2019

The Cascajal Block - 3D Digital Documentation Project

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2019

THE CASCAJAL BLOCK - 3D DIGITAL DOCUMENTATION PROJECT

INFORME PRESENTED TO THE CONSEJO OF THE NATIONAL INSTITUTE OF ANTHROPOLOGY AND HISTORY MEXICO CITY, UNITED STATES OF MEXICO

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Applications using 3D digitization with structured light scanning and high resolution imaging are adding clariety to carved details, revealing additional markings and inscriptions, and documenting specifics of the form and function of the Cascajal Block. The block is a rectangular-shaped serpentinite stone with carved inscriptions that was uncovered in 1999 at the archaeological site of Cascajal, located in the town of Lomas de Tacamichapan, approximately 15 km from the major Olmec center of San Lorenzo Tenochtitlan (Figure 1). New examination of the stone suggests the confirmation of the block as a reusable writing slab, revealing areas of additional incisions and remnants of palimpsest carving. The documentation provides an archive of the artifact that can be digitally preserved and shared into the future.

In April 1999, authorities from the Municipality of Jáltipan, Veracruz, requested representatives from Mexico's National Institute of Archaeology and History (INAH) to inspect the stone, which had been found by residents of Lomas de Tacamichapan in one of the site's mound structures that was being used as a local gravel quarry for road construction material. Archaeologists Carmen Rodríguez, of the Instituto Nacional de Antropología e Historia (INAH), and Ponciano Ortiz, of the Institute of Anthropology at the University of Veracruz, examined and registered the stone in the presence of the historical authorities of the municipality (Rodríguez Martínez and Ceballos 1999). Rodríguez and Ortiz, along with other researchers who have studied the object, concluded the artifact dated to between 1000 and 800 BC and that it had the distinctive markings that could be of importance in understanding the development of early writing in Mesoamerica (Doering and Collins 2008; Houston 2004). Subsequent visual and geological examinations of the stone and its carving supported its authenticity and antiquity (Ortíz Ceballos et al. 2007);Rodríguez Martínez et al. 2006:1611-1612).

The Cascajal Block 3D Digital Documentation Project is an ongoing collaborative effort between archaeologists Córdova Tello and Meza Rodríguez of Centro Morelos Instituto Nacional de Antropología e Historia (INAH), and Dr. Travis Doering, Dra. Lori Collins, and Jorge González García of the Digital Heritage and Humanities Collections (DHHC) at the University of the South Florida (USF) Libraries. The purpose of the project is to digitally document the Cascajal Block using high-resolution, imaging and 3D scanning techniques. The primary objective was to digitally record the object in an effort to detect additional carvings or details that have not been previously observed on the stone. The results of the project indicate that there are other incised elements on the stone.

Background

The primary subject of previous investigations has been the interpretation of the reported 62 icon- or glyph-like elements inscribed on one face of the stone. Explanations as to their meaning, content, and

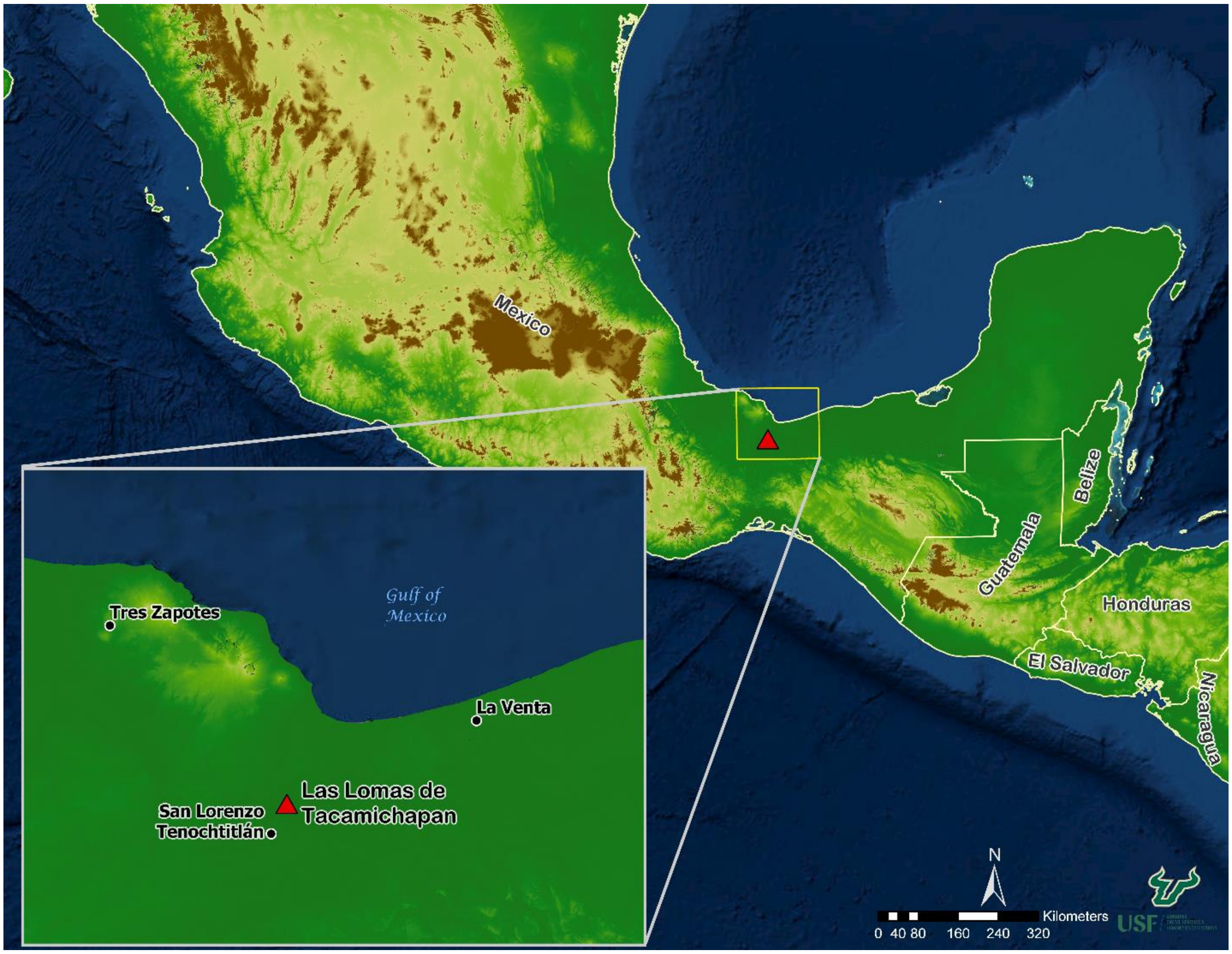

Figure 1. Map of southern Veracruz, Mexico showing locations of Las Lomas de Tacamichapan and San Lorenzo Tenochtitlan.

authenticity have been diverse. Rodríguez-Martínez and associates (2006; Houston 2004) argue that the block contains the elements required for a writing system. Mora-Marín (2009) offered a variant for the reading format and order of the symbols while Justeson (2012) speculates that the "tablet shares far more with the specialized subsystem of abbreviated celt iconography, with its excised symbolic elements, than with writing." Freidel and Reilly (2010:659) propose that the "Cascajal Block is an incised representation of three opened bundles with their contents laid out in precise ritual order." Magni (2008:69) believes the contents to be "eminently religious in nature, although one can detect socio-political concerns underlying this message." Cyphers (2007a, 2007b) seems ambivalent regarding the artifact. Alternatively, Bruhns and Kelker (2007:1365-1366) are skeptical and question the legitimacy of the stone pointing to the fact is was not archaeologically excavated and came from a disturbed context. Debate over the stone's authenticity and meaning continue.

In this current consideration, the authors have placed emphasis on creating a digital surrogate for study, analysis, sharing and archival preservation of the piece. Utilizing the latest technologies in high resolution surface scanning and imaging, a goal of our research is to provide epigraphers, iconographers, and others with an optimum visualization and 3D viewing capacity, to better understand the piece, and to create a permanent archival digital record of the piece as it exists in its current condition. Prior to this project, the presentation of imagery of the sculpted stone has been limited, and only a small group of researchers have observed the stone firsthand. Several researchers have shared the excellent photographs taken by Houston during his examination in 2005 (Doering and Collins 2008). Still other investigators have "only seen the low-resolution greyscale images published and re-published in a number of other news providers" (Everson 2006). Other than maximal dimensions, there has been no thorough metrological or morphological documentation of the object (Rodríguez-Martínez et al. 2006; Rodríguez Martínez and Ceballos 1999). There are substantial variations in the six individual surfaces of the stone, and differing depths, scales, and spacing of the individual symbols carved and re-carved areas.

The Cascajal Block, like many other Formative period Mesoamerican monuments, has been subjected to damage and surface degradation through physical and biological weathering and anthropogenic actions (see Doering and Collins 2008;Doering and Collins 2010;Ismail 2004; Kahl and Berg 2006). These degradation processes often diminish researchers' ability to "see" the carved content and detail. Customary 2D documentation methods, such as standard photography and hand drawings, have visual, scalar, and analytical limitations (Graham 1989:243;see also L. D. Collins and Doering 2006, 2009; Doering and Collins 2010a; Doering and Collins 2010b, 2010c) that, in the case of the Cascajal Block, have led to differing results or interpretations (see Carrasco and Englehardt 2015:636; Doering and Collins 2008:Figure 4, 1612; Everson 2005; Justeson 2012:841). A comparison of the glyphic elements shown on previous drawings of the Cascajal block demonstrate a number of differences in the details and spacing of the individual inscriptions.

The Cascajal Block 3D Digital Documentation Project

The rationale for this project was based on two factors. The first is that previous observations, documentation, visualizations, interpretations, and descriptions of the incised elements on the Cascajal piece have been based on two-dimensional imagery (i.e., photography and hand drawings). The incisions on the stone are faint, abraded, effaced, and potentially traces of previous inscription have been written over by later inscriptions. These types of details are more clearly understood and portrayed with three-dimensional analyses and visualization. Further complicating the consideration of the Cascajal carvings is the asymmetrical surface of the stone itself. These issues hinder a comprehensive documentation, analysis, and assessment of the stone's surfaces using two-dimensional techniques, and line drawings derived from these techniques may be incomplete or inaccurate as a result. Based on the authors' experience documenting Mesoamerican carved stone monuments, such as our previous work at Chalcatzingo, La Venta, Kaminaljuyú, and Takalik Abaj, we considered there was a possibility that more information could be extracted from the stone through the use of high-definition three-dimensional techniques (B. D. Collins et al. 2009; L. D. Collins et al. 2011; M. Córdova Tello et al. 2015; M. Córdova Tello, Travis Doering, Lori Collins, and Carolina Meza Rodríguez 2016; Doering 2009; Doering and Collins 2010a, 2011; Doering and Collins 2008, 2010c; Doering et al. 2006). Results derived from the newly collected data support the validity these lines of reasoning, with additional carved details and features of the stone now recognized. These digital data support some previously proposed hypotheses as well as raise additional new questions regarding the stone's use and reuse.

On June 11, 2018, Doering, Córdova Tello, Meza Rodríguez, and González García accompanied anthropologist Catalina Arias Mayo and Mayor Valentín Goméz of Jáltipan de Morelos in the Municipality of Jáltipan, Veracruz, to the community of Lomas de Tacamichapan. The visitors were welcomed by Cástulo Gabriel Cruz at the home Victor Gabriel Jimenez, the current caretaker of the block under INAH registration, and was joined by Victor Gabriel's wife and son. The purpose and methods of documentation were explained to the family, and they were assured that the technologies were non-contact, non-invasive, and non-destructive. On the covered patio at the rear of the Jimenez home, the object was removed from its custom-designed wooden container to allow access for the 3D documentation process.

