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Roman Black-Gloss Pottery from the Capitoline Museums at the University of Missouri

*A New 3D Scanning Project for Use Wear Analysis**

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In the summer of 2014, archaeologists at the University of Missouri began documenting a collection of antiquities from the Antiquarium, a little-known storehouse of the Capitoline Museums in Rome. Their loan to the University of Missouri was the result of an agreement unprecedented in the United States, the *Hidden Treasures of Rome* project, which was facilitated by the Sovrintendente Capitolino Claudio Parisi Presicce and funded by Enel Green Power, an Italian-American energy company. The Capitoline Museums lent 249 Roman black-gloss and other vessels, many of which are nearly whole, for morphological and chemical analysis (Fig. 1). The vessels arrived in August 2014 and for a period

Fig. 1. An assemblage of pottery on exhibit in the Gallery of Ancient and Byzantine Art, Museum of Art and Archaeology, selected from the 249 vessels on loan to the museum from the Capitoline Museums, Antiquarium Comunale. Photo: Kenyon Reed.

of two years underwent morphological analysis by Dr. Johanna Boyer, then a graduate student in Art History and Archaeology, and chemical analysis by Dr. Michael Glascock, at the University of Missouri Research Reactor's Archaeometry Laboratory (MURR).[1]

Dr. Marcello Mogetta, who joined the Department of Art History and Archaeology in July 2015, brought on two colleagues, Dr. Rachel Opitz of the University of South Florida, and Dr. Laura Banducci of Carleton University in Canada, to undertake a program of 3D scanning of these vessels. This expanded on previous efforts to capture the 2D surface texture of decorated (stamped) items using RTI, or reflectance transformation imaging, a technique that improves our ability to see an object's surface shape and color through its interactive re-lighting from any direction. RTI is commonly used in archaeology and cultural heritage projects to enhance small details on the surfaces of objects, bringing out traces that are almost invisible to the naked eye.

The specific aim of the new initiative was to both study in detail minute traces of production and use of these vessels and produce a digital record of their form before they returned to storage in Rome in September 2016. The pilot project, titled *Hidden Treasures of Rome: Capturing the Life Cycle of Roman Pottery*, began in January 2016 and also involved the collaboration of several researchers from the University of Arkansas and the Université Bourgogne Franche-Comté, in France. The results have been used to lay the groundwork for a larger proposal, titled *CaLC-Rome: Capturing the Life Cycle of Ceramics in Rome*, which is currently being funded by the University of Missouri System Research Board in connection with the second iteration of the loan agreement.

Origins of the Artifacts

After the unification of Italy in 1871, downtown Rome underwent rapid development with the construction of new government buildings. In an 1888 guide of Rome for American students, Rodolfo Lanciani wrote: "between January 1, 1872, and December 31, 1885, 82 miles of new streets have been opened, paved, drained, and built; new quarters have sprung up which cover an area of 1,158 acres; 3,094 houses have been built or enlarged, with an addition of 95,260 rooms . . . and the population, which fourteen years ago numbered 244,000 souls, exceeds now the considerable figure of 379,000."[2] Rescue excavations for this building program during the late nineteenth and early twentieth centuries recovered a large quantity of archaeological material that was quickly excavated.

Initially, the bulk of the finds was stored in temporary depositories across the city. A new exhibition wing was built in the early 1870s in the Palazzo dei Conservatori for artifacts that could be displayed, but then more materials were unearthed. To solve the lack of storage space, construction of an ad hoc Magazzino Archaeologico Comunale, located on the Caelian Hill, was planned in 1884 and completed in 1890. It was originally conceived as an urban museum where the archaeological material would have been organized both chronologically and topographically to provide a picture of the development of the city of Rome from its earliest times. Renamed the Antiquarium in 1900, the complex was reorganized in 1925–1928 and transformed into a museum for the

display of the "minor arts" of ancient Rome. Materials were arranged according to major media, such as glass, bronze, or pottery. Where possible, objects that could be associated with a specific monument or defined area were kept together, particularly in the case of votive deposits and funerary assemblages.[3] Ceramic vessels were on display by class in the Sala V, together with anatomical votives.[4]

