Farmers into Sailors: Ship Maintenance, Greek Agriculture, and the Athenian Monopoly on Kean Ruddle (*IG* II^2 1128)

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A RIDDLE of long-standing is posed by *IG* II^2 1128. This fragmentary fourth-century B.C. Athenian inscription records parts of decrees passed by three Kean *poleis* requiring that they export their μίλτος exclusively to Athens.[1] *Miltos*—ruddle or red ochre—consisted essentially of red iron oxides, but often mixed with earth, sand, clay, or other impurities.[2] As a primary pigment it had manifold uses in

[1] Detailed commentary, with text and English translation, can be found at Rhodes/Osborne, *GHI* 40. Still particularly useful is J. Vélissaropoulos, *Les nauclères grecs: recherches sur les institutions maritimes en Grèce et dans l'Orient hellénisé* (Geneva 1980) 184–189 (translation and commentary) and 344–345, no. 7 (text). Little subsequent to Rhodes/Osborne is essential, but a thorough discussion, with additional bibliography, is in A. Carrara, *La fiscalité des échanges extérieurs dans le monde grec (Égypte exclue) du VI^e siècle à la conquête romaine* (diss. Bordeaux 2011) I 247–268 (with text and translation). The inscription is now in the Athens Epigraphic Museum (inv. 7570). Its lettering and political context suggest a date in the period between the Athenian settlement imposed on Iulis in 363/2 (*IG* II^2 111) and 350 B.C. For the argument that these measures amount to punishment after the Kean revolt and should date to 362 or soon thereafter see A. Giovannini, *Les relations entre états dans la Grèce antique* (Stuttgart 2007) 299–300 (brief commentary) and 320–321, no. C6 (partial translation). For a concise summary of historical context and political developments at Keos during this period see Rhodes/Osborne on *GHI* 39.

[2] On the nature and varieties of *miltos* see E. R. Caley and J. F. C. Richards, *Theophrastus On Stones* (Columbus 1956) 172–173, 176–180; on red ochres more generally, C. Fuller, "Natural Colored Iron Oxide Pigments," in P. A. Lewis (ed.), *Pigment Handbook*^{2} (New York 1988) I 281–286.

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antiquity.[3] Theophrastus suggests that Kean *miltos* was of unusually high quality, a fact confirmed by modern investigation.[4] Relying on scant literary references, Johannes Hasebroek held that Athens' interest in Kean *miltos* reflects the fact that it was "indispensable in the painting of triremes," without, however, suggesting why.[5] He was followed by a host of scholars, who often assume that *miltos* played a vital role in waterproofing or preserving ships.[6] That theory seemingly has been discredited.[7] There is no explicit evidence that Athens

[3] For *miltos* in the ancient sources see W. Kroll, "Minium," *RE* 15 (1931) 1848–1854, at 1851–1853; H. Blümner, *Technologie und Terminologie der Gewerbe und Künste bei Griechen und Römern* IV (Leipzig 1887) 478–482.

[4] Theophr. *De lap.* 52; E. Photos-Jones, A. Cottier, A. J. Hall, and L. G. Mendon, "Kean Miltos: The Well–Known Iron Oxides of Antiquity," *BSA* 92 (1997) 359–371.

[5] *Trade and Politics in Ancient Greece* (London 1933) 141. Similar reasons are advanced by E. Ziebarth, *Beiträge zur Geschichte des Seeraubs und Seehandels* (Hamburg 1929) 66, 72, 132.

[6] E.g. F. Heichelheim, "Monopole," *RE* 16 (1933) 147–199, at 156; H. Michell, *The Economics of Ancient Greece*[2] (Cambridge 1957) 103–104; M. M. Austin and P. Vidal–Naquet, *Economic and Social History of Ancient Greece* (London 1977) 117 and 295–297, no. 86 (partial translation); R. J. Hopper, *Trade and Industry in Classical Greece* (London 1979) 60, 174; Vélissaropoulos, *Nauclères* 188–189; M. H. Crawford and D. Whitehead, *Archaic and Classical Greece: A Selection of Ancient Sources in Translation* (Cambridge 1983) 530, no. 282; F. Meijer and O. van Nijf, *Trade, Transport and Society in the Ancient World: A Sourcebook* (London 1992) 34–35, no. 47; V. Gabrielsen, *Financing the Athenian Fleet: Public Taxation and Social Relations* (Baltimore 1994) 140; C. M. Reed, *Maritime Traders in the Ancient Greek World* (Cambridge 2003) 47.

[7] Hasebroek's theory is rejected already by Tod (*GHI* II 162, p.185), who notes the multiplicity of attested ancient uses for ruddle, but fails to address Hasebroek's key point that none of these other uses can have been of strategic interest to Athens (on which see below). More compelling arguments are advanced by J. F. Cherry, J. L. Davis, and E. Mantzourani, "*Miltos* and Metallurgical Extraction," in *Landscape Archaeology as Long-Term History: Northern Keos in the Cycladic Islands from Earliest Settlement until Modern Times* (Los Angeles 1991) 299–303, at 300. These are adopted, expanded, or elaborated especially by Robin Osborne, "The Economy and Trade," in *CAH Plates to Volumes V and VI* (1994) 97, "Religion, Imperial Politics,

ever used *miltos* to paint or otherwise maintain her triremes. Furthermore, it is pitch that made ancient wooden hulls watertight and nothing suggests that *miltos* could have served any necessary purpose in sealing or preserving the hulls of triremes.[8] Finally, Athens already had local sources of ochres, especially from the mines at Laurion.[9] The current consensus

and the Offering of Freedom to Slaves," in V. Hunter and J. Edmondson (eds.), *Law and Social Status in Classical Athens* (Oxford 2000) 75–92, at 86–89 (repr. with additional comments, *Athens and Athenian Democracy* [Cambridge 2010] 229–243), and likewise the commentary on Rhodes/Osborne, *GHI* 40.

[8] For the argument that Kean *miltos* can have served no necessary naval purpose, see Cherry et al., *Northern Keos* 300. Michell, *Economics* 103, suggests that perhaps it was "mixed with some poisonous compound such as red mercuric sulphide" and thus used as biocidal paint, but fails to explain why *miltos* itself should have been necessary. More recently, it is claimed that the "biocidal properties" of *miltos* "must have been known to ancient shipbuilders" who used it for "anti-fouling as well as colouring": M. C. Lentini, D. Blackman, and J. Pakkanen, "The Shipsheds of Sicilian Naxos: A Second Preliminary Report," *BSA* 103 (2008) 299–366, at 349. But red ochre is universally described as non-toxic and I can find no scientific evidence to suggest that *miltos* would have had any biocidal properties. T. T. Katsaros suggests as much, but the experiment he attempted, which submerged variously treated and untreated wood in the sea for only a period of seven days (the length given at *Od.* 10.80–81 for Odysseus' voyage from Aeolus to the land of the Laestrygonians!) is entirely insufficient, not least because Katsaros erroneously assumes that *miltos* is, in fact, *minium* (Pb_3O_4, lead oxide or 'red lead'): "The Redness of Ulysses' Ships: A Case of Aesthetics or an Application of Mycenaean Maritime Technology?" in S. A. Paipetis (ed.), *Science and Technology in Homeric Epic* (Berlin 2008) 385–389. Nevertheless, red ochre is well known as a pigment in durable paints like the traditional mixtures of ruddle and cod liver or seal oil especially familiar from Newfoundland and Labrador, and it seems a reasonable assumption that any paint, whether it included *miltos* or not, would, at least in the short term, offer better protection than bare wood.

[9] Red ochres were available at Laurion but yellow ochre was abundant and of especially high quality (see Caley and Richards, *Theophrastus* 173–174). An efficient process of manufacturing red from yellow ochre is mentioned by Theophrastus (*De lap.* 53) and described by Pliny *HN* 35.35: *rubrica autem nascitur et in ferrariis metallis. ea e<t> fit ochra exusta in ollis novis luto*

can be summarized by Rhodes and Osborne, who conclude that "even allowing for the higher quality of Cean ochre, it is hard to see any functional necessity for Athenian import of ochre from Ceos."[10]

Here I argue that the scarce literary evidence for the use of *miltos* in marine applications offers even less reliable testimony than many previous discussions assume, and yet Hasebroek's theory remains the likeliest explanation for the Athenian monopoly.[11] That would be true even in the absence of additional evidence. But a range of overlooked archaeological evidence proves that ruddle was used more widely in ship maintenance than our literary sources might suggest. Furthermore, this evidence indicates that *miltos* was not used merely as a pigment in decorative paints, but seems to have been considered useful for the proper maintenance of hulls. Finally, I

circumlitis. quo magis arsit in caminis, hoc melior, "[Red ochre/*rubrica*] is also manufactured from ochre burnt in new ceramic vessels sealed with clay. The more thoroughly it is heated in the kilns, the better its quality." The quality of red ochre that resulted depended also on the iron content of the yellow. Given the reputation of Attica's yellow ochres it should have been possible to manufacture a high quality red. But Theophrastus claims that the process was invented by a certain Kydias (*De lap.* 53; Caley and Richards, *Theophrastus* 181–182). If this is the same artist whom Pliny names as a contemporary of Euphranor (*HN* 35.130), whose *floruit* he places in the late 360s (35.128), the process may not have been widely known when *IG* II² 1128 was inscribed. On the other hand, the account Theophrastus gives of Kydias' chance discovery is a familiar and scarcely believable kind of tale, whereas, given that ochres were used for pottery washes already during the Archaic period (see below), it is safe to assume that the basic conversion of yellow to red would have been known much earlier than the 360s.

