Metallurgical Analysis of Southern Palestinian Coins of the Persian Period[1]

HAIM GITLER
Israel Museum, Jerusalem
gitler@imj.org.il

MATTHEW PONTING
University of Liverpool
m.ponting@liverpool.ac.uk

OREN TAL
Tel Aviv University
orental@post.tau.ac.il

Abstract
By means of inductively coupled plasma atomic emission spectrometry (ICP-AES), metallurgical analyses of southern Palestinian coins of the Persian period were performed. The main group of analyzed coins consists of dome-shaped quarter *sheqels* ("*drachms*"), which were struck from worn, recut and repolished obverse dies that based on their circulation were defined as Edomite. In addition, several Philistian coins were analyzed as a reference group. Our results suggest that much of the silver bullion used for striking the Edomite and Philistian coins originated in the Greek world, most probably from Athenian 'owls' and that Edomite coinage was probably produced by a central Philistian minting authority based on identical silver content.

A year ago, a so far unknown group of peculiar Athenian-styled Palestinian coins was published in this journal (Gitler, Tal and van Alfen 2007). This group, which includes mainly quarter *sheqels* ("*drachms*") but some *ma'ehs* ("*obols*") as well, were struck from worn obverse dies (meaning dies damaged by prolonged use),[2] which were then recut and repolished. As a result, the coins' obverse in many cases is simply dome-shaped, with no recognizable traces of Athena's head or helmet (Fig. 1).

Fig. 1. A typical dome-shaped coin (Gitler, Tal and van Alfen 2007: Pl. 5:41)

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2 A closely related phenomenon is noted for the *Yehud* coins, where dies were significantly damaged in one way or another; see Fontanille (this volume).

The coins' distribution suggests that they circulated in the boundaries of Edom in the later part of the Persian period and might well have been the silver money mentioned in several Edomite ostraca (see Tal 2007:17–19). The current paper presents a new metallurgical analysis of this group of coins and the social and economic implications gleaned from their results.

RESULTS

Previously analyzed by surface x-ray fluorescence (XRF), the coins were re-analyzed by inductively-coupled plasma atomic emission spectrometry (ICP-AES), in order to obtain an accurate data-set of chemical composition. Samples were taken from each coin by drilling into the edge; details of the methodology and technique are presented in the appendix (below). During the sampling of the coins, two previously unsuspected plated coins were discovered; Cat. Nos. 34 and 36, both quarter *sheqels* of the "prominent dome-shaped motif" (catalogue numbers refer to those in Gitler, Tal and van Alfen 2007). The previous XRF analyses had indicated that they were solid silver coins containing 96.6% and 97.1% elemental silver respectively (Gitler, Tal and van Alfen 2007:58). The silver foil coatings on these coins are relatively thick and were competently applied, thus making visual recognition of plated coins difficult. This discovery further underlines the potential for erroneous results inherent in any non-destructive methodology (cf. Gitler and Ponting 2003:12–13, 49–51, see also Beck, Bosonnet, Réveillon, Eliot and Pilon 2004: esp. p. 161). The use of a minimally destructive representative sampling technique also resulted in the identification of three quite base coins, two of which (Cat. Nos. 25 and 57) had been previously analyzed by surface XRF and recorded as containing 97.2% and 89.1% elemental silver respectively. The true elemental silver content of these two coins is now established as 81.5% and 16.8% respectively. The third coin (Cat. No. 42) was initially thought to be plated and so not analyzed by XRF, however, closer examination revealed it to be a base coin containing 34.2% elemental silver. The analysis of representative bulk samples has shown that the overall silver content of these coins is generally high, with the exception of the coins just discussed. The average silver content (with the two plated coins removed) is 87.9% for the 17 Edomite coins (Table 1), and 96.9% for the 6 Philistian coins analyzed (as reference group, see Table 2). The other major elements are copper and lead, although in some coins the concentration of these elements is down to trace levels. The minor components are gold, bismuth, nickel, arsenic, antimony and cobalt. The elements chromium, iron, manganese, tin and zinc were also measured, but very few concentrations above detection limits were found in the purer silver coins.

