THE EAST ASIAN JOURNAL OF CLASSICAL STUDIES
Volume 1, 2022: Article

A Study of the Material and Firing Reactions of Relief Dots on Ancient Greek Red-figure Pottery[1]

Chia-Lin Hsu[2],
Tunghai University

Abstract

Red-figure pottery (c.530-c.250 BCE) is one of the most representative objects of ancient Greek civilization. Inscriptions on the pottery preserve ancient Greek words, while paintings thereon reflect the images people had of gods and goddesses. The paintings also record several aspects of society and the life at that time. The technique used for the pottery has attracted scholars' attention since the eighteenth century, and better accounts are still sought. This paper is concerned with the decorative relief dots on ancient Greek red-figure pottery. The relief dots are found to consist entirely of black gloss which could have been produced with ease during firing. This recalls the Greeks' interest in convenient but precise techniques. Such characteristics helped this pottery technique to be learned and spread without much difficulty. Since the Greeks tended to be conservative toward customs and traditions, they passed this technique down from generation to generation. By way of trade and colonization it was brought to a wide area where the Greek culture reached to. The technique was, and became,

[1] Assistant Professor, History Department, Tunghai University, Taiwan. This article was first published in Chinese in a Taiwanese Journal, *Journal of Archaeology and Anthropology* (考古人類學刊), vol. 87 (December 2017) 37-66. The author would like to thank the journal's editor in charge of this paper and the two anonymous reviewers for their invaluable comments. The paper was first prepared in 2012/2013, and the author is deeply grateful to the following people who offered help. Dr Chris Doherty read and commented earlier versions. Dr Louise Calder kindly proof read one, which is included in this version. Sir John Boardman commented on this and offered very much needed encouragement. Nicholas Koss corrected the English of this version and has generously helped this publication. This research was facilitated with access to museum collections. Professor Donna Kurtz introduced the museums, and special thanks to Mrs Ursula Kästner (Antikensammlung, Berlin); Dr Laura M. Gadbery, Dr John Herrmann, Dr Christine Kondoleon (MFA, Boston); Dr Alexandra Villing, Dr Dyfri Williams (BM, London); Dr Kenneth Lapatin (Getty, Malibu); Dr Florian Knauss (Antikensammlungen, Munich); Dr Joan Mertens (Met., New York); Dr Susan Walker, Professor Michael Vickers (Ashmolean, Oxford); Dr Martine Denoyelle (Louvre, Paris); Dr Maurizio Sannibale (Vatican); Dr Irma Wehgartner (Martin von Wagner, Würzburg).

[2] Assistant Professor, History Department, Tunghai University. The author would like to thank the editor in charge of this paper and the two anonymous reviewers for their invaluable comments in helping to improve this paper.

one symbol of Greek civilization.

Keywords: Ancient Greece, red-figure pottery, relief dots, black gloss, firing

Background of Research

Ancient Greek red-figure pottery and the black gloss applied on it are among the most representative objects and materials of the civilization. As shown below, relief dots on this type of pottery can reveal the properties of black gloss and why it was widely used by the Greeks. This study shows that black gloss could have been easily produced during firing, while the products are of high quality, recalling other Greek techniques that were convenient but precise. For example, John Boardman proposes a multiple brush fitted to a compass that was used to draw concentric circles on pottery of the Protogeometric period, c. 110-900BCE (Boardman 1998: 14). In addition, the Getty Conservation Institute, the Aerospace Corporation, and the SLAC National Accelerator Laboratory in Stanford University received a generous reward by the National Science Foundation, USA, for a three-year project on ancient Greek pottery starting from January 2011, hoping to reveal the secret of the black gloss technique. If the Greeks were able to produce such precise a product with a simple technique, this would be inspiring for modern advanced technologies.[3]

Decorations with black gloss include relief dots. Works with these are not in large quantity, but many are the best pieces of red-figure pottery. The black gloss of relief dots is much thicker than that of other decorative elements, for example, the black background of the red-figure, which is very thin. The thickness of the relief dot is beneficial to our understanding of the manufacturing process of the pottery, as various effects of production on black gloss could be seen more clearly in relief dots than, for example, in the thin black background. The properties of black gloss can be revealed more easily in relief dots.

This study of relief dots shows the advantages of black gloss and explains why the Greeks used the same material generation after generation, over a period of more than five hundred years. Black gloss represents technical characteristics of ancient Greece: it was easy to use while producing precise results. The technique also represents the conservative attitude of the Greek culture, as people usually followed customs and traditions. In 399 BCE, the philosopher Socrates was executed for corrupting the

[3] 'Deciphering the Elements of Iconic Pottery'. Discoveries. National Science Foundation. Web. Access June 28, 2017. https://www.nsf.gov/mobile/discoveries/disc_summ.jsp?cntn_id=119082&org=NSF

young, showing that the Greeks usually did not accept the philosopher's teaching of re-thinking and challenging the social tradition (Field 1970). Black gloss symbolizes the pursuit of simple but perfect techniques in ancient Greek civilization, and it recalls the conservative attitude and inheritance of existing customs of the people. Through trade, colonization and other types of movement, Greek pottery technique was brought to a wide range of areas surrounding the Mediterranean and the Black Seas, and to the inlands of Europe and Africa. The pottery technique was so learned and used by people in numerous city-states and regions.

Among Greek pottery decorated with black gloss, red-figure pottery is the type that has been studied most thoroughly, and the scholarship has been influential for studies of other types of Greek pottery, for example, the black-figure. This study focuses on black relief dots on red-figure pottery, but the result can be applied on other Greek pottery decorated with black gloss. Here is an introduction of red-figure pottery in ancient Greek society and culture.

Ancient Greek Red-figure Pottery

Ancient Greek red-figure pottery (c. 530-300BCE, Fig. 1) is so named because figures drawn on the pottery are reddish. This color is not due to an application of a red pigment on the pottery, but it is the original color of the clay after the firing of the pottery. Craftsmen applied black gloss raw material in areas surrounding the figures, and it became black after the firing, resulting in a decoration of reddish figures against a black ground. Details of figures were drawn or filled in with black gloss, occasionally incised with lines. Various shades of added red, ranging from orange-red to purplish-red, could be used to represent blood and to paint ribbons and wreaths worn on the head. Added blue and green colors, and even gilded ornaments, can be seen on some of red-figure vases dated in the fourth century BCE, whose colorful effect is characteristic of this special type of red-figure.

Figure 1a- Athenian red-figure pottery, 6th cent. BCE, amphora shape, by painter Euthymides, from Vulci. Munich, Antikensammlungen, no. 8730 (J378) (2307).

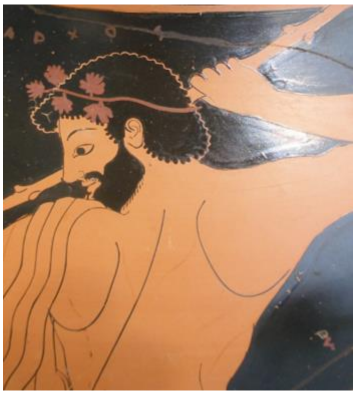

Figure 2b- detail of Fig. 1a. Field of view 5 cm wide.

