Archaeological and Anthropological Sciences (2022) 14: 20
https://doi.org/10.1007/s12520-021-01394-1

ORIGINAL PAPER

Pigment nomenclature in the ancient Near East, Greece, and Rome

Hilary Becker[1]

Received: 18 January 2021 / Accepted: 30 June 2021 / Published online: 30 December 2021

Abstract

This article surveys pigment terminology attested in ancient Egypt, Mesopotamia, Greece, and the Roman Empire. Various source material is available for exploring pigment nomenclature, including archaeological evidence as well as a range of ancient sources, such as lists of medical ingredients, and encyclopedic texts that sought to explore the available corpus of known pigments. While the etymology is not understood for all early pigments, one trend in the Near East was that pigment names could be borrowed from more prestigious natural materials, such as lapis lazuli or gold. In the Greek and Roman worlds, a greater variety of pigments were available especially due to the broader geographic expanse from which to mine or produce pigments. A few trends persist in Greco-Roman pigment nomenclature. Some pigments continue to be named after natural materials. Other pigments are named after factors such as their provenance, color, an innovator, or their process of manufacture.

Keywords Pigment terminology · Pliny the Elder and Dioscorides · Natural materials · Metonymic nomenclature · Pigment provenance · Color in art

Premise

This Topical Collection (TC) covers several topics in the field of study, in which ancient architecture, art history, archaeology and material analyses intersect. The chosen perspective is that of a multidisciplinary scenario, capable of combining, integrating and solving the research issues raised by the study of mortars, plasters and pigments (Gliozzo et al. 2021).

The first group of contributions explains how mortars have been made and used through the ages (Arizzi and Cultrone 2021; Ergenç et al. 2021; Lancaster 2021; Vitti 2021). An insight into their production, transport and on-site organization is further provided by DeLaine (2021). Furthermore, several issues concerning the degradation and conservation of mortars and plasters are addressed from practical and technical standpoints (La Russa and Ruffolo 2021; Caroselli et al. 2021).

The second group of contributions is focused on pigments, starting from a philological essay on terminology (this paper). Three archaeological reviews on prehistoric (Domingo Sanz and Chieli 2021), Roman (Salvadori and Sbrolli 2021) and Medieval (Murat 2021) wall paintings clarify the archaeological and historical/cultural framework. A series of archaeometric reviews illustrate the state of the art of the studies carried out on Fe-based red, yellow and brown ochres (Mastrotheodoros et al. 2021), Cu-based greens and blues (Švarcová et al. 2021), As-based yellows and reds (Gliozzo and Burgio 2021), Pb-based whites, reds, yellows and oranges (Gliozzo and Ionescu 2021), Hg-based red and white (Gliozzo 2021) and organic pigments (Aceto 2021). An overview of the use of inks, pigments and dyes in manuscripts, their scientific examination and analysis protocol (Burgio 2021) as well as an overview of glass-based pigments (Cavallo and Riccardi 2021) are also presented. Furthermore, two papers on cosmetic (Pérez-Arantegui 2021) and bioactive (antibacterial) pigments (Knapp et al. 2021) provide insights into the variety and different uses of these materials.

Introduction

There was utility for artists and patrons in knowing not only the properties of the materials that they used but also

This article is part of the Topical Collection on *Mortars, plasters and pigments: Research questions and answers*.

✉ Hilary Becker
hbecker@binghamton.edu

[1] State University of New York, Binghamton University, Binghamton, New York, USA

the names of these materials.[1] Pigment names made it possible for artists and patrons to keep materials straight so it would have been clear which pigment should be applied in what manner. This paper will review the ancient terms for pigments in the ancient Near Eastern and Mediterranean worlds. A list of such vocabulary communicates at once the varied colors that were potentially available. Pigment nomenclature also reflects the implicit complexity in terms of the mining, manufacturing, and trading network that made the circulation of so many colorful materials possible. Importantly, a few trends emerge in such a survey of nomenclature practices utilized in the ancient Near Eastern and Mediterranean worlds. The first is that names for pigments do not usually utilize generic color terms which would be used to describe a color generally (e.g., red, blue, black in English). Instead, more discrete names are often utilized for the nomenclature of pigments, often finding inspiration from the names of other materials (e.g., lapis lazuli, gold). Some of these pigment names in all periods evoke materials more precious than comparatively quotidian materials such as pigments. Pigment nomenclature could also draw inspiration from toponyms, innovators, production processes, among other sources.

John Baines observed that, "color is more easily painted than talked about" (Baines 1985, 289). Indeed, with the adept mixing of pigments that was possible at certain times in the ancient world, certainly more shades and tones were available than there were pigments. By the time of the ancient Greeks and Romans, at least from Pliny's encyclopedic account of pigments, there were potentially multiple choices to be made among pigments.[2] Since there were material differences between the red ochres or white earths, for example, having discrete names for pigments would have had real utility.

Pigment nomenclature in the ancient Near East

The pigment nomenclature practices in Egypt and Mesopotamia will be reviewed. In Egypt, it is possible to know more about the names for pigments because there are inscriptions documenting mining pigments (which will be discussed shortly) and also documenting specific workers as they used pigments. With such information, not only are the Egyptian terms for color made clear, but also vocabulary related to describing these materials, such as the terms *ryt* (pigment/ink), and *dríw/dr* (to paint/color) (Bryan 2016, 16–17).

Reds

Red ochre

The primary red pigment in the ancient Near East was red ochre. Red ochre was a widespread and common pigment, which is found in many varied regions across the world in the iron-rich deposits of the continental crust (along with yellow ochre) (Blom-Böer and Warburton 2019, 242). Thus, it is not surprising that red ochre often has a name of its own, and not a name that refers to some other, more prestigious material. The terms for red ochre in Egyptian hieroglyphics were mnš.t and *ṯmḥ.y*; these terms differed from the general color term for red in Egyptian, *dšr* (Harris 1961, 154; Blom-Böer and Warburton 2019, 243).

In the Renaissance, Cennini advised artists to sketch outlines of their figures using *sinopia*, a red outline whose etymology will be explained shortly. Outlining figures using red ochre was also practiced in ancient Egypt. In an *ostracon* (1479–1430 B.C.) from Deir el-Bahri documenting the work of Egyptians painting a tomb, "the scribe Imhotep laid out pigments (wꜣḥ ḏríw). Red ochre ink cakes 20 completed" (Bryan 2016, 9, 15–16, Fig. 1.12: *ostracon* 63). Thus, 20 cakes of red ochre were used for the outlining of figures on that day. Red ochre was not only a very popular pigment in Egypt in all periods, but red ochre from Elephantine also had a mythological purpose in the Book of the Dead. The pigment was to be ground up until it was blood red in color and mixed with beer and then given to Hathor (Shaw 2014, 56–58). In Akkadian the term for red ochre was *šaršarru*; this term is related to the Hebrew term *šāšar* (red paste) (Thavapalan 2020, 352–354). The term *šaršarru* was evidently a familiar enough term that it could also be used to compare the color of another object, in so far as an object was "like (the color of) *šaršarru*(-pigment)" (Thavapalan 2020, 354).

Other red colorants

Realgar, on the other hand, was *ꜣw.t-jb* in Egyptian. Realgar (and orpiment) would have had to be imported from a distance — from the Kharga Oasis or from an island in the Red Sea—at the closest (Bryan 2010, 990; Lucas and Harris 2012, 348 and 467; Blom-Böer and Warburton 2019, 243). The name for a different red Egyptian colorant can be documented from an inscription from a pigment mining expedition. Two royal expeditions to collect pigment from the Dakhla Oasis are recorded in Khufu's reign

[1] I thank Elisabetta Gliozzo, Ariadne Kostomitsopoulou Marketou, Jeffrey Becker, Katherine Larson, and the anonymous readers for their advice. Any errors that remain are my own.

[2] This range of choice is confirmed by finds, inter alia, at Pompeii and in Rome (Augusti 1967; Beeston and Becker 2013).

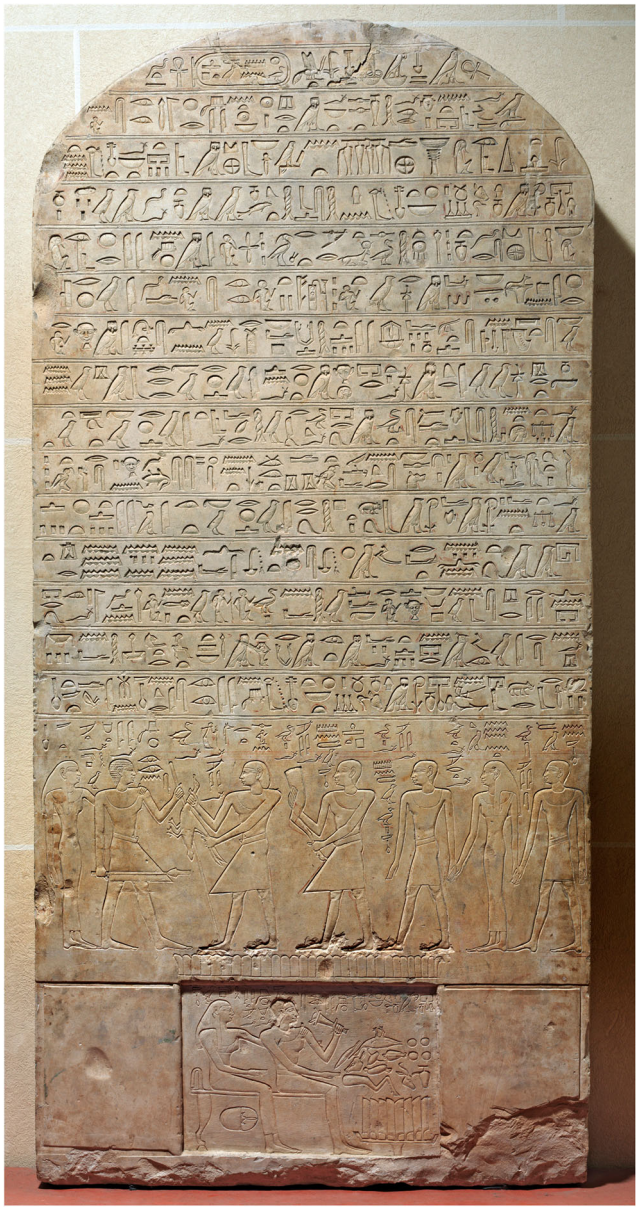

Figure 1 Stele of Irtysen, an Egyptian craftsman who knew how to make pigments. Abydos, 2033 - 1982 B.C. © Musée du Louvre.

from inscriptions recorded in a mining camp there. One of these expeditions (ca. 2582 B.C.) set out to "...produce powder (*mfȝt*) from the pigment (*sš*) of the desert district (*w ḥȝst/smyt*). They (both) took the sacks (or semi-precious minerals, (*mjnw*))…" (Kuhlmann 2002, 136). Kuhlmann states that a variety of colors could be found in this area and notes that white sandstone with variegated ochre is present. Kuhlmann posited that "it seems likely that these colourful earthy substances, the *sš* pigment referred to in the text…" may have been "a colorful shale or sandstone usable for making paint" (Kuhlmann 2002, 137). This pigment would have been ground into a powder and shipped to Memphis, possibly for use in painting the Fourth Dynasty pyramid complexes and nearby tombs.

Yellows

The Egyptian terms for yellow ochre were *mnš.t* and *sty/stj*; these terms may have come from Nubia (Harris 1961, 151; Blom-Böer and Warburton 2019, 241 and 243–244). In Akkadian, the term for yellow ochre was *kalû*, which was a Sumerian loan word (Thompson 1936, 31–33; Thavapalan 2019, 187 n. 43; Thavapalan 2020, 197 and 347–350). Beeswax and *kalû* could be mixed together to make a writing board. The Akkadian term *kalgukku* was written with the Akkadian terms for yellow ochre and carnelian (Thavapalan 2019, 188). It was a pigment that was used in the glass and leather industries and had a color that "mimics the appearance of gold" but its identity is not clear (Thavapalan 2019, 187 n. 43). *Kalgukku* is thought to have been yellow or orange or red in color and identifications that have been suggested include a yellow lead-based pigment (bindheimite or wulfenite?) or even red ochre (Thavapalan 2019, 187–188; Thavapalan 2020, 197, 211–212, and 346–347).

Orpiment is a yellow arsenic sulfide, which is geologically related to realgar (Eastaugh et al. 2008, 291). The Egyptian term for orpiment was *qnj.t*; it was not found in Egypt but could have been found in places such as St John's Island (Red Sea), Anatolia, Armenia, Kurdistan, Iran, or copper ore from the Sinai (Colinart 2001, 3; Le Fur 2019; Lucas and Harris 2012, 350; Blom-Böer and Warburton 2019, 244). Note that there was not a generic color term for yellow in Egyptian and so gold *nb.w* was used (Warburton 2016; Blom-Böer and Warburton 2019, 243–244). This term, however, could be used in contexts to refer to pigments (e.g., ochre and orpiment) that were not gold (Warburton 2008, 225 and 228, 244).

The Ritual of Embalming Papyrus (*Pap. Boulaq* No.3; 1st–2nd c. A.D.) detailed pigments among the materials that were used for the wrapping of the body. "Draw Isis in pure orpiment on a single fringed cloth…Add a fringed cloth with an image of Re painted on it in orpiment, and an image of Min in Nubian ochre…" (Cannata 2020, 238). These materials are each specifically cited so that the correct yellow pigment could be employed where it was needed (Chapman 2017, 59 Table 1).

Greens

In Ancient Egypt, it has been proposed that the term *wȝḏ* represented malachite; David Warburton explained that this term described a "highly valuable greenstone", and Harris wondered whether the same term could have also referred to verdigris (Harris 1961, 143–145; Aufrère 1991, 543; Warburton 2008, 243–244). The term *šsm.t* has also been proposed as a term for malachite (Blom-Böer and Warburton 2019, 242). Egyptians could paint with malachite but

importantly, this material was also frequently used as a copper source in Egypt when making Egyptian blue (Lee and Quirke 2000, 109–112).

Blues

Lapis lazuli

It does not seem that lazurite, the constituent mineral of the lapis lazuli rock, was used to make a pigment in the ancient Near East. Importantly for a discussion of pigment nomenclature, lapis lazuli was a prestige material with a vivid color that also lent its name to other materials. Significantly, the terminology for lapis lazuli will have a profound impact on pigment nomenclature over millennia in numerous ancient cultures and this impact continues today. Thus, it is fruitful to briefly review these terms, as they provide useful background for understanding the names of blue pigments in the ancient Near East.

Lapis lazuli was known as *uqnû šadî* in Akkadian, *iqnu* in Ugaritic, *kuwanno* (or *ku(wa)nnas*) in Hittite, and *ḫsbd* in Egyptian (von Rosen 1988, 25; Warburton 2008, 217–218; Panagiotaki et al. 2015; Warburton 2016, 365; Thavapalan 2020). In Akkadian, there was the idea of real lapis lazuli *uqnû šadî*, "lapis lazuli from the mountain" and glass, which was "lapis lazuli from the kiln" (*uqnŭ kūri*) (Shortland 2012, 140; Nicholson 2012, 16). Thus, there is a difference between the actual material and a manmade version that was evocative of the original in some way. Paul Nicholson notes that a new name was not developed for the new material (Nicholson 2012, 16).

In one of the first written attestations of glass in Egypt, varieties of glass are named after semi-precious stones, most of which could be used as pigments. Thus, Thutmose III both depicts and lists gifts he gave to the god Amun on a relief in the Hall of Annals of the temple at Karnak in Thebes. One gift is termed "Menkheperre lapis-lazuli" and the other "malachite" (Nicholson/malachite" (Nicholson 2012, 17; Shortland 2012, 141–143; Hodgkinson 2019, 131) (Fig. 2a–b). Since Menkheperre is the throne name of Thutmose III, he is associating this new material with himself. None of the pigments from this region have a crown name comparable to the names of this glass. The most comparable example can be found in the Roman period, where at least one pigment takes a name from an innovator (see Vestorian blue, below).

