Mesoamerican Sculpture: Three-Dimensional Documentation to Dissemination

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Abstract

The use of close-range, three-dimensional laser scanning for the documentation of ancient Mesoamerican sculpted artifacts (e.g., stone, ceramic, stucco, wood) provides significant advantages in issues of conservation, research, analysis, and dissemination. A series of case studies will illustrate how scan data have been used as a core element in the development of expandable, research databases that offer substantial benefits and advancements to archaeological investigations. Results from this approach have substantially expanded opportunities for international study and collaborative research initiatives. Innovative analytical techniques for the examination and interpretation of Mesoamerican sculpture, the development of research and educational resources, the recording of metadata, and methods of electronic dissemination are discussed.

The results from projects in the United States, Mexico, and Guatemala will show how researchers have access to data sets that allow for comparative and metrological analyses of size, shape, features, and surface detail of Mesoamerican carved artifacts. Examples include the use of close-range scanning technology as a foundational referent that improve, enhance, and increase the extraction of the detail and information carved and encoded on Mesoamerican sculpture. These objects can be analyzed, visualized, measured, and evaluated more effectively and precisely than if the researcher were in the field or had the physical object in their presence. Perhaps the most exciting capability of 3-D scanning of Mesoamerican sculpture is its ability to capture data that can be used to rescue or resurrect carved details on damaged or degraded monuments that have not been previously discernable.

In addition to other advantages produced by this laser scanning technique, it is possible to disseminate these data resources to an international audience of researchers, educators, students, and interested parties via web-based platforms. This type of presentation offers exceptional opportunities for the development of specialized techniques and improved methods for epigraphic and iconographic analysis and interpretation. Along with these benefits, however, come a variety of disparate issues that must be addressed. Foremost are the rights and privileges of the owners or stakeholders of the artifacts that have to be recognized and protected. Potential problems that could arise from the dissemination of the data must be identified and safeguards put in place to prevent their improper use.

***Key words**:3-D laser scanning, Mesoamerica, stone sculpture*

1 Introduction

Sculpted artifacts and monuments from Mesoamerica contain graphic images and contextual information that illustrate socioeconomic, political, and ideological practices and beliefs of the ancient people who produced them. Further, these carved objects present a developmental continuum of intra-regional and inter-regional iconography and epigraphy. By implementing the "best available technologies" for the data capture, processing, and presentation, a more detailed and comprehensive analysis of the objects and their illustrative content becomes achievable. We will demonstrate how the combination of three-dimensional documentation through the use of close-range laser scanning and the dissemination through a web-based portal can directly lead to better understanding and interpretation the information encoded on these

items. This paper will primarily focus on Mesoamerican sculpted stone monuments, however, we have conducted similar work on ceramic vessels and objects of carved bone, shell, wood, and stucco with equal success.

2 THE SIGNIFICANCE OF MESOAMERICAN SCULPTURE

The emergence of complex societies across Mesoamerican during the Formative period (c. 1800 BC to AD 150) and their subsequent evolution throughout the Classic and Postclassic periods (c. AD 150 to 1519) have intrigued researchers and the general public for centuries [1, 2].

The carved stone monuments from Mesoamerica contain narrative scenes, a sequence of vignettes that portray the fundamental principles of power, rulership, and ideology. Guernsey [3:ix] considers these types of monuments to be "more than a reflection of the dramatic changes" that took place across Mesoamerica, but are instead, one of the "forces directly responsible for motivating and structuring" the significant social, political, and economic events that shaped the social trajectories within this culture area.

To arrive at an understanding of these cultural developments, all lines of archaeological data and inquiry are necessary. Nevertheless, one of the best ways of understanding the motivations of these ancient peoples is through the study of the allegorical and expository content embedded on their carved monuments. In addition to the content, the differing styles and forms illustrate the continuity, modification, and deviation in the portrayal of ancient lifeways that occurred across considerable space and time [4]. The political and cosmological messages incorporated in these monuments could cross multiple ethnic and civic boundaries or be used to demarcate those same borders.

