Using Reflectance Transformation Imaging and 3D Laser Scanning Confocal Microscopy to Evaluate Relief and Contour Lines on Ancient Attic Greek Vases

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Introduction

Relief lines and contour lines—two unique decorative features found on ancient Greek red-figure vases—were studied on a group of vases and vase fragments in the conservation laboratory of the Worcester Art Museum (Worcester, MA) using two surface examination methods: reflectance transformation imaging (RTI) and 3D laser scanning confocal microscopy (LSCM). These methods helped characterize the lines and answer questions regarding tools, techniques, and production sequence used by Greek vase painters.

Red-Figure Pottery

Red-figure pottery—a quintessential Greek pottery style depicting figures in silhouette surrounded by a painted black background—emerged out of the black-figure tradition (depicting painted black figures on the red pottery) during the sixth century BCE, a period of significant transition in Ancient Greece. During this time the inhabitants from numerous autonomous, and often adversarial, city states (*poleis*) unified with the goal of becoming stronger and therefore able to defend their lands and identity from neighbors like the powerful Persians.

Red-figure pottery remained popular throughout the fifth century BCE until its demise in the 320s BCE—around the time of the death of Alexander the Great. The red-figure technique allowed vase painters to become far more expressive and realistic in their rendition of anatomy and dress than their predecessors, the black-figure painters, who used gravers to incise lines for eyes, mouths, garment folds, etc. The quality of these lines was rugged and awkward, because in order to produce visible lines within the black figure portions, the gravers had to get through the black paint layer, which technically was a fired glaze. The red-figure painters, on the other hand, could now paint these lines onto the red vases with the glaze material before the pot was fired using brushes. Depending on the degree of the concentration of the glaze material, they could achieve lines ranging from honey-colored, to brown and black, and even produce lines so thick that they stood proud of the surface, called *relief lines*. Depending on the size of their brushes, different line widths could be achieved also. While fine lines within the red figures were painted with very thin brushes, the black background around the figures was painted with wide brushes. The outline (visible only upon close inspection) within the black background that surrounds the red figures is called *contour line*.

Pottery shapes. The Greeks had a wide range of pot shapes, each one associated with a different activity or function. Among them is the *stamnos*, a large footed vase used for mixing wine and water (Greeks never drank only wine) that has two small handles on each side of the wide body; the elegant *kylix*, the favorite drinking cup among the Greeks consists of a wide shallow bowl with delicate handles that is balanced on a flared foot; and the popular *amphora,* a large vessel used for storing and transporting wine, olive oil, or water that has two sturdy handles on its shoulder.

Research goals. Debates continue among scholars over multiple aspects relating to the production of Greek vases. One such debate centers on what tools and methods created certain decorative features such as the relief lines on red-figure ware. There are also conflicting opinions as to the sequence of the applied decoration, in particular which came first, the relief line or the contour line surrounding the red figures.

In 2011, the authors published an article describing their research on a *stamnos* by the Tyszkiewicz Painter in the collection of the Worcester Art Museum (Figure 1) [1]. A step-by-step description was given of the decorative process on this vessel, followed by a topographic study of the relief and contour lines using RTI and LSCM. These examination methods allowed for the lines to be characterized more fully and ultimately helped determine what tools and techniques were used to produce them. Since then, further investigations have tested if the findings made regarding this *stamnos* are applicable to Greek red-figure vases more broadly by examining additional vases from the collection of the Worcester Art Museum, as well as vase fragments from the collection of the Harvard University Art Museums. These additional investigations resulted in a

Figure 1: Stamnos attributed to the Tyszkiewicz Painter, c. 480 BCE. Scale = 10 cm. Courtesy of Worcester Art Museum, 1953.92. Republished with permission of Maney Publishing, from [2]; permission conveyed through Copyright Clearance Center, Inc. (CCC).

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Figure 2: The Worcester Art Museum's portable fixed-light array RTI dome. Republished with permission of Maney Publishing, from [2]; permission conveyed through CCC.

second publication [2]. An overview of the Worcester Art Museum research is summarized in this article.

