



Internationale Konferenz »Ari und das Laurion von prähistorischer Zeit bis heute«

International Conference »Ari and the Laurion from Prehistoric to Modern Times«

Διεθνές Συνέδριο »Αρί και η Λαυρεωτική απο την προϊστορική εποχή έως σήμερα«

1.–3. November 2019 – November 1st–3rd 2019 – 1η–3η Νοεμβρίου 2019



Tagungsort: Institut für Archäologische Wissenschaften / Institut of Archaeological Studies,
Ruhr-Universität Bochum, Am Bergbaumuseum 31, 44791 Bochum, Hörsaal 1

Gefördert von DFG Deutsche Forschungsgemeinschaft /
Supported by German Research Foundation



Institut für Archäologische Wissenschaften der RUB
Institute of Archaeological Studies RUB



Internationale Konferenz »Ari und das Laurion von prähistorischer Zeit bis heute«
International Conference »Ari and the Laurion from Prehistoric to Modern Times«
Διεθνές Συνέδριο »Αρί και η Λαυρεωτική απο την προϊστορική εποχή έως σήμερα«
1.–3. November 2019 – November 1st–3rd 2019 – 1η–3η Νοεμβρίου 2019

PROGRAM

Donnerstag, 31.10.2019

Arrival of the participants and speakers. Check-in at the Acora Hotel Bochum.

15.30 h: Guided tour through the recently re-opened Deutsches Bergbaumuseum at Bochum

Freitag, 01.11.2019

- | | |
|---------------|---|
| 9.00–9.15 h | Opening of the conference (S. Brüggerhoff, H. Lohmann, F. Hulek) |
| 9.15–10.00 h | Eleni Andrikou – Eleni Papafloratou – Elena Tselepi, The Pottery Context of the Litharge Items Found at Keratea, Attica |
| 10.00–10.45 h | Olga Kakavogianne – Kerasia Douni – Myrto Georgakopoulou, The Cupellation of Argentiferous Lead in Mesogeia, East Attica, during Prehistoric Times |
| 10.45–11.15 h | Coffee Break |
| 11.15–12.00 h | Andreas Kapetanios: Silent People of a Deafening Land: The Dynamics of the Lavrion Landscape |
| 12.00–12.45 h | Margarita Nazou: The Prehistoric Finds from Mine 3 at Thorikos and their Relationship to the Thorikos Mining Community |
| 12.45–14.00 h | Lunch. – Lunch for the speakers will be served at the restaurant Parkschlösschen, Bergstraße 65, 44791 Bochum |
| 14.00–14.45 h | Adonis Fotiadis: A New Geological Map of Ari (Anavyssos/Attica) |
| 14.45–15.30 h | Hans Lohmann: A Survey at Ari (Anavyssos/Attica) |
| 15.30–16.15 h | Denis Morin – Serge Delpech: Open Cast and Underground Minings at Ari (Anavyssos/Attica) |
| 16.15–16.45 h | Coffee Break |
| 16.45–17.15 h | James Ross – Panagiotis Voudouris – Vasilios Melfos – Markos Vaxevanopoulos – Kostis Soukis – Kelly Merigot – Frank Bilki: Mineralisation, Supergene Alteration and Geochemistry of the First and Third Contacts at Lavrion |
| 17.15–18.00 h | Panagiotis Voudouris – A. Tarantola – M. Pouliou – C. Scheffer – O. Vanderhaeghe – A. Photiades – D. Morin: Analysis of Ores from Mine 3 at Ari (Anavyssos / Attica): The Mineralogy of galena-sphalerite ores from mine Ari 3 at Charvalos area and comparison to other silver-rich ores from Lavrion district, Greece |
| 18.00–18.45 h | E. Filippaki: Analytical and Archaeometallurgical Studies at Thorikos: Preliminary Results |
| 20.00 h | Dinner. – Dinner for the speakers will be served at the Restaurant Fässle, Nordring 44, 44787 Bochum |

Saturday, 02.11.2019

- 9.00–9.45 h Frank Hulek: The Trial Excavation in the Ergasterion Ari 63
- 9.45–10.30 h Sophia Nomicos – Konstantina Tsaimou: Pottery Assemblages from Workshops Excavated by K. Tsaimou at Ari (2005–2008)
- 10.30–11.00 h Coffee Break
- 11.00–11.45 h Roald Docter: The Cistern No. 1 Workshop at Thorikos
- 11.45–12.30 h Markos Vaxevanopoulos – James Ross – Panagiotis Voudouris – Vasilios Melfos – Kostis Soukis: Lavrion Shafts Mapping: A More Detailed Investigation of the Lavrion Stratigraphy
- 12.30–14.00 h Lunch. – Lunch for the speakers will be served at the Ristaurante Pizzeria Romanella, Herner Str. 104, 44791 Bochum
- 14.00–14.45 h Sophie Duchène: The Ore Mills of the Laurion
- 14.45–15.30 h Anno Hein: In-situ measurements of Olynthus Millstone Fragments at the Ari-Harvalo Washeries Using Portable Energy Dispersive XTF (pEDXRF)
- 15.30–16.00 h Coffee Break
- 16.00–17.45 h Hélène Morin-Hamon: Buddling. Flat-bedded Washeries: Ore Process Revisited through XVIth-XIXth Centuries Mining Engineers Archives
- 17.45–18.30 h Athanassia Markouli: 19th / 20th Cent. Mining and Metallurgy in Lavrion
- 20.00 h Dinner. – Dinner for the speakers will be served at the Restaurant Fässle, Nordring 44, 44787 Bochum

Sunday, 03.11.2019

- 9.00–9.45 h Alexandre Tarantola – C. Scheffer – O. Vanderhaeghe – P. Voudouris – A. Fotiades: Fluid Circulation and Ore Deposition in the Geodynamic Evolution of the Lavrio Area
- 9.45–10.30 h Christophe Flament: Fiscal and Administrative Aspects of the Laurion's Mining Leases
- 10.30–11.15 h Nikiforos Meimaroglou: Lavrion Hydraulic Mortars and Clay Mortars
- 11.15–12.00 h Effie Photos-Jones: The Multifaceted Character of the Extractive metallurgy of Laurion
- 12.00–12.30 h Final Discussion
- 13.00 h Lunch. – Lunch for the speakers will be served at the Ristaurante Pizzeria Romanella, Herner Str. 104, 44791 Bochum



Institut für Archäologische Wissenschaften der RUB
Institute of Archaeological Studies RUB



Internationale Konferenz »Ari und das Laurion von prähistorischer Zeit bis heute«
International Conference »Ari and the Laurion from Prehistoric to Modern Times«
Διεθνές Συνέδριο »Αρί και η Λαυρεωτική απο την προϊστορική εποχή εως σήμερα«
1.–3. November 2019 – November 1st–3rd 2019 – 1η–3η Νοεμβρίου 2019

ABSTRACTS

Freitag, 01.11.2019, 9.15–10.00 h

Eleni Andrikou – Eleni Papafloratou – Elena Tselepi:

The Pottery Context of the Litharge Items Found at Keratea, Attica

At Zapani at Keratea region, Attica, three Early Helladic sites were excavated in 2007 – 2008 during the construction works of the new Industrial Area of Keratea. Site 1 just below the top of a hill was characterized by heaps of stones and limited architectural relics and a great number of fragmentary litharge items. At Site 2, located at the plain 350 m to the SW, isolated clusters of pottery or obsidian tools came to light and many scattered litharge items. At Site 3, about 250 m S of Site 1, a hut and storage pits were unearthed.