Prehispanic societies from practically every region throughout Mesoamerica produced prodigious quantities of monumental sculpture. The Olmec of the Southern Gulf Coast Lowlands created some of the earliest and most massive monuments that demonstrate "remarkable naturalism of the three-dimensional figures" [5:28]. The tradition of monolithic stone sculpture spread across Mesoamerica: along the Soconusco Coast at places like Izapa, Tonala, and Takalik Abaj, to Kaminaljuyu in the Guatemala Highlands and Chalchuapa in western El Salvador. Ancient monumental sculpture appears in Puebla, Oaxaca, Guerrero, Morelos, the Valley of Mexico, Tabasco, Veracruz, Chiapas, the Huasteca Region, across the Yucatan Peninsula, and Jalisco, Michoacan, Colima, and Nayarit in West Mexico. Stone carvings are present throughout Guatemala, Belize, and Honduras. These monuments are artistic

1. Elizabeth P. Benson, 'History of Olmec Investigations', in *Olmec Art of Ancient Mexico*, eds. E. P. Benton and B. de la Fuente (Washington, DC: National Gallery of Art, 1996).

2. Michael D. Coe and Rex Koontz, *Mexico: From the Olmecs to the Aztecs*, Fifth ed. (New York: Thames and Hudson, 2002).

3. Julia Guernsey, *Ritual and Power in Stone: The Performance of Rulership in Mesoamerican Izapan Style Art*, (Austin: University of Texas Press, 2006).

4. Mary Ellen Miller, *The Art of Mesoamerica: From Olmec to Aztec, Thames and Hudson World of Art*, Fourth ed. (New York: Thames and Hudson, 2006).

5. Esther Pasztory, *Pre-Columbian Art*, (Cambridge: University of Cambridge Press, 1998).

6. J. E. Clark and M. Blake, 'The Power of Prestige: Competitive Generosity and the Emergence of Rank Societies in Lowland Mesoamerica', in Factional Competition and Political Development in the New World, New Directions in Archaeology, eds. E. M. Brumfiel and J. W. Fox (Cambridge: Cambridge University Press, 1994).

7. David C. Grove and Susan D. Gillespie, 'Archaeological Indicators of Formative Period Elites: A Perspective from Central Mexico', in Mesoamerican Elites: An Archaeological Assessment, eds. D. Z. Chase and A. F. Chase (Norman: University of Oklahoma Press, 1992).

8. Joyce Marcus, 'Leadership and Rulership', in Archaeology of Ancient Mexico and Central America: An Encyclopedia, eds. Susan Toby Evans and David L. Webster (New York: Garland, 2001).

9. Lee A. Parsons, 'Post-Olmec Stone Sculpture: The Olmec-Izapan Transition on the Southern Pacific Coast and Highlands', in The Olmec and Their Neighbors: Essays in Memory of Matthew W. Stirling, ed. Elizabeth Benson (Washington. DC: Dumbarton Oaks Research Library and Collections, 1981).

representations of the sociopolitical canons of the cultures that arose during the pre-Columbian era.

Across this span of nearly 3,000 years, social complexity emerged, ritual and rulership became the focal point of many cultures, and monumental stone sculpture evolved into the preferred physical manifestation of political power by the elite [6-9]. Unlike handheld, portable objects or elite grave goods these stone markers were intended to be public confirmation of rulership and authority that would remain visible and accessible for extended periods of time [10]. Through iconographic and epigraphic representations, the sculpted scenes could be used to demonstrate a leader's right to rule through affirmation of their connection to ancestors or deities [11, 12]. Victories in battle and the taking of captives were memorialized, as on Piedras Negras Stela 12, and elite rituals were depicted as on Yaxchilán Lintel 24. Deities and supernaturals were portrayed on façades at Teotihuacán, Tula, El Tajin, and on the Yucatan's Chenes and Puuc structures. At places like Loltún, Pijijiapan, and Xoc, narrative scenes were carved into the face of natural rock.

