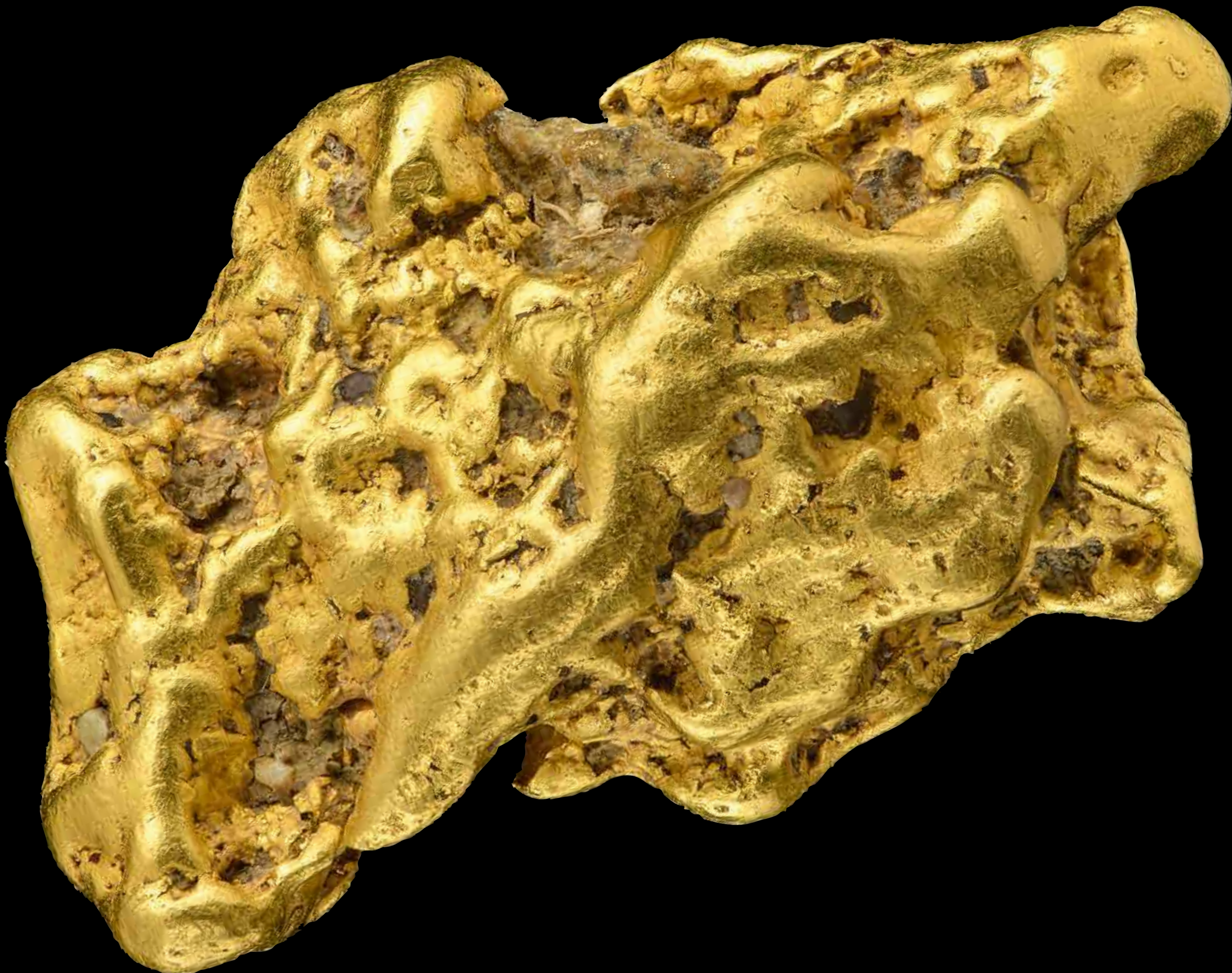

Metalle der Macht – Frühes Gold und Silber

Metals of power – Early gold and silver

6. Mitteldeutscher Archäologentag
vom 17. bis 19. Oktober 2013 in Halle (Saale)

Herausgeber Harald Meller, Roberto Risch und Ernst Pernicka

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Inhalt / Contents

Band I

Sektion Allgemeines / Section General Perspectives

Sektion Herkunft und Verarbeitung / Section Procurement and craft

Bergbau / Mining

Archäometrie / Archaeometry

Band II

Sektion Kontext und Interpretation / Section Context und interpretation

Osten / East

Mittelmeer / Mediterranean sea

Silver vessels in the Mycenaean Shaft Graves and their origin in the context of the metal supply in the Bronze Age Aegean

Zofia Anna Stos-Gale

Zusammenfassung

Silbergefäße in mykenischen Schachtgräbern und deren Herkunft im Kontext der Metallversorgung in der bronzezeitlichen Ägäis

Eines der frühesten Ziele in der Erforschung früher Metalle war die Bestimmung der geologischen Herkunft des Metalls, das für besondere Metallobjekte genutzt wurde. Dafür wurden Aspekte des Handels, Handelsbeziehungen und der Zirkulation der einzelnen Objekte behandelt. In den Jahren 1975–2001 unternahm die Universität Oxford ein groß angelegtes Forschungsprogramm zur Bleiisotopenanalyse, um die Metallquellen und Handelsrouten im bronzezeitlichen Mittelmeerraum zu ermitteln. Die Ergebnisse des Projektes sind nun auf der Universitätswebsite einsehbar: http://oxalid.arch.ox.ac.uk. Eine der interessantesten Gruppen der analysierten Metalle in diesem Projekt sind die Metalle der Schachtgräber aus Mykene. Vor allem die Silbergefäße aus diesen Gräbern fallen auf, da ihr Metall nicht aus dem ägäischen Raum stammt. Die kürzlich veröffentlichten neuen Bleiisotopendaten der Silber-, Blei- und Kupfererze aus Zentraleuropa erlauben eine aktuelle Interpretation zur Herkunft dieser Gefäße. Die meisten der 32 analysierten Silbergefäße aus den mykenischen Schachtgräbern haben eine Bleiisotopenzusammensetzung, die auf ein nicht aus der Agäis stammendes Silber hindeutet. Die Bleiisotopenzusammensetzungen dieser Metalle stimmen mit den Au-Ag-Cu-Erzen aus den südöstlichen Karpaten überein. Diese Schlussfolgerung wird von der Tatsache unterstützt, dass – obwohl die Handwerkskunst der meisten Metallgefäße in den Schachtgräbern aus Mykene eine minoische Hand vermuten lässt – auch ein Element einer andersartigen, vielleicht »nomadischen« oder »Pontischen« Kultur erkennbar ist. Es erscheint möglich, dass die Krieger aus Mykene auf der Suche nach Gold und Zinn in die Bergregion der Karpaten reisten.

Summary

From very early in the study of ancient metals, one important goal was to establish the geological origin of the metal used to make particular metal artefacts, thus directly addressing issues of trade, trade relationships and movement of objects. In the years 1975–2001 a large programme of lead isotope analyses was undertaken at the University of Oxford to establish sources of metals and the trade routes in the Bronze Age Mediterranean. The results of this project are now available on the University website: http://oxalid.arch.ox.ac.uk. One of the most interesting group of metals analysed in this project were the metals from the Shaft Graves in Mycenae. In particular some of the silver vessels from these graves stood out as metals of non-Aegean origin. The recently published new lead isotope data for the silver, lead and copper ores from central Europe allowed an up-to-date interpretation of the origin of these vessels. The majority of the 32 analysed silver vessels from the Mycenaean Shaft Graves have lead isotope compositions of non-Aegean silver. The lead isotope compositions of these metals are consistent with the Au-Ag-Cu ores from the south-east Carpathians. This conclusion is supported by the fact that, while the workmanship of the majority of the metal vessels in the Shaft Graves in Mycenae represents Minoan craft, there is also an element of a different, perhaps »nomadic« or »Pontic« culture in the design of some of these objects. It seems possible that the Mycenaean warriors were travelling to the region of the Carpathian Mountains in search of gold and tin.

Introduction

Mycenae is a citadel built in the 2nd millennium BC on a hill overlooking a plain about 10 km north of the town of Argos in the Peloponnesus in Greece. The significance of this Bronze Age site is reflected in the fact that a whole period of Greek prehistory with common characteristics is named after it: the Mycenaean civilisation. Of primary significance for the birth of the Mycenaean civilisation is the appearance towards the end of the Middle Bronze Age (about 1600 BC), of a number of centres of power in the Aegean where considerable wealth was acquired by a small ruling class. This is especially clear in Mycenae where the excavations by H. Schliemann in 1876 and in 1952–1956 by G. Mylonas and Y. Papademetriou brought to light the riches deposited in the 16th century BC graves of this elite. The kings of Mycenae were buried in deep shaft graves located in two circles: Shaft Graves of Circle A within the Acropolis and, somewhat earlier, Grave Circle B outside the walls of the citadel. The enclosure A contained six large royal Shaft Graves numbered from I–VI. All six were family tombs: they are large rectangular pits measuring from 3.5 m x 3.0 m (grave III) to 4.5 m x 6.4 m (grave VI). The shafts were 3.0 or 4.0 m deep with ledges to support a wooden roof over the body. The cavity above the

Fig. 1 The assemblage of gold and silver items from the Shaft Graves in Mycenae as exhibited in the National Archaeological Museum in Athens.

Abb. 1 *Die Sammlung der Gold- und Silberobjekte aus den Schachtgräbern von Mykene in der Ausstellung des Archäologischen Nationalmuseums in Athen.*

Fig. 2 A gold crown from Shaft Grave III, reassembled by H. Schliemann; length 62.5 cm, heigt c. 27.0 cm.

Abb. 2 *Eine Goldkrone aus Schachtgrab III, von H. Schliemann wieder zusammengesetzt, Länge 62,5 cm, Höhe ca. 27,0 cm.*

roof was filled with earth after the burial and the place was marked by an upright stele, either plain or decorated. The kings and their families were buried with their belongings, known in Greek as *»kterismata«*, these grave goods were particularly abundant and sumptuous in the graves of Circle A. It has been estimated that in Circle A eight men, nine women, and two children were buried.

Schliemann meticulously recorded thousands of luxury objects from these tombs, including gold and silver jewellery, sheet gold ornaments, gold plate, amber beads, and crystal sceptres, as well as over 100 swords (some with gold ornaments on the hilts) and gold inlaid daggers. Some of the gold from the Shaft Graves in Mycenae is shown in Figures 1 and 2. Perhaps the most famous objects from these graves are the gold funeral masks (Fig. 3; Schliemann 1878). Additionally, the graves contained several ceramic and metal vessels of copper, silver, and gold (Karo 1930/33). Altogether it is reported that the weight of gold found in the Shaft Graves was about 14–15 kg. The silver vessels have not survived as well as the gold ones, the majority being heavily corroded, but in most cases their shapes and decorations were still visible. The vast majority of the silver vessels found in the Shaft Graves in Mycenae exhibit technical features paralleled in silver plate found in Protopalatial and Neopalatial Crete. The bulk of these silver vases are therefore identified either as imports from Crete or as products of Minoan craftsmen made on demand for mainland patrons at Mycenae.

Fig. 3 The golden funeral mask from the Shaft Grave V has been excavated by H. Schliemann who named it the »Mask of Agamemnon«.

Abb. 3 *Die goldene Totenmaske aus dem Schachtgrab V wurde von H. Schliemann ausgegraben, der sie als »Maske des Agamemnon« bezeichnete.*

The jewellery, of gold or silver, is largely of types already current on the mainland and which have a long Aegean ancestry; however, there are some foreign elements including large amber beads. Many of the vessels of precious metal show a considerable Cretan influence but there are, however, also metal vessels imitating or inspired by mainland pottery forms. It can be said that nearly all of the precious metal ware are likely, on typological grounds, to have been made in the Aegean. An important feature of the Shaft Grave material is its remarkable heterogeneity, suggesting that the craftsmen responsible for its production had freedom to experiment and were making indigenous artefacts rather than a rigidly established corpus of types. O. Dickinson (1977) has argued persuasively that the character of the Shaft Grave material would fit a situation where new industries were being established on the mainland in the absence of a strong previous tradition. Many of the objects show Cretan influence, but there are many mainland features as well; many of the objects, if not imported, were surely made at Mycenae by craftsmen trained in or inspired by the Cretan tradition. The overall character of the Shaft Grave goods does not suggest that the buried kings were foreign; certainly nobody now believes that they were Cretan conquerors. It is much more probable, and similar developments in the shape of rich graves at Thebes, tholos tombs and fortresses in Messenia and tumuli at Marathon support this, that they were native rulers. It is even possible that Mycenaean power and expansion in the Mediterranean had begun already by the time of the first Shaft Graves of Circle B (Iakovides 1979). What certainly needs explanation is the extraordinary wealth of the Shaft Graves. »Royal« graves III, IV, and V alone held over 13 kg of gold, including 22 vessels; more than 30 vessels of silver; over 70 (mostly very large) vessels of copper or bronze; well over 100 weapons and tools; other vessels of faience, stone, ostrich egg, and lead; boxes of inlaid or plated wood; 1400 amber beads, and much more. Included are many examples of outstanding craftsmanship, and the total is to be divided between hardly more than a dozen individuals. It is important to determine the source of this wealth, closely linked as it is with the understanding of Mycenae's rise to power.

A long-running research project in Oxford devoted to the identification of sources of metals in the Bronze Age Aegean provided nearly 2000 lead isotope analyses of copper, lead and silver objects from this region (OXALID: http://oxalid.arch.ox.ac.uk). The results of this project proved that the mines in Lavrion in Attica provided silver for artefacts in the Aegean since the Early Bronze Age (Gale et al. 1982) and many lead and silver artefacts from the Shaft Graves are also consistent with the origin from this deposit (Stos-Gale/Gale 1982; Stos-Gale/Macdonald 1991). However, amongst the silver vessels from Mycenae there is a large group that represents silver with lead isotope ratios not found amongst the Mediterranean and Anatolian ores. Also, their lead isotope compositions are quite distinct from other analysed Bronze Age silver objects from Crete, the Greek mainland and the Aegean islands.