About 49,000 pieces of red-figure have been published,[4] and the total amount of the excavated can be a hundred or thousand times more, *i.e.* probably reaching a number of a few million or even more. The red-figure is therefore among the most representative objects of the ancient Greek civilization. It is found all over the Mediterranean region, as well as inland in Europe and Africa, and in the coastal areas of the Black Sea. The red-figure was so widely spread because the Greeks brought them to these places by way of trade and colonization. The latter could be testified by the foundation oath of Cyrene, Libya, sworn by the Theraeans when they decided to establish it as a colony (Fornara 1977: Nr. 18, Parker 2014: 78-79). The Theraean assembly selected colonists, and these were to build a new city-state with the culture of the motherland. As pottery was essential for daily life, it is reasonable that potters were sent to the colony. The pottery technique was therefore spread. In addition, the

[4] According to the number in the online database of the Beazley Archive, University of Oxford. www.beazley.ox.ac.uk

Greek should have brought pottery with them when they travelled to colonies or for trading; some pottery pieces would be for personal use, while others could be goods. This should have been another way to spread Greek pottery.

The red-figure pottery is associated with ancient Greek civilization essentially because ancient Greek was written on some pieces. About one tenth of the pottery were painted or inscribed in Greek. In the 18th century, a large number of the pottery were excavated in Italy, and they were originally regarded as Italian products made by the Etruscans before ancient Rome. However, inscriptions on the pottery were later confirmed as Greek, including names of mythological figures, *kalos* and *kale* names which indicate handsome men or women, and occasionally dialogues from Greek drama. Inscriptions on red-figure preserve samples of ancient Greek language and have been studied linguistically. (Kretschmer 1894: 73-225, Bothmer 1987, Cook 1997: 241-246, Immerwahr 1990: 57-80, Wachter 2001).

Another reason to associate red-figure with ancient Greek civilization is the figures on the pottery, who often recall characters in Greek mythology (Graf 1987). Red-figure vase-painting has therefore become an important source for the study of Greek iconography. For example, some figures on red-figure have the inscription of Zeus, and they represent how vase-painters or their contemporaries imaged the god. Also, for example, Athena on red-figure pottery is often shown as holding a shield and a spear and wearing a helmet and a chest plate -- the aegis, on which the head of Medusa is hung. This image is similar to the depiction of Athena in the epic poem *Iliad* (5.733-7) attributed to Homer. Likewise, scholars have been able to identify other figures mentioned in Greek literature on red-figure pottery. Red-figure vase-painting also preserves Greek daily-life scenes, such as fishing, farming, warfare, weddings, funerals, symposia, education, women and domestic affairs, *etc.* Greek red-figure pottery provides images of ordinary people in Greek antiquity.

Greek red-figure pottery has played an important role in dating archaeological sites. The pottery is dated between c. 530 and c. 250 BCE, when the Greek civilization was flourishing, and what Athens achieved was the most prominent. So far, dating of red-figure pottery has been largely based on the style of the figure drawing, which is traditionally believed to change from a severer style to a freer style during the period of production. Some vases are dated from c. 530-400 BCE partially because the styles of the drawings are similar to those of some sculptures dated more certainly around the same period (Langlotz 1920: 17-23, Philadelpheus 1922, Pyne 1933: 272, 275, Brinkmann 1994). Another reason is that some drawings on vases are similar to those of a few painters recorded in literature, whose flourishing dates are known (Pausanias 1979: 10.25.1-10.31.12, Stansbury-O'Donnell 1989, 1990, Pollitt 1990: 126-141).[5] Some vases were excavated from particular places and contexts which probably are related to certain battles recorded in history (Schliemann 1884, Staes *et al.* 1890, Staes 1890, 1891, 1893, Karo 1930, Schilardi 1977). These vases are therefore believed to be made not too long before the battles. Red-figure pottery dated from c. 400-300 BCE corresponds to no styles in objects and paintings whose dates are certain, except two red-figure vases that were found with fourth-century coins.[6] Vases that are dated from the fourth century are relatively late because their styles are more decorative, with more added colors and, in large vases, with compositions that are more complex. These are believed to be features of later development. The dating of Greek red-figure pottery has been based on the style of vase-painting. The pottery was excavated in large quantities in the 18th and 19th centuries, and authoritative theories about it were gradually formed. Archaeology was in an early stage of developing, and stratigraphy and other dating methods were not the mainstream and were not applied on the pottery. The style of vase-painting was the major consideration in dating the pottery, which is still in use today. Numerous vase-painting styles have been carefully distinguished, and their relationships have been thoroughly studied. This helps to establish a systematic chronology that could be applied to the pottery as a whole. When red-figure pottery is found in an archaeological site, the date of the site usually relies on the date of the pottery pieces.

Finally, Greek red-figure pottery is important for Western culture and scholarship because of its good quality and technique of production. Its black gloss is lustrous and has attracted the attention of scholars since the 18th century, being the first ancient material to be analysed scientifically (Jones 1986: 798). So far, the technique of the pottery has not been fully understood, and we still wait for more precise answers, including those about the drawing instrument, the clay source, the raw material of black gloss, and the way of firing the pottery. This study investigates relief dots on red-figure pottery, which are black in colour, and are associated with the properties of black gloss. How this reacted in firing is crucial for the success of production. This study starts from the definitions of relief dots and of black gloss, proceeding to X scientific research, and finally it explains why the Greeks used black gloss to decorate pottery over a very long time.

---

5 For example, the Niobid Painter's work Louvre G341, the Meidias Painter's work BM E224, and a work of the Painter of Bologna 279, Ferrara 3031.

6 *Notizie degli Scavi*, 1962, 366, 'vasi e figure rosse', no. 2; 367, 'monete', no. 1, 348, fig. 3h. *Notizie degli Scavi*, 1931, 588-594, 614, figs. 8-10.

Relief Dots

Relief dots, black in colour, about 0.1-2.0 mm in diameter, are used to indicate protruding hair locks¸ or spherical objects such as grapes. Classical archaeologists usually regard Joseph Veach Noble (1988) as the authority on the technique of Greek painted pottery, but he did not discuss the technique of the relief dot, though a photograph illustrating relief lines also include relief dots. As far as I know, the most important past study is Beth Cohen (1997). She discusses the raw material of black gloss according to the phenomena on a few vases: First, some relief dots on a vase-painting by Euphronios are damaged and reveal an orange material beneath the black surface. Second, another vase-painting, also by Euphronios, is decorated with black relief dots as well as relief dots covered by gold leaves. She says that black relief dots were made by application of a thin layer of black gloss on relief clay dots, which was similar to the way of adhering gold leaves to clay dots. Nevertheless, my study shows various phenomena of broken relief dots on different vases, and the phenomena can all be explained if the dots were entirely made of black gloss material. This formed both the volume and color of relief dots.

Black Gloss

The black decorative material on red-figure pottery is called 'black gloss' by scholars of the field, who avoid referring it as 'glaze' because its properties differ from those of ordinary glazes. First, the silica content in black gloss is between 42% and 48% by weight (Table 1), which is relatively insufficient in comparison to glaze, whose silica content is usually between 45% and 80% (Shiue 2013: 22). The silica content in black gloss is close to the lower limit, or even less, than that in glaze. Second, black gloss is not fused as a true vitreous glaze (Tite *et al.* 1982, Jones 1986, Maniatis *et al.* 1993), although a research group discovered a very thin glassy film (c. 0.1 μm) on Greek black gloss. This film can reflect light in a particular manner, and they call such black gloss 'glazed black gloss', to differentiate from others with no such film (Maniatis *et al.* 1993). The current study does not use 'glaze' to describe the black decorative material on Greek pottery. This is to avoid confusion with ordinary glazes, and 'black gloss' is used throughout this paper. In addition, opinions in Th. Schumann (1942) and Adam Winter (1978) have been widely accepted, which say that the raw material of black gloss was the finest particles derived from clay of the vase body. Black gloss's Chinese translation, 'black clayish-coating on pottery', should be suitable.