[10] Rhodes/Osborne, *GHI* p.280.

[11] Carrara, *Fiscalité* I 252, argues that Athens' interventions amount to conditions of monopsony, where a market is dominated by a single buyer, rather than monopoly, where multiple buyers meet a single seller. But Athens is not acting as either buyer *or* seller, and here I follow common practice in using the term 'monopoly' in a more general sense of 'exclusive control'.

argue that this belief can be explained by evidence suggesting that Greek farmers attempted to protect against rot and especially woodboring larvae by applying *miltos*—sometimes mixed specifically with pitch—to the roots or trunks of vines and trees. This evidence reflects general notions about both the causes of decomposition and the properties of *miltos*. While red ochre may *in actual fact* have served no necessary strategic purpose, the epigraphic, archaeological, and literary evidence is sufficient not only to suggest that Athenians believed that Kean *miltos* played a vital role in the maintenance of their fleet but also to explain why.

Ancient sources, modern theories

On the basis of *IG* II² 1128 it is hard to avoid the deduction that Athens believed it had a vital interest in Kean ruddle. It is clear that the Kean decrees, while showing local variations and reflecting "a degree of flexibility," are orchestrated by Athens.[12] The Athenian decree(s) that led to the motions on Keos must have been moved and discussed in the council and the assembly at Athens, and compelling public arguments must have been offered for why these measures were in Athens' interest. In sending ambassadors and in eventually inscribing a record on the acropolis, the city bore real costs, and even if most of these devolved onto the Keans a limited regulatory burden remained in place. Furthermore, the Athenians were clearly intent on ensuring that the entire supply of Kean ruddle arrived at Athens, and *only* at Athens, with the city even taking pains to contract designated ships for its transport and fixing the cost of freight at a reasonable rate of an obol per talent.[13] Likewise, penalties and enforcement

[12] Rhodes/Osborne, *GHI* pp.206, 209; more recently, P. Low, *Interstate Relations in Classical Greece: Morality and Power* (Cambridge 2007) 87–89.

[13] Lines 12–14: ἐξάγειν ἐμ πλοίωι ὧι [ἂν Ἀθηναῖοι ἀποδείξωσιν, ἐν ἄλλωι] δὲ πλοίωι μηδενί, ναῦλλον δὲ τελεῖν ὀβολὸν τοῦ [ταλάντου ἑκάστου τοῖς ναυκλήροις τοὺ]ς ἐργαζομένους. Parallels are adduced by Vélissaropoulos, *Nauclères* 188–189. Carrara, *Fiscalité* I 159–161, proposes to restore τοῦ [στατῆρος for Boeckh's τοῦ [ταλάντου but the argument, al-

mechanisms are severe.

Previous to Hasebroek scholars had suggested that Athens was interested in Kean ruddle for its manifold commercial uses, or specifically to be used in the production of the city's distinctive pottery.[14] It seems that in the Archaic and Classical periods Athenian potters did use ochres both for washes and

though elaborate, is not persuasive. Smaller units of measure used to retail *miltos* have nothing to do with how merchants would have charged freight or measured the tonnages of their ships (on which see H. T. Wallinga, "Nautika (I): The Unit of Capacity for Ancient Ships," *Mnemosyne* 17 [1964] 1–40). A *naul(l)on* of one obol per talent would give a shipping cost of more than 800 drachmas for a modest-sized ship of 5000 talents capacity, fully loaded. This might represent a small fraction of the value of the cargo but for such a short journey by sea it is a considerable sum. A *naulon* of an obol per stater would result in absurdly high shipping costs. Finally, anticipating the argument that there could exist a ready correlation between amphoras and talents, Carrara suggests we have no evidence that *miltos* was shipped in amphoras. But remains of Late Archaic and Classical amphoras used to store *miltos* have been recovered from the Athenian Agora and in ship sheds recently excavated on Naxos: M. L. Lawall and A. Jawando, "Notes from the Tins 2: Research in the Stoa of Attalos," *Hesperia* 71 (2002) 415–433, at 416–419; Lentini et al., *BSA* 103 (2008) 349–350. Amphoras and other large ceramic vessels are known to have been used to transport processed minerals and dyes. See I. Radic-Rossi, "The Mljet Shipwreck, Croatia: Roman Glass from the Sea," *Minerva* 16.3 (2005) 33–35, for the large ovoid jars and conical amphoras containing powdered *minium* and probably *alum* discovered in a first-century A.D. Roman shipwreck off the coast of Croatia.

[14] That these decrees served commercial interests at Athens is argued already by August Boeckh, *Die Staatshaushaltung der Athener*[3] (Berlin 1886) II 315–316, whom Hasebroek characterizes all subsequent scholarship as following (*Trade and Politics* 141). For the notion that Athens aimed to protect specifically her ceramics trade see e.g. P. Gardner, "Coinage of the Athenian Empire," *JHS* 33 (1913) 147–188, at 152–153; C. T. Seltman, *Athens: Its History and Coinage before the Persian Invasion* (Cambridge 1924) 13 (suggesting that Athenian interest in Kean ruddle developed with its Archaic pottery trade); J. V. Noble, *The Techniques of Attic Painted Pottery* (New York 1965) 61 (ruddle decrees intended "to insure an uninterrupted supply which was essential for the pottery industry").

in glazes.[15] But, as argued persuasively by Hasebroek, strictly commercial interests of any kind are unlikely,[16] and concerted efforts to protect the pottery 'industry' especially so.[17] The known public uses of *miltos* at Athens—such as to stain the rope used to round up crowds for the assembly—can hardly be described as vital to the public interest, would not have required anything close to the quantities of ruddle available from Keos' apparently productive mines,[18] and could, it seems, have easily been accomplished with local supplies. Hasebroek pointed instead to a passage in the Old Oligarch

[15] For the use of *miltos* (and also yellow ochre, which would turn red when fired) in washes: G. M. A. Richter, *The Craft of Athenian Pottery* (New Haven 1923) 53–59; Noble, *Techniques* 60–61. For glazes: M. Farnsworth and H. Wisely, "Fifth Century Intentional Red Glaze," *AJA* 62 (1958) 165–173.

[16] *Trade and Politics*, esp. 140–142. While recent scholarship has challenged Hasebroek on any number of points (see e.g. A. Bresson, *L'économie de la Grèce des cités* [Paris 2007–2008] II 72–97), his broader observations about the nature of civic decrees and their relationships to commerce remain valid; on this same point and specifically with respect to *IG* II^2 1128 see T. J. Figueira, *The Power of Money: Coinage and Politics in the Athenian Empire* (Philadelphia 1998) 232.

[17] Recent research has only reinforced the conclusions of historians such as Austin and Vidal-Naquet, who note that Athenian pottery production was "always small scale" and carried out by artisans in a social class marginal to the polis (*Economic and Social History* 114–115). For Athenian pottery not as a primary item of trade but as 'free riders' see D. W. J. Gill, "Pots and Trade: Spacefillers or *objets d'art*?" *JHS* 111 (1991) 29–47, and Bresson, *L'économie* II 167–170. For a remarkable analysis of the scale and organization of production see P. Sapirstein, "Painters, Potters and the Scale of the Attic Vase-Painting Industry," *AJA* (forthcoming). Sapirstein shows that during its Late Archaic and Early Classical height of production the industry employed only approximately 200 potters, painters, and assistants, and by the late fifth century this number had decreased by at least half.

[18] For the archaeological evidence see Photos-Jones et al., *BSA* 92 (1997) 360, and in greater detail, Cherry et al., *Landscape Archaeology* 300–303 (with references); specific mines are attested by Theophr. *De lap.* 52 and Hsch. s.v. μιλτωρυχεῖα. For the ruddle-stained rope used at Athens see Ar. *Eccl.* 378–379 (with schol.) and *Ach.* 21–22.

(2.11–12) that famously treats Athens' interest in securing from abroad supplies of materials considered necessary for building and maintaining her fleets, and concluded that "ruddle belongs precisely to the class of shipbuilding materials mentioned … and for that reason alone were the Athenians interested in it."[19] The closest parallels for the Kean measures likewise suggest strategic, and especially naval, interests.[20]

But of course the Old Oligarch does not name *miltos*. Indeed, literary evidence for the use of *miltos* on ships of any kind is decidedly slight, and what exists is perhaps less than it seems. The Homeric epics twice employ the epithet μιλτοπάρῃοι, "ruddle-cheeked," to describe ships stained with red ochre.[21] With perhaps the exception of a single passage in Herodotus, all subsequent references to ships and *miltos* depend on Homer.[22] Herodotus' claim in the context of the Samians' raid on Siphnos that "long ago *all* ships were stained

[19] *Trade and Politics* 141.

