Der Anschnitt, Beih. 50, pp.247 – 254, 2023, https://doi.org/10.46586/DBM.264.405

Effie Photos-Jones

Beyond the silver 'owls': Laurion lead and its contribution to synthetic lead-based minerals for the health care/medicines market (4th century BC)

ABSTRACT: *This short paper aims to highlight the use of lead metal from Laurion in the 4th century BC, not merely as a functional metal, but as a raw material in the manufacture of synthetic lead-based minerals, (psimythion, $PbCO_3$) aimed at the health care/pharmaceuticals market of antiquity and as pigments. The paper brings together past and recent work by the author and her colleagues. Past work relates to the analysis of tailings from ore processing recovered from the 1980s excavations of the washeries at Agrileza, Laurion. Recent work concerns the examination of pellets of psimythion ($PbCO_3$) from Athens and Boeotia dating to the 4th century BC, now in the collection of the National Archaeological Museum, Athens (NAM). Comparison of the relative concentrations of Ag and Pb in the three data sets (as grams of Ag to ton of Pb) suggests a preference for an Ag-rich source (whether Pb metal or Pb ore). It is therefore suggested that a) the pellets of psimythion must have been made, if not in Laurion, but of Laurion lead, and b) for the manufacturing of psimythion for the health care/medicines industry, silver-rich lead metal seems to have been preferred over de-silverized lead. Presently, and in view of small data sets, it cannot be said with confidence whether this was a deliberate choice or not.*

After nearly 150 years of continuous research into Laurion's 5th – 4th century BC activities associated with the production of the Athens silver coinage (owls), it is perhaps now timely to begin looking for evidence for other Pb/Ag-based industrial activities servicing other markets, as well; in that context it is important to keep an open mind as to what we define as 'waste'. Lithargyros (translated as litharge), thought to have been the 'waste' product of silver making was another synthetic mineral in its own right.

KEYWORDS: PSIMYTHION, LEAD CARBONATE, LITHARGYROS, ATHENS SILVER COINAGE(OWLS), AGRILEZA TAILINGS, HEALTH-CARE PRODUCTS

Introduction

Of the Athenian argyreia, and their "ore"

Our view of Classical/Hellenistic Laurion has been largely shaped by its well-documented association with silver extraction and the minting of Athens' powerful coinage, the silver "owl". There are many contemporary references to Laurion as the locality of the silver mines (*argyreia metalla*) of Athens (or of the Athenians).[1] In the Byzantine sources Laurion is referred to as the gold mines (*chrysseia metalla*) of the Athenians, rather than their silver mines (Suda Lexicon). Nevertheless, we know from the numismatic evidence that gold owls were indeed minted in the 3rd century BC. Interestingly, also in the later periods, Laurion is mentioned in two capacities: first, as having mines (of silver or other metals) (*echon metalla*) and second, as making metal (silver or other) (*poion metallon*).[2] The distinction makes it clear that the word *metallon* (plural *metalla*) could cover, spatially and processually, both the mine (locality of extraction) as well as the activities associated with the manufacture of the finished product, the metal.

But what is the name Athenians gave to the "ore(s)" they extracted in Laurion? There is mention of silver-rich earth (*argyritis ge*) of the Athenians.[3] Lead-rich sand (*molybditis ammos*) is also invoked, in this case as a source of *lithargyros* but not in direct relation to Laurion (Dioscorides *Mat. Med. V.87*). There is an additional reference to *argyritis ammos* again not in direct association