Litharge items are discussed and an effort is made to explain their presence as well as the connection of Zapani with other sites in Attica which have yielded litharge items.

The preliminary study of the pottery from Sites 1 and 2 dates the occupation in EH I and EH II period. The typology and the decoration of the pottery from both sites is discussed and compared to each other and to pottery from other sites mainly in the Mesogeia plain. Through the analysis of the various pottery categories and their distribution in the excavated areas, an attempt is made to elucidate the human activities at both sites.

Εφορεία Αρχαιοτήτων Ανατολικής Αττικής; Leof. Andrea Siggrou 98-100, GR 117 41 Athina; E-Mail: eandrikou@culture.gr; elspapa@yahoo.com; tselel@yahoo.gr

Freitag, 01.11.2019, 10.00–10.45 h

Olga Kakavogianne – Kerasia Douni – Myrto Georgakopoulou:

The Cupellation of Argentiferous Lead in Mesogeia, East Attica, During Prehistoric Times

Despite the widely accepted significance of Lavrion as a prehistoric lead and silver source, remains of prehistoric mining and smelting of relevant ores or cupellation of argentiferous lead, are not preserved in the metalliferous region of Lavreotiki. This is due to the extensive exploitation of ores and metallurgical residues during the ancient and modern times and thus paradoxically, cupellation workshops or byproducts (litharge) are identified primarily not in Lavreotiki, but in the Mesogeia plain.

In 2002, during new Public Works at Lambrika (Koropi district), an EH settlement was revealed alongside the regional road “Varis- Koropiou”. Houses of EH I-II date and a metallurgical workshop for the cupellation of argentiferous lead were excavated in an area of 2,500m². The workshop consisted of a central large oblong pit of 2m in diameter, dug into the bedrock with 5 cavities opened along the southern and northern sides of its border. The cavities had a white coating internally and hundreds of litharge fragments were recovered from the filling of the surrounding area (more than 1000 fragments totaling 165 kg in weight). The morphology of these litharge fragments is very characteristic; they are shaped like

small shallow bowls and have circular depressions on their upper surface. Evidently, the depressions were in all cases arranged systematically in 3 rows of 3-4-3 depressions, a total of 10 depressions on each piece. The Lambrika workshop constitutes the first prehistoric cupellation workshop installation found in Greece and was dated to the EH I period, while some of the litharge finds come from EHII contexts, suggesting the metallurgical activities continue throughout the life of the settlement.

During the extensive excavations in Merenda (2000-2004), 5 clusters of subterranean dwellings were revealed in a settlement of LN-EH II date. Numerous litharge fragments (88) were recovered from their fillings, which have been dated to the middle of the 4th mill. BC, earlier than those recovered at Lambrika. Similarly to Lambrika, these litharge fragments correspond to shallow bowls, but strikingly these have no evidence for the characteristic depressions seen at Lambrika.

Lambrika, Merenda and a number of other sites from southeastern Attica, testify to the importance of Lavrion as a silver source already from the 4th mill. BCE and through the EBA, despite the unavoidable dearth of evidence in the direct vicinity of the metalliferous region itself. These are complemented by contemporary finds from other regions, such as Sifnos and Thassos, that show both similarities but also differences in the cupellation technology, most characteristic the absence of depressions on the litharge, so far a characteristic feature of EBA south-eastern Attica silver production.

E-Mail: olgakkj@yahoo.gr; g_myrito@yahoo.gr

Freitag, 01.11.2019, 11.15–12.00 h

Andreas Kapetanios:

Silent People of a Deafening Land: The Dynamics of the Lavrion Landscape

It's been almost 160 years since the first systematic exploration and assessment of the Lavrion district (A. Kordhélas, F. Négrès) as to its unique link to the material and social dimensions of an ancient political society, the Athenian Polis. And almost 2500 years since the writing of the first known socioeconomic analysis of the same region (Xenophon). How have we progressed to date? Even though an impressive amount of work has been done, it seems that essential questions originally set, remain unanswered.

An overview of these questions is presented, addressing metal-production issues such as the evolution of ore-processing methods, related built structures and their dating as well as the understanding of the full *chaîne opératoire* involved, or sociopolitical issues such as the political topography of *Demes* and the evolution of habitation / production spatial organisation through out the antiquity, or the multiply emblematic issue of slaves and slavery.

Persisting questions, yet an overwhelming corpus of data. The understanding of Lavrion, has fallen victim to its unusually large scale: multidisciplinary research remains dispersed, unlinked, and thus, sometimes repeating itself and, certainly, overall unfocussed.

It is argued that a certain *landscape-archaeology* approach may function as the cohesive framework for an integrated, consciously interlinked, question-orientated, multidisciplinary research.

Examples of such an approach are given as regards *landscape structuring principles*: taskscapes linking production, habitation, geology and geomorphology, the *osmosis* between a surface and an underground landscape, the links between a mortuary landscape and power relations of land ownership, the notional maps of the *Polêtae Records* are all examined through their link to the material record, organised in *nested scales of reference*.

In this manner, an attempt is made to integrate studies of architectural remains of workshops, tombs and collective centres in valleys, bioarchaeological studies of the dead, geological, geoarchaeological-hydrological studies of the landscape features, material studies (artefacts and geofacts) of the workshops and of the underground galleries and shafts.

The examples presented are linked mainly to ongoing research in *Lavreôtikê* and they represent a dialogue between the micro scale of sampling hydraulic mortars or bones, to the large scale of spatial organisation of anthropogenic features at the regional level.

Topos is thus, the vehicle suggested for tackling questions. Lavrion, having been already included in Unesco's tentative list, not as a complex archaeological site, but as a unique, unbreakable totality of an active historical landscape, seems to be the ideal terrain for developing a productive methodology which, in parallel, unifies humanities and physical science into an *epistêmê*.

Ionian University, Corfu (IONIO), Department of History; E-Mail: akapetanios@ionio.gr

Freitag, 01.11.2019, 12.00–12.45 h

Margarita Nazou:

The Prehistoric Finds from Mine 3 at Thorikos
and their Relationship to the Thorikos Mining Community

The paper discusses the earliest prehistoric pottery excavated from Mine 3 at Thorikos: the most ancient mine gallery in the Lavrion, exploited intensively since prehistoric times. The mine was discovered by the Belgian School at Athens in 1975 and was excavated from 1976 to 1981 by a team led by Herman Mussche and Paule Spitaels; Spitaels also wrote a preliminary report of the finds in 1984. The study of the Mine 3 excavated pottery assemblage presents the macroscopic fabrics, shapes and surface treatments/decorations of the diagnostic Neolithic and Early Bronze Age sherds. A preliminary distinction between local and imported pottery was possible through macroscopic fabric group analysis. A typological study of the shape repertoire as well as the surface treatments and decoration of the pottery is presented in reference to parallels from other prehistoric sites in the southern Aegean. In the conclusion of the paper, the controversial issue of the chronology of the earliest exploitation of the Thorikos ores extracted in Mine 3 is reviewed based on the new evidence provided by the current study. The excavation data is not sufficient for a systematic investigation of taphonomic processes of the finds, which could have been associated with phases in mining activities. Yet the recovery of Late Neolithic, Final Neolithic and Early Bronze Age I pottery from the excavated area of the mine could be used as evidence for open-air mining in these periods (the 4th and early 3rd millennia BC), before the gallery was dug into the Velatouri hill in the Early Bronze Age II period. In conclusion, the Mine 3 prehistoric pottery assemblage offers important insights into ceramic production and consumption at Thorikos and helps us unravel the history of a prehistoric mining community in the Lavrion.