The lead isotope provenance method is based chiefly on comparisons of lead isotope and elemental compositions of ores and slags from known ore deposits and from the ancient artefacts. In the last 20 years the published comparative database of the European, Near- and Middle-Eastern deposits of lead-silver and copper ores and Bronze Age artefacts has increased steadily. Also the methodology of comparing the data has been vastly improved due to the possibilities of computer software not available thirty years ago. So it is now appropriate to re-examine the lead isotope and elemental data of these unique silver vessels deposited in the Shaft Graves in Mycenae, to provide more information about the possible origin of their metal and social mechanism of the presence of this silver in the Mycenaean Greece.

Methodology of interpretation of lead isotope data

The methodology of interpreting lead isotope data relies on the identification of ore deposits that were used for production of metals in antiquity via direct comparisons of available lead isotope data for minerals from different mines and the data obtained from samples of ancient artefacts. The ancient artefact is regarded as fully consistent with the origin from a given ore deposit if the three independent lead isotope ratios of the artefact are identical within the ±0.1 % analytical error for each ratio with a group of lead isotope ratios obtained for the ores from this deposit. The current database used for interpretation of lead isotope data includes the data published on the OXALID, and by other researchers (see references in this paper, and also in Cattin et al. 2009; Stos-Gale/Gale 2009). In the last twenty years the new data was published for lead-silver ores from the Iberian Peninsula, Turkey, Iran, the Carpathians, Harz, southern Alps, and Erzgebirge.

The initial stage of identifying the possible sources of archaeological artefacts is *»Microanalysis«*, this includes:

1. Finding for each artefact the ore samples that have identical values (within ±0.1 % of the error) for all three lead isotope ratios. This is done using the TestEuclid procedure (Stos 2009) searching the database comprising all ore data (currently over 5000 data points).
2. Plotting the lead isotope ratios of the artefacts on two lead isotope diagrams that are projections of the 3D data points on two planes positioned at 90°, together with the data for all ore deposits that appear to show matching lead isotope ratios in the TestEuclid procedure. The plots allow comparison of the respective positions of groups of analysed ores from various ore deposits relative to the groups formed by LI ratios representing the archaeological artefacts.

The second stage of the process of interpretation of the analytical data is the *»Macroanalysis«*. This procedure considers a broader picture of the possible origin of metals including:

1. Rejection of the ore deposits that on geochemical or chronological ground could not have supplied copper for these artefacts.
2. Comparisons with the lead isotope and elemental data for the artefacts from various related archaeological sites.

In addition, the interpretation process involves a comparison between the elemental compositions of the analysed artefacts and the ore regions identified by the isotopic investigation. The elemental compositions of metals can to a considerable degree reflect the type of the ore used, and certain typical impurities are often characteristic of certain deposits. Furthermore, the trace element signatures can discriminate metal groups that not only reflect various ore types, but are important for comparison with previously analysed artefacts from various regions and certain chronologies. However, it is important to stress that the identical lead isotope characteristics of a group of metals do not guarantee that their elemental characteristics will also form a group and *vice versa* (Rychner/Stos-Gale 1998; Pernicka 1999). Silver artefacts usually do not contain added lead, but only traces of lead (normally below 0.5 %) and small amounts of copper added to Bronze Age silver (less than 5 % in all analysed Bronze Age Aegean samples) do not change the lead isotope compositions of the original silver ore.

It is important also to consider the possibility of melting together silver from different sources to make a new artefact. The effect of this activity on the lead isotope provenance studies has been discussed at length in the past (for summary see Ling et al. 2014). The problem of mixing can be assessed by examining the distribution of the data points on the lead isotope plots: each metal obtained from mixing two other sources will plot somewhere along a straight line <u>between</u> the data points representing these other sources. Therefore, looking for example at a $^{208}Pb/^{206}Pb$ plot of lead isotope data for ores and artefacts, the points representing artefacts that are lowest on the left and the highest on the right cannot have originated from mixing of metals from the ores that are represented by the data points situated in the middle of this plot (see for example plot on Fig. 5). This observation applies also to the $^{204}Pb/^{206}Pb$. On lead isotope plots the »mixing lines« run diagonally following the general trend of the radioactive decay lines (Stos-Gale 2001a).

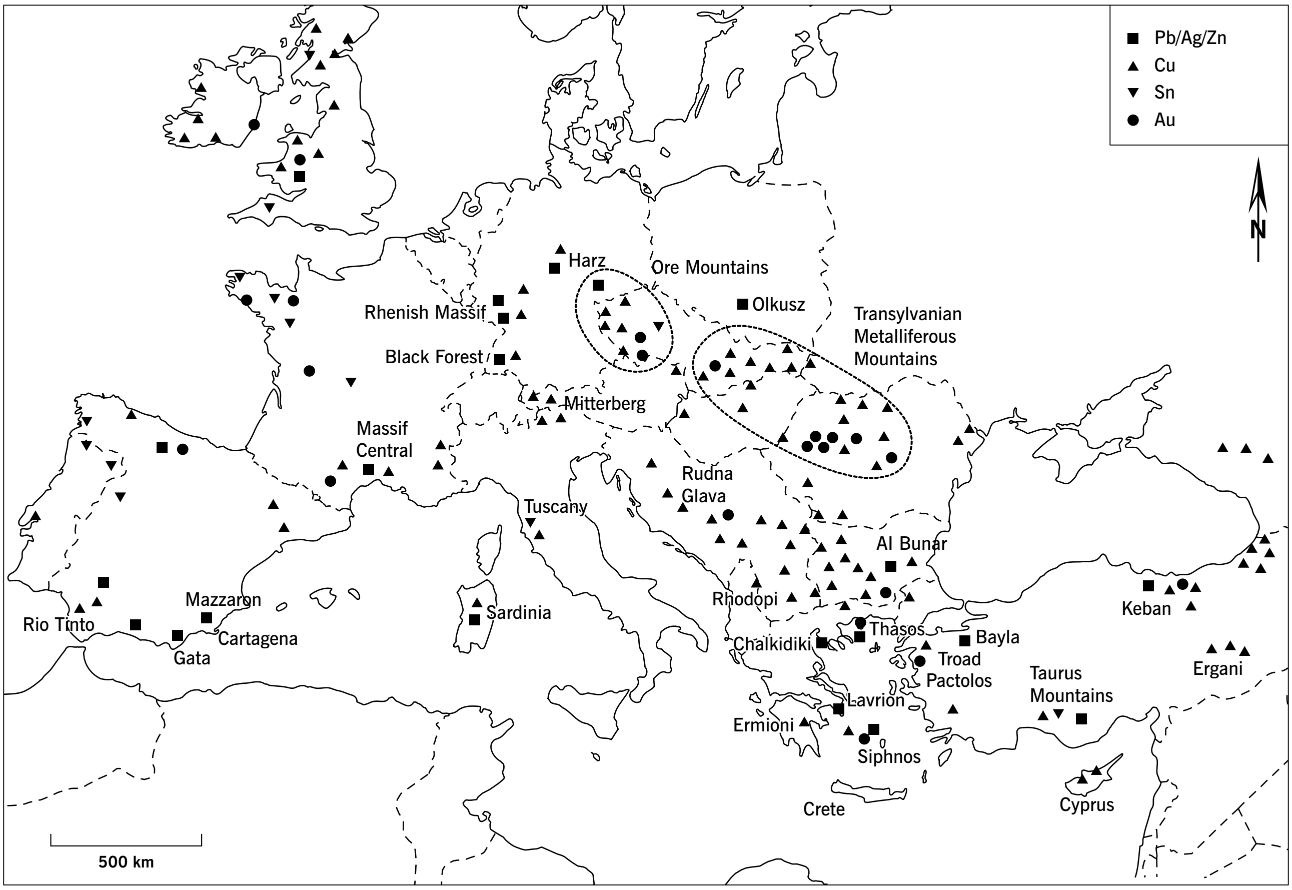

Fig. 4 Location map of the metal deposits in Europe and Anatolia that were or might have been exploited in the Bronze Age.

Abb. 4 *Verbreitungskarte der Metalllagerstätten in Europa und Anatolien, die in der Bronzezeit sicher oder vermutlich ausgebeutet wurden.*

Silver and gold sources in the eastern Mediterranean and the evidence of their exploitation

The exceptional furnishings of the Mycenaean Shaft Graves indicate that the men and women were rich enough to be buried with large quantities of metals. While copper and tin for making bronzes in the middle of the 2nd millennium BC were readily available in Europe (Pare 2000), silver and gold are less common. The availability of silver in the Aegean in the Bronze Age is well known and has been discussed on many occasions[1]. Figure 4 shows a sketch map of known ore sources that were, or might have been exploited in the Bronze Age. In principle there are three deposits of lead-silver in the Aegean that are significant enough to have been exploited in the Bronze Age. These are found in Lavrion in Attica, on the Cycladic island of Siphnos and in the Chalkidiki Peninsula. Archaeometallurgical research has provided the evidence that the silver ores from Siphnos were mainly exploited in the Early Bronze Age (3rd millennium BC) and in the 1st millennium BC (Pernicka/Wagner 1985; Pernicka et al. 1985). There is also mention of gold being recovered from Siphnian ores in the 5th century BC (Gale/Stos-Gale 1981a, 195), but it is unlikely that gold was obtained from Siphnos in the Bronze Age. The extraction of silver from the ores from Lavrion has been more or less continuous from the 3rd millennium BC until the Roman period (and later) (Conophagos 1980). For Chalkidiki there seems to be no evidence of silver exploitation in the Bronze Age (Wagner et al. 1986). Further afield there are silver-bearing ores in the Taurus Mountains in southern Turkey (Yener et al. 1991) and in south-east and north-west Turkey (Seeliger et al. 1985; Wagner et al. 1985).

Gold sources are quite limited and there is no certainty which of the known occurrences were exploited to a large extent in the Bronze Age (Fig. 4). Gold has been known to be mined in Egypt (Klemm/Klemm 1989) and extensively used in the royal burials there in the Bronze Age long before the period of the Shaft Grave, thus it is often assumed that the gold at Mycenae was in some way obtained from Egypt. However, there are also considerable gold sources in northern Greece and in Bulgaria. There is as yet no proof of Bronze Age exploitation of gold in northern Greece, where both alluvial gold and reef gold certainly occur. Gold was deposited in the 5th millennium BC cemetery near Varna

1 Gale/Stos-Gale 1981; 1981a; Pernicka/Wagner 1982; 1985; Pernicka et al. 1985; Pernicka 1987; Wagner et al. 1986.

on the Black Sea coast, on a scale quite unknown so early elsewhere, thus it can truly be thought of as the first gold of Europe (Ivanov 1988). The gold deposits in the western and southern part of Bulgaria as well as in the south-east near Malko Tarnovo on the border with Turkey are of particular interest, because there are at least three natural routes from Bulgaria to the Aegean: the rivers Maritza, Mesta/Nestos and Struma/Strymon (which also carries gold-bearing sands). I. Ivanov suggests that the gold used at Varna probably came from gold deposits within the confines of the modern territory of Bulgaria, and more specifically from the eastern part, but so far this hypothesis has not been substantiated by scientific evidence (Popov/Jockenhövel 2010). Somewhat further to the north-west from Bulgaria there are well known gold-bearing ores in the Carpathians. The richest part of this mineralisation is in present day Romania, where the Romans established the new province of Dacia at the beginning of the 2nd century AD specifically to exploit gold and silver ores in the Apuseni Mountains in the south-east Carpathians (in the metalliferous Transylvanian Mountains; see Fig. 4). This area covers about 900 km^2 and even today contains large amounts of epithermal gold-silver, as well as porphyric copper-gold ores (Neubauer et al. 2005; Kouzmanov et al. 2005; Baron et al. 2011). Some distance north in the Baia Mare part of the eastern Carpathians there are further silver ores (Kouzmanov et al. 2005a; Marcoux et al. 2002). It is quite possible that these rich gold, silver, and copper deposits were exploited in the 2nd millennium BC.

While so far there is no scientific evidence as to the origin of Bronze Age gold artefacts found in the Aegean, there is reasonable evidence as to the origin of silver. Lead ores, especially galena, usually contain silver, and were the main source of silver in antiquity. The production of silver from argentiferous galena first involves the roasting and smelting of the ore (probably the same operation) to produce impure lead which carries with it the silver. The silver is then recovered by cupellation in which the lead is heated to about 1000°C and oxidised to litharge (lead oxide) by blowing air over or through the molten lead. The litharge is removed by skimming or by absorption in the crucible walls, leaving behind the silver metal (which always contains a trace of lead). It is very probable that lead would also have been very largely used in the production and purification of silver from native silver or the dry silver ores such as argentite or cerargyrite (Gale et al. 1980; 1981b). Silver has been extracted from argentiferous galena in the Aegean since the 3rd millennium BC (Gale/Stos-Gale 1981; 1981a). Therefore, lead found on Bronze Age sites might represent also the source of silver, if the lead signature is consistent with that from the deposit that contained the argentiferous galena.

Lead isotope analyses indicate that in the Mycenaean period (Late Helladic I–III, i.e. 1600–1100 BC) the lead used in Crete, the Cyclades, and mainland Greece originated mainly from Lavrion, which is known as one of the most prominent sources of silver in later antiquity. In particular, in the 5th century BC the silver from Lavrion was used for minting Athenian silver coinage during the Persian Wars (Gale et al. 1980). Figure 5 shows plots of lead isotope data obtained from samples of lead from Mycenae and two contemporary sites in the vicinity, Tiryns and Lerna. All analysed lead from these sites is clearly identical with the lead isotope ratios of galena from the mines in Lavrion. The lead isotope analyses show Lavrion to be the overwhelmingly dominant source of lead for Thera (Late Minoan IA; Stos-Gale/Gale 1990) and Crete. More lead isotope data for Late Bronze Age lead artefacts from the Cycladic islands and Crete are listed on the OXALID database. The great majority of these artefacts also originated from the lead ores of Lavrion.

