The Organization of Mining and Metal Production in Aegean Thrace from the Archaic to the Roman Period

Nerantzis Nerantzis – Sabine Nodin – Stratis Papadopoulos

Abstract

The significant metal deposits of the North Aegean were renowned in the ancient world through mentions in myths and historical accounts. Long before the arrival of the Greeks in the Thracian littoral, the processing of minerals to produce copper, lead-silver, and the collection of alluvial gold was common among the native populations. With the gradual establishment of Greek colonies and *emporia* in the Archaic period, an increase in mineral exploration and metal production is manifested by relevant archaeological findings. Interdisciplinary research in this region was initiated in the early 1980's when several mining shafts and metallurgical sites were located across Mount Pangaeon and the Lekani mountain range. In recent years renewed interest on the study of mining landscapes in Aegean Thrace combined with new excavation projects brought about important new information. This paper discusses the issue of mining and metallurgical activity across this region from the Classical to the Roman period in light of recent archaeological data. The ongoing excavation project at Pistyros (Pontolivado), a Thasian *emporion* west of the Nestos estuary, has yielded large volumes of metallurgical slag. Initial examination has confirmed that these residues derive from the reduction of iron ores in furnaces and forging of the blooms, as well as copper and lead/silver extraction dating to the Classical and Hellenistic periods. While the evidence for mining exists at various localities in the Lekani, presumably in Thracian territory, secondary processing and the manufacture of objects was achieved within this Greek fortified site. In this context, accessing, controlling, and negotiating mineral resources among the indigenous Thracian populations and the inhabitants of the Greek settlements are fundamental in understanding the organization of metals production in the North Aegean.

Introduction

The north Aegean is a region well-known for its mineral wealth, with abundant evidence for mining and metal production over long periods of time. Ancient literary sources such as Herodotus,[1] Thucydides[2] and Strabo[3] refer to extensive gold and silver extraction undertaken by local Thracian tribes and Greek colonists alike. Until recently, limited studies have focused on establishing a detailed chronology for the emergence and gradual development of this strategic technology, crucial for economic expansion in the ancient world. Archaeological research of the last twenty years provided proof for the earliest stages of this metallurgical tradition, which emerged in the Late Neolithic

Published in: Frank Hulek – Sophia Nomicos (Eds.), Ancient Mining Landscapes, Panel 4.2, Archaeology and Economy in the Ancient World 25 (Heidelberg, Propylaeum 2022) 65–84. DOI: *https://doi.org/10.11588/propylaeum.896.c11647*

with the extraction of copper and silver; this was further consolidated and expanded during the Early Bronze Age. Most of the studied evidence consists of small assemblages of copper production residues deriving from the prehistoric settlements of Promachon-Topolnica,[4] Sitagroi,[5] Dikili Tash[6] on the mainland, Limenaria[7] and Aghios Antonios[8] on Thasos, and Mikro Vouni on Samothrace. For the periods after the Greek colonization, the evidence becomes more substantial, with large mining regions featuring underground tunnels, installations for ore enrichment, voluminous heaps of metallurgical slag, and the increasing deposition of metal artefacts in settlements and cemeteries.

Some early attempts to investigate the organization of metal extraction in antiquity were initiated in the 1980's, when several mining and metallurgical sites were located across Mount Pangaeon, the Lekani mountain range, and Thasos. The then IH΄ Ephorate of Antiquities and the Institute for Geological and Mineral Explorations (IGME) were responsible for these pioneering efforts to locate and document the evidence in the field.[9] At the same time, ancient literary references to mining and metal production were studied in detail, given their potential to complete our knowledge. In recent years it became clear that trying to understand the technical developments in transforming minerals into metals involves examining the social organization and cultural context within which the communities of the region interacted with their natural environment.[10] Thus, further issues have started being addressed such as settlement patterns, the organization of space as a reflection of social relationships, degrees of social stratification directly linked to labor division, and the scales of specialization in crafting.[11] An approach that introduces the concept of productive landscapes is more precise at explaining the long term interaction of human communities within certain environmental settings.

Colonization and Metals Production in the North Aegean

Colonial expeditions of the Archaic period brought Greeks of the Aegean islands and Asia Minor to the Thracian shores, which were renowned for their riches from earlier contacts in the Mycenaean period.[12] In general, an increased interest in this region is manifested especially around the end of the 6th century and throughout the Classical period until the Macedonian conquest. This interest was related to precious metals, fertile agricultural land, and the thickly wooded territories exploited for their timber.[13] The major settlements that were established were colonies and *emporia* that formed a broad network across the littoral. They often had conflicting interests, and occasional alliances and hostilities with the local Thracian populations inhabiting the hinterland (fig. 1). This colonial system was characterized by certain means of production that were necessary to fuel their economic expansion in new territories by appropriating natural resources.[14] Its success was based on a capacity to adapt to the given settings by incorporating the indigenous labor force in the exploitation of resources and the

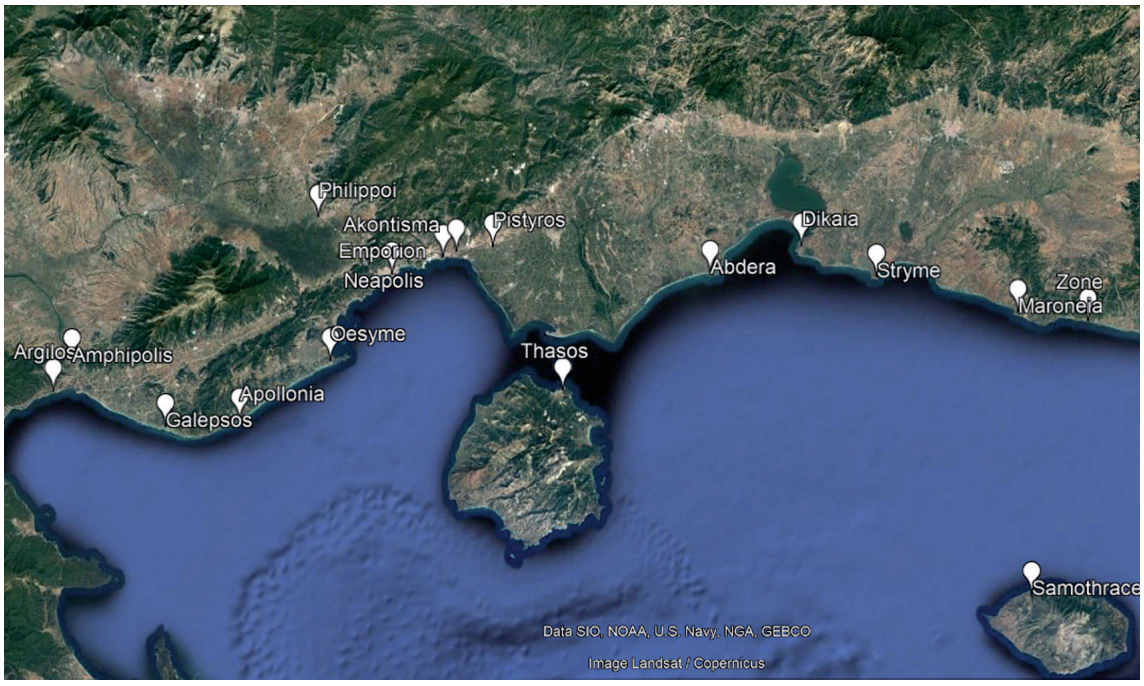

Fig. 1: Map of the region showing the major colonies and *emporia.*

local elites into this system of controlling production and consumption. The striking of silver coins in a number of mints across this region is a clear indicator of either direct or indeed negotiated access to precious metals.[15] Therefore, this region represents a characteristic case study for approaching the organization of mining and metallurgy, particularly through the co-existence of producer and consumer populations representing diverse cultural backgrounds.