The primary method used in the documentation, was color 3D surface scanning with a structured blue light imaging instrument. The manufacturer's specifications state that the ability of a measurement to match the actual value of the quantity being measured, or the 3D point accuracy, is 0.05 mm; and the ability to resolve detail in the object that is being scanned, or its resolution, is 0.1 mm. Prior to scanning the Cascajal Block, a complete calibration of the system was performed and checked for accuracy to specifications. The system operates with a combination of projected light patterns and a camera system with a data acquisition speed that collects up to one million points per second. These specifications meet or exceed the resolution needs for the scale and metrological considerations for this project and have been shown through our past experiences to offer high quality rendering and analytic models for similar artifact surface textures and qualities. More controlled environmental setting for the laser scanning and photogrammetric and imaging documentation would be preferable for our future planned work with the monument, and controlled lighting and other variables will enhance our capacities in the future.

Photography was used in conjunction with the surface scanning, with a Nikon D850 camera utilized to capture surface and texture details in high-resolution (45.7 megapixel) for the entire stone. These images provided an additional method of documentation and provide potentials for photogrammetric consideration and are used for color and surface characteristic evaluation. The multiple datasets were post-processed in the DHHC computer laboratories at the University of South Florida Libraries in Tampa.

Visualizing the Data

A primary goal of the project was to determine if there is more information carved, scratched, incised, or otherwise entered onto the surfaces of the stone that has not been previously recognized or that may not be visible to the unaided human eye. The acquired 3D data were post-processed using several 3D rendering and modeling software programs, and were studied using numerous lighting, surface inspection, and coloring techniques. Specialized software was used to register and align scans together, and to create high resolution mesh models. 3D and 2D rendered images and models were created from these data, with rendering including a variety of texture, lighting, and shadowing methods such as ambient occlusion (AO) renders to examine faint carved surface details and to be able to highlight and accentuate depth and surface variability where light might not ordinarily reach. Combined, these techniques enhance visualization of carved and scratched surface elements. Visual analyses were performed over small portions of the surface rather than the entirety of the surfaces. The curvature and complexity of the stone's morphology required that each segment be viewed from a combination of perspectives, and lighting angles. Approaches to presenting and visualizing the block included all surfaces to avoid biased selection of carved areas, and also examined shape and geometric properties of the entire block, looking at wear, use, and modification (Figure 2).

Observations on the Cascajal Block – The Material, Shape, and Finish

The Cascajal Block is made from a slab of serpentinite, a fine-grained metamorphic rock composed of several related minerals. Serpentinite was often used by the Olmec of the Southern Gulf Coast lowlands (Curtis 1959). In the alluvial river basins of southern Veracruz, including the region surrounding San Lorenzo Tenochtitlan, the only naturally occurring stone is river gravel (Sisson 1976), therefore, igneous and metamorphic rock, such as serpentinite, had to be imported to the region. Two potential sources of this stone have been proposed: the southern slopes of the Tuxtla Mountains, 40 to 60 km to the north northwest (Heizer et al. 1965) or from "the metamorphic region of the central

Figure 2. 3D render of the Cascajal Block with an AO render shading technique, showing digitized front, back, and side surfaces of the stone. Scanning captured the complete surface area at sub-millimeter scale.

part of the Isthmus of Tehuantepec" (Coe and Diehl 1980:391) a nearly equal distance to the south southwest. We propose that non-destructive elemental testing could provide a more definitive answer as to the source of the Cascajal Block as a next planned step in our research.

The block's shape can be described geometrically as a cuboid, a three-dimensional solid object that is bordered by six basically rectangular sides, with three sides meeting at each vertex. The form is not an organic or naturally occurring shape. It is apparent that the block has been formed, modified, and smoothed on its surfaces. For identification purposes in this analysis, each of the six sides of the stone has been assigned a number as shown in Figure 3. Measured drawings and gridded metrology and volumetric considerations have also been resultant from these 3D laser scan data (Figure 4).

Figure 3. 3D laser scan renders showing the identification of the six sides of the Cascajal Block, shown in perspective views.

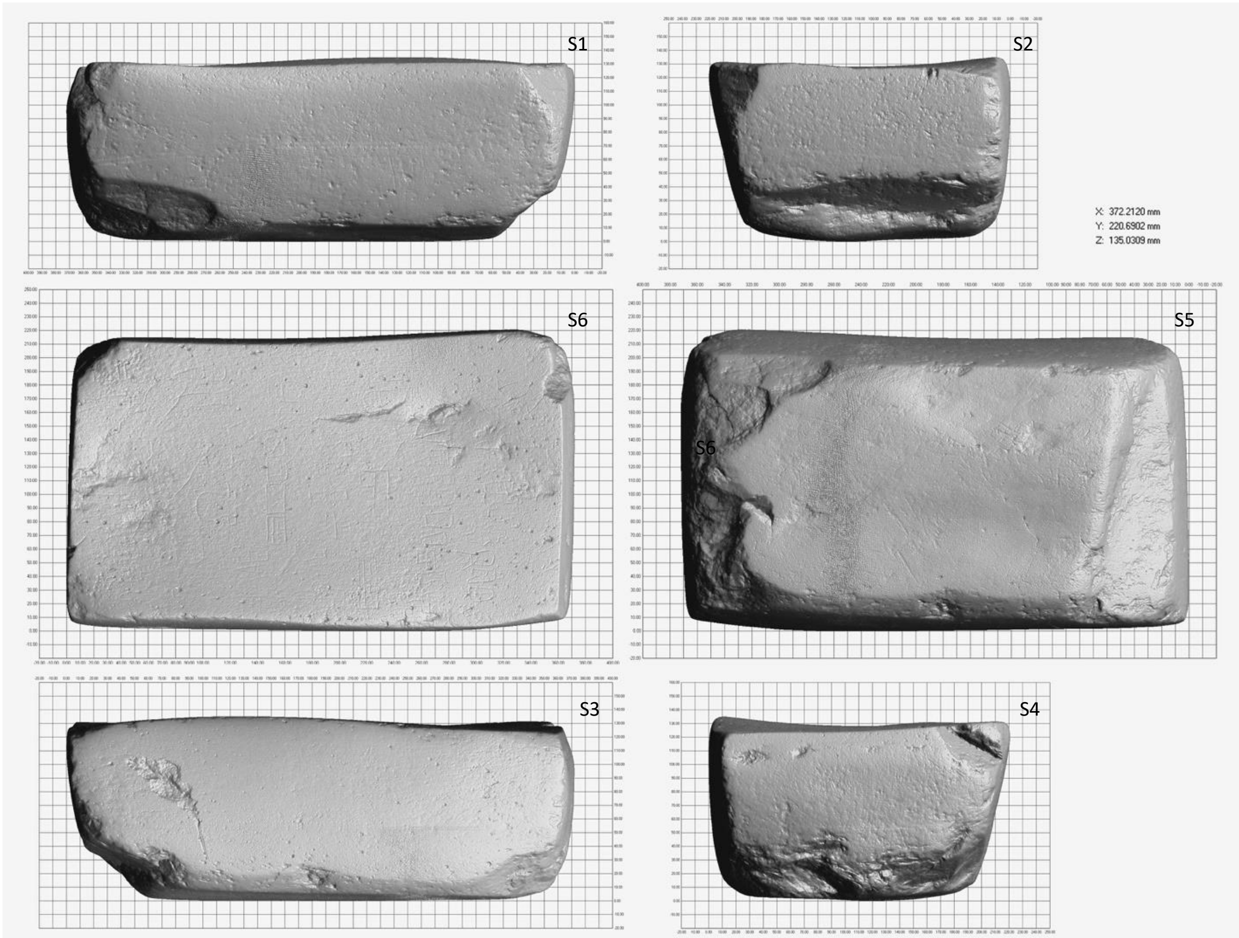

Figure 4. 3D laser scan model showing complete metrological consideration for each of the six sides of the Cascajal Block. Dimensions for the piece, measured at maximum points, are given as 372.2 mm (length) x 220.7 mm (width) x 135mm (height).

Serpentinite is affected by physical (mechanical) weathering (Baumeister 2012) that influences the structure of a rock (e.g., erosion of rock surfaces, formation of cracks or cavities). This process is a result of mineral dissolution, which occurs when individual grains are loosened by wind, water, and, potentially in this case, tectonic movement (see Franco et al. 2013). The loosened grains eventually fall out of the rock leaving holes that are now evidenced on the surface.

Most of the cracks and cavities in portions of the stone surfaces are the result of mechanical weathering or natural imperfections in the rock. Areas surrounding the deeper cavities or recesses, especially on side S6 are rounded or smoothed, indicating long-term exposure that suggests the crevasses were present prior to the Formative period use of the stone. Using the 3D data, we created specialty texture maps of the monument surface to accentuate details, such as crevice and shadowing that allows better visualization across the surface of the stone and enhances carved detail areas (Figure 5). These render techniques also enable the identification of areas showing surface weathering and change that are especially apparent on side S6 of the Cascajal Block. Cracking and exfoliation are noted on this surface and are likely related to both mechanical weathering and use wear. Cracking can also continue to occur along these weaken cavity areas. Substantial portions of the stone's six surfaces have been finished or prepared, and contrast with the rough, natural unfinished or naturally weathered and broken areas of the stone (Figure 6).

One exception to the natural weathering and ancient modifications found on the block is a curved linear mark on side S3 that appears to be the result of a heavy blow to the stone's surface (Figure 7 and 8). The varying depth, regular curvature, and sharply jagged edges on the perimeter of the mark suggest this to be more recent, perhaps from being struck with a metal tool. The block had been found in a "quarry, which had been mined over the course of several years for road construction materials" (Skidmore 2006:2), and the surface scan data are suggestive that the manual extraction of gravel with metal tools could be the cause of this fracture on the stone.

All six sides of the block have been modified or finished to varying degrees. Finished sides are shown in Figures 9-14, that illustrate modifications that include shaping to achieve a basically rectangular form and further smoothing or burnishing achieved a smoother surface. Note that the gray areas shown in these figures indicate deviation from the finished planes depicted by the color surface texture. Our analyses of these data suggest that there are intentional (e.g., incised icons or symbols) and unintentional markings that occur on the stone. Markings thought to be unintentional are likely from scratching, grazing, or scoring and could relate to the stone's movement over course or grit-like material either during its use-life or following its deposition.

