Brockage Coins

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[PLATES 19-20]

Abstract. Brockage coins have been insufficiently researched despite their potential for providing a fresh approach in understanding ancient minting techniques and procedures. The article presents rare brockages resulting from the use of more than one die per anvil and discusses die link diagrams that may be indicative of such a production method. Examples are also provided demonstrating how such minting errors provide insight into better understanding various characteristics, features and anomalies resulting from the minting process.

THE introduction of the assembly/production line is generally attributed to modern times, in particular as the brainchild of Henry Ford for his mass production of the model T cars.[1] As a consequence, the mass production line today has become a crucial necessity in any manufactory; however, is it a modern invention or can its origins be traced back to the production of ancient coins?

It is well attested that ancient coins were produced individually by striking a disk-shaped blank piece of metal (flan) between two dies to produce in relief the images on the dies. In fact, the same method is still used today, albeit in mechanised form. The idea is that a lower die (mostly the obverse) was placed on a sturdy station, referred to as an anvil, and an upper punch die (mostly the reverse) was held in the hand and struck with a hammer to simultaneously impress images on both sides of the flan. This process was repeated by swapping the struck coins and replacing them with fresh blanks. A Trajanic inscription and a minting scene depicted on a bronze *tessara* indicate that three workmen operated per anvil (at least in the Roman period): *malliatores* (those who wield a hammer, or 'strikers'), *suppostores* (those who (re)place the blanks, 'replacers') and *signatores* (those who hold the upper die).[2] Other staff would be needed to prepare the flans, but they need not necessarily be present at the workstation during the striking process.[3] In principle, efficiency in producing these coins would have been just as important for mint officials in the past as for modern industrialists, particularly when considering that coins were produced in their millions, with estimates of 3,000 coins being produced daily per anvil.[4]

[1] Although he himself got the idea from a meat processing factory (Ford 1922, p. 34).

[2] See Woytek 2012 and 2013 for a thorough discussion on the division of labour in the Roman mint. Note that, technically, a single person can also operate a workstation, as was the case for Sellwood (1963) who 'working entirely on [his] own' (p. 226) managed to produce thousands of tetradrachms. Although in his case multiple blows of the hammer were required to produce a single coin, experiments using heavier hammers (held by both hands, hence requiring a second person) a single blow was sufficient, see Faucher *et alii* 2009.

[3] We know from the imperial mint at Rome that flans were produced elsewhere (Woytek forthcoming).

[4] de Callataÿ 1995, p. 301. A modern experiment conducted by an inexperienced team produced up to 1,200 in a single day (Faucher *et alii* 2009).

The study of ancient mint production methods and techniques has attracted renewed interest due to the increasing number of die studies in recent years. Various ideas have been proposed ranging from the use of multiple anvils, referred to as 'workstations'[5] to the random use of numerous prefabricated dies, referred to as a 'die box'.[6] Naturally, if multiple workstations, each using a pair of dies, operated simultaneously in a mint, this would increase productivity and decrease the time needed to produce a certain preset quantity. The idea of the use of a die box has primarily focused on reverse dies, since if a die broke, instead of production being halted until a new die was cut, the striking process would continue with a spare die.[7] The die(s) would then be placed back in a 'box' at the end of the day for security reasons, so that the following day, when production resumed, a random die would be picked from the box.[8] The idea of an obverse die box has been mentioned by scholars,[9] albeit with some reservation since obverse dies, being sturdily placed in an anvil, might be difficult to remove each day and therefore may not have had a dedicated box.[10]

A method which seems to have been somewhat overlooked is the idea of placing more than one die on an anvil. Hill, nearly a century ago, discussed the idea of coins being struck on an anvil in which multiple dies were placed.[11] He verified it by illustrating specimens having impressions of two dies on the same side of the coin (**Pl. 19, 1**): 'The blank was evidently placed so as to lie partly on two obverse dies, and the reverse die was brought down on it; thus a complete reverse impression was associated with two partial obverses.'[12] Since then, the phenomenon of multiple anvil

[5] Carroccio 2011; Bracey 2012.

[6] Esty 1990; Carter and Nord 1992.

[7] This is because reverse dies tend to break more frequently since they directly absorb the impact of the hammer and are not protected in a sturdy base, unlike the obverse die.

[8] Unless if there was strict control and dies were marked and assigned to each team (Woytek 2012, p. 89, citing Crawford 1974). If indeed this method was employed it would render impossible the identification of die boxes.

[9] The first(?) mention of an obverse die box is by Kraay (1956, p. 12), although he rejects the idea. In the conclusion of the die study conducted on the denarii of the Roman Republican moneyer Lucius Julius Bursio, it is suggested that 'a large reverse die box was in use, and a large number of anvils', which may also imply the use of an obverse die box (De Ruyter 1996, p. 115). See also Butcher (2004, p. 131) who states 'obverse and reverse dies appear to have been shared at random, producing a wide variety of couplings. This is most vividly apparent on the third century issues, and supports the theory of a "die box" in which dies lay randomly mixed between production,' but it is not entirely clear if the variety of couplings was produced by the use of both obverse and reverse die boxes or just the latter. However, see Carter and Nord (1992, p. 164) who conclude, on the basis of mathematical calculations from a study of Roman Republican denarii of P. Crepusius, that both an obverse and a reverse die box were in use and that the obverse die box may have contained as many as 20 ready-made dies. For a more recent discussion advocating the use of obverse die boxes see Watson (forthcoming).

[10] In the medieval period it was common for the lower die to be firmly mounted and fixed in a block of timber such as a sturdy tree trunk (Sellwood 1976, p. 70). The idea was that even if they were not placed in a locked cabinet overnight, it would be impossible for fraudulent mint workers to strike a coin with just an obverse die, unless they created so-called 'two-headed' coins (see below in text).

[11] Hill 1922, pp. 36-37.

[12] Hill 1922, p. 37. For recent examples of the phenomenon see: Duyrat 2005, pp. 163, 179 (cat. nos 2526 and 2966); Flament 2010, p. 11; Syon 2015, p. 41, fig. 1; Lopez 2017. Le Rider 1977, pp. 423-4, discusses a case of different denominations set side by side (cited in Duyrat 2005, p. 179).

dies has become well established with examples from the Greek, Celtic, Seleucid, Parthian, and (early) Roman world.[13]

It has been suggested that a hub was used to create these multiple dies quite close to each other, to explain why the blank at times overlapped two dies.[14] But why would the dies be placed so close to one another? One explanation could be that the blanks were cast *en chapelet*, placed on the anvil as a connected group, and separated only after striking.[15] Another reason may simply be that multiple dies were engraved on a metal plate (of limited surface area) which itself was stabilised on an anvil or sturdy post. As to why multiple dies were placed on a single anvil, the reason may be efficiency in mass producing coins at a rapid pace,[16] with multiple (individually separated) blanks placed side-by-side on the anvil and struck 'in bursts'.[17]

The above method can be demonstrated only if the anvil dies were placed very close to one another, allowing the impression of two dies on a single coin placed accidentally between them. However, if the dies are placed at some distance from each other, this production method would be impossible to prove, if it were not for brockages.