Table 1 Chemical Composition of Greek Black Gloss (w%)

	Si O_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5
Pavićević (1974)	43.12	0.43	29.00	14.15	0.02	1.69	0.35	n.d.	3.69	_
Tite *et al.* (1982)	45.81	0.73	29.38	14.62	n.d.	1.92	0.67	0.82	5.75	0.30
Maggetti *et al.* (1981)	45.89	0.41	29.12	15.64	0.09	3.17	0.17	0.83	4.89	n.d.
Maggetti *et al.* (1981)	45.06	0.32	28.86	14.09	0.11	2.21	0.65	0.88	6.98	-
Maggetti *et al.* (1981)	45.02	0.48	28.80	14.40	0.12	2.35	0.76	0.94	6.74	-
Kingery (1991) No. IV	47.3	0.5	29.3	12.8	_	1.7	0.9	0.3	6.9	_
Kingery (1991) No. V	47.8	0.3	28.7	12.7	_	2.0	1.0	0.7	6.7	0.1
Maniatis *et al.* (1993)	46.8	0.5	31.7	13.5	0.1	1.9	0.9	0.6	4.1	_
Maniatis *et al.* (1993)	46.7	0.6	31.0	13.1	0.1	1.8	0.3	0.8	5.5	_
Maniatis *et al* (1993)	43.4	0.6	29.8	15.4	0.1	2.2	0.9	0.9	6.1	0.5

Maniatis *et al.* (1993)	45.6	0.9	29.2	15.3	0.1	1.9	0.6	0.8	4.7	0.4
Maniatis *et al.* (1993)	45.3	0.4	30.9	14.8	_	1.9	_	Tr	6.5	_
Maniatis *et al.* (1993)	45.8	0.6	32.4	15.5	0.1	1.6	0.3	0.5	3.0	_
Maniatis *et al.* (1993)	45.6	1.2	29.1	14.4	0.2	2.0	0.9	0.7	5.6	_
Maniatis *et al.* (1993)	42.6	1.1	28.6	17.2	_	1.8	1.1	0.7	6.5	_

The flux in Greek black gloss, which helped melting, is possibly potassium oxide (K_2O). According to Table 1, the proportion of silica to potassium oxide (SiO_2 : K_2O) in black gloss is between 9.5 : 1 and 25 : 1, and it is closer to the proportion in high temperature glaze, which is 10 : 1, and much different from the proportion in low temperature glaze, which is 2 : 1. High temperature glaze melts in a temperature above 1300 ˚C (Shiue 2013: 22), but scholars believe that Greek black gloss was fired in a temperature considerably below 1300 ˚C. As far as I know, there have been three analyses of the firing temperature of the pottery, and they report the temperature between 940˚C and 1100˚C (Tite 1969), between 850 ˚C and 1050˚C (Maniatis 1976), and between 770˚C and 840˚C (Schilling 2003), respectively. These figures indicate that the pottery was not fired in a high temperature as defined by modern potters. It could have been fired in a temperature below the range of low temperature glaze, whose lower limit is 900˚C. The highest possible firing temperature of red-figure pottery could reach the range of low-to-medium temperature glaze, whose firing temperature is between 1000˚C and 1160˚C (Shiue 2013: 18). This means that black gloss of red-figure pottery was not fired above 1300 ˚C and did not melt.

The proportion of aluminium oxide to silica (Al_2O_3 : SiO_2) in Greek black gloss also shows that this is not an ordinary glaze, and it is impossible to follow the principle of ordinary glaze to anticipate the firing reaction of black gloss on the basis of its chemical composition.

According to modern potters, the proportion of aluminium oxide to silica is better between 1:8 and 1:12, and a shiny black glaze can be produced (Shiue 2013:24). In Greek black gloss, however, the proportion is between 1:2 and 1:3, far away from the ideal proportion for glaze. In addition, Greek black gloss contains a considerably high concentration of iron oxide, between 12% and 18%. The reaction of iron oxide in black gloss is different from that in glaze because black gloss did not melt. Other materials, such as magnesium oxide (MgO), should have interacted with iron oxide in black gloss differently, in comparison to the situation in melted glaze. In Greek black gloss, materials containing alkaline earth metals, such as magnesium oxide (MgO) and calcium oxide (CaO), are low in concentration: calcium oxide (CaO) is below 1.3% and magnesium oxide (MgO) is below 2.2%. These could have functioned as the flux of small quantity in the firing temperatures analysed mentioned above: 940-1100˚C (Tite 1969), 850-1050˚C (Maniatis 1976), 770-840˚C (Schilling 2003). In short, the composition and firing temperature of Greek black gloss are considerably different from those of ordinary glaze, and the reaction of black gloss in firing did not follow the principles of glaze.

So far, scientific analyses of Greek black gloss show that the color of the pottery is due to the content of iron oxide between 12% and 18% by weight. Iron is the colorant of Greek black gloss, and some compounds containing iron of low oxidation states contribute to the dark shade of black gloss. Some samples of black gloss contain manganese below 0.2%, which is a very small amount compared to the iron content and is not so important in the coloration of Greek black gloss. The black gloss's chemical composition appears to relate to clay (Kingery 1991, Maggetti et al. 1981, Maniatis et al. 1993, Pavićević 1974, Tite et al. 1982) (Table 2), and the general opinion is therefore that black gloss raw material was clay or contained clay. Scholars of this opinion believe that the raw material of black gloss was a fine slip obtained from levigation of the same clay as was used in the body of the vase (Schumann 1942, Winter 1978). Levigation is to mix clay with water and let this settle. Larger and heavier particles usually settle earlier, while the smaller and lighter usually accumulate in the upper part of the sediment. Fine particles can be obtained by repetitive levigation of the upper part of the sediment each time.

Table 2 Chemical Composition of Clay of Greek Pottery Decorated with Black Gloss

Sample	Si O_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5
Maggetti *et al.* (1981) No. 1	59.97	0.75	16.78	6.14	0.10	3.13	9.66	0.99	2.95	0.28
Maggetti *et al.* (1981) No. 2	58.07	0.77	17.42	5.91	0.10	2.74	10.53	0.98	2.98	0.69
Maggetti *et al.* (1981) No. 3	58.37	0.81	17.90	6.68	0.10	2.99	8.60	1.01	3.25	0.67
Kingery (1991) No. III, 5th century	51.4	0.8	27.4	8.1	_	3.8	4.2	0.2	3.6	_
Kingery (1991) No. IV, 4th century	52.4	0.9	24.7	7.6	_	3.8	6.5	0.3	3.3	0.1
Kingery (1991) No. V, 4th century	47.5	0.7	26.7	7.6	_	3.5	8.1	0.4	2.8	1.4
Maniatis *et al.* (1993) ATT-1, from Paros	50.1	1.1	19.9	10.5	0.2	4.9	8.6	0.7	3.8	_
Maniatis *et al.* (1993) ATT-2,	54.0	1.0	21.0	9.0	0.1	3.5	6.1	0.9	4.3	_

from Paros										
Maniatis *et al.* (1993) ATT-3, from Paros	53.3	1.0	20.1	8.6	0.2	4.3	7.7	0.7	4.3	_
Maniatis *et al.* (1993) ATT-4, from Paros	54.0	1.0	20.1	9.0	0.2	3.5	6.8	0.9	4.5	_
Maniatis *et al.* (1993) ATT-5, from Paros	57.5	0.9	17.9	7.9	0.1	4.7	5.8	0.9	4.0	_
Maniatis *et al.* (1993) ATT-6, from Paros	57.2	1.0	18.8	8.1	0.1	4.8	5.6	0.7	3.4	_
Maniatis *et al.* (1993) AH-11, from Turkey	50.2	1.1	17.8	10.9	0.3	4.8	9.5	0.8	3.8	_
Maniatis *et al.* (1993) LIO-9, from Athens	50.2	1.0	18.2	10.5	0.3	5.2	9.2	0.8	3.9	_

The theory that black gloss raw material was derived from clay of the vase body, cannot solve one problem: the concentrations of some elements in these two materials are significantly different (Kingery 1991, Maniatis et al. 1993, Pavićević 1974, Tite et al. 1982). The concentration of calcium is very low in black gloss, between c. 0.01 and c. 0.25 times of the concentration in the clay of the vase body. Experiments of repetitive levigation cannot always reduce the concentration of calcium in clay to a level similar to that of black gloss (Maniatis et al. 1993). Experiments of repetitive levigation also cannot increase the concentration of iron in clay to a level similar to that in black gloss (Kingery 1991, Maniatis et al. 1993, Tang et al. 2001, Tite et al. 1982).

