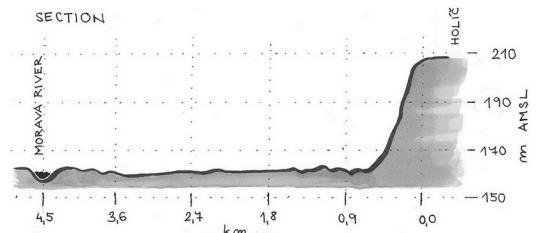

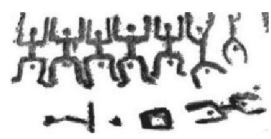
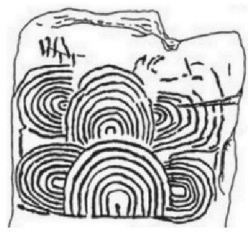


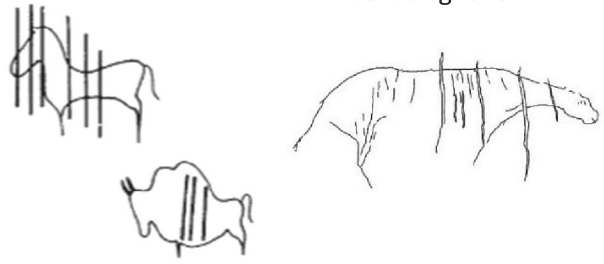





Fig. 3 | Relief map with highlighted locations and section of the whole area with Morava river. The site with finding was at the top of the sloped terrain in Holic. (source: authors).

Table 1 | Comparison of motifs depicted by Neolithic societies with the engravings in Holíč, Slovakia

Motives	Slovakia, Holíč	Site with megalithic art in Europe		
Human Circle Curve		Italy, Naquane, Valcamonica, rock 32 	France, Gavrinis, orthostat L4 	Scotland, Achnabreck 
	Animal		Italy, Balzi Rossi, Grotta del Caviglione 	
Tool		France, Bretagne 	France, Bretagne 	

Sources: Italy, Naquane, Valcamonica, rock number 32, 20; Gavrinis – orthostats number L4, 21; Scotland, Achnabreck, Argyllshire, 16; Italy, Balzi Rossi, Grotta del Caviglione, 22; France, Bretagne, 23. The depiction in the middle is borrowed from the table in the article from Lewis-Williams and Dowson 24(Lewis-Williams and Dowson). (Source of the simplified black drawings from Holíč: authors).

Methods

This study focused on the reconstruction of engravings on three stones from the Holíč site. One engraving remains clearly visible due to its execution using the large-trace technique described by Le Roux (2004)², which proved more resistant to weathering. The other two engravings, carved using finer lines, were no longer visible in situ during the 2022 investigation.

To document current surface morphology, the team conducted 3D laser scanning using a Leica RTC360 scanner. The instrument has an angular accuracy of 18", length accuracy of 1.0 mm + 10 ppm and length noise of 0.4 mm (within a 10 m circuit). The resulting point cloud, with 3D point accuracy of 1.9 mm over a 10 m range, was processed and analysed in CloudCompare. This lasergrammetry (the use of laser scanning to create detailed 3D models of surface morphology) builds on methods applied in previous studies of Neolithic engravings¹⁸.

The primary visual reference for the engravings came from photographs taken by Mr Rudolf Irša at the time of discovery, between 1990 and 2000. These images provided the clearest documentation of the motifs before significant degradation occurred. The photos of each engraving were also taken from different angles (Fig. 7), so the authors had good visuals to predict the depth and details of these petroglyphs. For more of the description of engraved lines from Mr Charles Tanguy Le Roux gave the most precise characteristics of these artworks. For example about the type of engravings shown in Fig. 7 he wrote: "The lines are very