Around the first third of the 7th century BC an expedition of Parian colonists was established on Thasos, where they founded a permanent settlement, while seeking to expand on the opposite shores.[16] Archilochos clearly mentions that the local inhabitants held control of the rich metal resources on the island, and Herodotus later mentioned their gold mines between Ainyra and Koinyra.[17] Gold was also mined near the acropolis at the outskirts of the Thasian metropolis but except for the mining galleries, limited data for gold working have been studied so far.[18] Yet, it is the large-scale extraction of argentiferous lead ores that left behind substantial material evidence (fig. 2) on the western part of the island, which was studied by an interdisciplinary project directed by the Max-Plank Institute for Nuclear Physics of Heidelberg and Bergbau Museum in the 1980's.[19] Moreover, based mainly on numismatic evidence, researchers have suggested that silver mining on Thasos witnessed two peaks, the first between 500 and 410 and the second around 370–310 BC.[20] A third peak in Thasian silver extraction has been suggested for the Roman period. In all these phases it is not clear if the labor force was drawn from a local population of the island working under colonial administration or

Fig. 2: Slag heap at Skoridia, western Thasos from the smelting of argentiferous lead ores.

if indeed slaves were brought from elsewhere. Whatever the case, a large number of laborers would have been necessary in the mines and processing workshops for the purification of silver and gold. On the Thracian littoral, the expansion of the Thasians was focused on the mineral-rich region of Lekani, described by Appianus as the mount of the *Sapaioi.*[21]

The evidence from further inland, around Mount Dysoron and the Rhodope mines in modern-day Bulgaria, suggests that Thracian silver and gold was exported but not minted as coin until later in the 4th century BC. Therefore, during the early phase of Greek colonial expansion, it is certain that some of the mines on the mainland were under the control of local tribes,[22] but it is unclear to what extent the Thracian tribes mined, extracted, and minted the silver. Some scholars tend to see the Thracian side as rather passive[23] or alternatively as striking their silver coinage in Greek mints as part of a deal for access to the mineral resources. But Thracian communities or powerful individuals who had both precious resources and access to international trade might have been interested in adopting the technologies of refining silver and striking coins.[24] As suggested by the numismatic evidence, the shared coin types between Thracian groups have given rise to a number of theories ranging from monetary and military alliances to a less formal co-operation in the use of mines or mints. Cooperative mining based upon arrangement between parties could account for the simultaneous minting of tribal, civic, and royal coinages in the region of the Strymon at a time when only the mines of Dysoron, Prasias and Pangaeon were operative.[25]

This reciprocal relation is reflected in the cases of Maroneia, founded by Chian colonists, and Abdera founded by Klazomenians and Teians in the 7th century BC. The circulation of silver coins struck in Maroneia by the end of the 6th century BC and the payment of increased tribute to the Delian League from 454 BC suggest that the city had access to a mining zone, possibly within its *chora.* Alluvial gold was most probably exploited along the course of rivers Lissos and Makropotamos and the region of Xylagani, where gold grains are found isolated or hosted in quartz bodies and iron-pyrites.[26] Remains of underground exploitations have been located at various sites mainly in the region of Konos-Kassitera in the form of mining galleries for the extraction of auriferous and argentiferous ores.[27] At a locality known as Ktismata, south of the Aghios Georgios hilltop, mining activity on a ferromanganese deposit has been identified and studied to a preliminary degree. Small-scale mining was conducted through a vertical shaft with three helicoidal galleries; analysis of the mineralization revealed high sulfide contents.[28] Pottery finds date these traces of exploitation to the 2nd century BC, suggesting that mining in the wider region of Maroneia was an important activity for at least 400 years. An expertise of the Maronitans in mining technology is echoed in a passage by Harpocration, who mentions a rich silver-bearing lode at Laurion that the Athenians named Maroneia possibly due to its exploitation by miners from Thrace.

In Abdera the striking of silver and gold coinage starts from 520/515 BC and the city's tribute to the Delian League demonstrates that the Abderitans also had access to precious metals. Within the *chora* of Abdera, its limestone and granite geology does not contain any significant mineral deposits and the closest source of precious metals lies near the modern village of Kimmeria to the north. This mining zone contains magnetite, iron-pyrite and chalcopyrite containing precious metals in significant contents.[29] It lies well within Thracian territory, highlighting again a reciprocal situation or a shared exploitation of metal resources between locals and colonists.

Moving on to the west of river Nestos and toward the Strymon estuary, we will focus our attention on the mineral-rich region where Thasian expansion was consolidated in the Classical period.[30] This extended coastal zone became known as the Thasian 'continent' and included the major colonies of Neapolis, Oesyme and Galepsos and smaller *emporia* such as Antisara, Akontisma, Pistyros and Skapte Hyle.[31] Ancient historians inform us that the Thasians extracted a large output in precious metals from the island and their mainland colonies until the Athenians took control of their mines (465 BC). Although the zone occupied by the Thasians is bound between the Aegean and the Lekani and Symvolo mountains, their sphere of influence appears to have extended beyond the southern foothills and into the mineral-rich uplands. According to Herodotus, during the Persian Wars the mines of Mount Pangaeon were exploited by the indigenous Thracian tribes, the Pieres, Odomantoi and Satres.[32] Since the Thasians had not penetrated the hinterland near Mount Pangaeon, their claims on mineral deposits should have stretched directly north of their coastal colonies on the hills that offered visibility to Thasos across the Lekani and Symvolo mountains.[33]

Geological prospection across this region has confirmed the existence of a rich mineralization bearing precious and base metals often associated with signs of ancient and more recent exploitation.[34] In particular, a large number of underground galleries with associated shafts and adits have been recorded at Lekani, with the most prominent ones located near the modern villages of Makrychori, Perni, Petropigi, Lefki, Anestias, Chalkero, Palaia Kavala, Kryoneri and Zygos.[35] The extracted metal-bearing ores were mainly contained in iron deposits of hydrothermal origin, which occurred in association with manganese and other metals such as lead, zinc, arsenic and copper with significant contents of silver and gold. Since mining is an activity that was continuous, often spanning many centuries, the exact dating of various extraction phases is often problematic, mainly due to the obliteration of earlier evidence by more recent interventions. In a few cases, the shape of the galleries and extraction techniques hint to their dating in antiquity but in many localities the re-opening of ancient mines in the Ottoman period has obscured issues of chronology.[36] In similar terms, the metallurgical waste that forms large heaps of accumulated material over centuries is notoriously difficult to date as the latest phases covered or significantly disturbed older material.

