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Close-range photogrammetry for analysis of rock relief details: An investigation of symbols purported to be Jewish Menorahs in Rough Cilicia

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Abstract

Close-range photogrammetry of certain rock reliefs in Rough Cilicia was used to investigate published claims that symbols in them represent Jewish menorahs, but with five branches instead of the usual seven. Details of ancient rock reliefs are difficult to assess because of mottled rock texture, color variation, wear or damage, and conditions of lighting. Thus, published photos of the rock reliefs in question are insufficient for evaluation of claims about them. Simple photogrammetry, however, produces 3D and digital elevation models that eliminate visual ambiguity and provide certainty of detail for analysis. This study describes the simple, non-invasive, and inexpensive data collection technique and the photogrammetry software processing workflow for creation of such models. Resulting models in various presentation formats provide factual data for reevaluation of the claimed menorahs themselves and their relationship to other elements of the reliefs. These findings contribute to informed discussion on interpretation of the symbols and their meaning. Adoption of the process described here is encouraged for subsequent publication, analysis, and interpretation of rock relief details in the region.

1. Introduction

Photogrammetry has firmly established itself as a tool in archaeology and recent years have seen a significant increase in its use [1]. The availability of unmanned aerial vehicles (UAVs), innovations in photogrammetry software, and the relative cost decreases in both have now made it a routine alternative to traditional methods for making site plans, elevations, and sections [1-2]. The most often employed form in archaeological work is modeling using the technique called "structure from motion" (SfM), in which tie points between overlapping photos, as well as camera positions and angles are determined and used by complex software packages. The principles and processes of SfM are well-established and documented [2-3] and do not need to be rehearsed here. Simple SfM photogrammetry can be utilized in the field efficiently, with data collection carried out by non-photogrammetry experts having minimal training [3].

The potential of SfM for high accuracy detail has been well-established in geomorphology [4]. In archaeology, its utility for detail detection is demonstrated by recent use in caves for reassessment of Paleolithic figural art [5] and to reveal artwork imperceptible to the human eye under difficult conditions [6]. Meanwhile, the technique has been increasingly used as a simple and low-cost option for documentation of petroglyphs [7] and other forms of rock art [8-9]. The combination of accuracy, ease, and low cost make SfM photogrammetry an ideal tool for analysis of detail in rock reliefs, as well as for routine documentation and presentation of them.

A recent review of SfM applications laments that most current publications are "proof-of-concept" studies, and that photogrammetry is rarely used for actual analysis of archaeological material [10]. This article presents such analysis; conducted with close-range photogrammetry to reveal and clarify details of previously published rock reliefs depicting certain symbols in the region known as Rough Cilicia.

Rock-cut reliefs are a prominent and significant feature of the archaeological remains in Rough Cilicia. Figural reliefs are especially well-documented, and their context is generally understood [11]. Symbols are also prominent in the region, appearing most often in relief on building components but also on living rock. These are more difficult to assess and interpret. Some symbols have been grouped and plausibly identified, [12] but their function and meaning for ancient persons remains obscure [13].

In many cases, assessment and identification of symbols is hampered in the field and in documentation for publication by problems inherent in rock reliefs. These include: conditions of lighting; mottled color and texture of the rock; growth of lichens; and wear or damage to the surface.

This study examines such a case; rock relief symbols I believe to be misidentified and misinterpreted. It also demonstrates the great potential of simple and low-cost close-range SfM photogrammetry for this type of research. Finally, it encourages adoption of this technology—heretofore underutilized by archaeological work in Rough Cilicia—for documentation, assessment, and publication of rock reliefs; and, indeed, for analysis and reevaluation of details as conducted here.

2. Method

The work reexamined a set of rock reliefs, each apparently including the same symbol. All were previously published in archaeological reports with monochrome photographs and verbal descriptions. Each relief was visited in December 2023 and documented in a non-invasive manner by digital cameras for later photogrammetric processing. The resulting 3D models greatly facilitated analysis of the subject examples. Results also provide exemplars for other archaeological research by demonstrating potential for presentation, analysis, and interpretation.

2.1. The Reliefs

The three subject reliefs examined here feature a certain symbol identified by various researchers as a Jewish menorah, a view questioned or rejected by other scholars [14], including a colleague and myself [15]. Hereafter, this symbol is designated by the neutral term *semeion* (ancient Greek *σημεῖον*, "sign," "token," or "mark") [16]. Each of the three reliefs feature the *semeion* in combination with known pagan symbols; two on door lintels at Köşkerli and OÖ rendibi, and one accompanying a larger figural scene called the Athena Relief. All occur in the territory of Olba, a city of the Hellenistic through late Roman periods in the present district of Mersin, part of the region known in antiquity as Rough Cilicia (Figure 1).

The basis for identification of the relief symbols as menorahs comes from a small limestone altar in the Silifke museum, said to originate from the Olba area, on which a *semeion* appears prominently (Figure 2). The original publisher identified the symbol as "without a doubt" related to Judaism, despite the fact that the *semeion* on the altar has only four "branches" as opposed to the usual seven on a Jewish menorah. He argued that the star above "replaced" one branch and that five branches is a "very frequent simplification" [17].

The same symbol in each relief of this study is called a "menorah" [18-19] and "five branched" by subsequent scholars [20]. Published photos do not provide the detail necessary to dispute this claim. Thus, these reliefs provide excellent examples of the difficulties in description of rock relief details, as well as the shortcomings of usual monochrome photographic documentation. More importantly, they demonstrate the advantages of close-range photogrammetry for those