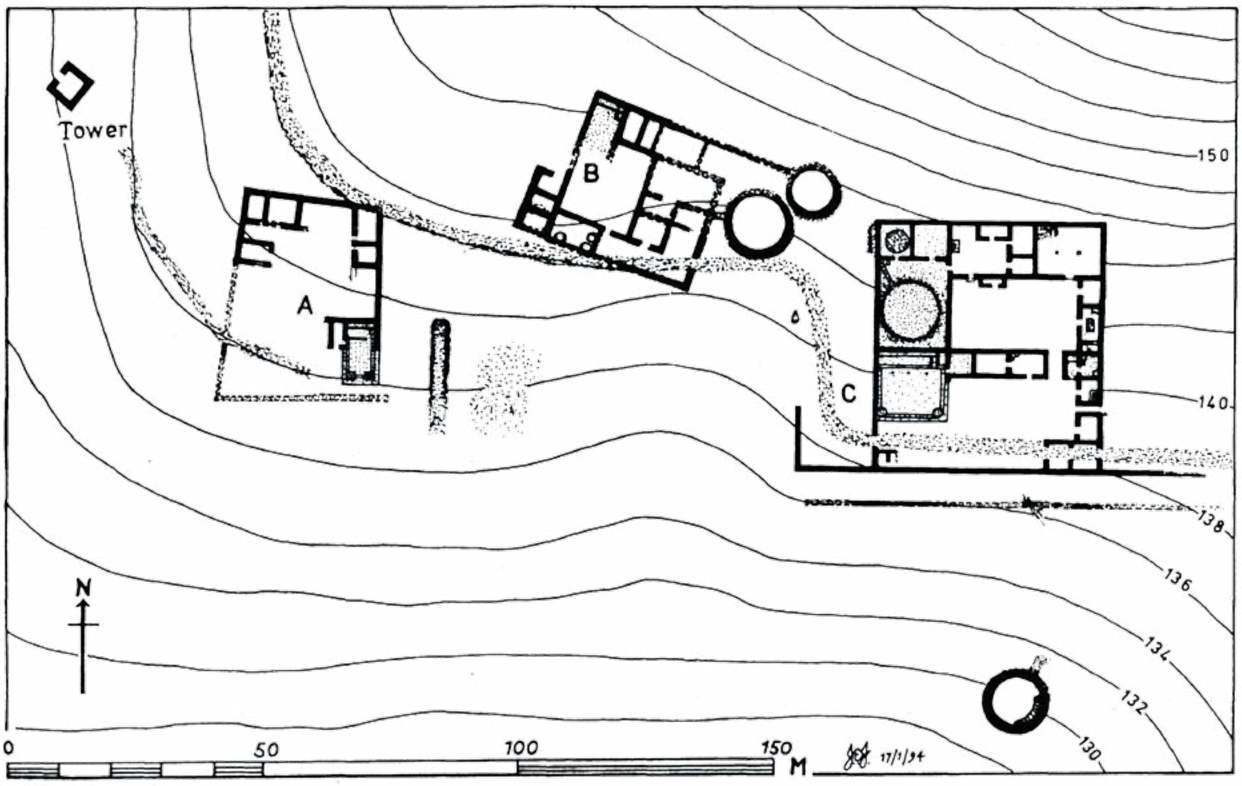

Fig. 1: Plan of Agrileza compounds A, B and C with cistern (bottom right) (after Photos-Jones and Jones, 1994, p. 314, fig. 1).

with Laurion. It is not clear what the difference between *argyritis ammos* and *molybditis ammos* was, apart from the possible assumption that the latter may have not contained silver.

It is curious that Theophrastus, in his treatise *On Stones,* is rather silent about Laurion in reference to silver making, despite the *argyreia* being both active at the time and relevant to his book’s title. There is only a mention to the Athenian Callias working the *kinnavaris* (*κιννάβαρις*) in the *argyreia,* for the express purpose of obtaining gold (*On Stones,* 59). This suggests that gold was extracted from *kinnavaris* but silver was extracted from another ore. *Kinnavaris* is thought to refer to cinnabar (mercury sulfide), yet that mineral remains elusive in Laurion.

Since the 19th century, when research interest in ancient Laurion started to take off, it has been acknowledged that Laurion’s 5th–4th century BC activities revolved around the extraction and processing of argentiferous galena (PbS). In searching for the "galena" reference in the texts, it has been argued that *molybdaina* (Dioscorides, *Mat. Med*. V. 85) (Beck, 2005) is the mineral that equates with it. But, strictly speaking, that "equation" cannot be correct because the description given for *molybdaina* is that it is yellow (*xanthi*), shiny (*stilvousa*/*ypostilvousa*) and orange-tawny (wax-like). This description does not match the colour of galena which is unmistakably lead grey. On the other hand, Dioscorides (*Mat. Med*. V.85) does not mention Laurion as *molybdaina*’s "site location" but Corycos, the NW promontory of Crete. He mentions that the *molybdaina* of Corycos and of Sevasti (another locality) is *also* mined (*esti de tis kai orykte*)[4], implying that the material described as *molybdaina* may have been extractable from both surface "outcrops" as well as underground veins.

One possible mineral to be equated with *molybdaina* might have been wulfenite ($PbMoO_4$), an orange-red oxide of Pb-Mo with an adamantine and resinous lustre. Wulfenite has been reported in Laurion at Adami mine 2 by Voudouris, et al. (2008, p.93) and in association with the evidence for molybdenite in Plaka. It has been highlighted that the elements Mo, Au, Bi, Sn, Ni exist in elevated concentrations across the Laureotiki but their exact geological origin needs further investigation (P. Voudouris, pers. comm.). Analysed tailings from Agrileza have shown elevated concentrations of Ni and Mo suggesting a tentative but not conclusive association with that deposit (Photos-Jones and Jones, 1994, p.337, tab. 2b).

Over the many years of research in Laurion, there has been little attempt to tie-in particular washeries (and whatever ore remains have been found within) with particular mine galleries, the implication being that mining exploration activities cannot be easily matched to their extractive metallurgical equivalents. Our own analysis of tailings from the processing of the "ore" at the Agrileza washeries (excavations of J.E. Jones in the 1980s) (Fig. 1) showed them to consist not of galena but of cerussite together with fluorite, calcite, quartz and muscovite (Photos-Jones and Jones, 1994, p.357). At the time we assumed that the cerussite detected was the oxidation product of galena and that little of the original "ore" would have been found on site.