The term brockage[18] refers to 'any coin which is mis-struck, but particularly applied to coins on which the same design is found in relief on one face and incuse on the other as a result of the preceding coin having remained on the die and left its impression on the next coin struck' (**Pl. 19, 2**).[19] Brockages do not seem to have been given any special attention in antiquity and were accepted as 'normal' currency, given the relatively high numbers in existence, with some estimates of up to 4%.[20] Also, brockages display more or less the same amount of wear as their ordinary counterparts, implying that they were readily circulated in the market. Additionally, it does not seem to be the case that brockages were systematically re-struck to

[13] Woytek 2006.

[14] Hill cites two individual coins (1922, Plate I, nos 19 and 23, but there are other examples, for example *BMC Palestine*, Plate XXII, 4) in which the designs are 'cut' so close to one another on the anvil that it would be impossible to strike a coin on one die without receiving a partial impression from the adjoining die as well. Hence, he concluded: 'This is additional proof that hubbing was practiced, since we can hardly suppose that such a mistake would have been made in the course of the much slower operation of direct cutting' (1922, p. 38).

[15] Hill 1922, 36-37. Indeed, there are examples of struck coins attached to one another, but this does not necessarily imply that they were all struck simultaneously, but rather consecutively in 'strips'. For a good example see the three attached Roman Republican asses of the moneyer L Calpurnius Piso Frugi (*RRC* 340/4, Plate LXV, 5). However, brockages should not occur in such a production method (Hoover 2008, p. 57), unless a coin breaks off the strip and adheres to the die (Hendin 2010, p. 36).

[16] For a discussion on 'efficiency' and 'perceived utility', see Stannard 2011.

[17] Woytek 2006, Figure 22; see also Lopez 2017 for a discussion with images (in particular Figures 1, 7 and 8) of multiple (obverse) dies of Celtic coinages and a modern experiment demonstrating their utility.

[18] Hill referred to them as 'accidentally incuse' coins (1922, p. 36); in French: "incuse accidentelle".

[19] Grierson 1975, p. 193.

[20] Evans 1987, pp. 118-19 (referring to the late Republican period), and Goddard (1993, p. 73), stating that the relatively frequent occurrence of brockages in hoards implies that they were not 'discriminated' against. However, de Callataÿ notes that brockages are very rare when compared to the many millions of surviving 'ordinary' coins (with some exceptions such as the Roman Republican issues) and therefore were not routinely put into circulation (personal communication).

correct the mistake,[21] although there are a few cases where the error was 'undone' simply by restriking: see **Pl. 19, 3**, a coin with relief designs on both sides with an intaglio design still partially visible underneath. There are also some examples of countermarked brockages, further evidence that they were accepted, or validated, as currency.[22] Brockages are more common in Roman Republican issues than Greek or Hellenistic;[23] this is attributed to the rise in production rates in the Roman period.[24]

Brockages have been largely overlooked by modern scholarship, with the only notable article dedicated to them, itself limited to the Roman period, being that of John P. Goddard.[25] Although Goddard's principal concern was to test if the frequency of brockages in public collections and hoards could be used to compile reliable data, he fully understood their potential in numismatic studies: 'Just as in the biological sciences much is learned about normal function by isolation and study of mutants which malfunction, so a study of brockages ("numismatic mutants") may provide insights into techniques of coin production which are not so readily discernible from study of properly struck coins.'[26]

Goddard points out three characteristics of brockages:

1. Because coins stuck on the lower anvil die are more easily detected (and removed) than those stuck on the upper punch die, coins with 'two obverses' or 'obverse brockages' are quite common, whereas 'two reverses' or 'reverse brockages' are rare (**Pl. 19, 4**).[27]

2. Brockages are more likely to occur in coins of smaller modules, since it is less likely for a large, heavy, coin to remain stuck on the upper die or go undetected if it remained on the lower.[28]

3. The frequency of brockages should depend on the production techniques and/or quality control.

In Goddard's last point the production technique is particularly important if it relates to the speed of production: the faster the production rate the higher the chances of adhered flans escaping notice, particularly during rush orders.[29] Consequently, brockages may theoretically be used to understand the rate and/or speed of production for certain coinages where they exist in relative abundance (if not removed from circulation). The issues of the Gallic Empire are a good case study, for a figure of 300 million antoniniani per year has been cited.[30] Goddard had noticed that obverse

[21] Goddard 1993, p. 76. Witschonke (2012, p. 77) suggests that brockages, even when noticed, were not pulled out and remelted as this would alter the total weight of the pre-weighed batch of flans.

[22] Schwabacher 1939, pp. 249, 259 and Plate XIV, no. 50.

[23] de Callataÿ 2011, p. 67. Roman imperial period brockages are rare, probably as a result of the strict control practiced by mint officials (Woytek, forthcoming, 5th page).

[24] Sellwood 1976, p. 71. It may also be due to simple technological changes in the production method, such as the use of lubricants such as oil or wax, on the surface of the dies to prevent the flans adhering to them; see Tobey and Tobey (1993, p. 29) for the use of lubricants.

[25] Goddard 1993. Holzer 1943 presents a more generic view of the phenomenon.

[26] Goddard 1993, p. 71.

[27] In Faucher's experiments the blank stuck only on the reverse die and never on the obverse (personal communication).

[28] Which is not to say that brockages of larger modules, such as tetradrachms and sestertii, are unknown.

[29] Faucher (2013 *et alii*, pp. 90-91) proved this hypothesis by his experiments.