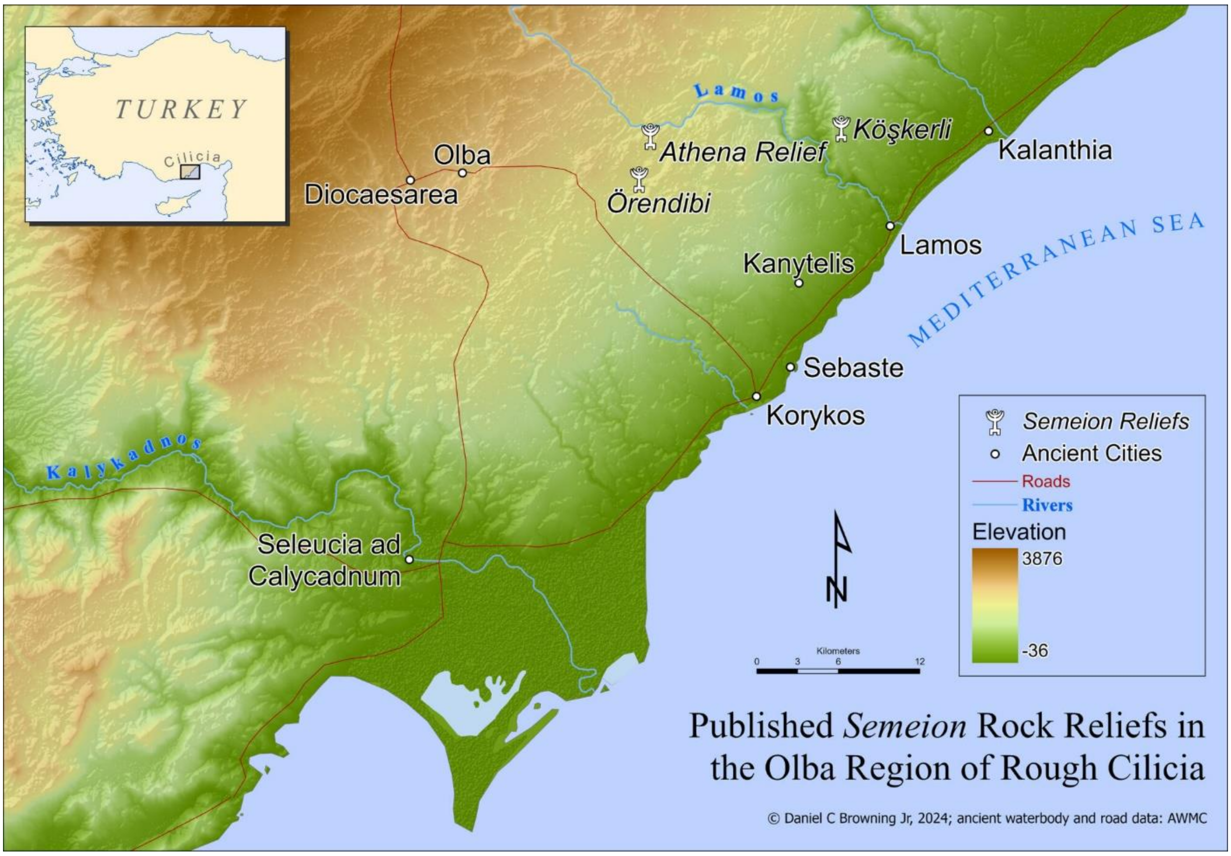


Figure 1. Map of published *semeion* relief sites in eastern Rough Cilicia.

tasks and its utility for reassessment by other researchers.

Figure 2. The Silifke Museum altar with *semeion* motif.

2.2. Photography

The sufficiency of inexpensive DSLR cameras for close-range object photogrammetry has already been established in archaeology [7, 21]. This study emphasizes the practical use of low-cost equipment and ease of data collection for survey projects. Accordingly, an older consumer grade Canon EOS Rebel T2i with a 50mm lens served as the main camera. Also on hand was a second Canon T2i with a 28-55mm zoom lens for tight areas and a UAV-mounted Hasselblad L1D-20c for high shots. The Canon T2i cameras do not contain onboard GPS and thus do not embed location or reference system information in image EXIF fields as do professional or specialized cameras like the Hasselblad L1D-20c.

Most photogrammetry tasks currently use SfM software, in which camera positions and angles are determined in image space without coordinates or scale. Professional software, however, automatically extracts geographic coordinate system and position information from EXIF data, if it is available, and creates position and scale. Even so, large projects such as UAV mapping, cultural monument documentation, or the like, employ ground control points (GCPs) to improve location accuracy and ensure precision in measurement. Experiments in SfM documentation of petroglyphs show that the time-consuming and complex use of GCPs is not required to obtain results comparable to laser scanning for such projects [3]. Moreover, placement of GCP markers involves physical contact with and potential damage to the artifact.

To avoid contact with the reliefs, GCP markers were not used in this study. However, as noted below (section 2.3.2), a reference scale is required for creating a digital elevation model (DEM). A 10cm photogrammetric scale was placed in the photographic scene where possible to provide that reference.

Reliefs of interest were photographed in a simple fashion without tripods or special lighting. Autofocus was used, but other camera settings were set manually for most images. Depending on lighting conditions, shutter speed was kept at 1/160 if feasible, and apertures as small as possible for greater depth of field. Each relief scene was covered entirely with maximum overlap of photos from numerous positions and an effort to keep angles at less than 30 degrees from perpendicular to the surface. More photos than needed were taken so lower quality ones could be identified by the software and excluded. Figure 3 illustrates camera positions relative to a sparse cloud of the Köşkerli lintel (after initial processing described below).

Photographic shooting requires only a single person in theory. However, the greatest impediment to full coverage of reliefs in Rough Cilicia is blockage by foliage, especially the ubiquitous scrub oaks of the region. For the fallen lintel at Köşkerli as well as the standing lintel at Örendibi, an assistant held back scrub branches to enable a clear view during shooting. Another potential impediment is orientation of fallen reliefs to the ground or other remains, limiting shooting distances or angles. Hence the backup Canon T2i with a wide angle zoom lens; but it was not required for these subjects. The Athena Relief, however, could not be photographed from above the symbols by hand-held camera without contact with the monument. Therefore, the UAV-mounted Hasselblad provided higher elevation photos and embedded reference data for scale.

2.3. Data Processing

2.3.1. Photogrammetry software and general workflow

All photogrammetry processing employed Agisoft Metashape Professional 2.1.0, which has emerged as the dominant software for archaeological work [10]. Table 1 outlines the basic "Workflow" steps in Metashape with options used for each relief. Metashape terminology appears hereafter with quote marks on first use. Photo organization and static output image processing used ACDSee Photo Studio Ultimate 2020, version 13.0.

The sequence in Table 1 was carried out for the full surface of each relief to provide perspective and relationship between the symbols. Each resulting full model "chunk" could then be duplicated and cut down using selection and delete tools to focus on *semeion* representations and other symbols of interest.