I conclude this brief introduction by suggesting that more attention be paid to the name(s) that Athenians (and/or others) used to refer to the lead and/or silver-rich ore extracted from their mines. If *argyritis ge* or *ammos* denotes the raw material extracted, then it is implied that it came with argillaceous materials attached and was of small (sand particle) size. In that scenario, the (pre-smelting) washing cycle would have been particularly targeted to the removal of that argillaceous earth, an activity which may have gone so far under the radar of recent archaeometallurgical investigations. In our paper (Photos-Jones and Jones, 1994) we highlighted the presence of clay minerals like muscovite and kaolinite in the tailings but the samples analysed have been too few to give confidence to the hypothesis.

On minerals *skevasta* and *autophye*

In this paper I shall argue a second point, namely that relatively little attention has been paid so far to antiquity's synthetic minerals. Nevertheless, Theophrastus is particularly informative about minerals, which are both natural (*autophye,* singular-*autophyes*) and prepared/synthesized (*skevasta,* singular-*skevastos*). He gives the example of *kyanos* (*On Stones,* 55), of which there were three varieties denoting "*both a particular blue precious stone and various blue pigments"* (Caley and Richards 1956,183). The terms "natural" and "prepared" (*skevazomenos* rather than *skevastos*) also occur together in Galen's *On Simple Drugs*.[5] Apart from *kyanos,* Theophrastus refers to two additional synthetic minerals: *psimythion* (*On Stones,* 56) and *ios xystos* (*On Stones,* 57). Galen also identifies them as prepared together with *hydrargyros*, *lithargyros* and *psorikon*[5].

However, again curiously, Theophrastus (*On Stones*) does not mention *lithargyros* and/or in association with Laurion. Yet modern archaeometallurgical scholarship has for long associated Laurion with *lithargyros* (litharge) (Conophagos, 1980), in the form of either dense tubes or thick slabs of PbO, and in either of its two polymorphs: the tetragonal litharge or the orthorhombic massicot. Both have been considered waste products of cupellation activities.

The *lithargyros* of Dioscorides (*Mat. Med*. V.87), however, is not a waste product at all, but a deliberately prepared material, serving as the raw material for the manufacture of other synthetic minerals. Dioscorides states that the *lithargyros* of Attica was the best; it was produced "of silver" and was called *lavritis.* Whether originating from Laurion, Sicily or Campania, *lithargyros* was subsequently placed in a pot, having been "cut up" into bean-sized pieces and processed further. There is little doubt that, whether as a desired product or an intermediate "waste", *lithargyros* would have consisted of PbO (yellow, as litharge, red as massicot). But assuming, *a priori,* that the PbO-rich materials encountered in Laurion were "waste" materials, particularly if de-silvered, is at best short-sighted.

XRD analysis of a relevant (PbO-rich) sample from Agrileza (sample 135) showed lead oxide (massicot rather than litharge) and a small amount of cerussite. ICP-OES/AAS analysis of the same showed it to be devoid of silver (Photos-Jones and Jones, 1994, p.346, tab. 6). We can speculate that Agrileza sample 135 was a *lavritis,* but there is need for more extensive analysis of these materials, starting perhaps with field-based, non-destructive methods, i.e.pXRF, for broader hypotheses to be formulated.

Lithargyros features prominently in the *Hippocratic Opus* often in tandem with *psimythion* and other mineral ingredients in the preparation of medicinals. Thus, in the process of examining the archaeometallurgical evidence from Laurion, or indeed anywhere where lead metal was being manufactured and worked, there is a need to exercise caution as to which materials one delegates *a priori* to the realm of "waste". Certainly, composition alone (as in the case of PbO) cannot be the sole defining criterion.

To conclude this cursory discussion into the Dioscoridean lead-based synthetic minerals, apart from *psimythion* and *lithargyros,* Dioscorides mentions another one, namely *molybdos kekaumenos* (*Mat. Med*. V.81). It was manufactured from lead metal sheets/plates *(molyvdou elasmata*) and placed, in layered form, with sulphur, within a cooking vessel (*lopas*) and heated from below. The cooking vessel implies heating, kitchen-oven style, rather than furnace-style, and Dioscorides warns against smelling the fumes from the pot by covering the nose (*skepasas tous rothonas*), since "whatever comes out" is deleterious to health (*vlavera gar e apophora).*

This brief report focuses on the relative concentrations of Ag and Pb in three data sets, presented in Tab. 1: in samples of pellets of *psimythion* from Athens and Boeotia, in the National Archaeological Museum, Athens and in samples of tailings from the washery at Agrileza in Laurion, all three sets dated to c. 4th c BC. The following two sections introduce each set.

