Debasement and Currency Fluctuations in Hellenistic Egypt: Compositional Analysis of Ptolemaic Silver and Bronze Coinage

Thesis submitted in accordance with the requirements of the University of Liverpool for the degree of Doctor in Philosophy

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In Memoriam

Добринка Г. Йосифова

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Abstract

This thesis investigates the chemical composition of both silver and bronze coinage from the Ptolemaic Dynasty through the use of microwave plasma atomic emissions spectrometry (MP-AES). The aim of this examination is to broaden the understanding of Ptolemaic currency by using this analytical data to pinpoint potential time periods where change occurred, and to place these into a broader historical, economic and political context.

Chapter 1 will introduce the aims and objectives of this thesis. Chapter 2 will comprise a brief examination of the Pharaonic economy, coupled with a comprehensive overview of changes brought to the economy by the Ptolemaic rulers. This information serves to provide the necessary economic context, into which the results of the scientific examination conducted by this study can be placed. Chapter 3 focuses on issues such as dating of Ptolemaic silver and bronze coins, the mints, denominations and production techniques of these, as well as on the relevant previous research into their composition. Chapter 4 comprises the sampling and analytical methodologies utilised by this project. Chapter 5 presents the results of the analysis conducted by the author, with the analysed data being presented first by coinage type (silver or bronze) and secondarily by reign. Chapter 6 seeks to place this scientific data into the historical context of the Ptolemaic Period, and examine potential links between specific events and compositional changes. Chapter 7 comprises the conclusions to the project, as well as a short section charting the potential for future research into the topic of Ptolemaic coinage.

The results presented in the current work demonstrate an undeniable debasement of both silver and bronze Ptolemaic coinage, starting from the mid Ptolemaic Period and reaching its zenith during the reigns of Ptolemy XII and Cleopatra VIII. Additionally, the analysis of the trace elements in the silver coinage, in particular gold, bismuth and lead, conducted as part of this research, could enhance further the understanding of Ptolemaic bronze and silver coins particularly with regards to the minting process and ore provenance. This thesis proposes the existence of a clear link between internal events and the debasement of bronze coinage, and external events influencing the composition of silver coins.

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Chapter 1: Introduction

Political and economic instability characterised much of the Ptolemaic Period, caused by territorial wars, Dynastic struggles and economic mismanagement in particular during the later part of the period. These factors have historically been investigated primarily using textual sources (for example the Zenon archive). The current thesis aims to conduct a wide-ranging investigation of the Ptolemaic economy throughout the period by tracing the debasement (the lowering of the precious metal content, for further discussion of the term see Chapter 5) of silver and bronze Ptolemaic coinage. This will be done by employing scientific analytical techniques, namely microwave-plasma atomic emission spectrometry (MP-AES), which allows for the detection of any changes in the chemical composition.

The thesis rests on three primary research questions: 1) To what extent is debasement present in the silver and bronze Ptolemaic coinage? 2) In what ways can the currency debasement be linked to historical events during the Ptolemaic Period? Here an examination of the scientific results placed within the historical events that took place in Egypt during this time frame will be used to assist when trying to determine if there was indeed a link. 3) Was there a division between the internal and external currency fluctuations and if so, can this be associated with the compositional changes of the silver and bronze coinage? The aim of this last question is to examine whether the essentially dualistic aspects of Ptolemaic bronze and silver coinage visible in the textual record (see Chapter 2 below) can be evidenced in the composition of the examined coinage as well. This examination will also allow a broader discussion of the intended users and purposes of the currency. In order to answer these questions in the most efficient way the study will also incorporate previous compositional results and interpretations, as well as scholarly works on the Ptolemaic economy. This will further enable the full and comprehensive understanding of the currency fluctuations that shaped the economy of Ptolemaic Egypt.

The official chronology of the Hellenistic period in Egypt commences with the conquest of Alexander the Great in 332 BCE. However, the actual Ptolemaic Dynasty began in 305 BCE, when Ptolemy I Soter was proclaimed king of Egypt, and ended with the death of Cleopatra VII in 30 BCE (Hölbl: 2001: 21, 248). This is the time span upon which the current research focuses. The Ptolemaic Period is particularly noted for infighting among the members of the royal family, largely due to frequent intermarriages, a practice initiated by Ptolemy II, who married his sister Arsinoe II (Hölbl: 2001: 35-36), as well as numerous territorial wars with neighbouring states, in particular the Seleucid Empire (Fig. 2.1).

The bulk of information regarding the Ptolemaic economy stems from Demotic and Greek textual sources, such as the Zenon and Tebtunis archives (Von Reden; 2007: 9) and initially most research into the Ptolemaic state economy was based predominantly on the translation of only the Greek sources (see for instance Rostovzeff: 1920: 161-178). However, as more Demotic sources are being translated and published, a shift in our understanding of the Ptolemaic economy is occurring (see for details sections **2.2.** and **2.3.**). The Ptolemies conducted a number of changes to the Egyptian state administration following the Macedonian model; for example, by dividing it into three sections: one focused on maintaining order and enforcing the law, another responsible for economic documentation and the final one concerned with economic management (Muhs, 2016: 213-214). Another element of these changes was the elaborate tax system and the largescale introduction of coinage. However, the notion of coinage was not wholly unknown in Egypt prior to the Ptolemaic Period, and the Ptolemies did retain some of the original Pharaonic state organisation (for details see Chapter 2). One of Alexander the Great's aims for his empire was to have a unified coin system, thus coinage was introduced as the official medium of exchange as soon as Egypt was conquered (Von Reden: 2007: 32). After Ptolemy I became king and satrap, he began minting coinage within the territory of Egypt itself and started making a number of weight and iconographical changes to the silver coins (for details see section **2.2.**). At the start of the period the coins were struck in three metals: gold, silver and bronze. The production of gold coinage was stopped at some point during the reign of Ptolemy VIII (Hazzard: 1995: 87). This is the primary reason why gold coinage was not analysed in the current research.

Here an important point must be made: Although economic changes via the prism of coinage composition in the Ptolemaic Period are the focus of this work it must be stated that this will encompass primarily the macro-economy of this time frame. The nature of the sampled material does not lend itself to micro-economic examinations as the sampling strategy was primarily geared towards securing a representative sample for the entire period rather than more comprehensive samples focused on specific types of coinage (for instance from different regions and specific mints, for details see Chapter 3) which would be required for an examination of specific micro-economic developments of the period. The difference between micro and macro economy is illustrated aptly by Scheidel and Von Reden (2002: xiv): “Micro-economy is concerned with the economy of the individual economic units (households, companies, etc.) while macro-economics focusses on the interplay of these units and the economy of a state or religion as a whole”. In the current research the macro-economy of the Ptolemaic state will be examined by tracing the currency fluctuations by means of observable changes to the chemical composition of the examined silver and bronze coins.

Chapter 2: Shaping Ancient Economies: The Ptolemaic System in Context

The aim of the present chapter is to present a brief overview of the Pharaonic economy (the three Intermediate Periods will be excluded, due to the fragmentary nature of the evidence concerning economic activity) followed by an examination of the Ptolemaic economy. In doing so the chapter aims to provide the necessary context for the broader issue of the compositional currency manipulation and debasement which is the main topic of this thesis. At the start of this current chapter some scholarly views regarding the native Egyptians and the Greeks are also presented, as they further inform the way this period has previously been studied and the changes in perception that are now emerging.

The Ptolemaic economy, similarly to the history of the period itself, has been almost exclusively studied from a Hellenistic perspective. This is not surprising as much of the evidence from this period are textual sources written in Greek. However, increasingly a different perspective is now being offered by scholars such as Manning which focuses on the Ptolemaic economy as "[…] a hybrid that combined elements of pharaonic, Persian, Macedonian and Greek practices, with new models of production and taxation" (Manning, 2010: 3).

The relationship between the Egyptians and the Greeks in Egypt prior to the Ptolemaic Period, is not a straightforward one. The culmination of their associations was without a doubt the Macedonian takeover of Egypt, and the subsequent creation of the Ptolemaic dynasty (Manning, 2010: 28), although the beginning of significant Greek presence in Egypt can be traced to the settlement of Naukratis, located at the Canopic branch of the Nile, and established around 625 BCE, during the reign of Pharaoh Psammetichos I (Möller, 2000: 188).

One of the most fundamental issues facing students of the Ptolemaic economy has been the historic tendency to classify the Greek portion of the population as a "dominant minority" and the Egyptians simply as a subservient "majority" (Bingen, 2007: 215). In addition, studies of the Ptolemaic Period and Ptolemaic economy has

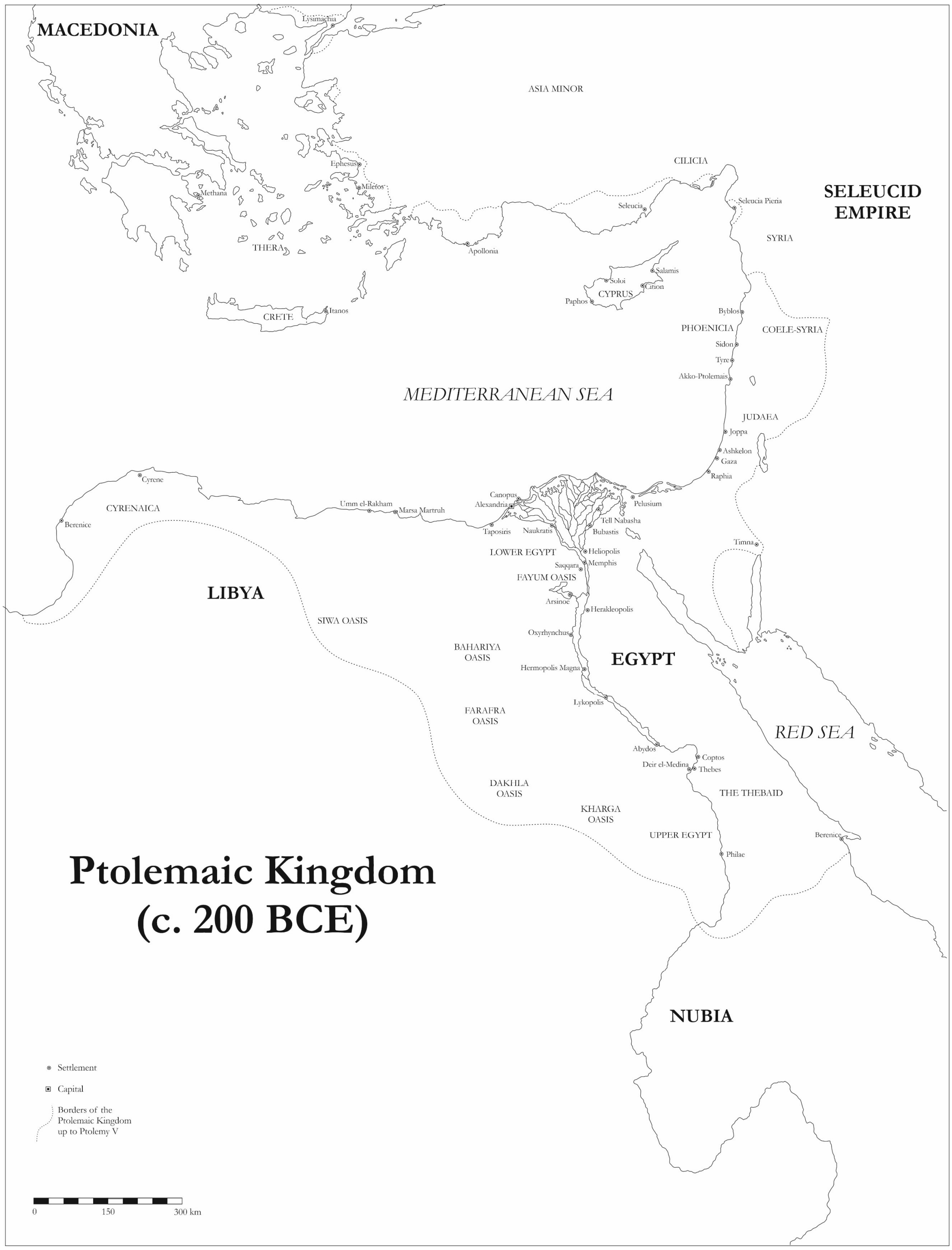


Fig. 2.1: Map of the territorial holdings of the Ptolemaic Kingdom during the reign of Ptolemy II (map by author).

also frequently incorporated economic and socio-economic theories derived exclusively from the Greek world and attempted to fit these into an Egyptian context (Samuel, 1983: 9). It must be made clear, that a large portion of the Ptolemaic society in Egypt did indeed consider itself Greek. Much of this Alexandria-based Greek elite also controlled significant portions of wealth in contrast to the majority of the population in the provinces.

However, an Egyptian elite, comprised mainly of priestly families (Hölbl; 2001: 223), continued to exist as it had done for centuries and even millennia. In addition, according to the Mendes stela, Ptolemy II began a policy in his 15th reginal year of including aristocratic young Egyptians into his bodyguard (Lorber, 2018a: 78). Some native Egyptians also made careers in the mostly Greek administration, after receiving a Greek education and often following the Hellenization of their names (Lorber, 2018a: 78). Unfortunately, insufficient examples for this practice have been found in the textual records as "bearers of dual names used them in different contexts, but the historical circumstances in fact suggest a broad integration of the Egyptian elite into the Greek administration" (Lorber, 2018a: 87). On the surface, this may suggest that the majority of the Egyptian population had become thoroughly Hellenised during the Ptolemaic Period. However, as with most ancient societies, our evidence base is almost exclusively linked to the elite, with far less material surviving to testify the experiences of the wider non-elite population. This focus on elite material culture and textual data may have further biased the interpretation of Ptolemaic Egypt and potentially helped to portray Egypt as having been more broadly Hellenised than was actually the case.

A striking example for this "Greek bias" in the scholarly literature can be found in Bingen (2007) which states that because of the monetarization of the economy, the Greeks acquired a "privileged role". The author then proceeds to lament the "poor Egyptians" who had to "turn over parts of their labour to an intermediary" concluding that the Egyptians needed the "protection of more important people, either Greek or priests" (Bingen, 2007: 228). This sort of attitude can be understood from someone like Rostovtzeff (1920: 161-178) whose work was coloured by a distinctly colonial way of thinking. However, it is difficult to understand Bingen's restricted view, especially given the wide range of evidence from Pharaonic times which demonstrate the same demand for compulsory labour in order for the royal agricultural estate to be cultivated (Muhs, 2016: 65). The Pharaonic evidence makes evident that the Egyptian labourers were used to working *for* someone and it would probably have made limited difference to them if they had to turn over parts of their labour and a portion of their harvest to the Pharaonic state, the temples and their priests, a wealthy Egyptian elite or a wealthy Greek one. Pap. Lansing even describes the harsh collections of centralised revenue from farmers during the New Kingdom long before any significant Greek presence in Egypt (although in this case this is probably exaggerated as the papyrus aims to demonstrate the superiority of the scribal profession): "His wife has gone down to the merchants and found nothing for barter. Now the scribe lands on the shore. He surveys the harvest. Attendants are behind him with staffs, Nubians with clubs. One says (to him): 'Give grain!' 'There is none!' He [the farmer] is beaten savagely. He is bound, thrown in the well, submerged head down. His wife is bound in his presence. His children are in fetters. His neighbours abandon them and flee. When it is over, there is no grain." (Lichtheim, 1976: 170-171).

Social tensions of course existed between Greeks and the Egyptians and also Hellenistic individuals held much of the economic and political power in the country (Manning, 2010: 52), but an attempt to stay objective and interpret the evidence without prejudice must be paramount when dealing with such a complex and multi-layered society. Moreover, in examining both the Pharaonic and the Ptolemaic economies here, no attempt to assign a single modern economical model to the Pharaonic, Ptolemaic or Greek economy will be made so as to avoid depicting these "ancient systems as static entities devoid of mechanisms of adjustment to changing circumstances" (Kemp, 1991: 233).

2.1. Pharaonic Economy

There is a significant amount of evidence, both textual and archaeological, which illustrate the workings of the Pharaonic economy. However, this evidence is fragmentary and often unprocessed, leading to the deduction that this amount of data does not "fit conveniently into an easy theoretical structure" (Eyre, 2010: 307). Furthermore, the "marriage of primary data with theoretical approach" (Eyre, 2004: 157) is something that is extremely difficult bordering on impossible to resolve when it comes to this type of economy. The main reason for this is that the traditional methods of studying ancient Egyptian economy have been lexical, meaning both that it has primarily utilised textual data, and has also included a significant focus on the meaning of specific terms in Egyptian and their meaning, and as Eyre states this is by no means a neutral approach (Eyre, 2004: 157). Most of the data (both textual and archaeological) comes from the New Kingdom, but due to the well-evidenced cultural and political regimes of the Old and Middle Kingdom, an image of, at least macro-economic activity can also be traced during these periods (Eyre, 2010: 291). However, the bulk of the data (from all periods of Pharaonic Egypt) represents a certain class – the elite – and often does not provide sufficient evidence for the people who lived in the countryside rendering it extremely difficult to discuss the economic activities conducted by farmers, labourers and craftspeople.

The essence of the Pharaonic economy was the barter or "in kind" payment that represented the exchange of goods and services for other goods and services. It must be noted that the terms 'barter' and 'in kind' are used through this chapter, however these are not indicative of the ancient Egyptian economy as it was a much more complex system. There remains some debate within the broader Egyptological community as to the extent of centralisation which was present (and needed) in order to collect revenues and the mechanics of this collection, however, the most likely scenario is one where the countryside existed with only limited governmental presence for the majority of the year, though officials would collect crops (and also livestock) for transport to the central collection point after harvest (Eyre, 2010: 292). An argument can be made that ancient Egypt was a rich country by the standards of the ancient world, and had the opportunity to store wealth in stable times (Kemp, 1991: 260). The key to Egypt's wealth was largely the Nile and its annual inundation. However, like all agriculture, Egypt's agrarian economy was exposed to climatic changes which with time would have serious impact on the overall system (Kemp, 1991: 260). In addition, the training and consequently the employment of people in the crafts that were considered high value and specialist, was conducted in the palace, state or temple workshops, as these institutions also provided the most obvious market for this type of production (Eyre, 2010: 299).

The earliest period of Egyptian history that presents evidence related to political economy, namely censuses and taxes paid by royal estates, is the Early Dynastic period. Individual tax obligations or taxation on private transactions, however, is not evidenced most likely due to the limited use of writing during this period (Muhs, 2016: 14-15). Evidence for the surveys and community tax come from fragmentary royal annals, inscribed several centuries later during the Fifth Dynasty (Muhs, 2016: 15). The means of recording transactions and taxations the collection of revenues required a "considerable administrative effort" (Eyre, 2010: 300). An assumption perhaps could be made that some of the religious annual processions such as the *Following of the Horus* during the Early Dynastic period could serve as a way to collect and consume revenues (Eyre, 2010: 300).

During the Old Kingdom writing became more prevalent, and included religious corpuses such as the Pyramid texts, biographies and both private and royal letters. The first evidence of accounts, such as those from the royal mortuary cult maintained at Abusir, also appears during this period, consisting of tablets with horizontal and vertical lines (Muhs, 2016: 23). The Old Kingdom provides evidence for dating formulae that mention the biennial counting of the cattle and other animals. The significance of these records is that, in order to provide the animals needed for sacrifice, the temples owned and reared large herds, and from these the crown received a regular supply, which could be viewed as way of taxation intermingled yet again with the religious establishment (Eyre, 2010: 301). On the other hand, the taxation of single animals belonging to individuals is difficult to establish with the evidence at hand (Eyre, 2010: 301). With the exception of this formulae connected to the counting of the cattle, there is still not sufficient evidence for centralized tax collection or a more complex economic model.

The Old Kingdom does provide some evidence for exchange of property, one example is the sale of a house in exchange for cloth and a bed found on Stela Cairo JdE 42787 (Strudwick, 2005: 185-186). Also, during this period weights of metal appeared as measurements of value, although these were only rarely attested as media of exchange in themselves (Muhs, 2016: 37). There are however, evidence for other commodities used as media of exchange such as cloth in exchange for property, and grain and bread in exchange for other goods and commodities recorded for instance in the famous reliefs of market scenes found in the Tomb of Niankhnum and Khnumhotep from Saqqara dating to the 5th Dynasty (Moussa and Altenmüller 1977: Fig. 10). The accompanying texts preserve details of individual transactions (the sale of cloth, sandals and foodstuffs for instance), using in-kind bartering: In one scene, for instance, a seller seated behind a small basket offers a buyer a beverage with the words: “Here’s a sweet beverage for you!” The buyer responds with the words: “And here’s a pair of sturdy sandals for you!” offering the sandals in exchange for the beverage (Lepsius, 1849: Pl. 96). For collection, processing and redistributing revenues from estates and towns, the state during the Old Kingdom used a number of institutions (such as granaries and treasuries) (Muhs, 2016: 38).

In the Middle Kingdom there were further developments and changes. Firstly, to the writing, which becomes more frequently used. In addition, the revenue collection was improved by documenting the objects of the taxation. The evidence for the documentation of objects from this time period derives from field surveys (for example Pap. Harageh 3) used most likely to calculate harvest taxes and census of people put in place to evaluate the compulsory labour service (Muhs, 2016: 62-64). The demand for compulsory labour was most probably due to the need of workforce that can cultivate the royal agricultural estates (Muhs, 2016: 64). A switch to an individual or household tax responsibility, from a communal tax responsibility, could have occurred during the Middle Kingdom. An assumption could perhaps be made that the economic unit in this period was that of a family household (Eyre, 2010: 294). This economic model is best attested in the Letters of Hekanakhte, a papyrus corpus containing the correspondence between Hekanakhte and his eldest son (Allen, 2002). The letters contain topics such as choices in crop – whether to use barley, emmer or flax; discussions on costs; ways of payment (for example rent is paid in advance with cloth and grain); ploughing; the herds belonging to the family; the weaving that is done in the household and hiring temporary workers during the harvest season (Eyre, 2010: 294).

Furthermore, during the Middle Kingdom weights of metal are again used as measures of value. Gold appears to have served as a standard measure; however, it would seem that because gold was too valuable and/or too rare it was not used as a medium of exchange in the majority of transactions (Muhs, 2016:75). The most common items used as media of exchange were copper, cloth and grain (Muhs, 2016:75), which were all mentioned by Hekanakhte in his letters. Treasuries and Granaries were employed in order to receive and redistribute revenues and commodities. These were processed and distributed with the aim to support royal projects, dockyards, palaces, mortuary temples that were associated with Thebes and with the provincial administrator's palaces and funerary chapels as well as local temples (Muhs, 2016: 77). During the Middle Kingdom an increase in the evidence concerning high value exchanges of lands, houses, slaves and more can also be observed (Muhs, 2016: 84). This is due to the increased use of writing which in turn leads to the discovery of more records during archaeological excavations. However, fewer scenes of market places have survived from the Middle Kingdom than from the Old Kingdom making it difficult to discuss the exchange of low value goods during this time period (Muhs, 2016: 84).

The New Kingdom is the time span that provides most data with regards to the Pharaonic economy, including high value foreign trade. During this period this type of trade was connected to the great temples due to their close ties with diplomatic and military powers (Eyre, 2010: 296). The term 'tribute of foreign rulers' was used to illustrate the incoming goods, in addition the Egyptian king also sent diplomatic gifts to different foreign rulers (Eyre, 2010: 296). The data from this period demonstrates that the barter economy continued within Egypt itself. Most goods and consumables were assigned a certain value which was conveyed in different units corresponding to amounts of other commodities (Kemp, 1989: 248). Similarly, to the Old and Middle Kingdoms, lead weights of a standard weight were used as media of exchange but not as coinage. Prices varied depending on the circumstances and the traded goods and services with little indication for centralised attempts by the state to interfere in private transactions as noted by Richet (2020: 13), regarding the New Kingdom economy and the role of centralised hierarchies within it: "Needs were fulfilled not only through local effort but also through extended supply chains of increasing complexity in a developing free market. None of these conditions happened fully by decree from an all-powerful hierarchical leader, but instead developed through the interdependence of participants in the society". In addition, the prices of labour and raw materials were also part of this system of value (Kemp, 1989: 248).

The most detailed evidence for small-scale economic transactions from the New Kingdom undoubtedly comes from the site of Deir el-Medina (Kemp, 1989: 248) (Fig. 2.1.), the village that housed the workers and artisans responsible for the construction and decoration of the Valley of the Kings from the end of the 18th Dynasty to the 20th

Dynasty. Values from the records found at the site were usually specified in deben of copper (Eyre, 2010: 295). The Deir el-Medina workmen, were paid in grain and other foodstuffs, although grain appears rarely in the lists that record their transaction commonly known as the *Commodity Lists* (Eyre, 2010: 297). Based on the textual sources from Deir el-Medina, the workmen were paid three times the amount of grain they could consume, thus providing them with obvious purchasing power (Eyre, 2010: 297).

Gold and silver (again as weights not in the form of coinage) could be used for purchasing commodities on occasion, even by people of modest status as evidenced by some of the transactions recorded in the Tomb Robbery papyri (Kemp, 1989: 258), although this must have been more common for people with higher status and greater wealth. The transactions from the Tomb Robbery papyri should of course be discussed only with the fairly obvious caveat, that much of the gold and silver wealth had been generated by the looting of royal tombs, and so these transactions between common people using unusual wealth can hardly be considered typical.

The primary state revenues from land during the Ramesside Period, were gained by rents (Eyre, 2010: 301). The annual grain harvest tax was the most important revenue for the state (including the temples) during this period, as it provided the necessary funds to support the large number of priests and dependent personnel (Muhs, 2005: 1). Papyrus Wilbour clearly demonstrates the direct exploitation of the arable land "by the temple through its personnel" as well as the lack of any mention of taxation on temple land (Janssen, 1975: 142, 146). In addition, intricacies of both tax collection and tax payment can be found in Papyrus Valencey I (Gardiner, 1948: 205-206), which describes several problems which the mayor of Elephantine encountered, when a temple scribe came to collect land taxes.

When discussing the economy of the Late Period (or Saite Period) and Persian Period, these are usually grouped together due to the historical overlap that occurs during this time frame. One of the most significant changes going into the Late Period and Persian Period relates to the officials responsible for the economic documentation: During the previous periods this role was held by the vizier, but during the Late Period this was changed to the shipping master, and then finally to the chief financial minister (Muhs, 2016: 182). These titles were not exclusive held by one individual, and there may have been multiple chief financial ministers serving simultaneously, each responsible for a specific region (Muhs: 2016: 182). Unlike the New Kingdom, there are no surviving field surveys or census lists from the Late or Persian Periods. However other textual sources do show that temple scribes continued to measure fields held by private individuals in the temple endowment and on that basis, calculate the harvest tax that was to be received by the temple (Muhs: 2016: 183).

Probably one of the most important issues during these periods is that the state and its agents, the temples, began collecting tax in money (coinage), alongside the in-kind and labour payments. This coinage was not state issued though there might have been a mint in Memphis (Fig. 2.1.) (the coins minted in Egypt were unmarked, and were most likely imitations of Athenian tetradrachms) (Muhs: 2016: 191). During the Persian Period, the most prevalent type of coinage was the Athenian tetradrachm, most likely paid to Egyptian merchants by Greeks in exchange for grain (Colburn 2014: 353). A potential example for this type of transaction is the Asuyt hoard (Beer, 1980: 1). The hoard contains a variety of coins from Greece and Asia Minor, and was accumulated between 490-475 BCE and brought to Egypt around 480 BCE (Gale, Gentner and Wagner, 1980: 3). Deep gashes are observable on a large number of the coins from this hoard, most likely the result of the "Eastern traders [testing] the purity of the silver coins they received in case any of them consisted plated base metal" (Beer, 1980: 1).

In addition, silver bullion – so-called *hacksilber* – was also used in a range of transactions throughout Egypt (on this topic see for instance the analysis of a hoard of Greek coins and silver ingots found in Egypt dating to the 5th century BCE in van Alfen, 2004-2005). Other types of coinage, including shekels of silver mentioned in the Aramaic Elephantine Papyri were used in the payment of Jewish mercenaries in southern Egypt (von Reden 2016). Persian coinage was also struck and used in Egypt, although – in particular during the second Persian Period, it still followed the established Attic standard. Coins of the Persian satrap in Egypt, Sabaces, for instance were minted following the weight of the Athenian tetradrachm (Colburn, 2014: 353, for an extensive overview of the use of the Attic standard in Persian Period Egypt and the minting of Egyptian imitation tetradrachms see also Colburn, 2018: 84-103). So, while coinage-based transactions were certainly used in Egypt well before the Ptolemaic Period, these transactions mostly involved either foreign merchants or mercenaries, or members of the Egyptian elite (von Reden, 2016). And although Greek coinage within Egypt was not a new notion, as it has been in circulation since the 6th century BCE (Lorber, 2018a: 22), its use outside the large urban centres and trade hubs was minimal. In earlier periods prior to the 4th century, according to Lorber (2018a: 22), coinage in Egypt was used primarily as a form of a bullion, while later it served as payment for "Greek mercenaries in the service of native pharaohs". What changed with the ascension of Ptolemy I was that, for the first time in Egyptian history, a native "[…] royal coinage for widespread use among the entire population" (von Reden, 2016: 2) was introduced.

2.2. Ptolemaic Economy

Our understanding of the Ptolemaic economy is based primarily on textual sources. The most significant of these is the Zenon Archive, comprising more than 1700 texts concerned primarily with the management of a large estate (Von Reden, 2007: 9). The estate belonged to Apollonious, but was administered by the official Zenon for a significant number of years from 262 to 239 BCE (Kehoe, 2010: 316). Apollonious was the chief administrator (*dioiketes*) of Ptolemy II, and his estate included a concession for 10.000 auroras which equals 6700 acres or 2700 hectares and was located near the village of Philadelphia in the Fayum (Fig. 2.1.) (Kehoe, 2010: 316). The estate was involved with agriculture, primarily the cultivation of vines, however, the production of clothing (from the raw materials to the finished goods) was also conducted there (Kehoe, 2010: 316). In addition to the Zenon archive, there are around 400 more papyrus fragments (from the Petrie Collection, the Lille and Sorbonne papyri and the Tebtunis archive) that provide evidence for the economic transactions during this period (Von Reden, 2007: 9). It should however be noted that the majority of this textual documentation comes from two areas of Egypt, namely the Fayum Oasis and the Oxyrthynchite nome, south of the Fayum in Middle Egypt with surprisingly few documents discovered in the Nile Delta and Alexandria despite these being large urban centres (Kehoe, 2010: 310). This may in part be explained by the generally poor survival rates of organic matter, such as papyrus, in the relatively wet soil of the Delta and the saline soil of the coastal region.

The new Ptolemaic rulers aimed to create a different economic model, the main purpose of which was to use Egypt and its assets in order to gain the means necessary to compete with their neighbours (Bugh, 2006: 83), although an argument could be made that this aim was not so different from the practice of the Egyptian Pharaohs themselves. A significant development of large urban centres was one of the first major projects undertaken by the Ptolemies, the most notable of these being the creation of the capital Alexandria (Manning, 2007: 441). In addition, the new administration also reclaimed land, seriously intensified agriculture and improved the transportation and communication systems (Von Reden, 2007: 7). A significant problem for the development of coinage was encountered early on, namely the lack of certain precious metal resources within Egypt – in particular silver. The solution for this was the currency imports received mainly via the export of Egypt's agricultural bounty (Von Reden, 2007: 7).

The main truly novel characteristic of the economy, was the monetarisation of all levels of society in Ptolemaic Egypt. When Ptolemy I became satrap and later king, he began to transform the currency and he was the first of Alexander's successors to place the latter's portrait on coins, but also the first one to abandon the use of Alexander's coin types and the first one to place his own portrait on his coinage (Lorber, 2018a: 24). In addition, Ptolemy I made the decision to move away from using the established Attic weight standard (to be discussed in detail in the next chapter) which none of the other successors did (Lorber, 2018a: 24). As to bronze coinage, no such currency was minted or indeed used in Egypt prior to the Ptolemies, although bronze coins from Asia Minor and later coins of Alexander did circulate in the country before the Ptolemies (Faucher and Olivier, 2020: 99).

In addition to the introduction of the coinage itself, legal and social institutions were also established in order to regulate the exchange and use of coinage (Von Reden, 2007: 5). For example, three types of banks were instituted (local, provincial and the village tax office), all of which were under royal control, and given their varying locations, may also have had subtly different purposes (Muhs, 2016: 235). The use of coinage was strongly encouraged by the state, although the limited supplies of coins necessitated the need of a number of money credits in order to preserve the redistribution networks as well as the exchange in kind (Muhs, 2016: 252).

For a significant period of time the standard measure of value continued to be calculated in weights of silver, although these were replaced gradually throughout the Ptolemaic Period with silver and bronze coinage (Muhs, 2016: 230). At the start of the period there were three types of coins issued: gold, silver (both large and small denominations), and bronze (Muhs, 2016: 231). However, during Ptolemy VIII's reign the production of gold coinage was stopped (Hazzard, 1995: 87). An interesting aspect of Ptolemaic coinage, is the lack of silver deposits in Egypt. The most likely source of silver ore would appear to be Greece, where this commodity may have been exchanged for Egyptian grain (Butcher and Ponting, 2014: 612). This lack of silver may have been the reasons for the creation of a closed-currency system (Von Reden, 2007: 43). The use of foreign coins within the borders of Egypt and the rest of the Ptolemaic coin zone (this includes Cyrene, Cyprus and Coile Syria (Fig. 2.1)) was prohibited by this system (Von Reden, 2007: 43) and by doing so Ptolemy I "enacted an official ban on the importation of foreign currency, thus separating Egypt monetarily from the rest of Alexander's former empire" (Lorber, 2018a: 44).

Evidence for this closed currency system can be found from the reign of Ptolemy II, who retained the closed currency system initially introduced by his father. The system is shown in action, in Pap. CairZen 59021, which was written by Demetrios, an official in the Alexandrian mint to Apollonious who was the chief administrator (*dioiketes*) of Ptolemy II (Edgar, 1917-1919 :168). The papyrus states:

> To Apollonius greeting from Demetrius. If you are in good health and your affairs are satisfactory, it is well. As for me, I am attending to the work as you wrote to me to do, and I have received in gold 57000 pieces, which I minted and returned. We might have received many times as much, but as I wrote to you once before, the strangers who come here by sea and the merchants and middlemen and others bring both their local money of unalloyed metal and the gold pentadrachms to be made into new money for them in accordance with the decree which orders us to receive and remint, but as Philaretus does not allow me to accept, not knowing to whom we can appeal on this subject we are compelled not to accept . . . ; and the men grumble because their gold is not accepted either by the banks or by us for . . ., nor are they able to send it into the country to buy goods, but their gold, they say, is lying idle and they are suffering no little loss, having sent for it from abroad and being unable to dispose of it easily to other persons even at a reduced price. Again, all the residents in the city find it difficult to make use of their worn gold. For none of them knows to what authority he can refer and on paying something extra

> receive in exchange either good gold or **silver**. Now things being as they are at present, I see that the revenues of the king are also suffering no little damage. I have therefore written these remarks to you in order that you may be informed and, if you think fit, write to the king about the matter and tell me to whom I am to refer on this subject. For I take it to be an advantage if as much gold as possible be imported from abroad and the king's coinage be always good and new without any expense falling on him. Now as regards the way in which certain persons are treating me it is as well not to write, but as soon as you arrive you will hear . . . And write to me about these matters that I may act accordingly. Goodbye. (Van Nijf and Meijer, 2014: 65).

As Schubart (1922: 74-80) states, this text clearly illustrates that all foreign coins entering Egypt had to be exchanged for Ptolemaic coins, and thus all monetary transactions were done using this native medium.

In addition to the introduction of the closed-currency system, considerable additional economic development was achieved during Ptolemy II's reign, mainly as a result of a number of monetary and fiscal changes and development projects the focus of which was the reclamation of the Fayum Oasis in the early 260s or 250s BCE (Von Reden, 2007: 25). The main purpose behind reclaiming this land was to create new settlements for the Greek *cleruchs* whose migration to Egypt Ptolemy II continued to encourage, thus developing an additional agricultural area which could in turn supply the capital and the army with food (Von Reden, 2007: 25).

These changes included the introduction of a monetary poll tax and a bronze reform from 266-262 BCE that focused on increasing the weight, size and circulation of the bronze coins, thus making them the primary currency in the Egyptian countryside (Von Reden, 2007: 25 and 63). Later on, some change to the currency was made, first in 230 BCE, and then in 220 BCE, that prompted the countryside to continue to use less and less precious metal coins in favour of bronze coinage. And while silver remained the preferred medium for exchange between the Ptolemies and their allies, bronze coinage was also used (Von Reden, 2007: 30). There are a few possible reasons behind this change to the bronze coinage. One, as proposed by Lorber (2018a: 110) was to "[…] inspire confidence in the new coinage by bringing its face value closer to the intrinsic value of the bronze opening the way for the bronze currency to play a more important role in the economy and ultimately replace silver coinage". Another reason that is not directly contradictory to the first is the idea of Egyptianizing the currency (Preaux, 1939: 276) by making the heaviest bronze denominations correspond to the native Egyptian weight unit deben (Mørkholm, 1991: 105).

As noted above, prior to the Ptolemaic Period, coinage was little-used in Egypt with the Egyptians instead relying on units of value, such as the deben weighing around 91g (Warburton: 1997: 20). If this theory of the weight similarity between the ancient Egyptian deben and the heaviest of the reformed bronze coins is correct, then the main purpose of it may have been to encourage the native population to more easily accept the idea of coinage (Mørkholm, 1991: 11). Although this is a difficult theory to prove, it does seem plausible, especially when considering that around this time the land reclamations of the Fayum had begun, and although the large estates were owned and managed by Greeks, they were worked mostly by native Egyptians who paid taxes partly in coinage and as such introducing coins of a familiar weight could have indeed been beneficial. The third theory with regards to the increased weight of these new bronze coins was proposed by Picard and Faucher (2012: 37), who hold that this increase was due to the introduction of an exchange commission in some of the bronze coin transactions. However, no substantial evidence in support of this theory were presented making it difficult to evaluate its validity. The preferred currency for large transactions continued to be silver, but bronze coinage was used extensively in every day exchange (Von Reden, 2007: 60).

Furthermore, redistributive networks began operating increasingly in coinage rather than in kind as it had in earlier periods. So, in order to obtain coins for taxes, the population had to exchange goods and services, and then pay the coin payments to the state (Muhs, 2016: 246). This might have been one of the reasons why the payments of salaries in coin, rather than in kind, increased significantly, and why the payment of compulsory labour was in coin, rather than in kind as during previous periods (Von Reden, 2011: 432). On the other hand, the temples continued to pay the priestly households in kind, resulting in the selling of surplus scribal labour or in leasing the produced revenues for coinage (Muhs, 2016: 252). Moreover, as a significant amount of the Egyptian population was most probably engaged with agriculture, their income was mostly in the form of grain and other produce and, due to the need to pay their taxes in coins, they would have been required to sell their surplus materials and labour in order to gain the coinage needed (Muhs, 2016: 252). The state itself paid its employees in a combination of coins and grain or on occasion bread, oil, clothing and wine (Muhs, 2016: 240) although the in-kind payments were often deducted from the cash payments making it difficult to distinguish between the sale and the redistribution of commodities.

Another new characteristic of the Ptolemaic economy was the division of the country's revenue into two components: Revenue in grain and revenue in coinage (Manning, 2011: 303). This dual revenue was the product of the new state policies, which were in turn the result of the previously mentioned fiscal reform conducted by Ptolemy II (Bard, 2008: 303). Agriculture however, was not the only revenue for the Ptolemaic state, another large source of income were the military campaigns. The revenues acquired in these campaigns were short and long term. The short-term revenues were the result of the plundering of the conquered area, while the long-term revenues were attainted through the taxing of the provinces added to the Ptolemaic state (such as Cyprus, Cyrenaica and Syro-Palestine) (Muhs, 2016: 249). It should, however, be noted that the most important change in the economic policy was the "shift from the control of labour and the taxation of labour services to a taxation system dedicated to raising revenue in cash" (Manning, 2010: 128).

As a result, the monetarisation of taxation of many sectors was the next change that the Ptolemaic administration introduced in Egypt. However, for a significant amount of time the most substantial economic income, i.e. harvesting, was not taxed in coinage (Von Reden, 2006: 170). This changed for Upper Egypt (Fig. 2.1.) in the late 3rd century BCE and for Lower Egypt (Fig. 2.1.) at the beginning of the 2nd century BCE (Von Reden, 2006: 170). Surveying and collecting harvest tax from both temples and state lands was managed by the state itself, resulting in the tax from the temples being assigned to the state, rather than temple granaries and the temples being given an allowance (Muhs, 2016: 221-222). The collection of harvest tax allowed the local granaries to be filled, and in turn the grain was potentially paid out as loans to the local farmers, or as part of the grain/bread part of the salaries given to the officials and of course as the above-mentioned allowance for temples (Muhs, 2016: 234). However, Von Reden (2011: 429) states that civil administration and the army actually purchased their grain rather than receiving it as distribution. Thus, the nature of the granaries and their redistributive power is difficult to establish with certainty.

2.3. Overview

As a whole, based on the evidence at hand, the Ptolemies significantly changed the face of the Egyptian economy, largely due to the monetarisation of the society and the centralization and expansion of the tax system. However, there are a number of issues when considering both Pharaonic and Ptolemaic economies: For example, a number of scholars, such as Eyre, have raised serious doubts about the use of the redistributive economic model when discussing the Pharaonic economy. His view on the matter is that "the term "redistribution" is … best avoided, for the false sense it creates of a central control over physical movement of real income and goods at a low level" (Eyre, 2010: 306). This argument is highly complex due to the fragmentary nature of the evidence from the Pharaonic time span, however the term "redistributive economy" has been used in this chapter on a number of occasions mainly for the ease of explanation, although an awareness that this can cause potential issues does exist. Furthermore, as mentioned in the introduction of this chapter, when it comes to interpreting Ptolemaic economy, the most significant issue stems from the traditional idea that the economy was entirely based on Macedonian and Greek models, whereas more recent authors like Manning and Von Reden are increasingly viewing the Ptolemaic economy as a hybrid, influenced by Greek practices as well as existing Pharaonic systems and constructs. Moreover, when discussing the correlations between the Pharaonic and the Ptolemaic economies it should also be noted that during the Pharaonic period there is a significant lack of evidence with regards to the management of private holdings (there are of course exceptions, such as Hekankhte's letters) and a more representative corpus with regards to the management of the royal and temple estates. The situation during the Ptolemaic period is completely reversed, with most of the evidence coming from private estates (for example the Zenon archive) and almost no evidence from the royal holdings.

The introduction of coinage to Egypt was not a sudden change that occurred the moment Alexander the Great arrived in the country, but rather a development, the origin of which can be traced to the Late and Persian Periods. In addition, when the issue of monetarisation of Egypt is discussed as Samuel (1984: 203) states, coinage and money are frequently equated, leading to the disregard of the fact that "coinage is only one type of money, and in making the equation, we carry over from the modern usage of coinage (and printed paper) to serve all the purposes of money". The reality, however, is that for at least a millennium, the ancient Egyptians had used metals as medium of exchange, a store of value and means of payment (Manning, 2010: 131) and that by the Late and Persian Periods the introduction of coinage was gradually escalated, firstly into the merchant classes of the society, and then to the elite who must have seen the benefit of coinage.

Nonetheless, establishing the attitude of the rural population to coinage, especially with regards to using it in everyday transactions and being paid in it, is difficult bordering on impossible due to the substantial lack of evidence from this societal group. As these people left little to no archaeological and textual sources behind, a conclusion cannot be reached with regards to their perception of the shift from a barter or an in-kind economy, to a cash one, and most importantly one can argue that because of this lack of evidence, a serious case can be made that they continued using the in-kind or barter economy for everyday transactions and used coinage (mainly if not solely bronze) only in transactions related to the state (paying taxes for example). Furthermore, the continued use of grain as a medium of taxation for a significant period of time after the introduction of Ptolemaic coinage to the Egyptian countryside, could also be used to illustrate the limited impact the monetarisation had on the rural population (Manning, 2007: 445).

Although, an argument can be made that after several generations the copper coinage was used in everyday transactions by the majority of Egypt's population (Samuel: 1984: 204). On the other hand, the most likely scenario when it comes to the Ptolemaic economy in the large urban centres such as Alexandria or Memphis was that of "an active centre of sale and purchase: cash passed hands, pawning was practiced when necessary, and prices were carefully watched" (Thompson, 2012: 69). Moreover, the dichotomy between the cities and the countryside, could stem from the fact that in order to develop large urban centres, in which wealthy landowners resided and which were beneficial for the state, the resources for the countryside were drained with little provided in return (Kehoe, 2010: 313). However, it should be noted that the disengagement between the central regime (and to certain extent the elite) and the peasant community is something that has existed and, in a sense, even become tradition from the early periods of Pharaonic history (Eyre: 2004: 167).

Thus, following Wells (1949: 47) one could argue that the Ptolemies did not change the economic system of Egypt very much, but rather adapted the existing model to fit with the Macedonian and Greek monetary economy. Based on the available evidence this does seem the most likely scenario. It would appear that the Ptolemies kept and maintained the Pharaonic infrastructures that worked, for example the agricultural installations and the knowledge of how to work the land (Jansen, 1975: 128). The changes they introduced were mainly connected to the distribution and use of coinage (for example banks and the more centralized authority with regards to taxation) and what is more a claim could be made that this was simply an administrative matter (Von Reden, 2007: 32) or an inevitable development that was long overdue.

The purpose of this chapter was to produce a broad context of the development of Pharaonic and Ptolemaic economy in Egypt into which the main aim of current thesis, the investigation of debasement of bronze and silver currency, can be placed. As clearly illustrated, the majority of the evidence both for the Pharaonic and Ptolemaic economy stems from a royal or elite context. As such it is extremely difficult to definitely investigate the state of the economy across all levels of society. This biased nature of the source material must be noted when presenting the conclusions of this chapter. With this caveat, and on the basis of the presented evidence, a conclusion can be reached that the two ethnic groups in Egypt, the Greeks and the Egyptians, made the Ptolemaic rule a complex hybrid state combining ancient social structures and new fiscal institutions (Manning, 2010: 74, 202).

Chapter 3: Previous Research on the Composition of Ptolemaic Silver and Bronze Coinage

The current chapter will examine a variety of issues, crucial to the discussion of Ptolemaic silver and bronze coinage and the composition of said coinage. First and foremost, the matter of how Ptolemaic coins are dated will be presented and some of the more novel ways currently under development will be discussed. Following this, a brief overview of the mints in which the coins were produced will be presented. In addition, the production technologies for both silver and bronze coinage will also be discussed. The denominations of both silver and bronze coins and the difficulties encountered in ascribing those will also be covered. The following section of the chapter will examine the previous research done on the chemical composition of silver and bronze Ptolemaic coinage.

3.1. Dating Ptolemaic Silver and Bronze Coins

One of the first catalogues of Ptolemaic coinage was produced by Reginald Lane Poole (1857-1939) in 1882. This publication was written under the auspices of the Department of Coins and Medals in the British Museum and listed predominantly the coins held within this collection. Following Poole's early work, Ioannis N. Svoronos (1863-1922) published a larger body of work on gold, silver and bronze Ptolemaic coins from collections around the world (Svoronos, 1904-1908). Subsequent work was presented in the *Sylloge Nummorum Graecorum Copenhagen* (SNG Cop.) showcasing the Greek coinage available in the Royal Collection of Coins and Medals in the National Museum in Copenhagen. Part 40, published in 1977, focused on Egypt. This volume (and the remaining volumes) was republished between 1981 and 1984, and in this newer publication Egypt was grouped with coinage from North Africa and Spain in Volume 8.

However, the publication that remains the most referenced, as well as to a certain extent the most detailed – as it presented Ptolemaic coins from a variety of collections – is that of Svoronos. In his publication he presented both precious metal coins and bronze coins together, and ascribed denominations to the gold and silver coins, but not to the bronze coins. This issue will be discussed in more detail in the section concerned with denominations below. Furthermore, he ascribed the coins to specific rulers, although, due to the date of the publication, as well as the development of the field of numismatics, it is clear that the publication needs to be revised and updated. Presented below are the two most recent discussions on the subject of dating Ptolemaic coinage.

The first of these is, perhaps not so much the needed revision of Svoronos, but rather a completely new system of dating and grouping Ptolemaic coinage, developed by Picard, Faucher and Olivier and detailed in a 2012 publication (Picard and Faucher, 2012). Their system was designed to focus predominantly on Egyptian bronze coins, as opposed to the broader scope of Svoronos' work. The publication includes 3527 Ptolemaic coins uncovered in the excavations of Alexandria, which began in 1990s as salvage works prompted by the increase of real estate development in the area. Following these initial forays, further excavation work in the area followed and to date more than 20 different excavations with different contexts (including underwater works) have been conducted in the region (Centre d'Études Alexandrines, n.d.).

Picard and Faucher's system separates the coins into series, rather than the previously used system of sorting the coinage by individual reigns of kings. This change was largely prompted by the difficulty of identifying some of the excavated material owing to poor preservation (Picard and Faucher, 2012: 17-18). The authors, furthermore, point out that as the images on the reverse and obverse of Ptolemaic coinage (especially the bronze issues) are quite similar throughout the Ptolemaic Dynasty, a question could be raised as to the validity of assigning coins to different rulers (Picard and Faucher, 2012: 17-18). The Series System instead groups the coins into ten chronologically successive series (on occasion subdivided into sub-series), and is based on the diameter, weight, size (according to the authors this is due to the production technique) and image of the coins (Picard and Faucher, 2012: 17-19). Significant attention is focused on the major currency reform of the second century and its impact on the division. This way of dating was incorporated by Faucher into his PhD research, focusing on the composition of the bronze coins, as well as on the manufacturing techniques utilized when manufacturing this type of coin (Faucher, 2013).

The organisation of this new dating system relies overwhelmingly on coin hoards, as explained in a publication by Faucher and Lorber (2010). Hoards can indeed be useful as a dating tool, as they present, in a sense, a time capsule that contains different type of coins grouped together. Based on the relevant chronology of the archaeological context in which the hoard was located, a potential date can be ascribed to the hoard, and to the coins within it. However, using hoards as a primary dating tool, does raise a number of concerns. For instance, there are 14 hoards on which the authors base their relative chronology of Series 06 and 07 (Faucher and Lorber, 2010: 60). Three of these hoards were excavated in the 1920s and 1930s, which is problematic as the recording of finds (of all types) during this period was less detailed than today, and as the concept of stratigraphy was not yet fully implemented on excavations in Egypt. As such, coins from different areas of a site were frequently grouped together. Occasionally coins (as well as other types of finds) that were not discovered at a specific site, but brought in by workmen, were recorded as belonging to that site. An example of this practice can be found in the 1934 report on the excavations at Bucheum, where one of the three coins recorded was "brought by children from provenance unknown" (Brazener, 1934: 117). In addition, at these periods taking finds out of Egypt was permitted, but some were kept in the country and some sent overseas, where they were then further divided between a number of museums, potentially introducing another element of confusion about their original context and provenance.

An example for both of these practises is Flinders Petrie's excavation at Tell Nabasha in the Eastern Nile Delta (Petrie, 1888) in 1886. Petrie notes that he found 25 Ptolemaic coins in a 'hoard', although only some were described in his journal and subsequent publications. The precise place of their discovery is not noted – aside from the very general context of 'House 100' – and after the excavation, the coins, in addition to the rest of the finds from the site, were divided between the British Museum, the Boston Museum of Fine Arts, The Cairo Museum and more than forty smaller collections across the world. To compound the potential for confusion, Petrie also bought a number of coins from locals which were added to assemblages of objects from the site ("Beside these a small lot of eleven later Ptolemaic coins was found elsewhere in the town, and brought in by Arabs […]", Petrie, 1888: 26) so it is now not possible to definitively state which coins came from the original hoard, and which were purchased from locals or found elsewhere (Petrie, 1888: 26). And even though Petrie's work at the site dates to 1886 this practice continued for a long period subsequently.

Given this state of confusion it is unclear how the authors behind the Series system can be certain that the three coins hoards discussed are indeed complete hoards from a clear, dated stratigraphy. Moreover, when discussing the publication of the Kom Trouga hoard, which includes both silver and bronze coins, the authors do in fact admit that the hoard was "reconstructed" from two boxes in the Alexandria Museum (Faucher and Lorber, 2010: 46). The coins were originally excavated in the 1930s and again the issue of reliability of the excavation records become pertinent: Was this really a hoard? Are all the coins even from the same site? And is the scholar who reconstructed the hoard certain that the coins from these two boxes were not mixed with material from other excavation sites during the last 70 years?

Furthermore, in their 2010 publication (and in the later publications mentioned above) Faucher and Lorber divide and/or subdivide the series based on breaks in the coin hoard record. However, this method fails to account for alternative explanations for a specific series of a coin missing from a given hoard: For example, a regional difference in coin usage, or simply that the type of coin missing was of a type most frequently used as a payment method. This possible difference in regional hoard record is illustrated by Lorber (2018a, 41) who provides an example for this practice: For the entirety of the third century, only one Ptolemaic hoard comprised of silver tetradrachms has been found in Cyprus. Lorber states that: "The rarity of hoard loss in third-century Ptolemaic Cyprus may reflect very secure conditions, or, alternatively, a scarcity of coinage relative to need, so that it was difficult to accumulate savings in silver" (Lorber, 2018a: 41).

In addition to using hoards as a reliable dating tool, another problematic premise presented by Faucher and Lorber's research is the issue of state involvement and reforms. Faucher and Lorber state that "[…] the authorities planned in advance" (Faucher and Lorber, 2010: 59) for a coin reform and demonetarization during the reign of Ptolemy IV. One could suggest that in adopting this argument of advanced planning the Ptolemaic state is viewed in a more modern and complex manner than the limited and incomplete evidence necessarily suggests it to have been. If we take the view of Eyre that the ancient Egyptian state was not truly efficiently centralised, but rather run on the basis of delegating administrative responsibility to regional centres (Eyre, 2004: 167) such a thing as advanced central planning for a new monetary system seems unlikely. An argument could be made that the Ptolemaic state was more organized than the Pharaonic state due the utilization of Greek administration in the country, however here again the problem of to what extent the Ptolemies attempted to genuinely change the administration of the country outside of Alexandria presents a point of contention, as discussed in Chapter 2. Of course, as the present research focuses on debasement which, if present, will most likely be due to a state manipulation, it is in some ways fragile to the exact same line of argumentation. However, a notable difference is that centralised debasement can be viewed more as a consequence of a policy or set of policies rather than a result of advanced planning. Debasement would also not require great levels of control across the entire country, but simply an extension of the centralised control to a relatively small number of royal mints. By contrast, the wholesale reform of currency and its patterns of use throughout the country would arguably require a greater level of state control well beyond the confines of the mints themselves.

Moreover, when discussing the Series System, there are a number of other issues which arise from ascribing the coins to specific groups. One such issue is the above-mentioned use of the images on the coins. Even though Picard and Faucher (2012: 17-18) note the similarity in the iconography that is used for the reverse and obverse of the Ptolemaic bronzes, they still utilize it as a criterion for grouping. In addition, as some of the excavated coins were badly preserved (Picard and Faucher, 2012: 17-18) both the reliability of the weight and size measurements, as well as the clear identification of their decoration can be called into question, and by extension, so can the reasoning by which they are included in specific series. In his 2013 publication Faucher analysed coins that were not minted or discovered in Alexandria, and he does note that the classification of these “external currencies” was based directly on the work done by Svoronos (Faucher, 2013: 65). The issue here is that when discussing the chemical composition of Ptolemaic bronzes - with some categorized using the new Series System and some using the Svoronos system - it raises issues about the degree to which they can be usefully compared and discussed, given that one system classifies coins by reign and the other does not.

While the Series System remains a work in progress, with some significant methodological issues as discussed above, it must be made clear that Picard, Faucher and Olivier with their work have presented a very significant point, which should be taken under consideration by scholars investigating, not only Ptolemaic bronze coins, but also silver coinage, namely the continuation of coin usage from one ruler to the next. The new Series System can be seen to illustrate a more relative chronology rather than an absolute one and according to Lorber (2018b: v) this could be a useful tool in future archaeological reports.

Alongside the work done by Picard, Olivier and Faucher discussed above, a second discussion concerning the dating of Ptolemaic coinage presented recently by Lorber (2018a and 2018b) is more along the lines of the much-needed update to the catalogue created by Svoronos. Lorber's work focuses on revising the chronology used by Svoronos, by utilizing the most recent developments in the field of numismatics such as archaeological finds (including hoards), analysis of the style of the coins as well as the use of control marks, die studies and mint contributions (Lorber, 2018a: v-vi). The author has catalogued the coins in "[…] the traditional manner […]" (Lorber, 2018: XX) meaning that they are attributed to individual reigns, in an arrangement which, as Lorber (2018a: vi) states: "[…] is largely congruent with Svoronos' arrangement" (Lorber, 2018a: vi). However, Lorber's catalogues includes many coin issues unknown to Svoronos in addition to addressing the errors he made when it came to attribution and interpretation of specific issues.

Furthermore, Lorber separates the bronze coinage from the precious metal coinage and thus creates two volumes of reference work (2018a and 2018b respectively). The reason for this division is due to the currency reforms of Ptolemy II, which after 272 BCE "[…] introduced separate control systems for bronze and precious metal coinage, and thereafter the control systems converged only occasionally" (Lorber, 2018b: v), leading to the difficulty of relating long sequences of precious metal and bronze coinage without the aid of these control links. As of the present date the two published volumes cover only the reigns of Ptolemy I to Ptolemy IV, as this new updated system is still in the process of being completed.

The current work will use the Svoronos system for dating (for both silver and bronze coins) as a foundation. However, due to the outdated nature of this dating system and the inherit issues that stem from this, a number of scholarly works will be used to re-date or clarify specific issues. Such an issue for example is the problem of mint location in Svoronos' work. He holds for instance that no coins were actually minted in Alexandria from the reign of Ptolemy VI to the reign of Cleopatra VII. He based this conclusion on the appearance of the control letters ΠΑ on the reverse right corner of most coins of this period, which is more commonly indicative of coins from the Cypriot mint of Paphos. The idea that the Alexandrian mint simply stopped producing silver coins seems unlikely, and a better explanation is that the ΠΑ control letters were simply used both at Paphos and Alexandria at this time for unknown reasons. This theory was suggested by Mørkholm, who states that: "A curious, and as yet unexplained phenomenon is the occurrence on the dated coins of Alexandria of the letters ΠΑ in the right field of the reverse" and that the use of these control letters continues "on the Ptolemaic silver of both Paphos and Alexandria right to the end of production at the two mints" (Mørkholm, 1975: 8). In order to resolve this problem, the work of Mørkholm (1983a: 69-79) has been used to establish if the coins were minted in Alexandria or in Paphos.

In essence for the silver coins of Ptolemy I to IV the dating proposed by Lorber (2018a) will be followed, for the later Ptolemaic silver coins in addition to the two publications by Mørkholm mentioned above, a number of other works such as Newell (1941), Nicolaou and Mørkholm (1976), Mørkholm (1983b) and Olivier (2015) will be utilised to inform the dating. Newell's 1941 work was originally published in 1939 as a short article in *The Coin Collectors Journal*. Newell largely laments the state of research into Ptolemaic coinage from the point of view of collectors, arguing that even the few specialised works on Ptolemaic coinage (certainly referring to Svoronos) is "far from crystal clear" to an outsider (and even some specialists). Newell envisaged his article (and later pamphlet) as a "general and not too bulky or complex a survey, which will enable the average collector to assign without too much trouble, and with a very considerable degree of certainty to this or that Ptolemy the coins which are likely to be found in his collection." (Newell, 1939: 83). Newell's typology includes only 60 coins presented across six plates, with most reigns represented only by one or two examples. Crucially, however, Newell's publication does contain some references to a redating of Svoronos' material: "As however Svoronos made certain errors in his attributions of coins to the later Ptolemies, it may prove of assistance to collectors and students to offer here a brief reclassification of the dated Soter-type coins (from Ptolemy IV to Cleopatra VII) as illustrated on Svoronos' plates." Newell does not however provide much in the way of methodological considerations as to how precisely he arrived at these new dates.

The other work used in the dating of the sampled and analysed silver coins is that of Nicolaou and Mørkholm (1976) concerning a vast coin hoard of 2484 silver coins from the mints of Paphos, Alexandria, Salamis and Kition covering the entire period between 185 and 97 BCE. Rather than present this hoard simply by reference to Svoronos, Mørkholm – using stylistic and coin die analysis – presents a re-evaluation of Svoronos' dating of the coins within this time period. Apart from the significant discovery that the coins marked with the mint assignation ΠΑ are not the exclusive product of the Paphos mint as Svorones claimed (as discussed above), Mørkholm was also able to present most of the coins in a chronological manner using both mint mark and regnal dates covering the reigns of Ptolemy V to Ptolemy X (Nicolaou and Morkholm, 1976: Appendix I). Mørkholm later added to his hypothesis with a die study which complemented the conclusions he made in his 1976 publication (Mørkholm, 1983b).

With regards specifically to the Cypriote production of Ptolemaic coinage, the work of Svoronos has been significantly revised in the later 20th century. In his publication, Svoronos links very few specific silver issues to Cypriote production prior to the second century BCE, suggesting instead that no significant minting of silver coinage took place on Cyprus prior to the reign of Ptolemy V. This argument was revised following the discovery of the Meydancikkale hoard published in 1989 by Davesne and Le Rider. On the basis of this hoard, the authors propose re-assigning a large series of 3rd century BCE silver coins from Alexandria to the three Cypriote mints of Salamis, Kition and Paphos (Davesne and Le Rider, 1989; for a useful summary of the Meydancikkale hoard and its significance in the revision of Svoronos' work, see Olivier, 2015). Lorber, in a more recent publication (Lorber, 2018a) goes even further, suggesting that production of silver coinage on Cyprus was inaugurated already during the reign of Ptolemy I rather than Ptolemy II as suggested by Davesne and Le Rider.

Summarising the arguments made with regards to the production of silver coinage on Cyprus, Olivier (2015) suggests that the production was neither continuous, nor regular from the 3rd to the 1st century BCE. Rather, the production rose and fell in intensity, most likely as a result of the production being shared by multiple mints in a relatively small area. Olivier also suggests that the production of silver coinage on Cyprus was centrally managed (most likely by the island's *strategos*). As stated above all of these publications will be taken under consideration to provide an updated chronology of the silver Ptolemaic coins, while using Svoronos as a foundation.

As to the bronze coinage, the coins of Ptolemy I, II, III and IV have been dated using Lorber's work (2018b). The rest, however, were dated using Svoronos. In the case of these later bronze coins, a strong understanding is present that some of them may be misdated and that is pointed out in the relevant sections in Chapter 5. In order to partially mitigate this, the current work provides a comprehensive database of all the sampled coins (Appendix I), which includes size (diameter), weight, description of the image on the reverse and obverse of the coin, the inscription (if any) on the reverse and obverse of the coin, reference (most often Svoronos and the corresponding series system where relevant) and photographs, all of which will allow a relatively quick and easy conversion of the sampled coins and the results of the analyses, into any of the two currently developing dating systems. In acknowledgement of the significant development to Ptolemaic bronze numismatics represented by Picard and Faucher (2012), a dedicated section of this thesis (5.5) presents a comparison of the results of the current study and those published by Faucher.

3.2. Mints and Denominations

This section will examine a further two topics, which are directly relevant to the broader discussion of Ptolemaic coinage, and should be taken into account when discussing both the sampled coins as well as the final results: mints and denominations. Svoronos (1904) attempted to place the Ptolemaic coins not only in chronological order, but to also ascribe denominational value (with the exception of bronze coinage as mentioned above) and finally to relate them to specific mints.

It must be noted that for the majority of its existence the Ancient Egyptian state did not use coinage (for details see Chapter Two), although due to the growing trade with the Greek city states during the Late Period, coins began to be produced in Egypt during this time period, for instance imitations of Athenian tetradrachms dating to the late fifth century (Von Reden, 2007: 32). These imitations were probably minted in Memphis, which is also the location of the first mint established in the country prior to Ptolemy becoming a satrap at the start of the 32nd Dynasty (Hazzard, 1995: 72). Initially (immediately after Alexander's conquest of Egypt) most of the coinage in circulation throughout the country did not come from Egyptian mints, but rather from other mints throughout Alexander's empire. This is not surprising as one of Alexander the Great's aims for his new empire, was to have a unified coin system (Von Reden, 2007: 32) based on Macedonian issues, although Ptolemy I sought to change this policy around 310 BCE (Mørkholm, 1991: 10). The mint in Memphis continued in use until around 311 BCE, when the capital of Egypt was moved to Alexandria (Hölbl, 2001: 26), where the new state mint was opened (Von Reden, 2007: 35). Ptolemy I not only started minting coins in Egypt, but he also changed their appearance (Von Reden, 2007: 35). The Imperial Alexander coinage that circulated in the conquered territories depicted Heracles with a lion skin on the obverse, and a seated Zeus carrying an eagle in his right hand on the reverse. However, this iconography was changed by Ptolemy I to depict a head of the young Alexander the Great with an elephant scalp and rams horn on the obverse, while the reverse was kept as before depicting Zeus. This may not seem a major change, however, as Von Reden (2007: 36) states: "The appearance of Alexander on the coinage was revolutionary. Until then only very exceptionally had human portraits been put on coins".

