Ancient Mining Landscapes: The Example of Laurion

Frank Hulek – Sophia Nomicos

Introduction

The economic importance of raw material exploitation, especially metal mining, for communities in antiquity has long been addressed. However, only during recent decades have scholars increasingly shifted the focus from technological questions[1] to the study of the wider landscape.[2] The material remains in mining regions include not only the primary mining remnants such as underground workings, process residues and installations for beneficiation, but also habitation sites and infrastructural remains that emerged in the course of exploitation.

If we assume that raw material exploitation can contribute to or even stimulate changes in a given economic system of a society, it is necessary to take a perspective beyond technological aspects in order to better understand possible interrelations. Consequently, taking into account the secondary structures such as agricultural installations, burial sites, sanctuaries or infrastructural remains may display networks that contributed to the success of ancient mining operations. Also, the working of raw material deposits by foreign communities has left traces in both the literary and archaeological record.[3] Such operations necessitated the introduction of new technologies as well as administrative measures. It therefore seems a promising approach to identify and describe indications of this process in the archaeological record by, for example, discussing aspects of technological transfer.

Such questions were addressed by the participants of the panel "Mining Landscapes", which was held at the 19th International Conference of Classical Archaeology "Archaeology and Economy in the Ancient World" at Cologne and Bonn in 2018. The proceedings of this panel are published in this volume.

The intention is, firstly, to provide an insight into existing and emerging research on ancient mining landscapes. Secondly, it aims to discuss how mining could affect not only the natural but also the cultural landscape. By focusing on select case studies, the third objective is to identify the material characteristics of mining areas, to highlight and explain differences, and to discuss possible recurring infrastructural and organizational patterns.

Theoretical and Methodological Background

As G. Weisgerber[4] argued, mining archaeological studies – like mining engineering[5] – should follow the different steps of the *chaîne opératoire,*[6] methodologically being highly process-orientated. This approach was expanded by Th. Stöllner, who developed a theoretical framework which takes not only the landscape of a given mining region into

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account but also other components of mining economies.[7] Th. Stöllner defines a mining region (or *Montanlandschaft*) as a "specialized region, whose primary economic structure is focused on the exploitation of (mineral) resources".[8] According to this concept, a *mining region* can be subdivided into a *mining district* that is a centre of production within the larger region, as well as an even smaller *mining ensemble* which, for example, consists of a mine, a smithy, and a smelting place.[9]

The success of mining, however, depends not only on spatial structures. Several components were identified by Thomas Stöllner that may contribute to long-lasting and productive mining operations in a given mining region:[10]

- The natural landscape
- The cultural landscape
- The mode of production
- The social and cultural tradition
- Trading modes
- And historical processes

Another constituent of past mining economies that the model considers is the *Duration of time.* Th. Stöllner distinguished between Phases of *extensive exploitation* (characterised by sporadic, seasonal grasp of the resources) and phases of *intensive exploitation.* This second category can be subdivided into an *anterior phase,* an *initial phase,* a *consolidation phase* and an *industrial phase.*[11] By applying the notion of an adaptive cycle[12] and adding a final *phase of collapse and reorganization,* a cyclical system of the usage of a deposit was established.[13]

Keeping these theoretical considerations in mind when analysing past mining economies may serve as a useful analytical tool when reconstructing the complex dynamics that led to sustained mining operations. Likewise, it can explain the rise and decline phenomena in mining landscapes.

Laurion

The Laurion mining landscape in Greece can serve as a particularly good case study regarding the interrelation of mining and landscape.[14] Here, the ancient written sources and the archaeological monuments – despite their destruction by modern mining activities – are incomparably numerous and well preserved.[15]

Mining in Laurion started at least in the Early Bronze Age.[16] The mining region, however, is primarily known as being the backbone of Athenian economy during the classical period. According to Herodotus (Hdt. 7, 144), the Athenian fleet that famously defeated the Persian army at Salamis in 480 BC was financed by the revenues of the Laurion mines. These are, furthermore, known for being the source of the silver from which the Athenian γλαῦκες Λαυριωτικαί[17] (i.e. the silver coins of Athens) were struck since the Archaic period[18] (fig. 1[19]).

Fig. 1: a: Archaic Athenian Tetradrachm av. b: Archaic Athenian Tetradrachm rv.