[20] See Vélissaropoulos, *Nauclères* 188–189, and Gabrielsen, *Financing the Athenian Fleet* 139–141, the latter concluding that "the main difficulty with which Athens had to cope seems not to have been lack of funds, public or private, to maintain the fleet, but acute, short-term shortage of supplies" (141). Related measures probably included bans on export of strategic naval materials like the ἀσκώματα (leather bags frequently included in the naval inventories), sailcloth, and pitch mentioned as contraband by Aristophanes (*Ran.* 362–364) as well as treaties providing for supplies of naval necessities like Macedonian oars. An alliance between Athens and Perdiccas during the Peloponnesian Wars stipulates that these oars (and probably also pitch, but the inscription is damaged) will be exported exclusively to Athens (*IG* I^3 89.31).

[21] *Il.* 2.637, *Od.* 9.125. A second epithet, φοινικοπάρῃοι, is used in the *Odyssey*, perhaps also to describe ships stained with red ochres (11.124, 23.271; Hsch. s.v. μιλτοπάρῃοι).

[22] In addition to the scholia, lexica, and commentaries to Homer, see e.g. Plin. *HN* 33.115; *Suda* s.v. μιλτοπάρῃαι νῆες; Hsch., s.v. μιλτόπρωρος. The paucity of literary evidence has been discussed by S. Lawrence, "*Miltopareoi*: Miltos and the Painting of Greek Ships," APA Annual Meeting, 2004 (abstract at http://apaclassics.org/images/uploads/documents/abstracts/lawrence.pdf).

with *miltos*" (τὸ δὲ παλαιὸν ἅπασαι αἱ νέες ἦσαν μιλτηλιφέες, 3.58) is often taken as good evidence for sixth-century B.C. practice.[23] But Herodotus obviously cannot have known in what fashion *all* ships had been painted, and his use of ἅπασαι is probably better taken as implying that in the latter half of the fifth century the practice of coating ships with red ochre was notably restricted. In that case it is possible that he has in mind a typically Athenian practice and is anticipating critics by suggesting that the practice had once been general. This would still support Hasebroek's argument. But Herodotus' remark could as easily depend on his most influential model, Homer. The historian intends to explain for his readers an oracle (3.57) that warned the Siphnians to guard against "a wooden host" (ξύλινόν τε λόχον, i.e. the fleet of the Samians) and "a red messenger" (κήρυκά τ' ἐρυθρόν, i.e. a painted ship). As the later grammarians frequently note, the Homeric epics use μιλτοπάρῃοι only of Odysseus' ships,[24] and we might imagine a kind of game, with Herodotus both successfully (de)coding an allusion to Homeric epic and further anticipating the objection that *miltos* is associated in those poems only with the fleet of Odysseus.

Or perhaps Herodotus preserves historical details and the Samians' ships really were painted with *miltos.* Even so, the literary sources would offer at best slender evidence, insufficient either to show that the use of *miltos* in naval applications was known at Athens in the Classical period or to suggest why it might have been considered useful, let alone strategically vital. Yet the existence of an Athenian monopoly on Kean ruddle remains. In the face of that puzzling fact, historians can perhaps be excused for seeking creative explanations. Osborne, for example, suggests that Kean *miltos* may well have served no necessary purpose: "It is possible that the regulation was in fact a gratuitous imposition intended to make Athenian politi-

[23] See most recently Carrara, *Fiscalité* I 254 n.1099.

[24] E.g. schol. *Il.* 2.637; Apollonius *Lex. Homericum* s.v. μιλτοπάρῃοι.

cal control felt."[25] That view is restated even more forcefully by Rhodes and Osborne, who describe Athens' actions as "extremely high-handed," with "[t]he worst that modern scholarship has to say on the decree … markedly understat[ing] the situation."[26] But even if Athens had reason to punish all of these Kean communities (there is no evidence that Koresia was involved in the revolts), the language of the inscription suggests that these measures were intended to restore a monopoly that had existed, at least in part, already in the past.[27] And stipulations allowing seized goods and the property of the condemned to be shared equally between informants and not Athens but the respective communities on Keos (lines 27–29 and 36–37) suggest neither hostility nor gratuitous imposition. While Osborne's theory is generally acknowledged, scholars are rightly hesitant to abandon, even in the absence of solid evidence, the more compelling hypothesis that *miltos* had naval applications.[28] Fortunately, better evidence does exist, with a range of archaeological data suggesting that *miltos* may have been widely used in ship maintenance.

Archaeological evidence for miltos and ship maintenance

In 1998 the construction of an Italian Railways building in Pisa uncovered the remains of ancient shipwrecks. It soon became clear that this was the site of an ancient harbor, and more than a decade of excavation has brought to light the remains of twenty or more vessels. Much of this material awaits publication, but results of the initial rescue excavations have

[25] Osborne, *CAH* 97.

[26] Rhodes/Osborne, *GHI* p.281.

[27] See for Koresia lines 10–12: κ]αθάπερ πρότερον ἦν· ὅπως δ' ἂν κύρια ἦι [τ]ὰ ψηφίσματα [τὰ πρότερον γεγενημένα Ἀθηναίων κ]αὶ Κορησίων τὰ περὶ τῆς μίλτου. No such language exists in the decree of Iulis, and that of Karthaia is too fragmentary to permit conclusion.

[28] E.g. B. Rutishauser, *Athens and the Cyclades: Economic Strategies 514–340 BC* (Oxford 2012) 192–194; Carrara, *Fiscalité* I 253–254.

been published in some detail.[29] Most interesting for our purposes are the remains of Ship C, a large twelve-oared vessel that likely dates to the late first century B.C. or early first century A.D.[30] It is unusually well preserved, with its hull still showing areas of red and white paint. Scientific analysis revealed the red pigment to be hematite, Fe_2O_3.[31] This is red ochre and the iron oxide most common in ancient *miltos*: hematite is the primary constituent of samples collected and analyzed from the Trypospilies mine on Keos, while also present in smaller quantities in samples collected from an open cut at Orkos.[32]

This recent evidence from Ship C at Pisa is of debatable significance for our understanding of *IG* II^2 1128. The surviving

[29] S. Bruni (ed.), *Le navi antiche di Pisa: ad un anno dall'inizio delle ricerche/The Ancient Ships of Pisa: After a Year of Work* (Florence 2000); more recently, A. Camilli, A. De Laurenzi, and E. Setari (eds.), *Pisa: un viaggio nel mare dell' antichità* (Milan 2006).

[30] See M. Bonino, "Il Gabbiano: una barca a remi di età augustea," in Camilli et al., *Pisa* 21–25. Finds from the ship suggest that it sank in the late Augustan period, or shortly thereafter. From a timber roughly inscribed with Greek letters and nailed to a table amidships, the ship is sometimes referred to as the *Alkedo* (from Latin for 'seagull').

[31] M. P. Colombini, G. Giachi, F. Modugno, P. Pallecchi, and E. Ribechini, "The Characterization of Paints and Waterproofing Materials from the Shipwrecks Found at the Archaeological Site of the Etruscan and Roman Harbour of Pisa," *Archaeometry* 45 (2003) 659–674; a brief summary, "La pittura e i trattamenti di impermeabilizzazione sullo scafo dell' *Alkedo*," in Camilli et al., *Pisa* 26–28. Of no less interest for our understanding of ancient marine technology, but less directly relevant to the argument here, is that the white paint was primarily cerussite, or white lead, widely attested over the *longue durée* as a bottom paint, including in a passage of Pliny (*HN* 35.37) that I hope to return to in a note treating ancient biocidal paints (see R. R. Stieglitz, "Copper Sheathing and Painting with Orpiment at Elephantine Island," *BASOR* 336 [2004] 31–35, for the use of arsenic trisulphide, probably as a biocidal paint, on ships at Elephantine).