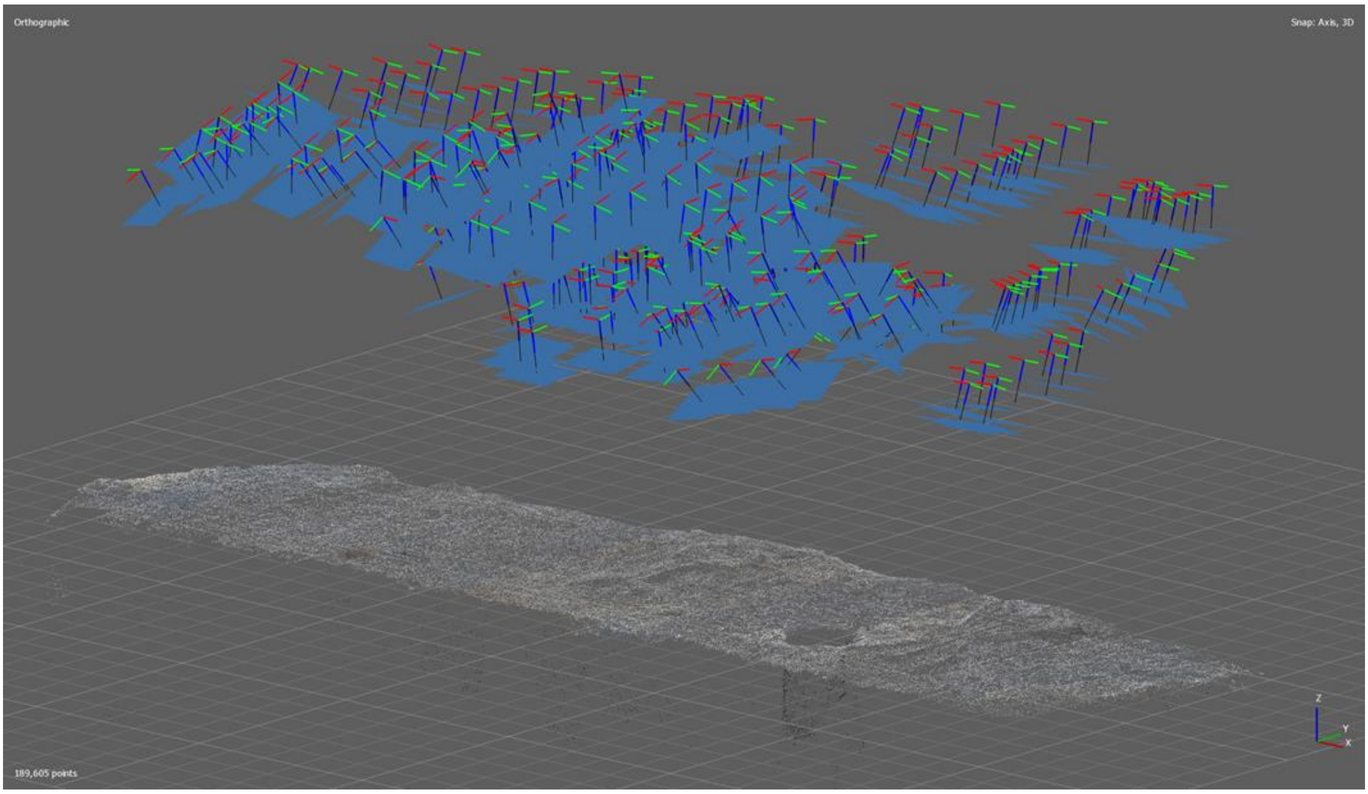


Figure 3. Metashape calculated camera positions and sparse cloud (tie points) for the Köşkerli lintel.

Table 1. Photogrammetry workflow in Agisoft Metashape Professional 2.1.0.

Metashape Workflow step	Non-default options used	Subsequent tools; operations prior to next step	Result (alternate terms)
Add Photos	(Add folders)	Estimate image quality; disable photos with value < 0.500	
Align Photos	Accuracy: High	Optimize Cameras; rotate and resize "region" to limit processing area	Tie point cloud (sparse cloud)
Build Point Cloud	Quality: High Depth filtering: Aggressive	Use selection tools to highlight and delete extraneous points	Dense cloud
Build Mesh	Surface type: Arbitrary (3D) ✓ Calculate vertex colors	Duplicate 3D model for multiple texture options	3D surface model (wireframe)
Build Texture	Diffuse and Occlusion	Reorientation and referencing required before DEM creation (details in text)	Photorealistic surface for model
Create DEM		Change display options for best visual representation	Orthometric DEM

2.3.2. Special considerations and procedures for analyzing rock relief symbols

The goal in photogrammetric analysis of rock relief symbols is clear revelation of the carved design details. Therefore, relative heights of various parts of the work above the background plane must be highlighted. For reliefs, the default background plane equals the X-Y axis plane and heights, or "elevations," are along the Z axis. Most rock reliefs have a vertical orientation, with heights along the Z-axis parallel to the ground towards a standing viewer. Therefore, a plan view ("top" view in Metashape) actually shows the front or "face" of the relief. Orientation of the photogrammetry-derived model to those axes is important for presentation and assessment, especially for depiction of relief height detail.

If photos with EXIF GPS data are used for processing, Metashape (and other software packages) automatically assigns a default geographic coordinate system as the reference system to the resulting digital model "object." This reference system must be cleared and replaced with a "local coordinate system" to align the object to the X, Y, and Z axes as noted above. If photos do not have embedded GPS data, the software assumes a local coordinate system without reference or precise scale and with arbitrary orientation, so object reorientation to the axes is still required.

For each relief, the digital model was rotated and moved so the background plane of the relief aligned with the X and Y axes. Because relief background planes (the rock surfaces) are not completely smooth or even, this procedure involved visual judgement. Viewing the object as a point cloud in the "elevation" display option along each axis provided the best means for making this judgement (Figure 4). Both the object and its "region" (the boundaries for processing) were rotated and adjusted using Metashape's transform tools. The "update transform" tool fixed the new orientation. This procedure could be done after creation of the point cloud or at any point later to the full model.

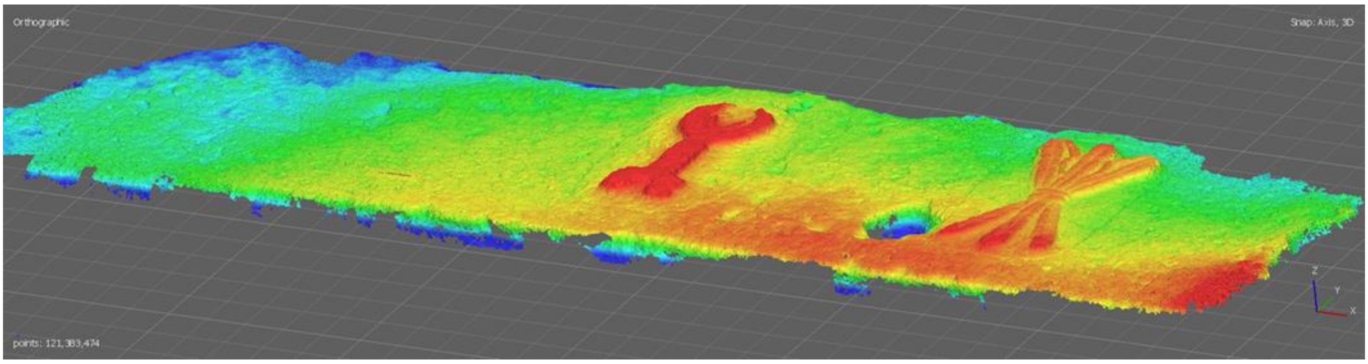


Figure 4. The Köşkerli lintel face dense point cloud with elevation display in Metashape.

To produce a DEM in Metashape, the properly oriented object must be referenced or scaled. The 10cm measuring card placed in the photographic scene allowed creation of reference scale using the following procedure (using tools in the reference pane of Metashape): 1) add markers at beginning and end of the 10cm scale; 2) select both markers; 3) create scale bar; 4) edit scale bar by assigning 0.01(m) to the distance field; and 5) update transform.

If no measuring scale could be safely placed and embedded GPS data from the photos were relied upon for scaling or reference, this will be lost when the reference system is cleared for reorientation to the X, Y, and Z axes. In this case, the following workaround was developed (described using Metashape tools and terminology): 1) add two or three pairs of separated markers at different orientations on the object's surface; 2) using the ruler tool, measure and note distances between each pair of markers; 3) clear GPS data from photos and "uncheck" them; 4) open reference settings for "chunk" and set coordinate system, camera reference, and marker reference to "Local Coordinates (m)"; 5) for each pair of markers, select and create scale bar; 6) edit scale bars by assigning noted distances; 7) "check" markers and scale bars; 8) update transform.

Using a local coordinate system for reference establishes arbitrary zero points for the main axes of each object. For this study no CGPs were placed, and no physical measurements were made of any monuments or remains. Therefore, all indicated elevation and other metric figures should be considered accurate relative to the objects concerned, but not verified in terms of absolute precision.

2.3.3. Output for display and analysis

The 3D model can be displayed within the software in various modes: as tie points, dense cloud, or polygonal surface model. Multiple display options exist for each mode. After the "Build Mesh" step, the resulting polygonal surface model can be displayed as a wireframe, showing the vertices of all polygons; or as a solid, with all polygons in the same neutral color. All mesh models for this study were built with the "calculate vertex colors" option, so polygon vertices have color determined by the dense cloud points. This allows the "shaded" display mode, described below. If the source photos were taken under conditions that created significant shadows and highlights, Metashape's "remove lighting" tool could mitigate these before creating texture. Photos for the models created here did not require this process.

