The Institute for
— DIGITAL —
ARCHAEOLOGY

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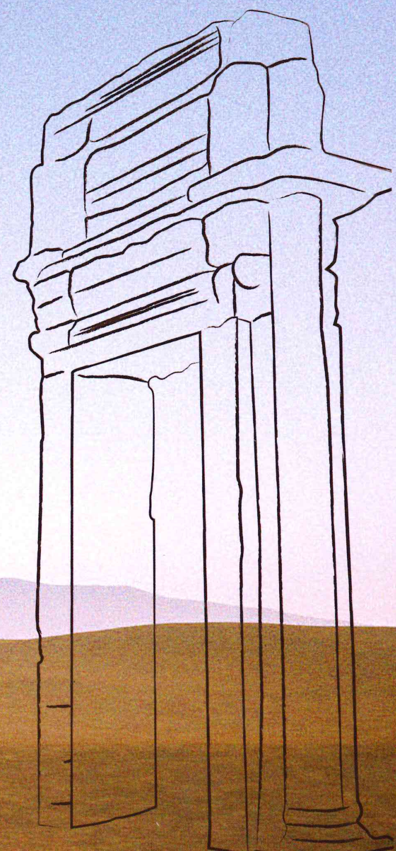
MUSEUM OF
THE FUTURE

THE FUTURE OF DIGITAL ARCHAEOLOGY:

THE IMPORTANCE OF PRESERVING AND RESTORING ANCIENT OBJECTS



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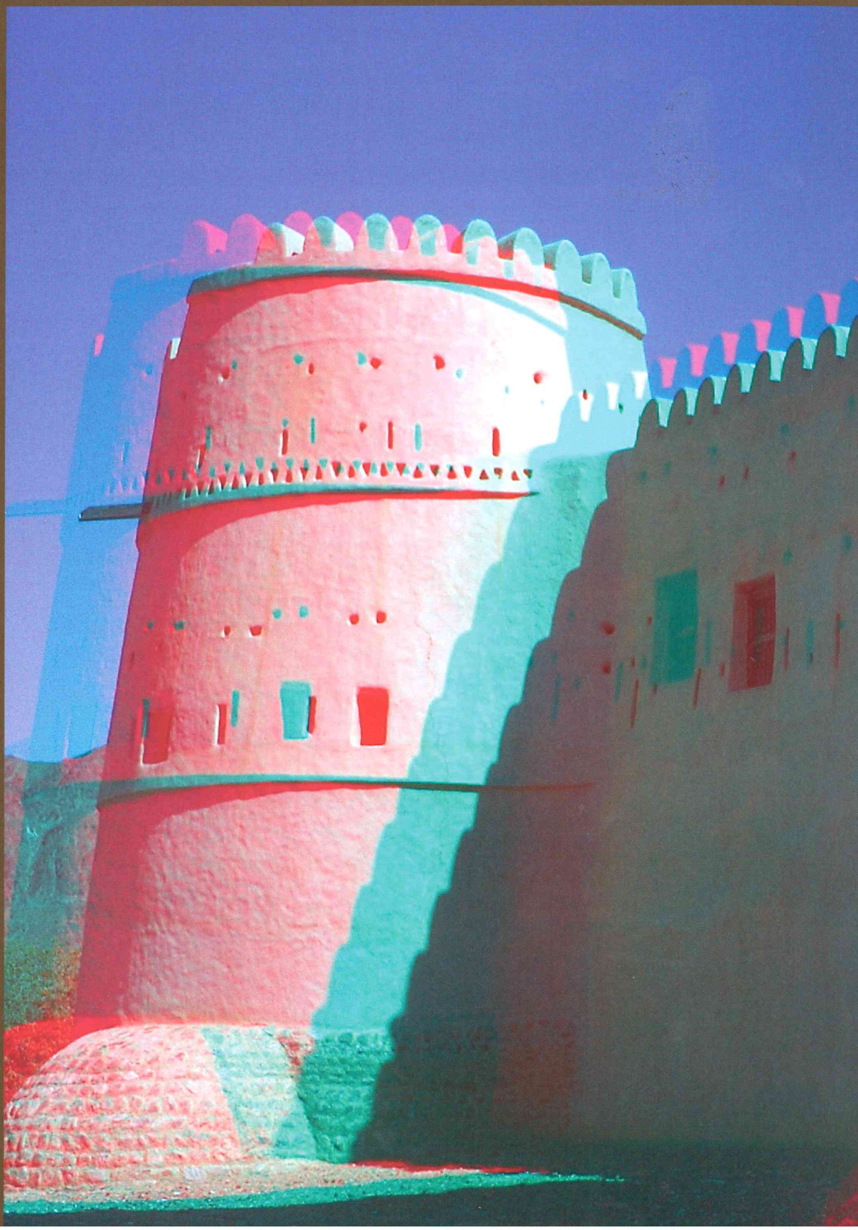

Digital archaeology represents the natural evolution of classical archaeology, permitting researchers to look at ancient objects in a whole new way, to uncover hidden inscriptions, invisible paint lines, the faintest palimpsests, and to share these discoveries with the world. Beyond that, as the IDA's celebrated Million Image Database demonstrates, it can put these crucially important repositories of our cultural identity and shared history forever beyond the reach of those who would destroy them.