Thasian Settlements and Metal Production in Southeastern Lekani: a Case Study

The region of the southern and southeastern Lekani in the prefecture of Kavala offers a unique opportunity to study metallurgy in a relatively clear chronological framework. This is mainly due to the existence of three colonial settlements of the Thasians and numerous locations with ancient mining and mineral processing evidence. A Thasian *emporion* that was established in the late 7th century BC is located near the modern village of Pontolivado and has been identified as Pistyros based on literary sources and relevant finds.[37] The site was discovered in 1971, but the recent systematic excavation initiated in 2014 has yielded large volumes of metallurgical slag representing direct proof for large-scale metallurgical practices.[38] It is important to note that this fortified *emporion* lies within short distance of a mining zone towards the northeast and northwest spreading across a radius of 8 km. About 5 km due west of Pistyros there are two more Thasian settlements both established in the 6th century BC that flank the modern village of Nea Karvali. They were investigated by Koukouli-Chrysanthaki, who suggested that the eastern one should be identified as Akontisma, while the second to the west remains unidentified.[39] The former is situated at the southern extremity of the mountain range controlling the entrance to the valleys of Anestias and Lefki towards the north, which are particularly rich in metallurgical evidence; the latter directly controlled the shipping of goods through a port.[40] The narrow zone where the three settlements were established, interlocked between the foothills and the sea, was certainly controlled by the Thasians at least until the Classical period as suggested by the finding

Fig. 3: Mine entrance west of Perni in the Lekani mountain range.

of numerous amphorae, coinage, and other finds. The mountain range to the north was inhabited by the Thracian tribe of the Sappaioi and the mining zone was within their territory.[41]

The southern foothills about 4.2 km northeast of Pistyros, between the modern villages of Perni and Petropigi, yielded evidence for surface and underground mining, as well as the primary processing of the ores.[42] During our recent field survey we confirmed the presence of iron mineralization, consisting mainly of goethite-limonite and secondary copper ores; according to previous geological research these contain significant amounts of precious metals.[43] An underground mine with a single entrance and narrow galleries of square profile measuring 1 × 1 m and running for a length of 150–200 m is located about 2 km west of the modern village of Perni (fig. 3). The tool-marks on the gallery walls made by miner's picks and hammers, as well as the characteristic profiles suggest a relative dating between the Classical and Hellenistic periods. Near the mine entrance there is abundant evidence for crushed hematite/goethite as well as stone slabs bearing tool marks caused by crushing, punchers, and pounders.

More substantial mining evidence comes from the valley that stretches north of Pistyros towards the modern village of Makrychori, located about 7 km to the northwest. Geological prospection has identified three mining locations that were opened to exploit the mixed sulphide deposits of Fe, Mn, Pb and Zn that contain significant levels of gold and silver.[44] The hills to the west and northwest of Makrychori are covered by numerous slag heaps across an extended area, suggesting an important locality for smelting the ores extracted in the above-mentioned mining locations (fig. 4). Based on pottery dating from the 4th to the 2nd century BC and the Roman period, at least part of these slag deposits should belong to antiquity. However, the largest volumes possibly

Fig. 4: Makrychori, mining location and metallurgy site, Lekani mountain range.

belong to the Ottoman period, when re-melting of ancient slag was practiced.[45] The presence of pottery, including Thasian amphorae and other domestic finds such as spindle-whorls, millstones, and mortars between the slag heaps and the village suggest the existence of some sort of a settlement that had developed to sustain the workforce or possibly a tower for controlling the operations as similar examples from Thasos suggest.

Our recent prospection in the valley of Anestias, 3.4 km northwest of Akontisma, resulted in finding a plateau by the banks of a stream where the processing and beneficiation of ores by crushing and grinding took place. The spot is reported by earlier researchers of the region, who located for the first time three large marble slabs bearing deep grooves or sluices (fig. 5) and interpreted these finds as structures for washing mineral ores.[46] This interpretation was based on similar finds that are known from Laurion, which were seen in conjunction with the rectangular washeries when they were discovered in the 1970's; together they were interpreted as helicoidal washeries used in the enrichment of argentiferous lead ores.[47] Initially, three such structures were found at Megala Pefka, Demoliaki and Bertseko, while more recently three more were discovered in better preservation at Ary II, III and IV.[48] In light of these new discoveries an alternative interpretation has been put forward whereby these structures are seen

Fig. 5: Marble slab with ridges, part of an edge runner mill at Anestias, Lekani mountain range.

as large, circular mills for crushing and grinding rather than washing the ores.[49] They are referred to as edge runner mills, which are circular structures with indentations forming the tracks for large wheel-shaped mills that were turned around a stable axis at the center. Similar structures recently discovered at Samut in the mining region of the Eastern desert of Egypt were also interpreted as edge runner mills.[50] It is worth mentioning that all such structures date to the Hellenistic period with no parallels predating or postdating this chronological horizon. Judging on the similarity of the finds from Anestias to the published examples, we suggest that they were used in the same manner for the grinding of the silver and gold bearing ores of the region, or the by-products such as litharge or slag to retrieve entrapped metals.

Once enrichment was complete, the next stage involved smelting the ores in furnaces. This stage is well attested by the residues or by-products of such a process, namely the metallurgical slag. A large volume of such material is being recovered from the ongoing excavation at Pistyros and our study aims at reconstructing the various metallurgical processes that took place. It is important to note in this context that several pieces of millstones were found during excavation within the layers that yielded metallurgical slag. Thus, it could be suggested that the last stages of ore beneficiation were probably practiced on site. A preliminary examination of these finds helped to identify a fragment of a rotative hand-mill, a type that was used in industrial applications (particularly the grinding of ores) in the late Hellenistic and Roman periods. A detailed study of crushing and grinding tools from the museum of Thasos[51] has not yielded a millstone of this type used for this particular use and makes this the first known example so far in this region.