2.3.3.1. Interactive 3D models

The final step for display of solid 3D models with a photo-realistic surface is creation of texture. The default texture for 3D models is a "diffuse map," with color for each polygon determined from the original photos. Models of the three examples below with diffuse texture provided detailed, realistic, and accurate representations for each relief. The diffuse display, however, retains some of the problems for interpreting relief details from photos or in person: the mottled color and texture of the rock (Figure 5).

A model can be exported from Metashape into any standard 3D object format and viewed with interactive rotation to inspect all details using a computer, tablet, or phone with proper software. Even with interactive 3D viewing, models with diffuse texture did not reveal the symbols as clearly and unambiguously as desired. Publishing 3D models online also requires permanent specialized accounts and/or embedded viewing software which creates complication, maintenance, and additional expense. Furthermore, interactive 3D models do not conform with most current print or journal publication options.

Metashape and other high-end photogrammetry software allow other display options that fit with this study's goal of demonstrating relatively simple and inexpensive options for publication and analysis of rock relief details. For each relief in the study, a wide variety of options were set up within Metashape and saved as static images. The following display types proved to be the most useful.

2.3.3.2. Static model display

The most straightforward method of creating figures for traditional publication is to save static images of 3D models in orientations that best illustrate details. But the limitations of the 3D model with a diffuse display were even more problematic with this approach (Figure 5). Other display options provided better detail clarity in both interactive 3D viewing and static display in a standard plan view.

Since polygon vertices were calculated with color while creating the mesh for each model, they could be displayed with effective realism without the textures map. The “shaded” view option displays polygons with colors interpolated from the vertices and shading created by a default ambient light. For each relief, this highlighted more surface detail (Figure 8a) than diffuse texture. More ambiguity was eliminated by the “solid” display option, in which all polygons have the same neutral color with relief highlighted by the default ambient lighting (Figure 8b).

Figure 5. Perspective of Köşkerli lintel *semeion* model with texture display.

The least ambiguous display for relief detail resulted from a technique used to achieve photorealistic display of 3D models or computer graphics. In the “Build Texture” step of general workflow (Table 1), one option allows creation of an “occlusion” map, in which each polygon is shaded according to how much ambient light reaches it. Normally combined with other textures to create shaded color, the resulting black-to-white ambient occlusion (AO) map revealed excellent detail when displayed alone without lighting (Figure 8c). This technique arguably provides the best illustration of the sculptor’s intent, as it incorporates the effects of ambient lighting with elevation of relief.

2.3.3.3. Point cloud with elevation display

Since elevation above the background plane is the essence of relief work, elevation display options in the software were extremely helpful in analysis. The point cloud display mode with elevation option facilitated orientation of the full relief models (section 2.3.2 and Figure 4). It also provided an option for presentation in plan view.

For analysis of individual symbols, the full relief model was duplicated and reduced with selection tools and deletion of unnecessary areas. In some cases the remaining model required reorientation to its own local background plane. The elevation color ramp for point cloud display is the same as for DEMs in Metashape, with the range determined by point cloud field thickness. Trimming extraneous points on the back side of the symbol model (invisible in plan view) modified the color distribution for optimal presentation. Adjusted in this way, point cloud representation as elevation dramatically revealed symbol details as relative height (Figure 6, 8d).

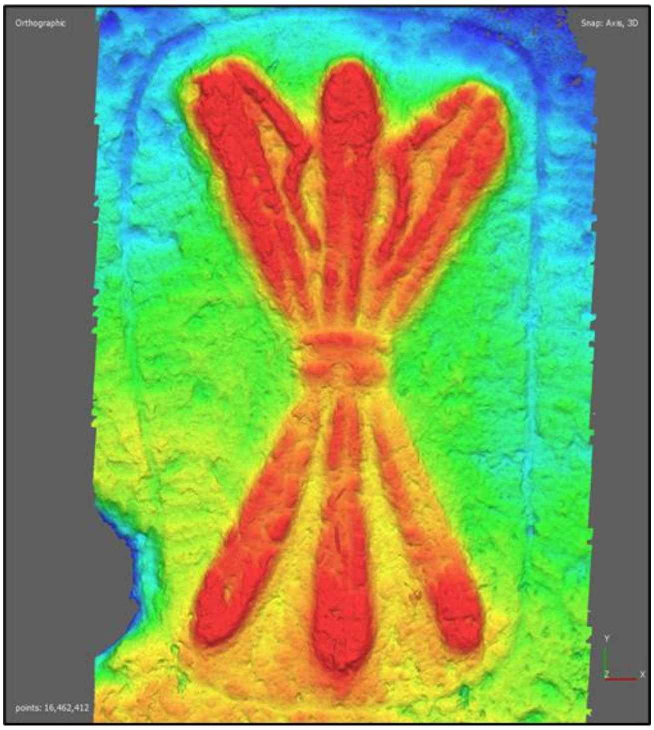


Figure 6. Köşkerli thunderbolt point cloud with elevation display option.

2.3.3.4. DEM and section profiles

Properly oriented and referenced models also permitted the creation of meaningful DEMs with relative elevations above the background plane. DEMs produced by Metashape (and other software, such as Pix4D) default to a widely used violet-to-red color ramp for stretch display. This accepted standard presents elevation changes in relief quite well when combined with hillshading (also a default in Metashape for DEMs). The stretch color ramp was manually adjusted by assigning values to colors in the palette for most effective presentation of specific reliefs (Figure 8e). Substituting a grayscale palette gives a different option suitable for publishing in black and white or as a basis for a drawing of the figure (Figure 8f).

From the DEM, cross section profiles were created for areas of interest on reliefs. In Metashape a polyline was created along a section of interest. The context menu “measure” tool produced sections with profiles using the elevation color ramp. These profiles proved instructive for defining relationships between symbols.

3. Results

These described methods result in a variety of graphic options for presentation and tools for analysis of details and relationships in rock reliefs. They are demonstrated in the following sections for the three rock reliefs of this study.

3.1. Köşkerli

About 125 m southeast of the Byzantine church ruins at Köşkerli lies a fallen and broken door lintel with a relief preserving a thunderbolt and *semeion* (Figure 7). The earliest published references to it describes the latter as a "simplified version of a menorah-candelabrum" [18] and (collectively with the following two examples) a menorah with "five arms" [20]. Both publications include the same black and white photograph from which the claimed descriptions cannot be verified or effectively refuted. The photogrammetric 3D model of the Köşkerli lintel relief removes ambiguity about the relief details and offers several display options that allow descriptive certainty. The *semeion* provides an excellent example.

