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Simulating coin hoard formation

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28.1 Introduction

The physical manifestations of wealth are highly varied, and the ways in which this wealth is obtained, stored, displayed, used and disposed of is a major area of research for archaeologists, anthropologists and sociologists alike (e.g. Renfrew & Shennan 1982). For example, the rôle of amber in the British Early Bronze Age (Beck & Shennan 1991, chapter 6) or copper beads in the Swiss Neolithic (Ottaway & Strahm 1975) has received detailed attention and analysis. Recent developments in theoretical archaeology have tended away from the 'trade and exchange' aspects of certain artefacts and more towards their 'symbolic meanings.' When, however, coinage appears in the archaeological record an ethno-centric attitude to the data becomes prevalent. Whereas coinage is in fact just another physical manifestation of wealth, be it a highly specific form, phrases such as the 'cash' or 'monetary economy' enter the literature without qualification. It has been shown that coinage does not perform the same 'functions' in every society at every period (e.g. Collis 1974a). The rôle of this particular form of physical wealth will reflect aspects of the society under consideration, and therefore the study of these artefacts should be, and is, going further than the purely numismatic (e.g. Aitchison 1988). It should also be noted that coin hoards are only one specific sort of hoard, and that the hoarding of other artefacts, occasionally in association with coins, continues (e.g. Reece 1988).

28.2 The numismatic background

28.2.1 Terminology

An aspect of coinage studies with which computer users will be painfully familiar is the use of specialized terms. Below are brief definitions of those used in this paper. A *hoard* is simply two or more coins brought together in a deliberate manner (Casey 1986, p.51). A hoard is not, therefore, necessarily hidden. (Casey 1986, p.12). A coin is a form of money. Many objects have been used as money from gold rings to woolen blankets. Coins are currency when they are acceptable as a means of exchange, and this will be circumscribed by time and place. An Athenian obol is a coin, and a form of money, but is no longer a form of currency. A modern thousand złotys note is money, although not a coin, but is only currency in Poland. A *cointype* is one particular design of coin. Most coins are struck with a pair of *dies*. A cointype may be produced by one or more sets of dies. The *obverse* of a coin is usually the side which bears a portrait or symbol of the issuing authority, frequently accompanied by an inscription or legend. The *reverse* usually bears the *type* or design. The *obverse die* is set into an anvil when the coin is struck, while the *reverse*

die is held in a pair of tongs and is struck with the hammer. An issue of coinage is a group of cointypes which can be seen to be related in some way. The *coinage pool* is all the coinage in circulation at any one time. Some coinages have a series of *control marks*. These usually consist of a series of letters, numbers or symbols and frequently can be related to the number of dies used in the production of a coin issue.

28.2.2 Coinage Studies

The coinage of the Roman period has been a subject of detailed study for a considerable time. Although many areas are still subjects of contention for numismatists, the basic framework of date, place of minting and type has been obtained, giving us a database of immense size and complexity. Numismatic study has already shown that within the Roman world coins performed different functions at different times. Inscriptions from Aezani show that by the fourth century the gold coinage had become worth its metallic value (Hendy 1984). The weight standard of the *solidus* basically remained steady from the Constantinian reform onwards. At the same time the silver and base metal coinage was constantly debased and reformed. This two tiered coinage system is quite different from the structured Augustan system where it appears the State attempted to maintain a fixed ratio of value between coins regardless of the actual value of the metal contained within those coins. The rôle of gold in the later Roman Empire is complicated (Kent 1956). Many state payments had to be made in gold, and therefore many taxes were payable only in gold (for example a Senatorial 'super-tax', Kent 1956, p. 195). It can be seen therefore that even within the limited realm of taxes and trade coinage can perform different functions. For an overview and discussion of the many facets of 'money' see Crump 1981 and Hart 1986.

For many periods and areas, the literary and epigraphic evidence used (by Kent) in the above example does not exist. To assume that the situation is identical on an Empire-wide basis would be naïve. It is obviously rarely possible to assess the function of coinage from the coins themselves. Therefore their associations, both within the coin assemblage, and the archaeological record as a whole has to be considered. The coinage evidence falls into two broad categories: site finds and hoards. Site finds represent casual losses. Intra-site spatial analysis may give some results. Inter-site comparisons and analysis have produced interesting results, although these can be difficult to interpret e.g. Hodder & Reece 1977, Reece 1982). These patterns, when seen on a regional scale, are essential in the interpretation of coin data from individual sites (Casey 1974, 1980, 1986).

Hoards, however, represent the deliberate collection, and usually deliberate deposition of coin. It is unlikely in most cases that the non-recovery of the hoard was as equally

deliberate and the possible reasons for non-recovery are quite varied. The analysis of coin hoards has been approached in a variety of manners. For example, a frequent approach is to look at the distribution in time and space of hoards (e.g. Crawford 1969) although this approach has its limitations (Kent 1974, Casey 1986, pp. 61–63). Another approach is to look at the structure of coin hoards in more detail (e.g. Reece 1974). Recently, attempts have been made to take the interpretation of this evidence further (e.g. Creighton 1989).

28.3   Background to the simulation

The context of the simulation was a study of 24 Roman Republican coin hoards (Lockyear 1989). These hoards were published in detail, although unfortunately not completely, in Roman Republican Coinage (RRC. Crawford 1974). Much of the work concentrated on a number of issues not directly relevant to this paper, mainly revolving around Crawford's original analyses which have been the centre of much criticism and debate (Hersch 1977, Mattingly 1977, Burnett 1987, Buttrey 1989). For this work the dating scheme of Crawford was taken literally, the later date being preferred if there was a date bracket. This allows cross-hoard comparisons although any use of the data which relied on actual calendar dates would have to consider the limitations of the evidence, and revisions to Crawford's scheme.

The structure of these coin hoards was examined and compared in detail by visual, and statistical methods including the use of correspondence analysis (Lockyear 1989, chapter 2). Figures 28.1 to 28.5 show some of the hoards plotted as histograms. As can be seen there is much variation in the data. The general trends are similar for the first half or more of the histograms, but the pattern becomes much more varied in the latter half.[1] The hoard data were also plotted as a series of scattergrams with the percentage for each year, or for the hoards with a longer time span for each five years, plotted. A selection of these are given in Figs. 28.6 to 28.8.

From these, and the other analyses, it became apparent that these hoards conformed to the pattern noticed by Reece when looking at the hoard evidence for Britain (Reece 1974, cf. Lockyear 1989, pp. 16–23). In general, hoards with broadly the same closing date have a very similar pattern in the representation of the earlier coins, but this pattern varies greatly towards the closing date. There are a number of possible reasons for this variation all of which have interesting implications for the way coin was circulating, being saved, and therefore, being used. Hoards with few coins minted near to its closing date have been categorised in the past as *savings* hoards and those with large numbers of those coins (e.g. Fiesole, see Figs. 28.1 and 28.6) as *emergency* hoards. These categories implicitly explain this variation in terms of the period of time over which the hoard was collected. Emergency hoards are collected and deposited rapidly. For example, a days takings at a market stall. Savings hoards on the other hand are collected over a longer period of time and therefore have lower numbers of the most recent coins.

In order to avoid this implicit explanation I have called these two categories Type One, and Type Two. Recently, other interpretations of this pattern have been put forward (Creighton 1989). However, no attempt to my knowledge had been made to assess the effects of the various factors which may produce this pattern. If we are to ever to use the coin evidence to reveal aspects of the society that uses the coinage, we must have some idea as to how the patterns we observe may have been produced. A simulation program was used to try and fill the gap.

28.4   The simulation program

The program firstly has to simulate the coinage in circulation at any one time and place, and then has to simulate the processes of collection of the hoard. In order to do this the program needs a number of pieces of information:

1. The number of obverse dies used *per annum*.
2. The number of coins minted per obverse die.
3. The 'introduction delay.'
4. The decay rate.
5. The type of hoard.
6. The size of the hoard.
7. For a Type One hoard, its date, for a Type Two hoard its start and end dates.