Catholic University Louvain-la-Neuve, AEGIS Research Group / Ghent University, Dept. of Archaeology; E-Mail: Nazoumarg@yahoo.com

Freitag, 01.11.2019, 14.00–14.45 h

Adonis Fotiadis: A New Geological Map of Ari (Anavyssos/Attica)

The Charvalos-Ari area, which lies at the western part of the Lavreotiki peninsula, belongs to the Attic-Cycladic Metamorphic Complex. This area consists of polyphased metamorphic nappe-stack, composed of an upper unit, i.e. the Lavrion blueschists bearing various marbles, and a lower unit dominated by marbles alternating with the Kamariza greenschists. These units are separated by a low-angle detachment fault (Scheffer *et al.*, 2016 in J. Geodyn. 96, 174–193). The metamorphic rocks are locally unconformably overlain by non-metamorphosed lacustrine Miocene deposits.

In earlier geological maps, a particular marble outcrop in Charvalos-Ari area was interpreted as a tectonic window of the Kamariza unit, like other marbles in the western Lavreotiki, emerging underneath the Lavrion blueschist unit.

Recent geological interpretations in the area (Fig 1a), however, suggest that the Charvalos hill (Fig.1b) is characterized by coarse-grained marble, whose northern slope reveals a mylonitic marble bearing N90-100° stretching lineation. This mylonitic front is associated with a low-angle detachment fault in contact with the N-dipping foliated blueschist unit. Furthermore, this marble in Ari gallery is tectonically emplaced in, and folded with, the blueschists and consists of a decimeter-sized brecciated marble sequence cemented by sulphides. Besides, this brecciated marble lithology also outcrops on the surface. Moreover, this mineralized cataclastic zone continues southwards at the western part of Charvalos hill, crosscutting the mylonitic marble by high angle faulting.

These tectonic features support that the marble of Charvalos hill and Ari mine are situated above the low-angle detachment fault and it is considered as detached mineralized tectonosomes or mega-blocks affected by ductile to brittle deformation and emplaced within the Lavrion blueschist unit. Additionally, these episodes have been related during Late Miocene post-orogenic exhumation coeval with the emplacement of the Plaka granodiorite pluton.

Consequently, the mylonitic-cataclastic low-angle detachment faulting episode has isolated individual blocks of the hanging-wall, so that they appear as islands of marbles floating on a “sea” of blueschists.

I.G.M.E. Ινστιτούτο Γεωλογικών και Μεταλλευτικών Ερευνών – Institute of Geology and Mineral Exploration; E-Mail: fotiadis@igme.gr

Freitag, 01.11.2019, 14.45–15.30 h

Hans Lohmann¹ – A. Kapetanios²:
A Survey at Ari (Anavyssos/Attica)

The Laurion mining district in Southeast Attica was the largest and most important industrial complex of ancient Greece. The period of its most intensive exploitation lasted from the Late Archaic to the Early Hellenistic period. After two hundred years of scholarly research, several key questions concerning the workflow from the mine to the final product (mostly lead and silver) remained unsolved.

The paper presented here concerns a survey project from 2014–2016 as a joint venture with the Ephoria of East Attica, represented by my colleague Andreas Kapetanios, and the German Archaeological Institute at Athens. Due thanks go to the Greek Ministry of Culture and to Dr. Eleni Adrikou, the ephore of East Attica for their support of the project. It has been devoted to the small mining district of Ari north of Anavyssos, the ancient deme of Anaphlystos, which forms the westernmost ore deposit of the whole Laurion district. It had a common border with the deme of Pherarhioi to the west, presumably marked by the rhevma Ari.

In a first step, substantial parts of Mt. Charvalos at Ari were cleaned, surveyed and mapped. This, together with a trial excavation in a classical workshop at Ari in 2016, on which Frank Hulek will report, may hopefully contribute to a better understanding of the workflow and present an overall picture of one of the smallest mining districts of Attica.

So far more than 120 sites have been mapped and surveyed, hundreds of pottery fragments collected and catalogued. Among these only 4 fragments of FN-pottery were discovered, while by far the largest amount dates between the early 5th and the early 3rd century B.C. Considering that the largest and most important EBA settlement of Southeastern Attica is situated on the hill of Mokrizia next to the ore deposits at Ari it seems most astonishing that no prehistoric tools were discovered during the survey. Especially the typical grooved mallets are completely missing. The Classical and Early Hellenistic period, however, was a period of intensive mining at Ari. Under closer inspection the two large shafts, the puit Skouzès and the Puit Damianos turned out to be ancient. They had presumably been enlarged for hoisting engines. The Puit Damianos provided access to the largest mine at Ari, the mine no. 3, but like the Puit Skouzès had been filled with garbage by the locals. No less than 18 workshops for the enrichment of ore have been identified on both sides of the Rhevma Ari during the survey, 6 of them west of the rhevma Ari i.e. within the territory of the deme Phrearhioi. Despite the fact, that two mines are attested in the mining leases from the Athenian Agora for Phrearhioi, only traces of ancient prospecting have been found west of the rhevma Ari. Evidently the numerous workshops within the deme of Phrearhioi worked ore from the mines at Anaphlystos.

The plain of Anaphlystos was extremely fertile compared to the more mountainous regions of Attica. The process of formation of settlements in this area started in the Iron Age as early as the ninth century BC. An even larger population can be estimated for the Classical period. Unfortunately due to the modern occupation of the region by summer houses little is left. On the Southern slope of the Melissia Iatrou, a small hill just west of the rhevma Ari, in 2011/12 a small classical farmhouse was excavated by the Ephoria. Farming and mining were closely associated. The pottery from the survey allows for a clear distinction between farmhouses and workshops. The workshops display an extremely limited spectrum of vessel shapes, strongly dominated by lekaneis and amphoras: almost no cooking vessels and only very

few fragments of black glazed pottery, but no loom weights, no beehives at all. This clearly shows, that the slaves working in the mines and the workshops did not enjoy what we might call a balanced nutrition.

References:

M. Psarros, Αγροτεμάχιο Κόκκορη – Δήμου, ADelt 67, 2012 [2016], B1, 59–63 Abb. 28–41

H. Lohmann, Ari – a Classical Mining District at Anavyssos (Attica), in: K. Sheedy (Hrsg.), Mines, Metals and Money in Attica and the Ancient World. Proceedings of the International Conference at the Epigraphic and Numismatic Museum, Athens, April 20–22, 2015 (in press).

1) Institut für Archäologische Wissenschaften der Ruhr-Universität Bochum, Am Bergbaumuseum 31, D – 44791 Bochum; E-Mail: Hans.Lohmann@rub.de; 2) Ionian University, Corfu (IONIO), Department of History; E-Mail: akapetanios@ionio.gr

Freitag, 01.11.2019, 15.30–16.15 h

Denis Morin¹ – Serge Delpech²:

Open Cast and Underground Minings at Ari (Anavyssos/Attica)

Located at the southeast end of the Peninsula of Attica (Greece), the Laurion mining district extends along the eastern coast from Cap Sounion to Vromopoussi; to the West it borders on the Keratea Valley. Its territory comprises exceptional mining works that are among the most spectacular in the ancient world. The mineralized area extends in an NNE-SSW direction and covers an area 17 km long by 6 km wide. The ore is concentrated at the contacts of a metamorphic complex of marbles and calcschists. The deposit consists of massive sulphides such as galena, blende and supergenic alteration products such as cerussite and smithsonite.

The Ari-Charvalos area is located NW on the margins of this district, dominated to the North by the Kiafa Maresa hill. Here, a field survey revealed open-pit mining works and a large underground mining complex.

This work presents the results of these explorations.