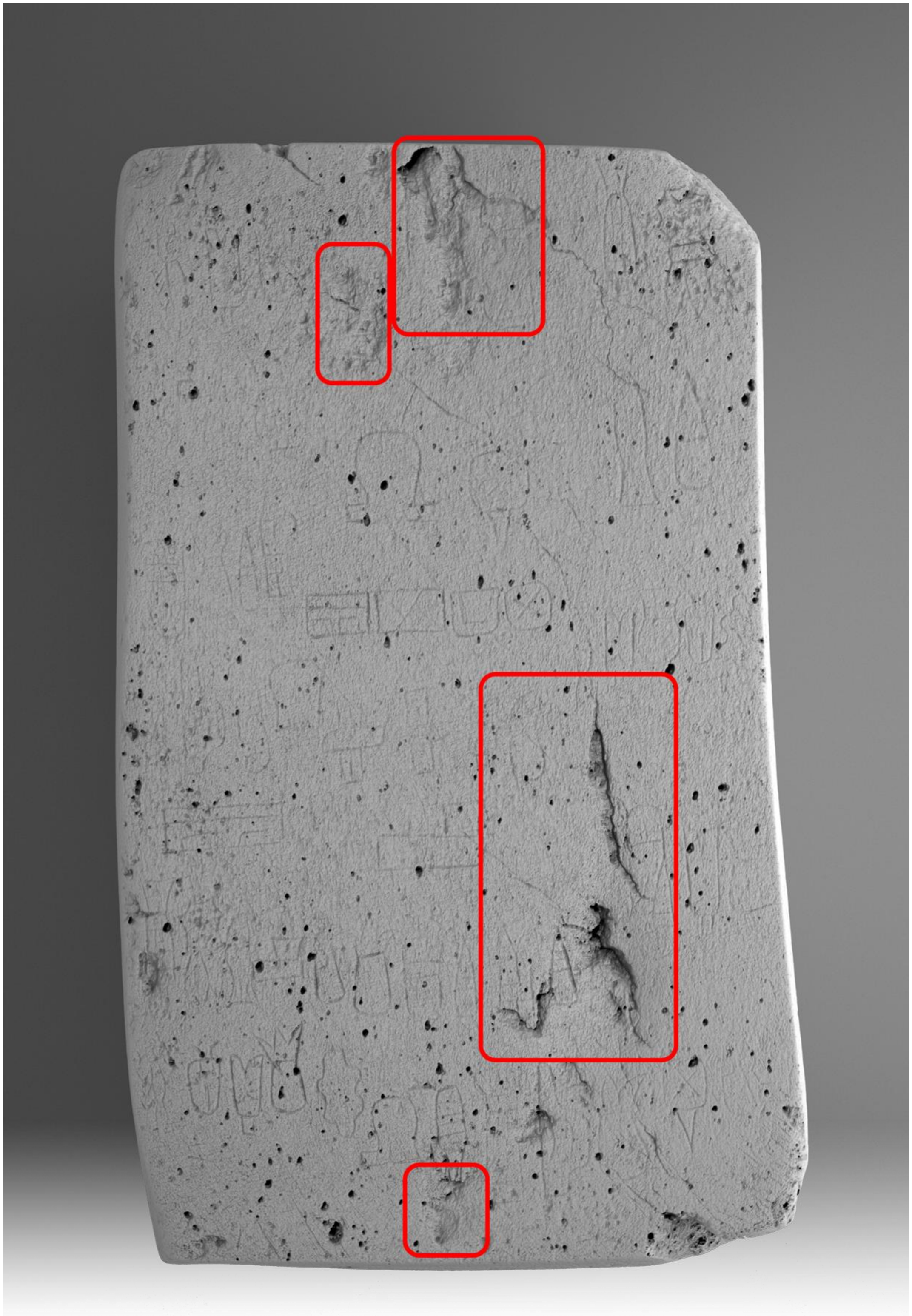

Figure 5. AO render from laser scan data showing side S6 of the Cascajal Block. Dark shading is applied to the crevice areas of the model to highlight areas of weathering and natural cervices in the stone (outlined in red).

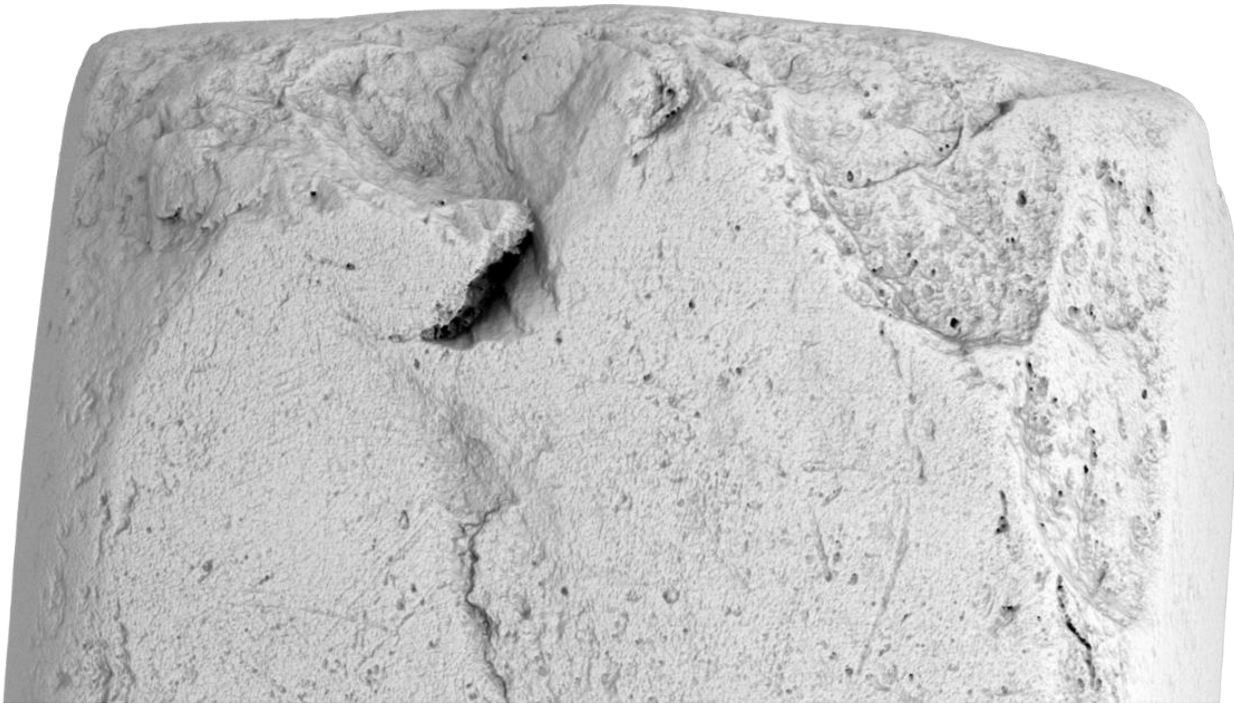

Figure 6. Example of areas with smoothed finished surface in proximity to rough unfinished surface areas on side S5 (3D AO render).

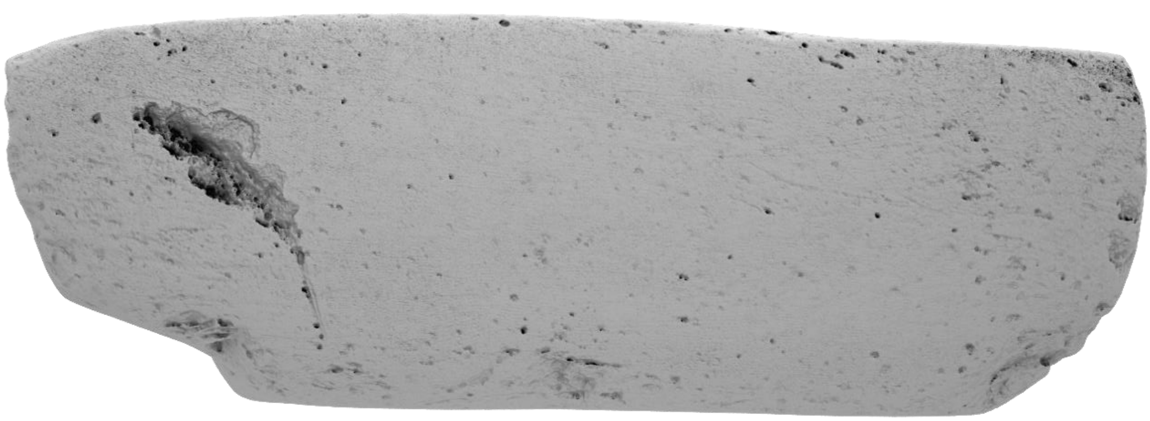

Figure 7. 3D AO render of the Cascajal Block side S3, showing large curved break in the surface.

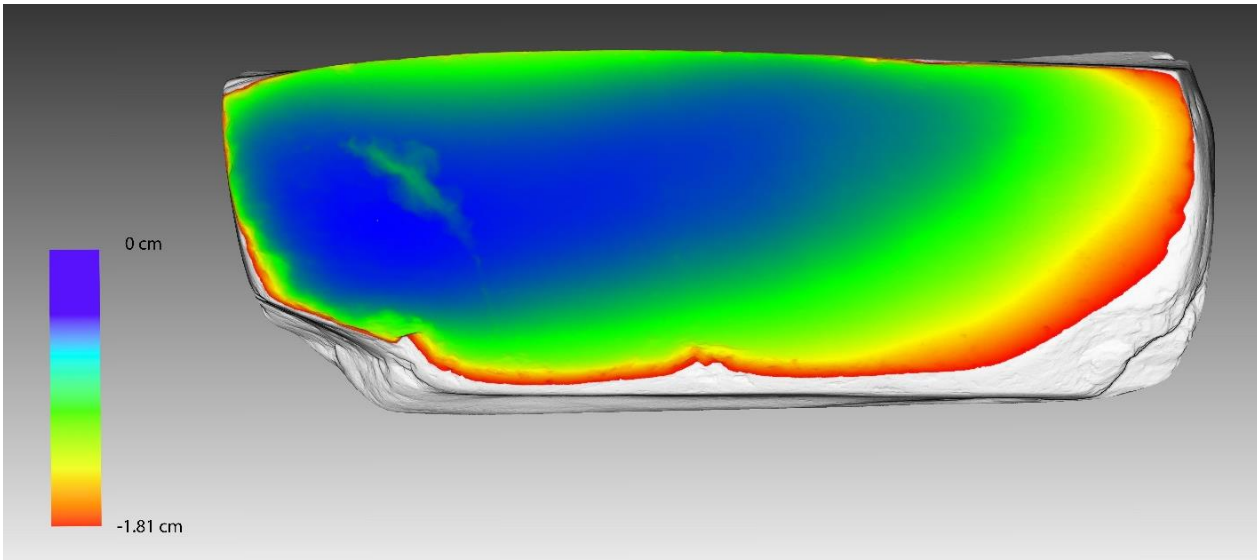

Figure 8. Digital elevation model showing the face of side S3 positioned to show the curved depression and gradual tapering or rounding of right and bottom edges of the stone. This figure also delineates the surface break shown in Figure 6 and provides visualization of the depth of the break.

Figure 9. Finished or prepared area of side S1 shown with color surface texture.

Figure 10. Finished or prepared area of side S2 shown with color surface texture.

Figure 11. Finished or prepared area of side S3 shown with color surface texture.

Figure 12. Finished or prepared area of S4 shown with color surface texture.

Figure 13. Finished or prepared area of side S5 shown with color surface texture.

Figure 14. 3D scan model showing the finished or prepared surface of side S6 with color surface texture information mapped to the S6 face.

Three-dimensional data allows for sectional consideration of the block, with longitudinal and transverse profiles and cross-sections readily derived. Profiles were taken at the mid-points of the highly incised side S6 of the stone (Figure 15), to reveal the morphology of the piece. The profiles from these sections illustrate the edges surrounding side S6 are significantly "sharper" than any other edge or corner on the stone, with other sides having well-rounded boundaries. The sharpened condition of the corners suggest that the surface of side S6 had been ground down, probably several times. This grinding also resulted in a central depression evident across the transverse surface (B-B') slice noted in Figure 14.