Table 1. Silver Content of Edomite Coins

Type		**Æ Content (%)**	**Cat. No. (Gitler, Tal & van Alfen 2007)**	**Reg. No.**
Transitional	1	95.5	9	PC
	2	96.2	10	IAA 101004
	3	98.6	11	JR 19
	N = 3; Mean = 96.8; Minimum = 95.5; Maximum = 98.6; Std. Deviation = 1.6			
Oblong flans	1	94.6	12	JR 21
	2	97.5	14	JR 27
	3	100.0	16	IM 26154
	N = 3; Mean = 97.4; Minimum = 94.6; Maximum = 100.0; Std. Deviation = 2.7			
Round flans	1	92.9	22	JR 3
	2	82.8	25	JR 7
	N = 2; Mean = 87.8; Minimum = 82.8; Maximum = 92.9; Std. Deviation = 7.2			
Dome-shaped	1	97.9	35	JR 11
	2	99.9	37	JR 18
	3	99.8	38	JR 28
	4	99.6	39	JR 4
	5	34.6	42	IM 26160
	6	93.6	51	JR 2
	7	96.7	54	JR 26
	8	17.0	57	JR 14
	9	96.9	58	JR 17
	N = 9; Mean = 81.8; Minimum = 17.0; Maximum = 99.9; Std. Deviation = 32.18			
Total	17 N = 17; Mean = 87.9; Minimum = 17.0; Maximum = 100.0; Std. Deviation = 23.9			

Abbreviations for coin collections:

IAA — Israel Antiquities Authority
IM — Israel Museum, Jerusalem
JR — Jonathan Rosen Collection (long-term loan at the IM)
PC — Private Collection

Table 2. Silver Content of Philistian Coins

Minting Authority		Æ Content (%)	Type (Gitler and Tal 2006)	Reg. No.
Ascalon	1	94.8	III. Ashkelon 20D[b]	IM 16176
	N = 1; Mean = 94.8; Minimum = 94.8; Maximum = 94.8; No Std. Deviation			
Gaza	1	95.2	VI. Gaza 1D[var-a]	IM 24584
	2	97.6	VI. Gaza 1D	IM 749
	3	99.1	VI. Gaza 1D	IM 16209
	4	95.1	VI. Gaza 1D[c]	IM 2363
	N = 4; Mean = 96.8; Minimum = 95.1; Maximum = 99.1; Std. Deviation = 1.9			
Gaza	1	99.7	VI. Gaza 10D	IM 8974
	N = 1; Mean = 99.7; Minimum = 99.7; Maximum = 99.7; No Std. Deviation			
Total	6 N = 6; Mean = 96.9; Minimum = 94.8; Maximum = 99.7; Std. Deviation = 2.2			

SILVER CONTENT

Silver bullion produced by traditional methods in antiquity is not chemically pure; it contains traces of other metals that relate to the ore smelted and/or the subsequent refining process. It is therefore more accurate to estimate the silver content of ancient coins (*contra* the true elemental silver content — see above) as the combined total of elemental silver together with the geo-chemically associated trace elements gold, bismuth and lead (Craddock 1995). The content of silver in the coins analyzed here is presented in Fig. 2. The average silver content for 6 Philistian coins (Table 2) is of a consistent, fineness (96.9%, standard deviation 2.2). The 19 Edomite coins, on the other hand exhibit a much wider range of finenesses, and include the 2 plated coins (Cat. Nos. 34 and 36). If the plated coins are disregarded, the average silver content is 87.9% (standard deviation 23.9). However, only three of these coins have less than 90% silver (Cat. Nos. 25, 42 and 57) and if these are discounted the spread of the remaining 14 coins has silver content that average 97.1% with a standard deviation of 2.4; virtually identical to that of the coins of Philistia. On the basis of these analyses, it appears that the Edomite coins are, for the most part, of the same fineness as the other Philistian coins, but that this group is characterized by the presence of some particularly base pieces with finenesses ranging from 83% to 17%. It is possible, of course that this difference may be due to the small number of coins from Philistia that were analyzed by ICP-AES. It should be stated however that we are familiar with several plated Philistian coins, which means that at least coin silver plating is known in both Edomite and Philistian coinages.