Structural damage to the Antiquarium during construction of the subway linking Rome's main train station with the new neighborhood caused the sudden abandonment of the complex in 1939. With the exception of inscriptions, architectural elements, sarcophagi, and mosaics, which remained in the gardens of the neighboring Orto Botanico, the rest of the artifacts were transferred over the years to temporary storage facilities.[5]

While we have no documentation of specific excavation context for any of the 249 objects that were lent to Missouri, at least three pots came with small scraps of paper indicating that they came from the Esquiline. These paper scraps are probably the remnants of the original inventory mapping carried out by the Archeological Commission that was assigned the task of cataloguing the finds from the Esquiline necropolis in 1877.[6] For example, one note with a jug indicates that the vessel came from a specific tomb, likely on the Esquiline Hill, and that it was excavated in July of 1875 (Antiquarium Comunale, Inv. no. 44325).[7]

It is not clear whether the objects from the Esquiline cemetery were kept together during the lifespan of the Antiquarium, but it is reasonable to assume that many of the pots from Sala V were excavated from the Esquiline. Items that are demonstrably from contexts other than the Esquiline necropolis, however, were also included among the 249 vessels. For example, one vessel (Antiquarium Comunale Inv. 44328) has a square of white paper glued to the wall near the base with the note that it was excavated in the Via della Consolazione in 1939.

Materials and Aims

Black-gloss pottery was made in central and southern Italy from the late fourth century B.C.E. through to the middle of the first century B.C.E. These are table wares, primarily plates and bowls, which played a role in Roman eating and drinking, and in ritual activities like pouring libations, and making dedications and offerings at sanctuaries and tombs.[8] The locations and manufacturing methods of these vessels are increasingly understood because of the application of a series of archaeometric techniques like Neutron Activation Analysis (NAA) and X-Ray fluorescence (XRF).[9]

The shapes and shiny iridescent black surface of these vessels suggest that they were produced, at least originally, to be a more affordable alternative to vessels made of silver or bronze. The quality of the ceramic vessels varies significantly, probably due to the different locations of production, the clay used, and the skill of the potters. Some vessels are better constructed, with finer walls and smoother clay, or have shinier or more consistent slip than other vessels in the collection. This indicates that even within black-gloss pottery there were different qualities of goods, perhaps acquired by customers of differing wealth.[10]

The study of use wear on artifacts is a developing field of archaeology. The analysis of ceramic vessels is, however, unusual. Assessing wear on complete or largely complete vessels is ideal, since we can understand the wear in the context of the whole object, and we can be confident that the object has undergone minimal post-depositional disturbance after it was discarded. That is, the wear we observe is likely a result of human use rather than natural processes of fragmentation or erosion after burial.[11] Unfortunately, the circumstances in which archaeologists excavate whole vessels are limited primarily to tomb and ritual contexts. Typically, settlement contexts reveal very fragmentary ceramics rather than complete vessels.

The minimal observations of use wear on ceramics have noted that vessels of different shapes have different patterns of wear—different abrasion patches or scratches from different types of contact with tools for stirring and scooping. For example, black-gloss bowls excavated in Musarna, Italy, display concentric scratches from stirring, while plates at the same site tend to have straighter scratches, likely from cutting.[12] Use wear studies have also been completed on Roman cutlery. The analysis of 339 silver, pewter, and bone spoons from Roman Britain and the Western Roman provinces demonstrated that certain spoon shapes were prone to certain types of wear and that some wear patterns showed that there was a tendency for users to be right-handed.[13]

The set of vessels from the Capitoline provides an unparalleled opportunity to study a large sample of black-gloss vessels, many of which are complete or nearly complete. Although we do not know the exact provenance of all the vessels, beyond those that can be linked to the Esquiline necropolis (forty vessels from our sample were previously published in the 1973 *Roma medio repubblicana* exhibition catalogue),[14] their complete condition strongly suggests that the remainder also were either deposited as grave goods in tombs or given as offerings at a religious site. Thus, the Capitoline collection also allows for the detailed study of an unusually large number of vessels from these types of contexts.