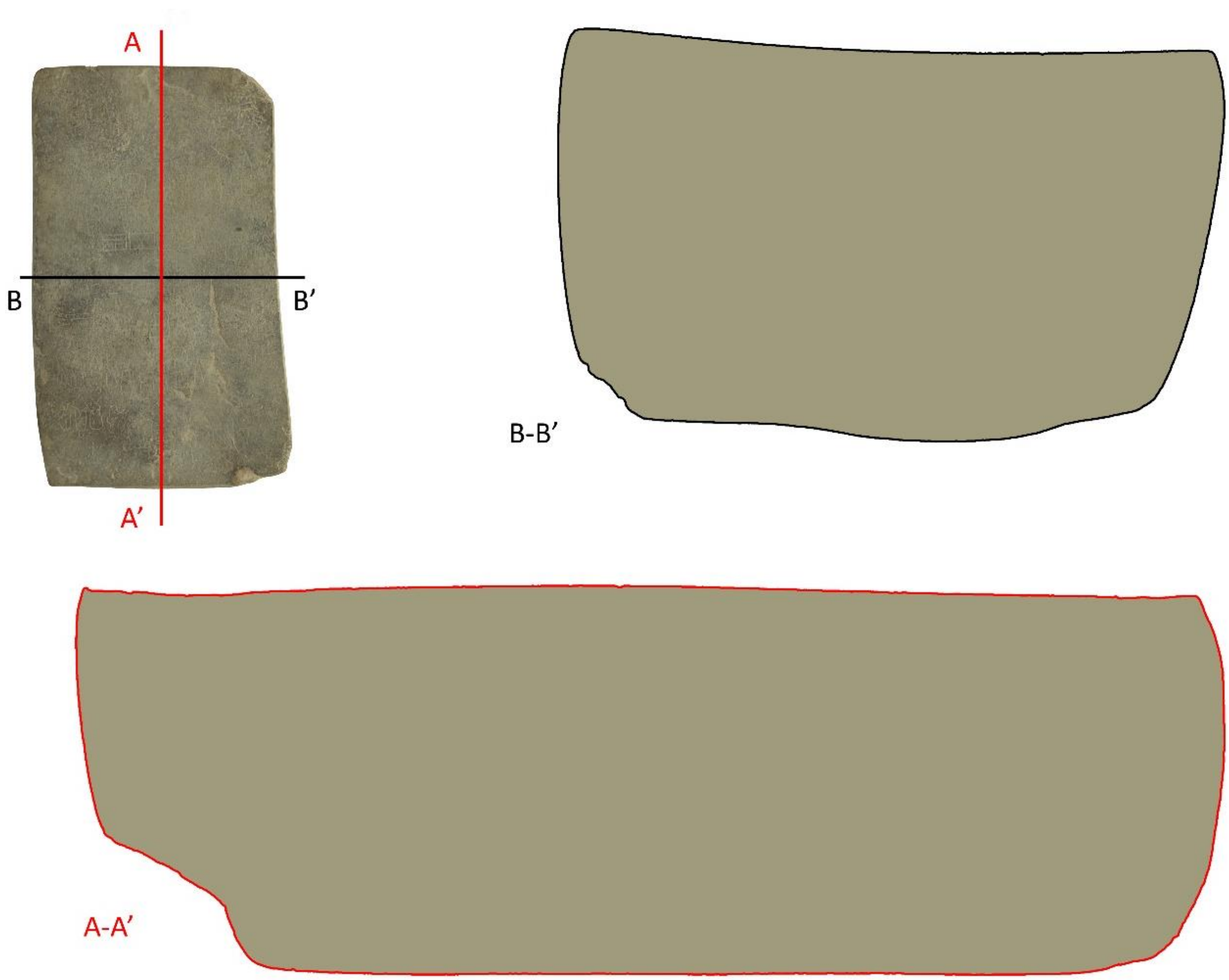

Figure 15. Transverse section profile of side S6 (B-B') and longitudinal section profile of side S6 (A-A'), both illustrating the reduction of the surface resulting in sharpened edges and central concavity.

In some respects, the Cascajal Block resembles the serpentine stones from La Venta's Massive Offering No. 2 that have been described as "polished" (Reilly III 1994:4) or "shaped and finished" (Adams 2005:76). Although examples from San Lorenzo and La Venta are similar in length and width, the Cascajal stone is notably thicker. This difference in thickness could suggest the Cascajal example was sized for a specific purpose other than construction. As previously noted, the examination of the stone and glyph-like incisions indicate that the mechanical weathering of the stone occurred prior to its use during the Formative period. This conclusion is evidenced by portions of the incisions extending into the recess of the surface openings, showing incisions on, around, and extending into these cavities. Noted again in this study are incisions with mineralization around the pitted areas, indicative of the antiquity of the piece. These same mineralized areas were noted by Rodriquez et al. (2006:1611-1612) and can be seen in Figure 16 as occurring within carved line areas.

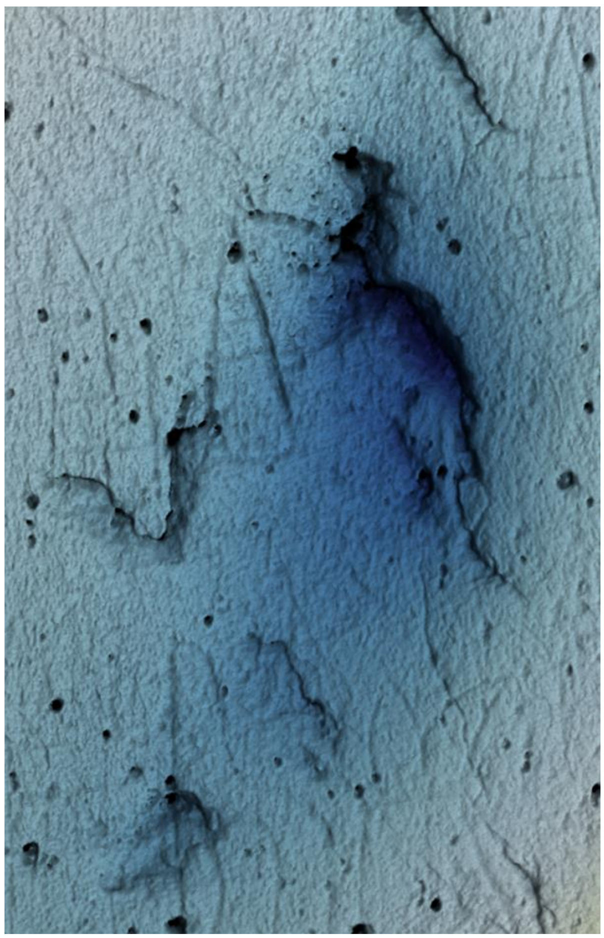

Figure 16. Detail from Digital Surface Model (DSM) of 3D data, showing side S6 with a portion of an incised icon extending downward into the edges of the surface cavity depicted in darker blue. Also visible are the pitted, mineralized areas occurring within portions of the carved lines and across the surface of the stone.

Observations on the Cascajal Block – The Incisions and Markings

The Cascajal Block contains numerous markings and features that have not previously been documented, identified, or discussed. Each of the six sides of the stone were examined and incisions or markings were detected on all surfaces. Complicating factors to visualizing these data in 2D, such as with standard photography, include issues such as the surface color, irregularity, material inconsistency, and the fact that not all markings or incisions can be seen in a single image, perspective, or lighting angle. Types of visualizations created from these data go beyond merely moving an artificial light source across and object but extend to the consideration of immediate changes in space that are not necessarily amplified by changes in light across a directional plane. The result of these techniques is the ability to control shadow in ways that can have profound impacts on visualizing details. Further, the ability to examine elevation, tomography sections, and surface wear and markings are important reasons for our imaging method selection. Using these data in a 3D environment, the entirety of the stone can be examined, color and texture can be added or removed, and factors such as lighting path, angle of the light ray, and shadowing, can be controlled. 3D applications allow for enhanced techniques that can highlight surface texture and markings, and can provide important sectional, perspective, depth and surface elevation considerations (Figure 17).

The block does have several markings that appear to be incidental scratches or scrapes likely from the surface of the stone coming into contact with gritty or abrasive materials (e.g., grains of sand or quartz, basalt or rock debris). This type of marking could have occurred during its usable life by sliding or moving the stone over a dirt or stone surface, or during deposition or internment. These types of marks are usually in the form of straight, often parallel lines that appear at various locations on the stone and are not unanticipated considering the context in which the block was buried and recovered.

There are other deliberate markings that do not appear to be incidental and have been found on all six sides of the stone. Various angles, circular lines, and designs suggest intentional carving of the stone occurred on all surfaces to varying degrees. The 3D model of the Cascajal Block was examined using rendering techniques mentioned previously, and digital line extraction and digital tracing were performed on all sides of the stone. Areas where incisions were suggested but could not be readily traced where marked on the 3D maps for further examination or enhanced imaging. These 3D maps along with the variety of renders and models produced allow for an enduring archive and sub-millimetric forensic examination tool into the future.

Side 1 (S1), is one of four lateral sides of the block that angles slightly inward from S6 to S5 or from the top to bottom. The face of this surface has been smoothed or polished, and each of its four corners

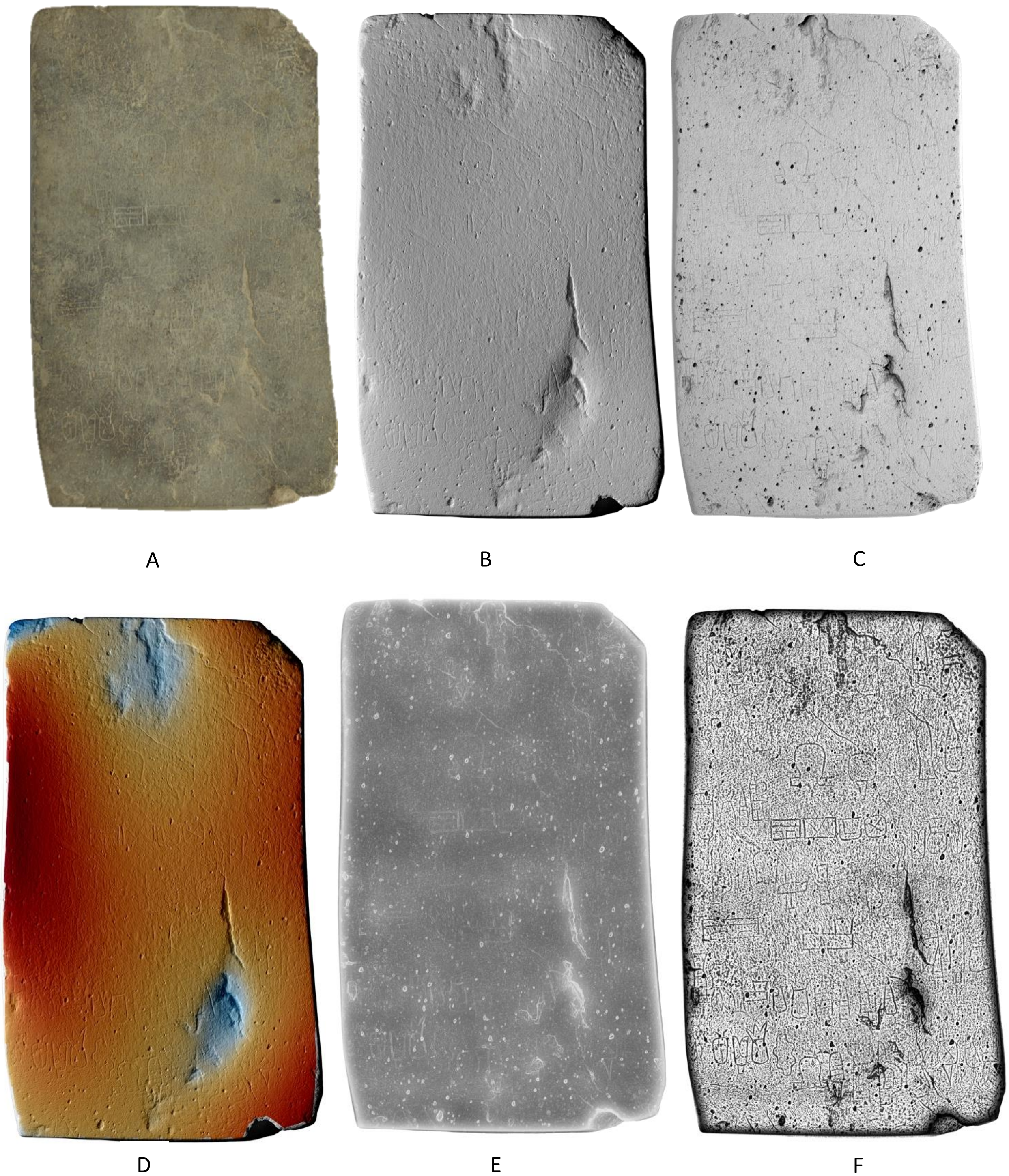

Figure 17. Examples of 3D rendering techniques to analyze surface characteristics. A. Color texture mapping provides true color material consideration; B. Color removal; C. ambient occlusion (AO) providing a point by point exposure control to accentuate detail through shading; D. Digital Surface Model (DSM) showing height variability; E. Edge isolation allowing light and dark to be controlled along edges, and F. Cavity mapping to create masking techniques for small scale ambient occlusions, used here to greatly enhance faint incised elements and to isolate the high points from the low points on the surface texture.

have been modified. Examination of the upper right corner of S1 reveals a series of marks on the surface of the stone (Figure 18). Figure 19 shows a 3D map with spatial locations of areas isolated during our analyses that were found to contain incision and carved markings.