The trend that materials lent their names to pigments and glass during this period is so pervasive that these materials also lent themselves to associations for colors in general.[3] In such cases, Shiyanthi Thavapalan argues, these metonymic color terms may also evoke the prestige of the original material itself and are not just evocative of the color. Similarly, Nicholson states that while the lapis may have reflected the color of the glass, the point was that that the glass, as the new material, was similar to "a precious stone" (Nicholson 2012, 22). The metonymic practice of naming other materials, such as lapis lazuli blue, after a semi-precious stone is continued in more modern practice with pigments such as the late nineteenth century man-made pigment emerald green.[4] Such a trend is also found in another ancient blue.

Egyptian blue

Egyptian blue, the artificial copper calcium silicate pigment, was developed before 3100 B.C. (Corcoran 2016) This new material needed a name and it was named in association with lapis lazuli. In Egyptian hieroglyphics, lapis lazuli was known as *ḫsbḏ*. Egyptian blue, on the other hand, was known as *ḫsbḏ iryt* or "lapis lazuli from the kiln" or "artificial lapis lazuli" (Harris 1961; Cavassa et al. 2010, 236; Frison and Brun 2016, 48; Thavapalan 2020, 364–365). The nomenclature for Egyptian blue in Mesopotamia was parallel. Whereas the Egyptians described Egyptian blue as "lapis lazuli from the kiln", the Akkadian term for Egyptian blue was *uknû merku,* which described, "moulded lapis lazuli" (Delamare 2013, 2; Thavapalan 2020, 214).

One Egyptian text of the Fifth Dynasty (ca. 2450 B.C.) described a king who had hieroglyphics on one of his monuments inscribed in "blue *ḫsbḏ*" (Baines 1985, 286). Since, lazurite was not used as a pigment in ancient Egypt, the pigment that was being described was in fact, Egyptian blue.[5] Indeed, when the term *ḫsbḏ* is used to refer to pigments, it is assumed that it refers to azurite or Egyptian blue (Harris 1961, 125–126 and 148). Egyptian blue could also be called "mfkȝ.t", which is the term for turquoise (Blom-Böer and Warburton 2019, 242; see Morris 2018, 43–44 where there is an account of this colorant being collected in the Dakhla Oasis).

Irtysen, a craftsman, scribe, and sculptor, erected a stele in Abydos (2033–1982 B.C.) celebrating his life and his knowledge as an artisan (Fig. 1). He states his abilities to write hieroglyphics and his abilities to draw particular kinds of figures. But noteworthy for this study is that Irtysen stated, "I know how to make pigments, and products that melt without fire burning them and are moreover insoluble in water." Certainly, a pigment that was manufactured in Egypt and that could be heated without melting would have been Egyptian blue, and Irtysen celebrates his prowess in making this and

[3] So much so, that as David Warburton argues for Egypt, these materials lent themselves to the terms for abstract colors (Warburton 2008).

[4] Eastaugh et al. 2008, 155. This pigment is a copper acetate arsenite.

[5] Note that cobalt blue, which was used for a brief period in ancient Egyptian history, may also have been referred to by the general moniker *ḫsbḏ* (Harris 1961, 148).

Figure 2 The Hall of Annals of Thutmosis III, Temple of Karnak in Thebes. (mid 15th c. B.C.) Thutmosis (Menkheperre) offers foreign gifts to Amun. Gifts to Amun include two substances that may have been glass which were depicted (as at right, 2b) and listed as, "Menkheperre lapis-lazuli" and "Menkheperre turquoise/ malachite". Photographs courtesy of P.T. Nicholson.

other colors (e.g., Egyptian green/frit?) upon his stele (Pagès-Camagna and Colinart 2003, 656).

Other color terms in the ancient Near East

White

The Egyptian term for calcium carbonate is thought to be the same as that for limestone. Interestingly, both of these materials borrow their terminology from silver *ḥḍ* (Blom-Böer and Warburton 2019, 243). Thus, as with blue, the pigment borrows its name from a more precious material.

Black

The Egyptian terms for carbon-based pigments reflect the material sources of this color. These terms included *ḏ'b.w*, for charcoal, and *wbd.w*, for soot (Blom-Böer and Warburton 2019, 240). These words, in turn, developed out of the term "to burn" and "fire" (*wbd, wbd.t*).

Pigment nomenclature in the ancient Near East in most cases was not identical to general terms used for color. It is also important to note that pigments or colored materials that were blue or even yellow could be described with the terms for lapis lazuli, turquoise, and gold. Thus, some of the terms describing pigments evoked the color and prestige of more precious materials.

Pigment nomenclature in Greece and Rome

There is substantially more information about the names of pigments in ancient Greece and Rome and this is especially because there were four extant authors (Theophrastus, Vitruvius, Pliny the Elder, and Dioscorides) who wrote extensively about pigments and related materials in ancient Greek and Latin. These ancient authors were clearly interested in helping their readers understand the meaning of these names and how they came about in so far as these names provide meaningful anchors for each pigment. Vitruvius and Pliny often provided the ancient Greek equivalencies of Latin pigment names — for example, "orpiment (*auripigmentum*), which in the Greek language is called ἀρσενικόν" (Vitruvius De architectura 7.7.5). They also knew well, as will be clear in the pages that

follow, that some of these pigment names overlapped (e.g., *cinnabar, minium, caeruleum*). For these reasons, these authors frequently offer details and context to help their readers keep pigment nomenclature clear.

There are more names for pigments in ancient Greek and Latin (in comparison with the documented Near Eastern terms), such that there were multiple names for red and yellow ochres and even Egyptian blues. This more layered nomenclature was a reflection of having a broader network that made it potentially possible to obtain pigments that came from far afield. Pigment names helped keep track of such materials and what made each variety qualitatively special. In addition, new types of pigments were available. Murex purple seems to have been previously unknown before the Bronze Age, whereas red lead and cinnabar would not come to Egypt until the Ptolemaic or Roman periods (Lee and Quirke 2000, 114).[6] These new additions all required names.

Naming a pigment directly or indirectly after another material (e.g., lapis lazuli) remains an operative, if etymologically latent, trend in ancient Greek and Latin nomenclature. In addition, especially in Rome, pigments could be named for a variety of different reasons. Pliny identifies how varied product nomenclature could be when he was discussing the names for different perfumes. The provenance of perfumes provided some names that were toponymic in nature (*cognomina dedere ...patriae*).[7] A place most associated with a type of marble was the most frequently evoked factor in differentiating between different types of marble in the Roman era (e.g., *marmor numidicum, phrygium*, etc.) (Russell 2013, 10). Pigment provenance will also be an important category for determining pigment names among the Greeks and Romans (Fig. 3). Other pigments will draw their names from factors such as a color, the method of their manufacture, or even a person associated with their manufacture.

Broader pigment categories in Greece and Rome

In ancient Greek, pigments were known as χρῶμα (and χρωμάτιον) as well as φάρμακον. The term φάρμακον described mostly drugs, remedies, and poisons, but could also describe pigments and dyes (e.g., Herodotus 1.98.6; Plato Respublica 420c). The Latin term for pigment is *pigmentum*, which is drawn from the verb *pingo, pingere*, "to paint". That there is a discrete term used mostly for colorants is interesting since many of these materials (e.g., red ochre, red lead) were used not just for painting, but also for cosmetics and drugs and unguents. Drugs and cosmetics would more often be labeled as *medicamenta*, but occasionally as *pigmenta* (e.g., Plautus Mostellaria 1.3.106; Cicero Epistulae ad Atticum 2.1.1).

There was a style of painting, wherein a picture was painted with only one pigment, known as *monochromata* (Pliny Naturalis Historia 33.39 and 35.11). Indian cinnabar (dragon's blood) was one color used for this. A palette of four colors (*quattuor colores*) had been used by certain Greek painters in the past (e.g., Apelles, Aetion, Polygnotos). The pigments that made up the tetrachrome palette were Melinum white, Attic yellow ochre, Sinopic red ochre, and *atramentum* (black) (Pliny Naturalis Historia 35.32; see also Cicero Brutus 18.70). Mark Bradley notes that the four colors are not colors but four specific pigments. "Pliny's *color* is a single specific pigment derived from a particular substance" (Bradley 2009, 101). The general categories represented by these specific pigment names—calcium carbonate, yellow ochre, red ochre, and carbon black were often the first four pigments available to artists in nature (think of Paleolithic paintings in France or the first pigments used by Etruscan painters, much later). In the fifth century B.C. or later, such artists who used this "four-color method" would have employed a stylistic limitation that would show off talents through the use and blending of only four colors (Bruno 1977).[8]

Pliny also divided pigments into two categories, the *austeri* and *floridi* (Pliny Naturalis Historia 35.12). *Austeri* pigments were dull and included: Sinopian red earth, red ochre (*rubrica*), *Paraetonium*, Melian earth, Eretrian earth, orpiment, yellow ochre, red lead (*cerussa usta*), realgar, sandyx (red lead and red ochre), *Syricum*, and *atramentum*. The six "bright" or *floridi* pigments included: cinnabar (*mercury sulfide*), azurite, Indian cinnabar, malachite, indigo, and *purpurissum*. The *floridi* pigments were some of the most expensive pigments and needed to be purchased at the patron's expense (Vitruvius De architectura 7.5.8; Pliny Naturalis Historia 35.12 and 35.26; for more on this, see Brecoulaki 2006 and Bradley 2009).

Just as the Egyptians had general categories for hard and soft pigments, these same ideas are found in Greek and Latin texts. Theophrastus classified ochres as earthy pigments (ἡ γῆ), Egyptian blue, malachite, and cinnabar as sandy pigments (ἡ ἄμμος), and materials such as realgar and orpiment as powdery pigments (ἡ κονία) (Theophrastus 40 and 58–59; Bailey 1929, 233 n. 158; Table 1). Pliny classified softer materials such as ochres as *limus* (a slime, thus clay) while firmer pigments like Egyptian blue, malachite, cinnabar, and red lead

[6] The Akkadian terms for purple, in the context of wools, from the first millennium were *argamannu* (for red purple) and *takiltu* (for blue purple) (Quillien 2015, 107 and 118; Thavapalan 2020, 168, 194, and 224–229). These terms are not specific to murex purple.

[7] Pliny Naturalis Historia 13.2. Pears also *patriae nomina habent*, "have the names of a country" (Pliny Naturalis Historia 15.16). (Note that all references to Pliny herein will refer to the chapter numbers, not section numbers.)

[8] See Brecoulaki 2006 for an excellent discussion on ancient sources discussing this restricted palette.

Figure 3 Map depicting representative locations for Greco-Roman provenance-based pigment nomenclature. © Ancient World Mapping Center, 2021.

are *harena* (literally a "sand") (Pliny Naturalis Historia 33.40, 33.56–57, and 35.28; Bailey 1929, 233 n. 158; Harris 1961, 141; Table 1). It is important to clarify such a pigment term, because it can be otherwise disconcerting to read Pliny explaining, *caeruleum harena est,* "blue pigment is a sand" (Pliny Naturalis Historia 33.57). Importantly, Bailey considered *limus* and *harena* "to have been almost technical terms for soft and hard pigments" (Bailey 1929, 233).

Reds

Red ochres

Red ochre (Fe_2O_3) is an earth pigment which is colored by the iron chromophore constituting hematite. There can be varied levels of iron, such that red ochres can range in shade from dark red to flesh color.[9] The ancient Greek term for red ochre was μίλτος (e.g., Herodotus 4.191.1; Plutarch Quaestiones Romanae 98; Photos-Jones et al. 2018). The name μίλτος stemmed from a Linear B term, evidenced by the phrase *mi-to-we-sa-e*, "painted with μίλτος" (Theophrastus 51; Dioscorides 5.95; Bailey 1932, 209 n. 33; Blakolmer 2004, 64; Photos-Jones et al. 2018, 180).[10] The general Latin name for a red ochre was inspired by its color, *rubrica* (Varro De re rustica 1.9). The ubiquity and inexpensive nature of this color meant that red was often used to highlight the first lines of text and to add emphasis elsewhere by filling in letters in red. This habit has provided us with the term "rubric" still used today. Importantly, other pigments (red lead and cinnabar) could also be used to rubricate. That the pigment known as *ochra* was different from the pigment termed *rubrica* is demonstrated by Pliny's statement, "*ea* [*rubrica*] *fit ochra exusta in ollis novis luto circumlitis*", "*rubrica* is made from yellow ochre burnt in new pots covered with mud." (Pliny Naturalis Historia 35.16). This type of red ochre, manufactured from dehydrating yellow ochre was also known as *ocra usta* (Nicola et al. 2016, 551).

Red ochres are widely available, but have significant differences in tone, intensity, and application. Some red ochres were named in ancient Greek and Latin due to their color while others were named after a place of origin. A pigment's provenance was a useful way of tracking that information in Greco-Roman antiquity. Theophrastus and Pliny the Elder both detailed a variety of ochres and a prominent discerning factor between these pigments is a label of origin. There was ochre that came from Cappadocia, Lemnos, Egypt, Keos, the Balearic Islands and Africa (Theophrastus 53; Vitruvius De architectura 7.7.2; Pliny Naturalis Historia 35.13; Dioscorides 5.95). These are not just places where each ochre could be found, but discrete varieties. Theophrastus spoke of "all sorts of red ochre" (μίλτον …παντοδαπην) and Pliny enumerates many varieties, even differentiating between varieties of

[9] Note Theophrastus who talked of a flesh-colored pigment ἀνδρείκελα (Theophrastus 51).
[10] See also Wachsmann 2013, 197.

Table 1 Greek and Latin nomenclature specific to hard and soft pigments. Translations from Caley and Richards 1956, Rackham 1952

REFERENCE	TRANSLATION
Theophrastus 40	In general a great many unusual types of such stones are found in mines; some of them are of an earthy nature, such as yellow ochre and red ochre, and some are sandy, like *chrysokolla* and *kyanos*, and others are powdery, such as realgar and orpiment and others that are like them.
Theophrastus 58-59	There is also a natural and a prepared kind of cinnabar… The prepared kind comes from one place only, a little above Ephesos. It is a sand that shines brightly and resembles scarlet dye; this is collected and ground in stone vessels until it is as fine as possible… Skill is needed for this process; for some people make a great deal and others little or nothing out of an equal amount of sand (ἄμμος).
	They say that Kallias, an Athenian from the silver mines, discovered and demonstrated the method of preparation; for thinking that the sand contained gold because it shone brightly, he collected it and worked on it. But when he saw that it did not contain any gold, he admired the beauty of the sand because of its color and so discovered this method of preparation.
Pliny Naturalis Historia 33.37	Theophrastus states that cinnabar was discovered by an Athenian named Callias, 90 years before the archonship of Praxibulus at Athens—this date works out at the 349th year of our city, and that Callias was hoping that gold could by firing be extracted from the red sand found in silver mines; and that this was the origin of cinnabar, although cinnabar was being found even at that time in Spain, but a hard and sandy kind, and likewise in the country of the Colchi on a certain inaccessible rock from which the natives dislodged it by shooting javelins, but that this is cinnabar of an impure quality whereas the best is found in the Cilbian territory beyond Ephesus, where the sand is of the scarlet colour of the kermes-insect…
Pliny Naturalis Historia 33.40	This gives a *minium* of second-rate quality, which is known to very few people, and is much inferior to the natural sands we have mentioned.
Pliny Naturalis Historia 33.56-57	Yellow ochre is strictly speaking a slime (*limus*)…The blue pigment is a sand (*Caeruleum harena est*). In old days there were three varieties: the Egyptian is thought most highly of; next the Scythian mixes easily with water, and changes into four colours when ground, lighter or darker and coarser or finer; to this blue the Cyprian is now preferred. To these were added the Pozzuoli blue, and the Spanish blue, when blue sand-deposits (*harena*) began to be worked in those places.
Pliny Naturalis Historia 35.28	Armenia sends us the substance named after it Armenian… A sand has been found all over the Spanish provinces that admits of similar preparation, and accordingly the price has dropped to as low as six denarii.

one subtype in so far as "there are three varieties of Sinopic red ochre" (*species Sinopidis tres*) (Theophrastus 53; Pliny Naturalis Historia 35.13).