The research questions are twofold, touching on both historical and methodological concerns. From a methodological perspective, we are interested in further refining how best to observe, record, and analyze use wear—in particular, abrasion on vessels.

We hope to determine:

- Whether 3D scanning and/or RTI allow us to note surface wear or to study elements of indicators of wear that are not visible to the naked eye;
- What the benefits or limitations are of 3D scanning imaging versus RTI in the study and recording of use wear;
- Whether it is possible to see scratches that overlap and determine which scratch came first;
- Whether it is possible to disentangle a palimpsest of abrasion, and thus, multiple instances of use or vessel multifunctionality;
- Whether there are patterns of use discernable from the comparison of the depth of scratches and the profile of scratches;

Whether it is possible to quantify the extent of the wear using digital imaging and analysis.

From a historical and archaeological perspective, our research questions center around issues of vessel function, use, and reuse. Since these artifacts are probably from funerary and sanctuary contexts, we are specifically interested in how better information about their use can contribute to our understanding of how the purchasing and deposition of artifacts worked in the Roman world in these ritual circumstances. The frequency and longevity of vessel use also affects our broader understanding of pottery consumption practices in the Roman economy. For example:

Did vessels deposited in these ritual circumstances likely have a use-life before they were deposited or were they purchased new for use in these special contexts?

What kinds of wear do vessels deposited in tombs or sanctuaries have? Does this wear suggest a consistent use of these vessels?

Are there patterns in the type or extent of wear that correlate with different vessel shapes?

Are there patterns in the type or extent of wear that correlate with different vessel quality (e.g., thick or shinier slip), which might suggest that higher quality vessels were used differently?

How does the use, reuse, and deposition of these vessels affect our understanding of the economy of ritual and the consumption patterns of pottery in Rome?

Methods and Observations

We carried out a campaign of high-resolution, high-precision 3D data capture on a subset of sixty-three vessels (twelve of which had previously been tested for NAA at MURR). The sample consisted predominantly of open forms with visible traces of use on their interior floors. In particular, we selected bowls and plates with relatively simple geometry, so as to make the scanning operations easier and faster. We used two different 3D scanners, which allowed us to experiment with four different resolutions in order to capture patterns of wear. The equipment included a Breuckman Smartscan-HE white-light scanner, which is commonly used for archaeological applications, and a GOM Atos triple-scan scanner. There are many scanners on the market today that are used to document archaeological objects. For our project, we chose to work with the Atos GOM scanner because it uses blue light, which makes it well suited for capturing data on dark and shiny surfaces, like those of black-gloss vessels. Laser and traditional fringe projection scanners are not as effective.[15] Since many of the objects in the collection we are studying have black and shiny surfaces, the ability to capture them in detail with ease was important. We partnered with a team from the Université de Bourgogne-Franche