But as the empire of the Ptolemies grew so did the need for coinage, and thus the need for more mints, often outside of Egypt itself, in occupied territories. For example, there were five mints in Phoenicia – Tyre, Sidon, Ptolemais (Caesarea), Joppa (Jaffa) and Gaza, in which coinage was struck continuously from the reign of Ptolemy II until the reign of Ptolemy III, when, due to the war between Ptolemy III and Seleucus II of Syria, the border province of Phoenicia was seriously affected (Mørkholm, 1991: 101-102). Moreover, bronze coinage was struck in Cyprus, Cyrene and Coile Syria reaching the other Ptolemaic provinces by circulation and transport (Von Reden, 2007: 25).

A discussion could be had whether, if there was indeed intentional state debasement, this would be visible both in coins from Alexandria and the provincial mints. Bronze coins from Phoenician Syria were analysed by Faucher (2013), but as he does not put these directly into the series system he uses for the analysed coins of Alexandria (as discussed above), it is difficult to draw direct parallels and conclusions. Unfortunately, as the current research was reliant predominantly on museum collections, the coins that are sampled here come mostly from Alexandria, with a smaller amount from some of the Ptolemaic possessions outside Egypt. As such, a direct meaningful comparison in compositional changes between mints is not possible and the sampled coins will be discussed as a whole. However, in the cases when a coin from a certain reign came from a provincial mint, and the results differ from the Alexandrian coins of the same date, this will of course be pointed out. Due to the relatively small sample sizes per ruler, a decision was made to not separate the provincial coins into a separate discussion section as was the case for example with Faucher's research (for details see section **3.5**).

The denomination of silver and bronze Ptolemaic coinage is also something that has a direct impact on the current work. As mentioned above, there are certain problems which arise when attempting to ascribe denominations to these coins, but it must be made clear that these issues mostly relate to the bronze coins. The silver Ptolemaic coins were originally struck following the Attic weight standard. Denominations are often ascribed to ancient coins based on weight, for instance the average weight of a group of coins, or a median weight, or taking the heaviest weight of an unbroken sequence of coins (Mørkholm, 1991: 7). The Attic weight standard owed its popularity to the coins depicting the Athenian owls and it very quickly became the prevailing international trade coinage after it was used by Philip of Macedon for his gold issues, and then later by his son Alexander the Great for both his gold and silver issues (Mørkholm, 1991: 8). In the 300 years during which the standard was used, it did undergo a series of changes: The silver tetradrachm (the most used trade coin) weighed 17.28g on the Attic weight standard at the time of Alexander, it was then subsequently reduced to c. 17.20g around 300 BCE, then to c. 16.80g around 172 BCE, then to 16.30g around 105 BCE, and then finally reaching c. 15.00g (Mørkholm, 1991: 8).

The initial silver coinage utilized in Egypt, even after Ptolemy I becoming satrap, was based on the Attic standard as well, however, around 310 BCE Ptolemy I decided to reduce the weight of the silver tetradrachm to c.15.80g, thus departing from the normal Attic weight (Mørkholm, 1991: 10). There were further reductions in the weight of the Ptolemaic tetradrachms, first to 14.90g, and the around 290 BCE to c. 14.30g/14.40g, which was the weight maintained (with a weight of c. 14.20g) until the early first century (Mørkholm, 1991: 10). The initial currency system established by Ptolemy I was based on two denominations: the gold stater and the silver tetradrachm, but between 313–311 BCE this system was changed to include smaller denominations in both silver and bronze (Lorber, 2018a: 26). The silver denominations included: pentekaidecadrachm, decadrachm, pentadrachm, 2½ drachm, didrachm, drachm, triobol, diobol, trihemiobol, obol, hemiobol, quarter obol; these are listed in descending order based on weight, and most are recorded by Svoronos who ascribed denominations to the Ptolemaic coinage on the basis of weight, although some have been more recently updated by Lorber (2018a 589-590). One useful function of the original two denomination system was to pay mercenaries, however the drive to expand the denomination system appears to be in order to "[…] meet the needs of a Greek city population accustomed to the use of coinage in daily transactions" (Lorber, 2018a: 26).

By contrast to the silver coinage, the denomination of the Ptolemaic bronze coinage has attracted some controversy with the earliest debates on the face value of the Ptolemaic bronzes occurring during the early 20th century (Hultsch, 1903). Svoronos (1904), chose not to ascribe value to the bronzes, but to classify them using their diameter, and provide alphabetic denomination lists ordered by decreasing diameter. The main concern with ascribing denominational value to the bronze coins stem from their wide variation of weight standards (Hazzard, 1995: 63) although more recent work such as that of Wolf (2013) on the metrology of the bronzes, has assisted greatly in distinguishing the face value of this type of coins.

Wolf (2013) used quantitative analysis of coin weights across a long time-span, aiming to establish the relationship between the coin values and their sizes. The study focused on weight, and more than 5000 coins were organized in digital databases (Wolf, 2013: 52). Wolf's later study focused on the reform of the bronzes conducted during the reign of Ptolemy II. This change included the introduction of new designs, larger sizes and weights as well as new manufacturing techniques. Wolf (2013) focused his work on comparing the weights of pre- and post-reform weights, arguing that "[…] the bronze coins' mean weights [were] nearly exactly proportional to their values (both pre-and post-Reform)" (Wolf, 2017: 540). The author's conclusion was, that following the reform only the bronze coins increased in weight, while the weight of silver and gold issues remained relatively stable, and that the bronze reform is best described as a move to raise the value of the smallest unit by 50% and thus introduce a wider range of denominations (Wolf, 2017: 541-543).

Lorber (2018b) using developments in the study of metrology (mainly the work of Wolf discussed above), as well as research concerning the metal content and its impact on the coins' face value, has ascribed denominations to the bronze coins in her new catalogue using the Attic divisional system. She argues that the expansion of the bronze currency occurred during the monetary reform of 294 BCE, and that changes in the minting techniques occurred as a result of the production of the large bronze denominations (Lorber, 2018a: 32). Thus, the coins fall in the following categories: chalkoi, dichalkoi, hemioboles, oboles, dioboles, trioboles, tetroboles, drachms and octoboles. Unfortunately, as Lorber's current catalogue presents coins only from the period between Ptolemy I and Ptolemy IV her complete list of issues by reign and their denominations remain unavailable.

The current research will provide the denomination values for silver (as listed by Svoronos) and the alphabetic denomination based on diameter (as listed by Svoronos) for the sampled coins in Appendix I. An awareness is present, that this may not be the most detailed approach to ascribing the denominational coin values on the sampled material, but as the current work is reliant on museum collections, the coins sampled were requested due to the reign they were ascribed to, not because of their denomination. As such, as with the mints, specific denominations were not targeted, and if any obvious compositional changes between the different coin denominations become evident, they will be discussed, but this is not the main aim of the current research. Because of the detailed appendix provided for the all the sampled coins, these can easily be adapted to any of the new dating and denomination systems currently being developed, which in the case of the bronze denominations will most certainly be warranted following the complete publication on Lorber's new catalogue series.

3.3. Production of Silver and Bronze Coinage

Although the production of coinage is not part of the primary research aim of this thesis, the thesis does, however, on occasion discuss the ways in which composition and compositional changes may be affected by production technologies. As such it is prudent to include a brief section on production techniques of silver and bronze Ptolemaic coinage.

There is little information available with regards to Greek coin minting, and that includes archaeological data (Faucher, 2017: 72). There are a number of known Roman mints, for instance the Capitoline mint, which functioned during the Roman Republic, before most likely being re-located after the fire in 80 AD. Based on the archaeological record the building that housed the mint has been positively identified as being located under the church of St. Clemente, east of the Colosseum (Howgego, 1995: 27).

Some information pertaining the manufacture of Hellenistic coinage production can be ascertained from the Athenian Agora, and more specifically from a large square building that was excavated there in the 1950s and again in 1978. Based on the large amounts of industrial debris, in addition to the large volume of unstruck bronze coin blanks, flans and pieces of bronze rods, this building was identified as being the bronze Athenian mint that was in operation from the 4th through the 1st century BCE (Camp II and Kroll, 2001: 127, 139). This mint is not however the mint that produced the famous silver Athenian coinage. This was determined following the lack of silver in the analysis conducted on some of the materials recovered from the building (Camp II and Kroll, 2001: 144). This analysis further indicates that most of the material is copper with "lesser amounts of iron and tin, and lesser amounts still of lead" (Camp II and Kroll, 2001: 144). This does seem to indicate that the primary commodity worked in this building was copper. With regards to Egypt, the largest and only mint in the country was that of Alexandria, and unfortunately no information (with the exception of some discovered flans, see below) as to its operation has been discovered (Faucher, 2017: 72). As for workshops, there are only two examples, one is from Upper Egypt, where imitative bronze coins were struck in the 2nd century BCE, and a second workshop located on the island of Cyprus, specifically in Paphos which was recognised in the archaeological record based on the presence of moulds, blanks and general evidence of metal working (Howgego, 1995: 28).

Due to the lack of textual and archaeological records to aid the understanding of coin production during the Ptolemaic Period, Faucher has suggested using the coins themselves, although he does state that most of the coins do not in reality give much indication of where or how they were produced (Faucher, 2017: 73). With regards to the production of silver coinage not much is known, especially concerning the production of blanks and the moulding of raw metal into flat and round shapes (Faucher, 2017: 74). And although there is a suggestion of a two-piece mould based on observable flatted edges on the flan and/or on the edge of the coin, Faucher (2017: 74) argues that this method could not have been widely used due to its time consuming and labour-intensive nature.

Understanding how bronze blanks were made is perhaps easier, due to discoveries made in different parts of the Greek world and in the East of stone or clay moulds and rods of metal (Faucher, 2017: 74). Based on the moulds discovered in Paphos and on flans discovered during the French excavations in Alexandria, as well as in the Karnak temple in Luxor, Faucher (2017: 75) proposes a number of different techniques used in the production of Ptolemaic bronze coins. He links those with the Series system used by him in dating Ptolemaic coinage. As the current research is not using this system (for details see **3.1**) here the techniques will be presented, but their link to the different series will not.

The first technique used a long bronze bar with a diameter smaller than the required coin, which was then cut into smaller discs using tongues and chisels thus producing small round discs (Faucher, 2017: 75). These were then flattened by hammering, thus manufacturing rather thick flans, which then go through different phases of annealing and hammering. Based on debris from the Athenian bronze mint, it can be concluded that this was the production technique used in the manufacturing of the coins in this location (Camp II and Kroll, 2001: 158). This is a well-attested practice at other ancient Greek sites such as Argos, Pella and Olynthos (Camp II and Kroll, 2001: 158-159). However, this technique was most likely not utilized in the production of the Ptolemaic bronze coins, as it was predominantly useful for the production of smaller coins, while large coins (as was the case for a number of the Egyptian issues) were struck from cast blanks (Camp II and Kroll, 2001: 159).

The use of cast blanks is the second technique presented by Faucher, and according to him the metal was poured into a "mold carved out of individual cavities with bevelled edges" (Faucher, 2017: 76). The third technique is similar to the second, but based on the even larger coin sizes, the indication of trimmed runners and most importantly, the central cavities located at the centre of the obverse and reverse of the coins, Faucher (2017: 76) states that there was a slight variation of the production, and that these coins were made by pouring the metal into a mould which then flooded "into the runners from cavity to cavity, filling up the mould with melted metal" (Faucher, 2017: 76).

Support of the theory that bronze coins were produced by casting (pouring the metal into a mould), rather than being struck can also be found in Caley's 1939 work. His conclusions were based on the examined dendritic structure of the coins and although the majority of the analysed coins were not Ptolemaic (as noted below in section **3.5**) he does examine some Ptolemaic bronzes too (Caley, 1939: 166). Further to this, he is of the opinion that there was a direct relationship between the size of the coin and the production method with the heavier coins displaying definite evidence of casting, which can be explained due to the absence of mechanical power which made it difficult to "impress a design satisfactory on a large bronze blank by means of dies, so that bronze coins much above the average in size were from considerations of technical convenience or necessity produced solely by casting" (Caley, 1939: 167).

As such, although some clarity can perhaps be found with regards to the production of the bronze coinage, the production of silver coinage remains difficult to ascertain. It is clear that the research into coinage production during this time period is one aspect of the study of Ptolemaic coins that requires further work. This however, is made particularly difficult due to the lack of textual and archaeological evidence, making it nearly impossible to reach concrete conclusions, at least precluding the discovery of further evidence from Ptolemaic mints, either in Egypt or elsewhere in the Ptolemaic sphere of influence.

3.4. Previous Research into the Composition of Ptolemaic Silver Coinage

This section will present the research that has previously been conducted on the composition of silver Ptolemaic coins, focusing on the techniques and the conclusions that were derived following the analysis of the sampled coins as well as pointing out any weakness that could be observed. For a chronological overview of the analytical methods employed in the analysis of Ptolemaic silver coinage please consult the table below (Table 3.1).

The first comprehensive analysis was conducted by Giesecke (1930, although an earlier analysis of a single tetradrachm of Ptolemy I minted in Tyre was conducted by A. von Rauch in 1874), with the main aim of his publication being to provide an overview of the Ptolemaic coinage with a primary focus on discussing issues such as succession, standard values, exchange rates and the state of accounting during the Ptolemaic and, briefly, Roman periods. To this end, he produced some basic chemical analysis. However, when considering the more scientific aspects of this work, more questions rather than answers arise. For example, the exact number of sampled and analysed coins is unclear, most likely this number is somewhere in the vicinity of ten (Giesecke, 1930: 88 and 93). Furthermore, there is no information as regards to the provenance of the sampled coins, whether they came from a museum collection, and if so, which one, or whether they originated from excavations, or the open market and were purchased for the purpose of this research. Date-wise it appears that the sampled material comprises coins from the reigns of Ptolemy I (both during his satrapy and as a king), Ptolemy II, Ptolemy IV, Ptolemy V, Ptolemy XI, Ptolemy XII and the joint rule of Cleopatra VII and her brother Ptolemy XIII (Giesecke, 1930: 88 and 93).

It is obvious that there are serious chronological gaps in this data set, but further to this, the aim of this scientific analysis was as a whole rather obscure, but might have related to an attempt to define the value relationships between silver and bronze coinage (Giesecke, 1930: 67). The analyses of the coins were carried out by the Chemical Institute of the University of Leipzig, however the exact methods employed are not specified. In addition, with the exception of a brief mention of five Ptolemy XII tetradrachms and a description of them being cut, the sampling methodology is not provided.

Author	Year of Publication	Analytical Method
Giesecke	1930	Wet Chemical Analysis
Caley	1955	Wet Chemical Analysis
Walker and King	1976	XRF
Hazzard and Brown	1984	1.Unspecified
		2.Neutron Activation
		3.Deutron Activation
Buckley	1985	PIXE
Hazzard	1990	1.Wet Chemical Analysis
		2.Neutron Activation
		3.Deutron Activation
		4.XRF
Gölitzer	2004	XRF
Kantarelou et al.	2011	XRF
Butcher and Ponting	2014	ICP-AES
Olivier	?	LA-ICP-MS

Table 3.1: Chronological overview of the previous analytical methods employed in the analysis of Ptolemaic silver coinage.

Hazzard who conducted analysis of Ptolemaic silver coins in the late 1980s and early 1990s (see section below) states that Giesecke used wet chemical analysis, a conclusion which Hazzard derives based on the chemical elements presented in Giesecke's work (Hazzard, 1990: 90-91). Hazzard (1990: 90) further states that: "Undoubtedly, wet chemical analysis remains the most reliable method for finding the metallic composition of a coin, but the method has principal limitations since every coin tested is damaged in the process". One can presume that this damage refers to the cutting of the coins mentioned by Giesecke himself, but how specifically these coins were cut, and how exactly this wet chemical analysis was performed is not specified by either author.

The elements presented in Giesecke's work are: silver, copper, lead, tin, gold, iron, calcium, chlorine, silica, phosphorus, molybdenum and platinum (Giesecke, 1930: 88 and 93). Following his analyses, the author places the change in silver percentage used in the coinage of the period to the reigns of Ptolemy X and XI (Giesecke, 1930: 58). He states that the coins were at this point no longer minted from pure silver, but rather from a mixture of silver and base metals (mainly copper), and that this change was due to the turmoil that was occurring in the dynasty. Giesecke further suggests that this change in the composition could not remain hidden from the population, and so resulted in a lowering of the intrinsic value of the silver coinage (Giesecke, 1930: 58). Moreover, Giesecke states that a fundamental deterioration of the silver coinage was reached during the reign of Ptolemy XII (Giesecke, 1930: 85). To what extent these early results are reliable cannot be definitively verified, however it must be noted that Hazzard did consider them reliable and used a number of the sampled coins in his own research both in the 1980s and in the 1990s.

In 1955 Caley published work on the chemical composition of silver Parthian coins. For the purposes of comparison, a few other ancient coins were also compositionally analysed. This included a coin from the reign of Ptolemy X. Wet chemical analysis was used for all the coins including that of Ptolemy X (Caley, 1955: 7). In his conclusion Caley states that the Parthian tetradrachms are of considerably lower fineness than contemporaneous Egyptian tetradrachms (Caley, 1955: 36). This conclusion is, of course, based on the single analysis of the coin of Ptolemy X which contained 87.49% silver, 10.24% copper and 1.46% lead. However, Caley does express doubt with how representative this one Ptolemaic tetradrachm was stating: “Many such coins have the appearance of base silver, and lower figures have been obtained for a few earlier ones in the series. … On the whole, it does not seem possible at present to draw any definite conclusions as to the relative fineness of contemporaneous Parthian and Ptolemaic coins.” (Caley, 1955: 36-37).

Next, in 1984 Hazzard and Brown tested approximately 60 coins using five separate chemical analyses performed by three methods. The first method was wet chemical analysis and it was used for around 10 of the coins under investigation, however the authors do not describe in detail neither the sampling method, or the sample preparation, nor do they provide details and specifics on the analytical techniques used (Hazzard and Brown, 1984: 232). In addition, three of the of coins presented for this method were copied from the earlier research of Giesecke, (1930). The analysis of the other seven coins was conducted in the Technical Service Laboratory in Toronto with the aim of the analysis being to serve as a standard by which the results of the neutron activation analysis also conducted by the authors could be compared, and also to determine the “[…] exact date at which various debasements took place” (Hazzard and Brown, 1984: 232).

The second method used by Hazzard and Brown was neutron activation analyses and it was used on most of the coins (approximately 30). As with the first method, no detail is provided for the sampling, sample preparation or the analytical approach (Hazzard and Brown, 1984: 232). However, the author did consider this technique as the least reliable, with a reliability in the span of 10% to 20%. The third and final technique utilised was that of deuteron activation, and again as with the previous two techniques no details as to sample preparation or technique specifications were provided (Hazzard and Brown, 1984: 232). The analysis was performed in the Institute of Nuclear Physics Research (I.K.O.) Amsterdam by two different analysts (Mayers and van Zelst).

The chemical elements listed in the table presenting the results (Hazzard and Brown, 1984: 238-239) are silver, copper, gold and lead. However, the silver and lead analyses has been given for only a few of the coins, gold is provided for most of the sampled coins and finally copper is the element provided in all cases (Hazzard and Brown, 1984: 233). The overall conclusion to this article is that there were three stages of debasement in the silver Ptolemaic coinage: the first stage, dated to between 205-180 BCE (copper content rises by 0.7%), the second stage taking place around 148 BCE (copper content rises by 2%), and the third stage occurring in 136 BCE (copper content rises with 8%) (Hazzard and Brown, 1984: 234-237). There are a number of issues with this paper, chief of which is the lack of any information that would allow other researchers to replicate any of the three techniques used. It would appear that the authors of the paper were not themselves conducting the sampling of the material or the subsequent analyses, which could potentially explain the lack of methodological description. In addition, because of the lack of information with regards to the sampling technique it is unclear how exactly the coins were treated, whether they were halved, or completely destroyed during the analytical process or whether the author's relied on surface analyses, which in turn can influence the conclusions reached. As to the final points made by Hazzard and Brown (1984), these seem rather vague.

Following this research, a brief study of only 10 Ptolemaic silver coins was published in 1985 as part of broader discussion into the composition of Hellenistic coins (Buckley, 1985). This work comprises of 31 coins that encompass three different civilizations: the Seleucid Empire (twelve coins were analysed), the Ptolemaic Empire (ten coins analysed) and the Bactrian/Indo-Greek kingdoms of Hellenistic Afghanistan and Pakistan (nine coins). The date of the sampled material is between 4th century BCE and the end of 1st century BCE. They were produced in 12 mints, in addition most of the Seleucid and Ptolemaic coins are tetradrachms (bar two which are didrachms) while the Bactrian/Indo-Greek group is more denominationally diverse and contains drachms, obols and one hemidrachm (Buckley, 1985: 103). The author, however does not provide any provenance for these coins and is thus unclear if they came from a museum collection, a private collection, from excavations or if they were specifically purchased for this analysis and if so where from.

The technique used for the analysis of the selected coins was particle induced X-ray emission (PIXE) which was conducted in the Australian Atomic Energy Commission Research Establishment near Sydney. The selected coins were cleaned before the analysis with particular attention paid to the areas selected for irradiation (Buckley, 1985: 102). "PIXE involves a beam of protons incident on a selected object's surface; X-rays are emitted, and from the resulting spectra, concentration levels for the different elements present in the surface are derived. Because PIXE is a surface technique, the possible interfering effects of surface enrichment (the depletion, over time, of baser metals from the outermost layers of a coin) had to be considered." (Buckley, 1985: 102). The author states that, based on previous research in the field of PIXE analysis, this issue of surface enrichment can be "greatly minimised" with the preparation of the coins beforehand and them having "good to excellent condition" (Buckley, 1985: 102). However, it is not stated how this condition should be achieved, or even what exactly is meant by 'good' to 'excellent' and how that is assessed.

Buckley (1985: 102-103) does state that the biggest issue with this research was the small sample size which is clearly visible for the sampled Ptolemaic material as it covers approximately half of the rulers: Ptolemy II, VI, VIII, X and XII. Further to this the sampled coins per ruler are between one and three. The results for this analysis are presented in a table and a brief discussion for the three different civilizations is also provided (Buckley, 1985: 103-107). The results for the Ptolemaic coins will be discussed further and compared to the present results in the Chapter 5.

Building on the 1984 article discussed above, Hazzard (1990) later published a more extensive study on the composition of Ptolemaic silver, analysing 140 coins, this time using four different methods and utilising some results from previous publications, such as that of Giesecke (1930, for further details see Hazzrd, 1990: 99). The methods used were wet chemical analysis, neutron activation, deuteron activation and x-ray fluorescence spectrometry (XRF) (Hazzard, 1990). As with the 1984 article, no information concerning the sampling technique, sample preparation and in-depth description of the techniques used for analysing the samples is provided. Nevertheless, some commentary on a number of the techniques is presented. For example, with regards to the neutron activation, Hazzard does note that gold and copper were relatively easily detected, but in order to prevent the coins remaining radioactive for a number of years, a special handling was required when the analysis of silver was performed. Finally, Hazzard states that lead cannot be detected using this technique at all (Hazzard, 1990: 91).

With regards to the analyses performed with XRF, Hazzard (1990: 91) clarifies that, as only a thin layer of each coin was analysed, this "[…] method of testing was the least satisfactory of those reported in the study". However, here a question arises: Was the analysis conducted on this thin layer on the surface of the coins, or was it conducted after the coin was halved on a fresh and un-corroded section? The conclusions of this article (Hazzard, 1990: 93-98) are not focused specifically on debasement, but rather the emphasis is put on attempting to present the results and the possible indications of debasement based on the analyses in a broader context of the economy during the Ptolemaic period. But as with the previous paper, and very much because of the same reasons, once more drawing conclusions based on these tests is potentially problematic and it is equally unreliable presenting these conclusions in a broader economical context due to the many unknown factors surrounding the sampling and analysis as presented.

Finally, in 1995 Hazzard published a book aiming to assist prospective collectors in understanding Ptolemaic coinage. In this book he provides an answer to the questions arising from the XRF analysis listed above, namely that this method was, in addition to the neutron and deuteron activation analyses, non-destructive (Hazzard, 1995: 51). This suggests that XRF was not used on halved coins, but on the surface of whole examples. By contrast, the wet chemical analysis is simply mentioned, and again information is not provided for neither the analyses nor the sample preparation, thus rendering any attempt to recreate any of these methods difficult. In the publication

Hazzard elaborates on his theory of a three-stage debasement, presenting dates and percentage ranges for these. They are as follows: the first stage, dating around 149-148 BCE (from 100% silver to around 98%), the second stage occurring in 137-136 BCE (from 98% to 90%) and the third stage to 53-52 BCE (from 90% to 33%) (Hazzard, 1995: 51-53).

In 2011 a further study regarding the chemical composition of Ptolemaic silver coinage was published (Kantarelou *et al*, 2011). The focus of this work was an assemblage of 82 silver coins from the Ionnes Demetrious collection currently housed in the Numismatics Museum of Athens. The coins are dated to the first five Ptolemaic kings, and the number of coins per ruler analysed was as follows: 15 coins from the reign of Ptolemy I, 22 coins from the reign of Ptolemy II, 3 coins from the reign of Ptolemy III, 8 coins from the reign of Ptolemy IV and 12 coins from the reign of Ptolemy V (Kantarelou *et al*, 2011: 681). The Ionnes Demetrious collection comprises of 13.000 coins from both the Ptolemaic and of the Roman administration in Egypt. What should be noted here is that the authors stated that they were unaware of how the collection was brought together, whether it was excavated, purchased or donated. In addition, it is unclear how the 82 coins were selected, whether the selection was based on their date, condition or a combination of both. The analysis of the coins was conducted using a milli-probe XRF (Kantarelou *et al*, 2011: 681). As noted above, surface analysis of coins, particularly silver coins, could be less reliable (this will be discussed at the end of this chapter in more detail), so it is perhaps unsurprising that the authors of the paper admit that using XRF "may not provide reliable bulk compositional data due to the possible presence of a surface, silver enriched layer" (Kantarelou *et al*, 2011: 681). As a result of this, the study conducted three complementary analytical methodologies in order to improve and assess the results from the XRF (Kantarelou *et al*, 2011: 681).

As the analysis of these silver coins was conducted on the surface, not much in the way of sample preparation should be expected. The authors note that based on the surface treatment of the coins they were grouped into five categories: untreated (U), superficially cleaned (S), mechanically treated (M), hard mechanical treatment (HM), chemically treated (C) and mechanically treated after a chemical treatment (CM) (Kantarelou *et al*, 2011: 682). The abbreviations for the surface treatments were presented in the results table, making it easier to see how a potential compositional alteration could be explained by any of these. The areas that were chosen for analysis were those that had a "good preservation state". These were then cleaned superficially using alcohol and acetone (Kantarelou *et al*, 2011: 682). Subsequently, both sides of the coin were then analysed using XRF. Following this preparation, the authors state that "Four coins were selected and tiny areas at the coin edges were mechanically cleaned with a thin scraper pin to remove surface corrosion and prepare an area of about 1mm for the application of the micro-XRF beam" (Kantarelou *et al*, 2011: 682).

It is not specified why this procedure was conducted on only four of the coins (rather than half of the analysed material), or how those four coins in particular were chosen. The scientific reasoning behind conducting the separate analysis of these four coins however, was to distinguish semi-quantative differences in the chemical composition by using micro-XRF on untreated sub-areas. A comparison between these results and the results from the milli-probe and scanning micro-XRF of the flat surfaces was then made (Kantarelou *et al*, 2011: 684). The results from both the flat surface and the cleaned coin edges were used to roughly estimate the minor elements (iron, copper, gold and lead), as well as indicators of the surface contamination and corrosion, and any possible association of those to composition of minor elements. It must be noted that a potential problem with this sort of calculations is, of course, that the coins would have had different corrosion levels, and surface contamination (further complicated by the different treatments they received after discovery), all of which would make a comparison of such sort difficult to say the least.

The analysis focused on eight elements in total: silver, copper, gold, lead, bismuth, iron, zinc and mercury. Most of the scholarly literature on the chemical composition of both silver and bronze Ptolemaic coins does focus on all of these chemical elements (see sections above as well as sections below) however, mercury is not usually present in the compositional analysis of Ptolemaic coins. That is usually the case, as the authors of this present paper point out, due to the fact that this element is usually associated with surface contamination (Kantarelou *et al*, 2011: 685). It would appear that this is also the case for the three coins in which this element was detected (Kantarelou *et al*, 2011: 685). Gold was detected in all analysed coins with a main concentration of around 0.7% (Kantarelou *et al*, 2011: 689). Gold in such low qualities is usually associated with the ore from which the silver comes, thus the authors of the paper presented a plot of the gold and lead results and argued that these could be indicative of a "small scale compositional differences between alloys of different time periods" (Kantarelou *et al*, 2011: 689).

In order for the information to be plotted, the analysed coins were divided into four chronological groups: Ptolemy I's coins comprise Group 1, those of Ptolemy II are part of Group 2, Group 3 includes the coins of Ptolemy III and the final fourth group contains the coins from the reigns of Ptolemy IV and V (Kantarelou *et al*, 2011: 689). The authors then propose that gold composition could be indicative of the silver source exploited, and lead composition could be an indicator for technical changes in the production process. Based on the results for gold, the authors suggest a change of silver ore during the reign of Ptolemy IV as the gold value increased during this time period (Kantarelou *et al*, 2011: 689). With regards to the lead results, based on the low level of this element in the composition of the coins from the reigns of Ptolemy I and Ptolemy II, the authors conclude that there was most likely a good refining process for this time period, which was then stopped during the reign of Ptolemy III, as the lead content increases from this period onward (Kantarelou *et al*, 2011: 689). As to the change of ore hypotheses based on the gold content, the authors themselves admit that further historical and analytical evidence are needed in order for this to be confirmed. As the present research is looking for both gold and lead, and the coins sampled and analysed cover the whole of the Ptolemaic period, both the gold and lead hypothesis will be discussed further in light of the results of the present work in Chapter 5.

Based on copper results, which were then plotted against the date of issue of the coins, the authors suggest that "A slight debasement trend is obvious, even in this Period of Ptolemaic peak power" (Kantarelou *et al*, 2011: 689). However, looking at the results, this statement seems rather optimistic, as none of the analysed coins contained more than 2% copper, and such small amounts could also be explained by an instrumental error or a minting error. With regards to the silver composition, the results indicate that it remained relatively high (most of the coins contain silver in the high 90s % and there is only one coin that contain 87% silver), thus the authors decided to examine the issue of surface enrichment in the case of a high silver content (Kantarelou *et al*, 2011: 685). Here of course the issue of chemical surface cleaning of these coins should again be taken under consideration when discussing a possible detection of a surface enrichment and the authors do admit that 75% of the analysed material was indeed chemically treated, but as no difference was observed in the silver concentration between the treated and untreated coins this was taken as a "strong indication against the presence of an Ag-enriched layer" (Kantarelou *et al*, 2011: 685).

Overall, this research contains a number of issues with regards to the reliability of the produced data, as it is based around a surface analysis (although the authors have attempted to mitigate some of these with further methodological approaches). Some of the hypotheses presented are interesting (e.g., the gold and lead correlation), but are ultimately difficult to prove as the analysed material covers only part of the Ptolemaic period. This issue of discussing only part of the dynasty is perhaps the most pressing one, as because of this approach, no real conclusion can be reached.

A more recent examination of the composition of Ptolemaic silver coins has been conducted by Julien Olivier from the Biblioteque Nationale de France. Unfortunately, a complete overview of this research is, at present, yet to be published. A brief methodological overview and partial results have been published in a recent volume on the topic of debasement (Faucher and Olivier, 2020: 97-109). Moreover, following a private correspondence with Olivier, he provided the exact number of silver coins sampled and analysed (150 in total), as well as confirming that most of the coins were dated using the Svoronos system. These 150 coins were analysed as part of Olivier's PhD thesis using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). The sample preparation is unclear, and as for the sampling technique, one must assume that none was necessary as LA-ICP-MS analyses the surface of the coin. The way this technique operates, is by penetrating the surface of the coin to a depth of 200 to 300 microns using the micro-ablation, which is invisible to the naked eye, and was chosen for this research as it was advantageous for use on material from museum collections (Faucher and Olivier, 2020: 97).

In addition, the heavily debased silver coins were also analysed using fast neutron activation analysis (FNAA) (for details see section **3.5.**), which was conducted when the limits of the LA-ICP-MS method were reached due to "the content of the alloy [not being] homogenous enough for a small sample to be representative of the whole coin"

(Faucher and Olivier, 2020: 98). A further reason for using FNAA on this type of coinage, according to Faucher and Olivier (2020: 98), was the potential indication, or a suspicion, that the first few microns under the surface of the coin would be significantly different from the original coin's content. However, the authors do not indicate what this indication entailed.

It must be assumed that most (if not all analysed coins) were from museum collections, although that is not directly specified. Here it must be noted, that there are potential issues which arise when results are taken from the surface of the coin as mentioned above. These issues will be presented and discussed at the end of the previous research sections of this chapter.

Following his analysis, Olivier concluded that there were three phases of debasement (similar to Hazzard's theory from 1995) into which the silver coinage should be arranged (Faucher and Olivier, 2020: 101). The first of these can be dated from the start of the Ptolemaic period until 155-154 BCE, at which point there is slight debasement which the author links with metrological changes (diameter reduction, weight specifications and addition of a date on the reverse of the coin). Here the author argues that the addition of 1 to 2% copper was not debasement as such and was not done so that the state could save silver and make a profit, "[…] but rather to balance the weight loss of the worn recalled tetradrachms" (Faucher and Olivier, 2020: 101). The second phase according to Olivier ran from around 140 BCE to 60 BCE where the composition of the coins was changed significantly by an increase of the copper and lead content, with a culmination of silver content registering between 77-87% dated to 107/6-105/4 BCE (Faucher and Olivier, 2020: 101).

The last phase began around 59-58 BCE, and, although an intensification of the compositional change can be observed at this time, there is a rather significant deviation within the results mainly concerning the coins from the reign of Cleopatra VII. This deviation is due to the varied and rather inconsistent results that were achieved: five coins were tested, two drachms and three tetradrachms. The two drachms contain 77% and 53% silver respectively, while the tetradrachms contain 39%,78.2% and 65.8% silver (Faucher and Olivier, 2020: 102). Furthermore, the author states that the second analysed tetradrachm was "originally composed of c.30-

40% silver", the explanation for this is that copper and lead amounts were leached out of the coin and that the original weight would thus have been 14.30g (rather than the measured 11.8g) and the silver content would then be around 64-65% (rather than the initial 78.2%) (Faucher and Olivier, 2020: 102). Here an issue that arises is about the copper and lead composition, and what percentage of these was seen in the initial analysis of this coin. Furthermore, if there were very small amounts of those chemical elements, the first considerations should have been given to the accuracy of the analytical method used, rather than an assumption of weight change and leaching out elements. Neither of these actions is given a reason, nor is it explained on what basis and how the recalculated weight and silver content was reached. As a whole this analysis clearly presents some potential issues, mainly to do with accuracy of the technique, and perhaps also with regards to some of the conclusions reached.

In addition to the above-discussed publications, a further series of analysis were conducted which focus predominately on Cleopatra VII silver tetradrachms and are usually presented in the context of the Roman silver coinage. The first of these is the analysis of 58 silver coins belonging to Ptolemy XIII (28) and Cleopatra VII (30), conducted by Walker and King in 1976. It must, however, be stated that although, throughout their publication, they refer to coins of Ptolemy XIII, these – based on the name epithet provided by the authors, Neos Dionysos (Auletes) – in reality belong to the reign of Ptolemy XII (Hölbl, 2001: 223). The technique used to test these coins was XRF. Walker (1976: 1) addresses the issue of surface enrichment and the potential misreadings this might cause when analysing material using this technique. To counteract this, the samples were repeatedly cleaned, but no detail is provided as to how this cleaning was conducted.

Based on the result tables presented (Walker and King, 1976: 141-142), it appears that the only elements detected were silver and lead. For the coins of Ptolemy XII, the silver percentages are between 80% to 97% with two coins containing 76% and 77% silver respectively and one coin containing 64% (Walker and King, 1976: 141). The lead percentages for this ruler are between 0.5% and 2.75%, with two coins containing more than 3% and one coin containing 0.25% (Walker and King, 1976: 141). The silver results for the coins of Cleopatra VII are mainly in the vicinity of 40%, with four coins containing over 50%, one coin containing 64% and one coin containing 36%

(Walker and King, 1976: 142). The lead amounts in this coinage are between 1% to 3%, with three coins containing more than 4% lead and one coin 5% (Walker and King, 1976: 142). The choice to focus the analysis solely on coins belonging to the last two Ptolemaic rulers is perhaps not surprising, as the aim of this work was to trace the decline of the fineness of Ptolemaic silver coinage, and the subsequent re-establishment of the fineness of the silver coinage used in Egypt during the Roman Period (Walker and King, 1976: 139-140).

In 2004 Gölitzer, once more using XRF, analysed one coin belonging to Ptolemy XII and three coins belonging to the reign of Cleopatra VII. In order to avoid the issue of surface enrichment, the x-ray fluorescence was conducted on the shaved edges of the coins, and the calibration was performed by using modern coins of known fineness. According to Gölitzer (2004: 32), the coin belonging to the reign of Ptolemy XII contained 46.31% silver and 2.34% lead. For one of Cleopatra VII coins analysis was performed on both sides (Zones 1 and 2), and thus for this coin there are two silver (61.22% and 33.78%), and lead readings (3.67% and 2.14%). The other two coins dating to the reign of Cleopatra VII have very different results, with one containing 36.50% silver and 2.26% lead and the other containing 93.65% silver and more than 5.09% of lead (Gölitzer, 2004: 32).

Most recently, in 2014, Butcher and Ponting published their work on the metallurgy of Roman silver coinage, and dedicated a section to the silver tetradrachms of Cleopatra VII. Two silver coins belonging to Cleopatra VII were analysed. All the coins presented in the work were analysed by inductive coupled plasma atomic emission spectrometry (ICP-AES) or atomic absorption spectrometry (AAS), the latter being used to determine only the silver and copper content (Butcher and Ponting, 2014: 112). However, the sampling method (drilling into the cylindrical edge of the coin) and the sample preparation (using two solutions) is well illustrated and does allow recreation of the analysis (Butcher and Ponting, 2014: 110-112). The conclusion of the analysis of the two silver tetradrachms belonging to Cleopatra VII was that they had similar fineness to one another with silver bullion (for details on this see Chapter 5) content of respectively 31% and 32.1% (Butcher and Ponting, 2014: 614).

3.5. Previous Research into the Composition of Ptolemaic Bronze Coinage

This section will examine the previous research into the composition of bronze Ptolemaic coins, the methodologies used, and the issues that arise when considering some of the achieved results. As a final point, a brief overview of issues concerning invasive, minimally invasive and non-invasive analytical techniques will be presented. For a chronological overview of the analytical methods employed in the analysis of Ptolemaic bronze coinage please consult the table below (Table 3.2).

The earliest analysis aiming to establish the composition of Ptolemaic bronzes dates to 1869. As far as it can be determined, only two (possibly three) Ptolemaic bronze coins were analysed. The method utilized was most certainly chemical, and involved dissolving the coins in strong acid (Bibra, 1869: 1-7). Only one of the coins analysed is ascribed to a specific ruler – Ptolemy IX. The other one (or two) are not (Bibra, 1869: 94-96). This is perhaps not surprising, as the first catalogue of Ptolemaic coinage was not published until 1882 (Poole, 1882). The conclusion reached by Bibra, following his analysis of the coins, was that the "[…] copper alloys of the Egyptians are a leaded bronze" (Bibra, 1869: 96).

The next analysis conducted on bronze coins from the Ptolemaic Period was that done on two coins discovered at the site of Bucheum on the west bank of the river Nile. The coins were published in a 1934 report, which encompassed two seasons of work conducted at the site by Robert Mond (1867-1938) in 1928-1929 and 1931-1932 (Mond, 1934).

Most of the coins from this site were Roman, two Ptolemaic coins were also found, although detail about their date is not provided. Rather, what is noted in two of the tables is simply "Ptolemaic… 200-100 BC" (Brazener, 1934: 115, 119). By consulting one of the tables provided in the publication, it would appear that only one of the two coins was analysed, and a potential reason for the lack of any date provided for these coins, could be that in the field titled "Micro-Examinations", it is noted that due to a large quantity of lead, the structure of the coin was obliterated (Brazener, 1934: 119).

Author	Year of Publication	Analytical Method
Bibra	1869	Wet Chemical Analysis
Brazener	1934	Unspecified
Caley	1939	Wet Chemical Analysis
Faucher	2010	FNAA
Faucher	2013	FNAA

Table 3.2: Chronological overview of the previous analytical methods employed in the analysis of Ptolemaic bronze coinage.

It is not clear what method was employed in the analysis of, not only this Ptolemaic coin, but also the rest of the coins discovered during the excavations. The section on the analysis, written by Brazener (1934: 119-120), mentions acid cleaning due to corrosion, microscopic examination, and provides a table containing seven chemical elements (copper, tin, lead, iron, nickel, zinc, silver and antimony) for which 17 of the coins were tested (including one of the Ptolemaic coins), but contains no indication as to how this was achieved.

The next publication concerning the composition of Ptolemaic bronzes dates to 1939 (Caley, 1939) and, compared to the previous two works, does provide an actual study of the material. Caley's (1939) work on the Ptolemaic bronzes aimed to put these in the context of ancient Greek bronze coins. Eight Ptolemaic bronze coins were analysed in total with Caley (1939: 96) stating that these represented "[…] nearly all parts of the long period of issue". This however, is incorrect as the coins tested can be assigned only to the reigns of Ptolemy I, Ptolemy II, Ptolemy IV, Ptolemy VI, Ptolemy VIII and Ptolemy X, omitting Ptolemy III, Ptolemy V, Ptolemy IX, Ptolemy XII and Cleopatra VII (Caley: 1939: 97). Two of the sampled coins date to the reign of Ptolemy IV and two others to the reign of Ptolemy VIII. Of course, as the author's aim was not a comprehensive study of the Ptolemaic bronzes, the gap in the record could be overlooked. The coins come from a variety of sources, that Caley claim to be genuine. The sources provided are Princeton University College, excavations (no details as to where these were conducted or when are listed), and some of the coins were also purchased from dealers both in the United States and elsewhere (Caley: 1939:5). The provenance of the coins coming from these dealers are of course potentially questionable, and so too are the results of their analysis. Unfortunately, as the author does not indicate the specific provenance of each coin, it is not clear which coins were purchased, and which were taken from excavated contexts.

However, Caley (1939: 6) does provide information with regards to his sample preparation methods. Firstly, a visual examination of the coins was performed, following which any points that had special interests (such as colour, patina, depth of corrosion) were recorded. The coins were then weighed. The next step was to remove any corrosion, as well as the outside metallic layer in order to obtain a clean sample not influenced by any presence of corrosion or electrolytic cleaning. This removal was done with a clean file (Caley, 1939: 6). A thin hacksaw was utilized for the removal of oxidised metal from the cracks and crevices of the coins. In order to obtain the required samples, the now clean blanks were split using a cold chisel (Caley, 1939: 6). A detailed description of the wet chemical analysis used is also provided by the author: "The main sample was dissolved in nitric acid and after evaporation of the solution to small volume, followed by a dilution and digestion, the hydrated tin oxide was filtered off on quantitative paper, washed well with hot diluted nitric acid, and ignited to constant weight over a Meker burner" (Caley, 1939: 6). The author then proceeds to explain that in the majority of the cases, the weight of the stannic oxide was used to calculate the tin content, following which he provides details of the analysis, and how the other chemical elements such as tin, copper, gold etc. were calculated (Caley, 1939: 7-11).

Caley (1939) then presents the results achieved by location: Macedon, Athens, Dependencies of Athens, Sicyon, Corinth, Various Localities in Greece Proper, Sicily, Olbia, Asia Minor, Syria and finally Egypt. For each of these he discusses the different chemical elements which are present in the sampled material. For the Ptolemaic coins that were tested Caley (1939: 99) notes that the earliest coin (belonging to the reign of Ptolemy I) contained an unusually low percentage of tin, which doubles in the second analysed coin (belonging to the reign of Ptolemy II). His explanation for this discrepancy, is that as there were two different methods of production for the coins – cast and struck – they would have also required different types of alloy. He further adds that this was likely the case for contemporary struck and cast coins from other cultures. Based on his analysis, Caley (1939: 99) states that "the early cast coins have a much lower tin content than the early struck coins". Another explanation for the reduction of the tin was a potential cost increase of this material, which was due to the production of the large cast bronzes (Caley, 1939: 140). However, by looking at Table XX (Caley, 1939: 97) this issue appears more complicated as, from all analysed coins, only two (Numbers 2 and 4) contain more than 10% tin (12.37% and 10.30%), while the rest of the coins have a tin content of between 4%-7%. The last two coins belonging to the reigns of Ptolemy VIII and Ptolemy X contain the lowest amounts of tin (4.17% and 4.49%), and when compared to the coin tested from the reign of Ptolemy I (5.41%), there is around 1% difference which could be due to a variety of reasons from an analytical error, to a simple mistake during production. Caley (1939: 99) does note that there is an insufficient number of examples on which to base any hard conclusions, especially with regards to coins 2 and 4.

As to the lead content in the analysed Ptolemaic coins, Caley (1939: 99) concluded that it varied similarly to the lead content in the coins of the other Hellenistic regions; being low in the early coins, and then increasing with time. The issue with this hypothesis is that, by considering the results presented in Table XX, this increase over time could be questioned. Firstly, by Coins 3 and 4 which have vastly different lead contents (0.68% and 10.36%) yet they belong to the same ruler (Ptolemy IV). Secondly, Coins 1, 2 and 3 contain different amounts of lead which does not increase with time – Coin 1 contains 2.21% lead (dated to Ptolemy I), Coin 2 contains 0.53% (dated to Ptolemy II) and then Coin 3 has a lead content of 0.68% (dated to Ptolemy IV). Finally, the coin with the highest lead content in the analysed Ptolemaic coinage is Coin 7 (36.76%), and according to the author this high lead percentage is the "highest ever found in a Greek bronze coin" (Caley, 1939: 99). The lower percentage of lead in Coin 6 (23.97%) is taken by the author as evidence that the lead percentage in Coin 7 was accidental, as they both belonged to the reign of Ptolemy VIII. Here again the problem of analysing only one coin per ruler (with the exception of Ptolemy IV and Ptolemy VIII) is very evident. Caley's hypothesis of a simple accident or mistake accounting for the high lead content (in this case of coin number seven) could be accurate, but it could also be due to analytical error, coin production or mint location.

The next element discussed by Caley (1939: 100) is cobalt. This is interesting as the results in Table XX indicate that only three of the eight tested coins contain any amount of cobalt at all, and in all cases less than 1%. Caley uses these traces of cobalt to discuss the possibility that some of the copper that was used in these coins came from local Egyptian sources. Based on slag heaps, broken crucibles and moulds, two Egyptian districts are indeed often associated with the mining of copper – the eastern dessert and the Sinai Peninsula. However, Caley (1939: 100) also simultaneously argues that it is unlikely that these were made using local ores, as these sources of copper were most likely worked out before the Ptolemaic dynasty; he suggests that the mines could perhaps have been reopened, or that new deposits were discovered and worked. Another possibility is that the copper source came from a mining district outside Egypt, such as Cyprus, under Ptolemaic control for most of the Hellenistic period. Finally, the author states that whatever the reason "the noticeable amounts of cobalt seem to be a characteristic of the Ptolemaic coinage bronze as distinguished from the Greek coinage bronze elsewhere" (Caley, 1939: 100). As noted above the very low quantity of cobalt, as well as its presence only in three of the sampled coins makes Caley's hypothesis somewhat uncertain.

The only discussion with regards to the copper content in the analysed Ptolemaic bronzes in Caley's publication is that Coin 7, which contained the lowest amount of copper (56.99%) ever found in Greek bronze coinage (Caley, 1939: 116). For the iron content, a similar observation is made, presenting Coin 7 as the one containing the highest iron percentage, not only among the Ptolemaic samples, but also the rest of the Greek coins analysed (Caley, 1939: 100). It should be noted that Coin 7 dating to the reign of Ptolemy VIII contains both the greatest amount of lead and iron, and also simultaneously the lowest level of copper. As this result is not mirrored in Coin 6, which is from the same time period, Caley could potentially be right in his assumption that this was the result of an accident or mistake during the manufacture of the coin, although it could be due to the reasons listed above (e.g. analytical error). The rest of the chemical elements present in Table XX (nickel, zinc, arsenic and sulphur) are not discussed. According to the author the reason for this was that the results for these elements were similar to results obtained from the analysis of coins from the other regions, and should therefore be considered unremarkable (Caley, 1939: 100). As a whole, Caley's publication – while being the first substantial study of Hellenistic bronze coins and their composition - is hampered by the small sample of Ptolemaic coins under analysis.

The next scholar who engaged with the composition of bronze Ptolemaic coins is Faucher. The first publication in which some of his results were provided is the 2010 article which he co-authored with Lorber, and which was discussed above with regards to using hoards as dating evidence. The primary purpose of the article was to present the developing series system, rather than the composition of bronze coins, and as such this topic is only briefly discussed in Appendix 3 (Faucher and Lorber, 2010: 69-72) where the results of the later series (6a to 7c or roughly from Ptolemy IV to about Ptolemy VIII) is presented. The appendix is co-authored by Blet-Lemarquand from IRAMAT where the research was conducted. The method used was fast neutron activation analysis using a cyclotron (FNAA), which was chosen for its non-destructive application and for its supposed ability to "[…] get beyond the corrosion layer of the copper alloy" (Faucher and Lorber, 2010: 69). This technique identifies ten elements in copper- and silver-based coins with "detection limits as a fraction of a part per million" (Faucher and Lorber, 2010: 69).

No sampling method or sample preparation is discussed by the authors; this could potentially be due to the fact that the technique did not require any, or that the authors chose to omit this from the publication as the compositional analysis was not its main aim. Furthermore, the publication lists only the major elements (copper, tin and lead), but omits the trace elements as they did not yield conclusive results. This is rather strange, as three years later Faucher (2013: 28) published a monograph based on his PhD research (discussed below), in which he used the same technique (FNAA). In this publication he does however include these same trace elements (antimony, gold, silver, arsenic iron, cobalt, nickel and zinc) which were absent from his 2010 article. Overall, the compositional analysis in the 2010 publication is primarily used to give credence to the new series system of dating.

As mentioned above, in 2013 Faucher published his PhD research in the *Etudes Alexandrines* series. The main aims of this research were to determine the constitution of the alloy used in the Ptolemaic bronze coins, and also to ascertain, if possible, the metal supply for the coinage. The latter aim was to be achieved by studying the trace elements present. In addition, the research aimed to contribute to the overall understanding of the system of coin production in Ptolemaic Egypt (Faucher, 2013: 31). The analysed coins come primarily from the Department of Coins and Medals at the Biblioteque Nationale de France. A number of coins were also purchased commercially (these were cut in order to examine their microstructure), and three coins from the Alexandrian series of Augustus were analysed for comparison, although their provenance is not specified (Faucher, 2013: 29). Most of the analysed Ptolemaic bronzes came from the mint at Alexandria, however around forty were from the Ptolemaic possessions outside Egypt, such as Cyprus, Phoenician Syria and Cyrenaica. Faucher (2013: 30) does point out that even though the Biblioteque Nationale de France has one of the most important collections of Ptolemaic coins in the world, it does have gaps in its records, for example the large Ptolemaic bronzes are more prevalent than the smaller ones, and there is only one coin of the first series of Ptolemy I (roughly at the start of Ptolemy's reign). Furthermore, the author also states that coins from the excavation at Alexandria that began in 1990s (see section on dating above for more detail) could not be analysed, as it was not possible to remove the coins (or any other finds for that matter) from Egyptian territory, and the means available to sample the coins on site (such as XRF) were not reliable (Faucher, 2013: 30).

The method used in the analysis of these coins was the above-mentioned FNAA. Faucher presents a description of the workings of the technology, e.g., that the coins were irradiated for a predetermined duration of time, which was dependent on their weight (Faucher, 2013: 28) following which the technique allowed for the detection of eleven elements: copper, tin, lead, iron, zinc, nickel, antimony, arsenic, silver, gold and cobalt. Additionally, according to Faucher (2013: 29), this method of analysis was remarkably precise, with very low detection limits. The author also provides two additional advantages to this method, the first one being that, as the technique is non-invasive, it allows for easier borrowing of materials from both private and public collections. The second advantage presented is that the whole of the coin is analysed, rather than only a small area (Faucher, 2013: 28). Faucher is certainly correct that wholly non-invasive analytical methodologies are advantageous when borrowing museum artefacts. However, the analysis of the whole coin does present a number of potential issues, similar to the analysis conducted by Olivier on silver coinage, which will be discussed below during the examination of the benefits and drawbacks of invasive versus non-invasive techniques. Faucher does not present any sample preparation methodology, possibly due to the fact that, as the whole of the coin was analysed, no preparation was needed, but even so, a commentary on this should have been provided, mainly to facilitate the replication of the method by other scholars.

The results of the analysis are presented by series, from one to ten with commentary on the different aspects, also denominations for the bronze coins are presented (see discussion on the subject in the relevant section above), and changes to the composition of these in the different series is on occasion discussed. Finally, the results of the coins from the provincial mints are presented. Here, like the results presented in the 2010 article by Faucher and Lorber, it would appear the composition of the bronzes was used to validate specific choices in the split of series and subseries of certain coins (Faucher, 2013). The results from Faucher's work will be discussed here as they are presented in the publication – namely following the series system, even if the current research does not utilise that particularly system.

Series 01, corresponding to the early Ptolemaic Period, is comprised of coins with an average 14.2% tin and 0.03% lead, with the remainder being copper. Faucher is of the opinion that the minute lead traces are due to the quality of the reduction, while the tin quantity is in the upper limit of alloys known as "low tin bronzes" (Faucher, 2013: 39). For the coins of Series 01 he states that "While the use of recovery material cannot be ruled out it is likely that the Ptolemaic authorities have used new metal stocks to strike this first bronze coinage" (Faucher, 2013: 39). Information with regards to the composition of the different denominations in Series 02 is presented, but it appears that the characteristics of this series is largely the same as those of Series 01: A relatively low amount of lead present in the samples, along with some limited presence of tin, with copper being the dominant element. Series 03 is connected with the monetary reform undertaken by Ptolemy II in 261-262 BCE, the main aim of which was most likely the introduction of bronze coinage as the primary exchange tool at the local level, a fact which could potentially explain the large size of the new bronze coins (Faucher, 2013: 44). A central cavity in the coins of this period, observable on both the obverse and reverse, also appears following this reform. Series 04 appears with Series 03 in a number of the hoards from the third century BCE, the only difference, according to Faucher (2013: 44), being the appearance of a cornucopia on new coin issues of the third century clearly indicating a change of series. Both Series 03 and 04 have largely similar metallic composition a high homogeneity of tin and low lead (not exceeding 4%) content (Faucher, 2013: 45).

Series 05 is presented by illustrating the different types of coins that represent it, and providing some general remarks (from their appearance to their composition) and concluding that this series was produced during a period of time when procuring metal was not an issue, and when striking coins was most likely a regular occurrence (Faucher, 2013: 48-50). At the beginning of the second century after a period of demonetization and countermarking (no detailed evidence to support this are presented) Series 06 was introduced. One of the main features of this series was the introduction of new types of obverse, and the other is the “mass arrival of lead” in the coins (Faucher, 2013: 51). The author tested 39 coins from Series 06, and determined that some of the coins were composed of an alloy that contained nearly 35% lead. However, Series 06 is subdivided into five subseries 06a-06e, the first few (6a to 6d) are characterised by a generally homogenous composition, with less than 5% lead. Serious heterogeneity can be observed in subseries 06e (Faucher, 2013: 52). Series 07 is seen by the author as encompassing a period of stabilisation following the changes in the 06 series. Series 07 has a high lead content, while the average tin content declines to less than 4% for some of the coins (Faucher, 2013: 54).

Some of the analysed coins from Series 08 have a tin content of less than 7% and lead content of 7.5%. Faucher (2013: 57) ascribes these tin values on a possible reform that recalled the previous coinage, melted it and used it as supply for the workshops. Here an issue arises as to the organisation of the Egyptian state and its ability and/or need to recall coinage. The reuse of resources is very likely, but this could have been accomplished following tax collection (which, as noted above, after the reform of Ptolemy II was paid using bronze coins) and the subsequent recycling of the coins after they were collected, negating the need for a deliberate governmental recall of specific coin issues, an idea central to Faucher’s publication, and one which is often used to justify a questionable change in between series. Yet, he does note that the exact transition between Series 07, 08 and 09 is still unknown. Based on the excavations conducted in Alexandria, Faucher states that the issues grouped under Series 09 were most likely produced on a large scale, as 306 of the 1159 excavated coins from Alexandria belonged to this series. Similarly, to Series 07, the composition of the coins in Series 09 is characterised by a high percentage of lead, as well as a decrease in the tin content (Faucher, 2013: 58). It would, however, appear that the coins from the excavations in Alexandria were tested with x-ray fluorescence, and even after surface cleaning, the achieved results were not reliable. Series 10 is linked to Cleopatra VII and the reform that took place during her reign in which, according to Faucher (2013: 60), the monetary system of the Ptolemaic Dynasty was completely changed.

As noted above, in addition to the coins minted in Alexandria, Faucher tested some coins from Ptolemaic possessions outside Egypt, however he clearly states that the focus of his work was the coinage from Alexandria, and that the analyses of the provincial coins was mainly for comparison (Faucher, 2013: 65). As mentioned in the section regarding Ptolemaic mints, while Faucher switches from the series system to the Svoronos system for dating these provincial issues, he nevertheless attempts to divide and often to ascribe some of them to the series systems (Faucher, 2013: 65). The coins from Phoenician Syria for example were divided into two groups: those marked with a central cavity and those without, or in other words: coins produced prior to Ptolemy II's reform and coins minted after (Faucher, 2013: 65-66). According to the analysis, no lead was added to these coins until the end of the third century BCE (Faucher, 2013: 68). Similarly, to the coins from Phoenician Syria, Faucher (2013: 70) also groups the analysed coins from Cyprus into ones containing a cavity and ones without. The Cypriot coins struck before c.261 BCE have high tin contents (average 9%), and traces of lead (average 0.11%), the coins struck after 261 BCE have a fairly high tin content (average 8.1%) and contain smaller amounts of lead (average 3.7%). (Faucher, 2013: 72-75). According to the results achieved by the author, the composition of the provincial coinage is quite similar to that of the coinage minted in Alexandria, which can be taken as an indicator of the homogeneity of the Ptolemaic economic policy (Faucher, 2013: 85).

In his conclusion Faucher (2013: 223) states that the reform that occurred during the reign of Ptolemy II (261 BCE), and based on the different hoards from the third century BCE, resulted in a surge of monetarisation of the Egyptian economy. He further states that the introduction of the octobol, the drachma and the other major denominations were a strong signal to the population (Faucher, 2013: 223) although precisely what it communicated is not discussed. Furthermore, the author is of the opinion that money in Ptolemaic Egypt was accepted for its face value, rather than its intrinsic value. This publication is undoubtedly the most current and relevant analysis of Ptolemaic bronze coins up to date. Nevertheless, it raises a number of issues, from dating the coins by Series, and more specifically the way the division is determined, to the (somewhat arbitrary) division of the regional coinage, to the technique used for the analysis itself. Comparison between the results achieved by the current research and those of Faucher, will however provide a good basis for a broader discussion into both the composition of Ptolemaic bronzes, but also of the Ptolemaic economy in general.

3.6. Discussion of Analytical Techniques

When any scientific analysis on ancient artefacts is performed, a number of decisions have to be taken. Chief of which is the selection of analytical techniques to be used. As presented above, both silver and bronze Ptolemaic coins have been analysed using a number of different techniques, but all of these, including the technique of the current research presented in the next chapter have a number of issues that are associated with them. Ponting, when discussing silver Roman coins, states that the most reliable way of determining the composition of the alloy used is to “cut a section from the coin and remove both surfaces of the metal slice, leaving a piece of core alloy” (Butcher and Ponting, 2014: 110). However, if research is reliant on museum collections as a source for the coins to be sampled (as is the case with the current work, and with the majority of the previous research), this method is largely out of the question. Instead, most recently, non-invasive analytical techniques have been used. Such analysis may be appropriate for some artefacts (like ceramic or faience), but it is potentially problematic for the purposes of determining the composition of metals and coins in particular. There are several reasons for this: First and foremost, because the surface of the coin (regardless of metal type; gold, silver or bronze) could have received specific surface treatment to change its physical appearance. Secondly, the process of corrosion also presents problems when using a non-destructive technique and so has the potential to create flawed results (Butcher and Ponting, 2014: 107). In addition, if the bulk of the sampled material comes from museum collections, it is not unlikely that at least some of the coins could have been chemically stripped or heavily cleaned at some point by museum staff, which in turn would also have a serious effect on any analysis conducted solely on the surface of the artefact.

If Faucher's (2013) technique is taken as an example, he states that the analysis is non-invasive and that the whole of the coin was tested. However, he does not address any of the points mentioned above, nor does he describe any counter-measures taken during sample preparation to address these, and prevent them from influencing the final results. Thus, some of the material sampled by Faucher could have been corroded, or chemically cleaned, or even surface-treated in antiquity or by museum staff, rendering the results of the analysis potentially compromised. The current research utilises a minimally invasive method (described in detail in Chapter 4) that samples the core of the coin, negating the potential contamination of the surface layer. However, even this minimally invasive technique, does present some potential problems and pitfalls. Chief among which is that, following sampling, a small hole is left on the cylindrical edge of the coin.

While this is a very minor blemish on the artefact, some museums may feel that even this limited damage to the artefact is unacceptable, and therefore disallow the sampling. Another potential issue is that the drill can easily slip and penetrate the surface of the coin, leaving a mark on its obverse or reverse, and in the worst case the drill tip can snap and remain lodged within the hole. However, all these issues can be resolved with the help of a conservator, and the hole on the edge can be easily disguised, although Ponting, who has been using this method for analysis on Roman coinage, does state that in his experience most institutions that provide access to their material for this type of sampling prefer the holes to remain open (Ponting, 2012: 21). To sum up, different methods and techniques naturally present different benefits and drawbacks, and often when relying on museum collections it can be difficult to obtain permissions for minimally invasive tests. However, in the case of the Ptolemaic silver and bronze coinage, a minimally invasive, thorough and detailed analysis, like the one conducted by the current project, can not only add to the bank of knowledge regarding the composition of these coins, but also serve as a control on the reliability of non-invasive analysis, such as those conducted in particular by Hazzard, Faucher and Olivier.

Chapter 4: Methodology of the Current Research

This chapter will present the provenance of the sampled silver and copper coins, the sampling technique, the chemical elements selected for sampling and the reason behind selecting those specific elements. Finally, it will present the instruments used to analyse the samples – microwave plasma atomic emission spectrometer (MP-AES) and scanning electron microscope with energy dispersive spectrometry (SEM-EDS).

4.1. Provenance of Sampled Silver and Bronze Coins

The majority of the coins analysed (both silver and copper) come from museum collections. These are the Garstang Museum of Archaeology, University of Liverpool (14 in total; 13 bronze and one silver), National Museums Liverpool (61 in total; 41 bronze and 20 silver), Manchester Museum (14 in total; 1 bronze and 13 silver) and the British Museum (47 in total; 16 bronze and 31 silver). Five silver coins were sampled by Matthew Ponting in Israel, where they were part of the finds discovered at the site of Mazor in the excavations recently conducted there. These coins are Cat. Numbers **1** to **5** in Appendix 1. This site of Mazor is situated in the central part of Southern Levant with its earliest occupation dating to the Hellenistic Period. The site was initially part of the Ptolemaic and then of the Seleucid empires. During recent excavations five silver Ptolemaic tetradrachms were discovered (see a recent publication of Hellenistic and Byzantine coins from Mazor by Ariel 2019 for further information concerning the site and excavations).

The coins sampled from UK museum collections were chosen by the current researcher and the museum curators responsible for the collection. The coins were chosen based on ruler and metal type. The first coins sampled were those from the Garstang Museum of Archaeology, and due to the small size of the Ptolemaic coin collection in this particular museum, and with the agreement of the curator in charge, all of the available coins from this time period in the collection were sampled. These coins are Cat. Numbers **6** to **9** and **11** to **20** in Appendix 1. Of these coins only three are associated with any information regarding their provenance, these being Cat. Numbers **9**, **16** and **19**. For Cat. Number **9**, this information is only a name recorded in the acquisition field, that of a Professor Gordon. The identity of this individual and their link to the Garstang Museum and the University of Liverpool is unclear, as is the potential provenance of the coin. For Cat. Numbers **16** and **19** the only acquisition information available is a line simply stating ‘Royal Institute’, although it is unclear whether these coins were donated, loaned or purchased from the institute, and also when they were added to the museum’s collection.