Roger Michel
Executive Director, IDA

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THE DIGITAL ARCHEOLOGY'S PHILOSOPHY

The IDA was founded in 2012 to promote the fusion of new digital imaging technologies and traditional archaeological techniques. A joint venture between Harvard University, the University of Oxford and Dubai's Museum of the Future, the IDA has offices in Cambridge, Massachusetts

and Oxford, England. The organization promotes the development and use of novel digital technologies in the fields of archaeology, epigraphy, art history and museum conservation. Further, through partnerships with institutions across the globe, the IDA creates accessible digital archives that encourage interdisciplinary collaboration and the crowd-sourcing of research.

Stereogram of the entrance to the Roman Baths, Carthage, Tunisa.

Indeed, the IDA, at least initially, was focused almost exclusively on creating and maintaining open-access archives of epigraphical images to assure both the wide dissemination and permanent availability of such materials. As the IDA's founder, Roger Michel, stated in his keynote address at the organization's first annual conference, «the IDA's approach to information sharing is designed to encourage a diverse, crowd-sourced and inter-disciplinary approach to the interpretation of archaeological discoveries. It is also intended to serve as a means of preserving and restoring cultural heritage artifacts at a time when large numbers of irreplaceable objects are under obvious threat of being lost forever.»

More recently, however, the IDA has moved beyond merely amassing and maintaining archives. In 2015, the IDA embraced the new field of large-scale 3D printing technology and launched what has become it signature initiative: the Million Image Database. As an initial matter, the Million Image Database represents a concentrated effort, in collaboration with a range of international partners, to document at-risk sites throughout the Middle East and North Africa. Specifically, in collaboration with UNESCO, engineering specialists at Oxford University, the Harvard University Classics Department, and the Museum of the Future, the IDA is in the process of capturing millions of 3D images of threatened objects. Armed with lightweight, discreet and easy-to-use 3D cameras, the IDA's dedicated volunteer photographers are capturing high quality scans at important sites in conflict zones throughout the Middle East and North Africa.

The Million Image Database relies almost entirely on volunteer photographers – ordinary men and women who live in conflict zones throughout the Middle East and North Africa who are passionate about preserving their cultural heritage and national treasures. The IDA supplies these eager volunteers with 3D cameras capable of producing high-quality sterographic images of buildings and objects. Approximately 5,000 of these low-cost, high-tech cameras ultimately will be distributed. Images from these devices are uploaded through a simple-to-use web portal for inclusion in the open-access Million Image Database. However, the Million Image Database project is about much more than merely creating a collection of photographs. While the images produced by the volunteer photographers will certainly form a unique photographic archive, available globally for research, heritage appreciation, and educational programs, they will also be used for the most exciting dimension of the Million Image Database project: 3D replication, including full-scale 3D replication, using proprietary cement, sandstone or marble based 3D printing and machining techniques. The IDA's first full-scale replications will take place starting in April, 2016 at sites including Dubai, London and New York City with further replications scheduled throughout 2016 and 2017. As Mr. Michel has stated, «the IDA's mission is to rebuild the landscape of the Middle East and the great symbols of our shared cultural heritage that have been destroyed or defaced. These symbols - the architecture and objects of the ancient world - speak powerfully to what unites the East and the West.»

This program is the first of its kind in both purpose and scale. However, it is manifestly intended as a model for future similar endeavors. As Newsweek observed recently in its November 11, 2015 cover story on the organization: "The destruction and exploitation of art and architecture has parallels to what occurred during World War II, and it would be criminal for the world to stand aside and let it go on unchallenged. Yet, unlike much of the artwork rescued during World War II, the endangered architecture in the Middle East can't be carted away to safety. But as the obstacles of preservation have evolved, so has the ability to address new situations." The Million Image Database and its 3D printing program are ideally suited to meet this challenge. As Mr. Michel said at the IDA's most recent annual conference: "While there are those who seek to encourage us to forget the past – to forget the shared history that unites us – we are dedicated to ensuring that the visual reminders that keep that history alive remain a part of the human experience."