Unexpectedly, the archaeological excavations of the Bronze Age sites on the mainland have not revealed much evidence of extensive silver extraction, apart from some litharge from Perati and Thorikos (Gale et al. 1982). In Lavrion itself large amounts of litharge were used for lining cisterns used in silver extraction in the 6th–5th century BC (Conophagos 1980; Ellis Jones 1988). It is possible that the litharge used in this way was not only from contemporary activities, but collected in this region from earlier times, which would partly explain the lack of litharge that can be dated to the Bronze Age. On the other hand, there is a compelling evidence of silver extraction in the Bronze Age towns on the Aegean islands, because considerable amounts of litharge dated to the Late Bronze Age have been found on the islands of Kea, Thera, and Melos and in Knossos on Crete. Also on Siphnos litharge can be found in several surface locations (Gale/Stos-Gale 1981; Pernicka et al. 1985).

Chemical analyses of litharge samples give an interesting insight into the economic and technical side of silver extraction in the Late Bronze Age Aegean: the silver concentrations in the Bronze Age litharge from Siphnos averaged 48 ppm and mainly lay between 5 and 50 ppm, similar to the figure of 14 ppm for the Middle Helladic litharge from Thorikos. Similar low silver concentrations have been reported by C. E. Conophagos (1980) for ancient litharge from the Lavrion, and Bronze Age litharge from Kea show silver at a similarly low level (Gale et al. 1984). In contrast, Bronze Age lead artefacts from Mycenae, Perati, Vapheio, Thorikos, Menidi, and Athens contain much more silver, from about 400–700 ppm and averaging about 490 ppm (Stos-Gale/Gale 1982). Thus the silver content of the lead artefacts is about ten times or more higher than the silver content of Bronze Age litharge, but is about ten times (or a little less) lower than the silver concentration in lead coming from the richer Lavrion ores.

Comparison of the silver content of the lead artefacts with that of Bronze Age litharge (all shown from lead-isotope compositions to have a Lavrion origin) proves that the lead metal in the artefacts was the direct product of smelting, and was not produced by the reduction of litharge. Comparison of the silver content of the lead artefacts with the silver content of Lavrion lead-silver ores strongly suggests that cupellation to recover silver from argentiferous lead was, in the Late Bronze Age, restricted to lead containing more than about 400–600 g of silver per ton. Silver was almost certainly the main sought-after metal with lead being a by-product; if this is so, it may well explain why the exceptionally silver-rich ores of Lavrion and Siphnos were singled out for exploitation in the Bronze Age Aegean, and many occurrences of silver-poor lead minerals were ignored.

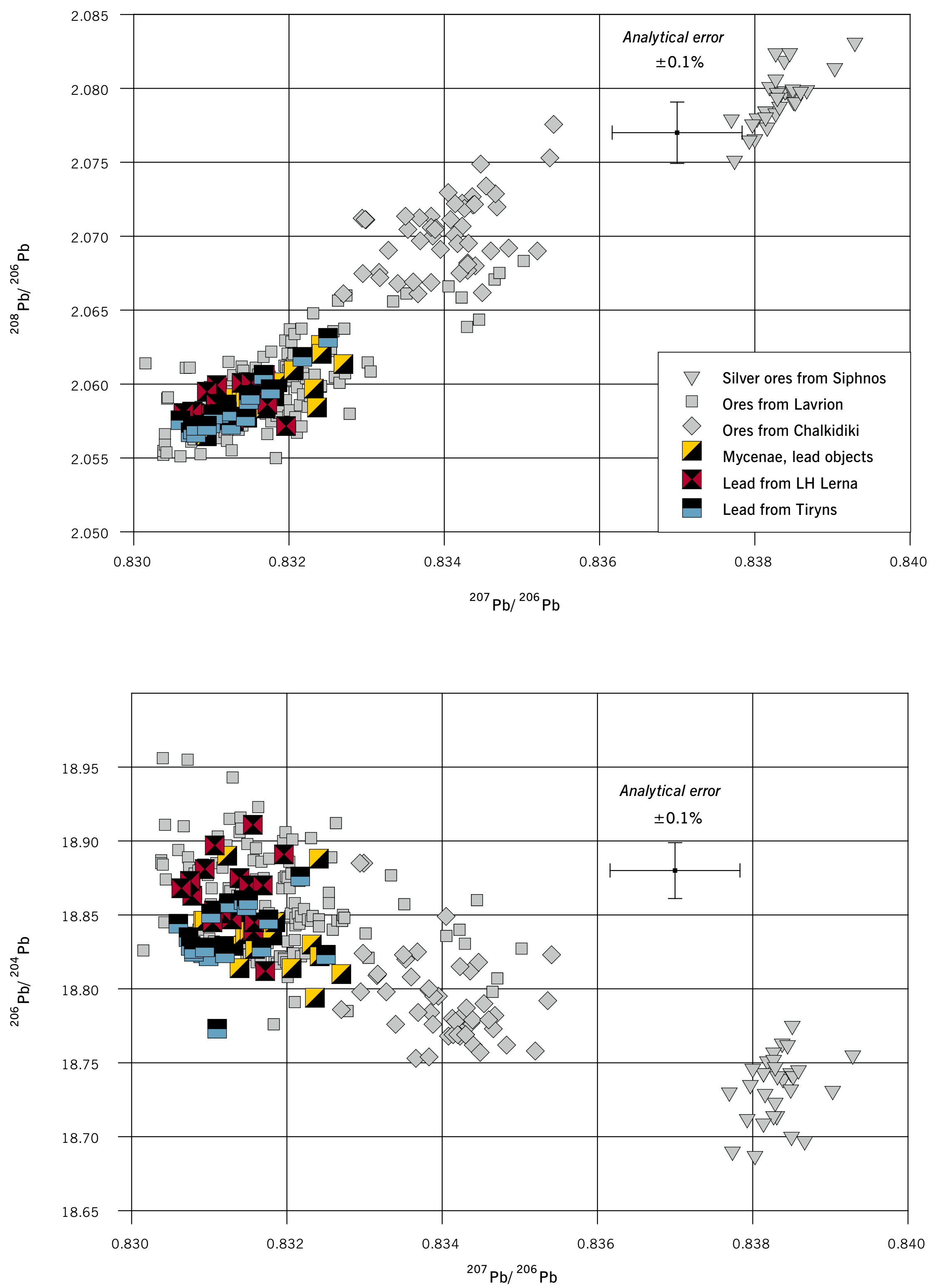

Fig. 5 Lead isotope plots of lead objects from Mycenae, Lerna and Tiryns are fully consistent with an origin from the ores mined in Lavrion, Attica.

Abb. 5 *Die Bleiisotopenverteilung der Bleiobjekte aus Mykene, Lerna und Tiryns stimmt mit der Signatur der Erze aus den Minen von Lavrion, Attika, als deren Quelle überein.*

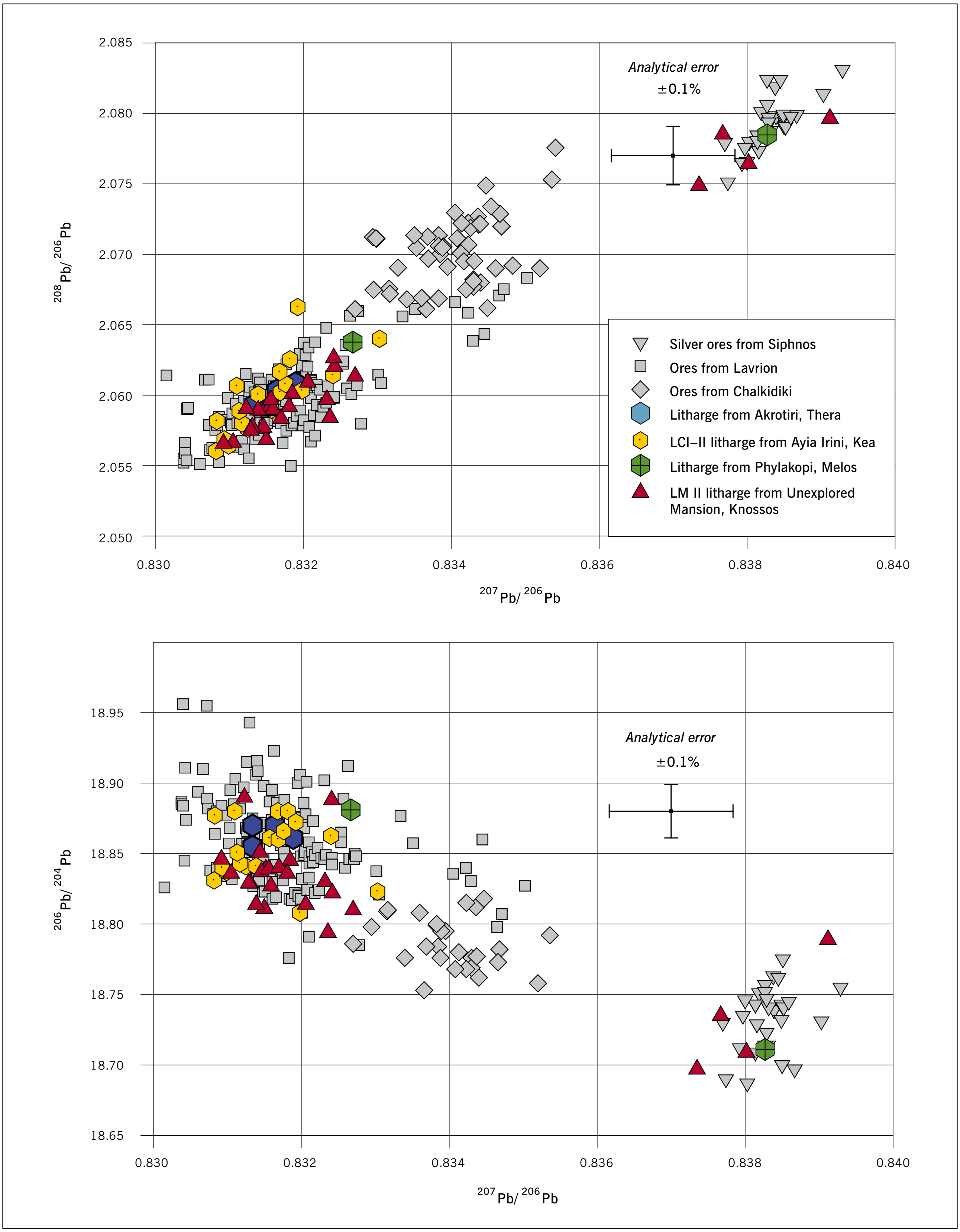

Fig. 6 Large quantities of litharge, which is a by-product of silver extraction, were found on the Aegean islands in the strata contemporary to the Myceneans Shaft Graves. Nearly all analysed pieces of this litharge are consistent with an origin from the galena occurring in Lavrion.

Abb. 6 *Große Mengen an Lithargit (oder Bleiglätte), ein Nebenprodukt bei der Silbergewinnung, sind auf den Ägäischen Inseln gefunden worden, in Schichten, die zeitgleich mit den mykenischen Schachtgräbern zu datieren sind. Beinahe alle analysierten Lithargitstücke zeigen eine Signatur, die mit dem Galenit (oder Bleiglanz) aus Lavrion als Quelle übereinstimmt.*

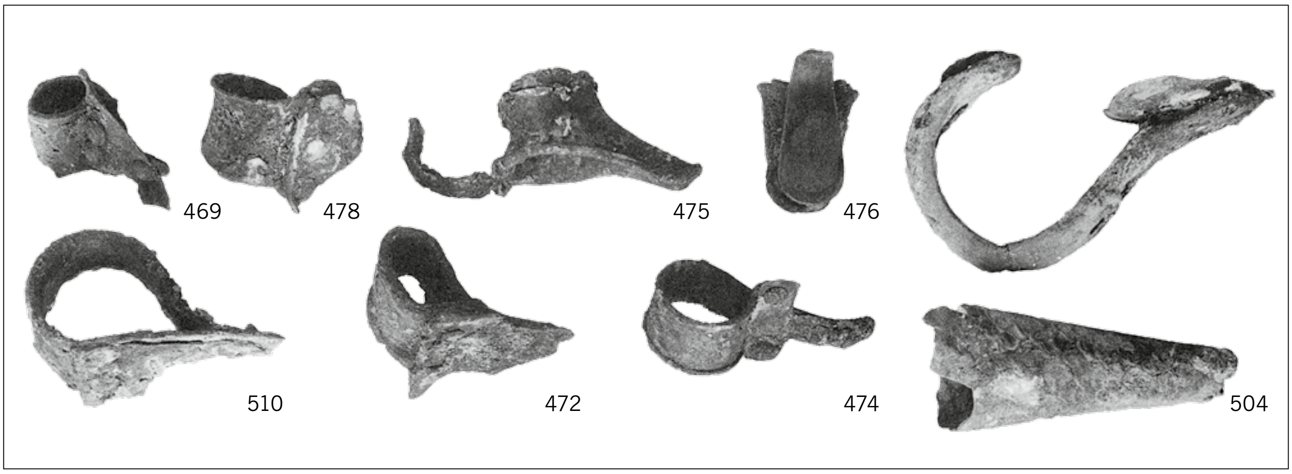

Fig. 7 Fragments of silver vessels from the Shaft Grave IV. Samples for lead isotope analysis were taken from fragments numbered 469 and 478. 469 height 5.0 cm; 472 height 5.1 cm; 474 height 6.5 cm; 475 height 4.5 cm; 510 height 7.0 cm; 476, 504 no scale.