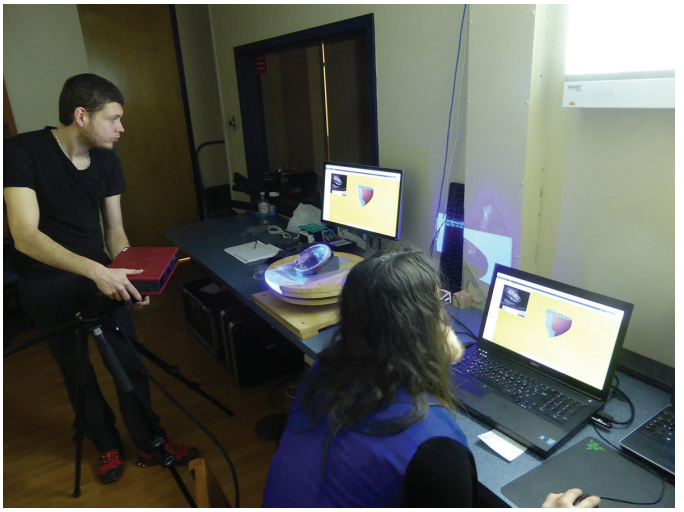

Fig. 2. Using the GOM Atos Triple scan blue light scanner, Damien Vurpillot and Valérie Taillandier from the Université Bourgogne Franche-Comté scan a black-gloss bowl (Capitoline Museums, Antiquarium Comunale, Inv. no. 10062).

Fig. 3. Snapshot of the 3D model of a black-gloss bowl (Capitoline Museums, Antiquarium Comunale, Inv. no. 8627) created with the GOM scanner (right, with pink shading for visibility; left, with color texture).

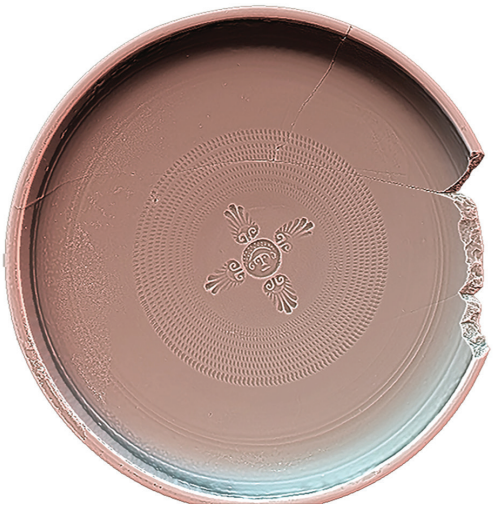

Fig. 4. GOM scan of a black-gloss bowl (Capitoline Museums, Antiquarium Comunale, Inv. no. 6438) showing stamped decoration on interior floor.

Comté, longtime collaborators of one of us (Opitz) and experienced in operating this type of scanner to collect data to support archaeological research (Fig. 2).

In terms of both clarity and measurability, the quality of images of the black-gloss vessels that the GOM produced has proved its utility (Figs. 3, 4).[16] The high-resolution is demonstrated when we compare a still of the 3D image at 70 µm with a high-resolution 2D color photograph. In the photograph (Fig. 5, right), we can see the four letters (an abbreviated name M. HAR) painted in white slip on the surface of the black vessel. In the 3D scan (Fig. 5, left) (with light shading here for visibility), you can make out the elevation of these letters, despite the fact that they have only been applied with slip. Scans also produce a high-quality permanent record of potters' fingerprints remaining in both the clay and the black gloss slip (Fig. 6). In contrast, the Breuckman scanner was adequate

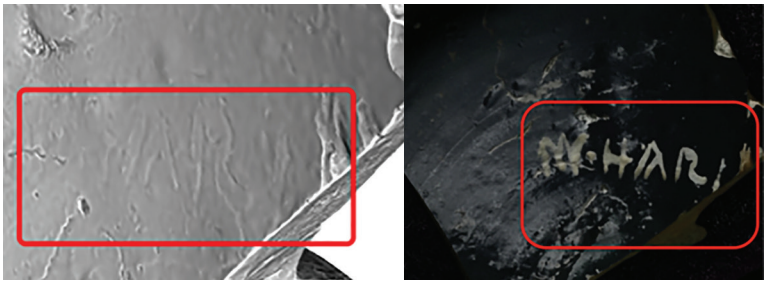

Fig. 5. Painted inscription (right) on a black-gloss bowl (Capitoline Museums, Antiquarium Comunale, Inv. no. 5055) compared to the inscription's visibility after scanning at a resolution of 70 µm (left).