Items 1 and 2 have been matters for intense numismatic debate. The number of obverse dies used *per annum* in the simulation is derived from a modification of Crawford's original method (Lockyear 1989, section 2.3; cf. Crawford 1974; see page 200). The number of coins minted per obverse die was kept constant at 30,000.[2] This is the figure used by Crawford, and is again a matter for debate. Minting experiments suggest a lower figures of 10,000 coins per die (Sellwood 1963). This figure will not affect the results unless this number is set at an unrealistically low figure, or the number of coins collected is set at an equally unrealistically high figure.

Item 3 encapsulates a number of factors. These are: 1) the delay in the release of coin from the mint, 2) the speed of circulation and 3) the distance from the area where the coinage is introduced into the pool from the area where coin hoard is being collected (see Fig. 28.9).

Item 4 is simply the number of coins lost per year. The figure of 2% calculated by Patterson for American silver coinage has been used in a number of other studies (Patterson 1972, Hopkins 1980). Preston (1983) calculated this value using a regression technique in order to be able to apply an 'age correction' to hoards when comparing them. This paper has, however, some serious flaws and will be discussed in detail in a future article.

The type of the hoard reflects the manner in which it was collected, see page 196. The two types are extreme theoretical examples and real hoarding practices are likely to be much more complex. The coins are collected randomly from the coinage pool for the appropriate year(s) calculated on the basis of the other parameters discussed above. The selection of coins for hoarding in reality is not a completely

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[1] Some of the recurrent gaps in the data are a result of Crawford's dating scheme. cf. Mattingly 1977, p. 203.

[2] The reason for using the obverse die totals is that the obverse die which was set in the anvil lasted longer than the reverse.
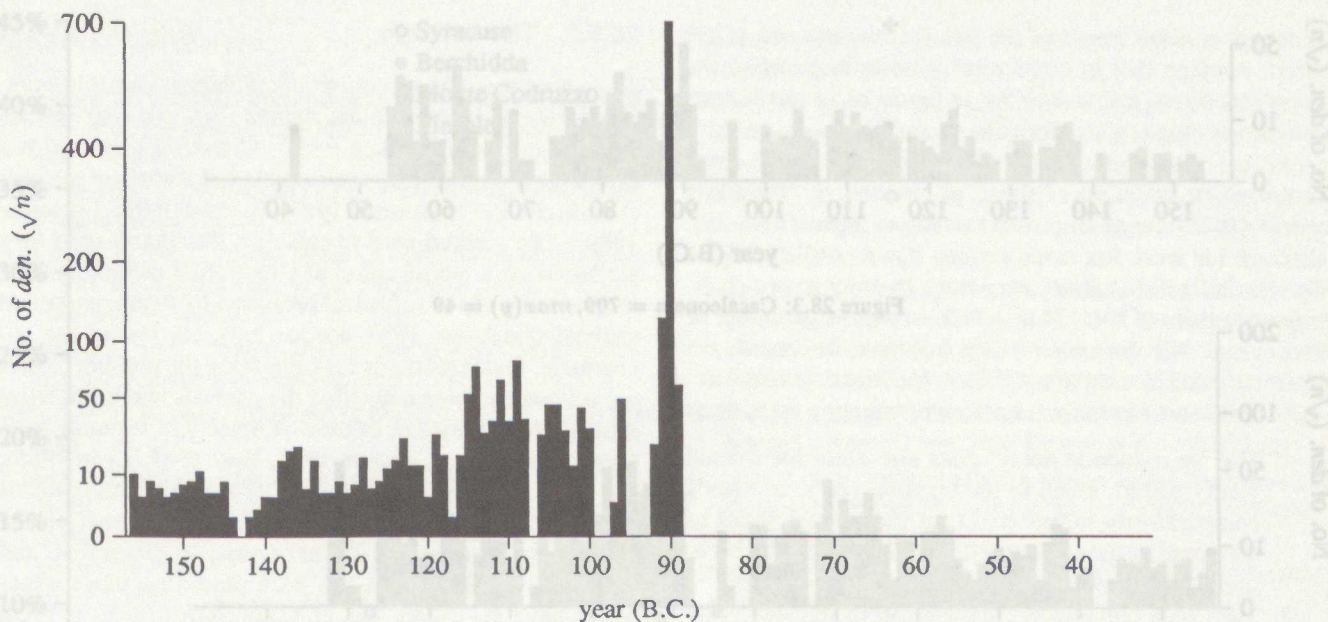
Figure 28.1: Fiesole $n = 1976, max(y) = 700$
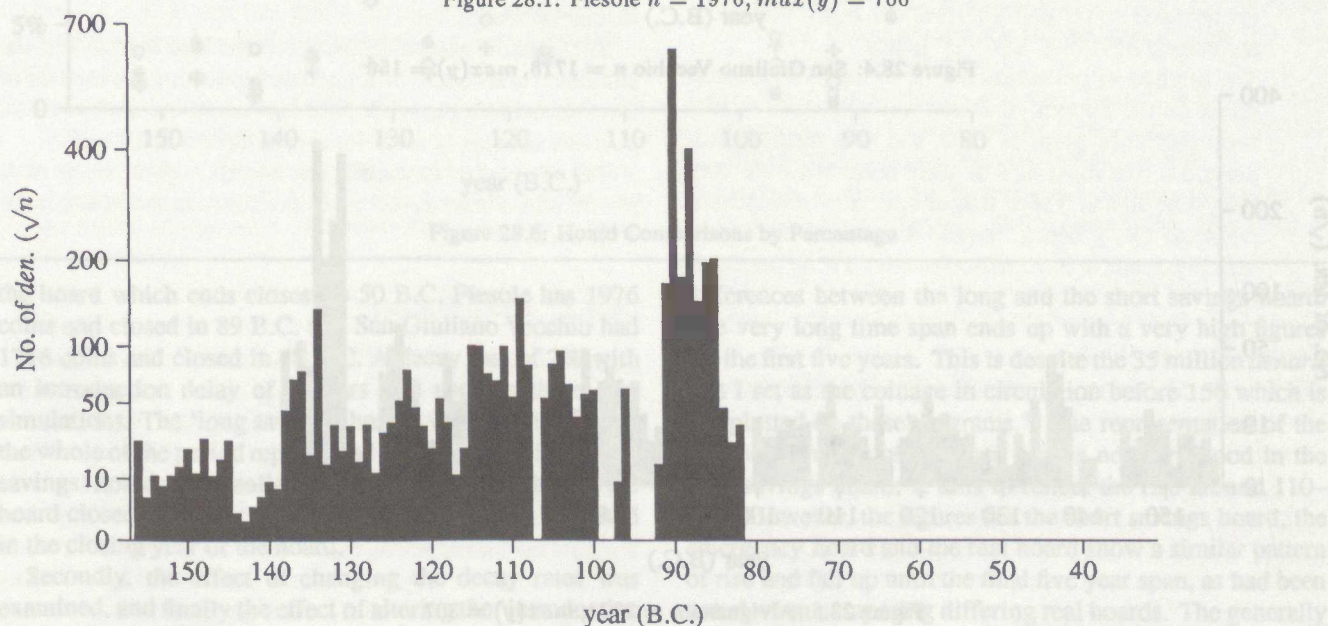
Figure 28.2: Monte Codruzzo $n = 4471, max(y) = 633$

random process. In this example, the coins being hoarded are all silver *denarii* and not the bronze denominations also being minted at the time. We also have the advantage that the coins were of a stable weight and fineness during this period. In other periods the selection of coins for hoarding is greatly influenced by the individual coins metallic content and weight. However, if all other factors are equal, the choice of coins for hoarding can be seen to be random selections from the coinage pool (e.g. Thordeman 1948).