[32] Photos-Jones et al., *BSA* (1997) 364–366, noting that hematite is likewise the primary iron oxide in the Spanish Red mined at Rio Tinto in Helva province, Spain.

patches of red paint are above the ship's waterline, and seem to have been applied over a base of white paint. The red paint seems to have consisted of hematite mixed with beeswax and resin. Like that which was sometimes used to paint ship's eyes or bow patches, this red could be interpreted as merely decorative.[33] While it has been suggested that decorative elements on triremes might be sufficient to explain the Athenian monopoly on Kean ruddle, that argument is not very compelling.[34] On the other hand, wax seems to have been widely used in ship maintenance and Pliny reports that when used on ships encaustic paints were known to be "immune to wind and sun and salt water" (*nec sole nec sale ventisve corrumpitur*).[35] The presence of both wax and resin in the samples of red paint from Ship C could also suggest a mixture used to waterproof hulls, not unlike that which Pliny tells us the Greeks called *zopissa*.[36]

[33] On painted bow patches see L. Casson, *Ships and Seamanship in the Ancient World* (Princeton 1971) 45 n.18 (suggesting that Homer's μιλτοπάρῃοι describes these decorative elements) and 210 n.49. For the evidence for painted ship's eyes, including a growing number of examples sculpted out of marble and decorated with paints that likely include red ochre, see D. N. Carlson, "Ship's Eyes in Classical Greece," *Hesperia* 78 (2009) 347–365.

[34] See Carrara, *Fiscalité* I 254, for the suggestion that a naval application is the likeliest explanation for the Athenian monopoly "même si l'ocre rouge ne servait que de pigment." Objections are noted already by Cherry et al., *Nothern Keos* 300: numerous other decorative colors are attested, while reasonable substitutes existed for Kean ochres, and for such purposes it is hard to see why the city should feel the need to guarantee an uninterrupted supply for itself, or to deny it to potential rivals.

[35] *HN* 35.149. It should be noted that in an earlier chapter Pliny does not list *miltos* among the pigments usefully employed in encaustic paints (35.49). On such paints and the use of wax on ships more generally see Casson, *Ships and Seamanship* 211–212 nn.46–47.

[36] *HN* 16.56: *non omittendum apud eosdem zopissam vocari derasam navibus maritimis picem cum cera, nihil non experiente vita, multoque efficaciorem ad omnia quibus pices resinaeque prosunt, videlicet adiecto salis callo*, "It ought not be omitted that among them [viz. the Greeks] the term *zopissa* ['living pitch'] is employed

Better evidence for the use of *miltos* not as a decorative pigment but in maintaining the integrity of ships' hulls does exist. After Lake Nemi was drained and Caligula's massive barges recovered in the late 1920s and early 1930s, the remains of these remarkable vessels were studied in admirable detail.[37] It was discovered that the outside of the wooden hulls had been covered in a thick layer of reddish pitch. Samples were examined by S. E. Parravano. In addition to identifying pitch, rosin (a translucent resin produced by the distillation of crude resin), and perhaps a tar-like bitumen, Parravano also isolated the red pigment. A test with potassium ferricyanide clearly revealed that it contained iron. Noting that the color did not match common, or yellow, ochre, Parravano concluded that this pigment was a red iron oxide—in Italian *minio di ferro*, *colcotar*, *rossetto di ferro*, but what the Greeks called *miltos* and the Romans *rubrica*.[38]

The significance of Parravano's finding seems to have gone unnoticed. Ucelli assumed that the red pigment was added simply to color the pitch,[39] and subsequently no one seems to have made the connection between this pigment and the *miltos*

for the pitch that is scraped from marine vessels together with wax and, since life leaves nothing untried, proves to be far more efficacious for everything for which pitches and resins are used, on account of the durability added by the salt." Vegetius describes the planking of ships as coated with wax, pitch, and resin (4.44, *unctasque cera et pice et resina tabulas*). He also notes that wax, when applied to ships' hulls, was often tinted (4.37, *cera etiam, qua ungere solent naves, inficitur*). For the ancient production and uses of pitch—the resin extracted primarily from pines—a detailed study is still wanting, but for a basic introduction see R. Meiggs, *Trees and Timber in the Ancient World* (Oxford 1982) 467–471; for the ancient terms for different resins and the products produced from them (such as oils and rosins) see J. André, "La résine et la poix dans l'antiquité: technique et terminologie," *AntCl* 33 (1964) 86–97.

[37] G. Ucelli, *Le navi di Nemi*[2] (Rome 1950).

[38] Ucelli, *Le navi* 179–180.

[39] Ucelli, *Le navi* 153.

of Herodotus and the Athenian monopoly at Keos.[40] There is little reason to believe that *miltos* was employed on the Nemi ships primarily as a pigment. The pitch it colored was used only on the outside of the hulls. After its application it was immediately covered by a dense fabric of wool that was in turn covered by lead sheathing.[41] Once applied, this red ochre was never intended to be visible to anyone. For reasons that we will explore, the builders of the Nemi ships employed *miltos* not as a pigment, but because they believed it would help protect the hull from rot and infestation.

This practice was likely more widespread. The Nemi ships are a wonderfully improbable kind of accident. Their remarkable state of preservation when excavated was owed largely to their having sunk in a sheltered freshwater lake. Yet no expense was spared in their construction, which employed not only the highest quality materials but also expert shipbuilders and other skilled craftsmen. At least some of these individuals were likely members of guilds of *fabri navales* like those attested at Portus and Ostia.[42] They brought to their task methods current in the marine shipyards near Rome. Hence, even if it was known that shipworm posed no threat in freshwater, for the designer of these ships and his craftsmen that fact made little difference: these barges would be carefully sheathed in

[40] Casson, *Ships and Seamanship* 211 n.46, summarizes Parravano's findings as indicating "a coat of pitch, with perhaps some slight admixture of bitumen, plus some substance containing iron, possibly minium, as coloring matter." There is considerable confusion (in sources both ancient and modern) between *minium*, most often 'red lead', and *rubrica*, red ochre; see Kroll, *RE* 15 (1931) 1848–1854. The red substance tested by Parravano cannot have contained *minium*: a test with dilute nitric acid was negative for the presence of lead (Ucelli, *Le navi* 179). By *minio di ferro* (and *ossido riscaldato*) Parravano refers to the process of manufacturing *miltos* from common ochre.

[41] Ucelli, *Le navi* 153.

[42] These guilds are studied in detail by H. Konen, "Die Schiffsbauer und Werften in den antiken Häfen von Ostia und Portus," *MBAH* 20.2 (2001) 1–36.

lead in the same manner as other large, seagoing merchant vessels. It can likewise be assumed that the mixture of pitch and *miltos* that was used to coat the hulls of the Nemi ships reflected a recipe employed at the time in marine shipyards near Rome.[43]

None of this is good evidence for practices any earlier than the first century A.D., let alone as early as the mid-fourth century B.C. However, there is additional archaeological evidence that suggests *miltos* was used in a similar fashion already during the Classical period. In excavations of an ancient dockyard at Naxos, apparently in use in the latter half of the fifth century B.C., the excavators recovered from a number of ship sheds remains of a red pigment, identified as hematite, or red ochre, plausibly attributed to the painting or maintenance of warships.[44] Again, it is possible that this paint was purely decorative and hence of doubtful strategic significance. But here we might take note of curious evidence afforded by one of our earliest, well-preserved Greek shipwrecks, the Kyrenia ship, whose construction can be securely dated to the fourth century B.C.[45] The ship seems to have had a long life and at some point, perhaps in the last decade of the fourth century, its shipworm-riddled hull underwent extensive repairs.[46] In places

[43] Ucelli, *Le navi* 153.

[44] See Lentini et al., *BSA* 103 (2008) 349–350, where, however, the authors seem not to recognize that this hematite-rich pigment was in fact ruddle. These findings are also described in a number of other reports and conference proceedings, e.g. D. Blackman and M. C. Lentini, "An Ancient Greek Dockyard in Sicily," in A. Hafner et al. (eds.), *Die neue Sicht: Unterwasserarchäologie und Geschichtsbild* (Basel 2006) 193–197, at 197.

[45] Carbon-14 dating suggests a date for the cutting of the ship's timbers of 389 B.C. ±44: H. W. Swiny and M. L. Katzev, "The Kyrenia Shipwreck: A Fourth-Century B.C. Greek Merchant Ship," in D. J. Blackman (ed.), *Marine Archaeology* (London 1973) 339–359, at 353.

[46] See J. R. Steffy, "The Kyrenia Ship: An Interim Report on its Hull Construction," *AJA* 89 (1985) 71–101. These repairs seem to have been undertaken not long before the ship sank. Carbon-14 dates from a load of almonds (288 ±62: Swiny and Katzev, in *Marine Archaeology* 353) and a

damaged planks were covered with a thin wood veneer, and over the entire hull sheets of lead were applied with copper tacks. By the fourth century, no doubt in response to shipworm, Greek merchant ships were sometimes, like the Nemi ships, sheathed in lead (or perhaps, but far more rarely, copper), and this practice seems to have become widespread during the Hellenistic period.[47] In the Kyrenia ship this lead was not applied directly to the hull, but over a thin matting that Steffy describes as composed of "agave leaves, simply woven and saturated in a red-brown resinous pitch … A few intact areas of the outer hull surfaces also contained traces of the red-brown residue."[48] The use of matting between hull and sheathing seems to have been standard. We are told by Moschion of Phaselis that the hull of Hiero's massive freighter was sheathed in lead over fabric coated with pitch, while mattings of wool and of linen were found in the Nemi and Grand Congloué shipwrecks respectively.[49] When the use of first lead and then copper sheathing was reinvented and then widely adopted in the 17th and 18th centuries similar fabrics saturated with pitch or tar were used.[50] In the Kyrenia shipwreck the

number of coins of Demetrius Poliorcetes and Antigonus Monophthalmus suggest that the ship sank in the last decade of the fourth century or very shortly thereafter (A. J. Parker, *Ancient Shipwrecks of the Mediterranean and the Roman Provinces* [Oxford 1992] 232).