The interpretive and analytical value of the corpus of Mesoamerican stone carving is invaluable to researchers. It presents a continuum that contained conspicuous and nuanced elements of style and form. Since the Formative period, there existed "a dynamic, multiethnic interaction sphere that included not only the dissemination of tangible goods, but the communication of symbolic ideas as well" [3:6]. Many of the changes that occurred in the evolving political and economic landscape of Mesoamerica were expressed and preserved in an active sculptural record see [13, 14]. Visual vocabularies emanated from these monuments, images carved in stone that exemplified the diversity and transmutation in the form and display of power and authority. For example, in the Formative period, "Olmec sculptures are usually three-dimensional, to be seen from all sides, not just from the front" [2:67, 15]. During the Classic period, bas relief carving and decorative architectural sculpture predominated. Sculpture in the round reappeared during the Postclassic period in areas of the Yucatan Peninsula, in Toltec and Aztec Central Mexico, as well as among the Tarascans of Michoacan and Huastecs of the northwest Gulf Coast [16:656, 17].

2 Threats to Mesoamerican Monumental Sculpture

The permanency of archaeological artifacts, monuments, features, sites, and even landscapes is variable over time. Today, the application of best available technologies to the recordation of carved monuments and inscriptions in Mesoamerica takes on a more urgent priority due to their loss and damage through natural and human-induced processes that are occurring at unprecedented rates [18, 19]. Natural processes, such as erosion, acid rain,

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10. Linda Schele and Mary Ellen Miller, *The Blood of Kings*, (Fort Worth: Kimbell Art Museum, 1986).

11. Travis F. Doering, 'An Unexplored Realm in the Heartland of the Southern Gulf Olmec: Investigations at El Marquesillo, Veracruz, Mexico', (Tampa: Department of Anthropology, University of South Florida, Tampa. http://kong.lib.usf.edu:8881///exlibris/dtl/d3_1/apache_media/111620.pdf, 2007).

12. David C. Grove, *Olmec Altars and Myths*, vol. 26, *Archaeology*, (New York: Archaeological Institute of America, 1973).

13. John E. Clark, 'The Birth of Mesoamerican Metaphysics: Sedentism, Engagement, and Moral Superiority', in *Rethinking Materiality: The Engagement of Mind with the Material World*, *McDonald Institute Monograph Series*, eds. Elizabeth DeMarrais, Chris Gosden, and Colin Renfrew (Cambridge: McDonald Institute 2005).

14. Lee Allen Parsons, *The Origins of Maya Art: Monumental Stone Sculpture of Kaminaljuyú , Guatemala, and the Southern Pacific Coast*, *Studies in Pre-Columbian Art and Archaeology*, *Number 28*, (Washington, D.C.: Dumbarton Oaks Research Library and Collection, 1986).

15. Mary Pohl, Lori Collins, and Travis Doering, 'Reporte Del Escudriñamiento Laser De Tres Dimensiones De Los Monumentos Y Artifactos De La Venta', vol. 2, (Informe al Consejo de Arqueología, Instituto Nacional de Antropología e Historia, Mexico City, D.F., Mexico, 2009).

16. Emily Umberger, 'Sculpture', in *Archaeology of Ancient Mexico and Central America: An Encyclopedia*, eds. S. T. Evans and D. L. Webster (New York: Garland, 2001).

17. Eduardo Williams, 'The Stone Sculpture of Ancient West Mexico: Description and Interpretation', Ancient Mesoamerica 2(1991): 181-92.

18. Christina Luke, 'The Antiquities Trade, Museums, Legislation, and Borders: Central America as a Case Study', Athena Review 4, no. 3 (2007): 46-54.