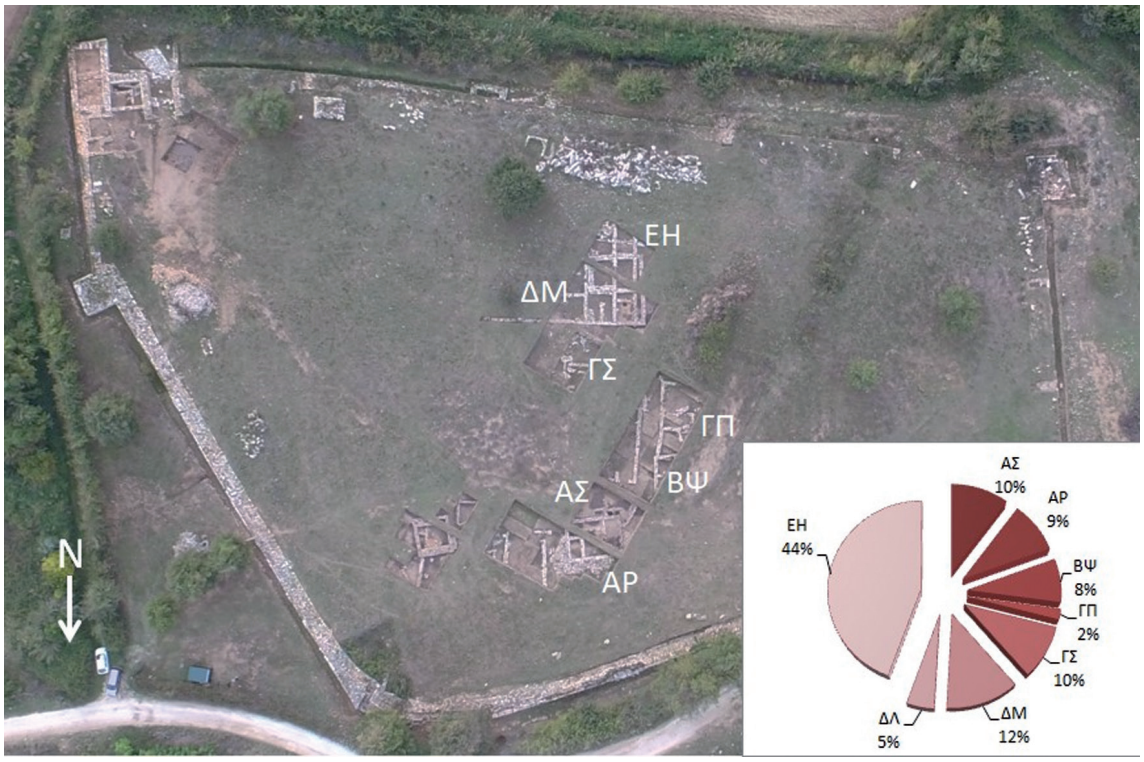

Fig. 6: Aerial photograph of Pistyros showing excavated trenches. The graph shows the relative abundance of metallurgical slag per excavated trench (Study seasons 2016–2017, total number of counted pieces: 2841).

The Thasian material consists of two types common for this particular period: Olynthian and giratory millstones. Therefore, based on our preliminary observations, the pre-treated ores that were transported to Pistyros were further processed and enriched; then they were introduced to the furnaces for extracting precious metals in addition to copper and iron that were also produced.

The metallurgical residues recorded so far (study seasons 2016 and 2017) derive from the surface and upper layers of the urban core (fig. 6). Substantial amounts derive from the destruction layer covering a building in the northern sector (trenches ΑΣ, ΑΡ) and a road with a north-south orientation (trenches ΓΠ, ΒΨ). They show a greater concentration in trench ΕΗ, which lies at a central area towards the south: its four squares (ΕΗ1–ΕΗ4) yielded 44% of the recorded material. This large volume of slag and a few furnace fragments were found associated with a complex building with multiple rooms of at least two architectural phases that dated to the 2nd century BC (fig. 7). Three areas with severely heated surfaces of reddish clay were revealed in proximity to wall corners of the southern rooms. Excavation of a circular, stone-built structure, filled with copper slag, is ongoing in order to elucidate its function and examine the possibility of any metallurgical associations.