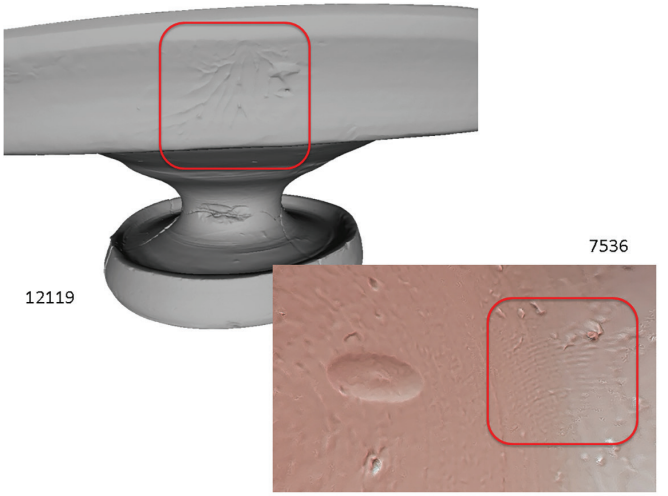

Fig. 6. Scans of fingerprints on the exterior base of a black-gloss bowl (Capitoline Museums, Antiquarium Comunale, Inv. no. 7536; bottom right) and on the exterior rim of a black-gloss plate (Capitoline Museums, Antiquarium Comunale, Inv. no. 12119; top left).

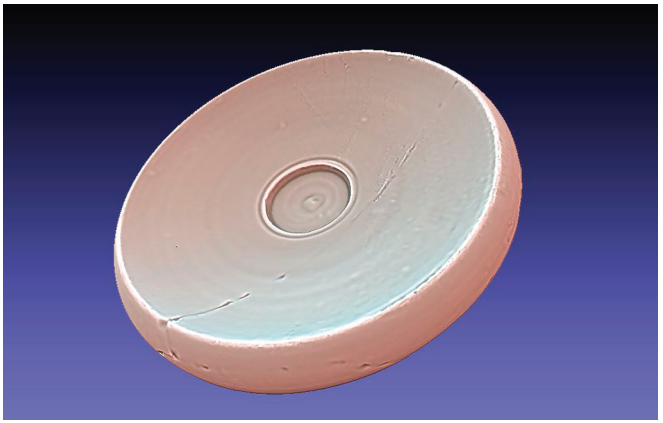

Fig. 7. 3D model of a black-gloss plate (Capitoline Museums, Antiquarium Comunale, Inv. no. 12115) created using the Breuckman scanner.

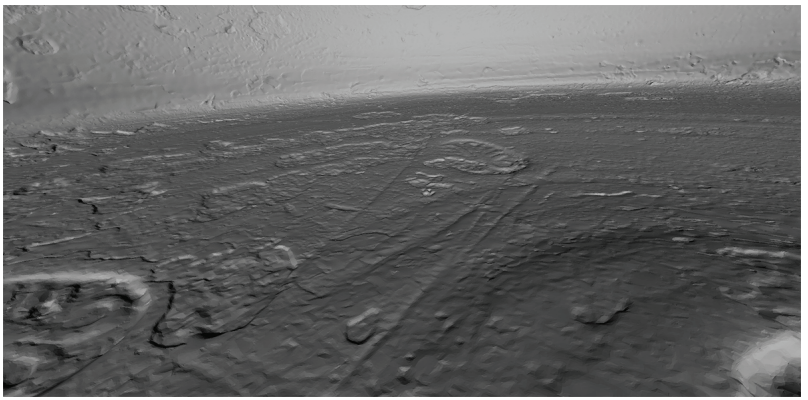

Fig. 8. Enlargement showing several overlapping scratches on the interior of a black-gloss bowl (Capitoline Museums, Antiquarium Comunale, Inv. no. 8626).

for creating accurate 3D images of the vessels for digital museum display[17] and more generalized studies of the objects' shapes, but the precision of the images is not quite high enough for use wear analysis (Fig. 7).