Materials and Methods

Vases. Ten vases or fragments thereof were examined with RTI and a 3D laser scanning confocal microscope (OLYMPUS LEXT OLS4000) as part of this research. These works were carefully selected to cover as broad a time span of the red-figure production period as possible using only dated works (c. 510 to c. 330 BCE). All of them except two have been attributed by scholars. Among them are eight vase fragments from the collection of the Harvard Art Museums, with the remainder from the Worcester Art Museum collection. In addition, a black-figure vessel from the late sixth century BCE and a red-figure vessel from South Italy, also from Worcester, were examined.

Methodology. The RTI instrument [1, 2] used for this project employed 40 fixed lights arrayed in a dome-like configuration and a high-resolution Canon EOS-1 Mark III digital camera mounted on an adjustable stand (Figure 2). To generate an RTI file, 40 individual digital images are taken of the same surface detail as it appears under the various angles of illumination provided by the fixed-light array. Fitting software combines the 40 images into one interactive file, resulting in a high-resolution 2D representation of an object's intricate 3D surface. Relevant RTI still-captures are illustrated in this article.

Figure 3 illustrates how topographical features—such as preliminary sketch lines, the broad contour line surrounding the figures, and relief lines used to outline the figures and to describe shapes like ears and eyes—are more readily discerned using RTI.

In addition to RTI, an OLYMPUS LEXT OLS4000 3D laser scanning confocal microscope [1, 2] was used for nanometer-level imaging and 3D topographical measurements of the

Figure 3: Split-image detail of Thetis's head depicted on the stamnos in Figure 1. The image shows RTI still-captures of the detail, one with specular enhancement (upper left) and the other under normal illumination (lower right). Republished with permission of Maney Publishing, from [2]; permission conveyed through CCC.

surfaces examined. This instrument features a dual confocal system and uses a 405 nm laser. Surface measurements can be presented in a number of modes including real-color 3D dual confocal images and 3D elevation maps. In its standard configuration, the microscope is equipped with 20×, 50×, and 100× objectives.

Results

Relief line. The type of line used for outlining figures and for painting details like eyes, mouths, hair, body parts, and folds in garments is called a relief line. These lines consist of black glaze material and—as their name suggests—exist in relief and have a 3D quality. They occur in a relatively wide range of lengths. Whereas longer lines like those typically used in garments are continuous, dynamic, and fluid, shorter lines are less fluid, can be quite thick, and are typically in higher relief. During examination of the Tyszkiewicz stamnos it was noticed that some relief lines have a profile characterized by a single peaked ridge, whereas other relief lines have a distinctly furrowed profile (Figure 4).

Debate remains as to what tools were used to produce relief lines. Tools that have been suggested include a reed pen [3] or a metal pen, a quill [3], the tip of a feather [4], a thin brush [5], a brush with only a few hairs [6, 7, 8], and a syringe-like instrument made from a feather quill and animal intestine or bladder used to extrude the glaze [9, 10]. Today there is a general consensus that reed or metal pens could not have produced the relief line because the thick glaze material cannot travel through the narrow pen channel, which functions by capillary action [8].

The two types of relief lines were successfully replicated through mockups and identified by the authors as follows: the *laid line*, characterized by a ridged profile, and the *pulled line,* characterized by a furrowed profile [1, 2]. Both line types were reproduced with brushes made with only a few hairs, as first