19. David Matsuda, 'The Ethics of Archaeology, Subsistence Digging, and Artifact Looting in Latin America: Point Muted Counterpoint', International Journal of Cultural Property 7, no. 1 (1998): 87-97.

pollution, and root intrusion can imperil the archaeological record. Natural hazards including hurricanes, floods, earthquakes, and landslides have impacted ancient and modern Mesoamerica [20-24]. Recently, exuberant plant and vine growth that has relentlessly enveloped archaeological sites and monuments in tropical environments has increased substantially [25, 26] (Figure 1). Videla [27:335] demonstrates that many Mesoamerican monuments are "suffering deterioration caused by environmental factors…and by the action of micro- and macro-biological communities." These latter factors are subsumed under the term biodeterioration, which is defined as any undesirable or detrimental alteration in the properties of a material caused by the vital activities of organisms [28, 29].

Figure 1. Example of natural destruction of carved stone stela at the site of Calakmul, Campeche, Mexico

Anthropogenic factors, such as wanton mutilation, vandalism, graffiti, and looting, also have had grievous impacts on the information available to the researcher [18, 30-32] (Figure 2). All of these processes, individually or in combination, have decreased the visibility and availability of objects and sites, or made them difficult, if not impossible, to adequately document for research, analysis, conservation, and preservation. These types of endangerment can impact all archaeological material, whether they have been recently uncovered or long curated. Moreover, significant contemporary population growth, expansion of economic development, and associated construction of roads and housing throughout

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20. Antonio Benavides, 'Campeche Archaeology at the Turn of the Century', Anthropological Notebooks 11(2005): 13-30.

21. John L. Beven, 'Blown Away: The 2005 Atlantic Hurricane Season ', Weatherwise 59, no. 4 (2006): 32-44.

22. G. Berz et al., 'World Map of Natural Hazards – a Global View of the Distribution and Intensity of Significant Exposures', Natural Hazards 23, no. 2-3 (2001): 443-65.

23. Alexander López and Alicia Jiménez, 'Latin America Assessment Environmental Conflict and Cooperation: The Mesoamerican Biological Corridor as a Mechanism for Transborder Environmental Cooperation', (Mexico City, Mexico: United Nations Environment Programme, Environment and Conflict Prevention Initiative of the of the UNEP's Division of Early Warning and Assessment, 2006).

24. Payson Sheets, *The Ceren Site: A Prehistoric Village Buried by Volcanic Ash in Central America*, (Fort Worth: Harcourt Brace Jovanovich, 1992).

25. James D. Nations, *The Maya Tropical Forest: People, Parks, & Ancient Cities*, (Austin: University of Texas Press, 2006).

26. Ramakrishna R. Nemani et al., 'Climate-Driven Increases in Global Terrestrial Net Primary Production from 1982 to 1999 ', Science 300, no. 5625 (2003): 1560-3 (accessed 6 June 2008).

27. H. A. Videla, P. S. Guiamet, and S. Gomez de Saravia, 'Biodeterioration of Mayan Archaeological Sites in the Yucatan Peninsula, Mexico', International Biodeterioration & Biodegradation 46, no. 4 (2000): 335-41 (accessed December 2008).

28. H. J. Hueck, 'The Biodeterioration of Materials: An Appraisal', in *Biodeterioration of Materials*, eds. A. H. Walters and J. S. Elphick (London: Elsevier, 1968).

29. Dennis Allsopp, Kenneth J. Seal, and Christine C. Gaylarde, *Introduction to Biodeterioration*, (Cambridge: Cambridge University Press, 2004).

30. Ian Graham and Richard D. Hansen, 'The History of a Continent in Jeopardy', in *Looting in Latin America*, ed. International Council of Museums (Paris: ICOM, 1997).

31. Paul F. Healy, 'The Anthropology of Mesoamerican Caves ', Reviews in Anthropology 36, no. 3 (2007): 245-78.

32. Logan McNatt, 'Cave Archaeology of Belize', Journal of Cave and Karst Studies 58, no. 2 (1996): 81-99.

Figure 2. Example of human destruction of carved stone stela at the site of Calakmul, Campeche, Mexico, where looters cut carvings from monument.

Mesoamerica is having a deleterious effect on the archaeological record [33].

