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Athenian Tetradrachms from Tel Mikhal (Israel): A Metallurgical Perspective

Plate 4

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This paper uses the analytical results from inductively-coupled plasma atomic emission spectrometry (ICP-AES) and lead isotope analysis (Q-ICP-MS) of a group of Athenian-style tetradrachms found in the excavations of Tel Michal to investigate their origins. The majority of these coins are thought to be Eastern imitations based on style, but the analysis suggests that all these coins may actually be authentic Athenian issues. This is because they were clearly produced from bullion that came from the silver mines of Laurion in Attica. Given the stylistic variability of the Athenian tetradrachms from Tel Michal, we can assume that they are representative of the 'owls' that were circulated in Achaemenid Palestine. Therefore, although it would be premature to argue that the term Eastern imitation is an erroneous scholarly convention, this paper demonstrates that it is a clear possibility.

Tel Mikhal is located in the southern Sharon plain, on the central coastal strip of Palestine.[1] The site has been excavated extensively, revealing in the main Persian (Achaemenid) period remains of the fifth and fourth centuries BC that relate to a series of fortresses on the mound, including cult, service, and possibly domestic buildings on the hills that surrounded the mound and a cemetery on the plain to its northeast.[2]

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[1] This study and its publication were supported by the 'Ancient Israel' project (New Horizons programme) of the Institute of Archaeology, Tel Aviv University.

[2] E. Stern (ed.), *The New Encyclopedia of Archaeological Excavations in the Holy Land, 3* (Jerusalem, 1993), s.v. Tel Michal; A. Gorzalczany, The 1996 Excavations along the Northern Hill at Tel Mikhal (Tel Michal), *'Atiqot* 52 (2006), pp. 1–21.

Among the finds retrieved in the course of the latest (salvage) excavation in 1996 are eleven Athenian and Athenian-style tetradrachms found in three adjacent loci (Plate 4, B1–B11).[3] The excavators described these finds as 'a dispersed hoard.' The three loci apparently represent fills.[4] The hoard report mentioned that there are no die-links between the eleven tetradrachms and that no graffiti were noticed on them.[5] According to Ariel, the low level of wear of most of the tetradrachms suggests that they belong to roughly the same date. He also suggested that they were contemporary with three silver Sidonian coins allegedly belonging to the 'hoard' and attributed to 'Abd'astart I/Straton I.[6] In fact, two of the Sidonian coins should be attributed to Ba'alšillem II (*c.* 401–366 BC), namely the single Sidonian coin illustrated in the publication (Plate 4, B12), and another similarly described coin (no. B13).[7] The third (no. B14), which is plated, may well also be attributable to Ba'alšillem I, though it is hardly legible. The 'hoard' also included a posthumous bronze of Alexander the Great (Plate 4, B15) which dates to 323–317 BC.[8] This coin was retrieved from Locus 464 which formed part of the 'hoard,' though it was overlooked by the excavators when they set a deposition date 'close to the mid-fourth century BC' on the basis of their dating of the Sidonian coins. We do not believe that the Athenian tetradrachms form part of a hoard, at least not in the sense that they were buried together with the Sidonian coins and the posthumous Alexander bronze.[9]

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[3] D. T. Ariel, Coins from Tel Mikhal (Tel Michal), '*Atiqot* 52 (2006), pp. 71–88.

[4] The relevant loci are 464, 473, and 509, though the latter is missing in the plan and loci list of Gorzalczany (n. 2), pp. 6, 15–16, which gives an overview of the 1996 excavation finds.

[5] However, our inspection of these tetradrachms did reveal graffiti on some coins, notably a Phoenician-Aramaic *gimmel* or Greek *lamda* on the reverse of B7 (cf. Ariel [n. 3], Figure 2; and see for comparison J. Elayi and A. Lemaire, *Graffiti et contremarques ouest-sémitiques sur les monnaies grecques et proche-orientales* (Glaux 13; Milan, 1998), p. 64, no. 151, Pl. 18). There are also graffiti on the right reverse field of B2 and on Athena's cheek on coin B11. It should also be noted that test-cuts which are commonly found on Athenian-style coins in the Levant are not found on these tetradrachms.

[6] Ariel (n. 3), pp. 73–75, 83–85, nos. B12–B14.

[7] J. Elayi and A. G. Elayi, *Le monnayage de la cité phénicienne de Sidon à l'époque perse (V^{e}–IV^{e} s. av. J.-C.)* (Transeuphratène, Supplement 11; Paris, 2004), Type IV.1.3.c, nos. 851–1191, pp. 136–174 (cf. esp. no. 928).

[8] M. J. Price, *The Coinage in the Name of Alexander the Great and Philip Arrhidaeus: A British Museum Catalogue* (Zurich and London, 1991), Tarsus, no. 3063, p. 378.

[9] In fact, on the basis of stylistic comparanda we are inclined to date the Tel Mikhal tetradrachms to the second half of the fifth century BC, much earlier than the Sidonian and posthumous Alexander issues. Kroll dates this type of Athenian coin to 454 to c. 415–413 BC, as he associates the beginning of the conventionalized style and the mass striking of this series with the removal of the Athenian League treasury from Delos to Athens in 454 BC,

Authentic Athenian or Athenian-style tetradrachms have been retrieved from several controlled archaeological excavations in Israel, including Bethsaida, Kh. Qastra, ʻAtlit, Dor, Megiddo, Kh. ʻEleq, Bet She'an, Tel Zeror, Samaria, Mt Gerizim, Aphek, Wadi ed-Daliyeh, Tell en-Naṣbeh, Ashkelon, Kh. ʻEtri, Beth-Zur and Lachish.[10] The present study aims to present an archaeo-metallurgical study of the silver content and trace elements (especially gold and bismuth) of the Athenian owls discovered in Tel Mikhal, and to compare them with those of contemporary indigenous Philistian coinage of the Persian period, in order to assess the origin of the metal ores. Earlier studies have shown that the metallic composition of several Athenian tetradrachms usually taken as ancient imitations (of Buttrey Style B and M)[11] does not differ from that of genuine coins.[12] These analyses however were made on coins purchased in the antiquity market whose place of retrieval is unknown.

Given that the Tel Mikhal tetradrachms are stylistically varied and given that the archaeological context of their find spots (three different loci) suggests that they most probably did not belong to a hoard, it seems likely that, although they were found in one site, they can be taken as representative examples of the issues of the Athenian owls which circulated in Palestine during the second half of the fifth and the first half of the fourth centuries BC.[13]

Results

The coins were analyzed by the use of inductively-coupled plasma atomic emission

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and its most probable termination with the decline in silver bullion income from Athens' allies and the Laurion mines (J. H. Kroll, *The Athenian Agora* 26: The Greek Coins [New Jersey, 1993], pp. 6–7, esp. no. 11, and *id.*, A Small Find of Silver Bullion from Egypt, *American Journal of Numismatics* 13 (2001), p. 3, n. 2).

[10] For a detailed list, see Ariel (n. 3), pp. 75–78, Table 1; H. Gitler and O. Tal, *The Coinage of Philistia of the Fifth and Fourth Centuries BC: A Study of the Earliest Coins of Palestine* (Collezioni Numismatiche 6; Milan, 2006), pp. 23–30, Table 2.1.

[11] T. V. Buttrey, Pharaonic Imitations of Athenian Tetradrachms, *Proceedings of the 9th International Congress of Numismatics, Berne, September 1979*, I (Louvain-la-Neuve, 1982), pp. 137–140.