The program as it stands now was written with a very specific task in mind and therefore will only deal with the period 156 to 50 BC. Output is limited to a listing, and the data summarized as PiCTEX scattergrams for inclusion in LATEX documents. The program is initialised with the simple command `simulate`. The user is prompted for a number of pieces of information (see Fig. 28.10). Having read in the die data, and the 'introduction delay' factor the program constructs a series of battleship curves for each

year's coinage which are fed into a two dimensional array. The coinage pool for each year from which coins will be collected is then calculated. The actual hoarding process is then simulated by simple random selection of coins from the pool. In the case of a Type One hoard the total number of coins requested will be collected as a series of random choices from the pool calculated for that year. For a Type Two hoard the opening and closing dates for the hoard are inputted, as well as the total number of coins that will be finally in the hoard. The program then collects the appropriate number of coins randomly from the coinage pool for each year.

28.5   The results

As with all simulations the number of possible variations that could be tested is immense. It was decided therefore
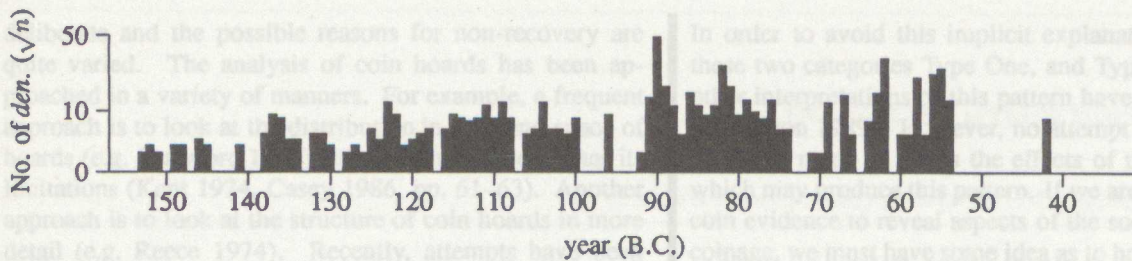
Figure 28.3: Casaleone $n = 709, max(y) = 49$
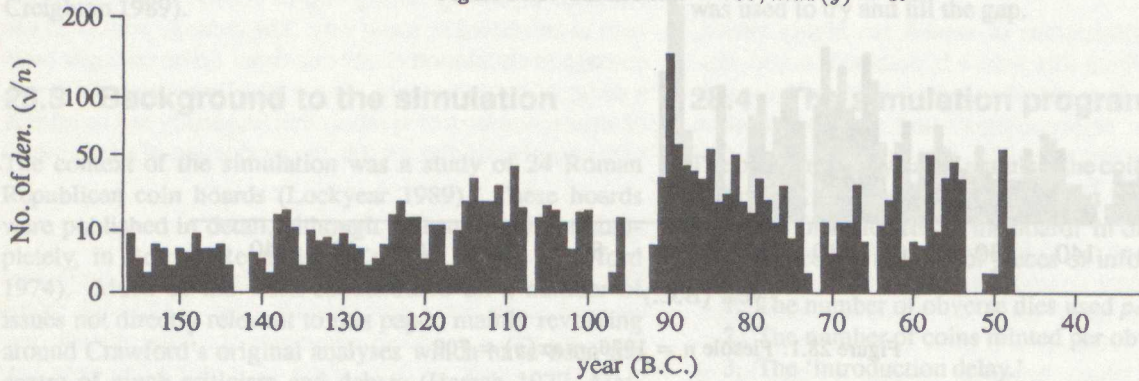
Figure 28.4: San Giuliano Vecchio $n = 1718, max(y) = 150$
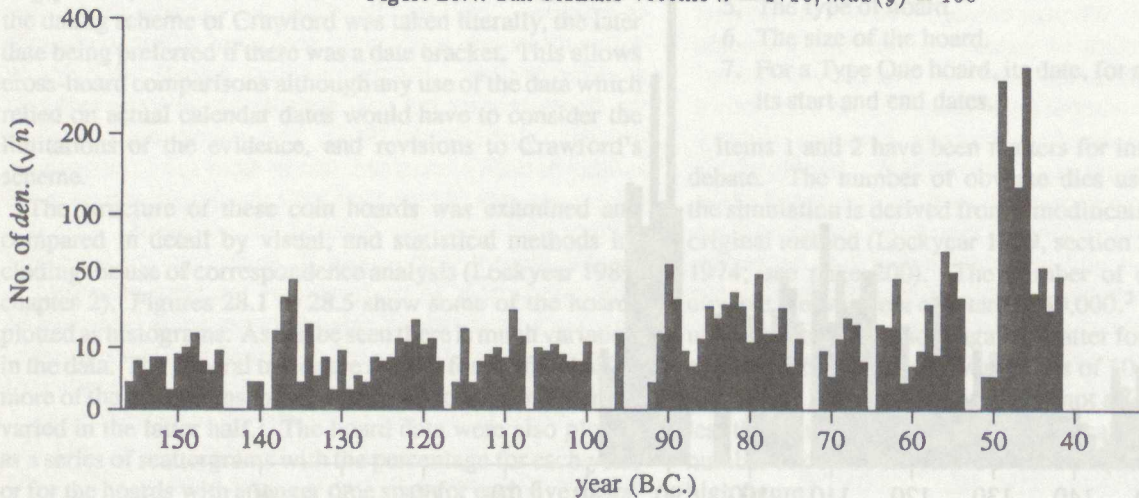
Figure 28.5: Alvignano $n = 2334, max(y) = 307$

to concentrate on the effects of three factors, the coinage 'decay rate,' the 'introduction delay,' and the manner of hoarding. Each of these was varied whilst keeping the other factors constant. Results from a number of runs using the same parameters showed that there was remarkably little variation between each run.[3] In order to enable a certain amount of comparison the size and date of two of the hoards studied were used. At this point I must emphasise a number of points.

1. As the die figures used in this program are derived from the hoards, any similarity between the simulated hoards and the real ones may contain a degree of circularity.

2. The simulation will *not* explain the factors which produced the hoard structure observed. The simulation by necessity is a simplification of the real situation,

and it would probably be possible to replicate the observed hoard structure in a number of ways.

3. As a result of the above, it is invalid to attempt any statistical comparison or correlation between the real, and the simulated hoards. It is not, therefore, worth writing the program in such a way that it alters its own parameters until it finds the closest 'fit' to a real hoard.

4. This program must be seen as a first step in the study of coin hoard formation, and not a definitive statement.

Firstly, the effects of altering the period of time taken to collect the hoard was examined. So that the simulated hoards could be compared with real hoards, the date and size of two of the hoards were used as parameters. These were the Fiesole hoard, as an extreme example of a hoard with high closing figures, and the San Giuliano Vecchio hoard as