Abb. 7 *Fragmente von Silbergefäßen aus Schachtgrab IV. Proben zur Bleiisotopenanalyse wurden von den Fragmenten mit den Nummern 469 und 478 entnommen. 469 Höhe 5,0 cm; 472 Höhe 5,1 cm; 474 Höhe 6,5 cm; 475 Höhe 4,5 cm; 510 Höhe 7,0 cm; 476, 504 o. M.*

This fact draws attention to two strands of evidence that are in accord with Renfrew's earlier view that, in the later Bronze Age, Aegean trade with foreign lands was minimal compared with the internal flow of goods and materials (Renfrew 1972, 440–475). K. M. Petruso has found evidence of a local trading network in the form of large quantities of balance weights, largely of lead and on a uniform weight standard of about 61 g, found in twenty sites in Crete and on Thera, Melos, Kea, and on the mainland at Thorikos, Malthi, and Vapheio (Petruso 1982). These weights were doubtlessly introduced to facilitate trade throughout the network. J. L. Davis (1979) has also drawn attention to a broad range of other archaeological evidence that strongly suggests the existence of a strong network between Crete, Thera, Melos, Kea, and the mainland (Attica and the north-east Peloponnesus) from at least Middle Minoan III to Late Minoan IA times. The evidence resulting from lead isotope data suggests that an important element in this trading network may have been silver, copper, and lead from Lavrion. Lead isotope analyses of many hundreds of copper-based artefacts from the mainland Greece and Crete show that Lavrion was also a very important source of copper[2]. Copper seems to have been also imported to the Aegean from Cyprus and southern Anatolia. The bibliography and lead isotope and elemental data that support this statement are available on the OXALID website.

Figure 6 presents lead isotope data for Late Bronze Age pieces of litharge from the sites on the Cycladic islands and from Knossos. These results show clearly that the silver-bearing ores from Lavrion and Siphnos were used for silver extraction in this period. Therefore, it would be expected that the silver vessels in these graves have been made from the local metal.

The origin of silver vessels from the Shaft Graves in Mycenae

Most publications related to the contents of the Shaft Graves in Mycenae discuss the gold masks, ornaments and vessels, and bronze weapons. The presence of large amounts of silver vessels in the Shaft Graves in Mycenae is not often mentioned in the literature. G. Karo, who was a Professor at the Martin-Luther-University Halle-Wittenberg between 1920 and 1936, compiled the definitive catalogue of the finds in the Shaft Graves from the earliest excavations. In this catalogue Karo reports over 40 of such vessels, many reconstructed from fragments after the excavation. Both, silver and bronze vessels mostly imitate the shapes of Minoan and Mycenaean pottery dating to the middle Early Bronze Age (Middle Minoan III–Late Minoan I). These are, for example, cups with arcaded fluting, stemmed goblets with one or two handles and the »Vapheio type« cup shape that goes back to Middle Minoan period on Crete (Davis 1977). The example of a silver pedestalled cup from Grave IV visible on Figure 1 with a succession of rosettes around its bowl is particularly characteristic of the Minoan pottery dated to Late Minoan I period at Knossos. Evans (1929, 26 f.) also noted some parallels with the Trojan pottery forms and even a wider European range.

In 1981 the Isotrace Laboratory in Oxford obtained a number of samples of metal artefacts from the Mycenaean Shaft Graves from the National Archaeological Museum in Athens with the permission of the Greek Ministry of Culture facilitated by the British School in Athens. The samples were taken by K. Asimenos. This group contained 32 samples of silver vessels from different tombs in and around the citadel. These samples included 25 from Grave Circle A that had been excavated by H. Schliemann: two from Shaft Grave III, 14 from IV and 9 from V. These objects are traceable to the publication of the contents of these graves by

2 Stos-Gale 2000; 2001; Gale et al. 2008; Muhly 2011, 42.

NAM no.	Find spot	Object description	References
SG 151	Shaft Grave III, circle A	Vapheio Cup, considered Mycenaean by Davis	Karo 1930/33, 62; Davis 1977, 236
SG 66 beta	Shaft Grave III, circle A	Vessel fragments	No reference
NM 453	Shaft Grave IV, circle A	Cup	No reference
SG 388	Shaft Grave IV, circle A	Rhyton in a form of a stag	Karo 1930/33, 94; Pl. CXV–CXVI
SG 469	Shaft Grave IV, circle A	Silver handle of a silver cup	Karo 1930/33, 105; Pl. CXXXIII
SG 478 b	Shaft Grave IV, circle A	Handle of a cup, strip	Karo 1930/33, 106; Pl. CXXXIII; Davis 1977, 202; Fig. 164–165
SG 478 a	Shaft Grave IV, circle A	Handle of a cup, Minoan?	Karo 1930/33, 106; Pl. CXXXIII; Davis 1977, 202; Fig. 164–165
SG 479	Shaft Grave IV, circle A	6 fragments of a vessel	Karo 1930/33, 106; Pl. CXXXIII; Davis 1977, 202; Fig. 164–165
SG 479 a	Shaft Grave IV, circle A	Vessel fragments	Karo 1930/33, 106; Pl. CXXXIII; Davis 1977, 202; Fig. 164–165
SG 479 b	Shaft Grave IV, circle A	Vessel fragments	Karo 1930/33, 106; Pl. CXXXIII; Davis 1977, 202; Fig. 164–165
SG 480	Shaft Grave IV, circle A	One-handled cup	Karo 1930/33, 106; Davis 1977, 194; Fig. 158
SG 481 a	Shaft Grave IV, circle A	Silver siege rhyton, considered Minoan by Davis	Karo 1930/33, 106–108; Pl. CXXII; Davis 1977, 227–230; Fig. 179–180
SG 481 b	Shaft Grave IV, circle A	Silver siege rhyton, considered Minoan by Davis	Karo 1930/33, 106–108; Pl. CXXII; Davis 1977, 227–230; Fig. 179–180
SG 505	Shaft Grave IV, circle A	Vessel fragments, uncertain shape	Karo 1930/33, 110
SG 520	Shaft Grave IV, circle A	One handled stemmed goblet	Karo 1930/33, 112; Pl. CXXVII; Davis 1977, 221; Fig. 175
SG 605	Shaft Grave IV, circle A	Krater with copper foot	Karo 1930/33, 119; Pl. CXXVIII–CXXXI; Davis 1977, 222–227; Fig. 176–178
SG 863	Shaft Grave V, circle A	Vessel fragments, uncertain shape	Karo 1930/33, 149
SG 865a	Shaft Grave V, circle A	Vessel fragments, uncertain shape	Karo 1930/33, 149; Davis 1977, 168–169
SG 865b	Shaft Grave V, circle A	Vessel fragments, uncertain shape	Karo 1930/33, 149; Davis 1977, 168–169
SG 867	Shaft Grave V, circle A	Vapheio cup, plain	Karo 1930/33, 149; Davis 1977, 149
SG 868	Shaft Grave V, circle A	Cup, spiral decoration	Karo 1930/33, 149; Fig. 64; Davis 1977, 142–143; Fig. 113
SG 869	Shaft Grave V, circle A	Vessel fragments, uncertain shape	Karo 1930/33, 150
SG 870/1	Shaft Grave V, circle A	Vessel fragments, uncertain shape	Karo 1930/33, 150; Fig. 65
SG 876	Shaft Grave V, circle A	Cup, shape uncertain	Karo 1930/33, 150
SG 880	Shaft Grave V, circle A	Vapheio cup, spiral decoration	Karo 1930/33, 151; Fig. 66; Davis 1977, 156; Fig. 123
SG 9563	Shaft Grave Circle B, gr. delta	Cup, straight sided, fragments, Repousse lion hunt, Mycenean according to Davis	Mylonas 1973, Pl. 71a; Davis 1977, 136; Fig. 105
SG 9588	Shaft Grave Circle B, gr. delta	Vessel fragments	No reference
SG 9594	Shaft Grave Delta, Circle B	Vessel fragments	No reference

Chronology	$^{208}Pb/^{206}Pb$	$^{207}Pb/^{206}Pb$	$^{206}Pb/^{204}Pb$	Ore source
LH I, 2nd half of the 16th cent. BC	2.06642	0.83312	18.771	Romania, Baia Mare district
LH I, 2nd half of the 16th cent. BC	2.05728	0.83299	18.852	Lavrion, Attica
LH I, 2nd half of the 16th cent. BC	2.07095	0.83368	18.809	Romania, Baia Mare district
LH I, 2nd half of the 16th cent. BC	2.08029	0.84194	18.650	?
LH I, 2nd half of the 16th cent. BC	2.06741	0.83261	18.827	Romania, Baia Mare district
LH I, 2nd half of the 16th cent. BC	2.06536	0.83105	18.875	Romania, Baia Mare district
LH I, 2nd half of the 16th cent. BC	2.06566	0.83149	18.857	Romania, Baia Mare distict
LH I, 2nd half of the 16th cent. BC	2.06702	0.83290	18.842	Romania, Baia Mare district
LH I, 2nd half of the 16th cent. BC	2.06847	0.83341	18.805	Romania, Baia Mare district
LH I, 2nd half of the 16th cent. BC	2.06812	0.83347	18.813	Romania, Baia Mare district
LH I, 2nd half of the 16th cent. BC	2.06554	0.83243	18.806	Romania, Baia Mare district
LH I, 2nd half of the 16th cent. BC	2.06757	0.83386	18.794	Romania, Baia Mare district
LH I, 2nd half of the 16th cent. BC	2.06737	0.83403	18.793	Romania, Baia Mare district
LH I, 2nd half of the 16th cent. BC	2.05915	0.83171	18.825	Lavrion, Attica
LH I, 2nd half of the 16th cent. BC	2.06150	0.83245	18.827	Lavrion, Attica
LH I, 2nd half of the 16th cent. BC	2.06723	0.83317	18.777	Romania, Baia Mare district
LH I, 2nd half of the 16th cent. BC	2.07025	0.83395	18.812	Romania, Baia Mare district
LH I, 2nd half of the 16th cent. BC	2.06886	0.83778	18.677	Romania, Apuseni
LH I, 2nd half of the 16th cent. BC	2.06935	0.83702	18.692	Romania, Apuseni
LH I, 2nd half of the 16th cent. BC	2.07118	0.83403	18.802	Romania, Baia Mare district
LH I, 2nd half of the 16th cent. BC	2.07080	0.83591	18.746	Romania, Baia Mare district
LH I, 2nd half of the 16th cent. BC	2.06093	0.83257	18.818	Lavrion, Attica
LH I, 2nd half of the 16th cent. BC	2.06574	0.83164	18.856	Romania, Baia Mare district
LH I, 2nd half of the 16th cent. BC	2.06516	0.83413	18.799	Romania, Baia Mare district
LH I, 2nd half of the 16th cent. BC	2.07874	0.84361	18.552	?
LH I, 1st half of the 16th cent. BC	2.05647	0.83094	18.846	Lavrion, Attica
LH I 1st half of the 16th cent. BC	2.06602	0.83324	18.762	Romania, Baia Mare district
LH I 1st half of the 16th cent. BC	2.06286	0.83393	18.779	Lavrion, Attica

NAM no.	Find spot	Object description	References
2384	Shaft Grave? or Chamber tombs excavated by Tsountas	Vessel fragments	No reference
2810	Chamber tomb	Vessel fragments	No reference
3013	Chamber tomb 78? Stais 3013	Fragments	No reference
4919	Shaft Grave ?	Vessel fragments	No reference

Tab. 1 Lead isotope data for the 32 samples of the silver vessels from the Shaft Graves in Mycenae that were analysed in the Isotrace Laboratory, University of Oxford.

Tab. 1 *Bleiisotopendaten der 32 Proben von Silbergefäßen aus den Schachtgräbern von Mykene, die am Isotrace Laboratory der Universität Oxford untersucht wurden.*

Karo (1930/33). Three samples of silver came from the Grave Circle B. Four samples of fragmented vessels had only the NAM numbers and while they are certainly from the tombs in the Mycenaean citadel, their exact find spot is at present not known. All analysed samples of silver vessels are listed and described, with references where available, in Table 1. The available photos from Karo (1930/33) are presented in Figures 7–14.

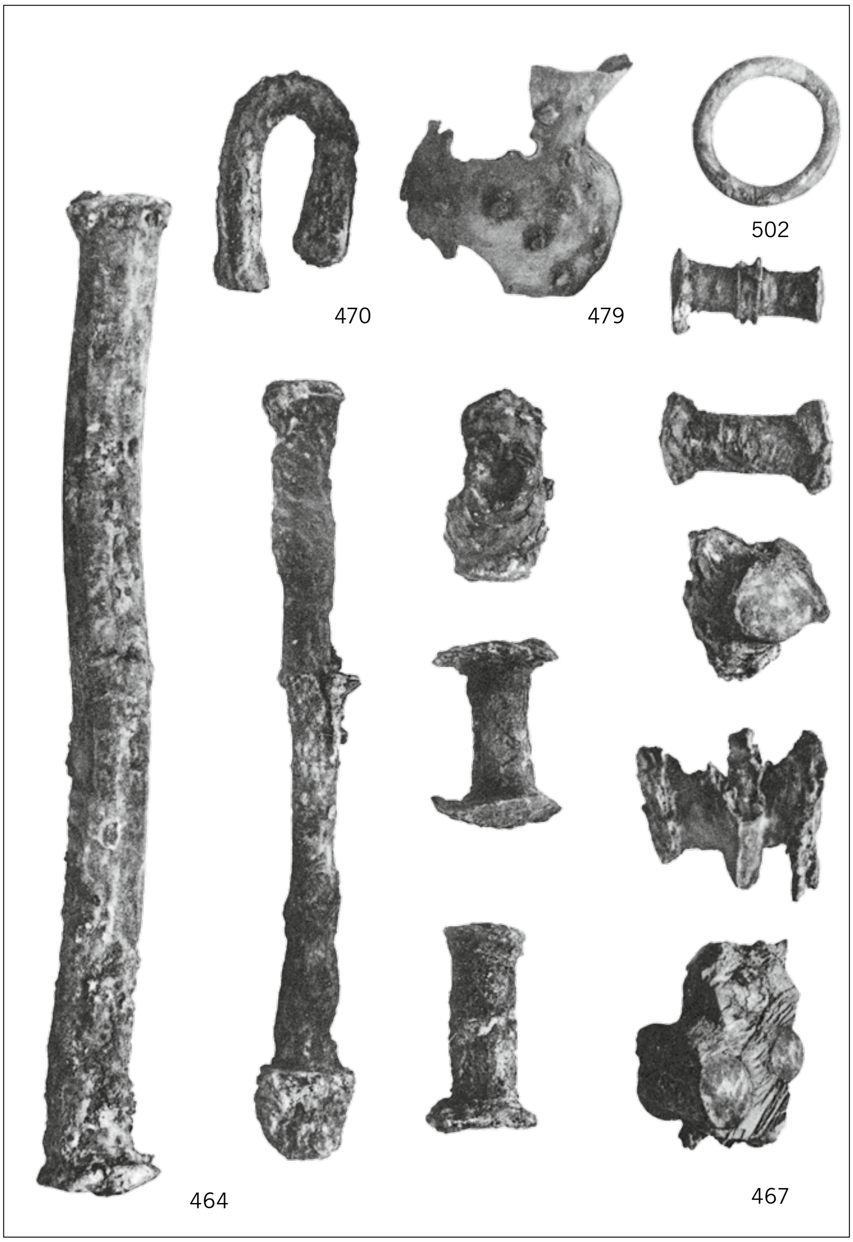

Fig. 8 Fragments of silver vessels from the Shaft Grave IV. A sample for lead isotope analysis was taken from the fragment numbered 479. 467 lenght 2.8 cm, diameter 1.6 cm; 470 lenght 3.2 cm; 502 diameter 1.8 cm; 464, 479 no scale.