The development of mining landscapes and more specifically those in the Laurion can be described according to Th. Stöllner's terminology[20] as phases of *extensive* and phases of *intensive* mining. After a period of extensive mining in the geometric and for most of the archaic period, mining was apparently intensified during the late archaic period[21]. It peaked during the 5th and again during the 4th century BC[22]; during the Hellenistic era, earlier residues were reprocessed.[23] There is no evidence for systematic mining operations during Roman imperial times,[24] mining, however, was taken up again in the early byzantine period and ceased around 700 AD.[25]

It can be shown, moreover, that there is a close correspondence between mining and settlement development in the Laurion.[26] More specifically, it is noticeable that during phases of completely lacking mining activity or during extensive mining, only parts of the Laurion showed settlement activity, especially the coastal areas with no metal deposits.[27] In contrast to this, during phases of intensive mining, most notably during the classical period, the entire Laurion region was densely settled. This can be explained by the fact that the inland area lacked sufficient natural water sources as well as good soils for agricultural use. More arable land and infrastructure, such as harbours, existed only in the periphery of the metalliferous zone.

Research at Ari in the Laurion

Recent research in the Laurion carried out by the Ruhr University Bochum, concentrated on a region called "Ari", some kilometres to the north of the village Anavyssos (fig. 2). The project on "the prehistoric and Classical exploitation of lead and silver in Ari (Attica)" directed by H. Lohmann, lasted from 2012 until 2017. It was conducted in

collaboration (synergasia) with the Ephorate of Antiquities of East Attica and the German Archaeological Institute at Athens. Its aim was to tackle open questions regarding ancient mining and metallurgy, both of which can be studied particularly well at Ari. Important characteristics of the project are the collaboration between mining and beneficiation engineers, mining archaeologists, natural scientists experienced in archaeometry, and Classical archaeologists.[28]

Ari forms the northwesternmost mineralization of the Laurion,[29] and the area covers approximately 5 km². The toponym Ari probably derives from the ancient Greek name Phrearrhioi, one of the demes (i.e. municipal subdivisions) of classical Athens.[30] Numerous ancient sites at Ari had already been documented in the "Karten von Attika" (sheets 16 and 17) in the 19th century,[31] such as ancient shafts, slag heaps and buildings. Also, more recent literature confirmed the density of sites in this small region, and recent excavations by the National Metsovian Technical University of Athens uncov-

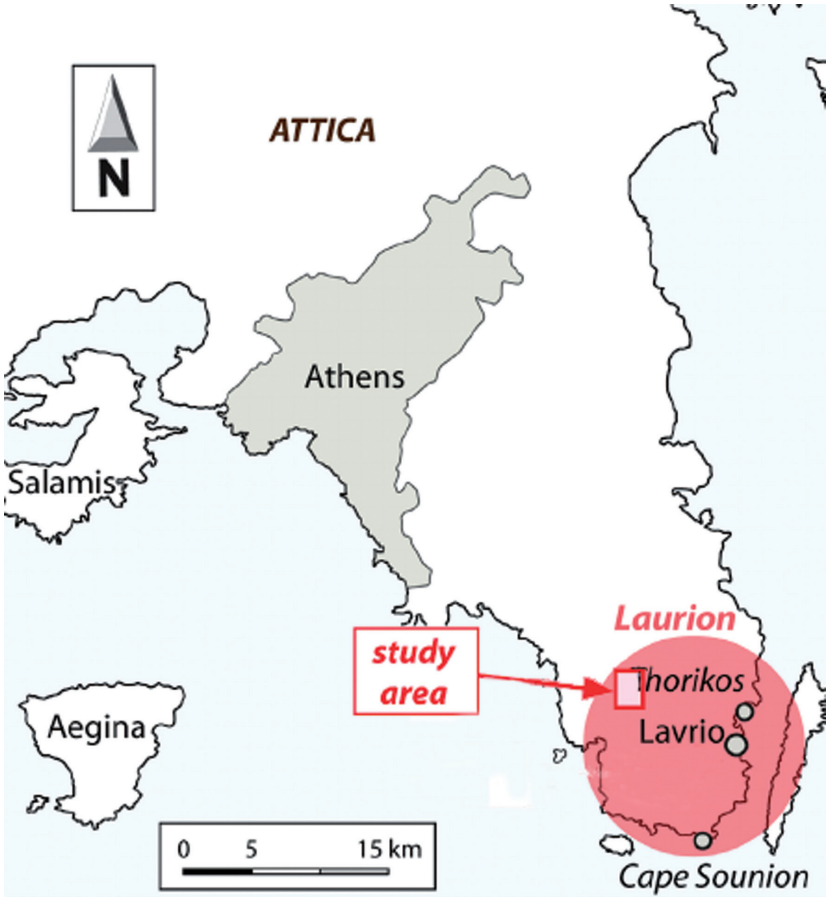

Fig. 2: Map of the Laurion.