It is fruitful to look at the name of the most favored variety of red ochre, which was Sinopic red ochre. It is worthwhile to look at just what this name signified and the afterlife of this pigment's nomenclature among not only artists' materials but also artists' practices. A *sinopia*, a rough under drawing or outline sketched out before a fresco was painted (using a pigment such as red ochre), as mentioned earlier in this study, was a basic technical term among late Medieval and Renaissance Italian painters.[11] The origin of this term lies in antiquity and is a direct referent to the town of ancient Sinope, which did not have mines that contained this famous red ochre, even though the pigment derived its name from the site name. Theophrastus explained, "…and the one called Sinopic. This is really Cappadocian red ochre, but it is brought down to Sinope" (Theophrastus 53; Caley and Richards 1956, 56; Fig. 3). Diodorus also knew that this pigment was mined in Cappadocia and then sold from Sinope (Diodorus Siculus 5.96.1; Bailey 1932, 208 n. 31).

Sinopic red ochre was named after the port city Sinope on the Black Sea which must have been strong enough to ship this pigment (originating from southeastern Turkey, Cappadocia) far beyond ancient Anatolia. This toponymic nomenclature finds parallel in later pigments which obtained their name not from their place of origin but from a "route of import", such as the more modern pigment 'Lombardy indigo' (Eastaugh et al. 2008, 200). The extent to which Pliny perceived the actual point of origin of Sinopic red ochre remains unclear. Pliny stated *Sinopis inventa primum in Ponto est* which translates to "Sinopis (red ochre) was first found/discovered/acquired in the region of Pontus." Since the verb *inventa est* can be translated in multiple ways, it is not clear

[11] Ward 2008.

whether Pliny understood that this pigment was not native to that region. To that end, it is important to point out that Pliny did not state that Sinopic red ochre actually came from Cappadocia and he may not have known it—in spite of the fact that Theophrastus, who was one of Pliny's sources on pigments, knew better (Pliny Naturalis Historia 1).

Sinopic red ochre is a term that is even more complex because not only was Sinope not a place where this ochre was mined, but other types of ochre coming from other areas of the Roman realm (far afield from Turkey) could also adopt the name Sinopic ochre (e.g., ochre from Egypt, the Balearic Islands, etc.) (Pliny Naturalis Historia 35.13). The previously postulated idea that Pliny may have been unfamiliar with the true source of red ochre shipped from Sinope itself comes from the fact that he listed Cappadocia as one of the many places where other Sinopic ochres can be found (including Lemnos, Egypt, etc.) (Pliny Naturalis Historia 35.13). Pliny's use of the term *primum*, cited above, seems to justify why, what in reality are ochres from different locales, nonetheless get a name that is derived from Sinope. Based on Pliny's account, the application of the blanket term Sinopic red ochre to a host of red ochres, provides an important onomastic precedent.

It is worth commenting on Sinopic red ochre as it was a frequent practice to draw the names of ancient materials from their provenance—but at the same time, it was also common for one moniker to be adopted for a larger group of materials that had the same features, even if they came from different places. Sinopic red ochre became a brand of sorts that represented materials that came from multiple places. Another product-based parallel for this practice is that of Coan wine which was developed in Cos but came to be made in multiple places.[12] Coan wine was flavored with sea water. Cato proved that Coan wine can be made from Italian wine (as Pliny put it) even if sea water was not available.[13] What united Coan wines together was their production process in so far as wine made in the same manner in other places evoked the original creation.

Returning to Sinopic red ochre, this was the large umbrella term. Beneath it, there was a further sub-categorization—three types of Sinopic ochre: "red" (*rubra*), "less red", and a variety in between the former two (Theophrastus 53; Pliny Naturalis Historia 35.13; Wharton 2016, 199–200). Bradley's comments on these gradations of Sinopic ochre are worth considering, "it is hard to decide if Pliny here was exploiting technical trading categories, or if these were colour observations in more general circulation, but the pigment appears to be represented in artistic gradations of redness based on brightness or intensity" (Bradley 2009, 97).

Lemnian ochre was also known to Theophrastus and Pliny (Theophrastus 52; Pliny Naturalis Historia 35.14). When Pliny wrote about this pigment, he clearly confused it with Lemnian earth. Importantly, Lemnian ochre was not the same substance as Lemnian *terra* or Lemnian *sphragis* which had medicinal properties and which received a stamp (*signata*) (Pliny Naturalis Historia 35.14; Dioscorides 5.97; Galen De Simplicium Medicamentorum temperamentis ac facultatibus 9.12; Bailey 1932, 209-11 n. 33; Caley and Richards 1956, 177–178 and 212; see Hall and Photos-Jones 2008).

Another red ochre that was named after a color was an ochre known to Pliny as *cicerculum*. This ochre was likely named because its color evoked the color of the chickpea (*cicer*) (Pliny Naturalis Historia 35.13). Alternatively, it could be that this ochre was so named because of its grainy texture (König et al. 1978, 178–179).

There is one other category of red ochre, called builder's red earth (τεκτονικὴ μίλτος), and this pigment variety was considered inferior to Sinopic red ochre (Dioscorides 5.96). Ochres in this category were natural red ochres from Egypt and Carthage, along with one red ochre (a calcined yellow) from southern Spain. Pliny seemed to have been familiar with this same red ochre which he described as *utilissima fabris*, "very useful for fresco painters" (Pliny Naturalis Historia 35.15).[14]

A final thought about the nomenclature of red ochre. Pliny also made a general statement that red ochre could be found in iron mines (Pliny Naturalis Historia 35.15). Did some local red ochre, that did not resemble favored types, not merit a specific title beyond *rubrica*? Looking at the nomenclature for red ochres immediately reveals some of the criteria employed for naming other Greco-Roman pigments. Lemnian ochre described ochre with a specific provenance. For Sinopic red ochre, both provenance and color gradient were used in order to identify and classify this pigment category. That case study shows that the nomenclature of ancient materials reveals the complex economic systems that helped transport materials. The names of these materials sometimes, as with Sinopic red ochre, made reference to a place connected to the pigment. Other ancient names for pigments connected pigments to their color (e.g., *rubrica* itself or perhaps *cicerculum*), or a material which that pigment resembles (e.g., lapis lazuli), or even an inventor.

[12] Cato De agricultura 112. Reger 2010, 21–22.

[13] Pliny Naturalis Historia 14.10: *Coum vinum ex Italico faciendi rationem Cato demonstravit…* (However, it should be noted that Pliny mentioned that there was also a sea-flavored wine (*tethalassomenon*) made in other places in a similar manner-so it clearly had its own name.)

[14] The term *fabris* is translated as "builders" in Rackham 1952 but a workman known as a *faber* can be found in a number of trades. In this context, this term best describes workers who were painting walls (e.g., *ita erit atramentum tectoribus non invenustum*, "and so *atramentum* will be a graceful color for painters" (Vitruvius De architectura 7.10.3)). Pliny stated that there were two varieties of the red ochre for builders, one from Egypt and one from North Africa—thus, while the places of origin were not as specific in Pliny's account as they were in that of Dioscorides (i.e., North Africa rather than Carthage), nevertheless these details overlapped.

Cinnabar

Owing both to its importance to many cultures and value, there is a good deal of terminology that pertains to the material mercury sulfide. Reviewing culturally specific labels for it helps demonstrate its lasting importance. The term for cinnabar in ancient Greek was μίνιον and it was *minium* in Latin (Dioscorides 5.94; Pliny Naturalis Historia 33.36). While there are different varieties of red ochre and Egyptian blue, there is only one name for cinnabar in Latin and this should be noted. Pliny was a procurator in Spain and his knowledge of terminology concerning goldmining, enriched with even local Iberian terms, has been noted (Healy 1987, 7–8). It is worth observing then that Pliny would likely have mentioned any particular terminology for cinnabar if it was operative (presumably tied to provenance). Likely, that was not necessary since state cinnabar from different sources (in Spain at least) traveled to Rome (Pliny Naturalis Historia 33.39).

In ancient Greek, cinnabar was also known as κιννάβαρι (Aristotle Meteorologica 387a26; Theophrastus 58). Pliny also informs us that the Greeks called *minium* "*cinnabaris*" (Pliny Naturalis Historia 33.38). In later Rome cinnabar was known as *ginnabareos* in Diocletian's Price Edict (301 A.D.). Isidore of Seville suggested that this pigment gave its name to the river Minius in Spain (today Miño in Spanish).[15] Or did the pigment draw its name from the river? Cinnabar's nomenclature also was used for the Latin verb *miniare*, which meant to paint in red (either with cinnabar or red lead). The term *miniature* will later develop from *minium* and the convention of writing small letters, especially in the Medieval period, in cinnabar or red lead.

Importantly, there was overlap with this term, in that there was some nomenclature double-parking among pigments that had the name *cinnabar* and *minium.* Dioscorides believed that *minium* was the proper name for mercury sulfide and took pains to differentiate it from Indian cinnabar, which he called κιννάβαρι (Dioscorides 5.94). Needing to specify just which pigment was intended is evident even in the Price Edict, where the term *ginnabareos* was reinforced with phrase, *hoc est mini* ("this is of *minium*") (Crawford and Reynolds 1979 sec. 34.74). In the Price Edict, and in Pliny's Natural History long before it, each pigment has a different price. One surviving coarse ware vase (its shape was known as a *chytra*) from Hellenistic Corinth shows an interest in keeping track of a pigment when it was shipped. The inscription on this vase calls cinnabar by its name and reads, χωρεῖ ὄγκος τῆς χύτρας κιννάβαριν μνᾶς τριάκοντα, "the capacity of this

Figure 4 Coarse ware vase with inscription mentioning cinnabar, mercury sulfide, from Corinth. Photo: author, with the permission of the Ephorate of Antiquities of Corinth.

chytra (is such that) it holds 30 *mnas*' worth of cinnabar" (trans. M. Lang: Amyx 1958, 212) (Fig. 4). Thus, when this vase was shipped it contained a particular weight (i.e., 30 minas) of cinnabar. Once it was received, it would be worth weighing the contents to make sure none of this valuable material had been purloined since it had left its destination. The name on this container helped to safeguard its contents.

Indian cinnabar

As we have already seen, there were two materials that had cinnabar as their name: cinnabar (mercury sulfide) and Indian cinnabar (*Indica cinnabaris*) (Pliny Naturalis Historia 33.38; Periplus Maris Erythraei 30.10.17; Bailey 1929, 217 n. 111). Indian cinnabar, or dragon's blood, is a resinous material sourced from semi-tropical and tropical plants of the genera *Daemonorops* and *Dracaena* (Brecoulaki 2006, 36 n. 30; Eastaugh et al. 2008, 148–149). Indian cinnabar was a pigment, but it (like most other pigments) was also an ingredient used in ancient drugs. Since cinnabar (mercury sulfide) and Indian cinnabar had somewhat overlapping names, Pliny stated that doctors might use the one material (mercury sulfide) in error with deleterious consequences (Pliny Naturalis Historia 33.38)!

[15] Isidore of Seville Origins 19.17.7; see also Justinus Epitome 44.3.4; Barceló 2006. This etymology calls to mind the river Scamander, also known as Xanthus (Homer Iliad 20.74). An Etruscan origin for this pigment's nomenclature has also been suggested (Pittau 2009, 137). Another possible origin is from the Persian *shangarf* (Senning 2019, 385).

Pliny stated that the Greeks gave this name to dragon's blood, and that seems to be accurate, since Dioscorides used this name for that material (Pliny Naturalis Historia 33.38; Dioscorides 5.94). One might wonder why there was such overlap, in that the name for one of these pigments borrowed from another pigment's name. However, this practice is parallel to the convention demonstrated by the Egyptians naming Egyptian blue after lapis lazuli—new and unfamiliar materials might be called after a name that was already familiar and by a name which evoked both a particular, vivid color and opulence.

Red lead

White lead, once heated with vinegar, became red lead (Pb_3O_4), *cerussa usta* (Pliny Naturalis Historia 35.20). Red lead could also be found in nature (Vitruvius De architectura 7.7.2; Pliny Naturalis Historia 33.40). Another name for artificial red lead was *minium secondarium* (Pliny Naturalis Historia 33.40; Bailey 1929, 217 n. 111). There were at least two types of red lead: an Asiatic red lead as well as a purple (*purpurea*). *Sandyx* was a mixture of equal parts of red lead and red ochre that was burned. Pliny seems to have been concerned that Vergil thought this material was a plant as he wrote of it as if it were a dye (Vergil Eclogues 4.45; Pliny Naturalis Historia 35.23). In the Price Edict, it seems that *sandyx* is at that later period called *sandugos* (Crawford and Reynolds 1979 sec. 34.78 and 209).

Kermes

Kermes dye was a red dye known as κόκκος in ancient Greek and *cocccum* in Latin. This is a dye made from an insect, although Pliny thought it was a grain or kernel (*grānum*) (Pliny Naturalis Historia 9.65 and 16.12). These terms are thought to come from an Indo-European root k^{w}rmi, for "larva" or "worm" and the Sanskrit etymological root (*krmi*) came from this, too (Donkin 1977, 10; Cardon 2007, 608–609; Eastaugh et al. 2008, 217). The Classical Latin term *vermiculus* for "little worm", would in medieval Latin come to denote the kermes worm (Vulgate Exodus 35.25; Donkin 1977, 10). The French term *vermillion* (English vermilion) was thus drawn from *vermiculus*. Today the term vermilion denotes artificial cinnabar, borrowed from kermes because of their shared intense red colors (Gettens et al. 1993, 159). The English color term "carmen" is also ultimately derived from kermes. There is no attestation, to date, of kermes itself being used alone as a pigment. However, Pliny reported that it could be used to make a variety of purple dye (*hysginum*) that was used to make a purple pigment (see in the purple section below).

Sandarach (Realgar) and related terms

Realgar, the red sulfide of arsenic (As_2S_2), was known as σανδαράκη/*sandaraca*.[16] Dioscorides and Pliny knew that *sandarach* was found in the same mines as orpiment and Pliny knew it could be found on Topazus in the Red Sea (modern Zabargad Island) (Bailey 1932, 205 n. 177 and 207 n. 178; Dioscorides 5.104–105; Pliny Naturalis Historia 34.56 and 35.22; Bailey 1932, 205 n. 177). Strabo even knew of a mine called Mt. Sandaracurgium (or Realgar mountain) in Paphlagonia (Strabo 12.3.40; Vitruvius De architectura 7.7.2; Caley and Richards 1956, 172).[17] The combination of red ochre and *sandaraca* produced Syrian (*Syricum*), which was a pigment mixture used to adulterate cinnabar (mercury sulfide) (Pliny Naturalis Historia 33.40; Bailey 1929, 220–221, n. 120).

Apparently, there was some confusion about the name for what to call white lead when it was heated (i.e., red lead), as Vitruvius (De architectura 7.12.2) incorrectly called this product *sandaraca*, which actually was the term for realgar (discussed above) (Bailey 1932, 206). Did this seemingly misapplied label result from a confusion between substances that when heated change color? Or did perhaps Vitruvius not know the lingo for fraudulent pigments? Reading Pliny, it is clear that heated red lead might be used as a fraudulent stand in for real realgar, thus a fake realgar (or at least realgar substitute) would be called *sandaraca adulterina* (Pliny Naturalis Historia 35.22; Augusti 1967, 89–90).