Side 2 (S2) also has been smoothed and the corners have been prepared or rounded except where it intersects with S6. The S2/S6 corner areas are sharpened rather than rounded, probably attributable to the heavy use and modification (grinding down) of side S6, as previously discussed. Side S2 contains several noted areas with incised lines and markings, including potential tool or modification marks. Figure 19 shows the planar surface of S2 using the AO and cavity 3D render to control shadowing and enhance incised surface indications. The 3D model of the block was used to map incised and carved elements to provide spatial control for continued investigation and digital documentation (Figures 20-21).

The major portion of the side 3 (S3) surface has been smoothed or polished. Of note on this side is a curve-shaped fracture in the stone (Figure 22). As previously discussed, this fracture has the appearance of damage to the stone that occurred potentially during its recovery, possibly damaged by a shovel strike causing a shattered and cracked impact fracture. Figure 23 (upper portion) illustrates a 3D render with color texture of side S3 and includes this damaged area, and also highlights noted areas of incision and carving along this surface. Where possible, to more clearly identify elements, we have line traced over these features. Many of these markings depicted on the 3D map must be viewed using a variety of rendering techniques (see for example Figure 17) in order to clearly see or delineate. The 3D mapping of surface markings (Figure 23 lower portion) is a critical tool for future assessment using the 3D data and can provide targeted indications for examination of where incisions or markings were discovered.

Side S4 is similar to S3 in that its main area has been smoothed but also contains an unfinished segment along its lower edge. At the upper right corner is a possible tool or modification mark that differs from the fracture seen on S3 (See: Figures 6,7, 8, and 12), and is suggestive of intentional shaping and modification of the stone. This surface has some indications of tool and other faint markings noted along the upper part of the S4 face, with mechanical weathering and an unfinished surface along the bottom edge (Figure 24). Using a material capture shading technique with the 3D data, these markings can be differentially lit and highlighted to better feature these markings (Figure 25).

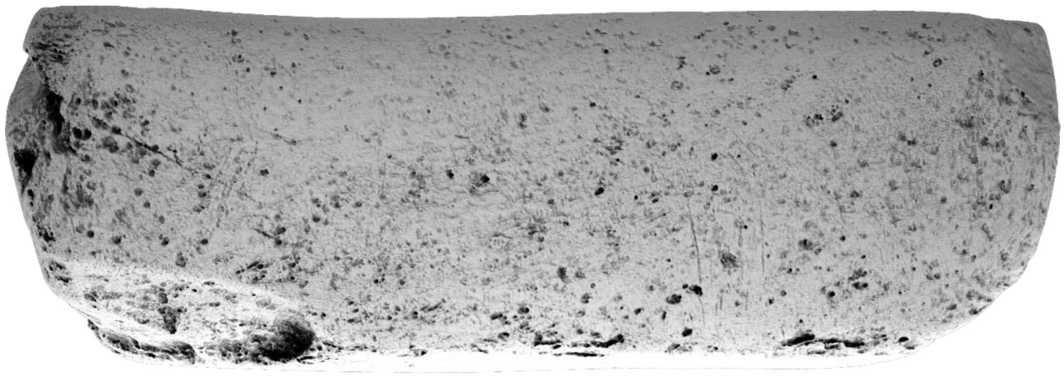

Figure 18. Planar surface of side S1 using AO and cavity render with 3D data, showing faint indications of incised carving. Corner modification and markings are also noted on this side, with detail allowing for examination for how the stone was shaped and modified now possible.

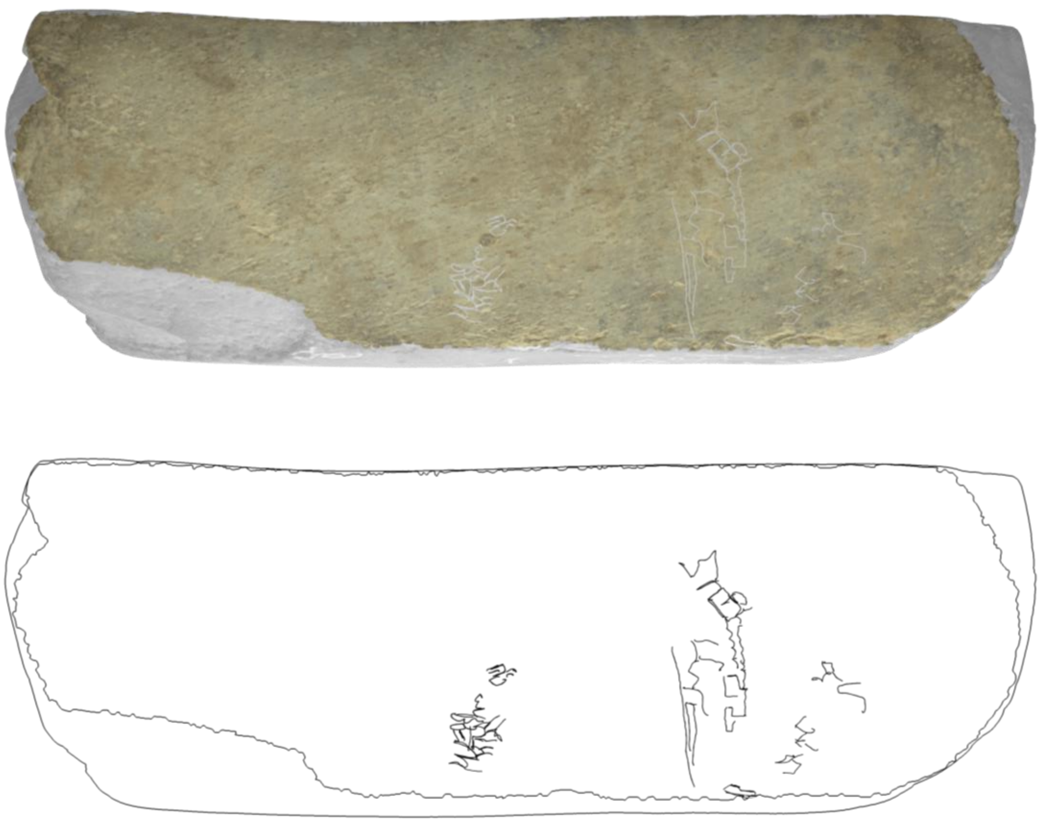

Figure 19. 3D render of finished surface (shown in brown texture above) of side S1 with edge detection and tracing and the 3D map showing with areas of detected faint incised markings. Note corner shaping and modification areas are also able to be readily considered using the 3D model information.

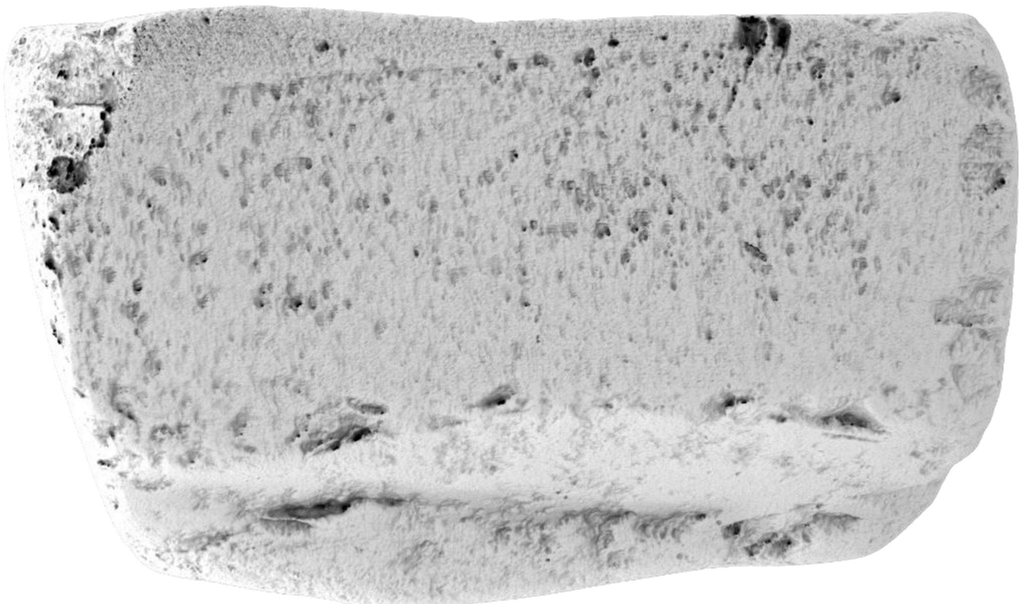

Figure 20. Planar surface of side S2 using AO and cavity render with 3D data, showing faint indications of incised carving. Corner modification and markings are also noted on this side, with detail allowing for examination for how the stone was shaped and modified now possible.

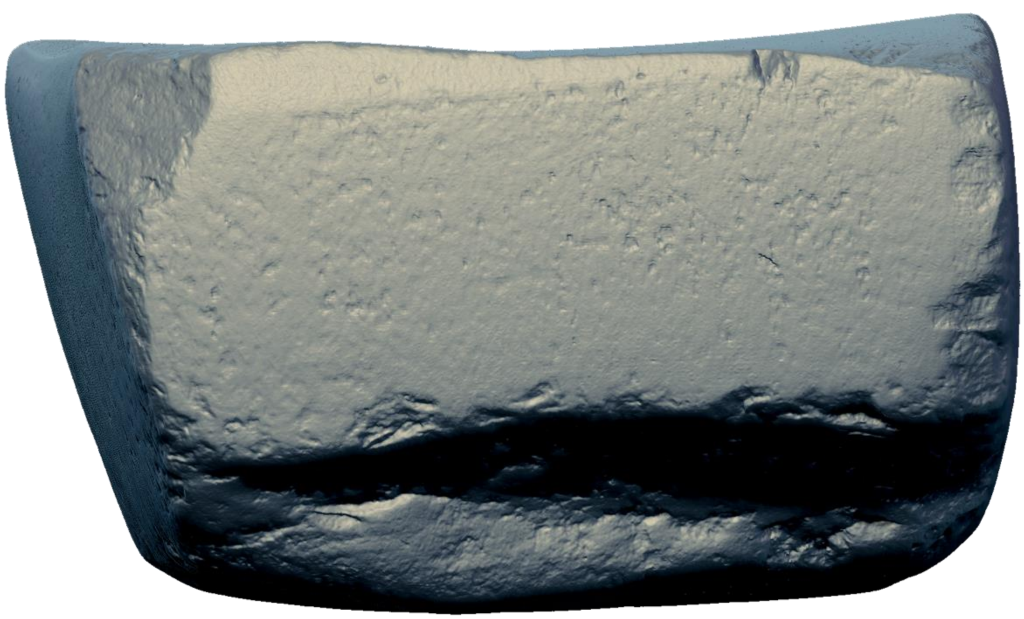

Figure 21. Perspective view showing side S2 using a material capture shading technique, helping to highlight evidence of distinctive tool and other faint markings evident on the stone's surface. Corner modifications and shaping of the stone can also clearly be seen from this perspective.