ered several ancient metallurgical installations (ore washeries and smelting furnaces).[32] Therefore, further research and especially a survey aiming at documenting all extant elements of this small mining region promised new results for our understanding of the various economic, social, and cultural aspects related to mining. The projects' results are currently being evaluated and will be published soon.[33]

During the survey, a site on the slope of the hill Charvalo was discovered and catalogued as Ari 63. It raised our interest because its layout and vestiges of waterproof plaster in one of the rooms made us suspect it to be an ancient *ergasterion,* (i.e. a workshop where lead-silver ore was concentrated by the use of water). In the summer of 2016, the author (F. H.) explored this complex with four trial trenches (fig. 3). The first target was the room in which we suspected an ore washery of the well-known rectangular type.[34] It indeed turned out to be an ancient ore washery, virtually undisturbed by later activities. Protected by the collapse of the clay walls of the complex, fine sintered material was obtained from the bottom of the washing channels. Anno Hein from the Demokritos-Institute (Athens) analyzed this fine sintered material that turned out to be residue of the washing process. This will hopefully provide more accurate information on the composition of the ore used and on the yield of the process steps.[35] The washing floor of the washery, an inclined plane, shows clear traces of wear caused most prob-

Fig. 3: Orthophotography trial trenches at Ari 63A.

ably by scrubbing ore on it. This evidence contradicts the prevalent assumption about the operating mode of the washeries with the use of sluices.[36] However, it corroborates the older theory which was first put forward by the beneficiation engineer (and later politician) Phokion Negris, that they functioned as plane tables.[37]

In an adjoining room, lying on the floor, turned upside down, a bowl was found, one of the youngest pieces of the pottery inventory; it provides information about the end of use of the workshop in the later 4th century BC. The ore washing workshop thus fits into the second *industrial phase,* ending in early Hellenistic times.

In 2017, the author (F. H.) worked on the material from an old excavation in the Archaeological Museum of Lavrion. The rescue excavation was conducted by the late Evangelos Kakavogiannis and Olga Apostolopoulou in 1969/70, on the site of the Public Power Corporation (ΔΕΗ) oil power plant, right by the Frankolimani bay.[38] There was an ensemble of various buildings and complexes, namely a battery furnace for melting the ore, a presumptive cupellation furnace, an ore washery, other buildings and two cemeteries, and a possible mine shaft. The metallurgical residues from the furnaces are being analyzed at the Demokritos Institute and will probably provide further insight into the ancient smelting process. The ceramic findings and coins provide a dating of the individual complexes. The battery furnaces were in use during the first half of the 2nd century BC and are thus another example of the relocation of the smelting furnaces to the coast as well as the reprocessing of older process residues.[39] At the same time, the finds show how densely populated the surrounding area of the Thorikos[40] mining center was and how profoundly the mining and processing of ore affected the landscape.

Overview of the contributions in this volume

The panel "mining landscapes" has brought together many different perspectives, such as social, administrative, and technical views on landscapes shaped by mining in Antiquity.

Effie Photos-Jones presents results from her long-term project on the mineral wealth of the volcanic island of Melos (Cyclades, Greece), where "miltos" was mined in antiquity and shipped to places around the Mediterranean. This material was used as pigment, cosmetic, washing powder, and medicine.

Raphael Eser and Fabian Becker present the results of their research on Elba (Tuscany, Italy), an island that was important for the iron production of Etruria. They show that the landscape of the island and its natural resources, not only the ore but also wood for fuel, were exploited in order to facilitate the production and export of iron. Furthermore, evidence points to the continuation of iron exploitation until the time of the Late Roman Republic, when the written sources state that the central administration decided to abolish mining in Italy.

Norbert Hanel, who during the conference gave us a glimpse into the results of a survey in the Iglesiente mining region on Sardinia (Italy), presents the results of chemical analyses of brass ingots which he conducted in collaboration with Michael Bode. They show that the Roman empire exploited the mineral resources of outlying mining regions in order to satisfy the needs for brass.

Nerantzis Nerantzis presents the research of his team in the Northern Aegean, namely the Pangaeum and Lekani mountain ranges. There, control over the mining landscapes was contested between the indigenous Thracian tribes and the Greek city states (*poleis*) of the region. Eva Steigberger and René Ployer investigate the mineral resources of the Norican Alps (Austria) as well as their exploitation and trade. Especially during Roman times, the exploitation was intensified and comprised a broad range of raw materials.