narrow (less than 1 cm wide). Their profile is a flared 'V' shape, at least for those that are still clearly legible, as these have naturally suffered the most from erosion and encrustation; this is why it has not been possible to determine their technique. These lines also form the most elaborate compositions (nested arches, zoomorphic, anthropomorphic). For more, Mrs Rudolf Irsa published in his book 1 the simple drawings of all engravings on different stones and which Mrs Charles Tanguy Le Roux refers to, because in 2004, it was still visible. Only the stone number 1 had 4 engravings originally, from which only the biggest one is visible. For more Mrs Irsa published in his book the simple drawings of engravings on all the preserved stones: from 1 to 24—at that time, there were 24 stones, now only 21 are in the site. However, these drawings are only very rough images of the actual engravings (Fig. 4). That is why the authors of this article decided to make a precise reconstruction of it.

The first step in reconstruction involved identifying the dimensions and position of the engravings, using these photographs in conjunction with the 2022 3D scan data. Particular attention was paid to subtle surface anomalies no longer discernible to the eye. A follow-up site visit in 2025 enabled further ground-truthing. Large-format paper was used to trace the contours and fine surface features of the stones, particularly in the regions where engravings had been previously recorded. These hand-drawn outlines were subsequently cross-checked against the 3D scans to confirm alignment and proportions.

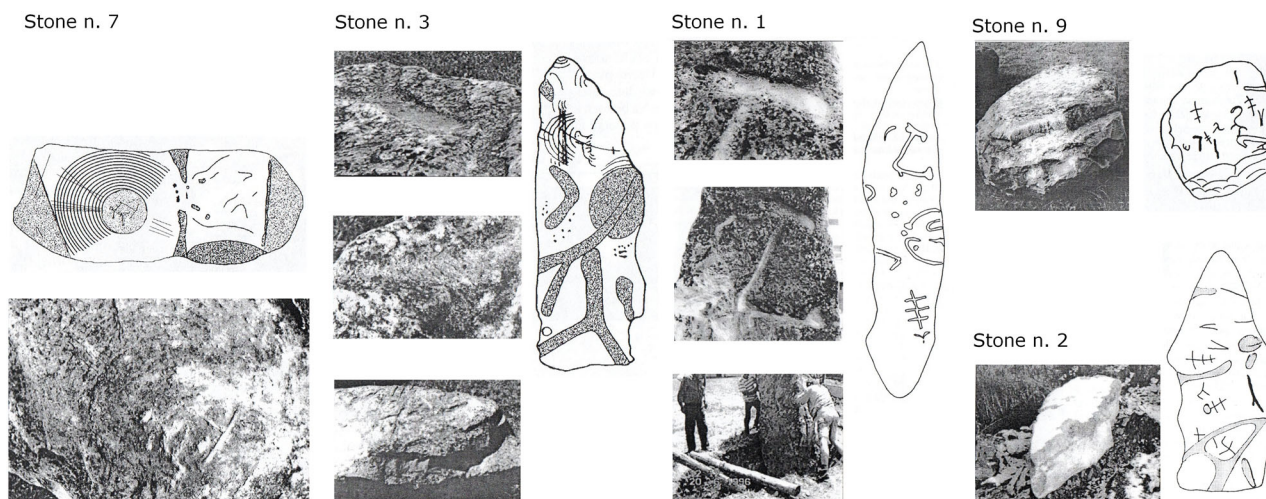


Fig. 4 | Examples of the engravings of different stones (photos taken in 1996) and simple drawings made by Mrs Irša 1.

The reconstruction process involved merging data from three sources: point cloud geometry from the 3D scans, hand-drawn surface tracings from 2025 and archival photographs. These were compared and integrated using AutoCAD. In AutoCAD programme all pictures were placed in real scale above each other as transparent images: the photos, the 3D scans, and the hand-drawn papers. The important points in the morphology of the 3D scans were identified, such as: deep point representing the head of the human figure, the deep points for the feet, very significant curved line from the inner circle and also a straight line that cut the whole depiction and is clearly visible on the 3D scan as well (Figs. 5, 6).

Final reconstructions were produced manually at real scale, with one example illustrated in Fig. 5, corresponding to stone number 7 in Irša's original documentation 1.