National Museums Liverpool also provided coins to be sampled from their collections, although unfortunately most of this collection (primarily with regards to the bronze issues) contains coins up to Ptolemy VIII and no later (with one exception, Cat. Number 44, belonging to the reign of Cleopatra VII). However, some later silver coins were available and testing on those was allowed. Cat. Numbers **21** to **81** in Appendix 1 represent the coins sampled from this collection. Only three of these coins have information with regards to their acquisition (Cat. Numbers **21**, **45** and **46**). Cat. Number **21** was gifted to the museum by P. D. Cursi, for whom no additional information with regards to occupation or position is provided. Similarly, the date of this gift is also not recorded, but based on the object number (which usually contains the acquisition year) it could potentially have been donated in 1963. Cat. Number **45** was purchased from a Mrs E. J. F. Harne in 1944, but how she came by it is not recorded. And finally, Cat. Number **46** was gifted to National Museums Liverpool from the Committee of Gloucester City Museum in 1953. Prior to this, this coin would have been part of the Frank Jones Collection, according to a note in the museum’s archives. Again, no provenance information could be located.

As Manchester Museum does not at present have a database comprising its numismatics collections, the coins that were available for sampling were only those that were on display, and could be easily located. Of these, the coins that were chosen for sampling were the ones that helped to fill existing chronological gaps. In Appendix 1 Cat. Numbers **82** to **95** refer to the coins that were sampled from the Manchester Museum collection. Unfortunately, no acquisition information was available for any of these coins.

The coins selected for sampling from the British Museum (Cat. Numbers **96** to **142**) served the same purpose as those from Manchester Museum: to fill remaining chronological gaps. The majority of these coins, unlike the ones from the other institutions, have more solid acquisition information, although on occasion this is only the date that the coin was added to the museum's collection. Cat. Numbers **96** and **97** were acquisitioned to the museum in 1971 having been donated to the museum by the Egypt Exploration Society, which in turn received them from the excavations the organisation sponsored at the site of Saqqara. Here it must be noted that these two coins are part of a group of silver coins, almost all of which show signs of burning, and most of which have a pattern that could be ascribed to a fabric that was surrounding them during the burning process. This perhaps could have been the cloth pouch that they were stored in. Remarkably no information about this group of coins, their exact excavation location or the condition of their surroundings can be found in the relevant excavation reports. It is possible that they were part of a small hoard of silver coins "originally contained in a linen bag" described by Emery following the 1964-1965 season, although Emery does describe this particular assemblage of coins as being in "mint condition" which cannot be said about the British Museum group. Emery also ascribes them to the reign of Ptolemy I rather than the reign of Ptolemy II (Emery, 1965: 6).

For Cat. Numbers **98** and **99** there is very little in terms of provenance information, only the years the museum acquisitioned them: 1982 and 1912 respectively. Coins number **100** and **101** were both acquisitioned in 1996, after being purchased from Sidney Mygind, who was a regular visitor to the Coins and Medals Study Room at the British Museum, and who also sold assemblages of Greek and Roman coins to this institution in 1996. Further to this, an acquisition note on the British Museum database indicates that the coins originate from a Phoenician hoard, but no further information is provided.

Cat. Number **102**, again is only associated with the date when it was added to the museum's collection: 1955. Cat. Number **103** was acquisitioned in 1877 being originally part of a Bank of England Collection, which was loaned to the British Museum in 1865 in order to make it more accessible to the public. This remained as a separate Collection until 1877, when the Bank Directors decided that it would be more useful for the museum, and the public, if it was incorporated permanently into the national collection. Cat. Number **104** (as well as Cat. Numbers **120**, **128** and **142**) entered the museum's collection in 1866 as a bequest by James Woodhouse, who formed a large collection of miscellaneous antiquities and coins while residing in

South Italy and Corfu. Upon his death this collection was donated to the British Museum. Cat. Number **105** was acquisitioned in 1871, and arrived in the museum after being purchased from the French auction house of Rollin & Feuardent. Cat. Numbers **115**, **116** and **122** were also purchased from this auction house, **115** being acquisitioned in 1871, while Cat. Numbers **116** and **122** were added to the collection in 1867.

The only available information for the acquisition of Cat. Number **106** is the date 1953. Cat. Number **107** was added to the museum's collection in 1919 following a donation to the museum by a W. Lindsay, although it is unfortunately unclear what the exact role of this individual with regards to the museum was. Cat. Number **108** was purchased from Burgoyne, Burbidges & Co and acquisitioned in 1877. Cat. Number **109** was acquisitioned in 1864 after being purchased from George Eastwood (1819-1866), an antiquities dealer from whom the British Museum obtained a variety of artefacts. Cat. Numbers **111**, **113**, **117**, **126** and **135** were also purchased from Eastwood, but they were added to the collection at different dates, Cat. Number **126** was added in 1857, Cat. Numbers **129** and **135** were added in 1863 and Cat. Numbers **111**, **113** and **117** similar to Cat. Number **109** were added in 1864.

Cat. Number **110** (as well as Cat. Number **141**) was acquisitioned in 1863 following a purchase from the town of Lincoln, from where the British Museum also acquired East Asian coins in 1876. For Cat. Number **112** only the date of acquisition is known, 1912. Cat. Number **114** was acquisitioned in 1824 after being bequeathed to the museum by Richard Payne Knight who was made a trustee of the British Museum in 1814, and bequeathed his collections of small bronzes, coins, gems, cameos, and old master drawings to the institution. The only information listed in the museum archives for Cat. Number **118** is its date of acquisition that being 1814. Cat. Number **119** was purchased from Harry Osborn Cureton, who was a dealer in coins and antiquities from whom the British Museum acquired many items, including items from the sale of the collection of John Robert Steuart, a collector who spent part of his life in Naples. The precise date of the purchase is not listed but the coin was acquisitioned in 1847. Cat. Number **121** was bought from Giulio Sambon, who was a Neapolitan antiquarian residing in Paris in the late 19th and early 20th century, and was added to the museum's collection in 1867.

Cat. Number **123** was acquisitioned in 1994 with 979 more coins following a bequest by a descendant of the collector Edward Gilbertson, who was born in London and apprenticed at the age of eighteen to an artist and engraver. He later abandoned this career and became a banker. In 1860 he was appointed secretary to the Ottoman Bank, and was later appointed director of the bank in Constantinople. During this period, he was also awarded honours by the Sultan for his services to the Turkish economy. In 1871, he returned to London and served on the board of the Ottoman Bank and the Improved Hardwood Paving Company. In his retirement he studied foreign languages and began a collection of Japanese art and ancient artefacts, presumably at this time acquiring a number of coins as well. The only information about Cat. Number **124** is the date it was added to the museum's collections, 1920. Cat. Number **125** was acquisitioned in 1895 by a purchase from Messrs. W. S. Lincoln and Son who were self-described 'Numismatists and antiquaries'

Cat. Number **127** was acquisitioned to the British Museum Collection in 1992. It was purchased from B. A. Seaby Ltd., a company dealing in coins, medals and other antiquities. Based on a note from the British Museum catalogues it would seem that this coin, in addition to four others, were part of a hoard, however it is unclear where this hoard was found and by whom. For Cat. Number **130** only the acquisition date is available, 1814. Similarly, Cat. Numbers: **131**, **132** and **133** have only the dates of acquisition (1947, 1913 and 1932 respectively).

Cat. Number **134** was acquisitioned in 1869 by a donation from Reginald Stuart Poole, who was appointed at the Antiquities Department of the British Museum in 1852 and, after the creation of a separate Coins and Medals Department in 1861, became an Assistant Keeper in 1866, and then Keeper in 1870 (and later helped to found the Egypt Exploration Fund in 1882). The coin collection under his management was published in British Museum Catalogues, a number of which were written by Poole himself. In 1883 he retired from the British Museum. Cat. Number **136** was purchased from Baron Knobelsdorf, who sold coins to the museum in 1847, which is also the acquisition date for this coin. Finally, Cat. Number **137** was acquisitioned in 1849, this coin being originally part of the Sir Thomas Reade collection. Sir Thomas was born in Congleton, Cheshire in 1782, and after a successful military career he was knighted at age 33. He was part of Napoleon's guard on St Helena, where he was stationed until Napoleon's death. From 1844 Sir Thomas was the British-Consul in Tunis, he held this position there until his death in 1849. While in Tunis he collected antiquities including artefacts excavated by Nathan Davies from the site of Carthage. After his death, his coin collection was brought back from Tunis and subsequently purchased by the British Museum.

For coins number **138** and **139** only the date of acquisition is available: 1906 and 1947 respectively. Cat. Number **140** was originally in the position of the 6th Duke of Devonshire – William Spencer Cavendish, the coin was then acquired by the auction house Christie's, following which it was bought by Harry Osborn Cureton, from whom the British Museum purchased it. The acquisition date for this coin is 1844.

A number of issues, which arose from the fact that the bulk of the sampled material came from museum collections, needs to be addressed. Firstly, the issue of mints must be discussed. The coins from the museum institutions were requested on the basis of the ruler whose reign they were attributed to, the issue of mint being secondary. As the sampling technique is minimally invasive (see for details below), it was difficult to acquire both a representative sample of the rulers and of the mints. As such, a significant portion of the sampled coins came from the mint in Alexandria. There are a number of coins that were minted in provincial mints (such as Paphos, Cyprus, Jaffa, Sidon and Cyrenaica) the specific Cat. Number, ruler and mint details are provided in Appendix I. A further discussion of any significant differences detected with regards to a variation between the mints within a specific reign, and overall metal type will be addressed and discussed in Chapter 5.

The second issue is that of denomination. As was the case for the mints, the coins that were sampled were not sampled because of their denominational value, but rather because of their date. As discussed in the denomination section in Chapter 3, the bronze coins that were sampled do not have denominations as such, but instead are classified by the letters "AE" indicating copper-alloy, and a number indicating their diameter. These were assigned by the museum registrars, and are based on the Svoronos dating system, which the current research is utilising. However, as Appendix I provides detailed information for each coin, it would not be difficult in future to ascribe denominations to the sampled bronze coins, following the completion of

Lorber's new catalogue, and thus potentially creating a platform for further research into potential denominational differences in the composition of Ptolemaic bronze coins. The current work provides the denominations for the sampled coins of Ptolemy I, II, III and IV following Lorber (2018b). Svoronos' system was also used (by the institutions providing the samples) when ascribing the denominations of the silver coinage that was sampled. The silver coins from Mazor, the Garstang Museum of Archaeology, National Museums of Liverpool, Manchester Museum and the British Museum are predominantly tetradrachms, and a smaller amount of didrachms. However, due to the small amount of the latter, any comparison between the compositions of the different denominations is at present not possible.

The number of coins that were sampled was, as noted above largely dependent on the institutions that were approached, and their willingness to allow minimally invasive sampling. An aim was established early on in the project to attempt to sample ten coins per ruler – five silver and five bronze. However, that was not always possible, and some of the rulers are represented by a broader spread than others (for details see Appendix 1 and Chapter 5). The purpose behind aiming to select five coins per ruler, was to ensure a representative sample which could be used to indicate changes of metal composition over time.

4.2. Sampling Technique

The sampling technique used by the current project was identical for both silver and bronze coinage. Firstly, a small hole was drilled in the cylindrical edge of the coin, subsequently the metal turnings were collected and formed the basis of the analysis. The drilling was conducted using a hand-held jeweller's drill (Fig. 4.1), the diameter of which was either 0.6mm or 0.8mm (Fig. 4.2) depending on the size and weight of the coin. The aim was to penetrate the body of the coin (between 5mm to 15mm) thus achieving a representative sample from across the body of the coin. Due to probability of contamination by the surface metal, the material gained from the first 2mm of sample was discarded. The ideal sample was 12mg of core material, however that was occasionally not achievable due to the differing thickness of the metal layer, which in museum collections can be influenced by a prior surface cleaning often done using different chemicals. This method of sampling has been used repeatedly by Ponting in

Fig. 4.1: Handheld Jeweller's Drill Fig. 4.2: Drill Tips (0.6mm and 0.8mm)*

his research into the composition of Roman silver coinage (for example see Butcher and Ponting 2014).

After the samples were collected, they were placed in gelatine capsules (Fig. 4.3), and then placed in a small clearly labelled plastic bag (Fig. 4.4) and then transported to the University of Liverpool's Professor Elizabeth Slater Archaeological Laboratories. There the samples were prepared for analysis. Firstly, they were weighed using a calibrated digital microbalance. This was done in three stages: first a new, clear glass vial was obtained and labelled accordingly, then the vial with its plastic lid was weighed. Following this the sample originally placed in the gelatine capsule was placed in the glass vial and weighed, and then finally both the glass vial and the sample were weighed. It must be noted that the samples from the silver coins were divided into two separate vials, the main one containing approximately 10mg of the drilling and the other containing roughly 2mg.

Checks and balances were put in place in order to monitor the quality of the analytical data in the current work. The way this was executed was by using certified reference materials. For silver those were AGA1 and AGA3 and for bronze 183 and 211. All of these reference materials are commercial and obtained from MBH Analytical LTD. The samples for these standards were prepared by induction melting and chill-casting, and the values were derived by using ICP-AES for all the elements. Additionally, the

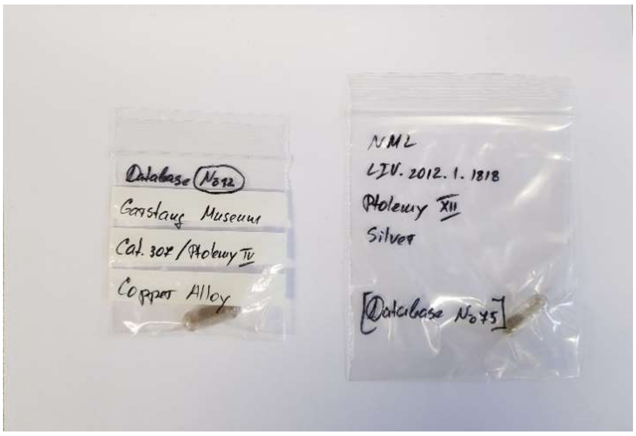


Fig. 4.3: Gel Capsule with sample

Fig. 4.4: Sample in gel capsule and labelled plastic bag

values for each element are a mean of four independent tests. These values can be seen in Appendix IV.

Next the vials containing the samples and the certified reference materials (this was the case for the main silver and all of the bronze, although the analysis of each was conducted separately) were placed on a hot plate, and their lids placed in a position that allowed an easy rematch later. A 0.25ml aliquot of concentrated nitric acid was added to each vial, followed by a drop of ultra-pure water after which the vial was swirled gently to mix the sample, the acid and the water. After 5 minutes on the hot plate 0.75ml of concentrated hydrochloric acid was added and then ultra-pure water. Then the vial was left for 15 more minutes on the hot plate. Following these initial steps, the solution in the vial was made up to 10ml by adding ultra-pure water. Finally, the vial with the solution inside was weighed.

For the samples that were taken from silver coins, the next step was to place the vials, and the now dissolved sample within them, into a centrifuge in order to separate the silver chloride, which is formed during the dissolving process, and can cause clogging of the sampling introduction system of the microwave plasma atomic emission spectrometer (MP-AES). After the sample was centrifuged, the supernatant liquid was pipetted out of the vial, leaving the silver chloride at the bottom to be discarded. This method however, meant that essentially all of the silver from the sample solution had been removed, rendering its measurement impossible. This first, or *main*, solution was analysed for all the elements *with the exception of silver*, which was instead determined by difference.

The second, smaller vial of silver material containing approximately 2mg of sample, was dissolved using only nitric acid, as this retained all the silver in the solution, which was then analysed only for silver and copper content. By measuring copper in the silver coins in both the main and smaller solution, a useful data point was formed to verify the consistency of the analyses. There was no need to create two separate solutions for the bronze samples, or place the bronze samples in a centrifuge, as the silver was only present in trace amounts, and thus could not result in precipitation issues.

The next stage, conducted prior to the analysis, was the preparation of the multi element calibration standards. The purpose of these calibration standards was to provide the instrument, the information needed for it to convert the energy intensities it measures into real concentrations via a calibration curve. The calibration solutions were prepared by adding the selected elements in the form of a concentrated standard solution to small amounts of ultra-pure water in a 200ml volumetric flask. Silver and antimony were the last elements to be added in order to avoid precipitation. The next stage was to add 10ml of aqua regia (3:1 ratio of nitric and hydrochloric acid) to three 100ml volumetric flasks that were clearly numbered. Based on pre-established and pre-calculated ratios (see for example Hughes, Cowell and Craddock, 1976), the volumes of the multi-element stock solution were added to these three flasks containing the aqua regia solution, and then the volume was made up by adding ultra-pure water. Finally, a calibration blank was made in a fourth clearly labelled 100ml volumetric flask of 10ml aqua regia and ultra-pure water only. The multi elements calibration standards, the blank and the certified reference materials (AGA1, AGA3 for silver and 183 and 211 for bronze), now standard reference solutions, were run at the start and end of each batch MP-AES run.

4.3. Description of Selected Chemical Elements

The current research aims to determine both the major and the trace elements of the sampled coins. As such, 14 elements were chosen for investigation. These were: silver, arsenic, gold, bismuth, cobalt, chromium, copper, iron, manganese, nickel, lead, antimony, tin and zinc. These chemical elements were not chosen at random. What today would be considered a pure metal (be that silver, gold or copper), is not actually what is contained in any ancient metal, due to the smelting procedures used in the past. If silver is taken as an example, the trace elements present within the original silver ore are usually strongly bound to the silver itself, making their removal nearly impossible in the smelting and refining processes practiced in antiquity (Butcher and Ponting, 2014: 101). The natural process of oxidation was the main process used to remove impurities, and although in practice this was feasible, it was still unable to make the metal chemically pure. Thus, amounts of the chemical elements found in the ore used to produce the coins (both silver and bronze), in addition to any minerals or metals that were added at the time of the refining and smelting processes, will be present in the overall composition of the coins (Butcher and Ponting, 2014: 101). However, these elements are often present in only very small amounts in the metal composition of the sampled coins.

With regards to silver, the most useful trace elements that can assist with identifying specific ores are gold and bismuth as "they are the least affected by cupellation and thus remain at similar concentrations to these in the original ores" (Butcher and Ponting, 2014: 102). Cupellation is aimed at refining noble metals by a high-temperature oxidising reaction that involves the mixture of the "impure gold or silver with an excess of lead, and placing the metal on a porous substate under a highly oxidising fire" (Martinón, Rehren, Thomas and Mongiatti, 2009: 435). Here it must be noted that there are no indigenous silver ores in Egypt (Gale and Stos-Gale, 1981), although small traces of silver are present in several galena ores from the Eastern desert. These quantities, however are too low to have been effectively extracted in ancient times (Gale and Stos-Gale, 1981: 106). XRF analysis of fifty-six ancient Egyptian artefacts raging in date from the Predynastic to the Late Kingdom, has furthermore suggested that some silver could be obtained from naturally silver rich gold ore (Gale and Stos-Gale, 1981: 110-113).

Due to the large amounts of silver that were necessary for the production of Ptolemaic silver coinage, the silver was most likely imported from outside the borders of Egypt; which considering the territorial span of the early Ptolemaic empire, may not have presented a serious challenge, although, during the nearly 300 years of the Ptolemaic

Dynasty, territories outside Egypt were lost and so were potential resource and/or routes. A further source of silver (if not the primary source) for the manufacture of Ptolemaic coinage, was the recycling of foreign coins that was made possible by the closed currency system (for details see Chapter 2, 5 and 6). However, methods such as cupellation and/or refinement would have been used regardless of the origin of the silver, thus the presence of trace elements such as lead, gold and bismuth, could be used to potentially illustrate the different ores and methods used in the smelting process of the silver coinage. Furthermore, when discussing the debasement of silver coinage, the focus falls on decreasing silver levels and increase in the copper levels.

With regards to the copper ores, these occur in Egypt itself in the Eastern Desert (where Ptolemaic mining activity has for instance been noted at Gebel Dara and Wadi Hamama, Masson-Berghoff et al, 2018:333) and Sinai, as well as outside Egypt in places such as Cyprus (Rademakers, Rehren and Pernicka, 2017: 63). Concerning the use of Cypriot copper during the Ptolemaic Period evidence can be found in the recent analysis of a trireme ram found off the coast of Israel and analysed by Ponting (in press). A well-known source of copper in ancient times was the Arabah Valley, in particular the largest copper deposit in the Faynan area located in the northeast of the Valley (Avner, 2014: 103). Recent lead isotope analysis conducted on copper artefacts from Naukratis and Cyprus, have shown that during the Late Period, copper was mined at Faynan and worked in Egypt and elsewhere in the Eastern Mediterranean (Masson-Berghoff et al, 2018: 333). Moreover, the presence of Ptolemaic coins at Faynan could indicate continued usage of the mines during the Ptolemaic Period, and furthermore this site also operated as a source of copper during the Roman Period (Kind *et al*, 2013). The second largest copper deposit located in the southwestern Arabah was the Timna Valley (Avner, 2014: 103). In 1969 and then in 1974 Rothenberg excavated part of the site of the Timna Valley, discovering an Egyptian Temple (also known as the Hathor Temple). Based on the 11 000 artefacts discovered there, the site was dated to the reign of pharaoh Seti I with continuing use in the time of Ramesses II up to Ramesses V (Avner, 2014: 104). In the 1970s Rothenberg continued his work on the mines in Timna concluding that they can be considered as the best example of New Kingdom copper mining and smelting (Avner, 2014: 104).

However, like silver, the composition of the ancient copper is by no means chemically pure, and the composition again depends both on the ores used, as well as on the production processes. Common impurities within the copper ores are elements such as iron, nickel, bismuth, cobalt and arsenic. The latter is present in a number of ore types, and there are traces of this element not only in the Ptolemaic coins, but also in artefacts from the earlier Pharaonic period (Ogden, 2000: 151). In addition, arsenic is frequently associated with antimony, which can appear either as part of the arsenic ore, or as a trace element within copper ores. As the current thesis focuses on the examination of the bronze coinage, what is expected to be observed compositionally is a specific mixture of exclusively copper and tin (app. 12%).

When examining the possible debasement of bronze coinage, the decrease of the copper content is not the only evidence for deliberate change to the composition, so is the reduction of the tin content. The use of tin bronzes became the norm from the end of the second millennium BCE. However, the upheavals in the Mediterranean at the end of the Bronze Age, and the significant distances in the tin distribution, makes the "ubiquity of tin bronze and the uniformity of its composition" surprising (Craddock, 1983: 61). This is also the case in Egypt, where tin, as metal is rare, although there are some deposits of cassiterite (a tin oxide mineral) and of tin itself in Nahr Ibrahim (Ogden, 2000: 171). When the copper and/or the tin content was decreased within the Ptolemaic bronze coins, it was substituted with lead. Through the first millennium BCE there is a notable increase in the content of lead in bronze, which reached a "plateau by the later part of the millennium that was maintained through the Hellenistic, Roman, Byzantine, Islamic and medieval periods" (Craddock, 1983: 61). It must however, be stated that the percentage of lead in individual bronzes is significantly varied, and as whole it is impossible to correlate lead content and object type (Craddock, 1983: 61). Although it does seem that ancient currency is potentially one of the categories that was more prone to the addition of lead (Craddock, 1983: 61).

Lead is insoluble in copper, and it also has a low melting point. As such, the mobility of the molten alloy can be significantly increased with up to 2% of lead. In addition, the melting point of the alloy can be decreased if the lead content is increased to more than 2%, which in turn clearly aids the casting process. Additionally, lead has always been more accessible than copper or tin, which helps when large numbers of casts are produced (Craddock, 1983: 61). However, on occasion there could also be severe disadvantages to the addition of lead into a copper alloy: "Ideally the lead remains dispersed through the copper as minute globules, but at concentrations of more than a few percent, there is an increasing tendency for the globules to link up to form more macroscopic "lakes" of lead with the lead-bronze interface forming a serious weakness that would tend to crack open if any deformation was attempted" (Craddock, 1983: 61-62). Consequently, hammered metal never contains more than minute quantities of lead.

Lead is easily obtained from galena (lead sulphide) and cerrusite (lead carbonate) ores by smelting (Ogden, 2000: 168). These two ores are available at several locations within Egypt e.g., on the Red Sea coast, although it must be stated that Stos-Gale and Gale (1980: 294) concluded that lead, and consequently silver, derived from galena in the Predynastic period may have had foreign, rather than Egyptian, origin. However, based on their analysis, a broadly similar chemical composition consistent with an Egyptian source can be observed for three Predynastic galenas and three Protodynastic galenas (Stos-Gale and Gale, 1980: 294), so although, Stos-Gale and Gale (1980: 294) do state that "local sources with the correct lead isotopic composition have not yet been discovered", it is unclear if, in the nearly 3000 years that passed between the Predynastic and Ptolemaic periods, these local galena sources were not developed. However, the evidence for this development into the Ptolemaic Period is still absent making it difficult to conclude whether the lead in the coinage of the Ptolemies came from within or from outside of Egypt.

To explain why lead began increasingly to be added to bronze from the second millennium BCE onwards, Craddock (1983: 62) puts forward the hypothesis that it could be as a result of the fact that lead was a by-product of silver production. And as silver production increased from this time period onwards, lead, as a result, became more widely available (Craddock, 1983: 62). Further to this Craddock (1983: 62) is of the opinion that from Hellenistic times onwards, the use of lead in copper alloys was "almost certainly due to the prodigious increase in silver production from argentiferous lead". The use of lead in the production of copper alloys was known to the ancient Egyptians from the Late Period (if not prior), based on the analysis of ten bronze statues of this period from the Egyptian Museum in Cairo (Gouda, Youssef and Ghany, 2012). Lead functioned as a cheap additive when it came to currency, a further indication that what can compositionally be observed in the analysed coins is indeed debasement (Craddock, 1983: 62-63)

As part of the analysis conducted by the current project, trace elements such as iron, cobalt, chromium, manganese, nickel and antimony were also analysed as they indicate the provenance, and/or the technology utilised in the production of the bronze (Craddock, 1983: 61; Pernika, 1999: 169-170) and silver coinage (Butcher and Ponting, 2014: 104). And although tracing the origin of silver and copper, or determining the precise production methods for the silver and bronze coinage, is not the aim of this thesis, providing the results for these elements could provide beneficial for the broader scholarly work on chemical composition of both coins and artefacts from the Ptolemaic Dynasty.

The elements mentioned in the paragraphs above are not restricted to only silver or bronze coins, but can be found in different quantities in both, which is also the case with zinc. However, zinc is often present only at very low levels as metallic zinc was not widely used in the ancient world. Zinc is most often found in association with copper and lead ores; however, it is only present in trace amounts due to its volatility during smelting which leads it to being lost, rather than absorbed by the copper (Craddock, 1978: 2). One of the main reasons to examine the coins sampled for this element, given its limited presence, was to detect possible fake bronze coins, as a high zinc content (more than 30%) indicate a likely modern origin (Craddock and Bowman, 1990: 281). And as most of the sampled material was obtained from museum collections, and, as noted above a fair number of the sampled coins did not have a known archaeological provenance, the zinc content was investigated in order to identify any potential modern fakes which could have jeopardised the results of the project. However, fortunately, no modern fakes were detected from among the sampled coins.

4.4. Instrumental Overview

Returning now to the discussion of the methodological strategies employed by the current work. After both the sample and standard preparations were ready, the samples (be that silver or bronze) and the standards were placed in racks, and placed in the

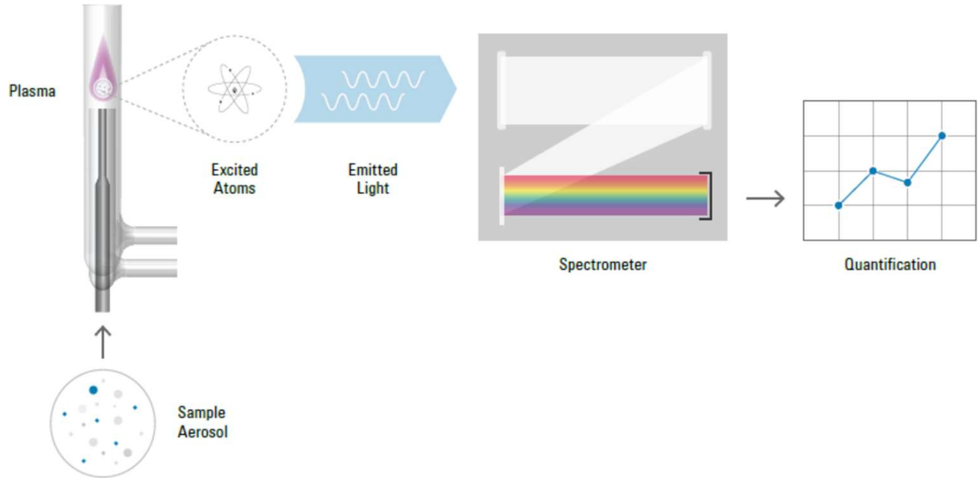


Fig. 4.5: Diagram of MP-AES (Agilent Technology, 2016: 5).

sample introduction system of the MP-AES. The basic principle of the microwave plasma atomic emission spectrometer is that once an atom is excited by the high temperature of the plasma, it emits light energy in a characteristic pattern of wavelengths. During analysis with the MP-AES, an aerosol is created from the liquid sample, and introduced into the centre of the hot plasma. The aerosol dries, decomposes and is then atomized (Fig. 4.5). The atoms remain excited, and emit light at specific wavelengths for each element, as they return to a lower energy state. It must, however be noted that detecting arsenic using MP-AES, can be challenging as the sensitivity of standard plasma spectroscopy for arsenic is poor (about 1 ppm in solution – so almost 1000ppm in the actual coin). To overcome this issue, a hydride generation system is used. This system generates an arsenic vapour which can be more easily detected by the MP-AES, and in turn considerably improves the achieved results.

Following this, the software uses the readings from the calibration standards to calculate the metal concentrations. The received data is presented in parts per million (ppm), this value is then multiplied by the dilution factor, meaning the ratio of concentration of stock solution to the concentration of the diluted solution. The dilution factor value is found by subtracting the weight of the vial and lid from the weight of the vial, lid and sample in its solution, and then dividing this value by the weight of the sample multiplied by a factor of 10, to convert the values into percentages. In order to normalize the data, the percentage values are divided by the total value of all elements and multiplied by a factor of 100. Appendix 2 comprised the results of the analysis of the silver coinage and Appendix 3 comprises the results of the bronze coinage.

It must be noted that the samples obtained from the 31 British Museum silver coins were smaller than the necessary 12mg, and thus the second smaller solution containing only 2mg of the sample along with nitric acid could not be created. Nonetheless, the main solution using aqua regia was used for these samples, but in order to establish the silver content with absolute certainty (not only by calculation as would have been the case, if only the results from the main solution were used) an alternative technique altogether was used: scanning electron microscope with energy dispersive spectrometry (SEM-EDS). This technique does not involve dissolving of the samples, and as the samples were only available in very small amounts, the sample preparation for this technique was different from the one used for the MP-AES: The remnants of the samples were placed on pure aluminium 12.5mm stubs prepared with adhesive ultra-low background carbon tabs, thus securing the sample to it. Subsequently, the stubs, now containing the samples, were placed into the sample chamber of the SEM. A very high resolution and magnification can be achieved with the SEM-EDS due to its use of electrons rather than visible light, as electrons possess shorter wavelengths than light. Electrons (which are negatively charged sub-atomic particles with low mass), can behave both as waves and as particles because of a wave-particle duality, which is a physical phenomenon that affects all matter. The way the SEM functions is by directing a beam of electrons down a column and through electromagnetic lenses, which condense and focus the beam.

The sample is then bombarded with electrons by the scanning electron microscope, after which a number of fundamental interactions take place, one of which is the emission of electrons, resulting in the SEM detecting three types of electrons - backscatter electrons, secondary electrons and Auger electrons, the latter of which are generally ignored. As the backscatter electrons come from the deeper regions of the sample, they have a higher sensitivity, so they were chosen in the analysis of the 31-silver samples from the British Museum. Consequently, in order to measure the chemical elements using the SEM, a focal point was the backscatter electron imaging, during which the electrons come down the column, hitting and reflecting from the sample, thus creating an elastic scattering.

When the electron beam hits the sample, it penetrates a certain depth of the material, and causes the ejection of an electron from a lower energy shell. The electrical imbalance created is corrected by the emission of a characteristic x-ray. These x-rays serve to identify the chemical elements within the sample. Here it must be noted, that in addition to examining the samples for silver content, the copper content was also determined in order to provide a check against the results achieved using the MP-AES. In addition, where detectable, the content of lead and gold were also measured. The data from the SEM was interpreted using the PhiRhoZ method, which displays lower error when producing data points.

The aim of this chapter was to present an overview of the methodology utilised in the current study, as well as present contextual and provenance information (where available) on the coins obtained for study. The following chapter will present and discuss in detail the results obtained by the above detailed sampling and analysis methods.

Chapter 5: Compositional Analysis Results

The present chapter will discuss the results of the compositional analysis of both silver and bronze coinage. The results will be presented in two parts, the first of which will focus on the silver coinage and the second on the bronze coinage. Each part will be subdivided by ruler, and in addition to the analytical results the sections will also discuss the number of coins tested, their institutional provenance, as well as their date. The discussion of the analytical results will for the most part be concentrated on the major elements: For the silver coinage these are silver (Ag), copper (Cu), and in some cases the composition of some of the trace elements such as gold (Au), bismuth (Bi) and lead (Pb) will also be further presented. For the bronze coinage the elements will mainly focus on copper (Cu), tin (Sn) and lead (Pb). Tables showing the major elements and some of the more significant minor elements will be presented for every ruler for both metal types.

In order to illustrate specific points concerning the correlation between weights and composition, as well as debasement, graphs for both types of coinage sampled will be presented. In addition, issues such as mint and denomination and their potential link to any compositional changes within individual reigns will also be examined. Moreover, where necessary, a brief description of the obverse and reverse images on specific coins (their issues) will be provided. This however, will not occur frequently, rather this type of information, in addition to the institution information, size, weight, denomination and a reference are provided in full in Appendix I. Finally, at the end of each section, an overall discussion of the results and a comparison to previous research will also be presented.

A total 141 coins (69 silver and 72 bronze) coins were sampled for the current study. The initial aim of the sampling was to provide five coins per ruler, though this was not always possible. As a result, some of the assemblages exceed this number and some contain fewer samples than the optimal number. For example, no bronze or silver coins belonging to the sole reign of Ptolemy XI were sampled, mainly because this king ruled only for around a year in total, the first six months of which Egypt was in actuality ruled by Cleopatra Berenice III (Hölbl, 2001: 213). By contrast, an example of a larger sample size are the 14 bronze coins belonging to the joint rule of Ptolemy VI and VIII. With regards to the silver coinage that can be dated to the joint rule of Ptolemy VI and Ptolemy VIII, only two coins were sampled. This was caused by a mistake in the original institutional dating of some of the sampled material, however later examination and consultation with the work of Svoronos (1904) and some of the more recent studies on the silver coinage from this period (for example see section **3.1** above) showed that some of these coins should be re-dated to earlier and/or later rulers.

Here it must be noted that a decision was made, when choosing coins for sampling, to combine the bronze coins dating to the reigns of Ptolemy IX and Ptolemy X as, due to the lack of clear dates on this set of coins, it is unclear to whose reign which individual coins should be ascribed. This issue stems largely from the grouping of Ptolemy IX and Ptolemy X in Svoronos' (1906) catalogue. A further issue is that Svoronos ascribes some of the coins belonging to these rulers to Ptolemy XI who as mentioned above ruled for only a single year. Svoronos' decision could potentially be due to the tumultuous historical period, and the fact that Ptolemy IX actually reigned twice, once from 116 BCE to 107 BCE and then returned to the throne in 88 BCE until his death in 81 BCE. A further reason for this omission and/or grouping by Svoronos could be that Ptolemy X's reign took place in between the two reigns of his brother Ptolemy IX. Furthermore, Ptolemy IX's initial reign (116-107 BCE) was for a time shared with his mother (Hölbl, 2001: 204-207). By contrast, the silver coinage for this period catalogued by Svoronos has regnal years inscribed on the reverse of the coins thus making it possible to separate this type of coins into two separate reigns. Unfortunately, the sampled silver material for the reign of Ptolemy IX consists of only two coins, both from his first period of rule over Egypt.

Throughout this chapter the term 'debasement' is used widely, and so requires a clearer definition. Although debasement can refer to the lowering of the weight of a coin (Allen, 2020: 43), in this chapter and more broadly throughout the thesis, debasement is used to indicate when the fineness of the main (usually precious) metal within the coin is lowered. In the case of the silver coinage, it must be noted that the silver available to ancient people was not chemically pure silver (Ag). This was the result of the insufficient refining technologies that were used and their inability to remove all trace elements. Consequently, the silver bullion (the silver in bulk before coining) used in the production of the coinage would have retained certain trace elements such as gold, bismuth (McKerrell and Stevenson, 1972) and often lead (Butcher and Ponting, 2014: 102). In the current thesis, when debasement is concerned, it will focus on the decrease of the silver bullion value rather than the pure silver (Ag) value and the deliberated addition of copper. Deliberate debasement of silver coinage will be considered as evidenced in coins containing >2% copper in their overall composition. This figure was selected on the basis that smaller trace amounts of copper could be naturally present in the silver bullion (Ponting, 2012).

With regards to the bronze coins, the percentage value at which debasement can be suggested is not as clear cut. The addition of small amounts of lead can help achieve a lower viscosity and make the casting of bronze blanks easier (Craddock, 2008: 110). Therefore, some addition of lead should be expected occasionally for production purposes. However, based on the current research and available results (for details see relevant sections below) a stipulation can be made that when the lead content in a coin is >5% then that should be considered deliberate debasement. This figure reflects the expected presence of some lead added for production purposes and errs on the side of caution in order to achieve clearer results. Furthermore, in the deliberately debased coins, the tin content is generally also lower than the content of lead.

Finally, through the sections below for both the silver and bronze coinage, the correlation of weight and composition is occasionally mentioned. However even in the cases where a connection between weight and composition can potentially be supported by the correlation coefficient (which is a statistical measurement of the strength of the relationship between two variables, for details see Fletcher and Lock: 1991), it must be stated that the relevance of this is perhaps questionable due to the sample sizes and the potential issue caused by corrosion impacting the weight of individual coins (for a more extensive discussion of this problem see Butcher and Ponting 2014, 90-92). A further uncertainty comes from the issue of whether the coins were weighed and adjusted individually (*al peso*) or whether whole batches of coins were weighed together in some sort of a container (*al marco*) after they were minted (Stannard, 1993: 45). The *al marco* system suggests that the output of the mint was a pre-weighed container (such as a bag, pot, barrel or potentially a box) of coins rather than individual coins (Witschonk, 2012: 75). This would mean that “The weights of individual coins in the bag might vary substantially from the standard, but the total weight of the bag would be correct for the number of coins in the bag" (Witschonk, 2012: 75). Although the *al peso* and *al marco* adjustment are discussed primarily with regards to Roman coinage (Stannard, 1993), they should be taken under consideration in the case of the Ptolemaic coinage. For instance, if it is assumed that the Ptolemaic mints employed the *al marco* system of adjustment, this would explain the occasional differences in some coin weights within individual regnal periods.

5.1. Chemical Composition of Silver Ptolemaic Coinage

5.1.1. Ptolemy I

Seven coins belonging to Ptolemy I (Cat. Numbers: **20**, **63**, **64**, **65**, **66**, **83** and **85**) were sampled (Table 5.1). Most of the coins were minted in Alexandria, with the exception of coin number **83** which is dated to the time of Ptolemy I's satrapy and was as such most likely minted in Memphis, as the mint in Alexandria may not have been functional at this time as the town itself was still not the royal residence (Hölbl, 2001: 26). The date range of the sampled coins is reasonably representative of Ptolemy I's reign. The oldest coin is as mentioned Cat. Number **83** (depicting the deified Alexander wearing an elephant headdress on the obverse and an enthroned Zeus holding an eagle on the reverse). This is followed by Cat. Number **20** (depicting again the deified Alexander with an elephant headdress on the obverse but here the reverse depicts Athena holding a shield) which can be ascribed to the early years of Ptolemy's reign (see for instance Sv. 142).

Coins numbers **63** to **66** represent the later part of Ptolemy's reign (see for instance Sv. 214), as well as a new obverse and reverse type which then continued in usage, with occasional changes, throughout the whole of the Ptolemaic Period. The obverse depicts Ptolemy I's head, and the reverse portrays an eagle. All sampled coins are tetradrachms.

The heaviest of the coins is Cat. Number **83**, weighing 16.59g. This heavy weight could be explained by the early date of this piece and is a potential indicator that the Attic standard was in use in the early years of Ptolemy's rule (for more detail on this see section **3.2.**). The lightest of the coins is Cat. Number **66**, weighing 13.84g, the rest

Cat. Number	Date (BCE)	Mint	Weight	Denomination	Ag	Au	Bi	Cu	Pb	Bullion
20	305-285	Alexandria	14.59g	Tetradrachm	99.28	0.36	0.003	0.29	0.04	99.68
63	305-285	Alexandria	14.06g	Tetradrachm	98.74	0.32	0.028	0.32	0.33	99.41
64	305-285	Alexandria	14.07g	Tetradrachm	98.86	0.32	0.040	0.16	0.59	99.81
65	305-285	Alexandria	14.04g	Tetradrachm	98.62	0.51	0.044	0.31	0.47	99.64
66	305-285	Alexandria	13.84g	Tetradrachm	99.39	0.18	0.009	0.25	0.14	99.71
83	320-313	Alexandria	16.59g	Tetradrachm	99.24	0.01	0.083	0.02	0.35	99.68
85	294	Uncertain	14.09g	Tetradrachm	98.94	0.45	0.004	0.13	0.45	99.85

Table 5.1: Silver (Ag), gold (Au), bismuth (Bi), copper (Cu), lead (Pb) and bullion values for the silver coins belonging to the reign Ptolemy I.

are all around 14g. There is no direct correlation between the weight and the composition of the coins. As Table 5.1 illustrates, the highest silver percentage is not found in the heaviest coin (Cat. Number **83**), but rather the lightest one (Cat. Number **66**). The second highest silver levels are however found in Cat. Number **83**, thus further demonstrating the lack of correlation between weight and silver composition. The silver percentage for all sampled coins is between 98% and 99%, demonstrating a very pure composition which lasted throughout Ptolemy I's reign. The bullion values are all in the 99% (Table 5.1) which further underlines the purity of these coins. No indications of debasement can be found as the levels of copper for all sampled coins remain below 0.5%. What can further be observed is that the bismuth levels for Cat. Numbers 20, 66 and 85 are lower compared to the remaining sampled coins for this reign. This could be indicative of a change in the ore (Ponting,2009:275) or it could simply have been an error that occurred during production.

Additionally, an interesting aspect here is that the gold content for Cat. Number **83** is the lowest of all the coins analysed for the reign of Ptolemy I and in addition the bismuth content for this coin is the highest. This could be a further indication that this coin was not minted in Alexandria but, as suggested above, in Memphis and that perhaps the source of the silver was different from that of the remaining coins. Moreover, a similarity between Cat. Number **20** and Cat. Number **83** can be observed, namely that the bullion for both of these coins is the same – 99.68%. This could of course be a simple coincidence, but given that these are the earliest of the analysed coins, it could also be indicative of either the same mint origin or that perhaps the composition of these early coins was monitored very strictly. It seems unlikely that they were part of the same batch of minted coins though, as the gold and bismuth values are significantly different and so are their obverse and reverse imagery and date. The other trace elements – arsenic, gold, bismuth, cobalt, chromium, iron, manganese, nickel, lead, antimony, tin and zinc are all under 1% (for more details see Appendix II). In general, the present analysis of these six coins clearly illustrates that while Ptolemy I's coinage underwent changes relating to weight and imagery, the composition remained remarkably steady throughout his reign.

5.1.2. Ptolemy II

Four coins in total were sampled from the reign of Ptolemy II - Cat. Numbers **84**, **86**, **96** and **97** (Table 5.2). All coins but one (Cat. Number **84**, which is from an unknown mint) were minted in Alexandria. The date of all the sampled coins falls within the same five-year time period between 285-270 BCE. Using Svoronos' catalogue a date of 275 BCE can be ascribed to Cat. Number **96** due to the Greek letter Λ that is located on the reverse of the coin between the eagle's legs (see for instance Sv. 579). One issue concerning the dating of these coins is that Cat. Number **84** could potentially be ascribed to the reign of Ptolemy I, due to the presence of a Δ on the obverse of the coin, just behind the portrait of Ptolemy I. But it has been classified here as belonging to the reign of Ptolemy II due to the monogram in the left field on the reverse of the coin which is commonly associated with Ptolemy II (see for instance Sv. 548). The presence of Δ on the obverse side of the coin could potentially also indicate that the coin was minted in Tyre (as coins from this mint sometimes include the same symbol). However, the monogram present in this coin does not appear in the coins from Tyre making this assignation unlikely. All the sampled coins are tetradrachms.

The weights of all of the sampled coins fall between 13.92g and 16.35g, with the majority weighing around 14.00g. The chemical composition of these coins is broadly similar to the ones belonging to Ptolemy I, the silver content being in the range of 99% to 98%, and again there is no clear correlation between the silver content and the weight of individual coins. The bullion content again demonstrates a great degree of similarity in the composition of coins from the reigns of Ptolemy I and Ptolemy II, with value of 99% (Table 5.2). The copper amounts are less than 0.5%, and with

Cat. Number	Date (BCE)	Mint	Weight	Denomination	Ag	Au	Bi	Cu	Pb	Bullion
84	285-270	Alexandria	14.08g	Tetradrachm	98.40	0.45	0.045	0.20	0.88	99.78
86	285-270	Alexandria	14.25g	Tetradrachm	99.15	0.46	0.032	0.14	0.19	99.84
96	275-272	Alexandria	16.35g	Tetradrachm	98.94	0.39	0.014	0.15	0.48	99.82
97	285-270	Alexandria	13.92g	Tetradrachm	98.26	0.31	0.026	0.18	1.19	99.79

Table 5.2: Silver (Ag), gold (Au), bismuth (Bi), copper (Cu), lead (Pb) and bullion values for the silver coins belonging to the reign of Ptolemy II.

regards to the trace elements there are is only one coin that has slightly unusual values: Cat. Number **97** which yields the highest lead value. This could be a production error but it could also be indicative of a less meticulous refining process (Butcher and Ponting, 2014: 33).

5.1.3. Ptolemy III

Four coins belonging to Ptolemy III - Cat. Numbers: **98**, **99**, **100** and **101** - were sampled (Table 5.3). From these sampled coins only one comes from an unknown mint, namely Cat. Number **98**. Cat. Numbers **99** and **101** come from the mint in Jaffa and Cat. Number **99** comes from the mint of Sidon. A precise date for all but one coin (Cat. Number **98**) can be provided, these being 241 BCE, 245 BCE and 244 BCE respectively. The denomination of all the sampled coins is tetradrachm. The weight of the coins is similar to that of the previous two Ptolemies – around 14.00g with the lightest being 13.93g.

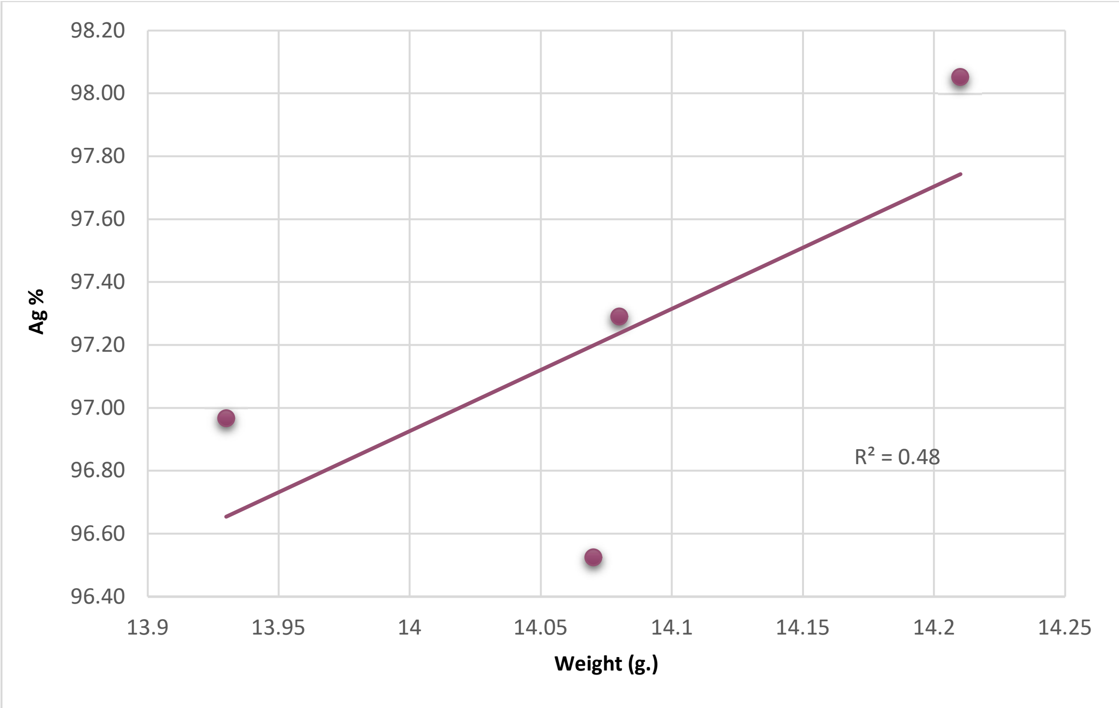
The composition of these coins is slightly different to the coins of Ptolemy I and II. Two of the sampled coins (Cat. Numbers **98** and **99**) contain around 96% of silver, one of the coins (Cat. Number **101**) contains 97.29% silver and the final one 98.05% silver (Cat. Number **100**). The bullion values are mainly in the 99%, with one exception, Cat. Number **98**, where the bullion value is 98% (Table 5.3) Furthermore, a relative correlation between weight and silver composition can be observed (Graph 5.1) in these coins, namely that the heaviest coin (Cat. Number **100**) contains the most silver – 98.05%. However, it should be noted that the lightest coin does not contain the smallest percentage of silver although it does contain the highest percentage of copper, nearly 2.00%. Graph 5.1 shows that the correlation coefficient between the weight of

Cat. Number	Date (BCE)	Mint	Weight	Denomination	Ag	Au	Bi	Cu	Pb	Bullion
98	Uncertain	Uncertain	13.93g	Tetradrachm	96.97	0.59	0.001	1.79	0.61	98.17
99	242-241	Jaffa	14.07g	Tetradrachm	96.52	0.49	0.024	0.32	2.56	99.60
100	246-245	Sidon	14.21g	Tetradrachm	98.05	0.37	0.081	0.24	1.14	99.64
101	245-244	Jaffa	14.08g	Tetradrachm	97.29	0.27	0.017	0.19	2.20	99.77

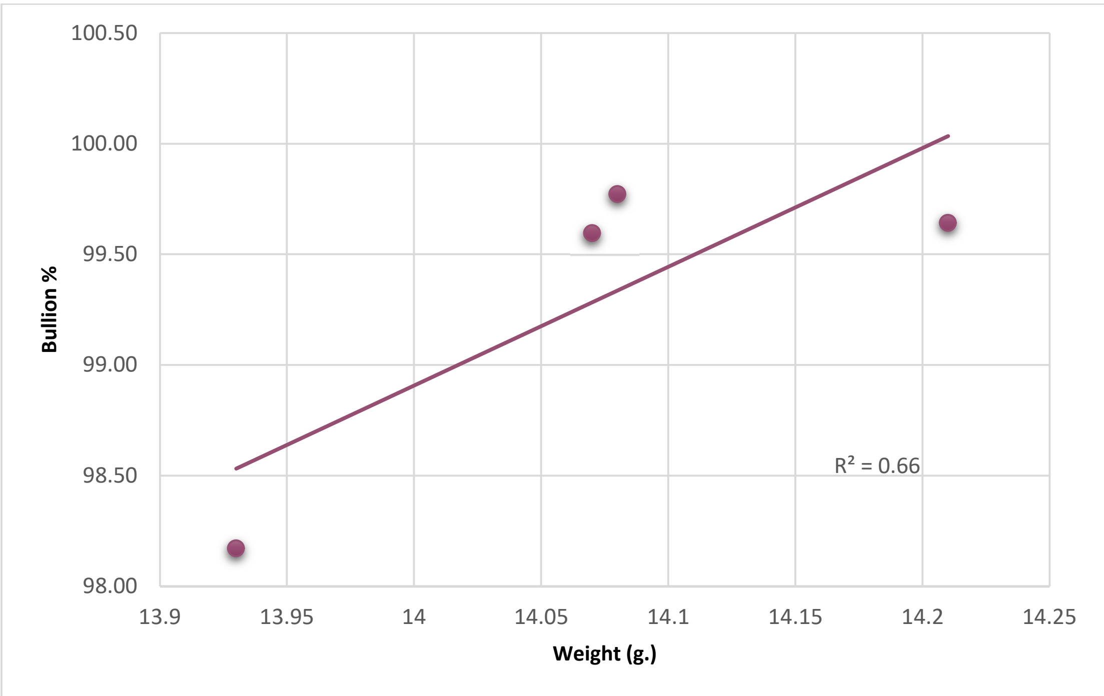
Table 5.3: Silver (Ag), gold (Au), bismuth (Bi), copper (Cu, lead (Pb) and bullion values for the silver coins belonging to the reign of Ptolemy III.

the coins and the silver content is 0.48, this value is even higher (0.66) in Graph 5.2, which shows the correlation between weight and the bullion. Although the R^2 values presented in these graphs are indicative of a positive correlation, it must be stated that due to the sample size unfortunately in this case the correlation coefficient is not significant (for details see Fletcher and Lock, 1991: 109 and 184). Moreover, unlike the coinage of the previous two rules, the content of lead for all but one of the coins (**98**) is above 1%, which as noted in the previous section could be indicative of a less intense smelting process. What is perhaps most notable is that Cat. Number **99** has both the lowest percentage of silver (96.52%) and simultaneously the highest percentage of lead (2.56%). The lead percentage coupled with the gold percentage for this coin could be indicative of the ore used, in this case the so called ‘dry ore’ (for more information on this see section **5.2**.).

When discussing the results of these five coins it must be noted that 3.5% of silver loss should not unquestioningly be considered as evidence of debasement especially when the values of the bullion is taken under consideration as in this case only one coin (Cat. Number **98**) has less than 99% silver bullion content. It seems unlikely that the addition of 1.79% copper was done in order to facilitate debasement, instead it is more likely that it could be an indication of a regional variety in production techniques and/or resources availability. Unfortunately, as no coins from Alexandria for this time period have been examined a direct comparison is at present not possible.



Graph 5.1: Weight and silver (Ag) value for the coins of Ptolemy III.



Graph 5.2: Weight and bullion value for the coins of Ptolemy III.

5.1.4. Ptolemy IV

The coins that were sampled from the reign of Ptolemy IV number five in total - Cat. Numbers **90**, **102**, **103**, **104** and **105** (Table 5.4). The mint of Cat. Number **90** is unknown, whereas Cat. Numbers **102** and **103** were minted in Sidon. Cat. Numbers **104** and **105** come from the Alexandrian mint. The coins are in the date range of 220 BCE to 203 BCE. The denomination of all coins is tetradrachm. The weight of the coins falls between 13.52g to 14.13g with most coins weighing in the higher end of this scale. The silver percentages are between 95% to 98%. The bullion content for these coins is between 96.97% and 99.90% (Table 5.4).

Cat. Number **90** which is the lightest coin from this group contains the lowest level of silver - 95.05%. This coin also has the highest copper percentage of 2.98% and also the highest lead percentage – 1.52%. Compared to the remaining coins from this reign this coin is definitely the one with lowest silver content and silver bullion. An explanation of this difference is potential error during production or a regional variation, which is difficult to establish as the mint is unknown. Moreover, as noted throughout this thesis Svoronos' dating is on occasion questionable, and that what is observed here is a potential misdating, and that this coin should be ascribed to a later ruler. However, this does seem unlikely as Lorber (2018a) has not re-dated this coin, which means it does most likely belong to the reign of Ptolemy IV. A further reason for the lower silver content found in this coin could be a question of its typology e.g., that the composition is different because the coin type (issue) is different from the remaining four coins. Although this explanation if plausible it seems unlikely as all five coins are from different issues and if the issues had a direct bearing on the composition, then a larger diversity between these coins should have been observed. Finally, it should be considered that this is in actual fact a debased coin, but as it is a single coin, and as no similar compositional changes are observed in the remainder of the coins of Ptolemy IV or even Ptolemy V this interpretation remains unlikely.

In terms of composition-to-weight ratio no correlation can be observed. What is noticeable however is that the coins from the provincial mint of Sidon are very close both with regards to weight and composition (including levels of gold and bismuth contents) to the coins minted in Alexandria, which could be taken as an indication that

Cat. Number	Date (BCE)	Mint	Weight	Denomination	Ag	Au	Bi	Cu	Pb	Bullion
90	220	Uncertain	13.52g	Tetradrachm	95.05	0.37	0.031	2.98	1.52	96.97
102	221-203	Sidon	13.72g	Tetradrachm	98.44	0.46	0.001	0.16	0.92	99.81
103	221-204	Sidon	14.03g	Tetradrachm	98.39	0.65	0.001	0.12	0.81	99.85
104	219-217	Alexandria	13.78g	Tetradrachm	98.99	0.46	0.002	0.08	0.45	99.90
105	Uncertain	Uncertain	14.13g	Tetradrachm	97.73	0.49	0.017	1.39	0.36	98.60

Table 5.4: Silver (Ag), gold (Au), bismuth (Bi), copper (Cu), lead (Pb) and bullion values for the silver coins belonging to the reign of Ptolemy IV.

during the reign of Ptolemy IV, there could have been a centralisation of coin production.

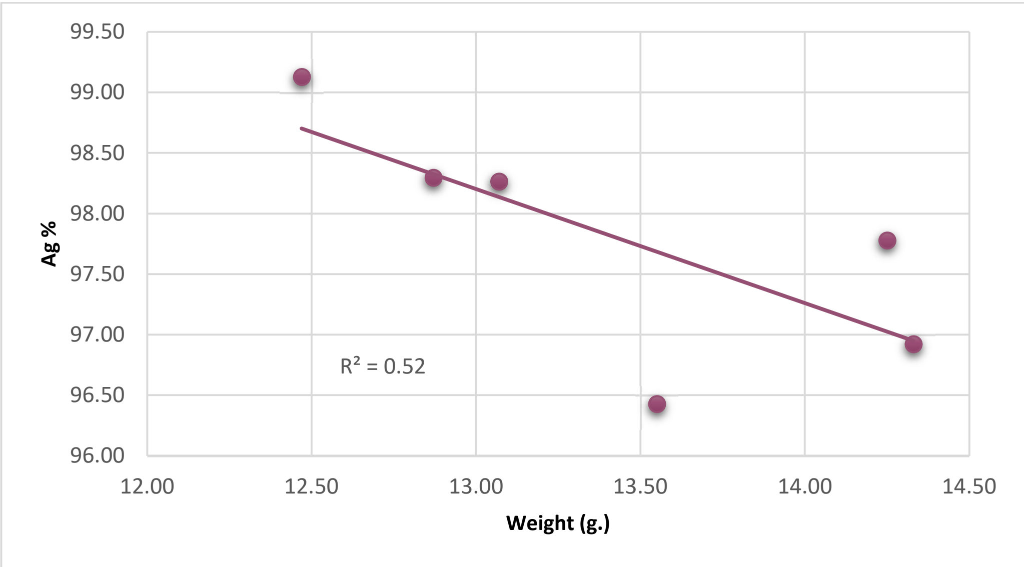
5.1.5. Ptolemy V

Six coins belonging to the reign of Ptolemy V (Cat. Numbers: **1**, **3**, **106**, **107**, **108** and **109**) in total were sampled (Table 5.5). These six coins come from three different mints: Cat. Numbers **1**, **107** and **108** are from the Alexandrian mint; Cat. Numbers **106** and **109** are from the mint in Cyrenaica and Cat. Number **3** is from the mint in Cition. The date range of the coins is from 203 BCE to 180 BCE. Here it must be noted that Cat. Number **3** was initially ascribed to the joint reign of Ptolemy VI and VIII, however based on weight as well as obverse and reverse imagery, this dating has been changed by the current author following Sv. 1349. All of the sampled coins are tetradrachms.

The weight range of these sampled coins is between 12.47g and 14.33g. What can be observed is that, unlike during the reign of Ptolemy IV, the coins minted in Alexandria are lighter than the coins minted in the provinces with the two coins from Cyrenaica being the heaviest in this group. When discussing the composition of these six coins it can be observed that the lightest coin (Cat. Number **1;** from the Alexandrian mint) has the highest silver percentage – 99.13%. In addition, the other two coins from Alexandria (Cat. Numbers **107** and **108**) have as observed the lowest weight of this group, yet they have the high silver percentages 98.30% and 98.26%. This correlation between weight and silver composition is potentially evident in Graph 5.3, where the correlation coefficient is 0.52. Although similarly to the previous correlation coefficients here regardless of the R^2 value the correlation coefficient is insignificant due to the sample size (for details see Fletcher and Lock, 1991: 109 and 184).

Cat. Number	Date (BCE)	Mint	Weight	Denomination	Ag	Au	Bi	Cu	Pb	Bullion
1	205-180	Alexandria	12.47g	Tetradrachm	99.13	0.67	0.004	0.07	0.11	99.91
3	203	Cition	13.55g	Tetradrachm	96.43	0.54	0.022	1.72	1.22	98.21
106	205-180	Cyrenaica	14.25g	Tetradrachm	97.78	0.60	0.015	0.85	0.75	99.14
107	205-180	Alexandria	12.87g	Tetradrachm	98.30	0.69	0.001	0.10	0.90	99.88
108	205-180	Alexandria	13.07g	Tetradrachm	98.26	0.57	0.004	0.71	0.43	99.27
109	205-180	Cyrenaica	14.33g	Tetradrachm	96.92	0.67	0.004	1.29	1.07	98.66

Table 5.5: Silver (Ag), gold (Au), bismuth (Bi), copper (Cu, lead (Pb) and bullion values for the silver coins belonging to the reign of Ptolemy V.



Graph 5.3: Weight and silver (Ag) value for the coins of Ptolemy V.

Cat. Number **3** has the lowest percentage of silver of this assemblage of coins – 96.43% and the highest copper (1.72%) and lead (1.22%) percentages respectively. As this is the only coin sampled from the mint in Cition, it cannot be determined whether this chemical composition was the norm or whether this coin is the result of a singular event. The two coins from Cyrenaica are as mentioned the heaviest, however they do not contain the highest percentages of silver (Cat. Number **106**: 97.78% and Cat. Number **109**: 96.92%). This latter coin is broadly similar to the coin from the Cition mint, silver composition in the 96% range and both copper and lead composition is over 1%. The bullion values for these coins are between 99.91% and 98.21% (Table 5.5). The gold composition for all of the sampled coins for this reign is very similar between 0.54% to 0.67%. Three of the coins (Cat. Numbers **1**, **108** and **109**) also contain the same amount of bismuth – 0.004%. This is interesting as they come from two different mints. Cat. Number **107** has the lowest bismuth content 0.001%, while Cat Numbers **3** and **106** have the highest amounts of bismuth – 0.022% and 0.015% and again both of these come from different mints. This coupled with the varied levels of lead could be taken as an indication that there were multiple sources for silver for this period and that their use was not mint-specific. In turn this could perhaps be a compositional indicator for the closed currency system (for details see section **2.2.**). This hypothesis will be explored further in the next chapter.

5.1.6. Ptolemy VI and Ptolemy VIII

Following the death of Ptolemy V, his eldest son Ptolemy VI (six years old at the time) co-ruled for a few years with his mother Cleopatra I until her death in 176 BCE (Hölbl, 2001: 143). Subsequently, two courtiers became co-regents of the young prince (Hölbl, 2001: 143). This led to a number of political problems for the young king (which will be discussed in more detail in Chapter 6) and eventually in 169 BCE Ptolemy VI was joined on the throne by his sister and wife Cleopatra II and their brother Ptolemy VIII (Hölbl, 2001: 182). This joint rule came to an end in 164 BCE when Ptolemy VIII became king of Cyrene (Hölbl, 2001: 184). Two coins were sampled from this period: Cat. Numbers **4** and **5**.

Both of the coins are from the Paphos mint and both are tetradrachms. Their weight is 13.37g (Cat. Number **4**) and 12.65g (Cat. Number **5**). The silver values are 98.83% (Cat. Number **4**) and 97.39% (Cat. Number **5**). The copper percentages do not exceed 2% (for more details see Appendix II) and the bullion values are 99.59% and 98.41%. The percentage of lead in these coins is under 1% and all the remaining elements are under 0.5% (see Appendix II).