[47] See D. J. Blackman, "Further Early Evidence of Hull Sheathing," *IJNA* 1 (1972) 117–119, and Casson, *Ships and Seamanship* 209–210 and 214–216, Appendix 1. Parker, *Ancient Shipwrecks* 27, notes evidence for lead sheathing at some 57 shipwrecks, the majority of these dating to the first centuries B.C. and A.D. His catalogue includes six shipwrecks that preserve evidence of at least partial hull sheathing in copper, all dating from the fourth through the second centuries B.C.

[48] *AJA* 89 (1985) 84.

[49] *FGrHist* 575 F 1 (Ath. 5.207B): μολυβδίναις δὲ κεραμίσιν ἐπεστεγνοῦντο πρὸς τὸ ξύλον, ὑποτιθεμένων ὀθονίων μετὰ πίττης. Grand Congloué: Casson, *Ships and Seamanship* 210 n.40.

[50] J. Knowles, *An Inquiry into the means which have been taken to preserve the British Navy from the earliest period to the Present Time, particularly from that species*

mysterious "red-brown residue" that coated the matting included pitch, but Steffy's description clearly indicates that it was distinct from the remains of pitch elsewhere evident on the wreck. Unfortunately, it seems that no chemical analysis has been conducted; but red iron oxides were the predominant red pigment in use in the Classical and Hellenistic periods, and given the evidence that we have surveyed it is likely that the repairers of the Kyrenia ship attempted to protect its badly shipworm-eaten hull both by adding lead sheathing and also by coating it with a mixture of pitch and *miltos*.[51]

of decay now denominated Dry-Rot (London 1821) 136–137. Lead sheathing is attested in Spain already in the 16th century (I. Lunn, *Antifouling: A Brief Introduction to the Origins and Development of the Marine Antifouling Industry* [Thame 1974] 8), and in England during the 17th (J. R. Harris, "Copper and Shipping in the Eighteenth Century," *Economic History Review* 19 [1966] 550–568, at 551–552 n.2). It proved remarkably effective at preventing shipworm but galvanization caused by the sheathing badly damaged iron fastenings. A similar problem occurred when copper sheathing was widely adopted by the Royal Navy in the late 18th century, and the problem was only finally solved by replacing iron with newly developed copper fastenings (Harris 552–560). In Classical and Hellenistic ships fastenings are typically of copper as are the tacks used to attach lead sheathing. It is perhaps no accident that the use of iron nails and fastenings increases in the third century A.D. (and eventually becomes standard) only after lead sheathing seems to have gone out of use in the second (Parker, *Ancient Shipwrecks* 27).

[51] It is possible that the choice of matting used with the hull sheathing could have been influenced by similar concerns, but any such speculation would require a more precise identification than "agave leaves," since agave is a New World genus. In a more recent account S. W. Katzev describes it somewhat differently as a "reed–like matting": "The Ancient Ship of Kyrenia, Beneath Cyprus Seas," in P. Valavanis and D. Hardy (eds.), *Great Moments in Greek Archaeology* (Oxford 2007) 286–299, at 292. Pliny describes the use of certain reeds in making ships watertight, but he seems to describe a woody plant that was pounded up and used to caulk seams (*HN* 16.158). If by "agave" Steffy has in mind succulent-like leaves, it is perhaps worth noting that various passages of the *Geoponika* cited below suggest that σκίλλα (usually sea squill, *Drimia maritima*, syn. *Scilla maritima*)

Such mixtures are known. They are possibly attested at fourth-century Athens: an account from Eleusis recording a payment for the transport of pitch and *miltos* (as well as wedges and black pigment) need not imply that the two commodities were used together,[52] but another fourth-century Athenian inscription, this one attesting repairs to the city's long walls, seems to attest pitch together with *miltos* and perhaps also a mixture of the two, μιλτόπισσα.[53] This is perhaps slender evidence, but such mixtures are also well attested in our sources pertaining to a very different, but culturally predominant, context—agriculture. The agricultural writers suggest that Greek farmers regularly mixed *miltos* with pitch or other substances and applied it to the trunks and roots of trees and vines, and that they did so for reasons that would have applied equally well to problems of ship maintenance. As such they are sufficient to demonstrate the second, more challenging part of this argument, which aims not just to show that *miltos* was used in ship maintenance but also to suggest why.

Farmers into sailors: miltos and traditional Greek agriculture

Admittedly much of the crucial evidence that follows is preserved only in the *Geoponika,* a Byzantine farming manual. But this anthology incorporates material from a wide range of ancient sources.[54] Pertinent evidence for the use of *miltos* is

was thought by farmers to be effective in preventing woodboring infestations.

[52] *IG* II² 1672.15–16 (329/8 B.C.): τῶι ἀπαγαγόντι τοὺς σφῆνας καὶ τὴν πίττ[α]ν καὶ τὴν μελαντηρίαν καὶ τὴν μίλτον Ἐλευσῖ(νάδε) Διοκλείδαι μισθὸς ⋮ΓΗΗΙΙΙ.

[53] While the relevant line is badly worn and the usual caution concerning square brackets is advisable, the restoration printed by Kirchner (aided by the fact that the inscription is stoichedon) gives good sense (*IG* II² 463.90 [307/6 B.C.]): καὶ [πίτ]τε[ι] καὶ μί[λτωι] καὶ μ[ιλτοπ]ίττ[ε]ι? ὡς ἕκαστα ἁρμ[όττει – – –].

[54] M. Decker, *Tilling the Hateful Earth: Agricultural Production and Trade in the Late Antique East* (Oxford 2009) 263–271; E. Lelli, *L'agricoltura antica* I *Geoponica di Cassiano Basso* (Soveria Mannelli 2010) xxvi–lxxxiii; A. Dalby,

found in passages attributed to four different agricultural writers whose own works seem to have largely compiled even earlier material, while additional or indirect evidence for the same or related practices can be gleaned from a range of authors both Greek and Latin. Recent research on ancient agriculture (and the *Geoponika* specifically) might challenge a portrait of Greek agriculture that is essentially timeless and unchanging,[55] but even nuanced accounts paying special attention to innovation and change proceed from the unavoidable premise that such change occurred against a backdrop of deeply rooted beliefs and practices.[56] The uses of *miltos* seem to belong firmly to that body of ancient, traditional practice.

A good starting point is a chapter in Book 10 of the *Geoponika* attributed to Florentinus.[57] It is accompanied by the heading *On how to prevent trees and vines from being harmed by worms or anything else* (Πρὸς τὸ μήτε δένδρα, μήτε ἀμπέλους, ὑπὸ σκωλήκων ἢ ἑτέρου τινὸς βλάπτεσθαι), and it recommends, in part, smearing a ruddle paste on trees' roots.[58] A second passage from Book 10 and ascribed to Leontinus encourages treating fig trees infested with scab by making a similar paste and smearing it on their trunks.[59] Scab (ψώρα) was popularly

Geoponika: Farm Work (Totnes 2011) 9–14.

[55] E.g. J. Banaji, *Agrarian Change in Late Antiquity: Gold, Labour, and Aristocratic Dominance* (Oxford 2001); Decker, *Tilling the Hateful Earth*.

[56] See Bresson, *L'économie* I 169–182.

[57] Little is know about this important agricultural writer. He wrote in Greek a *Georgika* in at least eleven books, probably in the first half of the third century A.D.: E. Oder, "Beiträge zur Geschichte der Landwirthschaft bei den Griechen," *RhM* 45 (1890) 58–98 and 212–222, at 83–87; Lelli, *L'agricoltura antica* I lii–lv. This work drew heavily on a Hellenistic tradition that is largely lost (Decker, *Tilling the Hateful Earth* 265).

[58] 10.90.1: μίλτον Λημνίαν καὶ ὀρίγανον μεθ' ὕδατος λειώσας τὰς ῥίζας ἄλειφε, καὶ σκίλλαν κύκλῳ περιφύτευσον, "Smear on the roots Lemnian ruddle and oregano made into a paste with water, and plant around squill."