Cave exploration techniques have been deployed to equip and to access some of these mines. Two of them have been surveyed. The Ari's open-pit mines are characterized by emptying mineralized concentrations close to the surface. A lot of small sorting and crushing workshops are often visible next to these pits. Each workshop is materialized by a pile of grano-classified gravel. Fragments of quadrangular trachyte millstones present on site attest to the use of grinding mills in the vicinity of the extraction areas as well.

Among the sites visited, a rectilinear open-cast mine (Ari n°119) parallel to the axis of the slope, thus develops at the foot of a slope 87m long and 7m wide. The depth varies between 5 and 7 metres in places. This work has shaped a characteristic mining landscape, whose morphology offers real similarities with karstic landforms. Some traces of cellular extraction can be considered as corrosion; they are, according to any hypothesis, the result of a firesetting process.

The wind mine (Ari n°63J) located on the side of an arid valley, was originally operated by a shaft and galleries, the junction of both these entries causes an air draught. This is a typical mining method: once the mineralization had been emptied out, miners would search for new concentrations in the extension of the vein axis or the mineralization already mined. The research galleries are quadrangular in cross-section and cut with chisel. Firesetting is also attested.

The deepest works (Ari n°03) are currently accessible through a modern inclined cross-cut adit. To reach the ore, ancient miners favoured access by shafts. It is possible that the Damianos shaft was originally sunk by ancient miners and then extended in a second phase by the French Mining Company of Laurion (CFML). Another access, currently blocked, has been identified south of the Damianos shaft. The vertical stoping stretches towards the South on a drop of 15/20 m and a thickness of several dozen meters. The intertwined mining works form a real labyrinth where progress is quite difficult: it takes place in a confined atmosphere and some galleries generally offer only a limited amplitude.

The remains belong to Antiquity with typical toolmarks, geometric shape and large fronts, but a generalized resumption of work was confirmed during the 4th - 5th centuries according to the remains of lamps abandoned on the ground.

Fracture rate, density, initial dip of the country rock and mineralizations, all influence and characterize the architecture of the galleries and the whole working area.

Such a method of exploitation raises the central question of the geological and mineralogical knowledge at the origin of these mining operations, particularly the deepest ones. How did the miners of Antiquity know how to locate these mineralizations and anticipate the implementation of such an organization? Observation of some outcropping works allows us to answer only part of these questions.

The still ongoing clogging of the shafts observed underground with considerable heights by polluting detritus, the degradation of the galleries by mineral merchants, finally raise the question of safeguarding and protecting these sites and more generally, this exceptional heritage that is the Laurion.

1) Université de Lorraine; E-Mail: denis.morin@univ-lorraine.fr; 2) Serge Delpech, ERMINA Society; E-Mail: Serge.Delpech@univ-lorraine.fr

Freitag, 01.11.2019, 16.45–17.15 h

James Ross^{1,2*} – Panagiotis Voudouris³ – Vasilios Melfos⁴ – Markos Vaxevanopoulos⁵ – Kostis Soukis³ – Kelly Merigot² – Frank Bilki⁶:

Mineralisation, Supergene Alteration and Geochemistry
of the First and Third Contacts at Lavrion

We present progressive outcomes of a comprehensive reassessment of the 150km² Lavrion mining district. This reassessment aims to improve our understanding of the mineral exploitation history of Lavrion and its archaeological implications. It includes a revised geological map which also provides a new framework for considering mineralisation, such as Ary, located a significant stratigraphic distance above the detachment.

The challenge of assessing the role of structure, stratigraphy and granodiorite intrusions in determining the location and form of the diverse and widespread mineralisation at Lavrion has been assisted by the priceless observations and recordings of a range of 19th Century professionals. These men had the opportunity to view many of the key mining areas prior to the significant reworking and extensions that occurred during the modern exploitation phase. When viewed collectively, the 19th century observations highlight significant differences in the form of mineralisation at the first and third contacts and illustrate how these were amplified by the more intense oxidation at the first contact. We have also drawn on the seminal Greek text of Marinou and Petrascheck, published in 1956, and their careful recording of the geology and previous mining activity.

The original mineralogy of the primary mineralisation was similar at both contacts and also at other locations, such as the second contact and above the detachment. The principal minerals were abundant pyrite and other iron sulphides, in addition to galena, sphalerite and chalcopyrite. However, mineralisation at the third contact was usually thicker and more continuous in contrast to the patchy and irregular mineralisation usually seen at the first contact. Most mineralisation at Lavrion has been oxidised to varying degrees, with intense oxidation resulting in Fe-rich gossans at the first contact and supergene (non-sulphide) assemblages of Pb, Zn, Cu, Ag and Fe at both contacts. Lesser oxidation has resulted in widely varying mixtures of supergene minerals and primary sulphides. These differences in oxidation, coupled with the interaction of topography and structure, have had a profound influence on exploitation of the Lavrion deposits for Cu, Ag, Pb and Fe since at least the fourth millennium BC and, in turn, its archaeological consequences.

Sixty-five analyses of galena-bearing mineralisation, mostly unpublished, have been assessed for evidence of systematic spatial variation in the silver content. These samples are split almost equally between the first and third contact and results have been normalised to ppmAg/tonne of Pb, a reliable indicator of the grade relationship between Pb and Ag in galena-bearing samples containing >1%Pb. The spatial distribution patterns for abundance of mineralisation and grade suggest that the events that gave rise to the mineralisation at the first and third contacts may be slightly separated in space and time, yet likely to be closely linked to the larger intrusion underlying the Plaka granodiorite.

This project includes development of a 3D model integrating mineralisation, stratigraphy, topography and surface geology, aimed at improving our understanding of the key influences on the location of mineralisation at both contacts and its exploitation.

1 Honorary Research Fellow, University of Western Australia; 2 Curtin University; 3 National and Kapodistrian University of Athens; 4 Aristotle University of Thessaloniki; 5 Ecole Normale Supérieure de Lyon; 6 Micromine Pty Ltd, Perth, Australia.

Freitag, 01.11.2019, 17.15–18.00 h

P. Voudouris – A. Tarantola – M. Pouliou – C. Scheffer – O. Vanderhaeghe – A. Photiades – D. Morin:
Analysis of Ores from Mine 3 at Ari (Anavyssos / Attica): The Mineralogy of galena-sphalerite ores from mine Ari 3 at Charvalos area and comparison to other silver-rich ores from Lavrion district, Greece

The Ari-Charvalos area, part of the famous Lavrion district, was an important mining center during ancient times and the 19th century, with minor exploitation up to the 1950's. According to Marinos and Petrascheck (1956), mixed sulfide ores with up to Pb 30%, Zn 30 %, were highly enriched in Ag (grades up to 16.000 gr/t Pb). This work presents new mineralogical and fluid inclusion data from mine Ari 3 at Ari-Charvalos area, compares its metallic assemblages with similar mineralization in Lavrion, and provides information with respect to the origin of the silver-rich breccia and vein-style mineralization in the district.