Results

Reconstruction of the Engravings

Visual examination at the original discovery site, near the apartment building in Holíč, revealed geological variability. The local bedrock ranges from fine-grained calcareous sandstone to siltstone. However, the megaliths themselves are macroscopically distinct, composed of heterogeneous sandy limestone with abundant fossil inclusions, particularly bivalve shells, deposited during the Sarmatian period in the Vienna Basin sea¹⁹. This material is susceptible to rapid degradation in outdoor conditions, which explains the extensive weathering of the engraved surfaces following exposure since 1989.

The archival photographs of the engravings were taken at various angles using lenses that introduced distortion. To accurately reconstruct the carvings, it was essential to identify reference points in the photos and align them with features still visible in the 2022 3D laser scans.

The engraving on stone number 7 preserved the most interpretable features. It includes long lines intersecting circular forms and additional markings that indicate a 'head', 'leg' and 'tool' held by the figure. Combining the archival photographs, the 3D scan data and full-scale hand tracing allowed the authors to produce a scaled reconstruction of the image (Fig. 6). In the original photograph, the white regions represent carved areas, while the darkened regions reflect stone discolouration due to weathering rather than shadows. The position of the flat engraved face, tilted during exposure, likely caused runoff to pool along one side, contributing to asymmetrical darkening. This alteration was accounted for in the reconstruction.

The engraving on stone number 3 had suffered more severe weathering, with only two lines remaining visible by 2022 (Fig. 7). The best available photograph, taken perpendicularly to the carved surface, captured a depiction interpreted as an animal. However, a secondary image showing the entire stone was taken at an oblique angle, introducing distortion and

complicating the reconstruction of the parallel circles above the figure. Despite this, the remaining lines and the scanned morphology enabled a plausible reconstruction based on proportional estimation.

The third engraving, located on stone number 1, was carved using large, flat-bottomed traces approximately 5 cm in width. This engraving remains clearly visible on the 6.8-metre-long erected stone (Fig. 1), and the 3D scan conducted in 2022 provided sufficient data for full-scale reconstruction (Fig. 8).

Comparative context: engravings in European megalithic sites

To contextualise the Holíč engravings within broader European Neolithic traditions, comparative analysis was conducted using examples from France, Italy and Scotland. Table 1 presents recurring motifs across sites such as Naquane (Valcamonica), Gavrinis, Achnabreck, Balzi Rossi and Brittany^{16,20–24}. Balzi Rossi engraving belongs to a much older cultural period than the other engravings – Palaeolithic, but there is evidence that the settlement continued in Neolithic in Balzi Rossi as well, so the engraving could belong to this period.

Geometrical analysis of the parallel circular engravings was conducted using AutoCAD (Fig. 9). The reconstructions adopted a groove width of 0.7 cm, based on Le Roux's measurement of the narrow traces². Notably, in both reconstructed examples, the concentric circles are centred on anatomically meaningful points: the head of the human figure and the heart of the animal.

Archaeoastronomical orientation

At the time of excavation, the stones were found lying horizontally. A simple site map published by Irša 1 indicates that eight of the stones were aligned westward, in the direction of the Morava River, which corresponds approximately with the sunset at the summer solstice (Fig. 10). The largest stone was positioned perpendicularly to this alignment. Le Roux suggested that the layout may once have formed a circular structure². Archival photographs and residual earthworks support this possibility, showing traces of circular earthen mounds. During the 2022 investigation, local residents reported that the original site contained more than 40 stones. Many were reportedly taken and reused for construction after the discovery.

Discussion

Although the Holíč site cannot be securely dated, there is strong circumstantial evidence that it may belong to a broader Neolithic tradition.