Because of the difficulty just mentioned, scholars have provided other suggestions about the raw material of black gloss. One suggestion involves the addition of iron oxide (Kingery 1991), another says that a special 'glaze clay' was used as the raw material, which would have been high in iron and low in calcium (Aloupi-Siotis 2008, Kingery 1991). The finest particles of such a clay from Kalami (Crete), and another from Krora (between Boeotia and Attica) have been successfully used for replication (Aloupi-Siotis 2008).

The raw material was transformed into black gloss by firing. Schumann's theory on firing of red-figure pottery is widely accepted in the field of classical archaeology (Schumann 1942). He suggests that the pottery was fired in three consecutive stages, where the atmosphere changed from oxidizing, to reducing and then to oxidizing again. In the first oxidizing stage, iron compounds in the pottery tended to be those with iron of a high oxidation state, and both clay and black gloss material were red. In the following reducing atmosphere, iron compounds transferred to those with iron of a low oxidation state, and both clay and black gloss material became black. At the same time black gloss was partially melt (sintered) and formed. In the third stage, when oxidizing atmosphere was re-introduced, black gloss was impermeable to gases and therefore remained black. However, the clay without a gloss covering was still porous and allowed oxygen to penetrate. As a result, the black iron compounds in the clay were oxidized, and the clay became red. Through these three firing stages, figures on the pottery, which are not covered with black gloss, expose clay and show a red color, while the background of figures was applied with black gloss and is black after firing.

Table 3 summarizes the minerals detected in black gloss samples, showing that magnetite is often found, but other iron compounds are also present. Mineralogical compositions can vary, and different iron compounds are associated with various shades and textures of black gloss (Giorgetti et al. 2004). These reflect firing conditions that differed in oxygen partial pressure (ibid.). Other factors affecting black gloss appearance include particle size and shape (Gliozzo et al. 2004, Oberlies and Köppen 1962, Vendrell-Saz et al. 1991), which were influenced by the source of the raw material, its refinement, and the firing conditions (Gliozzo et al. 2004, Tang et al. 2001). Normal black gloss is amorphous and has layers (Maniatis et al. 1993), but misfired gloss in red or green is porous (Newman 2008)

Table 3 Minerals Detected in Greek Pottery Decorated with Black Gloss Dated from the Sixth to the First Century BCE

Minerals	**Technique**	**Sample Characteristics**	**Publication**
Wüstite (FeO)	XRD	3 samples, Classical Greek type	Bimson (1956)
Hercynite, or possibly a compound in the Fe_3O_4-$FeAl_2O_4$ series	XRD	Greek type	Oberlies (1968)
Fe_3O_4	Magnetic test, XRD	1 sample, 5th-century skyphos, Athenian type	Farnsworth and Wisely (1958)
Fe_3O_4	Magnetic test	Athenian type	Noble (1988)
Perhaps Fe, (Mg, Fe) SiO_3, or tiny crystals entrapped in quartz	XRD	Athenian type	Noble (1988)
Magnetite, hercynite	XRD	Athenian type	Hofmann (1966)
Magnetite, hercynite, maghemite, quartz	XRD	2 lekythoi, Athenian type	Noll *et al.* (1974)
Hercynite, hypersthene, magnetite, quartz	XRD, microprobe	1 sample, Athenian type	Pavicevic (1974).

A compound in the series magnetite-hercynite (Fe_3O_4-$FeAl_2O_4$)	SEM, microprobe, XRD	2 samples, Athenian type	Tite *et al.* (1982)
Magnetic component associated with impure form of magnetite	MS (X-ray scattering)	1 sample, Athenian type	Longworth and Tite (1979)
Magnetite, titanomagnetite (Fe_2TiO_4)	TEM	8 samples, Athenian type	Maniatis *et al.* (1993)
Quartz, hercynite, magnetite, maghemite, ferrian spinel, hematite	Synchrotron X-ray Diffraction	2 samples, Athenian type	Tang *et al.* (2001)
Magnetite (Fe_3O_4), carbon (lampblack)	Raman microspectroscopy	5 samples, Athenian type	Pérez and Esteve-Tébar (2004)
A compound at the Fe_3O_4 end of the Fe_3O_4-$FeAl_2O_4$ series; ferrous iron, perhaps $(Mg, Fe)_7Si_8O_{22}(OH)_2$	MS (backscattering & absorption)	1 sample, late 6th century, from Cerveteri, Greek Etruscan type	Longworth and Warren (1975)
Two phase associations: (1) hercynite, magnetite, haematite, quartz, sanidine (2) hercynite, magnetite, quartz, sanidine	XRD	11 samples, Campanian type	Maggetti *et al.* (1981).

According to the studies mentioned here, the appearance of black gloss can vary, depending on source, refinement and firing. It can be of various textures and exhibit reddish, greenish and blackish shades. This paper investigates whether relief dots were entirely made from black gloss raw material, and whether shades in relief dots are associated with black gloss properties. It is on the bases of past studies on nature and variation of black gloss that this paper explains different phenomena of relief dots. This paper adopts an approach different from Cohen's (1997) and shows that black gloss material can be altered in many ways upon firing, which past studies on the subject do not include (Bimson 1956, Binns and Frazer 1929, Durand-Gréville 1891, Schumann 1942). As explained below, although relief dots' inner parts can be in different shades after firing, the surface of the relief dot is always black. This shows that the firing was not precisely the same, and that oxidizing and reducing stages, each could differ in strength and duration. The firing of Greek black gloss was a feasible technique. This was easy to learn, and the knowledge was easy to spread. It would continue to be used over a very long time in a society that was conservative and disliked change.

Research Method

This study approaches the problem theoretically and not by instrumental analysis because of some reasons in reality. Although the number of pieces of red-figure pottery is large, so far there have been no scientific analysis of relief dots, probably because vases decorated with relief dots are regarded particularly precious. These vases are among the best of red-figure pottery, and they are not many. Usually their prices are high, for example, a large vase painted by Euphronios, previously in the collection of the Metropolitan Museum of Art in New York (museum number 1972.11.10), now returned to Italy and in the Villa Giulia Museum in Rome (museum number L.2006.10).[7] This vase-painting includes a mythological figure Sleep, whose hair is partially decorated with relief dots. It cost one million three hundred thousand US dollars in 1972 when the Metropolitan Museum bought it from an antiquarian dealer. This may be an extreme example, but other red-figure vases of good quality are not cheap either. Usually museums highly prize these vases, and even specialists of the research field may not touch them. It would require extraordinary communication and special arrangement in order to analyse relief dots instrumentally. Even so, I think it is possible to understand the material of relief dots to a certain extent on the basis of the phenomena mentioned below. This understanding could help us to select the most suitable raw material for replication experiment, as materials fired black are many. The understanding could also help us to choose a possible firing protocol, as firing varies greatly.