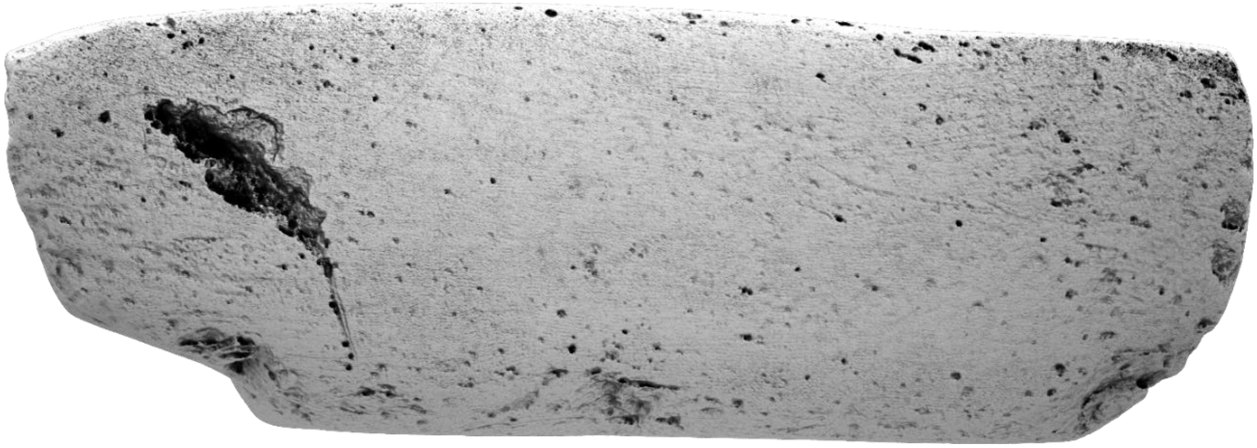

Figure 22. Planar surface of side S3 using AO and cavity render with 3D data, showing faint indications of incised carving. This face shows the base modification and shape of the stone, as well as the rounding and squared off morphology of this planar surface in relation to the stone shape. Note as well the large fracture to the left side of the face.

Figure 23. 3D render of finished surface (shown in brown texture above) of side S3 with edge detection and tracing and the 3D map showing of S3 with areas of detected faint incised markings. Note corner shaping and modification areas are also able to be readily considered using the 3D model information.

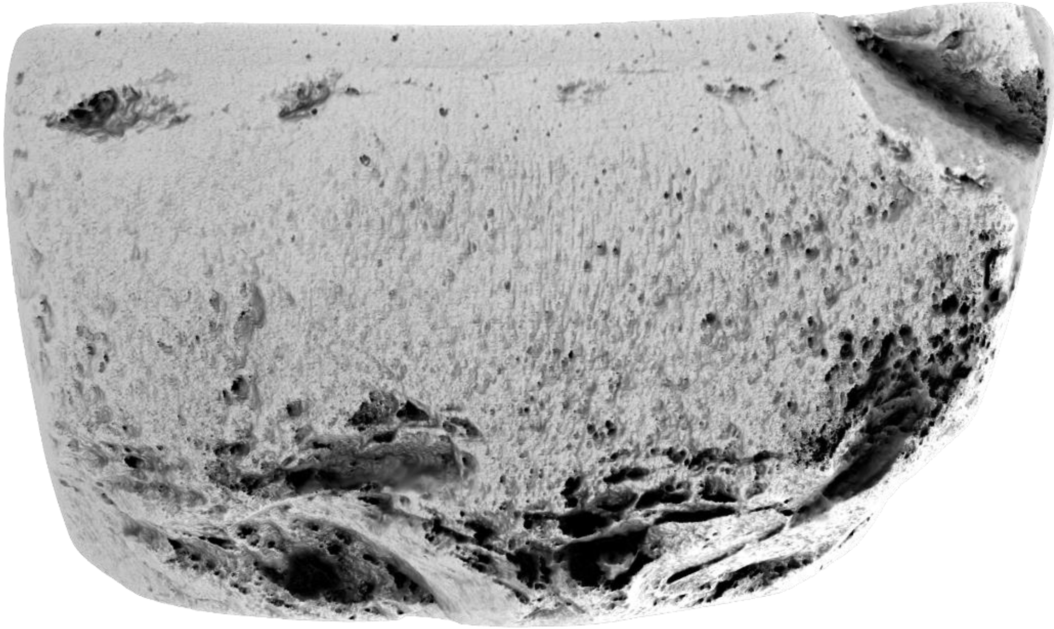

Figure 24. Planar surface of side S4 using AO and cavity render with 3D data, showing faint indications of incised carving, edge shaping and modification, tool markings, and natural mechanical weathering of the rock.

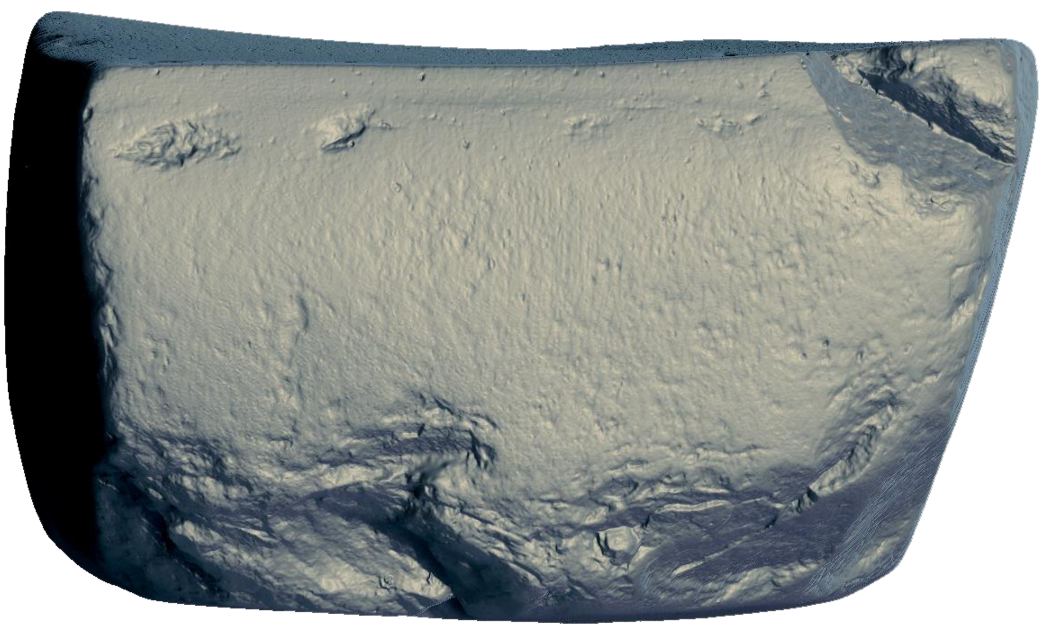

Figure 25. Perspective view of side S4 using a material capture shading technique to show shape, lighting and reflective aspects of the stone, highlighting tool markings, shape modification, and areas of mechanical weathering.

Side 5 (S5) is considered the basal portion of the stone, but substantial parts of it have been smoothed as a prepared surface and are well patinated (Figure 26). Several straight parallel lines are noted on the face of this side that appear to suggest marks made by the movement (sliding) of the stone across a surface that contained abrasive materials, such as sand or quartz (Figure 26). These marks are deeper and wider than the purposefully incised carved markings noted on the stone, and these may be related to modern or ancient activities or movement. A Digital Elevation Model (DEM) derived from the 3D data, is used to illustrate the bare surface of side S5, showing the variance in surface height across the transverse portion of the stone and elevation consistency in the longitudinal direction (Figure 27, see also Figure 14 for section comparisons).

Side 6 (S6) has been the primary focus of the previous investigations of the Cascajal Block with readily apparent carved script elements covering the surface (Figure 27). S6 is the only side of the stone where the finished area basically covers the entire surface. A total of 62 script-like elements have been noted (Doering and Collins 2008) and interpretive line drawings of the S6 surface have been produced largely relying on photographs that were taken of the piece. S6 has been referred to as flat (Skidmore 2006:2), and the 2D representations (i.e., photographs and drawings) also give the impression that the surface is even or uniform. A digital surface model (DSM) generated from the 3D scan data is used to illustrate the elevations of surface details such as differences across carved elements as well as the smooth surface of the stone. The DSM of S6 shows that there is substantial variation in height across the surface, with a low to high range of 17.1 mm or 0.66 inches (Figure 29). Importantly, the stone is curved, with higher elevations along the sides and edges of the stone and with data suggestive of an abrading or polishing that is reminiscent of the grinding surface of metates. In the case of the Cascajal Block, the concave pattern is along the longitudinal axis as opposed to the transverse axis common on metates. The groove is uneven and not symmetrical across the plane, which suggests a different method of smoothing or rubbing than is typically seen with used metates. We propose using 3D and imaging technologies to conduct a re-examination of the "ground stone artifacts" (Skidmore 2006:2) that were recovered with the block. Combining these data with the data from the Cascajal Block, could potentially offer further insight into functional aspects of the piece.

Previous investigators of the Cascajal Block considered the S6 surface to be an "erasable document that could be removed and revised" (Doering and Collins 2008:1612), and others had observed that some of the designs or icons seem to have been erased (Ortiz Ceballos et al. 2007). Analysis of the 3D data support these earlier conclusions. The surface of S6 was re-finished (e.g., ground or polished) in attempts to erase or remove previous incisions. This repeated use or recycling has created a palimpsest-like surface

Figure 26. 3D render of side S5 using AO and cavity shading techniques. Of note are faint indications of incised markings and straited lines and scratches that are suggestive of abrasion caused by movement of the stone. Also noted are edge shaping, breakage and modification, tool markings, and natural mechanical weathering of the rock.

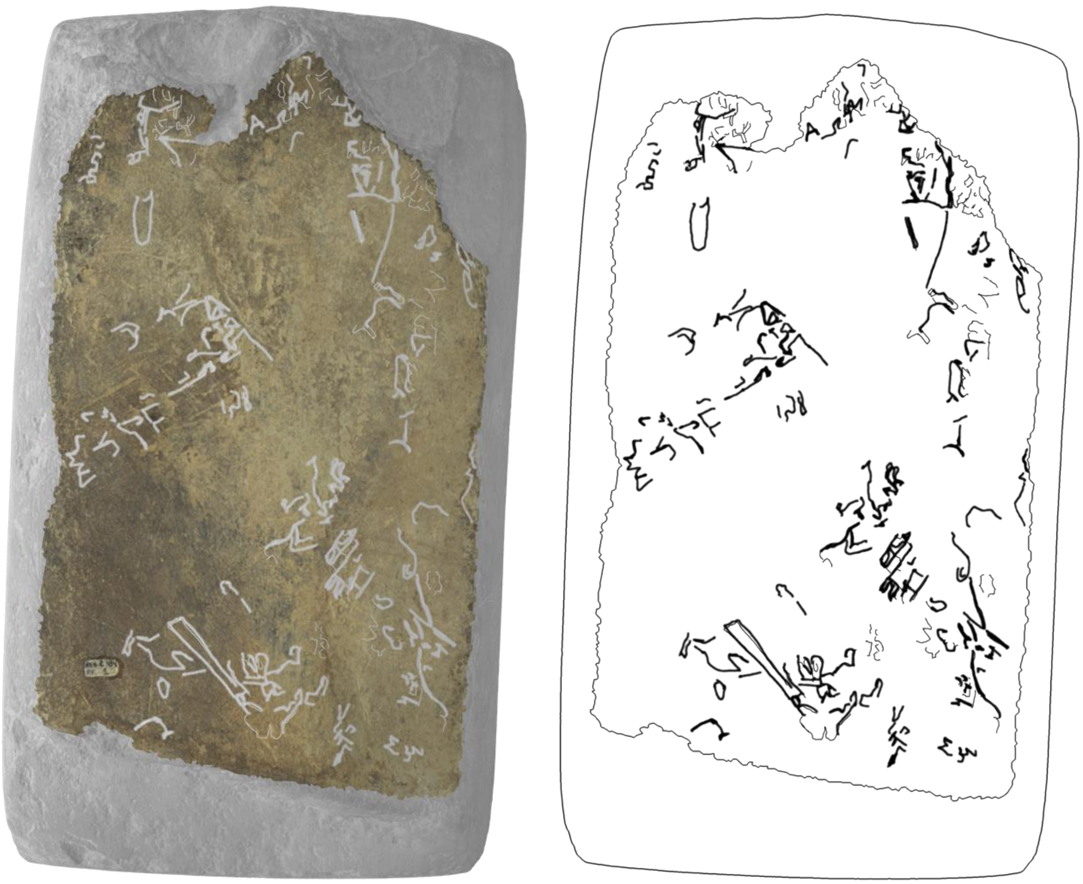

Figure 27. 3D map depicting finished surface of S5 with incised markings depicted (left). Numerous lines were detected in the scan data, many having the appearance of striations or scratches possibly attributable to moving or dragging of the stone. Edge highlight tools and digital tracing in the 3D environment were performed using raking light, occlusion, and other render processing techniques to better discern and depict these elements (right). Areas of stone modification and tool marks also are also seen on the S5 surface, especially along edges and at corners of the stone.