Due to the small sample size and the provincial nature of the coins, the current research cannot definitively conclude that the silver coinage minted during this joint reign was not debased. However, based on the present results in addition to the fact that this period of co-ruling was short lived and on the available previous research (see section **3.4**) it seems that the silver coinage of this time saw no deliberate debasement.

5.1.7. Ptolemy VI

In 163 BCE the sole rule of Ptolemy VI began, and it lasted until his death in 145 BCE (Hölbl, 2001: 184-194). Six coins belonging to the solo reign of Ptolemy VI were sampled and analysed. These are Cat. Numbers: **2**, **87**, **88**, **89**, **114** and **115**. All of the coins come from the mint in Alexandria, however their exact date is unknown. Four of the sampled coins (Cat. Numbers **2**, **87**, **88** and **115**) are tetradrachms and two (Cat Numbers **89** and **114**) are didrachms. With the exception of the two didrachms (which both weigh more than 6.5g) the remaining four coins vary in weight between 12.00g to 14.00g.

Despite the different denominations and the varied weight, the coins all have a similar silver content in the vicinity of 98%. Cat. Number **89** has the lowest silver content - 97.53%. An unusual aspect of this coin is also that instead of a higher copper percentage and perhaps a slightly increased lead percentage to make up the slight dip in the silver which would be expected, the analysis shows instead a low copper amount (0.14%) but a significantly higher lead amount (2.15%). This unusual composition could be indicative as mentioned before of either an ore specification or of the level of refining of this coin. However, it would appear unlikely that the lead in this coin is indicative of a 'dry ore' as the gold amount within this coin is too low for this type of ore (Butcher and Ponting, 2014: 102). Another option is that the lead amount could be indicative of the use of recycled silver (Ponting, 2009: 279), an explanation which in turn could be seen as potential evidence for the existence of a closed currency system.

A further indication of the 'purity' of the coins for this ruler is the bullion values all in the 99% (Table 5.6). The gold content for these coins is quite unified, falling between 0.75% and 0.82%, the only exception being Cat. Number **89** where the gold amount is only 0.11%. The bismuth content for four of the coins (Cat. Numbers **87**, **88**, **114** and **115**) is the same – 0.001%, Cat. Number **2** has a slightly higher amount – 0.007%. Finally, Cat. Number **89** has the highest bismuth content – 0.05%. This higher bismuth amount in Cat. Number **89** could perhaps be taken as a further evidence that despite the high lead amount this is not a coin minted from a 'dry ore' as this would have resulted in a lower bismuth level (Butcher and Ponting, 2014: 102). The copper content in these coins is quite homogenous with amounts between 0.11% to 0.17 %. Although

Cat. Number	Date (BCE)	Mint	Weight	Denomination	Ag	Au	Bi	Cu	Pb	Bullion
2	Uncertain	Alexandria	14.21g	Tetradrachm	98.75	0.82	0.007	0.04	0.35	99.92
87	Uncertain	Alexandria	12.77g	Tetradrachm	98.92	0.78	0.001	0.17	0.10	99.80
88	Uncertain	Alexandria	14.23g	Tetradrachm	98.66	0.75	0.001	0.07	0.50	99.90
89	Uncertain	Alexandria	6.82g	Didrachm	97.53	0.11	0.050	0.14	2.15	99.85
114	Uncertain	Alexandria	6.64g	Didrachm	98.95	0.79	0.001	0.11	0.13	99.87
115	Uncertain	Alexandria	13.48g	Tetradrachm	98.82	0.77	0.001	0.14	0.25	99.84

Table 5.6: Silver (Ag), gold (Au), bismuth (Bi), copper (Cu), lead (Pb) and bullion values for the silver coins belonging to the reign of Ptolemy VI.

two of the coins (Cat. Numbers **2** and **88**) have lower copper values. The lead amounts are varied but most of the values are between 0.10% to 0.50%, the only exception is again Cat. Number **89** the characteristics of which are explained above.

5.1.8. Ptolemy VIII

Ptolemy VIII became king after the death of his brother in 145 BCE and he remained so until his death in 116 BCE. Five coins in total were sampled for his sole reign – Cat. Numbers **92**, **110**, **111**, **112** and **113** (Table 5.7). Four of the sampled coins are from the mint in Alexandria (Cat. Numbers **110**, **111**, **112** and **113**) and one is from the mint in Cition (Cat. Number 92).

The coins cover a relatively wide time-span, from 143 BCE to 119 BCE and all of the sampled coins are tetradrachms. Their weight is between 13g to 14g, most of the coins being closer to the latter. In terms of chemical composition these five coins vary significantly. The highest percentage of silver is 95.55% and the lowest 89.98%. There is no weight to silver composition ratio. The only visible correlation is for the heaviest, coin number **110,** which has the lowest silver content (89.98%) and the highest copper (7.11%) and lead (2.31%) content.

This varied compositional analysis could potentially be ascribed to dating, namely that the coins from the start of the reign have a higher silver content, which decreases towards the end of Ptolemy VIII's reign. This can perhaps tentatively be supported here as the coins from begging of Ptolemy VIII's reign are the ones with the highest bullion content (Cat. Numbers **92** and **113**). However, the remaining three coins do not appear to follow this pattern. Whatever the reason behind these compositional

Cat. Number	Date (BCE)	Mint	Weight	Denomination	Ag	Au	Bi	Cu	Pb	Bullion
92	143-142	Cition	14.14g	Tetradrachm	95.53	0.19	0.31	2.31	1.63	97.66
110	132-131	Alexandria	14.42g	Tetradrachm	89.98	0.48	0.04	7.11	2.31	92.80
111	122-121	Alexandria	14.15g	Tetradrachm	93.76	0.46	0.16	4.05	1.54	95.92
112	120-119	Alexandria	13.40g	Tetradrachm	92.22	0.46	0.09	4.73	2.25	95.02
113	133-132	Alexandria	14.38g	Tetradrachm	95.55	0.17	0.31	3.26	0.67	96.70

Table 5.7: Silver (Ag), gold (Au), bismuth (Bi), copper (Cu), lead (Pb) and bullion values for the silver coins belonging to the reign of Ptolemy VIII.

variations, one thing can be stated with certainty: during the reign of Ptolemy VIII the first clear evidence of debasement of the silver currency can be observed. This is in particular evident after the bullion values are taken under consideration (Table 5.7).

The coin that illustrates debasement best is Cat. Number **110** with 7.11% copper and a bullion value of 92.80%. Another example albeit a tentative one can also be Cat. Number **112** as its copper value is nearly 5% and the bullion value is 95.02%. These two coins also have the highest lead amounts, the remaining three coins have more varied lead amounts, which makes it difficult to conclude the extent to which the lead amounts are related to the overall bullion composition. Returning to Cat. Numbers **110** and **112** if the gold values are taken under consideration in addition to the lead values, a possible explanation for the high lead content suggests itself: namely that the silver used in the manufacture of these particular coins was extracted from a 'dry' ore source (Butcher and Ponting, 2014: 102). Another possible explanation, which would be relevant for all the sampled coins, could be that the amounts of lead is varied because the silver used in the production of these coins was recycled and that the lead was a deliberate addition (Ponting, 2009: 279).

5.1.9. Ptolemy IX

Only two coins from this ruler were sampled namely Cat. Numbers **116** and **117.** Both of the coins were minted in Alexandria and they can be dated to 116-115 BCE (for Cat. Number **117**) and 115-114 BCE (for Cat. Number **116**) which places them in the first half of Ptolemy IX's reign. As mentioned in the introduction to this chapter Ptolemy IX reigned twice, although unfortunately no coins belonging to the second of his reigns could be sampled for the present work. Both of these coins are tetradrachms.

Cat. Number **116** weighs 14.19g and Cat. Number **117** weighs 13.79g. Their composition is similar with 95.42% silver for Cat. Number **116** and 93.52% silver for Cat. Number **117**. The copper content is 3.33% (**116**) and 4.44% (**117**). The bullion content for Cat. Number **116** is 96.64% and for Cat. Number **117** is 95.52%. When debasement is considered in the context of these two coins it is clear based on their copper levels that both of these coins were debased.

So, it would appear that the composition alteration of adding copper, that started with Ptolemy VIII continued through the reigns of his successors.

5.1.10. Ptolemy X

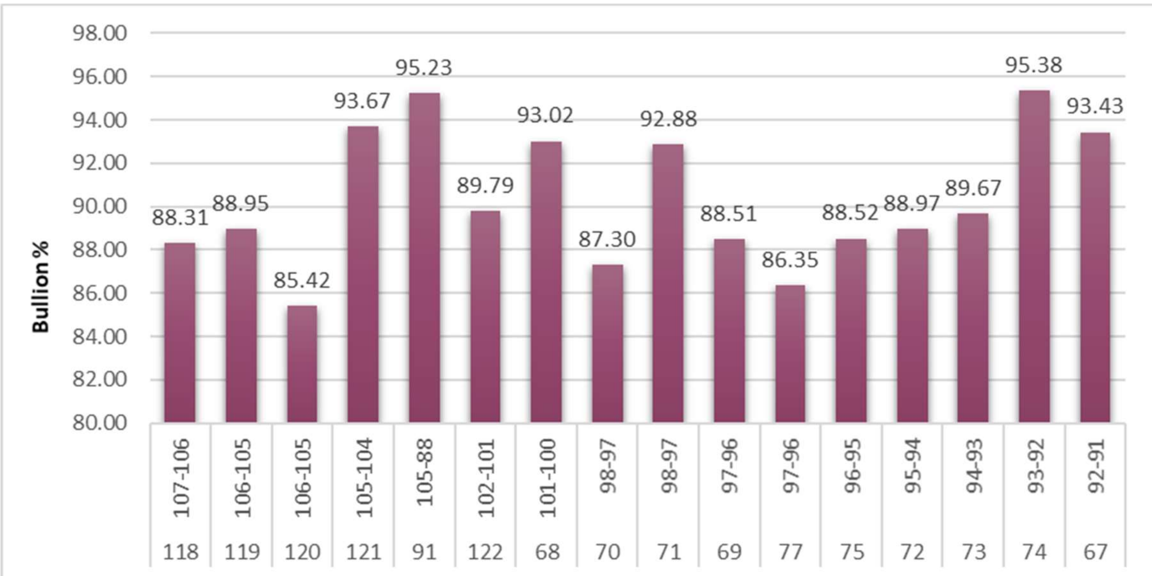
Sixteen coins ascribed to the reign of Ptolemy X were sampled - Cat. Numbers: **67**, **68**, **69**, **70**, **71**, **72**, **73**, **74**, **75**, **77, 91**, **118**, **119**, **120**, **121** and **122** (Table 5.8). All of the coins, with the exception of one, were minted in Alexandria. The coin that is not from those mints is Cat. Number **91** and according to Svoronos it was minted in Cyprus but the exact mint is not specified. These coins represent a significant part of Ptolemy X's reign spanning from 107 BCE to 91 BCE. All of the coins – with the exception of coin **91** – are tetradrachms. Coin **91** is a didrachm.

The weight of these coins fluctuates with the lightest coin being the didrachm weighing 6.74g and the heaviest Cat. Number **118**, weighing 18.85g. The composition of these coins is also relatively varied, with silver contents between 93.51% and 74.70% and copper contents between 23.41% and 4.42%. The amount of lead remains mostly steady around 1.5% although there are three exceptions (Cat. Numbers **68**, **77** and **120**) in which the lead content is 2% or more. No direct correlation between the weight of these coins and their composition can be made. What can be observed though is that the didrachm (Cat. Number **91**) has the highest silver content, and the lowest copper content.

A very tentative connection between the date of the coins and their bullion composition could perhaps also be made (Graph 5.4): At the start of the period (107 BCE to 106 BCE) the bullion values in the sampled and analysed coins falls between 88%-85%. From about c. 105-104 BCE there appears to be an increase of the bullion content with

Cat. Number	Date (BCE)	Mint	Weight	Denomination	Ag	Au	Bi	Cu	Pb	Bullion
67	92-91	Alexandria	13.41g	Tetradrachm	91.82	0.04	0.11	6.46	1.46	93.48
68	101-100	Alexandria	13.45g	Tetradrachm	90.55	0.41	0.06	6.86	2.00	93.45
69	97-96	Alexandria	13.70g	Tetradrachm	86.46	0.49	0.07	11.34	1.50	89.01
70	98-97	Alexandria	13.80g	Tetradrachm	85.60	0.37	0.11	12.59	1.22	87.67
71	98-97	Alexandria	13.08g	Tetradrachm	90.67	0.50	0.09	7.04	1.62	93.38
72	95-94	Alexandria	13.44g	Tetradrachm	86.84	0.07	0.08	10.94	1.98	89.04
73	94-93	Alexandria	13.27g	Tetradrachm	88.09	0.12	0.08	10.22	1.38	89.79
74	93-92	Alexandria	12.99g	Tetradrachm	93.41	0.18	0.07	4.56	1.72	95.55
75	96-95	Alexandria	13.43g	Tetradrachm	86.71	0.07	0.08	11.37	1.66	88.59
77	97-96	Alexandria	12.36g	Tetradrachm	83.84	0.29	0.10	13.55	2.13	86.64
91	105-88	Cyprus	6.74g	Didrachm	93.51	0.33	0.15	4.42	1.23	95.56
118	107-106	Alexandria	14.38g	Tetradrachm	86.30	0.42	0.06	11.63	1.53	88.74
119	106-105	Alexandria	18.85g	Tetradrachm	86.95	0.09	0.09	10.95	1.81	89.04
120	106-105	Alexandria	14.23g	Tetradrachm	82.85	0.22	0.10	14.43	2.25	85.64
121	105-104	Alexandria	13.70g	Tetradrachm	91.65	0.29	0.14	6.28	1.59	93.97
122	102-101	Alexandria	14.33g	Tetradrachm	87.66	0.32	0.06	10.13	1.74	90.13

Table 5.8: Silver (Ag), gold (Au), bismuth (Bi), copper (Cu), lead (Pb) and bullion values for the silver coins belonging to the reign of Ptolemy X.



Graph 5.4: Bullion values in chronological order for the coins of Ptolemy X.

percentages in the 93% range however, from c. 97-96 BCE another decrease can be observed. This decrease does not last long and around 93-92 BCE there is a further increase of the bullion content. The coin with the highest bullion value is Cat. Number **74**. This coin can be dated towards the end of Ptolemy X's reign. This coin as well as the preceding and following coins (Graph 5.4) could be used to suggest an attempt of increasing the bullion values in the coins and stabilizing their rather erratic composition. This is however, is difficult to determine for certain as no coins after 91 BCE were analysed. This leaves a three years gap until the end of Ptolemy X's reign (88 BCE) and additionally as no coins of the second half of Ptolemy IX's reign were sampled the gap becomes approximately 10 years. During this time, it is unclear if the bullion values were stabilised in mid-90% or if the trend of increase and decrease continued.

A further interesting point in the coins analysed from Ptolemy X reign is that there are three sets of coins that share a date. These are*:* Cat. Numbers **119** and **120** (106-105 BCE), Cat. Number **70** and **71** (98-97 BCE) and Cat. Numbers **69** and **77** (97-96 BCE). The difference in the bullion content in the coins from 106-105 BCE is slightly more than 3.5%, for the coins from 98-97 BCE the difference is slightly over 5.5% while the set from 97-96 BCE has a difference in bullion percentage of only 2.2%. A potential reason for this difference is that in two of the three sets the coins that are heavier are also the coins that have the higher bullion value. That is the case for Cat. Numbers **119** (18.85g) and **120** (14.32g) and for Cat. Numbers **69** (13.73g) and **77** (12.36g), however that does not appear to be the case for Cat. Numbers **70** (13.80g) and **71** (13.08g) where the lighter coin is the one containing the highest bullion value. It should also be noted that the difference in weight in Cat. Numbers **74** and **78** is only 0.05g so to what extent this really would have influenced the composition is questionable.

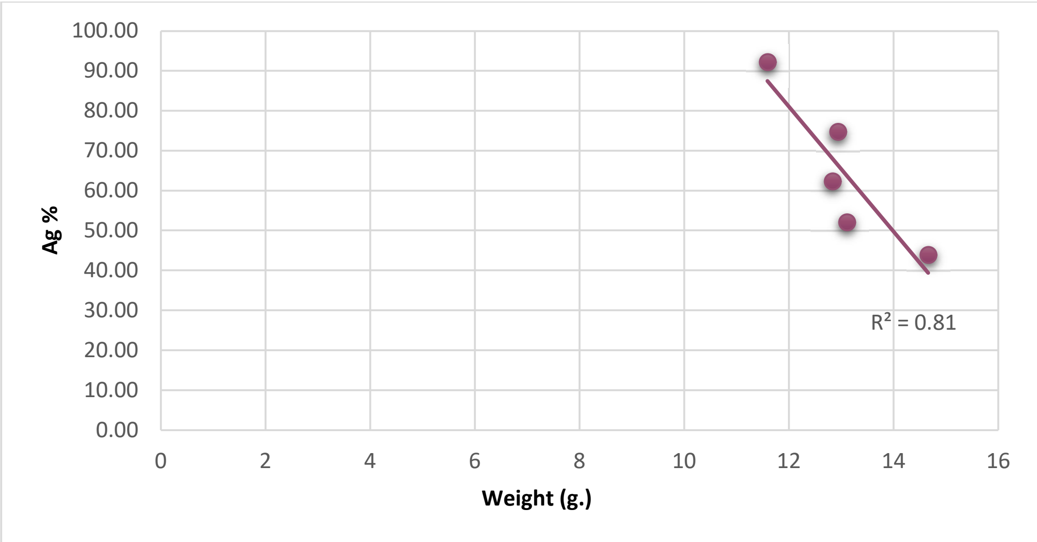
Another reason for the discrepancies in these sets of coins could perhaps be linked to the *al marco* system of weighing and could in turn be used to indicate that the coins were weighed together and not individually. Regardless what the data clearly shows is that by this point in Ptolemaic history the silver content was going through some rapid increases and decreases in very short amounts of time. However, even though some of bullion values in the analysed coins are in 90% range, they are still not as high as at the start of the Ptolemaic period.

5.1.11. Ptolemy XII

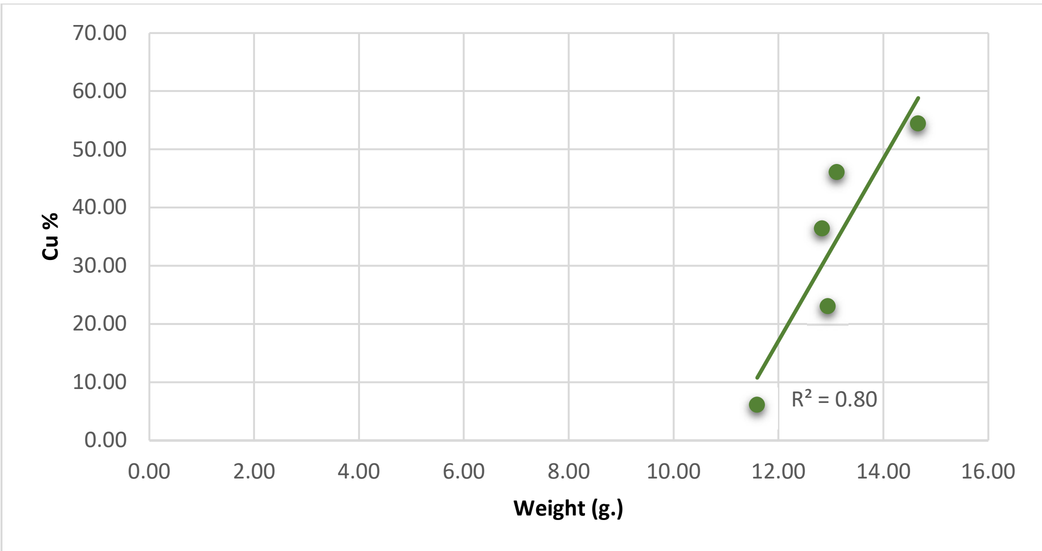
Five coins from the reign of Ptolemy XII were sampled, these being Cat. Numbers: **78**, **93**, **94**, **95** and **123** (Table 5.9). All of the coins come from the mint in Alexandria.

Cat. Number	Date (BCE)	Mint	Weight	Denomination	Ag	Au	Bi	Cu	Pb	Bullion
78	60-59	Alexandria	12.94g	Tetradrachm	74.70	0.049	0.031	23.11	1.84	76.84
93	52-51	Alexandria	14.66g	Tetradrachm	43.90	0.064	0.043	54.48	1.20	45.39
94	64-63	Alexandria	11.59g	Tetradrachm	92.19	0.010	0.108	6.17	1.23	93.81
95	55-54	Alexandria	12.83g	Tetradrachm	62.32	0.029	0.033	36.46	0.95	63.48
123	53-52	Alexandria	13.11g	Tetradrachm	52.02	0.085	0.025	46.09	1.28	53.72

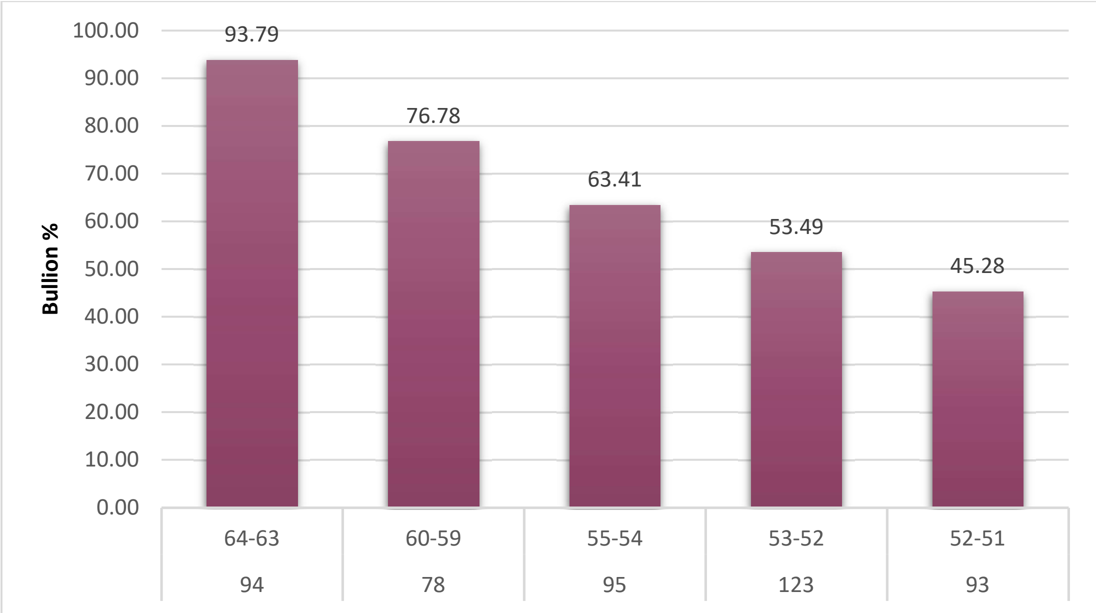
Table 5.9: Silver (Ag), gold (Au), bismuth (Bi), copper (Cu), lead (Pb) and bullion values for the silver coins belonging to the reign of Ptolemy XII.



Graph 5.5: Weight and silver (Ag) value for the coins of Ptolemy XII.



Graph 5.6: Weight and copper (Cu) value for the coins of Ptolemy XII.



Graph 5.7: Bullion values in chronological order for the coins of Ptolemy XII.

They are dated to between 64 BCE and 51 BCE. The coins weigh between 11g to 14g. Their composition is wide-ranging with the highest percentage of silver being 92.19% and the lowest 43.90%. A correlation between the weight of the coins and their silver and copper content can be observed (Graphs 5.5 and 5.6). However, this correlation between weight and silver composition and weight and copper composition similarly to the previous correlation coefficients regardless of the R^2 value is insignificant due to the sample size (for details see Fletcher and Lock, 1991: 109 and 184).

The bullion values are between 93.79% and 45.28% (Table 5.9). A clear relation between the bullion composition and the dates of these sampled coins can be observed (Graph 5.7). It is clear that the earlier coins have a higher bullion content that then decreases steadily through the period. The mid 90% bullion content in Cat. Number **94**, could additionally further the suggestion made above that Ptolemy X attempted to stabilise the coin content towards the end of his reign. However, the debasement of silver coinage is undeniable here and the best example for this is Cat. Number **93** in which the missing 10% of silver is replaced by almost the exact amount of copper.

The lead percent for all the sampled coins is between 0.95% and 1.8%, while the rest of the trace elements are all under 0.5%. These coins present clear evidence of debasement, although unfortunately, due to the lack of any coins sampled from provincial mints for this period, it cannot be stated whether this debasement encompassed the whole of the Ptolemaic empire, or whether it was exclusive to the coins minted in Alexandria.

5.1.12. Cleopatra VII

The coins sampled from the reign of Cleopatra VII are seven in total: Cat. Numbers: **76**, **79**, **80**, **81**, **124**, **125** and **126** (Table 5.10). All of the sampled coins with the exception of one (Cat. Number **125**) come from the Alexandrian mint. Cat. Number **125** was minted at Antioch in northern Syria (RPC I 4094, see also an extensive discussion of the minting of Cleopatra VII and Mark Antony coinage in northern Syrian both in Butcher, 1991: 78-80 and Butcher, 2004) as opposed to the Cyrenaica mint suggested by Svoronos (Sv. 1897). Overall, the sampled coins date from 47 BCE to 36 BCE, representing an 11-year span of Cleopatra VII's reign. Six of the coins are tetradrachms (Cat. Numbers **76**, **79**, **80**, **81**, **124** and **125**) Finally, Cat. Number **126** is a didrachm. The weight of these coins is between 12g and 14g, with the didrachm weighing 2.98g.

The composition of these coins is relatively similar across the sample, with a silver content of around 30%. However, the exception is Cat. Number 125, which has the highest silver content of 68.5% (and a bullion value of 70.43%) and the lowest copper content of 29.48%. This relatively high bullion value is due to the Syrian origin of this coin as discussed above: A similar composition with a silver fineness of roughly 67-70% was also noted in Syrian tetradrachms from 47 BCE onwards (Ponting and Butcher, 2014: 604 and Table 19.28). The lead content for all these coins is around 1.5% and the remaining trace elements are all under 0.5%. One thing however is made very clear by these seven silver coins, namely that the silver content continues, in most of the cases, to follow the downward trajectory from the previous few rulers and that they are compositionally significantly different from the coins of the earlier Ptolemaic rulers.

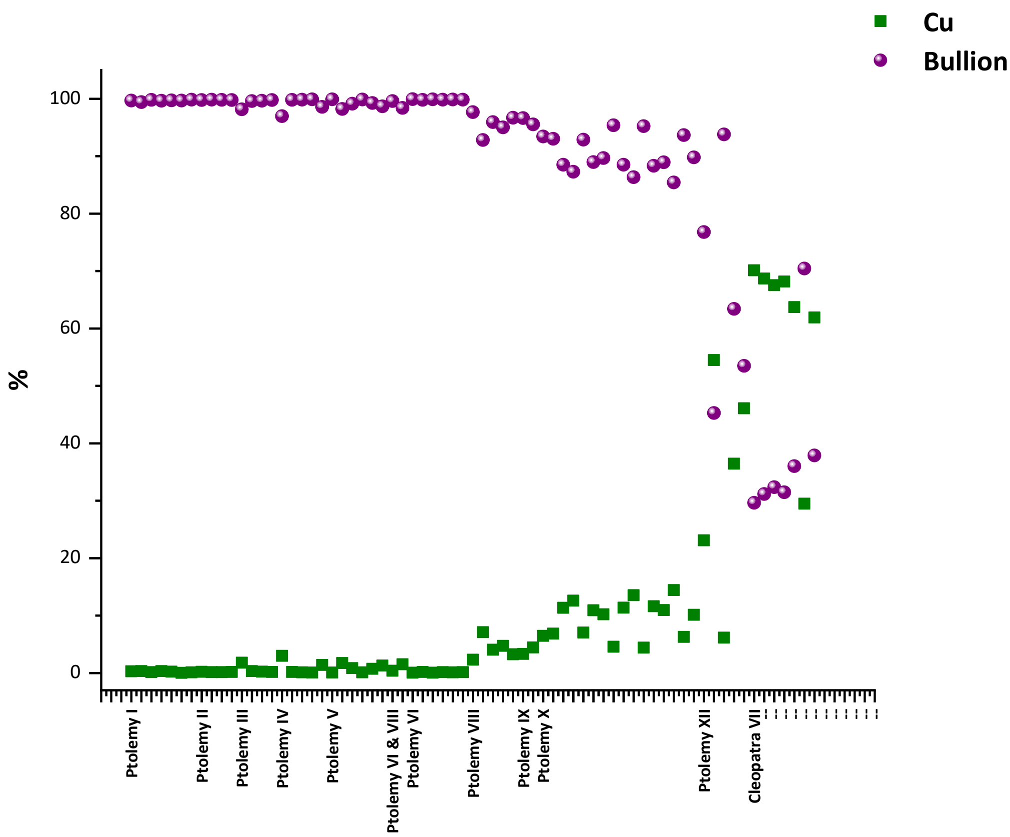
Cat. Number	Date (BCE)	Mint	Weight	Denomination	Ag	Au	Bi	Cu	Pb	Bullion
76	37-36	Alexandria	13.85g	Tetradrachm	28.58	0.13	0.03	70.14	0.90	29.63
79	37-36	Alexandria	13.07g	Tetradrachm	29.52	0.14	0.04	68.69	1.47	31.17
80	42-41	Alexandria	12.66g	Tetradrachm	31.02	0.15	0.03	67.52	1.15	32.35
81	42-41	Alexandria	12.73g	Tetradrachm	29.91	0.15	0.01	68.19	1.41	31.49
124	37-36	Alexandria	14.09g	Tetradrachm	34.75	0.13	0.03	63.73	1.14	36.04
125	Uncertain	Syria	14.30g	Tetradrachm	68.54	0.27	0.02	29.48	1.59	70.43
126	47-46	Alexandria	2.98g	Drachm	36.79	0.13	0.02	61.92	0.94	37.88

Table 5.10: Silver (Ag), gold (Au), bismuth (Bi), copper (Cu), lead (Pb) and bullion values for the silver coins belonging to the reign of Cleopatra VII.

5.2. Discussion of Silver Results

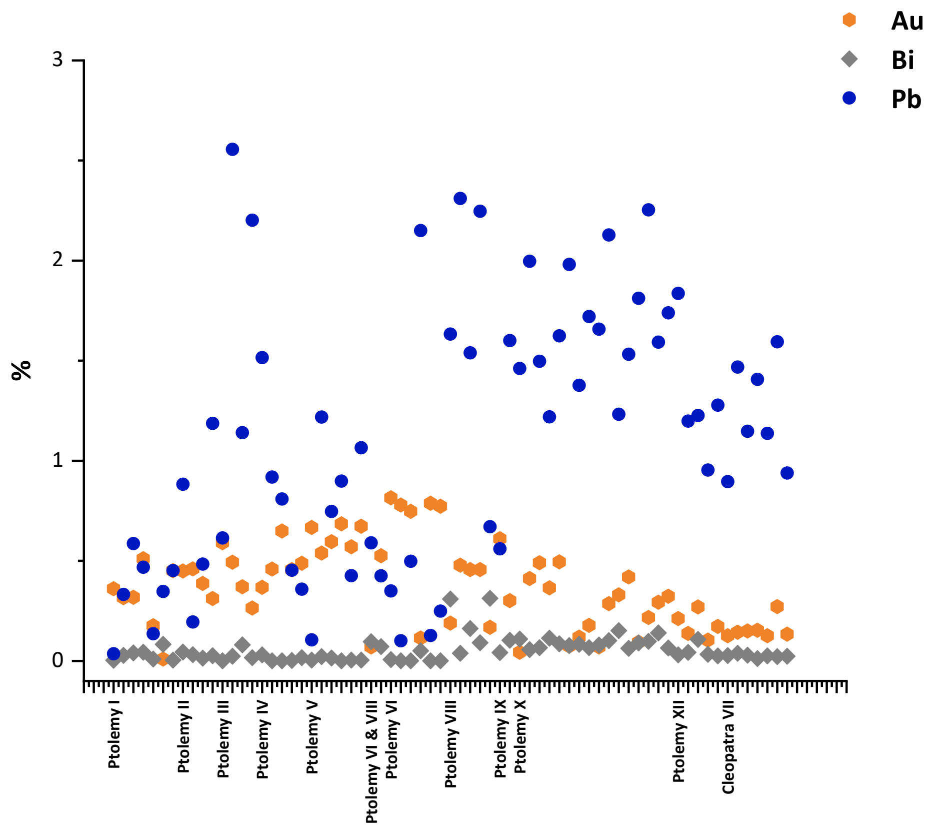
The results of the analysis of the sampled silver material clearly illustrates that there was extensive debasement of this type of Ptolemaic coinage. The question that is perhaps more prudent is what can be considered as a beginning to this debasement. Based on the scatter plot presented below (Graph 5.8) this start date could be ascribed to the rule of Ptolemy VII (145-132 BCE). As mentioned in the relevant section for this ruler, five coins were sampled and of those five, four have over 2% copper content. This as noted at the start of the chapter is direct indication of debasement. Additionally, to this increased copper content the silver bullion as a whole begins to decrease with values reaching 92.80%.

However, here it must be stated that these four coins in question all come from the Alexandrian mint, making it difficult to determine if this observable compositional change was solely implemented in the Egyptian capital or if this was the case for the whole of the Ptolemaic empire. The only provincial coin sampled and analysed for this ruler is Cat. 92 and although here the copper content is 2.30%, this amount is too low to indicated deliberate debasement. But this as this is only one provincial coin, this



Graph 5.8: The overall percentage content of silver bullion and copper (Cu) in the analysed sample set.

result cannot be taken as an indication that the coins in the provinces were not debased. Regardless, Graph 5.8 clearly illustrates that from Ptolemy VIII silver bullion began declining, while the copper amounts began increasing. Further to the silver and copper compositions there are a few potential points of interest with regards to the trace elements that should be examined. The first one of these is the lead content in the sampled material. The first noticeable significant amount of this metal that was observed was in the coins of Ptolemy III, where three of the four sampled coins contain a significant amount of lead, from 1% to 2.5%. These coins are from the provincial mints of Jaffa and Sidon, with the coins from Jaffa containing 2% lead and above, a feature which could potentially be ascribed to regional variation. The content of lead remained relatively steady (usually around 0.5%) with an occasional 1% or 2% visible for a specific coin throughout the reigns of Ptolemy IV, V, VI and VIII and VI. This changed during the reign of Ptolemy VIII onward when a lead content of between 1% to 2% (or over) became more the norm than the exception (Graph 5.9). As mentioned



Graph 5.9: The overall percentage content of gold (Au), bismuth (Bi) and lead (Pb) in the analysed sample set.

in the relevant sections above the reason for these different lead amounts could be either due to the silver ore used or due to the refining process during production. For example, if the silver used in these coins was extracted from lead ores (argentiferous) using a process known as cupellation (Craddock, 2008: 104; see section **4.3.)** the silver had to be refined, but if the refining was done on larger scale, it would become more difficult to remove the lead and this could explain the higher quantity of lead in some of these coins. As a general rule if the lead content is 0.5% or less this can be taken as an indication of a thorough refining process, but if the lead content is more than 1% this demonstrates a less accurate refining method (Butcher and Ponting, 2014: 33).

Furthermore, if the gold and bismuth compositions are taken under consideration alongside the lead composition, a further indication of the type of ore used to extract silver can be provided: namely the above-mentioned ‘dry’ ores. Dry ores would have contained silver, but unlike the argentiferous ores would not have needed cupellation and so "would have retained their original chemical and isotopic signature" (Butcher and Ponting, 2014: 102). The gold percentage from this type of ore is commonly around 0.5% with a lead signature of up to 2.5% – another possible explanation for the above-mentioned high values of lead (Butcher and Ponting, 2014: 102). Most of the sampled coins contain around 0.5% gold, although this amount begins to decline around the reign of Ptolemy X (Graph 5.9). It must be noted that bar the specifically mentioned coins, the lead amounts in these sampled and analysed coins are on the low side, making it difficult to determine for certain if this type of ore was the main source of silver for these coins.

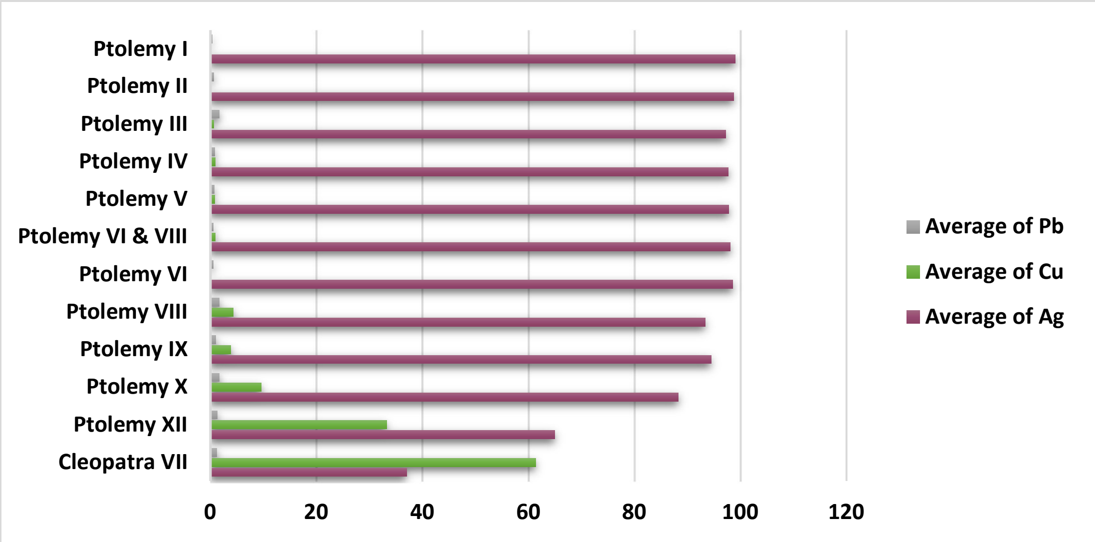
Moreover, it must be stated that determining the ore from which the silver in the Ptolemaic coinage came is potentially extremely problematic. Due to the lack of silver ores is Egypt, much of the raw material utilised in the production of new coins could have been acquired by reminting foreign and outdated silver coinage in the so-called closed currency system (for more details see section **2.2.**). The lead composition in these sampled and analysed coins could then perhaps be indicative of this process – rather than evidence of a specific ore type, as lead was commonly used in the extraction of silver from recycled coins (Ponting, 2009: 279). This hypothesis could explain the varied nature of the observed composition not only through the period but often within individual reigns as well. This theory in addition to the available evidence for the closed currency system will be examined further in Chapter 6.

When comparing the current results to previous examinations of the chemical composition of Ptolemaic silver coins it must first be noted that none of the scholars who have previously analysed this type of coinage have provided bullion values, or in any way discussed these in their work. As such it is not possible to compare the bullion values of the current project with previous research. Instead, comparisons will be made between the individual values of silver, copper and lead.

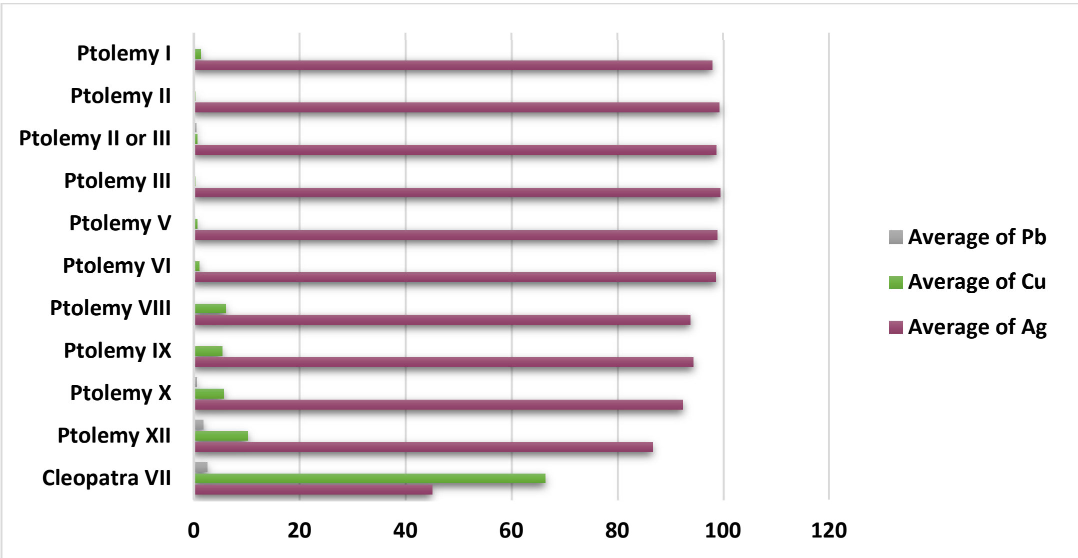
The first comparison which can be made is to Hazzard's (1995) research, the problems and limitations of which are discussed in detail in section **3.4.**. The most obvious is Hazzard's theory regarding debasement, which states that there were three stages: the first stage, dating around 149-148 BCE (from 100% silver to around 98%), the second stage occurring in 137-136 BCE (from 98% to 90%) and the third stage to 53-52 BCE (from 90% to 33%) (Hazzard, 1995: 51-52). As stated above the current research does not indicate a significant change prior to 145 BCE. In addition, the material sampled and analysed by Hazzard contains some significant chronological gaps, for example: While a large number of coins are listed as belonging to the reigns of Ptolemy II and Ptolemy III, there were no coins analysed belonging to the reigns of Ptolemy IV or the joint reign of Ptolemy VI and VIII, and the overwhelming amount of the material on which Hazzard bases his conclusions dates from the reigns of Ptolemy XII and Cleopatra VII (see for more details Table 5.11).

A further issue with Hazzard's data is, as illustrated by Table 5.11, that most of the results of the analysed coins from the reigns of Ptolemy XII and Cleopatra VII in particular lack the amounts of copper and/or gold, making it difficult to determine how much copper was actually used in the debasement of these coins. Also, the lack of bismuth and frequently the lack of lead in Hazzard's results, coupled with the fact that he did not record the amount of gold present in the coins for the last two rules makes it impossible to calculate the bullion values for these analysed coins.

Graphs 5.10 and 5.11 represent the average of the analysis from the current research compared with the average for the results presented by Hazzard. Some slight differences are clearly visible: For example, Hazzard's data suggests a slightly elevated amount of copper in the silver coins dating to the reigns of Ptolemy VIII, IX and Cleopatra VII as well as some higher amounts of silver in the coins of Ptolemy X and XII compared to what can be observed in the present research. However, while the results are not by any means completely identical, and while Hazzard's results do not contain any bullion values, both sets of data nevertheless demonstrate similar points, namely a decrease of silver and an increase in copper content which can clearly be linked to the reign of Ptolemy VIII.



Graph 5.10: Average composition for silver (Ag) copper (Cu) and lead (Pb) in the current research on silver Ptolemaic coinage.



Graph 5.11: Average composition of silver (Ag), copper (Cu) and lead (Pb) adapted from Table 1 (Hazzard, 1990: 100-102).

Reign	Date	Mint	Weight	Ag	Cu	Au	Pb
Ptolemy I	c. 312-300	Alexandria	15.587g	95.1	2.7	2.2	
Ptolemy I	c. 312-300	Alexandria	15.678	98.6	1	0.6	
Ptolemy I	c. 300-282	Alexandria	14.744	99.4	0.3	0.6	
Ptolemy I	c. 300-282	Alexandria	14.942	98.4	1	0.6	
Ptolemy II				99.1	0.36	0.1	
Ptolemy II			13.097	99.4	0.3	0.6	
Ptolemy II	265-264	Alexandria	3.28	99.2	0.2	0.8	
Ptolemy II	255-254	Sidon	14.058	99.4	0.3	0.6	
Ptolemy II or III		Alexandria		98.3	0.24	0.72	0.72
Ptolemy II or III		Alexandria		98.2	0.2	0.71	0.88
Ptolemy II or III		Alexandria	32.811	99.6	0.2	0.4	
Ptolemy II or III		Alexandria		99.5	0.2	0.35	0.15
Ptolemy II or III		Alexandria		98.9	0.68	0.45	0.1
Ptolemy II or III		Alexandria		97.8	2.2	0.14	0.15
Ptolemy III	246-222	Alexandria	13.853	99.4	0.3	0.6	
Ptolemy V	204-200	Coele-Syria	12.825	99.2	0.3	0.8	
Ptolemy V	204-201	Coele-Syria	13.468	98.5	0.9	0.6	
Ptolemy VI	c.155	Alexandria	13.699	98.1	0.9	1	
Ptolemy VI	160-159	Kition		99	0.95		
Ptolemy VI	160-160	Kition		99.8	0.22		
Ptolemy VI	158-157	Kition	14.3	99	0.95		
Ptolemy VI	156-155	Salamis	13.789	98.2	1.4	0.4	
Ptolemy VI	153-152	Salamis	12.195	99.1	0.6	0.3	
Ptolemy VI	153-152	Paphos	14.3	98.9	1.08		
Ptolemy VI	150-149	Alexandria	13.93	98.6	0.8	0.6	
Ptolemy VI	149-148	Paphos	14.289	99	0.6	0.4	
Ptolemy VI	149-148	Paphos	13.11	99.14	0.37	0.24	
Ptolemy VI	149-148	Kition	12.841	97.2	2.4	0.4	

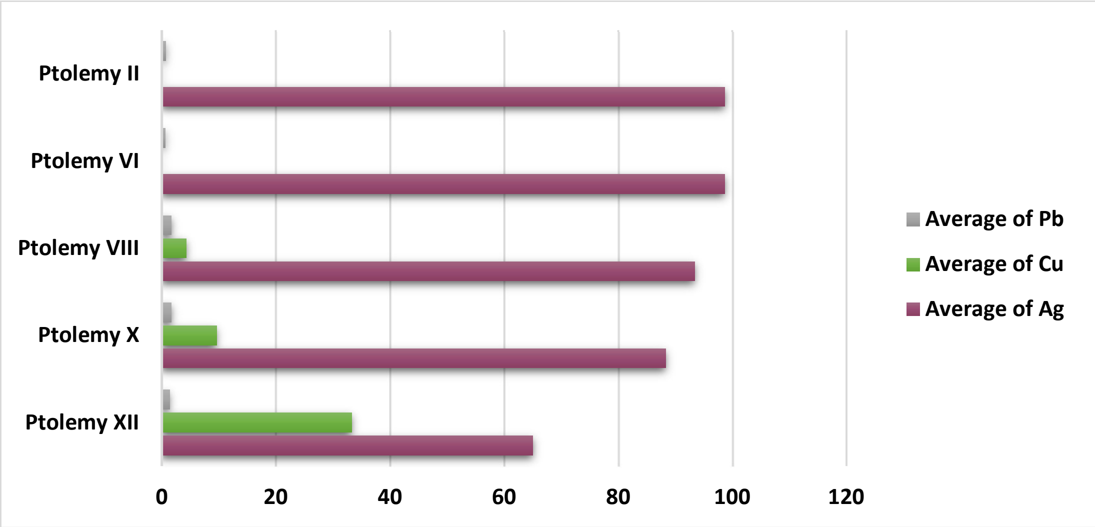
Reign	Date	Mint	Weight	Ag	Cu	Au	Pb
Ptolemy VI	149-148	Alexandria		97.6	2.34		
Ptolemy VIII	141-140	Kition	13.842	97.4	1.8	0.8	
Ptolemy VIII	140-139	Kition	13.123	97.6	1.8	0.6	
Ptolemy VIII	139-138	Kition		98	1.99		
Ptolemy VIII	139-138	Salamis		97.4	2.62		
Ptolemy VIII	138-137	Salamis	14.189	97.5	1.9	0.6	
Ptolemy VIII	138-137	Kition	14.18	97.6	2.39		
Ptolemy VIII	137-136	Salamis	14.05	92.3	7.39		
Ptolemy VIII	137-136	Kition	14	86.7	13.32		
Ptolemy VIII	133-132	Paphos		96	4.04		
Ptolemy VIII	132-131	Salamis	13.75	96	4.04		
Ptolemy VIII	127-126	Kition		93.2	6.78		
Ptolemy VIII	126-125	Salamis	13.832	90.8	8.8	0.4	
Ptolemy VIII	123-122	Paphos		88.8	11.23		
Ptolemy VIII	120-119	Paphos	12.9	96.3	3.73		
Ptolemy VIII	119-118	Salamis		93	6.97		
Ptolemy VIII	119-118	Kition		82.2	17.78		
Ptolemy IX	109-108	Alexandria	14.218	92.1	7.7		
Ptolemy IX	108-107	Alexandria	12.614	95.9	3.7	0.2	
Ptolemy X	107-106	Alexandria	13.884	94.1	5.6	0.3	
Ptolemy X	102-101	Alexandria	12.91	90.66	5.74	0.84	0.54
Ptolemy IX	98-97	Alexandria	13.364	96.1	3.7	0.2	
Ptolemy IX	98-97	Alexandria	12.612	93.13	6.52	0.05	
Ptolemy XII	80-79	Alexandria	14.03	84			1.25
Ptolemy XII	80-79	Alexandria	12.26	91			2.5
Ptolemy XII	79.78	Alexandria		87.8	12.16		
Ptolemy XII	76-75	Alexandria	12.901	88.42	10.24	0.07	
Ptolemy XII	75-74	Alexandria	13.56	90			1
Ptolemy XII	75-74	Alexandria	13.26	93			2.75
Ptolemy XII	75-74	Alexandria	13.95	92.5			1.5
Ptolemy XII	74-73	Alexandria	13.65	97			0.5
Ptolemy XII	74-73	Alexandria	14.54	91			2
Ptolemy XII	73-72	Alexandria	13.71	91.75			1
Ptolemy XII	68-67	Alexandria	12.37	83	13.7	0.46	1.6
Ptolemy XII	68-67	Alexandria	12.52	81.5			1
Ptolemy XII	67-66	Alexandria	12.682	89.4	10.3	0.3	
Ptolemy XII	67-66	Alexandria	14	92.5			
Ptolemy XII	67-66	Alexandria	13.72	92.5			

Reign	Date	Mint	Weight	Ag	Cu	Au	Pb
Ptolemy XII	65-64	Alexandria	14.02	80			1.5
Ptolemy XII	64-63	Alexandria	12.72	90			3.25
Ptolemy XII	64-63	Alexandria	13.26	83			1.25
Ptolemy XII	64-63	Alexandria	14.3	82			1.5
Ptolemy XII	63-62	Alexandria	13.38	91.75			1
Ptolemy XII	63-62	Alexandria	13.43	88.5			2
Ptolemy XII	63-62	Alexandria	13.18	77			1
Ptolemy XII	63-62	Alexandria	13.91	82			0.25
Ptolemy XII	62-61	Alexandria	13.63	89			1.5
Ptolemy XII	62-61	Alexandria	13.2	76			1.25
Ptolemy XII	62-61	Alexandria	13.88	89			6.5
Ptolemy XII	61-60	Alexandria	14.351	91.1	8.7	0.2	
Ptolemy XII	61-60	Alexandria	13.3	85			3.75
Ptolemy XII	60-59	Alexandria	12.95	87			1.75
Ptolemy XII	60-59	Alexandria	13.28	82.5			0.5
Ptolemy XII	55-54	Alexandria	13.14	90.1		0.09	
Ptolemy XII	54-53	Alexandria	14.22	80			2.75
Ptolemy XII	54-53	Alexandria	13.9	83			1.5
Ptolemy XII	54-53	Alexandria	10.261	92.2	7.5	0.3	
Ptolemy XII	54-53	Alexandria	11.52	87.1	11	0.17	
Ptolemy XII	53-52	Alexandria	11.98	90.19	7.84	0.47	
Ptolemy XII	53-52	Alexandria	12.75	64			3
Cleopatra VII	51	Alexandria	14.354	31	69	0.4	
Cleopatra VII	51	Alexandria	10.67	58.5			1
Cleopatra VII	51	Alexandria	10.37	46.5			1
Cleopatra VII	51-50	Alexandria	11.71	34	64.1	0.1	1.01
Cleopatra VII	49-48	Alexandria	9.48	64			2.5
Cleopatra VII	45-44	Alexandria	13.6	49			2
Cleopatra VII	44-43	Alexandria	13.39	43.25			3.25
Cleopatra VII	44-43	Alexandria	13.48	56			4.5
Cleopatra VII	43-42	Alexandria		33.59	63.58		1.09
Cleopatra VII	43-42	Alexandria	13.59	36			2
Cleopatra VII	43-42	Alexandria	14	47			
Cleopatra VII	43-42	Alexandria	12.98	44.5			1
Cleopatra VII	42-41	Alexandria	12.85	42			
Cleopatra VII	41-40	Alexandria	11.25	47			
Cleopatra VII	41-40	Alexandria	13.7	40.5			
Cleopatra VII	40-39	Alexandria	10.93	41			2.25

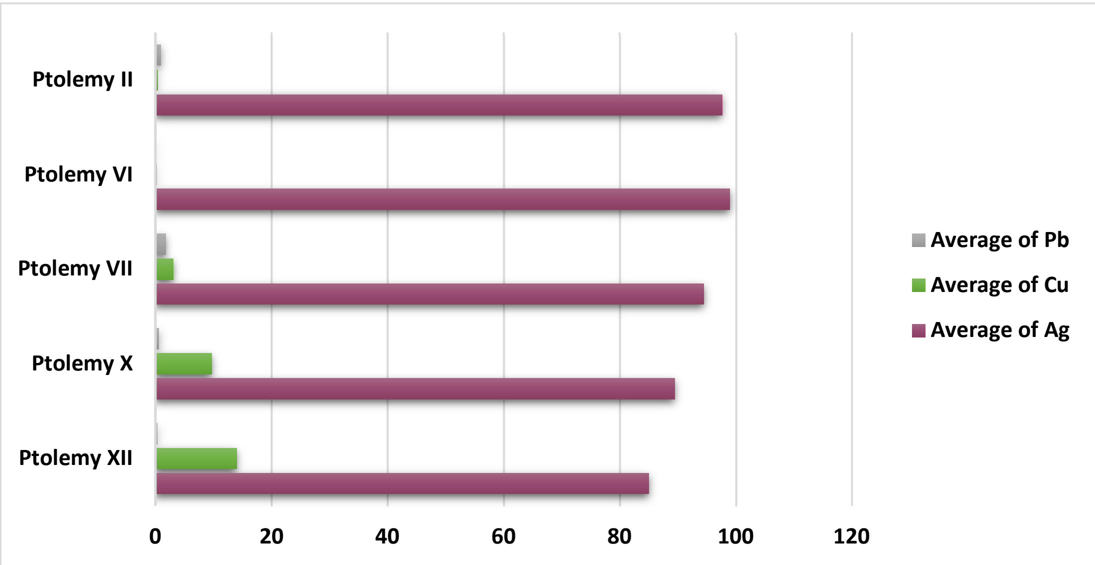
Reign	Date	Mint	Weight	Ag	Cu	Au	Pb
Cleopatra VII	40-39	Alexandria	13.28	41			2.5
Cleopatra VII	39-38	Alexandria	13.75	44.5			3
Cleopatra VII	39-38	Alexandria	10.54	64			3.25
Cleopatra VII	38-37	Alexandria	13.08	47.5			1
Cleopatra VII	38-37	Alexandria	10.76	50.5			3
Cleopatra VII	37-36	Alexandria	13.3	43			1.75
Cleopatra VII	37-36	Alexandria	12.97	45.25			4.25
Cleopatra VII	36-35	Alexandria	12.35	44.25			3.5
Cleopatra VII	36-35	Alexandria	13.52	43.75			3.75
Cleopatra VII	35-34	Alexandria	10.68	49			2.75
Cleopatra VII	35-34	Alexandria	13.4	46			2
Cleopatra VII	34-33	Alexandria	13.12	36			5
Cleopatra VII	34-33	Alexandria	11.13	42.5			
Cleopatra VII	33-32	Alexandria	13.273	31	69	0.3	
Cleopatra VII	33-32	Alexandria	11.09	40.5			4.5
Cleopatra VII	33-32	Alexandria	12.55	47.5			
Cleopatra VII	33-32	Alexandria	14.71	52.5			1.5
Cleopatra VII	31-30	Alexandria	11.91	48			

Table 5.11: Sampled silver coins from Hazzard's research; adapted from Table 1 (Hazzard, 1990: 100-102).

In his 1985 article Buckley examined 10 Ptolemaic coins (for details see section **3.4**.) focusing on eight chemical elements in total: nickel, copper, zinc, gold, lead, bismuth bromine and silver (Buckley, 1985: 105-106). As noted above the coins sampled belonged to the reigns of Ptolemy II, Ptolemy VI, Ptolemy VIII, Ptolemy X and Ptolemy XII, which as a whole do not represent the entirety of the Ptolemaic Period but is indicative of the later debasement that took place as noted by the author. When comparing the present results for silver, copper and lead to Buckley's results (see Graphs 5.12 and 5.13) it can be noted that the results for the coins of Ptolemy II, Ptolemy VI, Ptolemy VIII and Ptolemy X are largely quite similar (with the occasional 1% difference for some elements). This changes for the coins of Ptolemy XII where Buckley's results (1985: 105-106) have higher silver content and lower copper and lead contents. The explanation for this could be either



Graph 5.12: Average composition for silver (Ag) copper (Cu) and lead (Pb) in the current research on silver Ptolemaic coinage for Ptolemy II, VI, VIII, X and XII.

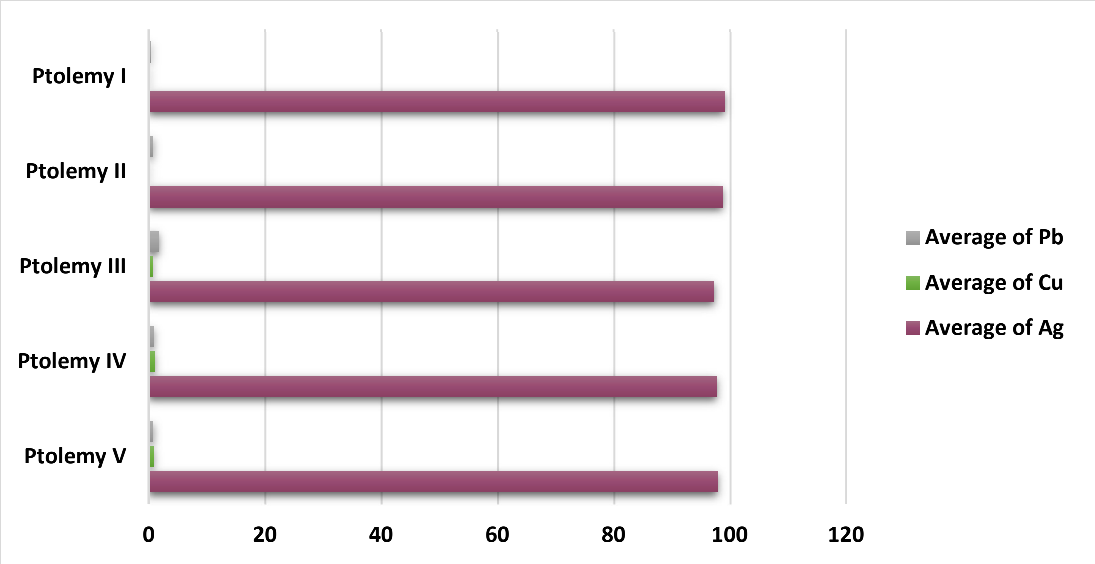


Graph 5.13: Average composition of silver (Ag), copper (Cu) and lead (Pb) adapted from Table of Results (Buckley, 1985: 105-106).

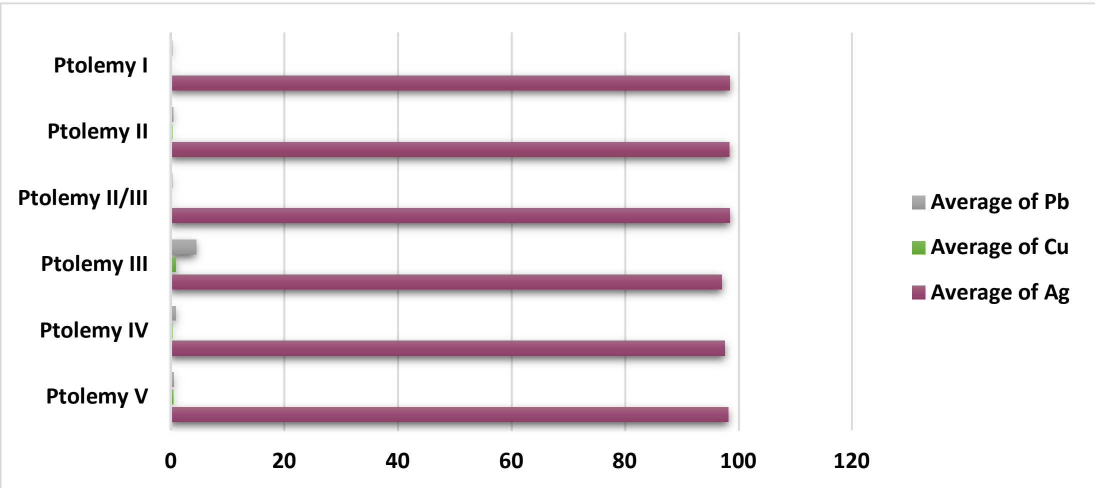
due to the different techniques used to analyse these coins, or more likely due to the fact that Buckley analysed only one coin from the reign of Ptolemy XII, while the current work has analysed a larger set for this ruler. Despite this discrepancy, Buckley's research does – similar to the current research - indicate that debasement of the Ptolemaic silver coinage certainly took place, and the author's conclusion that this debasement could be linked to the general decline of the Ptolemaic empire seems valid (Buckley, 1985: 104).

A further comparison can be made with the 2011 XRF analysis on silver Ptolemaic coins conducted by Kantarelou (Kantarelou *et al*, 2011). This work, as mentioned in section **3.4.**, focused only on the first five Ptolemies, and as such does not allow for an overall discussion of the debasement which occurred post-Ptolemy V. Graphs 5.14 and 5.15 do however demonstrate that the difference in the results of that study and the current work is marginal for both silver and copper – around 1% for these elements. Often the current results have the slightly higher values for these elements (with a few exceptions). The lead is the only element that sees a significant difference between the two sets of results. This difference however, is limited to the coins belonging to the reign of Ptolemy III. The difference in the averages between the current results for the lead content of Ptolemy III's coins and that of the XRF research is 2.80%, while the difference in the average results for the remaining rulers is less 0.5%.

This difference in the lead composition between the two studies can be explained in a number of ways. The first is that the difference is just a result of sample size: The current research has analysed only 4 coins from the reign of Ptolemy III, white Kantarelou et al. analysed 22. It should be stated that of those 22 coins, only 5 contain elevated (1% to 2%) levels of lead. Another explanation for the discrepancy in lead content between the two sets of results could be due to the fact that Kantarelou's analysis was surface-based, and that all the sampled coins (not only those for Ptolemy III) had received some sort of surface treatment (for more details on this see section **3.4.**). Interestingly, 4 of the 5 coins with elevated lead amounts had in fact been mechanically treated after a chemical clean, which could have influenced the results. Although this treatment procedure was conducted on a number of other coins, so the



Graph 5.14: Average composition for silver (Ag) copper (Cu) and lead (Pb) in the current research on silver Ptolemaic coinage for the first five rulers.



Graph 5.15: Average composition of silver (Ag), copper (Cu) and lead (Pb) adapted from Table 1 (Kantarelou et al, 2011: 683-684).

extent of its influence over the results seems overall small. Finally, the difference in the results could potentially be due to a regional difference but only 2 of the five coins share a mint the rest are from different mints making this unlikely. The most likely explanation thus remains the first one that the differences between the results are due to the significantly different sample size of the two sets of analysis.

As to the conclusions of their research, the authors state that following a correlation between the date of all the sampled coins and the copper amount a "slight debasement trend is obvious, even in this peak of Ptolemaic power" (Kantarelou *et al*, 2011: 689). This however seems unlikely as copper levels do not exceed 2% and so could be explained as the result of a minting error, regional difference or simply an instrumental error. A further suggestion by the authors is that, based on the gold and lead levels observed in their results, there was a change of silver source during the reign of Ptolemy IV (Kantarelou *et al*, 2011: 689). This hypothesis is made on the basis of a gradual increase in the gold content (between 0.8% - 1%) for the coins from the reigns of Ptolemy I, II and III and higher values in the coins from the reigns of Ptolemy IV and V. In addition, the authors also suggest, based on the lead content of the sampled material, that the refining processes used during the reigns of Ptolemy I and Ptolemy II (where lead content never exceeded 0.7%) were more efficient than those used during the reigns of Ptolemy III and Ptolemy V (where the lead content rose to up to 2%) (Kantarelou *et al*, 2011:689).