This study shows phenomena of relief dots that have not been discussed before, and it provides a new theory of their material. This is worked out by studying the phenomena, and the material should have been entirely made of black gloss. Through the discussion of various phenomena, this study provides different opinions on the formation of black gloss and on the firing of the pottery. Several past studies propose theories of Greek black gloss raw material and of the firing procedure, and some experimentally replicated the pottery (Bimson 1956, Binns and Frazer 1929, Durand-Gréville 1891, Farnsworth and Wisley 1958, Kahn and Wissinger 2008, Noble 1988, Schumann 1942). The properties of black gloss revealed by past studies are the basis of this research to investigate various phenomena of relief dots. This

[7] When this English version of the article was prepared, the vase was in Museo Nazionale Cerite, Cervetri.

study of relief dots also shows other characteristics of black gloss that were not known before.

Samples Analysed

Red-figure vase-paintings are rarely decorated with relief dots, about twenty among nearly a thousand red-figure vases I have seen. Such vases are usually the finest of the pottery and are highly prized. Most of them are in collections of museums. As mentioned before, it would require extra negotiation and arrangement to analyse them instrumentally. Nevertheless, even without instrumental analysis, it is possible to understand some characteristics of the relief dots through their phenomena.

The twenty samples analyzed for this study (Table 4) are on works of the Andokides Painter (c. 530BC), the Pioneer Group (including Euphronios, Phintias, Euthymides, c. 530-500BC), the Berlin and Kleophrades Painters (c. 500-450BC), the Meidias Painter and his manner (c. 450-425BC). They represent different periods and styles of painting. On seven samples, some relief dots are broken and their interior colors are shown, usually in ranges of orange, brown and blackish gray. The relief dots on the other thirteen samples are intact and do not show their interior colors, but it is still possible to study their characteristics and production procedures, with the help of sizes, shapes and ground colors of the relief dots. This study is based on personal examination of the samples, published photographs, the images in the Beazley Archive (Oxford), and digital photographs taken by the author.

Table 4 Samples of Relief Dots

Vase	**Painter**	**Diameter**	**Rounded boundaries**	**Lighter ground**	**Inside colour**	**Reference**
MFA 99.538	Andokides Painter	c. 1.5mm	+			AJA 2008：10.
Berlin F2159	Andokides Painter	c. 0.5-1.0mm	+	+		
BM B193	Andokides Painter	c. 0.5-1.5mm	+			
Getty 77.AE.86.1-	Euphronios	c. 0.2-1.2mm	+		brown	Cohen 2006, 122.

2						
Getty 86.AE.313.1-7	Euphronios	c.1.5-2.0mm	+	+		Cohen 2006, 124. White-ground vase.
Met L.1999.36.1	Euphronios	c. 0.3-1.5mm	+			
Louvre G103	Euphronios	c. 0.3-0.5mm	+			
Met 1972.11.10	Euphronios	c. 0.3-1.5mm	+			
Louvre G42	Phintias	c. 0.8-1.5mm	+	+	Gray; dark gray	
Munich 2590	Phintias	c. 0.3-0.6mm	+		blackish gray	
Louvre CA2981	Berlin Painter	c. 1.5mm				Beazley Archive
Vatican 17907	Berlin Painter	c. 1.2-1.8mm				Beazley Archive
Würzburg L500	Berlin Painter	c. 0.3-1.0mm	+			Beazley Archive
BM E459	Berlin Painter	c. 1.5-2.0mm			Both gray and brown (few)	
Ashmolean 1891.689	Kleophrades Painter	c. 0.3-0.8mm	+		Single dark gray, few dark brown	
Met 13.233	Kleophrades Painter	c. 1.5mm	+			Noble 1988, 139. Cohen 2006, 107, fig. 1.

Berlin F2170	Kleophrades Painter (Late)	c. 0.6-1.2mm	+		Orange ; dark brown
Louvre G50	Kleophrades Painter (Later)	c. 0.3-1.5mm	+		Dark brown
BM E224	Meidias Painter (name-vase)	c. 0.5-1.0 mm	+		
BM 95 10-29 2	Manner of Meidias Painter	c. 0.3-1.0mm	+		
BM E698	Imitation of, connected to Meidias Painter	c. 0.3-1.0mm	+	+	

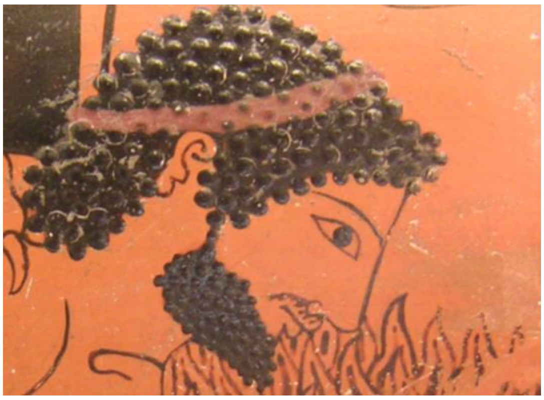

Figure 2 Round relief dots. Field of view c. 4 cm wide. Athenian red-figure pottery, 6th century BCE, amphora shape, by Andokides Painter, from Etruria. London, British Museum, no. B193.

Figure 3 Relief dots with orange and brown interiors. Field of view 1.5cm wide. Athenian red-figure pottery, 5th century BCE, pelike shape, by Kleophrades Painter, from Cervetri. Berlin, Antikensammlung, no. F2170.

Figure 4 Relief dots with blackish gray interiors. Field of view c. 2cm wide. Athenian red-figure pottery, 6th century BCE, cup, by Phintias, from Vulci. Munich, Antikensammlungen, no. 2590.

Observations and Discussion

The relief dots of all samples are very small and with diameters of between c. 0.2 and c. 2.0 mm. The black color of the relief dots provides strong contrast when applied on areas of the paler clay ground of the vase, or of a ground treated with a lighter tone of diluted black gloss (Figures 5-6). The interior of these dots, however, vary in color and may be orange, brown, gray or blackish gray (Figures 3-5). These phenomena can be all explained if the entire dots, including their insides, were made of the same black gloss material. This can be argued for in all relief dot contexts, as follows.

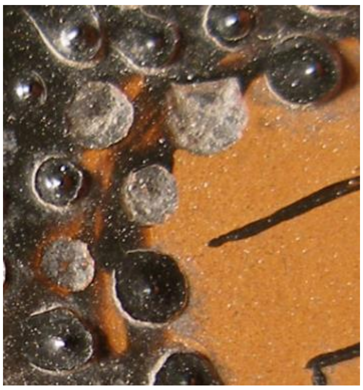

Figure 5 Broken relief dots show a dark gray material beneath. Brush-strokes can be seen in the space between the dots. Field of view c. 8.6 mm wide. Athenian red-figure

pottery, 6th century BCE, amphora shape, by Phintias, from Vulci. Paris, Louvre Museum, no. G42.

Figure 6 Relief dots and their ground are in different shades. Field of view c. 4.5 mm wide. Athenian white-ground pottery, c. 510-500 BCE, fragment of cup, attributed to Euphronios. Malibu, J. Paul Getty Museum, 86.AE.313.1-7. Cropped image of a photograph from Digital image courtesy of the Getty's Open Content Program. Title of the photograph: Attic White-Ground Cup (Lipped Inside) Fragment with Dionysos and a Satyr and One Black-Gloss Cup Fragment (rim).