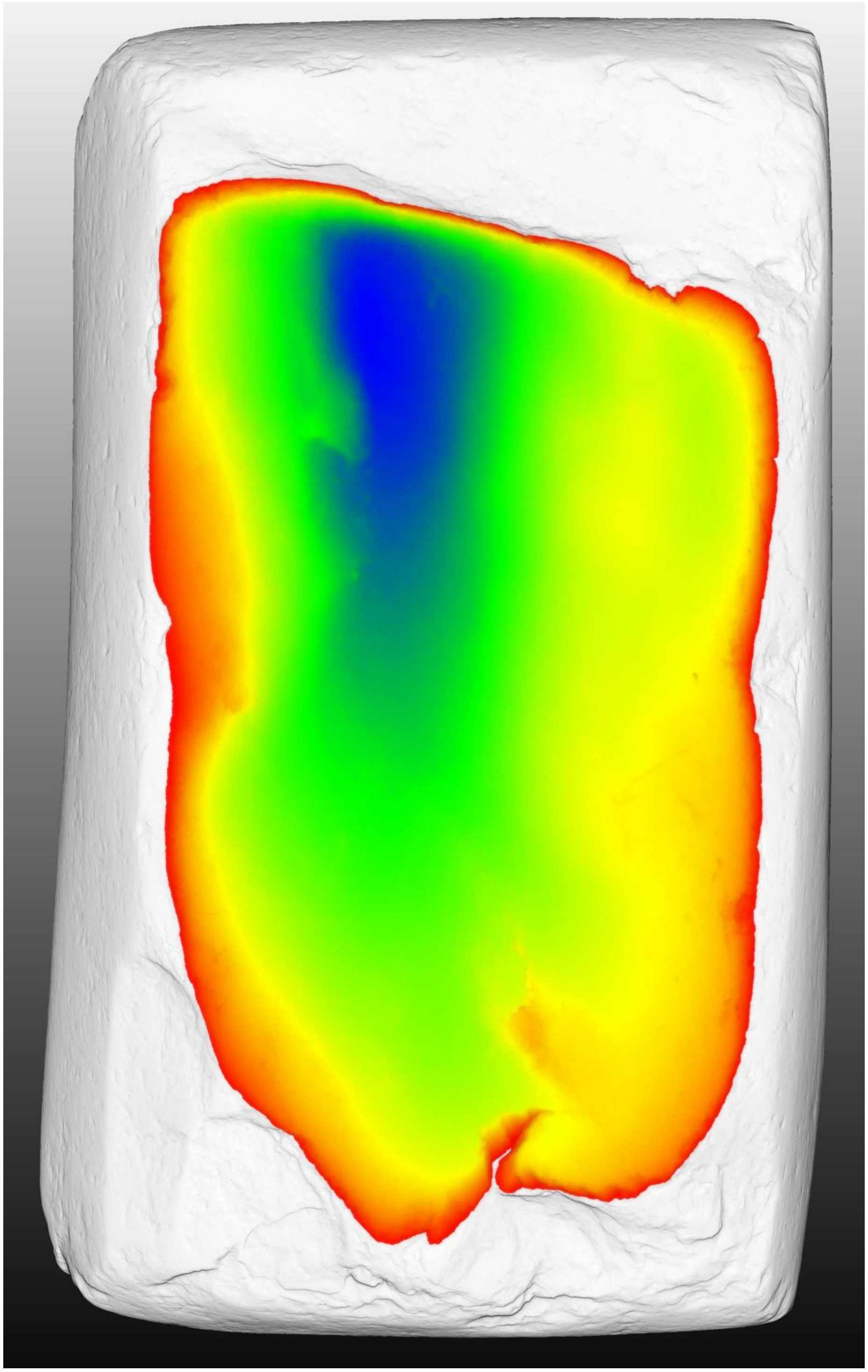

Figure 28. Digital elevation model (DEM) of side S5 created with the 3D data and showing height difference from blue (higher/flattened areas) to red (more convex portions). The DEM illustrates modification of the surfaces to create a prepared or smoothed face.

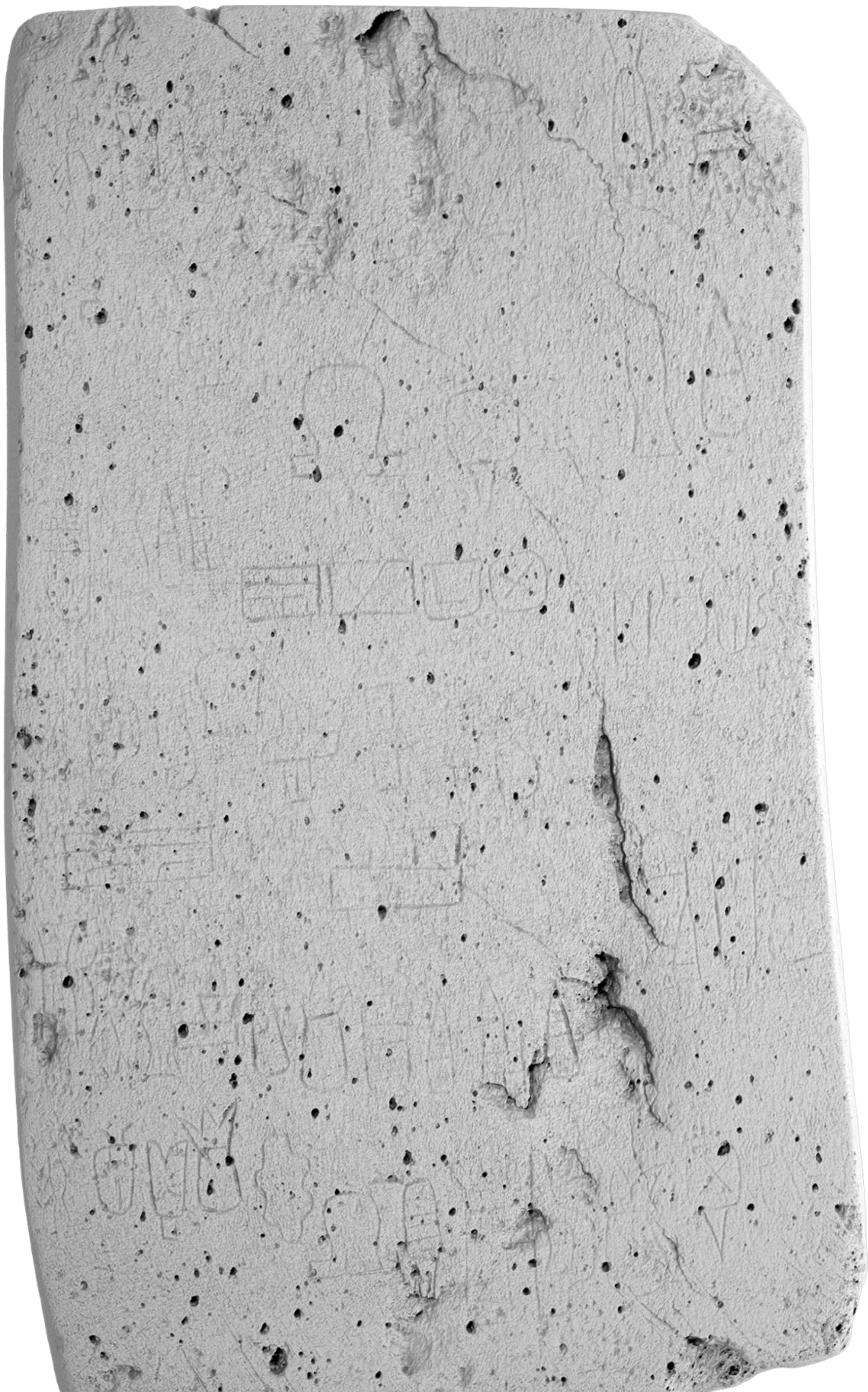

Figure 29. Detail of side S6 illustrating incisions that have been detected.

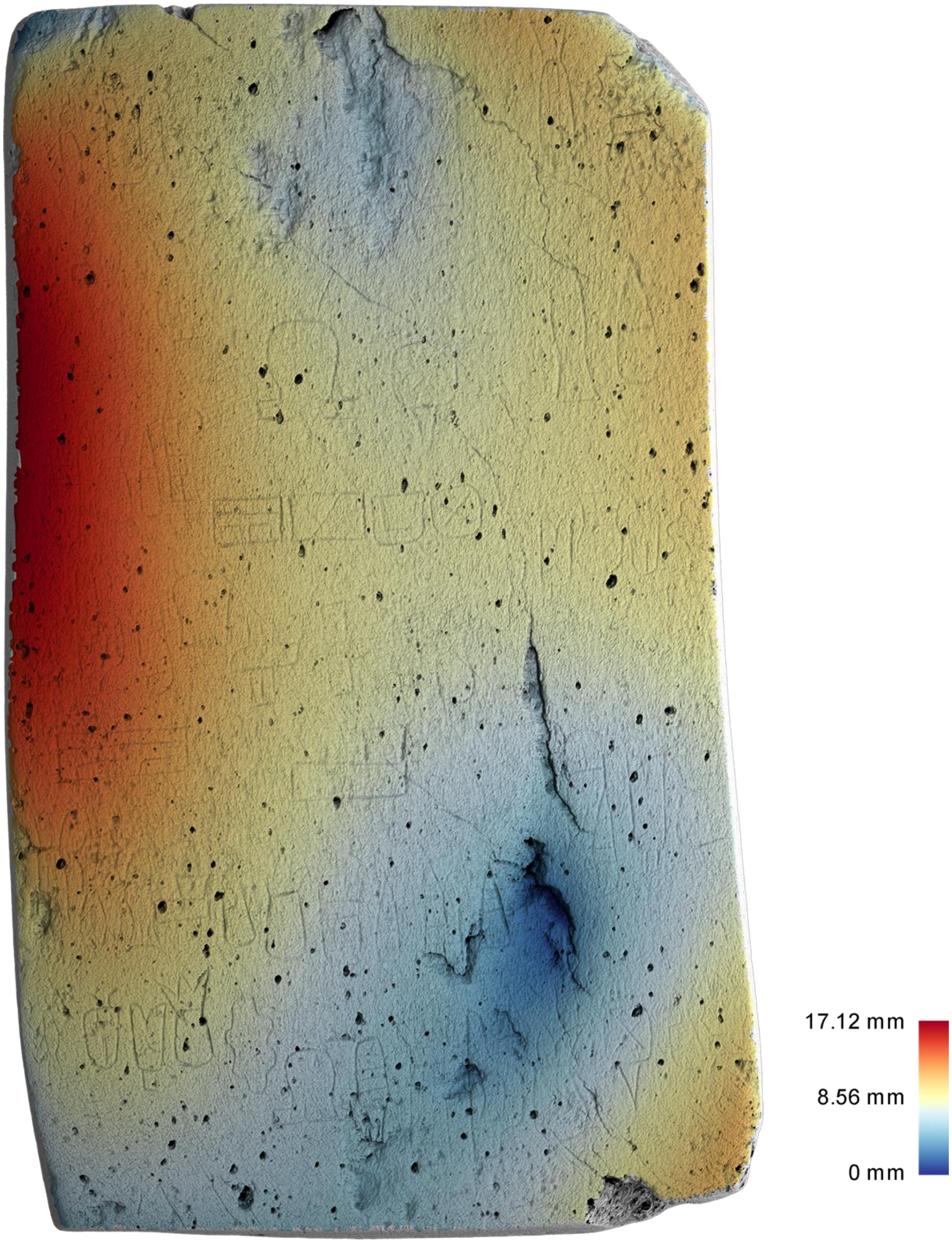

Figure 30. A digital surface model illustrating the variability of the surface contour on S6. High areas are depicted in red, mid-level in yellow, and low areas in blue.