[12] Cf. C. Flament, A propos des styles d'imitations Atheniennes definis par T.V. Buttrey, *Revue belge de numismatique et de sigillographie* 147 (2001), pp. 37–50; C. Flament, Imitations athéniennes ou monnaies authentiques? Nouvelles considerations sur quelques chouettes athéniennes habituellement identifiées comme imitations, *Revue belge de numismatique et de sigillographie* 149 (2003), pp. 1–10; C. Flament and P. Marchetti, Analysis of Ancient Silver Coins, *Nuclear Instruments and Methods in Physics Research* B 226 (2004), pp. 179–184.

[13] However, only a few of the Tel Mikhal tetradrachms show low level of wear and this may support the idea that they circulated in Palestine (and beyond?) at the time, and may be seen as a representative group of southern Levantine Athenian owls.

Table 1. Silver bullion content of the Tel Mikhal tetradrachms

No. (Cat. No. in Ariel 2006)	Weight / Axis	Bullion	Reg. No.
1 (B1)	16.29 g / 9	99.0	IAA 81274
2 (B2)	16.09 g / 9	98.2	IAA 81277
3 (B3)	16.25 g / 9	98.9	IAA 81278
4 (B4)	16.66 g / 9	99.8	IAA 81275
5 (B5)	16.28 g / 9	99.4	IAA 81283
6 (B6)	16.20 g / 7	99.8	IAA 81284
7 (B7)	16.71 g / 9	99.7	IAA 81276
8 (B8)	16.85 g / 7	99.9	IAA 81280
9 (B9)	16.24 g / 7	99.6	IAA 81281
10 (B10)	14.37 g / 7	97.8	IAA 81282
11 (B11)	16.41 g / 6	99.4	IAA 81279
Total N	11	11	11
Mean	16.21 g	99.2	
Minimum	14.37 g	97.8	
Maximum	16.85 g	99.9	
Std. Deviation		0.7	
Total N		11	11
Mean		99.2	
Minimum		97.8	
Maximum		99.9	
Std. Deviation		0.7	

spectrometry (ICP-AES) on turnings obtained by drilling into the edge of the coin. Details of the analytical technique are given in the Appendix below.[14]

Silver Content

Silver produced by traditional methods in antiquity is not chemically pure but

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[14] Describing coin no. B9, Ariel (n. 3), p. 83, notes that "In the plate, on the reverse, there appears a circle-like symbol close to the owl in the right field. In fact this is an area of corrosion that was removed after the photography. There is nothing in the right field of the reverse besides the inscription." Recently an Athenian tetradrachm with a symbol which seems to be an intaglio Θ in the right field between the owl and the Greek legend was found at the excavations of Tel Dor (Yoav Farhi, personal communication). Coin B9 in the Tel Mikhal hoard may have a similar symbol.

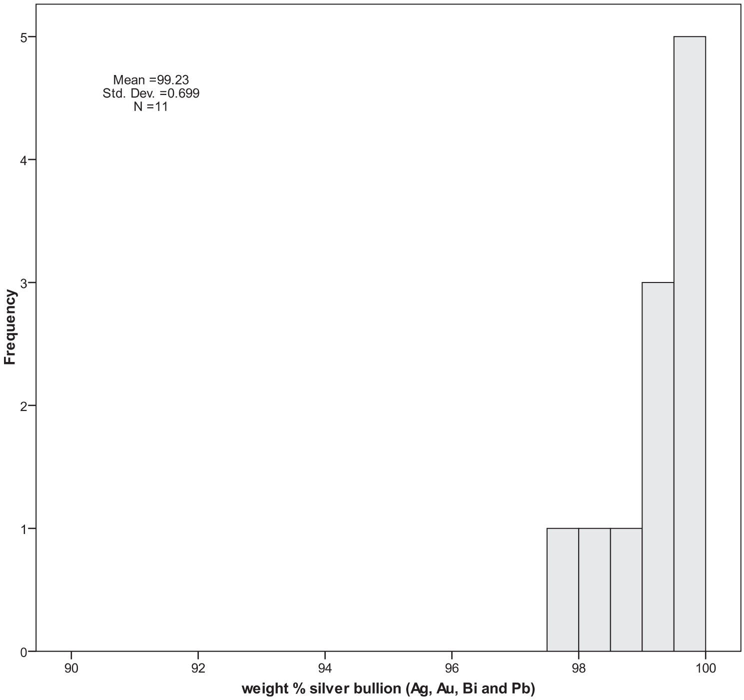

Figure 1. Silver bullion content of the Tel Mikhal tetradrachms.

contains traces of other metals that relate to the ore smelted or the subsequent refining process. It is therefore a more accurate estimate of the silver bullion content of ancient coins to regard the proportion of silver metal in an alloy as the combined total of elemental silver together with traces of the geochemically related elements gold, bismuth and lead. The silver bullion content of the coins analyzed here is presented graphically in Figure 1. The average bullion content for the Tel Mikhal tetradrachms is 99.2% with a standard deviation of only 0.7, suggesting well-controlled production, or at least a consistent source of supply. There is no significant difference in fineness between the single coin (B4) identified as authentically Athenian (although it appears with a question mark i.e., "Autonomous Athens?") and three coins (B5, B9, and B10) defined as "Autonomous Athens or imitation" in the original report and the remaining tetradrachms which were defined as imitations (B1, B2, B3, B6, B7, B8, and B11).[15]

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[15] Ariel (n. 3 above), pp. 74–75, 83–85. It should be noted that B10 is of a slightly lower bullion content and its weight is significantly lighter that the rest of the analyzed tetradrachms.

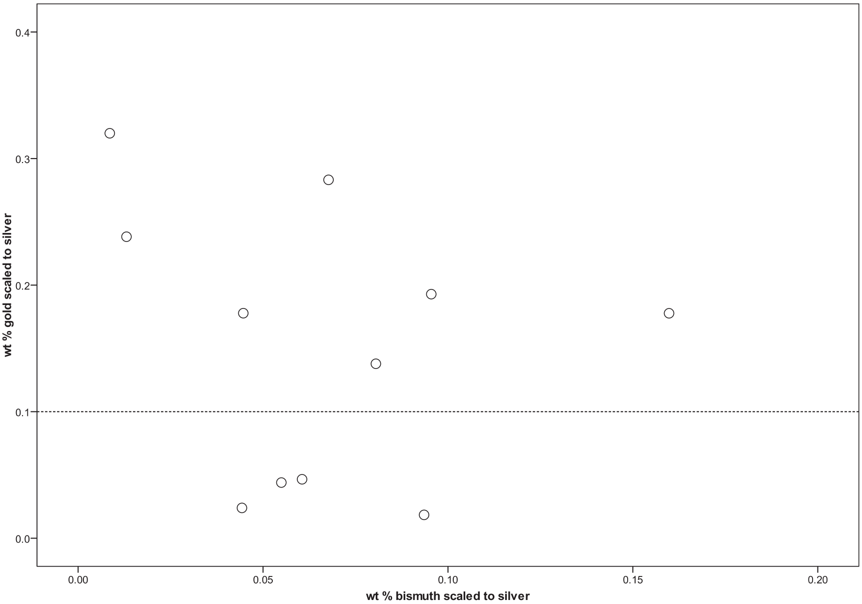

Figure 2. Gold and bismuth contents of the Tel Mikhal tetradrachms.