First, relief dots may be against an obviously lighter ground, and this disagrees with the argument of Cohen (1997). She believes that relief dots were made by application of black gloss slip on hemi-spherical clay granules. She also believes that a single application of black gloss served both dots and ground, and so the dots and their ground are equally black. Sometimes, however, the space between the dots is filled with brush-strokes that are up to c. 1.7mm wide and loosely juxtaposed, leaving orange strips where the clay is exposed (Figure 5).[8] Against such loosely painted ground, roundish and solid black relief dots stand out. Significantly the diameters of the dots are wider than the brushstrokes, which are sometimes lighter, indicating that the coloring of the dots was not by these sweeping brushstrokes. Instead, each dot was formed by a separate application, which defined a roundish black area each time. This application procedure is again clearly seen on some other vases (Figure 6),[9] on which the relief dots are distributed over a ground of diluted black gloss slip that turned grey or translucent brown. The dots and their background are by separate applications.

[8] Berlin F2159, Louvre G42.

[9] Getty 86.AE.313.1-7, BM E698.

Second, individual dots vary in both size and shape, revealing a technical requirement. Each relief dot was made individually, and its instrument should have been able to make dots of hemi-spherical shape each time with ease. Dots differ in size and shape, and it seems unreasonably onerous to make molds of individual tiny dots, to cover each mold with a black gloss slip, and to print its corresponding dot. It would be difficult to paint individual tiny dots with a brush, as brushstrokes would easily extend beyond the bases of the dots. The easiest and probable method would be to use the black gloss slip as the material to make up each entire dot, so that it formed both volume and color. Regardless of size and shape, each dot accurately turned black on the surface after firing.

Technical aspects of relief dots can also be revealed by studying phenomena of the relief dots' surfaces and interiors. As past studies show, mentioned above, variation in firing can cause different colors and textures of black gloss. Relief dots are black on the surface, while their interiors can be in other shades, which can be explained by the variation of the black gloss raw material. Likewise, some vase-paintings use black gloss both for the thin (5-100μm) black layer and for the protruding relief lines whose interiors show a range of colors (Figures 7-8). Reactions in black gloss raw material are more complicated than Schumann (1942) proposed, and products other than black gloss could be formed at different depths of a relief dot.

Figure 7 Color difference between surfaces and interiors of relief lines. Field of view c. 4mm wide. Athenian red-figure pottery, 5th century BCE, oinochoe shape, by Niobid Painter, from Athens. Paris, Louvre Museum, no. L62.

Figure 8 Color difference between the surface and interior of black gloss background. A part of a figure is shown in the lower right corner. Field of view c. 2cm wide. Athenian red-figure pottery, 5th century BCE, oinochoe shape, by Niobid Painter, from Athens. Paris, Louvre Museum, no. L62.

Though entirely made of the same material, a relief dot can have different colors through its interior. The surface is black, while the interior varies between orange and blackish gray. As established by past studies on black gloss, these colors are caused by differing iron compounds, resulting from different kiln atmospheres. The relief dots' surface is black gloss, whose formation is associated with carbon monoxide. Mavis Bimson showed experimentally that, when the atmosphere becomes slightly reducing, black gloss material turns jet black, while the clay of the vase does not immediately change its color (Bimson 1956). This suggests that black gloss material was sensitive to carbon monoxide and could be easily reduced, and that it was during the reducing stage that a black glossy layer was formed. Carbon monoxide will reduce iron compounds, which will then stabilize in lower oxidation states, such as in the form of magnetite (Fe_3O_4), wüstite (FeO), or hercynite (Table 3). These are black (Bruni et al. 2005). Magnetite is an anti-flux, and so does not help fusion (Hamer 2004). Since it does not interact with the surrounding material, it often persists and can be detected in black gloss (Table 3). Wüstite (FeO) is a product of further reduction of magnetite (Bogdandy and Engell 1971, 18). It is a strong flux and will interact with the material around it (Hamer 2004, 39). As it is often altered during fusion, it is rarely detected in black gloss but contributes to the amorphous vitreous matrix of black gloss, which Yannis Maniatis and his colleagues found (Maniatis et al. 1993). In Table 3 only Bimson (1956) reports wüstite in black gloss; other studies with XRD technique do not obtain the same result. It is wüstite, a compound with iron of low oxidation state and likely formed in the reducing stage of firing, that facilitates vitrification and plays the key role in the formation of black gloss.

The interior, though made of the same material as the surface, did not necessarily become black, but in colors of orange, brown or blackish gray, indicating that it sometimes underwent a different chemical process. Orange and brown interiors (Figure 3), indicate that the dominant color sources are Fe^{III} compounds (Schwertmann 1993, Cornell and Schwertmann 2003). Carbon monoxide must have been either absent or insufficient to form black gloss. Factors limiting the supply of carbon monoxide to the interior of relief dots include the thickness of the dots and their fine texture. The interior received less carbon monoxide, while the surface was in contact with a higher concentration of carbon monoxide. This resulted in differing chemical processes inside and on the surface. The surface was reduced by carbon monoxide to be fully vitrified and form black gloss. In the interiors, however, weaker reducing conditions existed and vitrification was incomplete. Here re-oxidation was possible and orange and brown colors could develop.

Various colors in the surface and interiors of relief dots are due to differing reactions in the firing of the pottery. According to the firing theory widely accepted so far, the atmosphere in the kiln that fired red-figure pottery changed from oxidation to reduction to oxidation again. If the reducing stage was too short to allow carbon monoxide to penetrate the relief dots, there was no reduction of iron compounds inside the relief dots. Fe^{III} compounds originally in the raw material would continue to exist, and some more could be formed in the following oxidizing stage. Interiors of relief dots would be red, orange or brown. Although the reducing stage was short, it was sufficient for black gloss to form on the dots' surface. This recalls Bimson's experiment (Bimson 1956), confirming that black gloss was formed in the early stage of the reducing period. Black gloss layer is impermeable and could again deter carbon monoxide coming inside relief dots. This made the interior reaction different from that on the surface.

The other way to produce orange and brown interiors concerns both reducing and oxidizing iron compounds. This involves carbon monoxide first penetrating relief dots, turning Fe^{III} compounds into those with Fe^{II}, such as magnetitie. Carbon monoxide was however insufficient, and unable to further reduce magnetite into wüstite (Bogdandy and Engell 1971, 18). Without this, the black gloss raw material could not fuse and remained porous. In the next oxidizing stage, magnetite and other Fe^{II} compounds contacted with oxygen and became Fe^{III} compounds again. Relief dots with orange or brown interiors indicate that the concentration of carbon monoxide was insufficient in the dots during the firing. The reducing stage was too short to generate wüstite, but the following oxidizing stage was sufficiently long for oxygen to fully permeate the relief dots.

Blackish interiors (Figures 4-5) are caused by black iron compounds containing Fe^{II}. These include magnetite, wüstite, and hercynite, formed when carbon monoxide reduced Fe^{III} compounds. There are three possibilities for blackish interiors. The first is a porous matrix. The atmosphere of carbon monoxide is weak in the interior of the relief dot. Some compounds with Fe^{II} are formed, such as magnetite, which however is not further reduced to wüstite. Without this, the matrix cannot fully vitrify and so remains porous. It will still retain its blackish color when the following oxidizing stage is short. Oxygen does not penetrate the dots and Fe^{II} compounds cannot be oxidized. The dots' interiors therefore remain blackish. The second possibility of a blackish interior is a sintered matrix. The reducing stage is longer than in the previous case, and so not only generates magnetite, but further reduces part of this to wüstite. The strong fluxing behaviour of wüstite causes significant vitrification, sealing other compounds with Fe^{II} in a sintered matrix. This prevents them from being oxidized in the later stages of firing, and the dots' interiors remain blackish until the present day. The third possibility of a blackish interior is a further sintered and amorphous material. It contains no magnetite because it is fully reduced to wüstite. This type of blackish interior is formed when abundant carbon monoxide penetrates the relief dots. As it is fully vitrified, the following oxidizing stage has no effect on it.