Both of these hypotheses do have merit, although the authors themselves state that such theories need "more evidence both historical and analytical to be confirmed" (Kantarelou *et al*, 2011: 689). The current research can provide both of these. The results of the present analysis indicate quite similar lead and gold amounts (see Graph 5.9) to those observed by Kantarelou et al. (2011), although it must be stated that the gold amounts observed in the current research begin to decline from the reign of Ptolemy VIII. Based on Kantarelou *et al* (2011) and the present results it does appear that there may have been a temporary change of the silver source from the reign Ptolemy IV to the reign of Ptolemy VI. However, the lead levels in the coins of this period are in addition, as discussed above, quite varied, a fact which could be taken to potentially indicate, not a change of ores, but rather evidence of a functioning closed currency system, a possibility which Kantarelou *et al* (2011) does not mention in their work.

As discussed in the section on Previous Research in Chapter 3, the most recent analysis of Ptolemaic silver coinage is that conducted by Julien Olivier. As his results are yet to be published, a direct comparison cannot be conducted at this present time, however based on an article published by Faucher and Olivier (2020), the latter's take on the three-stage debasement can be summarised (for details see section **3.4.**). Here a correlation with the current research can also be seen. Olivier suggests that the start of the debasement of Ptolemaic silver coinage should be dated to the middle of Ptolemy VI's reign. Due to the uncertain date of the sampled and analysed coins of Ptolemy VI this interpretation cannot be supported by the current research. In addition, Olivier observed a change in the concentration of gold, which was not observed by the current research, and so cannot substantiate Olivier's hypothesis that this change in the concentration of gold was a result of the re-melting of old coinage in order to supply mints. The second stage of debasement according to Olivier can be placed between the reigns of Ptolemy VIII and half of the reign of Ptolemy XII, and the final stage encompasses the second half of the latter's reign and that of Cleopatra VII. This division is broadly the same as observed in the current research (see Graph 5.8).

To conclude, based on the analysis conducted here, and in line with the previous research conducted into the composition of Ptolemaic silver coins (particularly with regards to Olivier's available work), a total of three overall stages or periods of compositional change can be observed in this type of coinage: Stage One, which is characterised by relative stability of composition began with Ptolemy I (c.305 BCE) and continued most likely until the reign of Ptolemy VI (c.157 BCE). Stage Two, which is characterised by a decrease in silver content and increase in copper can be dated to the reign of Ptolemy VII (c.145-132) through to (and including) the first half of Ptolemy XII reign (c. 61 BCE). The final third stage was marked by a significant decrease in the silver content which was substituted (more often than not) with a high amount of copper, a stage datable to the second half of reigns of Ptolemy XII (c. 60 BCE) and that of Cleopatra VII (51-30 BCE).

5.3. Chemical Composition of Ptolemaic Bronze Coinage

5.3.1. Ptolemy I

Only two coins dating to the reign of Ptolemy I were sampled, Cat. Numbers **22** and **62**. Cat. Number **22** was minted in Alexandria, but the mint of coin number **62** is unknown. No specific reign date can be ascribed to those two coins, and as explained in section **3.2.** no denomination can at present be ascribed to these two coins (or any of the bronze coins that will be presented below). The weight of the coins is 13.75g (Cat. Number **22**) and 16.85g for Cat. Number **62**.

The lighter coin (**22**) contains a higher percentage of copper (86.55%) and tin (8.60%) but the heavier coin (**62**) has a higher lead content (7.63%). The difference between the major elements for these two coins is between 2% and 3%, however what can be observed is that the lead and tin contents in Cat. Number **62** are almost identical, which is slightly unusual as what is expected in a bronze coin is a higher tin percentage and very minimal lead percentage. The higher lead amount would technically qualify as a potential case of debasement, however given its early date the slightly unexpected composition may simply be explained by either a minting error possibly as a result of the nascent Ptolemaic minting industry. The remaining trace elements are all under 0.5%. A direct correlation between weight and composition as well as a potential for higher lead content cannot at present be confirmed as the norm for the coinage belonging to Ptolemy I due to the small size of the analysed material.

5.3.2. Ptolemy II

The coins that were sampled from the reign of Ptolemy II number five in total - Cat. Numbers: **6**, **24**, **25**, **29** and **82** (Table 5.12). Later examination following analysis showed that Cat. Number **6** belongs to a series of coins referred to as the 'Galatian shield without Σ' series, which can be distinguished "from the regular coinage of Ptolemy II in part by style, borders, die axes, fabric, and control convention, and in whole by provenance, metrology and the lack of fractional denominations" (Wolf and Lorber, 2011: 7). Following a study of these series Wolf and Lorber (2011) concluded that some of these coins (including Cat. Number **6**) were minted by Hieron II of Syracuse in Sicily to imitate the coinage of Ptolemy II (Wolf and Lorber, 2011: 23-25) and as such this coin cannot be considered Ptolemaic.

Cat. Number	Date (BCE)	Mint	Weigh	As	Cu	Pb	Sn
6	Uncertain	Sicily	17.88g	1.01	93.79	0.14	4.65
24	260s	Alexandria	9.68g	0.59	90.77	0.30	7.95
25	260s	Alexandria	7.45g	0.11	88.19	0.00	11.56
29	260s	Alexandria	65.11g	0.14	92.50	0.08	6.96
82	260s	Alexandria	73.24g	0.39	86.07	1.25	11.96

Table 5.12: Arsenic (As), copper (Cu), lead (Pb) and tin (Sn) values for the bronze coins belonging to the reign of Ptolemy II.

Although an imitation, the analysis of this coin did demonstrate certain noteworthy result from the chemical composition analysis (see below) and it was therefore retained in the current study. Most of the coins are ascribed to the mint in Alexandria (Cat. Numbers **24**, **25**, **29** and **82**) the other coin. The date of the majority of the sampled coins is around 260s BCE, the specific year of production for Cat. Number **6** is not known.

The weight of the sampled coins varies significantly, with the lightest coin being 7.45g and the heaviest being 73.24g. This could be due to the difference in denominations as of the five sampled coins, four have different denomination. No denomination is ascribed on Cat. Number **6** due to its provincial origin, Cat. Number **24** is an obol, Cat. Number **25** is tritartemorion and the heaviest coins Cat. Numbers **29** and **82** are both drachms (Lorber, 2018b). Additionally, the different weight could be due to the date of these coins. This suggestion is substantiated by the scholarly work that has suggested that a bronze reform was conducted by Ptolemy II (for details see section **2.2.**) between 266 BCE and 262 BCE. No direct correlation between composition and weight can be observed in the sampled material.

It is evident that despite the significant difference in weight the copper content remains relatively stable between 86% and 93%, the tin content does vary substantially more however, going as low as 4.65% and as high as 11.96%. The lead content is, as expected, low, mostly under 0.5%, with one exception where the amount is 1.25% (Cat. Number **82**). A possible explanation for the high lead amounts observed in this coin, could be that the copper ore used came from lead rich ores such as those found in Faynan and Timna (Rademakers, Rehren and Pernicka, 2017: 56) as opposed to the relatively ‘pure’ copper ores found in Egypt’s Eastern Desert (see for instance Abdel-Motelib *et al*, 2012). The remaining trace elements are under 0.5%, with the exception of arsenic for which Cat. Number **6** has 1%.

Here a brief discussion of the arsenic content not only in Cat. Number **6** but in general for all the sampled and analysed bronze coins is warranted. Craddock (1976) states that an arsenical bronze (where the arsenic was deliberately added to the copper) is a term used to encompass all bronzes containing more than 1% arsenic, while Lechmann (1996) is of the opinion that this level should be lowered to 0.5% and finally Tylecote (1991) argues this level should be around 2%. From all the analysed bronze Ptolemaic coins only one (Cat. Number **6**) contains more than 1% (1.01% to be precise) arsenic this can be explained by the fact that this coin is not in point of fact Ptolemaic as discussed above. A number of coins scattered thorough the reigns contained more than 0.5% of arsenic. These coins could potentially be considered arsenical-bronzes, although an alternative to this interpretation is that the arsenical levels observed for all the coins are the result of re-cycling of arsenical-bronzes, and so should be considered “remains of arsenical ores, such as realgar or orpiment (i.e., in sulphide form), previously smelted with copper ores to produce an arsenical copper alloy, which was then recycled several times” (Giumlia-Mair *et al*, 2005: 205) each time reducing the level of arsenic even further. Yet it is difficult to conclude that with any certainty, as a further possibility could be simply that the arsenic amounts observed in the current work are due to natural arsenical impurities that can occur in copper ores (Giumlia-Mair *et al*, 2005: 205). And as of now there is no scholarly consensus on what the minimal arsenical levels of re-cycled arsenical bronzes versus impurity levels should be.

5.3.3. Ptolemy III

Twelve coins from the reign of Ptolemy III were sampled, these are Cat. Numbers: **7**, **8**, **9**, **13**, **21**, **23**, **31**, **32**, **33**, **34**, **35** and **45** (Table 5.13). The majority of the sampled coins were minted in Alexandria. Two were minted in Cyrenaica – Cat. Numbers **8** and **13**. Unfortunately none of these coins could be ascribed to a specific date within the reign of Ptolemy III. The weight of these coins is quite varied, but a large portion weigh between 34g and 36g. This difference in weight is most likely due to the difference in denomination, According to Lorber’s (2018b) work the denomination of

Cat. Number	Date (BCE)	Mint	Weigh	As	Cu	Pb	Sn
7	Uncertain	Alexandria	98.02g	0.39	90.32	0.08	8.76
8	Uncertain	Cyrenaica	1.52g	0.57	88.77	0.07	10.34
9	Uncertain	Alexandria	44.64g	0.81	89.02	0.76	8.95
13	Uncertain	Cyrenaica	2.15g	0.65	89.32	1.30	8.29
21	Uncertain	Alexandria	42.40g	0.12	89.79	0.51	9.09
23	Uncertain	Alexandria	10.79g	0.48	86.37	0.32	12.44
31	Uncertain	Alexandria	34.85g	0.48	85.27	0.25	13.54
32	Uncertain	Alexandria	35.49g	0.12	85.73	0.19	13.49
33	Uncertain	Alexandria	36.60g	0.45	85.57	0.17	13.38
34	Uncertain	Alexandria	36.46g	0.10	87.12	0.18	12.12
35	Uncertain	Alexandria	34.83g	0.47	85.35	0.66	13.07
45	Uncertain	Alexandria	36.99g	0.37	90.52	0.08	8.66

Table 5.13: Arsenic (As), copper (Cu), lead (Pb) and tin (Sn) values for the bronze coins belonging to the reign of Ptolemy III.

the coins are as follows; Cat. Numbers **7** and **23** are obols, Cat. Numbers **8** and **13** are dichalkons, Cat. Numbers **9** and **21** are tetrobols, Cat. Numbers **31**, **32**, **33**, **34**, **35** and **45** are all triobols.

The copper content, similarly to the coins of Ptolemy II, is relatively stable between 85% and 90%, however a slight increase of the tin content in comparison to Ptolemy II coinage can be observed with quantities between 12% and 13%. The lead content of all the coins, bar one (Cat. Number **13**) is under 1%. No direct correlation can be observed between weight and composition. The trace elements for all six analysed coins are also all under 0.5%. Although only two coins from outside Egypt were analysed from the rule of Ptolemy III in the present work, it seems that perhaps the compositional stability observed in the coins from Alexandria was also characteristic of the whole of the Ptolemaic empire. However, in order to determine that for certain a larger corpus of provincial coins should be sampled and analysed.

5.3.4. Ptolemy IV

Eight coins dating to the reign of Ptolemy IV, were sampled, Cat. Numbers: **11**, **12**, **26**, **27**, **28**, **30**, **36** and **46** (Table 5.14). All of the analysed coins for this ruler were minted in Alexandria. The dates of the coins are all around 219 BCE. The weight of

Cat. Number	Date (BCE)	Mint	Weigh	As	Cu	Pb	Sn
11	219	Alexandria	68.02g	0.52	85.40	1.23	12.12
12	219	Alexandria	68.70g	0.45	85.79	2.18	10.77
26	219	Alexandria	67.27g	0.76	87.05	0.29	11.39
27	220-219	Alexandria	72.00g	0.57	84.52	5.46	8.63
28	219	Alexandria	64.90g	0.39	89.18	0.07	10.00
30	220-219	Alexandria	62.52g	0.40	88.57	0.34	10.18
36	220-219	Alexandria	33.90g	0.45	89.00	0.28	9.81
46	219	Alexandria	63.86g	0.15	90.08	0.12	8.84

Table 5.14: Arsenic (As), copper (Cu), lead (Pb) and tin (Sn) values for the bronze coins belonging to the reign of Ptolemy IV.

the coins is in the mid-60s to low 70s rang, with one exception Cat. Number 36, which weighs 33.90g. This low weight is most likely due to the different denomination of this coin, according to Lorber (2018b) this coin (Cat. Number 36) is a triobol, while the remaining sampled and analysed coins are all drachms. No correlation between weight and composition can be observed in these coins.

However, it must be stated that Cat. Number **27** (the heaviest coin of the sampled assemblage) not only contains the lowest amount of copper and highest amount of lead, but also the lowest tin content (8.63%). Although the lead levels are more than 5%, debasement can be excluded as a reason for this compositional oddity, as the percentages of lead in Cat. Number **27** does not exceed the percentage of tin. Instead, a more likely explanation for the high level of lead in this coin is linked to a change in copper ore (for a discussion of lead in copper ore, see section on Ptolemy II above).

With regards to the remaining trace elements Cat. Numbers **9**, **11**, **26** and **27** have more than 0.5% arsenic, perhaps this could be indicative, especially for Cat. Numbers **9** (0.81%) and **26** (0.76%), of the use of re-cycled arsenical-copper (Pollard *et al*, 2015: 710). The remaining trace elements are all under 0.5%.

5.3.5. Ptolemy V

Seven coins were sampled for this ruler, Cat. Numbers: **37**, **38**, **43**, **50**, **51**, **52** and **53** (Table 5.15). All of the coins (with one exception) are from the mint in Alexandria,

Cat. Number	Date (BCE)	Mint	Weight	As	Cu	Pb	Sn
37	205-180	Alexandria	7.46g	0.16	88.06	2.30	9.27
38	205-180	Alexandria	16.26g	0.91	85.57	3.47	9.39
43	205-180	Alexandria	5.00g	0.32	84.56	8.37	6.12
50	205-180	Cyrenaika	6.47g	0.56	86.14	4.01	8.88
51	205-180	Alexandria	4.17g	0.31	86.16	6.65	6.18
52	205-180	Alexandria	3.93g	0.27	71.97	23.16	3.55
53	205-180	Alexandria	8.51g	0.33	84.57	8.69	5.80

Table 5.15: Arsenic (As), copper (Cu), lead (Pb) and tin (Sn) values for the bronze coins belonging to the reign of Ptolemy V.

the exception is Cat. Number **50**, which was minted in Cyrenaica. The date of these coins is between 205 BCE and 180 BCE, but none of them can be dated to a specific year. The weight of these coins is significantly smaller, than the coins analysed from Ptolemy IV reign, these coins are between 3.93g and 16.26g. The copper content of these sampled coins is between 88.06% and 71.96%, the tin content is between 9.39% and 3.55%, and finally the lead composition is between 2.30% and 23.16%. With the exception of the lightest coin (Cat. Number **52**) no direct correlation between weight and copper content can be made here.

Cat. Number **52**, is the coin with the lowest copper content (71.97%) not only for the coins sampled from the reign of Ptolemy V, but for all the analysed material so far, additionally this is the coin that has also the highest lead content – 23.16%. Of the seven sampled and analysed coins for this ruler, four (Cat. Numbers **43**, **51**, **52** and **53**) demonstrate clear deliberate debasement with lead values >5% and tin values lower than the lead values. What is further of interest is that the coin from Cyrenaica does seem to be compositionally and weight-wise similar to some of the Alexandrian coins, which could be taken as an indication that there was some level of centralization with regards to the production of bronze coinage. This of course could be verified by sampling more coins from provincial mints and comparing them to the present results, although this is outside the scope of the current research. With regards to the remaining trace elements, all are under 1%. What can clearly be observed from the sampled material is that there was a significant change in the composition of the bronze coinage between Ptolemy IV and V, which is indicated by the rapid decrease of the coin's weight as well as the clear increase in the lead composition.

5.3.6. Ptolemy VI and Ptolemy VIII

As mentioned at the start of this chapter there are 14 coins (Cat. Numbers: **16**, **17**, **18**, **41**, **42**, **48**, **49**, **58**, **60**, **61**, **127**, **128**, **129** and **130**) that were sampled for this joint rule (Table 5.16), this being the largest analysed assemblage for any ruler and any metal type in the present research. This was due to a number of errors in dating when these coins were first acquisitioned.

All of the coins are from the mint in Alexandria and their date is between 169 BCE and 165 BCE. However, here it must be stated that based on their weight and composition (both discussed further below) some of these coins could have been misdated by Svoronos. As mentioned on a number of occasions, in the current work, Svoronos' dating is problematic at times and should be taken critically in some circumstances, as in the current discussion. The 14 analysed coins have an extremely varied weight, from 5.88g to 34.83g. This could be, as mentioned, due to misdating, but it could also be indicative of a denominational difference (for further details regarding the denominations of bronze coins see section **3.2.** above).

What is clear is that the coins weighing between 5.8g and 9.7g have a significantly lower copper content, between 68% and 56%, a lower tin content (between 1% and 6%) and a very high lead content of between 26% to 39%. However, the heaviest coins (25g and above) have a relative high copper content and in only one of these coins (Cat. Number **16**), is the lead content more than that of tin. The coins in the middle of the weight scale (more than 9.75g up to 25.83g) contain between 86% and 90% copper, and a lead content that is anywhere between 1.36% and 5.96%, but a relatively steady tin content around 6%-7%.

Cat. Number	Date (BCE)	Mint	Weight	As	Cu	Pb	Sn
16	169-165	Alexandria	34.83g	0.28	83.53	12.07	3.00
17	169-165	Alexandria	9.65g	0.31	66.41	28.70	2.65
18	169-164	Alexandria	9.77g	0.39	86.42	5.94	6.54
41	169-165	Alexandria	21.14g	0.01	90.90	1.36	6.86
42	169-164	Alexandria	11.17g	0.29	88.01	4.51	6.49
48	169-164	Alexandria	22.98g	0.33	74.97	18.31	5.80
49	169-164	Alexandria	25.88g	0.36	89.07	2.49	7.22
58	169-164	Alexandria	8.40g	0.29	68.00	26.85	4.39
60	169-164	Alexandria	8.00g	0.26	60.45	34.57	4.21
61	169-164	Alexandria	7.95g	0.20	56.44	39.63	1.68
127	169-164	Alexandria	32.75g	0.34	85.57	5.20	7.85
128	169-164	Alexandria	23.40g	0.18	69.33	23.62	5.95
129	169-164	Alexandria	9.71g	0.15	63.62	31.75	4.32
130	169-164	Alexandria	5.88g	0.22	64.08	28.79	6.65

Table 5.16: Arsenic (As), copper (Cu), lead (Pb) and tin (Sn) values for the bronze coins belonging to the join reign of Ptolemy VI and Ptolemy VIII.

Working on the above assumption of a potential dating error on Svoronos' part, these middle coins (Cat. Numbers **18**, **42**, **41** and **49**) could perhaps be re-dated using their weight and chemical composition and thus Cat. Numbers **18** and **42** would fit in the reign of Ptolemy V while Cat. Numbers **41** and **49** could be considered as a possible candidate for the reign of Ptolemy IV. But even if the assumption of these coins being misdated is correct, it still leaves a rather large gap both with regards to weight and composition in the remaining coins. This could be explained by the existence of a heavy and light denomination during this period. If that was indeed the case, then it is striking that the lighter denomination is the one that shows clear debasement, while the heavier coinage does remains relatively stable. Another possible explanation for these discrepancies in this sampled material is that not all coins were actually minted in Alexandria (as Svoronos claims) and that what can be observed is a difference between the coinage in the capital and the coinage produced in the provinces. A potential solution to this issue could be the upcoming second volume of Lorber's updated Svoronos catalogue, as she does intend to provide denominations for the bronze coinage as well as change some of the dating and minting locations.

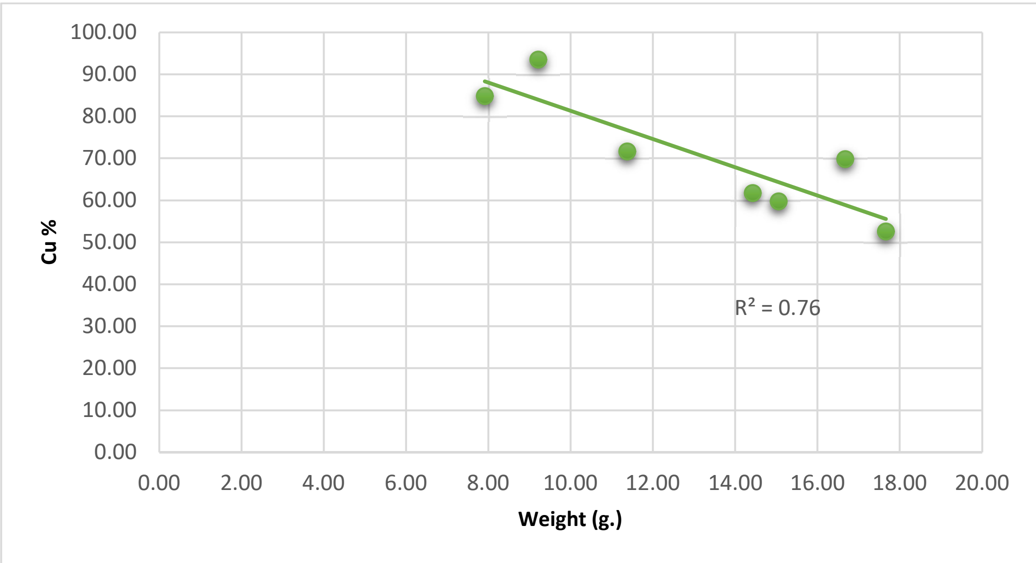
With regards to the trace elements, what is observed is an increase in the iron content in some coins (Cat. Numbers **17** and **61**) it is more than 1%, which could potentially be indicative of an ore change i.e., the use of an ore rich in iron (Craddock and Meeks, 1987: 202) or it could be indicative of a change in the smelting process (Craddock and Meeks, 1987: 202). However, if this latter suggestion is to be believed it seems to have been in force only for the very brief joint reign as the amounts of iron for the remaining Ptolemies rarely exceed 0.47% (for details see Appendix III). All the remaining trace elements for this reign are under 0.5%.

5.3.7. Ptolemy VI

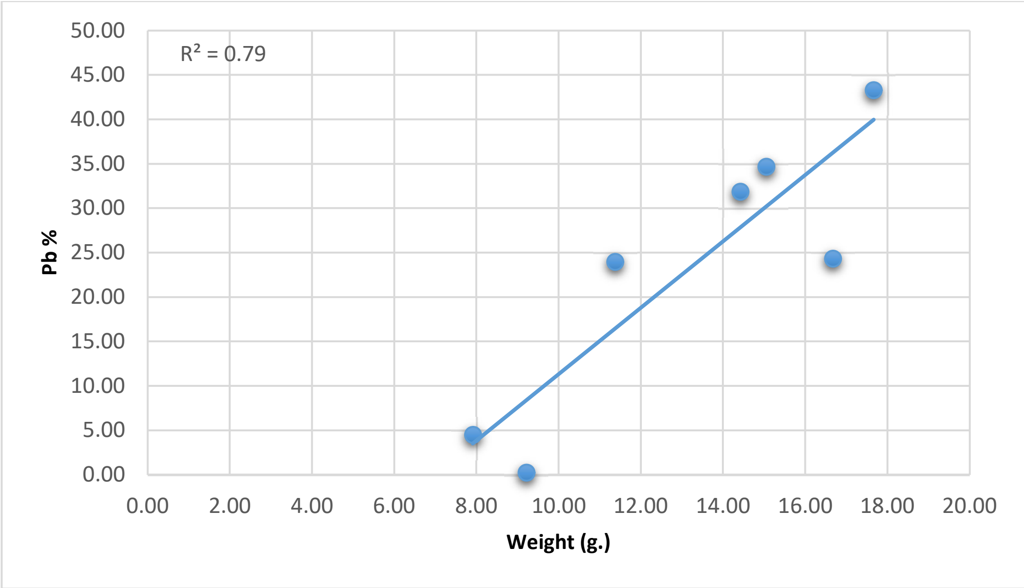
Seven coins belonging to the sole rule of Ptolemy VI were sampled and analysed, these are Cat. Numbers: **14**, **15**, **39**, **40**, **47**, **56** and **57** (Table 5.17). All of the coins were minted in Alexandria. The date of the coins is from 180 BCE to 145 BCE. Cat. Numbers **47**, **56** and **57** are the earlier coins and they are ascribed by Svoronos to the co-rule of Ptolemy VI and his mother Cleopatra I and thus prior to the joint rule with Ptolemy VIII. The remaining coins (Cat. Numbers **14**, **15**, **39** and **40**) are the later coins after Ptolemy VIII left Egypt and Ptolemy VI ruled alone. The weight of these coins is between 7.91g and 17.66g and a relative correlation between the weight and the copper and the weight and the lead compositions can be observed. With correlation coefficient of 0.76 and 0.78 respectively (Graphs 5.16 and 5.17) and based on the sample size this correlation does seem to be potentially significant (for details on the relationship between correlation coefficient accuracy and sample size see Fletcher and Lock, 1991: 109 and 184.). What is evident is that the coins under 10g (Cat. Numbers **39** and **40**) have the highest copper content and the content of the tin is consistently higher than that of the lead. This however changes as the weight of the coins increase, the copper content and tin content decrease and the lead content increases. The heaviest coin (Cat. Number **57**) is the one that contains the highest lead content (43.29%) and the lowest tin (3.46%) and copper contents (52.69%).

Cat. Number	Date (BCE)	Mint	Weight	As	Cu	Pb	Sn
14	180-145	Alexandria	16.67g	0.80	69.85	24.31	4.67
15	180-145	Alexandria	11.37g	0.32	71.68	23.96	3.67
39	180-145	Alexandria	7.91g	0.50	84.91	4.50	8.09
40	180-145	Alexandria	9.21g	0.20	93.60	0.22	5.17
47	180-169	Alexandria	15.05g	0.51	59.80	34.65	4.71
56	180-169	Alexandria	14.42g	0.24	61.76	31.86	5.45
57	180-169	Alexandria	17.66g	0.21	52.69	43.29	3.46

Table 5.17: Arsenic (As), copper (Cu), lead (Pb) and tin (Sn) values for the bronze coins belonging to the reign of Ptolemy VI.



Graph 5.16: Weight and copper (Cu) value for the coins of Ptolemy VI.



Graph 5.17: Weight and lead (Pb) value for the coins of Ptolemy VI.

A potential explanation for what is observed could be that the coins represent two different denominations. As to the date of these coins, the earlier ones belonging to the co-rule of the young Ptolemy VI and his mother Cleopatra I are some of the heavier coins and thus the ones that present clear compositional changes. Regardless, the heavier coins exhibit clear signs of debasement, by the decreased amount of copper and tin that can be observed, but mainly by the heavily increased amount of lead that cannot in these cases be explained for instance as a simple change in the minting technique.

Cat. Number	Date (BCE)	Mint	Weight	As	Cu	Pb	Sn
19	145-116	Cyrenaika	3.70g	0.73	93.98	2.16	2.63
54	134-129	Alexandria	4.79g	0.21	76.75	19.79	3.03
55	134-129	Alexandria	40.56g	0.23	72.70	23.08	3.75
59	134-129	Alexandria	12.05g	0.22	76.11	19.82	3.64

Table 5.18: Arsenic (As), copper (Cu), lead (Pb) and tin (Sn) values for the bronze coins belonging to the reign of Ptolemy VIII.

5.3.8. Ptolemy VIII

Four coins from the sole reign of Ptolemy VIII were sampled; Cat. Numbers: **19**, **54**, **55** and **59** (Table 5.18). Three of the coins were minted in Alexandria (Cat. Numbers **54**, **55** and **59**) and one of the coins comes from the mint in Cyrenaica (Cat. Number **19**). The relative date span for Cat. Number **19** is between 145 BCE and 116 BCE the remaining three coins are dated to between 134 BCE and 129 BCE.

The weight of these coins is between 3.70g and 40.56g. Cat. Number **19** is the lightest coin and the one that contains the most copper, and also slightly more tin than lead. Whether this different composition is based solely on weight or whether this is a regional difference unfortunately cannot be determined as this is the only coin from the mint at Cyrenaica sampled for this ruler. Cat. Number **55** is the heaviest coin (40.56g) and it is also the coin containing the smallest copper percentage and the highest lead percentage. This coin belongs to a type that bears the epithet *Eurgetes* on the reverse inscription. Svoronos ascribes these heavy coins to the reign of Ptolemy VIII, as this was his epithet, although it should be noted that he was the second Ptolemaic ruler to use this name, the first one being Ptolemy III.

This fact raises the possibility that Cat. Number **55** is misdated, and indeed weight-wise this coin does fit better with those belonging to Ptolemy III. However, compositionally Cat. Number **55** differs from the coins belonging to the earlier ruler significantly, therefore presenting a potential problem with this hypothesis. It is unknown on what basis Svoronos decided to ascribe this type of coins to Ptolemy VIII rather than Ptolemy III, and it is by no means impossible that, although compositionally different, they could still be dated to the reign of Ptolemy III, hence presenting the possibility of an earlier debasement date. However, based on the overall

Cat. Number	Date (BCE)	Mint	Weigh	As	Cu	Pb	Sn
131	116-80	Uncertain	5.52g	0.19	74.13	21.13	4.23
132	116-80	Uncertain	8.64g	0.14	75.32	23.44	0.96
133	116-80	Uncertain	16.60g	0.18	65.99	28.09	5.49

Table 5.19: Arsenic (As), copper (Cu), lead (Pb) and tin (Sn) values for the bronze coins belonging to the reign of Ptolemy IX/X.

results seen in the present research, it seems most like that Svoronos' date for this type of coins is correct, and the heavier weight is perhaps an indication of a denominational change or even based on the epithet used it could have been a commemorative issue, that was debased in a similar manner to the other coins issued during this period.

5.3.9. Ptolemy IX/X

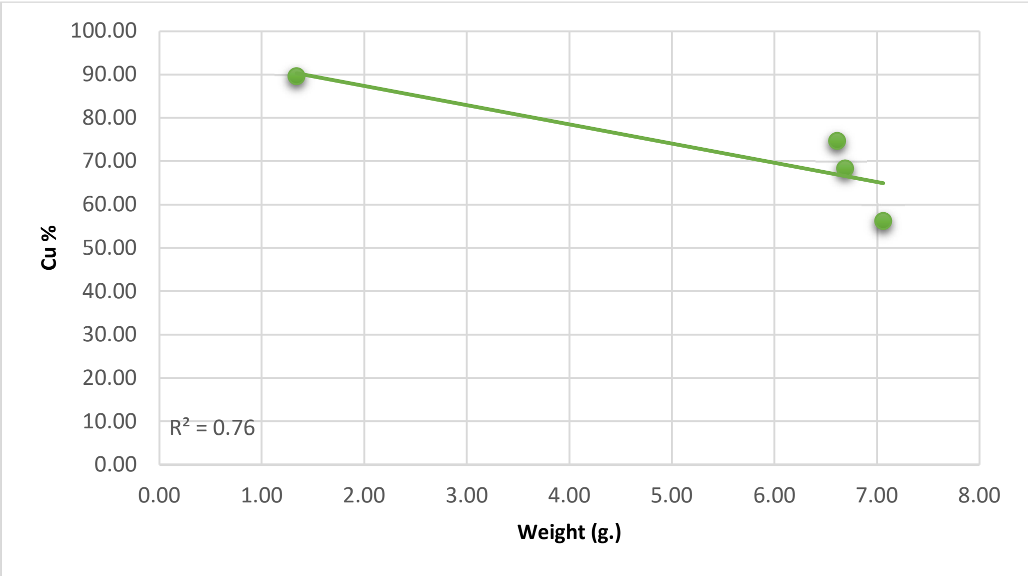
Only three coins belonging to these two rulers were sampled and analysed: Cat. Numbers: **131**, **132** and **133** (Table 5.19). The mint that produced these coins is unknown, as is their exact date. They are simply dated to between 116 BCE and 80 BCE, thus making it impossible to determine whether they belong to Ptolemy IX or X. All three coins have less than 80% copper, less than 5.5% tin and over 20% lead. Cat. Numbers **131** and **132** have similar copper and lead contents but their tin contents differ with Cat. Number **132** having less than a percent of tin, the lowest not only for the coins of this ruler, but also for the previous ones. Cat. Number **133** has 65.99% copper, 5.49% tin and 28.09% lead. These coins clearly illustrate that debasing the copper coinage by decreasing the copper and tin content and increasing the lead content had become the new norm with regards to Ptolemaic bronze coinage. Although it must be acknowledged that for these two rules this a small sample, and it is also unclear from which mint these coins originated, they still depict a clear downward trend in the composition of Ptolemaic bronze coins.

5.3.10. Ptolemy XII

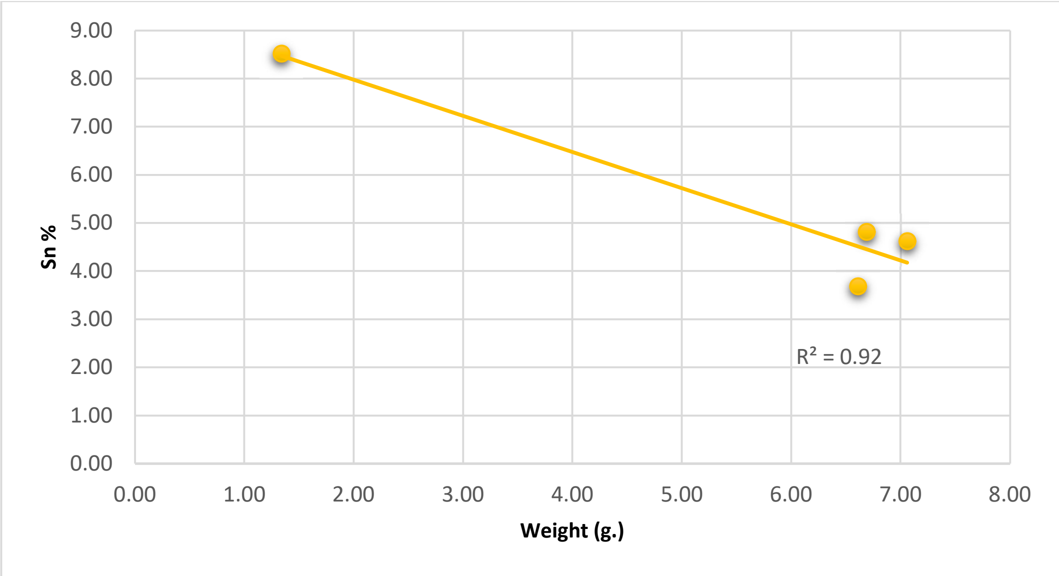
Four coins from Ptolemy XII were sampled and analysed Cat. Numbers: **134**, **135**, **136** and **137** (Table 5.20). Unfortunately, no mint or specific date can be ascribed to these four coins. Their weight is between 1.34g and 7.06g and here again a correlation between weight and composition can be observed with the heaviest coins having less

Cat. Number	Date (BCE)	Mint	Weight	As	Cu	Pb	Sn
134	80-51	Uncertain	7.06g	0.17	56.18	38.26	4.62
135	80-51	Uncertain	6.69g	0.26	68.36	25.43	4.81
136	80-51	Uncertain	6.61g	0.22	74.70	21.13	3.68
137	80-51	Uncertain	1.34g	0.32	89.60	1.40	8.52

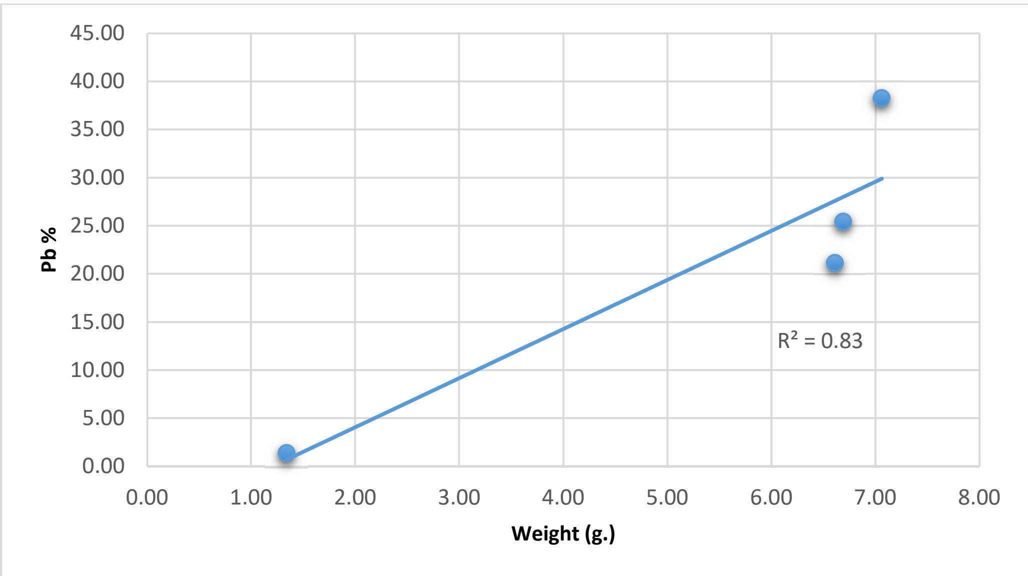
Table 5.20: Arsenic (As), copper (Cu), lead (Pb) and tin (Sn) values for the bronze coins belonging to the reign of Ptolemy XII.



Graph 5.18: Weight and copper (Cu) value for the coins of Ptolemy XII.



Graph 5.19: Weight and tin (Sn) value for the coins of Ptolemy XII.



Graph 5.19: Weight and lead (Pb) value for the coins of Ptolemy XII.

copper and tin (Graphs 5.18 and 5.19) and more lead (Graph 5.20). Although the R^2 numbers presented are indeed indicative of a positive correlation, it must be stated that due to the sample size unfortunately in this case the correlation coefficient may not be significant (for details see Fletcher and Lock, 1991: 109 and 184). With the exception of Cat. Number **137**, the remaining coins all have a lead content of more than 20%, the highest being 38.26% in Cat. Number **134**, which is also the heaviest coin.

The lightest coin (Cat. Number **137**) has the highest copper and tin content and the lowest lead content. Most of these coins clearly depict a compositional change in the bronze coinage of this date. Based on the significantly decreased amounts of copper and tin and the increased amounts of lead an argument can be made that this is the result of debasement. The remaining trace elements for these analysed coins are all under 0.5%.

5.3.11. Cleopatra VII

Six coins in total were sampled and analysed from the reign of Cleopatra VII. Cat. Numbers; **44**, **138**, **139**, **140**, **141** and **142** (Table 5.21). Five of them were minted in Alexandria (Cat. Numbers: **44**, **138**, **139**, **141** and **142**) while one, Cat. Number **140,** was minted in Cyprus. The date of these coins is between 51 BCE to 30 BCE and unfortunately none of them can be dated to a specific regnal year. The weight of these coins is varied with weights being between 8.49g and 19.08g which could indicate that there was more than one denomination minted for this ruler.

No direct correlation between weight and composition can be observed in these coins. What can however, be noted, is that the copper content in most of these coins is between 65% and 72%. Exceptions are Cat. Number **138** (which is the coin with the highest copper percentage of 83.70%) and Cat. Number **140** (which is the coin with the lowest copper percentage of 54.96%). The low amount of copper in this latter coin could potentially be due to its provincial origin, unfortunately as this is the only coin analysed from the mint in Cyprus for this reign this observation cannot be verified.

The lead amounts in these six coins are varied with percentages being between 9.90% to 39.08%. It is nonetheless evident that the lead contents are linked to that of the copper – the more copper in the coin, the less lead. Even more notable, in these coins,

Cat. Number	Date (BCE)	Mint	Weight	As	Cu	Pb	Sn
44	51-30	Alexandria	19.08g	0.16	72.56	17.58	8.99
138	51-30	Alexandria	8.83g	0.29	83.70	9.90	5.69
139	51-30	Alexandria	8.49g	0.20	70.74	17.22	11.50
140	51-30	Cyprus	17.82g	0.15	54.69	39.08	5.93
141	51-30	Alexandria	12.11g	0.20	69.20	19.42	10.79
142	51-30	Alexandria	8.57g	0.23	65.00	23.50	10.96

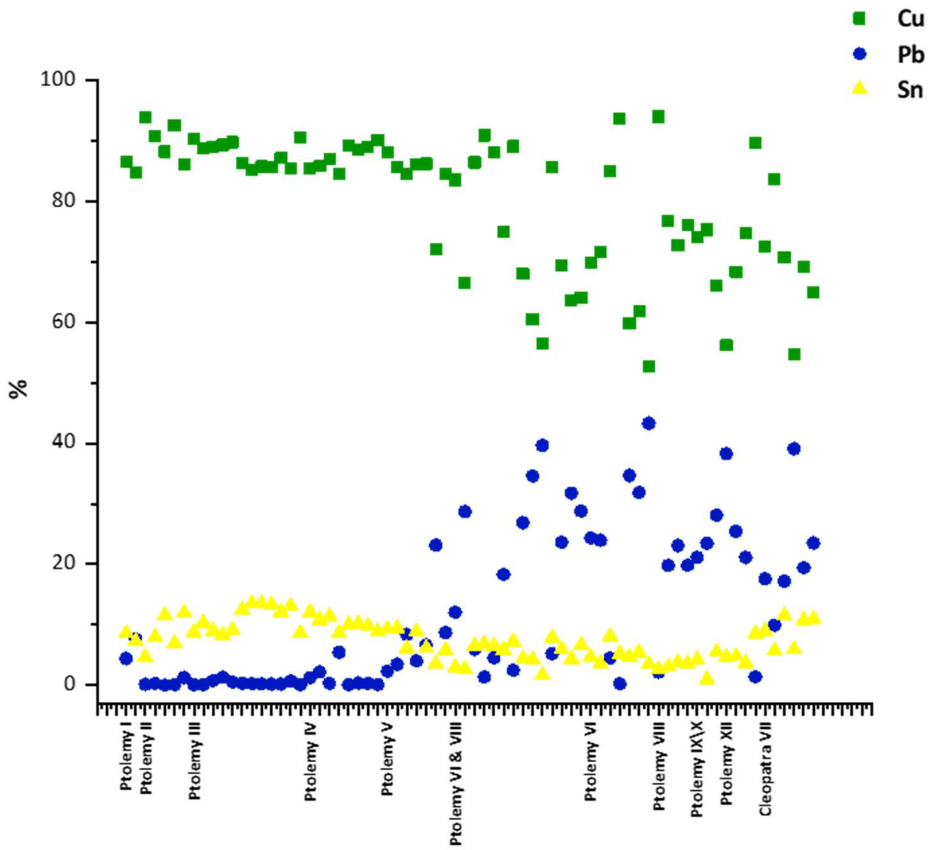
Table 5.21: Arsenic (As), copper (Cu), lead (Pb) and tin (Sn) values for the bronze coins belonging to the reign of Cleopatra VII.

is the tin content, which is rather higher compared to those of the previous rulers, with amount varying between 5.69% and 11.50%. Three of the six sampled coins contain more than 10% tin, which is something that has not been observed in the current analysis of Ptolemaic bronzes since the reigns of Ptolemy II and Ptolemy III.

It is unclear why this change occurred, although it could potentially be linked to a suggestion made in the previous section discussing the silver coinage dating to the reign of Cleopatra VII: that she made an attempt to stabilise the coinage and make it more reliable, although there is no direct evidence available to substantiate this notion. Regardless, based on the analysis conducted on the bronze Ptolemaic coins, it is clear that by the reign of Cleopatra VII their composition had changed radically compared to the early Ptolemaic Period with very high values of lead and low amounts of copper being the rule, rather than the exception.

5.4. Discussion of Bronze Results

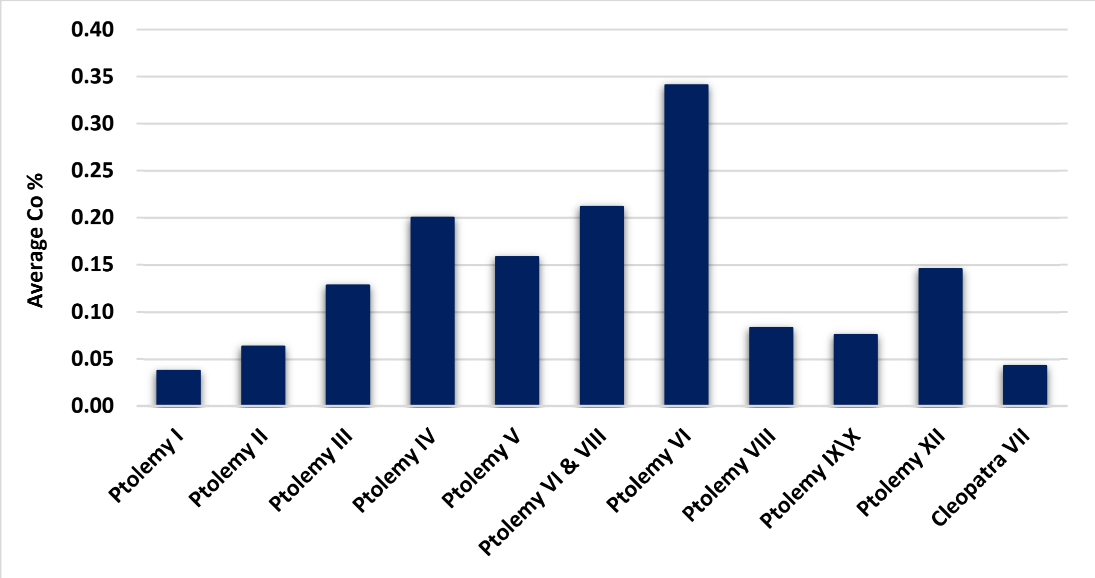
When discussing the results of the analysis of the bronze coinage it must be stated that it is more challenging to determine what can be classified as debasement in this type of coinage compared to the silver coinage. To what extent should a decrease in copper content, or an increase in lead content or even a decrease in tin content be considered debasement? Based on the results presented here, the current research demonstrates that a reliable base-line for potential debasement is when the lead content in an individual coin is >5%. It is more complicated to determine how the tin content fits in the debasement discussion for the Ptolemaic bronze coins, but what can be observed is that when the copper content is lowered and replaced with lead so is the tin content,



Graph 5.21: The overall percentage content of copper (Cu), lead (Pb) and tin (Sn) in the analysed sample set.

ensuring most often the tin content does not exceed 5%, and certainly does not exceed the lead content in the coins. Based on these guidelines it would appear that the changes in the bronze coinage began at some point during the reign of Ptolemy V. It is possible that the desired outcome of adding lead was primarily to reduce the quantity of tin, a relatively rare metal in the Eastern Mediterranean, with the reduction of copper merely being a by-product of the process.

The compositional changes observed in the present analysis are very well illustrated by Graph 5.21. What this scatter plot demonstrates is the increased levels of lead from the reign of Ptolemy V as well as the decrease of copper and tin also starting from this time period. This debasement continued before reaching its peak in the coins belonging to Ptolemy XII and Cleopatra VII. Moreover, what the scatter plot further demonstrates is that the decline of copper content is not linear and on occasion specific coins had a higher-than-expected copper content (for example Cat. Number **19**, dated to the reign



Graph 5.22: Average composition of cobalt (Co) based on the results of the current research

of Ptolemy VIII). Furthermore, what can be observed in Graph 5.21 is the above-mentioned increase in tin content in the coins of Cleopatra VII.

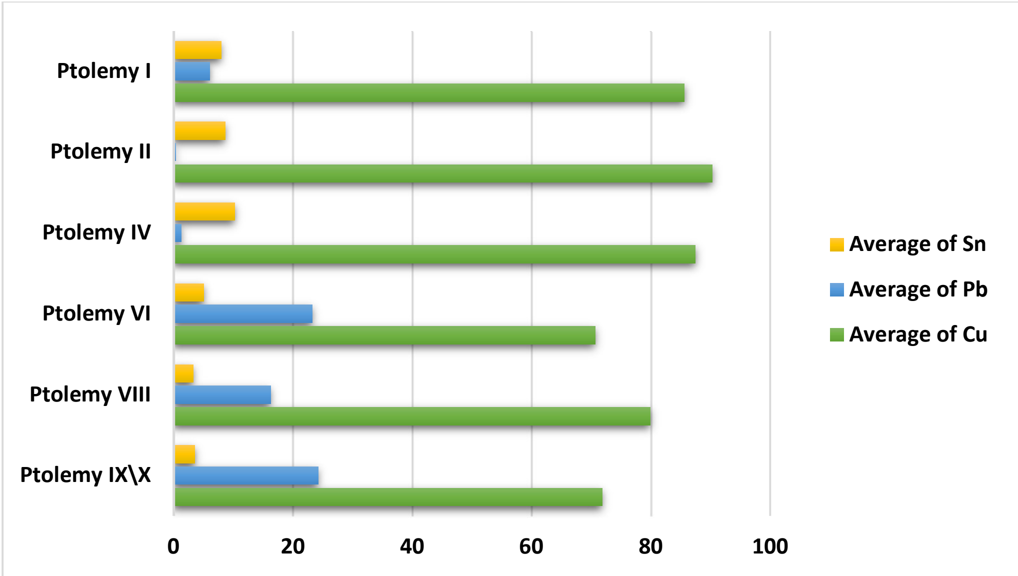
A further point of interest with regards to the composition of the bronze coinage are the cobalt amounts (Graph 5.21). What is observed is a relatively steady increase from the start of the period that reaches its peak in the coins of Ptolemy VI. However, the cobalt amount does not remain stable, neither does it begin a slow decrease. Instead, what occurs is a very sudden decrease that then steadily continues descending until eventually it reaches the same levels as those from the start of the period. According to Caley (1939: 100) the cobalt amounts could be indicative of the copper ore that was used in the coin production, so what is observed here is perhaps exactly that. Whether this is indeed the case is uncertain and this was not more fully investigated as it is not within the scope of the current thesis as stated in section **4.3.**. However, these amounts could in future assist with pinpointing the origin of the copper ores used for the minting of the bronze Ptolemaic coins.

Overall, the current analysis demonstrates that there was a significant amount of compositional change in the Ptolemaic bronze coinage that began at some point during Ptolemy V's reign and continued relatively steadily, culminating with the last rulers of this period. However, the debasement of the bronze coinage does not follow the same stages of compositional changes observed in the silver Ptolemaic coinage. Instead, a two-stage debasement process can be suggested: The first stage consists of a period of relative compositional stability lasting until the reign of Ptolemy V. The second stage is characterised by the above-mentioned increases in lead and decreases in copper and tin.

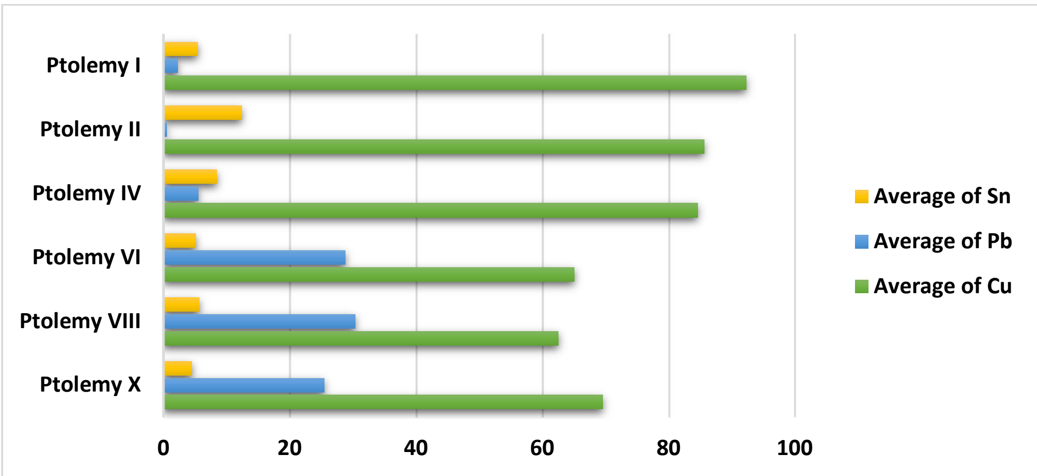
It must however, be noted that although the current work attributes these visible changes to debasement, an alternative is provided by Faucher and Olivier (2020) who are of the opinion that these changes are simply the effect of production (see section **6.2**. for details). Faucher is also the author of the most recent research into the composition of Ptolemaic bronze coins, however before discussing his results and how they can be compared to the present research, a discussion of the first significant analysis on Ptolemaic bronze coins and their results (Caley, 1939) should be presented.

Section **3.5.** details Caley's research and findings, but what can be observed from his sampled and analysed material (eight coins in total belonging to the reigns of Ptolemy I, II, IV, VI, VIII and X) is a definite decrease of copper and increase of lead from the reign of Ptolemy I onwards (Caley, 1939: 97). Caley's results with regards to the coins of Ptolemy I are slightly different to the results achieved in the present research, his copper content is higher, while both the lead and tin content are lower than was observed in the current analysis of the Ptolemaic coins (Graphs 5.23 and 5.24). As to the coins belonging to Ptolemy II, here the copper levels in the present work are about 4% higher than what Caley lists, however the tin composition in his work for this ruler is higher than the results seen in the current research. The lead amounts for Ptolemy II for both sets of results is similar. For Ptolemy IV the current results demonstrate higher amounts of both copper and tin (over 3% for copper and over 1% for tin), but Caley's analysis with regards to the lead content in the coins of Ptolemy IV shows higher values than the present work.

For the coins analysed for Ptolemy VI, the present work demonstrates higher copper values, but Caley's demonstrates higher lead values, on the other hand the tin percentages in both sets of results are quite similar. In the present research the copper amounts are higher than in Caley's for the reign of Ptolemy VIII, but his tin and



Graph 5.23: Average composition of tin (Sn), lead (Pb) and copper (Cu) based on the results presented in the current research.

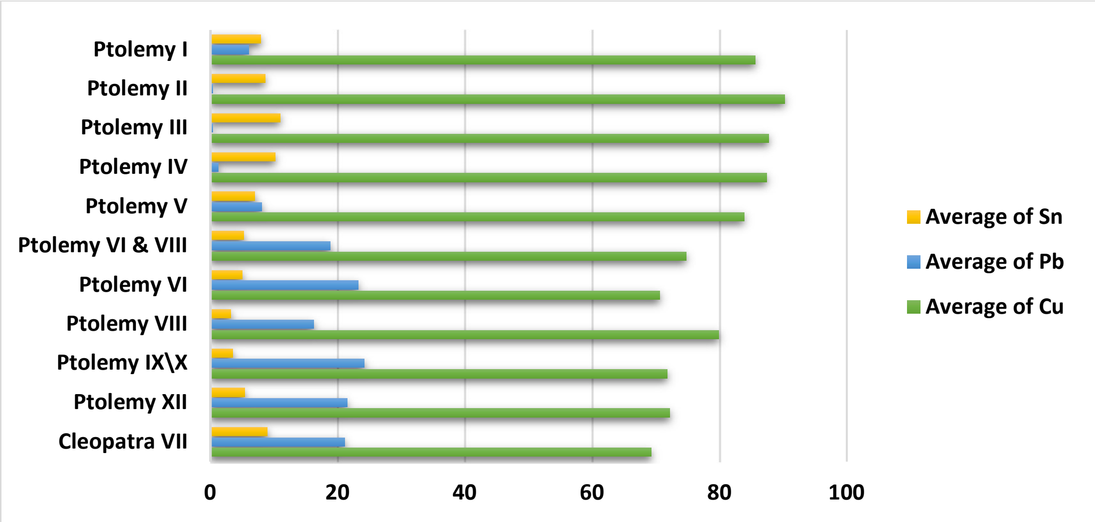


Graph 5.24: Average composition of tin (Sn), lead (Pb) and copper (Cu) adapted from Caley's analytical results (Caley, 1939: 97).

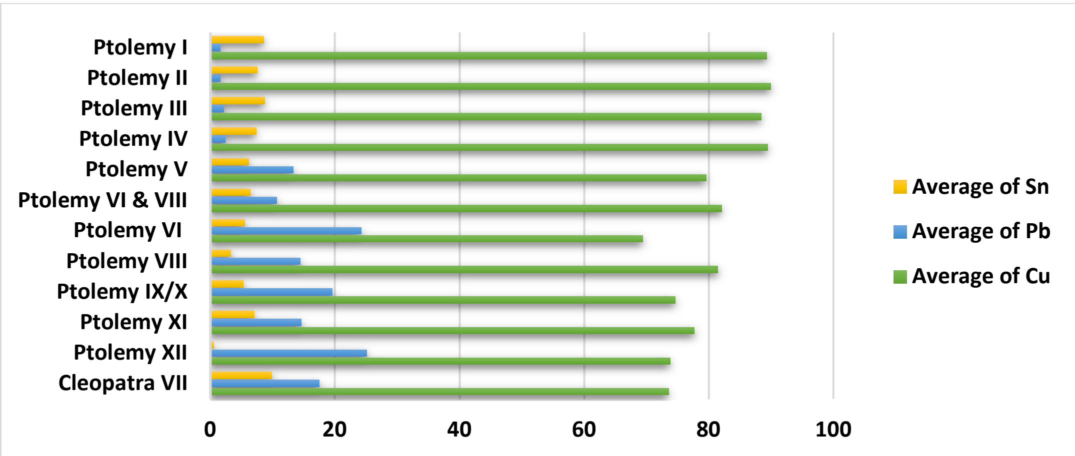
especially his lead values are higher for this ruler. Finally, the results for Ptolemy X demonstrate higher (over 3%) copper levels for the current research, the tin composition is similar between the two sets, but Caley's results have a higher (over 1%) lead composition (Graphs 5.22 and 5.23). It must be noted that this publication is from 1939, so the discrepancy of a few percent between these results and the current are to be expected, due to the difference in the sample sizes and the development in instrumental precision, but as a whole this research also indicates the overall change in the composition of the Ptolemaic bronze coins.

Returning to the more recent analysis and results, namely those of Faucher, it must be noted that he sampled and analysed a total of 128 bronze coins, a slightly larger amount than what was analysed by the present work. He presents his results based on the newly designed series system of dating this type of coinage. He does, however provide the Svoronos numbers for the analysed coins (Faucher, 2013: 313-317) making it possible to determine the ruler to whom these coins can be ascribed. Moreover, Faucher separates his results by presenting first the coins minted in Alexandria and then the coins minted in provincial mints. Table 5.22 presents Faucher's results chronologically ordered by ruler, following the provided Svoronos numbers and groups provincial mints and the Alexandrian mint coins together under the ruler they are ascribed to. However, four coins sampled and analysed by Faucher were not included in Table 5.22 as three of them were provided with reference numbers that were not based on Svoronos and one was not provided with a reference at all thus making it impossible to ascribe a ruler to those coins. Although a direct ruler to ruler comparison between the coins analysed at the present work and by Faucher is not feasible here due to the size of both data sets, Graphs 5.25 and 5.26 present the average results for both of these analyses so observation with regards to similarities and differences in the results can be made.

From the two graphs presenting the average results, it can be seen that the coins of Ptolemy I show relatively similar percentages of copper and tin content, but the lead amount differs being higher in the results of the current research. This could perhaps be explained by the difference in the analytical techniques used (for detail on this see section **3.5.** and Chapter 4 above) and as Faucher uses a surface analysis, this discrepancy could be due to the fact that the current minimally invasive technique



Graph 5.25: Average composition of tin (Sn), lead (Pb) and copper (Cu) based on the results presented in the current research.



Graph 5.26: Average composition of tin (Sn), lead (Pb) and copper (Cu) adapted from Table 5.22 based on Faucher's analytical results (Faucher, 2013: 313-317).

provides more precise results with regards to trace elements. The coinage of Ptolemy II and III shares similar copper contents in both analyses, but the lead amounts observed in Faucher's results are higher, on the other hand the tin results for these rulers indicate a higher percentage in the present work.

The copper content for the coins of Ptolemy IV is similar although Faucher's results are about 2% higher, difference is observed in the lead percentages which seems marginally higher in Faucher's research, and again the tin content in the current analysis is higher. The copper and tin contents for the coins of Ptolemy V does indicate a level of resemblance, but it does appear that the coins analysed by Faucher show a higher lead content. For the coins belonging to the joint reign of Ptolemy VI and VIII Faucher's results indicate higher copper levels, but the results from the current work show significantly more lead for this type of coinage. The tin content in the coins of this period is just marginally higher in the samples analysed by Faucher. The coinage of Ptolemy VI sole rule does seem to share similarities in both copper and tin levels (although a slight elevation is noticeable in Faucher's results for this element) the lead content in Faucher's work seems to be higher than what can be observed in the present results.

The tin and lead contents in the coins of Ptolemy VIII seems to be within the same margins in both data sets, a difference here is the elevated copper level over 1.5% observed in the results presented by Faucher (2013). The coins from the reigns of Ptolemy IX/X demonstrates higher copper, and tin levels in Faucher's analysis, but the lead in the current results has a higher percentage. No comparison can be made for the coin of Ptolemy XI as the current research was unable to sample and consequently analyse material from this reign. The lead and copper contents in the coins of Ptolemy XII analysed by Faucher (2013) are higher than those of this ruler analysed in the present work. This however is not the case for the tin content which is significantly higher in the results presented by the current research. The coinage of Cleopatra VII presented by Faucher contains higher copper and tin amounts, but the levels of lead in these coins are lower than the sampled and analysed material of the present research. Despite these differences which could stem from variation of instrumental precision and/or sample size what is evident in both of these data sets is that the change in the composition of Ptolemaic bronze coins begins around the reign of Ptolemy V and can be characterized with increased lead and decreased copper content. The interpretation of these changes varies between the current work and that of Faucher (2013), and as mentioned above, these interpretations and the supporting evidence will be discussed in the next chapter.

5.5. Model Testing the Series System

As discussed previously, the series system proposed by Pichard and Faucher (2012) is not utilised as a dating tool for the sampled and analysed bronze coins presented in this thesis. Instead, the thesis uses the reign-based system of dating utilised by Svorones (1906), Lorber (2018b) and others. However, given the significance of the series system within the field of Ptolemaic numismatics, it was nevertheless thought prudent to conduct a detailed comparison between these two dating systems. As such, the purpose of this section is to reframe the results of the bronze coin analysis conducted as part of the current research, and fit the results into the Series System thereby providing an additional point of comparison between (a) the results of the current research fitted into the Series System and (b) the published results of Faucher's analysis. This will provide an opportunity to discuss any divergence between the two sets of results, and, in a broader sense, provide a test model for future researchers with regards to the use of the Series System versus the reign-based system.