Trace Elements

As well as gold, bismuth and lead, other metallic elements may also relate to the original ore, such as copper, tin or nickel; however, these elements may have been added to the metal as, or as contaminants within, the major alloying components. In particular, in cases where copper is present at levels greater than 0.5–1.0 %, it is likely that it was added as an alloying component and that any tin or nickel present would have come as contaminants within it. Only the gold and bismuth can be reliably regarded as associated solely with the silver source/s, while the lead relates to the technology and scale of the refining process. The gold levels are not significantly altered by smelting and refining whilst the bismuth levels are altered only slightly. For these reasons the gold and bismuth traces are regarded as the most useful trace elements in ancient silver.[16] In the coins analyzed here, the gold and bismuth contents suggest two groups: one with a gold content of between 0.1% and

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16. H. Mackerrel and R. B. K. Stevenson, Some Analysis of Anglo-Saxon Associated Oriental Silver Coinage, in E. T. Hall and D. M. Metcalf (eds.), *Methods of Chemical and Metallurgical Investigation of Ancient Coinage: a Symposium held by the Royal Numismatic Society in London on 9–11 December 1970* (London, 1972), pp. 195–209. E. Pernicka and H. G. Bachmann, Archäometallurgische Untersuchungen zur antiken Silbergewinnung in Laurion, *Erzmetall* 36 (1983), pp. 592–597, conducted more rigorous experiments that both confirm and dispute Mackerrel and Stevenson's work.

0.45%, and another with a lower gold content of less than 0.08% (Figure 2). The group with lower gold content contains the only coin in Tel Mikhal that has been identified by Ariel as an authentic Athenian coin; the majority of coins (7 or 64%) are in the group with higher gold content.

Useful comparanda are to be found in the analyses of a sample of coins from the Asyut hoard (*IGCH* 1644), deposited in Egypt about half a century before the beginning of our period in around 475 BC. This hoard of about 900 coins appears to be a representative sample of coins circulating in the eastern Mediterranean at the time and comprises primarily coins of Athens and Aegina, together with coins of the Orrescii, Thasos, Acanthus, Corinth, Chios, Samos, Cyprus and Cyrenaica, as well as Persian sigloi.[17] Analyses were conducted on 120 coins from this hoard, representing all the issuing authorities, with the aim of identifying the sources of silver and determining how the coins of the different authorities related to one another.[18] The study presented the results of both bulk chemical analysis (by neutron activation and atomic absorption spectroscopy of drilled samples) and lead isotope measurements (by thermal ionisation mass spectrometry). This combination of chemical and isotopic analysis is a particularly powerful analytical approach which can enable conclusions based on one set of data to be clarified, expanded and often confirmed by the other. The interpretation of these analyses revealed at least three sources of silver used for coin production: Laurion in Attica, Siphnos in the Aegean, and at least one unidentified source. Athenian coins were made exclusively from silver from Laurion, while Aeginetan coins were initially made predominantly from Siphnian silver but gradually started using Laurion silver later in the fifth century BC. Corinth and Samos used bullion from both Laurion and Siphnos and may thus have used Aeginetan coins or a combination of Aeginetan and Athenian coins as its source. The coins of Acanthus and Thasos were more problematic, but appeared to be produced from silver from at least one other unknown source, while the coins of the Orrescii have a unique isotopic signature and a tightly defined chemistry suggesting a relatively small local source, possibly on Mount Pangaeon, which is reported by Herodotus to have had silver deposits.[19] Likewise and unsurprisingly, the Persian sigloi appear to be made of silver from neither Laurion nor Siphnos. Since this publication, further work has established the isotopic signature for the silver mines on Thasos and shown that this silver source was used to make a significant proportion of Thasian silver coins.[20]

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[17] M. Price and N. Waggoner, *Archaic Greek Coinage: The Asyut Hoard* (London, 1975).

[18] N. H. Gale, W. Gentner, and G. A. Wagner, Mineralogical and Geographical Sources of Archaic Greek Coins, in D. M. Metcalf and W. A. Oddy (eds.), *Metallurgy in Numismatics* 1 (RNS SP 13; London, 1980), pp. 3–49.

[19] Herodotus, V, 23; VII, 112.

[20] G. A. Wagner and G. Weisgerber (eds.), *Antike Edel-und Buntmetallgewinnung auf Thasos*, *Der Anschnitt* Beiheft 6 (Bochum, 1988), esp. pp. 212–223 by N. H. Gale, O. Picard, and J.-N. Barrandon.

The Tel Mikhal coins fit the Asyut chemical data remarkably well. The two groups distinguished by their differing gold and bismuth content correspond with Asyut coins struck from what appears to be, respectively, Laurion silver and Siphnian silver. Figure 3 shows all the data together and clearly shows the two main fields separated by gold content of below and above 0.1%.

The predominantly Athenian group is composed of the majority of Asyut coins which have a Laurion lead isotope signature and can be chemically defined as having low gold and low bismuth. The group also includes some coins with a non-Laurion signature such as the coins of Thasos and Acanthus. This group contains four of the Tel Mikhal tetradrachms, including the coin regarded as an authentic Athenian issue (B4); the other three are classified as imitations by Ariel (B6, B7, and B11). This may imply as well that B6, B7, and B11 are authentic Athenian issues.

The so-called 'Siphnian' group comprises the Asyut coins attributed by lead isotope analysis to silver ore sources in Siphnos but also includes the Aeginetan coins and the coins of Corinth, Zankle, Samos and Caria that also have a 'Siphnian'-type lead isotope signature. This gold/bismuth group also includes the Persian sigloi and a group of Lydian silver staters and half-staters from sixth century Sardis made from silver *parted* from electrum from the river Pactolus,[21] as well as the remaining seven tetradrachms from Tel Mikhal. It is quite clear, therefore, that the simple gold/bismuth plot is not sufficient to separate all the sources of the silver in these coins, but it does clearly separate Laurion and so-called 'Siphnian' silver, although this latter compositional group clearly includes non-Siphnian coins. Further study of the graph shows that, although the silver used by the Orrescii has a gold and bismuth content within the broadest confines of the Laurion cluster, the coins cluster tightly enough together to suggest that the source of the silver is different; a suggestion confirmed by the quite different lead isotope signature that these coins have.[22]

The 'Siphnian' group can also be sub-divided; the Aeginetan coins cluster tightly together with the Corinthian, Zankle, and Carian coins attributed to Siphnian silver by lead isotopes, but are also joined by one Persian siglos and the Lydian staters, while the Tel Mikhal tetradrachms cluster with the other two Persian sigloi and the Corinthian, Samian, and Lycian issues also attributed to a Siphnian silver source by lead isotope analysis. It is worth noting that one of the early Lydian staters appears far to the low bismuth/high gold end of the scatter, suggesting the existence of a third compositional group, situated between the Laurion group and the 'Siphnian' group, consisting of the Tel Mikhal tetradrachms with more than 0.1% gold, one of the early Lydian staters and two of the Persian sigloi. Both of these sub-groups, however, also contain coins that have been attributed by lead

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[21] A. Ramage and P. T. Craddock, *King Croesus' Gold* (London, 2000). The data for Lydian silver used in these analyses are from this publication.

[22] Gale *et al.* (n. 18), p. 44.