Blackish interiors are generated at the second stage of firing in a reducing atmosphere, which should be satisfactorily long, to supply sufficient carbon monoxide to permeate the relief dots. Otherwise, the interiors will remain red, orange or brown as the result of the first oxidizing stage. The third stage of firing in oxidizing atmosphere, is sometimes decisive for interior color. If the interiors turn blackish in a reducing atmosphere and are not melted, remaining porous, and the third stage in oxidizing atmosphere is too short, in the end the interiors will not be oxidized and will remain blackish. In contrast, if the oxidizing atmosphere at the third stage is long, it is possible to oxidize blackish materials in the interiors and turn them to red, orange or brown color. Interior colors of relief dots can provide information about the relative length and strength of the reducing and oxidizing atmospheres at the second and third stages of firing.

Conclusion

This study has investigated the material of relief dots on red-figure pottery, and concludes that relief dots were granules entirely consisting of black gloss material. It also deduces the firing procedure from phenomena of relief dots and confirms that black gloss could be easily produced in firing. The Greeks used this material and the technique over hundreds of years and spread them to places where the Greek civilization reached. Both the easy firing technique of black gloss and the lustrous effect of the product fulfil the ideal of technique that the Greeks sought. This should be feasible while precise. The black gloss technique was passed down generation after generation, and the products are among the most characteristic of ancient Greece. It recalls the conservative attitude of the Greeks, who did not usually change an existing tradition.

This paper demonstrated a set of phenomena of relief dots and concludes differently from Cohen (1997) in terms of the producing technique and procedure. It shows that relief dots were not clay reliefs painted over with a thin layer of black gloss, but granules entirely consisting of black gloss material. They turned black precisely within roundish areas as small as c. 0.2 to c. 2.0 mm in diameter, and those projecting from the edge of a black area show boundaries in neat arcs. Additionally, on a few vases, relief dots and the spaces in between are in different shades; the two are separate applications, disproving the theory that a single application of black gloss material was over the dots and the spaces. As the dots and the spaces normally refer to the same thing and are in the same or similar shades, it would be unnecessary to paint such small dots so precisely with a brush. The whole dots were made of black gloss material and turned black within their round areas.

The shades inside the relief dots indicate the various reactions of black gloss material, which is more complicated than Schumann (1942) suggests. The reduction of iron compounds has a few stages, and whether wüstite is generated or not, significantly affects the coloration of the relief dot. Various colors inside relief dots show that the firing was not precisely the same: the second stage of firing in reducing atmosphere, and the third in oxidizing atmosphere, each could differ in strength and duration. Flexible firing conditions made the pottery easy to produce. Black gloss was readily formed at the beginning of the reducing stage and was not affected by the following firing process. Meanwhile, the clay remained porous, and was responsive to oxygen and became reddish at the final oxidizing stage. As a result, pottery with figures in red color against a black background was formed.

The firing of red-figure pottery is considerably flexible, and this explains why the technique of this kind of pottery with red and black could be easily learned and spread. It was passed down from one generation to the next over three hundred years between the sixth and the third century BCE. In places where the Greek civilization reached, such as Athens and South Italy, archaeologists have found kiln sites, misfired and test pieces of the pottery, showing signs of the spread and function of the pottery technique. A large number of red-figure vases were continuously produced in three hundred years, and about 49,000 have been published. The wide spread of the pottery was partially due to the firing technique of black gloss, which was relatively feasible. Knowledge of the skill became known in more and more places through the expansion and colonization of the Greeks. This is supported by the current study on relief dots.

Works Cited and Consulted

Aloupi-Siotis, Eleni. “Recovery and Revival of Attic Vase-Decoration Techniques: What Can They Offer Archaeological Research?” *Papers on Special Techniques in Athenian Vases*, edited by K. Lapatin, J. Paul Getty Museum, 2008, pp. 113-128.

Bimson, Mavis. 1956 “The Technique of Greek Black and *Terra Sigillata* Red.” *The Antiquaries Journal*, vol. 36, 1956, pp. 200-204.

Binns, Charles F., and A. D. Frazer. “The Genesis of the Greek Black Glaze.” *American Journal of Archaeology*, vol. 33, no. 1, 1929, pp.1-9.

Boardman, John. *Early Greek Vase Painting*. Thames and Hudson, 1998.

Bogdandy, Ludwig von, and H.-J. Engel. *The Reduction of Iron Ores*. Springer-Verlag, 1971.

Bothmer, Dietrich von. “Greek Vase-Painting: Two Hundred Years of Connoisseurship.” *Papers on the Amasis Painter and His World*, edited by M. True, J. Paul Getty Museum 1987, pp. 185-186.

Brinkmann, Vinzenz. *Beobachtungen zum Formalen Aufbau und zum Sinngehalt der Friese des Siphnierschatzhauses*. Biering & Brinkmann, 1994.

Bruni, Silvia, F. Cariati, and V. Guglielmi. “Case Study: Field and In Situ Identification of Pigments in Works of Art by Micro-Raman and Visible-NIR Reflectance Spectroscopies: A Polychrome 16th Century Italian Fresco and Black Coloured Etruscan Pottery.” *Raman Spectroscopy in Archaeology and Art History*, edited by H. G. M. Edwards and J. M. Chalmers, Royal Society of Chemistry, 2005, pp. 142-151.

Cohen, Beth. “Bubbles= Baubles, Bangles, and Beads: Added Clay in Athenian Vase Painting and its Significance.” *Greek Vases. Images, Contexts and Controversies*, Leiden 2004, pp. 55–71.

---. *The Colors of Clay*. Getty Publications, 2006.

Cook, Robert M. *Greek Painted Pottery*. 3rd ed. Routledge, 1997.

Cornell, Rochelle M., and U. Schwertmann. *The Iron Oxides*. Wiley-VCH, 2003.

Durand-Gréville, Emile. “Couleur du décor des vases grecs.” *Revue Archéologique*, Jul.-Dec, 1891, pp. 99-118.

Farnsworth, Marie, and Harriet Wisley. “Fifth Century Intentional Red Glaze.” *American Journal of Archaeology,* vol. 62, 1958, pp. 165-73.

Fornara, C.W. *From Archaic Times to the End of the Peloponnesian War*. Johns Hopkins UP, 1977.

Giorgetti, Giovanna, Elisabetta Gliozzo, and Isabella Memmi. “Tuscan Black Glosses: A Mineralogical Characterization by High Resolution Techniques”. *European Journal of Mineralogy*, vol. 16, no. 3, 2004, pp. 493-503.

Gliozzo, E., I. W. Kirkman, E. Pantos, and I. M. Turbanti. “Black Gloss Pottery: Production Sites and Technology in Northern Etruria. Part II: Gloss Technology.” *Archaeometry* vol. 46, 2004, pp. 227-246.

Graf, Fritz. *Griechische Mythologie: Ein Einführung*. 2nd ed. Artemis, 1987.

Hamer, Frank, and Janet Hamer. *The Potter's Dictionary of Materials and Techniques*. A & C Black, 2004.

Hofmann, U. “Die Chemie der antiken Keramik.” *Naturwissenschaften,* vol. 53, no. 9, 1966, pp. 218-223.

Homer. *Iliad*. Translated by Richmond Lattimore. U of Chicago P, 1962.

Immerwahr, Henry R. *Attic Script*. Clarendon P, 1990.