David Quixal Santos presents research on the pre-Roman metal exploitation on the Eastern Iberian Peninsula and the results of the excavation of a furnace at Los Chotiles (Spain). The survey research by Victor Martinez Hahnmüller and Roald Docter covers a similar time span in the Punic sphere of influence around modern Cartagena. They describe the exploitation and organization of the hinterland of the Carthaginian colony.

Focusing on Roman times, Linda Gosner also examines mining on the Iberian Peninsula. She focuses on the subsidiary industries (e.g. esparto grass basket-making), which, as she corroborates, were stimulated during phases of intensified mining production in the region.

Regula Wahl-Clerici uses quantifying methods in order to reconstruct the Roman Empire's expenditures and revenues from the gold mines of Trêsminas and Jales (Portugal).

For organizational reasons, two papers which match this volume's topic are published in this volume, although they were presented in other panels during the conference. Alfred Hirt critically assesses the archaeological and literary sources for the organization of the mines and the processing of argentiferous lead ore from around Carthago Nova (Cartagena, Spain) during Roman times. He corroborates that the mines were leased to large scale public contractors. Luc Long and Christian Rico present an updated synthesis of how they reconstruct the maritime trade of iron in the Roman period, mainly from archaeometric analyses of iron ingots in shipwrecks at Les Saintes-Maries-de-la-Mer (Camargue, France).

Finally, four papers which were presented at the AIAC-conference, are not included in this publication. Thomas Faucher had already published elsewhere his results on Samut in the Eastern Desert (Egypt),[41] as did Hannah Friedman with her research on the copper mining landscape in the Faynan valley (Jordan).[42] Béatrice Cauuet spoke about the impact of gold and tin mining on certain territories in Gallia (France). Brais Currás presented a paper on the mining region along the rivers Tagus (today Tejo or Tajo in Portugal and Spain, respectively).

Desiderata

Having assembled these different perspectives, it became clear that there is a lot of regional variation in how mining transformed the natural and social landscape. Furthermore, there was support for the view that there are common denominators of mining regions that may enable us to predict theoretically how mining landscapes may have developed in a given region. This is especially relevant when distinct historical and archaeological information is lacking. In view of the differences, it is crucial to analyse the complexity of each mining landscape independently and to subsequently compare it with other regions in order to further refine the existing methodological framework of examining past mining landscapes.

Notes

[1] See e.g. Healy 1978; Craddock 1995; Craddock 2008.

[2] Stöllner 2003; Stöllner 2006; Stöllner 2008; Stöllner 2014; Bartels – Küpper-Eichas 2008; Lohmann 2005; Alonso Campoy 2009; Bebermeier et al. 2016; Nomicos 2021; Eisenach et al. 2017; García-Pulido et al. 2017, Baron et al. 2017.

[3] Cf. Domergue 2008; Hirt 2010; Papers by Nerantzis and Steigberger – Ployer in this volume.

[4] Weisgerber 1989; Weisgerber 1990.

[5] Cf. Handbooks of mining engineering such as Grumbrecht 1949.

[6] Leroi-Gourhan 1964.

[7] Stöllner 2004; Stöllner 2008; Stöllner 2014; Stöllner 2017.

[8] Stöllner 2008, 76 f. fig. 4.

[9] Stöllner 2004, 429 f.; Stöllner 2008, 76 f. fig. 4.

[10] Stöllner 2008, 72–75 tab. 2.

[11] Stöllner 2004, 430–439; Stöllner 2008, 77–80.

[12] See: Holling et al. 2002.

[13] Stöllner 2014, 138–140 fig. 7.3.

[14] This was the subject of the PhD thesis submitted to the Faculty of History of Ruhr University Bochum by the author, see: Nomicos 2017a. It was published in 2021 (Nomicos 2021) as a supplement volume of *Der Anschnitt*. For preliminary results, see Nomicos 2014 and Nomicos 2017b.

[15] From the abundant literature on the Laurion mines only a few titles are cited here: E. Dodwell in Boeckh 1828, 677 f.; Ardaillon 1897; Conophagos 1980; Lohmann 2005; Kakavogiannis 2005.

[16] Spitaels 1984; Nazou 2013. For recent finds indicating an even earlier use of Laurion ores, see: Kakavogianni et al. 2003; Kakavogianni et al. 2008, 45–57; Kakavogianni et al. 2009, 237–248.

[17] Aristoph. Av. 1106.