Thus far, we have examined use wear on these vessels with the naked eye and from the scans. The benefit of studying ceramic wear from 3D scans is in the zooming and metrical possibilities. Zooming in to the surface of the vessel allows us to examine individual traces of wear greatly magnified (Fig. 8). We can measure the length and depth of these scratches to a high level of accuracy and also characterize the shape of their profiles. Similar close examination of cut profiles has been undertaken by zooarchaeologists examining animal bones and trying to understand what types of tools were used by ancient butchers and cooks.[18]

It is also possible to see overlap in the scratches and to determine which scratch came first. This can be important when determining both natural behaviors and gestures, e.g., do Romans cut with knives on black-gloss vessels? It is also useful for distinguishing the difference between wear marks from use during the life of the vessel and those occurring while buried or, indeed, while being excavated.

The next phase of research will be to explore further the possibilities for doing high-precision measurements and description of these traces of abrasion. Since we have produced digital models of the black-gloss vessels, we can use various extant software packages to analyze their surface morphology in detail. Currently we are developing metrics (meaningful measurements and calculations) to characterize quantitatively different types of wear, a crucial step toward differentiating clearly between production, use, and post-depositional abrasion. The metrics under development are based primarily on a detailed assessment of the form and structure (morphology) of individual traces of wear, e.g., the profile curvature at inflection points, the openness of the scratches' interior, and the consistency of tangential curvature. In addition to developing metrics targeted at individual traces of wear, we are also investigating the validity and utility of zonal metrics, e.g., location on the rim vs. the interior vs. the exterior, in order to establish dominant types of wear on different parts of the vessel. The surface metrics analyses are, at present, implemented using SAGA GIS (System for Automated Scientific Analyses, Geographic Information System), scientific software traditionally used for detailed landscape studies. One of our basic questions is how to distinguish between similar scratches or types of wear. Each scratch, seen in microscopic detail, has a complicated and irregular shape, so we cannot simply categorize them as V-shaped vs. U-shaped or scratches with square bottoms vs. scratches with rounded bottoms. In order to compare these irregular 3D shapes and reliably understand the differences between them, we are using algorithms developed for image processing and machine learning. These are the same techniques used to spot human faces in Facebook photos and to drive Google's "search by image." The development of both the metrics to characterize the morphology of the traces of different types of wear and the similarity metrics necessary to distinguish among them are a key part of our ongoing research.

While many of our vessels have wear that seems to stem from use, some show no signs of this at all. A further important consideration for future research is to examine how the use of vessels corresponds or correlates to particular shapes or particular production locations, as determined by NAA.

We hope to show that the use of advanced imaging technologies can help us address new research questions in artifact analysis and can deliver and communicate our results to a broader community. Since reuse of the digital data produced through this research project has great potential, the development of a publicly accessible archive for use by other scholars carrying out their own investigations of this otherwise difficult to access material has been a priority. With the goal of extending the 3D data beyond the life cycle of our project, a partnership with University of South Florida's Library's Academic Resources and Digital Scholarship Services has been established in order to create a digital

collection of the 3D content and augment it with metadata compliant with the main international standards for cultural heritage. The collection is available at http://digital.lib.usf.edu/htr/all. Basic descriptive data of the vessels is available to everyone, and interested persons may apply to the library for permission to view the complete collection, including the 3D models and RTI images (Figs. 9, 10). The digital publication of a previously unstudied collection, held by a national museum in a source country that rarely offers such broad opportunities for access and study, provides one solution to the challenges