Scholars have also pointed out a lack of relevant comparative examples or adequate documentation of Mesoamerican artifacts hinders research and analysis. Poor illustrations, inadequate descriptions, and biased samples have prevented a holistic and in-depth analysis of the sculpted evidence [34:2]. Michael Coe [35] decried the omissions, insufficient photography, and the subjective recording of the sculpture. Graham [36:242] related that "the frequent problems of poor photographs at unsatisfactory angles, inappropriate or inadequate lighting, failure to clean monuments to reveal detail…[in]attention to the formal properties of the sculpture…result in misconceptions, and hinders or even precludes serious study." Of the objects that are published, most are those that are considered of the fine quality, a factor that eliminates the majority of sculptures from consideration [37:21]. The widespread distribution of artifacts to museums and collections around the world led Michael Smith [37:24] to state that, "We need to be able to use museum collections for research without visiting all of the collections in person."

In addition to the losses, damage, and limitations described above, multiple levels of subjectivity in the recording process also cause difficulty and restrain the analytical process. It is, therefore, imperative that sculpted objects, as well as other Mesoamerican artifacts and features, be documented as completely as possible using the best available technology at our disposal. Attempts are necessary to document the as much of the archaeological record as possible, whether the objects are in museum collections, storage facilities, in situ, or in the field. The best case scenario, for present and future archaeological excavations or investigations, is to record objects as they are uncovered and add them to an expanding corpus of material. The images and descriptions of these objects should then be made as accessible and broadly disseminated as possible.

3 Improving Documentation and Analysis of Mesoamerican Sculpture

In a report to the Getty Conservation Institute regarding stone monuments, Clifford Price [38: 30] stressed the importance of recording and

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33. Catherine M. Cameron, 'The Destruction of the Past: Nonrenewable Cultural Resources ', Natural Resources Research 3, no. 1 (1994): 6-24.

34. Richard A. Diehl and Janet Catherine Berlo, *Mesoamerica after the Decline of Teotihuacan, A.D. 700-900*, (Washington, DC: Dumbarton Oaks, 1989).

35. Michael D. Coe, 'Cycle 7 Monuments in Middle America: A Reconsideration', American Anthropologist, New Series 59, no. 4 (1957): 597-611.

36. John A. Graham, 'Olmec Diffusion: A Sculptural View from Pacific Guatemala', in *Regional Perspectives on the Olmec*, eds. R. J. Sharer and D. C. Grove (Cambridge: Cambridge University Press, 1989).

37. Michael E. Smith, 'Aztec Materials in Museum Collections: Some Frustrations of a Field Archaeologist', The Nahua Newsletter Center for Latin American and Caribbean Studies, Indiana University, 38(2004): 21-8 (accessed November 2008).

documenting stone sculpture. He stated, "If we cannot preserve stone forever, it is imperative that we make the best possible record of it. Indeed, one could argue that recording should have a higher priority than preserving the stone itself" [38:30]. He adds that conventional methods still have a place in recording, but attention is turning increasingly to techniques of three-dimensional recording.

High Definition Digital Documentation (H3D) is an approach to archaeological research that involves a suite of exceedingly accurate three-dimensional and high-resolution spatial data collection and processing techniques see [39, 40, 41 15]. These proven procedures provide capabilities for in-depth comprehensive documentation, research, and analysis in ways that have not been possible earlier. At the center of H3D is three-dimensional laser scanning, an advanced spatial data acquisition technology that significantly improves, enhances, and increases the extraction of detail and information that is carved and encoded on Mesoamerican stone sculpture. Typically, high definition scanning is considered the systematic and automated collection of three-dimensional data of a particular surface or object at a relatively high rate and in near real time [42, 43]. Boehler [44] provides a technical description of various scanning processes.

The type of laser scanning conducted in our projects does not require physical contact with the objects, and is a non-invasive, non-destructive process that, in our experience, has offered optimal results. The minute detail observable in the spatially exact data, in many instances, is superior to stereophotography and photogrammetry methods that only convey an illusion of depth and only from a single viewpoint. Holography is visually striking, but does not supply a quantitative record. Traditional techniques of molding and casting are not practical on the fragile, damaged, or deteriorated surfaces that are common on Mesoamerican stone sculpture. Scanning data collection is rapid, taking minutes or hours compared to other methods that could take days or weeks to complete.