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[3] The random number generation was checked very carefully in case it was inadequate. The similarity is easily explained when one notes the limited number of possible choices (107) and the large number of selections (minimum in this study of 1716). This effect is increased when the dominance of some issues is noted, and the fact that the coins are plotted in five year groups. Smaller hoards, or those plotted by individual year, show less similarity.
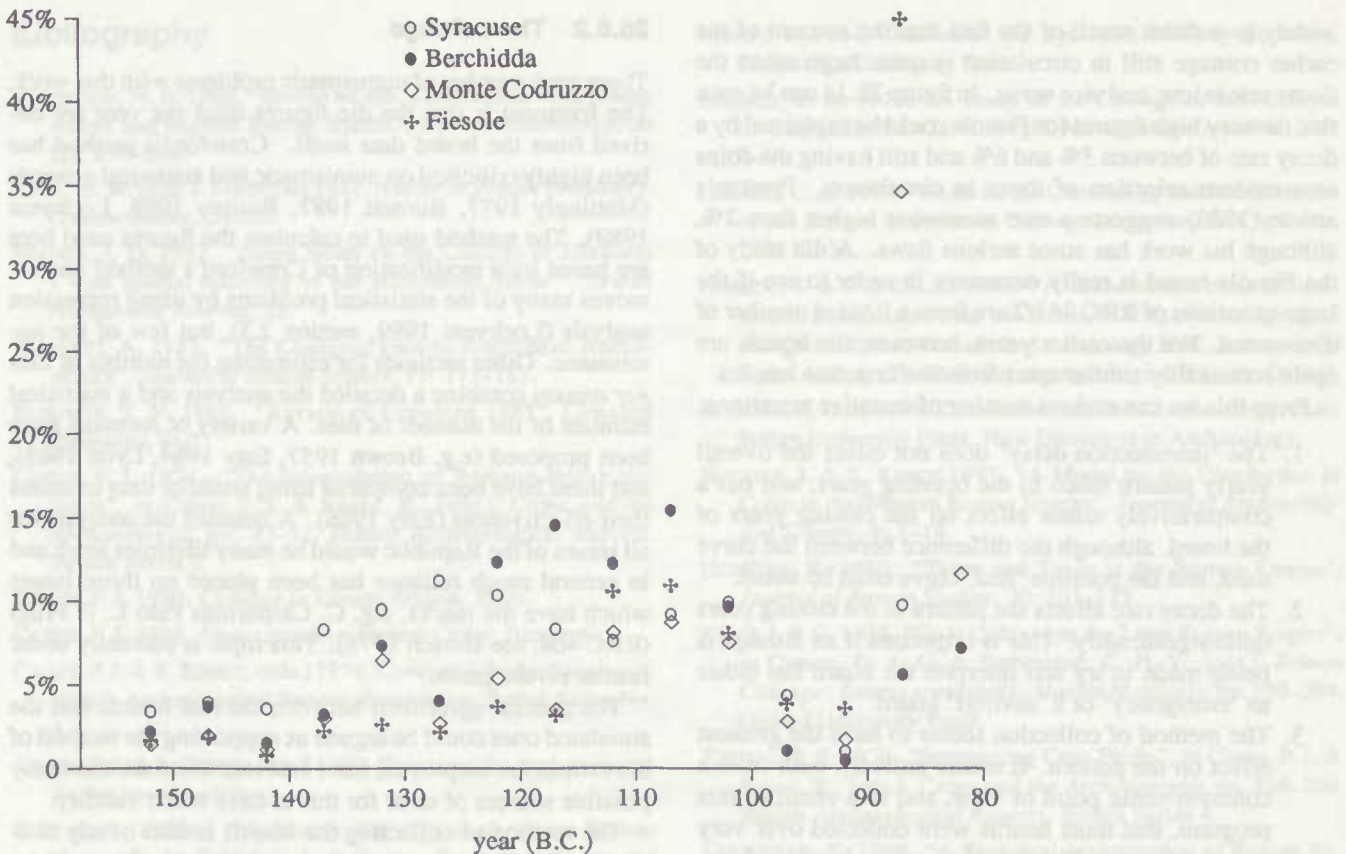
Figure 28.6: Hoard Comparisons by Percentage

the hoard which ends closest to 50 B.C. Fiesole has 1976 coins and closed in 89 B.C. and San Giuliano Vecchio had 1716 coins and closed in 48 B.C. A decay rate of 2% with an introduction delay of 5 years was used in these first simulations. The 'long savings' hoards were collected over the whole of the period represented by the hoard. The 'short savings' hoards were collected over the ten years before the hoard closed. The emergency hoard is obviously collected in the closing year of the hoard.

Secondly, the effect of changing the decay rates was examined, and finally the effect of altering the 'introduction delay.' For these runs the Fiesole date and total of 1976 coins and 89 B.C. were used. The Type One, emergency hoard, model was used for these. The decay rates tried were $\frac{1}{2}$%, 3% and 6% per annum. The introduction spans were 20 years, 10 years, and 1 year.

To illustrate the results of changing the period of time over which the hoard was collected, one set of figures from each of the three simulations for the 'Fiesole' type hoard have been plotted on the same graph with the Fiesole figures (Fig. 28.11) and the same for San Giuliano (Fig. 28.12). Also presented are one set of figures for each of the differing decay rate simulations (Fig. 28.14) and the introduction delay time simulations (Fig. 28.13) along with the actual figures from Fiesole.

In Fig. 28.11 it can be seen that the results for the Fiesole simulation unsurprisingly show that the emergency hoard was the nearest to the Fiesole hoard itself, but that even this was not anywhere as high as the real result for Fiesole in its final five year span. The other interesting thing to note is the

differences between the long and the short savings hoard. The very long time span ends up with a very high figures for the first five years. This is despite the 35 million *denarii* that I set as the coinage in circulation before 156 which is not plotted on these diagrams.[4] The representation of the relative numbers of dies per year is not very good in the long savings hoard; it fails to reflect the rise around 110–115. However, the figures for the short savings hoard, the emergency hoard and the real hoard show a similar pattern of rise and fall up until the final five year span, as had been noted when comparing differing real hoards. The generally lower percentage for the real hoard is due to the affect of the very high percentage for the last five year span.

The San Giuliano simulation shows a remarkable similarity between the short savings hoard and the San Giuliano hoard itself. Again, the long time span savings hoard has a very odd pattern to it, most unlike any of the real hoards looked at in the dissertation, but the short savings, emergency, and real hoard data are very similar until the last ten years. Again, this is very like comparing a number of real hoards.

In figure 28.13 it is interesting to note that the introduction rates used did not greatly affect the pattern of the curve. This is possibly a function of the formula for the curves. However, the battleship curve that is employed so widely is only a theoretical shape for the introduction and decay of coinage, although it seems to be a very likely approximation of the real situation (Collis 1974b).

The decay rates are interesting for the way that they affect the results. The figures for the last time bracket vary so

[4] There are a number of problems with this, but it is used as it is Hopkins' best guess at this figure (Hopkins 1980).

widely as a direct result of the fact that the amount of the earlier coinage still in circulation is quite large when the decay rate is low, and *vice versa*. In figure 28.14 can be seen that the very high figures for Fiesole could be explained by a decay rate of between 3% and 6% and still having the coins as a random selection of those in circulation. Preston's article (1983) suggests a rate somewhat higher than 2%, although his work has some serious flaws. A die study of the Fiesole hoard is really necessary in order to see if the large quantities of RRC 341/2 are from a limited number of dies or not. For the earlier years, however, the hoards are again remarkably similar apart from the first date bracket.

From this we can make a number of tentative assertions.

1. The 'introduction delay' does not effect the overall yearly pattern much in the opening years, and has a comparatively minor effect on the closing years of the hoard, although the difference between the curve used, and the possible 'real' curve must be noted.

2. The decay rate affects the pattern in the closing years quite significantly. This is important if an attempt is being made to try and interpret the hoard has either an 'emergency' or a 'savings' hoard.

3. The method of collection seems to have the greatest effect on the pattern. It seems unlikely, both from a common sense point of view, and as a result of this program, that most hoards were collected over very long time spans. There will of course be exceptions, the most likely being 'temple hoards' where votive deposits seem to have collected over a long period of time.

28.6 Problems, and areas for improvement

As this program was written as a small part of a M.Sc. dissertation it was not possible to test, and refine many factors. These points have to be noted and discussed.