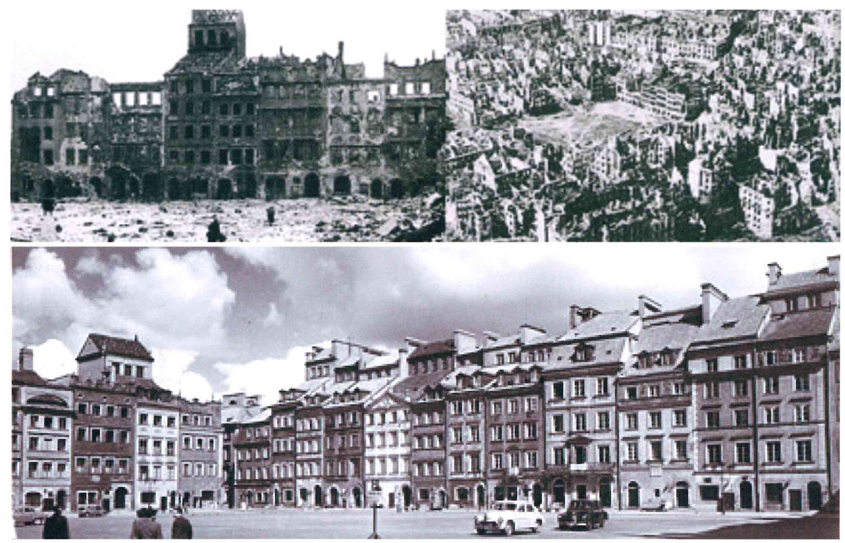
And while some might question the value of reconstructions, one need only visit great cities like London, Warsaw, Rome or Berlin to appreciate how history cannot just endure but thrive amid reconstructed architecture. All of these great cities suffered large-scale destruction during World War II and then were reconstructed in the post-war years. Indeed, nearly the entire old city of Warsaw was leveled, only to be painstakingly recreated under guiding hand of UNESCO. Likewise, vast sections of the ancient city of London were reconstructed after the war. And yet anyone who visits these great urban centers today cannot fail to appreciate the richness and depth of their historical resonances. Indeed, the fact that they embody reconstructions seems wholly irrelevant to their function as visible reminders of history and heritage.

The fact that reconstructions can serve this purpose is wholly unsurprising. It has always been the IDA's guiding principle that, while appreciating the technical history embedded in original objects is an important experience that is worthy of being protected and preserved – and the IDA has the utmost respect for the people and institutions dedicated to that purpose – the greatest value of ancient objects and architecture lies in their ability to serve as visual reminders of the cultural heritage and social history that resides in the memories of those for whom those structures hold importance. This notion of structures as avatars for history, rather than mere tangible objects to be appreciated for their physical qualities alone, is perfectly illustrated by Japan's Ise Grand Shrine, arguably Shinto's most holy site. It is a fascinating and historic structure. "The architectural style of the Ise shrine is known as shinmei-zukuri, characterized by extreme simplicity and antiquity: its basic principles date back to the Kofun period (250-538 C.E.). The shrine buildings use a special variant of this style called Yuitsu-shinmei-zukuri (唯一神明造), which may not be used in the construction of any other shrine." However, this ancient and holy site is not, in fact, ancient at all. "The old shrines are dismantled and new ones built on an adjacent site to exacting specifications every 20 years at exorbitant expense, so that the buildings will be forever new and forever ancient and original. The present buildings, dating from 2013, are the 62nd iteration to date and are scheduled for rebuilding in 2033." A reconstruction to be sure, but the Ise Temple is no less significant as a reminder of the past for being so. Indeed, for those for whom the shrine holds sacred value, the rebuilding process is a means of honoring and remembering the history that it represents. Indeed, the reconstruction process, at least in the case of the Ise Temple, only deepens the appreciation of the historical resonances of the site.

There is nothing unique about this idea that a reconstruction can be imbued with important symbolic value. Anyone who has visited the World Trade Center site in New York City cannot have failed to appreciate the extraordinary power of the reconstructed tower that now rises there. The same is certainly true of the reconstructed old city of Warsaw, a testament to man's determination to resist the intentional blotting out of history through violence. In London and Berlin, too, there can be little question that a powerful sense of history resides in these ancient, but largely reconstructed, capitals.

On the strength of these other examples of reconstructed architecture, it is the IDA's hope that its own reconstructions of ancient and historic sites throughout the Middle East and North Africa will provide visitors with the opportunity to remember the rich past of these regions – a history that, by virtue of ancient wanderings, unites East and West – even as they provide livelihoods for local residents that rely on these sites for their income. Indeed, without reconstructions, destroyed sites will, in time, be swallowed by the sands and forgotten, and with them the history for which they provided the last remaining visual cues. The IDA is dedicated to resisting that cycle – to preserving the history of a region that defined the artistic, literary, scientific and architectural traditions of the world.

The Temple of Bel in Palmyra, Syria was almost completely destroyed in the Fall of 2015. Satellite images (right) taken before and after show the extent of the damage to the celebrated site.



Above: In World War II, The city of Warsaw was damaged by aerial bombing almost beyond recognition. Below: a pioneering photograph-based reconstruction of the Market Square, an iconic public space, was complete by 1953.

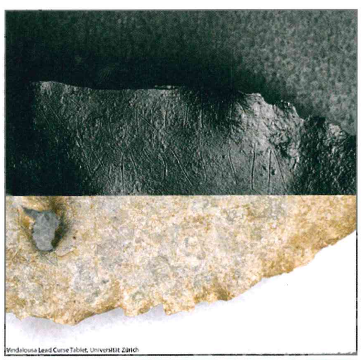
THE FUTURE OF DIGITAL ARCHEOLOGY'S TECHNOLOGY

A technological revolution is afoot in the field of archaeology, and the IDA is committed to leading the way toward this new era. While archaeology has often benefitted from expanded excavations and deeper trenches, the field is now entering an age in which the most spectacular finds are not coming out of the ground but out of existing museum collections. Digital Archaeology is allowing experts to uncover secrets in plain sight; indeed, to go beyond the boundaries of human sight to document sketch lines under layers of paint, transcribe badly eroded inscriptions, and recover the faintest palimpsests. With the power of these technologies growing exponentially, the next ground-breaking find could just as easily be discovered in the basement of a museum as under the streets of Naxos.