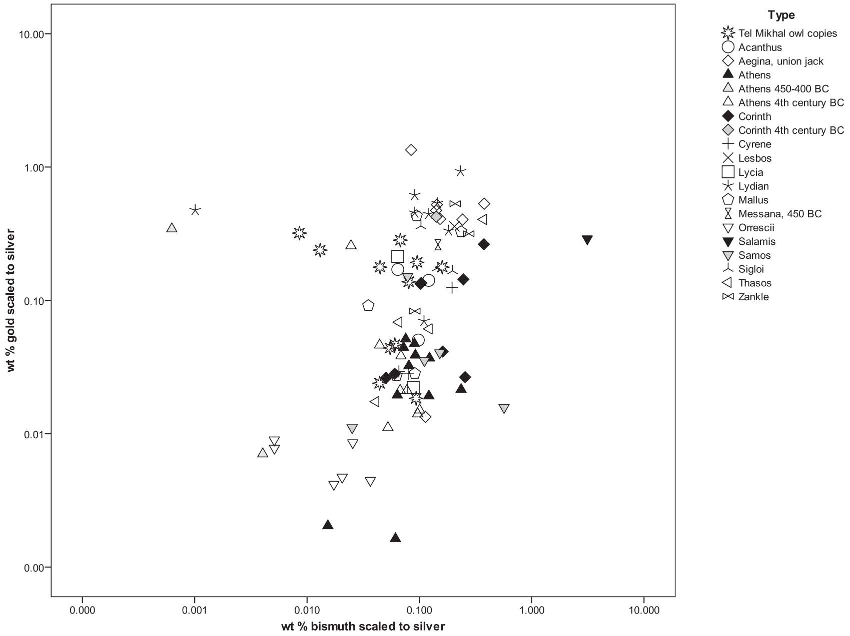

Figure 3. Comparison of the composition of the Asyut hoard coins and the Tel Mikhal tetradrachms.

isotope analysis to the island of Siphnos, although the number of these are in the minority (less than one-third in group 1 and less than one-quarter in group 2). The bulk of the Asyut hoard coins in both groups (68% and 78% respectively) are either attributed by lead isotope analysis to the 'intermediate' group according to Gale *et al.* or to Lydia by the archaeology.[23] Furthermore, Gale *et al.* speculate that some of these 'intermediate' lead isotope group coins could be produced from silver from either Macedonia (Mount Pangaeon), a view supported by subsequent lead isotope analyses, or from Lydia,[24] while suggesting that those coins struck by Lesbos, Salamis, and Lycia are from a source that 'should probably be sought rather in Anatolia.'[25]

Comparison of the gold and bismuth content of the Tel Mikhal coins with the published work on the Asyut and Sardis material therefore suggests that they can be divided into two groups; those with low gold and low bismuth corresponding to silver with a Laurion lead isotope signature (B4, B6, B7, and B11) and those with high gold and low to moderate bismuth that largely correspond to coins with a non-Laurion signature and that include coins with a Siphnian and 'intermediate'

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[23] *Loc. cit.*
[24] *Ibid.*, p. 42.
[25] *Ibid.*, p. 45.

(between Laurion and Siphnos) signature. The majority of the Tel Mikhal coins are found in this second 'non-Laurion' group.

Other chemical elements measured in the Asyut and Tel Mikhal coins can also provide useful information. The lead can be seen as an indictor of technological differences in silver refining, while the copper and nickel can be used to indicate when copper was intentionally added to the silver.

The lead contents plotted against the gold contents allow some separation of the two main groups on the basis of technology. The coins of the Orrescii stand out as containing relatively high lead with an average of 2.1% indicating quite poor cupellation. The Aeginetan coins, on the other hand, are characterised by particularly low levels of lead (average 0.3%, but with the majority containing less than 0.1%), suggesting good cupellation technology. The bulk of the early Lydian staters also stand out as a group with relatively low levels of lead (average 0.2%). All the Athenian tetradrachms from the Asyut hoard appear to fall into lower and higher lead groups that correspond to a fourth century BC group (plus four fifth century coins) and a group made up of solely fifth century BC coins, an interpretation being that cupellation technology improved with time. It is therefore worth noting that, with one exception (B11), the low-gold Tel Mikhal tetradrachms all fall within the earlier higher lead sub-group and include the only Athenian coin identified as authentic (B4), although the type is clearly of late fifth century date.

The copper contents of Greek silver coins of this period are generally quite low; the plot of copper against nickel (Figure 4) shows that the bulk of the Asyut coins have copper contents which are mostly less than 1% and thus might at first glance be assumed to have been present in the original ore rather than intentionally added. However, it should also be noted that in the majority of cases where the copper content of Asyut hoard coins reaches between 0.5 and 1% or more, the copper is correlated with nickel. This suggests that copper at these levels and above was intentionally added because the strong correlation shown is typical of copper metal from certain sources; indeed Gale *et al.* also notice this phenomenon and comment that copper from Siphnos appears to contain in the order of 1.5% nickel.[26] However, the Tel Mikhal tetradrachms show no evidence of a similar correlation, despite the fact that four coins have copper contents equal to or greater than 1%. Such an amount of copper is unlikely to be a naturally occurring contaminant, especially if these coins are produced from silver stocks comprising largely remelted Athenian and other Greek coins—though there are some Asyut coins, even Athenian, with high copper contents—and so may have been intentionally added. The fact that the copper in these coins is not correlated with the nickel indicates that its source is not the same as that of the copper added to the Asyut coins. This is supported by the fact that the level of arsenic and cobalt measured in the Tel Mikhal tetradrachms is generally greater than that in the Asyut coins (Figure 5).

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[26] *Ibid.*, p. 21.

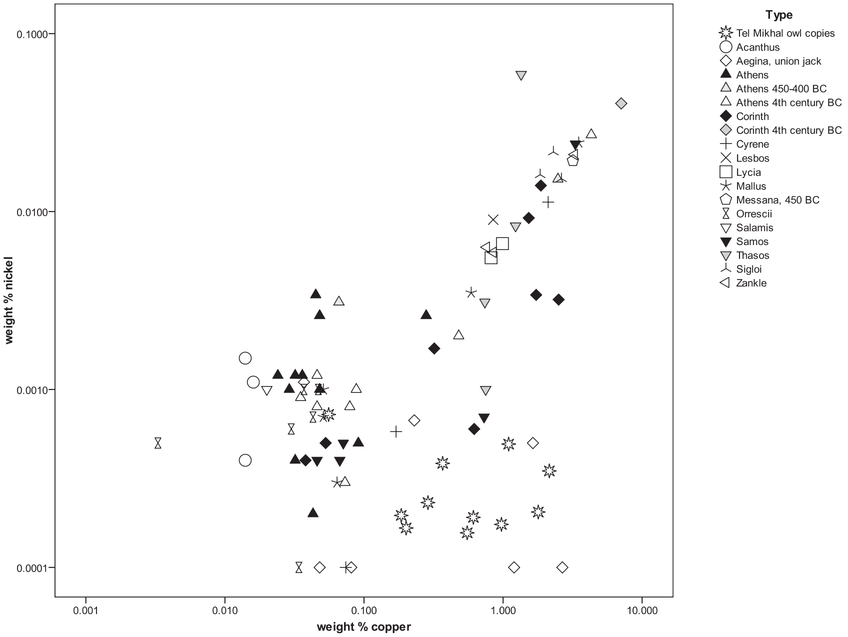

Figure 4. Copper and nickel contents of the Tel Mikhal tetradrachms and the Asyut hoard coins.