The tailings at Agrileza washery C and their Ag/Pb ratios

Our work at Agrileza, both in the early 1990s (Photos-Jones and Jones 1994) and subsequently, in the mid-1990s (the work over two seasons 1995 and 1997 is still pending full publication) aimed to analyse materials recovered from the site. Agrileza consisted of three washeries, Agrileza A, B and C combining workshop and residential quarters (Fig. 1).

The material recovered primarily from compound C was: a. "tailings" representing fragments of "ore" either *prior* to being washed in the washery or *after* they were recovered from the washery. Tailings derived from different rooms within the compound as well as the washery floor proper (Tab. 1); b. fragments of building materials like plasters, cements; c. a few (iron and lead based) slags and litharge. The latter two types of materials are not included in the present discussion.

XRD analysis of a select few samples revealed that the "ore" recovered from the site was not galena but rather cerussite (Photos-Jones and Jones,1994, p.352). There was sparse evidence for clay minerals, at least in the samples collected. The following represent some analytical results from the original 1994 publication.

Sample 6, tailings from in Room XII: fluorite (CaF_2), calcite ($CaCO_3$), barium muscovite ($BaAl_3Si_30_{10}(OH)_2$, quartz, cerussite ($PbCO_3$).

Descriptor	Sample no	Pb%	Ag (ppm)	Ag (g)/Pb (ton)
Athens psimythion pellet 01	13676b-1	47,8	1702	3561
Athens psimythion pellet 02	13676b-2	47,7	1742	3652
Athens psimythion pellet 03	13676b-3	43,5	1883	4329
Athens psimythion pellet 04	13676b-4	44,2	1602	3624
Athens psimythion pellet 05.1	13676b-5.1	44,3	1562	3526
Athens psimythion pellet 05.2	13676b-5.2	41,0	1479	3607
Athens psimythion pellet 06	13676b-6	47,3	1561	3300
Athens psimythion pellet 07	13676b-7	43,2	1607	3720
Athens psimythion pellet 08	13676b-8	45,0	1625	3611
Athens psimythion pellet 09	13676b-9	48,4	1617	3341
Athens psimythion pellet 10	13676b-10	42,5	1499	3527
Boeotia simythion pellet 03	11332-3	57,8	2156	3733
Boeotia simythion pellet 04	11332-4	53,7	1921	3579
Boeotia simythion pellet 05	11332-5	54,1	1908	3529
Boeotia simythion pellet 06	11332-6	57,5	2348	4082
Boeotia simythion pellet 07	11332-7	57,3	2009	3509
Boeotia simythion pellet 08	11332-8	56,2	2205	3923
Boeotia simythion pellet 09	11332-9	53,6	1973	3681
Boeotia simythion pellet 10	11332-10	53,0	1885	3557
Boeotia simythion pellet 11	11332-11	56,0	2021	3609
Tailings, Room XII, Compound C	6	5,47	183	3346
Tailings, Room XII, Compound C	11	7,49	118	1575
Tailings, Room XII, Compound C	16	5,03	185	3678
Tailings, Room XII, Compound C	29	4,02	69	1716
Tailings, S Court, Compound C	30	5,08	50	984
Tailings, S Court, Compound C	37	4,87	49	1006
Tailings, S Court, Compound C	38	4,40	110	2500
Tailings, Room VI, Compound C	39	3,05	122	4000
Tailings, Room VI, Compound C	40	3032	120	3614
Tailings, Room XXI, Compound C	76	4,91	260	5295
Tailings, Room XXI, Compound C	102	3,67	163	4441
Ore washery tailings, Washery C	111	2,94	73	2483
Ore washery tailings, Washery C	114	7,14	299	4188
Ore washery tailings, Washery A	115	4,01	142	3541
Tailings, Room XV, Compound C	142	3,41	97	2845
Tailings, Room NC, Compound C	149	5,20	77	1464
Tailings, Room II, Compound C	196	4,33	153	3533
Tailings, Room II, Compound C	197	6,11	61	998
Ore washery tailings, Washery C	116,1	5,29	284	5369
Ore washery tailings, Washery C	116,2	5,71	345	6042
Ore washery tailings, Washery A	172,1	3,09	96	3107

Tab. 1: Composite data sets consisting of data presented in Photos-Jones and Jones (1994) and Photos-Jones, et al. (2020) showing silver and lead concentrations and their ratios. Different analytical techniques have been used: AAS for Agrileza, pXRF for psimythia.

Sample 116, tailings on washery C floor: fluorite (CaF_2), calcite ($CaCO_3$), barium muscovite ($BaAl_3Si_30_{10}(OH)_2$, quartz, cerussite ($PbCO_3$), in addition to kaolinite.

Sample 135, a piece of litharge: red massicot and small amounts of cerussite.