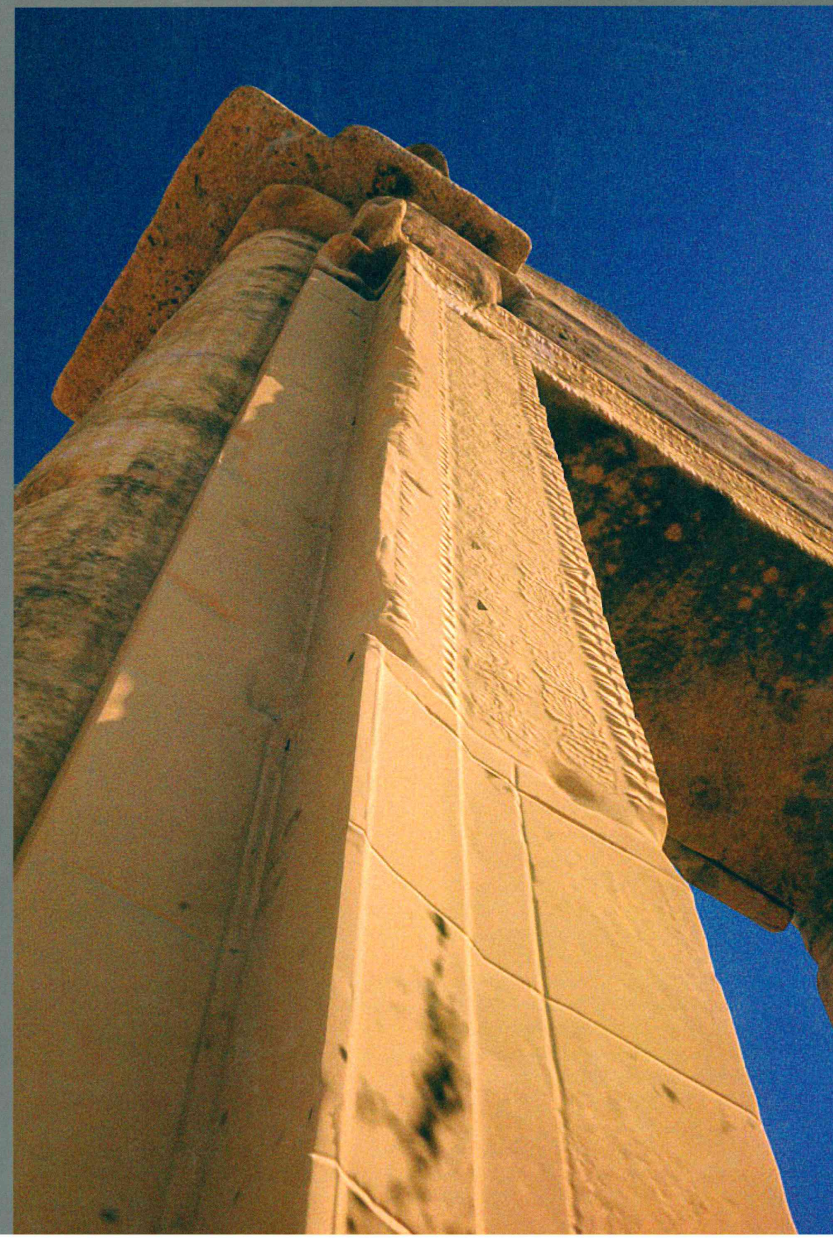
Polynomial Texture Mapping (PTM) is a powerful computational photographic technology that is literally shedding new light on ancient objects. Its ability to analyze the smallest features of surface topology has led to breakthroughs in the fields of epigraphy, archaeology, and papyrology. The discoveries have been so frequent and significant that museums and archaeologists around the world are seeking to make PTM the standard international protocol for artifact documentation.

More than anything else, it is the sheer volume of data gathered by PTM that sets it apart from what is currently the most common documentation method used in museums: simple photography. While a conventional photograph can adequately capture color information, it can only convey a very crude sense of shape and surface texture, primarily through depictions of highlights and shadows. By contrast, PTM, in addition to capturing superb color data, can also record detailed shape and texture measurements at the level of individual pixels. This massive quantity of incremental data not only provides a far more comprehensive method for object documentation than simple photography, it also opens up a range of opportunities for computer-driven rendering techniques – including potentially the use of 3D printers – for creating highly detailed depictions of objects for study and analysis.