The Ari-Charvalos area is in a distal position (about 3 km W) relative to the Plaka intrusion-related ore system evolved in time and space, within and peripheral to the Miocene Plaka granodiorite. The mine Ari 3 consists of a Pb-Zn-Cd-Ag mineralization associated with brecciated marbles hosted within the Lavrion schists of the Blueschist Unit. Ore deposition took place under brittle conditions and occurs above the detachment fault, which separates the Kamariza Unit in the footwall from the Lavrion Unit in the hangingwall. The mineralization occurs in the form of cockade breccias around the marble fragments and comprises base metal sulfides in a carbonate gangue. It consists of colloform-banded sphalerite and galena with minor amounts of other sulfides (pyrite, chalcopyrite, greenockite) and sulfosalts (Ag-rich tetrahedrite, famatinite, pyrargyrite, stephanite and bournonite), included in galena. Supergene oxidation resulted in replacement of galena by cerussite and secondary deposition of the silver-bearing sulfide acanthite. Microprobe analyses in galena indicates no or only minor silver content occurring as isomorphous substitution for Pb. High contents in Ag (up to 0.8 wt. %), Sb (up to 0.9 wt.%) and Au (up to 0.3 wt.%) in galena, are probably due to the presence of submicroscopic grains of pyrargyrite, stephanite and native gold respectively. In addition to the above mentioned Ag-bearing phases, other Ag-carriers in the mineralization include Ag-tetrahedrite (up to 15.3 wt.% Ag) and famatinite (up to 1.5 wt.% Ag). Sphalerite contains 0.8 to 6.3 wt.% Fe corresponding to 1.3 – 10.8 mole % FeS. The main Cd carrier in the mineralization is greenockite since Cd content of sphalerite is lower than 0.8 wt.%. The presence of silver-antimony sulfosalts in galena from mine Ari 3 suggests low temperatures of formation, consistent with the fluid inclusion studies, which show low temperatures (~100° to 200 °C) and intermediate to high salinity (13 to 22 wt.% NaCl equiv.) for the mineralizing fluids. Ore deposition at Ari 3 took place in a distal setting from the Plaka granodiorite. It is considered here that the ore fluids migrated away from the heat source along the detachment fault in a brittle regime. Overpressured fluid circulation within marble under brittle condition could be responsible to its brecciation and then to the metal deposition. The metallic assemblage and fluid characteristics from mine Ari 3 resembles those in other breccia and/or vein mineralization in Lavrion district, such as in Kamariza, Km3, Thorikos, Esperanza mine and Vein 80 at Plaka, thus indicating similar mineralizing processes along the detachment system in the Lavrion district.

E-Mail: voudouris@geol.uoa.gr

Freitag, 01.11.2019, 18.00–18.45 h

Eleni Filippaki:

Analytical and Archaeometallurgical Studies at Thorikos: Preliminary Results

An assemblage of various archaeometallurgical residues, stored in the Museum Andrea Kordellas at Lavrion, were analysed with a portable XRF instrument to determine their chemical composition. The assemblage consisted of slags, furnace fragments, litharges and lead objects (lead sheets or molten lead). The analysis of the assemblage of the aforementioned archaeometallurgical residues gave some interesting results whereas it raised some even more interesting but intriguing issues that need further research. The first, rather secure, conclusion that derives from the above results is that all of the analyzed lead objects, either lead sheets or scraps, are made from lead coming from the Lavrion mines. Regarding the slags' and the furnace fragments' analyses, the question addressed was whether these are remnants for producing silver or iron. Since the slags and the furnace fragments date in the historic times, they can

originate either from silver or iron smelting. The results of the analyses showed no silver content which would offer a vague indication that these slags were the residues for silver production.

N.C.S.R DEMOKRITOS, Institute of Nanoscience and Nanotechnology, GR – 153 10 Athen, Ag. Paraskevi, Neapoleos 10; E-Mail: e.filippaki@inn.demokritos.gr

Saturday, 02.11.2019, 9.00–9.45 h

Frank Hulek:

The Trial Excavation in the Ergasterion Ari 63

In 2016 a trial excavation in the ergasterion Ari 63 took place as a synergasia between the Ephoria of East Attica, the German Archaeological Institute at Athens and the Ruhr-University at Bochum. The site had already been cleaned and mapped the year before. It was presumably an ergasterion, due to the typical ground plan, the remains of waterproof mortar in one of the rooms and a round cistern adjoining it. The first trench was opened where the washery was suspected. The following trenches concerned two adjacent rooms to the East and the corridor to the West.

The main focus was on four questions: First of all, whether the complex was disturbed by the activities of the modern mining companies. This could clearly be denied, but traces of byzantine treasure seekers were detected. Secondly, when was the ergasterion built and when was it abandoned? Thirdly, which process steps had been performed there and finally, what could be learned about the different steps of the enrichment of the ore by scientific analysis of the samples of metallurgical remains and waste products collected.

The paper will present the preliminary results of the trial excavation, especially some observations on the process step carried out in the ore washery which worked according to the principle of a so-called plane-table.

Archäologisches Institut der Universität zu Köln, Albertus Magnus Platz, D–50923 Köln; E-Mail: f.hulek@uni-koeln.de

Saturday, 02.11.2019, 9.45–10.30 h

Sophia Nomicos – Konstantina Tsaïmou:

Pottery Assemblages from Workshops Excavated by K. Tsaïmou at Ari (2005–2008)

The general outline of the Laurion mining history as presented in the ancient literary evidence has been known to scholars at least since the 19th century. Excavations in a number of ore beneficiation workshops since the 1960s, however, have refined the picture considerably. Most importantly, they showed that it was not the 5th but the 4th century BC that has left a distinct imprint on the landscape. However, there are still open questions that concern not only the overall fine chronology but also the daily life in an *ergasterion*. In order to approach these questions, the material remains from four workshops excavated by K. Tsaïmou at Ari were studied in 2012 at the Archaeological Museum of Lavrio. Section drawings of characteristic finds and photographs of the pottery were made. It is the aim of this paper to present first results concerning the typology and chronology of the finds. It will be discussed to what extent and in what way they can contribute to the existing picture of the Laurion mining chronology. Moreover, the workshops are of special interest, because each of them contained a milling device of the edge-mill type that used to be known as a helical washery and that has not yet been securely dated. By establishing a chronology for the material finds from the workshops at Ari, it will hopefully be possible to narrow down the time frame for the introduction of these milling devices in the Laurion.

1) Institut für Klassische und Christliche Archäologie und Seminar für Alte Geschichte, Westfälische Wilhelms-Universität Münster, Domplatz 20-22, D – 48143 Münster; E-Mail: nomicos@uni-muenster.de; 2) National Technical University of Athens (EMIT), School of Mining and Metallurgical Engineering (Σχολή Μηχανικών Μεταλλείων - Μεταλλουργών)

Saturday, 02.11.2019, 11.00–11.45 h

Roald Docter:

The Cistern No. 1 Workshop at Thorikos

Situated within Macrosquare A'51 just above the Industrial Quarter of Thorikos, a rectangular cistern and the ergasterion to which it belonged have been the object of study between 2010 and 2012. The present contribution to the conference will discuss the results of the excavation, additional analyses and hydrological studies, conducted as a project of the Belgian School at Athens and Ghent University in collaboration with Utrecht University and under the aegis of the then Second Ephorate of Prehistoric and Classical Antiquities (B' EPIKA).

The cistern had been mentioned by Herman Mussche in his seminal work *Thorikos. A Mining Town in Ancient Attica* of 1998, but had remained unstudied. Mussche estimated its capacity to be 80m³, hence to be the largest one discovered on the Velatouri Hill. The chronology and layout of the workshop to which the cistern belonged, remained uncertain. It clearly depended upon the yield from Mine No. 2. In comparison to the chronology of other ergasteria in Thorikos and the Laurion, we hypothesized that the workshop had been constructed somewhere during the second half of the 5th or, more probably, the 4th century BCE (Kakavoyannis 2001; Docter, Van Liefveringe 2010). Although the finds from within the stratigraphy inside and outside the cistern may be suggestive of a late 5th century chronology, this should be considered as a t.a.q.