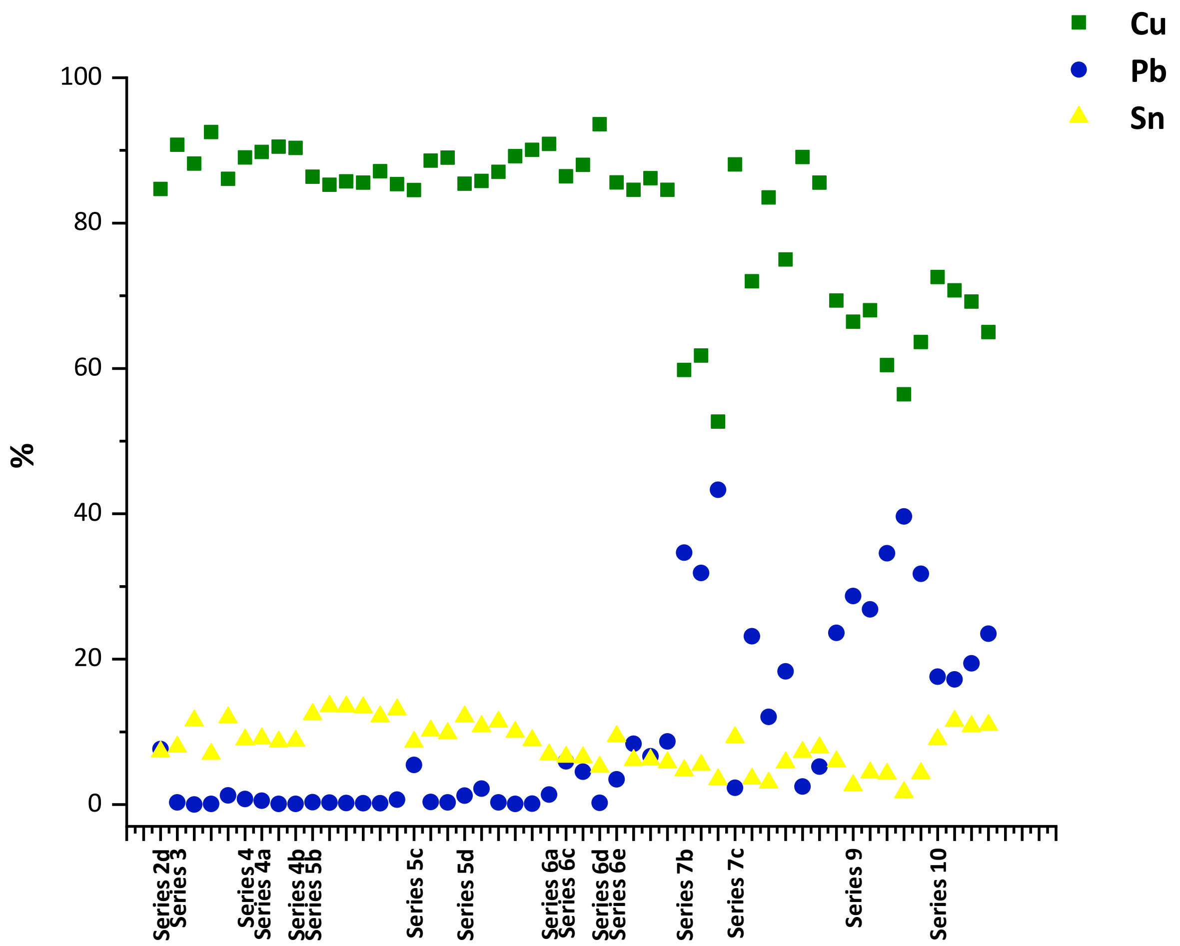
Firstly, when comparing the results of the current research arranged by reign (Graph 5.21) and by series (Graph 5.27) there is overall a great deal of similarity. However, some significant differences are also apparent. Most of these differences relate to the division of the joint reign of Ptolemy VI and VIII into four different series: 6a, 6c, 7c and 9. Because of this division, the results shown in Graph 5.27 appear less dispersed than in Graph 5.21. Secondly, certain reigns – particularly those of Ptolemy VIII and all of the coins related to the reign of Ptolemy XII could not be directly converted from a reign-based dating system to the series system. This is because, as noted in Faucher's research, the series system for coins coming from provincial mints is still being developed and is not clearly comparable to the system devised for coins originating in the Alexandrian mint. As a result of this, the available sample of bronze coins is somewhat smaller in Graph 5.27 than in Graph 5.21. This has a direct impact on the observable decrease of lead (particularly regarding a number of Cleopatra VII coins) which is more pronounced in Graph 5.21 as opposed to Graph 5.27 due to exclusion of part of the sampled coins.

Turning now to a comparison between the results presented in this thesis arranged into series, and the results published by Faucher (Graph 5.28). Firstly, it must be noted that the results display a very high degree of similarity, although there are some minor points of divergence.

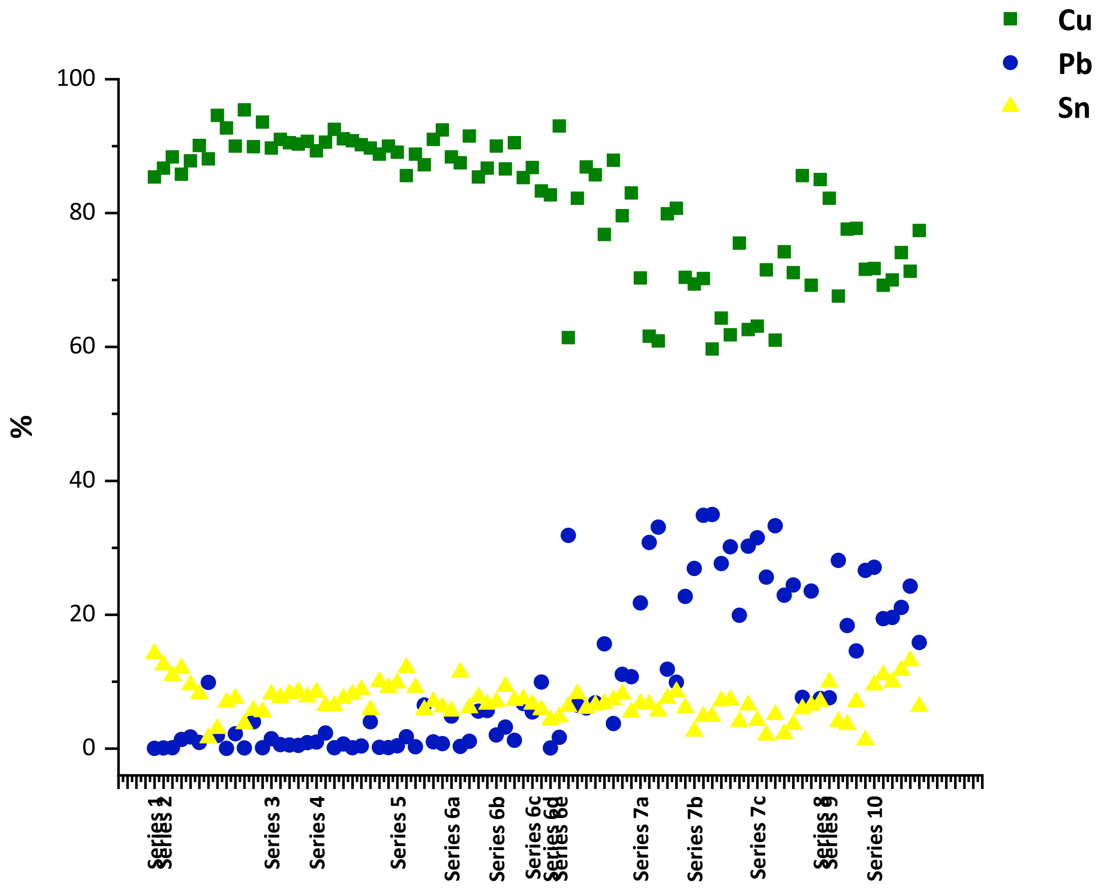
Part of this divergence can be explained by the larger sample size presented by Faucher, which leads to a more detailed picture. Because of this larger sample size, there is also more variety in the series and sub-series in Faucher’s published results by comparison to those presented in this thesis. Another small but interesting point of divergence between the two sets of results is the lower tin levels observed by Faucher by comparison to the current research. This difference, as noted above, is most likely related to differences in the analytical methods used by the two studies.

A small number of the coins presented in this thesis have somewhat higher lead and copper levels than those presented by Faucher. However, as this is the case for a small number of samples (see Graph 5.27 and 5.28), it is potentially not that significant and could be the result of a minting error or because of different analytical methods employed by the two studies. In addition, when there are two increases of lead observed, one starting under Ptolemy VIII and one under Cleopatra VII that are observed in Graph 5.21 but not Graphs 5.27 and 5.28. This is again the result of the omission of provincial mints from the series system. Overall, however, regardless of some minor points of divergence, both datasets broadly agree with regards to the start of the period of debasement, the lowering of copper and the increase of lead. Both sets of results show significant debasement beginning around series 6e, which encompasses part of the reign of Ptolemy V. Both sets of results also demonstrate a similar rise in the observable tin levels in Series 10, which is broadly relatable to the reign of Cleopatra VII.

As this section has clearly demonstrated, the results of the current analysis can be converted, at least partially, into the series system. However, there remains a fundamental issue: One of availability. Faucher’s results are based on a large assemblage of coins from a few sources, whereas the current research relies on a more dispersed sample from multiple collections. From the collections approached as part of the data collection for this thesis, only one allowed the current author to visit and personally select the coins prior to sampling. In all other cases, the coins to be sampled had to be requested by reign and were then located by museum curators, and in some cases were later found to have been misdated in the museum catalogues. The series system is an excellent framework and tool for the dating of Ptolemaic bronze coinage, although it relies on a high level of collections access which not all researchers can emulate. Additionally, as noted above, the series system was mostly developed on the basis of Alexandrian coinage, meaning a further potential restriction for researchers attempting to date their samples using this system.



Graph 5.27: The overall percentage content of copper (Cu), lead (Pb) and tin (Sn) in the analysed sample set dated using the series system.



Graph 5.28: The overall percentage content of copper (Cu), lead (Pb) and tin (Sn) adapted from Annexe 1: Analyses de composition mètallique (Faucher, 2013: 313-316).

Number	Ruler	Mint	Weight	Cu	Sn	Pb	Sb	Au	Ag	As	Fe	Co	Ni	Zn
1	Ptolemy I	Alexandria	4.46g	85.4	14.2	0.03	0.2	0.006	0.038	0.04	0.19	0.02	0.52	
2	Ptolemy I	Alexandria	3.78g	86.7	12.5	0.1	0.054	0.003	0.036	0.28	0.27	0.08	0.041	
3	Ptolemy I	Alexandria	5.29	88.4	10.9	0.11	0.061	0.011	0.062	0.09	0.12	0.03	0.022	0.17
4	Ptolemy I	Alexandria	5.38	85.8	12	1.36	0.03	0.003	0.022	0.14	0.51	0.11	0.048	
5	Ptolemy I	Alexandria	7.8	87.8	9.5	1.74	0.038	0.005	0.033	0.17	0.43	0.2	0.055	
6	Ptolemy I	Alexandria	7.93	90.1	8.2	0.91	0.048	0.002	0.033	0.24	0.3	0.18	0.049	
7	Ptolemy I	Alexandria	13.75	88.1	1.6	9.87	0.031	0.002	0.021	0.09	0.14	0.04	0.027	0.012
8	Ptolemy I	Alexandria	14.04	94.6	3	1.93	0.024	0.002	0.025	0.16	0.13	0.08	0.05	
9	Ptolemy I	Alexandria	19.16	92.7	6.9	0.04	0.028	0.002	0.014	0.25	0.03	0.01	0.031	
10	Ptolemy I	Alexandria	16.76	90	7.5	2.21	0.033	0.005	0.3	0.17	0.07	0.02	0.04	
99	Ptolemy I	Cyrenaica	4.02	88.8	10	0.9	0.021	0.003	0.021	0.13		0.1	0.026	0.045
100	Ptolemy I	Cyrenaica	6.27	91.8	6.7	1.19	0.028	0.003	0.021	0.11	0.04	0.09	0.41	
106	Ptolemy I	Cyprus	8.3	90.5	9	0.11	0.019	0.004	0.022	0.08	0.18	0.09	0.025	0.002
11	Ptolemy II	Alexandria	11.11	95.4	3.7	0.1	0.042	0.004	0.02	0.37	0.05	0.09	0.6	0.125
12	Ptolemy II	Alexandria	16.65	89.9	5.7	4	0.03	0.003	0.025	0.12	0.19	0.02	0.035	0.025
13	Ptolemy II	Alexandria	14.86	93.6	5.5	0.11	0.048	0.004	0.023	0.04	0.12	0.1	0.052	0.059
14	Ptolemy II	Alexandria	8.16	89.7	8.1	1.46	0.049	0.004	0.026	0.26	0.15	0.19	0.66	0.05
15	Ptolemy II	Alexandria	11.73	91	7.6	0.6	0.06	0.004	0.031	0.3	0.27	0.19	0.043	0.04
16	Ptolemy II	Alexandria	7.73	90.5	8.2	0.54	0.052	0.004	0.025	0.27	0.07	0.19	0.079	0.08
17	Ptolemy II	Alexandria	12.36	90.3	8.5	0.46	0.05	0.004	0.024	0.27	0.15	0.15	0.065	0.049
18	Ptolemy II	Alexandria	9.37	90.7	7.7	0.87	0.065	0.004	0.03	0.27	0.26	0.09	0.043	
19	Ptolemy II	Alexandria	80.68	89.3	8.4	0.97	0.059	0.005	0.029	0.35	0.56	0.22	0.14	
20	Ptolemy II	Alexandria	101.81	90.6	6.4	2.32	0.0038	0.004	0.027	0.23	0.2	0.19	0.067	

Number	Ruler	Mint	Weight	Cu	Sn	Pb	Sb	Au	Ag	As	Fe	Co	Ni	Zn
21	Ptolemy II	Alexandria	87.98	92.5	6.4	0.13	0.049	0.008	0.024	0.25	0.41	0.17	0.068	
22	Ptolemy II	Alexandria	89.02	91.1	7.5	0.68	0.066	0.004	0.029	0.27	0.11	0.14	0.069	
23	Ptolemy II	Alexandria	96.15	90.8	8.1	0.12	0.4	0.003	0.023	0.32	0.26	0.31	0.087	
91	Ptolemy II	Tyre	3.25	90.3	9.2	0.03	0.01	0.001	0.01	0.15	0.06	0.17	0.025	
92	Ptolemy II	Sidon	10.24	90.7	6.3	2.56	0.037	0.002	0.026	0.16	0.05	0.08	0.046	
93	Ptolemy II	Tyre	22.77	87.4	11.33	0.19	0.056	0.004	0.025	0.39	0.29	0.21	0.07	
94	Ptolemy II	Tyre	14.97	87.9	8.4	2.41	0.069	0.004	0.036	0.46	0.35	0.23	0.104	
95	Ptolemy II	Tyre	5.56	88.3	10	0.89	0.045	0.004	0.022	0.34	0.09	0.17	0.069	0.1
96	Ptolemy II	Tyre	5.39	88.1	10.6	0.55	0.046	0.003	0.021	0.35	0.13	0.16	0.068	0.038
107	Ptolemy II	Cyprus	7.21	88	11.4	0.11	0.018	0.005	0.015	0.11		0.23	0.037	
108	Ptolemy II	Cyprus	10.5	89	10.7	0.02	0.012	0.003	0.012	0.09	0.09	0.01	0.023	
109	Ptolemy II	Cyprus	8.31	88.8	10.8	0.08	0.016	0.004	0.015	0.1	0.13	0.05	0.022	
110	Ptolemy II	Cyprus	5.98	85.1	6.6	7.68	0.054	0.002	0.028	0.24	0.2	0.2	0.049	0.005
111	Ptolemy II	Cyprus	15.07	93.6	3.5	2.52	0.02	0.002	0.018	0.14	0.15	0.15	0.033	0.004
121	Ptolemy II	Thrace (?)	1.77	87.2	4.1	8.4	0.034	0.003	0.021	0.07	0.15	0.05	0.039	0.03
122	Ptolemy II	Sicily	16.43	94.7	4.1	0.16	0.062	0.006	0.035	0.5	0.24	0.06	0.065	
123	Ptolemy II	Sicily	13.96	84	4.6	4.87	0.293	0.011	0.127	0.18	0.52	0.01	0.207	5.19
24	Ptolemy III	Alexandria	15.55	90.2	8.8	0.39	0.047	0.004	0.022	0.23	0.06	0.13	0.074	
25	Ptolemy III	Alexandria	14.34	89.7	5.8	4	0.065	0.003	0.031	0.27	0.08	0.15	0.05	0.044
28	Ptolemy III	Alexandria	76.2	89.1	9.8	0.41	0.057	0.004	0.044	0.23	0.21	0.12	0.068	
29	Ptolemy III	Alexandria	35.37	85.6	12.1	1.75	0.024	0.004	0.02	0.19	0.17	0.14	0.052	
30	Ptolemy III	Alexandria	31.76	88.8	9.1	0.27	0.02	0.003	0.015	0.28	0.73	0.61	0.099	
31	Ptolemy III	Alexandria	36.15	87.2	5.8	6.49	0.005	0.001	0.11	0.26	0.11	0.2	0.127	0.055

Number	Ruler	Mint	Weight	Cu	Sn	Pb	Sb	Au	Ag	As	Fe	Co	Ni	Zn
90	Ptolemy III	Gaza?	8.08	88.9	10.3	0.21	0.023	0.004	0.022	0.2	0.05	0.22	0.047	
112	Ptolemy III	Cyprus	2.98	87.6	8.1	3.7	0.053	0.003	0.029	0.27	0.21	0.17	0.05	0.024
26	Ptolemy IV	Alexandria	9.66	88.8	10	0.17	0.079	0.007	0.045	0.59	0.06	0.15	0.114	
27	Ptolemy IV	Alexandria	11.04	90	9.1	0.14	0.057	0.005	0.033	0.31	0.14	0.14	0.081	
32	Ptolemy IV	Alexandria	34.36	91	7	1	0.057	0.002	0.026	0.3	0.5	0.3	0.075	0.041
33	Ptolemy IV	Alexandria	41.94	92.4	6.2	0.73	0.054	0.003	0.3	0.29	0.16	0.2	0.061	0.064
38	Ptolemy IV	Alexandria	7.24	86.7	6.6	5.67	0.042	0.003	0.022	0.26	0.34	0.3	0.066	0.059
75	Ptolemy IV	Alexandria	18.78	85	7	7.46	0.029	0.004	0.027	0.12	0.16	0.08	0.07	0.044
97	Ptolemy IV	Tyre	36.15	91.2	7.4	0.5	0.06	0.002	0.023	0.23	0.4	0.15	0.063	0.034
102	Ptolemy IV	Cyrenaica?	14.55	94.6	4.1	0.95	0.022	0.002		0.18		0.22	0.033	0.082
103	Ptolemy IV	Cyrenaica	14.59	86.2	9.4	3.37	0.042	0.003	0.021	0.32	0.18	0.24	0.083	0.075
104	Ptolemy IV	Cyrenaica	16.56	88.6	6.8	3.9	0.036	0.003	0.018	0.28	0.19	0.29	0.057	0.023
39	Ptolemy V	Alexandria	27.13	90	7	2.02	0.04	0.004	0.025	0.32	0.21	0.26	0.103	
40	Ptolemy V	Alexandria	28.81	86.6	9.3	3.2	0.042	0.003	0.021	0.32	0.18	0.23	0.086	
46	Ptolemy V	Alexandria	14.6	93	4.7	1.68	0.039	0.003	0.018	0.27	0.25	0.29	0.052	0.074
47	Ptolemy V	Alexandria	16.9	61.4	6.3	31.83	0.051	0.002	0.019	0.14	0.16	0.07	0.036	0.036
48	Ptolemy V	Alexandria	19.91	82.2	8.2	6.49	0.061	0.005	0.034	0.46	2.07	0.36	0.132	0.041
49	Ptolemy V	Alexandria	22.96	86.9	6	6.07	0.038	0.003	0.02	0.26	0.35	0.3	0.073	0.021
50	Ptolemy V	Alexandria	8.84	85.7	6.5	6.83	0.038	0.004	0.021	0.26	0.24	0.26	0.071	0.051
51	Ptolemy V	Alexandria	9.42	76.8	6.7	15.64	0.035	0.003	0.022	0.24	0.16	0.24	0.6	0.049
52	Ptolemy V	Alexandria	3.73	87.9	7.3	3.74	0.04	0.004	0.028	0.29	0.3	0.31	0.074	0.047
53	Ptolemy V	Alexandria	1.96	79.6	8.1	11.07	0.042	0.003	0.023	0.28	0.41	0.28	0.068	
54	Ptolemy V	Alexandria	2.35	83	5.4	10.74	0.042	0.003	0.023	0.25	0.21	0.26	0.059	

Number	Ruler	Mint	Weight	Cu	Sn	Pb	Sb	Au	Ag	As	Fe	Co	Ni	Zn
68	Ptolemy V	Alexandria	14.53	63.1	4.2	31.49	0.054	0.005	0.21	0.23	0.54	0.16	0.053	0.151
69	Ptolemy V	Alexandria	2.84	71.5	2	25.6	0.047	0.002	0.021	0.25	0.49	0.26	0.048	0.01
70	Ptolemy V	Alexandria	2.25	61	5.1	33.27	0.039	0.003	0.021	0.2	0.23	0.17	0.051	
124	Ptolemy V	Cyrenaica?	3.85	85	4.9	9.3	0.042	0.002	0.02	0.26	0.37	0.27	0.5	0.005
34	Ptolemy VI & VIII	Alexandria	37.97	88.4	5.6	4.86	0.033	0.003	0.019	0.23	0.46	0.31	0.067	0.044
35	Ptolemy VI & VIII	Alexandria	21.2	87.5	11.4	0.32	0.047	0.004	0.026	0.35	0.12	0.14	0.082	0.039
36	Ptolemy VI & VIII	Alexandria	29.91	91.5	6.1	1.09	0.03	0.003	0.023	0.26	0.53	0.31	0.066	0.063
37	Ptolemy VI & VIII	Alexandria	35.64	85.4	7.7	5.58	0.054	0.005	0.029	0.38	0.25	0.44	0.126	0.03
41	Ptolemy VI & VIII	Alexandria	35.52	90.5	7.17	1.24	0.038	0.004	0.022	0.28	0.4	0.29	0.072	
42	Ptolemy VI & VIII	Alexandria	33.11	85.3	7.4	6.73	0.019	0.002	0.016	0.13	0.17	0.17	0.039	0.025
43	Ptolemy VI & VIII	Alexandria	14.12	86.8	6.6	5.47	0.034	0.003	0.024	0.28	0.37	0.3	0.067	0.07
44	Ptolemy VI & VIII	Alexandria	9	83.3	5.8	9.95	0.036	0.003	0.02	0.26	0.23	0.28	0.063	0.045
71	Ptolemy VI & VIII	Alexandria	2.59	74.2	2.2	22.9	0.083	0.002	0.01	0.2	0.1	0.23	0.041	0.311
72	Ptolemy VI & VIII	Alexandria	20.35	71.1	3.6	24.43	0.039	0.003	0.033	0.22	0.24	0.23	0.053	
73	Ptolemy VI & VIII	Alexandria	22.26	85.6	5.93	7.65	0.046	0.003	0.022	0.25	0.18	0.23	0.07	
74	Ptolemy VI & VIII	Alexandria	22.93	69.2	6.43	23.52	0.053	0.002	0.02	0.2	0.25	0.22	0.057	
76	Ptolemy VI & VIII	Alexandria	6.08	82.2	9.94	7.59	0.025	0.001	0.01	0.09	0.06	0.02	0.028	
77	Ptolemy VI & VIII	Alexandria	7.35	67.6	4	28.12	0.035	0.003	0.024	0.14	0.02	0.04	0.04	
45	Ptolemy VI	Alexandria	11.59	82.7	4.3	0.08	0.016	0.003	0.018	0.21	2.17	0.5	0.051	
55	Ptolemy VI	Alexandria	22.29	70.3	6.7	21.75	0.033	0.002	0.019	0.21	0.48	0.48	0.075	
56	Ptolemy VI	Alexandria	23.15	61.6	6.6	30.79	0.04	0.001	0.01	0.14	0.29	0.51	0.022	
57	Ptolemy VI	Alexandria	23.3	60.9	5.6	33.09	0.034	0.001	0.012	0.12	0.08	0.18	0.042	
58	Ptolemy VI	Alexandria	6.12	79.9	7.5	11.85	0.041	0.003	0.023	0.24	0.06	0.18	0.063	0.054

Number	Ruler	Mint	Weight	Cu	Sn	Pb	Sb	Au	Ag	As	Fe	Co	Ni	Zn
59	Ptolemy VI	Alexandria	6.58	80.7	8.5	9.92	0.04	0.003	0.02	0.24	0.22	0.3	0.074	
60	Ptolemy VI	Alexandria	3.62	70.4	6.1	22.73	0.04	0.003	0.022	0.21	0.13	0.26	0.071	0.046
61	Ptolemy VI	Alexandria	14.96	69.4	2.6	26.9	0.035	0.001	0.016	0.29	0.7	0.41	0.036	0.016
62	Ptolemy VI	Alexandria	16.2	70.2	4.8	34.83	0.04	0.003	0.021	0.2	0.14	0.18	0.054	
63	Ptolemy VI	Alexandria	17	59.7	4.8	34.97	0.036	0.002	0.018	0.19	0.1	0.17	0.046	
64	Ptolemy VI	Alexandria	17.15	64.3	7.1	27.63	0.042	0.002	0.017	0.14	0.39	0.28	0.031	
65	Ptolemy VI	Alexandria	7.88	61.8	7.3	30.13	0.08	0.003	0.019	0.2	0.19	0.21	0.049	
66	Ptolemy VI	Alexandria	8.91	75.5	4	19.9	0.047	0.003	0.021	0.25	0.17	0.15	0.068	0.004
67	Ptolemy VI	Alexandria	7.25	62.6	6.5	30.22	0.063	0.002	0.019	0.32	0.05	0.15	0.098	
116	Ptolemy VI	Cyprus	13.78	67.6	4.4	27.4	0.032	0.002	0.019	0.2	0.08	0.14	0.052	
117	Ptolemy VI	Cyprus	7.55	73.1	1.4	25.24	0.016	0.002	0.014	0.09	0.04	0.08	0.038	
78	Ptolemy VIII	Alexandria	2.05	77.6	3.6	18.39	0.037	0.003	0.025	0.16	0.04	0.05	0.058	
101	Ptolemy VIII	Cyrenaica	4.43	94.3	4.1	0.66	0.053	0.005	0.026	0.38	0.14	0.18	0.127	
105	Ptolemy VIII	Cyrenaica	8.8	85.1	2.8	11.4	0.044	0.002	0.022	0.13	0.01	0.09	0.055	0.345
113	Ptolemy VIII	Cyprus	8.65	86.8	6.2	5.26	0.028	0.003	0.019	0.5	0.4	0.73	0.086	
114	Ptolemy VIII	Cyprus	52.18	90.5	3.3	5.86	0.019	0.003	0.021	0.11	0.04	0.05	0.033	
115	Ptolemy VIII	Cyprus	2.53	54.4	0	45.05	0.033	0.011	0.18		0.2	0.048	0.085	
80	Ptolemy IX/X	Alexandria?	4.66	71.6	1.3	26.6	0.012	0.003	0.015	0.13	0.07	0.19	0.054	0.036
118	Ptolemy IX/X	Cyprus	6.43	89.8	7	2.76	0.062	0.005	0.032	0.17	0.05	0.07	0.034	0.073
119	Ptolemy IX/X	Cyprus	6.01	62.5	7.7	29.42	0.035	0.003	0.021	0.16	0.05	0.1	0.051	
79	Ptolemy XI	Alexandria	1.6	77.7	7	14.59	0.074	0.004	0.05	0.19	0.12	0.22	0.093	0.049
125	Ptolemy XII	Cyrenaica?	7.02	73.8	0.6	25.1	0.014	0.001	0.017	0.16	0.2	0.19	0.035	0.034
81	Cleopatra VII	Alexandria	17.91	71.7	9.5	27.07	0.092	0.003	0.043	0.17	0.08	0.06	0.191	0.034

Number	Ruler	Mint	Weight	Cu	Sn	Pb	Sb	Au	Ag	As	Fe	Co	Ni	Zn
82	Cleopatra VII	Alexandria	18.4	69.2	11	19.4	0.053	0.003	0.035	0.1	0.09	0.07	0.128	
83	Cleopatra VII	Alexandria	18.92	70	9.9	19.57	0.056	0.003	0.034	0.11	0.11	0.07	0.108	
84	Cleopatra VII	Alexandria	11.1	74.1	11.7	21.07	0.051	0.003	0.039	0.15	0.11	0.03	0.102	
85	Cleopatra VII	Alexandria	11.32	71.3	13.1	24.25	0.086	0.003	0.044	0.16	0.1	0.05	0.137	
86	Cleopatra VII	Alexandria	12	77.4	6.3	15.85	0.053	0.002	0.04	0.15	0.04	0.05	0.12	
120	Cleopatra VII	Cyprus	17.35	67.5	9.2	11.87	0.042	0.002	0.021	0.14	0.02	0.14	0.039	
126	Cleopatra VII	Berytos	3.72	73.1	11.38	15.22	0.026	0.004	0.031	0.13		0.04	0.037	
127	Cleopatra VII	Chalcis	9.13	82.8	6.8	9.67	0.133	0.004	0.053	0.13	0.25	0.1	0.063	
128	Cleopatra VII	Chalcis	5.44	78.2	10	11.12	0.238	0.003	0.072	0.12	0.12	0.05	0.052	

Table 5.22: The results of the analysis of Ptolemaic bronze coins adapted from Faucher (2013: 313-317).

Chapter 6: Discussion

The current chapter aims to place the analytical results presented in the previous chapter into the broader historical framework of the Ptolemaic period. The chapter will be split into three chronological sections. The first section (Early Ptolemaic Period) will start with the reign of Ptolemy I and conclude with Ptolemy IV. The second section (Middle Ptolemaic Period) will include the reigns of Ptolemy V up to Ptolemy X and the final section (Late Ptolemaic Period) will cover the reigns of Ptolemy XII and Cleopatra VII. As Ptolemy XI ruled for less than a year, and as no coins of this ruler were sampled, this reign will not be discussed here. A concise overview of the individual reigns will be presented focusing on events such as international wars, civil wars and revolts, events which could have influenced the composition of both the silver and the bronze coinage.

6.1. Coinage Manipulation and Debasement During the Early Ptolemaic Period (from Ptolemy I to Ptolemy IV)

6.1.1. Ptolemy I

The sampled and analysed silver and bronze coins belonging to Ptolemy I do not indicate any significant compositional changes occurring during his reign. This is interesting in itself, especially with regards to the silver coinage, as changes to the obverse and reverse imagery, as well as manipulations of the weight standards of these coins, occurred several times. Following the death of Alexander, the Great, Ptolemy did not immediately become king of Egypt. Instead, from 323 BCE to 306 BCE he served merely as a satrap of Egypt (Hölbl, 2001: 14-29). Nevertheless, he began minting coins in Egypt around 323 BCE, and the first change to this coinage occurred in 319 BCE when a second series of tetradrachms were issued (Lorber, 2012: 213). These new issues had a different obverse image (the head of deified Alexander with the horn of Amun and wearing an elephant headdress) but retained the reverse image depicting Zeus seated on a throne holding an eagle (Lorber, 2012: 213). Following this initial change, in 312 BCE the obverse image of Alexander was refined and a year later a new reverse image was introduced: the goddess Athena holding a spear and a shield. These changes could be indicative of a move of the court, and royal mint, from

Memphis (Fig. 2.1.) to Alexandria (Lorber, 2012: 213). The first bronze coins linked to the satrapy of Ptolemy were most likely minted around 315 BCE (Lorber, 2007: 135).

Further to these changes Ptolemy actively encouraged the immigration of Macedonians, Greeks and non-Egyptians to Egypt, largely to function as part of his military forces: "[…] but also to fill the upper positions in the royal administration and to provide a pool of concessionaries to whom the government could contract tax farming and other functions" (Lorber, 2018: 18). The success of this venture is attested by Fischer-Bovet (2011: 143) who estimates that by 319 BCE around 32.000 immigrants had made the move to Egypt. According to Diodorus (20.73.3 – 20.76.6) with the thus amassed military might, Ptolemy became king of Egypt at end of 305 BCE or early 304 BCE. Around this date can also be observed the first weight reduction in the Ptolemaic silver coinage and a move away from the Attic standard (for details see section **3.2.** above). The coins were made 1.50g lighter and "[…] recoined to a norm of 15.70g" (Lorber, 2012: 214). Lorber (2012: 213-214) considers this change to be the result of the continuous war with Antigonus and the destruction of the Ptolemaic fleet in the battle of Salamis (Fig. 2.1). As the rest of the Greek world was using the Attic weight standard Ptolemy's decision caused issues for foreign merchants who bought Egyptian grain and other goods. They were obliged to exchange their Attic tetradrachms for the reduced weight Egyptian coins, thus ensuring that the Egyptian government in effect earned 1.50g of silver on each exchanged coin (Le Rider, 1997-1998: 789-792). With regards to the bronze coinage, a change in the imagery of the obverse (still retaining the image of Alexander but with longer hair) can be observed after Ptolemy took the throne of Egypt, and according to Lorber (2007: 136) they exhibit "[…] control links to a series of reduced weight Alexander/Athena tetradrachms."

Around 300 BCE a further change in the weight of the silver coinage occurred when it was reduced from an average of 15.70g to 14.20g. (Jenkins, 1967: 62). In addition to the weight reduction this new type of coinage presented new obverse (the portrait of Ptolemy) and reverse (eagle standing on a thunderbolt) images which, as noted in the previous chapter became the typical coin image used throughout the remainder of the Ptolemaic Period (Jenkins, 1967: 62). These monetary changes undertaken by

Ptolemy I can be credited with helping the government conserve the supply of silver, and in turn expand the monetary supply with the ultimate aim being to support the court and the administration in their growth (Lorber, 2012: 214). As mentioned above despite these changes in weight, the bullion composition of the silver coins of Ptolemy I remained remarkably pure, indicating that Ptolemy's nascent bureaucracy was able to acquire the needed silver for the growing Egyptian economy with the slight weight reduction alone. This in itself raises an important question: if Ptolemy I knew Egypt could not sustain silver coinage, and if he was willing to depart from the Attic standard and reduce the weight of this type of coinage multiple times in order to secure the required silver resources for minting, then why not debase them, rather than lower their weight and depart from the Attic weight standard? Perhaps an answer can be found in the way the ancient Greeks viewed money, not only as a medium of exchange but as a symbol. Seaford (2004: 4) explains this concept very aptly: "Money coined and uncoined, was stored in huge quantities in sanctuaries, and might be imagined as belonging to deity. … Coins were often stamped with image of a deity. Money was often imagined as having superhuman will of its own".

This explanation certainly accounts for the decisions taken by Ptolemy I with regards to the silver coinage minted during his reign: reducing the weight of the coinage was evidently seen as a less invasive move than debasing its metallic composition. Furthermore, although Ptolemy began using his own image on the obverse of the coins, the divine association suggested by Seaford is still valid as in Egypt Pharaoh was the semi-divine representative of the pantheon on Earth, and mediator between the profane and the divine. Debasing the coinage would mean disrespecting this divine association and this could be the reason why debasement was treated as the method of last resort. The bronze coinage of Ptolemy I underwent mainly iconographical changes. The current analysis has demonstrated (although it must be acknowledged that only two coins were analysed for this ruler) that the copper, tin and lead contents in no way indicate any significant compositional changes during this reign.

6.1.2. Ptolemy II

Ptolemy II became sole king of Egypt in 282 BCE following two years as joint-ruler with his father Ptolemy I. Similarly, to his father, he continued the war with the Seleucid empire (Fig. 2.1.) as well as further military involvement on the Greek mainland (Hölbl, 2001: 37-46). However, he also undertook significant internal development projects as noted in Chapter 2. During this period Ptolemy II also introduced the so-called salt-tax and a reform of the bronze coinage, increasing the size of individual coins (some weighing as much as 100g) and also increasing the production of the bronze coinage. Chapter 2 presents some hypothesis as to why that action was undertaken, but based on the current analysis of the bronze coins of Ptolemy II, no indication of debasement can be observed. In fact, the bronze coins of Ptolemy II demonstrate a lower lead content and a purer composition than those of Ptolemy I. With regards to the silver coinage of Ptolemy II, no significant weight reductions or coinage reforms occurred. The changes made were mainly iconographic and aimed at court propaganda (Lorber, 2012: 215-216). And indeed, the current analysis demonstrates that the silver bullion in the coins of this period remained incredibly pure, never falling below 99%.

As noted in Chapter 2 the creation of the closed-currency system began with Ptolemy I, but what the present analysis of the silver coins from the two reigns of Ptolemy I and Ptolemy II could potentially indicate, is that it was only during the later reign of Ptolemy I and from Ptolemy II's reign onwards that foreign silver coins collected by the State during this exchange were re-cycled and used in the minting of Ptolemaic silver coins. This is indicated by the fluctuating levels of lead apparent in the Ptolemaic silver coinage beginning with the reign of Ptolemy II, which, as mentioned through Chapter 5, is a typical feature of silver recycling. As such, a hypothesis can be presented here that Ptolemy I closed the Ptolemaic market for foreign coins, and decreased the weight of the silver coinage in order to stretch the silver supply in his possession, and in the later years of his reign, as the demand for silver increased, he began an active policy of using the incoming foreign silver to produce the silver Ptolemaic coinage, a policy which then became the norm from the reign of his son onwards. The benefits of this system are clear: as long as Egypt had something to trade there would be a steady stream of silver arriving at the royal mints. This hypothesis of increased demand is supported by the current analysis, and also by the territorial expansion overseas and the opening of mints in Sidon, Tyre, Akko-Ptolemais, Joppa and Gaza (Fig. 2.1.) during the early Ptolemaic Period (Jenkins, 1967: 64).

Another interpretation of the data, in particular of the fluctuating levels of lead, could also be that they relate not to re-cycling of silver coinage, but rather are indicative of different ores used in the minting process. (for details see **5.1**.). However, given the additional evidence (such as textual sources, see section **2.2.**) to the existence and operation of a closed currency system implemented during the early Ptolemaic Period, this interpretation of the data is perhaps less likely.

6.1.3. Ptolemy III

Ptolemy III became king of Egypt in early 246 BCE and immediately began a policy of administrative re-organisation of the country (Hölbl, 2001: 46-47) focusing on the creation of new cities and ports. Similarly, to his predecessors Ptolemy III engaged in war with the Seleucid empire resulting in the Third Syrian War. Ptolemy III was victorious and broke off his campaign in 245 BCE in Mesopotamia appointing governors for the newly added territories of Euphrates and Cilicia (Mooren, 1975). Although Ptolemy III returned home with a large quantity of spoils, he was still faced with some internal strife. Hölbl (2001: 49) labels this particular event an "uprising of the local Egyptians" arguing that during the reign of Ptolemy II and as a result of the Second Syrian War, pressure was put on the native Egyptian population to make as much land as possible available to the crown. These demands continued with the Third Syrian War and coupled with the king's absence; some kind of uprising may have been triggered. McGing (1997: 274-275) however, argues that the textual material from this period can be interpreted in several different ways, and questions if there was indeed an uprising or simply a failed palace coup, or even frustration by the Egyptian farmers at the fact that the government had no notion as to how farming actually worked. When Ptolemy III returned to Egypt he was furthermore faced by agricultural problems, most likely a genuine emergency, resulting from a low Nile Inundation in 245 BCE (Bonneau, 1971 and Hauben, 1990). As a result, grain had to be imported to Egypt from Syria, Phoenicia and Cyprus (Fig. 2.1).

The Third Syrian War did not end in 245 BCE but continued until 241 BCE when peace was finally reached and the empire of the Ptolemies now included "[…] with only a few gaps, the whole of the eastern Mediterranean basin from the Eastern part of the Greater Sytre in Libya up to Thrace where it directly bordered Macedonia" (Hölbl, 2001: 51). These different events do not seem to have had much influence on the composition or iconography of the coinage of Ptolemy III. Only a few iconographical changes to the silver coins were made and some new issues (the silver pieces of Berenice) were minted (Lorber, 2012: 217-218). Following the acquisition of Asia Minor and Thrace (Fig. 2.1.) Ptolemaic coinage began to be minted in these locations as well (Lorber, 2012: 218). An interesting point to consider is that around 241 BCE the significant minting of Ptolemaic coins in Phoenicia began to decrease, possibly because the coins minted there were mainly used for war-expenditure and as the war had ended, there was no longer a sufficiently high demand for coins thus causing the reduced production levels (Jenkins, 1967: 65). Jenkins further states that during the second half of the third century, silver was becoming difficult to obtain for the Ptolemies and gives this as a reason for their interest in Asia Minor and the silver deposits found there (Jenkins, 1967: 65).

If this is indeed true, it is not reflected in the composition of the coins. As noted in **5.1.3.** above the silver coins of Ptolemy III are pure, with a bullion percentage between 98% and 99%. This could potentially indicate that the Ptolemies were not faced with any genuine significant shortages of silver, most likely because the exchange and re-cycling of foreign coinage was supplying the demand, and the continuing variable levels of lead could again be taken as an indication for this. The purity of the silver coins could also be explained as a result of silver booty, brought back from Asia Minor following Ptolemy III's victories, being incorporated into the minting of new coins.

With regards to the bronze coinage of Ptolemy III a further increase in the weight and diameter was made (Lorber, 2007: 139). Only one of these larger bronze coins was sampled and analysed in the present work and its composition is not unusual. However, what was mainly analysed for this ruler, were coins weighing around 30g which do not indicate any significant compositional changes. This is potentially significant as if there was indeed a native revolt during the reign of Ptolemy III, as Hölbl (2001: 49) has argued, then perhaps some debasement was to be expected in order to mitigate against the non-payment of taxes (as indeed becomes apparent during uprisings in later periods, for details see section on Ptolemy V below). This could perhaps support McGing's (1997: 276) theory that there was no revolt, but rather simply some discontent among the farming community. Moreover, the apparent stability of the bronze coins raises the question of the severity of the agricultural emergency in 245 BCE as presumably the importation of grain to Egypt would have cost the government a substantial amount, and yet the composition of both silver and bronze coinage remains stable.

Lorber (2007: 139) presents an interesting hypothesis with regards to the introduction of the new heavier Ptolemy III bronzes, namely that they were issued to appease the public following what she describes as civil unrest and a "severe famine". Further to this, she suggests that the introduction of these heavier bronzes could be indicative of the demonetisation of earlier coins (Lorber, 2007: 139). As the sampled and analysed bronze coins of the present research cannot be ascribed to a specific date it is unclear if they are from the earlier or later part of Ptolemy III's reign the current results cannot contribute to this debate, nor suggest whether there was indeed a recall of earlier coins, a question which as Lorber (2007: 139) states even when the hoard records are taken under consideration still remains inconclusive.

6.1.4. Ptolemy IV

At approximately 20 years of age Ptolemy IV became king of Egypt at the beginning of 221 BCE (Hölbl, 2001: 127). His reign was marked by yet another war with the Seleucid empire (the Fourth Syrian War) and what was undeniably several native Egyptian revolts. The Fourth Syrian War began in 219 BCE after Antiochos, the Seleucid king, attacked and captured the Ptolemaic naval stronghold of Seleukia (Fig. 2.1.) (Grainger, 1991: 90-97). At the end of 219 BCE the Egyptian and Seleucid troops agreed to a ceasefire lasting four months, making the military situation in Coele Syria (Fig. 2.1.) "[…] very unclear and confused" (Hölbl, 2001: 129).

The temporary ceasefire potentially benefitted both sides: For the Egyptians it gave them time to think of potential ways to stop the invasion into Syria, while Antiochos hoped that it would provide him with the opportunity to build up his armies so that he could capture Syria with minimal effort (Hölbl, 2001: 129). The Egyptians began significant war preparations in Alexandria and according to Polybius (V.63.8-65.11) solders were gathered and recruited from all foreign territories with particular interest in men from Crete, Greece, Thrace and Galatia. In addition to these efforts, military changes were also enacted, the major of this was the creation of a regular force of Egyptian troops numbering 20.000 armed in the Macedonian style (Hölbl, 2001: 131). This was highly unusual as while Egyptian cohorts (known as *machimoi*) of a significant size had served in the Ptolemaic army, they had done so only occasionally and they were neither trained in the Macedonian way of combat nor armed appropriately (Goudriaan, 1988: 121-125).

Polybius (V.79-86) states that in 217 BCE Ptolemy IV together with his sister-wife Arsinoe marched from Pelusium (Fig. 2.1.) and arrived southwest of Gaza near Raphia (Fig. 2.1.), where Antiochos was waiting. Polybius provides the date of 22nd of June 217 BCE as the start of the battle of Raphia. The battle was won by the Ptolemaic phalanx and the large contingent of *machimoi*, forcing the Seleucid king to admit defeat and retreat to Antioch (Hölbl, 2001: 131). Ptolemy returned victorious to Egypt and, according to the Raphia Decree 1.11,37, he rewarded his victorious army with 300.000 pieces of gold (Thissen, 1966).

What followed upon the return to Egypt of the king and his army is not exactly clear. Polybius (V.107) states that the Egyptian *machimoi* immediately after the battle of Raphia launched a war, presumably what he means is a revolt, as they were elated by their victory and were of the opinion that they should govern themselves under their own chosen leadership. However, McGing points to some discrepancies between this description and other sections of Polybius' work, where he states that upon return to Egypt Ptolemy IV turned to a life of ease (McGing, 1997: 280), an odd turn of phrase if he had indeed been faced with an immediate and significant revolt. A further issue with the notion of this native and *machimoi*-headed revolt taking place directly after the battle of Raphia, is that the Memphis degree of 217 BCE does not in any way mention it, although as McGing (1997: 280) states this could be due to the fact that the decree followed immediately after the battle, and if the revolt was not yet put down, it would not be expected to be mentioned. Peremans (1978) on the other hand proposes that given how chronologically vague Polybius' accounts are, then the revolt mentioned could be identified as the Theban revolt which occurred at the end of Ptolemy IV's reign. McGing (1997: 280) does agree with Peremans that the revolt did not take place immediately after the battle of Raphia, but later in Ptolemy IV's reign. He however is of the opinion that the revolt took place in the Delta (Fig. 2.1.) based on a description found on the Rosetta Stone where Ptolemy V states that he executed those rebels who revolted in his father time, which in turn can be linked to Ptolemy IV's storming of the Delta.

While somewhat confusing, what can be said with some degree of certainty, is that there was indeed a revolt during Ptolemy IV's later reign which may either have taken place in the Delta or the Thebaid (Fig. 2.1.). Regardless, when the war efforts and expenditures, Ptolemy IV's life of 'ease' and the revolt are all taken under consideration, then an economic tremor in the Ptolemaic empire seems more than likely. Indeed, this is evident in the body of scholarly work dedicated to the inflation of Ptolemaic bronze coins. According to Segre (1942: 191) the inflation of the coinage was directly linked to both the political situation in the late third century and to the Ptolemaic efforts to keep Egypt a great world power. Furthermore, he connects the decline of the Egyptian currency with the years preceding the Fourth Syrian War (Segre, 1942: 191). Reekmans (1951: 61) also places the copper inflation, and thus the changes in the Egyptian currency, to the first half of Ptolemy IV's reign. His conclusions are based on textual sources (such as BGU 1277 dated to 215-214 BCE), which demonstrate that penalties imposed on farmer's leasing agricultural land was between 100% and 125% higher than they were during previous reigns.

Reekmans (1951: 63) further questions whether the doubling of the prices was as a result of economic causes or simply a rise in the market price of wheat from 1.5 drachma to 7.5 drachmae. His conclusion is that these higher penalty prices were the result of monetary changes which in turn affected the prices of wheat, resulting in the "doubling of the nominal value of all the coins" and a 100% inflation. However, with the exception of one textual source (UPZ 149 1.24) Reekmans does not provide evidence for his theory and its validity is hard to assess. He further takes Ptolemy IV's life of ease and his perceived apathy to both internal and foreign affairs, for which there are no real evidence, at face value and concludes that this had a serious effect on the supply of silver concluding that between 221 BCE and 216 BCE Ptolemy doubled the nominal value of all bronze coins (Reekmans, 1951: 67). As Reekmans himself admits, no direct information on wages is available for this time period, although this does not prevent him from stating that the copper coins which had doubled in value were used to pay "[…] with advantage certain sums which had been fixed in copper money" and that these sums were wages for the administration, army and the state (Reekmans, 1951: 67-68).

Cadell and Le Ride (1997) on the other hand explain the price increase during Ptolemy IV's reign as an actual economic inflation resulting in the oversupply of coinage and the under-supply of goods, causing price fluctuation. Von Reden (2007: 75) summarizes the situation as follows: "[…] changes in the levels of prices attested from the end of third century onwards can be explained in terms of changes in the *chora* and a resulting increase in the prices of the silver stater".

However, this supposed lack of silver and the inflation to the bronze coinage is in no way reflected in the chemical composition of the coins sampled and analysed at the present work. Nor is it visible in the silver and bronze results of respectively Hazzard (1990) and Faucher (2013) This could be an indication that, as during earlier periods, the debasing of coinage was still viewed by the Egyptian royalty and elite as an option of last resort choosing instead to confine themselves to changing the size of the coins and their values and in doing so attempting to maintain the Ptolemaic economy.

6.2. Coinage Manipulation and Debasement During the Middle Ptolemaic Period (from Ptolemy V to Ptolemy X)

6.2.1. Ptolemy V

Following the death of Ptolemy IV, the throne was eventually taken by his son, the young Ptolemy V who ruled as a ward of two of Ptolemy IV's chief ministers (Hölbl, 2001: 134). During a period of unrest caused largely by infighting between various advisors of the young king (see for instance Abel, 1983: 283-286), Antiochus IV of the Seleucid Empire instigated the Fifth Syrian War. The war continued until 195 BCE when peace was reached by the engagement of the then 16 years old Ptolemy V and the daughter of Antiochos III, their wedding taking place in Raphia in 194 or 193 BCE (Hölbl, 2001: 140). As part of the peace settlement the Ptolemaic kingdom gave up their possessions in Asia, and thus lost territories in Anatolia and Coele Syria (in particular the trade centres of Tyre and Sidon) (Hölbl, 2001: 140). According to Mørkholm and Kromann (1984) the void left by the lost territories was to be filled by Cyprus.

While the Fifth Syrian War was underway the situation within Egypt itself was deteriorating. In 205 BCE in Thebes, the nobleman Haronnophris was proclaimed pharaoh thus heralding the start of the most serious native revolt against the Ptolemies (McGing, 1997: 285). This revolt continued until 186 BCE when Chaonnophris the heir to Haronnophris was finally defeated. One of the most serious issues that this revolt resulted in was that the taxes from the Thebaid, indeed from most of Upper Egypt (Fig. 2.1), seized around 207 BCE and did not resume until 192-191 BCE (Pestman, 1995: 103). Perhaps in order to renew the flow of taxes from this region, Ptolemy V allowed rebels who returned home to retain their properties. This information is derived from the Memphis Decree or more commonly known as the Rosetta Stone (1.19-20 Greek text, 1.11-12 Demotic text, for full translation see Budge 1913) and according to McGing (1997: 288) is the only clear but rather brief section that deals with the situation in Thebes. Another part of the Memphis decree is concerned with the benefactions of Ptolemy V which largely focus on the temples and the priesthood. This is not surprising as the government and the king needed the legitimation of the Egyptian priesthood to underpin their rule (McGing, 1997: 287). The aim of these benefactions was very clearly to ensure that regardless of the revolts and the situation in Thebes, the remaining priestly classes in Egypt were not dissatisfied (McGing, 1997: 287). McGing (1997: 287-288) sees these benefactions as the desperate need of support from the priestly classes in order to battle the "nationalistic opposition". This of course seems valid; however, an additional effect would have been the creation of more jobs and the insurance of some taxes (albeit lower than usual) being paid into the treasury.

With regards to the state of the Ptolemaic bronze and silver coinage during these turbulent times, the loss of the mints in Syria and Palestine was, as mentioned above, remedied by the mints in Cyprus with regular production of tetradrachms of the standard Ptolemaic type commenced in the mints of Salamis and Cition (Fig. 2.1.) (Lorber, 2012: 221). During the reign of Ptolemy IV in addition to the already mentioned devaluation of the bronze coins, a further reform of their weight (aimed at reducing it) has begun and this practice continued under Ptolemy V (Lorber, 2007: 141). The reduction of the weight for both of these Pharaohs is clear evidence of a lack of resources and the need for existing resources to be stretched. This was perhaps even more the case during Ptolemy V's reign as the cost of the war and the consequent loss of territories meant loss of resources. More significantly perhaps was the fact that for nearly 16 years one of the larges provinces in Egypt did not pay royal taxes. If it is assumed that the bronze coinage paid in taxes was, when required, used to produce new updated coinage, this would explain why the existing supply of coinage could not keep up with the expenditure and so needed to be stretched. Another possible explanation for the weight reduction at this specific time in Ptolemaic history, may have been a temporary loss of access to the copper deposits in Egypt's Eastern Desert which were usually accessed from settlements such as Coptos and Thebes itself, settlement which because of the Thebaid revolt were outside royal control. A loss of royal authority in the region could potentially have led to a curtailment of resource procurement missions to these areas, further reducing the State's access to copper.

The severity of this issue is illustrated by the current results - the bronze coins demonstrate signs of debasement (i.e. the lowering of the copper and tin amounts and the increasing of the lead content) all while decreasing in weight. As Faucher and Olivier (2020) have pointed out, adding lead in order to save a few tons of copper makes little financial sense. While this is certainly true, this argument is only valid if we assume that the purpose of debasing the bronze coinage was to preserve large amount of raw copper and/or tin. However, the lowering of the weight of the coinage coupled with the historical events described above may rather suggest that the purpose was to stretch the available coinage via a process of continuous debasement. In this way copper coinage collected in taxes could be re-minted as a larger amount of increasingly leaded coins which were also made smaller in weight and size.

In this way the data suggests that the debasement observed here was a debasement of both weight (as described above) and fineness (Butcher and Ponting, 2014: 41). The addition of lead to the bronze coinage could also have been a result of the minting process itself as suggested by Faucher and Olivier as the addition of lead (not exceeding 35%) would have allowed a lower melting point thus resulting in a faster and cheaper minting process (Faucher and Olivier, 2020: 104). However, if this was the case then it should be expected that the lead levels within the bronze coins would have remained relatively stable (after the initial addition of lead), as opposed to the increase observable in the current data. As such while a change in the minting process may have contributed to the compositional changes observed in the coins of Ptolemy V and later rulers it does not fully account for the observable increases in lead content. Moreover, the Egyptian were aware of the benefits of adding lead to bronzes to aid production (from at least the Late Period) as mentioned in section **4.3.** A further explanation could be the wider availability of lead as a by-product of silver production elsewhere in the Mediterranean (for details see section **4.3.**) Furthermore, Lorber (2007: 142) suggests that the rapid reduction in the weight of the bronze coins resulted in a large-scale demonetisation which combined with the papyrological sources "[…] reflect dramatic monetary events in the reigns of Ptolemy IV and V" that include changes in the bronze to silver ratio and manipulation of the face value of the bronze coinage.

6.2.2. Ptolemy VI and Ptolemy VIII

According to Diodorus (XXIX.29) Ptolemy V was poisoned by his generals in 180 BCE as they thought that he planned to cut their income in order to finance his reconquest of Coele Syria. This meant that the Egyptian throne was once again left to a child of only six years of age – Ptolemy VI. He was accepted by the Alexandrian elite, and his mother the sister of the new Seleucid king – Cleopatra I became his guardian and official regent (Hölbl, 2001: 143). Although there were plans for war with the Seleucids, due to her familial relationship the Queen decided against that. Cleopatra died in 176 BCE leaving the kingdom in an unstable situation (Ray: 1976: 79) with the state essentially under the control of the new guardians and regents of the king, Lenaios and Eulaios (Hölbl, 2001: 143). In order to secure Ptolemy VI's position on the throne, and thus their own, they arranged for him to marry his sister Cleopatra II in 175 BCE (Walbank, 1979: 323).

In the meantime, in the Seleucid empire, the second brother of Cleopatra I – Antiochos IV became king in 175 BCE and shortly after this he sent an envoy to attend a great festival in Alexandria (Hölbl, 2001: 143). Upon his return the envoy informed the king that the Egyptian attitude towards the Seleucids has most definitely shifted and become hostile. This resulted in Antiochos IV's decision to place troops on the border zone between Syria and Palestine (Hölbl, 2001: 143). Around 170 BCE the two regents proclaimed that the three Ptolemaic siblings (Ptolemy VI, Cleopatra II and Ptolemy VIII) would all rule together. To address the rising tensions between the Seleucids and the Ptolemies Rome was involved as a mediator (Hölbl, 2001: 144). During these negotiations Egypt was seen by Rome as the aggressor, and it was assumed that, despite the negotiations, they had already started military manoeuvres against the Seleucid kingdom. (although Gruen (1984: 655) argues that the Ptolemies attacked *after* the negotiations). The forces of Antiochos IV achieved victory over the Ptolemaic forces in the region between Pelusium and Mount Kasios and after a brief ceasefire the Seleucid king captured the Ptolemaic fortress in Pelusium (Hölbl, 2001: 145).

An attempt was made to seize Alexandria, but the siege was unsuccessful and, following the return of Ptolemy VI to Alexandria, and a Roman intervention which caused the Seleucid army to retreat from Egyptian territory, the three Ptolemies ruled together.

The three Ptolemies continued to rule together until 164 BCE and during their joint rule, there were at least two native revolts taking place in 165 BCE and 164 BCE. The first one was once more in the Thebaid, but was put down relatively quickly (McGing, 1997: 291). The clashes in 164 BCE were due to social conditions in the Fayum (Fig. 2.1.) (Hölbl, 2001: 181). The Sixth Syrian War and its burden on the people can clearly be seen as the causes for these revolts with higher taxes leading to a depopulation of villages, agricultural land being left unattended and tax revenues reducing. The result of this was the institution, for the first time, of the practice of forced cultivation which as McGing (1997: 294) points out demonstrates the desperation of the administration. The joint rule came to an end in 164 BCE when Ptolemy VI and his sister-wife left Egypt for Cyprus while Ptolemy VIII was left to rule in Alexandria (Hölbl, 2001: 183). Diodorus (XXXI.17c) explains that due to his tyrannical rule Ptolemy VIII was unpopular in Alexandria and the elite there demanded the return of his brother from Cyprus, which he did in 163 BCE and he was reinstated as king (Hölbl, 2001: 183).

The accuracy of the dating of the joint coinage of Ptolemy VI and VIII by Svoronos has been discussed several times in the present work. But if his dating is accepted, then the results from the current analysis show a very similar compositional picture to the one seen in the coinage of Ptolemy V. There is no direct evidence of debasement of the silver coinage during this period with the bullion percentages remaining at around 99%. This is not however the case for the bronze coins. As mentioned in the previous chapter the bronze coins of this joint rule are the largest corpus sampled in the present research and what they show is that the practice of debasement (both lowering the weight and adding lead) continued during this period. This is not surprising considering the mismanagement and war losses coupled with the native revolts. Here again the need for bronze coinage used to pay salaries all over the kingdom (Von Reden, 2007: 58, 150) evidently far outstripped the income collected taxes were providing resulting in the double debasement of the bronze coinage, by fineness and by weight.

6.2.3. Ptolemy VI

Although Ptolemy VI was reinstalled as king by the Alexandrian elite in 163 BCE this was not the end of the infighting between the two siblings. In an effort to reconcile with his brother, Ptolemy VI decided to divide the kingdom between them, thus making Ptolemy VIII the king of Cyrene (Fig. 2.1.) (Hölbl, 2001: 184). As king, Ptolemy VI attempted to address his domestic political situation by issuing amnesty decree pardoning some crimes and offences committed prior to 17 August 163 BCE (McGing, 1997: 294). However, while Ptolemy VI was visiting Memphis and making donations and offerings to the temples there, Ptolemy VIII, dissatisfied with his rule over Cyrene, made a plea to the Roman senate to once more intervene in Egyptian affairs and according to Polybius (XXXI.10.2-3) for their assistance in procuring the territory of Cyprus. The senate's decision was largely in favour of Ptolemy VIII, and a delegation was sent to Egypt to facilitate the reconciliation between the two Ptolemies and to secure the territory of Cyprus for the younger sibling (Hölbl, 2001: 185). The explanation given by Polybius (XXXI.10) of the reason behind Rome's decision to not only intervene but also support the claim of Ptolemy VIII was simply in order to divide the Ptolemaic empire even further.

However, the Senate wanted to achieve this division without violence, and this is evidenced by the events that followed Ptolemy VIII's departure from Rome. The young king recruited soldiers in Greece and was ready to launch an attack on Cyprus, but the Roman delegation persuaded him to discharge his soldiers and await the results of the negotiations with Ptolemy VI at the Libyan-Egyptian border (Hölbl, 2001: 186). Ptolemy VIII proceeded to the border without his army, but while on Crete he recruited additional 1000 soldiers and then proceeded to Umm el-Rakham west of Marsa Martruh (Fig. 2.1.) where, while waiting for news of the negotiations, he was made aware that the people of Cyrene have revolted against the governor he left in charge (Hölbl, 2001: 186). Although the outcome of this revolt is unknown, what is known is that despite Ptolemy VIII having 1000 Cretan soldiers under his command he still lost his military engagements against the people of Cyrene (Hölbl, 2001: 186).

In the meantime, the negotiations between the Roman envoys and Ptolemy VI were initially stalled by the Egyptian king, but when he received the news of the situation in Cyrene, he declined the Roman proposal and stated that he would only honour the original agreement in which he was to rule over Egypt and his brother over Cyrene (Hölbl, 2001: 186). Polybius (XXXI.20) states that in the winter of 162–161 BCE emissaries of both Ptolemy VI and Ptolemy VIII were heard in the Senate, but subsequently the Senate banned Ptolemy VI's envoys thus breaking off diplomatic relations with him. This action by the Senate was interpreted by Ptolemy VIII as clear evidence of their support of him, and he began once more to enlist soldier for his conquest of Cyprus (Polybius XXXI.20), although due to the lack of military support by Rome Ptolemy VIII was unable to achieve his goals. The younger Ptolemy however did not give up his desire to acquire the military assistance of the Romans and after a failed attempt on his life in 156-157 BCE, he made a will in which he promised that if he should die without heirs then his kingdom (which he did not clearly define) was to be left to the Romans (Hölbl, 2001: 187). Although there is no direct evidence that the Romans took this will seriously, Ptolemy VIII used the assassination attempt as a plea to the Senate to assist him in his claim. The Senate did provide the young Ptolemy with some military assistance but it was understood that they were mainly for show and that if it came to military action, he would have to conduct it with his own forces (Hölbl, 2001: 188). Ptolemy VIII succeeded in taking possession of Cyprus but ultimately suffered defeat by Ptolemy VI who, most likely as a show of respect to the Romans, was lenient to his younger sibling and gave him the province of Cyrene (Hölbl, 2001: 188).

After resolving the situation with his younger brother, Ptolemy VI focused his attention on regaining the territory of Coele Syria. At the time there was a dynastic struggle at the Seleucid Empire and Ptolemy VI took part supporting one of the candidates – Alexander Balas, who after a decisive battle at Antioch in 150 BCE became the new Seleucid king (Hölbl, 2001: 192). A union was made between Alexander Balas and Ptolemy VI by the marriage of his eldest daughter to the new king in 150/149 BCE (Hölbl, 2001: 186). The wedding took place in Ptolemais (Ake) in Phoenicia and Ptolemy VI personally accompanied his daughter and her considerable gold and silver dowry (Hölbl, 2001: 192).

Alexander Balas was killed shortly before the Egyptian king himself died thus allowing Demetrios II to become the unchallenged king of the Seleucid empire and due to the death of Ptolemy VI, he was also able to retain the territory of Coele Syria.

The reign of Ptolemy VI was certainly a turbulent one, and these socio-political upheavals are reflected in the coinage and its composition. Financial documents from about 160/161 BCE show that the silver tetradrachm and its price fluctuated dramatically perhaps due to the weight of this type of coin (Lorber, 2012: 225). Burkhalter and Picard (2005) demonstrate that in 161/160 BCE in Memphis one silver tetradrachm was exchanged for 1100 bronze drachms but that amount more than doubled to 2130 drachms in 159 BCE. The dwindling supplies of silver for minting new coins is further supported by the research of Hazzard (1990) and Olivier (Faucher and Olivier 2020) which demonstrate that there was most definitely debasement of the fineness of the silver coinage of this ruler. What is of interest here is that in the earlier periods of the Ptolemaic rule more specifically around 230 BCE payments in silver listed in the papyrological record were evidently reduced following a reform of the bronze coinage. This reform was most likely intended to relieve pressure from the silver coinage (Von Reden, 2007: 68) but as mentioned above, compositionally no change in the silver was visible for that period, neither in the current work, nor in previous research (see section **5.2.**). So, if the silver coinage was not used as readily prior to Ptolemy VI's reign, but still maintained its purity through severe wars, territorial loses and significant native revolts, then the question becomes why it began to decline in fineness at the present period when nothing that extraordinary occurred which might have explained it.

One possibility is that simply reducing the weight and the amount of silver coins produced was no longer enough to maintain the demand. This theory is supported by Olivier's (2018) suggestion that during the reign of Ptolemy VI there was a mobile mint and towards the end of his reign coins were minted also in Coele Syria in order to finance the king's political and military goals in the region. Another potential explanation could be that in addition to the cost of both the infighting and the campaigns in Syria, Ptolemy spent vast sums of gold and silver for his daughter's dowry, thus causing a further shortage of silver currency. Although it must be stated that based on the results from the current work debasement is not observable on the sampled and analysed silver coins of Ptolemy VI. As stated in the previous chapter this might be due to the uncertain date of the sampled coins. The hypothesis of a silver debasement for this rule is proposed on the basis of the larger corpus analysed by Hazzard (1990) and some of Olivier's (2020) conclusions. As to the bronze coinage of this period, their weight and composition continued to be varied with increasing lead levels suggesting the continued debasement and stretching of available resources.

6.2.4. Ptolemy VIII

After the death of Ptolemy VI, Ptolemy VIII became king of Egypt and married his sister, and the widow of his brother – Cleopatra II and she was allowed to retain her status of co-regent which was granted to her by Ptolemy VI (Hölbl, 2001: 194-195). Ptolemy VIII persecuted his political opposition harshly either killing or driving them out of Alexandria, however simultaneously he began a policy aimed at winning the population of Egypt (Hölbl, 2001: 194-195) by issuing amnesty decrees and guaranteeing the Egyptian temples their revenues (Piejko, 1987). Ptolemy VIII also made the decision to recall his forces from the Itanos, Thera and Methana (Fig. 2.1.) which were the last Ptolemaic bases in the Aegean (Van 't Dack: 1973: 84-89). Thus, the Ptolemaic kingdom was reduced to Egypt, the northern part of Nubia, Cyprus, Cyrenaica and some strongholds in the Red Sea (Fig. 2.1.) (Hölbl, 2001: 195). Around 144 BCE Diodorus (XXXIII.13) mentions the birth of a son to the royal couple which took place around the time of Ptolemy VIII coronation ceremony in Memphis. Ptolemy VIII, soon after the birth of his son, began a relationship with Cleopatra III who was the daughter of Ptolemy VI and Cleopatra II, thus his niece and step-daughter (Hölbl, 2001: 195). He then married Cleopatra III in 141/140 BCE and she also similarly to her mother now held the rank of queen.