Concentric circles or parallel curves are one of the most frequent motives on megalithic stones, and chosen ones are presented in Table 1. Some interpretations of other megalithic sites have suggested symbolic or environmental interactions involving energy, vibration, or frequency,

Fig. 5 | The example of the process with combining old photos taken between 1990–2000 by Mr Rudolf Irša, 3D scan from 2022, full-scale hand drawing with existing traces from 2025 in the programme Autocad. The result was performed by hand in a full-scaled picture. The example is from the stone n. 7 according to the numbers from Mr Rudolf Irša 1.

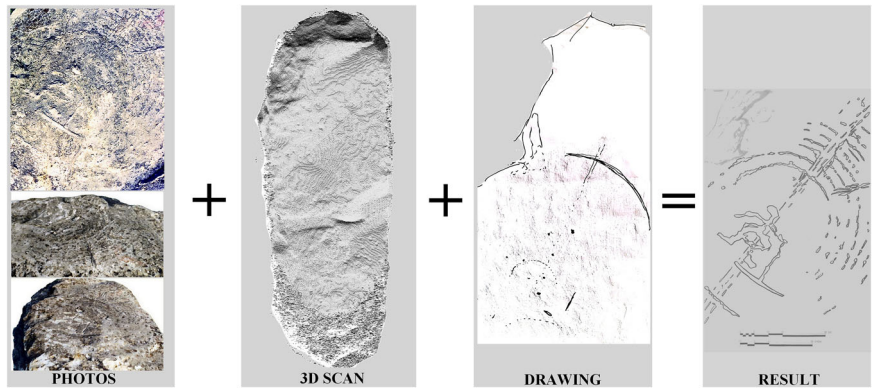


Fig. 6 | The reconstruction of the engraving on stone number 7. The figure may depict a human holding a tool, although the gender and precise function remain uncertain. The outer circle diameter is around 88 cm, 34.65 inches, the human figure is around 25 cm, 9.84 inches high. The circles have a distance of approximately 3.5 cm, 1.38 inches between the axes of the curves. The drawing was done after the visit of the site using paper on the stone to take significant morphological marks 10th of July 2025. The presented drawing and the photo are taken along its longitudinal axis of the stone on its eastern side. So, the depiction's main line is in 50° angle to the longitudinal axis of the stone. (Source: left photo of Mr. Rudolf Irša, right full-scale drawing of the author).