Photos-Jones and Jones (1994, various tables) reported the major, minor and trace elements in these and other samples determined by ICP and AAS analysis, the latter for Pb and Ag. Tab. 1 above combines the Pb and Ag concentrations and the Ag/Pb ratio determined as grams of Ag to a ton of Pb of the ICP-determined Agrileza tailings. The mean ratio is 3119 (st. dev. 1528). We return to this table after presenting the NAM pellets of *psimythion.*

4th century BC *psimythion* pellets at NAM and their Ag/Pb ratios

Psimythion is widely reported as face whitening material (Aristophanes *Ecclesiazusae* 1072; *Plutos* 965), but it also made a strong appearance in the *Hippocratic Opus* as a mineral ingredient in medicines, often together with *lithargyros*. The *Thesaurus Linguae Graecae* (TLG) research digital data base of Greek texts from Homer to the end of Byzantium contains no less that 1,200 entries for *psimythion,* a number of them in association with other metallic minerals and as ingredient in remedies.

Psimythion in the form of either standardised white pellets or small lumps have been found within (usually but not exclusively) female burials and within clay pots (*pyxides*). These materials have for long been assumed to be items of beautification that the deceased took to her grave. Despite the commonality of the *psimythion* (used often together with the plant-based rouge, *eghoussa)*, its appearance amongst the burials offerings is surprisingly rare. So far, there are no more than a dozen published such clusters of artefacts found within burials across various localities in Greece (Photos-Jones, et al., 2020, tab. 1). There is currently an attempt to bring together the extant archaeological evidence for such finds from burials across Greece, in an effort to address this question (Oikonomou and Photos-Jones, forthcoming).

Regarding the method of *psimythion* preparation, Theophrastus (*On Stones*, 56) gives a detailed account:

> *"(...) lead about the size of a brick is placed in jars over vinegar (oxos) and when this acquires a thick mass, which it generally does in ten days, then the jars are opened and a kind of mold (evros) is scraped off the lead, and this is done again until it is all used up. The part that is scraped off is ground in a mortar and decanted frequently, and what is finally left at the bottom is white lead (psimythion)" (Caley and Richards 1956, p.188) ([oxos] and [evros] have been inserted by this author).*

Oxos is translated as *"poor wine or vin ordinaire"* or *"vinegar produced from oxos"* (see entry in LIddell-Scott-Jones Dictionary – www.perseus.tufts.edu). In the second meaning, it is made clear that *oxos* is distinct from and not synonymous with *vinegar.* For long it has been assumed that *oxos* "equals" vinegar, however the

Fig. 2: Pyxides NAM13676a and 13676b (photograph courtesy of National Archaeological Museum, Athens).

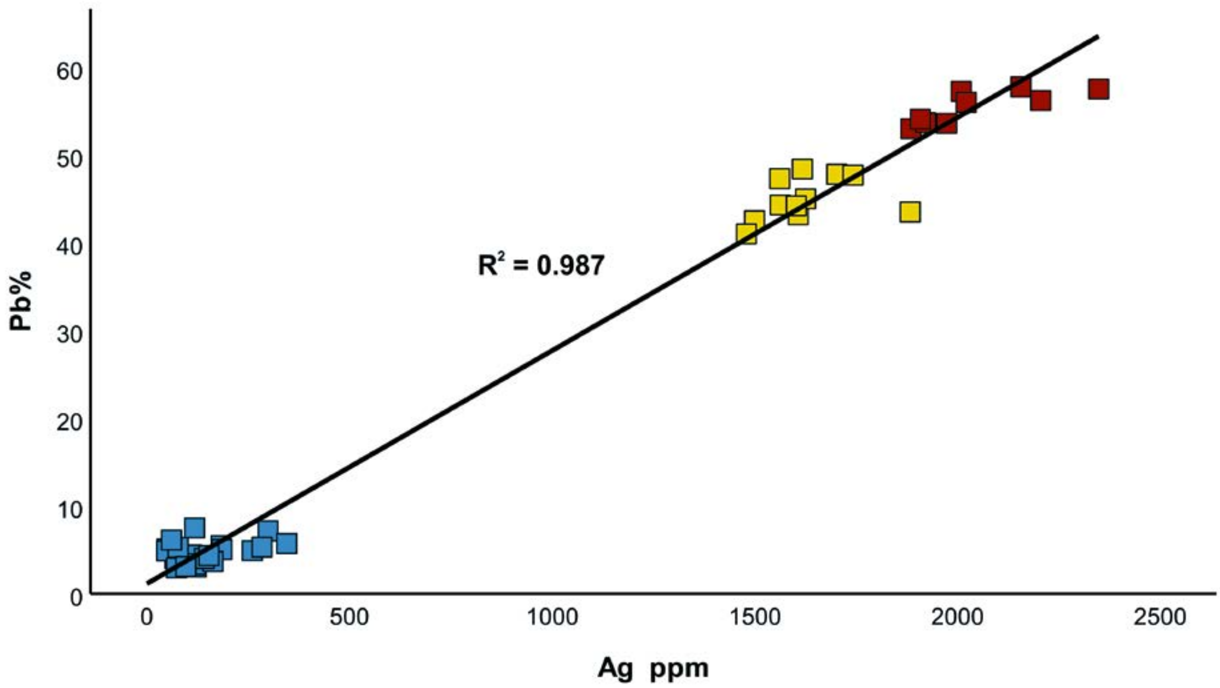

Fig. 3: Plot of Pb vs Ag data shown in Table 1. Coloured in blue are the Agrileza tailings; in yellow, the Athens/Attica psmythia; in red, the Boeotia psimythia.