Madder

Madder in Latin was *rubia*, connecting this substance to a basic Latin color term meaning red.[18] In ancient Greek, madder was ἐρυθρόδανον (*erythrodanon*), coming from the adjective ἐρυθρός that signaled red (Dioscorides 3.143; Schaefer 1941). Madder lake is made from the root of the madder plant (*rubia tinctoria* or *rubia peregrina*) (e.g., Pliny Naturalis Historia 19.17 and 24.56; Dioscorides 3.143). The dye was converted to a pigment by dyeing it over a substrate and was used as pigment in ancient Greece, Etruria, and Rome (Cardon 2007, 108 and 122). For Pliny, madder was one of the materials that could be added to murex purple or used to make a pigment on its own (Vitruvius De architectura 7.14.1; Pliny Naturalis Historia 35.26).

[16] Pliny Naturalis Historia 34.55; Bailey 1932, 205 n. 177; André 1949, 160; Eastaugh et al. 2008, 324-25; Kakoulli 2009, 51. The modern term for realgar comes from the Arabic phrase, *rahj al-ghar*, "powder of the mine" (Senning 2019, 386).

[17] This mountain is said by Strabo to be near Pimolisa but the precise location is unknown (Foss 2000, 1224).

[18] E.g., the verb *rubeo*, *rubere* "to be red" and the adjective *ruber, rubra, rubrum* — "red, ruddy". For this color term in Pliny, see Wharton 2016, 192.

Yellows

Yellow ochre

The ancient Greek term for yellow ochre was ὤχρα (*ochra*), whereas it was *sil* in Latin (e.g., Vitruvius De architectura 7.7.1). There were various types of yellow ochre that drew their names from their provenance, some of which were the Gallic, Attic, and Lydian (although the latter two varieties were no longer available according to Vitruvius and Pliny) (Vitruvius De architectura 7.7.1; Pliny Naturalis Historia 33.56; Dioscorides 5.93).[19] There was also a variety of yellow ochre known as *marmorosum*, which presumably had a marbled or dappled color. Alternatively, perhaps *marmorosum* derived its name because it was as hard as marble.[20] Interestingly, Pliny reported that one variety of yellow ochre had a different name depending on where it was used, which tells us much about pigment nomenclature. One type of yellow ochre was called *pressum* by some—and this could either describe the color "dark" or "gloomy" (but this name, alternatively, could have also connoted a "dense" texture instead). Importantly, other people called this same pigment *Scyricum*, or Scyric yellow ochre (after Scyros, an island in the Aegean Sea) (Fig. 3). The Scyric yellow ochre came to be also found in Achaia (Pliny Naturalis Historia 33.56). For all the various ochres that Pliny was familiar with, each with different qualities and prices, it is interesting that in the Maximum Price Edict of Diocletian (301 A.D.) ochres are listed as a single product (*ochrae*) with one price (Crawford and Reynolds 1979, 184 n. 107).

Other yellow pigments

In ancient Greek, orpiment was known as ἀρσενικόν/ ἄρρενικόν (*arsenicon/ arrenicon*), from which the modern word "arsenic" is derived (Theophrastus 40, 50, 51; Vitruvius De architectura 7.7.2; Dioscorides 5.104; Celsus De medicina 5.5; Bailey 1932, 207 n. 178; Eastaugh et al. 2008, 291). Orpiment was also known as *arrhenicum* in Latin (e.g., Pliny Naturalis Historia 34.56; Bailey 1932, 207 n. 178 and 208 n. 30). Today's term for orpiment, yellow sulfide of arsenic (As_2S_3), clearly comes from the Latin, *auripigmentum*—a pigment made of gold—the term evoking its bright gold-like color (Vitruvius De architectura 7.7.2; Pliny Naturalis Historia 33.22, 34.56, 35.12). Ingrid Blom-Böer and David Warburton, thinking about this pigment's evocative nomenclature, note that "orpiment is superior to all substances in imitating the colour of gold, in both hue and luminosity" (Blom-Böer and Warburton 2019, 243–244). Warburton comments further that, "…the clearly visible etymology of the word "orpiment" shows that it was understood as being a substitute for gold in painting…" (Warburton 2008, 243–244). Caligula, perhaps observing that the term *auripigmentum* had gold in its name, even tried an alchemical experiment, hoping to produce gold from this pigment (Pliny Naturalis Historia 33.22; Bailey 1932, 207 n. 178).

Vitruvius told of a yellow vegetal pigment made from violets, which was a good stand in for the no longer available Attic ochre (Vitruvius De architectura 7.14.1). Vitruvius did not provide a name for this pigment. At Pompeii, Augusti identified two yellow organic pigments which were lakes that were dyed over a calcium carbonate substrate (Augusti 1967, 97–98). These pigments, upon examination, contained silicon, aluminum, and magnesium; Augusti believed that these pigments were produced from violets.

Greens

Malachite

It is now fitting to explore the green copper carbonate pigment malachite, a semi-precious mineral which was used as a pigment and also in ancient medicaments. The same term was employed by both ancient Greek and Latin authors for this pigment, namely χρυσοκόλλα/ *chrysocolla* (Theophrastus 26; Vitruvius De architectura 7.5.8, 7.9.6; Pliny Naturalis Historia 33.26-29; Dioscorides 5.89). As occasionally happened with pigment nomenclature, the Romans adopted the term wholesale from the Greeks. Pliny named three different varieties of malachite, based on how finely ground its particles were: *aspera* ("rough"), *media* ("middle"), and *attrita* ("worn down") (in order of decreasing particle size) (Pliny Naturalis Historia 33.27).

The etymology of this term in ancient Greek stems from χρυσός (*chrysos*), "gold" and κόλλα (*colla*), "glue". This is because this material was used as a gold solder, e.g., the adjective χρυσόκολλος, "soldered with gold" (Theophrastus 26; Liddell and Scott 1889, 896; Caley and Richards 1956, 105–106 (note that Caley and Richards provide instructions for using it when soldering); Augusti 1967, 101–104; Gettens and FitzHugh 1993, 184). The term malachite itself derives from ancient Greek and the term μαλάχη (*malache*), or "mallow", a reference to its leafy green color (Eastaugh et al. 2008, 254; Senning 2019, 386). Importantly, the term *chrysocolla* does not describe malachite in modern mineralogy but instead is a copper silicate hydroxide hydrate International Mineralogical Association species (Gettens and FitzHugh 1993, 184 and 193; Anthony et al. 1990; Eastaugh et al. 2008, 109). The term *krysos*, from which *chrysocolla*

[19] With the term Gallic ochre, Pliny used a geographic descriptor that potentially applied to a vast geography that today encompassed France, Belgium, and part of the Netherlands (partially depicted in the map in Fig. 3).

[20] Marble yellow ochre was the most resistant to lime, leading Bailey to wonder whether this ochre was a "hard hematite", one that was resistant to dehydration (Bailey 1929, 234). Pliny talks about burning this marble yellow ochre at Rome to make red ochre (Pliny Naturalis Historia 35.20).

descended, was used as a color term and had a long history in Greece. It descended from the Linear B term *ku-ru-so*, which also meant gold (Warburton 2008). As will be clear below, Linear B's terms for a bluish material, as well as purple, both find their origin outside of Greece. So too with *ku-ru-so*, which mimicked the sounds of the aforementioned Akkadian term for gold, *ḫurāṣu* (Warburton 2008; Warburton 2016; Thavapalan 2020, 367).

A papyrus from Oxyrhynchus preserves a bill for a temple renovation from 117 A.D. and lists the materials and their weight and cost.[21] Pigments and related materials are listed towards the end of the account, including Egyptian blue, yellow ochre, a pumice stone, and three sponges. One material is listed as Μακεδονικῆς (Oxyrhynchus, HGV SB 14.11958, ll. 81). Swiderek in her commentary on this papyrus proposed that it was "rouge?", but I believe another color was more likely connoted by this appellation (Swiderek 1957-1958). Macedonia was one of the known ancient sources of malachite and one specifically listed by Pliny and Dioscorides (Pliny Naturalis Historia 33.27; Dioscorides 5.89).

Pliny described a dyed malachite that he called *orobotin* (Pliny Naturalis Historia 33.27). Like *cicerculum* red ochre, this dyed material's name was inspired by a food and was called "like a chickpea" (ὀροβῖτις). Thus, it seems that yet another pigment's name was inspired by another material. It has been suggested that this pigment, in particular, drew its name from being formed into little balls that looked like chickpeas (the *globulis* mentioned by Pliny) (Bailey 1929, 206–207). There are two subvarieties of this pigment, a "purified" type (*eluta*) ("which is kept in paste form") and the *liquida*, or liquid type.

Verdigris

Verdigris denotes a number of copper acetates used as pigments (see inter al. Caley and Richards 1956, 191–193). In antiquity, this color was known as ἰὸς or ἰὸς ξυστός ("rust of copper") in ancient Greek and *aerugo*/*aeruca* in Latin (Theophrastus 57; Vitruvius De architectura 7.12.1-2; Pliny Naturalis Historia 34.26-28; Dioscorides 5.79). Two varieties of this multi-purpose material were Rhodian verdigris and Cyprian verdigris (Pliny Naturalis Historia 34.26-27; Dioscorides 5.79). Another was known as *ios scolycos* (Pliny provided the form *scoleca*), which was made of copper ground with alum and salt or soda and a strong white vinegar; this material will look like little worms, thus inspiring its name (from the ancient Greek term σκώληξ, for earthworm) (Bailey 1932, 174; Pliny Naturalis Historia 34.28). The modern term verdigris is likely derived from the later term *vert de Grece (viride graecum)*, which is one of the names for this pigment in medieval manuscripts (Eastaugh et al. 2008, 391–392).

Green earth

Green earth was known as *creta viridis;* our term green earth is a direct translation of that phrase (Vitruvius De architectura 7.7.4). One variety of green earth, which Vitruvius believed was the best, was named θεοδότιον, because a man named Theodotus owned the land in Smyrna on which that pigment was first discovered.[22] Thus, this pigment received its name due to a man who was thought to have a pivotal role in its mining. There was also a green pigment that could stand in for or counterfeit malachite; this pigment is thought to have been a variety of green earth (Pliny Naturalis Historia 35.29). It was named *appianum,* perhaps because its color was evocative of parsley (i.e., *apiacum*) (Rackham 1952, 297). Augusti agreed that this pigment was a green earth, but suggested, without support, that it was green earth that had been washed and purified (Augusti 1967, 101).

Vegetal green

There was also at least one vegetal green that could serve as a cheap replacement for malachite. Pliny stated that the pigment was known as *lutea* and it was called after the yellow dye plant that was then mixed with a blue substance (*caeruleum*) (Pliny Naturalis Historia 33.27). *Lutum* was weld (*reseda luteola*) (Granger 1934, 128; Cardon 2007, 168–177). Vitruvius, before him, accounts for perhaps a different vegetal green pigment, which was also used as a replacement for malachite (Vitruvius De architectura 7.14.2). To make this pigment, a blue substance is dyed with *lutea*. Interestingly, Vitruvius knew this pigment not as *lutea* but as *infectiva* or "dyed stuff" (*haec autem infectiva appellatur*: "this is called 'dyed stuff'").

Blues

Was there a term among the Mycenaeans for the color blue and for blue pigments? At the very least, there was a blue material, a cobalt blue glass, known as *ku-wa-no* in Linear B (e.g., PY TA 714; Delamare 2013, 11; Ventris et al. 2015, 339–340 and 399; Panagiotaki et al. 2015, 1770). This term was clearly inspired by the Hittite term (*kuwanno*) and ultimately descended from the Akkadian *uqnû* and Ugaritic *iqnu* (von Rosen 1988, 25; Warburton 2008, 217–218; Panagiotaki et al. 2015; Warburton 2016). This color term provides a hint that just as blue pigments, such as cobalt and lapis lazuli, were traded from the east, so, too, were the terms for these materials. And this makes sense — the

[21] Oxyrhynchus, HGV SB 14.11958; Swiderek 1957; Thiboutot 2020, 160; http://papyri.info/ddbdp/sb;14;11958

[22] Vitruvius De architectura 7.7.4; Reinach 1921, 13 n. 23. Pliny had a different story and associated a Theodotus of Smyrna with lead white (*cerussa*) (Pliny Naturalis Historia 35.19).

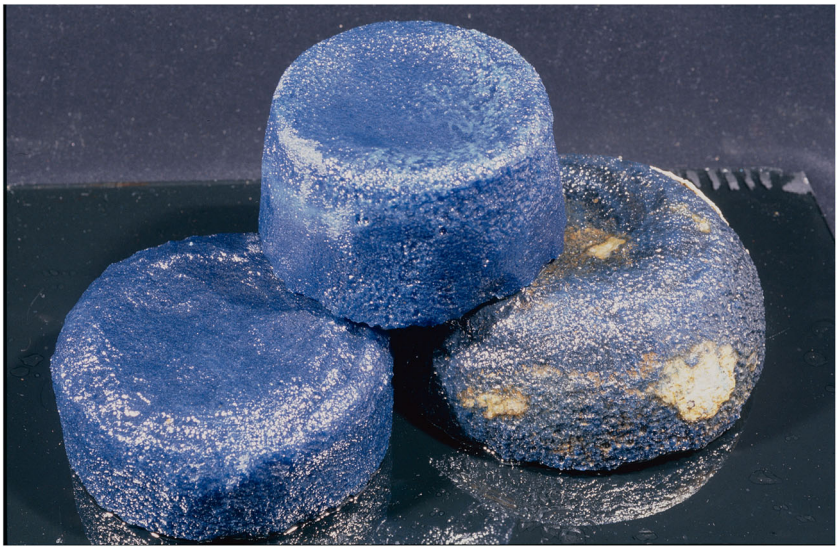

Figure 5 Cobalt glass ingots from the Ulu Burun shipwreck (late 14th c. B.C.). © Institute of Nautical Archaeology.

Mycenaeans were not likely to encounter local, natural stones that were so deeply blue. Archaeological evidence supports this etymology, too. The Ulu Burun shipwreck (late 14th c. B.C.) contained many items from the eastern Mediterranean world with materials from Egyptian, Canaanite, Assyrian, Mycenaean Greek cultures, and more (Pulak 1998). Thus, who was sending this ill-fated ship and what its final destination might have been is still unknown. For this study, one set of artifacts that stand out are the cobalt glass ingots (Fig. 5). A cast of these Ulu Burun ingots fits into the cylindrical terracotta molds at Amarna, although admittedly similar molds could have been shipped out such that the glass could have been worked at a different site (Nicholson et al. 1997). While these ingots could have been made at Amarna or another Egyptian site, new evidence suggests that the cobalt used to make the colorant did not come from the Kharga and Dakhla oases in southern Egypt as long suspected (Rehren 2001; Hope et al. 2010) but from Iran (Wood and Yi-Tang 2019). The Ulu Burun shipwreck demonstrates a moment when this glass ingot (with a potentially complex material pedigree) was being shipped abroad. The blue glass circulated around, as the Ulu Burun shipwreck demonstrated, and so, too, did a foreign term for it, *ku-wa-no* in Linear B. Thus, when a Mycenaean Greek encountered blue glass similar to that found in the Ulu Burun shipwreck, they used a term that was ultimately derived from the Near East where the dark blue color could be found in nature, in lapis lazuli.

The terms κύανος and *caeruleum* were general color terms describing blue or black or dark colors. In the context of pigments, both terms described natural pigments and an artificial pigment that were blue in color in ancient Greece and Rome (André 1949, 162–171, for *caeruleum*).[23] The Latin term, *caeruleum*, comes from the root κύανος. Both of these colors are descendants from Linear B's *ku-wa-no* that reflected Near Eastern terms that described or reflected lapis (Theophrastus 31; Caley and Richards 1956, 126; Berlin and Kay 1991, 71). Thus, at their core, all these ancient "blue" terms point back to lapis lazuli. Importantly, while the Greek term κύανος did not always describe something blue (it also was used to describe a "dark" or "black" color (so, too, with *caeruleum*)), what is important is that this term descended from and was meant to evoke lapis lazuli.[24]

The Romans were fully aware that their general color terms, terms like *caeruleum*, had a wide gamut. Aulus Gellius, thinking of the color terms red (*ruber*) and green (*viridis*), wrote that there are more distinctions between colors perceived by the eye than expressed in nomenclature and speech (Aulus Gellius Noctes Atticae 2.26; Romano 2003, 41). Thus, while certain colors, like *ruber* (or here *caeruleum*), actually had single names (*singula vocabula*) they in fact have many shades of difference in terms of their visible tones (*multas autem species differentis habent*). This is important for blues, since, in ancient Greek and Latin, the names for these pigments are based on simple color terms.