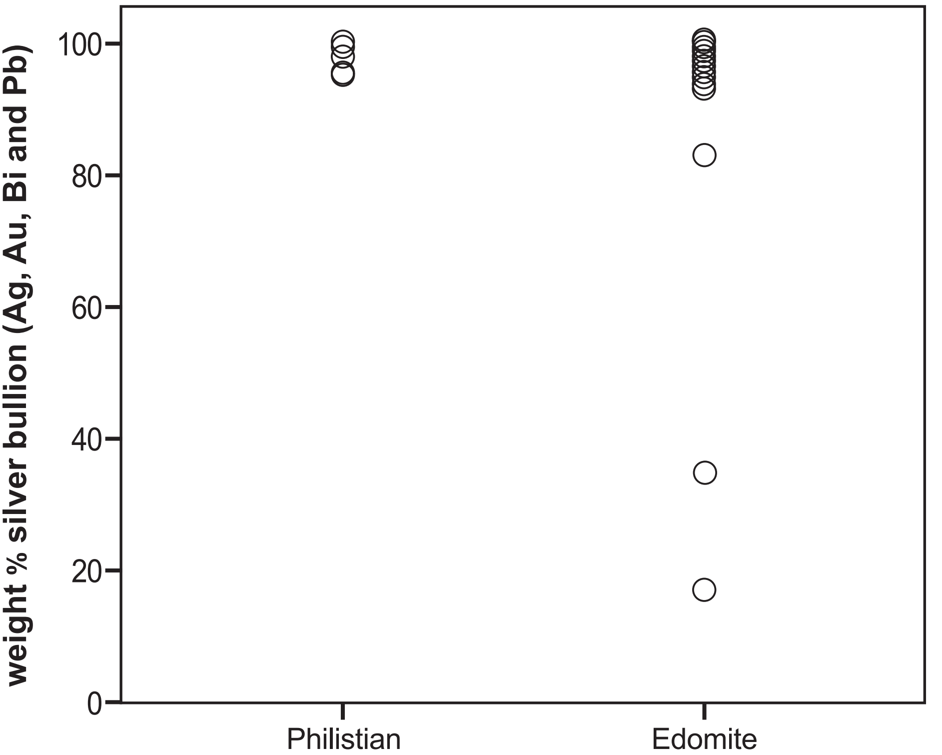

Fig. 2. Silver content

TRACE ELEMENTS

Besides gold, bismuth and lead, some other metallic elements may also relate to the original ore, such as copper, tin or nickel. However, these latter elements may also have been added to the metal as major alloying components, or as contaminants within these components. In particular, in cases where copper is present at levels greater than 0.5–1.0%, it is likely that this metal was added as an alloying component and that any tin or nickel present would have come as contaminants with it. Only the gold and bismuth can be reliably regarded as being associated with the silver source(s), whilst the lead relates to the technology and scale of the refining process. For these reasons the gold and bismuth traces are regarded as the most useful trace elements in ancient silver (Mackerrel and Stevenson 1972).

In the coins analyzed here, the gold and bismuth contents define two compositional groups; one with a gold contents of between 0.1% and 0.45% and another with a lower gold content of less than 0.08% (Fig. 3). Most of the Edomite issues (12 out of 17) and five out of the six Philistian coins are in the high-gold group and there appears to be no discernible variation according to mint or type.