The latest - and relatively large part of the - pottery in the fill of the cistern may be dated to the 6th or 7th century CE, which offered a totally new perspective upon the latest phase of Thorikos' occupation and metallurgical activities in the area of Mine no.2 (cf. Docter et al. 2010). the basin of the cistern turned out to be much deeper than expected and can now be shown to have a capacity of 209m³.

References:

R. F. Docter – K. Van Liefveringe, Thorikos and the Industrial Quarter: A mine of information on the silver industry of ancient Attica, in: P. Iossif (ed.), *"All that glitters..." The Belgian Contribution to Greek Numismatics*, Athens, 52–59.

R. Docter – P. Monsieur – W. van de Put, Late Archaic to Late Antique Finds from Cistern No. 1 at Thorikos (2010 Campaign), in: R.F. Docter (ed.), *Thorikos Reports and Studies* (Thorikos 10), Gent 2011, 86–123.

E. Kakavoyannis, The silver ore-processing workshops of the Laurion region, *The Annual of the British School at Athens* 96, 2001, 365–380.

K. Van Liefveringe – R. Docter – T. Pieters – F. van den Eijnde, The Excavation of Cistern No. 1 at Thorikos (2010–2011 Campaigns), in: R.F. Docter (ed.), *Thorikos Reports and Studies* (Thorikos 10), Gent 2011, 61–85.

K. Van Liefveringe – M. van den Berg – C. Stal – R. Docter – A. De Wulf/N. Verhoest, Reconsidering the Role of Thorikos within the Laurion Silver Mining Area (Attica, Greece) through Hydrological Analyses, *Journal of Archaeological Science* 41, 2014, 272–284

Dep. of Archaeology, Ghent University, Sint-Pietersnieuwstraat 35, B-9000 Gent (Belgium); E-Mail: Roald.Docter@UGent.be

Saturday, 02.11.2019, 11.45–12.30 h

Markos Vaxevanopoulos¹ – James Ross^{2,3} – Panagiotis Voudouris⁴ – Vasilios Melfos⁵ – Kostis Soukis⁴:
Lavriion Shafts Mapping: A More Detailed Investigation of the Lavriion Stratigraphy

The ancient mining territory of Lavriion in Attica-Greece comprises over 500 shafts opened since antiquity in order to exploit the silver bearing ore deposits. These vertical constructions possibly have served a multipurpose role as artificial conduits for uplifting the extracted material, exploration shafts as well as ventilation chimneys. They are situated in an area of 150 m³ and their depth varies from a few meters to over 100 m. The main contacts of the Lavriion rock sequences, where the ore mineralization is hosted, are visible in the majority of the shafts. The main extracted minerals found in the primary and oxidised hydrothermal replacement deposits are galena, cerussite and anglesite. The ore mineralization is hosted in mantos and stockwork clearly visible in the shafts' interior.

This study presents the results of the "Lavriion Shafts Project" that took place during 2018 with primary objective the description of the stratigraphy in selected mining shafts at Lavriion. Another main objective of the project was the location of several shafts depicted on the maps of Lavriion district, which enables

the intergration of the subsurface survey to the surface data. Twenty five mining shafts were located and speleologically explored. The laser meter DISTO-X was used for the topographical mapping of the shafts. Geological mapping was performed at the inner part of the shafts. Tectonic features were also included in the map of every vertical construction. The gained stratigraphic data provides enough information for the future construction of a 3D geological model of the Lavrion mining district.

1) *Ecole Normale Supérieure de Lyon*, E-Mail: Vaxevanopoulos@hotmail.com; 2) *University of Western Australia*, 3) *Curtin University*, 4) *National and Kapodistrian University of Athens*, 5) *Aristotle University of Thessaloniki*

Saturday, 02.11.2019, 14.00–14.45 h

Sophie Duchène:

The Ore Mills of the Laurion

From Classical times onwards, crushing and grinding implements were used at least at two stages of the silver production process in the Laurion: before the washing, to crush and grind silver-rich lead ore, and after the cupellation, to recycle litharge. Some scholars have discussed them, like C. Tsaimou (1988, pp. 24–36, 91, 126), C. Conophagos (1980, pp. 216–223), and E. Kakavoyannis (2005, pp. 220–224). However, uncertainties remain. Olynthus mills, also called hopper-rubber mills, were found in ore-processing workshops and are assumed to have played an essential role in the silver production. However, the use of hopper-rubber mills in these workshops is not fully understood yet. Were they all used to grind ore, or were they also used to grind cereals for the workers? Within the framework of my Ph.D. about crushing and grinding implements in Thorikos, I study the morphology, macro-traces, and raw material of these mills to answer this question. Other uncertainties also remain about how the massive stone slabs, found in many workshops, were used, or about the utilization of rotary mills to grind ore.

This presentation gives an overview of crushing and grinding implements generally held to have been used in the course of the silver-production process. It is divided into three main parts. The presentation will start with a brief introduction about the utilization of crushing and grinding implements to process the ores. The second part will present the implements assumed to have been used for ore comminution in the Laurion in Classical times. The last part will address the question of their function. Were they all ore-mills?

References:

Conophagos, C. (1980) *Le Laurium antique et la technique grecque de la production de l'argent*. Athènes: C. Conophagos.

Kakavoyannis, E. (2005) *Μέταλλα εργάσιμα και συγκεχωρημένα. Η οργάνωση της εκμετάλλευσης του ορυκτού πλούτου της Λαυρεωτικής από την Αθηναϊκή Δημοκρατία*. Αθήνα: Ταμείο Αρχαιολογικών Πόρων και Απαλλοτριώσεων.

Tsaimou, C. G. (1988) *Εργασία και Ζωή στο Αρχαίο Λαύριο σε εγκατάσταση εμπλουτισμού μεταλλευμάτων τον 4ον Αιώνα π.Χ. Διδακτορική διατριβή στο Ε.Μ.Π.*

Dep. of Archaeology, Ghent University; E-Mail: Sophie.Duchene@UGent.be

Saturday, 02.11.2019, 14.45–15.30 h

Anno Hein:

In-situ measurements of Olynthus Millstone Fragments at the Ari-Harvalo Washeries
Using Portable Energy Dispersive XTF (pEDXRF)

During the surveys in the area of Ari-Harvalo a considerable number of fragments of Olynthus millstones were discovered at several sites, which were apparently related to metallurgical activities. The question was raised whether the Olynthus millstones were possibly used for the grinding of lead ores or other materials, such as litharge, which would potentially have left metal residues adhered to the surface. Therefore a pilot study was initiated in order to analyze surface and body of selected fragments at two of the sites with non-invasive portable energy dispersive X-ray fluorescence (EDXRF). At two sites a total number of 16 millstone fragments were examined and the surface of a presumptive ‘anvil’, assumedly used for hammering of lead ores. For comparison measurements of the ambient soil were taken at both sites, as the environment in the area of Laurion presents a biased lead content due to the past metallurgical activities. Further pEDXRF measurements in the following year concerned an excavated washery at Ari-

Harvalo. Within the present context washing tables and plasters of reservoirs, channels and basins were investigated. Scope was to examine the surfaces for metal residues and to investigate water tightening lining materials used in the installations. Results of the pEDXRF measurements taken so far will be presented and discussed in view of function and application of the examined objects and installations.