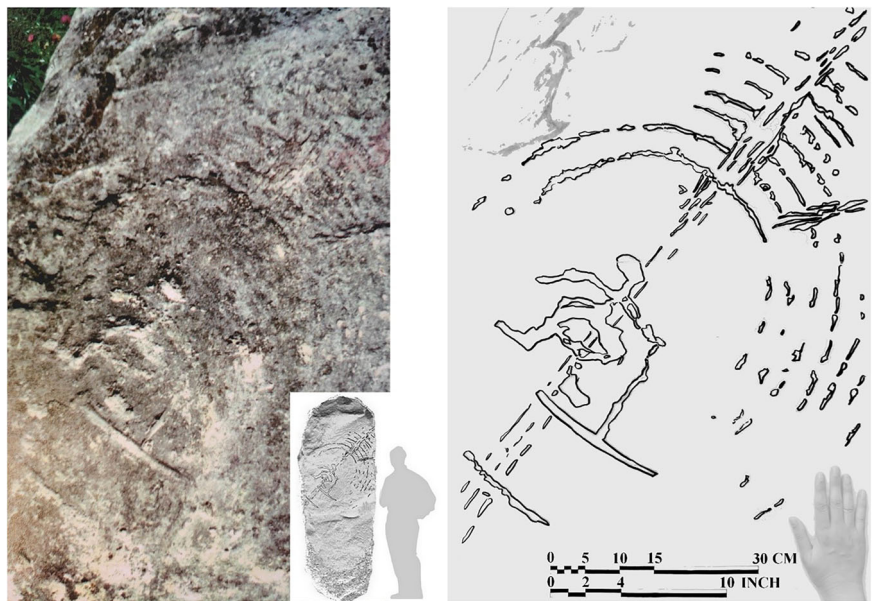


Fig. 7 | Reconstruction of the engraving on stone number 3. The depiction is visible on the photo of the whole stone on the top side in the right part. The reconstruction using 3D scan and full-scale hand drawing mainly considered the two markedly visible lines on the top of the depiction. The depiction can represent an animal with parallel parts of the circles above. Can the animal be a sheep? The animal is around 20 cm, 7.87 inches high. The