[59] 10.50: τὴν ψωριῶσαν συκῆν θεραπεύσεις, σκίλλαν ὑποφυτεύων παρὰ τὰς ῥίζας, ἢ μίλτον ὕδατι διείς, καὶ περιχρίων τὸ πρέμνον, "You will heal a

conceived of as the result of an imbalance between wet and dry, and Theophrastus discusses fig scab as among the plant diseases caused by too much moisture.[60] Similar thought is reflected in another passage in the *Geoponika*. Attributed to Didymus,[61] it concerns the timely planting and care of figs (Περὶ καιροῦ φυτείας σύκων, καὶ ἐπιμελείας), noting that "too much water damages the natural health of the figs, causing them to easily rot" (10.45.4, τὸ γὰρ πολὺ ὕδωρ λυμαίνεται τὸ φύσει κάλλος τῶν σύκων, καὶ ῥαδίως σήπεσθαι αὐτὰ ποιεῖ). That concern best explains a subsequent observation that in the care of fig trees "some apply to their roots ash, but others *miltos*" (10.45.10, τινὲς τέφραν, ἄλλοι δὲ μίλτον ἐπιβάλλουσι ταῖς ῥίζαις). A similar practice is attested by Latin authors such as Columella, who suggests diluting ruddle with olive-oil lees and human feces and placing it around the roots.[62]

fig-tree afflicted with scab either by planting around its roots squill, or by making a paste of ruddle and water and smearing it around the trunk." The identity of this Leontinos (or Leontios or Leon) is uncertain. More than a dozen passages are attributed to him in the *Geoponika* (Oder, *RhM* 45 [1890] 80; Lelli, *L'agricoltura antica* I lvi–lvii).

[60] Theophr. *Caus.pl.* 5.9.9–10 treats various diseases of trees and vines caused by too much water (πολυδρία), among them fig scab (ὡς ἐπὶ τὸ πολὺ δ' ἐκ τῶν τοιούτων συμβαίνει συκῇ μὲν ψωριᾶν). He notes in a subsequent chapter (5.9.12) that "some" think it is owed to a different cause (the occurrence of a light rain at the rising of the Pleiades); so too at *Hist.pl.* 4.14.5.

[61] Little is known about the Alexandrian Didymus, but he perhaps lived toward the end of the fourth century A.D. His *Georgika* was in fifteen books and chiefly compiled earlier material: M. Wellmann, "Didymus (7)," *RE* 4 (1895) 445; Oder, *RhM* 45 (1890) 213–222; Lelli, *L'agricoltura antica* I xlvii–xlix.

[62] *De arbor.* 21.2: *semper proderit, simul ac folia agere coeperit ficus, rubricam amurga diluere et cum stercore humano ad radicem infundere; ea res efficit uberiorem fructum et fartum fici speciosius et plenius*. Similarly *Rust.* 5.10.10 and Plin. *HN* 17.256. These lees (ἀμόργη in Greek, *amurga/amurca* in Latin) are not the pressed olives themselves but primarily the bitter water that is pressed out together with the oil, settling below it.

A final passage from the *Geoponika*, this one attributed to Paxamus,[63] attests the practice of protecting trees from ants by mixing *miltos* with pitch and applying it to their trunks.[64] Pliny attests the same practice.[65] Columella treats infestations of larvae and ants together when describing how best to prevent damage after pruning (*Rust.* 4.24.6):

> *neque est difficile mox alleuatas plagas terra, quam prius amurga madefeceris, linere: nam et teredinem formicamque prohibet, solem etiam et pluuias arcet eiusmodi litura, propter quae celerius coalescit et fructum viridem conseruat.*
>
> And it is not at all difficult to apply earth, first moistened with olive-oil lees, immediately to the smoothed-off wounds. For a paste of this sort keeps out the teredo and the ant, and also protects it from sun and rain, allowing the wound to heal more quickly and keeping the fruit vigorous.

Columella does not specifically call for the use of ruddle, *rubrica*:[66] where Greek writers suggest using ruddle, Columella

[63] The same passage notes that ants will not go near an open jar of honey if white wool is placed around it or if it is encircled with a line of white earth or *miltos* (13.10.8). Paxamus is apparently the same author mentioned by Athenaeus (9.376D) and the *Suda* (s.v. Πάξαμος). He seems to have written during the first century B.C.: W. Morel, "Paxamos," *RE* 18 (1949) 2436–2437; Lelli, *L'agricoltura antica* I.1 lix–lx.

[64] 13.10.15: εἴρξεις τοὺς μύρμηκας χολὴν ταυρείαν καὶ πίσσαν μετὰ ἀμόργης μίσγων, καὶ χρίων τὸ πρέμνον. τὸ αὐτὸ ποιεῖ καὶ μίλτος καὶ πίσσα μιγνυμένη καὶ ἐπιχριομένη, "You will fend off ants by mixing pitch and bull's bile with olive-oil lees, and applying it to the trunk. *Miltos* mixed with pitch and applied to the tree accomplishes the same."

[65] *HN* 17.266: *sunt arborum pestes et formicae. has abigunt rubrica ac pice liquida perunctis caudicibus, nec non et pisce suspenso iuxta in unum locum congregant aut lupino trito cum oleo radices linunt.*

[66] It is possible that for his mixture of earth and *amurca* Columella had in mind not just any earth, but *terra rubrica*. Columella chiefly uses *rubrica* to describe a kind of ruddle-rich soil (*Rust.* 3.11.10; so too Varro *Rust.* 1.9.2; Plin. *HN* 17.25, 17.33), which is especially suitable for crops like beans (*Rust.* 2.10.4; so too Cato *Agr.* 34.2; Plin. *HN* 18.135, 18.163). He otherwise notes the use of ruddle primarily in marking vines or trees to indicate those that are most productive for later grafting and in order to preserve their

follows Cato in preferring olive-oil lees.[67] As with woodboring larvae, trees were thought to be made more susceptible to ants if exposed to too much moisture, encouraging rot. It was commonly thought that many such woodborers were generated within the wood itself and *caused by* rot. Theophrastus, for example, says that the genesis of grubs is caused by decomposition, or *sepsis*.[68]

Columella's notice is more important for our purposes in that it suggests the essential nexus between agricultural and maritime practice. The term Columella uses to describe terrestrial woodborers, *teredo*, is borrowed from the Greek τερηδών. This word is sometimes used specifically of shipworm (which is not a worm at all but a marine mollusk), "the principal enemy of wooden-hulled ships in Mediterranean waters."[69] Other

orientation when replanted (*Rust.* 5.6.20, 5.9.3, 5.9.8; *De arbor.* 2.1, 17.4, 20.2; so too Cato *Agr.* 115.2). These uses are also attested in two passages in the *Geoponika* (3.12, 9.11). Columella similarly notes that ruddle can be used for marking bees (*Rust.* 9.8.8).

[67] Pliny noted how Cato extolled *amurga* for its manifold uses (*HN* 15.33–34), some of which find close parallels in uses elsewhere attested for *miltos* or *rubrica*, such as for treating ulcers of the mouth (*HN* 35.32).

[68] *Caus.pl.* 5.9.3. Theophrastus further argues that "acrid trees are least susceptible to grubs, not only because they resist decomposition, but also because their pungency hinders their genesis" (5.9.4, ἥκιστα δὲ σκωληκοῦται τὰ δριμέα, οὐχ ὅτι ἄσηπτα μόνον, ἀλλ' ὅτι καὶ ἡ δριμύτης κωλύει ζῳογονεῖν). Olive wood, especially that of the bitter wild olive, was considered particularly resistant and perhaps for that reason acrid olive-oil lees were thought to be similarly effective.

[69] J. S. Morrison, J. F. Coates, and N. B. Rankov, *The Athenian Trireme*[2] (Cambridge 2000) 186. The standard study of the many species of *Teredenidae* remains R. D. Turner, *A Survey and Illustrated Catalogue of the Teredinidae* (Cambridge [Mass.] 1966). Of those present in the Mediterranean, *Teredo navalis* is the most destructive. For a detailed study of the biology and ecology of Mediterranean shipworms see F. Roch, "Die *Teredinidae* des Mittelmeeres," *Thalassia* 4.3 (1940) 1–147; for a brief summary, A. G. Steinmayer, Jr., and J. M. Turfa, "Effects of Shipworm on the Performance of Ancient Mediterranean Warships," *IJNA* 25 (1996) 104–121, at 105–106.

Latin writers are aware of that more specific usage,[70] and Pliny acknowledges that some authors insist that it is the only correct one (*HN* 16.220). But elsewhere Pliny follows what was apparently a more common practice of using *teredo* as a general term for woodborers of all types, whether marine or terrestrial.[71]

Our Greek sources suggest a similarly broad range of usage.[72] Theophrastus is careful to note that τερηδών only exists in the sea and even describes physical differences between it and other woodborers (*Hist.pl.* 5.4.4–5). But it is just as telling that he discusses shipworm together with σκώληκες and θρῖπες, and his insistence on the correct usage acknowledges the more common one. Where shipworm and other woodborers are distinguished that distinction is merely between marine and terrestrial habitat. Otherwise they were thought to be the same or fundamentally similar in their natures, including with respect to their spontaneous genera-

[70] E.g. Ov. *Pont.* 1.1.69.