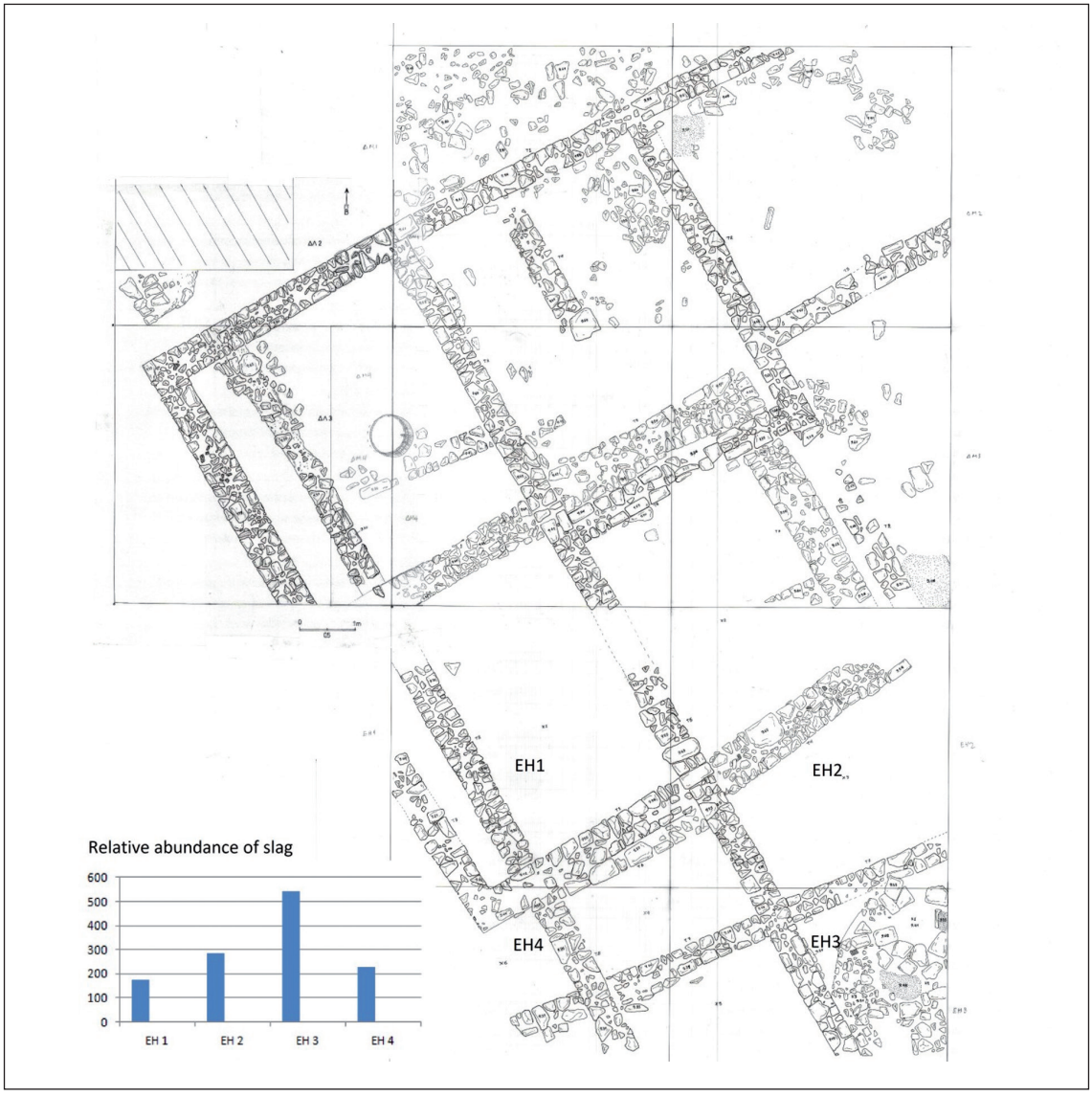

Fig. 7: Pistyros, plan of the Hellenistic building with metallurgical residues. Insert graph shows the relative abundance of slag pieces per square in trench EH (square EH3 yielded over 500 pieces).

A preliminary examination of the residues from the central trenches provided some clues regarding the main metallurgical processes represented here. Thus, the great majority of finds consists of smelting slag deriving from the reduction of iron, copper, and to a lesser extent, lead-bearing ores possibly associated with the Eastern Lekani deposits that contain such mineral assemblages.[52] Certain indicative characteristics such as oxidation crusts and surface inclusions were used to confirm the extraction of iron and copper, but prior to the analytical study more details are not available. The first category of iron smelting slag can be divided in two main subgroups: a) tap slag with ropey, flow patterns, and b) porous furnace slag. Another category of finds consists of forging or smithing slags deriving from the compaction of blooms and the fabrication of iron objects. Based on the preliminary assessment it could be suggested that forging was a common activity for producing blades, tools and various smaller objects. A third category consists of copper smelting slag, which were identified by the characteristic green-colored nodules of copper oxide minerals on their surface. A fourth category of finds is related to the processing of lead-containing minerals. These latter residues appear to derive from an initial smelting stage targeting to purify the ores from the gangue minerals. It is highly possible that if the lead contained appreciable silver contents, a second stage of separation would have been attempted on site. For the moment, no litharge fragments deriving from such a secondary process have been noted but only a small percentage of the finds has been recorded so far. It could be suggested that lead/silver separation through a cupellation stage took place on site or in the vicinity but for the moment the evidence is inconclusive. With the continuation of the macroscopic study and the subsequent instrumental analysis more substantial data will become available in order to better understand the processes by which metals were produced at Pistyros.

Conclusions and Prospects

Examining the geographical distribution of resources, mining evidence, and the sites where metallurgy was practiced helps to better understand the various stages of producing metals as steps in a dynamic process enacted within the landscape.[53] A hypothetical model for the organization of metal production across the Lekani is presented in fig. 8. The first stage of extracting the ore by underground mining was achieved at several localities, depicted as stars in the figure. The stage of enrichment by sorting, crushing, grinding, or washing is not always evident but should have taken place either near the mines or near the slag heaps, where smelting of the ores was conducted in furnaces. Access to water and fuel were equally important determining parameters as was access to minerals. West of Perni there is evidence for underground mining and exploitation of the surface mineralization, with evidence for crushing; no evidence for beneficiation or smelting is known in the vicinity. The valley of Anestias and the

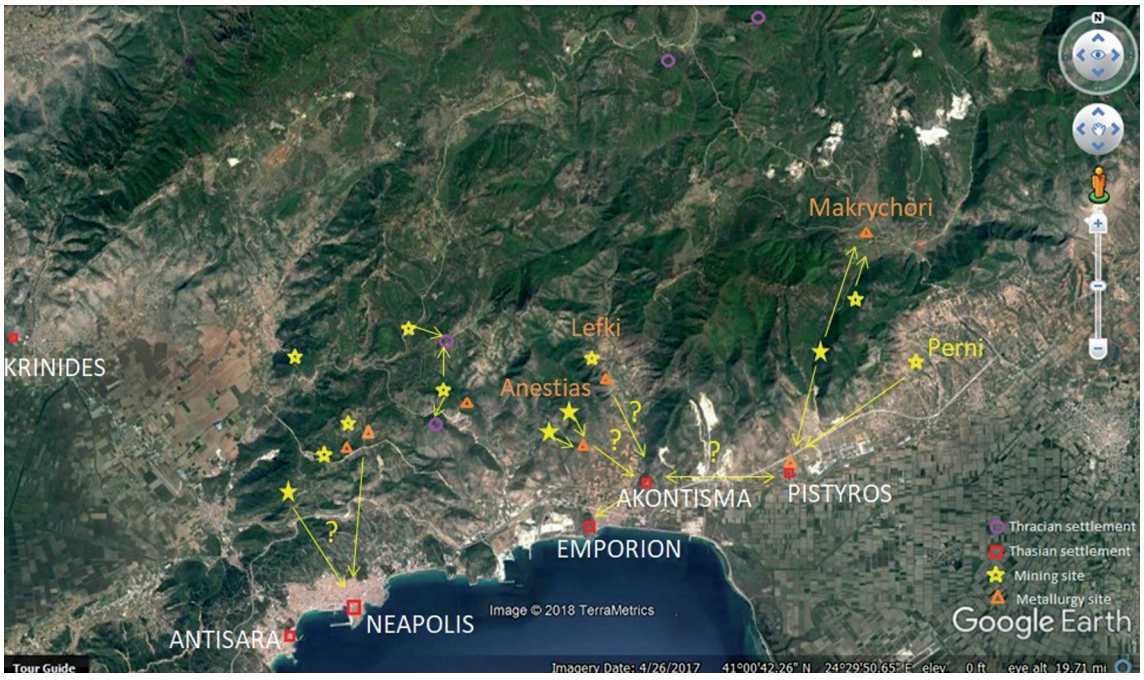

Fig. 8: Hypothetical model for the organization of metals production at Lekani.

nearby valley of Lefki have also yielded mining evidence, while the processing of the ores by grinding was conducted with edge runner mills as suggested by the relevant finds presented above. Small-scale smelting was also practiced near the processing sites (as suggested by the few pieces of slag), but it seems that the processed ores were transported somewhere else for the crucial stage of precious metal extraction, possibly in a centrally administered site under state control.[54] Thasian amphorae were found among the slag heaps at Makrychori and there were certain technological similarities of the metallurgical processes to those found in Pistyros. Thus, it could be argued that at least for a certain period in the Late Hellenistic and Roman times, both sites were producing metals simultaneously. Taking all the evidence together it appears that a chain of operations linking the described sites was enacted on a large-scale, with the valleys that had a north-south orientation playing a crucial role in the organization of production. Addressing consumption patterns is also important to better understand the demand that influenced production rates. Therefore, it is necessary to examine how metals were consumed in the Thracian littoral and in what cultural contexts.