[30] Burnett 1987, p. 123.

and reverse brockages occurred in roughly equal proportions implying that obverse and reverse dies were 'interchangeable', i.e., randomly placed on the anvil or punch. This argument can further be backed by the presence of 'two-headed' and 'two-tailed' specimens (discussed below) in the series, and particularly because a more or less equal ratio of obverse to reverse dies has been identified for some Gallic emperors.[31]

Mass production

Brockages can also provide conclusive evidence for mass production methods, particularly if more than one die was used on a single anvil. If this method was practiced then a brockage would be struck from different obverse dies. For example, assume that two lower obverse Dies O and O' are set side by side on an anvil. The replacer places Blank 1 on Die O and Blank 2 on Die O'. The striker strikes Blank 1 with his upper reverse Die R creating Coin 1 from Dies O and R, and then positions Die R on Blank 2, strikes, and creates Coin 2 from Dies O' and R. If, however, Coin 1 were to be stuck on Die R and the striker moved on to strike Blank 2, this would create a brockage struck from the obverse of Coin 1 (effectively Die O) and Die O'. In fact, such specimens have been identified, such as a 4th cent. BC stater of Corinth clearly struck from two different obverse dies (**Pl. 19, 5**).[32] Another example is a 1st cent. BC triobol of Sikyon (**Pl. 19, 7**).[33] Close inspection of the two sides of this coin indeed reveals that it is a brockage struck from different dies. This was confirmed by superimposing on one another line drawings of the two sides created by graphics-editing software. This showed that the two dies were different: there were 7 feathers on the relief side, but 8 on the incuse; the length of the individual feathers on the relief side is different from those on the incuse; the 'pellets' in the wing on the relief side are arranged from top to bottom in the order 1-2-2-1-1, but on the incuse 2-2-2-1; the eye seems to be in a slightly different position; and there are general differences in the contours of the dove. Furthermore, a second specimen from the same mint and period is also known (**Pl. 19, 9**),[34] showing that the first specimen was not merely a 'one-off' exception.[35] It should however be emphasized that these are the only such cases known to the author,[36] despite a search through several hundred images of brockages of all time periods and regions.[37]

[31] Goddard 1993, pp. 75-76, with statistical examples.

[32] Attribution to Corinth (*BMC Corinth* 33-34) is confirmed by a die link to an ordinary issue of that mint (**Pl. 19, 6**).

[33] From the BCD Collection; 1965 Diakofto hoard (*ICGH* 262). A die link was established between this brockage and a normal coin, allowing its classification (**Pl. 19, 8**).

[34] From the BCD collection; 1965 Diakofto hoard (*IGCH* 262).

[35] The suggestion is that perhaps the punch die with the stuck coin was transferred to another workstation, hence to a different obverse die; or that the anvil die broke and was replaced, while the coin was still stuck to the punch die, and minting was resumed.

[36] The coin illustrated in Schwabacher 1939, Plate XIV, no. 50, may be a brockage struck from two different obverse dies, but it is difficult to confirm due to the countermark on the reverse and the corresponding damage on the obverse.

[37] Other specimens may come to light in future, but it should be noted that, if the obverse dies were produced by a hub, then it would be difficult, if not impossible, to differentiate between the two sides (O and O') of a brockage (see detailed discussion below with a potential example provided).

The above case shows that in addition to multiple workstations in a mint and the use of die boxes, production could have been conducted on a single anvil with multiple obverse dies. But what is the advantage of this method? The production speed is limited not to how fast a flan can be struck but to how fast it can be replaced, assuming a sufficient supply of blanks is available in advance. The production speed can be significantly increased if the striker continues rhythmically striking coin after coin, while others remove the struck coins and replace them with fresh blanks.[38] For example, Carter and Nord estimated an average of three seconds to strike a single coin,[39] but this included the time spent by the striker waiting for the coin to be replaced. Thus in principle each coin can be struck in one second if the waiting time is eliminated by having blanks already placed on the anvil in advance. Sellwood had already suspected such a rapid pace when he wrote 'The fact that such a phenomenon [brockages] can occur at all in hand-striking means that production must have been at the rate of one coin every second or so.'[40]

In many ways the above method is similar, at least in principle, to modern concepts of the assembly/production line. This ancient production technique also has wider implications for our understanding of efficiency in pre-modern economies and the related formalist/substantivist debate. Without going deeper into this highly contested argument, one can say that, at least in the case of Corinth and Sikyon, the mint officials had a modernist approach similar to Henry Ford some two millennia later.[41]

Die studies

Efficiency in production would have certainly been a factor in ancient mints, if not necessarily for economic purposes, but surely for time, particularly in cases where mints were required to produce a large quantity within a short span of time. Accordingly, both multiple workstations and the use of multiple dies per anvil would speed up production.[42] However, if the latter method was efficient, why was it not widespread?[43] One explanation is that it may have been exhausting for the workers,

[38] In fact, this method of multiple obverse dies on a single anvil may better explain the occurrence of double struck coins and die clashes resulting from the fast pace of work.

[39] 1992, 155. A modern experiment required a minimum of 5 seconds (Louis Brousseau, personal communication, keeping in mind that the team was inexperienced).

[40] Sellwood 1963, p. 218.

[41] As Sellwood remarked when discussing the workings of a mint 'an early exercise in ergonomics applied to mass-production' (1976, p. 72).

[42] Hackens (1975) proposed that adding a second workstation would double the rate of production (cited in Bracey 2009). With the multiple dies per anvil method, if an anvil die were to break, the rate of production would not entirely cease, since minting would continue on the unbroken die until the damaged one was replaced (assuming they are not too tightly placed), but for a workstation employing a single anvil die production would fully cease until the replacement was ready. The obverse die box method, although it was probably in use, has no effect on the speed or quantity of production, except that a spare would be readily available when needed (note that a box containing dies to be distributed to the workers/anvils on a daily basis and a box containing spares to be used when needed may not necessarily be the same).

[43] As attested by the vast majority of 'one-die brockages'.

particularly the strikers, to maintain a constant rapid pace as opposed to the more rhythmic gentler pace of separate workstations.[44] Another factor may have been the need to keep the blanks in place on the multiple dies given the repeated shock of the hammer on the anvil.[45]

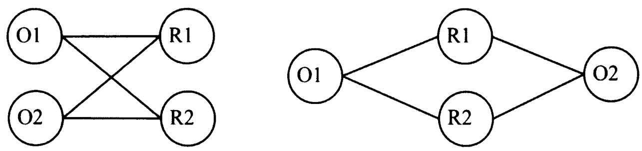

Diagram 1: left, die links with crossing lines; right, die links redrawn to achieve planarity.

How is it possible to know which method was employed in an ancient mint? As demonstrated above, brockages are direct proof for the use of one method or the other, but in their absence a die study and the resulting die charts (diagrams drawn to demonstrate die links) may be able to reveal the production method(s) employed. When preparing a die chart it is important, as far as possible, to achieve planarity, the capacity to draw the complex links without crossing lines, to 'decode' and better understand the order of production.[46] Thus, when crossing lines do occur, a common solution is to place the obverse dies in two columns in the chart, while keeping the reverse dies on a single column (*Diagram* 1). If this type of diagram occurs, then it is stated that two workstations were operating at the same time, i.e., the obverse dies are used in *parallel* at different workstations, along with a common set ('box') of reverse dies. It may be argued that the same pattern could be produced if both reverse and obverse dies were placed in a common die box, hence the 'parallel' use of obverse dies by a *single* workstation.[47] Cases where it is impossible to draw all the links without crossovers (even when applying the above method of two columns) are referred to as UG; effectively a non-planar diagram (*Diagram* 2).[48] In this case it is proposed that at least three workstations were in use.