[71] He uses it most often to refer to the woodborers that with their remarkable teeth "are most suited to make a meal of wood" (*potissimumque e ligno cibatum fecit*, *HN* 11.3), but without differentiating between marine and terrestrial (16.65, 16.182, 16.189, 23.134). Certain kinds of wood, he suggests, are more susceptible to *teredo* on land, others in the sea (16.219). Elsewhere he uses *teredines* to describe not only the woodboring larvae of moths (11.65) but also those that devour textiles (8.197). On occasion it is even used of parasitic infestations of other types, such as that affecting the Pisidian iris (21.42), while emmer wheat is said to be susceptible to a little parasite "like *teredo*" (*teredini similis*, 22.121). It can even describe maggots in meat (28.264) or parasitic infestation in bee hives (21.81).

[72] LSJ s.v. τερηδών; many of the sources are discussed by Steinmayer and Turfa, *IJNA* 25 (1996) 104–121. For the common association of τερηδών with terrestrial woodborers, in addition to the passages discussed below, see e.g. the definitions in Pausanias Atticista s.v. τερηδών· σκώληξ ξυλοτρώκτης οἰκῶν ἐν ξύλῳ, likewise Hsch. s.v. Some manuscripts of Aristotle's *Historia animalium* suggest that also in Greek parasites that infest beehives were known as τερηδόνες (605b17: ἐγγίνονται δὲ καὶ κάμπαι ἐν τοῖς σμήνεσιν [ἃς καλοῦσι τερηδόνας], ἃς οὐκ ἀμύνονται αἱ μέλιτται).

tion in damp and rotting wood.[73] This larger theory of decay helps explain why when our ancient accounts touch on ship maintenance they tend to focus primarily on the importance of preventing hulls from becoming "waterlogged" (διάβροχοι, Thuc. 7.12.3).[74] While natural resistance or susceptibility to τερηδών was clearly an important consideration when choosing ship timbers (Theophr. *Hist.pl.* 5.4.4–6), and Vitruvius even suggests that the construction of shipyards should be undertaken with these destructive mollusks in mind (*De arch.* 5.12.7), shipworm was often conceived of as but one facet of a more general problem. It is only from this larger point of view —Greek conceptions of natural causes—that the range of applications for ruddle in both agricultural and nautical contexts makes sense. Ruddle was thought not only to offer resistance to woodborers but was thought more generally to have drying properties. This is reflected in Pliny's casual reference to the fact that "all ruddle is desiccative" (*omnis autem rubrica siccat*, *HN* 35.35).

These same notions are reflected in the uses prescribed in

[73] Theophrastus is aware that certain woodboring larvae are deposited, such as those of hornworm, but he nevertheless assumes that others are the product of *sepsis* (*Hist.pl.* 5.4.5). That grubs are sometimes deposited in wood was also known to Aristotle (*Hist.an.* 489b1), but far more widely attested in our sources is the popular notion that woodborers are generated spontaneously under the right conditions. Sometimes these accounts specifically mention shipworm. See e.g. Polybius' discussion of the inherent weaknesses of constitutions, for which he offers as a metaphor the spontaneous generation of shipworm and other woodborers in the presence of rot (6.10.3): ξύλοις δὲ θρῖπες καὶ τερηδόνες συμφυεῖς εἰσι λῦμαι. Likewise Plut. *Mor.* 636D1–2: σκόπει δ' ὅτι σκνῖπες ἐν δένδρῳ καὶ τερηδόνες ἐμφύονται ξύλῳ κατὰ σῆψιν ὑγρότητος ἢ πέψιν· ὧν οὐδεὶς ἂν ἀξιώσειεν μὴ προϋποκεῖσθαι μηδὲ πρεσβύτερον εἶναι φύσει τὸ γεννῶν, "Observe that insects in a tree and τερηδόνες in wood are present in proportion to the rot and decay from moisture. No one could correctly deem that what engenders them did not preexist them and is not by nature older."

[74] See Casson, *Ships and Seamanship* 89–90 n.64; Steinmayer and Turfa, *IJNA* 25 (1996) 107–108.

Greek medical texts. The properties of *miltos* are summarized by Dioscorides in the first century A.D. in his *De materia medica* (5.92). That notice is copied with a few additional details by the late but learned Aëtius:[75]

> μίλτος δύναμιν ἔχει στυπτικὴν ἐμπλαστικὴν ἀναξηραντικήν· διὸ καὶ ἐμπλάστροις τραυματικαῖς μίγνυται καὶ τροχίσκοις ξηραίνουσι καὶ στεγνωτικοῖς. ἴστησι δὲ κοιλίαν σὺν ὠοῖς τηγανιστοῖς λαμβανομένη καὶ ἐγκλυζομένη, κατάγει δὲ καὶ ἕλμινθας πινομένη.
>
> *Miltos* has properties that are astringent, binding, and drying. Accordingly it is mixed in plaster for wounds and used in pills that are desiccative and constipating. Taken with fried eggs and as an enema it checks the bowels. Taken as a drink *it even drives out worms.*

The medical uses of *miltos* reflect the same logic and the same perceived properties suggested by the agricultural writers. Not only is it generally held to be astringent, binding, and drying, but it is even considered by Aëtius to be effective against intestinal parasites, just as in other contexts against woodboring larvae, ants, and shipworm.[76] In fact, translations like "desic-

[75] *Libri medicinales* 2.5 (*CMG* VIII.1 157). Aëtius probably belongs to the late fifth or early sixth century. His entry for *miltos* for the most part duplicates that of Dioscorides, but added details include ruddle's usefulness against intestinal worms.

[76] The same basic understanding is reflected in the medical uses for ruddle described by Pliny (*HN* 35.32). While Aëtius refers to intestinal parasites as ἕλμινθες, elsewhere in the medical and veterinary writers these too are frequently τερηδόνες. See LSJ s.v. τερηδών, and for veterinary usage the various passages collected in a chapter of the Byzantine *Hippiatrika* titled Περὶ τερηδόνων (*Hipp. Berolinensia* 41 [K. Hoppe and E. Oder, *Corpus hippiatricorum Graecorum* I (Leipzig 1924)]). For the sources of the *Hippiatrika*, which, like the *Geoponika*, relies on a wide range of ancient material, see A. E. McCabe, *A Byzantine Encyclopaedia of Horse Medicine: The Sources, Compilation, and Transmission of the Hippiatrica* (Oxford 2007). In the medical writers τερηδών is also used with a distinct sense to describe caries ('tunneling' usually caused by bacteria) in the skull and other bones (e.g. Hippoc. *Morb.* 2.7); as noted by Steinmayer and Turfa, *IJNA* 25 (1996) 106, this is likely by analogy to the appearance of wood damaged by shipworm.

cative" or "constipating" are perhaps misleadingly technical: a term like στεγνωτικός derives from a common verb that can simply mean "make watertight,"[77] while a verb like ξηραίνω can as easily refer to the drying that was essential to ship maintenance.[78]

Conclusion: miltos and the Athenian fleet

A number of basic conclusions are no doubt already visible in outline. The title of this article suggests, perhaps somewhat provocatively, that the use of *miltos* in ship maintenance reflects the adaptation of traditional agricultural practices. It makes sense that the Archaic Greek farmers whom Hesiod imagines trading their agricultural surpluses by sea (*Op.* 641–694) would have applied to the problems of ship maintenance whatever limited experience they had available. But it must be acknowledged that otherwise the evidence could as easily be used to make the opposite argument that agricultural practice borrowed from maritime.[79] But for the narrower purposes of this article's arguments it makes little difference in which directions the influences ran. For farmers, rot and infestation were constant problems, and for sailors the most inexorable threat was always shipworm. The complex lifecycle of the marine mollusk was not known and there is little reason to believe that either farmers or sailors would have recognized a difference between shipworm and other woodborers. Furthermore, all such pests were conceived of as a phenomenon related to the more fundamental problem of keeping wood dry. Here it is clear that the perceived properties of *miltos* would

[77] See LSJ s.v. στεγνόω.

[78] E.g. Thuc. 7.12.5, ἀποξηρᾶναι τὰς σφετέρας (ναῦς).

[79] It has been suggested that ruddle was used in painting or maintaining ships already during the Bronze Age. Lentini et al. report that pigments (including red ochre) have been discovered in excavations at Mochlos and the port of Knossos, in buildings that they interpret as "ship sheds": *BSA* 103 (2008) 349 n.39. As far as I know this material still awaits final publication.

have been attractive in ship maintenance, whether used together with wax alone as an encaustic paint, in mixtures with wax and pitch or resin like what Pliny terms *zopissa*, or simply applied together with pitch. For those ships that were assiduously maintained—routinely hauled up and dried and freshly pitched—the addition of ruddle would perhaps even have been deemed efficacious.