28.6.1 The theoretical basis

A criticism concerns the validity of simulation studies. Simulation was once seen as a sophisticated tool for trying to understand many processes (Doran 1970, Hodder 1978). Recently, the use of this technique has been implicitly criticized as being deterministic, scientistic and reductionalist (for a summary see Shanks & Tilley 1989). In this context it can be seen that coinage does generally act as a 'system.' The effect of 'agency' in the formation of hoards is not ignored. Hoards which have been subjected to unusual collection patterns can be seen clearly against the wider patterns. (In another period, the coin hoard associated with the Sutton Hoo ship can be clearly seen to be unusual). In order to work from the data to an understanding of the society which created it, we must have at least an idea of how the data were formed, and in the context of this hoard study simulation is a valid method. This is not to say that all simulations are valid, as with the application of any other tool. It also doesn't mean that the interpretations of the coin evidence in the light of the results has to be within a 'scientistic' framework.

28.6.2 The coinage

There are a number of numismatic problems with this work. The foremost is that the die figures used per year are derived from the hoard data itself. Crawford's method has been highly criticised on numismatic and statistical grounds (Mattingly 1977, Burnett 1987, Buttrey 1989, Lockyear 1989). The method used to calculate the figures used here are based on a modification of Crawford's method and removes many of the statistical problems by using regression analysis (Lockyear 1989, section 2.3), but few of the numismatic. Other methods for estimating the number of dies *per annum* combine a detailed die analysis and a statistical estimate of the number of dies. A variety of formulæ have been proposed (e.g. Brown 1957, Esty 1984, Lyon 1965), and these have been compared using artificial data to assess their effectiveness (Esty 1986). A detailed die analysis for all issues of the Republic would be many lifetimes work and in general much reliance has been placed on those issues which have die marks, e.g. C. Calpurnius Piso L. F. Frugi (RRC 408, see Hersch 1976). This topic is currently under further investigation.

The general agreement between the real hoards and the simulated ones could be argued as supporting the method of die estimation employed, but I feel that there are too many possible sources of error for this to have much validity.

The method of collecting the hoards is also overly simplistic and a variety of other possible methods could be employed.

28.6.3 The program

Following the criticisms of simulation studies in archaeology (Freeman 1988) the seeding of the random number generator could be changed from using the UNIX function time () to manual input. Although some differing random number generators available in the SUN/UNIX library were tried these ought to be compared more systematically. The formula for the battleship curve was a simple approximation and this could be improved along the lines of that used by Herzog and Scholar (1988). The program was also very specific to the period under consideration. Simulate v2 will hopefully be much more widely usable.

Acknowledgments

Bibliography

AITCHISON, N. B. 1988. "Roman wealth, native ritual: coin hoards within and beyond Roman Britain", *World Archaeology*, 20 (2): 270–284.

BECK, C. W. & S. J. SHENNAN 1991. *Amber in British Prehistory*. Oxbow Books, Oxford.

BROWN, I. D. 1957. "Some Notes on the Coinage of Elizabeth I with special reference to her Hammered Silver ", *British Numismatic Journal*, 28.

BURNETT, A. 1987. "The Changing Face of Republican Numismatics", *Journal of Roman Studies*, 77: 177–183.

BUTTREY, T. V. 1989. "Review of Crawford 1985", *Classical Philology*, 84/1.

CASEY, P. J. 1974. "The Interpretation of Romano-British site Finds", *in* Casey, P. J. & Reece, R., (eds.), *Coins and the Archaeologist*, pp. 37–51. British Archaeological Reports. British Series 4.

CASEY, P. J. 1980. *Coinage In Roman Britain*. Shire.

CASEY, P. J. 1986. *Understanding Ancient Coins*. Batsford.

CASEY, P. J. & R. REECE, (eds.) 1974. *Coins and the Archaeologist*. British Archaeological Reports, first edition. British Series No. 4.

CASEY, P. J. & R. REECE, (eds.) 1988. *Coins and the Archaeologist*. Seaby, second edition.

COLLIS, J. 1974a. "A Functionlist Approach to pre-Roman Coinage", *in* Casey, P. J. & Reece, R., (eds.), *Coins and the Archaeologist*, pp. 1–11. British Archaeological Reports. British Series 4.

COLLIS, J. 1974b. "Data for Dating", *in* Casey, P. J. & Reece, R., (eds.), *Coins and the Archaeologist*, pp. 173–183. British Archaeological Reports. British Series 4.

CRAWFORD, M. H. 1969. "Coin Hoards and the Pattern of Violence in the Late Republic", *Papers of the British School at Rome*, pp. 76–81.

CRAWFORD, M. H. 1970. "Money and Exchange in the Roman World", *Journal of Roman Studies*, 60.

CRAWFORD, M. H. 1974. *Roman Republican Coinage*. Cambridge University Press.

CRAWFORD, M. H. 1985. *Coinage and Money under the Roman Republic*. Methuen.

CREIGHTON, J. 1989. Paper delivered to the Conflict or Co-operation conference held at the Univerisity of Oxford Department of Extra-Mural Studies, October 1989.

CRUMP, T. 1981. *The Phenomenon of Money*. Routledge and Kegan Paul, London, Boston and Henley.

DORAN, J. 1970. "Systems theory, computer simulations and archaeology", *World Archaeology*, 1: 289–298.

ESTY, W. W. 1984. "Estimating the Size of a Coinage", *Numismatic Chronicle*, 144: 180–3.

ESTY, W. W. 1986. "Estimation of the Size of a Coinage: a Survey and Comparison of Methods.", *Numismatic Chronicle*, 146: 185–215.

FREEMAN, P. 1988. "How to simulate if you must", *in* Ruggles, C. L. N. & Rahtz, S. P. Q., (eds.), *Computer and Quantitative Methods in Archaeology 1987*, International Series 393, pp. 139–46. British Archaeological Reports, Oxford.

HART, K. 1986. "Heads or Tails? Two sides of the Coin", *Man*, 21: 637–56.

HENDY, F. 1984. *Studies in the Byzantine Monetry Economy*. Cambridge University Press.

HERSCH, C. A. 1976. "A Study of the Coinage of the Moneyer C. Calpurnius Piso L. F. Frugi", *Numismatic Chronicle*, 136: 7–63.

HERSCH, C. A. 1977. "Notes on the Chronology and Interpretation of the Roman Republican Coinage", *Numismatic Chronicle*, 137: 19–36.

HERZOG, I. & I. SCOLLAR 1988. "A mathematical basis for simulation of seriatable data", *in* Rahtz, S. P. Q., (ed.), *Computer and Quantitative Methods in Archaeology 1988*, International Series 446, pp. 53–62. British Archaeological Reports, Oxford.

HODDER, I., (ed.) 1978. *Simulation Studies in Archaeology*. Cambridge University Press. New Directions in Archaeology.

HODDER, I. & R. REECE 1977. "A Model for the Distribution of Coins in the Western Roman Empire", *Journal of Archaeological Science*, 4: 1–18.

HOPKINS, K. 1980. "Taxes and Trade in the Roman Empire", *Journal of Roman Studies*, 70: 101–125.

KENT, J. P. C. 1956. "Gold Coinage in the Later Roman Empire", *in* Carson, R. A. G. & Sutherland, C. H. V., (eds.), *Roman Coinage: Essays presented to Harold Mattingly*, pp. 190–204. Oxford University Press.

KENT, J. P. C. 1974. "Interpreting Coin Finds ", *in* Casey, P. J. & Reece, R., (eds.), *Coins and the Archaeologist*, pp. 184–200. British Archaeological Reports. British Series 4.

LOCKYEAR, K. 1989. "A Statistical Investigation of Roman Republican Coin Hoards". M.Sc. Dissertation, University of Southampton.

LYON, C. S. S. 1965. "The Estimation of the Number of Dies Employed in a Coinage", *Numismatic Circular*, 73: 180–1.

MATTINGLY, H. B. 1977. "Coinage and the Roman State", *Numismatic Chronicle*, 137: 199–215.