*NCSR DEMOKRITOS Institute of Nuclear and Particle Physics, GR – 153 10 Athen, Ag. Paraskevi, Neapoleos 10;
E-Mail: a.hein@inn.demokritos.gr*

Saturday, 02.11.2019, 16.00–17.45 h

Hélène Morin-Hamon:

**Buddling. Flat-bedded Washeries: Ore Process Revisited
through XVIth-XIXth Centuries Mining Engineers Archives**

The research carried out on mining in the Laurion and particularly on the underground networks and the importance of the volumes extracted raise the crucial question of ore dressing and therefore the process used. The presence of flat-bedded washeries, flanked by tanks and accompanied by grinding workshops, near the extraction areas, raises also the question of their functioning and the role of workers in such devices.

The washing facilities used by the miners of the Laurion have given rise to numerous interpretations and controversies.

The aim of this work is to update the various hypotheses and to compare evidences with the devices implemented by the miners during the 18th and 19th centuries.

In the reports that the mining engineering students at the Paris School of Mines wrote, the washing installations, and particularly the buddles, are meticulously described. A buddle is an elementary device used to separate the ore from its gangue by means of a water stream. The oldest and simplest forms were an oblong, shallow pit dug into the ground, or a shallow, slightly inclined wooden channel. The process is simple: the mixture of ore and gangue was placed and agitated in a stream of water; the lighter particles were carried away, leaving behind them the much heavier galena fragments. The typical length of the buddles is around two metres, as are the floor at Laurion.

Research carried out on washing technologies of 18th and 19th century large-scale washing of iron alteration ores in eastern France has led us to make comparisons with the systems in place at the Laurion. The proposed model is based on both field observations and iconographic and documentary sources from 18th/19th century mining engineers.

The washing process is relatively explicit as soon as the primary product has undergone a first regular grinding treatment; the whole process, but also the gestures and the device, as soon as we immerse ourselves in the descriptions of the users or in the mining treatises that are based on evidences. This is the case of an unknown mining treatise, *First Principles of the Science of Mining and Salt Mining*, written by Franz Ludwig von Cancrin (Cancrinus), a prominent mining man, metallurgist and mineralogist, (1738-1816), from Hessen, dated from the 18th Century, preserved in the Zürich Library in Switzerland, which proves to be perfectly consistent with the process in use in the Laurion.

The flat-bedded washeries had a tank in which a large volume of water could be stored. Water flowed out on a slightly inclined surface: a buddling floor. The water was distributed on a small amount of finely ground ore under the outlets, probably assisted by raking. The particles were washed in a stream of water by depositing the heavier particles first.

Below this buddle floor was a catch-channel for water and sediment. This channel surrounds a central square plan (a drying floor) and functioned as a clarifying system with overflow facilities like the labyrinths on many 19th century sites. The layout of the channels, with storage tanks at each corner and narrow inclined channel suggest that sedimentation was occurring gradually.

The ingenuity of the ancient miners lies in the total control of hydraulics and particularly of the supply of washing systems in an arid context. The enrichment model chosen corresponds to washing by stirring and settling. It was a simple, ingenious and effective process that made it possible to recycle water continuously in a closed space while achieving optimal separation of sediments and a progressive

classification of low-grade ore: a precious material with high added value. The buddle technique is mastered here in vessels designed and built with perfect waterproofing and protected from the sun to avoid evaporation, hence the quadrangular standard construction, which could be declined in different proportions adapted as well as the volume to be treated, and which constitutes a perfect technical engineering model.

Université de Lorraine, Nancy; E-Mail: withleen@hotmail.fr

Saturday, 02.11.2019, 17.45–18.30 h

Athanassia Markouli:

19th / 20th Cent. Mining and Metallurgy in Lavrion

The mine-related works carried out in ancient Lavrio were, in chronological order: the extraction of ores, their enrichment and finally “metallurgy”, or the production of metals.

The ores of interest to the ancient Greeks were mainly the following: 1) rich oxidized and sulphur-bearing minerals of argentiferous lead 2) rich mixture of sulphides of lead, zinc and iron, the so-called B.P.G.

The first step was the mining followed by the enrichment. Through enrichment, ancient Greek were able to exploit even the poorest ores since enrichment improves their metallurgical content of useful ingredients by rejecting part of the unproductive content.

For an ore to reach enrichment, it had first to pass through the crushing stage. After *enrichment*, the ore then needed to be smelted, which produced liquid metal and removed sulphur. It was done in a special furnace at a high temperature. The next step was to separate the silver from the lead, which was done through what is called the *cuppelation* process.

As the years passed through, the mining and metallurgical processes stopped till 1929, when I. Kapodistrias became interested in Lavrio. After him G. Pachys came to Lavrion and requested permission to exploit the slag heaps like Serpieri did some years later. Andreas Kordellas visited Lavrion, studied the slag heaps and determined that their exploitation would be profitable.

After many discussions and investigations, on 29 April 1864, the firm Hilarion Roux et Cie was established in order to exploit the slag heaps and to resmelt them.

With the resolution of the exciting Lavriot Issue, the company of Hilarion Roux et Cie ended its works and, from it, two new companies were created: “The Metallurgical Company of Lavrio” (1873-1927) and J.B. Serpieri’s company, “The Mines of Kamariza”, which two years later evolved into the “French Mining Company of Lavrio” (1875-1981, FMCL).

Metallurgical processing by the initial company of Hilarion Roux et Cie focused on smelting the tailings and lead oxide, the final product being argentiferous metallic lead. It suffices to note that during the period of processing the wastes, up to eighteen furnaces of the Castilano type were required. FMCL installed a full metallurgical complex that included roasting ores containing sulphur enrichments, making bricks of finely granulated rich ores and reduction smelting.

Reduction smelting was now done in new, larger furnaces of the Water Jacket type. The technology of reduction smelting was very similar to that of the ancients but with advanced equipment and separate outpourings of slag and lead

The production of metallic argentiferous lead by the three most important mining and metallurgical companies of Lavreotiki was as follows:

- The company *Hilarion Roux et Cie* (1865-1873), 60,000 tons.
- The *Metallurgical Company of Lavrio* (Greek Company) (1873-1917) 311,259 tons and 2,244 tons between 1924-1927, for a total of 313,503 tons.
- The production of silver by the *French Mining Company of Lavrio* between 1942-1977 was 225 tons. In previous years, silver was withdrawn from production in Greece by all three large companies and was instead done abroad.

The operation of the two large mining and metallurgical companies, Greek and French, which also absorbed various other smaller firms that became active in the region, made Lavrio an important mining and metallurgical centre, among similar ones in Europe.

National Technical University of Athens (EMII), School of Mining and Metallurgical Engineering (Σχολή Μηχανικών Μεταλλείων - Μεταλλουργών); E-Mail: amarkoulis@yahoo.gr

Sunday, 03.11.2019, 9.00–9.45 h

Alexandre Tarantola – C. Scheffer – O. Vanderhaeghe – P. Voudouris – A. Fotiades:
Fluid Circulation and Ore Deposition in the Geodynamic Evolution of the Lavrio Area

Fluids are the main carriers of heat and elements within the Earth's crust. The presence of hydrothermal ore deposits at the crustal scale is evidence of fluid flow that leads to leaching, mobilization, transport, and deposition of elements of economic interest. Such fluids can be of magmatic, metamorphic, connate, marine, or meteoric origin. Constraining the source of ore-forming fluids is key to determining the origin of metallic elements in ore deposits. Our work aims to link fluid circulation and ore deposition within the general frame of the geodynamic evolution of the Lavrio area.

The Lavrio area is part of the Hellenides Domain formed along the Africa-Eurasia convergent plate boundary active for the last 80 m.y. Rocks of the European platform were transported to high pressure and temperature conditions in the subduction zone. The progressive slab retreat to the South was accompanied by magmatism and exhumation of metamorphic rocks along low-angle detachment systems. This is what is observed today at the scale of the Lavrio peninsula with a more or less horizontal contact between the upper and lower units, made of marble and schists, which corresponds to the main location of the detachment.