With the above die chart patterns in mind, a die study conducted on a series having a 'two-die brockage', such as the specimens from Corinth or Sikyon, may demonstrate

[44] Crawford (1981, p. 176) proposed that perhaps multiple coins were struck *simultaneously* using two or more dies mounted side by side. This would imply that more than one die was placed on a single hand-held punch. This scenario is possible, but if it were used it would be for small modules, since it would be difficult to strike several large coins (such as tetradrachms) at once, unless multiple hammer blows were needed, which would offset any gain in efficiency.

[45] I would like to thank Thomas Faucher and Louis Brousseau for bringing this to my attention. Although, this situation may be less of a problem for smaller modules, requiring 'softer' blows of the hammer, or if the anvil was very sturdy.

[46] Carroccio 2011; Bracey 2012, p. 71.

[47] See Esty 1990 (in particular pp. 214 and 221) for a good theoretical explanation of die linkages and consequent problems. See also Watson (forthcoming) for cases from late antiquity where obverse dies were removed overnight.

[48] See Bracey 2012 for a discussion on identifying UG ('Utility Graph' as part of the mathematical field of topological graph theory) in die charts.

how the die links might appear in a chart for such a production method.[49] However, it would most probably be simply identical to a chart created by two workstations or an obverse 'die box' containing two dies. It follows that a die study conducted on a coinage which has a 'one-die brockage', the vast majority of cases,[50] can prove the hypothesis of multiple workstations or the use of an obverse die box based on the linkages observed.

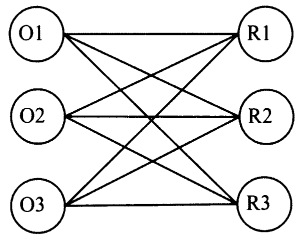

Diagram 2: a non-planar UG die chart where crossing lines cannot be avoided.

Yet another scenario would be if a mint employed two strikers operating at one workstation, each holding a reverse punch die (R and R'), and striking on a single obverse anvil die (O). The reason for this method would be to maintain a sustainable rate by allowing the strikers to rest at intervals, since it would be difficult to continuously wield a hammer.[51] But in this scenario there are two options: either each striker has an individual punch die (R and R') or both share the same die (R).[52] In all of the cases discussed above it would be logical to employ (reverse and obverse) die boxes for practical reasons.

Hubs

The use of hubs has been long contested by scholars.[53] Crawford's review article is a detailed survey of early viewpoints on hubs.[54] Hill,[55] as discussed above, was the first to propose their use, but Noe,[56] Naville[57] and le Rider[58] rejected the idea. Other early

[49] A die study of the Corinthian type is planned, but only a very few specimens of the Sikyonian type were compiled (online and in catalogues), rendering a die study inviable.

[50] Such as a die study on tetradrachms of Caracalla minted in Akko-Ptolemais containing a 'one-die brockage' (CNG EA 331, 215; Nurpetlian forthcoming).

[51] The stamina of the striker(s) when wielding a heavy hammer must be taken into consideration: see the practical experiments of Faucher (2013 *et alii*, p. 90). Woytek (2012, p. 111) remarks that the Trajanic inscription discussed at the beginning lists significantly more *malliatores* (32) than *suppostores* (11). See also Woytek (forthcoming, 4th page) for a medallion depicting a person (striker?) waiting behind the person wielding the hammer.

[52] Assuming that the striker is also holding the die; but note Sellwood's solo production of tetradrachms.

[53] In this paper the term 'hub' is used in the generic sense. For a proposed terminology of various types of hubs and related devices see Stannard 2011, p. 59.

[54] Crawford 1981.

[55] 1922.

[56] 1956, pp. 34-35.

[57] 1951, pp. 113-119.

[58] 1958. Le Rider backed his argument by citing a specimen having traces of the impression of two different anvil dies on one side of the coin; hence, although the two dies were indeed placed very close side by side on the anvil, he concluded that a hub was not used to create them. As a good example of the

proponents of the idea were Seltman,[59] Ravel[60] and Schwabacher.[61] The main dispute was initiated by Sellwood who in his experiment to produce ancient coins noted the extreme usefulness of hubs for preparing his dies and concluded that ancient mint workers would certainly have done so too.[62] It has also been proposed that hubs may have been mass produced by casting[63] or by themselves being hubbed, a single 'master hub' (in negative) being used to produce multiple 'auxiliary hubs' (in positive).[64] It seems that counterfeiters also used (makeshift) hubs for convenience.[65] More recently, Stannard has presented a history of the development of the modern hub, by analyzing previous scholarship and discussing cases for and against the use of various types of hubs, including piece punches (basically a partial hub),[66] and concludes that 'there is no convincing use of hubs by official Greek and Roman mints [...] Such tools were used only by forgers, frontier communities without official mints, and peoples beyond the frontiers.'[67]

It is beyond the purpose of this article to investigate whether or not hubs were used, but the reason they are introduced here is because there may be a correlation between the technique of placing multiple dies on an anvil and hubbing. As presented above, the specimens depicted in Hill and le Rider, and subsequently the evidence brought forward in recent times, prove that more than one die per anvil was in use and that they *may* have been produced by hubs or piece punches. Hence, it would be informative to have a die study on a coinage where hubs were potentially used, and thus, hypothetically, the use of multiple dies per anvil. The main aim would be to investigate if this production method creates a specific pattern in the die chart diagram.[68] In fact, Gerin's article on obols of the Arcadian League of the 3rd cent.

differences in detail see the coin depicted in Noe 1956, p. 34. However, one should bear in mind that certain hubs may have been used to create only the general outlines of a design with details later added by hand, creating the illusion that they were not products of the same basic die.

59 1924, p. 44.

60 1926, p. 320. Ravel even proposed (p. 319) that a hub was 'recycled' by re-cutting it into another hub with a completely new design but having traces of the older design still visible underneath, but this was not so (see the correction in Ravel 1935, pp. 9-10).

61 1939, p. 258.

62 Sellwood 1963, p. 221.

63 Balog 1955 (for Islamic period coins).

64 Schwabacher 1966, p. 41. If indeed 'master hubs' were used, this might also help to partly explain the perplexing phenomenon of widespread obverse 'die-sharing' in (mostly) 3rd cent. AD Asia Minor (Kraft 1972, Johnston 1974 and more recently Watson, forthcoming), where obverse dies may have been 'mass produced' and distributed or sold on demand to various cities (Schwarz 2000); however, I do not have an independent view on this matter.