OTTAWAY, B. & C. STRAHM 1975. "Swiss Neolithic copper beads: currency, ornament or prestige items", *World Archaeology*, 6: 307–321.

PATTERSON, C. C. 1972. "Silver Stocks and Losses in Ancient and Modern Times", *Economic History Review*, 25: 207–10.

PRESTON, H. S. 1983. "Roman Republican Coin Hoards: an Age Correction and Other Comments", *Annali*, 30: 83–93.

REECE, R. 1974. "Numerical Aspects of Roman Coin Hoards in Britain", *in* Casey, P. J. & Reece, R., (eds.), *Coins and the Archaeologist*, pp. 78–94. British Archaeological Reports. British Series 4.

REECE, R. 1982. "Roman Coinage in the Western Mediterranean: A Quantitative Approach", *Opus*, 1: 341–50.

REECE, R. 1988. "Interpreting Roman hoards", *World Archaeology*, 20 (2): 261–269.

RENFREW, C. & S. SHENNAN, (eds.) 1982. *Ranking, resource and exchange: aspects of the archaeology of early European society*. Cambridge University Press. New Directions in Archaeology.

SELLWOOD, D. 1963. "Some Experiments in Greek Minting Techniques", *Numismatic Chronicle*, 123: 217–31.

SHANKS, M. & C. TILLEY 1989. "Archaeology into the 1990's", *Norwegian Archaeological Review*, 22: 1–12.

THORDEMAN, B. 1948. "The Lohe hoard: a contribution to the methodology of numismatics", *Numismatic Chronicle*, 108: 188–204.
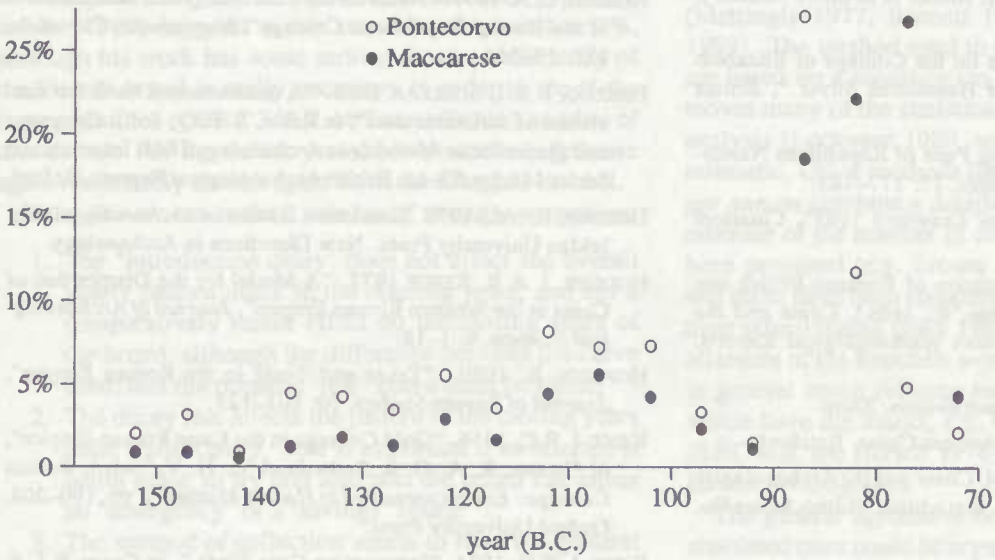
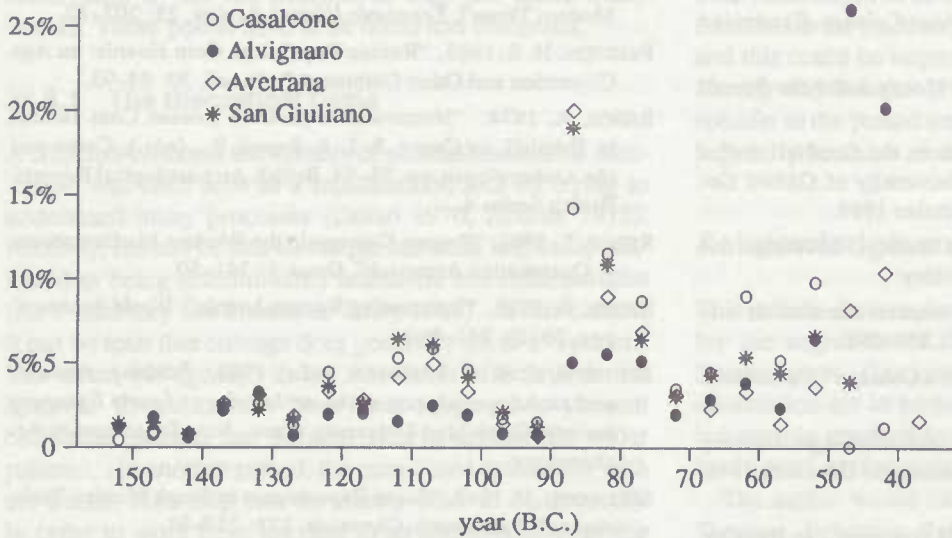Figure 28.7: Hoard Comparisons by Percentage
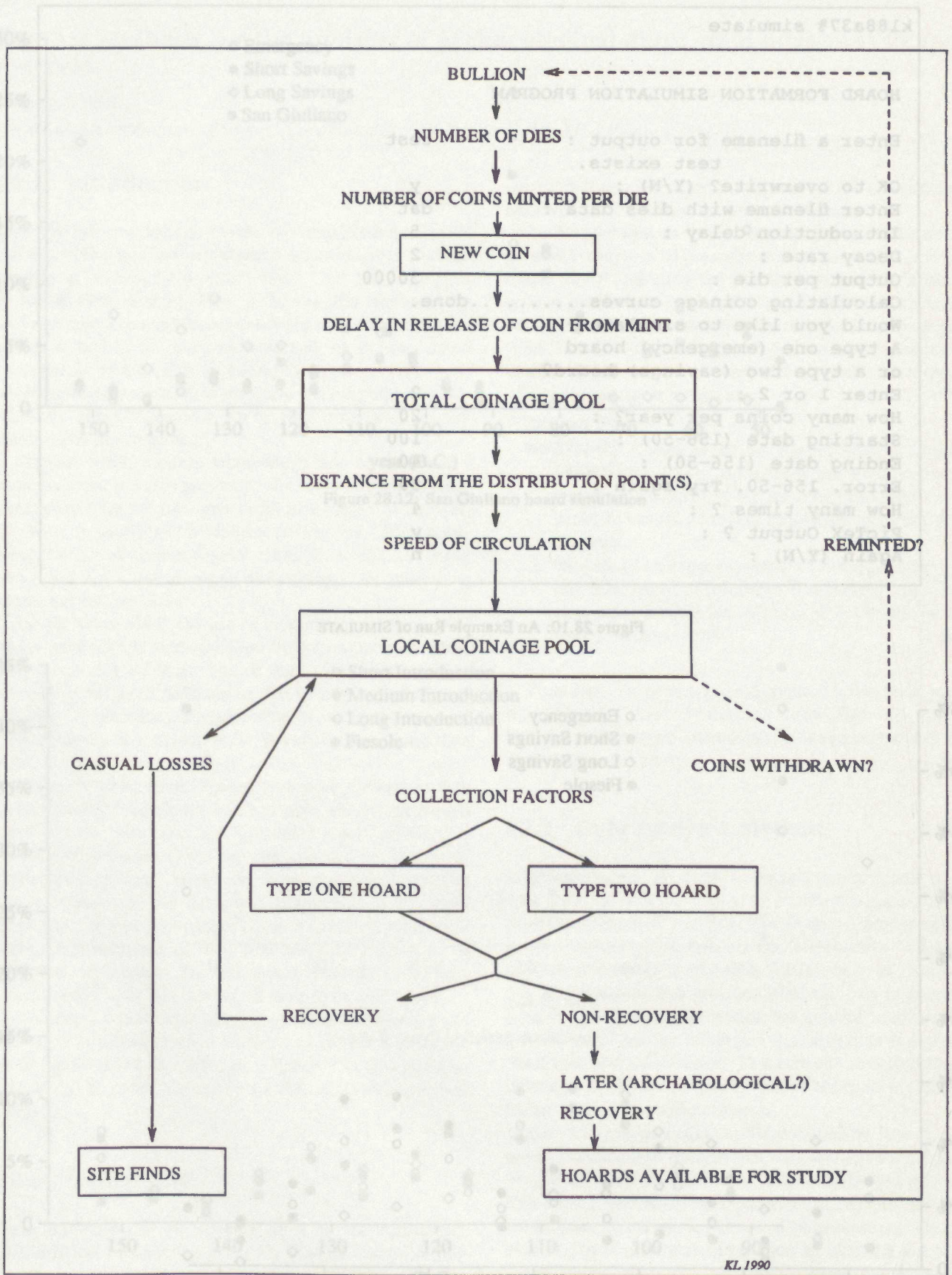