The formation of ore deposits in the Lavrio Pb-Zn-Ag district was associated with this Miocene detachment that accommodated orogenic collapse and exhumation of high-grade nappes across the ductile-brittle transition. This district consists of (1) low-grade porphyry Mo style, (2) Cu-Fe skarn, (3) high-temperature carbonate replacement Pb-Zn-Ag, and (4) vein and breccia Pb-Zn-Ag mineralization.

The porphyry and skarn deposits show a strong spatial and genetic relationship to the causative Plaka magmatic intrusion, with the metals and fluids being attributed to exsolution of the magma. Carbonate replacement is associated with intense decarbonation and liberation of CO₂ at the ductile to brittle transition during exhumation. The fluid inclusions trapped in fluorite and calcite of the last stages of vein and breccia mineralization are compatible with the ore fluid being the result of mixing of meteoric water with evaporated seawater during brittle deformation closer to the surface.

Although the observations show clearly that the Plaka granodiorite played a major role on ore deposition, the question regarding the source of metals is not solved yet. Does all the metallic stock derive from the magmatic intrusion or does this intrusion only play a role as generating convective hydrothermal system driving circulation of fluids and remobilized earlier pre-concentrated metals?

Université de Lorraine, Faculté des sciences et technologies, UMR 7359 GeoRessources, Campus Sciences, rue Jacques Callot; BP 70239-54506 Vandoeuvre-lès-Nancy, France; E-Mail: alexandre.tarantola@univ-lorraine.fr

Sunday, 03.11.2019, 9.45–10.30 h

Christophe Flament:
Fiscal and Administrative Aspects of the Laurion's Mining Leases

This communication is devoted to the fiscal and administrative aspects of the mining leases in Laurion. Several crucial questions will be examined: What happened to the silver after the melting process? Could the lessees freely dispose of this metal? How did Athens earn revenues from the mines? What orders of magnitude were they? Were they sufficient to maintain the large Athenian war fleet?

To answer those questions, we must first look at the operating system of the mines, including discussions about their legal status, drawing mainly from the text of the Aristotelian *Constitution of Athens*.

The next stage will be to determine the order of magnitude of the state incomes from the Laurion mines, asking the question of the distribution of the metal extracted from the mines between lessees and the city.

We will first investigate the prices of the mining concessions, and then try to estimate the yearly output of the mines by developing a model based on the mining sector's profitability: for the working of the leasing system as it was organized in Athens, the profits generated had of course to be greater than the expenses that can be reasonably estimated for the mid-4th century at ca. 700 talents (ca. 18 tons) of silver per year.

At this point, the main challenge will be to determine what lessees did with their metal so that they could be able to pay the costs associated with mining activities. It is advocated in this paper that many of – if not nearly all – the silver produced in Laurion was actually converted into coins, the renowned Athenian “owls”. In those conditions, the break-even point fixed for the mining activities in Athens (ca. 700 talents), would thus correspond to the minimal quantity of silver produced in Laurion yearly, but also to the amount of metal coined every year (the equivalent of 4,200,000 drachmas). Several important consequences for the Athenian monetary history follow from this conclusion, regarding the role of state authorities in the monetary process, the parameters determining the rhythm and scale of the monetary production, as well as the dissemination of the Athenian coinage in Athens and all over the Aegean area.

Université catholique de Louvain, FIAL, Place Blaise Pascal 1, L3.03.13; 1348 Louvain-la-Neuve; E-Mail: christophe.flament@uclouvain.be

Sunday, 03.11.2019, 10.30–11.15 h

Nikiforos Meimaroglou:

Lavrion Hydraulic Mortars and Clay Mortars

In Lavrio, silver bearing ores of lead have been processed to produce silver from prehistoric times. During the fifth and the fourth century B.C., an intense exploitation of these ores took place, correlated with the sudden increase in wealth and power of Athens. As a result, structures associated with ore processing are still well-nigh ubiquitous in the area. This presentation focuses on the mortars, both hydraulic and earthen, used in these structures. At first, a common building pattern has to be acknowledged and explained. Earth mortars were used as structural mortars of stone masonry, while hydraulic mortars were used only as renders. The preferential use of earth mortars instead of hydraulic mortars as load-bearing elements, can be attributed to fuel scarcity, aesthetic reasons and the deep knowledge of earthen building materials by the Athenians. The latter is proved by the properties of the earth mortars examined, which are similar to those proposed nowadays in earth building handbooks and standards.

The hydraulic renders are in most instances applied on structures in contact with water. These include the cisterns, the washeries and some ancillary structures. The system of plastering comprised of two distinct materials, both hydraulic. 1) The outermost brown waterproofing thin coat, that has been already thoroughly examined and found that consists of lime mixed with a mix of ores or/and litharge, which were previously melted together and quenched to obtain a non-crystalline, amorphous material. What is untold so far is that If this procedure, melting and quenching, wasn't applied, the material wouldn't possess hydraulic properties. Therefore, a knowledge and perception of pozzolanic activity and hydraulicity by the craftsmen of that time can be assumed. This knowledge, can't have been obtained accidentally, as in the case of mixing lime with volcanic earth or crushed ceramics, which are the two most well-known sources of hydraulicity in ancient mortars. 2) The concrete substrate, for which only a few researches have been conducted, each with different purpose, and has been thought to be a typical aerial-lime mortar. New scientific evidence, combined with the existent studies suggest that it is not an aerial-lime mortar but a high-performance concrete with hydraulic properties. Some properties, that can be considered unique for historic mortars, are the high compressive strength, the high density and the low porosity of this material. Further consistent, interdisciplinary research on this material is required because a) some of its properties are beyond our knowledge of historic mortars and are comparable with modern concrete. B) The use of hydraulic binders by Greeks during the classical antiquity is still a matter of dispute and the common narrative has that hydraulic binders were first used extensively during the third or the second century B.C by the Romans. So, there are gaps in building materials history that need to be filled.

National Technical University of Athens, Laboratory for Earthquake Engineering, School of Civil Engineering, Zografou Campus, 9 Iroon Polytechniou str., 15780 Zografou, Greece; E-Mail: nikmeim@gmail.com

Sunday, 03.11.2019, 11.15–12.00 h

Effie Photos-Jones:

The multifaceted character of the extractive metallurgy of Laurion

Although mining and minerals processing dominate our understanding of the archaeological landscape of Classical/Hellenistic Laurion, the extractive (pyrometallurgical) aspect of it is still not sufficiently scrutinised. For example, there is still little association between particular mining galleries, smelting furnaces and heaps of metallurgical waste or little understanding as to whether any particular extant heap of metallurgical waste reflected the production of lead OR silver OR both.

Our view of Laurion is for ever dominated by the drive to extract silver, taking the lead metal production as an inevitable ‘by product’. Yet the production of the latter, an undisputedly essential metal to everyday life, was also the driving force for the set-up of other industries, with no pyrometallurgical basis, like that of synthetic minerals used as pigments or medicines. The manufacture of these synthetic minerals was recorded in detail in the works of Theophrastus, Dioscorides or Pliny and is certainly not exclusive to Laurion. We are referring to psimythion or synthetic lead carbonate. This paper will give a short account of the manufacture of the above mineral in a 5th–4th century BC, Athens /Attica context. To our knowledge, there are no such workshops found in Laurion, or indeed anywhere else in contemporary Athens, but the lead metal used was undisputedly of Laurion origin.

University of Glasgow, School of Humanities; E-Mail: Effie.Photos-Jones@glasgow.ac.uk