Recent research in the broader region, particularly the numerous mining and smelting sites on Mount Pangaeon is already producing important results that add new information to our understanding of ancient metal production in northern Greece. The most important and extended mining area was located at Asimotrypes, where eight ancient mining adits have been recorded along a steep valley.[55] Further mining evidence comes from Mavrokorfi, while an important metallurgical center was established at Valtouda,

on the southern flanks. At the latter, copper, gold, and silver were extracted during the Roman period.[56] With power centralized in Roman times at the *colonia* of Philippoi and the major urban center of Amphipolis, mining intensified to meet increasing demands across the territories of Lekani and Pangaeon respectively. It is still premature to arrive at certain conclusions as to how Roman administration and local elites impacted the leasing of mining contracts to safeguard the uninterrupted extraction of silver and gold. Surely, conscious political control over resources and state legislation played an important role for the expansion and ultimate decline in mining activity by late Roman times. More interdisciplinary research in the future could help towards investigating the identity of miners, metal producers and craftsmen, as well as their living spaces and relations with the consumers from the vibrant urban centers of the Thracian littoral and beyond.

Acknowledgements

We would like to thank INSTAP for generously funding the Research Project: 'Early Metallurgy on Thasos and the Thracian mainland' directed by the first author. Special thanks go to Stavroula Dadaki, Director of the Ephorate of Antiquities of Kavala-Thasos for substantial help in the conduct of the Systematic Excavation at Pistyros.

Notes

[1] Hdt. 6, 46–47.

[2] Thuk. 1, 100; 4, 105.

[3] Strab. 14, 5, 28; 7, 331–334.

[4] Koukouli-Chrysanthaki – Bassiakos 2002.

[5] Renfrew – Slater 2003.

[6] Seferiadis 1992.

[7] Bassiakos 2012.

[8] Nerantzis et al. 2016.

[9] Koukouli-Chrysanthaki 1990; Photos et al. 1986; 1989.

[10] Knapp et al. 1998.

[11] Stöllner 2015; Nerantzis 2015.

[12] Bolohan 2005, 167; Baralis 2009, 102.

[13] Tiverios 2008; Papadopoulos 2014, 188.

[14] Archibald 2000.

[15] Picard 2006; Kosmidou 2011.

[16] Graham 1978; Blondé et al. 2002.

[17] Hdt. 6, 46–47.

[18] Kozelj – Muller 1988; Grandjean 1999.
[19] Wagner – Weisgerber 1988.
[20] Pernicka et al. 1981.
[21] App. civ. 4, 13, 103.
[22] Hdt. 7.112; Xen. hell. 11, 5, 2. 11–43.
[23] Loukopoulou 2007.
[24] Tzochev 2015, 421.
[25] Kosmidou 2011, 442.
[26] Triantafyllos 2009, 192.
[27] Triantafyllos 2009, 192.
[28] Papastamataki et al. 2001.
[29] Melfos et al. 2003, 1203.
[30] Koukouli-Chrysanthaki 1980; Zannis 2014.
[31] Koukouli-Chrysanthaki 1990.
[32] Hdt. 7, 112, 1.
[33] Koukouli-Chrysanthaki 1990.
[34] Fornadel et al. 2011; Melfos – Voudouris 2016, 158.
[35] Vavelidis et al. 1996; 1997a; 1997b.
[36] Nerantzis 2016.
[37] Koukouli-Chrysanthaki 1972; 1973; Zannis 2014, 171.
[38] Koukouli-Chrysanthaki et al. forthcoming.
[39] Koukouli-Chrysanthaki 1980.
[40] Nikolaidou 2009.
[41] Zannis 2014, 167.
[42] Koukouli-Chrysanthaki 1990.
[43] Vavelidis et al. 1997b.
[44] Photos et al. 1989; Fornadel et al. 2011.
[45] Koukouli-Chrysanthaki 1990, 507.
[46] Photos et al. 1989; Koukouli-Chrysathaki 1990.
[47] Conophagos 1980.
[48] Tsaimou 2005.
[49] Papadimitriou 2016; see also: Nomicos 2013 and Nomicos 2021, 50–57.
[50] Brun et al. 2013.
[51] Nodin 2016.
[52] Melfos – Voudouris 2016.
[53] Nerantzis 2015, 74.
[54] Nerantzis 2015, 75 f.; Nodin 2016, 150.
[55] Vaxevanopoulos et al. 2017.
[56] Vaxevanopoulos et al. 2018.

Image Credits

Fig. 1: source: Google Earth. – Fig. 2. 3: by the author. – Fig. 4: Photos with authors' credits, map source: Google Earth – Fig. 5–7: by the author. – Fig. 8: source: Google Earth

References

Archibald 2000

Z. H. Archibald, Space, Hierarchy and Community in Archaic and Classical Macedonia, Thessaly and Thrace, in: R. Brock – S. Hodkinson (eds.), Alternatives to Athens, Varieties of Political Organization and Community in Ancient Greece (Oxford 2000) 212–233.

Baralis 2009

A. Baralis, The Chora Formation of the Greek Cities of Aegean Thrace. Towards a Chronological Approach to the Colonization Process, in: P. Guldager Bilde – J. H. Petersen (eds.), Meetings of Cultures in the Black Sea Region: between Conflict and Coexistence, Black Sea Studies 8 (Aarhus 2009) 101–130.

Bassiakos 2012

Y. Bassiakos, Πρώιμη παραγωγή χαλκού και αργύρου στα Λιμενάρια Θάσου: Μια τεχνολογική προσέγγιση, στο Σ. Παπαδόπουλος και Δ. Μαλαμίδου (εκδ.), Πρακτικά Ημερίδας Δέκα Χρόνια Ανασκαφική Έρευνα στον Προϊστορικό Οικισμό Λιμεναρίων Θάσου (Thessaloniki 2012) 197–225.

Blondé et al. 2002

F. Blondé – A. Muller – D. Mulliez, Evolution urbaine d'une colonie à l'époque archaïque. L'exemple de Thasos, in: J.-M. Luce (ed.), Habitat et urbanisme dans le monde grec de la fin des palais mycéniens a la prise de Milet (494 av. J.-C.), Pallas 58 (Toulouse 2002) 251–265.

Bolohan 2005

N. Bolohan, The Danube, Balkans, and Northern Aegean. Trade Routes, Influences and Buffer Zones in the Late Bronze Age, in: R. Leffineur – E. Greco (eds.), EMPORIA, Aegeans in the Central and Eastern Mediterranean, AEGEUM 25 (Liège 2005) 161–170.