parts of the circle are around 2.2 cm, 0.87 inches between the axes of the curves. The drawing was created after the site visit, using paper on the stone to capture significant morphological marks on July 10, 2025. The position of the depiction is still visible on the old full stone photo on the right part. (Source: photo from Mr. Rudolf Irša, drawing by the author).

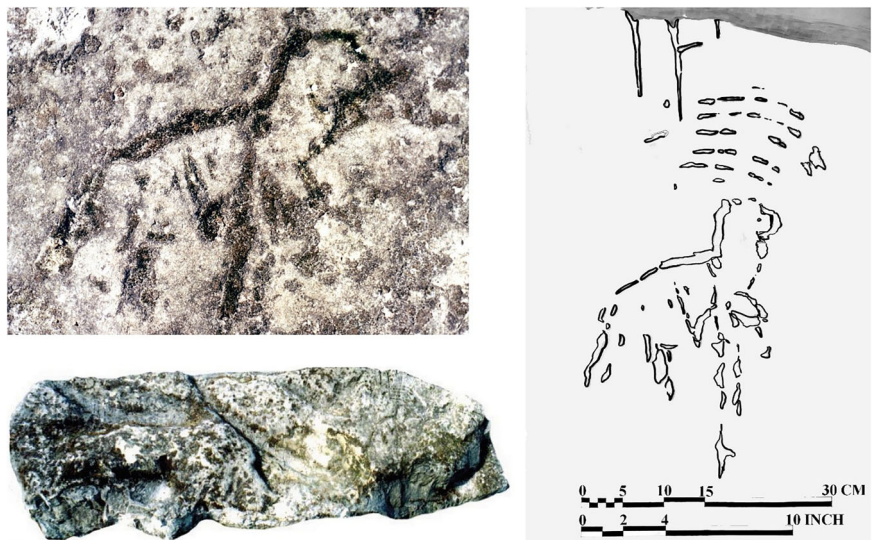
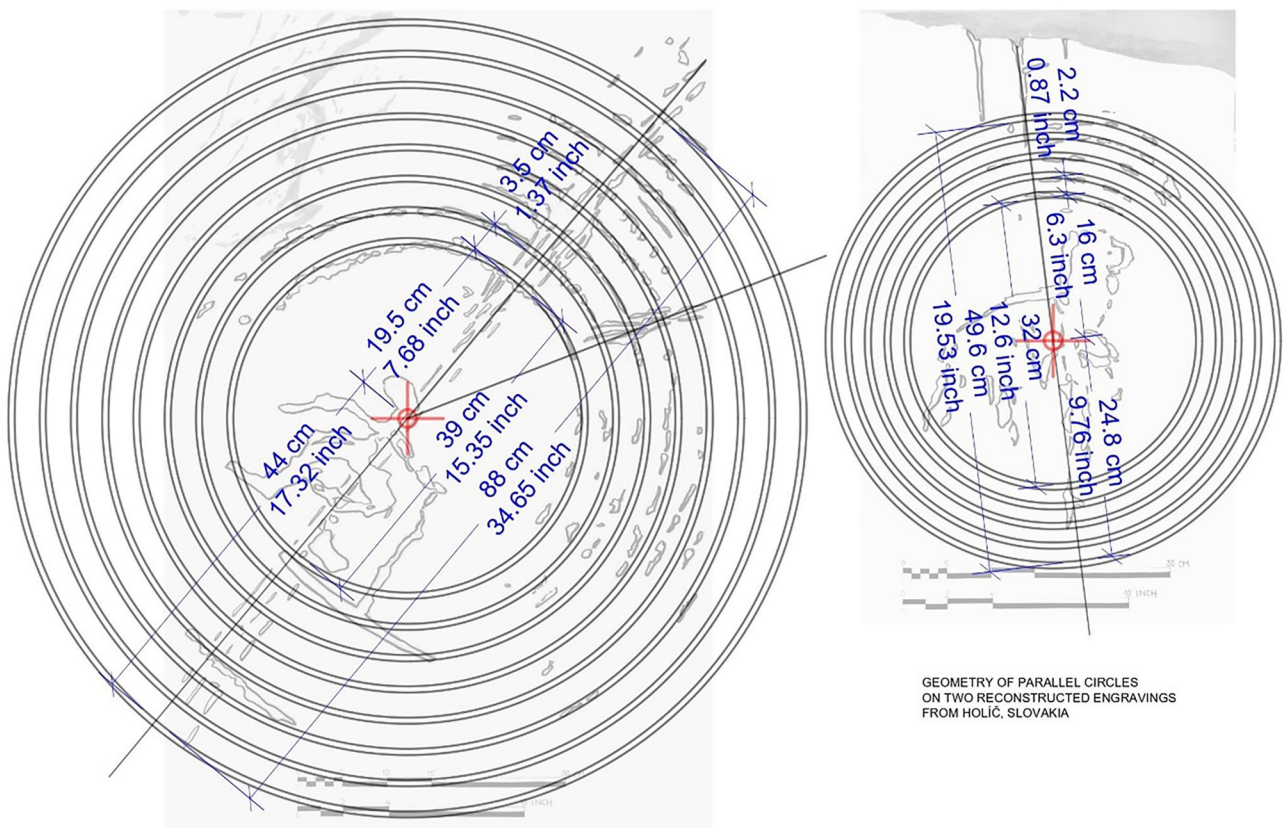
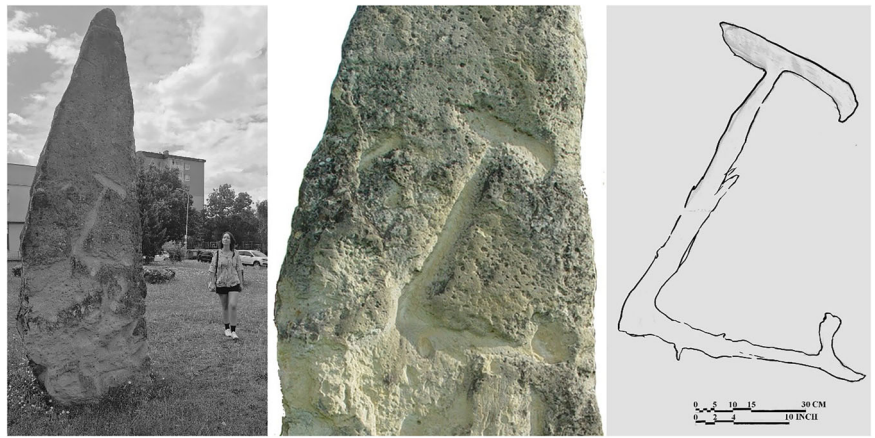