Figure 7. Köşkerli: fallen lintel with relief of thunderbolt and *semeion.*

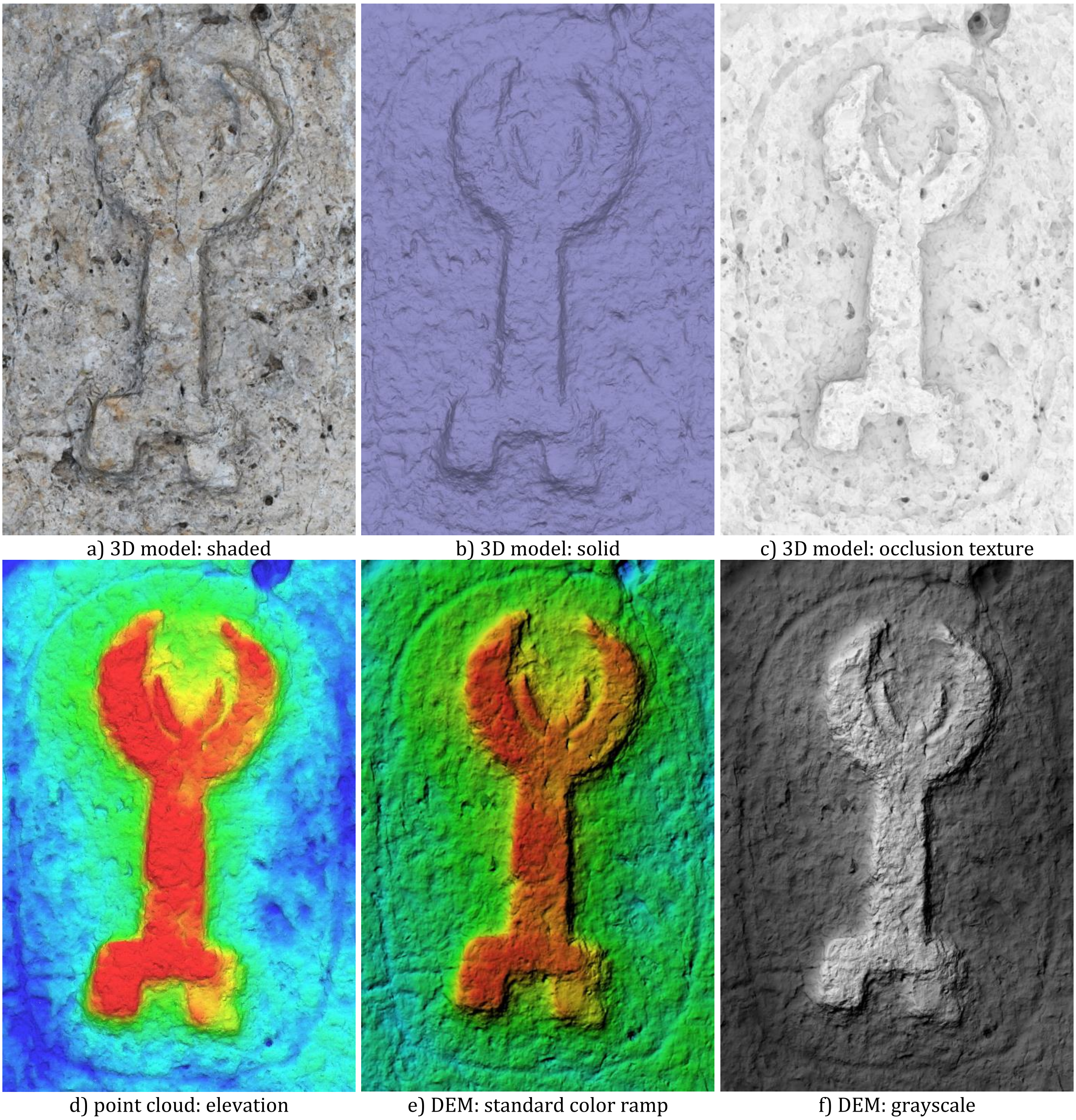


Figure 8. The Köşkerli lintel *semeion*: photogrammetric model in various display options.

As shown above, the 3D model displayed with diffuse texture does not reveal detail (Figure 5). A shaded view (Figure 8a) offers slight improvement and a solid view (Figure 8b) even more. These views make it clear that the symbol features two nested crescent shapes on a column rising from a two-footed stand or base; the same elements as the symbol on the Silifke museum altar (Figure 2) but with differing proportions and lacking the star above.

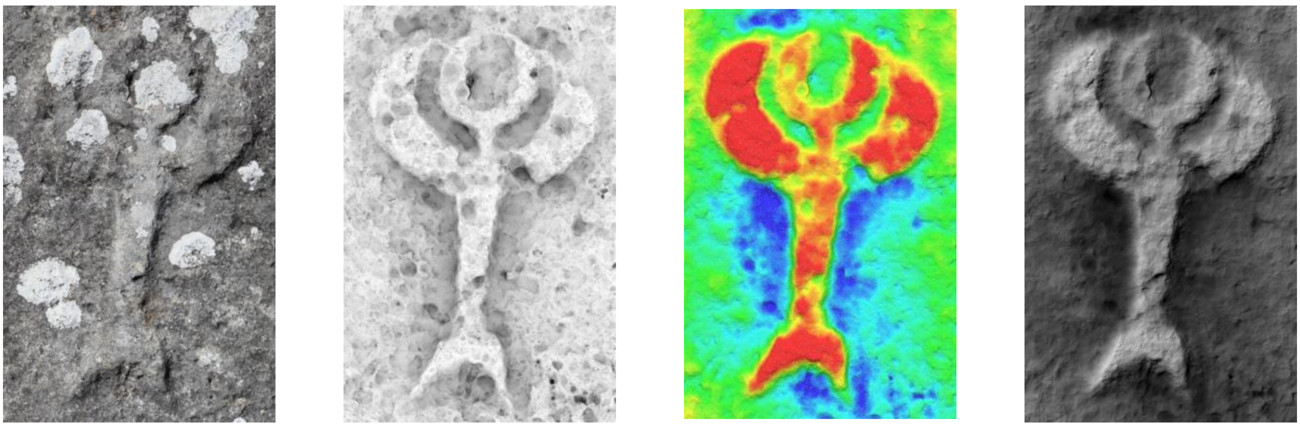
An optical illusion created by fissures and the ambient lighting on the 3D model in the shaded and solid views allows the viewer to imagine a central fifth "branch," as claimed by earlier interpreters [20]. Model views with occlusion only (Figure 8c) and point cloud elevation (Figure 8d), however, eliminate that possibility. They also preclude any claim that a star (substituting for a fifth branch per the original publication of the Silifke museum altar) [17] was part of the figure. The DEM displays (Figure 8e, 8f) offer additional confirmation and provide alternate views suitable for presentation or publication.

3.2. Örendibi

Ruins called Örendibi, west of the village of Somek, contain a standing door lintel with three symbols in relief: an apparent *semeion*, thunderbolt, and shield (Figure 9). The *semeion* is somewhat smaller than the other two symbols, slightly skewed, and less detailed than those at the other sites. It was identified by the initial investigator as a "candlestick" (Türkçe *şamdan*) [22], later as a "menorah-candelabrum" [19], and then as a menorah having "five arms" [20]. Of these, only the latter publication contains a photo; again, with insufficient detail for judgement and without showing the full lintel.