This potential powder keg of familial alliances exploded in late 132 BCE when a civil war broke out between Ptolemy VIII and Cleopatra II (Thompson, 1994). When the royal palace in Alexandria was set on fire Ptolemy VIII escaped to Cyprus with his niece/step-daughter and wife Cleopatra III (Hölbl, 2001: 197). There he began planning his return to Egypt aiming to use the troops that were loyal to him on the island as well as new recruits (Hölbl, 2001: 197). In the meantime, Cleopatra II was made sole queen of Alexandria. While preparing for his return to Egypt, Ptolemy VIII ordered his young son by Cleopatra II murdered, cut his head, hands and legs and sent his remains to his mother the night before her birthday celebrations (Hölbl, 2001: 197). Diodorus' (XXXIV/XXXV.14) describes how the queen then displayed the murdered and mutilated remains of the crown prince in Alexandria, a move aimed at arousing the wrath of the people. Although Cleopatra II had the support of the Greeks and the Jews both in Alexandria and in the chora, she lacked the support of the native Egyptians, who were largely on the side of Ptolemy VIII (Hölbl, 2001: 197).

Ptolemy VIII returned to Egypt with his army in 130 BCE and based on documents it appears that he established his rule in Thebes in the same year. Despite this he was unable to retake Alexandria where Cleopatra II was firmly ensconced (Hölbl, 2001: 199). The queen however was completely isolated, and so sent envoys to the Seleucid king Demetrios II offering him the Egyptian throne in exchange of military assistance (Hölbl, 2001: 200). Demetrios II left for Egypt and reached Pelusium where Ptolemy VIII was waiting for him. However, in 128 BCE the Seleucid troops revolted and Demetrios II had to give up his plans of ruling Egypt and return home (Houghton and Le Rider, 1988: 410). In Alexandria Cleopatra's situation was worsening, and she eventually fled to Syria taking the Ptolemaic state treasures with her (Hölbl, 2001: 200). In order to stop any possible assistance that Cleopatra II might receive from the Seleucid kingdom, Ptolemy VIII sent forces to Syria in 126 BCE and there Demetrios II was defeated and murdered (Hölbl, 2001: 200).

Based on dating formulae it appears that by 124 BCE the civil war had come to its end and that Ptolemy VIII and the two Cleopatras were ruling together, although it is unclear why and how the war came to an end. While there was peace for the moment, the consequences of the civil war and the military involvement in Syria had left the kingdom and its population in a precarious position (McGing, 1997: 296). In order to mark their reconciliation Ptolemy VIII, Cleopatra II and Cleopatra III issued an Amnesty Decree (P. Tebt. I,5; C. Ord. Ptol. 53) and similarly, to previous amnesty decrees, it attempted to persuade people to return to their homes and occupations, remittances for dues were also given and benefactions and grants were given to the Egyptian priesthood (McGing, 1997: 296). Although this decree was intended to restore normality to the country McGing (1997: 296) sees it as further evidence for the breakdown of the government and the wide-spread corruption that was further plaguing the land. He provides a number of examples for this state of affairs, such as the illegal seizures and tolls conducted by the Alexandrian customs officers and the unauthorized actions of the granary officials (McGing, 1997: 296).

These socio-economic and political upheavals are clearly reflected in the compositional analysis conducted for the present research. The silver coinage of Ptolemy VIII shows clear evidence of debasement: rather than a bullion percentage of 99-98% seen in the results of the earlier kings, the values drop to respectively 97%, 96%, 95% and 92%. In addition, the levels of copper within the coins steadily begin to rise, with levels between 2% and 7%. Although the debasement in these coins cannot be denied, it is still somewhat low considering the potential effect of the civil war. Probably the most serious issue during the war with regards to coinage was its impact on trade in Alexandria, given that the bulk of the silver used in the minting of Ptolemaic coinage was most likely the material received by the exchanged foreign coinage at the port. The low levels of debasement seemingly suggest that, despite the upheavals in Alexandria, the system continued, although perhaps not as efficiently as it had during previous reigns.

In the results of the bronze coinage again the addition of lead continues to be observed, which is not surprising due to the situation in the Egyptian chora at the time, summarized quite aptly by McGing (1997: 296) "If the farmers have not been paying their dues, they have also been neglecting their work on the vital embankments; they have not been planting as required; and they have been cutting down trees, all matters of the greatest importance in the running of the country". The lack of paid taxes meant that there was not enough bronze coinage going into the royal mints, thus necessitating the stretching of the available resources. The abandonment of agricultural land could perhaps further explain the silver debasement as Egypt's main export – grain – arrived in Alexandria in smaller quantities thereby prompting lower levels of trade in this commodity. These events clearly demonstrate the link between the coinage and the political situation in the kingdom during this time period.

6.2.5. Ptolemy IX and Ptolemy X

Ptolemy VIII died in 116 BCE and he left his throne to Cleopatra III and to whomever of their sons she chose (Hölbl, 2001: 204). Although Cleopatra III wanted her younger son Ptolemy X as co-regent, her mother Cleopatra II and the army preferred the older brother – Ptolemy IX and so he became the new Egyptian king (Beckerath, 1984: 292). In 116 BCE Cleopatra II died and from then until 107 BCE Cleopatra II and Ptolemy IX ruled together, while Ptolemy X was strategos of Cyprus and later from 114/113 BCE became the king of Cyprus (Hölbl, 2001: 205). Cleopatra III however, began to plot against her eldest son and spread rumours that Ptolemy IX was planning to assassinate her, thus turning the Alexandrian elite against him, and in 107 BCE he had to flee the city (Hölbl, 2001: 207). Ptolemy X left Cyprus and was upon his return to Alexandria made king and co-regent of Cleopatra III. After leaving Alexandria Ptolemy IX fled to Cyprus, but was unable to settle there as Cleopatra III's troops occupied the island. Instead, he headed to Selukia, where he was once again attacked by his mother's forces. Eventually he managed to conquer Cyprus and from 106/105 BCE he ruled the island as a sovereign ruler (Hölbl, 2001: 208).

This however, was not the end of the internal power struggles. In 103 BCE the inhabitants of Ptolemais (Ake) asked Ptolemy IX for help as they were under attack from the Jewish king Alexander Iannios, Ptolemy arrived to support the inhabitants but, in the meantime, they had changed their minds and refused his support (Hölbl, 2001: 208). Fearing Ptolemy IX's involvement, Alexander Iannios broke off the siege of the city, and attacked the Egyptian ruler directly, but Ptolemy IX was ultimately able to defeat the Jewish king. Ptolemy IX with his army close to Egypt's borders launched an invasion and in 102 BCE he marched towards Pelusium. Ptolemy X however, managed to drive his older brother back and he eventually returned to Cyprus where he remained until 88 BCE (Hölbl, 2001: 209). Cleopatra III led a campaign against the Seleucids aiming to re-capture Coele Syria and although she was successful in capturing the city of Ptolemais at the end, she signed a treaty and returned to Egypt without reconquering the region (Hölbl, 2001: 209).

Internal power struggles between Ptolemy X and Cleopatra III followed and during Cleopatra's Syrian War, the king had escaped from his mother. Eventually he was persuaded to return and upon his return sometime in 101 BCE he had Cleopatra III killed (Hölbl, 2001: 210). This however did not bring peace to Egypt. Indeed in 96 BCE the Ptolemies lost their oldest foreign territory – Cyrenaica. Initially under the control of Ptolemy IX in 102 BCE this region went to Ptolemy Apion, most likely with the help of Cleopatra III, and after the death of Apion Cyrenaica according to his will was to be given to Rome (Hölbl, 2001: 210). Further to this, another revolt in southern Egypt took place in 91 BCE (McGing, 1997: 297-298). Following these events Ptolemy X was forced to flee Alexandria in 88 BCE due to a revolt of the Alexandrians and the military asked Ptolemy IX to return to the capital (Van 't Dack, 1989: 136-150). Upon his return Ptolemy IX put down the revolt in Southern Egypt and in the Theban province in particular, although during the three years of revolt Ptolemaic rule over Lower Nubia was lost and only a small part of it was subsequently regained (Hölbl, 2001: 211).

While in exile Ptolemy X aimed to conquer Cyprus, so he recruited soldiers and again involved Rome by asking the Senate to lend him funds to pay his soldiers promising them the Ptolemaic Kingdom in exchange if he passed away without an heir (Badian, 1967). Ptolemy was defeated in his attempts to conquer Cyprus and he lost his life (Hölbl, 2001: 211). Due to disagreements in the Roman Senate, the question of the Egyptian succession and Rome's involvement in the matter was left pending. Ptolemy IX's second reign was spent peacefully, but the dynastic power struggles, the international wars and the native revolts left a serious mark on the social and economic life on Egypt. The abandonment of agricultural land reached its peak and according to textual evidence from 83/82 BCE a whole village near Herakleopolis in Middle Egypt (Fig. 2.1.) was abandoned as result of over taxation and economic difficulties (Maehler, 1983).

The mark of the civil wars and intrigue on the social and economic life of Egypt is noticeable in the composition of both silver and bronze coinage of the period. As mentioned in the previous chapter only two silver coins from the first rule of Ptolemy IX and none from the second were sampled. These two coins do have a bullion percentage of 96-95% which can be taken as demonstration of continual practices from Ptolemy VIII's reign. And as there are only two coins it is very difficult to establish if with time the silver quantity was decreased in favour of copper. However, this seems to definitely be the case for the coins of Ptolemy X, where the highest silver bullion percentage is 95% and where the copper levels are between 4% to 14%. This is clear indication of debasement and that silver as a resource was becoming even more difficult to obtain. If an assumption is made that the majority of the silver used in the coins was from re-cycled foreign silver coinage mainly used in trade then perhaps one explanation of the silver debasement is that the levels of trade at this time continued to fall. This in turn can be explained, similarly to the reign of Ptolemy VIII, with the abandonment of agricultural land and thus the loss of one of Egypt's most priced commodities, grain. If there was not enough grain to trade, then not enough silver would have gone into the government's coffers necessitating, similarly to the bronze, a debasement of the fineness of the silver coinage in order to stretch the available resources.

As to the bronze coinage only three coins were sampled and due to the lack of any dating on the coins it is difficult to ascribe them to either Ptolemy IX or X but what is observed is the continued increase of lead with quantities all in the vicinity of 20% unlike in the reign of Ptolemy VIII where only one coin had such a high amount. This could be taken as an indication of a deliberate addition of lead to extend the quantities of bronze coinage produced against a background of shrinking tax income as a result of the abandonment of settlements, agricultural land and the loss of Cyrene.

6.3. Coinage Manipulation and Debasement During the Late Ptolemaic Period (from Ptolemy XII to Cleopatra VII)

6.3.1. Ptolemy XII

The Alexandrian elite, fearful that Ptolemy X's will would be taken seriously by the Romans, crowned one of the sons of Ptolemy IX, Ptolemy XII, as king of Egypt and the other son also named Ptolemy as king of Cyprus, thus marking the island a separate kingdom (Michaelidou-Nicolaou, 1976: 20). Hölbl (2001: 223) suggests that Rome may have used the will of the late Ptolemy X as means of extorting revenues from Ptolemy XII but as a whole for about 20 years after the latter became king Rome seems not to have been much concerned with possessing Egypt. However, from about 60 BCE Egypt and its resources became a source of conflict between the rival political leaders of Rome (Sonnabend, 1986: 27-30). One of the plans was a direct annexation of Egypt as a Roman province, but due to disagreement this was not pursued further. In order to prevent this annexation as well as to ensure that Egypt and the Ptolemaic dynasty would retain their sovereignty and in order to be recognized as king by the Senate, Ptolemy XII began a campaign of bribing the different political factions in Rome (Hölbl, 2001: 224).

In order to raise the money for this policy Ptolemy XII increased taxes and cut back some of the administrative costs, thus making the socio-economic situation in Egypt even more precarious than before (Hölbl, 2001: 224). This, of course, resulted in a native revolt and as Ptolemy XII did not have the resources to put it down, he asked Pompey for support, but the latter refused as he was fighting a war with Judea (Fig. 2.1.). Despite Pompey's refusal to assist Ptolemy XII with the revolting natives, the Egyptian king still sent equipment for the forces of Pompey thus further putting strain on the state revenues and as a result, he was forced to borrow money from Roman lenders (Hölbl, 2001: 224). Due to the politically precarious situation in Rome, Ptolemy XII offered 6000 talents as a bribe to Julius Caesar (roughly equivalent to the entire annual revenue of Egypt) to ensure that he, Ptolemy, was recognized by the Roman Senate as the legitimate king of Egypt (Hölbl, 2001: 224). This audacious bribe worked and in 59 BCE during his consulship Caesar made sure Ptolemy XII was confirmed as king of Egypt (Hölbl, 2001: 224-225). Ptolemy XII however had neglected to negotiate the addition of Cyprus to his territories and as the island was included in Ptolemy X's will, and was an independent kingdom from 80 BCE, it was made into a Roman province (Hölbl, 2001: 225). Ptolemy XII did not object to this, which in addition to his wasteful bribes incensed the Alexandrian elite and in 58 BCE he was forced to leave Egypt (Bloedow, 1963: 51-53). Ptolemy XII had no other choice but to head to Rome and in 57 BCE he was accepted in Pompey's villa (Strabo XVII.1.11).

The Alexandrian elite put Berenice IV, Ptolemy XII eldest daughter on the throne together with her mother Cleopatra VI (Huβ, 1990). In the meantime, in Rome the Senate was debating the 'Egyptian question' (Shatzman, 1971) the focus of which was reinstating Ptolemy XII as king of Egypt. This of course was in the interest of quite a number of people in Rome, chief among which were the creditors of the disgraced Egyptian king. Initially the decision was to abstain from helping Ptolemy XII with military forces, but during the consulship of Pompey and Crassus, and most likely after Ptolemy XII had again bribed various Roman politicians, a decision was made to assist the Egyptian king in regaining his throne (Strabo XVII.1.11). The Roman army took control of Egypt and in 55 BCE Ptolemy XII was once again made king of Egypt (Hölbl, 2001: 229). In order to secure his throne, and in true Ptolemaic fashion, Ptolemy XII had his daughter Berenice IV and her supporters killed (Hölbl, 2001:

229). After making his eldest daughter Cleopatra VII a co-regent in 52/51 BCE and specifying in his will that she was to take her younger brother Ptolemy XIII in joint rule, Ptolemy XII died in 51 BCE.

Although Ptolemy XII managed to maintain the sovereignty of the Ptolemaic kingdom, his policy of bribing and amassing debt, as well as his reliance on Rome was the beginning of the end for the Ptolemaic dynasty. The shocking financial situation is made obvious by the composition of the silver coinage dated to his reign. Of the five silver coins sampled and analysed in the present research only one has a silver bullion percentage of over 90%, the rest are under 75% with the lowest reaching 45%, with a copper percentage of 55%. This is a clear debasement intended to replace the silver with copper and was evidently a direct result of the poor economic policies conducted by Ptolemy XII. It is clear that despite the commodities offered in Alexandria, the need of the king was far greater than the income he possessed compelling him to rather rapidly reduce the silver content in the newly minted coins. As Graph 5.5 in the previous chapter illustrates this debasement was most likely linked to the date, the later in his reign the coins are dated, the less silver in their composition. A link can perhaps be made between Ptolemy XII's excessive borrowing and the decreasing silver content.

The bronze coinage follows the same pattern to that of previous times of decreasing size and increasing lead content, which is mostly in the vicinity of 20%. This underlines the essentially dualistic nature of the Egyptian silver and bronze coinage, with the silver coinage, as an international currency, being particularly vulnerable to external policy decisions such as large-scale bribes, while the internal bronze coinage was more susceptible to internal disruptions such as the abandonment of agricultural land and shrinking tax revenues.

6.3.2. Cleopatra VII

For a short while Cleopatra VII ruled with her brother Ptolemy XIII as per the will of her father, however the marriage that was supposed to take place most likely never did (Criscuolo, 1989). Cleopatra VII consequently expelled her brother from the joint kingship, and began ruling independently (Ricketts, 1980: 12-21). The situation in Egypt was deteriorating swiftly as a result of Ptolemy XII's reign, and based on textual evidence it appears that all grain and produce from Middle Egypt were to be transported straight to Alexandria in an attempt to prevent looming hunger riots (Hölbl, 2001: 231). Politically the situation in Egypt was also unstable. Ptolemy XIII, who was only twelve years old, was now under the influence of three courtiers who acted as his guardians (Hölbl, 2001: 231-232) and who successfully overthrew Cleopatra VII at some point in 49 BCE (Heinen, 1966). Initially the queen retreated into the Theban area but eventually she had to flee from Egypt altogether in 48 BCE and ended up in Syria from where she hoped to regain her position (Hölbl, 2001: 232).

As Caesar was the person who secured Ptolemy XII's throne during his first consulship he tried to resolve the dynastic dispute between Ptolemy XIII and Cleopatra VII and ordered both of them to dismiss their armies (Caesar *Civ*. III. 107.2). The young king agreed a joint meeting but retained his forces, while Cleopatra agreed to a private audience with the Roman general. In this private meeting it was decided that she was to return to the throne and rule jointly with her brother Ptolemy XIII (Hölbl, 2001: 233-235).

Although the young king and a large portion of the Alexandrian elite were unhappy with this re-establishment of the joint rule, Caesar claimed that it was the will of Ptolemy XII and in order to 'sweeten the deal' he offered the youngest Ptolemaic siblings (Ptolemy XIV and Arsinoe IV) the rule of Cyprus thus in effect returning the island to the Egyptians after only ten years as a Roman province (Hölbl, 2001: 235). However, Ptolemy XIII and his advisors rejected Caesar's attempted negotiations and summoned the royal garrison numbering 20.000 to Alexandria taking Caesar by surprise.

Maehler (1983) states that due to the cessation of the civil war and the re-acquisition of Cyprus some improvement of the financial and economic situation within Egypt occurred. In the summer of 47 BCE Cleopatra VII gave birth to Ptolemy XV Caesar (aka Caesarion) and in 46 BCE Cleopatra and her son were invited to Rome as guest of Caesar. The main purpose of this visit for the Egyptian queen was the confirmation of her son as the only heir to Caesar, but due to the latter's death in 44 BCE this did not occur and Cleopatra and Ptolemy XV returned to Egypt a month after Caesar's death (Hölbl, 2001: 239). Upon her return to Egypt, Cleopatra had her brother Ptolemy

XIV killed and her son made a co-regent (Hölbl, 2001: 236). Famine became a serious concern in Egypt due to low or entirely absent Nile Inundations in 48 BCE, 43 BCE and 42 BCE (Bonneau, 1971: 231). The citizens of Alexandria received grain from the royal warehouses, but the chora and especially Upper Egypt did not receive any royal assistance (Hölbl, 2001: 239).

Cleopatra was, as one would expect, on the side of the Caesarians in the Roman Civil War, and after Mark Antony defeated Brutus and Cassius and was given command of the east, Cleopatra met him in 41 BCE and they became allies. In 37/36 BCE Antony reorganized the entire Near East and bestowed more territories (such as the kingdom of Chalkis in Lebanon, estates on Crete and the town of Cyrene) to the Ptolemaic Kingdom, with the aim of restoring Ptolemaic Egypt to its previous status (Hölbl, 2001: 242). Sometime in 34 BCE after a successful campaign against Armenia, Antony and Cleopatra announced their plan for a great Egyptian and Hellenistic empire (Plutarch *Ant*. 54). Cleopatra was confirmed as the ruler of Egypt and Cyprus, Ptolemy XV Caesar was to receive the title 'king of kings', Mark Antony and Cleopatra's children: Alexander Helios and Cleopatra Selene were to rule over Armenia and Media and Cyrene and Libya respectively, while the youngest son of Cleopatra and Antony Ptolemy Philadelphos received Phoenicia and Cilicia (Fig. 2.1.) (Hölbl, 2001: 244). This division, although it did not directly change anything, was not to Rome's liking and especially not to Octavian's, as Ptolemy XV was presenting a real danger to his status of heir to Caesar (Hölbl, 2001: 245)

Mark Antony and Cleopatra VII were married in 34 BCE, but the marriage was not considered legal in Rome, as Antony was already married to Octavian's sister Octavia (Hölbl, 2001: 244-245). In 32 BCE Antony requested a divorce from Octavia which was taken as an insult by Octavian and he declared war on Cleopatra and Antony (Plutarch *Ant*. 57.4-5). The senate took a decision that Antony would not be made consul in 31 BCE, and declared Cleopatra enemy of the people (Plutarch *Ant*. 60.1). The war between Octavian and Mark Antony and Cleopatra broke out in the spring of 31 BCE. After winning a number of significant battles Octavian entered Alexandria on August 1st 30 BCE thus officially bringing the end of the Ptolemaic Dynasty and its rule over Egypt and the start of the Roman rule over the land of the pharaohs.

The economic picture of this period is perhaps not as clear as that of previous times, influenced both by the regaining of some territories, but at the same time by the sustained financial losses incurred from the constant support of Antony's military campaigns. Additionally, there were environmental issues and famines, which would have caused issues both with regards to feeding the population and securing enough commodities for trade but also with regards to the depopulation of villages and the amassing of unpaid taxes. The silver coinage of Cleopatra is even more severely debased than that of Ptolemy XII: From the seven sampled and analysed coins of this reign only one has a silver bullion percentage of over 70% the remaining five coins are all in the vicinity of 30% and thus the dominant compositional element in these coins is copper not silver. This of course is not surprising given that the queen inherited heavily debased silver coinage, as well as a highly unstable economy so although she re-gained some territories, and most likely booty as a result her expenditures did not in any way decrease.

On the contrary due to the campaigns fought by her and Mark Antony, an assumption can be made that they increased substantially. With regards to the bronze coinage Lorber (2007: 146-147) states that there was a bronze reform aimed at "reviving denomination of moderate size" and significantly improving the workmanship." Compositionally however, the coins retained their high amount of lead, but what is observed is that based on the Svoronos references provided by Lorber for the reformed bronze coinage, they contain, for the first time since the reign of Ptolemy IV, tin values of more than 9% thus illustrating clearly this reform. The remaining high quantities of lead are perhaps explained by the fact that, despite this reform, and perhaps the addition of fresh resources, they still were not enough to revive and support a system relying so heavily on debased coinage for such an extended period of time.

6.4. Overview

As demonstrated in Chapter 5, the Ptolemaic silver and bronze coins were certainly debased (see Graphs 5.8 and 5.21) but by placing the current analytical results into the broader historical context of the Ptolemaic period, a pattern of dichotomy emerges. This pattern is perhaps not surprising due to the dualistic nature, not only of the transactions conducted in coinage, but also more fundamentally of the clearly perceived rift between the large urban centres and the country side (chora). The start of the duality in the use of the coinage could perhaps be linked to the bronze currency reform conducted by Ptolemy II, but it became even more obvious during his son's reign when the silver coinage pretty much disappeared from the countryside (Von Reden, 2007: 30). A further supposition in the current work was made that based on the lead levels within the silver coinage an idea of the start of a serious policy of re-cycling (dated to the reign of Ptolemy II) can be made, the so-called closed currency system. Although this is a tempting hypothesis it must be stated that due to the lack of silver deposits in Egypt the silver used in the coins of the Ptolemies was mostly re-cycled in any case, thus to what extent the start date can be pinpointed remains somewhat uncertain.

The pattern that emerges based on the analysed material is that internal issues, such as native revolts, civil wars, and environmental factors, such as draught and famine are more closely linked to the compositional changes of the bronze coinage, thus cementing even further these types of coins to the internal Ptolemaic economy. The debasement of the silver coinage is predominantly linked with external issues such as losses of wars, territories and excessive spending in the form of dowries or bribes, equally confirming the status of the silver coinage as an international economic commodity. It is clear of course that some factors, such as drought, could have impacted both types of coinage: The implications of a drought for the countryside are clear, namely that a bad harvest means a serious potential for famine and inability to pay taxes.

However, this would then in turn have larger consequences for the ability of the Egyptian state to trade grain as drought would have necessitated resources to be kept for internal consumption. A further potential link between the silver and bronze coinage – and their debasement – could be that one of the motivations behind the reduction of copper in the bronze coinage could be the need to redirect supplies of copper towards the manufacture of silver coinage once these began to be significantly debased towards the end of the period. In this way, the debasement of bronze coinage with lead could perhaps be explained as a direct result of the debasement of silver coinage with copper.

Therefore, this illustrated dichotomy of the coin usage seems to be a symptom of the above-mentioned split between the large urban centres and the chora and subsequently the elite and the peasantry. Though, at the start of the monetarisation process of Egypt by Ptolemy I, and perhaps due to the novelty and large scale of this process the dualistic transactional nature of the coinage is not present. An argument could be made that the monetary system in Egypt was not originally set up in this way, but when Ptolemy II became king, the circumstances changed. This change is most likely linked to his bronze reform which aimed to make the payment of tax in the countryside with bronze coins the norm and as such the similarly to the deben (for details on this see section **2.2**) can also be aptly put in context.

Therefore, if these circumstances are coupled together with the needs of a growing empire and an expanding rift created between the elite and the peasantry this could be seen as the cause for the coinage dichotomy. But with time and with the ever-present demand on the land and the people working it, this became the symptom and subsequently the norm, and by default it transfers into the dualistic nature of the observed debasement, culminating with the severely debased silver and bronze coinage of the period.

Chapter 7: Conclusion

As outlined in the introduction to this thesis, its overarching purpose was to examine a representative sample of Ptolemaic bronze and silver coins to determine the extent to which currency manipulation – debasement – took place throughout the Ptolemaic Period. This was accomplished by the scientific examination of the chemical composition of silver and bronze Ptolemaic coinage sampled from several different UK museum collections and analysed using MP-AES and SEM. In order to place the resulting data into the context of the economic and political history of the Ptolemaic Period three questions were set in the introduction of the present work and tackled at different chapters. These will be summarised here:

The first question was: To what extent is debasement visible in the silver and bronze Ptolemaic coinage? Based on the results achieved by the sampling and analysis, it is clear that debasement was present in both the silver and bronze coinage of this period. Although the beginning of the silver debasement is linked by previous scholars (Hazzard, 1990 and Olivier, 2020) to the sole reign of Ptolemy VI, based on the current results debasement is observable from the reign of Ptolemy VIII onwards. Bronze debasement can be dated to the reign of Ptolemy V. Neither the silver nor the bronze debasement is sudden, rather the process is gradual and, in the case of the silver coinage, a three-stage change of the composition can be clearly observed. As discussed in section **5.2.** the first stage encompasses the reigns of Ptolemy I to the joint rule of Ptolemy VI and VIII and most likely the solo reign of Ptolemy VI. During this time there are no detectable signs of silver debasement. The second stage runs from the reign of Ptolemy VIII up to and including the first half of Ptolemy XII's reign and is characterised by a gradual debasement of the silver coinage with silver bullion values reaching around 70%. The final stage of this process of debasement includes the second half of Ptolemy XII's reign and the reign of Cleopatra VII. During this period the silver bullion values (with a few exceptions) go to their lowest levels of between 30% to 60%.

It must be stated that, as Chapter 3 illustrates, the present work is not the first to examine the existence of debasement in bronze and silver coinage of this period. But it is the first to use the minimally invasive sampling technique outlined in section **4.2.** in combination with micro-wave plasma atomic emission spectrometer in the analysis of Ptolemaic coinage. It is also the first study to include a comprehensive and simultaneous study of *both* silver and bronze coinage. And although the results achieved here are broadly comparable to Hazzard's silver analysis, the method utilised in this study has provided far more precise signatures for the trace elements than Hazzard (1990) accomplished and, in addition, none of the sampled coins were destroyed as was most likely the case with some of coins analysed by Hazzard in the 1980s. With regards to the bronze coinage, here again the results are broadly similar to those of Faucher (2012) and although his chosen analytical technique of neutron activation is entirely non-invasive, it nevertheless gives rise to a number of accessibility issues which the current methodology has avoided: The first issue is that of cost and, in the case of neutron activation technique used by Faucher (and on a few occasion by Olivier), of access to a cyclotron, which is both expensive and time consuming (according to Faucher and Olivier (2020: 98) for a sample of 12 coins the analytical process takes a full week to process). By contrast, the current work grouped the samples in batches between 20 to 50 which took approximately three days to prepare and analyse per batch.

Further to this is perhaps what can be considered the main issue: that of sampling. Although no sampling is needed for the technique used by Faucher it does require for the museum institution or institutions from where the chosen coins are obtained, to lend the coins to the researcher so that they can be taken to the laboratory and analysed. In general, and increasingly, few museums are willing to allow large portions of their collections to leave the museum, unless in the form of loans to other museum institutions. So, although the technique used by the present author is minimally, rather than non-invasive, the sampling can be conducted in the museum setting and under the observation of museum curators and conservators if required.

The second question posed by this present study was: In what ways can currency debasement be linked to historical events during the Ptolemaic Period? Answering this question was the main purpose of Chapter 6 where the analytical results were put in historical context and where a clear link was evidenced between issues such as external and internal wars, revolts and environmental circumstances and the composition of the silver and bronze Ptolemaic coinage, in particular during the latter part of the Ptolemaic Period. However, this link between the historical events and debasement is often complex, and for example in situations where the Ptolemaic state undertook large expenditures and where debasement might therefore be expected, in reality the scientific analysis does not always demonstrate that link. The prime example of this is the Fourth Syrian War and more precisely the Battle of Raphia, a victory which cost the Egyptian state large quantities of wealth (Hölbl: 2001: 130-131) and after which textual sources indicate an inflation of the bronze coinage in Egypt. Yet the present work as well as the work by Caley (1939) and Faucher (2012) do not indicate any debasement of the bronze coinage, nor do the present research or Hazzard's (1990) results indicate any silver debasement.

The explanation for this somewhat unexpected decision by the Egyptian state not to debase, in particular the silver coinage even though they had lost a great deal of resources following the battle and the war, is most likely linked to the Greek's perception of coinage as attributed with a divine essence and that changing the purity of the coinage could be seen as causing offense to the gods. The decision to avoid debasement could also be more practical, as a debased coinage could create economic instability and undermine the general trust in the Ptolemaic coinage both internally and externally, essentially exacerbating economically precarious situations. Regardless of the reason why, it is clear that debasement was viewed as a method of last resort and perhaps that is why it is not observed earlier and why the Ptolemies did everything they could (decreasing weight, changing the value of both silver of bronze) to avoid resorting to debasement. However, the general trend of historical events influencing the debasement of the coinage during the second half and the end of the Ptolemaic Dynasty, as set out in Chapter 6, is undeniable.

The third and final question focused on the division between internal and external currency fluctuations and their link to the compositional changes of the silver and bronze coinage. Section **6.4.** addressed this issue, and it is evident that although the division of transactional use of the silver and bronze coins, with silver being used primarily for large and international payments and bronze largely used for smaller-scale payments of, for instance, taxes by farmers, was not initially intended, it became the norm most likely following the large bronze reform of Ptolemy II and thus increased the ever-growing gap between the large urban centres and the countryside. As such it is perhaps not surprising that the debasement of the bronze coinage can be linked predominantly to internal issues such as revolts, the abandonment of agricultural lands and the resulting unpaid taxes, the best example for this practice being the reign of Ptolemy V and the start of the bronze debasement, while the silver debasement can be linked primarily to external affairs such as international wars or, during the reign of Ptolemy XII for instance, to large-scale bribes paid to Roman officials to legitimise his reign.

The present thesis aimed to illustrate the debasement of silver and bronze coinage by the utilization of MP-AES and by placing the results in a broader historical context and in doing so, illuminate some of the mechanics and reasons behind this debasement. However, this is by no means the last word in the study of Ptolemaic coinage and there are a number of issues, which lie beyond the scope of the current work, but which would be beneficial in furthering the study of the Ptolemaic silver and bronze coinage. The first of these is linked with ascribing denominations to the bronze coinage and the revision of the dating system by Svoronos. This, as mentioned in Chapter 3, is a project currently underway by Lorber and the first volumes that includes the coinage of Ptolemy I, Ptolemy II, Ptolemy III and Ptolemy IV are already available (Lorber, 2018a, b). But when this work is completed, it will allow for a more comprehensive examination of the bronze denominations and perhaps a further study focused on the investigation of compositional changes within these denominations which will in turn enable the detection of more subtle intricacies between the issues and create a more useful dataset for the examination of micro-economic developments of the period.

With regards to both the silver and the bronze coins, but perhaps more usefully focusing on the silver coinage, important research could also be conducted into the regional variations between coins minted in Alexandria and those minted in the provinces. Such a project would require a much bigger dataset than is realistically achievable within the confines of this project, but it would provide a more nuanced view of the workings of the Ptolemaic mints and the state as a whole. Finally, an extensive isotopic study of the silver and bronze Ptolemaic coinage could be used to illustrate not only from where certain metals were obtained, but also potentially – in the case of the silver coinage – provide further evidence to support the existence and function of the closed-currency system.

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Glossary

Atomic absorption spectroscopy (AAS): An analytical procedure which determines the composition of chemical elements through the excitation of atoms by a high temperature flame. The excited atoms absorb light energy directed through the flame that is specific to each element measured. These absorbances can then be converted to concentrations by measuring them against a calibration curve created by measuring the absorbance of standards of known composition.

Bullion: Gold or silver in bulk before coining.

Calibration blank: A calibration standard that does not contain the analyte(s) of interest at a detectable level.

Chora: A term used in studies of Ptolemaic Egypt to denote the rural provinces of Egypt.

Cleruch: Hellenistic mercenaries and settlers, often related to the cavalry, who obtained land and position in Egypt during the Ptolemaic Period.

Correlation coefficient: A statistical measurement of the strength of the relationship between two variables, for example R^2 values.

Deben: A measure of weight and/or value used in Egypt from the Old Kingdom to the Late Period by which time it had become in effect a proto-currency.

Dilution factor: Amount by which solutions/samples are diluted prior to analysis.

Dynasty: A division originally employed by the 3rd Century BCE Egyptian Priest, Manetho, to sub-divide Egypt's history by ruling family.

Early Dynastic Period: A period comprising Dynasties 1 and 2 immediately following the Unification of Egypt (c. 2920-2575 BCE).

Fast neutron activation analysis (FNAA): A rapid and non-destructive analytical technique operating by bombarding the nuclei of the sample with high energy neutrons using a cyclotron, which then emit gamma rays of which those with the shortest half-lives can be measured. The measured emissions are then converted to concentrations through the usual calibration method.

First Intermediate Period: A period of decentralisation comprising Dynasties 7-10 and part of Dynasty 11 (c. 2150-1975 BCE).

Inductively coupled plasma atomic emission spectrometry (ICP-AES): A form of emission spectrometry that employs an argon plasma to excite the atoms in a sample. The light energy emitted by this process is measured by an emission spectrometer and the pulses generated are converted to a concentration through the usual calibration procedures.

Inductively coupled plasma mass spectrometry (ICP-MS): A type of mass spectrometry characterised by using an argon plasma as an energy source. The plasma ionizes the sample creating ions which can be detected and quantified in the mass spectrometer.

Laser ablation inductive coupled plasma mass spectrometer (LA-ICP-MS): Similar analytical technique to ICP-MS (see above) the difference being the use of a laser to evaporate and ionize the sample material.

Late Period: A period comprising Dynasty 26, as well as the period of Persian occupation of Egypt, Dynasties 26-30 (664-332 BCE).

Limit of detection (LOD): The lowest quantity of a substance that can be measured reliably above the background noise. The limit of detection is specific to any given analytical technique.

Machimoi: A category of infantry soldiers in the Egyptian army during the Late Period and Ptolemaic Period. Originally descendants of the Libyan dynasties of the Third Intermediate Period, but later synonymous with the native Egyptian army as opposed to Hellenistic mercenaries.

Microwave plasma atomic emission spectrometer (MP-AES): Similar analytical technique to ICP-AES (see above) the difference being the use of nitrogen plasma rather than argon plasma to atomise the sample material.

Middle Kingdom: A time period comprising part of Dynasty 11 and Dynasties 12-13 (c. 1975 BC to 1640 BC).

Neutron activation analysis (NAA): An analytical technique similar to FNAA (see above), the difference being that NAA uses a nuclear reactor as oppose to a cyclotron and measures gamma rays with longer half-lives.

New Kingdom: A period of time comprising Dynasties 18 to 20 (c. 1535 BC to 1075 BC).

Nile Inundation: The annual flooding of the River Nile as a result of snowmelt and rainfall in the Ethiopian highlands.

Nome: An administrative division used to sub-divide the Pharaonic State since at least the Early Dynastic Period.

Old Kingdom: A period consisting of Dynasties 3 to 6 (c. 2575 BC to 2150 BCE).

Part per million (ppm): A part-per notation used for the measurement of small amounts. Denotes one part per million parts.

Particle induced X-ray emission (PIXE): A non-destructive analytical technique which uses an ion beam to provoke atomic interactions within a material that emits measurable x-ray energy that can be calibrated to produce quantified data.

Predynastic Period: The period of Egyptian prehistory immediately prior to the Unification of Egypt (c. 6000-3150 BCE).

Ramesside Period: Dynasties 19 and 20 during the New Kingdom, named after the Ramesses family who ruled at the time.

Scanning electron microscope with energy dispersive spectrometry (SEM-EDS): An analytical technique which relies on two different components: the SEM which provides high resolution images of the sample using a focused electron beam, and the EDS which uses the electron beam to create x-ray emissions which are then measured.

Second Intermediate Period: A period of Egyptian history characterised by the conquest of northern Egypt by a Levantine grouping known as the Hyksos (c. 1640 – c. 1535 BC). Dynasties 15-17.

Strategos: An administrative and/or military titles often translated as either 'general' or 'military administrator'. In an Egyptian context the strategoi were originally responsible for the Hellenistic cleruchs, but later became *de facto* nome governors and administrators.

Thebaid: An area covering most of Upper Egypt from Abydos to Aswan which includes the major settlement of Thebes (modern-day Luxor).

Third Intermediate Period: A period of time characterised by decentralisation of power within Egypt as well as several periods of foreign occupation (c. 1070-664 BCE). Dynasties 21-25.

Wet Chemical Analysis: Fully quantitative analytical technique used prior to the development of instrumental analysis. The method was very destructive, requiring relatively large samples that were dissolved in strong acids and used reactions with various reagents to produce quantifiable amounts of compounds that were then back calculated to specific elements. The method was very time consuming but, in the hands of an experienced chemist, produced very accurately measure separate element results

X-ray fluorescence spectrometry (XRF): Similar technique to PIXE (see above) but instead uses an x-ray generator to create atomic interactions. X-rays are less energetic that an ion beam and so the technique is of poorer sensitivity and lower penetration.

Museum Concordance

Key:

Mazor Coins	MR
Garstang Museum of Archaeology	GMA
National Museums Liverpool	NML
Manchester Museum	MM
The British Museum	BM

Number	Institution	Institution Code		Number	Institution	Institution Code
1	MR	M49053		**33**	NML	LIV.2012.1.1857
2	MR	M49003		**34**	NML	LIV.2012.1.1858
3	MR	M49025		**35**	NML	LIV.2012.1.1859
4	MR	M49024		**36**	NML	LIV.2012.1.1860
5	MR	M49034		**37**	NML	LIV.2012.1.1882
6	GMA	Cat.300		**38**	NML	LIV.2012.1.1883
7	GMA	Cat.301		**39**	NML	LIV.2012.1.1884
8	GMA	Cat.303		**40**	NML	LIV.2012.1.1886
9	GMA	Cat.304		**41**	NML	LIV.2012.1.1887
11	GMA	Cat.306		**42**	NML	LIV.2012.1.1888
12	GMA	Cat.307		**43**	NML	LIV.2012.1.1893
13	GMA	Cat.308		**44**	NML	LIV.2012.1.1897
14	GMA	Cat.309		**45**	NML	44.19.75
15	GMA	Cat.310		**46**	NML	53.109.38
16	GMA	Cat.311		**47**	NML	LIV.2012.1.1908
17	GMA	Cat.312		**48**	NML	LIV.2012.1.1912
18	GMA	Cat.313		**49**	NML	LIV.2012.1.1916
19	GMA	Cat.314		**50**	NML	LIV.2012.1.1885
20	GMA	Cat.299		**51**	NML	LIV.2012.1.1895
21	NML	1963.68.80		**52**	NML	LIV.2012.1.1898
22	NML	LIV.2012.1.1613		**53**	NML	LIV.2012.1.1899
23	NML	LIV.2012.1.1835		**54**	NML	LIV.2012.1.1900
24	NML	LIV.2012.1.1879		**55**	NML	LIV.2012.1.1904
25	NML	LIV.2012.1.2224		**56**	NML	LIV.2012.1.1906
26	NML	LIV.2012.1.1849		**57**	NML	LIV.2012.1.1909
27	NML	LIV.2012.1.1850		**58**	NML	LIV.2012.1.1910
28	NML	LIV.2012.1.1851		**59**	NML	LIV.2012.1.1936
29	NML	LIV.2012.1.1853		**60**	NML	LIV.2012.1.1939
30	NML	LIV.2012.1.1854		**61**	NML	LIV.2012.1.1943
31	NML	LIV.2012.1.1855		**62**	NML	LIV.2012.1.2229
32	NML	LIV.2012.1.1856		**63**	NML	LIV.2012.1.1757

Number	Institution	Institution Code		Number	Institution	Institution Code
64	NML	LIV.2012.1.1760		**104**	BM	1866,1201.39
65	NML	LIV.2012.1.1761		**105**	BM	1871,0702.56
66	NML	LIV.2012.1.1763		**106**	BM	1953,0404.1
67	NML	LIV.2012.1.1774		**107**	BM	1919,1104.2
68	NML	LIV.201.1.1794		**108**	BM	1877,0406.9
69	NML	LIV.2012.1.1805		**109**	BM	1864,1118.11
70	NML	LIV.2012.1.1807		**110**	BM	1863,0813.4
71	NML	LIV.2012.1.1808		**111**	BM	1864,1118.14
72	NML	LIV.2012.1.1811		**112**	BM	1912,1013.44
73	NML	LIV.2012.1.1814		**113**	BM	1864,1118.14
74	NML	LIV.2012.1.1815		**114**	BM	RPK,p207D.1.Ptol
75	NML	LIV.2012.1.1818		**115**	BM	1871,0702.59
76	NML	LIV.2012.1.1824		**116**	BM	1867,0702.15
77	NML	LIV.2012.1.1827		**117**	BM	1864,1118.119
78	NML	LIV.2012.1.1828		**118**	BM	TC,p.237.6
79	NML	LIV.2012.1.1836		**119**	BM	1847,0519.8
80	NML	LIV.2012.1.1837		**120**	BM	1866,1201.39
81	NML	LIV.2012.1.1838		**121**	BM	1867,0704.41
82	MM	1422		**122**	BM	1867,0702.17
83	MM	1408		**123**	BM	1994,0915.96
84	MM	1408		**124**	BM	1920,0611.25
85	MM	1408		**125**	BM	1895,0508.23
86	MM	1408		**126**	BM	1857,0822.46
87	MM	1408		**127**	BM	1992,1138.5
88	MM	1408		**128**	BM	1866,1201.39
89	MM	1408		**129**	BM	1863,0727.16
90	MM	1437		**130**	BM	TC,p.236.7.PtoVIII
91	MM	1438		**131**	BM	1947,0606.21
92	MM	1439		**132**	BM	1913,0212.49
93	MM	1408		**133**	BM	1932,0809.7
94	MM	1441		**134**	BM	1869,1231.12
95	MM	1408		**135**	BM	1863,0727.20
96	BM	1971,1207.12		**136**	BM	1847,1101.21
97	BM	1971,1207.6		**137**	BM	1849,0717.42
98	BM	1982,0734.1		**138**	BM	1909,0504.56
99	BM	1912,1013.32		**139**	BM	1947,0606.21
100	BM	1996,0402.4		**140**	BM	1844,0425.99
101	BM	1996,0402.3		**141**	BM	1863,0813.7
102	BM	1955,0410.10		**142**	BM	1866,1201.3920
103	BM	BNK,G.912				

Appendix I: Description and Reference of Sampled Coins

Cat. Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
1	Silver	Ptolemy V	204-180	Alexandria	12.47g	29mm	Tetradrachm	Diademed head of Ptolemy I with aegis right, dotted border	Eagle with closed wings standing left on thunderbolt, dotted border	N/A	[ΠΤΟΛΕΜΑΙΟΥ] ΒΑΣΙΛΕΩΣ	Sv. 1231
2	Silver	Ptolemy VI	169-164	Alexandria	14.21g	29mm	Tetradrachm	Diademed head of Ptolemy I with aegis right, dotted border	Eagle with closed wings standing left on thunderbolt, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ	Sv. 1489
3	Silver	Ptolemy V	203	Cition	13.55g	26mm	Tetradrachm	Diademed head of Ptolemy I with aegis right, dotted border	Eagle with closed wings standing left on thunderbolt regnal date (LB) and a control (cornucopia?) to the left, KI	N/A	[ΠΤΟΛΕΜΑΙΟΥ] ΒΑΣΙΛΕΩΣ LB KI	Sv. 1349
4	Silver	Ptolemy VI & VIII	166-165	Paphos	13.37g	26mm	Tetradrachm	Diademed head of Ptolemy I with aegis right, dotted border	Eagle with closed wings standing left on thunderbolt regnal date (LK) to the left, ΠΑ	N/A	[ΠΤΟΛΕΜΑΙΟΥ] ΒΑΣΙΛΕΩΣ LK ΠΑ	Sv. 1432
5	Silver	Ptolemy VI & VIII	166-165	Paphos	12.65g	27mm	Tetradrachm	Diademed head of Ptolemy I with aegis right, dotted border	Eagle with closed wings standing left on thunderbolt regnal date (LM) to the left, ΠΑ	N/A	[ΠΤΟΛΕΜΑΙΟΥ] ΒΑΣΙΛΕΩΣ LM ΠΑ	Sv.1514

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
6	Copper Alloy	Hieron II imitation of Ptolemy II		Sicily	17.88g	26mm	AE24	Laureate head of Zeus	Eagle standing left on thunderbolt, legend around; Φ (?) below tail	N/A	[ΠΤΟΛΕΜΑΙΟΥ] ΒΑΣΙΛΕΩΣ	SNG Cop.118; Sv. 623
7	Copper Alloy	Ptolemy III		Alexandria	98.02g	46.5mm	Octobol	Laureate head of Zeus right	Eagle standing left, head right, wings extended; E between legs	N/A	ΒΑΣΙΛΕΩΣ ΠΤΟΛΕΜΑΙΟΥ Ε	Sv. 446; Series 4b
8	Copper Alloy	Ptolemy III		Cyrenaica	1.52g	13.5mm	Dichalkon	Diademed head of Ptolemy I right (with aegis)	Female head (poss. Libya) right with narrow cord round head and hair in long formal curls	N/A	ΒΑΣΙΛΕΩΣ ΠΤΟΛΕΜΑΙΟΥ	SNG Cop.439; Sv. 873
9	Copper Alloy	Ptolemy III		Alexandria	44.64g	38mm	Tetrobol	Amun head right, dotted border	Eagle standing left, head right, on left shoulder cornucopia bound with fillet; Λ between legs	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ Λ	SNG Cop.221; Sv. 1166; Series 4
11	Copper Alloy	Ptolemy IV	219	Alexandria	68.02g	42mm	Drachm	Amun head right wearing taenia, dotted border	Eagle standing left on thunderbolt, cornucopia to left; ΔΙ between legs	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ ΔΙ	Sv. 1125; Series 5d

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
12	Copper Alloy	Ptolemy IV	219	Alexandria	68.70g	42.5mm	Drachm	Amun head right wearing taenia, dotted border	Eagle standing left on thunderbolt, cornucopia to left; ΔI between legs	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ ΔΙ	Sv. 1125; Series 5d
13	Copper Alloy	Ptolemy III		Cyrenaica; Cyrene	2.15g	16.5mm	Dichalkon	Head of Ptolemy I right with aegis	Female head (poss. Libya) right with narrow cord round head and hair in long formal curls; cornucopia behind	N/A	[ΒΑΣΙΛ]ΕΩΣ ΠΤΟΛΕΜΑΙΟΥ	SNG Cop.445; Sv. 873
14	Copper Alloy	Ptolemy VI	180-145	Alexandria	16.67g	26.5mm	AE26	Head of Zeus Amun right with diadem and floral ornament	Eagle standing left on thunderbolt, cornucopia to left, EVA (?) between legs	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ EVA	SNG Cop.293; Sv. 1396
15	Copper Alloy	Ptolemy VI	180-145	Alexandria	11.37g	22.5mm	AE22	Head of Zeus Amun right with diadem and floral ornament	Eagle standing left on thunderbolt, to left lotus; ΕΥΑ between legs	N/A	Π[ΤΟΛΕΜ]ΑΙΟΥ ΒΑΣΙΛΕΩΣ ΕΥΑ	SNG Cop.295; Sv. 1401
16	Copper Alloy	Ptolemy VI & VIII	169-164	?	34.83g	32.5mm	AE32	Head of Zeus Amun right with diadem and floral ornament	Two eagles standing left on thunderbolt	N/A	ΠΤΟΛΕΜΑΙΟΥ [ΒΑΣΙΛΕΩΣ]	SNG Cop.305; Sv. 1424; Series 7c

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
17	Copper Alloy	Ptolemy VI & VIII	169-164	Alexandria	9.65g	20mm	AE21	Head of Zeus Amun right with diadem and floral ornament	Two eagles standing left on thunderbolt, to left cornucopia	N/A	[ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ]	SNG Cop.311; Sv. 1426; Series 9
18	Copper Alloy	Ptolemy VIII	145-116	Alexandria	9.77g	22mm	AE20	Bearded head of Herakles right, wearing lion's skin	Eagle standing left on thunderbolt	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ	SNG Cop.339; Sv. 1494; Series 6c
19	Copper Alloy	Ptolemy VIII	145-116	Cyrenaica	3.70g	18mm	AE16	Diademed head of Ptolemy I right	Female head, (Libya (?)) right, single cornucopia in front	N/A	ΠΤΟΛΕΜΑΙΟΥ [ΒΑΣΙΛΕΩΣ]	SNG Cop.451; Sv. 1658
20	Silver	Ptolemy I	310-305	Alexandria	14.59g	27mm	Tetradrachm	Head of Alexander the Great, right, with horn of Amun, with elephant scalp and aegis	Athena right, shield on raised left arm, spear in raised right arm; monogram to left, eagle in lower right field; ΔI to right	N/A	ΑΞΞΑΝΔΡΟΥ ΔΙ	SNG Cop.21; Sv. 142
21	Copper Alloy	Ptolemy III		Alexandria	42.40g	39mm	Tetrobol	Head of Amun right with taenia, dotted border	Eagle standing left on thunderbolt, head facing right and cornucopia on right shoulder, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕ[ΩΣ]	Not listed (Pos. Sv. 1166); Series 4a

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
22	Copper Alloy	Ptolemy I	304-283	Alexandria	13.75g	25.5mm	Diobol	Laureate head of Zeus right	Eagle standing left on thunderbolt	N/A	Not listed & not legible	Sv. 300 (or pos.272)
23	Copper Alloy	Ptolemy III	246-221	Alexandria	10.79g	24mm	Obol	Horned Amun head right, wearing taenia, dotted border	Eagle with closed wings standing left on thunderbolt, cornucopia on left, monogram between legs, dotted border	N/A	N/A	SNG Cop.178; Sv. 967 (here though the eagle is with closed wings); Series 5b
24	Copper Alloy	Ptolemy II	260s	Alexandria	9.68g	23mm	Obol	Horned head of deified Alexander in elephant headdress, right, dotted border	Eagle with spread wings standing left on thunderbolt, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ	SNG Cop.162; Sv. 424; Series 3
25	Copper Alloy	Ptolemy II	260	Alexandria	7.45g	20mm	Tritartemorion	Horned head of deified Alexander in elephant headdress, right	Eagle with spread wings standing left on thunderbolt	N/A	Not listed & not legible	Not listed (Pos. Sv. 440); Series 3
26	Copper Alloy	Ptolemy IV	219	Alexandria	67.27g	42mm	Drachm	Head of Amun right wearing taenia, dotted border	Eagle standing left on thunderbolt, cornucopia on right ΔI between legs	N/A		BMC 107; Sv. 1125; Series 5d

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
27	Copper Alloy	Ptolemy IV	220-219	Alexandria	72.00g	41mm	Drachm	Head of Amun right wearing taenia, dotted border	Eagle standing left on thunderbolt, cornucopia on left ΛI between legs, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ ΛΙ	BMC 107; Sv. 1126; Series 5c
28	Copper Alloy	Ptolemy IV	219	Alexandria	64.90g	41.5mm	Drachm	Head of Amun right wearing taenia, dotted border	Eagle standing left on thunderbolt, cornucopia on left ΔI between legs, dotted border	N/A	ΠΤΟΛΕΜΑΙ[ΟΥ ΒΑ]ΣΙΛΕΩΣ ΔΙ	BMC 107; Sv. 1125; Series 5d
29	Copper Alloy	Ptolemy II	260s	Alexandria	65.11g	41.5mm	Drachm	Diademed and horned (?) Amun head right, dotted border	Two eagles with closed wings standing left on two thunderbolts, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣ[ΙΛ]ΕΩΣ	Pos. Sv.413; Series 3
30	Copper Alloy	Ptolemy IV	220-219	Alexandria	62.52g	41mm	Drachm	Head of Amun right wearing taenia, dotted border	Eagle standing left on thunderbolt, cornucopia on left ΛI between legs, dotted border	N/A	[ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕ]ΩΣ Λ	BMC 108; Sv. 1126; Series 5c

Number	**Metal**	**Ruler**	**Date (BCE)**	**Mint**	**Weight**	**Diameter**	**Denomination**	**Obverse Description**	**Reverse Description**	**Obverse Inscription**	**Reverse Inscription**	**Reference**
31	Copper Alloy	Ptolemy III		Alexandria	34.85g	36mm	Triobol	Horned head of Amun right wearing taenia, dotted border	Eagle standing left on thunderbolt, cornucopia on left monogram between legs	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ	BMC 87; Sv. 965; Series 5b
32	Copper Alloy	Ptolemy III		Alexandria	35.49g	35mm	Triobol	Horned head of Amun right wearing taenia, dotted border	Eagle standing left on thunderbolt, cornucopia on left, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ	BMC 87; Sv. 965; Series 5b
33	Copper Alloy	Ptolemy III		Alexandria (?)	36.60g	35.5mm	Triobol	Horned head of Amun right wearing taenia, dotted border	Eagle standing left on thunderbolt, cornucopia on left monogram between legs, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ	BMC 87; Sv. 965; Series 5b
34	Copper Alloy	Ptolemy III		Alexandria	36.46g	35.5mm	Triobol	Horned head of Amun right wearing taenia, dotted border	Eagle standing left on thunderbolt, cornucopia on left, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ	BMC 87; Sv. 965; Series 5b

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
35	Copper Alloy	Ptolemy III		Alexandria	34.83g	34mm	Triobol	Horned head of Amun right wearing taenia, dotted border	Eagle standing left on thunderbolt, cornucopia on left monogram (?) between legs, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ	BMC 87: Sv. 965; Series 5b
36	Copper Alloy	Ptolemy IV	220-219	Alexandria	33.90g	35mm	Triobol	Head of Amun right wearing taenia, dotted border	Eagle standing left on thunderbolt, cornucopia on left, dotted border	N/A	[ΠΤΟ]ΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ	BMC 110; Sv. 1128; Series 5c
37	Copper Alloy	Ptolemy V	205-180	Alexandria	7.46g	21mm	AE20	Head of deified Alexander right (?) in elephant headdress (?), dotted border (?)	Eagle with spread wings (?) standing left on thunderbolt, dotted border	N/A	[ΠΤΟ]ΛΕΜΑΙΟΥ [ΒΑΣΙΛΕΩΣ]	SNG Cop.253 (This reference is incorrect), Pos. Sv. 1239; Series 7c
38	Copper Alloy	Ptolemy V	205-180	Alexandria	16.26g	26mm	AE25	Head of Amun right, dotted border	Eagle with closed wings standing left on thunderbolt, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ	SNG Cop.293; Sv. 1234; Series 6e

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
39	Copper Alloy	Ptolemy VI	180-145	Cyprus	7.91g	22.5mm	AE21	Head of Amun right, dotted border (?)	Eagle with closed wings standing left on thunderbolt, lotus flower in left field (?) dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ	SNG Cop.295; Sv. 1407
40	Copper Alloy	Ptolemy VI	180-145	Alexandria	9.21g	24.5mm	AE23	Bearded head of Herakles right in lion skin, dotted border	Eagle with closed wings standing on thunderbolt, dotted border	N/A	[ΠΤΟΛΕ]ΜΑΙΟΥ ΒΑΣΙΛΕΩΣ	SNG Cop.270; Sv. 1376; Series 6d
41	Copper Alloy	Ptolemy VI & VIII	169-164	Alexandria	21.14g	29mm		Bearded head of Herakles right in lion skin, dotted border	Eagle with closed wings standing on thunderbolt, dotted border	N/A	ΠΤΟΛΕΜΑΙ[ΟΥ ΒΑΣΙΛΕΩΣ]	SNG Cop.333; Sv. 1492; Series 6a
42	Copper Alloy	Ptolemy VI & VIII	169-164	Alexandria	11.17g	23.5mm	AE23	Bearded head of Herakles right in lion skin, dotted border	Eagle with closed wings standing on thunderbolt, dotted border	N/A	[Π]ΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ	SNG Cop.339; Sv.1494; Series 6c

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
43	Copper Alloy	Ptolemy V	205-180	Alexandria	5.00g	19mm	AE18	Isis head right, crowned with grain, dotted border	Eagle with closed standing left on thunderbolt, head reverted, cornucopia on shoulder, dotted border	N/A	[ΠΤΟΛΕΜΑΙΟΥ] ΒΑΣΙΛ[ΕΩΣ]	SNG Cop.256; Sv. 1238; Series 6e
44	Copper Alloy	Cleopatra VII	51-30	Alexandria	19.08g	27.5mm	AE24	Diademed and draped bust of Cleopatra VII right, dotted border (?)	Eagle with closed wings (?) standing left on thunderbolt, dotted border (?)	N/A	ΚΛΕΟΠΑΤΡΑΣ [ΒΑΣΙΛΙΣΣΗΣ]	SNG Cop.419; Sv. 1871; Series 10
45	Copper Alloy	Ptolemy III		Alexandria	36.99g	39mm	Tetrobol	Head of Amun right, dotted border	Eagle with closed wings standing left on thunderbolt, head reverted, dotted border	N/A	[ΠΤΟΛΕ]ΜΑΙΟΥ [ΒΑΣΙΛΕΩΣ]	Sv. 1166; Series 4a
46	Copper Alloy	Ptolemy IV	219	Alexandria	63.86g	41mm	Drachm	Head of Amun right wearing taenia, dotted border	Eagle with closed wings standing left on thunderbolt, cornucopia on the left, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ	SNG Cop.205; Sv. 1125; Series 5d

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
47	Copper Alloy	Ptolemy VI	180-169	Alexandria	15.05g	27mm	AE26	Isis head right, crowned with grain, dotted border (?)	Eagle with spread wings standing left on thunderbolt, monogram in left field (?), dotted border(?)	N/A	ΠΤΟΛΕΜ[ΑΙΟΥ ΒΑΣΙΛΕΩΣ]	BMC 6f; Sv. 1384; Series 7b
48	Copper Alloy	Ptolemy VI & VIII	169-164	Alexandria	22.98g	30.5mm	AE27	Head of Amun right, dotted border	Two eagles with closed wings standing left on two thunderbolts, double cornucopia left (?), dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩ[Σ]	BMC 29; Sv. 1424; Series 7c
49	Copper Alloy	Ptolemy VI & VIII	169-164	Alexandria	25.88g	31mm	AE30	Head of Amun right, dotted border	Two eagles with closed wings standing left on two thunderbolts, double cornucopia left (?), dotted border	N/A	ΠΤΟΛΕΜΑΙ[ΟΥ ΒΑΣΙ]ΛΕΩΣ	BMC 29; Sv. 1424; Series 7c

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
50	Copper Alloy	Ptolemy V	221-140	Cyrenaica	6.47g	21mm	AE20	Diademed head of Ptolemy I with aegis (?) right, club behind (?), dotted border (?)	Libya head right, double cornucopia (?) before	N/A	ΒΑ[ΣΙΛΕΩΣ] ΠΤΟΛΕΜΑΙΟΥ	SNG Cop.443; Sv. 1268
51	Copper Alloy	Ptolemy V	205-180	Alexandria	4.17g	17mm	AE18	Isis head right, crowned with grain, dotted border (?)	Eagle with closed wings (?) standing left on thunderbolt, cornucopia on shoulder (?), dotted border (?)	N/A	[ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ]	SNG Cop.256; Sv. 1238; Series 6e
52	Copper Alloy	Ptolemy V	205-180	Alexandria	3.93g	16mm	AE15	Head of deified Alexander in elephant headdress right, dotted border	Eagle with spread wings standing left on thunderbolt, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ [ΒΑΣΙΛΕΩΣ]	SNG Cop.260; Sv. 1239; Series 7c
53	Copper Alloy	Ptolemy V	205-180	Alexandria	8.51g	21mm	AE21	Head of deified Alexander in elephant headdress right, dotted border (?)	Eagle with spread wings standing left on thunderbolt, dotted border (?)	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑ[ΣΙΛΕΩΣ]	SNG Cop.249; Sv. 1236; Series 6e

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
54	Copper Alloy	Ptolemy VIII	134-129	Cyrene	4.79g	19.5mm	AE19	Head of Amun right, dotted border (?)	Eagle with spread wings standing left on thunderbolt, ΘE in left field, dotted border (?)	N/A	[ΠΤΟΛΕΜΑΙΟΥ ΒΑ]ΣΙΛΕΩΣ ΘE	SNG Cop.655; Sv. 1651
55	Copper Alloy	Ptolemy VIII	134-129	Cyrene	40.56g	43.5mm	AE43	Head of Amun right, dotted border	Eagle with spread wings standing left on thunderbolt, Φ (?) in right field, dotted border	N/A	[ΕΡΓΤΟΥ ΒΑ]ΣΙΛΕΩΣ ΠΤΟΛΕΜΑΙΟΥ	BMC 78; Sv. 1641
56	Copper Alloy	Ptolemy VI	180-169	Alexandria	14.42g	27mm	AE25	Isis head right, crowned with grain, dotted border	Eagle with spread wings (?) standing left on thunderbolt, monogram in right field (?), dotted border (?)	N/A	[ΠΤΟ]ΛΕΜΑΙΟΥ ΒΑ[ΣΙΛΕΩΣ]	BMC 6f; Sv. 1384; Series 7b
57	Copper Alloy	Ptolemy VI	180-169		17.66g	22mm		Isis head right, crowned with grain, dotted border	Eagle with spread wings standing left on thunderbolt, monogram in right field (?), dotted border (?)	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ	Pos. Sv. 1384; Series 7b

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
58	Copper Alloy	Ptolemy VI & VII	169-164	Alexandria	8.40g	21mm	AE20	Head of Amun right, dotted border (?)	Two eagles with closed wings standing left on two thunderbolts, dotted border (?)	N/A	ΠΤΟΛΕΜΑΙΟΥ [ΒΑΣ]ΙΛΕΩΣ	BMC 34 (Pos. Sv. 1426); Series 9
59	Copper Alloy	Ptolemy VIII	134-129	Cyrenaica	12.05g	26.5mm	AE27	Head of Amun right, dotted border (?)	Eagle with spread wings standing left on thunderbolt, Φ (?) in right field, dotted border (?)	N/A	[ΒΑΣΙΛΕΩΣ ΠΤΟΛΕΜΑΙΟΥ ΕΡΓΤΟΥ]	SNG Cop.652; Sv. 1642
60	Copper Alloy	Ptolemy VI & VIII	169-164	Alexandria	8.00g	21mm	AE20	Head of Amun right, dotted border (?)	Two eagles with closed wings standing left on two thunderbolts, dotted border (?)	N/A	ΠΤΟΛΕΜΑΙΟΥ [ΒΑ]ΣΙΛΕΩΣ	SNG Cop.311; Sv. 1426; Series 9
61	Copper Alloy	Ptolemy VI & VIII	169-164	Alexandria	7.95g	20mm	AE20	Head of Amun right, dotted border	Two eagles with closed wings standing left on two thunderbolts, dotted border	N/A	[ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ]	SNG Cop.311; Sv. 1426; Series 9
62	Copper Alloy	Ptolemy I	294		16.85g	28mm	Diobol	Laureate head of Zeus right, dotted border	Eagle with spread wings standing left on thunderbolt, monogram (?) in left field, dotted border (?)	N/A	[ΠΤΟ]ΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ	Sv. 184; Series 2d