[18] cf. Ath. Pol. 10,1–2. – e.g. Head 1888, VIII–XX pl. 1; cf. Seltman 1924;Kraay 1956; Kraay 1975; Cahn 1975; but cf. Kroll – Waggoner 1984; Holloway 1999, 7–11; Kroll 2012; Konuk 2012; Flament 2007; van Alfen 2012, 88–104.

[19] Archaic Athenian silver coin ca. 500 BC: coin collection of Ruhr University Bochum, inv. M 1310. Diam.: 2,1 cm, weight 17,17 g, see: Nomicos 2015.
[20] Stöllner 2008.
[21] cf. Kakavogiannis 1989, 71–88; Kakavogiannis 2001, 365–380; Gill – Vickers 2001, 233 f. fig. 2 Tab. 2.764; Boardman 1963, 1–7; Cavanagh – Laxton 1984, 32–36; Nomicos 2020; Nomicos 2021, chapter 3.2.
[22] Compare: Conophagos 1980; Lauffer 1979; Kalcyk 1982; Lohmann 2005; Nomicos 2021, chapter 3.3 and 3.4.
[23] Strab. 9,399; Kalcyk 1982, 144 f.; Lohmann 1993, 244–246; Goette 2000, 106; Howgego 2000, 56 f.; van Alfen 2012, 97; Nomicos 2021, chapter 3.5.
[24] Pomp. Mela, 2,46; Paus. I,1,1; Kahrstedt 1954, 63; Lauffer 1979, 125. 134; Kakavogiannis 2013, 321–327; Nomicos 2021, chapter 3.6.
[25] Paul. Sil. Ecphr. S. Sophiae 679 f. – Lohmann 1993, 260; Salliora-Oikonomakou 2007, 46; Mattern 2010, 220; Kakavogiannis 2013, 326–341; Nomicos 2021 chapter 3.7.
[26] see Nomicos 2021.
[27] Nomicos 2021.
[28] Lohmann 2005; Lohmann 2020.
[29] Marinos – Petraschek 1956, 104 f.
[30] Traill 1975, 45. 62. 67; Vanderpool 1970; Lohmann 1993, 74. 78; Bultringhini 2005, 36–38, but cf. Salliora-Oikonomakou 1996–1997, 137.
[31] Milchhöfer 1889, 25; Kaupert – Curtius 1904, maps 16. 17; Ardaillon 1897, 31; cf. Marinos – Petraschek 1956, 104 f.
[32] Tsaimou 2005; Tsaimou 2006; Tsaimou 2007; Tsaimou 2008; Tsaimou 2010; Tsaimou – Tsaimou 2010; Tsaimou et al. 2015; cf. also Parras 2010, 145.
[33] Lohmann 2016; Lohmann 2020; Hulek 2019/2020.
[34] Cordella 1869, 96; Negris 1881; Conophagos 1980; 224–245; Domergue 1998; Kakavogiannis 2005, 229–252; Lohmann 2005, 114.
[35] Cf. similar analyses on material from Agrileza (Laurium): Photos-Jones – Ellis Jones 1994, 327–355; Rehren et al. 2002.
[36] Konophagos 1970; Conophagos 1980, 224–245; Meier 1998, 6–8; Papadimitriou 2017, 400–403; but cf. Kakavogiannis 2005, 240–242; Kepper 2005, 7 f.
[37] Negris 1881; Ardaillon 1897, 68 f.; Nomicos 2021, 63–68.
[38] Liagouras – Kakavogiannis 1972, 150 f.; Konophagos 1974, 243–247; Conophagos 1980, 280; Kalcyk 1982, 144. 149. 208 fig. 24; p. 211; Kakavogiannis 2005, 261 f. 270–273. 283. 294; cf. Trikkalinos 1977, 319; Kakavogiannis 2005, 270 f. n. 668.
[39] Lohmann 1993, 244; Kakavogiannis 2005, 283; Börker 2018, 69–72; cf. above n. 25. – Doubts expressed by Mussche 1998a, 66.
[40] On Thorikos and the respective bibliography, cf. Mussche 1998b; Docter – Webster 2018; Laffineur – Docter forthcoming
[41] Brun et al. 2013; Redon – Faucher 2017; Faucher 2018.
[42] Friedman 2013.

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Fig. 1a: coin collection of Ruhr University Bochum inv. M 1310, Nomicos 2015, fig. 1. – Fig. 1b: coin collection of Ruhr University Bochum inv. M 1310, Nomicos 2015, fig. 2. – Fig. 2: after Rosenthal et al. 2013, 90 fig. 1. – Fig. 3: Ari-Project, Ruhr University Bochum, F. Hulek.

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