The photogrammetric model permits detailed assessment of the Örendibi symbol. The 3D model diffuse texture display (Figure 10a) retains the difficulties of a photo, in this case complicated by lichen growth. The other display options (Figure 10b-10d) reveal the *semeion* design clearly, with a two-footed stand and shaft supporting nested crescent shapes. As at Köşkerli, the symbol elements match those of the Silifke museum altar *semeion* but in different proportions and without the star. Some incongruities are notable in the field but not shown in the only previously published photo of the Örendibi lintel [20]. The three symbols are not arranged in the center of the lintel and the right side of the lintel is quite rough, hinting that something there was effaced in antiquity (Figure 9). The *semeion* is significantly smaller than the thunderbolt and shield. If another symbol once existed to the right of the shield, separated congruently with the thunderbolt opposite, those three symbols (alone, without the *semeion*) would compose a set appropriately centered on the lintel. A 3D model of the full lintel face provides easy access to data for discussion. A plan view of the shaded model (Figure 11) confirms field observations of the spacing of symbols and roughness on the right side. The DEM of the lintel face (Figure 12) highlights degradation on the right side and reveals that the smaller *semeion* symbol is executed in lower relief than the thunderbolt and shield. A section profile (Figure 12, top) further demonstrates the lower relief of the *semeion* and suggests a lowered background plane than for the other two symbols. It also underscores the extent of damage to the surface on the right side of the lintel. These details are consistent with the following possibilities: 1) an original third large symbol on the right side of the lintel was intentionally effaced; and 2) the *semeion* was added after the large symbols by lowering the background plane left of the thunderbolt and executing the symbol in much lower relief.

Figure 9. Örendibi: standing lintel with (l to r) *semeion*, thunderbolt, and shield.



a) 3D model: textured b) 3D model: occlusion c) point cloud: elevation d) DEM: grayscale

Figure 10. The Örendibi lintel *semeion*: photogrammetric model in selected display options.

Figure 11. Örendibi lintel model in shaded view.

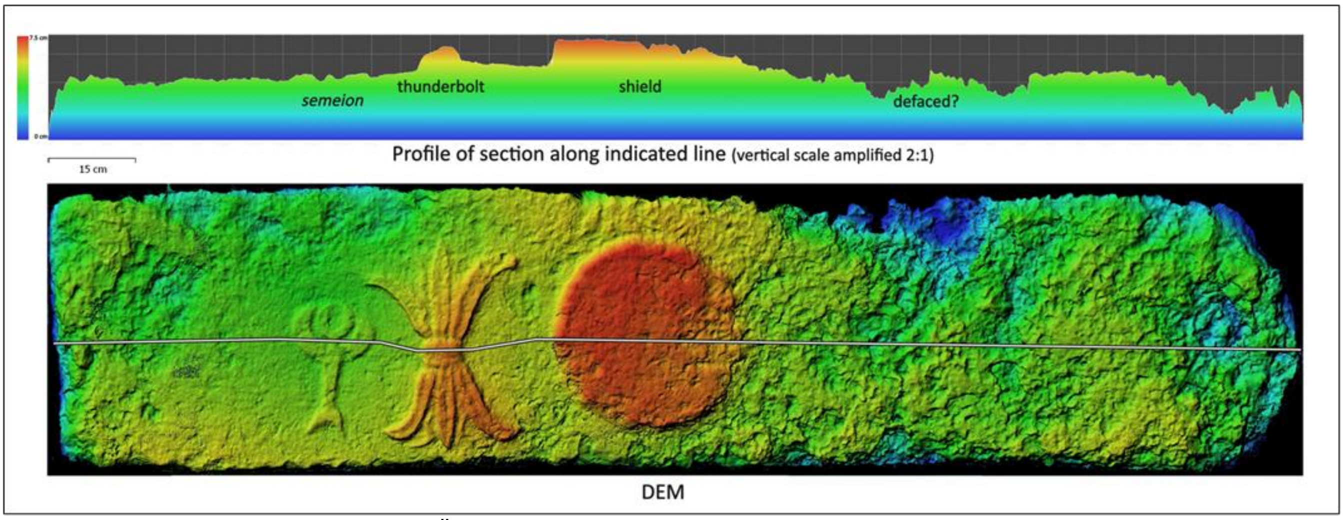


Figure 12. Örendibi lintel DEM (below) with section profile (above).

3.3. Athena Relief

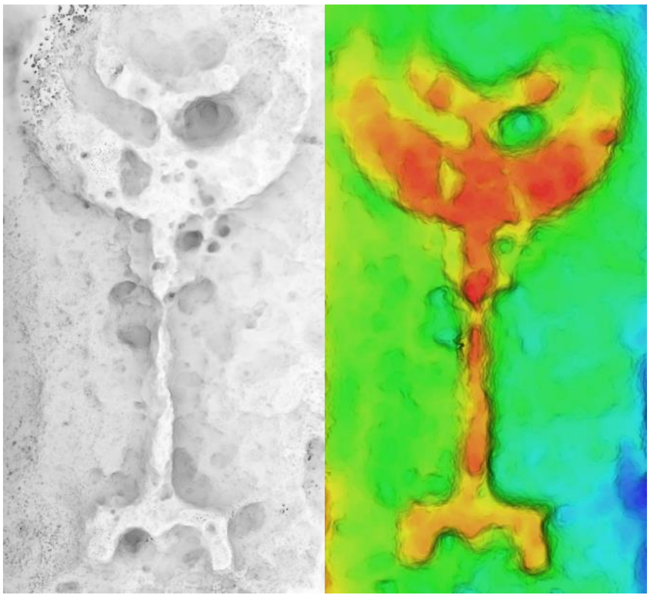
A similar situation exists at the Athena Relief near Sömek, where a *semeion* and other symbols are found as adjuncts to an impressive shrine created for the goddess Athena (Figure 13) [11]. Two pilaster columns frame the scene; the one on the viewer's right decorated with three figures in relief: a crescent and star, an unidentifiable defaced object, and a thunderbolt. Outside the frame, right of the pilaster, a *semeion* in relief stands alone.

3.3.1. The Semeion

The Athena relief *semeion* is the clearest of the three rock relief examples in this study. The two-legged base, shaft, and nested crescents are evident in person and discernable in published photographs [11, 20]. Like the symbols at Köşkerli and Örendibi, however, it has been cited without argument as a "five-branched menorah" [20] when a fifth "branch" is not at all evident. One commentator, apparently relying on the assumption that a star substitutes for a fifth branch in the Silifke museum altar *semeion* [17] (see section 2.1 and Figure 2), asserts that Athena Relief example "contains a star at the top center of the menorah" [23].

The rock surface and texture could allow an observer to imagine a much-eroded star above the crescents. But the photogrammetric model eliminates speculation and doubt. Multiple views demonstrated that there is no fifth "branch" and no evidence for a star substituting for one. The 3D model with occlusion map display and DEM views are provided here (Figure 14a-14b).

Figure 13. Athena Relief.



a) 3D occlusion b) DEM

Figure 14. Athena relief *semeion* model views.

3.3.2. Chronological order of the relief and symbols

The relationship of the symbols to the Athena relief is somewhat enigmatic and therefore subject to speculation. The original investigator assumed that the symbols were all part of the original design [11]. Some details, however, allow the possibility that the symbols were added later. Collectively, the symbols are more detailed and sharper than the Athena composition inside the pilaster frame, suggesting a different sculptor. Also, the pilaster surfaces are noticeably set back from their capitals and base (only the right base is preserved); more than necessary and even awkwardly. This would be the case if symbols in relief were added later by trimming back the pilaster. The full model of the Athena relief supplies data for discussion.

Figure 15 shows a DEM of the entire Athena relief with the XY plane as the background surface behind the goddess and the outer surface of the two pilaster column capitals at the same z-elevation. The DEM representation highlights certain details not immediately obvious in the field or in photos. Figure 16, created by assigning dense cloud points to "classes" in Metashape, provides a key for discussion.