Fig. 8 | Reconstruction of the engraving on stone number 1 in Holič, Slovakia. The largest of all stones has multiple engravings, which were still clearly visible during the investigation in 2022. The largest part is around 90 cm long, 35.4 inches. The drawing was created after the site visit on July 10th, 2025. (Source: photo from Mr. Rudolf Irša, drawing: authors).



GEOMETRY OF PARALLEL CIRCLES ON TWO RECONSTRUCTED ENGRAVINGS FROM HOLIČ, SLOVAKIA

Fig. 9 | Analysis of the geometry of parallel circles on two engravings performed in the programme AutoCAD. The width of the carved circle is 0.7 cm, according to the size description from Charles Tanguy Le Roux 2.

though these remain speculative and unproven. As Pierre Mereaux stated, ‘Menhirs are known to attract lightning.’ Burke and Halberg add: ‘This is not surprising because at the base of these giant stones he (Mereaux) measured negatively charged electric ground currents that interacted with the positive atmospheric electric field... Passage graves were placed on spots of magnetic variation’²⁵, p. 104–105. A magnetometer survey at the Rollright Stones revealed that ‘the average intensity of the geomagnetic field within the circle was significantly lower than that measured outside, as if the stones acted as a shield’²⁶, p. 105. At Avebury, electromagnetic measurements recorded by a spectrum analyser showed ‘the strongest recorded trace of electromagnetic signal transmits energy to other standing stones’²⁷, p. 41.

Stonehenge has been found to possess distinct acoustic properties, the amplification could have aided speech communication and the

reverberation improved musical sounds²⁸. Earlier work by Devereux and Wozencroft showed similar acoustic effects at other Stone Age sites²⁹.

Sound, like magnetism, is an energetic phenomenon perceptible to humans. It is plausible that megalithic structures were situated and shaped to interact with such forces. While these ideas cannot be confirmed at Holič due to the absence of direct geophysical measurements, they offer a comparative framework for considering how prehistoric communities may have perceived and interacted with their environments.

The river was probably much larger in the age of neolith, because the continental glacial sheet was melting. The river Morava spanned the whole valley and probably contained many branching streams. The rock environment in the wider surroundings of Holič belongs geologically to the Vienna Basin and has a very complex geotectonic development on the

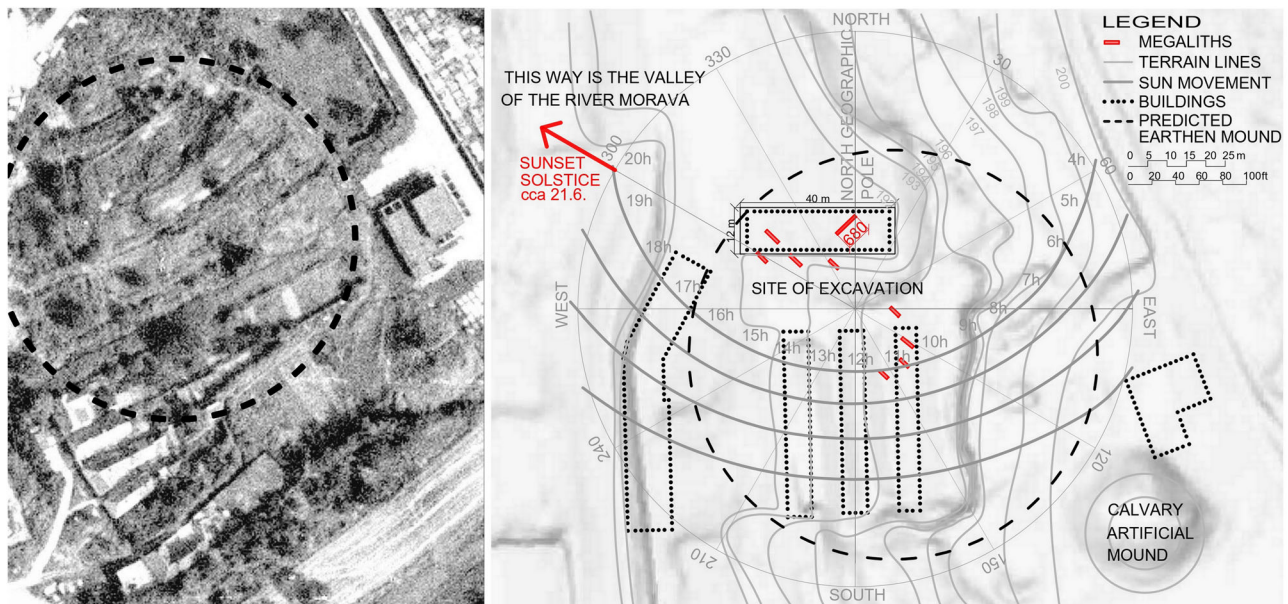


Fig. 10 | The old photo of the site with partly visible circular mound of the previous structure and the actual morphology map with solar diagram and indicated previous structure with dashed line. (Source: photo taken by Mr. Rudolf Irša between 1950 and 1988 and geometry performed by authors in AutoCAD).