Beyond the spatial problems of parallax distortion and limited perspectives, traditional techniques of recording include various levels of subjectivity that, intentionally or unintentionally, lead to incomplete or erroneous interpretation see [10:22]. The subjective biases, inherent in conventional methods of documentation, are introduced by the recorder's decision as to what is important and what is to be captured. Outstanding elements may be recorded at the expense of others that the individual instinctively deems unimportant but, in reality, may be vital to the interpretation of the artifact or message. Further interpretive problems arise when a single or limited view is presented, a common limitation of current two-dimensional images. Laser scan data allows the entire visible surface of the piece to be observed three-dimensionally, the way the sculpture was originally intended to be viewed.

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38. Clifford A. Price, *Stone Conservation: An Overview of Current Research*, *Research in Conservation*, (Santa Monica, CA: The Getty Conservation Institute, J. Paul Getty Trust., 1996).

39. Lori D. Collins and Travis F. Doering, 'Mapping the Moundbuilders: Revisiting the National Landmark Site of Crystal River (8ci1), Florida, Using Integrated Spatial Technologies', (Division of Historical Resources Grants in Aid, Survey and Planning Program, State of Florida, Tallahassee, 2007).

40. Travis F. Doering and Lori D. Collins, 'Revisiting Kaminaljuyú Monument 65 in Three-Dimensional High Definition ', in *The Place of Sculpture in Mesoamerica's Preclassic Transition: Context, Use, and Meaning*, The 2007 Dumbarton Oaks Pre-Columbian Symposium, Antigua, Guatemala, 5-6 October 2007, eds. John E. Clark, Julia Guernsey, and Barbara Arroyo (Washington, D.C.: Dumbarton Oaks, forthcoming).

41. Travis F. Doering and Lori D. Collins, 'The Kaminaljuyú Sculpture Project: An Expandable Three-Dimensional Data Base, Final Report', (Crystal River, FL: Foundation for the Advancement of Mesoamerican Studies, Inc. (FAMSI), http://www.famsi.org/reports/07007/index.html, 2008).

42. Wolfgang Boehler et al., 'High Quality Scanning and Modeling of Monuments and Artifacts ' (paper presented at Proceedings of the FIG Working Week, Athens, Greece, May 22-27, 2008).

43. Erwin Frei, Jonathan Kung, and Richard Bukowski, 'High-Definition Surveying (Hds): A New Era in Reality Capture', International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences XXXVI, no. 8 (2004): 262-71.

44. Wolfgang Boehler, Guido Heinz, and Andreas Marbs, 'The Potential of Non-Contact Close Range Laser Scanners for Cultural Heritage Recording' (paper presented at CIPA International Symposium Proceedings, Potsdam, Germany, 2008).

The use of three-dimensional scanning on Mesoamerican sculpture is based on its numerous advantages over other recording techniques, and its ability to produce and visualize details on carved stone monuments to a degree of precision and clarity that have not been possible previously. This ability to literally "see" the narrative scenes more clearly and in greater detail will allow its analysis and interpretation to move to a higher level as well. In sum, most sculpture has not been sufficiently documented to permit critical comparative morphologic, iconographic, or epigraphic analyses. Three-dimensional scanning substantially lessens, if not eliminates, most of the difficulties and limitations including much of the subjective nature inherent in other methods of documentation. Thus, laser scanning is currently the most appropriate technological method for the majority of applications, which, besides thorough comparative analyses, includes archiving, restoration, reconstruction, replication, and monitoring for damage and deterioration [38: 30, 45, 46].