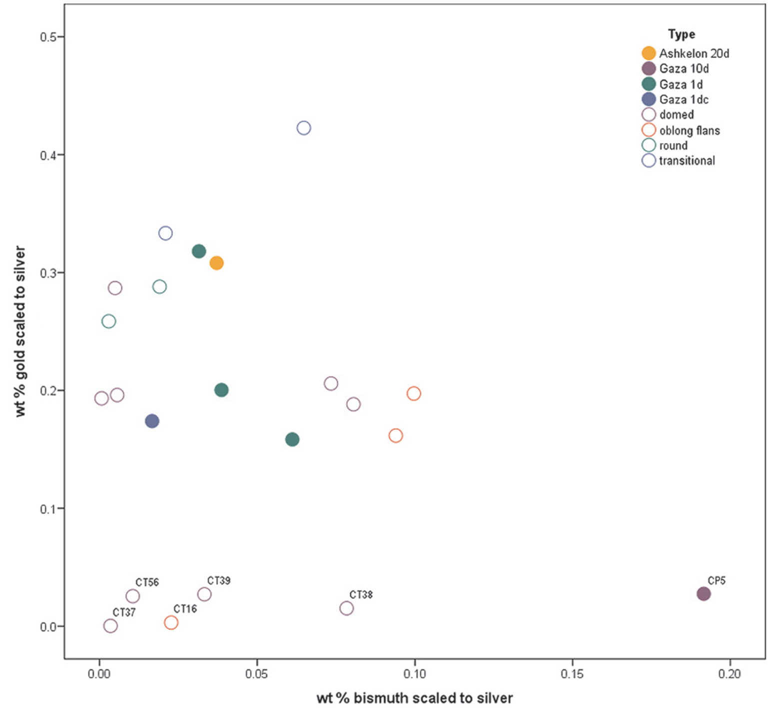

Fig. 3. Gold and bismuth contents of Edomite and Philistian coins (Cat. No. 11 has a particularly high gold content — 1.44% — and is off the scale of the graph.)

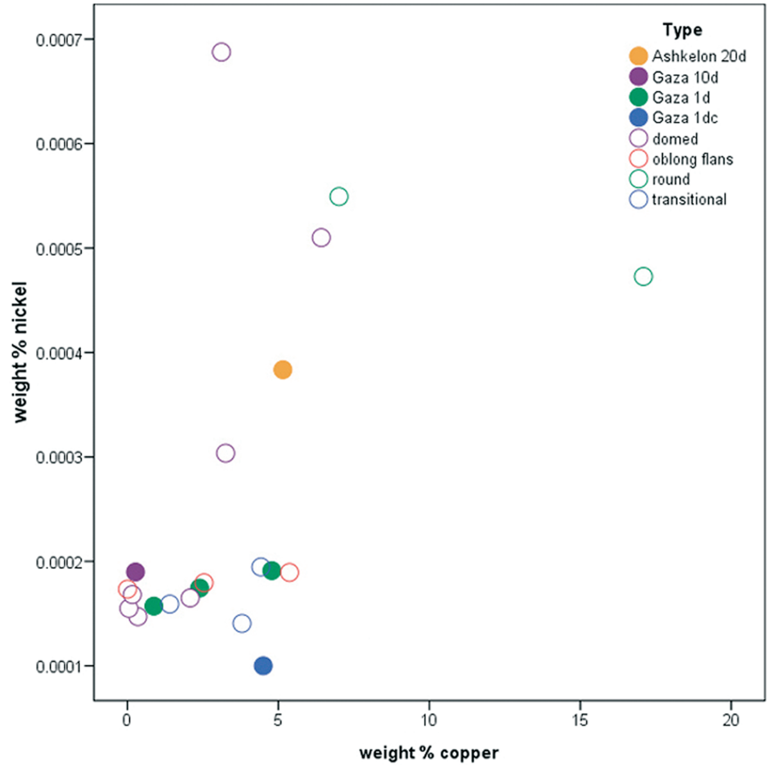

Fig. 4. Copper and nickel contents of Philistian and Edomite coins.