Brun et al. 2013

J.-P. Brun – T. Faucher – F. Tereygeol, L'or d'Égypte: L'exploitation des mines d'or dans le désert Oriental sous les Ptolémées, L'archéologue 126 (Les Albres 2013) 56–61.

Conophagos 1980

C. Conophagos, Το Αρχαίο Λαύριο και η Ελληνική Τεχνική Παραγωγής Αργύρου (Athens 1980).

Fornadel et al. 2011

A. P. Fornadel – P. G. Spry – V. Melfos – M. Vavelidis – P. Voudouris, Is the Palea Kavala Bi-Te-Pb-Sb ± Au District, Northeastern Greece, an Intrusion-related Ssystem? Ore Geology Reviews 39, 2011, 119–133.

Graham 1978

A. J. Graham, The Foundation of Thasos, BSA 73, 1978, 61–98.

Grandjean 1999
Y. Grandjean, Installations artisanales dans le Quartier de la porte du Silène à Thasos, in: Ch. Koukouli-Chrysanthaki – A. Muller – S. Papadopoulos (eds.), Thasos, matières premières et technologie de la préhistoire à nos jours, Actes du colloque international, Liménaria-Thasos, Septembre 1995 (Athens 1999) 161–169.

Knapp et al. 1998
A. B. Knapp – V. C. Pigott – E. W. Herbert, Social Approaches to an Industrial Past. The Archaeology and Anthropology of Mining (London 1998).

Kosmidou 2011
E. Kosmidou, Macedonian and Thracian Relations in Northern Greece after the Persian Wars with Particular Reference to the Coinage and Politics of Alexander I, Travaux de Symposium International les Livre. La Roumanie. L'Europe, Tome IV (Bucarest 2011) 439–452.

Koukouli-Chrysanthaki 1972
Ch. Koukouli-Chrysanthaki, Via Egnatia-Ακόντισμα, Αρχαιολογικά Ανάλεκτα εξ Αθηνών 5, 1972, 474–478.

Koukouli-Chrysanthaki 1973
Ch. Koukouli-Chrysanthaki, Ειδήσεις εκ της Θασίων Ηπείρο, Αρχαιολογικά Ανάλεκτα εξ Αθηνών 6, 1973, 230–240.

Koukouli-Chrysanthaki 1980
Ch. Koukouli-Chrysanthaki, Οι αποικίες της Θάσου στο Β. Αιγαίο. Νεώτερα ευρήματα, Α' Τοπικό Συμπόσιο στην Καβάλα 'Η Καβάλα και η περιοχής της', Ίδρυμα Μελετών Χερσονήσου του Αίμου (Thessaloniki 1980) 309–325.

Koukouli-Chrysanthaki 1990
Ch. Koukouli-Chrysanthaki, Τα "μέταλλα" της Θασιακής Περαίας, *Μνήμη Δ. Λαζαρίδη: Πόλις και Χώρα στην Αρχαία Μακεδονία και Θράκη, Πρακτικά Αρχαιολογικού Συνεδρίου* (Καβάλα 1986), Ελληνογαλλικές Έρευνες I (Thessaloniki 1990) 493–514.

Koukouli-Chrysanthaki – Bassiakos 2002
Ch. Koukouli-Chrysanthaki – Y. Bassiakos, Slagging Copper Production of the 5th Millennium: The Evidence from the Neolithic Settlement of Promachon-Topolnica (Eastern Macedonia, Greece), 8th EAA Annual Meeting (Thessaloniki 2002) 193 f.

Koukouli-Chrysanthaki et al. forthcoming
Ch. Koukouli-Chrysanthaki – S. Papadopoulos – A. Zannis, Η Πίστυρος της Αιγαιακής Θράκης, ΑΜΕΘ 30 (forthcoming).

Kozelj – Muller 1988
T. Kozelj – A. Muller, La mine d'or de l'acropole de Thasos, in: G. A. Wagner – G. Weisgerber (eds.), Antike Edel- und Buntmetallgewinnung auf Thasos, Der Anschnitt Beih. 6 (Bochum 1988) 180–197.

Loukopoulou 2007
L. D. Loukopoulou, The Thracian Bone of Contention, in: A. Iacovidou (ed.), Thrace in the Graeco-Roman World: Proceedings of the 10th International Congress of Thracology, Komotini–Alexandroupolis, 18–23 October, 2005 (Athens 2007) 339–343.

Melfos et al. 2003
V. Melfos – M. Vavelidis – K. Bogdanov, Occurrence, Mineralogy and Chemical Composition of Primary Gold from Tertiary Ore Mineralisations in the Rhodope Massif (Greece-Bulgaria), in: D. G. Eliopoulos (ed.), Mineral Exploration and Sustainable Development (Rotterdam 2003) 1201–1204.

Melfos – Voudouris 2016
V. Melfos – P. Voudouris, Fluid Evolution in Tertiary Magmatic-hydrothermal Ore Systems at the Rhodope Metallogenic Province, NE Greece. A Review, Geologia Croatica 69, 2016, 157–167.

Nerantzis 2015
N. Nerantzis, Rhesos' Gold, Heracles' Iron: the Archaeology of Metals Exploration in Northeast Greece (Glasgow 2015).

Nerantzis 2016
N. Nerantzis, Pre-Industrial Iron Smelting and Silver Extraction in North-eastern Greece: An Archaeometallurgical Approach, Archaeometry 58, 2016, 624–641.

Nerantzis et al. 2016
N. Nerantzis – Y. Bassiakos – S. Papadopoulos, Copper Metallurgy of the Early Bronze Age in Thassos, North Aegean, Journal of Archaeological Science: Reports 7, 2016, 574–580.

Nikolaidou 2009
M. Nikolaidou, Έλληνες και Θράκες στα όρια της Θασιακής Περαίας: Δυο περιπτώσεις εγκατάστασης, in: Z. Bonias – J. Perreault (eds.), Greeks and Thracians in Coastal and Inland Thrace During the Years Before and After the Great Colonization (Thasos 2009) 83–96.

Nodin 2016
S. Nodin, L'outillage lithique dans la minéralurgie grecque à partir de l'exemple de Thasos (unpublished Master Dissertation, University of Lille 3).

Nomicos 2013
S. Nomicos, Laurion: Some Remarks on the Settlement Pattern and the "Helicoidal Washeries", Metalla 20/2, 2013, 25–27.

Nomicos 2021
S. Nomicos, Laurion. Montan- und siedlungsarchäologische Studien zum antiken Blei-Silberbergbau. Raw Materials, Innovation, Technology of Ancient Cultures RITaK 7. Der Anschnitt Beiheft 44 (Bochum 2021).