Although the PTM capture process requires precision and specialized equipment, it is completely non-invasive. This is an important virtue and accounts, in part, for its increasingly widespread adoption. Older methods – such as taking paint samples and squeezes – require extensive contact with an object and always present a risk of damage or wear. Since these destructive processes are antithetical to the preservation ethos of most museums, such techniques are used sparingly. For many fragile or important artifacts, the use of these processes is simply out of the question altogether. Consequently, many scholars have come to rely on PTM as a safe and thorough way of documenting an object. While no more harmful to an object than conventional photography, PTM provides far more topographical data than the destructive technologies of old.



Fragment of the Vindalousa Lead Curse Tablet. Below: To the naked eye, the text is virtually invisible. Above: Using texture mapping, the detail of the surface comes to life.

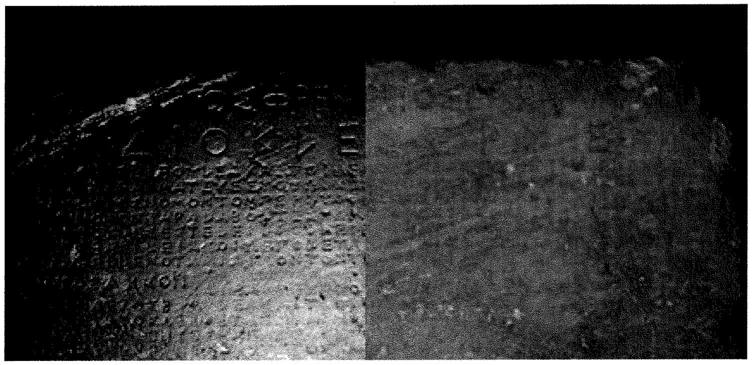


The fundamental concept underlying PTM technology could not be simpler. Indeed, anyone who has ever rotated an object in the sunlight to get a better view of its surface has employed the same principles on which PTM is based. PTM monitors and records the properties of both the incoming light striking an object and the reflection of that same light. Based on the relationship between the measured properties of the incoming and reflected light, the equipment can determine the precise surface structure of an object. In essence, PTM creates a topographical map of an object that shows even the most minute peaks and valleys – right down to faintest minim in a barely visible palimpsest. This is, in fact, precisely what your eye does every time you turn a worn coin in the light to read the date. PTM merely quantifies, records and maps the data for future reference and close examination. The PTM equipment also optimizes the lighting and capture technique to assure best results.

The mechanical functionality of PTM is likewise straightforward. When using PTM to record the surface of an object, a sequence of images is captured in which camera and object are fixed in position relative to one another while a light source is moved around the object through a range of predetermined positions. A variety of specific capture techniques may be used consistent with this basic approach. One common technique employs a dome with between fifty and seventy computer-triggered LED lights arrayed at regular intervals. Images are created at all of these fifty to seventy positions. These individual images are then combined by PTM software into a single image with maximum contrast, clarity and surface detail. A second technique – perhaps better adapted to field-work due to its smaller size and more robust construction – uses a mobile flash unit as its light source and solid reflective spheres to provide precise reference points. By using the highlights on the spheres in place of the programmed light positions of the dome, PTM software maps the surface of an object using the same basic principles employed in the dome array.

However, it is not just the amount of information PTM gathers that sets it apart from traditional techniques, but also the ways in which the image files can be manipulated. While Adobe Photoshop, Lightroom and other well-known "digital darkroom" technologies are in wide use, these products alter chiefly color, contrast and sharpness. PTM provides dramatically increased flexibility, permitting a skilled technician to manipulate also the presentation of shape and texture for maximum image clarity. Through the use of the "diffuse gain" tool, an operator can identify and then exaggerate the peaks and troughs on a surface to provide increased contrast. Suddenly the palimpsest or etched line appears deeper and more distinct. This mode is used extensively in the recovery of severely worn inscriptions where crucial differences between letters can be extremely slight. Through judicious use of diffuse gain, even the most badly worn letters suddenly appear well-delineated. Tools like diffuse gain also have wide application for conservators. As inscriptions on impermanent materials like papyrus deteriorate over time, museum conservationists can track the rate of loss to help allocate restoration resources more rationally. Further, the earliest signs of cracking in stones, vases, or sculptures are often hard to see and yet the effects escalate quickly and non-linearly if neglected. Identifying a problem before it becomes irreparable is crucial to preserving artifacts.

PTM also surpasses traditional imaging techniques in its ability to manipulate color and topographical information separately. Specifically, through the use of the "specular enhancement" tool, the amount of color and reflectance in an image file can be carefully adjusted to isolate these properties from data relating to shape and texture. This allows archaeologists to study an object without the distractions of discoloration. In the study of inscriptions, epigraphers use this mode to discern letters even on surfaces that have been badly tarnished or corroded. In particular, PTM analysis of silver and bronze surfaces often graphically illustrates the value of this technique. Surface discoloration often inhibits the reading of text or the decipherment of iconography on such objects by sharply reducing local contrast. Once the color is extracted, however, the inscriptions are far easier to discern and/or transcribe. In the study of ancient art, the ability to remove color and focus only on topography allows archaeologists to isolate and analyze important details like the shape of tool marks and brush strokes. Using specular enhancement on pottery fragments, for example, will often emphasize the shape of surface structures on the artwork. Different paint thicknesses and sketch lines suddenly become starkly apparent. Elements of the decorating process such as these are nearly impossible to distinguish without PTM technology.