65 Crawford 1974, p. 561. But see Stannard 1988 for a rebuttal of an article by Garcia-Bellido and Rovira 1986.

66 Stannard 2011; see p. 67 for a trove containing such tools.

67 2011, p. 76. See also the detailed discussion against the use of hubs or piece-punches in Stannard and Fischer-Bossert 2011. Stannard's convincing argument against the official use of hubs is widely accepted, but this begs the inevitable question as to why hubs were not used by *official* mints if the technology clearly existed (keeping in mind the argument of 'perceived utility' mentioned above).

68 Keeping in mind that if hubs, but not piece-punches, were indeed used, it would be difficult, if not useless, to find accurate die links (Stannard 2011, pp. 59, 62).

BC has provided a good case study for this approach.[69] Gerin proposed that a hub was used for the production of the series and that 'many obverse dies [were placed] beside one another on the anvil.'[70] Fortunately, she presented her study with a small, but rather complex, die chart (*Diagram* 3). For present purposes, an attempt was made to unravel the diagram in such a way as to minimize crossing lines, i.e., to see if planarity or UG exists. Using modern software, the diagram was digitally redrawn with the lines/links permanently attached to the circles/coins to allow rearrangement without losing the connections. After a few attempts it was possible to show UG (*Diagram* 4). Interestingly, it is important to note that more obverse dies (19)[71] were identified in the study than reverse (10), contrary to results from the majority of die studies. Consequently, Gerin states that the 'extremely close resemblance of dies [and] the disproportionate number of obverses relative to the reverses [...] seem to provide some credibility for the old theory that hubs were used in die production.'[72]

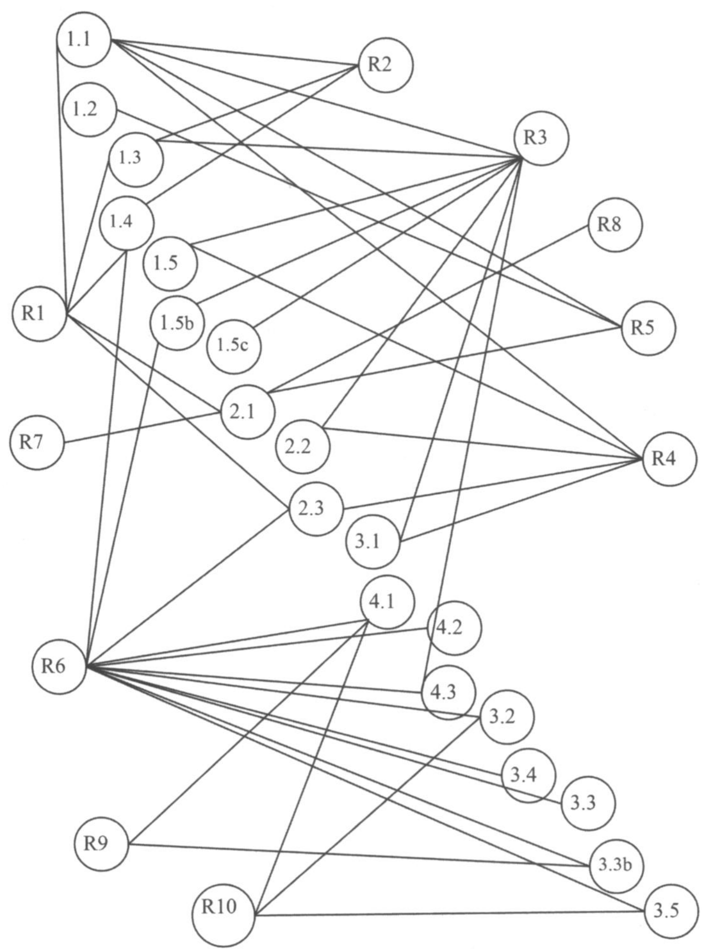

Diagram 3: die chart of Arcadian League obols as illustrated by Gerin (1993, p. 27, Plate 2).

[69] Gerin 1993.
[70] Gerin 1993, p. 22.
[71] 16 if repaired dies are excluded.
[72] 1993, 22. Although Gerin herself acknowledges that both are inconclusive in themselves.

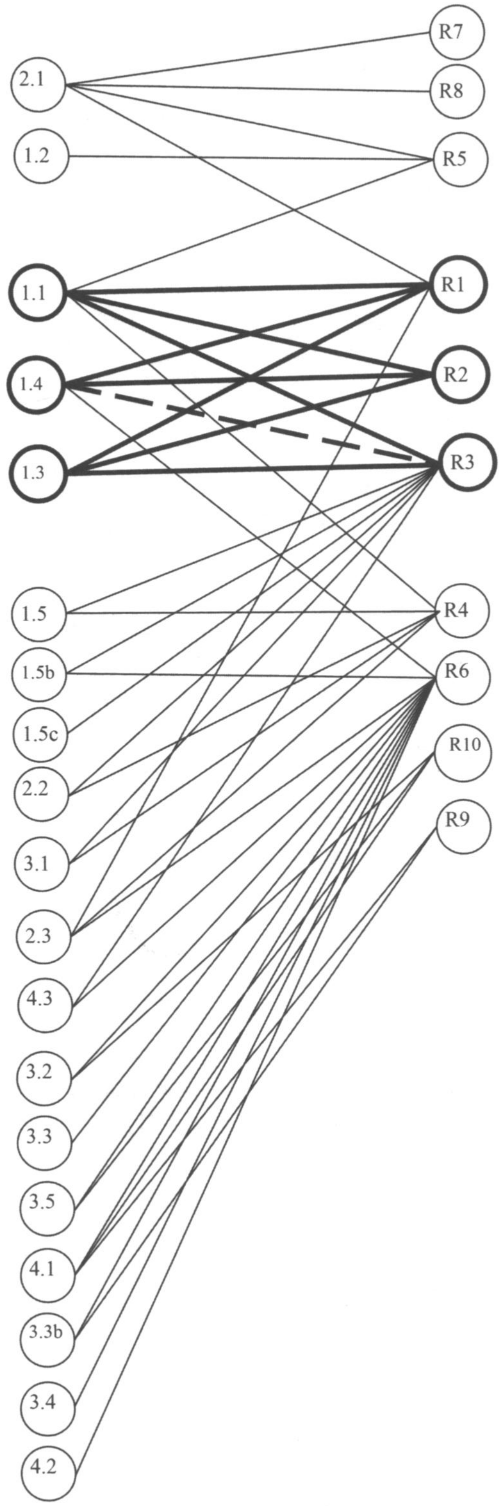

Diagram 4: rearrangement of Gerin's die chart to show UG in bold lines. The dashed line is a missing link needed to complete the UG, keeping in mind that the die study is incomplete. However, an indirect link can be established via 1.4 - R6 - 1.5b - R3. Note other potential UGs also.