The following observations stand out: 1) the left pilaster column surface is cut back more than the right; 2) the right pilaster column's left edge is uneven adjacent to the relief figures on it because of undercutting by the relief inside the frame; 3) three composition elements inside the frame (snake head, horse snout, and shield) seem truncated where they extend out to the plane of the adjacent pilaster surface; 4) a small "channel" separates the rim of Athena's shield from the right pilaster edge (left of the thunderbolt); 5) the natural rock falls away rapidly outside the right pilaster; and 6) the background surface for the *semeion* to the right inclines inward towards the pilaster. Section profiles of the DEM model enhance these observations (Figure 17-18).

The overall low height of the column surfaces as seen in section A-A' (Figure 17, top) is consistent with the theory that they were cut back at a later period to allow placement of the symbols on the right pilaster. Vertical section C-C' (Figure 18) also supports that supposition. That three elements—the snake's head on the upper left, the horse's snout on the right, and the rim of Athena's shield below the horse—would extend beyond the frame of the pilasters in the original composition seems unlikely. Their truncation at the existing pilaster face planes (Figure 15) is thus also consistent with a suggestion that the symbols were added later. For the rim of the shield, reduction of the pilaster would also have created a need for the defining "channel" between it and the pilaster surface. Section B-B' (Figure 18) highlights that relationship.

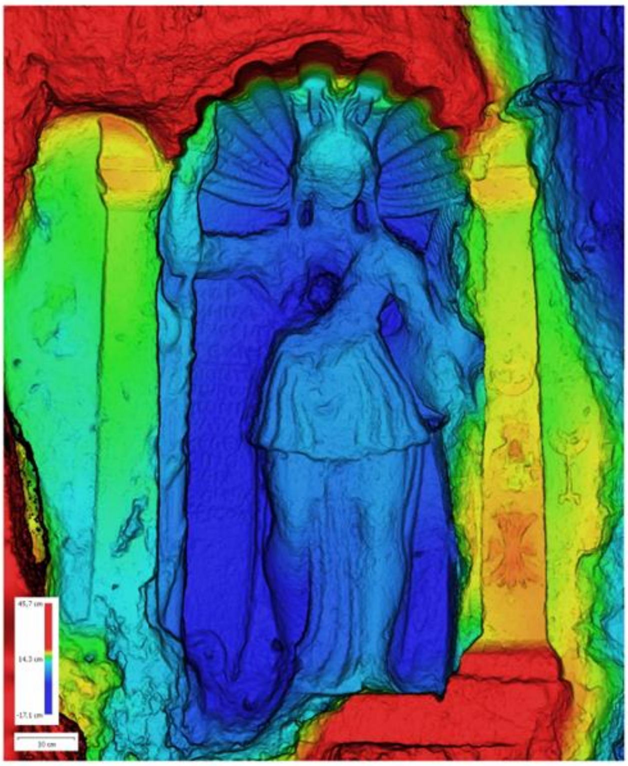


Figure 15. Athena relief: DEM.

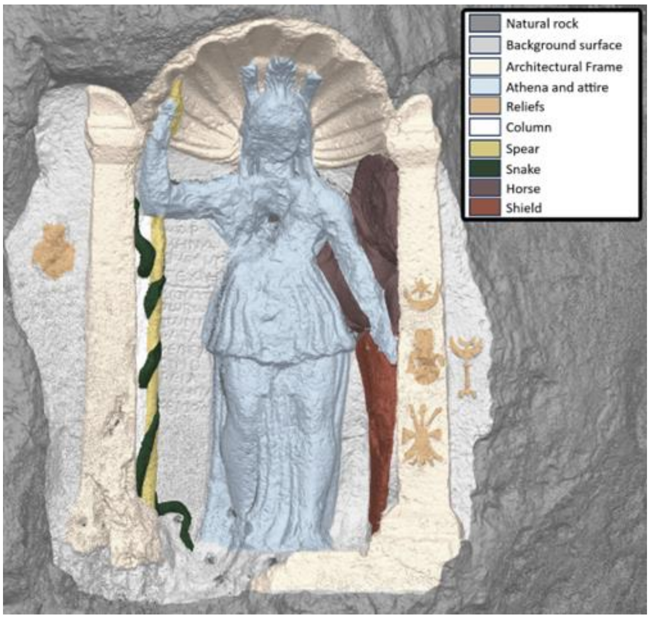


Figure 16. Athena relief: key for discussion.

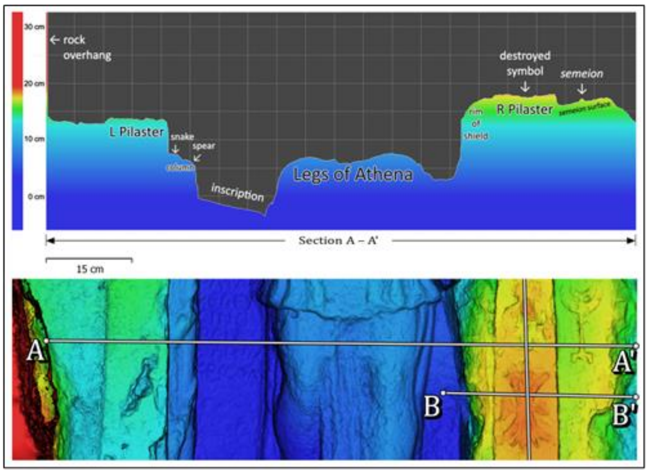


Figure 17. Athena Relief detail: DEM showing section lines (bottom) with section profile A-A' (top)

Finally, sections A-A' and B-B' clearly demonstrate the inclined background surface for the *semeion* carved outside the right pilaster (Figure 17, 18). If the *semeion* was added after the symbols on the pilaster itself, creation of such a surface would have constituted the most economical solution in the limited space still available.

4. Discussion

4.1. The Semeion: Data for Identification and Interpretation

Photogrammetric 3D models created in this study supply unambiguous data for discussion and evaluation of the Köşkerli, Örendibi, and Athena reliefs. Details illuminate the semeion representations as well as their relationship to other symbols appearing in the reliefs.

The models demonstrate conclusively that the symbols of interest in the three reliefs share the following features: 1) a two-legged base; 2) a vertical shaft; and 3) two nested crescent shapes of unequal size supported by the shaft.

These same features are found in the Silifke museum altar example. It is thus reasonable to equate the symbols; that is, each represents a semeion in the naming convention adopted here. However, the encapsulated star above the semeion on the altar is not present with the three rock relief symbols. Nor is there any other evidence for an additional arm or branch on them. Consequently, the published descriptions of the semeions at Köşkerli, Örendibi, and the Athena relief as "five branched" menorahs must be rejected as false.

Other details shown by the models are certain but require interpretation. For example, in every semeion, the nested crescent shapes taper to pointed ends. They resemble lunar crescents, horns, or even wings, rather than evoke the branches of menorahs. Also, the two crescents of each semeion are not always geometrically similar. The ones at Köşkerli and Örendibi are quite dissimilar when compared to the uniformity of the Silifke museum specimen. One reasonable conclusion is that the two crescent shapes are meant to represent two separate ideas. Taken together, these features mitigate against identification of the symbols as Jewish menorahs.