with the original incising abraded and effaced as the stone was reused. Traces of these earlier inscriptions remain (Lyons 2011:215) and are clearly evident in the 3D data. Many of the markings are tantalizingly faint and are often indecipherable, with a number of S6 incisions indistinct or covered over. The concavity of the surface makes for difficult visualization of the entire area using a single image or photograph. Appropriate surface examination requires methods using 3D software viewing that allow consideration of individual segments or portions and provide alternating light, angle of ray, shadow, color, and texture.

Concluding Remarks

The technologies used to digitally document the Cascajal Block in 3D have revealed substantial evidence of previously unrecognized incised elements on faces of the stone, including those not previously considered on the primary (side S6) portion of the block. The analysis of the morphology has also provided more insight into the stone's form and function. 3D visualization and modeling allow for variable examination and afford new directions for continued analysis and inquiry. Capturing a digital surrogate also provides an archival record for the piece and serves as a tool for conditional assessment and documentation into the future. Compared to earlier photographs and drawings made in 1999 of the piece there are slight surface degradation and change areas we noted. These change considerations and concern for the permanence of the piece, demonstrate the vital importance of having a metrologically accurate surrogate record.

These 3D data, when compared to previous images and drawings made of the side S6, suggest new incised markings and elements, evidence of reuse, traces of additional carved elements, and variation from previous studies of some of the iconographic depictions. Further, we found evidence of markings, striations, and tool modifications on all sides of the piece that are important considerations in its life use and function. Figure 31 shows our rendered 3D model perspective of side S6, with digital edge and line extraction applied to reveal more readily identified markings that were able to be digitally traced using the model as a base reference. We further applied these techniques on areas of faint markings to examine palimpsest traces that remain, and we use line weight differences to show these fainter markings in relation to the deeper incised and carved-over elements.

As a result of this project, a 3D map of the entirety of the Cascajal Block inclusive of all dimensional and carved details and textural information has been archivally captured, allowing for a digital surrogate for preservation and study of the piece as it currently exists. This digital record can be compared (Figure 32), readily shared, and analyzed in variable ways to allow for new insights and understandings to emerge

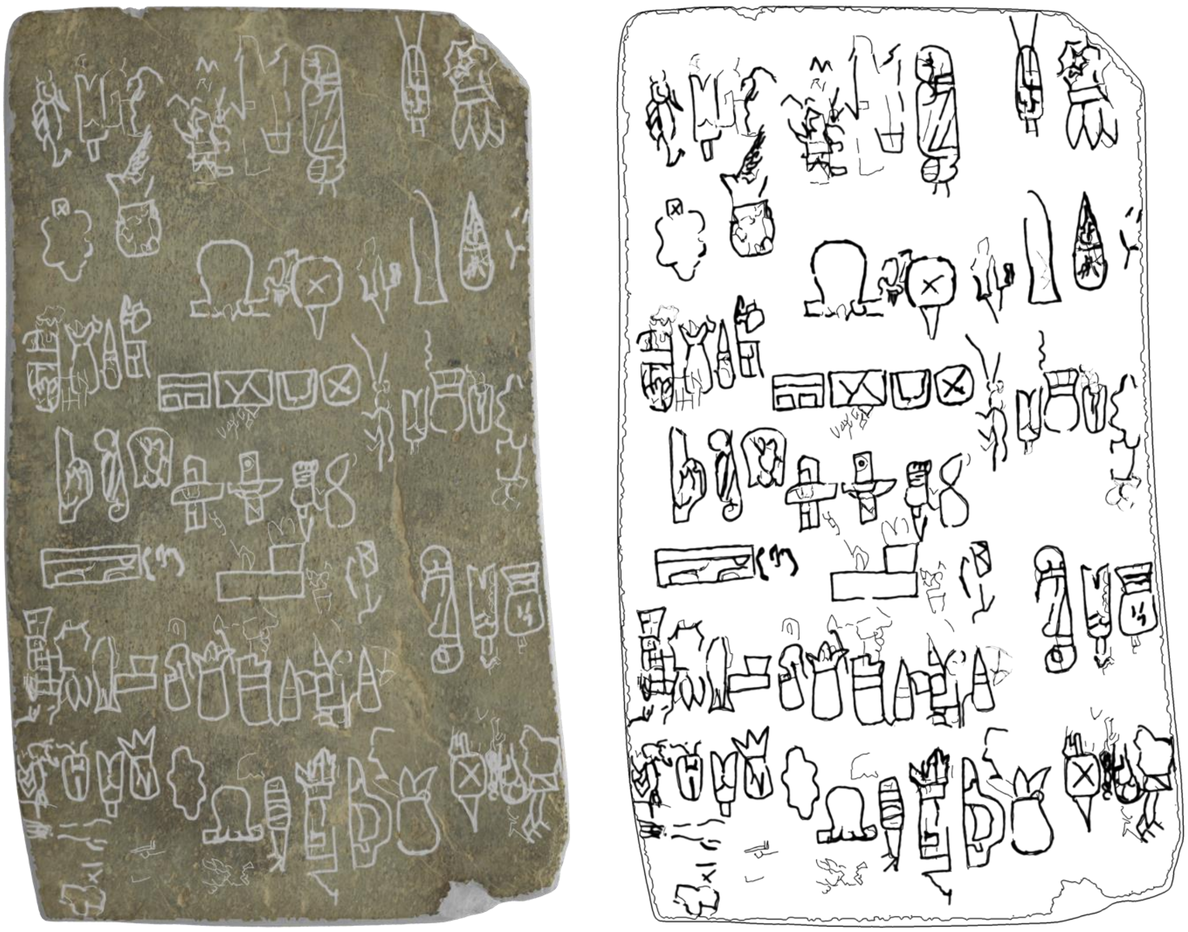

Figure 31. Edge and line interpretation using 3D model (left) and showing the areas of script signs isolated from side S6 (right).

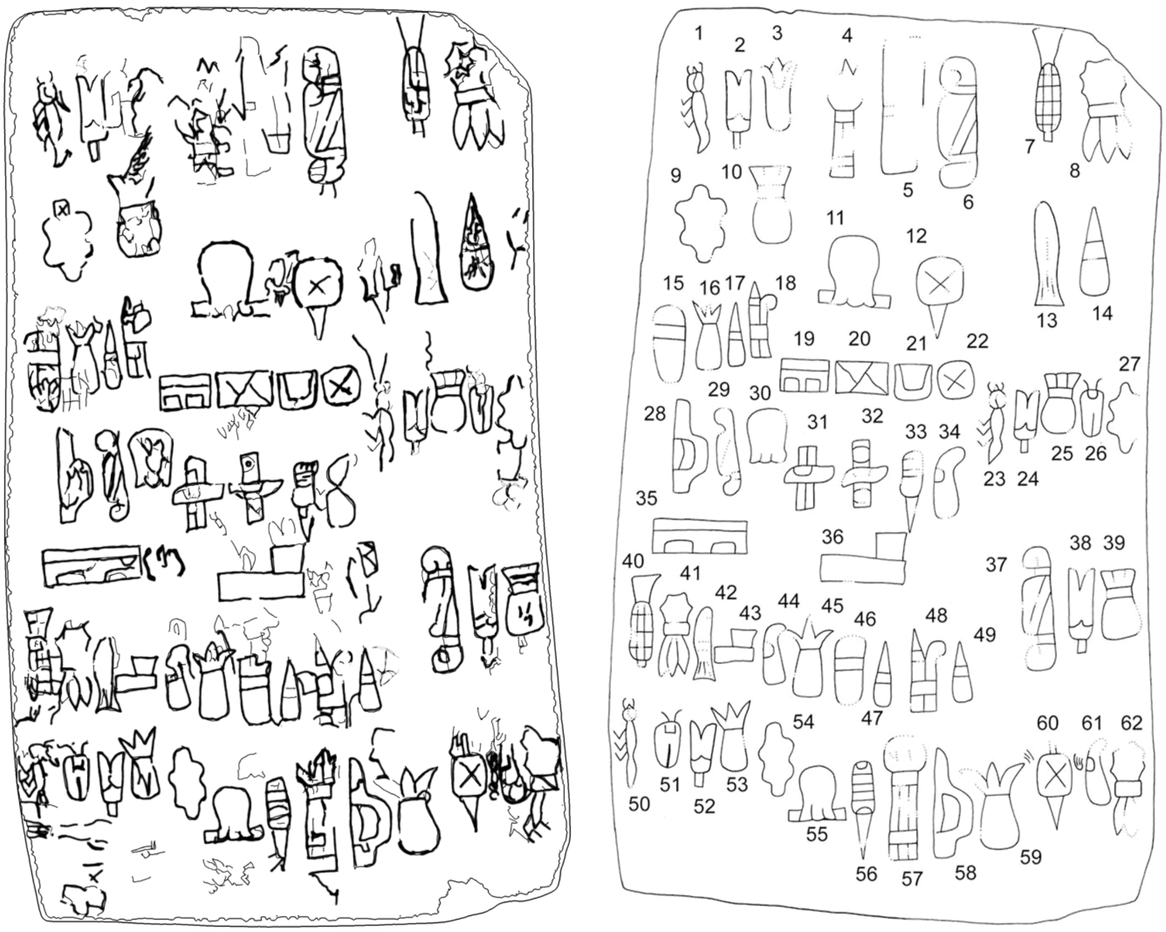

Figure 32. Edge and line interpretation using 3D model (left) to show the areas of script icons isolated from side S6. Previous investigation and epigraphic drawing (right) demonstrated 62 isolated signs (Rodríguez Martínez et al. 2006: 1612). Slight differences in line interpretation exist, as do the number of signs discovered, and the trace remains of areas that have been effaced to make room for later signs (see also Figure 31). Note that when compared to previous drawings, errors in the shape and orientation of the stone have been made.

as to the possible use, association, and temporal affiliations for this important stone artifact. Our documentation and analyses offer a proposed direction for additional inquiry and provide a foundation for research, interpretation, conditional assessment, and associative examination into the future. Since the time of our fieldwork, the Cascajal Block has been moved to the custody of the Instituto Nacional de Antropología e Historia (INAH), and the piece has been on interpretative display at Museo Nacional de Antropología (MNA), in Mexico City. Our planned follow-up analyses and targeted documentation will take advantage of a more controlled museum environment, and our plans are to focus on areas shown to contain possible markings and modifications from this study, utilizing imaging and structured light scanning at potentially higher resolution than was previously possible in field settings.

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