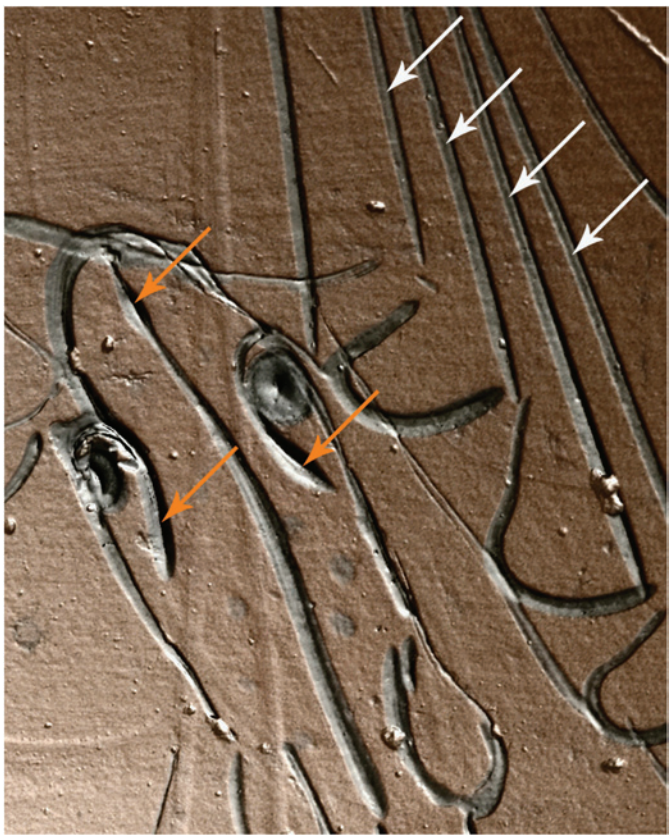

Figure 4: RTI still-capture of a detail of the stamnos in Figure 1. Examples of ridged lines are indicated with orange arrows, and furrowed lines with white arrows. Republished with permission of Maney Publishing, from [2]; permission conveyed through CCC.

proposed by Seiterle [8]. Two different application techniques were used to produce the two types of lines. As the name indicates, laid lines are produced by laying the glaze-dipped hairs of the *linierhaar* down onto the surface of the vessel followed by lifting the brush straight up, creating the distinctive ridged profile of the line. In contrast, the *pulled line* was created by setting down all or part of the brush, and while leaving the hair in contact with the vessel, the brush was pulled across the surface creating a characteristic furrowed profile as the tip of the brush dragged through the glaze medium producing lines that are longer than the length of the brush hair. For example, the eye of Thetis on the Tyszkiewicz stamnos consists of lines with a central ridged profile like that produced using the laid-line technique (Figure 5). The lines that define the outline of the eye were painted first, followed by those that outline the iris. Both the real-color confocal image and the 3D elevation map clearly show an additive effect where the lines overlap. In contrast, the pupil was painted with a more dilute application, probably with a conventional brush. A preliminary sketch of the eye inscribed into the surface with a hard tool is also discernible just above the eye.

The Museum of Fine Arts Boston has in its collection a fragmentary kylix attributed to the Antiphon Painter from c. 480 BCE (Figure 6). The fragment depicts a male figure seated on a chair holding a kylix in his left hand and a stylus-like (pen-like) tool in his right. When examined under magnification with raking light, a single relief line connecting the tool and the surface of the vessel is discernible and can convincingly be argued to depict a *linierhaar* [1, 2]. The man also holds a small pointy implement between his left thumb and index finger, which the authors believe could be a a small container holding the glaze material.

Contour line. In addition to the relief line, another decorative feature of interest in this research is the study of the contour line, a wide line forming part of the black background that often surrounds the figures on red-figure vases (Figure 7). The black background was painted in two stages with glaze more dilute than that of the relief lines, using a wider, more traditional type of brush. The contour line was applied with the purpose of creating a safe margin around the silhouettes of the figures to protect them from being disrupted by the broadly applied brush strokes of the background glaze, an action probably executed at a relatively fast pace.

Application sequence. One question considered in this study is which came first, the relief line or the contour line. Whereas Greek vase scholars Norbert Kunisch [11] and Beth Cohen [12] suggest that the relief lines outlining the figures preceded the application of the contour line, other vase experts like Joseph V. Noble and Alexander Boix propose a reverse sequence [10, 7], though Boix claims that there are exceptions. The sequence proposed by Kunisch and Cohen was observed by Artal-Isbrand and Klausmeyer on the Tyszkiewicz stamnos where the overlap of the contour line over the relief lines extending into the background at the nape of the figure's neck results in a softer, more rounded appearance of the otherwise crisp relief lines (Figure 7) [1]. This sequence was also observed on all the other Attic vases and vase fragments that were part of this study [2].