product of the reaction of lead metal with acetic acid would have led to the formation of lead acetate, a soluble salt and thus unsuitable as a pigment (Stevenson, 1955). In their attempt to find a source of CO_2 which would have driven the reaction to the production of lead carbonate, Caley and Richards (1956, p.188) correctly proposed an alternative source of carbon dioxide like "*spoiled grape juice undergoing both alcoholic and acetous fermentation"*. This, they reasoned, would have provided "*ample carbon dioxide"*.

In our recent study, permission was given by the NAM to sample and analyse destructively three very fragmented pieces, one from each pyxis (13676a, 13676b, 11332) (Photos-Jones, et al., 2020). XRD analysis showed that the samples consisted of near-pure cerussite with only very small amounts of hydrocerussite (usually not exceeding 3% and only in one out of ten cases with amounts c. 11%). More extensive analysis was allowed, non-destructively, by portable XRF on twenty pieces: ten of 13676b from Athens and ten of 11332 from Boeotia. Calibrated pXRF elemental analyses showed only two main elements i.e. Pb and Ca with c. 80% Pb and 2–3% Ca. The uncalibrated pXRF analyses for trace elements showed Ag, Cu, Sn, Sb and Cd (in ppm). Results are shown in Tab. 1. Column 5 in the same table shows the ratio of silver to lead, reported as grams of Ag to a ton of Pb. The mean ratio for *psimythion* pellet is 3635 (st. dev. 238).

Demonstrating that the 4th century BC *psimythia* (Fig. 2) in the National Archaeological Museum, Athens (NAM) consisted of near pure synthetic lead carbonate (cerussite, $PbCO_3$) runs contrary to the long-held assumption, namely that it was basic lead carbonate (lead white or hydro-cerussite ($2PbCO_3 \cdot Pb(OH)_2$)) that would have been made in the Theophrastus pot (Photos-Jones, et al., 2020). Lead white used as pigment has been the predominant compound arising from the industrial-scale Dutch/stack process of the later centuries, but the source of the CO_2 in the two different set-ups (that of Theophrastus vs. that of later periods) is not the same. As early as the middle of the 19th century researchers wondered whether the Theophrastus pot could have sustained the production of any compound beyond lead acetate (from the reaction of acetic acid vapour with lead metal).

In our attempt to understand the presence of Pb carbonate as the main phase, we hypothesized a series of possible reactions which could have taken place between the biotic (both aerobic and anaerobic microorganisms) component in the pot and the abiotic i.e. the lead metal; since lead metal and *oxos* were not in contact, this interaction would have been via the gas phase over the surface of the liquid (Photos-Jones, et al., 2020, figs. 5 and 6). We suggested that the conditions within the pot and in the course of the ten-day cycle would have been dynamic, the oxygen-full environment of the first few days gradually depleting and the CO_2 increasing; at the same time, there would be different minerals forming on the lead metal surface starting with lead hydroxide, followed by lead acetate, and then by hydrocerussite; the simultaneous gradual increase of CO_2 would have pushed the equilibrium from the hydrocerussite to the cerussite.

We turn now to the main topic of this paper, namely the relative concentrations of Ag and Pb within the NAM pellets of *psimythion*; for the Athens pellets the relationship between the two elements is linear but their correlation is poor (R^2=0.11). This suggests that the pellets have originated from different batches of $PbCO_3$ making and by extension of lead metal (different smelts or co-melts). The corresponding plot for the Boeotia *psimythia* again shows a linear relationship but with greater correlation (R^2=0.62), suggesting that most of the pellets have come from the same batch of $PbCO_3$ making. Finally, when the same plot is generated for the Agrileza tailings, again there is poor correlation (R^2=0.14). This means that the samples we chose to analyse from the plethora dispersed across the site originated from "ore" deriving from different mines/sources within the Laureotiki and/or they may have originated from different stages of washing.

When all three data sets are treated in a single plot (Fig. 3) there is nevertheless a good correlation between all three data sets (R^2=0.99). Fig. 3 does not suggest that the source for all three groups is the same, but rather that all three groups have a high Ag content relative to their Pb content. Furthermore, and in the case of *psimythion* pellets, it suggests that there was little attempt to de-silver the Pb metal prior to inserting it within the Theophrastus-type pot and converting it (after 10 days) to the Ag-rich lead carbonate. We do not know at this stage whether the decision to use non-desilvered Pb, namely material in theory destined for cupellation and the minting of the silver owls, was deliberate or not. If it can be demonstrated, through the analysis of many more such pellets which are in themselves rather rare, that it may have been deliberate, then one has to surmise that antiquity may have had some understanding of silver’s antibacterial properties.