Polynomial texture mapping has revolutionized the study of ancient inscribed texts around the world.

PTM has been especially useful in the study of the techniques used in the making and decorating of ancient Greek pottery. Since no ancient writer described the exact process for pottery production during this period, archaeologists and art historians must depend entirely on the evidence provided by the vases themselves. Based on PTM analysis, combined with the art-historical evidence, it has become possible to make many general observations about early Greek pottery, the absence of direct historical sources notwithstanding. Based on PTM examination of finished surfaces, it now appears that vases of the Archaic and Classical periods were turned on a fast spinning wheel. Indeed, vase-paintings confirm that after the orange, iron-rich clay used to make these objects was turned on fast wheels not unlike those used by some artisanal potters today. PTM analysis also shows that the objects were shaped with heavy clay, while the paint consisted of a lighter clay slip, diluted with water. Depending on the degree of dilution, Attic clay could fire from a deep lustrous black to a light yellow hue. Upon close surface examination, handles, feet and other parts appear to have been attached using a thinned clay slip after the pot was thrown. Once the completed vase was leather hard, paint was applied.

Black-figure vases very rarely show traces of preliminary sketches. However, PTM scans show that painters using the red-figure technique usually sketched the painted scene with a pointed instrument. Such marks presumably make it easier to paint the background without painting over the figures. PTM has also demonstrated that details of individual figures (such as eyes, muscles and drapery) were painted with diluted clay varying in thickness. Relief lines, characterized by a central groove, stand proud of the surface by fractions of an inch to catch the light and emphasize the image. After the figures were completed, the painter added the ornaments, and then painted in the background. Finally, a red wash was applied to enhance the red of the reserved background, and details such as fillets or inscriptions were added. All of these features are only evident upon PTM examination.

While the foregoing is certainly not an exhaustive description of the early Greek pottery-making process, it represents a very significant start toward that goal. However, to date, only a relatively small number of Greek pottery objects have been subjected to PTM analysis. A larger-scale study covering more styles and examples of pottery, would almost certainly lead to a broader understanding of the Attic potters' heretofore enigmatic techniques.

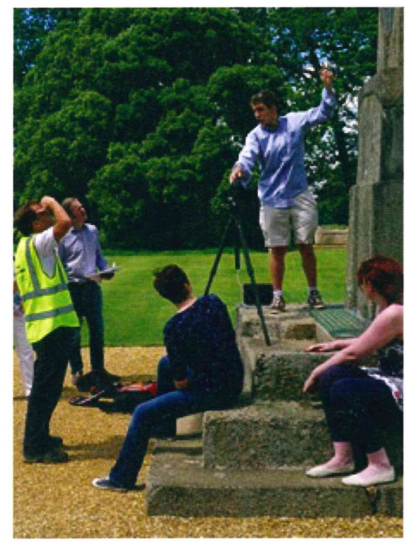
Without question, PTM offers extraordinary opportunities for scholarship by virtue of the unprecedented glimpse it offers into the surface of things. However, it presents another, perhaps equally important opportunity, as well. Specifically, PTM offers scholars the chance to customize image files to suit the particular demands of their own research even after the image has been captured. Stated differently, the unique features of PTM files permit users to interact with an object as if they were handling it themselves. Once a PTM file is built, the user can relight a virtual representation of the object from any direction. This allows every element of an object to be seen and documented by rotating the item through an essentially infinite number of positions. By contrast, even one hundred conventional photographs, regardless of their quality, are necessarily limited in the specific views they can portray.

The fact that PTM files are manipulable even after capture also provides extraordinary opportunities for collaborative research – and this is perhaps PTM's most important advantage over other forms of object documentation. Many objects are fixed in place; they are either attached to structures or too heavy to move. Political, financial or institutional restraints also limit the free mobility of objects. Previously, this placed significant limits on the extent to which the crowdsourcing of knowledge could be brought to bear on the examination of objects. Now, PTM allows the real-time transfer of manipulable image files over great distances. It will be easy for an archaeologist in the field to obtain a paleography or art history consult with a colleague a continent away. And the quality of the image will be the same for both collaborators, on-site and remote. PTM also permits object examination to occur in a relaxed setting, with access to any required reference resources, and with no time constraints. Needless to say, that is rarely the case with objects in the field or in closely guarded museum collections. For all of these reasons, there is no doubt that PTM is a far better method of object documentation than any of the traditional techniques now in use. For museums and archaeological field workers, it is well worth the initial investment in technology and training required to add PTM to their toolkits. The IDA is strongly committed to providing assistance technical and financial assistance to organizations that wish to add PTM to their technical quiver.