Herodotus' claim that in the sixth century *all* ships were stained with *miltos* implies that by the late fifth century the practice was more restricted, but it is clear that traditional beliefs about its efficacy persisted. Whereas Hellenistic and Roman merchant ships could attempt to combat shipworm and rot both with lead sheathing and with coatings of pitch and *miltos*, only the latter was an option for Classical triremes. Sheathing added considerable weight to the hull and was therefore not a viable option for the triremes, which relied on dry, light hulls for speed and maneuverability. For these triremes shipworm posed a serious threat, a fact well known to the audience of Aristophanes, one of whose triremes in *Knights* imagines herself being "devoured by shipworm" (ὑπὸ τερηδόνων σαπεῖσ', 1308). Estimates suggest that a modest infestation of shipworm increased by at least a factor of nine the rate at which ancient triremes became waterlogged.[80] The Sicilian disaster offered a stark lesson as to the potential consequences. Nikias' letter to Athens (Thuc. 7.12) stressed how the expedition's circumstances had been made increasingly desperate, describing how, without an opportunity to beach and dry their ships (τὰς μὲν γὰρ ναῦς οὐκ ἔστιν ἀνελκύσαντας διαψύξαι), their fleet, once immaculately maintained (τὸ γὰρ ναυτικὸν ἡμῶν … τὸ μὲν πρῶτον ἤκμαζε καὶ τῶν νεῶν τῇ ξηρότητι), had become increasingly waterlogged (νῦν δὲ αἵ τε νῆες διάβροχοι), no longer a match for the properly maintained fleet of the Syracusans (ἀποξηρᾶναι τὰς σφετέρας μᾶλλον ἐξουσία). As Theophrastus notes, damage from shipworm is ir-

[80] Steinmayer and Turfa, *IJNA* 25 (1996) 112–114.

reversible (*Hist.pl.* 5.4.4), and it is not surprising that after the Athenians finally abandoned their fleet, no concerted effort was made by the Syracusans to recover these ships (Thuc. 7.74). Like the oars frequently recorded as no longer serviceable in Athenian naval inventories,[81] these ships were probably too badly worm-eaten to be salvaged.

In the fourth century there seem to have existed at Athens efficient mechanisms for maintaining the city's fleet.[82] Triremes were carefully inspected by designated *dokimastai* and graded according to the condition of their hulls.[83] It was the responsibility of each trierarch to return his ship at the end of his term of office in the same working condition, with exceptions allowed only for damage due to battle or storm. With their triremes subject to careful inspection, and themselves personally liable for any damage, trierachs were, given the immense sums required to replace a hull, powerfully incentivized to guard against shipworm.[84] Given the overall size of the fleet, assiduous attention to routine maintenance must have required large quantities of commodities like pitch. These materials are typically not recorded in the inventories. But an inventory of 330/29 B.C. happens to record miscellaneous stores and includes entries for various types and quantities of a substance designated ὑπαλοιφή (*IG* II^2 1627.313–317):

> ὑπαλοιφὴ ἐμ φιδακνίωι μέλαινα· ἑτέρα ἐν ἀμφορεῖ μέλαινα· ἑτέρα λευκὴ ἐμ φιδακνίωι· ἐν ἀμφορεῦσι δυοῖν λευκή·
>
> *Hypaloiphe* in a cask, black; another kind in an amphora, black; another white kind in a cask; in two amphoras, white.

[81] E.g. ἀδόκιμοι κῶπαι in *IG* II^2 1604 (377/6 B.C.), at lines 3, 11, 12, etc.; for the suggestion that these oars were shipworm-eaten see Steinmayer and Turfa, *IJNA* 25 (1996) 106 and 119 n.2.

[82] See B. A. Kaiser, "The Athenian Trierarchy: Mechanism Design for the Private Provision of Public Goods," *Journal of Economic History* 67 (2007) 445–480.

[83] Gabrielsen, *Financing the Athenian Fleet* 129–131.

[84] Gabrielsen, *Financing the Athenian Fleet* 136–139.

The term ἀλοιφή is sometimes used of the resins or paints applied to ships, and here *hypaloiphe* would seem to be a "bottom paint" used to coat the wetted surfaces of triremes.[85] It appears twice in a single, somewhat earlier account (*IG* II^2 1622.715 and 740 [ca. 342/1]), but without the curious detail given in the later account, which seems to suggest a range of different mixtures. Its classification broadly according to color finds an interesting analogy in the terminology used during the 17th and 18th centuries in the British navy, which "graved and payed" its wooden hulls with "black stuff" (a mixture of pitch and tar), "white stuff" (a mixture of rosin, whale oil, and sulfur), or "brown stuff" (a mixture of "black stuff" and sulfur).[86] As to the specific nature of the substances listed in the Athenian account, Morrison, Coates, and Rankov suggest that "[t]he black substance is likely to be pitch of two varieties," while "[t]he white is likely to be resin, probably mixed with lime."[87] In my view, the "white" in the inventory is as likely to have contained cerussite as calcite (lime),[88] while either or both of the "blacks" could have included *miltos*.[89]

[85] Morrison et al., *Athenian Trireme* 187–188.

[86] See B. Lavery, *The Arming and Fitting of English Ships of War, 1600–1815* (London 1987) 57–58. Graving and paying usually involved first dry-docking or careening a ship on a beach or shelf, then softening its pitch coating with controlled fires ('breaming') before scraping off ('graving') the softened and fouled pitch and then applying fresh pitch ('paying'); see Lunn, *Anti-fouling* xiii–xiv.

[87] *Athenian Trireme* 187.

[88] See n.31 above.

[89] The adjective μέλαινα is perhaps better translated here as "dark" and could describe any number of dark tints (see LSJ s.v. μέλας), including probably the reddish-black of pitch mixed with *miltos*. The same is true when the adjective is used as a common epithet for ships in the Homeric epics: as often noted it does not describe a black paint but rather the hue taken on by wooden ships when coated with pitch (see Casson, *Ships* 212 n.50; Morrison et al., *Athenian Trireme* 186). As noted by Colombini et al., *Archaeometry* 45 (2003) 672, the red paint on Pisa Ship C was mixed with a transparent resin rather than pitch to allow the red pigment to show.

It is possible that red ochres have properties yet unknown to science, but it is more likely that critics of Hasebroek's theory are correct in maintaining that *miltos* cannot have played any essential role in preserving the hulls of Athenian triremes. Nevertheless, a wide range of evidence—for basic Greek notions regarding the causes of rot and infestation, for the perceived properties of *miltos*, and for agricultural practice—allows us to reconstruct a belief that ruddle was useful in preventing shipworm and rot. That belief is the only plausible explanation for the use of *miltos* on the hulls of the Nemi ships and probably too in repairing the Kyrenia ship. Theophrastus offers reliable evidence that in the fourth century Kean ruddle was still acknowledged to be of the very highest quality, even if during the Hellenistic period it was quickly overshadowed by that of Sinope.[90] As in later medical texts where the efficacy of medicinal cures is directly linked to the use of the highest quality ingredients (including Sinopic ruddle), to Athenians interested in maintaining a renewed maritime confederation their monopoly on the very best Kean *miltos* seemed of vital strategic importance. That interpretation can only strengthen an already existing suspicion that Athens' renewed or continued interest in maintaining a monopoly on Kean *miltos* is best understood in the context of perceived threats to its maritime confederation in the late 360s and early 350s.[91] The

[90] After the fourth century, literary sources frequently hold that the finest ruddle is from Sinope (e.g. Strab. 12.2.10; Vitr. *De arch.* 7.7.2; Plin. *HN* 35.31), a fact similarly attested in a second-century B.C. inscription from Lebadeia (*Syll.*[3] 972.155–159). This ruddle originated in Cappadocia, but was widely exported from Sinope (Theophr. *De lap.* 52–53; Strab. 12.2.10; Caley and Richards, *Theophrastus* 178–180). After Theophrastus, virtually nothing is heard of Kean ruddle. It is sometimes suggested that this is because the supply was exhausted (Caley and Richards 52), but that silence can as easily be explained on economic grounds (e.g. the Athenian monopoly limiting wider trade and the discovery and development of other sources).

[91] See most recently Rutishauser, *Athens and the Cyclades* 175–180. The evidence for fifth-century Athens is well known (see n.20 above), but an

evidence does not allow us to claim with certainty that the Kean revolts in 364/3 are directly tied to the Thebans' construction of a fleet and Epaminondas' campaigns in the Aegean. But the threat posed by that fleet, or subsequently those of Jason of Pherae or rebellious allies during the Social War, could explain the fresh insistence that Kean ruddle arrive *only* at Athens.[92]

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agreement between Amyntas III and the Chalcidians (*Syll.*[3] 135; Rhodes/Osborne, *GHI* 12), which guaranteed the latter access to Macedonian pitch and shipbuilding timbers (lines 9–14), suggests that competition for naval resources was a common feature too of fourth-century interstate relations.

[92] For a number of important suggestions I want to thank audience members at the 2013 Annual Meeting of the APA in Seattle and this journal's anonymous readers, as well as Aurélie Carrara, who was kind enough to provide me a copy of her very useful dissertation, Thanos Webb, and, especially, Josh Sosin.