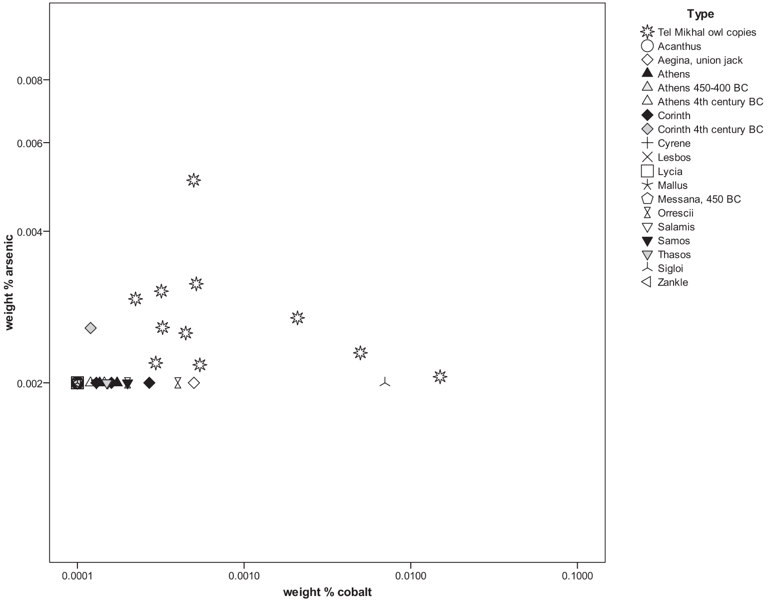

Figure 5. Arsenic and cobalt contents of the Tel Mikhal tetradrachms and the Asyut hoard coins.

Table 2. ICP-AES analyses of the Tel Mikhal tetradrachms. All data are in weight percent. Where an element was not detected, or the measured value was below the 3σ limit of detection, a value of half the limit of detection was used (see Appendix for technical details).

sample ref		silver	arsenic	gold	bismuth	cobalt	chromium	copper	iron	manganese	nickel	lead	antimony	tin	zinc	bullion
B1	IAA 81274	98.2	<0.002	0.314	0.008	0.0050	<0.00005	0.974	0.002	<0.00003	<0.0002	0.462	<0.002	<0.002	<0.0001	99.0
B2	IAA 81277	96.9	<0.003	0.172	0.043	0.0021	0.00016	1.792	0.005	0.00007	<0.0002	1.057	<0.002	<0.002	<0.0001	98.2
B3	IAA 81278	98.2	<0.003	0.234	0.013	0.0005	0.00034	1.097	0.003	0.00032	0.0005	0.412	<0.002	<0.002	<0.0001	98.9
B4	IAA 81275	97.7	<0.002	0.018	0.091	0.0003	0.00020	0.201	0.002	0.00020	<0.0002	1.934	<0.002	<0.002	0.0003	99.8
B5	IAA 81283	98.0	<0.003	0.135	0.079	0.0004	<0.00006	0.612	0.003	<0.00003	<0.0002	1.134	<0.002	<0.002	<0.0001	99.4
B6	IAA 81284	97.1	<0.003	0.045	0.059	0.0003	<0.00006	0.185	0.003	0.00005	<0.0002	2.571	<0.002	<0.002	<0.0001	99.8
B7	IAA 81276	98.2	<0.003	0.023	0.043	0.0003	0.00019	0.288	0.002	0.00018	<0.0002	1.454	<0.002	<0.002	0.0006	99.7
B8	IAA 81280	97.8	<0.003	0.174	0.156	0.0002	<0.00006	0.056	0.004	0.00009	0.0007	1.833	<0.002	<0.002	0.0010	99.9
B9	IAA 81281	98.7	<0.005	0.190	0.094	0.0005	<0.00012	0.368	0.005	<0.00006	<0.0002	0.646	<0.004	<0.002	<0.0001	99.6
B10	IAA 81282	96.8	<0.002	0.274	0.066	0.0005	<0.00005	2.151	0.004	0.00017	0.0003	0.688	<0.002	0.053	<0.0001	97.8
B11	IAA 81279	98.5	<0.002	0.043	0.054	0.0150	0.00059	0.552	0.002	0.00006	<0.0002	0.830	<0.002	<0.002	0.0004	99.4

Lead Isotope Analyses

It is clear that elemental analyses alone cannot provide answers to all the questions posed by these enigmatic issues and so the samples taken from the Tel Mikhal coins were submitted for lead isotope analysis.[27] This form of lead isotope analysis is less accurate than traditional thermal ionisation mass spectrometry (TIMS) or multi-collector ICP-MS, however direct comparison of data using multi-collector ICP-MS and the system used here from the same samples indicate that accuracies of 0.1% can be obtained for most isotope ratios, whilst those based on Pb204 can be as poor as 1%. However, for the purposes of the discussion here, it is felt that these data are adequate.[28] The results are presented in Figures 6 and 7 and clearly show the majority of the Tel Mikhal coins to have a lead isotope signature consistent with Laurion metal. There is a slight extension of the field created by the Tel Mikhal coins out of the Laurion field and into the areas covered by the Halkidiki and Macedonian isotope fields, suggesting that some of the silver is of a mixed origin. Indeed, there are examples of lead/silver ores from Turkey that also have similar isotope signatures.

The low-gold low-bismuth group of Tel Mikhal coins that so closely matches the Athenian tetradrachms from the Asyut hoard (B4, B6, B7, and B11) is not differentiated from the high-gold group by the lead isotopes to any significant degree. This suggests that there are two groups of metal with a Laurion lead isotope signature that can only be distinguished chemically and this may have a technological rather than provenance-related explanation. Lead metal was usually added to scrap silver metal during melting in order to separate the silver from any added copper; the silver would dissolve in an excess of lead and the resulting silver-rich lead would then be cupelled to extract the silver in the usual way, leaving any copper or other impurities behind with the oxidized lead. The effect of this process would be for the lead isotope signature of the added lead to effectively obscure the underlying lead isotope signature of the original silver source. If Laurion lead was added to refine foreign silver, then the lead isotope signature of the refined silver would be that of the Laurion lead and not of the silver source. However, because of its low chemical reactivity, the concentration levels of the gold in the original silver ore will be carried through the smelting and refining processes largely unchanged and therefore remain as an indicator of the original ore source (Pernicka and Bachmann 1983, n. 16).

[27] The authors are extremely grateful to Dr. Scott Young (School of Biosciences, University of Nottingham) for undertaking the lead isotope analyses.

[28] Since this paper was submitted the Tel Mikhal samples have been re-analyzed by multi-collector ICP-MS by the NERC Isotope Geochemistry Laboratory of the British Geological Survey. Whilst the increased accuracy is evident, the conclusions and interpretations presented here are confirmed and supported. The new data are to be published elsewhere.

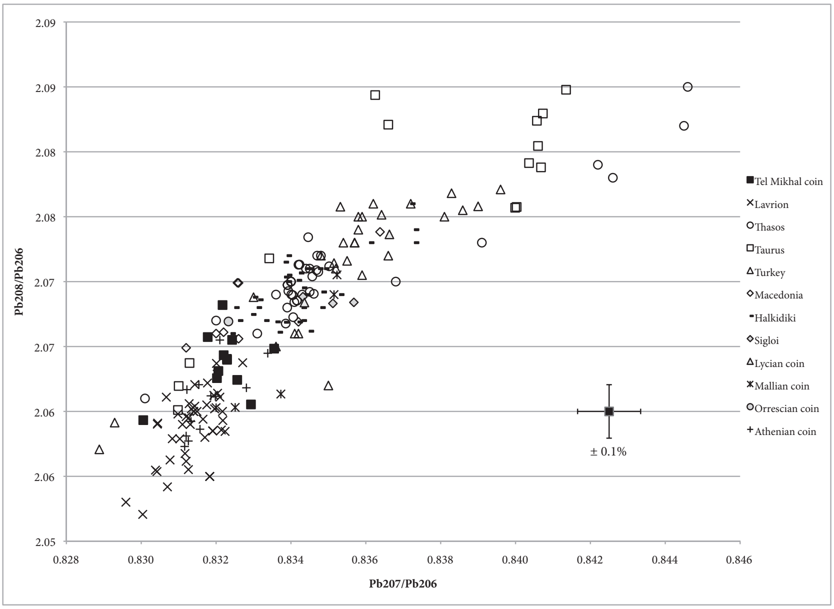

Figure 6. Plot of lead isotopes ratios 208/206 and 207/206.
The point with error bars represents the estimated error of the analyses.