Although PTM was introduced to archaeology relatively recently, it is responsible for some of the most ground-breaking discoveries of the last few decades. The age of digital archaeology has begun a quiet revolution in classical studies, particularly in the fields of epigraphy, archaeology and papyrology. Scholars no longer feel limited by what they can see with their own eyes. Moreover, they recognize that conventional photography is not the best means – not by a long chalk – for preserving data. However, as promising as these new imaging technologies are, scholars must be realistic in looking toward the future. Reexamining every promising object is going to take decades and certainly not every PTM assay will result in the rewriting of history. That said, the discoveries that have already come from modern imaging technologies make it clear that there are objects in museum collections around the world that hold the answers to questions that have remained unanswered for centuries. These artifacts are patiently waiting for someone to come along, shine the right light on them, and unlock their secrets.

An important and inevitable adjunct to improved imaging technologies – and one strongly championed by the IDA – is high-resolution 3D printing. 3D printing is useful not only for providing table-top size objects for study or appreciation, but increasingly holds the promise of allowing organizations like the IDA to consider wholesale and full-scale replacement of damaged or destroyed objects. The increasing ease, speed and low-cost with which high quality scans (including images that incorporate PTM techniques) of objects and architecture can be obtained raises the possibility of bringing this technology to sites not previously accessible to scanning technology, and so creates the potential for the recreation of objects that, due to their inaccessibility might otherwise be lost forever. Such recreations lie at the heart of the mission of the IDA. It is for this reason that the Million Image Database is intended to be as inclusive as possible.

PTM image of redware pottery from the Beazley archive, Oxford, UK.

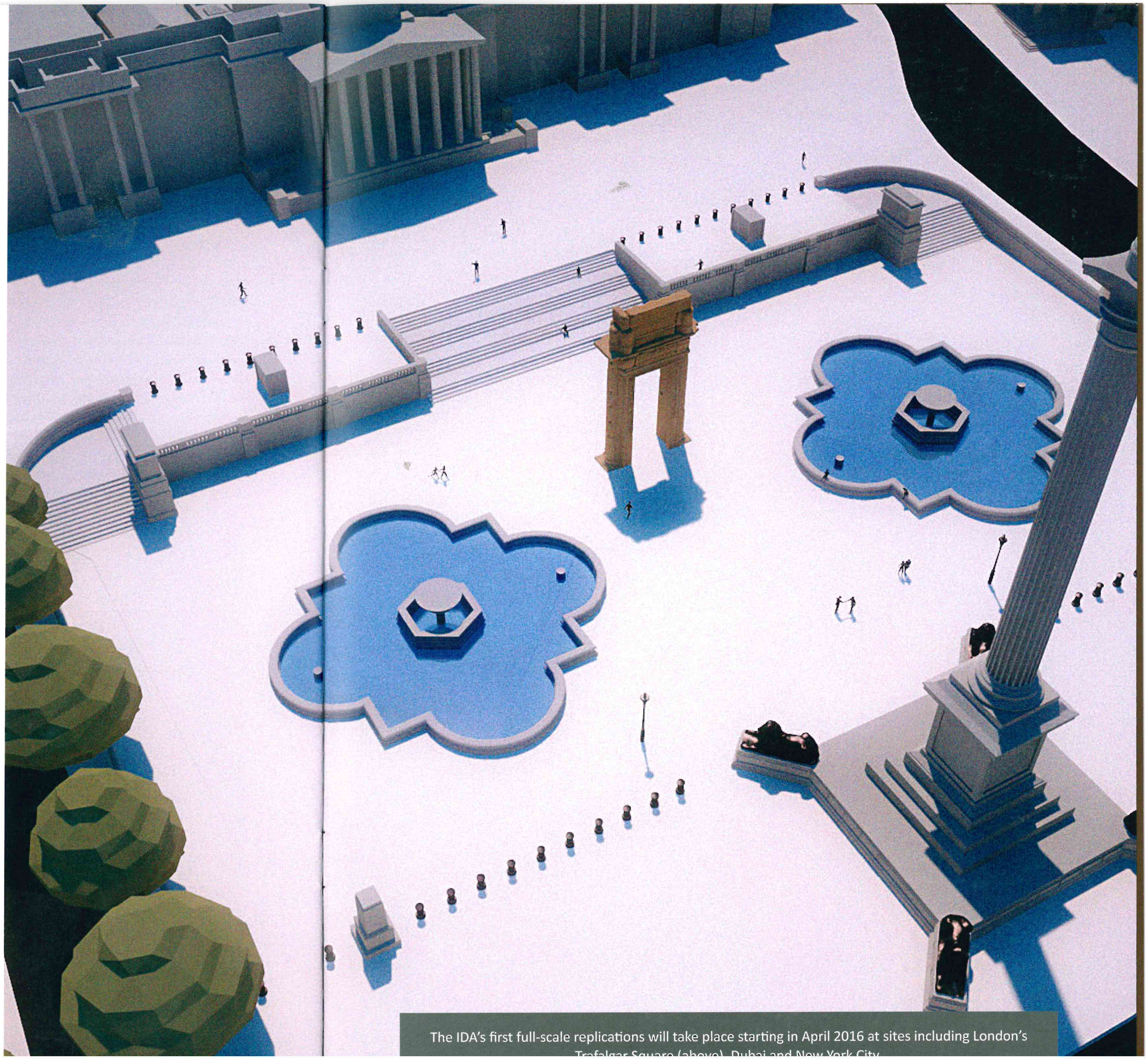


The IDA team makes PTM images of the Philae Obelisk at Kingston Lacy.