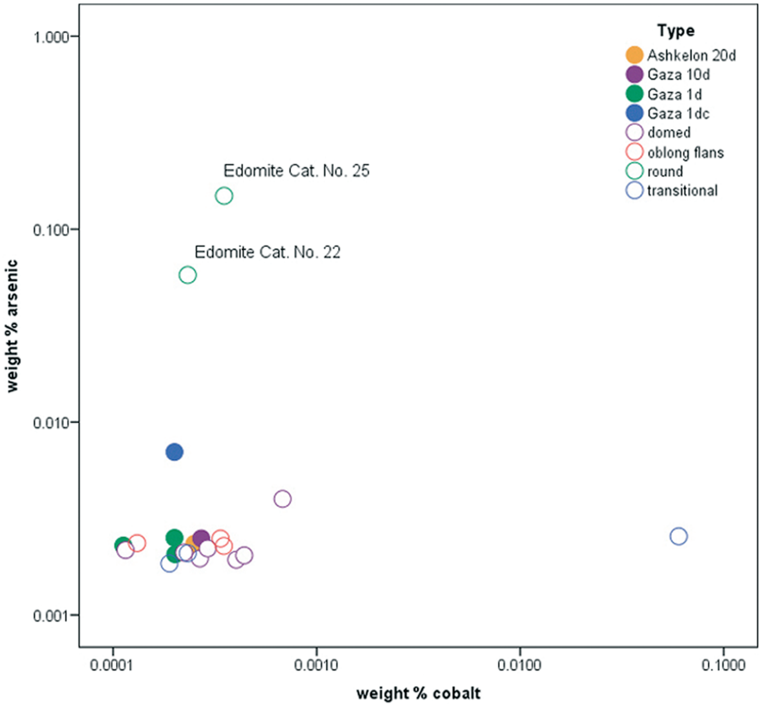

Fig. 5. Arsenic and cobalt contents of Philistian and Edomite coins.

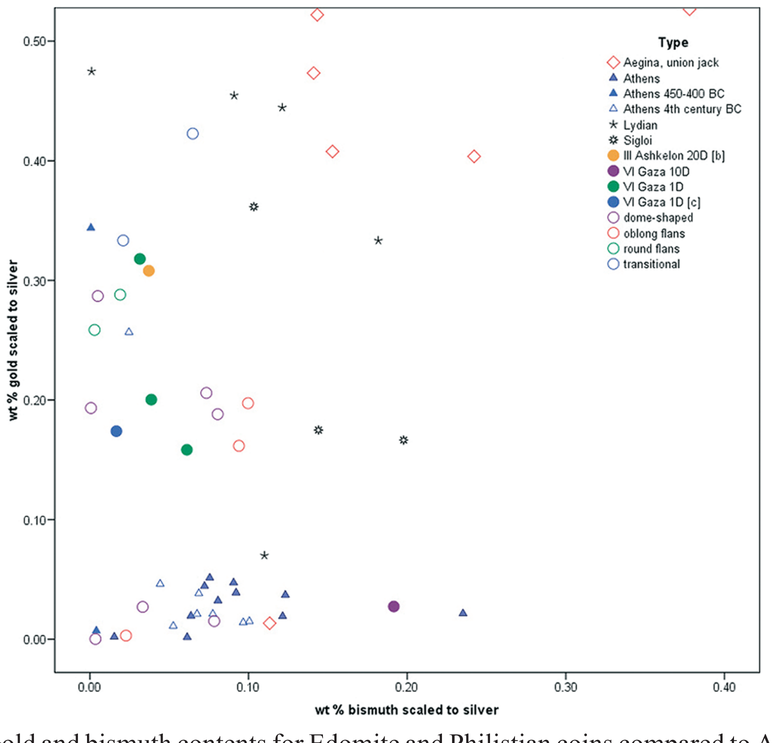

Fig. 6. Gold and bismuth contents for Edomite and Philistian coins compared to Athenian, Aeginetan and Persian issues.

There is also a suggestion of a correlation between the copper and nickel concentrations (Fig. 4) in those coins that contain more than 3% copper indicating that copper at these levels was an intentional addition. The coins in question are the single Philistian issue of Ascalon (Table 2), three of the Edomite coins (Cat. Nos. 51, 54 and 58) and the two baser 'round flan' coins (Cat. Nos. 22 and 25). The latter two are further characterized by having particularly high arsenic content (0.06% and 0.015% respectively, Fig. 4); this also appears to reflect the fact that these two coins are quite base (93% and 83% silver respectively). Furthermore, significant traces of arsenic and nickel have been observed as characteristic of copper metal produced in the region of Syria-Palestine in later periods and may very well indicate that locally produced copper was used to adulterate the alloy used for these coins (Ponting 2002).

The concentrations of the different trace elements measured in the silver of these coins have produced a picture of complex interrelationships between elements due to geo-chemical affinities, technological differences and anthropogenic interference. Since the existence of some link with contemporary Athenian coinage is clear from the borrowed iconographical motifs of the Philistian and Edomite coinages, a comparison of these data with the published analyses of Greek silver coins was deemed worthwhile. Analyses of fifth-century BCE Athenian, Aeginetan and Persian coinage from the Asyut hoard (Gale, Gentner and Wagner 1980) and earlier Lycian silver (Ramage and Craddock 2000) were compared to the data presented here and a strong similarity between Athenian coins and the low-gold (< 0.1%) Philistian and Edomite issues (Fig. 6), is very clear.