Abb. 8 *Fragmente von Silbergefäßen aus Schachtgrab IV. Eine Probe zur Bleiisotopenanalyse wurde vom Fragment mit der Nummer 479 entnommen. 467 Höhe 2,8 cm, Durchmesser 1,6 cm; 470 Höhe 3,2 cm; 502 Durchmesser 1,8 cm; 464, 479 o. M.*

Chronology	$^{208}Pb/^{206}Pb$	$^{207}Pb/^{206}Pb$	$^{206}Pb/^{204}Pb$	Ore source
LH	2.06889	0.83316	18.828	Romania, Baia Mare district
LH	2.06594	0.83558	18.763	Romania, Apuseni
LH IIb–IIIA	2.06481	0.83148	18.858	Romania, Baia Mare distict
LH	2.06361	0.83382	18.780	Romania, Baia Mare district, or Lavrion

The lead isotope and chemical analyses of 18 of these samples were published more than twenty years ago (Stos-Gale/Gale 1982; Stos-Gale/Macdonald 1991). The conclusions as to the origin of these 18 silver vessels were based on a very small comparative database. The overall conclusions reached in these papers were that the majority was most probably consistent with the silver from Lavrion, which was strengthened by lead isotope analyses of lead, indicating that the ores from Lavrion were used for extracting silver. However, there were quite a few objects that did not show consistency with any of the Aegean silver ores. The Minoan or Mycenaean techniques of manufacture of the objects elucidated by archaeologists showed no correlation with their lead isotope data. Amongst the objects sampled were the »Siege Rhyton« (Fig. 9; SG 481) and the Vapheio cup with spiral decoration (Fig. 14; SG 880). Also, another quite unusual vessel that was analysed is the famous »Stag Vessel« (Fig. 15; SG 388). As it has been said earlier (Stos-Gale/Macdonald 1991, 272) this vase is not made of silver-lead as catalogued by Karo, but of 99 % silver.

For clarity, the lead isotope plots of the data presented in Figures 5 and 6 show only the data for the lead and litharge most closely associated geographically and chronologically with the Shaft Grave period. These data clearly demonstrate that in the period of the Shaft Graves in Mycenae (late Middle Helladic to Late Helladic I, i.e. about 1600–1500 BC), silver was being produced by cupellation from silver-rich lead mined in Lavrion, and perhaps also from Siphnos. However, lead isotope analyses of over 1000 lead objects from the Bronze Age sites in the Aegean indicate that in the 2nd mil-

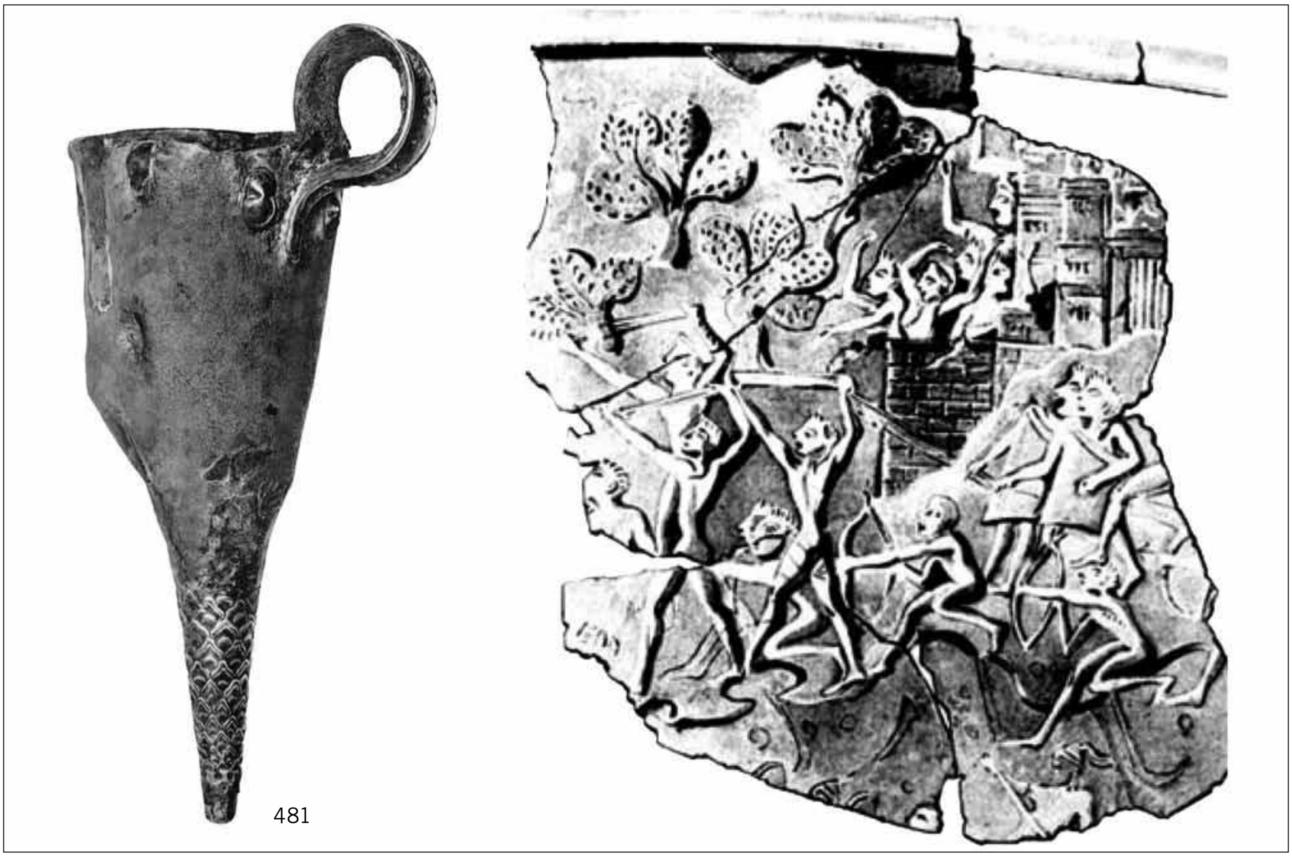

Fig. 9 The silver »Siege Rhyton« from Shaft Grave IV, Karo No. 481. The sample for lead isotope analysis was taken from the rim of this fragment, height 22.9 cm, mouth diameter 11.1–11.3 cm.

Abb. 9 *Das silberne »Belagerungs-Rhyton« aus Schachtgrab IV, Karo Nr. 481. Die Probe zur Bleiisotopenanalyse wurde vom Rand des Fragmentes entnommen, Höhe 22,9 cm, Mündungsdurchmesser 11,1–11,3 cm.*

Fig. 10 One-handled stemmed silver goblet from the Shaft Grave IV, sampled for lead isotope analysis, Karo No. 520. Silver cups, Karo No. 519 and 509. 520 height c. 7.0 cm; 519 height 4.7 cm; 509 height c. 7.0 cm.

Abb. 10 *Silberner Becher mit Fuß und einem Henkel aus Schachtgrab IV, Probe entnommen zur Bleiisotopenanalyse, Karo Nr. 520. Silberne Tassen, Karo Nr. 519 und 509. 520 Höhe ca. 7,0 cm; 519 Höhe 4,7 cm; 509 Höhe ca. 7,0 cm.*

lennium BC lead was mainly obtained from the region of Lavrion in Attica (data on the OXALID).

The lead isotope data for the 32 samples of the silver vessels from the Shaft Graves in Mycenae that were analysed in the Isotrace Laboratory, University of Oxford, are listed in Table 1. Figure 16 shows these data compared with those for the Aegean ores and litharge plotted on Figure 6. TestEuclid comparisons and comparative plot of these data demonstrate that only a small number of the analysed vessels are isotopically consistent with an origin from the Aegean ore deposits. As can be seen on Figure 16, out of the 32 analysed silver vessels from the Mycenaean Shaft Graves only six are

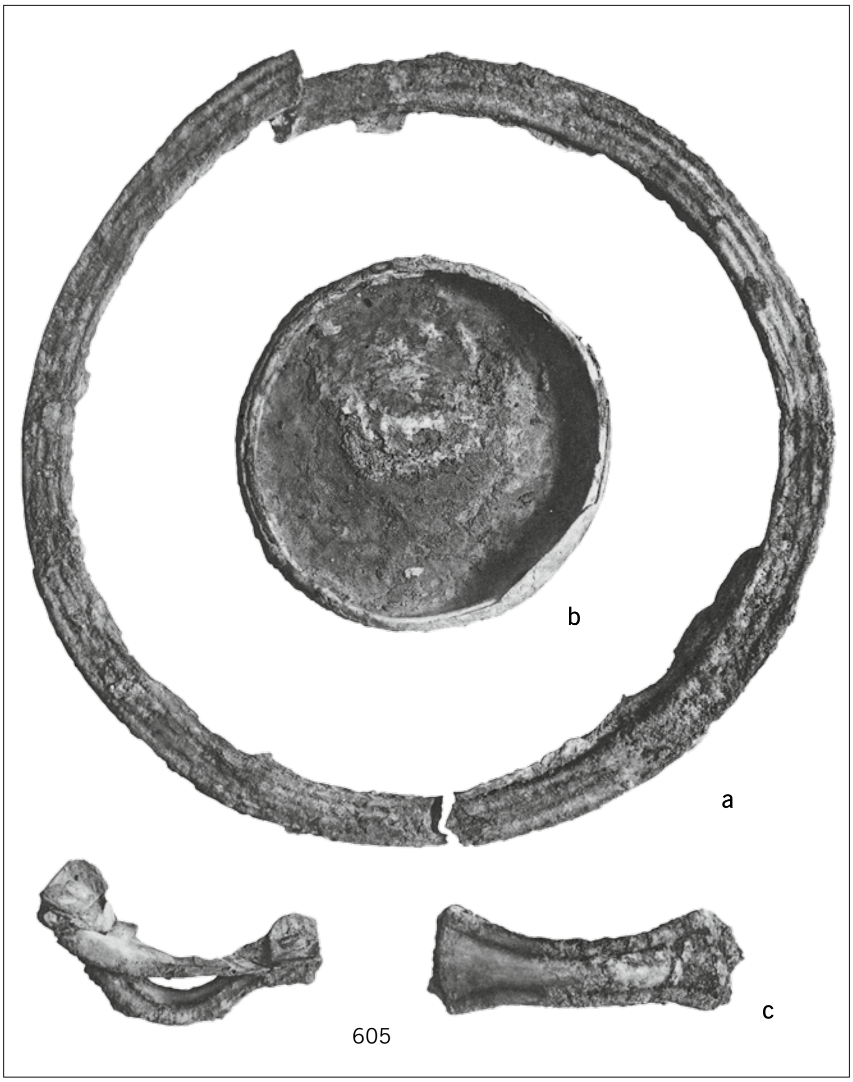

Fig. 11a–c Fragments of silver vessels from the Shaft Grave IV, Karo No. 605. The sample for lead isotope analysis was taken from the rim. a Diameter 40.5 cm; b Diameter 18.0 cm; c No scale.

Abb. 11a–c *Bruchstücke von Silbergefäßen aus Schachtgrab IV, Karo Nr. 605. Die Probe zur Bleiisotopenanalyse wurde vom Rand entnommen. a Durchmesser 40,5 cm; b Durchmesser 18,0 cm; c o. M.*

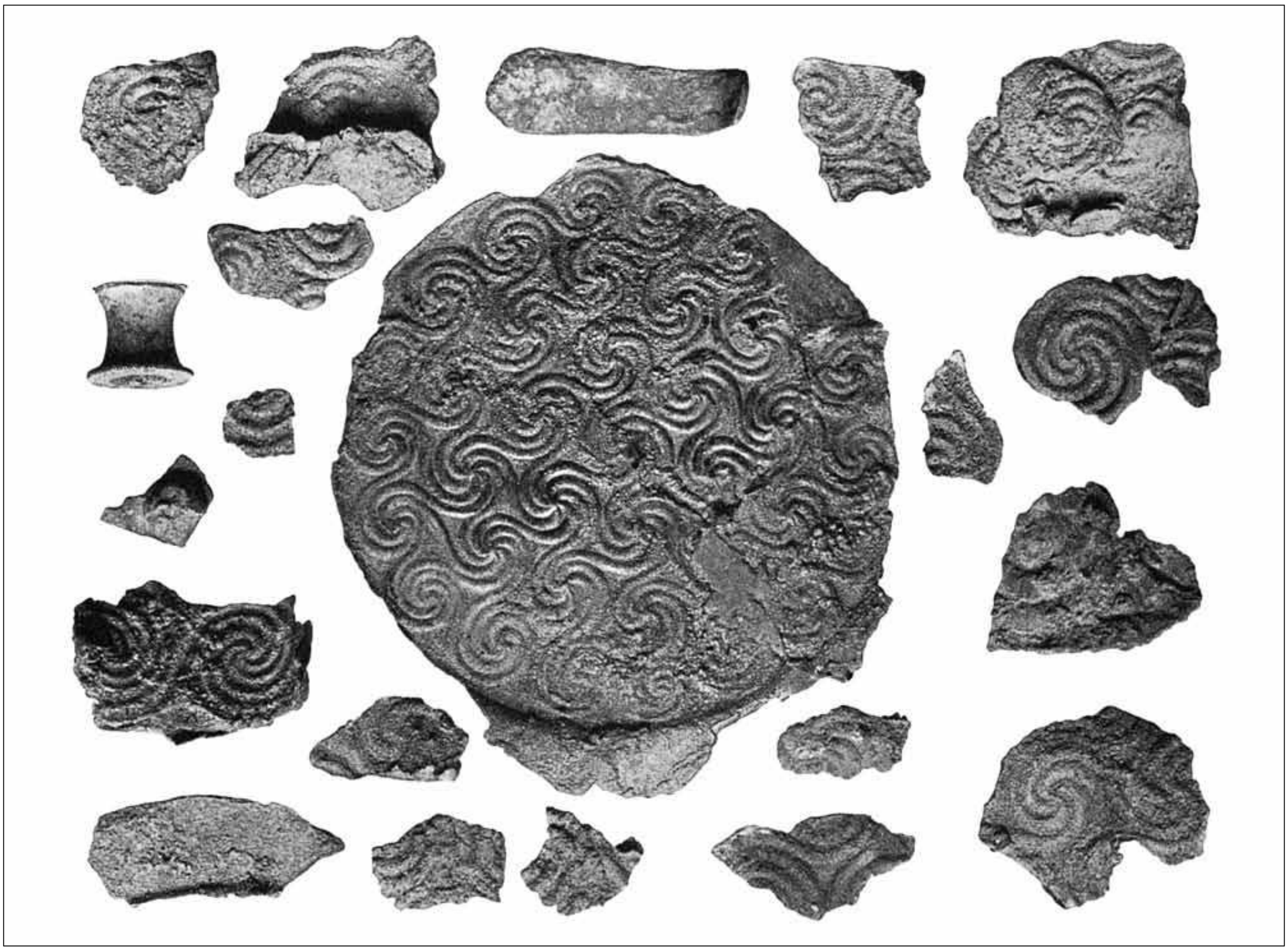

Fig. 12 Fragments of silver vessels from Shaft Grave V, Karo No. 868. The sample for analysis was taken from the large circular piece. Diameter large circular piece 10.5 cm.