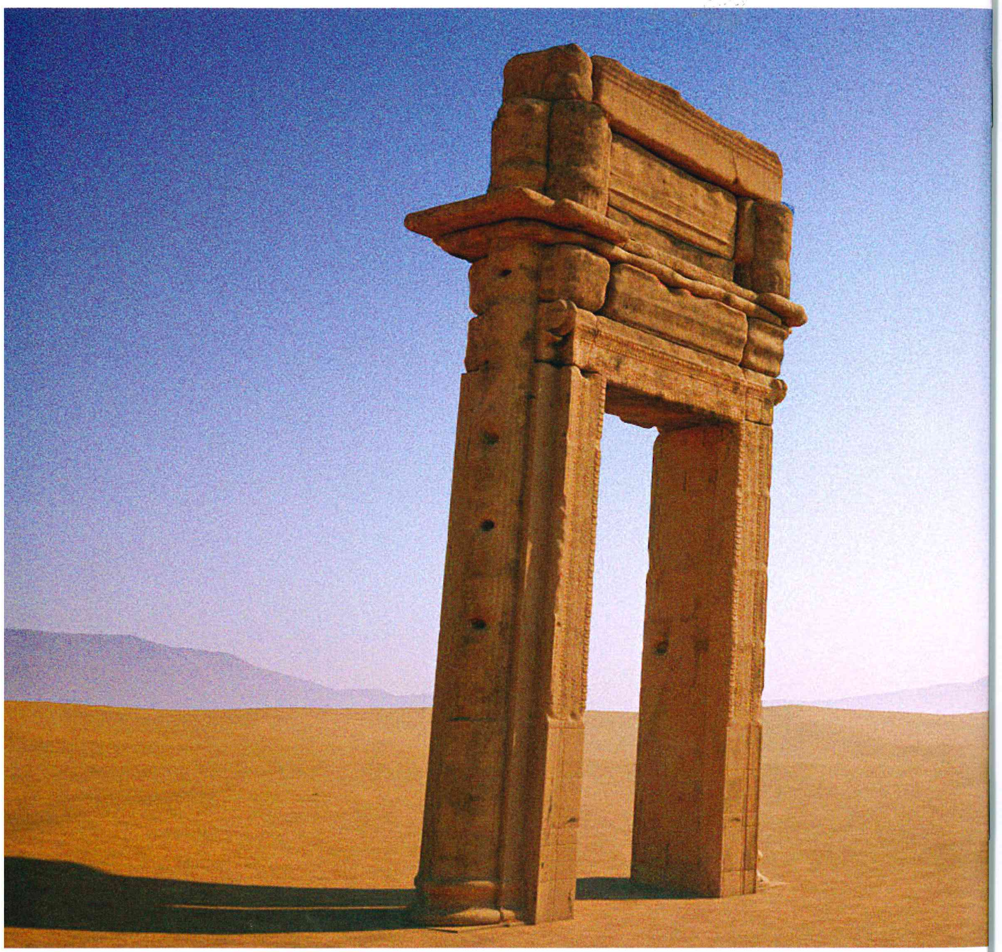
ARCHEOLOGY'S FUTURE VISION

As the IDA closes in on its goal of having one million 3D images in its Million Image Database by the end of 2016, it is now turning its attention to the task of perfecting large-scale 3D printing technology for the purpose of recreating ancient objects and structures. Working with technical collaborators in the USA, UK, Italy, China and Dubai, the IDA has settled on a mix of marble and sandstone based 3D printing and machining technologies that appear to be ideally suited for reproducing accurate, full-scale replicas of even the largest monuments. As proof of concept, and as a fulfillment of our promise to the thousands of regional stakeholders, particularly in conflict zones, who have assisted us by providing 3D images for the Million Image Database, the IDA will undertake a series of large-scale reconstructions in the Spring and Fall of 2016. Spanning the globe from Dubai to London to New York City, the IDA will recreate ancient monuments from threatened sites in the Middle East. It is our intention in doing so to provide an optimistic and constructive response to a destructive threat to history and heritage. We hope to signal the potential for the triumph of human ingenuity over violence and celebrate images from the past that unite the cultures they represent. We also hope to provoke thoughtful dialogue about the significance of heritage material. In particular, we hope that visitors to the reconstruction sites will consider the role of physical objects in defining their history and weigh carefully the question of where precisely history and heritage reside. Finally, we hope to raise awareness of the human cost of lost heritage and enlist a new generation of volunteers to assist in efforts aimed at historical preservation and study. As Martin Luther King, Jr. famously said, "We are not makers of history. We are made by history." Keeping alive the past that defines us is the task to which the IDA and its partners are firmly committed. We believe it is a worthy goal.

The authors gratefully acknowledge the assistance of Dr. Thomas Mannack of the Beazley Archive for providing invaluable advice and assistance regarding early Greek pottery techniques.



The IDA's first full-scale replications will take place starting in April 2016 at sites including London's Trafalgar Square (above), Dubai and New York City.



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