The higher-gold group (> 0.1%) also contains some Athenian issues, but is also close to Persian *sigloi* and Lydian issues and is therefore indeterminate without further analyses. The compositional link between Philistian and Greek coinages is discussed in more detail in another paper (Gitler, Ponting and Tal, *forthcoming*), but the use of Attic silver or silver from melted Attic coins to produce a significant proportion of the Philistian and Edomite coinages is clearly indicated.

CONCLUSION

These analyses present a complex picture of silver procurement in Achaemenid Palestine. The conclusion is that it appears that much of the silver for the Edomite and Philistian coinages originated in the Greek world, most probably from Athenian 'Owls.' However, this silver was often eked out by the addition of varying amounts of local copper to such an extent that some of the coins produced were made of very base metal indeed. Quality control appears to have been particularly poor in the Edomite coinages and the consistency of fineness is notably worse than that of the Athenian and Athenian-styled *tetradrachms* found in Palestine, whose silver content is indistinguishable from that of their source material (Gitler, Ponting and Tal, *forthcoming*). The Edomite mints were also diluting the silver with copper with great variability, unlike the producers of the Athenian and Athenian-styled *tetradrachms*, who appear to have been merely recycling the metal, adding it to silver from other sources.

Comparison of these analyses with those of the Greek silver coins from the Asyut hoard suggest that much of the bullion for both the Philistian and Edomite coinages derived from the silver mines at Laurion in Attica. But other silver sources are also indicated; the silver coins of the Persian Empire in particular, as well as those of Lydia and the island of Siphnos, where silver for Aeginetan coins was mined. The use of Persian silver is, of course, not surprising; it is rather the large proportion of Greek silver that was finding its way into Philistian coins that is of interest and which strengthens the notion of economic links with the Greek world already attested by the dominance of the Athenian 'Owls' as the prototype of choice for both Philistian and Edomite coinages. Future lead isotope analyses might be able to demonstrate the use of both Greek and Persian silver in Philistian and Palestinian coins, or even the possibility of identifying other (Near Eastern) silver sources.

As stated above, several of the Edomite and Philistian coins are plated. The plating of some of these coins can easily be distinguished by visual inspection when the silver coating is corroded and one can see the copper core (e.g., Gitler and Tal 2006: V. Gaza. 16Dc, VI. Gaza. 1D[variant]b, XI. Imitation. 6Db, XIII. Obverse Athenian-styled. 16Da, XIV. Reverse Athenian-styled. 33Db), or when only the copper core remains (VI. Gaza. 1D[variant]c, XIII. Obverse Athenian-styled. 16Db) [Fig. 7].

In other cases, only once the coin is drilled, such as the Edomite issues analyzed and discussed above (Cat. Nos. 25, 34, 36, 42 and 57) it becomes evident that these are plated coins.[3] It is thus clear that coin-plating occurred in both the Edomite and the Philistian coinages. Authorities in ancient times suspected that coins were being forged by this or other procedures and ordered the random testing of coinage in order to ascertain the purity of the metal. The coins selected would have first undergone a non-destructive inspection, namely, the coins were observed, felt, and checked. One check would have been to drop the coin on to a hard surface: a silver-plated coin makes a different sound from that of a coin produced from an alloy of high silver. Coins that were still suspected as forgeries were then subjected to a destructive inspection, namely test cuts made by a chisel.

3 Silver-plating of a coin was achieved through a straightforward method of covering a base-metal core with silver foil and then striking it. The method of attaching the foil can vary, either hard-soldering or diffusion-bonding, but those are technical niceties — the principle remains the same. Straightforward plating of base metal coins is common in many periods (Zwicker, Meeks and La Niece 1993; Bursche 1996; La Niece 1993; Caramessini-Oeconomides 1966; Crawford 1968).

Fig. 7. Upper row, silver coated corroded surface on a quarter *sheqel* ("*drachm*") of Gaza (VI. Gaza. 1D[variant]b), second row, copper core of a quarter *sheqel* of the same coin-type (VI. Gaza. 1D[variant]c), third row, silver coated corroded surface on a Philistian a quarter *sheqel* (XIII. Obverse Athenian-styled. 16Da), lower row, copper core of a quarter *sheqel* of the same coin-type (XIII. Obverse Athenian-styled. 16Db).