In fact, it is possible to see the above pattern in other die studies as well. A similar attempt was made on a die chart presented by Kraay on the coinages of Himera (*Diagram* 5).[73] With the above digital method it was shown that UG also potentially exists, although less evident than the above example (*Diagram* 6). It may be the case that multiple dies were set on the anvil.[74] It is interesting to note again that this series has more obverse dies (13) than reverse dies (8).

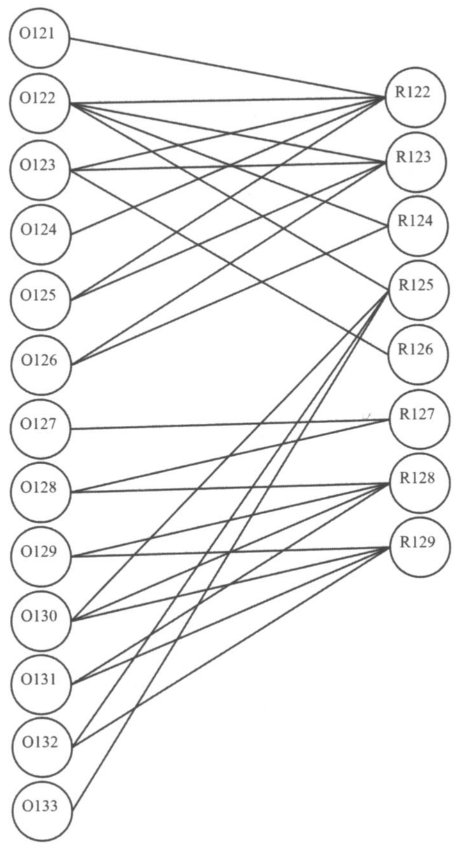

Diagram 5: die study of coins of Himera presented by Kraay (1984, 78, Group VII).

[73] Kraay 1984, Group VII.

[74] Although Kraay does not mention this and classifies the series as a product of two parallel anvils striking concurrently while sharing a stock of reverse dies (1984, pp. 45, 78, Fig. 16).

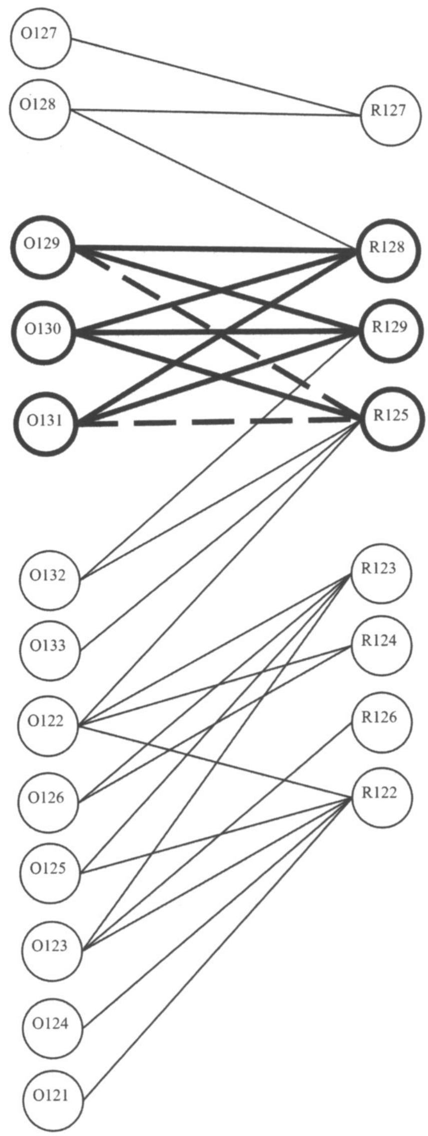

Diagram 6: die chart of Kraay rearranged to show UG in bold lines (dashed lines represent missing links) with more potential cases likely.

Despite the above cases, the question remains as to why the two obverses (O and O') of the Corinthian and Sikyonian brockages discussed above are clearly distinguishable from one another, if indeed multiple dies on an anvil were sunk by a hub.[75] This raises the question if the vast majority of brockage coins *seem* to be struck from one obverse die (O) only because the dies (O, O', O'', etc.) were hubbed and therefore indistinguishable from one another. This situation, although

[75] This is most distinctive for the wing of Pegasos (and also that of the dove) and the distance between its hind legs on each side of the coin.

most unlikely,[76] can be resolved by observing not the differences in detail of the designs on both sides of the brockage, but rather differences in the condition of the impressions/dies, such as wear, die breaks or repairs. An example of such a case may possibly be provided by a brockage denarius of Hadrian (**Pl. 19, 10**) on which both sides present very similar features and proportions with the distinct exception of the last wreath leaf (missing on the incuse side).[77] However, one example does not suffice to settle the question as the specimen concerned may simply be a 'fluke';[78] further examples are needed.

An additional paradox is that if indeed multiple obverse dies were placed on an anvil and only one reverse die was used, it should have deteriorated at a very rapid rate indeed.[79] Yet we know from the above examples that a disproportionately greater number of obverse dies than reverse dies was identified. An explanation could be that many more obverse dies than necessary were prepared in advance (with the simple ease of a hub?) for the purposes of efficiency in rapidly mass-producing an issue.[80] An alternate explanation could be that the above cases concern coins of small module (obols, drachms, hektai, etc.), where less strain would have been exerted on the reverse die,[81] as Gerin has observed for her series.[82]

Thus, there seems to be potential for indirectly identifying more cases of the use of multiple dies per anvil in various coinages (without the presence of two-die brockages or specimens having impressions from two dies set side by side), once it becomes clear what to look for.[83]

Heads or tails?

Brockage coins should not be confused with the so-called 'two-headed' or 'two-tailed' coins, which are essentially coins having two *relief* obverses or reverses struck from two obverse or reverse dies of the same design (**Pl. 19, 11**).[84] An alternative

[76] It is worth citing Bernhard Woytek's close inspection of dies, using more than 40,000 images of coins from certain periods of Trajan's reign, and his remark that 'I have found no evidence whatsoever for the mechanical reproduction of dies; all the dies are more or less easily distinguishable, and none of them was used to strike a disproportionately large number of coins: so probably no hubbing was involved in Rome in that period' (personal communication cited in Stannard 2011, p. 76).

[77] It cannot be the case that the leaf is not well impressed due to a weak strike since the other leaves, and the remains of the inscription above the 'missing' leaf, are clearly present.

[78] It may be the case that the obverse anvil die was repaired/modified while this coin was still stuck on the reverse punch die.

[79] For example, to make four coins the reverse die is used four times, whereas each of the four obverse dies only once.

[80] Duyrat 2005, pp. 163, 179.

[81] See de Callataÿ 1999. A die study conducted by Louis Brousseau on coins of Poseidonia has demonstrated that the ratio of obverse to reverse dies for smaller sizes tends to approach 1:1 (personal communication).