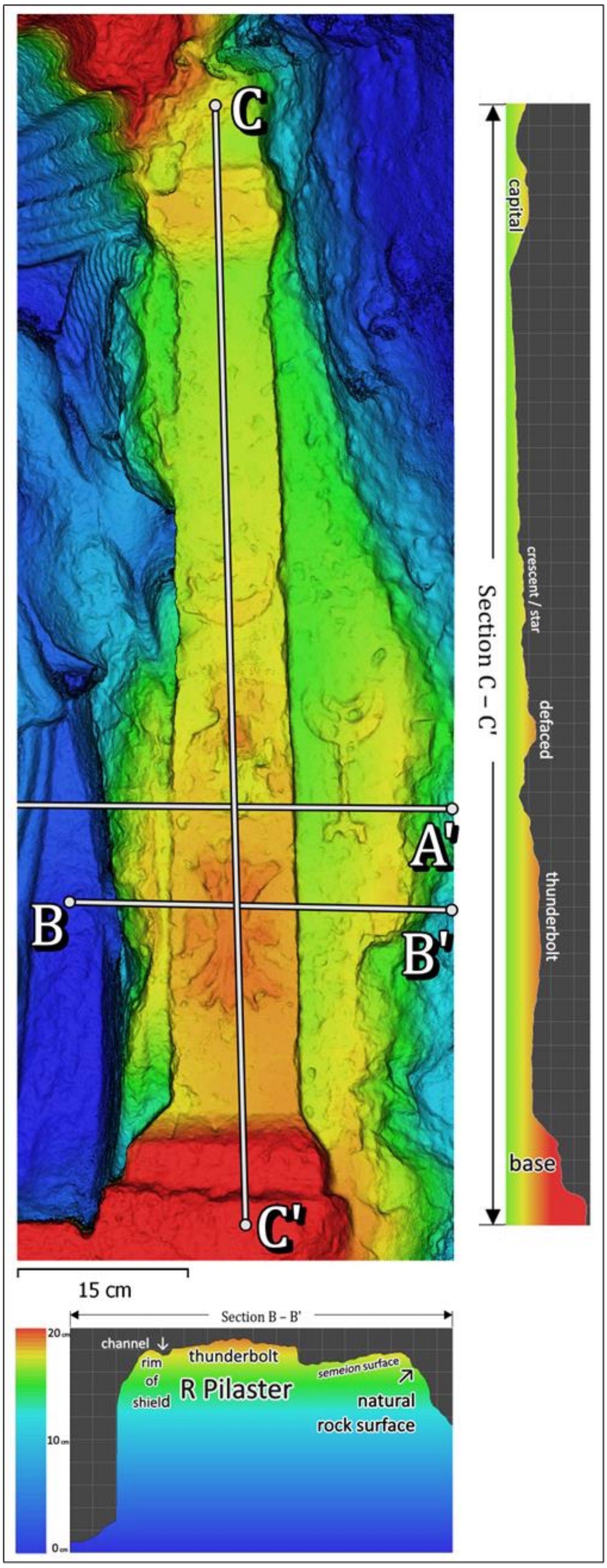


Figure 18. Athena Relief, right pilaster and symbols: DEM with section lines (top); section B-B' profile (bottom); and section C-C' profile (right).

Whether identified as menorahs or not, the relationship between the semeion and other symbols in each relief remains a question of interest. For this also, photogrammetry provides relevant data for discussion and interpretation. Setting the Silifke museum altar aside, it is noteworthy that in each published rock relief in which the semeion appears, it occurs alongside a thunderbolt, conventionally understood as a symbol of Zeus. In two cases it occurs with a shield, the symbol of Athena: on the lintel at Örendibi (Figure 9, 11-12), and at the Athena relief where the shield is part of the main composition (Figure 16). The lintel at Köşkerli is broken (Figure 7), so it would be unsurprising to find a shield relief on the missing portion if it were located.

As observed in section 3.2, the semeion at Örendibi is smaller than the thunderbolt and shield. The DEM for the lintel shows it is also carved in significantly lower relief than the accompanying symbols. It also suggests that the area around it was lowered so the semeion could be added after the original composition. Furthermore, the right side of the lintel is heavily pitted and damaged, consistent with the intentional effacing of a now-lost symbol that would have evenly balanced the original composition without the semeion.

The Athena relief also has attributes that suggest later addition of the symbols to the right pilaster. The 3D model facilitates inspection of these features, while the DEM and section profiles add visual representation to their description and furnish factual data for arguments. The details outlined above (section 3.3.2) provide solid evidence to support a hypothesis that the symbols on the right pilaster were added to the Athena relief sometime after the original composition. They also provide support for conjecture that the semeion outside the frame represents an even later supplement to the monument.

Taken together, the photogrammetric data from Örendibi and the Athena relief give pause to any assumption that combinations of symbols including the semeion were always created together. This is an important consideration for any attempt to interpret the symbols and their collective meaning.

4.2. Close-range photogrammetry as a tool for archaeological presentation and analysis

Claims for identification of symbols like the semeion must be based on accurate description of their attributes. This is difficult when dealing with details of rock reliefs because of lighting conditions in the field, texture or color variations in the rock itself, lichen growth, and wear or damage. After identification and publication, evaluation of claims and reinterpretation become equally difficult for scholars relying on documentation by written description and/or monochrome photographs only.

The use of close-range photogrammetry provides objective presentation views with explicit detail and graphic representation of spatial relationships. These permit evaluation or reevaluation based on empirical evidence and allow arguments for identification founded on certainty. To put it another way, photogrammetry can eliminate subjective and potentially spurious claims involving physical details. Reconstruction and interpretation always involve some level of subjectivity in social sciences like archaeology and ancient history. Photogrammetry, however, provides one way to decrease uncertainty and provide more factual data in cases like the one in this study.

The above discussion (section 4.1) concerning the identification of the semeion and its relationship to other symbols was made possible by a simple process of collecting a sufficient number of suitable photographs in the field. The data collection process requires minimal training, can be performed with widely available and inexpensive equipment, and takes very little time. The only appreciable expense is the software for processing the data and the only expertise required is that of the software user. For most survey or synthesis research, the latter elements could easily be incorporated through inter-departmental cooperation and/or interdisciplinary project design.

5. Conclusion

The simple close-range photogrammetry method utilized in this study leads to conclusions in the specific case investigated, as well as for archaeological methodology.

For the *semeion*, this study demonstrates conclusively that prior identifications of the symbol as a “five branched” menorah are based on inaccurate assessments of the three rock reliefs and must be rejected. Other questions of interpretation remain open, such as whether the *semeion* has any connection to the Jewish menorah and how it relates to the other symbols with which it appears in the rock reliefs. For these issues, the photogrammetry results provide factual data that can be incorporated into interpretive arguments. This is not the appropriate venue for complete evaluation and historical interpretation of this intriguing symbol. A forthcoming study will present full arguments elsewhere.

For archaeological methodology, this analysis shows the value of close-range SfM photogrammetry for reevaluation of previously published rock relief symbol identifications. By extension, it also highlights its potential utility for initial assessment and publication of such elements. Given the relative ease and economy of simple close-range photogrammetry for data-gathering, it should become a standard part of research design for all projects that involve the reporting, identification, and interpretation of rock relief details—perhaps especially in Rough Cilicia, where reliefs with enigmatic symbols abound

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Conflicts of interest

The authors declare no conflicts of interest.

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