One wonders if an ancient artist would have merely specified κύανος or *caeruleum* when referring to a pigment and whether that would have been sufficiently clear among artists.[25] When ancient authors describe these pigments, if an accompanying adjective is not provided, these pigments must be identified on the basis of context clues and elimination (Caley and Richards 1956, 183–184). For example, when Theophrastus describes a natural κύανος found with

[23] By the early 4th c. A.D., the Maximum Price Edict of Diocletian is referring to a blue pigment as *cyaneus* (34.83-84; Crawford and Reynolds 1979, 183; see also André 1949, 180).

[24] Pastoureau 2001, 25; Warburton 2008, 217–218. κύανος in Homer as a type of black (Brecoulaki 2014, 20).

[25] Although it should be stated that Egyptian blue was the most commonly used blue pigment overall and pigments such as azurite may not have been very common—indeed they were hardly ever used on ancient wall paintings. Lazurite, if it was, indeed, used as a pigment, discussed briefly below, would have been rare indeed (Becker, n.d.).

chrysocolla, this must be azurite since these copper carbonates are found together in nature (Theophrastus 39). Similarly, when Vitruvius discussed Egyptian blue, he only listed it as *caeruleum* (Vitruvius De architectura 7.11.1). However, mentioning that Egyptian blue was first made at Alexandria was enough to identify the particular pigment under discussion; it is important to point out Vitruvius' inaccuracy since Egyptian blue was manufactured long before Alexandria was founded in 331 B.C. The aforementioned Oxyrhynchus papyrus from 117 A.D. (mentioned in the malachite section) may offer a clue as well. While the papyrus is fragmentary, a blue is listed, followed by a unit of measurement (*mina*), (κυανοῦ μν(ῶν)).[26] Thus, it seems that this pigment was listed only as blue—Egyptian blue is the most likely candidate for the decoration of a temple, but azurite was also possible.

Since the sources of these blues were so different, it is not surprising that the different varieties of blue pigments were often differentiated by means of a two-part name tied to a provenance associated with that color. In ancient Greek these pigments began with the term κύανος and in Latin, began with the term *caeruleum*. In order to differentiate between the different types of blue pigments, the places associated with these different blues *Aegyptium*, *Cyprium*, and *Scythicum* were utilized.[27] Thus, these blues found their names from both a material association (κύανος) and provenance. While Cyprus was not the only source of azurite in antiquity, it was a prominent enough source to give its name, as a brand of sorts, to all azurite (Caley and Richards 1956, 183) This usage demonstrates an important trend in pigment nomenclature, which was demonstrated earlier with Sinopic red ochre, that an attached place name was not an exclusive marker of a pigment's actual place of origin.

Azurite: Cyprian blue and *armenium*

Azurite was termed Cyprian blue (*caeruleum Cyprium*) because Cyprus was a natural source of this blue pigment (Theophrastus 55; Pliny Naturalis Historia 33.57 and 35.12).[28] Azurite was also known by a second name in ancient Greek and Latin and this was also drawn from its provenance.[29] As Pliny noted, "Armenia sends the pigment which is called after its name" (Pliny Naturalis Historia 35.28). There has been debate as to whether *armenium* was indeed azurite, or whether it was lazurite.[30] The identity of this pigment is important because it is one of the six *floridi* pigments that Pliny stated a patron needed to purchase (Pliny Naturalis Historia 35.12). Germany was also a potential source of azurite in antiquity, but it did not apparently give its name to this material.[31]

Scythian blue

Importantly, there is a debate about whether the pigment lazurite, the mineral form separated from lapis lazuli, was used in antiquity. The debate is not so much about the distance, which was considerable since lapis lazuli was mined in the Kokcha River valley in northeastern Afghanistan. Instead, the question is whether lazurite could have been successfully extracted from lapis lazuli, since considerable technological processes were required to remove the gangue (e.g., pyrite, calcite).[32] Lazurite has been detected as a pigment in a small number of Greek and Roman contexts from the Bronze Age to the Roman Imperial period.[33] The sites where lazurite has been detected will need further analysis. Additionally, as more ancient painted surfaces are tested, this will increasingly give

[26] Oxyrhynchus, HGV SB 14.11958, line 82; Swiderek 1957; Thiboutot 2020, 160; http://papyri.info/ddbdp/sb;14;11958

[27] Theophrastus uses these all together at 51, and Pliny mirrors this at Naturalis Historia 33.57.

[28] Caley and Richards 1956, 183.

Note that Dioscorides identifies one blue (5.91) as simply κύανος without a descriptive adjective to aid in identification. Caley and Richards (1956, 182) and this author believe that this κύανος was azurite. Beck, however, identified Dioscorides' κύανος as lazurite. However, Dioscorides stated that this blue was found in copper mines in Cyprus—and such attributes seem to describe azurite and not lazurite (Beck 2005, 373: 5.91). Another recent translation of Dioscorides, instead, considered this blue as describing yet another material, a "Cyanochroite — blue hydrous Sulphate of Copper and Potassium" (Osbaldeston and Wood 2000, p. 798 no. 5.106).

[29] Vitruvius De Architectura 7.5.8; Dioscorides 5.90; Pliny Naturalis Historia 35.12 and 35.28. Reinach 1921, 13 n. 23; Siddall 2006, 21. Rackham stated that *armenium* is "a rich blue color (from Armenia), the modern azurite" (1952, 282 n. d.).

[30] August Nies wrote that *armenium* was lazurite (Nies A 1895. "Armenium." In Paulys Realencyclopädie der classischen Altertumswissenschaft, Band II,1. Druckenmüller Verlag, Stuttgart, 1187–1188). Note that Granger translated *armenium* as "Armenian ultramarine" (Granger 1934 pp. 109 and 121; Vitruvius. On architecture. Harvard University Press, Cambridge, Mass, 109 and 121). Bailey seemed to have mostly decided that *armenium* was azurite, stating that the pigment was "probably azurite… perhaps lazurite" (Bailey 1932, 15 (and 220)). Pastoureau translates *armenium* as azuríte, too (Pastoureau 2001, 22).

One of Nies' reasons for identifying *armenium* as lazurite was the location. But while Armenia could have been a transit point for lazurite, it certainly was a place where both azurite and malachite could be found in antiquity. To this point, Dioscorides said that the best malachite could be found in Armenia (Dioscorides 5.89). Nies' other reason for identifying *armenium* as lazurite was the high price listed by Pliny (Naturalis Historia 35.28), but this entirely depends on whether the price is read as *tricenis* (30) or *trecenis* (300) sesterces. Thus, this argumentation is not the most conclusive evidence for identifying a pigment.

[31] Körlin G 2010. "Luxusgut Blau - Römischer Azuritbergbau in Wallerfangen." *Der Anschnitt* 62, 174–189. The name German azurite (e.g., *azur todescho*) will appear in the Middle Ages and the Renaissance (Thompson DV 2013. The materials and techniques of medieval painting. Dover Publications, New York; Spear RE 2010. "A Century of Pigment Prices: Seventeenth-Century Italy." In Trade in artists' materials: markets and commerce in Europe to 1700. Edited by Kirby J, Nash S and Cannon J. Archetype Publications, London, pp 275–296.)

[32] Siddall 2018 and Ruth Siddall, personal communication, June 2019.

[33] Brécoulaki 2014, 8 and Becker, n.d.

clarity to the question of whether lazurite was a pigment that was utilized in the Greco-Roman world.

Importantly, for this debate, there was a term for lazurite as a pigment. Lazurite was known as Scythian blue (*caeruleum Scythicum*) in antiquity (Theophrastus 55; Pliny Naturalis Historia 33.57). Pliny used this term in his section on pigments in book 33 of his Natural History so he must have considered it to be a pigment. The pigment, *caeruleum Scythicum*, also has a name that evoked a place. The nomenclature of Scythian blue seems to parallel that of Sinopic red ochre, since this pigment was not mined in Scythia, but in eastern Afghanistan. Earle Caley and John Richards suggested that, "the name 'Scythian' probably became attached to this particular blue pigment because it was exported to Mediterranean countries by Scythian traders, who had received it from still more distant peoples" (Caley and Richards 1956, 184). When lapis lazuli is referred to as a gemstone, it is called σάπφειρος*/sappheiros/sappir* or κύανος (e.g., Theophrastus 37; Pliny Naturalis Historia 37.39; Caley and Richards 1956, 126 and 136–137; Brecoulaki 2014, 21).

Dioscordes refers to this material, used as a medicinal ingredient, as κύανος (Dioscorides 5.91). The medical-magical book known as the Cyranides (1st–2nd c. A.D.), refers to lazurite as λαζοῦριν, a pigment that came from the stone (Panayiotou 1990, 321–322; Frison and Brun 2016, 49). The term *ultramarinum* would not develop until at least the 13th c. A.D. (Cyranides 1.18.10; Frison and Brun 2016, 47).

Egyptian blue

Pliny identifies four varieties of Egyptian blue (*caeruleum Aegyptium*) in his time. There was the standard Egyptian blue, Vestorian blue (*Vestorianum*), Puteolan blue (*Puteolanum*), and *lomentum* (Pliny Naturalis Historia 33.57). Egyptian blue was a pigment first developed in Egypt, according to Theophrastus (Theophrastus 55). Thus, this artificial pigment was associated with the place of its origin. Vestorian blue was the "most refined part of Egyptian blue" according to Pliny.[34] Gaius Vestorius, a banker and entrepreneur, was known to Cicero and introduced the production of this pigment to Italy. Vestorius, so far as we know, did not innovate Egyptian blue. He likely used one of the varied sets of instructions that may have been circulating around the Mediterranean in the first century B.C. (Vitruvius De architectura 7.11.1). Vestorius was associated with the material because he was credited as being the person who brought the manufacture of this pigment to Italy. Many other materials drew their names from individuals associated with them, such as the Dolabellian pear or the Livian fig (Pliny Naturalis Historia 15.16 and 15.19; Kron 2012, 165). But Vestorius' blue draws its name in the same way as *Luculleum marmor*, for Lucullus was the first to import the marble to Rome (Pliny Naturalis Historia 36.8).[35]

In at least one instance with respect to Vestorian blue, it appears as though this nomenclature came to be the brand name for this pigment category, replacing any other appellation. More than two centuries later, the Price Edict of Diocletian listed the maximum prices for two types of Egyptian blue as Vestorian blue.[36] Thus, in time, it seems, Vestorian blue would come to be the generic name for Egyptian blue. Much as in American parlance, kleenex has become the general term (or proprietary eponym) for a facial tissue, even if the Kleenex™ brand is not being used (Gordon 2019).

There was also a Puteolan blue (Pliny Naturalis Historia 33.57). Pliny stated that Puteolan blue was good for painting in general just like other Egyptian blues and also (apparently durable) when painted near windows. However, there is an odd element to this pigment's nomenclature. Whereas, with the yellow ochre *pressum*, Pliny made it clear that some people called it by that name, but others instead knew it as *Scyricum*. In this case, on the other hand, Pliny explained what Puteolan blue was and then finished with the statement, "they call it *cyanon*."

There is another variety of Egyptian blue which Pliny called *lomentum,* which was made by washing and grinding the blue (Pliny Naturalis Historia 33.57). Since the term *lomentum* speaks to a paste-like mixture, specifically a bean paste, the name for this color was likely derived from its texture as it was being produced. *Lomentum*, its nomenclature inspired by a food, finds parallel with other pigment names such as the red ochre *cicerculum* (chickpea) and potentially *appianum* (parsley). Pliny stated that *lomentum* is a paler color than regular Egyptian blue. Washing and grinding Egyptian blue would result in a material of finer granulometry and therefore a lighter tone. There was a third variety of blue, which was a more refined *lomentum*. This was Vestorian *lomentum* and it was made from the most refined parts of Egyptian blue. It retailed for eleven *denarii* (or 176 *asses*).

There is a fourth variety of Egyptian blue that sold for drastically less than the other blues (Becker 2021, 198–199). *Tritum* is a ground *lomentum*—the Latin title simply describes that the material has been ground. If *lomentum* is made from ground up *caeruleum*—what happened to the rough, leftover bits? Perhaps *tritum* is made up of the leftovers, as well as

[34] Pliny Naturalis Historia 33.57. Morel 1983, 29–30.

[35] Although the association was different, for Pliny pointedly talks about the nomenclature stating this was the first marble to get its name from an admirer.

[36] These blues (listed as *cyaninu* (*sic*) and *cyaneus*) are specifically called Vestorian, "Hoc est Vestoriani." Price Edict, 34.83–84 (Crawford and Reynolds 1979, 183, 193 and 209). Just as with cinnabar, stating the color term was not enough—so after stating blue, the author added more specification as to which specific pigment was intended.

other natural ingredients to stretch the color further. If this hypothesis is true, one would anticipate that this blue would be considerably washed out in color.[37]

Indigo

Indigo (Ἰνδικόν in ancient Greek and *indico* in Latin) drew its name from its provenance, as that is the area where this material was produced (Vitruvius De architectura 7.9.6; Pliny Naturalis Historia 35.27; Dioscorides 5.92; Bradley 2009, 99–100). Indigo can also be known as *caeruleum* (Pliny Naturalis Historia 33.57). Indigo has been detected as a pigment used on Fayum portraits from Roman Egypt, where it was mixed with madder (Salvant et al. 2018, 824).

Purple

The term for murex purple, *po-pu-re-ja,* appears in Linear B tablets and seems to be associated with purple textiles (Burke 1999, 78; Brecoulaki 2014, 10).[38] This purple is used in the context of royal or otherwise opulent textiles, thus, by the Bronze Age this is a color that seems to have been especially associated with social elites. The Minoans also used murex purple as a pigment. The term itself is thought to be of Semitic derivation and if so, the name traveled with the substance.

In ancient Greek, purple pigment could be known by the term πορφύρα, which described the murex as well as purple dye and textiles dyed with it. Purple pigment was also described as ὄστρεον (or ὄστρειον), which is the term for oyster (Plato Respublica 420c; Bogensperger 2017, 246). Vitruvius calls the purple pigment made from Tyrian purple *ostrum* (Vitruvius De architectura 7.13; André 1949, 102–103; Bradley 2009, 193; Bogensperger 2017). The standard term for the color purple in Latin was *purpura*; this term, like its ancient Greek progenitor, describes, inter alia, not only the color, but also the murex shells, dyed fabric, rank, etc. (André 1949, 91; Bradley 2009, 189–202; Wharton 2016, 192–193).

Importantly, a different Latin name was used to describe solid materials made from murex purple and this was *purpurissum*, deriving from the Greek πορφυρίζον (Pliny Naturalis Historia 35.26). *Purpurissum* was a unique term in Latin that only describes a pigment or a cosmetic (for the latter, Plautus Mostellaria 1, 3, 104; Augusti 1961; Bradley 2009, 98–99). There were varieties of purple pigment, based on their provenance: Puteolan purple, Tyrian, Gaetulian, Laconian, and Canosan (Pliny Naturalis Historia 35.26).[39] Importantly, these toponyms are not just a part of Pliny's interest in geography and natural history — as such labels were applied to purple in daily life, such that papyri document purple dyes (or dyed products) from Berenice and Tyre (*P.Oxy*. XX 2273.10 (late 3rd c. A.D.), *P.Hamb*. I 10.23 (2nd c. A.D.); Bogensperger 2017).

As stated before, madder was a material that could be added to murex purple to make a pigment, according to Pliny. Another material that could be added to make a purple pigment was *hysginum* (Pliny Naturalis Historia 35.26). *Hysginum* (ὕσγινον) was made by combining murex purple with the kermes dye (Pliny Naturalis Historia 9.55; Bailey 1929, 158, n. 158; Bogensperger 2017, 246).[40] This term may have originated from a Gallic term (ὗς) for the kermes insect (*kokkos*) (Pausanias 10.36.1).