Minimally, the technology provides the finest archival documentation possible for museum or collection registration, heritage preservation planning and management, public presentations, and educational applications. The benefits to long-term research and analysis, however, are exceptional. Perhaps the most exciting capability of three-dimensional scanning is its ability to capture data that can be used to rescue or resurrect sculpted details that, through wear, erosion, or other causes, have not previously been known or discernable [40]. Additionally, the life history of use, re-use, and recycling of the stone can be deduced from the data. New perspectives and considerations of the sculpture are provided by the ability to electronically manipulate, visualize, and measure the object. Evidence of tool marks, wear, grooving, etching, and abrading that, heretofore, may not have been visible to researchers can be analyzed and enhanced through the electronic cross-sectioning of the piece.

4 An Expandable Electronic Archive: Web-Based Dissemination

In 2006, the University of South Florida's Alliance for Integrated Spatial Technologies (AIST) and the Foundation for the Advancement of Mesoamerican Studies, Inc. (FAMSI) began a collaborative effort entitled the Mesoamerican Three-Dimensional Imaging Database. The result is a freely accessible resource data base <http://research.famsi.org/3D_imaging/index.php> that is hosted on the FAMSI web site. The database is an ongoing developmental effort to make high definition, three-dimensional laser scans of Mesoamerican objects viewable to researchers online.

The electronic archive was designed to address a number of deficiencies and limitations in data previously available for iconographic, epigraphic, and other comparative research and analysis. Previously, many Mesoamerican sculptures have not been adequately documented or organized in a comprehensive manner. These artifacts are dispersed in museums and collections around the world, a factor that makes access to them difficult. There have been instances where pieces have been misplaced or misidentified. Frequently, when traditional methods of recording have been made, the images, scale, and detail are not adequate for the type of comprehensive study required. The recording and images of sculpted monuments has been, at best, irregular and it remains incomplete today.

The data base is intended to accommodate continued use and development and is designed to be a living document. On-going and future recordation of other Mesoamerican artifacts, features, architecture, sites, and landscapes are being conducted by the authors, and will be made available to the research community. We would like to encourage other researchers using these and other forms of documentation and visualization in their

45. Lori D. Collins and Travis F. Doering, 'Integrated Spatial Technologies: High Definition Documentation of the Miami and Royal Palm Circles', The Florida Anthropologist 59, no. Special Issue: The Miami Circle: Fieldwork, Research and Analysis II with additional commentary by Robert Carr (2006): 161-77.

46. Lori D. Collins, Travis F. Doering, and Chris Branas, 'High Definition Documentation Survey (Hdds) of the Yulee Sugar Mill, Citrus County, Florida', (Technical project report submitted to the Florida Park Service, Department of Environmental Protection, Tallahassee, FL, 2006).

work to contact us about adding to and improving the web portal. To date, this archive contains more than 80 documented monuments, and is part of the FAMSI web portal that receives more than 746,108 hits per month.

5 Research and Analytical Capabilities

Archaeological research and analysis are substantially enhanced and facilitated by the use of scan data sets, and in-depth, comprehensive examinations of the stone and its sculpture can be conducted in a virtual computer environment. Our work has demonstrated that the 3-D data acquired through scanning allows objects to be analyzed, visualized, measured, and evaluated more effectively and precisely than if the researcher were in the field or had the physical object in their presence (Figure 3). The objects can be virtually rotated 360º and viewed in true three-dimensions. The angle of the light source can be maneuvered across the laser images to better observe and accentuate any portion of the object, sub-millimeter measurements can be made of any segment of the piece directly on the computer screen, and numerous visualization techniques can be used to enhance and clarify details. Also, we have developed methods of cross-sectional and profile analysis and Surface Elevation Modeling techniques expressly for investigation of carved stone monuments [40] (Figure 4).