Figure 28.8: Hoard Comparisons by Percentage

BULLION

NUMBER OF DIES

NUMBER OF COINS MINTED PER DIE

NEW COIN

DELAY IN RELEASE OF COIN FROM MINT

TOTAL COINAGE POOL

DISTANCE FROM THE DISTRIBUTION POINT(S)

SPEED OF CIRCULATION

LOCAL COINAGE POOL

REMINTED?

CASUAL LOSSES

COINS WITHDRAWN?

COLLECTION FACTORS

TYPE ONE HOARD

TYPE TWO HOARD

RECOVERY

NON-RECOVERY

LATER (ARCHAEOLOGICAL?)
RECOVERY

SITE FINDS

HOARDS AVAILABLE FOR STUDY

KL 1990

Figure 28.9: Factors affecting coin hoard data.

```
kl88a37% simulate

HOARD FORMATION SIMULATION PROGRAM

Enter a filename for output :        test
                 test exists.
OK to overwrite? (Y/N) :             y
Enter filename with dies data :      dat
Introduction delay :                 5
Decay rate :                         2
Output per die :                     30000
Calculating coinage curves.........done.
Would you like to simulate -
A type one (emergency) hoard
or a type two (savings) hoard?
Enter 1 or 2 :                       2
How many coins per year? :           20
Starting date (156-50) :             100
Ending date (156-50) :               40
Error. 156-50. Try again :           80
How many times ? :                   4
PicTeX Output ? :                    y
Again (Y/N) :                        n
```
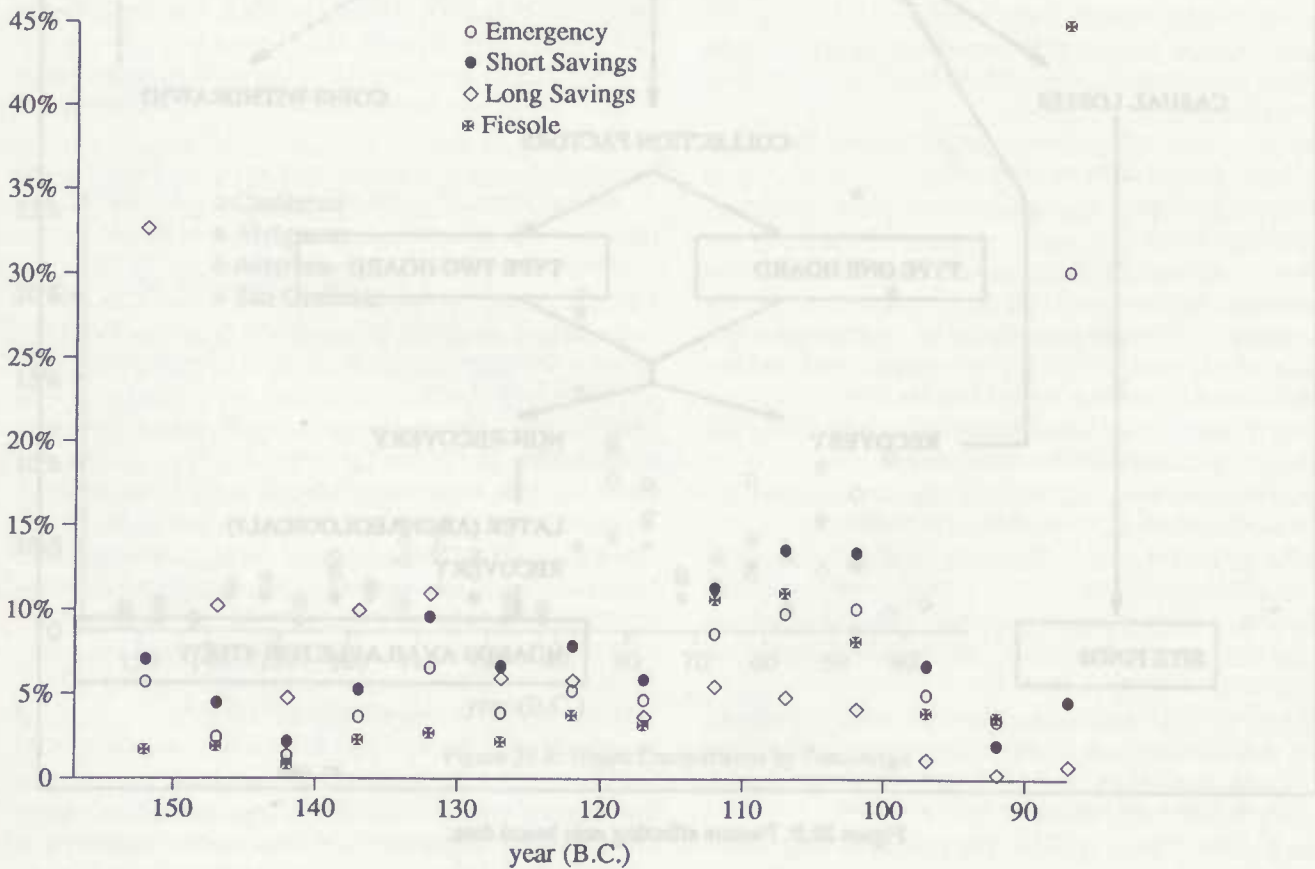
Figure 28.10: An Example Run of SIMULATE