This phenomenon was widespread in early coinages found or struck in Palestine and elsewhere in the Levant (e.g., Gitler and Tal 2006: passim and especially pp. 312–313; Price and Waggoner 1975; Milne 1905; Kraay and Moorey 1968; Hurter and Pászthory 1984; *IGCH* 1650; *CH* 8.126, 133). Test cuts were intended to examine dubious issues in order to refute or validate their authenticity. Coins that had been test-cut were transformed into so-called issues of confidence or trust (if the coin was indeed made of the desired silver alloy). Whoever handled the coins that had been tested would be able to see whether the specific coin was indeed silver through the cut. However, based on the fact that we do have die-links between silver and silver-plated coins in the Samarian[4] and Edomite[5] coinages, it is possible that southern Palestinian minting authorities produced silver-plated coins in certain circumstances (e.g., shortage of silver bullion requiring a certain amount of coins to be circulated regardless of their quality in the turnover of capital in order to meet the demand for coins in the market). This means that the production of coins with bronze-, lead- or copper-alloy cores might not be necessarily defined, a priori, as *falsa moneta*.[6]

Our trace element analysis shows that the silver content is virtually identical in both the Philistian and Edomite coinages. It is thus tempting to see the Edomite coinage as a product of a Philistian minting authority. Elsewhere we argue the existence of a collective mint (that is, one central minting authority) for Persian-period Philistia, based on die-links and axis and weight statistics occurrences (Gitler and Tal 2006:315–328). This suggests that the coins with the legends of Ashdod, Ascalon and Gaza together with the other epigraphic and anepigraphic coins of Philistia were all produced in a single regional mint. Such a collective mint would benefit a region which practiced coined economy, because of the technological, economic and political difficulties involved in coin production in such an early stage. Given the identical silver content that the Edomite and Philistian coins analyzed here show, we are tempted to consider that a southern Palestinian collective mint operated for the production of the coinage of Edom as well.

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4 Cf. Meshorer and Qedar 1991:67. Since the authors do not specify in the catalogue which coins are plated we can only speculate on this from the photographs in the plates: e.g., in the die-link group Nos. 71–100: 75, 78, 79, 96 and 99 are apparently plated; in group Nos. 101–143: 102, 105, 108, 109 116, 121 and 142 are apparently plated; in group Nos. 154–162: 154 are apparently plated.

5 Gitler, Tal and van Alfen 2007:55, Cat. Nos. 34–39 are struck from the same reverse die and include two silver-plated coins: Cat. Nos. 34 and 36.

6 For example, Athens produced 'official' silver plated 'Owls' (*drachms* and *tetradrachms*) as an emergency procedure, probably in response to a political and economical crisis, as is evident from issues found in Piraeus. Kroll dated these subaerates to 406/405 BCE, the pressing final years of the Peloponnesian War, when Athens experienced a shortage in silver bullion (Kroll 1993:7).

APPENDIX

The coins selected for analysis (Table 3) were sampled by drilling into the edge of the coin with a 0.6-mm diameter drill and collecting the turnings. The first millimeter 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 a modified version of the procedure devised by Hughes et al. (1976). The dissolved sample was then made up to a final volume of 10 ml. 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 that 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, 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