A final purple question is whether the term *purpurissum* would also be used to describe a purple pigment with very little true purple in it (i.e., one that included true purple and *hysginum*)? It is entirely possible. One reason for this is the price that Pliny provided for a pound of *purpurissum*—it ranged in cost from one to thirty *denarii* per pound. There are many different factors that impacted the cost per pound of purple dye or purple pigment, including whether the pigment was made in the first dip of purple (the strongest) or the last (Becker 2020). But one of the factors in the cost differential, very likely, was how much true purple was used to make the pigment. However, would the term still be used to describe a purple pigment with no true purple in it? Likely, not. On the Price Edict, dyed wool prepared with different types of purple colors had different names and very different prices (Tyrian purple, Milesian purple, kermes from Nicaea?, and lichen purple) (section 24 of the Edict; Kropff 2016; Becker 2021). Color names continued to have real import.

Other colors

White pigments

Importantly, the wall plaster itself (*calcis*, in Latin) was an important white color in terms of background within a painting (Béarat and Fuchs 1996, 42; Gliozzo 2007, 78; Ceci and Becker 2020, 426). A room in *insula* 1 at Aventicum (Switzerland) (ca. 100 A. D.) was painted with five different white pigments (Béarat and Fuchs 1996). These five pigments

[37] In a study of a fresco in Rome, Sciuti et al. label *tritum* with the abbreviated term, "lomen. reject." There is no discussion of this comment, but this agrees with my own reading (Scuiti et al. 2001, 137 Table 3). See also Colombo 1995, 96.

[38] See also Nosch ML 2004. "Red Coloured Textiles in the Linear B Inscriptions," In Colour in the Ancient Mediterranean World. Edited by Cleland L, Stears K, Davies G. BAR Publishing: Oxford, 32–39. André suggests a possible Semitic origin for this term (André 1949, 91). For more on that topic, see Astour MC 1965. "The Origin of the Terms "Canaan," "Phoenician," and "Purple"" Journal of Near Eastern Studies 24.4: 346–350 and Reinhold M 1970. History of purple as a status symbol in antiquity. Latomus: Brussels, e.g., 8–11.

[39] On the location of the Gaetulian islands, see Pliny Naturalis Historia 6.36 and Bogensperger 2017, 242.

[40] Note that *hysginum* when referring to dyes could have described a combination of varied dyes, as will be discussed (Bogensperger 2017, 246–247).

(dolomite, aragonite, chalk, anular chalk, and diatomite) did not have identical properties to one another. This room in Aventicum demonstrates that a variety of different white pigments, most of which were naturally occurring, were potentially available to Greco-Roman artists. Basic chalks, *creta*, had a variety of functions for numerous industries and were also used as pigments. Within this category of pigments, *Paraetonium*, Melian earth, and Eretrian earth will be discussed here.

Paraetonium was a white shelly calcium carbonate pigment. *Paraetonium* was a thick pigment that modern scholars identify with the pigment aragonite (Mazzocchin et al. 2006, 384).[41] As stated, a pigment's provenance often provided an inspiration for Roman naming practices. This is clear with the pigment *Paraetonium*. "*Paraetonium* has its name, truly, from those places where it is mined," Vitruvius explained (Vitruvius De architectura 7.7.3). And while Paraetonium (modern Marsa Matrouh, Egypt) gave this pigment its name, the pigment could also be found in Cyrene and on Crete (Pliny Naturalis Historia 35.18). While *Paraetonium*'s name was drawn from one place, its name served as an umbrella name for similar pigments mined in other locations. Another umbrella category was Melian earth (Μηλία γή or *melinum*), a calcium carbonate. This pigment could be mined on Melos, but it was also found at Samos (Vitruvius De architectura 7.7.3; Pliny Naturalis Historia 35.19; Dioscorides 5.159; Aelianus Varia Historia 2.2.2; Gliozzo 2007, 75). Importantly, Pliny states that only the variety from Melos was suitable for painting. (See Gibney-Vamvakari et al., this volume, for more on Melian Earth). Eretrian earth (*Eretria creta*) was a white or ashy color and was found in Eretria, Greece; it may have been magnesite (Vitruvius De architectura 7.14.1; Pliny Naturalis Historia 35.12 and 21; Dioscorides 5.152; Bailey 1932, 214, Rackham 1952, 283 fn. k; Gliozzo 2007, 77).

There were manmade whites, as well, and also white pigments that could be used to make other colors. Ring white, or anular chalk (*anulare*) or *creta anularia*, was a pigment made from a white earth (*creta*) mixed with crushed cheap glass used to make rings (Pliny Naturalis Historia 35.29; Vitruvius De architectura 7.14.2; Béarat and Fuchs 1996, 43; Gliozzo 2007, 76–77; Bradley 2009, 100). When making a pigment intended to look like indigo, one can dye ring white or Selinuntine earth (*creta Selinusia*) with woad dye (Pliny Naturalis Historia 35.27; on Selinuntine earth, see Dioscorides 5.155 and Gliozzo 2007, 77). For making *purpurissum*, Pliny recommended using the white earth known as silversmith's earth (*creta argentaria*). This earth would be dipped into the purple dye bath (Pliny Naturalis Historia 35.26; Rackham 1952, 292 fn. d).

An important manmade white was ψιμύθιον in ancient Greek and *cerussa* in Latin, which represented especially lead (Theophrastus 56; Vitruvius De architectura 7.12; Scribonius Largus Compositiones 184.1; Pliny Naturalis Historia 35.19; Dioscorides 5.88; Bailey 1932, 204; Caley and Richards 1956, 187–191; Gliozzo 2007, 78; Kunzelman 2008). Importantly, Caley and Richards noted that these names can also include lead white (lead carbonate); it entirely depends on the context of how the term was used as these materials are very similar. Caley and Richards observed that, "however, if attention is paid to the ancient authors who discuss the products derived from lead by the corrosive action of vinegar, it seems certain that these terms were general ones that included both soluble lead acetate and insoluble lead carbonate, and that the particular product depended upon the details of the procedure" (Caley and Richards 1956, 187). Lead acetate ($Pb(C_2H_3O_2)_2$) can be transformed to lead white ($(PbCO_3)_2.Pb(OH)_2$) with atmospheric CO_2.[42] Thus, while ψιμύθιον and *cerussa* could potentially describe a variety of products, in the context of painting these terms referred to lead white (i.e., not lead acetate).

Black pigments

Whereas the adjectives *ater, -tra, -trum* and *niger, -ra, -rum* were the general terms describing the "black" or "dark" in Latin, the noun *atramentum* was reserved for describing black materials, whether that was cuttlefish ink (Cicero De natura deorum 2.50; Pliny Naturalis Historia 9.2), a black dye for leather (Pliny Naturalis Historia 34.32), writing ink (Pliny Naturalis Historia 27.28 and 35.25 and 35.49; Celsus De medicina 6.4), and pigments (Vitruvius De architectura 7.10; Pliny Naturalis Historia 35.25; Gliozzo 2007, 80–82; Bradley 2009, 98). From Pliny's explicit discussion, the term *atramentum* clearly covered a range of different pigments and artisanal materials including natural materials (such as ferrous sulfate or copper sulfate, bone black, and varied carbon blacks (including burnt wood and resin)) (Bailey 1932, 178–179; Croisille 1985, 160). It is also clear that which material was used to make *atramentum* had an impact on its potential applicability. Shoemakers' black (*atramentum sutorium*) referred to the dyes used by shoemakers (i.e., ferrous sulfate or copper sulfate). Attaching a descriptive term *atramentum librarium* versus *atramentum tectorium* helped to separate black ink from black pigment. Comparable terms in ancient Greek were painters' ἀσβόλη and writers' μέλαν (Dioscorides 5.161–162) as well as the term μέλανος for a black pigment (= μέλας, μέλαινα, μέλαν= black, dark) (*P.Cair. Zen.* 4 59767). A pigment made from the skins of

[41] The nomenclature for the modern pigment known as aragonite is also drawn from a toponym, Molina de Aragón, Spain (Senning 2019, 396).

[42] Smith CS and Hawthorne JG 1974. "Mappae Clavicula: A Little Key to the World of Medieval Techniques." Transactions of the American Philosophical Society 64.4: 1–128, see page 27.

grapes was known by the term for wine-lees in ancient Greek, *tryginon* (Pliny Naturalis Historia 35.25).[43] Ivory black was called *elephantinon*. Pliny reported that there was also an *indicum* that was a black (but not indigo), but he did not know its nature (Bailey 1932, 216–217 n. 42).

Concluding summary of key concepts

Calling materials by their names provides an opportunity to learn about how people see and process their world. As Bradley said when thinking about Pliny's use of color, "categories (*nomina*) represent our understanding of what we perceive" (Bradley 2009, 196). Pigment nomenclature, in particular, is a tangible reflection of a culture's worldview and what they knew about and had experienced. In all of these cultures, there were names for pigments, names that were usually different from general terms for colors. These color names allowed each ancient color to go beyond the color name and to make a "connection between colour and object" (Bradley 2009, 101).

It can further be observed that pigment nomenclature is an index of the connectivity of the ancient world. Artisans in the ancient Near East and later the Mediterranean gathered materials from near and far, all the time needing a name for each material. In the aforementioned mining expedition in the Dakhla Oasis, care was taken, it seems, to explicitly state the particular name of the pigment that was collected—because it had meaning.

Some of the pigment names are not discrete. Almost all of the blues were etymologically connected (however distantly in some cases) to the word for lapis lazuli. As Warburton explained, "through the second millennium B.C., color terms are mostly rooted in materials" (Warburton 2016). That in the Near East and occasionally in the Mediterranean, the terms for pigments reflected more prestigious materials such as lapis lazuli or gold, reveals at once a reverence for both materials and color. This brings up the first set of human stories gleaned in this study—what do people do when a new material is encountered—a material that is unfamiliar and not native? Often, one adopts the term for the material along with the material, adapting it to one's own language. Most terms for blue, whether from the ancient Near East or the Greco-Roman world, were evocative of a prestigious material, a material that spoke to status. As Egyptian blue is developed it is named after the one natural stone that it most resembles, something which was qualitatively superior. So, too, with *auripigmentum* much later on—its golden color was evocative of gold. Even Caligula wanted to see how gold a pigment that proclaimed it was *pigmentum auri*, literally a "pigment of gold", might be.

Orpimentum demonstrates that the practice of naming pigments after precious materials continued among Greco-Roman pigments. Indeed, a number of ancient Greek and Latin pigment names were inspired by what the pigment looked like (e.g., an insect, a food, a flower). When making an artificial pigment (such as *ios scolycos, lomentum, cicerculum,* or *lutea*) there is a need for a name and so borrowing a new product's name from one of its ingredients or its resemblance to a similar item would have been an easy fix and created a relatable name. Even the process of manufacture (e.g., *infectiva* "dyed stuff"), apparently could provide relatable pigment monikers.

In at least three cases, Greek pigment names can be traced back to Mycenaean roots—and in at least two of these cases (e.g., blue and gold), the term can be traced back to a loan word from another culture. Ancient Greek and Latin pigment names have some overlap, whether that is through loan words such as the term for blue, or terms like *chrysocolla* and *minium*. Another element of nomenclature that provided overlap is self-evident. If the most vivid red ochre came from Sinope—would you not refer to that branded material as Sinopic whether you are speaking in ancient Greek or Latin? For such pigments, the place names and what made that pigment worth tracking would be shared in common. Such names reflect the global nature of the Greco-Roman pigment trade.

A pigment such as Sinopic ochre leads to another question. Elisabetta Gliozzo wondered "whether in any one period the name identifying a given pigment was ascribed to a pigment with a provenance different from that of the original" (Gliozzo 2007, 82). This focused study has allowed us to understand that yes, this certainly happened under umbrella pigment labels. We have been able to backtrack and understand how if a pigment such as Sinopic red ochre or *Paraetonium* came to be known first, whenever another, very similar pigment was found in another place, that pigment would also come to be known under the umbrella moniker of the best-known pigment of that type.

Rarely, pigments might be named after an individual associated with a pigment's discovery or manufacture (e.g., θεοδότιον and Vestorian blue). These examples find parallel with Menkheperre's glass ingots from Egypt—revealing a nomenclature trend for materials with a long tradition. Other pigments were named after (or at least inspired by) their color *(rubrica*, *atramentum, purpurissum*). Importantly, however, some of these pigments had a unique name for the material, which was not identical to a term for a color (e.g., *atramentum*, *purpurissum*).

The four principal authors who focus on pigments, Theophrastus, Vitruvius, Pliny, and Dioscorides were all interested in the natural history of these pigments—what these pigments were like, their color, and their applicability. Part of

[43] The term stems from ἡ τρύξ, which was new, unfermented wine or wine with the lees in it (Lewis and Short 1889, 822; Reinach 1921, 10 n. 2). Dioscorides discussed only the medical properties of τρύξ (Dioscorides 5.114).

what made these discussions of pigments compelling was their stories. Pliny and his colleagues had an implicit question as they shared the background for each pigment—do you know why a pigment is called *Theodotion, minium,* or *anulare*? Not to worry, there is a story! In this vein, it was unusual to have a case where a pigment's name was unrecorded, such as the unnamed vegetal yellow recorded by Vitruvius that could approximate the color of Attic yellow ochre. This can be contrasted with the black *indigo* mentioned by Pliny—he knew the pigment's name, but not what it was. The name itself was worthy of being remembered and included in his inventory.

Pigment names in ancient Rome were not merely academic and something that belonged in an encyclopedic treatment such as Pliny's—these were names that were used regularly as documented in texts reflecting daily life. It is worth considering: did every patron necessarily know (or need to know) all the names for the pigments? Perhaps not. Think of Plato (not a patron perhaps but the ultimate academic) who was considering (in a simile) if a statue should have been painted with purple instead of black.

> "So it is just as if we had painted a statue and someone approached us and criticized it because we were not applying the most beautiful color to the most beautiful part of the image. For the eyes, the most beautiful part, had been painted not with purple dye (ὀστρείῳ), but black" (Plato Respublica 420d, trans. Emlyn-Jones and Preddy (2013)).

In this case, Plato used the correct term for murex purple (ὄστρεον) and not the color term. But in some cases, it is possible that a patron or even an artist approached at least their painting thinking of only the color before they thought what materials, what pigments, would be needed. Three examples from Roman Egypt come to mind. The first is an artist's rough draft on a wood panel from Tebtunis, Egypt (140–160 A.D.), where an artist left notes around the sketch of the portrait as to how it was to be painted (Fig. 6) (Phoebe Apperson Hearst Museum of Anthropology, Berkeley, Inv. 6–21378a verso; Walker and Bierbrier 1997, 122–123; Fournet 2004; Becker 2021).[44] One area of the portrait needed to be painted purple and was marked as such with a note instructing where the color should go, using the partially preserved term πορφύ[ρα]. Without an accompanying adjective, it seems most likely that this purple also refers to murex purple (Bogensperger 2017). In this case, it seems that the painter was specific about their pigment and called it by its name. However, elsewhere on this panel the instructions were less specific. The instructions stated, "she wears a green necklace". The color is described as διά | Χληρον. Susan Walker and

Figure 6 Rough draft sketch on a wooden panel with instructions to the artist, 140 – 160 A.D. Phoebe Apperson Hearst Museum of Anthropology, Berkeley, and the Regents of the University of California, Inv. 6–21378a; Infrared reflectography image conducted by Salvant et al. 2018. Image courteously shared by M. Walton.

Morris Bierbrier noted that "the qualifying word διά meaning either completely or interspersed with 'green'." A general color term for green was used (χλωρός) but a specific pigment was clearly not stated. Presumably the decision was left to the artist who knew which green would best suit the medium, budget, and desired look for the composition. Further, the fragmentary inscription stated that the eyes should be painted with "two pigments" but did not specify which pigments (Walker and Bierbrier 1997, 123, although note that Fournet does not read the term "colors" (χρωμα) but "golds" (χρυσᾶ) (Fournet 2004, 97).