[82] 1993, p. 25, n. 16. Sellwood (1963, p. 227) managed to produce 7786 tetradrachms with a single punch die, and in principle he should have been able to produce a considerably larger quantity of smaller coins using the same experimentally modified and reinforced device.

[83] For example, see Healy (1993, p. 13) arguing for the use of hubs for the hektai of Mytilene with 438 anvil dies identified for only 512 reverses; unfortunately a die chart is not provided. See also Bracey (2012, pp. 74-79) who revisits a complex die chart of coins of Herod and identifies UG.

[84] For a detailed discussion see Stannard 1987.

explanation for this may be that, if a coin stuck on the upper punch die were to fall, flip over and land on the second blank immediately prior to striking, two coins would be created, whereby the lower (second) coin would be a brockage consisting of an 'ordinary' obverse in relief and an incuse of the *reverse* die (**Pl. 19, 12**),[85] and the upper (first) coin would be effectively a 'two-tailed' coin (with two *relief* reverses).[86] Although cases where coins have flipped over and and been (re)struck are known (**Pl. 19, 13**), it is highly unlikely to be the case for most of the 'two-headed' or 'two-tailed' specimens known, since it would imply that the coin, which fell and flipped, must have landed almost perfectly centered on the blank below in the majority of cases.

A curious example of the above scenario is a Roman Republican issue of Q. Pompeius Rufus (**Pl. 19, 14**) where the two sides were not struck from the same die. The auctioneers provide the following explanation: 'This piece must be the result of two simultaneous errors: 1) not noticing the struck planchet sticking to the punch, which with its exposed obverse in relief created an incuse of the obverse as a new reverse; 2) replacing the obverse die in the anvil with a reverse die, which produced as a technical obverse the reverse type in relief.'[87] This explanation is valid, but complicated. An alternative and simpler explanation would be that it is the product of a flipped coin, as explained above, particularly as the strike is not centered.[88] If true, this should imply that the dies were either 'interchangeable'[89] or, more likely, that the obverse of this series is the side with the name of Sulla and the reverse that of Q. Pompeius Rufus.[90] If this last observation is true, it would add another use for brockage coins in differentiating between obverse and reverse dies for issues having similar designs on both sides.

With the above in mind, brockages can be particularly useful in distinguishing between obverse and reverse dies of issues where portraits do not occur, or if indeed there is a portrait on both sides of the coin. This approach can be applied to Islamic coins, since the vast majority have calligraphic inscriptions without images, or indeed portraits, causing difficulty in knowing which is the 'primary' side.[91] Brockages have also been used for this purpose where the ratio of reverse to obverse dies is nearly 1:1, and it is difficult to determine which side was placed in the anvil (the deduction being that coins tend to stick on the upper punch die more regularly).[92]

[85] See Goddard 1993, pp. 76-77, Plate 1, no. 17.

[86] Albeit with some traces of the obverse undertype still visible if not fully struck.

[87] Gemini LLC, Auction IV, 332.

[88] A third interesting scenario could be that the coin is a brockage struck from two different dies placed on a single anvil, although the second would have been a reverse die, and not an obverse as is customary, which may very well be the case since the obverse and reverse designs are nearly identical (curule chairs).

[89] It is known that obverse and reverse dies were at times chosen randomly for placement on an anvil (Goddard 1993).

[90] Crawford (1974, p. 456, no. 434/1) lists the obverse as the side having the inscriptions Q. Pompeius Rufus and the reverse Sulla. Note that a second contemporary series has the portrait of Sulla listed by Crawford as the obverse and that of Q. Pompeius Rufus as the reverse (434/2).

[91] For a dedicated article on this issue with tentative results see Bacharach and Awad 1973, in particular pp. 187-189.

[92] De Ruyter 1996, pp. 94-95, although, when ratios of nearly 1:1 are observed it is sometimes assumed that the obverse and reverse dies were interchangeable.

Hot or cold striking

An interesting aspect of brockages is that they provide proof that coins can be struck with a 'die' made of the same material: 'only a small difference between two materials enables the stronger to impress upon the weaker a quite considerable amount of detail. Ancient brockages confirm this.'[93] In the case of brockages the main difference is not the material but rather the temperature and hardness. Hence, if the coins were hot-struck, the coin stuck to the die would be cooler, allowing it to make an impression on the hotter, hence softer, fresh flan. If, however, the coins were cold-struck, this scenario is more problematic since the struck coin should, in principle, be slightly warmer then the fresh flan due to it having changed its shape rapidly, which raises the question as to how it managed to impress an image on an object made of an identical material yet cooler. The reason is that the coin adhering to the die would have been work-hardened due to the striking forces, particularly if it had struck many brockages. The fact is that as long as the two objects are colliding with one another, an impression should be visible on both, although less so in the case of one which is warmer and softer than the other. Therefore, the intensity of the impression left on the brockage coin, in addition to metallographic examination, can, at least theoretically, be used to identify the production method, such as hot- or cold-striking.[94]

In any case, traces would certainly be left on the coin adhering to the die, but it seems that no work has been done to identify such traces which, if distinctive (such as noticeably flattened edges of the design on one side of the coin but sharp edges on the other), can be used to identify the existence of 'ghost' brockages in a series, without their physical presence being necessary; from this, production techniques could in theory be determined (such as hot or cold striking, rhythm and speed, ratios, etc.).[95] For example, on certain brockages the design on the incuse side is noticeably larger than the relief side, although both are the product of the same 'die' (**Pl. 19, 15**). This phenomenon, referred to as 'spreading',[96] is the result of the progressive striking of a fresh blank with the stuck coin causing its relief surface to expand, i.e., spread. Potentially, the amount of 'spread' can help in calculating the number of coins struck with the adhered coin,[97] although many variables have to be considered (alloy, striking force, cold- or hot-striking, etc.). These calculations can help to *estimate* the original number of brockages in a series and from it the *estimated* original number of coins produced on the basis of the ratio of the brockages identified in an issue.[98]

[93] Sellwood 1963, p. 218.

[94] Assuming that the striker maintained the same amount of force exerted by the hammer.

[95] It would be an interesting test to create deliberate brockages in a modern coin minting experiment, in addition to 'flipped' brockages.

[96] Stannard 2011, p. 74.

[97] Stannard (2011, p. 75, Fig. 11) displays a brockage denarius of Trajan 'spread' by 36% and estimates that *if* spreading occurred by 0.1% with every strike, this would imply that some 360 brockages were produced from the initial stuck coin. If correct, these calculations would imply that the brockages went unnoticed (or were allowed to pass) for an hour or so!

[98] See also n. 20 above.