Conclusions

Classical/Hellenistic Laurion is pre-eminently associated with the extraction of silver from lead derived from the smelting of the local argentiferous galena. The silver was used in the minting of the powerful Athenian coinage, the silver "owl". As a result, relatively little attention has been paid to the "fate" of the lead metal *per se,* its role seen more as that of a supporting "actor" to the production of silver. However, a closer look at contemporary and later texts makes it clear that lead metal had many and varied applications beyond being a functional metal and/or a vehicle for silver acquisition. It was used, *inter alia*, for the manufacture of lead-based synthetic minerals like *psimythion, lithargyros*, or *molybdos kekaumenos,* the carbonate, the oxide, and (likely) the sulphate of lead, to mention only three. Far from being a waste material, *lithargyros* was considered a mineral useful in its own right and as a starting material for other processes.

Comparison between the *psimythia* of NAM and the Agrileza tailings, makes it clear that both sets of archaeological materials have a considerably elevated Ag content with respect to the Pb present. The question then arises whether the choice of high-silver lead metal for *psimythion* making was deliberate or not. Was there an empirical observation that Ag-rich lead and, by extension, Ag-rich *psimythion* may have been the "preferred" raw material in pharmacological preparations?

Silver is known as an antibacterial (Mijnendonckx, et al. 2013) and the antibacterial action of silver nano-particles (AgNPs) has been well researched (Oei, et al. 2012), and it has been claimed that the antimicrobial action of silver metal was already known in antiquity. Clement and Jarrett (1994) mention the reference in Herodotus about Xerxes using silver vessels to store water. The bioactivity testing of the *psimythion* pellets from Athens and Boeotia was never carried out as part of our recent work, the assumption being that no microorganism would live in the vicinity of so much Pb, the latter being toxic to life. Whether the silver concentration (and particle size?) present within the NAM *psimythion* pellets is sufficient to impart (some) antimicrobial properties to the pellets, in the presence of lead carbonate, will remain at present an open question.

In conclusion, I argue that:

a) it is timely to begin looking at Laurion’s activities beyond the ‘lead-for-silver’ owls narrative, which has dominated Laurion studies for a very long time.
b) there is a need to revaluate our own definitions of what may have constituted "ore" and/or archaeo-metallurgical "waste" in the context of 5th/4th century Laurion and how the "owl"-making industry fed into or worked in parallel with ancillary industries which may have also had a need for silver-rich lead.
c) industries involving mineral synthesis using (argentiferous) lead as one of the raw materials and their representation in the archaeological record is a relatively little-researched field. This is on account of the sparsity of residues it leaves behind, at least compared to pyrometallurgical waste.

On a final note, the greater Lavreotiki peninsula would have also provided the second major ingredient needed in the manufacture of synthetic minerals like *psimythion and ios xystos* (verdigris). This is the good wine of the modern Mesogheia, turned (on "demand") into *"oxos"* for the purposes of the pharma industry of antiquity!

Notes

1 For the purposes of this short paper, only Greek sources were explored and within the comprehensive digital DB, *Thesaurus Linguae Greacae* (http://stephanus.tlg.uci.edu). Translations of individual words, derive from Liddell-Scott-Jones (LSJ) Greek-English Lexicon (www.philolog.us); also, the Greek name is given in Latin characters to retain the meaning of the original. *τὴν·Πάραλον·γῆν·καλουμένην·μέχρι·Λαυρείου, οὗ·τὰ ἀργύρεια μέταλλά·ἐστιν·Ἀθηναίοις (*Thucydides Hist 2.55); *τὰς τοῦ Λαυρείου τῶν αργυρείων μετάλλων προσόδους* (Thucydides Hist 6.91); *Λαύρειον·τόπος·τῆς·Ἀττικῆς,·ἐν·ᾧ ·τὰ ἀργύρεια ἦν μέταλλα* (Photius Lexicogr); *Θουκυδίδης α΄·χρῆσίν τ’ ἔχει τῶν χρυσείων μετάλλων. ὥσπερ καὶ αργύρεια λέγεται δευτέρᾳ. μέχρι Λαυρίου, οὗ τἀργύρεια μέταλλά ἐστιν*

Ἀθηναίοις (Suda Lexicon under Ἀργυροῦν καὶ Χρυσοῦν); *ἐν Λαυρίῳ γὰρ τὰ μέταλλα τὰ αργυρεία (*Hesyschius, Lexicon); *Καὶ πρῶτον μὲν τὴν Λαυρεωτικὴν πρόσοδον ἀπὸ τῶν αργυρείων μετάλλων ἔθος ἐχόντων Ἀθηναίων διανέμεσθαι* (Plutarchus, Biography of Themistocles); *ὡς τῶν περὶ τὴν Ἀττικὴν αργυρείων* (Plutarchus, De defectu oraculorum).