A papyrus preserves an account about the painter Theophilos of Alexandria (ca. 255 B.C.). Theophilos outlined to the overseer Zenon painting that he proposed to do for the house of Diotimos (P.Cair. Zen. III.59445; Nowicka 1979 and Nowicka 1984).[45] Theophilos had submitted a drawing of the work and in this text outlined that a picture rail would be

[44] I thank Caroline Cheung for pointing out this portrait to me.

[45] For the text, see http://papyri.info/ddbdp/p.cair.zen;3;59445.

painted in purple ([κυ]μάτιον περιπόρφυρον) and indicated that elsewhere there would be a multicolored band (θρᾶνος ποικίλος). Perhaps Theophilos did not need to concern the patron about which pigments or even colors would be used, describing just a multicolored area and stopping only to list the purple. In a fragmentary papyrus documenting other work of Theophilos, where he was painting in the encaustic style, a fragmentary invoice of Theophilos's supplies has survived (P.Cair. Zen. 4 59767; Nowicka 1979).[46] In this invoice, Theophilos is precise about the materials that he used, "bowls of Sinopic red ochre" (μίλτου Σιν[ωπικῆς κρατῆρες), "black" (μέλανος), "glue" and "wax of Bousiris". When it was time for this artist to work, the precise names of materials were useful for accounting purposes. As in the example from Plato and in the case of the artist's rough draft, more precision about materials was offered because it connected to a specific product.[47] Think back to the house at Aventicum, where five different whites were utilized in one room. Knowing how to tell an anular chalk from an Eretrian white from a Cimolian earth (the latter used in the dye industry) would have had clear utility—especially when it is time to paint a wall and five different white pigments would be used for their distinctly different properties (e.g., differing in covering strength, tone, luminosity).

In such a situation, keeping track of pigment nomenclature offered manifold practical advantages. Further, the prices of Roman pigments would have offered incentives to keep track of these pigments, especially in so far as these prices are tied to material differences in a pigment's application, color, and other properties (Becker 2020). If *Paraetonium* costs over 8 *denarii* a pound, but Melian earth only one quarter of a *denarius*, surely there would have been incentives for keeping track of the difference and pigment names would have facilitated this (Pliny Naturalis Historia 35.18). Keeping track of pigment type, generally, was important for obtaining the particular qualities that an artist desired. However, since one type of Melian white was not useful for painting, there would have been utility in keeping track of such differences. In this case, we might think about the labeled cinnabar vase from Corinth or think of the lead tags from the related dye industry. Inscribed lead tags found in many areas of western Europe were likely created to help Roman dyers keep track of garments they were tasked to dye. Such tags show a robust color vocabulary, capable of naming a number of colors that were beyond simple, generic color terms. These tags documented colors such as *caeru(leus)*, but also *caesius* (grey), *coccineus* (scarlet), *ferrugineus* (iron grey), *purpureus,* and a likely *topas (i)us* (green-blue) (Radman-Livaja 2013, 93-95; Becker 2021). Calling a product by a specific name, so that you can get what you hope, was important in the dye industry, too.

So, what is in a name? It would certainly be useful to understand the difference between cinnabar (mercury sulfide) and Indian cinnabar, and that is true whether you were a painter, a perfumer, a cosmetic maker or a druggist. In this light, it is fruitful to think about Pliny's caution with the product names of medical ingredients. Pliny believed that doctors made sure they knew the names of medical ingredients (e.g., like pigments) but did not really know anything beyond the names (Pliny Naturalis Historia 34.25). Pliny stated that doctors "obey (or even trust) the names" (*parent nominibus*) of the drugs without question and thus "were ignorant". Such doctors, then, could make mistakes if they did not know how the real product was supposed to look or behave. Such doctors were judging the drugs by their names (a book by its cover)—and thus might not catch an adulteration or might mistake *minium* for *minium secundarium*. Such mistakes in medicine could have more amplified consequences than making the same mistake when painting.

Twice this study has explicitly discussed Pliny's concern for names. On the one hand, Pliny carefully delineated the different ways that perfumes could be named—and this served as a template for understanding the ways that the pigments discussed in this study were named. And now, we learn of Pliny's concern that learning a name alone is not enough—that it is necessary to know the name and what it meant. And thus, clearly, Pliny would not have agreed with Shakespeare's Romeo—"What's in a name? that which we call a rose by any other name would smell as sweet" (Romeo and Juliet 2.2.46-47). Pliny would not hazard to treat the natural world so casually. For him there is a rigorous set of categories and types that is backed up by a rationalist outlook. This explains that if the world can be categorized and rationalized, a more orderly engagement with the objects of the natural world is possible.

What stands out here is that pigment nomenclature provided a handle, one which helped to sort through a variety of similarly hued materials, so that the artist or patron could find (in a robust market) the material desired. But for Pliny the name was one part of the handle—as there were other qualities about each product (the color, the texture, the weight, the price) that marked each material as unique (Becker 2020). The need for these distinct names served to distinguish between products in a landscape that was increasingly crowded. Whether the consumer sought to purchase a particular type of marble, perfume, or even pigment, the specifity of these labels, especially those which especially favored provenance, potentially would have helped more informed choices to be made.

Thus, pigment nomenclature reviewed herein served two practical purposes. The first is how such a naming system

[46] http://papyri.info/ddbdp/p.cair.zen;4;59767

[47] David Wharton, considering the variety of colors that were used on the aforementioned lead tags, discussed the utility of an extensive vocabulary for such workmen. He stated, "one wonders that the workers in these trades likely had an even more robust and detailed color vocabulary for describing their materials, processes, and products which never percolated up to the literary productions of wealthy Romans" (Wharton 2020, 285).

helped to aid ancient peoples in an academic understanding of their world, serving to describe what they may not know, providing a fixed name, and identifying what a material is and why it was called that. For quotidian use, such names were helpful and necessary, too. An artisan or a doctor wanted to find particular materials for practical purposes—they want to use this material to paint, dye, heal, make scents. Does having a name help to find the right material (i.e., to distinguish Lemnian ochre from Lemnian earth) so that an artisan can create what they want?

Ultimately, this study has shown that pigment names are not just names—pigment nomenclature provides a path and framework for understanding what painters understood about their natural world and their materials and how they used these pigments.

Data and materials availability Data sharing is not applicable to this article as no new data were created or analyzed in this study.

Code availability Not applicable

Declarations

Conflicts of interest The author declares no competing interests.

References

Aceto M (2021) The palette of organic colourants in wall paintings. Archaeol Anthropol Sci. https://doi.org/10.1007/s12520-021-01392-3

Amyx DA (1958) The Attic Stelai: Part III. Vases and Other Containers. Hesperia 27(3):163–254

André J (1949) Etude sur les termes de couleur dans la langue latine. Librairie C. Klincksieck, Paris

Anthony JW, Bideaux RA, Bladh KW, Nichols MC (1990) Handbook of Mineralogy. Mineral Data Publishing, Tucson

Arizzi A, Cultrone G (2021) Mortars and plasters – How to characterise hydraulic mortars. Archaeol Anthropol Sci. https://doi.org/10.1007/s12520-021-01404-2

Aufrère S (1991) L'univers minéral dans la pensée égyptienne. Institut français d'archéologie orientale du Caire, Le Caire

Augusti S (1961) Sui colori degli antichi: il purpurissum. Rendiconti della Accademia di Archeologia Lettere e Belle Arti XXXVI:123–130

Augusti S (1967) I Colori Pompeiani. De Luca, Rome

Bailey KC (1929) The elder Pliny's chapters on chemical subjects, part I. E. Arnold & Co., London

Bailey KC (1932) The elder Pliny's chapters on chemical subjects, part II. E. Arnold & Co., London

Baines J (1985) Color terminology and color classification: ancient Egyptian color terminology and polychromy. Am Anthropol 87: 282–297. https://doi.org/10.1525/aa.1985.87.2.02a00030

Barceló P (2006) Minius. In: Antiquity volumes edited by Cancik H, Schneider H, English edition by Salazar CF, Classical tradition volumes edited by Landfester M, English edition by Gentry FG. Brill's New Pauly. Consulted online on 25 September 2020. https://doi.org/10.1163/1574-9347_bnp_e805540

Béarat H, Fuchs M (1996) Analyses physico-chimiques et minéralogiques de peintures murals romaines d'Aventicum. Bulletin de l'Association Pro Aventico 38:35–51

Beck LY (2017) De materia medica by Pedanius Dioscorides. Olms-Weidmann, New York

Becker H (2020) Grading for color: Pliny's hierarchy of pigment quality. In: Anguissola A, Grüner A (eds) Materiality in Pliny the Elder's Natural History. Brepols, Turnhout, pp 194–200

Becker H (2021) Color technology and trade. In: Biggam C, Wolf K (eds.) and Wharton D (editor of the antiquity volume). Cultural History of Color, volume I. Bloomsbury, London, pp 35-48.

Becker H (n.d.) Commerce in color: the mechanics of the Roman pigment trade. Manuscript in preparation

Beeston R, Becker H (2013) Investigation of Ancient Roman Pigments by Portable X-ray Fluorescence Spectroscopy and Polarized Light Microscopy. In Armitage RA, Burton J (eds) Archaeological Chemistry VIII, American Chemical Society Symposium Series. American Chemical Society, Washington, D.C, pp 19–41

Berlin B, Kay P (1991) Basic color terms: Their universality and evolution. University of California Press, Berkeley

Blakolmer F (2004) Colour in the Aegean Bronze Age: From Monochromy to Polychromy. In: Cleland L, Stears K, Davies G (eds) Colour in the Ancient Mediterranean World. BAR Publishing, Oxford, pp 61–67

Blom-Böer I, Warburton DA (2019) The Composition of the Colour Palette and the Socio-Economic Role of Pigments Used in Egyptian Painting. In: Thavapalan S, Warburton DA (eds) The Value of Colour. Material and Economic Aspects in the Ancient World. Edition Topoi, Berlin, pp 231–255

Bogensperger I (2017) Purple and its Various Kinds in Documentary Papyri. In: Gaspa S, Michel C, Nosch M-L(eds) Textile Terminologies from the Orient to the Mediterranean and Europe, 1000 BC to 1000 AD. Zea Books, Lincoln, NE, pp 235–249

Bradley M (2009) Colour and Meaning in Ancient Rome. Cambridge University Press, Cambridge

Brecoulaki H (2006) Considérations sur les peintres tétrachromatistes et les colores austeri et colores floridi: l'économie des moyens picturaux contre l'emploi des matériaux onéreux dans la peinture ancienne. In: Rouveret A, Dubel S, Naas V (eds.) Couleurs et matières dans l'Antiquité. Textes, techniques et pratiques. Rue d'Ulm, Paris, pp 29–42

Brecoulaki H (2014) Precious colours in ancient Greek painting and polychromy: material aspects and symbolic values. Révue Archéologique 1:1–36. https://doi.org/10.3917/arch.141.0003

Bruno VJ (1977) Form and Color in Greek Painting. W. W. Norton, New York

Bryan BM (2010) Pharaonic Painting through the New Kingdom. In: A Companion to Ancient Egypt, edited by Lloyd AB. Wiley-Blackwell, Chichester, pp 990–1007

Bryan BM (2016) The ABCs of painting in the mid-eighteenth dynasty terminology and social meaning. In: Ritner RK (ed) Essays for the Library of Seshat: Studies Presented to Janet H. Johnson on the Occasion of Her 70th Birthday. The Oriental Institute of the University of Chicago, Chicago, pp 1–26

Burgio L (2021) Pigments, dyes and inks – their analysis on manuscripts, scrolls and papyri. Archaeol Anthropol Sci. https://doi.org/10.1007/s12520-021-01403-3

Burke B (1999) Purple and Aegean Textile Trade in the Early 2nd Millennium B.C. In: Betancourt PP, Karageorghis V, Laffineur R, Niemeier W-D (eds) Meletemata: Studies in Aegean Archaeology Presented to Malcolm H. Wiener as he enters his 65th year. University of Texas at Austin, Austin, pp 75–82

Caley ER, Richards JF (1956) Theophrastus on stones: Introduction, Greek text, English translation, and commentary. Ohio State University, Columbus, Ohio

Cannata M (2020) Three hundred years of death: The Egyptian funerary industry in the Ptolemaic period. Brill, Boston

Cardon D (2007) Natural dyes – sources, tradition, technology and science. Archetype, London

Caroselli M, Ruffolo SA, Piqué F (2021) Mortars and plasters – How to manage mortars and plasters conservation. Archaeol Anthropol Sci. https://doi.org/10.1007/s12520-021-01409-x

Cavallo G, Riccardi MP (2021) Glass-based pigments in painting. Archaeol Anthropol Sci (https://doi.org/10.1007/s12520-021-01453-7)

Cavassa L, Delamare F, Repoux M (2010) La fabrication du bleu égyptien dans les Champs Phlégréens à l'époque romaine. In: Chardron-Picault P (ed) Actes du colloque sur l'artisanat romain-Autun, septembre 2007, Revue archéologique de l'Est. 28e supplement. RAE, Dijon, pp 235–249

Ceci M, Becker H (2020) Uso dei colori e scelta dei pigmenti nel mondo romano. In: Sampaolo V, Giulierini P, Coralini A (eds) Picta Fragmenta. La Pittura Vesuviana. Una Rilettura. National Archaeological Museum, vol 2018. Naples, Italy, September 12th-16th, vol. Silvana Editoriale, Milan, pp 421–427

Chapman SL (2017) The embalming ritual of Late Period through Ptolemaic Egypt. University of Birmingham, Dissertation.