border of the Western Carpathians and the Northern Limestone Alps. The rocks are of sedimentary origin and were deposited during the Ottnang to Upper Badenian periods, which were mainly a marine environment. From the Middle Badenian onwards, the basin gradually became an epicontinental sea bay and salinity decreased. In the Sarmatian to Pannonian period, the waters were brackish. But by the end of the Pannonian, the waters of the isolated basin were fresh. The source of the clastic material was the rising mountains around the basin³⁰.

This study provides the first detailed reconstruction of three engravings from the Holíč site (Figs. 2–4). Two are especially elaborate: one shows a human figure holding a tool and surrounded by parallel circles or a spiral (Fig. 2); the other depicts an animal with similar circular forms above it (Fig. 3). Although parallel circles occur at other Neolithic sites such as Achnabreck, Gavrinis, Newgrange and Malta^{15,16,31}, depictions combining such geometry with anthropomorphic or zoomorphic figures are rare in the European context. For more, the concentric circles on both pictures have its centres in significant anatomical points shown in Fig. 9. In the case of a human figure, the centre of the circles is on the head, more precisely the nape of the neck. In the case of the animal figure, the centre of the circles is situated in the heart.

Our comparison of the Holíč engravings with other sites (Table 1) highlights their unusual complexity. No bronze or iron artefacts were reported from the 1988 excavation, conducted three metres below the original surface 1, supporting a possible Neolithic origin, aside from a single unshaped piece of iron, found without a clear stratigraphic context. Most other finds were worked stone, some showing signs of burning and edge shaping. The execution of the largest engraved circle (measuring 88 cm in diameter) is particularly remarkable, raising questions about the techniques and tools used. It is unlikely such precision was achieved by chance. As observed elsewhere^{16,32}, Neolithic engravers often worked with the natural contours of the stone, and this pattern is also evident in the Holíč carvings (Figs. 2 and 3). The compositions may reflect symbolic thought and purposeful arrangement by the creators, consistent with interpretations at other Neolithic sites. Unfortunately, because of the lack of materials found on the site, the engravings cannot be securely assigned to any period.

Finally, the original alignment of eight stones toward the summer solstice sunset (Fig. 6) supports a possible astronomical function. The site's elevated position overlooking the Morava River valley and its historic name, Albas Ecclesia (meaning 'white assembly' in Latin), may reflect an earlier

sacred or ceremonial landscape. Although key archaeological materials were lost and no stratified context remains, the engravings and reconstructed site plan suggest symbolic, possibly astronomical or ritual significance. These findings indicate that Holíč may represent an overlooked locus of monumental culture in Central Europe. Further interdisciplinary research and heritage protection are warranted, though all interpretations must remain provisional in the absence of direct dating.

Data availability

All data supporting the findings of this study, including 3D scan point clouds, photographic records, hand-drawn reconstructions and comparative geometric analyses, are available from the corresponding author upon reasonable request. Due to cultural heritage considerations and ongoing site protection discussions, precise geolocation data are restricted but may be shared for academic research purposes subject to approval.

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Author contributions

I.D. conceptualised the project, developed the methodology, made the reconstruction of the engravings, and the hand-drawings, comparative analysis, archaeoastronomy. Unfortunately, our great colleague P.P. passed away (22.10.2025) after the Manuscript was sent for publication (1.8.2025) and that is why we miss his valuable comments for the review process. During the work on a topic, he directed the 3D scanning, lasergrammetry processing and geological analysis of the site and stones as well as the geological context in comparison with other Megalithic sites. S.I. contributed to developing the topic as a valuable part of human history, the interpretation of findings and supported the drafting and revision of the manuscript. All authors approved the final version. This study received no funding.

Competing interests

The authors declare no competing interests.

Additional information

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