2 *Λαύρειον τόπος ἐν Ἀττικῇ ἔχων μέταλλα* (Aelius Herodianus and Pseudo-Herodianus); *Λαύρειον*: *ἔστι δὲ τόπος τῆς Ἀττικῆς ποιῶν μέταλλον* (Aelius Herodianus and Pseudo-Herodianus); *Λαυρείω; τῆς Ἀττικῆς γίνονται χρύσεια μέταλλα* (Suda Lexicon).

3 *αργυρίτις γή των Αθηναίων* (Scholia in Aelium Aristidem).

4 There is one that is also mined.

5 *Γαληνοῦ, Περὶ κράσεως καὶ δυνάμεως τῶν πλῶν φαρμάκων* (XII. 237,12 – 16 Kühn): [*λβ΄. Περὶ ὑδραργύρου*] *Ὑδράργυρος οὐκ ἔστι τῶν αὐτοφυῶν φαρμάκων, ἀλλὰ τῶν σκευαζομένων, ὥσπερ ψιμμύθιόν τε καὶ οἷος καὶ ψορικὸν λιθάργυρος. ἔχω δ' αὐτῆς οὐδεμίαν πεῖραν οὔθ' ὡς ἀναιρούσης, εἰ καταποθείη, οὔτ' ἔξωθεν ἐπιτιθεμένης*.

Acknowledgements

The author wishes to thank her present and past collaborators for their invaluable assistance in the better understanding of "all things" archaeo-metallurgical and more recently.. archaeo-metallopharmaceutical. I am particularly grateful to Professor George Papadimitriou for reading the original manuscript carefully and gently teasing out inconsistencies; and to Dr Efi Oikonomou, NAM, for the photograph in Fig. 2. I would also like to thank the organizers of this conference for keeping research interest in Laurion very much alive.

Bibliography

Beck, L.Y. 2005. *De Materia Medica by Pedanius Dioscorides*. Hildesheim: Olms-Weidmann.

Caley, E. and Richards, J. 1956. *Theophrastus on Stones*. Ohio: Ohio University Press.

Conophagos, C.E., 1980. *Le Laurium antique et la technique grecque de la production de l'argent.* Athens: Ekdotike Hellados.

Clement, J.L. and Jarrett, P.S. 1994. Antibacterial Silver. *Met Based Drugs* 1 (5–6), 1994, pp. 467–482. doi: 10.1155/MBD.1994.467

Oei, J.D., Zhao, W.W., Chu, L., DeSilva, M.N., Ghimire, A., and Rawls, H.R., 2012. Antimicrobial acrylic materials with in situ generated silver nanoparticles. *Journal of Biomedical Materials Research. Part B. Applied Biomaterials,* 100, pp. 409–415. doi: 10.1002/jbm.b.31963

Oikonomou, E. and Photos-Jones E, Psimythion: concept, material and artefact (5th–3rd c BCE), forthcoming

Mijnendonckx, K., Leys, N., Mahillon, J., Silver, S., Van Houdt, R. 2013. Antimicrobial silver: uses, toxicity and potential for resistance. Biometals. 2013 Aug; 26(4):609–21. doi: 10.1007/s10534-013-9645-z. Epub 2013 Jun 15. PMID: 23771576.

Photos-Jones, E. and Jones, J. E. 1994. The building and industrial remains at Agrileza, Laurion (fourth century BC) and their contribution to the workings at the site. *Annual of the British School at Athens*, 89, pp. 307–358.

Photos-Jones, E., Bots P., Oikonomou E., Hamilton, A., and Knapp, C.W. 2020. On metal and 'spoiled' wine: analysing psimythion (synthetic cerussite) pellets (5th–3rd centuries BCE) and hypothesising gas-metal reactions over a fermenting liquid within a Greek pot *Archaeological and Anthropological Sciences* 12, p. 243. https://doi.org/10.1007/s12520-020-01184-1

Stevenson, L., 1955. On the meaning of the words cerussa and psimithium. *Journal of the History of Medicine and Allied Sciences,* 10(1), pp. 109–111.

Voudouris, V., Melfos, P.G., Spry, T., Bonsall, M., Tarkian, M., and Economou-Eliopoulos, M. 2008. Mineralogical and fluid inclusion constraints on the evolution of the Plaka intrusion-related ore system, Lavrion, Greece. *Mineralogy and Petrology*, 93, pp. 79–110. https://doi.org/10.1007/s00710-007-0218-0

Author

Effie Photos-Jones – Analytical Services for Art and Archaeology (Scotland) Ltd., Glasgow, UK / University of Glasgow, School of Humanities, Archaeology, Glasgow, UK

Correspondence and material requests should be addressed to: effie.photos-jones@glasgow.ac.uk