'Central holes'

Numerous ideas have been put forward for the so-called 'central holes'[99] on the surface of some coins (**Pl. 20, 16**), ranging from pins inserted in the die to better grip the flan to depressions left by pincers for holding hot flans.[100] However, these proposals are doubtful, given that the dimples are not always on the same axis on both sides of the coin and that coins struck from the same die may or may not have dimples, and when dimples do appear they can occur in different locations on the same side of the coin. Recent work conducted on dimples show that they were part of the (unstruck) flan, and not created after the process of striking, the strike itself often not being powerful enough to completely obliterate them.[101] This proposal is primarily based on the presence on some coins of turning-marks in the form of concentric circles around the dimple, the idea being that the surface of cast blanks was smoothed and cleaned of debris by turning them. It seems that each side was turned separately with a tool[102] to clean the surface in preparation for striking (**Pl. 20, 17**).[103]

Brockages can provide further evidence that dimples were indeed part of the flan before striking as illustrated by a coin with two of these features on the incuse side, where one is a dimple and the other a raised bump (**Pl. 20, 18**). The idea is that the dimple on the adhered coin was transformed into a bump on the brockage coin, which already had a dimple prior to striking. Closer inspection of other brockages with 'central holes' show the ghostly remains of what seems to be a flattened bump on the surface next to a more highly visible dimple (**Pl. 20, 19**; note the faint bump immediately under the emperor's nose on the incuse side).[104]

Conclusion

The purpose of this article has been to demonstrate how informative brockages can be in revealing certain techniques used by mints in the past. Evidently, various systems of coin production existed and the material presented above provides further evidence for the method of placing multiple dies on an anvil. On the basis of the preliminary results presented here, it seems that this method was used to a limited extent in the Greek period and fell out of favour in the Roman era, raising the question that, if

[99] The term 'central hole', although commonly used in the literature, is a misnomer since the feature is neither a hole nor necessarily central, but rather a small dimple.

[100] See Hill 1922, pp. 9-10, for an early discussion of this phenomenon.

[101] See Bouyon 2000 and Faucher 2013, pp. 242-57, for a technical approach and detailed analysis of the phenomenon.

[102] This is deduced from the asymmetrical alignment of the dimples on each side of a coin, which excludes the idea that the coin was axially fixed and rotated on a lathe.

[103] However, these circular tool marks could have been created after striking, perhaps by a rotating polishing tool. It is standard practice that hand-made jewelry, particularly those which are produced by casting, undergo a final finishing process of polishing; certain coins, such as the large and attractive Ptolemaic issues, may have undergone this process. Metallographic examinations can be used to clarify such cases, if any.

[104] These observations are based on the faint shadow cast by these features visible in images of coins and not physical inspection of the specimens; they therefore require confirmation. Of course, it may also be the case that two dimples can collide if by chance they are situated on the same spot during striking.

indeed it was efficient, why was it apparently not used in later periods despite the growth of the minting industry?[105] The article also poses the question as to whether these various production techniques can be identified. Potentially, die studies and die charts can be a very important tool for achieving this. Yet, this approach may be problematic, given that complete die studies, where all the obverse and reverse dies have been identified, are nearly impossible to achieve, or if the various methods produce identical die links.[106] Additionally, the main complication would be if several of these methods were simultaneously used in a mint: multiple workstations each with multiple obverse dies per anvil, freely sharing obverse and reverse die boxes;[107] the die charts would be very complex indeed, which might explain why certain intricate die diagrams remain inexplicable.[108] Consequently, it would be worthwhile for scholars to revisit previously published die studies to try and identify certain patterns which may indicate different production methods, and to keep this in mind when they conduct new die studies, ideally incorporating brockages.

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[105] A statistical analyses was not conducted on the ratio of brockages in different time periods, materials used (silver, copper alloy, etc.) or denominations, as this might furnish misleading results, as discussed above, if not conducted with caution.

[106] Unless complex mathematical formulae can resolve this limitation. According to Carter and Nord (1992, pp. 154, 159-161), there is as yet no method for calculating the number of anvils/workstations operating in a mint for large issues.

[107] It should also be noted that a die may have been used and then kept 'dormant', for whatever reason, only to be reused again at a later date, production of the series in the meantime being continuous (for an interesting case see Elks 1973).

[108] As in the case of the Damascene tetradrachms of Alexander (Taylor 2017; Simon Glenn, forthcoming).

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Key to plates

1. Alyzia. AR Stater. Hill 1922, Plate I, 23.
2. Illyria. AR Stater 8.09g. Savoca Numismatik GmbH & Co. 6, 170 (December 2015).
3. Judaea, Agrippa I. Prutah 2.37g. CNG EA 335, 276 (September 2014).
4. Rome. Elagabalus. Denarius 3.33g. CNG EA 340, 377 (December 3, 2014).
5. Corinth. AR stater 8.58g. CNG EA 150, 83 (October 18, 2006).
6. Corinth. AR stater 8.13g. CNG EA 255, 106 (May 4, 2011).
7. Sikyon. AR triobol 2.39g. CNG Coin Shop 775216.
8. Sikyon. AR triobol 2.38g. LHS Numismatics 96, 350 (May 8, 2006).
9. Sikyon. AR triobol 2.36g. CNG Printed Auction 81, 2162 (May 20, 2009).
10. Hadrian. Denarius 3.10g. Auktionshaus H.D. Rauch GmbH 94, 889 (April 9, 2014).
11. Rome. Denarius 3.78g. Numismatica Ars Classica NAC AG 63, 272 (May 17, 2012).
12. Heraclea Thracia. Galerius. Follis 5.97g. CNG EA 165, 285 (May 30, 2007).
13. Antioch. Alexander II Zabinas. Æ 8.22g. CNG Coin Shop 840530.
14. Rome. Q. Pompeius Rufus. Denarius 3.87g. Gemini LLC, Auction IV, 332 (January 8, 2008).
15. Rome. Severus Alexander. Denarius 3.02g. CNG Printed Auction 79, 1161 (September 17, 2008).
16. Alexandria. Ptolemy VI and Ptolemy VIII. Æ 31.04g. CNG EA 264, 241 (September 21, 2011).
17. Rome. Vespasian. Æ Sestertius 21.48g. CNG EA 355, 501 (July 15, 2015).
18. Thrace. Gordian III. Æ 12.78g. CNG EA 155, 242 (January 3, 2007).
19. Thrace. Gordian III with Tranquillina. Æ 12.13g. CNG Coin Shop 160765.

1 2 3 4 5 (1.5x)

6 7 (1.5x) 8 9 (1.5x) 10

11 12 13 14 15

NURPETLIAN, BROCKAGE COINS (1)

16

17

18

19 (1.5x)

NURPETLIAN, BROCKAGE COINS (2)