The high-gold Tel Mikhal coins group nicely with Asyut hoard coins from Cyrene, Acanthus, Lycia, and two of the three Persian sigloi and therefore suggest a northern Greek and/or Anatolian origin. It should also be stressed that the lead isotope abundances for certain of the Tel Mikhal coins in this high-gold group (B1, B2, B3, B8, and B9) also fall on the edge of or just outside the Laurion lead isotope field. This may suggest that these coins are made of mixed metal from other Greek sources, the most likely of which appear to be Macedonia and/or Halkidiki or even sources in Anatolia. This would fit with the 'intermediate group' suggested by Gale et. al.[29] If future lead isotope and chemical analysis attributes additional 'Eastern owls' to this group, rather than to the Laurion field, it would provide important evidence for further discussion of the origins of these coins and their relationship to the tetradrachms of Athens proper.

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[29] Gale *et al.* (n. 18), p. 44.

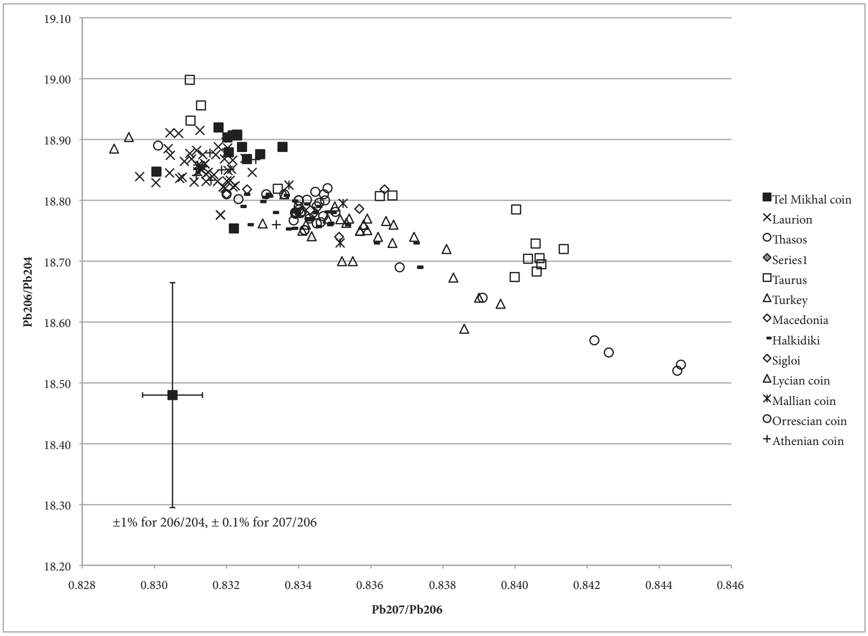

Figure 7. Plot of lead isotopes ratios 206/204 and 207/206.
The point with error bars represents the estimated error of the analyses.

Table 3. Quad-ICP-MS lead isotope data (see Appendix for technical details).

Sample	207/206	208/206	206/204	208/204	207/204
B1	0.832	2.064	18.907	39.023	15.736
B2	0.833	2.062	18.868	38.913	15.709
B3	0.832	2.064	18.754	38.714	15.607
B4	0.832	2.066	18.920	39.083	15.737
B5	0.832	2.063	18.903	38.990	15.728
B6	0.832	2.068	18.907	39.103	15.734
B7	0.832	2.063	18.879	38.949	15.708
B8	0.832	2.066	18.888	39.013	15.723
B9	0.833	2.061	18.876	38.894	15.722
B10	0.830	2.059	18.847	38.812	15.644
B11	0.834	2.065	18.888	39.000	15.744

CONCLUSIONS

These analyses present a complex picture of silver procurement in Persian-period Palestine. It seems clear that much of the silver for both Tel Mikhal tetradrachms and the Philistian and Edomite coinages[30] probably originated in the Greek world, especially Athens. There are close compositional links between the Tel Mikhal tetradrachms and the Philistian and Edomite coins and it seems possible that the same sources of bullion were being used for both coinages.[31] Both the chemical and lead isotope analyses reported here indicate that a significant proportion of this bullion came from the silver mines at Laurion in Attica, as original bullion or in the form of melted Athenian and other Greek city coins used for making Eastern owls.[32] Other Greek silver sources are also indicated, in particular Halkidiki and Macedonia. However, the use of Greek silver is only part of the picture. The analyses of the Tel Mikhal coins also suggest that some of the silver may also have had its origins in the imperial coins of Persia and the earlier issues of Lydia. This is, of course, not surprising. It is rather the fact that so much Greek silver was finding its way into the Athenian copies from Tel Mikhal which is of interest and which corroborates the economic links with the Greek world already attested by the dominance of the Athenian owl as the prototype of choice.[33]

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30. See H. Gitler, M. Ponting, and O. Tal, Metallurgical Analysis of Southern Palestinian Coins of the Persian Period, *Israel Numismatic Research* 3 (2008), pp. 13–27.

31. *Ibid.*

32. Here one must refer to the *kršn* (*karsh*), *š* (*šheqels*) and *ḥ* (*ḥallures*) denominations used for the weighing of silver ores(?) carried in Ionian ships sailing to Egypt mentioned in the *Customs Account* of Elephantine, dated to year 11 of Xerxes I—475 BC or Artaxerxes I—454 BC. For the published edition, see B. Porten and A. Yardeni, *Textbook of Aramaic Documents from Ancient Egypt, 3: Literature, Accounts, Lists* (Jerusalem, 1993), §C3.7. The information from this document concerns maritime trade, including the kinds of ships sailing to and from Egypt and the kinds of goods they carried, as well as the system of duty collection and royal accountancy in Egypt at the time; see A. Yardeni, Maritime Trade and Royal Accountancy in an Erased Customs Account from 475 B.C.E. on the Aḥiqar Scroll from Elephantine, *Bulletin of the American Schools of Oriental Research* 293 (1994), pp. 67–78; P. Briant and R. Descat, Un registre douanier de la satrapie d'Égypte a l'époque achéménide, in N. Grimal and B. Menu (eds.), *Le commerce en Égypte ancienne* (IFAO, Bibliothèque d'Étude 121; Cairo, 1998), pp. 59–104.