Papadimitriou 2016
G. D. Papadimitriou, The so-called 'helicoidal' Ore Washeries of Laurion: their actual Function as Circular Mills in the Process of Beneficiation of Silver and Lead Contained in Old Ltharge Socks, in: E. Photos-Jones (in collaboration with Y. Bassiakos – E. Filippaki – A. Hein – I. Karatasios – V. Kilikoglou – E. Kouloumpi (eds.), British Archaeological Reports S2780, Proceedings of the 6th Symposium of the Hellenic Society for Archaeometry, BARIntSer 2780, 2016, 113–118.

Papadopoulos 2014
J. K. Papadopoulos, Greece in the Early Iron Age: Mobility, Commodities, Polities and Literacy, in: A. B. Knapp – P. van Dommelen (eds.), The Cambridge Prehistory of the Bronze and Iron Age Mediterranean (Cambridge 2014) 178–195.

Papastamataki et al. 2001

A. Papastamataki – B. Orphanos – D. Demetriou – D. Triantafyllos – Ch. Karadima, Ένα άγνωστο μεταλλείο στη Μαρώνεια Κομοτηνής, in: Y. Bassiakos – E. Aloupi – Y. Facorellis (eds.), Archaeometry Issues in Greek Prehistory and Antiquity, Athens Hellenic Society of Archaeometry and Society of the Messenian Archaeological Studies (Athens 2001) 617–631.

Pernicka et al. 1981

E. Pernicka – W. Gentner – G. A. Wagner – M. Vavelidis – N. H. Gale, Ancient Lead and Silver Production on Thasos, Greece, Actes du 20e Symposium international d'archéométrie, Paris 26–29 mars 1980 (Rennes 1981) 227–237.

Photos et al. 1986

E. Photos – Ch. Koukouli-Chrysanthaki – G. Gialoglou, Extractive Iron Metallurgy on Thasos and the East Macedonian Mainland, in: R. E. Jones – H. W. Catling (eds.), Science in Archaeology, Proc. Meeting held at the British School at Athens. Fitch Laboratory Occasional Paper 2 (Athens 1986) 43–47.

Photos et al. 1989

E. Photos – Ch. Koukouli-Chrysanthaki – R. F. Tylecote – G. Gialoglou, Precious Metals Extraction in Palaia Kavala, NE Greece, An Archaeometallurgical Attempt to Locate Skapte Hyle. International Old World Archaeometallurgy Conference, Der Anschnitt (Heidelberg 1989) 179–190.

Picard 2006

O. Picard, Mines, monnaies et impérialisme: conflits autour du Pangée (478–413 av. J.-C), in: A. M. Guimier-Sorbets – M. B. Hatzopoulos – Y. Morizot (eds.), Rois, cités, nécropoles: institutions, rites et monuments en Macédoine:actes des colloques de Nanterre (Décembre 2002) et d'Athènes (Janvier 2004). Centre de Recherches de l'antiquité Grecque et Romaine, Fondation Nationale de la Recherche Scientifique, Meletemata 45 (Paris 2006) 269–283.

Renfrew – Slater 2003

C. Renfrew – E. Slater, Metal Artefacts and Metallurgy, in: E. S. Elster – C. Renfrew (eds.), Prehistoric Sitagroi: Excavations in Northeast Greece, 1968–70, 2. The Final Report, Monumenta Archaeologica 20 (Los Angeles 2003) 302–311.

Seferiadis 1992

M. Seferiadis, Le Metal, in: R. Treuil (ed.), Dikili Tash: Village Prehistorique de Macedoine Orientale 1. Fouilles de Jean Deshayes (1961–1975), BCH Suppl. 24 (Athens 1992) 113–119.

Stöllner 2015

T. Stöllner, Mineral Resources and Connectivity in the Mediterranean and its Hinterland, in: A. Lichtenberger – C. von Rüden (eds.), Multiple Mediterranean Realities, Current Approaches to Spaces, Resources and Connectivities, Mittelmeerestudien 6 (Paderborn 2015) 121–148.

Tiverios 2008

M. Tiverios, Greek Colonisation of the Northern Aegean, in: G. Tsetskhladze (ed.), Greek Colonisation An Account of Greek Colonies and other Settlements Overseas, 2 (Leiden 2008) 1–154.

Tsaimou 2005

K. G. Tsaimou, Νέα στοιχεία για την εμπλουτιστική διαδικασία των αργυρούχων μεταλλευμάτων στο αρχαίο Λαύριο, Mineral Wealth 137, 2005, 19–28.

Tzochev 2015

Ch. Tzochev, Trade, in: J. Valeva – E. Nankov – D. Graninger (eds.), A Companion to Ancient Thrace (Malden 2015) 412–425.

Vavelidis et al. 1996

M. Vavelidis – G. Gialoglou – G. A. Wagner – B. Melfos, Σκαπτή Ύλη: Ένα αρχαίο μεταλλείο χρυσού στην τοποθεσία Μάνδρα Καρή, Παλιάς Καβάλας. Proceedings of the 2nd Symposium Hellenic Archaeometric Society (Thessaloniki 1996) 23–35.

Vavelidis et al. 1997a

M. Vavelidis – G. Christofidis – V. Melfos, Αρχαία μεταλλευτική δραστηριότητα στην ευρύτερη περιοχή Καβάλας-Φιλίππων. Αρχαία Ελληνική Τεχνολογία, Πρακτικά του 1ου Διεθνούς Συνεδρίου (Thessaloniki 1997) 95–101.

Vavelidis et al. 1997b

M. Vavelidis – G. Christofidis – V. Melfos, Ancient Gold Mines near Krinides in Philippi Area (Macedonia, N. Greece), Archaeometrie und Denkmalpflege (Wien 1997) 84–86.

Vaxevanopoulos et al. 2017

M. Vaxevanopoulos – M. Vavelidis – D. Malamidou – V. Melfos, Ανασκαφική έρευνα σε αρχαία μεταλλεία και μεταλλουργικές θέσεις του όρους Παγγαίου (Ασημότρυπες, Βαλτούδα), ΑΕΜΘ 26 (Thessaloniki 2012) 547–552.

Vaxevanopoulos et al. 2018

M. Vaxevanopoulos – M. Vavelidis – V. Melfos – D. Malamidou – S. Pavlides, Ancient Mining and Metallurgical Activity at the Gold-silver-copper Ore Deposits in Mavrokorfi Area, Mount Pangaeon (Northeast Greece), in: E. Ben-Yosef (ed.), Mining for Ancient Copper, Essays in Memory of Beno Rothenberg, Monograph Series 31 (Tel Aviv 2018) 385–398.

Wagner – Weisgerber 1988

G. A. Wagner – G. Weisgerber, Antike Edel- und Buntmetallgewinnung auf Thasos, Der Anschnitt Beih. 6 (Bochum 1988).

Zannis 2014

A. G. Zannis, Le pays entre le Strymon et le Nestos: géographie et histoire (VIIe–IVe siècle avant J.-C.), Meletemata 71 (Athens 2014).