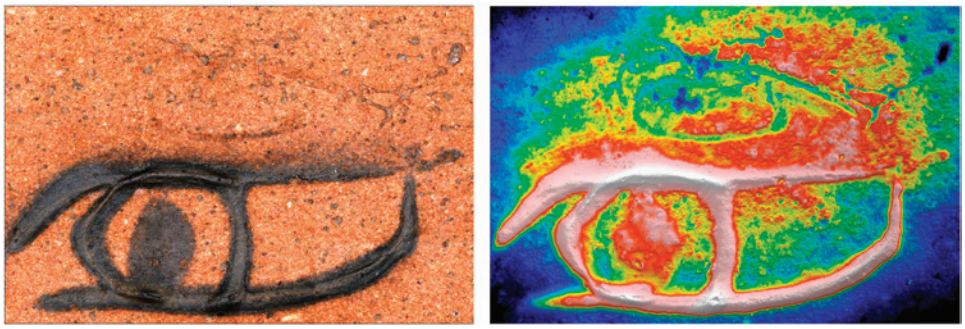

Figure 5: Real-color confocal image (left) and the corresponding 3D elevation map (right) of Thetis's proper left eye. The relief lines exhibit the central ridged profile characteristic of laid lines. Evidence of a preliminary inscribed sketch is visible in the surface directly above the eye. The dimensions of each image are 3.45×2.35 mm, and the images were stitched from 32 individual area scans taken with a 50× objective. The distance from the substrate surface to the highest elevation on the lines was 40 µm. Republished with permission of Maney Publishing, from [2]; permission conveyed through CCC.

Discussion

In this research, two types of relief lines were identified by the authors: the laid line, characterized by a ridged profile, and the pulled line, characterized by a furrowed profile. As the name indicates, laid lines are produced by laying the glaze-dipped hairs of the *linierhaar* down onto the surface of

Figure 6: Left: Kylix fragment attributed to the Antiphon Painter, c. 480 BCE. Courtesy of Museum of Fine Arts, 01.8073. Right: Detail of the fragment showing what is likely a *linierhaar* in the painter's right hand and possibly a small container holding the glaze in his left. Republished with permission of Maney Publishing, from [2]; permission conveyed through CCC.

Figure 7: RTI still-capture with specular enhancement showing the use of a wide contour line around the head of a female attendant depicted on the stamnos, which is part of the broadly applied background glaze. The white circle in the magnified detail on the right illustrates how the contour line overlaps the ends of the relief lines that extend into the background area, indicating that the application of the relief lines preceded the contour line. Republished with permission of Maney Publishing, from [2]; permission conveyed through CCC.

the vessel followed by lifting the brush straight up, creating the distinctive ridged profile of the line. The resulting line is typically no longer than the length of the brush hair. In contrast, the pulled line is created by setting down all or part of the brush, and while leaving the hair in contact with the vessel, the brush is pulled across the surface creating a characteristic furrowed profile as the tip of the brush drags through the medium producing lines that are longer than the length of the brush hair.

While the pulled-line technique was used on all Attic red-figure vases, the laid-line technique seems to have become more prevalent as a second line type during the peak of the red-figure period in the fifth century BCE [2]. Before then, painters—probably unaware of the laid-line technique—also made shorter lines using the pulled-line technique. The result is that these lines are often truncated and of varying thickness compared with the more even and controlled lines produced later with the laid-line technique.

This study also gives insight into the production sequence used by red-figure painters. During the process of surface decoration by Attic painters, relief lines were applied first to describe the general outline of the red-figure portions of the composition as well as features like the arms, legs, eyes, ears, and folds and other details in the garments. The next step consisted of painting contour lines around the figures to create a safe margin and prevent the broadly applied background glaze from disrupting the edges of the figures. Examination by RTI of the areas where relief and contour lines meet revealed that on every Attic piece in this study the contour line overlaps the relief lines where the relief lines extend into the black background, confirming that the contour line was painted after the relief line as Kunisch and Cohen propose.

Conclusion

RTI and 3D LSCM, two complementary surface examination methods not previously used together in the study of ceramics, have led to new insights in the study of ancient Greek vases. These nondestructive, noninvasive methods enable researchers to examine surface topography more in-depth by providing qualitative (RTI) and quantitative (3D LSCM) data. This combination will prove useful in future investigations where surface examination is central, not only to determine fabrication methods, but also to evaluate the impact of art conservation treatments and examine and document surface degradation.

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