Abb. 12 *Bruchstücke von Silbergefäßen aus Schachtgrab V, Karo Nr. 868. Die Probe zur Bleiisotopenanalyse wurde von dem großen runden Fragment entnommen. Durchmesser des großen runden Fragments 10,5 cm.*

Fig. 13 Fragments of silver vessels from Shaft Grave V, Karo No. 870/1. A sample for lead isotope analysis was taken from one of the larger pieces.

Abb. 13 *Bruchstücke von Silbergefäßen aus Schachtgrab V, Karo Nr. 870/1. Die Probe zur Bleiisotopenanalyse wurde von einem der größeren Fragmente entnommen.*

Fig. 14 Silver Vapheio-shaped cup from Shaft Grave V, Karo No. 880. The sample for analysis was taken from the broken edge. Height c. 9.0 cm.

Abb. 14 *Silberner Vaphio-Becher aus Schachtgrab V, Karo Nr. 880. Die Probe zur Analyse wurde von der abgebrochenen Kante entnommen. Höhe ca. 9,0 cm.*

consistent with ores from Lavrion (they are identified in Tab. 1), none with the ores from Siphnos.

On Figure 17 the data for the silver vessels from Mycenae are compared with the ores from Chalkidiki and Troad. Eight silver vessel fragments have lead isotope compositions consistent within ± 0.1 % with the ores from Chalkidiki. However, as mentioned earlier, G. A. Wagner (et al. 1986) in their archaeometallurgical and chemical study of the ores from Chalkidiki found no evidence for silver extraction in Chalkidiki in the Bronze Age. They concluded that the elemental compositions of Late Bronze Age lead with the lead isotope compositions matching the ores from Chalkidiki excluded the possibility of its origin from this deposit (Wagner et al. 1986, 183–185).

Five fragments of silver vessels are consistent with the data for various mines in the Troad, but none of these mines is accepted as an ancient silver mine (Pernicka et al. 2003). Therefore it seems unlikely that the silver vessels in the Shaft Graves were made of silver from the northern Aegean. The remainder of the analysed vessels (13) do not appear to originate from Aegean ores.

It should be noted that the lead isotope data for these thirteen vessels demonstrate that the silver used in their manufacture could not have resulted from mixing metal from Lavrion and Siphnos. The lead isotope ratios for this group are tightly clustered, suggesting that they come from a single source, and furthermore, they do not fall on any obvious »mixing lines« for known European silver ores.

Unfortunately, not all fragments of silver vessels from the Mycenaean Shaft Graves discussed here were analysed for their elemental compositions. Most fragments were very small and highly corroded, but EDXRF analyses indicated that several samples contained gold at concentrations above 1 % by weight (Stos-Gale/Macdonald 1991, 288 Tab. 1). For example: silver cup No. SG 880, and vessels SG 865 and SG 867 contain about 1.5 % of Au and 1.5 % of Cu. The published analysis of the fragment of SG 9563 shows very high gold content (13 %), but repeat analyses of this sample show lower gold; most probably the vessel had gilded parts.

In the recent years several papers have been published discussing the ancient silver, gold and copper deposits in the eastern Carpathian Mountains (Neubauer et al. 2005). These papers contributed to the lead isotope and chemical database for the ores from Romania that was missing for the earlier work (Marcoux et al. 2002; Baron et al. 2011). The southern Apuseni Mountains and the Baia Mare district have a long history of mining and were particularly famous for gold ore deposits. Both localities are still the most important copper, gold, silver and lead mines of Romania (Kouzmanov et al. 2005; 2005a). The Baia Mare district is located in the north-eastern part of the Carpathians, which extends from Slovakia, through Hungary and Ukraine to Romania. This volcanic area contains some important gold-polymetallic ore deposits. The mineral assemblages include sulphides (pyrite, chalcopyrite, galena, stibnite), sulphosalts (tetrahedrite, jamesonite, bournonite, pyrargiryte) and native gold and silver. A vertical zonation of the ore is prominent in some mines with gold-silver mineralisation in the upper levels, a polymetallic ore near the centre and a copper-rich zone at greater depth. The Apuseni Mountains represent an isolated massif in westcentral Romania. Neogene igneous rocks in the Apuseni Mountains host the major gold and base metal deposits. In antiquity the most important deposits in the Apuseni Mountains were the mid Miocene acidic rock hosted Au-Ag epithermal ore deposits in Rosia Montana (Baron et al. 2011; Hauptmann et al. 1995).

Comparisons of the lead isotope data for the silver vessels from the Mycenaean Shaft Graves show that 24 out of 32 silver vessels from the Shaft Graves in Mycenae and six other silver objects from other Late Helladic sites in Greece seem to be consistent with lead isotope compositions of the multimetallic, but mainly gold-silver ores from south-east Carpathians. The majority of silver from the Shaft Graves in Mycenae has lead isotope compositions consistent with the Baia Mare district of Romania and from the gold mining region of Rosia Montana (Apuseni), just south from Baia Mare. Figure 18 shows comparisons of the lead isotope data for all analysed silver vessels from Mycenae and the lead isotope data for the ores from Baia Mare and Rosia Montana. The consistency of the majority of the Bronze Age silver objects with the ores from Romanian silver-gold deposits is striking. On this figure the data for the ores from Lavrion were omitted for clarity and only the line indicates the geo-chronological trend and the position of the data for the minerals from Lavrion. Silver objects from other Late Helladic sites that are consistent with the Transylvanian ores are from the tombs in Perati in Attica (rings), Kokla in Argolid (broken jewellery) and two silver vessels from Peristeria in Messenia. These data have not been previously published but are included in the OXALID database.

Two artefacts that do not seem consistent with the ores from the Carpathians are the cup decorated with spirals SG 880 (Fig. 14) and the famous silver »Stag Vessel« SG 388 (Fig. 15). The »Vapheio cup« with spiral decoration is considered by E. David (1977) to be of Minoan workmanship. The lead isotope ratios of its silver are not fully consistent with any currently known data for the silver ore deposits. From the point of view of the geological age of the ore from which the silver was extracted it seems possible that such silver could be obtained from the ores found in other regions of the Carpathians, or perhaps in the Taurus Mountains in southern Turkey, or even in Iran. Another silver ore deposit that has lead isotope compositions in the same range is in the Massif Central in southern France (Baron et al. 2006), but at present this possibility seems quite uncertain in view of the lack of evidence of exploitation of this silver mines in 1600 BC.

The silver »Stag Vessel« SG 388 has often been described as most likely of an Anatolian origin. Its lead isotope ratios are closer to the lead isotope ratios of the silver ores from Rosia Montana, than to any of the silver ores from Turkey, but based on the lead isotope evidence alone it is not impossible that this stag was made from the silver originating in the Aladag range of the Taurus Mountains. There were at least three archaeometallurgical expeditions to the Taurus Mountains in the last 30 years that resulted in some archaeological information and lead isotope data (Yener et al. 1991; Wagner et al. 1986a; Hirao et al. 1995). These mountains are very wild and difficult to explore, but there is no doubt that at least in some parts of this region the copper, lead and

Fig. 15 Silver »Stag Vessel« No. 388 from Shaft Grave IV. Height 16.2 cm (bottom to mouth), 21.7 cm (bottom to top of the antlers).

***Abb. 15** Silbernes Hirschgefäß Nr. 388 aus Schachtgrab IV. Höhe 16,2 cm (Basis bis zur Mündungsöffnung), 21,7 cm (Basis bis zur Geweihspitze).*

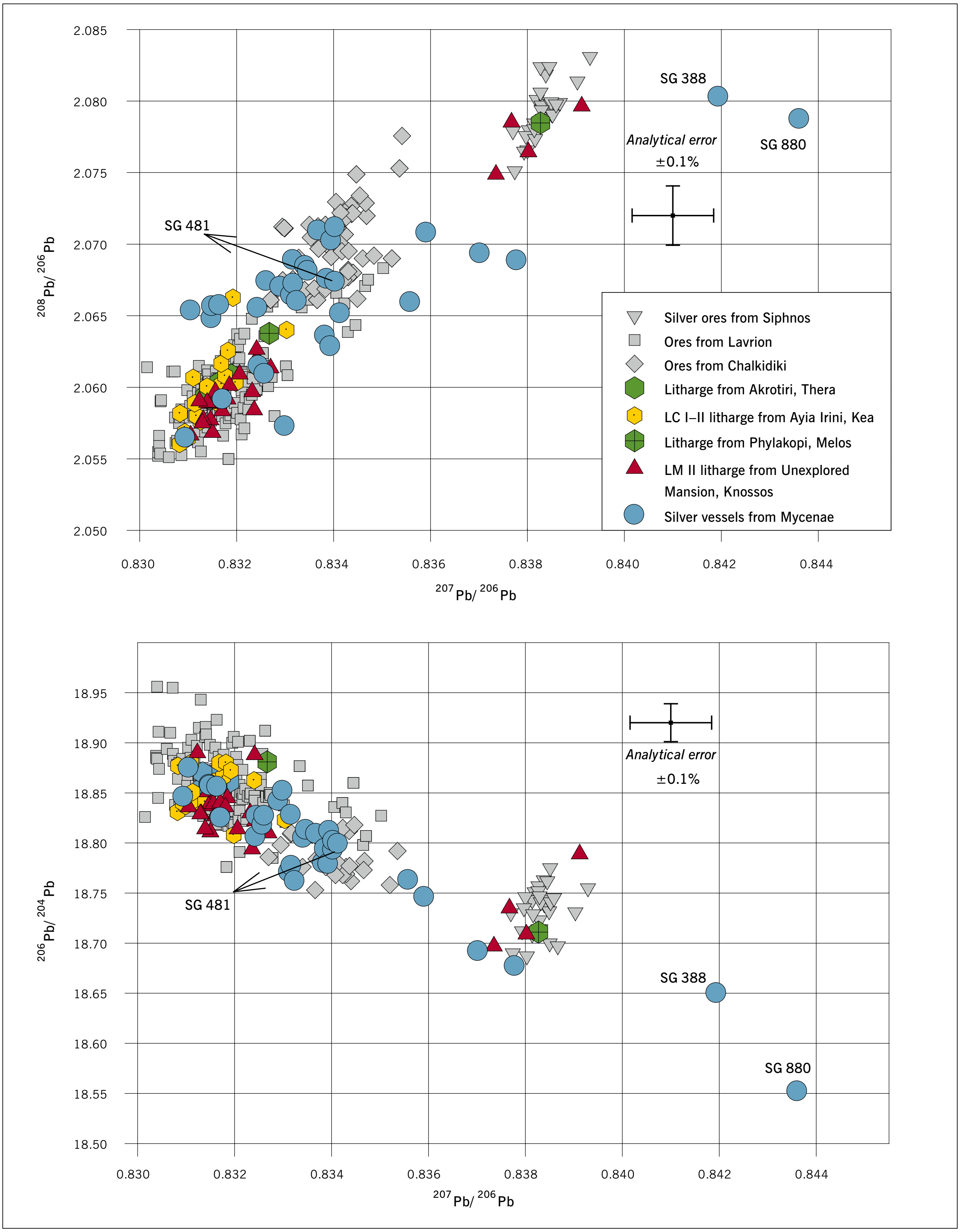

Fig. 16 32 samples of silver vessels from the Shaft Graves in Mycenae were analysed in the Isotrace Laboratory, University of Oxford, for their lead isotope compositions. The comparative lead isotope plot shows clearly that only six of these silver vessels are fully consistent with the origin from the ores from Lavrion in Attica. Another group (13 vessels) appears to be consistent with ores from Chalkidiki, north-west Turkey. The remainder (13 vessels) are not consistent with an origin of the Aegaean ores.