33. The Athena/owl motif was borrowed by the southern Levantine societies (Philistian, Samarian, Judean, Edomite) because it symbolized the accepted currency of the period; it probably had no mythical connotations for them. The prototype for the local Palestinian Athenian-style issues was the tetradrachm. This is evident from the fact that in local issues of all denominations (sheqels ['tetradrachms'], quarter-sheqels ['drachms'], one-eighth sheqels ['hemidrachms'], *ma'ehs* ['obols'], half-*ma'ehs* ['hemiobols'], and even smaller denominations: see O. Tal, Coin Denominations and Weight Standards in Fourth-century

However, it should be stressed that, on the basis of the analyses presented here, it is also possible that all the Tel Mikhal coins are authentic Athenian coins, although only B4 is considered a possibility from a stylistic point of view and B5, B9 and B10 were classified as 'Autonomous Athens or imitation.'[34] If we accept the attribution of these coins in Ariel's report, then the Eastern owls will have been produced from either Greek ores or melted Athenian and other Greek city coins.[35] The other interpretation of the data could be that the attribution of these coins on stylistic grounds is erroneous and that they are in fact authentic Athenian issues.[36] Two considerations support this notion. First of all, why would anyone melt an authentic Athenian tetradrachm in order to produce a tetradrachm which looked almost identical?[37] In case chopped, cut or worn authentic Athenian coins were used for this purpose one would expect different chemical composition and a lower level of pure silver. This holds true for other types of 'intermediate' phases in which melted authentic Athenian coins were used. Secondly, the number of late sixth and fifth century BC coins retrieved from controlled archaeological excavations in Israel is relatively small, and the same can be said of stray finds in the

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BCE Palestine, *Israel Numismatic Research* 2 [2007], pp. 17–28) a crescent appears in the upper left field between the olive and the owl. In the authentic Athenian issues the crescent occurs only on the tetradrachms.

[34] Ariel (n. 3), p. 74.

[35] Palestine has no silver sources of its own so all silver used in the region must have come from outside.

[36] For example, the attribution of Roman *denarii* to mints was traditionally based on stylistic criteria, which have a number of limitations and need to be supplemented by metallurgical analysis. Thus, although chemical analysis has revealed that traditional attributions of Severan *denarii* are generally accurate, it has also shown that about 10% of attributions are false, and has allowed a significant proportion of uncertainly attributed *denarii* to be given definite attributions: see H. Gitler and M. Ponting, *The Silver Coinage of Septimius Severus and his Family (193–211 AD): A Study of the Chemical Composition of the Roman and Eastern Issues* (Glaux 16; Milan, 2003), esp. pp. 52, 63–78).

[37] One might note that the 17.2 g theoretical weight of the Athenian tetradrachm (see H. Nicolet-Pierre, Metrologie des monnaies grecques. La Grèce centrale et l'Egée aux époques archaïque et classsique (VI^{e}–IV^{e} s.), *Annali* 47 [2000], p. 41; J. Elsen, La stabilité du système pondéral et monétaire attique (VI^{e}–II^{e} s. avant notre ère), *Revue belge de numismatique et de sigillographie* 148 [2002], p. 23) is some 4% heavier than the average weight of our coins which is 16.5 g (B4 is 16.66 g; B6 is 16.20 g; B7 is 16.71 g; and B11 is 16.41 g. But, given the relative scarcity of Eastern owls found in controlled archaeological excavations or as strays in Palestine (Gitler and Tal [n. 8], pp. 23–30), such a small difference would not have prompted the melting down of Athenian coins in order to produce lighter local coins with the same types since the profit would be too low and would hardly cover the cost of the procedure.

region.[38] One might thus argue that too few Greek city coins reached the region to support the production of Eastern owls in any great quantity. Nonetheless, hoards containing relatively large numbers of early Greek coins have been found both in the southern Levant and Egypt,[39] and it may be that most such coins were consigned to the melting pot to produce local coins before they had had a chance to circulate.

Our metallurgical analyses thus cast some doubt on Ariel's identification of ten of the Tel Mikhal tetradrachms as Eastern imitations and suggests that many of the owls which circulated in Palestine could in fact be authentic Athenian coins. Given the stylistic variability of the Tel Mikhal tetradrachms, it is reasonable to assume that many of the Athenian-style tetradrachms found in Palestine will reveal similarly complex metallurgical results. It would be premature however to argue that the term Eastern imitations—and its derivatives i.e., Eastern/Palestinian/southern Levantine owls—is an erroneous scholarly convention of mental rationalization based on their 'non-canonical' craftsmanship, given the relative small number of analyzed coins and their provenance in a single site.

The mean silver content of all 11 tetradrachms is 99.2% and the lowest silver content is 97.8% which is still higher than the average silver content of Philistian coinage analyzed by the same method (ICP-AES).[40] This suggests that the silver content of the Eastern owls was as strictly controlled as authentic Athenian tetradrachms and provides further evidence to support the view that these coins are either authentic Athenian products or some form of centrally minted eastern issues produced from Greek silver. Given the stylistic variability of the Tel Mikhal tetradrachms and our metallurgical analyses, it seems that authentic Athenian and

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[38] Gitler and Tal (n. 10), pp. 13–30.

[39] See e.g., H. Gitler, A *Hacksilber* and Cut Athenian Tetradrachm Hoard from the Environs of Samaria: Late Fourth Century BCE, *Israel Numismatic Research* 1 (2006), pp. 6–7, Table 1 *passim*.

[40] Cf. Gitler, Ponting, and Tal (n. 26), Table 2. This is also true of southern Palestinian coinages analyzed by a different method (XRF); thus the average silver bullion (= Ag + Au + Pb + Bi) of the 271 Philistian issues analyzed in the course of Gitler and Tal's work on the Philistian coinage (Gitler and Tal (n. 10), pp. 329–334 *passim*) is 95%; the average silver content of the 66 Samarian issues analyzed in Gitler and Tal's work on new Samarian coin types (H. Gitler and O. Tal, Coins with the Aramaic Legend *Šhrw* and Other Unrecorded Samarian Issues, *Schweizerische Numismatische Rundschau* 85 [2006], Table 1) is 92.5; the average silver content of 24 Edomite 'drachms' (plated coins excluded) discussed in H. Gitler, O. Tal, and P. van Alfen, Silver Dome-shaped Coins from Persian-period Southern Palestine, *Israel Numismatic Research* 2 (2007), Table 4, is 97.5%; and the average silver content of the 32 Persian-period *yhd* coins discussed in H. Gitler and C. Lorber, A New Chronology for the Ptolemaic Coins of Judah, *American Journal of Numismatics* 18 (2006), Table 4, is 97.7%.

Eastern owls could hardly be distinguished from one another, so that that Eastern owls would be readily acceptable in Athenian and other Greek markets. Who then would benefit from the production of Eastern owls? Some have argued that the minting of silver bullion in the earliest stages of the monetary economy in the southern Levant was connected with payments to the army—that is, funding for the activities of the Phoenician fleet on behalf of the Achaemenids, or for the major urban centers responsible for supplies to the army.[41] Others have claimed that the minting of Athenian-style Eastern issues was intended to address the lack of Athenian coinage in the markets of the Near East after the Peloponnesian War.[42] Both suggestions may well explain the high standard of production of the Eastern owls. If they were aimed at Greek markets (mercenaries and merchants), we may suggest that the Achaemenid authorities controlled their production and circulation in order to facilitate international interactions and trade. The Eastern owls were produced at the same time as the local Philistian, Samarian, Judean, and Edomite (autonomous) coinages. Their function however differed: the latter formed part of an intra-city or intra-regional monetary system for they are rarely found outside the political boundaries of the issuing authorities,[43] while the former formed an international currency since they are found well beyond the boundaries of the Fifth Satrapy. Elsewhere we have argued that much of the silver for the Philistian and Edomite coinages originated in the Greek world, most probably from Athenian coins.[44] It would thus be reasonable to suggest that the Philistian minting authority was one of the production centres that made the Eastern owls for the Achaemenid and Greek markets, while at the same time producing a local coinage with a lower bullion content. The fact that the first production stage of Philistian coinage shows a high degree of similarity in weight, flan, fabric, and even in some of the motifs shown in the Eastern owls may suggest that some of the latter were locally produced and may be regarded as the forerunners of local Philistian types or contemporary counterparts. Palestine had a long tradition of using bronze, silver, gold, and different metal alloys in trade, as the *Hacksilber* hoards found at biblical sites in Palestine attest.[45]

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[41] Cf. Babelon, *Traité* II.2, p. 671; J. Elayi, L'ouverture du premier atelier monétaire phénicien, *Bulletin du Cercle d'Études Numismatiques* 32 (1995), pp. 73–78.