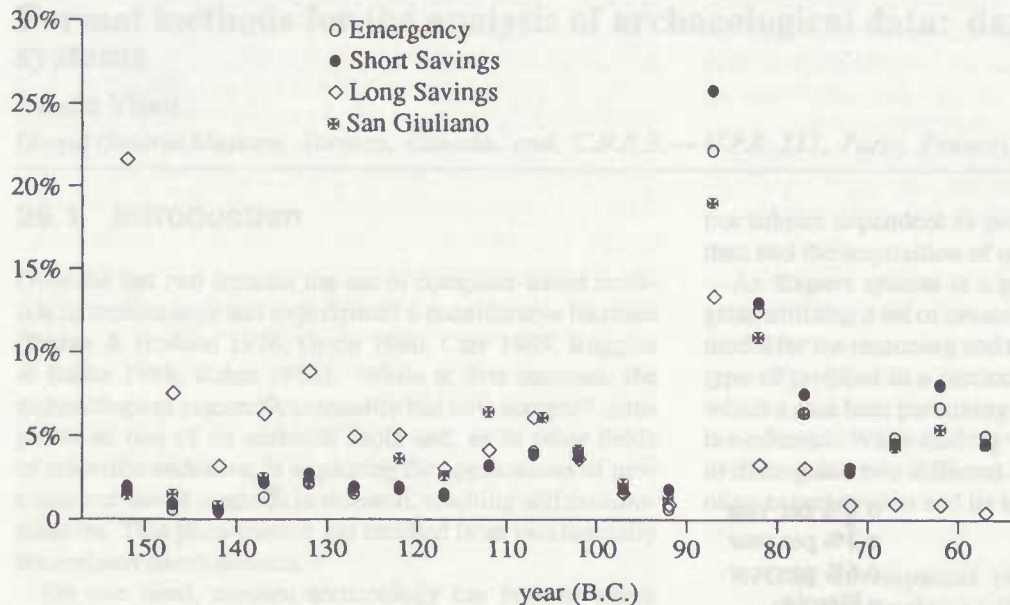Figure 28.11: Fiesole Hoard Simulation
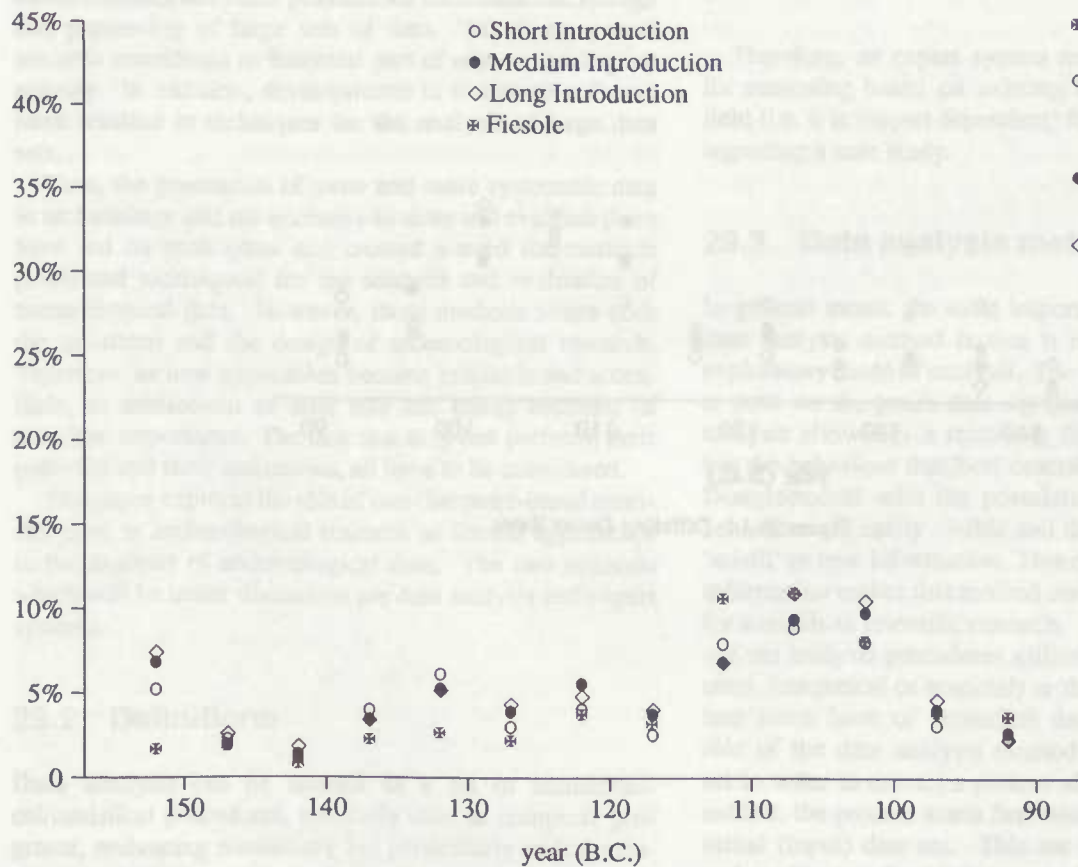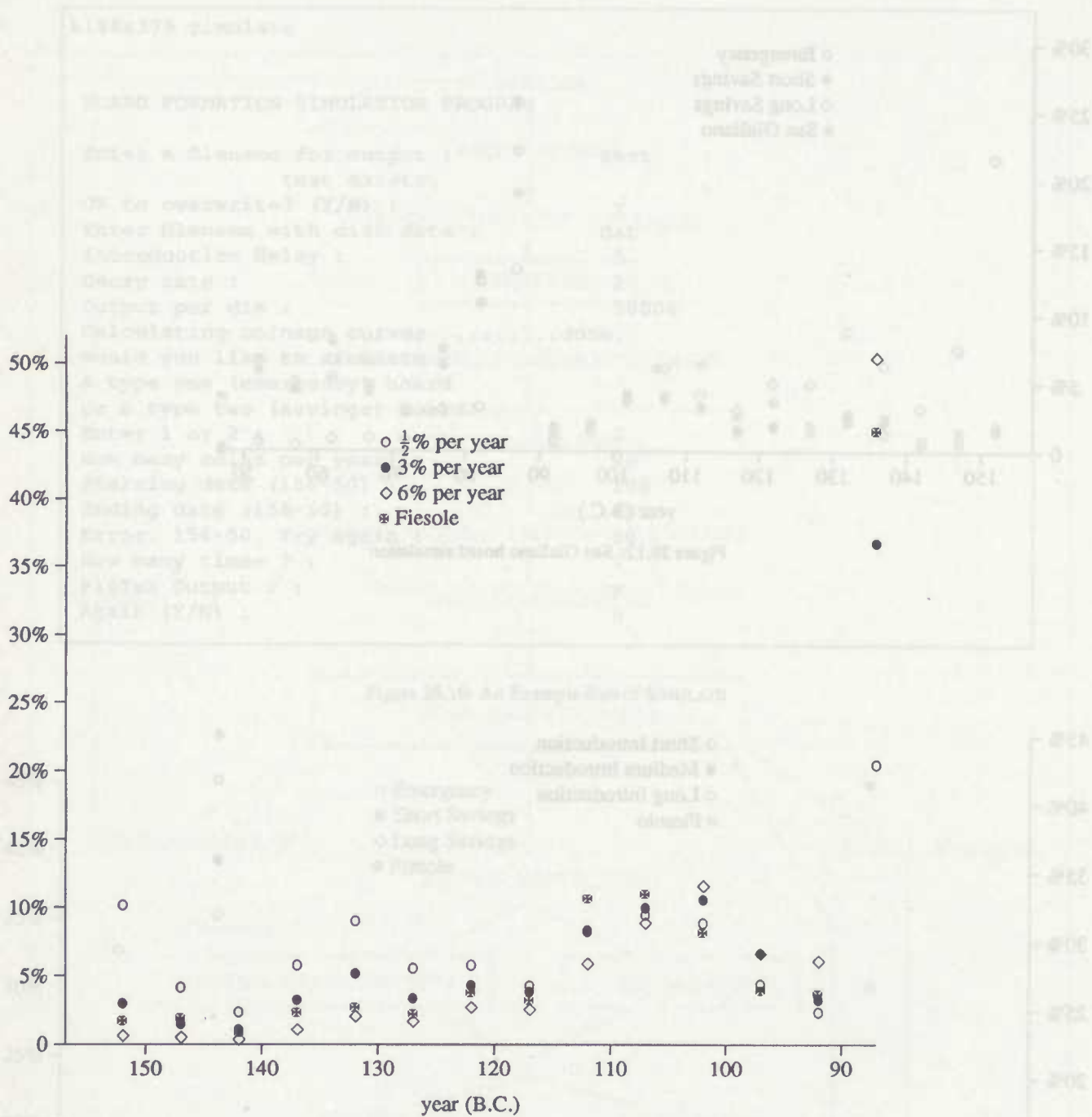
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Figure 28.12: San Giuliano hoard simulation

Figure 28.13: Differing Introduction Spans

Figure 28.14: Differing Decay Rates