Abb. 16 *Die Bleiisotopenanalyse von 32 Proben von Silbergefäßen aus den Schachtgräbern Mykenes wurde im Isotrace Labor der Universität Oxford vorgenommen. Der vergleichende Datenplot zeigt deutlich, dass nur sechs dieser Silbergefäße mit einer Erzquelle aus Lavrion (Attika) übereinstimmen. Eine weitere Gruppe (13 Gefäße) scheint mit Erzen von der Halbinsel Chalkidiki in der Nordwesttürkei übereinzustimmen. Der Rest (13 Gefäße) stimmt nicht mit Erzsignaturen aus der Ägäis überein.*

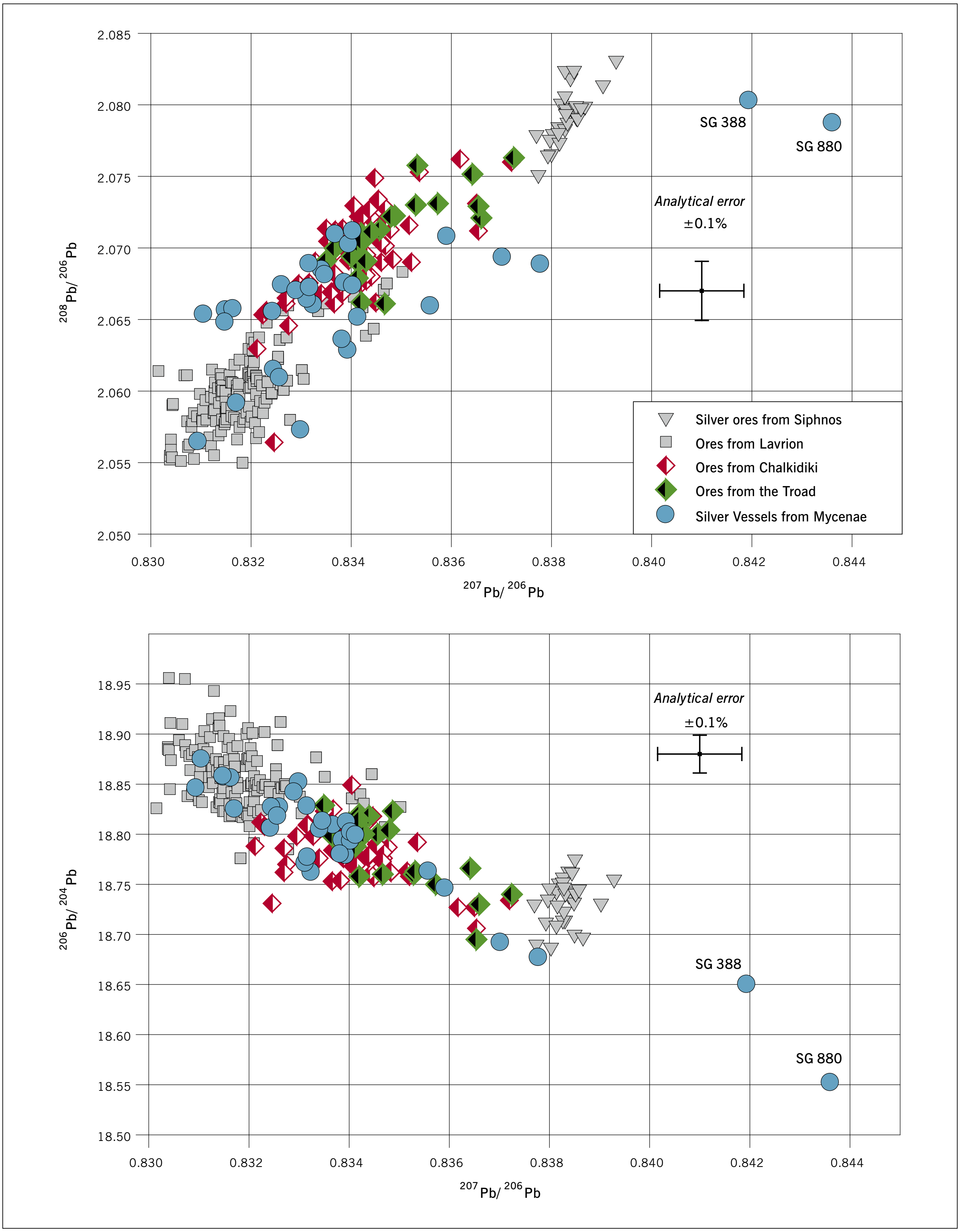

Fig. 17 Eight silver vessel fragments have lead isotope compositions consistent within ±0.1 % with the ores from Chalkidiki. However, Wagner et al. (1986) found no evidence for silver extraction in Chalkidiki in the Bronze Age. Five fragments are consistent with the data for various mines in the Troad, but none of these are accepted as an ancient silver mine (Pernicka et al. 2003).

***Abb. 17** Acht Silbergefäßfragmente haben eine Bleiisotopenzusammensetzung, die zu ±0,1 % mit Erzen aus der Chalkidiki übereinstimmt. Wagner (et al. 1986) haben jedoch keinerlei Beweise für bronzezeitliche Silbergewinnung auf der Chalkidiki gefunden. Fünf Fragmente stimmen mit Signaturdaten für verschiedene Minen in der Troas überein, aber keine kann als eine antik genutzte Silbermine angesehen werden (Pernicka et al. 2003).*

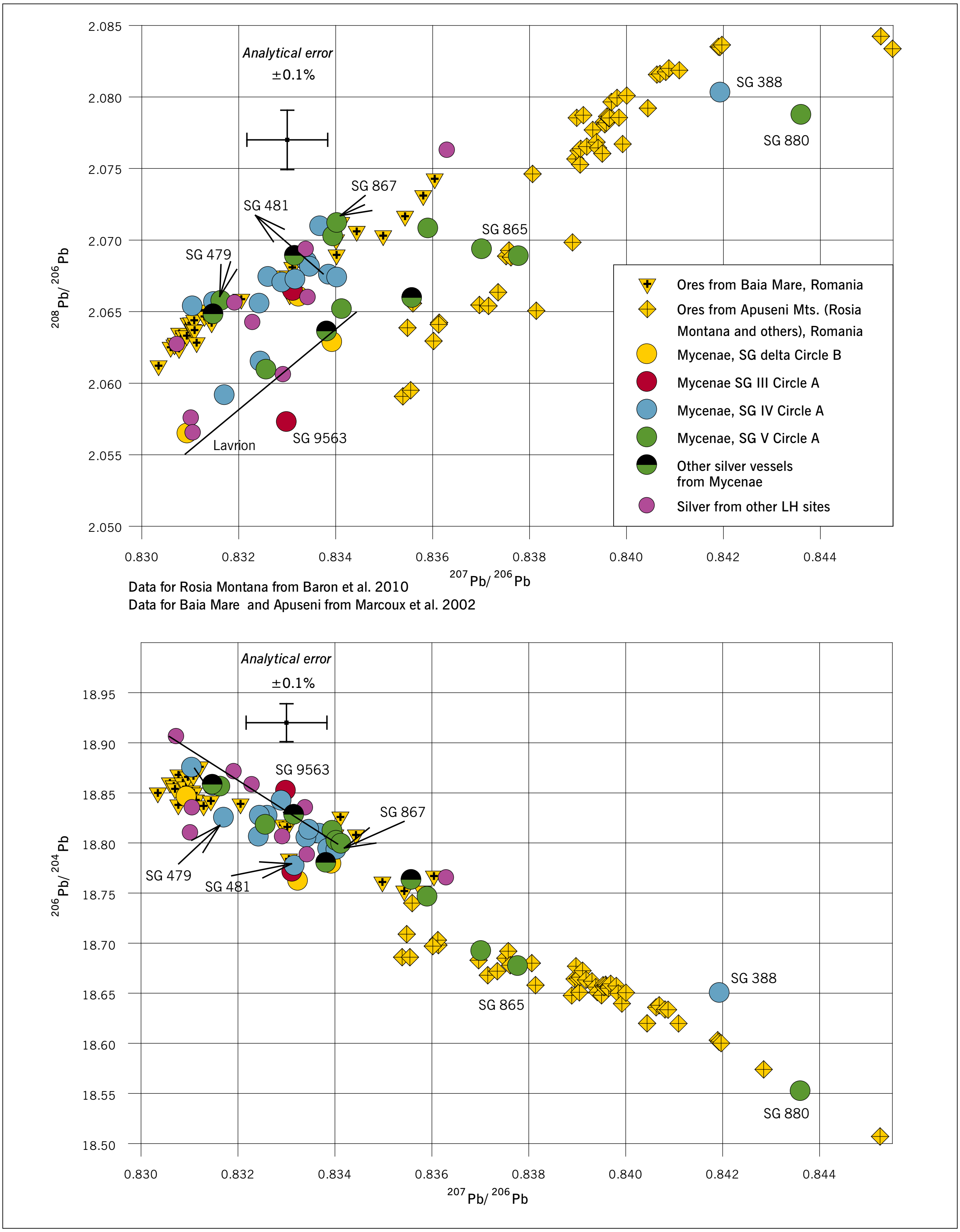

Fig. 18 Comparisons of the lead isotope ratios of the silver vessels from Mycenaean Shaft Graves with the data for gold-silver ores in the south-east Carpathians shows that 24 silver vessels and six other silver objects from other Late Helladic sites in Greece are fully consistent with the origin from these ores.

***Abb. 18** Ein Vergleich der Bleiisotopenverteilung der Silbergefäße aus den mykenischen Schachtgräbern mit Daten für Gold-Silbererze in den südöstlichen Karpaten zeigt, dass 24 Silbergefäße und sechs weitere Silberobjekte von anderen späthelladischen Stätten in Griechenland mit diesen Erzquellen völlig übereinstimmen.*

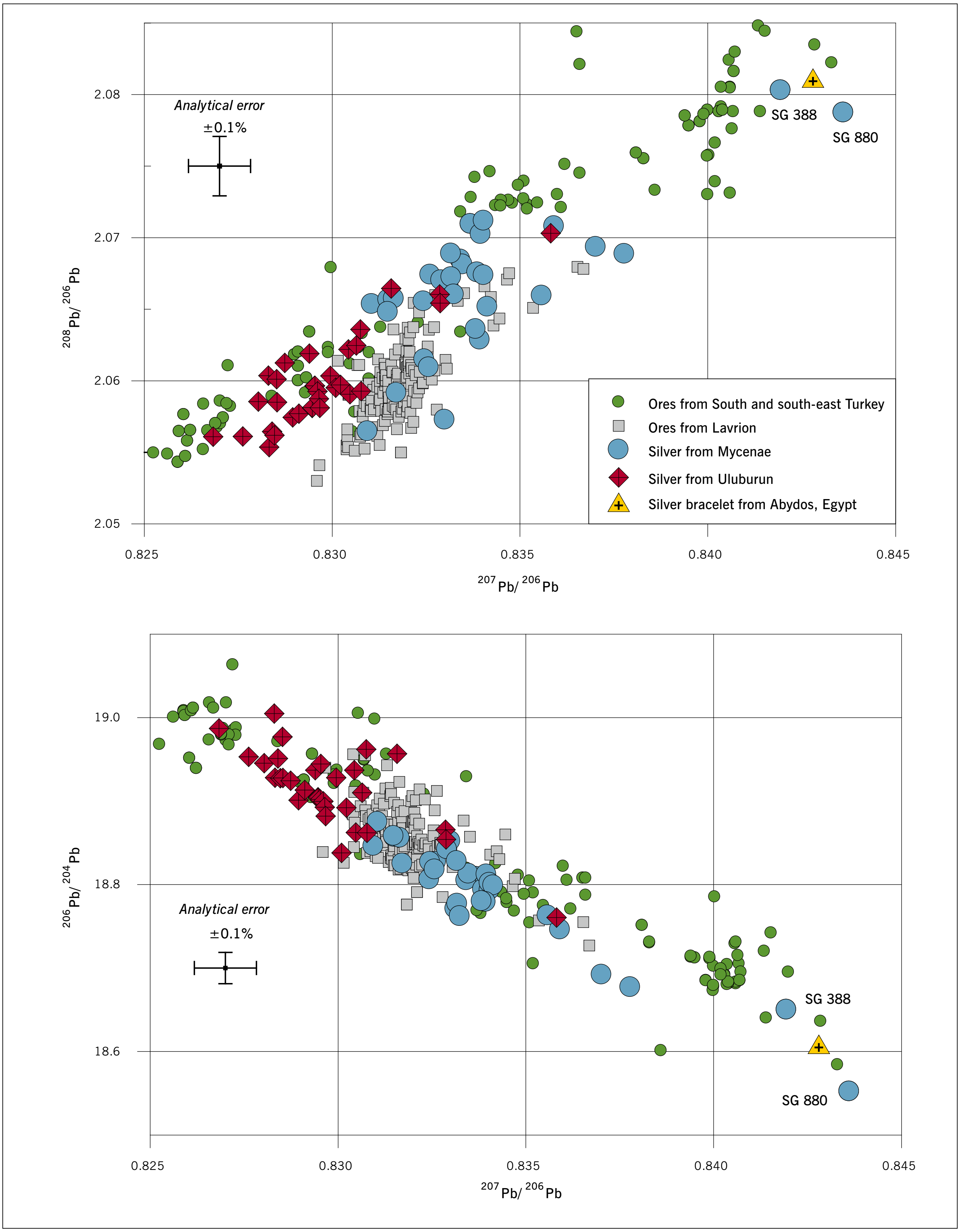

Fig. 19 Two vessels, the Vapheio cup SG 880 and the »Stag Vessel« SG 388, are not consistent with the origin from any silver ores so far analysed. The similarity of their lead isotope compositions to the ores from the Aladag range in the Taurus Mountains in South Turkey needs further confirmation, because so far it seems that only the ores from the Bolkardag in the Taurus were exploited for silver, as demonstrated by the Bronze Age silver artefacts from the 14th century BC Uluburun shipwreck.