Jones, R. E. *Greek and Cypriot Pottery, A Review of Scientific Studies*. British School at Athens, 1986.
Kahn, Lisa C., and John C. Wissinger. "Re-creating and Firing a Greek Kiln." *Papers on Special Techniques in Athenian Vases*. Edited by K. Lapatin, J. Paul Getty Museum, 2008, pp. 129-138.
Karo, Greg. "Archäologische Funde aus dem Jahre 1929 und der ersten Hälfte von 1930." *Archäologischer Anzeiger*, 1930, pp. 90-92.
Kingery, W. D. "Attic Pottery Gloss Technology." *Archeomaterials,* vol. 5, no. 1, 1991, pp. 47-54.
Kretschmer, Paul. *Die Griechischen Vaseninschriften, ihrer Sprache nach Untersucht*. C. Bertelsmann, 1894.
Langlotz, Ernst. *Zur Zeitbestimmung der strengrotfigurigen Vasenmalerei und der gleichzeitigen Plastik.* E. A. Seemann, 1920.
Longworth, G., and M. S. Tite. "Mössbauer Studies on the Nature of Red or Black Glazes on Greek and Indian Painted Ware." *Journal de Physique*, Colloque N° 2: International Conference on the Application of the Mössbauer Effect, vol. 40, 1979, pp. 460-461.
Longworth, G., and S. E. Waren. "Mössbauer Spectroscopy of Greek 'Etruscan' Pottery." *Nature*, vol. 255, 1975, pp. 625-627.
Maggetti, M., G. Galetti, H. Schwander, M. Picon, and R. Wessicken. "Campanian Pottery: The Nature of the Black Coating." *Archaeometry,* vol. 23, 1981, pp. 199-207.
Maniatis, Y. *Examination of Ancient Pottery Using the Scanning Electron Microscope*. 1976. U of Essex, PhD dissertation.
---. E. Aloupi, and A. D. Stalios. "New Evidence for the Nature of the Attic Black Gloss." *Archaeometry,* vol. 35, 1993, pp. 23-34.
Newman, Richard. "Ferrous and Ferric: A Review of Scientific Research on the Iron in Attic Greek Glazes." *Papers on Special Techniques in Athenian Vases*, edited by K. Lapatin, J. Paul Getty Museum, 2008, pp. 105-112.
Noble, Joseph V. *The Techniques of Painted Attic Pottery*. London: Thames and Hudson, 1988.
Noll, W., R. Holm, and L. Born. "Die Malerei auf polychromen attischen Lekythoi als Dokument antiker keramischer Technik." *Neues Jahrbuch für Mineralogie Abhandlungen,* vol. 122, no. 2, 1974, pp. 119-144.
Oberlies, F., and N. Köppen."Untersuchungen an griechischen Gefässfragmenten aus verschiedenen Jahrhunderten v. Chr." *Berichte der deutschen keramischen Gesellschaft,* vol. 39, 1962, pp. 19-31.
Parker, Victor. *A History of Greece: 1300 to 30 BC.* John Wiley & Sons, 2014
Pausanias. *Description of Greece*. Translated by W. H. S. Jones. Harvard UP, 1979.
Pavićević, M. K. "Untersuchung der schwarzen Malschicht attischer Vasen mit der Electronenmikrosonde." *Berichte der Deutschen Keramischen Gesellschaft,* vol. 51, no. 3, 1974, pp. 61-63.

Pérez, J. M., and R. Esteve-Tébar. "Pigment Identification in Greek Pottery by Raman Microspectroscopy." *Archaeometry,* vol. 46, 2004, pp. 607-614.
Philadelpheus, Alexandre. "Bases Archaïques Trouvées dans le Mur de Thémistocle à Athenes." *Bulletin de la Correspondance Hellénique*, vol. 46, 1922, pp. 1-35, figs. 2-3, 6-7, pls. 1-7.
Pollitt, Jerome J. *The Art of Ancient Greece: Sources and Documents*. Cambridge UP, 1990.

Pyne, H. G. G. “Archaeology in Greece, 1932-1933.” *Journal of Hellenic Studies*, vol. 53, 1933, pp. 266-299. 272, 275, fig. 6.

Schilardi, Demetrius U. *The Thespian Polyandrion (424 BC): The Excavations and Finds from a Thespian State Burial*. 1977. Princeton U, PhD dissertation.

Schliemann, Heinrich. “Das sogenannte Grab der 192 Athener in Marathon.” *Zeitschrift für Ethnologie* vol. 16, 1884, pp. 85-88.

Schilling, M. R. “Estimation of Ceramic Firing Temperatures by Means of Thermomechanical Analysis.” J. K. Papadopoulos, *Ceramicus Redivivus: The Early Iron Age Potters' Field in the Area of the Classical Athenian Agora*, Hesperia Supplement 31, American School of Classical Studies at Athens, 2003, pp. 317-335.

Schumann, Th. “Oberflächenverzierung in der antiken Töpferkunst. Terra sigillata und griechische Schwarzrotmalerei”. *Berichte derDeutschen Keramischen Gesselshaft E.V.* vol. 23, no. 11, 1942, pp. 408-426.

Schwertmann, U. “Relations between iron oxides, soil color, and soil formation.” *Soil color*. Edited by J. M. Bigham and E. J. Ciokosz, Soil Sci. Soc. Am. Spec. Publ. 31, 1993, pp. 51-69.

Shiue, Ruei-Fang 薛瑞芳. *You yaoxue* 釉藥學 *Glaze*. Artist Magazine, 2013.

Staes (Β. ΣΤΑΗΣ), V. *Δελτίον Αρχαιολογικόν*, 1890, pp. 123-132, pl. Δ΄.

---. *Δελτίον Αρχαιολογικόν*, 1891, p. 34, p. 67, p/ 97.

---. “Ο ΕΝ ΜΑΡΑΘΩΝΙ ΤΥΜΒΟΣ.” *Mittteilungen des deutschen archäologischen Institus: Athenische Abteilung*, vol. 18, 1893, pp. 46-63, pls. II-V.

Stansbury-O'Donnell, Mark. “Polygnotos's *Iliupersis*: A New Reconstruction.” *American Journal of Archaeology,* vol. 93, 1989, pp. 203-215.

---. “Polygnotos's *Nekyia*: A Reconstruction and Analysis.” *American Journal of Archaeology,* vol. 94, 1990, pp. 213-235.

Tang, C. C., E. J. MacLean, M. A. Roberts, D. T. Clarke, and E. Pantos. “The Study of Attic Black Gloss Sherds Using Synchrotron X-ray Diffraction.” *Journal of Archaeological Science***,** vol. 28, 2001, pp. 1015-1024.

Tite, M. S. “Determination of the Firing Temperature of Ancient Ceramics by Measurement of Thermal Expansion: a Reassessment.” *Archaeometry,* vol. 11, 1969, pp. 131-143.

---. M. Bimson, and I. C. Freestone. “An Examination of the High Gloss Surface Finishes on Greek Attic and Roman Samian Wares”. *Archaeometry*, vol. 24, 1982, pp. 117-126.

Vendrell-Saz, M., T. Pradell, J. Molera, and S. Aliaga. “Proto-Campanian and A-Campanian Ceramics: Charaterization of the Differences between the Black Coatings”. *Archaeometry*, vol. 33, 1991, pp. 109-117.

Wachter, Rudolf. *Non-Attic Greek Vase Inscriptions*. Oxford UP, 2001.

Winter, Adam. *Die Antike Glanztonkeramik, Praktische Versuche*. P. von Zabern, 1978.

This article was published by
The East Asian Journal of Classical Studies
and is contained in Volume 1, 2022
(ISBN: 979-8-9870802-0)
and may be found at www.teajcs.com.