[42] Cf. J. P. Six, Observations sur les monnaies phéniciennes, *Numismatic Chronicle* 67, Part II (1877), pp. 177–239; J. G. Milne, The Origin of Certain Copies of Athenian Tetradrachms, *Iraq* 4 (1937), pp. 57–58.

[43] Gitler and Tal (n. 10), pp. 49–51.

[44] Gitler, Ponting, and Tal (n. 30).

[45] Gitler and Tal (n. 10), pp. 9–12.

ANALYTICAL APPENDIX

The coins selected for analysis were first sampled by drilling into the edge of the coin with a 0.6 mm diameter drill and collecting the turnings. The first millimetre or two of metal was always discarded to avoid contamination by corrosion products and unrepresentative surface metal. Approximately 10 mg of the sample was weighed into a glass vial and dissolved according to the procedure devised by Hughes *et al.*[46] The dissolved sample was made up to a final 10ml volume with purified water (18.2 MΩ) and centrifuged to ensure that all the precipitated silver chloride settled out. Silver was calculated by difference and checked by atomic absorption spectrometry. Analysis was conducted on a Perkin Elmer DV3000 series inductively coupled plasma atomic emission spectrometer (ICP-AES) which was calibrated using matrix-matched multi-element standards. Instrumental drift and analytical precision were monitored by specially prepared quality control solutions which were measured after every ten samples. Accuracy was checked by the use of two certified standard reference materials (SRMs): Bundesanstalt für materialprüfung No. 211 and Silver standard Gliwice AG5-chem. The relative accuracy based on two analyses of both SRMs at the beginning and at the end of the analysis is better than 8% for all major and minor elements (copper <1%), with the exception of lead (9.2% error at a concentration of 0.74%). The relative accuracy of the trace elements is better than 10%, again with the poorer values occurring when the concentrations approach the limits of detection (i.e., manganese with a 13.5% error on a certified value of 0.0019%). Instrumental precision (coefficient of variation across three replicate analyses of the same sample) is generally better than 3%, while analytical precision (coefficient of variation of two analyses of the same SRM across all analyses) is generally better than 3% for major, minor and trace elements over all analyses, with the exception of manganese, antimony, and bismuth, which are poor because the certified values are close to the limit of detection (LOD). The LODs for the analysis (expressed as parts per million), calculated at 3 σ, are:

Ag	As	Au	Bi	Co	Cr	Cu	Fe	Mn	Ni	Pb	Sb	Sn	Zn
0.001	0.039	0.005	0.013	0.002	0.001	0.041	0.001	0.0004	0.003	0.013	0.029	0.029	0.002

Lead isotope ratios were determined by quadrupole ICPMS (*Thermo-Fisher Scientific* X-Series^{II}). The dwell times used were: 10, 10, 2.5, 2.5 and 2.5 ms for ^{202}Hg, ^{204}Pb, ^{206}Pb, ^{207}Pb and ^{208}Pb respectively. These represent a compromise between the need for stability for individual isotope count rates and an attempt to minimise 'plasma flicker' during each run. The isotope ^{202}Hg was included to provide an isobaric correction for ^{204}Hg on ^{204}Pb. Ten analytical runs per analyte were employed.

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[46] M. J. Hughes, M. R. Cowell, and P. T. Craddock, Atomic Absorption Techniques in Archaeology, *Archaeometry* 18 (1976), pp. 19–37.

Isotope ratios were determined from blank-corrected cps data. Mass bias correction (K-factors) of raw cps data was undertaken by running the isotopic reference NIST-981 after every four samples and calculating K-factors for each sample by extrapolation. Quadrupole stability was checked from a plot of K-factor against mass difference (Δmass) for the isotope ratios (K-factor = 1.0 at Δmass = 0). Detector 'dead time correction' was optimised by running several concentrations (5 – 40 μg L^{-1}) of NIST-981 at the start of each experiment and adjusting to minimise variation in the ratio $^{206}Pb/^{208}Pb$ across the concentration range. (Information on the instrumentation and procedures employed for the lead isotope analyses was kindly provided by Dr. Scott Young).[47]

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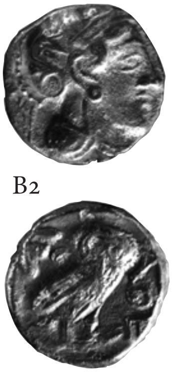
[47] Comparative lead isotope data are from the following: Gale *et al.* (n. 18); I. L. Barnes *et al.*, Isotopic Analysis of Laurion Lead Ores, in C. W. Beck (ed.), *Archaeological Chemistry* (Washington, 1974), pp. 1–10; G. A. Wagner *et al.*, Early Bronze Age Lead-Silver Mining and Metallurgy in the Aegean: The Ancient Workings on Siphnos, in P. T. Craddock (ed.), *Scientific Studies in Early Mining and Extractive Metallurgy* (London, 1980), pp. 63–80; N. H. Gale, Some Aspects of Lead and Silver Mining in the Aegean, *Thera and the Aegean World*, II (London, 1980), pp. 161–195; V. E. Chamerlain and N. H. Gale, The Isotopic Composition of Lead in Greek Coins and Galena from Greece and Turkey, in E. A. Slater and J. O. Tate (eds.), *Proceedings of the 16th International Symposium on Archaeometry and Archaeological Prospection* (Edinburgh, 1980), pp. 139–155; N. H. Gale, W. Gentner, and G. A. Wagner, Mineralogical and Geographical Silver Sources of Archaic Greek Coinage Special, *Publications of the Royal Numismatic Society* 13 (1980), pp. 3–49; N. H. Gale and Z. A. Stos-Gale, Cycladic Lead and Silver Metallurgy, *The Annual of the British School at Athens* 76 (1981), pp. 169–224; *id.* Thorikos, Perati and Bronze Age Silver Production in the Laurion, *Attica Miscellanea Graeca* 5 (1982), pp. 97–103; E. Pernicka *et al.*, Archaometallurgische Untersuchungen in Nordwestanatolien, *Jahrbuch des Romisch-Germanisches Zentralmuseums* 31 (1984), pp. 533–599; Z. A. Stos-Gale, N. H. Gale, and G. R. Gilmore, Early Bronze Age Trojan Metal Sources and Anatolians in the Cyclades, *Oxford Journal of Archaeology* 3 (1984), pp. 23–44; N. H. Gale, O. Picard, and J. N. Barrandon, The Archaic Thasian Silver Coinage, *Der Anschnitt* Beiheft 6 (Bochum, 1988), pp. 212–223; K. A. Yener *et al.*, Stable Lead Isotope Studies of Central Taurus Ore Sources and Related Artifacts from Eastern Mediterranean Chalcolithic and Bronze Age Sites, *Journal of Archaeological Science* 18 (1991), pp. 541–577; Z. A. Stos-Gale, N. H. Gale, and N. Annetts, Lead Isotope Data from the Isotrace Laboratory: Archaeometry Data Base 3. Ores from the Aegean: Part 1, *Archeometry* 38 (1996), pp. 381–390.

Plate 4


B1


B2


B3


B4


B5


B6


B7


B8


B12


B9


B10


B11


B15

Athenian Tetradrachms from Tel Mikhal