Abb. 19 *Zwei Gefäße, der Vaphio-Becher SG 880 und das Hirschgefäß SG 388, stimmen mit keiner bisher analysierten Silberquelle überein. Die Ähnlichkeit ihrer Bleiisotopenzusammensetzung mit Erzen aus dem taurischen Hochgebirge des Aladag in der südlichen Türkei bedarf weiterer Bestätigung, da es momentan so aussieht, als ob nur die Erze aus dem Bolkardag im Taurus zur Silbergewinnung genutzt wurden, wie die bronzezeitlichen Silberobjekte aus dem Schiffswrack von Uluburun aus dem 14. Jh. v. Chr. zeigen.*

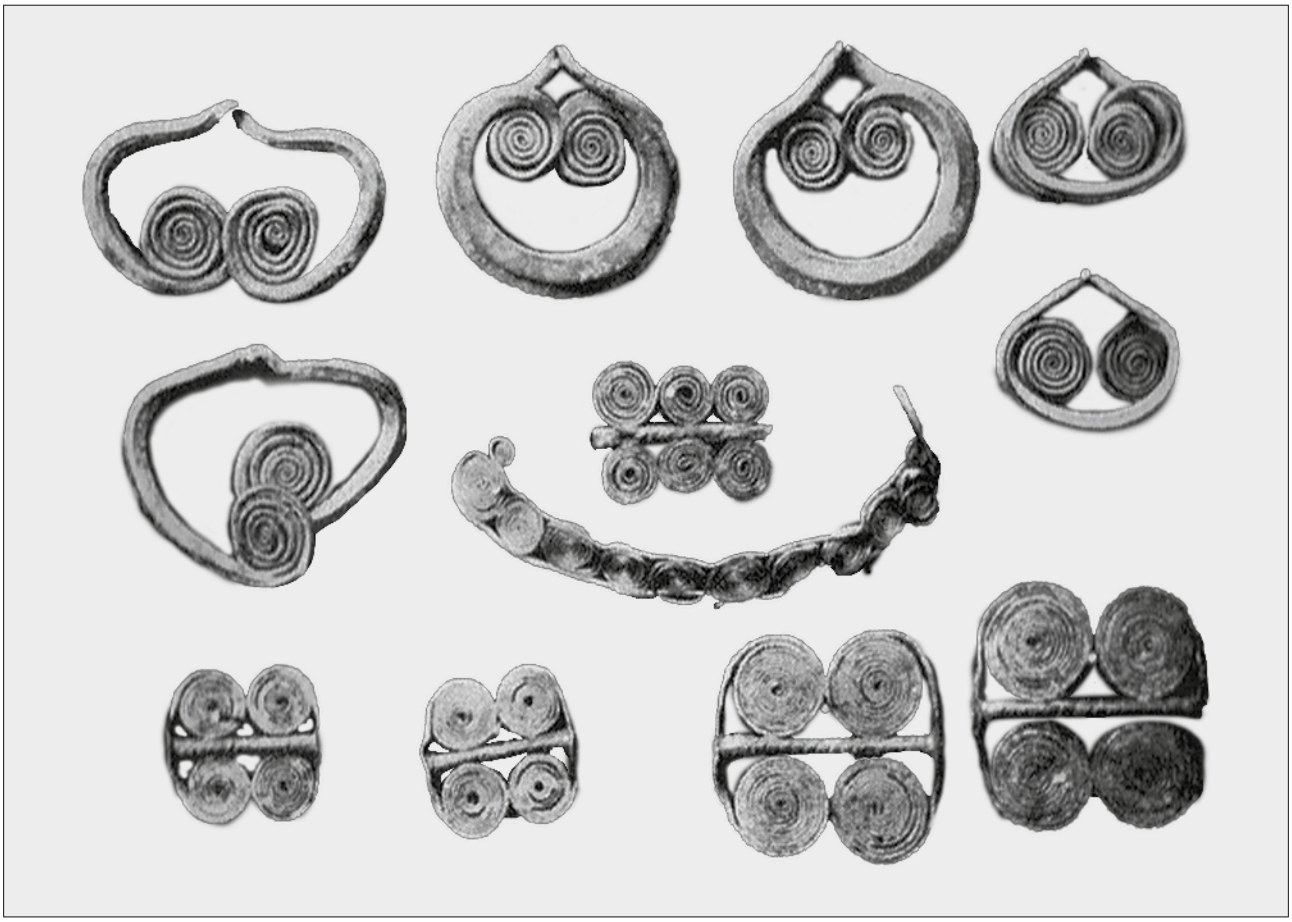

Fig. 20 Spiral earrings and other gold jewellery objects from Shaft Grave III, described by A. Evans (1929, 15) as »typical to Unetice culture centred on Transylvania«.

Abb. 20 *Ohrringe mit Spiralen und andere goldene Schmuckstücke aus Schachtgrab III, die von A. Evans (1929, 15) als »typisch für die Aunjetitzer Kultur mit Zentrum in Transylvanien« beschrieben wurden.*

silver ores (and perhaps also tin) were exploited in the Bronze Age. Many Bronze Age copper-based artefacts from various sites in the eastern Mediterranean show lead isotope ratios consistent with the ores from the Bolkardag and Aladag mountains in the Taurus (Stos-Gale 2001; 2014). However, so far the only evidence of silver extraction from the ores in the Taurus Mountains in the Bronze Age comes from the lead isotope analyses of silver from the Uluburun shipwreck dated to the end of the 14th century BC. Nearly all silver carried on this ship has lead isotope compositions fully consistent with the ores from the Bolkardag region of the Taurus (Gale/Stos-Gale 2005). Figure 19 shows the lead isotope data for the silver from Uluburun, lead, silver and copper ores from the Taurus Mountains and the silver vessels from the Shaft Graves. The silver from Uluburun and the silver vessels form two separate groups and none of the latter is fully consistent with the data for the ores from the Taurus. Additionally the cup SG 880 and the silver stag SG 388 have lead isotope ratios in the proximity of the ores from the Aladag range, for which there is no evidence of silver extraction in the Bronze Age. No other silver-bearing ores from Turkey published so far have lead isotope compositions matching those of the »Stag Vessel«. There are not many lead isotope analyses of Bronze Age silver artefacts from the eastern Mediterranean but amongst them there is only one artefact that has the same lead isotope ratios: it is a silver bracelet from the Middle Kingdom tombs in Abydos in Egypt, presently in the Ashmolean Museum Oxford (museum number E3293). This bracelet is not consistent with any of the so far analysed silver ores from Egypt, or elsewhere, thus this comparison does provide any further information as to the origin of these three Bronze Age silver objects. However, it perhaps indicates that after all, this particular source of silver is to be found in the Middle or Near East, rather than in the Carpathians or Massif Central.

Conclusions: Silver for the vessels in the Mycenaean Shaft Graves from Transylvania?

It has to be emphasised here that the evidence of the origin of silver used for making the vessels in the Shaft Graves as not of Aegean origin does not imply that these objects are imports, but that such silver was available to the Mycenaean or Minoan craftsmen at that time. It is most likely that the silver vessels, like nearly all other artefacts deposited with the dead in the Shaft Graves of Mycenae, were manufactured locally and according to a contemporary local taste. However, the lead isotope evidence that this particular group of objects was possibly made of silver imported from Transylvania, while local silver from Lavrion and Siphons was at the same time circulating in the Aegean, invites further discussion.

The contacts between Mycenaeans and southern Europe have been discussed frequently (Evans 1929; Hänsel 1982; Harding 1984). A recent paper by C. Metzner-Nebelsick (2013) explores the economy of north-western Romania (which contains the gold-silver and copper deposits) in the period of the Shaft Graves and postulates that just at the time when the Mycenaeans were developing the new palatial system in mainland Greece, Transylvanian societies were abandoning their social complexity, which led to a conflict and the development of new trade strategies. She proposes (after Hänsel 1982) that the Mycenaeans were searching for metals in Transylvania.

Regarding the possible presence of imported goods in the Shaft Graves, A. Evans wrote: »An exceptional series of gold ornaments found in Grave III [...] where there were three skeletons, all of them female, possibly shows that there had been intermarriage with princesses of non-Minoan stock who clung to some native fashion of their own. These consist of spiral wires on either side of gold tubes, [...] bracelets of spiraliform fabric and three pairs of ear-rings which, however, must have been hooked on to the ears. All of these recall types of gold ornaments found in the treasures of the Second and Third Cities of Troy. [...] Hubert Schmidt has well shown that the typical form of the earrings [...] is common to a large Central and Eastern European Province [...] and would seem to have centred in that early Eldorado, Transylvania.« (Evans 1929, 47 f.). This jewellery from Shaft Grave III is represented on Figure 20.

These pieces of gold jewellery to which the princesses »clung« suggest that at least some of the females buried in the Shaft Graves were foreign. This is a very interesting conclusion in view of the recent strontium isotope research conducted on the teeth of the individuals from Shaft Graves III and V (Nafplioti 2009). Out of eleven individuals studied in this project three formed a group (B) that have strontium isotope compositions which by comparison with the local Mycenaean fauna, and the other skeletons in the Shaft Graves, indicate them as non-locals at Mycenae. One of the skeletons in this group was a female from the Shaft Grave III (Nafplioti 2009, 286; 289).

At this point one can ask if the story of these gold and silver rich graves is connected with the forays of the Mycenaean warriors into the region of Transylvania, bringing back many kilograms of gold and silver, and the brides. B. Hänsel (1977, 89) suggested that the rich ore sources of Baia Mare in Romania was the main focus of the Mycenaean forays into Transylvania. Further, it seems that some old elemental analyses of gold from the Shaft Graves might indicate its origin from Transylvania (Müller-Karpe 1998, 97 f.). This hypothesis might be supported by the EDXRF analysis of ten gold beads and two diadems from Mycenae from the collection of the Ashmolean Museum in Oxford that contain on average 16.0 % of silver and 0.2–4.0 % of copper (OXALID), because Hauptmann et al. (1995) published analyses of gold from Rosia Montana containing a similar average of 22.0 % for silver and < 0.5 % of copper. These results are in contrast with 180 EDXRF analyses of gold and electrum from Egypt in the collection of the Ashmolean Museum which show a much wider range of gold/silver/copper (OXALID). However, the recently excavated gold mine in south-east Bulgaria in Ada Tepe Hill in the Eastern Rhodopes, near the town of Krumovgrad should also be considered as the source of Mycenaean gold (Popov 2012).

The long-running lead isotope research into the origin of metals in the Mediterranean Bronze Age indicates that the sources of copper, lead and silver in the eastern Mediterranean were quite sufficient for the local economy (Stos-Gale 2000). Copper from Lavrion and Cyprus was predominantly used in the Aegean in the Late Bronze Age. Silver was extracted from the silver rich ores mined in Lavrion and Siphnos in the towns on the islands of Kea, Thera and Crete, with lead being also produced in large quantities. However, with the introduction of tin-copper alloy, i. e. bronze, as the most advanced material for tools and weapons the lack of tin in the region must have been of great importance. Most of the search for tin sources for the Bronze Age eastern Mediterranean metallurgy is directed towards the Near and Middle East[3]. There are also, frequently repeated in the literature, theories of Mycenaeans getting tin from Cornwall. However, much closer to the Aegean are the geologically well-known tin ores in the western Carpathians (Beran/Sejkora 2006) and in the Erzgebirge, where, for example, historical records show that tin has been exploited in Ehrenfriedersdorf since 1248 AD and was still carried out in 1986 (Baumann et al. 1986, 315–318). Unfortunately, there is no evidence at present of the Bronze Age exploitation of these deposits, but their significance cannot be underestimated as a possible source of this important ingredient of bronze and a possible magnet for the Mycenaeans in their foreign exploits.

It seems also significant that silver with the lead isotope ratios consistent with the Transylvanian ores was found amongst all groups of vessels from different graves and also from other Mycenaean sites, not only from Mycenae. This result shows that the supply of silver from Transylvania to Peloponnesus was a continuous activity for over more than 100 years, rather than just one expedition in the 16th century BC. My suggestion is that this imported silver was perhaps just a by-product of a lucrative import of tin and gold from the Carpathians. Other luxury items might have also travelled this way: for example, salt (Dietrich 2010) and amber. It has been suggested that the Mycenaeans were producing large amounts of wool, which could have been exchanged for these goods that were lacking in the Aegean. Therefore, the wealth of the Mycenaean kings might have originated from two main trading networks: the short distance, basically Aegean trade in copper, lead and silver from Lavrion, and the long-distance forays into the Carpathians for tin, gold and salt. Perhaps further research will reveal more evidence of this extended network.

3 Muhly 1973; 1976; Yener et al. 1989; Pernicka et al. 2011.

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10	Karo 1930/33, 110–112; Taf. CXXVII
11	Karo 1930/33, 119; Taf. CXXVIII
12–13	Karo 1930/33, 150
14	Karo 1930/33, 151
15	Isotrace Laboratory archive, Oxford
16–19	author
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Bislang erschienene Bände in der Reihe »Tagungsbände des Landesmuseums für Vorgeschichte Halle«

Die Reihe der Tagungsbände des Landesmuseums wurde 2008 ins Leben gerufen. Anlass dazu war die Konferenz »Luthers Lebenswelten«, die im Jahr 2007 in Halle ausgerichtet wurde. Bereits der zweite Tagungsband widmete sich mit dem Thema »Schlachtfeldarchäologie« dem Mitteldeutschen Archäologentag, der seit 2008 jährlich von Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt veranstaltet und zeitnah publiziert wird. Dem großen Anteil internationaler Autorinnen und Autoren entsprechend, erscheinen viele Beiträge dieser Reihe in englischer Sprache mit deutscher Zusammenfassung.

Mit dem bislang zuletzt erschienenen Tagungsband konnten die Vorträge und Posterpräsentationen des 5. Mitteldeutschen Archäologentags »Rot – Die Archäologie bekennt Farbe« in zahlreichen Artikeln renommierter Forscher verschiedenster Fachdisziplinen vorgelegt werden.

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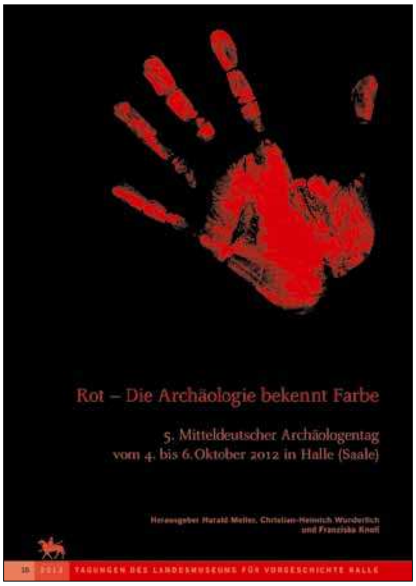

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