Figure 3. Scan image of Kaminaljuyu, Guatemala Stela 10

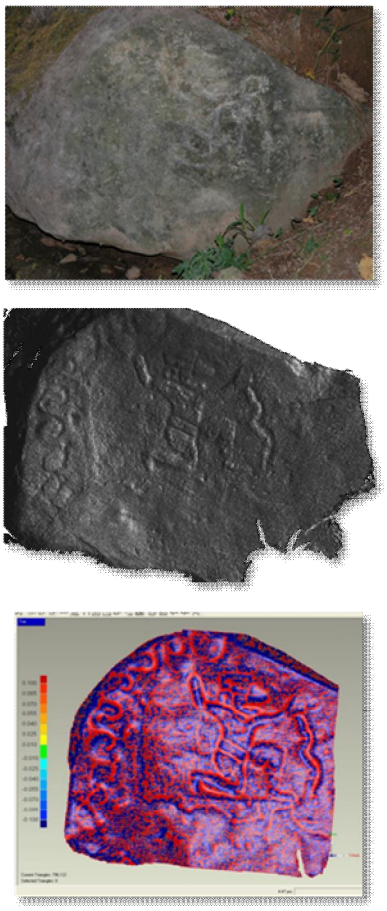

Figure 4. Takalik Abaj, Guatemala Monument 64 photo (top), details become visible in scan image (center), and surface elevation model reduces subjectivity in determination of carved and non-carved surface details (bottom)

One of the most remarkable and appealing capabilities of 3-D scanning to researchers, however, is its ability to capture data that can be used to rescue or resurrect details of damaged monuments that have not been previously legible or discernible [40]. We have developed 3-D data acquisition and post-processing techniques that significantly improve and facilitate the ability to visualize and analyze Mesoamerican sculpture [40, 41, 45, 47]. These ongoing efforts provide archaeologists,

47. Travis F. Doering, Lori D. Collins, and Dan Perreault, 'Guatemala Three-Dimensional Laser Scanning Project', (Technical project report submitted to the New World Archaeological Foundation, Brigham Young University, Provo, Utah, 2006).

epigraphers, iconographers, and other researchers an increased capacity to recognize and interpret information from the stone monuments.

In addition to the iconographic features, the life history of the stone can frequently be traced through the identification of tool and other marks. Through examination of these clues it is possible that the manufacturing process, transport methods, and re-use and recycling of the stone can be deduced. In this manner, it may be possible to differentiate between specific "ethnic" or "cultural" episodes. The stone monuments can include classification and comparison according to morphology, style, associated context, design attributes, and other features capable of description.

Metadata, or information about how the data was collected and processed, is available for each monument included in the archive. This metadata includes information such as resolution, number of scans taken, native and post-processing software used, and any editing or transformations conducted during the processing of these data. For carved stone monuments of the material types encountered in Mesoamerica, these post-processing procedures have included, noise reduction, hole-smoothing and filling, and color adjustments. The need for these software transformative procedures relates to the surface features of the stone material (basalt and limestones), which can be highly textured or pitted. These conditions require noise reduction applications to allow for visualization of carved surfaces and hole smoothing and filling in areas where, due to the relief of the sculpture, full data acquisition is missing or limited.

Other analytical techniques performed and documented for sculpted pieces include 3D surface comparisons, that allow for sculpted surface to be exaggerated and smoothed and then compared to reveal carved surface detail elements more completely.

6 Closing Remarks

Results from the application of close-range laser scanning to the Mesoamerican sculptural corpus have demonstrated the effectiveness of this technique. In some cases, previously indistinguishable features can now be perceived, and the life history of the stone (e.g., tool marks, abrading, re-use, recycling, and other production piece to be observed as the original artist meant it to be viewed.

The research potential for three-dimensional scan data is immeasurable. It is a tool that offers significant additional interpretative insight into Mesoamerica's past. Through the various collaborative projects that we have conducted, the analytical power of the scanning technology has been demonstrated repeatedly. For purposes of archival documentation, preservation planning, and management, three-dimensional scanning documentation is an exceptional and multipurpose record. It is only through the broad dissemination of these data sets, however, that the full analytical value of the technology will become a reality. The outcome has to be applied in practice in order that the research can contribute to the understanding and interpretation of the information encoded on the stone sculptures, as well as the care and conservation of the heritage. We believe the methods that have been outlined above will assist researchers to conduct more comprehensive and precise examination of sculpted artifacts and monuments, and our next step is to develop a best practices methodological workflow that will maximize the extraction of that information.

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