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
63	Silver	Ptolemy I	305-285	Alexandria	14.06g	27mm	Tetradrachm	Diademed head of Ptolemy I right, with agis, dotted border	Eagle with closed wings standing left on thunderbolt, monogram in left field, dotted border	N/A	[Π]ΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩ[Σ]	BMC 2; Sv. 214
64	Silver	Ptolemy I	305-285	Alexandria	14.07g	26mm	Tetradrachm	Diademed head of Ptolemy I right, with agis, dotted border	Eagle with closed wings standing left on thunderbolt, monogram in left field, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ	BMC 2; Sv. 214
65	Silver	Ptolemy I	305-285	Alexandria	14.04g	27mm	Tetradrachm	Diademed head of Ptolemy I right, with agis, dotted border	Eagle with closed wings standing left on thunderbolt, monogram in left field, dotted border	N/A	[ΠΤΟΛΕΜΑΙΟΥ] ΒΑΣΙΛΕΩΣ	BMC 32; (Pos Sv. 214)
66	Silver	Ptolemy I	305-285	Alexandria	13.84g	26.5mm	Tetradrachm	Diademed head of Ptolemy I right, with agis, dotted border	Eagle with closed wings standing left on thunderbolt dotted border (?)	N/A	[ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ]	BMC 24 (?)
67	Silver	Ptolemy X	92-91	Alexandria	13.41g	24.5mm	Tetradrachm	Diademed head of Ptolemy I right, with agis, dotted border (?)	Eagle with closed wings standing left on thunderbolt, LKΓ in left field, ΠΑ in right field, dotted border (?)	N/A	[ΠΤ]ΟΛΕΜΑΙΟΥ [ΒΑΣΙΛΕΩΣ]	BMC 48; Sv. 1684

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
68	Silver	Ptolemy X	101-100	Alexandria	13.45g	25mm	Tetradrachm	Diademed head of Ptolemy I right, with agis, dotted border (?)	Eagle with closed wings standing left on thunderbolt, LIΔ in left field, ΠΑ in right field, dotted border (?)	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ ΠΑ	Sv. 1674
69	Silver	Ptolemy X	97-96	Alexandria	13.70g	27mm	Tetradrachm	Diademed head of Ptolemy I right, with agis, dotted border (?)	Eagle with closed wings standing left on thunderbolt, LIH in left field, ΠΑ in right field, dotted border (?)	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ ΠΑ	Sv. 1678
70	Silver	Ptolemy X	98-97	Alexandria	13.80g	26mm	Tetradrachm	Diademed head of Ptolemy I right, with agis, dotted border (?)	Eagle with closed wings standing left on thunderbolt, LIı in left field, ΠΑ in right field, dotted border (?)	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩ[Σ] ΠΑ	Sv. 1677
71	Silver	Ptolemy X	98-97	Alexandria	13.08g	24mm	Tetradrachm	Diademed head of Ptolemy I right, with agis, dotted border (?)	Eagle with closed wings standing left on thunderbolt, LIı in left field, ΠΑ in right field, dotted border (?)	N/A	[ΠΤΟ]ΛΕΜΑΙΟΥ ΒΑΣΙΛ]ΕΩΣ [Π]Α	Sv. 1677

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
72	Silver	Ptolemy X	95-94	Alexandria	13.44g	24mm	Tetradrachm	Diademed head of Ptolemy I right, with agis, dotted border (?)	Eagle with closed wings standing left on thunderbolt, regnal year in left field, ΠΑ in right field, dotted border (?)	N/A	ΠΤΟΛΕΜΑΙΟΥ [ΒΑΣΙΛΕΩΣ] LK ΠΑ	Sv.1680
73	Silver	Ptolemy X	94-93	Alexandria	13.27g	25mm	Tetradrachm	Diademed head of Ptolemy I right, with agis, dotted border (?)	Eagle with closed wings standing left on thunderbolt, LKA in left field, ΠΑ in right field, dotted border (?)	N/A	[ΠΤΟ]ΛΕΜΑΙΟΥ ΒΑΣΙ[ΛΕΩΣ] LKA ΠΑ	BMC 41; Sv. 1681
74	Silver	Ptolemy X	93-92	Alexandria	12.99g	25mm	Tetradrachm	Diademed head of Ptolemy I right, with agis, dotted border (?)	Eagle with closed wings standing left on thunderbolt, LKB, ΠΑ in right field, dotted border (?)	N/A	[ΠΤΟ]ΛΕΜΑΙ[Ο Υ ΒΑΣΙΛΕΩΣ] LKB ΠΑ	BMC 46; Sv. 1682

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
75	Silver	Ptolemy X	96-95	Alexandria	13.43g	25mm	Tetradrachm	Diademed head of Ptolemy I right, with agis, dotted border (?)	Eagle with closed wings standing left on thunderbolt, regnal year in left field(LIΘ), ΠΑ in right field, dotted border (?)	N/A	[ΠΤΟΛΕΜΑΙΟ]Υ ΒΑΣΙΛΕΩ[Σ] LIΘ ΠΑ	BMC 35; Sv. 1679
76	Silver	Cleopatra VII	37-36	Alexandria	13.85g	24.5mm	Tetradrachm	Diademed head of Ptolemy I right, with agis, dotted border	Eagle with closed wings standing left on thunderbolt, regnal year in left field LI, ΠΑ in right field, dotted border (?)	N/A	[ΠΤΟ]ΛΕΜΑΙΟ[Υ ΒΑΣΙΛΕΩΣ] LI ΠΑ	Sv. 1830
77	Silver	Ptolemy X	97-96	Alexandria	12.36g	24mm	Tetradrachm	Diademed head of Ptolemy I right, with agis, dotted border	Eagle with closed wings standing left on thunderbolt, LIH in left, ΠΑ in right field, dotted border (?)	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕ[ΩΣ] LIH ΠΑ	SNG Cop.367; Sv. 1678
78	Silver	Ptolemy XII	60-59	Alexandria	12.94g	24mm	Tetradrachm	Diademed head of Ptolemy I right, with agis, dotted border (?)	Eagle with closed wings standing left on thunderbolt, LKB in left field (?), ΠΑ in right field, dotted border (?)	N/A	ΠΤΟΛΕΜΑ[ΙΟΥ ΒΑΣΙΛΕΩΣ] LKB ΠΑ	SNG Cop.371; Sv. 1682

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
79	Silver	Cleopatra VII	37-36	Alexandria	13.07g	21mm	Tetradrachm	Diademed head of Ptolemy I right, with agis, dotted border	Eagle with closed wings standing left on thunderbolt, regnal year in left field (?ιI), ΠA in right field, dotted border (?)	N/A	[ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ] ?ιI ΠA	Sv. 183
80	Silver	Cleopatra VII	42-41	Alexandria	12.66g	21mm	Tetradrachm	Diademed head of Ptolemy I right, with agis, dotted border (?)	Eagle with closed wings standing left on thunderbolt, regnal year in left field (LIA), ΠA in right field, dotted border (?)	N/A	[ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ] LI(?) ΠA	Sv. 1858
81	Silver	Cleopatra VII	42-41	Alexandria	12.73g	26mm	Tetradrachm	Diademed head of Ptolemy I right, with agis, dotted border (?)	Eagle with closed wings standing left on thunderbolt, regnal year in left field, ΠA in right field, dotted border (?)	N/A	[ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ ΠA]	Sv. 1824
82	Copper Alloy	Ptolemt II	260s	Alexandria	73.24g	40mm	Drachm	Diadem and horned head of Zeus Amun right, with flower over forehead	Two eagles with closed wings standing left on thunderbolt, control letter T between legs	N/A	[Π]ΤΟΛ[ΕΜΑΙΟΥ] ΒΑΣΙΛΕΩ[Σ] T	Sv. 504; Series 3

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
83	Silver	Ptolemy I as Satrap	320/19-314/313	Egypt	16.59g	28mm	Tetradrachm	Diademed and horned head of Alexander the Great, right, with elephant headdress and aegis	Zeus enthroned left, holding eagle in extended right hand and resting left on sceptre, feet on footrest, thunderbolt in left field, monogram under throne dotted border	N/A	ΑΛΕΞΑΝΔΡΟΥ	Sv. 22
84	Silver	Ptolemy II		Alexandria	14.08g	25mm	Tetradrachm	Diademed head of Ptolemy I right, with agis, tiny Δ behind ear	Eagle with closed wings standing left on thunderbolt, control in left field	N/A	[ΠΤ]ΟΛΕΜΑΙΟΥ ΒΑΣΙΛ[ΕΩΣ]	Sv. 548
85	Silver	Ptolemy I	294	Uncertain	14.09g	26mm	Tetradrachm	Diademed head of Ptolemy I right, with agis	Eagle with closed wings standing left on thunderbolt, control in left field	N/A	[ΠΤΟΛ]ΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ ΣΤ ΚΙ	Sv. 366
86	Silver	Ptolemy II	285-270	Alexandria	14.25g	26mm	Tetradrachm	Diademed head of Ptolemy I right, with agis	Eagle with closed wings standing left on thunderbolt, regnal year in left field, ΓΤ and Δ in right field, dotted border	N/A	[ΠΤΟΛ]ΕΜΑΙΟΥ ΒΑΣΙΛΕΩ[Σ] ΠΤ Δ	Pos. Sv. 532

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
87	Silver	Ptolemy VI		Alexandria	12.77g	26mm	Tetradrachm	Diademed head of Ptolemy I right, with agis, dotted border	Eagle with closed wings standing left on thunderbolt, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ	Sv. 1489
88	Silver	Ptolemy VI		Alexandria	14.23g	27mm	Tetradrachm	Diademed head of Ptolemy I right, with agis	Eagle with closed wings standing left on thunderbolt, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ	Sv. 1489
89	Silver	Ptolemy VI		Alexandria	6.82g	21mm	Didrachm	Diademed head of Ptolemy I right, with agis	Eagle with closed wings standing left on thunderbolt, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑ[ΣΙΛΕΩ]Σ	Sv. 1490
90	Silver	Ptolemy IV	220		13.52g	27mm	Tetradrachm	Diademed head of Ptolemy I right, with agis	Eagle with closed wings standing left on thunderbolt, monogram in left field, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΣΩΤΗΡ[ ] Λ	Sv. 1207
91	Silver	Ptolemy X	105-80	Cyprus	6.74	17mm	Didrachm	Diademed and draped bust of young Ptolemy V right, wearing an ivy wreath, thyrsos over shoulder	Eagle with spread wings standing left on thunderbolt, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛ[ΕΩΣ]	Sv. 1789

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
92	Silver	Ptolemy VIII	143-142	Cition	14.14g	25mm	Tetradrachm	Diademed head of Ptolemy I right, with agis	Eagle with closed wings standing left on thunderbolt, LKH in left field, KI in right field, dotted border (?)	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ LKH KI	Sv. 1476
93	Silver	Ptolemy XII	52-51	Alexandria	14.66g	26.5mm	Tetradrachm	Head of Ptolemy I right, with agis	Eagle with closed wings standing left on thunderbolt, laurel branch over shoulder, regnal date LΛ above Isis headdress in left field, ΠΑ in right field	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕ[ΩΣ] LΛ ΠΑ	Sv. 1840
94	Silver	Ptolemy XII	64-63	Alexandria	11.59g	24.5mm	Tetradrachm	Diademed head of Ptolemy I right, with agis, dotted border	Eagle with closed wings standing left on thunderbolt, IIH in left field, ΠΑ in right field	N/A	ΠΤ[ΟΛΕΜΑΙΟΥ] ΒΑΣΙΛΕ[ΩΣ] IIH ΠΑ	Sv. 1865

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
95	Silver	Ptolemy XII	55-54	Alexandria	12.83g	25.5mm	Tetradrachm	Head of Ptolemy I right, with agis	Eagle with closed wings standin left on thunderbolt, laurel branch over shoulder, regnal date LKI above Isis headdress in left field, ΠΑ in right field	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣ[ΙΛΕΩΣ] LKI ΠΑ	Sv. 1836
96	Silver	Ptolemy II	275-272	Alexandria	16.35g	29.5mm	Tetradrachm	Entirely obscured due to burning (?)	Eagle with closed wings standing left on thunderbolt, monogram over shield in left field, Λ between eagle's legs	N/A	[ΠΤ]ΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΟΣ Λ	Sv. 579
97	Silver	Ptolemy II	285-270	Alexandria	13.92g	21.5mm	Tetradrachm	Head of Ptolemy I right, with agis	Eagle with closed wings standing left on thunderbolt, monogram in left field, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙ[ΛΕΟΣ]	Sv. 548
98	Silver	Ptolemy III			13.93g	25.5mm	Tetradrachm					
99	Silver	Ptolemy III	242-241	Jaffa	14.07g	25mm	Tetradrachm					Sv. 1044

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
100	Silver	Ptolemy III	246-245	Sidon	14.21g	25mm	Tetradrachm	Head of Ptolemy I right, with agis	Eagle with closed wings standing left on thunderbolt, ΣΙ over ΝΙ in left field, Β over monogram in right field	N/A	ΓΤΟΛΕΜΑΙΟΥ ΣΩΤΗΡ[ΟΣ]	Sv. 1025
101	Silver	Ptolemy III	245-244	Jaffa	14.08g	25mm	Tetradrachm	Head of Ptolemy I right, with agis, dotted border	Eagle with closed wings standing left on thunderbolt, Jaffa monogram over control in left field, regnal date - Γ over control - □ in right field	N/A	ΓΤΟΛΕΜΑΙΟΥ ΣΩΤΗΡ[ΟΣ] Γ □	Sv. 1041
102	Silver	Ptolemy IV	221-203	Sidon	13.72g	25mm	Tetradrachm					Sv. 1186
103	Silver	Ptolemy IV	221-204	Sidon	14.03g	25.5mm	Tetradrachm	Diademed and draped bust of Ptolemy IV right, dotted border	Eagle with closed wings standing left on thunderbolt, ΣΩ in left field, ΣΙ between eagle's legs, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ ΣΩ ΣΙ	Sv. 1185

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
104	Silver	Ptolemy IV	219-217	Alexandria	13.78g	25.5mm	Tetradrachm	Jugate bust of Zeus Sarapis, diademed and with lotus over forehead, and Isis, wearing horned disc right, dotted border	Eagle with closed wings standing left on thunderbolt, head reverted, holding filled cornucopia over shoulder, ΔΙ between legs, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ ΔΙ	Sv. 1124
105	Silver	Ptolemy IV		Uncertain	14.13g	27mm	Tetradrachm					Sv. 1121
106	Silver	Ptolemy V	205-180	Cyrenaica	14.25g	25.5mm	Tetradrachm	Diademed and draped bust (barley ear on diadem) of young Ptolemy V right, dotted border	Eagle with closed wings standing left on thunderbolt, M in left field, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ Μ	Sv. 1263
107	Silver	Ptolemy V	205-180	Alexandria	12.87g	28mm	Tetradrachm	Diademed head of Ptolemy I with aegis right, dotted border	Eagle with closed wings standing left on thunderbolt, monogram in left field, spearhead in right field, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΣΩΤΗΡΟΣ	Sv. 1250

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
108	Silver	Ptolemy V	205-180	Alexandria	13.07g	26mm	Tetradrachm	Diademed head of Ptolemy I with aegis right, dotted border	Eagle with closed wings standing left on thunderbolt, monogram in left field, spearhead in right field, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΣΩΤΗΡΟΣ	Sv. 1250
109	Silver	Ptolemy V	205-180	Cyrenaica	14.33g	26mm	Tetradrachm	Diademed and draped bust of young Ptolemy V right, dotted border	Eagle with closed wings standing left on thunderbolt, monogram in left field, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ	Sv. 1260
110	Silver	Ptolemy VIII	132-131	Alexandria	14.42g	27mm	Tetradrachm	Diademed head of Ptolemy I with aegis right	Eagle with closed wings standing left on thunderbolt, regnal date - LΛ□ in left field, mintmark - ΠΑ in right field	N/A	[ΠΤΟ]ΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ LΛ□ ΠΑ	Sv. 1513
111	Silver	Ptolemy VIII	122-121	Alexandria	14.15g	25mm	Tetradrachm					Sv. 1520
112	Silver	Ptolemy VIII	120-119	Alexandria	13.40g	25.5mm	Tetradrachm					Sv. 1527

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
113	Silver	Ptolemy VIII	133-132	Alexandria	14.38g	25.5mm	Tetradrachm	Diademed head of Ptolemy I with aegis right	Eagle with closed wings standing left on thunderbolt, regnal date - LΛH in left field, mintmark - ΠA in right field	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ LΛH ΠA	Sv. 1512
114	Silver	Ptolemy VI		Alexandria	6.64g	21mm	Didrachm	Diademed head of Ptolemy I with aegis right, dotted border	Eagle with closed wings standing left on thunderbolt, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ	Sv. 1490
115	Silver	Ptolemy VI		Alexandria	13.48g	27mm	Tetradrachm	Diademed head of Ptolemy I with aegis right, dotted border	Eagle with closed wings standing left on thunderbolt, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ	Sv. 1489
116	Silver	Ptolemy IX	115-114	Alexandria	14.19g	27mm	Tetradrachm					Sv. 1663
117	Silver	Ptolemy IX	116-115	Alexandria	13.79g	26mm	Tetradrachm					Sv.1660
118	Silver	Ptolemy X	107-106	Alexandria	14.38g	24.5mm	Tetradrachm	Diademed head of Ptolemy I with aegis right, dotted border	Eagle with closed wings standing left on thunderbolt, double regnal dates - LIA over H in left field, ΠA in right field	N/A	[ΠΤΟ]ΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩ[Σ] LIA H ΠA	Sv. 1727

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
119	Silver	Ptolemy X	106-105	Alexandria	18.85g	24.5mm	Tetradrachm	Diademed head of Ptolemy I with aegis right	Eagle with closed wings standing left on thunderbolt, double regnal dates - LIA over Θ in left field, ΠA in right field	N/A	[ΠΤΟ]ΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩ[Σ] LIA Θ ΠΑ	Sv. 1728
120	Silver	Ptolemy X	106-105	Alexandria	14.23g	25mm	Tetradrachm	Diademed head of Ptolemy I with aegis right, dotted border	Eagle with closed wings standing left on thunderbolt, double regnal dates - LIA over Θ in left field, ΠA in right field	N/A	[ΠΤΟ]ΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩ[Σ] LIA Θ ΠΑ	Sv. 1728
121	Silver	Ptolemy X	105-104	Alexandria	13.70g	24.5mm	Tetradrachm	Diademed head of Ptolemy I with aegis right, dotted border	Eagle with closed wings standing left on thunderbolt, double regnal dates - LIΓ over I in left field, ΠA in right field	N/A	[ΠΤΟ]ΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩ[Σ] LIΓ I ΠΑ	Sv. 1729

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
122	Silver	Ptolemy X	102-101	Alexandria	14.33g	24mm	Tetradrachm	Diademed head of Ptolemy I with aegis right	Eagle with closed wings standing left on thunderbolt, double regnal dates - LIC over IΓ in left field, ΠA in right field	N/A	[ΠΤΟ]ΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩ[Σ] LIC IΓ ΠA	Sv. 1731
123	Silver	Ptolemy XII	53-52	Alexandria	13.11g	25mm	Tetradrachm	Diademed head of Ptolemy I with aegis right	Eagle with closed wings standing left on thunderbolt, laurel branch over shoulder, regnal date - LKΘ above Isis headdress in left field, ΠA in right field	N/A	ΠΤΟΛΕ[ΜΑΙΟΥ ΒΑΣΙΛΕΩΣ] LKΘ [ΠA]	Sv. 1839
124	Silver	Cleopatra VII	37-36	Alexandria	14.09g	24mm	Tetradrachm	Diademed head of Ptolemy I with aegis right	Eagle with closed wings standing left on thunderbolt, laurel branch over shoulder, regnal date - LA above Isis headdress in left field, ΠA in right field	N/A	[ΠΤΟΛΕΜΑΙΟΥ] ΒΑΣΙΛΕΩΣ LA ΠA	Sv. 1816

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
125	Silver	Cleopatra VII		Syria	14.30g	28.5mm	Tetradrachm	Diademed and draped bust of Cleopatra with necklace right, dotted border	Head of Marc Antony right, dotted border	ΒΑCΙΛΙCCΑ ΚΛЄ[ΟΠΑΤΡΑ ΘЄΑ ΝЄϹƆΤЄΡΑ]	ΑΝΤϹƆΝΙΟCΑΥΤΟΚΡΑΤ[ϹƆΡ ΤΡΙ]ΤΟΝ ΤΡΙϹƆΝ ΑΝΔΡΩΝ	RPC I 4094
126	Silver	Cleopatra VII	47-46	Alexandria	2.98g	16mm	Drachm	Diademed and draped bust of Cleopatra right, dotted border	Eagle with closed wings standing left on thunderbolt, regnal date of Cleopatra LC above Isis headdress in left field, ΠΑ in right field, dotted border	N/A	[ΚΛΕΟΠ]ΑΤΡΑ[C ΒΑCΙΛΙCCΗC] LC ΠΑ	Sv. 1853
127	Copper Alloy	Ptolemy VI & VIII	169-164	Alexandria	32.75g	33.5mm	AE29/34	Amun head right	Two eagles with closed wings standing left on two thunderbolt, dotted border	N/A	[ΠΤΟ]ΛΕΜΑΙΟΥ ΒΑΣΙΛ[ΕΩΣ]	Sv. 1424; Series 7c

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
128	Copper Alloy	Ptolemy VI & VIII	169-163	Alexandria	23.40g	28mm	AE29/34	Amun head right, dotted border	Two eagles with closed wings standing left on two thunderbolt, double cornucopia in left field dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕ[ΩΣ]	Sv. 1424; Series 7c
129	Copper Alloy	Ptolemy VI & VIII	169-163	Alexandria	9.71g	20.5mm	AE19/22	Amun head right	Two eagles with closed wings standing left on two thunderbolt, double cornucopia in left field dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ	Sv. 1426; Series 9
130	Copper Alloy	Ptolemy VI & VIII	169-163	Alexandria	5.88g	18mm	AE16/18	Amun head right, dotted border	Two eagles with closed wings standing left on two thunderbolt, double cornucopia in left field (?) dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ [ΒΑΣΙΛΕΩΣ]	Sv. 1427
131	Copper Alloy	Ptolemy IX/X	116-80		5.52g	20mm	AE18	Amun head right, dotted border	Filled double cornucopia, two starts above, [Σ-Ω] Θ-Ε across field, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ [ΒΑΣΙΛΕΩΣ] [Σ-Ω] Θ-Ε	Sv. 1718

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
132	Copper Alloy	Ptolemy IX/X	116-80		8.64g	23mm	AE22	Amun head right	Eagle with closed wings standing left on thunderbolt, star over T in left field	N/A	[ΠΤ]ΟΛΕΜΑΙΟΥ [ΒΑΣΙΛΕΩΣ]	Sv. 1711
133	Copper Alloy	Ptolemy IX/X	116-80		16.60g	30mm	AE30	Amun head right	Two eagles with closed wings standing left on thunderbolts, wreath in left field, dotted border	N/A	ΠΤΟΛΕΜΑΙΟΥ [ΒΑΣΙΛΕΩΣ]	Sv. 1701
134	Copper Alloy	Ptolemy XII	80-51		7.06g	23mm	AE22/25	Amun head right, dotted border	Two eagles with closed wings standing left on thunderbolt, Isis headdress atop monogram in left field	N/A	[ΠΤΟΛΕΜΑΙΟΥ ΒΑΣΙΛΕΩΣ]	Sv. 1842

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
135	Copper Alloy	Ptolemy XII	80-51		6.69g	24mm	AE22/25	Amun head right, dotted border	Two eagles with closed wings standing left on thunderbolt, Isis headdress atop monogram in left field	N/A	[ΠΤΟΛΕΜΑΙΟΥ] ΒΑΣΙΛ[ΕΩΣ]	Sv. 1842
136	Copper Alloy	Ptolemy XII	80-51		6.61g	24mm		Amun head right, dotted border	Two eagles with closed wings standing left on thunderbolt, Isis headdress in left field	N/A	ΠΤΟΛΕΜΑΙΟΥ [ΒΑΣΙΛΕΩΣ]	Sv. 1843
137	Copper Alloy	Ptolemy XII	80-51		1.34g	12mm	AE12/15	Amun head right	Isis headdress	N/A	[ΠΤ]Ο - ΛΕ - [ΒΑΣΙΛ]	Sv. 1845
138	Copper Alloy	Cleopatra VII			8.83g	22mm						
139	Copper Alloy	Cleopatra VII	51-29	Alexandria	8.49g	21mm	AE22	Diademed and draped bust of Cleopatra VII right	Eagle with closed wings standing left on thunderbolt, double cornucopia in left field, M in right field	N/A	ΚΛΕΟΠΑΤΡΑΣ ΒΑ[CΙΛΙCCΗC] Μ	Sv. 1872; Series 10

Number	Metal	Ruler	Date (BCE)	Mint	Weight	Diameter	Denomination	Obverse Description	Reverse Description	Obverse Inscription	Reverse Inscription	Reference
140	Copper Alloy	Cleopatra VII	51-29	Cyprus	17.82g	29mm	AE27	Diademed bust of Cleopatra VII as Aphrodite right, with stephane and sceptre, suckling infant Ptolemy Caesarion as Eros	Filled double cornucopia, monogram in right field, dotted border	N/A	[ΚΛΕΟ]ΠΑΤΡΑΣ ΒΑΣΙΛΙΣ[ΣΗΣ]	Sv. 1874
141	Copper Alloy	Cleopatra VII	51-29	Alexandria	12.11g	26mm	AE22	Diademed and draped bust of Cleopatra VII right	Eagle with closed wings standing left on thunderbolt, double cornucopia in left field, M in right field	N/A	[ΚΛΕΟΠ]ΑΤΡΑΣ ΒΑCΙΛΙC[CΗC] M	Sv. 1872; Series 10
142	Copper Alloy	Cleopatra VII	51-29	Alexandria	8.57g	20mm	AE22	Diademed and draped bust of Cleopatra VII right	Eagle with closed wings standing left on thunderbolt, double cornucopia in left field, M in right field	N/A	ΚΛΕΟΠΑ[ΤΡΑΣ ΒΑCΙΛΙCCΗC] M	Sv. 1872; Series 10

Appendix II: Silver Coins Results

Cat. Number	Ruler	Ag	As	Au	Bi	Co	Cr	Cu	Fe	Mn	Ni	Pb	Sb	Sn	Zn
20	Ptolemy I	99.28	0.020	0.361	0.003	0.0016	0.00003	0.290	0.005	0.0003	0.0006	0.036	0.003	0.002	0.001
63	Ptolemy I	98.74	0.170	0.316	0.028	0.0010	0.00026	0.321	0.043	0.0011	0.0038	0.332	0.025	0.012	0.009
64	Ptolemy I	98.86	0.023	0.318	0.040	0.0001	0.00003	0.160	0.003	0.0002	0.0005	0.586	0.003	0.002	0.001
65	Ptolemy I	98.62	0.031	0.511	0.044	0.0003	0.00004	0.313	0.004	0.0002	0.0005	0.468	0.004	0.002	0.001
66	Ptolemy I	99.39	0.029	0.176	0.009	0.0006	0.00003	0.247	0.003	0.0001	0.0005	0.136	0.003	0.002	0.001
83	Ptolemy I	99.243	0.007	0.010	0.083	0.2647	0.01069	0.024	0.006	0.0001	0.0001	0.347	0.003	0.001	0.001
85	Ptolemy I	98.94	0.014	0.452	0.004	0.0007	0.00003	0.128	0.004	0.0002	0.0009	0.451	0.003	0.002	0.001
84	Ptolemy II	98.40	0.015	0.449	0.045	0.0005	0.00003	0.198	0.004	0.0001	0.0006	0.883	0.003	0.002	0.001
86	Ptolemy II	99.15	0.016	0.460	0.032	0.0007	0.00003	0.135	0.002	0.0002	0.0006	0.194	0.003	0.002	0.001
96	Ptolemy II	98.94	0.017	0.387	0.014	0.0004	0.00015	0.151	0.002	0.0002	0.0001	0.484	0.003	0.002	0.001
97	Ptolemy II	98.26	0.018	0.312	0.026	0.0006	0.0002	0.179	0.006	0.0002	0.0006	1.186	0.004	0.002	0.002
98	Ptolemy III	96.97	0.012	0.591	0.001	0.0011	0.0002	1.789	0.019	0.0002	0.0001	0.615	0.003	0.002	0.001
99	Ptolemy III	96.52	0.049	0.493	0.024	0.0016	0.0007	0.319	0.023	0.0006	0.0001	2.555	0.004	0.003	0.002
100	Ptolemy III	98.05	0.034	0.371	0.081	0.0001	0.0003	0.236	0.005	0.0003	0.0006	1.141	0.077	0.001	0.001
101	Ptolemy III	97.29	0.019	0.265	0.017	0.0003	0.0002	0.190	0.004	0.0001	0.0001	2.202	0.011	0.001	0.001
90	Ptolemy IV	95.05	0.014	0.368	0.031	0.0015	0.0000	2.983	0.027	0.0002	0.0010	1.515	0.003	0.002	0.001
102	Ptolemy IV	98.436	0.013	0.460	0.001	0.0001	0.0002	0.164	0.001	0.0001	0.0001	0.918	0.005	0.001	0.001
103	Ptolemy IV	98.394	0.015	0.649	0.001	0.0003	0.0002	0.123	0.002	0.0001	0.0001	0.809	0.004	0.001	0.001
104	Ptolemy IV	98.991	0.011	0.457	0.002	0.0002	0.0002	0.080	0.002	0.0001	0.0001	0.453	0.002	0.001	0.001
105	Ptolemy IV	97.732	0.011	0.488	0.017	0.0002	0.0002	1.387	0.001	0.0001	0.0001	0.359	0.003	0.001	0.001
1	Ptolemy V	99.13	0.013	0.667	0.004	0.0002	0.0002	0.073	0.005	0.0001	0.0001	0.105	0.003	0.0005	0.001
3	Ptolemy V	96.43	0.031	0.539	0.022	0.0002	0.00014	1.719	0.005	0.0001	0.0002	1.218	0.010	0.019	0.002

Cat. Number	Ruler	Ag	As	Au	Bi	Co	Cr	Cu	Fe	Mn	Ni	Pb	Sb	Sn	Zn
106	Ptolemy V	97.78	0.011	0.596	0.015	0.0001	0.0002	0.846	0.001	0.0001	0.0001	0.747	0.002	0.0013	0.001
107	Ptolemy V	98.30	0.009	0.685	0.001	0.0001	0.0002	0.101	0.002	0.0001	0.0001	0.898	0.002	0.0012	0.001
108	Ptolemy V	98.26	0.014	0.570	0.004	0.0001	0.0002	0.711	0.003	0.0001	0.0001	0.426	0.004	0.0018	0.001
109	Ptolemy V	96.92	0.036	0.673	0.004	0.0014	0.0003	1.290	0.002	0.0001	0.0001	1.065	0.003	0.0014	0.001
4	Ptolemy VI & VIII	98.83	0.016	0.070	0.096	0.001	0.0002	0.389	0.004	0.0001	0.0001	0.590	0.004	0.001	0.002
5	Ptolemy VI & VIII	97.39	0.042	0.525	0.071	0.0002	0.00010	1.526	0.003	0.0002	0.0001	0.425	0.012	0.004	0.002
2	Ptolemy VI	98.75	0.014	0.815	0.007	0.0010	0.00029	0.043	0.008	0.0002	0.0001	0.350	0.008	0.001	0.002
87	Ptolemy VI	98.92	0.019	0.779	0.001	0.0020	0.00004	0.166	0.008	0.0001	0.0007	0.100	0.004	0.002	0.001
88	Ptolemy VI	98.66	0.017	0.747	0.001	0.0018	0.00003	0.066	0.005	0.0002	0.0006	0.497	0.003	0.002	0.001
89	Ptolemy VI	97.53	0.005	0.114	0.050	0.0016	0.00002	0.136	0.006	0.0001	0.0006	2.149	0.002	0.001	0.001
114	Ptolemy VI	98.95	0.012	0.788	0.001	0.0001	0.00021	0.113	0.002	0.0001	0.0001	0.127	0.003	0.001	0.001
115	Ptolemy VI	98.82	0.013	0.773	0.001	0.0006	0.0002	0.135	0.001	0.0001	0.0001	0.249	0.003	0.002	0.001
92	Ptolemy VIII	95.53	0.003	0.189	0.309	0.0009	0.00003	2.314	0.018	0.0002	0.0011	1.633	0.003	0.001	0.001
110	Ptolemy VIII	89.98	0.057	0.478	0.038	0.002	0.0010	7.115	0.004	0.0008	0.0048	2.310	0.007	0.003	0.002
111	Ptolemy VIII	93.76	0.022	0.457	0.162	0.001	0.0002	4.048	0.002	0.0001	0.0010	1.539	0.004	0.002	0.001
112	Ptolemy VIII	92.22	0.033	0.457	0.091	0.001	0.0009	4.731	0.053	0.0008	0.0009	2.246	0.159	0.003	0.002

Cat. Number	Ruler	Ag	As	Au	Bi	Co	Cr	Cu	Fe	Mn	Ni	Pb	Sb	Sn	Zn
113	Ptolemy VIII	95.55	0.022	0.169	0.313	0.001	0.0003	3.255	0.003	0.0002	0.0001	0.671	0.010	0.002	0.002
116	Ptolemy IX	95.42	0.021	0.611	0.042	0.0007	0.00021	3.330	0.003	0.0001	0.001	0.560	0.003	0.002	0.001
117	Ptolemy IX	93.52	0.023	0.302	0.104	0.0003	0.00021	4.442	0.002	0.0001	0.001	1.600	0.004	0.002	0.001
67	Ptolemy X	91.82	0.083	0.043	0.109	0.0002	0.00308	6.458	0.011	0.0003	0.001	1.461	0.005	0.003	0.002
68	Ptolemy X	90.55	0.060	0.412	0.057	0.0060	0.00004	6.863	0.026	0.0002	0.003	1.996	0.004	0.017	0.003
69	Ptolemy X	86.46	0.120	0.491	0.067	0.0034	0.00073	11.336	0.009	0.0004	0.003	1.496	0.008	0.004	0.003
70	Ptolemy X	85.60	0.055	0.365	0.114	0.0025	0.00004	12.595	0.013	0.0005	0.015	1.219	0.015	0.002	0.002
71	Ptolemy X	90.67	0.048	0.495	0.086	0.0009	0.00132	7.038	0.017	0.0003	0.003	1.624	0.008	0.002	0.001
72	Ptolemy X	86.84	0.063	0.075	0.077	0.0015	0.00003	10.939	0.006	0.0002	0.002	1.980	0.018	0.002	0.001
73	Ptolemy X	88.09	0.087	0.119	0.083	0.0003	0.00003	10.217	0.007	0.0002	0.002	1.377	0.018	0.002	0.001
74	Ptolemy X	93.41	0.034	0.178	0.067	0.0035	0.00003	4.558	0.016	0.0002	0.002	1.720	0.008	0.002	0.001
75	Ptolemy X	86.71	0.086	0.070	0.079	0.0001	0.00003	11.367	0.009	0.0002	0.002	1.657	0.019	0.001	0.001
77	Ptolemy X	83.84	0.043	0.286	0.101	0.0012	0.00003	13.550	0.016	0.0002	0.007	2.128	0.026	0.002	0.004
91	Ptolemy X	93.51	0.007	0.330	0.151	0.3296	0.0123	4.416	0.004	0.0002	0.0000	1.233	0.002	0.001	0.001
118	Ptolemy X	86.30	0.021	0.420	0.063	0.0010	0.0002	11.625	0.005	0.0002	0.003	1.532	0.026	0.002	0.001
119	Ptolemy X	86.95	0.055	0.093	0.090	0.0007	0.0002	10.954	0.007	0.0001	0.008	1.812	0.024	0.001	0.001
120	Ptolemy X	82.85	0.110	0.217	0.098	0.0002	0.0001	14.427	0.011	0.0002	0.006	2.253	0.026	0.002	0.001
121	Ptolemy X	91.65	0.026	0.293	0.140	0.0009	0.0003	6.280	0.013	0.0004	0.001	1.593	0.002	0.001	0.001
122	Ptolemy X	87.66	0.035	0.324	0.064	0.0016	0.0002	10.133	0.016	0.0002	0.003	1.739	0.003	0.018	0.001
78	Ptolemy XII	74.70	0.049	0.212	0.031	0.002	0.0000	23.108	0.017	0.0002	0.014	1.836	0.015	0.019	0.001
93	Ptolemy XII	43.90	0.064	0.138	0.043	0.0106	0.00003	54.482	0.065	0.0002	0.042	1.198	0.003	0.050	0.004
94	Ptolemy XII	92.19	0.010	0.270	0.108	0.001	0.0000	6.165	0.013	0.0002	0.001	1.226	0.008	0.008	0.001

Cat. Number	Ruler	Ag	As	Au	Bi	Co	Cr	Cu	Fe	Mn	Ni	Pb	Sb	Sn	Zn
95	Ptolemy XII	62.32	0.029	0.105	0.033	0.004	0.0000	36.463	0.024	0.0001	0.023	0.953	0.003	0.042	0.004
123	Ptolemy XII	52.02	0.085	0.173	0.025	0.009	0.0001	46.093	0.124	0.0002	0.034	1.278	0.009	0.142	0.010
76	Cleopatra VII	28.58	0.091	0.126	0.027	0.005	0.0000	70.143	0.086	0.0002	0.040	0.895	0.003	0.001	0.001
79	Cleopatra VII	29.52	0.071	0.144	0.038	0.0004	0.00003	68.686	0.022	0.0002	0.043	1.468	0.009	0.001	0.001
80	Cleopatra VII	31.02	0.040	0.150	0.029	0.0017	0.00003	67.525	0.020	0.0004	0.057	1.147	0.003	0.002	0.001
81	Cleopatra VII	29.91	0.081	0.154	0.012	0.0094	0.00003	68.185	0.025	0.0002	0.043	1.407	0.003	0.163	0.006
124	Cleopatra VII	34.75	0.100	0.126	0.025	0.0025	0.00028	63.725	0.038	0.0003	0.037	1.137	0.059	0.001	0.001
125	Cleopatra VII	68.54	0.039	0.272	0.022	0.0006	0.00010	29.482	0.009	0.0001	0.015	1.594	0.009	0.014	0.001
126	Cleopatra VII	36.79	0.103	0.134	0.024	0.0065	0.00015	61.922	0.023	0.0002	0.042	0.939	0.004	0.014	0.002

Appendix III: Bronze Coins Result

Cat. Number	Ruler	Ag	As	Au	Bi	Co	Cr	Cu	Fe	Mn	Ni	Pb	Sb	Sn	Zn
22	Ptolemy I	0.026	0.252	0.001	0.001	0.024	0.00009	86.546	0.068	0.0004	0.028	4.388	0.058	8.597	0.010
62	Ptolemy I	0.065	0.159	0.002	0.001	0.051	0.00002	84.696	0.045	0.0002	0.032	7.627	0.043	7.276	0.003
6	Ptolemy II	0.035	1.010	0.004	0.002	0.057	0.00026	93.787	0.113	0.0010	0.057	0.143	0.099	4.649	0.043
24	Ptolemy II	0.027	0.587	0.002	0.001	0.105	0.00002	90.773	0.099	0.0002	0.051	0.300	0.070	7.952	0.031
25	Ptolemy II	0.020	0.109	0.002	0.001	0.014	0.00002	88.187	0.048	0.0004	0.019	0.000	0.035	11.562	0.002
29	Ptolemy II	0.030	0.142	0.004	0.002	0.065	0.00030	92.502	0.044	0.0004	0.060	0.082	0.068	6.958	0.043
82	Ptolemy II	0.080	0.392	0.0003	0.002	0.074	0.00002	86.074	0.084	0.00002	0.040	1.249	0.038	11.964	0.003
7	Ptolemy III	0.021	0.388	0.002	0.001	0.140	0.00002	90.324	0.139	0.0003	0.062	0.082	0.056	8.762	0.022
8	Ptolemy III	0.021	0.570	0.002	0.001	0.050	0.00002	88.768	0.048	0.0002	0.053	0.073	0.058	10.345	0.012
9	Ptolemy III	0.030	0.812	0.003	0.002	0.126	0.00003	89.021	0.114	0.0023	0.062	0.759	0.092	8.946	0.031
13	Ptolemy III	0.027	0.648	0.002	0.001	0.139	0.00002	89.320	0.107	0.0003	0.061	1.300	0.075	8.289	0.029
21	Ptolemy III	0.030	0.117	0.002	0.002	0.132	0.00014	89.785	0.126	0.0014	0.064	0.515	0.086	9.094	0.046
23	Ptolemy III	0.025	0.484	0.002	0.001	0.109	0.00002	86.372	0.109	0.0005	0.051	0.321	0.064	12.436	0.025
31	Ptolemy III	0.027	0.477	0.003	0.001	0.140	0.00002	85.266	0.143	0.0003	0.064	0.251	0.057	13.537	0.034
32	Ptolemy III	0.025	0.124	0.002	0.002	0.142	0.00003	85.728	0.139	0.0003	0.061	0.191	0.056	13.487	0.044
33	Ptolemy III	0.028	0.450	0.003	0.001	0.144	0.00002	85.565	0.104	0.0009	0.063	0.170	0.056	13.379	0.037
34	Ptolemy III	0.024	0.103	0.002	0.002	0.143	0.00003	87.116	0.156	0.0005	0.057	0.178	0.055	12.116	0.048
35	Ptolemy III	0.025	0.472	0.003	0.001	0.141	0.00002	85.349	0.137	0.0003	0.056	0.661	0.049	13.069	0.038
45	Ptolemy III	0.024	0.370	0.003	0.001	0.132	0.00002	90.516	0.059	0.0007	0.070	0.081	0.045	8.656	0.042
11	Ptolemy IV	0.023	0.516	0.002	0.001	0.152	0.00002	85.403	0.408	0.0016	0.045	1.226	0.070	12.121	0.029
12	Ptolemy IV	0.022	0.453	0.002	0.001	0.227	0.00002	85.792	0.413	0.0002	0.064	2.184	0.049	10.769	0.024
26	Ptolemy IV	0.038	0.759	0.007	0.001	0.124	0.00033	87.054	0.103	0.0011	0.053	0.291	0.076	11.390	0.103

Cat. Number	Ruler	Ag	As	Au	Bi	Co	Cr	Cu	Fe	Mn	Ni	Pb	Sb	Sn	Zn
27	Ptolemy IV	0.030	0.574	0.004	0.001	0.377	0.00009	84.523	0.211	0.0021	0.095	5.457	0.062	8.629	0.034
28	Ptolemy IV	0.023	0.385	0.006	0.002	0.108	0.00054	89.185	0.077	0.0014	0.056	0.075	0.055	9.996	0.031
30	Ptolemy IV	0.023	0.396	0.003	0.001	0.149	0.00002	88.572	0.184	0.0003	0.060	0.338	0.050	10.176	0.046
36	Ptolemy IV	0.025	0.452	0.006	0.001	0.142	0.00029	88.996	0.066	0.0007	0.058	0.281	0.053	9.806	0.115
46	Ptolemy IV	0.023	0.150	0.008	0.001	0.320	0.00037	90.078	0.316	0.0008	0.047	0.125	0.025	8.839	0.068
37	Ptolemy V	0.026	0.155	0.004	0.001	0.035	0.00009	88.061	0.066	0.0004	0.034	2.304	0.037	9.271	0.006
38	Ptolemy V	0.137	0.915	0.006	0.001	0.143	0.00002	85.574	0.185	0.0002	0.057	3.468	0.056	9.392	0.066
43	Ptolemy V	0.024	0.321	0.004	0.001	0.216	0.00002	84.560	0.262	0.0004	0.053	8.371	0.050	6.118	0.020
50	Ptolemy V	0.035	0.560	0.004	0.001	0.111	0.00002	86.142	0.089	0.0002	0.060	4.011	0.072	8.880	0.035
51	Ptolemy V	0.073	0.310	0.004	0.001	0.220	0.00002	86.158	0.273	0.0003	0.054	6.653	0.055	6.177	0.023
52	Ptolemy V	0.141	0.267	0.004	0.003	0.170	0.00050	71.974	0.599	0.0002	0.045	23.162	0.069	3.552	0.014
53	Ptolemy V	0.025	0.326	0.003	0.001	0.216	0.00002	84.569	0.253	0.0003	0.052	8.686	0.048	5.801	0.021
16	Ptolemy VI & VIII	0.021	0.276	0.003	0.001	0.321	0.00002	83.525	0.674	0.0006	0.030	12.065	0.051	2.996	0.037
17	Ptolemy VI & VIII	0.023	0.313	0.005	0.001	0.218	0.00002	66.411	1.520	0.0005	0.040	28.695	0.066	2.653	0.027
18	Ptolemy VI & VIII	0.025	0.391	0.003	0.001	0.231	0.00002	86.424	0.308	0.0003	0.055	5.943	0.058	6.539	0.022
41	Ptolemy VI & VIII	0.024	0.015	0.006	0.001	0.254	0.00064	90.897	0.454	0.0005	0.052	1.365	0.036	6.861	0.035
42	Ptolemy VI & VIII	0.025	0.291	0.004	0.001	0.232	0.00002	88.010	0.316	0.0003	0.053	4.510	0.044	6.492	0.024

Cat. Number	Ruler	Ag	As	Au	Bi	Co	Cr	Cu	Fe	Mn	Ni	Pb	Sb	Sn	Zn
48	Ptolemy VI & VIII	0.022	0.330	0.003	0.001	0.193	0.00002	74.971	0.240	0.0002	0.048	18.314	0.061	5.795	0.021
49	Ptolemy VI & VIII	0.025	0.356	0.003	0.001	0.253	0.00002	89.073	0.450	0.0002	0.053	2.485	0.044	7.219	0.037
58	Ptolemy VI & VIII	0.022	0.293	0.002	0.001	0.146	0.00002	67.996	0.166	0.0002	0.043	26.853	0.063	4.394	0.021
60	Ptolemy VI & VIII	0.022	0.257	0.002	0.001	0.113	0.00002	60.453	0.248	0.0001	0.038	34.571	0.065	4.209	0.020
61	Ptolemy VI & VIII	0.030	0.201	0.003	0.002	0.157	0.00002	56.442	1.668	0.0002	0.023	39.629	0.053	1.684	0.108
127	Ptolemy VI & VIII	0.021	0.342	0.000	0.002	0.379	0.000	85.566	0.553	0.000	0.048	5.201	0.031	7.854	0.003
128	Ptolemy VI & VIII	0.010	0.182	0.000	0.002	0.356	0.000	69.335	0.516	0.000	0.016	23.617	0.016	5.947	0.003
129	Ptolemy VI & VIII	0.023	0.155	0.000	0.002	0.037	0.000	63.618	0.024	0.000	0.026	31.751	0.041	4.320	0.003
130	Ptolemy VI & VIII	0.020	0.216	0.000	0.002	0.070	0.000	64.084	0.070	0.000	0.036	28.791	0.059	6.649	0.003
14	Ptolemy VI	0.028	0.800	0.002	0.001	0.079	0.000	69.855	0.058	0.001	0.085	24.309	0.113	4.668	0.001
15	Ptolemy VI	0.023	0.319	0.005	0.001	0.111	0.00026	71.679	0.055	0.0005	0.046	23.959	0.090	3.670	0.042
39	Ptolemy VI	0.021	0.495	0.018	0.002	1.368	0.05214	84.911	0.354	0.0021	0.066	4.495	0.076	8.094	0.044
40	Ptolemy VI	0.024	0.202	0.004	0.002	0.399	0.00004	93.602	0.238	0.0007	0.059	0.220	0.038	5.171	0.041
47	Ptolemy VI	0.029	0.506	0.004	0.007	0.083	0.00002	59.797	0.072	0.0005	0.067	34.649	0.065	4.711	0.010

Cat. Number	Ruler	Ag	As	Au	Bi	Co	Cr	Cu	Fe	Mn	Ni	Pb	Sb	Sn	Zn
56	Ptolemy VI	0.032	0.241	0.006	0.001	0.226	0.00019	61.762	0.255	0.0007	0.036	31.860	0.075	5.446	0.058
57	Ptolemy VI	0.019	0.211	0.002	0.001	0.118	0.00002	52.687	0.104	0.0002	0.034	43.288	0.058	3.458	0.018
19	Ptolemy VIII	0.027	0.727	0.003	0.001	0.139	0.00002	93.977	0.145	0.0002	0.095	2.158	0.078	2.630	0.018
54	Ptolemy VIII	0.048	0.207	0.006	0.001	0.052	0.00026	76.751	0.007	0.0005	0.049	19.792	0.059	3.026	0.001
55	Ptolemy VIII	0.026	0.234	0.003	0.001	0.076	0.00002	72.703	0.025	0.0002	0.048	23.080	0.057	3.745	0.002
59	Ptolemy VIII	0.027	0.217	0.002	0.001	0.063	0.00002	76.114	0.012	0.0002	0.047	19.817	0.057	3.639	0.003
131	Ptolemy IX\X	0.033	0.191	0.000	0.002	0.069	0.000	74.128	0.053	0.000	0.058	21.132	0.101	4.229	0.003
132	Ptolemy IX\X	0.010	0.145	0.000	0.002	0.055	0.000	75.319	0.004	0.000	0.029	23.438	0.033	0.962	0.003
133	Ptolemy IX\X	0.013	0.175	0.000	0.002	0.102	0.000	65.994	0.046	0.000	0.031	28.095	0.048	5.491	0.003
134	Ptolemy XII	0.003	0.174	0.002	0.005	0.160	0.000	56.182	0.467	0.000	0.020	38.256	0.037	4.624	0.070
135	Ptolemy XII	0.084	0.257	0.003	0.003	0.307	0.000	68.358	0.629	0.000	0.054	25.433	0.045	4.812	0.015
136	Ptolemy XII	0.028	0.222	0.003	0.003	0.079	0.000	74.698	0.029	0.000	0.063	21.126	0.047	3.681	0.020

Cat. Number	Ruler	Ag	As	Au	Bi	Co	Cr	Cu	Fe	Mn	Ni	Pb	Sb	Sn	Zn
137	Ptolemy XII	0.007	0.318	0.004	0.005	0.036	0.000	89.603	0.034	0.000	0.042	1.401	0.028	8.516	0.005
44	Cleopatra VII	0.038	0.158	0.003	0.001	0.036	0.00043	72.557	0.397	0.0006	0.115	17.584	0.087	8.995	0.029
138	Cleopatra VII	0.025	0.286	0.003	0.003	0.050	0.000	83.698	0.064	0.000	0.139	9.899	0.135	5.694	0.003
139	Cleopatra VII	0.028	0.203	0.003	0.004	0.041	0.000	70.739	0.077	0.000	0.111	17.216	0.072	11.499	0.007
140	Cleopatra VII	0.004	0.154	0.001	0.002	0.036	0.000	54.687	0.036	0.000	0.022	39.083	0.042	5.932	0.003
141	Cleopatra VII	0.035	0.202	0.002	0.003	0.046	0.000	69.198	0.110	0.000	0.122	19.418	0.075	10.787	0.003
142	Cleopatra VII	0.000	0.225	0.002	0.002	0.046	0.001	64.997	0.060	0.000	0.116	23.503	0.087	10.959	0.003

Appendix IV: Silver and Bronze Reference Materials

Silver Batch 1

	As	Au	Bi	Co	Cr	Cu	Fe	Mn	Ni	Pb	Sb	Sn	Zn
AGA1a													
Results Values	0.046	1.557	0.184	0.057	0.003	22.415	0.044	0.007	0.011	0.180	0.051	0.232	0.224
Certified Values	0.026	1.480	0.194	0.041	0.002	19.950	0.039	0.006	0.012	0.207	0.050	0.291	0.211
AGA1b													
Results Values	0.024	1.454	0.175	0.059	0.003	21.628	0.042	0.007	0.011	0.175	0.043	0.263	0.213
Certified Values	0.026	1.480	0.194	0.041	0.002	19.950	0.039	0.006	0.012	0.207	0.050	0.291	0.211
AGA3a													
Results Values	0.026	0.097	0.040	0.000	0.004	5.341	0.021	0.009	0.035	1.346	0.303	0.727	0.742
Certified Values	0.008	0.258	0.048	0.005	0.086	4.910	0.015	0.098	0.045	1.890	0.459	0.921	0.816
AGA3b													
Results Values	0.000	0.100	0.029	0.001	0.004	5.124	0.020	0.009	0.035	1.358	0.290	0.719	0.742
Certified Values	0.008	0.258	0.048	0.005	0.086	4.910	0.015	0.098	0.045	1.890	0.459	0.921	0.816

Silver Batch 2

	As	Au	Bi	Co	Cr	Cu	Fe	Mn	Ni	Pb	Sb	Sn	Zn
AGA1a													
Results Values	0.022	1.533	0.195	0.041	0.002	20.589	0.043	0.007	0.012	0.197	0.048	0.219	0.234
Certified Values	0.026	1.480	0.194	0.041	0.002	19.950	0.039	0.006	0.012	0.207	0.050	0.291	0.211
AGA1b													
Results Values	0.015	1.473	0.195	0.040	0.002	20.571	0.042	0.007	0.011	0.190	0.048	0.283	0.223
Certified Values	0.026	1.480	0.194	0.041	0.002	19.950	0.039	0.006	0.012	0.207	0.050	0.291	0.211
AGA3a													
Results Values		0.270	0.045	-0.006	0.005	4.952	0.026	0.009	0.035	1.827	0.463	0.855	0.847
Certified Values		0.258	0.048	0.005	0.009	4.910	0.015	0.010	0.045	1.890	0.459	0.921	0.816

AGA3b													
Results Values		0.268	0.047	-0.006	0.005	4.985	0.026	0.009	0.034	1.865	0.461	0.921	0.837
Certified Values		0.258	0.048	0.005	0.009	4.910	0.015	0.010	0.045	1.890	0.459	0.921	0.816

Bronze Batch 1

	Ag	As	Au	Bi	Co	Cr	Cu	Fe	Mn	Ni	Pb	Sb	Sn	Zn
183a														
Results Values	0.023	0.478	0.000	-0.002	0.004	0.000	85.275	0.031	0.000	1.515	3.359	0.249	6.735	3.267
Certified Values		0.150		0.008			84.500	0.028		1.520	3.400	0.250	6.690	3.250
183b														
Results Values	0.023	0.159	0.000	0.002	0.003	0.000	83.759	0.031	0.000	1.502	3.348	0.240	6.752	3.230
Certified Values		0.150		0.008			84.500	0.028		1.520	3.400	0.250	6.690	3.250
211a														
Results Values	0.052	0.542	0.003	-0.008	0.001	0.000	89.308	0.111	0.003	0.124	0.759	0.057	10.912	0.567
Certified Values	0.059	0.021					87.710	0.110	0.002	0.122	0.740	0.033	10.600	0.560
211b														
Results Values	0.050	-0.060	0.000	-0.003	0.000	0.000	87.711	0.110	0.002	0.120	0.741	0.044	10.666	0.561
Certified Values	0.059	0.021					87.710	0.110	0.002	0.122	0.740	0.033	10.600	0.560

Bronze Batch 2

	Ag	As	Au	Bi	Co	Cr	Cu	Fe	Mn	Ni	Pb	Sb	Sn	Zn
183a														
Results Values		0.157	-0.007	0.006	0.000	-0.003	88.214	0.025	-0.003	1.579	3.278	0.249	6.938	3.120
Certified Values		0.150		0.008			84.500	0.028		1.520	3.400	0.250	6.690	3.250
183b														
Results Values		0.163	0.001	0.004	0.003	0.000	87.321	0.029	0.000	1.550	3.448	0.239	6.905	3.274
Certified Values		0.150		0.008			84.500	0.028		1.520	3.400	0.250	6.690	3.250

211a															
Results Values		0.060	0.029	-0.008	-0.001	-0.003	-0.003	90.974	0.111	-0.001	0.124	0.476	0.031	10.843	0.307
Certified Values		0.059	0.021					87.710	0.110	0.002	0.122	0.740	0.033	10.600	0.560
211b															
Results Values		-0.026	0.029	0.000	0.002	0.000	0.000	90.400	0.114	0.002	0.129	0.791	0.031	11.143	0.553
Certified Values		0.059	0.021					87.710	0.110	0.002	0.122	0.740	0.033	10.600	0.560

Plates

Plate I


Cat. No. 1 Obverse


Cat. No. 1 Reverse


Cat. No. 2 Obverse


Cat. No. 2 Reverse


Cat. No. 3 Obverse


Cat. No. 3 Reverse


Cat. No. 4 Obverse


Cat. No. 4 Reverse


Cat. No. 5 Obverse


Cat. No. 5 Reverse


Cat. No. 6 Obverse


Cat. No. 6 Reverse


Cat. No. 7 Obverse


Cat. No. 7 Reverse


Cat. No. 8 Obverse


Cat. No. 8 Reverse


Cat. No. 9 Obverse


Cat. No. 9 Reverse


Cat. No. 11 Obverse


Cat. No. 11 Reverse

Plate II


Cat. No. 12 Obverse


Cat. No. 12 Reverse


Cat. No. 13 Obverse


Cat. No. 13 Reverse


Cat. No. 14 Obverse


Cat. No. 14 Reverse


Cat. No. 15 Obverse


Cat. No. 15 Reverse


Cat. No. 16 Obverse


Cat. No. 16 Reverse


Cat. No. 17 Obverse


Cat. No. 17 Reverse


Cat. No. 18 Obverse


Cat. No. 18 Reverse


Cat. No. 19 Obverse


Cat. No. 19 Reverse


Cat. No. 20 Obverse


Cat. No. 20 Reverse


Cat. No. 21 Obverse


Cat. No. 21 Reverse

Plate III

Cat. No. 22 Obverse

Cat. No. 22 Reverse

Cat. No. 23 Obverse

Cat. No. 23 Reverse

Cat. No. 24 Obverse

Cat. No. 24 Reverse

Cat. No. 25 Obverse

Cat. No. 25 Reverse

Cat. No. 26 Obverse

Cat. No. 26 Reverse

Cat. No. 27 Obverse

Cat. No. 27 Reverse

Cat. No. 28 Obverse

Cat. No. 28 Reverse

Cat. No. 29 Obverse

Cat. No. 29 Reverse

Cat. No. 30 Obverse

Cat. No. 30 Reverse

Cat. No. 31 Obverse

Cat. No. 31 Reverse

Plate IV


Cat. No. 32 Obverse


Cat. No. 32 Reverse


Cat. No. 33 Obverse


Cat. No. 33 Reverse


Cat. No. 34 Obverse


Cat. No. 34 Reverse


Cat. No. 35 Obverse


Cat. No. 35 Reverse


Cat. No. 36 Obverse


Cat. No. 36 Reverse


Cat. No. 37 Obverse


Cat. No. 37 Reverse


Cat. No. 38 Obverse


Cat. No. 38 Reverse


Cat. No. 39 Obverse


Cat. No. 39 Reverse


Cat. No. 40 Obverse


Cat. No. 40 Reverse


Cat. No. 41 Obverse


Cat. No. 41 Reverse


Cat. No. 42 Obverse


Cat. No. 42 Reverse


Cat. No. 43 Obverse


Cat. No. 43 Reverse


Cat. No. 44 Obverse


Cat. No. 44 Reverse


Cat. No. 45 Obverse


Cat. No. 45 Reverse


Cat. No. 46 Obverse


Cat. No. 46 Reverse


Cat. No. 47 Obverse


Cat. No. 47 Reverse


Cat. No. 48 Obverse


Cat. No. 48 Reverse


Cat. No. 49 Obverse


Cat. No. 49 Reverse


Cat. No. 50 Obverse


Cat. No. 50 Reverse


Cat. No. 51 Obverse


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Cat. No. 56 Reverse


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Cat. No. 57 Reverse


Cat. No. 58 Obverse


Cat. No. 58 Reverse


Cat. No. 59 Obverse


Cat. No. 59 Reverse


Cat. No. 60 Obverse


Cat. No. 60 Reverse


Cat. No. 61 Obverse


Cat. No. 61 Reverse


Cat. No. 62 Obverse


Cat. No. 62 Reverse


Cat. No. 63 Obverse


Cat. No. 63 Reverse


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Cat. No. 64 Reverse


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Cat. No. 66 Reverse


Cat. No. 67 Obverse


Cat. No. 67 Reverse


Cat. No. 68 Obverse


Cat. No. 68 Reverse


Cat. No. 69 Obverse


Cat. No. 69 Reverse


Cat. No. 70 Obverse


Cat. No. 70 Reverse


Cat. No. 71 Obverse


Cat. No. 71 Reverse


Cat. No. 72 Obverse


Cat. No. 72 Reverse


Cat. No. 73 Obverse


Cat. No. 73 Reverse


Cat. No. 74 Obverse


Cat. No. 74 Reverse


Cat. No. 75 Obverse


Cat. No. 75 Reverse


Cat. No. 76 Obverse


Cat. No. 76 Reverse


Cat. No. 77 Obverse


Cat. No. 77 Reverse


Cat. No. 78 Obverse


Cat. No. 78 Reverse


Cat. No. 79 Obverse


Cat. No. 79 Reverse


Cat. No. 80 Obverse


Cat. No. 80 Reverse


Cat. No. 81 Obverse


Cat. No. 81 Reverse


Cat. No. 82 Obverse


Cat. No. 82 Reverse


Cat. No. 83 Obverse


Cat. No. 83 Reverse


Cat. No. 84 Obverse


Cat. No. 84 Reverse


Cat. No. 85 Obverse


Cat. No. 85 Reverse


Cat. No. 86 Obverse


Cat. No. 86 Reverse


Cat. No. 87 Obverse


Cat. No. 87 Reverse


Cat. No. 88 Obverse


Cat. No. 88 Reverse


Cat. No. 89 Obverse


Cat. No. 89 Reverse


Cat. No. 90 Obverse


Cat. No. 90 Reverse


Cat. No. 91 Obverse


Cat. No. 91 Reverse


Cat. No. 92 Obverse


Cat. No. 92 Reverse


Cat. No. 93 Obverse


Cat. No. 93 Reverse


Cat. No. 94 Obverse


Cat. No. 94 Reverse


Cat. No. 95 Obverse


Cat. No. 95 Reverse

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Cat. No. 110 Reverse

No image available

Cat. No. 111 Obverse

No image available

Cat. No. 111 Reverse

Plate XII

No image available	No image available	Image copyright protected	Image copyright protected
Cat. No. 112 Obverse	Cat. No. 112 Reverse	Cat. No. 113 Obverse	Cat. No. 113 Reverse
Image copyright protected	Image copyright protected	Image copyright protected	Image copyright protected
Cat. No. 114 Obverse	Cat. No. 114 Reverse	Cat. No. 115 Obverse	Cat. No. 115 Reverse
No image available	No image available	No image available	No image available
Cat. No. 116 Obverse	Cat. No. 116 Reverse	Cat. No. 117 Obverse	Cat. No. 117 Reverse
Image copyright protected	Image copyright protected	Image copyright protected	Image copyright protected
Cat. No. 118 Obverse	Cat. No. 118 Reverse	Cat. No. 119 Obverse	Cat. No. 119 Reverse
Image copyright protected	Image copyright protected	Image copyright protected	Image copyright protected
Cat. No. 120 Obverse	Cat. No. 120 Reverse	Cat. No. 121 Obverse	Cat. No. 121 Reverse

Image copyright protected

Cat. No. 122 Obverse

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Cat. No. 122 Reverse

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Cat. No. 123 Obverse

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Cat. No. 128 Reverse

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Cat. No. 129 Obverse

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Cat. No. 129 Reverse

Image copyright protected

Cat. No. 130 Obverse

Image copyright protected

Cat. No. 130 Reverse

Image copyright protected

Cat. No. 131 Obverse

Image copyright protected

Cat. No. 131 Reverse

Image copyright protected	Image copyright protected	Image copyright protected	Image copyright protected
Cat. No. 132 Obverse	Cat. No. 132 Reverse	Cat. No. 133 Obverse	Cat. No. 133 Reverse
Image copyright protected	Image copyright protected	Image copyright protected	Image copyright protected
Cat. No. 134 Obverse	Cat. No. 134 Reverse	Cat. No. 135 Obverse	Cat. No. 135 Reverse
Image copyright protected	Image copyright protected	Image copyright protected	Image copyright protected
Cat. No. 136 Obverse	Cat. No. 136 Reverse	Cat. No. 137 Obverse	Cat. No. 137 Reverse
No image available	No image available	Image copyright protected	Image copyright protected
Cat. No. 138 Obverse	Cat. No. 138 Reverse	Cat. No. 139 Obverse	Cat. No. 139 Reverse
Image copyright protected	Image copyright protected	Image copyright protected	Image copyright protected
Cat. No. 140 Obverse	Cat. No. 140 Reverse	Cat. No. 141 Obverse	Cat. No. 141 Reverse

Plate XV

Image copyright protected

Cat. No. 142 Obverse

Image copyright protected

Cat. No. 142 Reverse