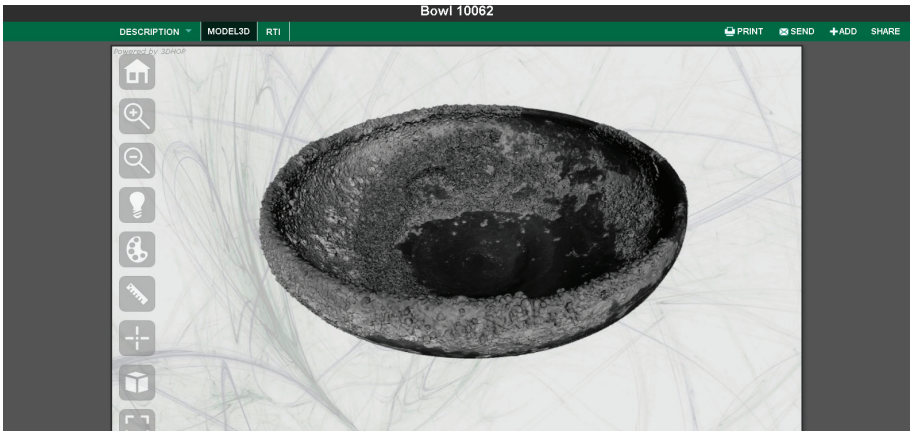

Fig. 9. 3D model of a black-gloss bowl (Capitoline Museums, Antiquarium Comunale, Inv. no. 10062) permanently stored in the *Hidden Treasures of Rome* digital collection of the University of South Florida Libraries.

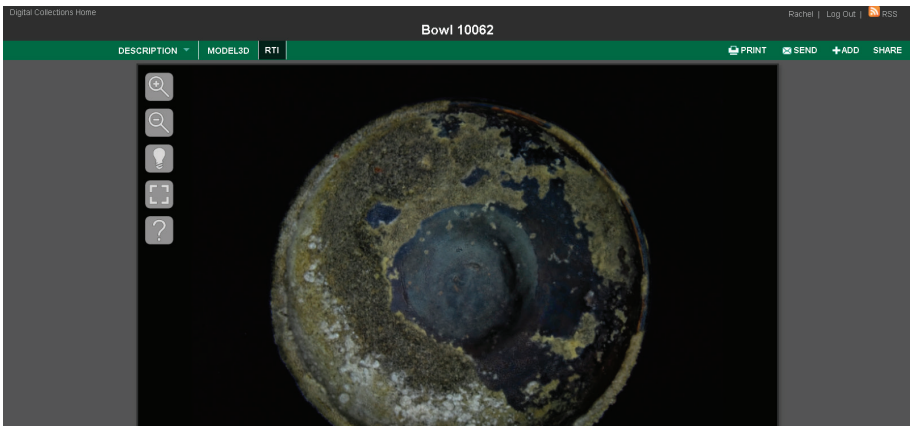

Fig. 10. RTI view of the interior floor of a black-gloss bowl (Capitoline Museums, Antiquarium Comunale, Inv. no. 10062) permanently stored in the *Hidden Treasures of Rome* digital collection of the University of South Florida's libraries.

faced by museums and archives holding collections much larger than they can display. Our project will ultimately illustrate not only the value of making these collections available to interested researchers and the general public but also the importance of international exchange and collaboration in support of the application of advanced technologies to study of collections of high cultural heritage value.

NOTES

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14. Boyer, "Hidden Treasures of Rome," pp. 45 and 52, n. 31.
15. Fringe projection scanners project a pattern of stripes of light onto the surface of the object being documented. These stripes are distorted by the shape of the object. High resolution images of the surface of the object, with the distorted stripes overlaid, are captured by two cameras fixed at known positions. The distortion between the projected pattern of stripes, which is straight, and the pattern of stripes captured by the two cameras is used to help calculate the 3D shape of the surface, resulting in a more precise model.
16. Of the sixty-three vessels that were scanned, thirty-one were scanned using GOM Atos.
17. A digital museum display presents interactive 3D models, which stand in for the objects themselves, and through a website provides descriptive information much like that found on a museum label or information panel. This is hosted by the University of South Florida, http://digital.lib.usf.edu/htr.
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