Table 3. Analytical Data

Type	Reg. No.	*INR* 2 Cat. No.	Silver	Arsenic	Gold	Bismuth	Cobalt	Chromium	Copper	Iron	Manganese	Nickel	Lead	Antimony	Tin	Zinc
Philistian	IM16176		93.6	<0.004	0.2884	0.035	0.0003	<0.00005	5.152	0.002	<0.00004	0.0004	0.894	<0.002	<0.002	<0.0001
	IM24584		93.5	0.003	0.1873	0.036	0.0002	0.00006	4.781	0.004	0.00007	<0.0002	1.500	<0.002	<0.002	<0.0001
	IM749		94.7	<0.004	0.3011	0.030	0.0001	<0.00005	2.393	0.002	<0.00004	<0.0002	2.574	<0.002	<0.002	<0.0001
	IM16209		96.1	<0.004	0.1522	0.059	0.0002	0.00011	0.877	0.003	0.00012	<0.0002	2.812	0.003	<0.002	<0.0001
	IM2363		93.7	0.007	0.1630	0.016	0.0002	0.00006	4.500	0.001	0.00005	<0.0002	1.260	0.006	<0.002	<0.0001
	IM8974		98.2	<0.004	0.0269	0.188	0.0003	0.00006	0.269	0.006	0.00015	<0.0002	1.288	<0.002	<0.002	<0.0001
Transitional	PC	9	93.8	0.003	0.3127	0.020	0.0601	0.00227	4.422	0.001	<0.00004	<0.0002	1.377	<0.002	<0.002	<0.0001
	IAA101004	10	93.8	<0.004	0.3967	0.061	0.0002	<0.00005	3.793	0.004	<0.00004	<0.0002	1.894	<0.002	<0.002	<0.0001
	JR19	11	95.1	<0.004	1.4410	0.006	0.0002	0.00013	1.401	0.001	<0.00004	<0.0002	2.073	0.003	<0.002	<0.0001
Oblong flans	JR21	12	93.2	<0.004	0.1840	0.093	0.0003	0.00006	5.367	0.004	<0.00004	<0.0002	1.102	<0.002	<0.002	<0.0001
	JR27	14	96.9	<0.004	0.1567	0.091	0.0001	<0.00005	2.540	0.002	0.00005	<0.0002	0.267	<0.002	<0.002	<0.0001
	IM26154	16	97.7	<0.004	0.0030	0.022	0.0003	<0.00005	0.004	0.002	0.00005	<0.0002	2.230	<0.002	<0.002	<0.0001
Round flans	JR3	22	90.0	0.058	0.2327	0.003	0.0002	<0.00005	7.009	0.002	<0.00004	0.0005	2.718	<0.002	<0.002	<0.0001
	JR7	25	81.5	0.149	0.2348	0.016	0.0004	<0.00005	17.092	0.001	<0.00004	0.0005	0.973	<0.002	<0.002	<0.0001
Dome-shaped	JR20	34	0.1	0.080	0.0003	0.001	0.0059	0.00006	99.453	0.123	<0.00004	0.0179	0.138	0.008	0.025	0.0018
	JR11	35	95.4	<0.004	0.2737	0.005	0.0001	0.00013	2.076	0.002	0.00004	<0.0002	2.240	<0.002	<0.002	<0.0001
	JR12	36	0.2	0.451	0.0003	0.001	0.0269	<0.00005	98.798	0.206	0.00004	0.1081	0.155	0.043	0.039	0.0109
	JR18	37	98.1	<0.004	0.0002	0.003	0.0004	<0.00005	0.051	0.006	<0.00004	<0.0002	1.840	<0.002	<0.002	<0.0001
	JR28	38	98.0	<0.004	0.0149	0.077	0.0003	<0.00005	0.161	0.001	<0.00004	<0.0002	1.718	<0.002	<0.002	<0.0001
	JR4	39	98.1	<0.004	0.0265	0.033	0.0004	<0.00005	0.346	0.002	<0.00004	<0.0002	1.510	<0.002	0.006	<0.0001
	IM26160	42	34.2	0.210	0.0671	0.002	0.0001	<0.00005	65.167	0.002	<0.00004	0.0147	0.327	0.008	<0.002	<0.0001
	JR2	51	92.3	<0.004	0.1900	0.068	0.0002	<0.00005	6.420	0.002	<0.00004	0.0005	0.974	<0.002	<0.002	<0.0001
	JR26	54	96.0	0.004	0.1806	0.077	0.0007	0.00009	3.254	0.003	0.00004	<0.0002	0.521	0.003	0.003	0.0002
	JR14	57	16.8	1.417	0.0043	0.002	0.0005	0.00013	81.196	0.002	0.00006	0.0134	0.235	0.343	0.017	0.0002
	JR17	58	94.8	<0.004	0.1833	0.001	0.0003	<0.00005	3.115	0.001	<0.00004	0.0007	1.854	<0.002	<0.002	<0.0001

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