Colinart S (2001) Analysis of inorganic yellow colour in ancient Egyptian painting. In: Davies WV (ed) Colour and painting in ancient Egypt. British Museum Press, London, pp 1–21

Colombo L (1995) I colori degli antichi. Nardini, Florence

Corcoran LH (2016) The Color Blue as an 'Animator' in Ancient Egyptian Art. In: Goldman RB (ed) Essays in Global Color History: Interpreting Ancient Spectrum. Gorgias Press, Piscataway, NJ, pp 41–63

Crawford MH, Reynolds JM (1979) The Aezani Copy of the Prices Edict. ZPE 34:163–210

Croisille J-M (1985) Pline l'Ancien. Histoire naturelle. Livre XXXV. Les Belles Lettres, Paris

DeLaine J (2021) Production, transport and on-site organisation of Roman mortars and plasters. Archaeol Anthropol Sci. https://doi.org/10.1007/s12520-021-01401-5

Delamare F (2013) Blue Pigments: 5000 years of art and industry. Archetype, London

Domingo Sanz I, Chieli A (2021) Characterising the pigments and paints of prehistoric artists. Archaeol Anthropol Sci. https://doi.org/10.1007/s12520-021-01397-y

Donkin RA (1977) Spanish red: an ethnogeographical study of cochineal and the Opuntia cactus. American Philosophical Society, Philadelphia

Eastaugh N, Walsh V, Chaplin T, Siddall R (2008) Pigment Compendium: A Dictionary and Optical Microscopy of Historic Pigments. Elsevier, Burlington

Emlyn-Jones CJ, Preddy W (2013) Plato. Republic: Volume 5. Books 1-5. Harvard University Press, Cambridge, Mass

Ergenç D, Fort R, Varas-Muriel MJ, Alvarez de Buergo M (2021) Mortars and plasters – How to characterise aerial mortars and plasters. Archaeol Anthropol Sci. https://doi.org/10.1007/s12520-021-01398-x

Foss C (2000) Map 86 Paphlagonia. In: Talbert RJA (ed) Barrington atlas of the Greek and Roman world: map-by-map directory. Princeton University Press, Princeton, pp 1217–1225

Fournet J-L (2004) Deux textes relatifs à des couleurs. In: Harrauer H, Pintaudi R (eds) Gedenkschrift Ulrike Horak (P. Horak). 2 vols. Gonnelli, Florence

Frison G, Brun G (2016) Lapis lazuli, lazurite, ultramarine 'blue', and the colour term 'azure' up to the 13th century. JAIC 16:41–55

Gettens RJ, Feller RL, Chase WT (1993) Vermilion and Cinnabar. In: Roy A (ed) Artists' pigments, A handbook of their history and characteristics, vol 2. Archetype Publications, London, pp 159–182

Gettens RJ, FitzHugh EW (1993) Malachite and green verditer. In: Roy A (ed) Artists' pigments, A handbook of their history and characteristics, vol 2. Archetype Publications, London, pp 183–202

Gliozzo E (2007) Supplying Italy with black and white pigments. In: Papi E, Bonifay M (eds) Supplying Rome and the Empire: the Proceedings of an International Seminar Held at Siena-Certosa di Pontignano on May 2-4, 2004, on Rome, the Provinces, Production and Distribution. Journal of Roman Archaeology, Portsmouth, R.I., pp 72–84

Gliozzo E (2021) Pigments –Mercury-based red (cinnabar-vermilion) and white (calomel) and their degradation products. Archaeol Anthropol Sci. https://doi.org/10.1007/s12520-021-01402-4

Gliozzo E, Burgio L (2021) Pigments –Arsenic-based yellows and reds. Archaeol Anthropol Sci. https://doi.org/10.1007/s12520-021-01431-z

Gliozzo E, Ionescu C (2021) Pigments –Lead-based whites, reds, yellows and oranges and their alteration phases. Archaeol Anthropol Sci. https://doi.org/10.1007/s12520-021-01407-z

Gliozzo E, Pizzo A, La Russa MF (2021) Mortars, plasters and pigments - Research questions and sampling criteria. Archaeol Anthropol Sci. https://doi.org/10.1007/s12520-021-01393-2

Gordon W (2019) How a brand name becomes generic. Pass the Kleenex, please. New York Times. June 24, 2019. https://www.nytimes.com/2019/06/24/smarter-living/how-a-brand-name-becomes-generic.html

Granger F (1934) Vitruvius. On architecture, volume II: Books 6-10. In: Harvard University Press, Cambridge, MA

Hall AJ, Photos-Jones E (2008) Accessing past beliefs and practices: the case of Lemnian Earth. Archaeometry 50(6):1034–1049

Harris JR (1961) Lexicographical Studies in Ancient Egyptian Minerals. Akademie Verlag, Berlin

Healy JF (1987) The language and style of Pliny the Elder. In: Della Corte F (ed) Filologia e forme letterarie, Studi offerti a Francesco della Corte volume, vol 4. Università degli studi di Urbino, Urbino, pp 3–25

Hodgkinson AK (2019) Manufacturing Colourful Glass Objects in New Kingdom Egypt: A Spatial and Statistical Analysis. In: Thavapalan S, Warburton DA (eds) The Value of Colour. Material and Economic Aspects in the Ancient World. Edition Topoi, Berlin, pp 125–176

Hope CA, Kucera P, Smith J (2010) Alum exploitation at Qasr el-Dakhleh in the Dakhleh Oasis. In: Ikram S, Dodson, A (eds) Beyond the Horizon: Studies in Egyptian Art, Archaeology and History in Honour of Barry J. Kemp, vol. 1, Supreme Council of Antiquities Press, Cairo, pp 165–179

Kakoulli I (2009) Greek Painting Techniques and Materials from the Fourth to the First Century BC. Archetype, London

Knapp CW, Christidis GE, Venieri D, Gounaki I, Gibney-Vamvakari J, Stillings M, Photos-Jones E (2021) The ecology and bioactivity of some Greco-Roman medicinal minerals: the case of Melos earth pigments. Archaeol Anthropol Sci. https://doi.org/10.1007/s12520-021-01396-z

König R, Brodersen K, Bayer K (1978) Naturkunde: lateinisch- deutsch 35. Buch XXXV Farben, Malerei, Plastik. Heimeran: Munich

Kron J (2012) Food production. In: Scheidel W (ed) The Cambridge Companion to the Economic History of the Roman World. Cambridge University Press, Cambridge, pp 156–174. https://doi.org/10.1017/CCO9781139030199.011

Kropff A (2016) An English translation of the Edict on Maximum Prices, also known as the Price Edict of Diocletian. Version 2.1. Published online: https://www.academia.edu/23644199/New_English_translation_of_the_Price_Edict_of_Diocletianus (accessed April 15, 2019)

Kuhlmann KP (2002) The 'Oasis Bypath' or the issue of desert trade in pharaonic times. Tides of the Desert – Gezeiten der Wüste. Contributions to the Archaeology and Environmental History of

Africa in Honour of Rudolph Kuper. Africa Praehistorica 14. Heinrich-Barth-Institut, Cologne, pp 125–170
Kunzelman D (2008) Sui pigmenti bianchi. OPD Restauro 20:100–120
La Russa MF, Ruffolo SA (2021) Mortars and plasters - how to characterise mortars and plasters degradation. Archaeol Anthropol Sci. https://doi.org/10.1007/s12520-021-01405-1
Lancaster LC (2021) Mortars and plasters – How mortars were made. The literary sources. Archaeol Anthropol Sci. https://doi.org/10.1007/s12520-021-01395-0
Le Fur D (2019) Les pigments dans la peinture égyptienne. In: Pigments et colorants de l'Antiquité et du Moyen Âge: Teinture, peinture, enluminure, études historiques et physico-chimiques. CNRS Éditions, Paris, pp 181–188
Lee L, Quirke S (2000) Painting materials. In: Nicholson PT, Shaw I (eds) Ancient Egyptian materials and technology. Cambridge University Press, Cambridge, pp 104–120
Liddell HG, Scott R (1889) An intermediate Greek-English lexicon. Clarendon Press, Oxford
Lucas A, Harris JR (2012) Ancient Egyptian Materials and Industries. E. Arnold, London
Mastrotheodoros GP, Beltsios KG, Bassiakos Y (2021) Pigments –iron-based red, yellow and brown ochres. Archaeol Anthropol Sci (forthcoming)
Mazzocchin GA, Orsega EF, Baraldi P, Zannini P (2006) Aragonite in Roman wall paintings of the VIII(a) Regio, Aemilia, and X(a) Regio, Venetia et Histria. Ann Chim 96(7-8):377–387
Morel JP (1983) Les producteurs de biens artisanaux en Italie à la fin de la République. In Les bourgeoisies municipales italiennes aux IIe et Ier siècles av. J.-C., Centre Jean Bérard, Institut français de Naples, 7-10 décembre 1981. Institut français, Naples, pp 21–39
Morris EF (2018) Ancient Egyptian imperialism. John Wiley & Sons, Hoboken, NJ
Murat Z (2021) Wall paintings through the ages. The medieval period (Italy, 12th-15th century). Archaeol Anthropol Sci. https://doi.org/10.1007/s12520-021-01410-4
Nicholson PT (2012) "Stone... That flows:" faience and glass as man-made stones in Egypt. Journal of Glass Studies 54:11–23
Nicholson PT, Jackson CM, Trott KM (1997) The Ulu Burun glass ingots, cylindrical vessels and Egyptian glass. J Egypt Archaeol 83: 143–153
Nicola M, Mastroppolito C, Masic A (2016) Iron Oxide-Based Pigments and Their Use in History. In: Faivre D (ed) Iron Oxides. From Nature to Applications. Wiley-VCH, Weinheim, pp 545–565
Nowicka M (1979) La peinture dans les papyrus grecs. Translated by Wolf J. Archeologia 30:21–28
Nowicka M (1984) Théophilos, peintre alexandrin, et son activité. In: Bonacasa N, di Vita A (eds) Alessandria e il mondo ellenisticoromano: Studi in onore di Achille Adriani, vol 2. Bretschneider, Rome, pp 256–259
Osbaldeston TA and Wood, RPA, trans. (2000) Dioscorides de materia medica: being an herbal with many other medicinal materials. Ibidis, Johannesburg.
Pagès-Camagna S, Colinart S (2003) The Egyptian green pigment: its manufacturing process and links to Egyptian Blue. Archaeometry. 45(4):637–658. https://doi.org/10.1046/j.1475-4754.2003.00134.x
Panagiotaki M, Tite MS, Maniatis Y (2015) Egyptian Blue in Egypt and beyond: The Aegean and the Near East. In: Kousoulis P, Lazaridis N (eds) Proceedings of the Tenth International Congress of Egyptologists, University of the Aegean, Rhodes, 22-29 May 2008 Vol. II Orientalia Lovaniensia Analecta. Peeters, Leuven, pp 1769–1789
Panayiotou G (1990) Paralipomena Lexicographica Cyranidae. Illinois Classical Studies 15(2):295–338
Pastoureau M (2001) Blue: the history of a color. Princeton University Press, Princeton
Pérez-Arantegui J (2021) Not only wall paintings – Pigments for cosmetics. Archaeol Anthropol Sci. https://doi.org/10.1007/s12520-021-01399-w
Photos-Jones E, Knapp CW, Venieri D, Christidis GE, Elgy C, Valsami-Jones E, Gounaki I, Andriopoulou NC (2018) Greco-Roman mineral (litho)therapeutics and their relationship to their microbiome: The case of the red pigment *miltos*. J Archaeol Sci Rep 22:179–192
Pittau M (2009) Dizionario comparativo latino-etrusco. EDES, Sassari.
Pulak C (1998) The Uluburun shipwreck: an overview. Int J Naut Archaeol 27(3):188–224
Quillien L (2015) Le manteau pourpre de Nabuchodonosor. Étude des circulations économiques de la laine pourpre en Mésopotamie au Ier millénaire avant J.-C. Hypothèses 18(1):105–118
Rackham H (1952) Pliny. Natural history. Books XXXIII-XXXXV. Harvard University Press, London
Radman-Livaja I (2013) Craftspeople, merchants or clients? the evidence of personal names on the commercial lead tags from Siscia. In: Gleba M, Pásztókai-Szeőke J (eds) Making Textiles in Pre-Roman and Roman Times: People, Places, Identities. Ancient Textiles Series, vol 13. Oxford Books, London, pp 87–108
Reger G (2010) Formation of Taste and Fashion. Perfumes and Imitations in the Hellenistic and Early Imperial World. Marburger Beiträge zur Antiken Handels. Wirtschafts- Und Sozialgeschichte 28:21–44
Rehren T (2001) Aspects of the production of cobalt-blue glass in Egypt. Archaeometry 43:13–24. https://doi.org/10.1111/1475-4754.00031
Reinach A (1921) Textes grecs et latins relatifs à l'histoire de la peinture ancienne: recueil Milliet. Tome I. Klincksieck, Paris
Romano E (2003) Il lessico latino dei colori: il punto sulla situazione. In: Beta S, Sassi MM (eds) I colori nel mondo antico. Esperienze linguistiche e quadri simbolici. Atti della giornata di studio, Siena, 28 marzo, vol 2001. Gamma, (Florence) Fiesole, pp 41–53
Russell B (2013) The economics of the Roman stone trade. Oxford University Press, Oxford
Salvadori M, Sbrolli C (2021) Wall paintings through the ages. The Roman period: Republic and early Empire. Archaeol Anthropol Sci. https://doi.org/10.1007/s12520-021-01411-3
Salvant J, Williams J, Ganio M, Casadio F, Daher C, Sutherland K, Monico L, Vanmeert F, De Meyer S, Janssens K, Cartwright C, Walton M (2018) A Roman Egyptian painting workshop: technical investigation of the portraits from Tebtunis, Egypt. Archaeometry 60(4):815–833. https://doi.org/10.1111/arcm.12351
Schaefer G (1941) The cultivation of madder. CIBA Review 39:1398–1406
Sciuti S, Fronterotta G, Vendittelli M, Longoni A, Fiorini C (2001) A Non-Destructive Analytical Study of a Recently Discovered Roman Wall Painting. Stud Conserv 46(2):132–140. https://doi.org/10.2307/1506843
Senning A (2019) The Etymology of Chemical Names. Tradition and Convenience vs. Rationality in Chemical Nomenclature. De Gruyter, Berlin
Shaw GJ (2014) The Egyptian myths: a guide to the ancient gods and legends. Thames & Hudson, London
Shortland AJ (2012) Lapis lazuli from the kiln: glass and glassmaking in the Late Bronze Age. Leuven University Press, Leuven
Siddall R (2006) Not a day without a line drawn. Pigments and painting techniques of Roman Artists. Infocus magazine: Proceedings of the Royal Microscopical Society 2:18–31
Siddall R (2018) Mineral pigments in archaeology: their analysis and the range of available materials. Minerals 8(5)201
Švarcová S, Hradil D, Hradilová J, Čermáková Z (2021) Pigments – copper-based greens and blues. Archaeol Anthropol Sci. https://doi.org/10.1007/s12520-021-01406-0
Swiderek A (1957-1958) Deux papyrus de la Sorbonne relatifs à des travaux effectués dans des temples de l'Héracléopolite. Journal of Juristic Papyrology 11-12:59–91

Thavapalan S (2019) Stones from the Mountain, Stones from the Kiln: Colour in the Glass Texts from Ancient Mesopotamia. In: Thavapalan S, Warburton DA (eds) The Value of Colour. Material and Economic Aspects in the Ancient World. Edition Topoi, Berlin, pp 177–199

Thavapalan S (2020) The meaning of color in ancient Mesopotamia. Brill, Leiden

Thiboutot G (2020) Egyptian Blue in Romano-Egyptian Mummy Portraits. In: Cartwright C, Svoboda M (eds) Mummy Portraits of Roman Egypt: Emerging Research from the APPEAR Project. J. Paul Getty Museum, Los Angeles, pp 139–161

Thompson RC (1936) Dictionary of Assyrian chemistry and geology. Clarendon Press, Oxford

Ventris M, Chadwick J, Wace AJB (2015) Documents in Mycenaean Greek: three hundred selected tablets from Knossos, Pylos and Mycenae with commentary and vocabulary. Cambridge University Press, Cambridge

Vitti P (2021) Mortars and masonry - Structural lime and gypsum mortars in Antiquity and middle ages. Archaeol Anthropol Sci. https://doi.org/10.1007/s12520-021-01408-y

von Rosen L (1988) Lapis lazuli in geological contexts and in ancient written sources. Åström, Partille

Wachsmann S (2013) The Gurob ship-cart model and its Mediterranean context. Texas A & M University Press, College Station

Walker S, Bierbrier M (1997) Ancient Faces: Mummy Portraits from Roman Egypt. British Museum Press, London

Warburton DA (2008) The Theoretical Implications of Ancient Egyptian Colour Vocabulary for Anthropological and Cognitive Theory.Lingua Aegyptia 16:213-259

Warburton DA (2016) Ancient Color Categories. In: Luo MR (ed) Encyclopedia of Color Science and Technology. Springer, New York, NY. https://doi.org/10.1007/978-1-4419-8071-7_75

Ward GWR (ed) (2008) Sinopia. The Grove Encyclopedia of Materials and Techniques in Art. Oxford University Press, Oxford, pp 603–604

Wharton D (2016) Abstract and Embodied Color in Pliny the Elder's Natural History. In: Short W (ed) Embodiment in Latin semantics. John Benjamins Publishing Company, Amsterdam, pp 177–208

Wharton D (2020) Prestige, color, and color language in imperial Rome. In: Ierodiakonu K, Derron P (eds) 66e Entretiens sur l'Antiquité classique de la Fondation Hardt. Psychologie de la couleur dans le monde gréco romain – Colour Psychology in the Graeco-Roman World. Fondation Hardt, Geneva, pp 271–308

Wood JR, Yi-Tang H (2019) An Archaeometallurgical Explanation for the Disappearance of Egyptian and Near Eastern Cobalt-Blue Glass at the end of the Late Bronze Age. Internet Archaeology 52. https://doi.org/10.11141/ia.52.3