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ANDREW DAVIES

LEAD POISONING IN THE ANCIENT WORLD

Lead was one of the seven metals of antiquity. Its discovery dates back to at least 3500 B.C. and lead artefacts have been discovered widespread throughout the ancient world.

Lead does not occur in an elemental state in nature although its sulphide ore galena (PbS) is common. It is probable that galena was first used in antiquity for making into ornaments or for use as an eye paint.[1] The discovery of metallic lead may well have resulted from the accidental dropping of galena on to a camp fire. Gowland[2] suggested that copper was discovered in this way when malachite was put on to a camp fire and his contention was that the camp fire was the original smelting furnace. The camp fire would have been more than sufficient as a lead smelter. The oxide of lead can be reduced at temperatures below 800°C, which are achieved in a domestic fire burning either dry wood or charcoal. In the process galena is reduced to its oxide which then reacts with the unchanged galena producing metallic lead according to the equation

$$2PbO + PbS = 3Pb + SO_2.$$

The lead so produced would melt in the fire (the melting point being only 347°C) and collect in the ashes from which it could subsequently be recovered.

Although lead may have been discovered in this way it is doubtful whether much use was found for the soft dull metal. It was not suitable for weapons and the need for water pipes and cisterns was not appreciated. Nevertheless, lead was of importance because of its association with silver. Although silver does occur in the native state, or in relation to gold, the most plentiful source in antiquity was from galena. Originally silver was a by-product of lead smelting. If lead smelted from galena is heated long enough it oxidises into a powdery ash leaving behind essentially pure silver. In the early centuries of the third millenium, tribes living on the Black Sea coast near to Pontus in Asia discovered the important process of cupellation.[3] This involved oxidising the lead to litharge (PbO) which was absorbed on to a bulk material such as bone-ash leaving behind the unaltered noble metal.[4]

So important was the recovery of silver from lead that lead mines were often called silver mines. The amount of silver contained in galena varied considerably. In the British galena the amount was not great, but some of the mines of Asia Minor produced lead ore yielding about 600 ounces of silver per ton[5] whilst the infamous Laurium mine on which the wealth of Athens was founded produced about 130 ounces to the ton.[6]

Perhaps because it was so easy to recover from its principal ore, and so easy to work, few traces of early lead technology have come to light. Nevertheless, there is sufficient evidence to indicate that the use of the metal was widespread.

In pre-dynastic Egypt lead occurs only sparingly although galena beads are found frequently in the tombs from this period.[7] In the eighteenth dynasty lead was abundant, used principally as sinkers for fishing nets. The metal was also used for inlaying wood, and small statuettes, especially of Osiris and Anubis, and other ornaments made of lead are common findings. The Ptolemaic and later papyri make mention of the plumber as one who makes and repairs water pipes[8] and lead is mentioned briefly in the Ebers papyrus.[9] Lead compounds, chiefly lead sulphide and lead carbonate, were used by the Egyptians as constituents of eye paints.[10]

Votive lead offerings were discovered in Cretan tombs dating from the EMII period and some stone chests found in the MM palace at Knossus were lead lined.[11] Gowland referred to some pieces of lead found in the excavations of Troy (3000–2500 B.C.) as 'perhaps the most ancient specimens of lead in the world,'[12] and lead objects, including a lead figure of a naked goddess, were found in all the Troy excavations.[13] In the Mycaenae tombs lead straps were discovered[14] and lead artefacts occur throughout the rest of the Mediterranean. Lead mines were worked in Sardinia and Carthage[15] whilst in Assyria in about 2000 B.C. lead was used as a form of currency together with gold, silver and bronze. Lead tumblers were found in the very early graves at Ur, but in general lead objects are scanty in early Sumerian remains.[16] Herodotus[17] mentions that lead was used in the construction of the piers of the bridge which queen Nitocris built over the Euphrates at Babylon and Diodorus Siculus[18] described how lead was incorporated into the structure of the Hanging Gardens of the city.

Although it is clear that lead was used almost universally throughout the ancient cultures it remained very much a background metal and assumed a pre-eminent position only when the Romans devised their elaborate projects for providing their towns and houses with water. The Romans' lead technology was impressive. They manufactured sheet lead by casting onto flat sand beds and had ingenious methods of rolling and jointing pipes which were the basis of their water-carrying systems.[19] The amount of lead consumed by the Romans was extraordinary. In building the great aqueduct at Lyons it had been estimated that 12,000 tons of lead were used on just one of the siphon units,[20] and the description of the construction of the leaden water systems given by Vitruvius[21] shows what major undertakings these were. The Romans were avid in their demand for lead, and after the conquest of Britain the native mines were extensively worked. They were a plentiful source, for Pliny describes lead being found 'in the surface stratum of the earth in such abundance that there is a law prohibiting the production of more than a certain amount.'[22]

The use of lead water systems represented a hazard to health, but both the Romans and the Greeks exposed themselves to a far greater risk. Pliny defines the problem when he writes: 'when copper vessels are coated with stagnum[23] the contents have a more agreeable taste and the formation of destructive verdigris is prevented . . .'.[24]

The Romans and Greeks found that by coating their bronze or copper cooking pots with lead, or lead alloys, not only was the leaching of copper from the pot prevented, thus avoiding spoiling the taste of the food, but also these were of great value in preparing wine and grape syrup which was used almost exclusively as a sweetening agent.

Marcus Cato is explicit in his instruction for preparing what he calls Greek wine. 'Take twenty quadrantals of mustum, pour it into a copper and lead vessel, place it over the fire and boil it.'[25]

Columella directed that 'the vessel in which either the sapa, or defrutum, is boiled should be lead, in preference to bronze; for in boiling . . . the bronze vessels give up verdigris thus spoiling the taste.'[26]

Sapa was prepared by boiling raw grape syrup until its volume was reduced by a third or a half. According to Columella, 'some boil away a quarter of the mustum in a leaden vessel; others evaporate a third; but beyond doubt, if you were to evaporate a half, you would have a better and more useful sapa.'[27]

Pliny also advocated this dangerous practice. He writes 'Preference should be given to lead vessels . . . in boiling defrutum and sapa.'[28]

One property lead has in common with other heavy metals is to inhibit enzyme activity, so it is not surprising that the Romans and Greeks found that sapa prevented fruit souring and fermenting and used it extensively as a preservative. In addition, sapa was found to improve the quality of a poor wine and to prolong the length of time for which any wine could be kept.

Poor wines were subjected to a number of techniques to improve their quality, the more important of which necessitated the addition of lead in one form or another. It was a practice so universal that Pliny remarked indignantly that 'genuine, unadulterated wine is not to be had now, not even by the nobility.'[29] And he was right to complain for, he comments, 'From the excessive use of such wines arise dangling . . . paralytic hands,'[30] echoing Dioscorides who wrote that corrected wine was 'most hurtful to the nerves'.[31]

For all that, descriptions of lead poisoning *per se* are uncommon amongst the extant works of the ancient writers. This may reflect the loss of the books of antiquity rather than the rarity of the disease for it is certain that as soon as the metal was brought into common use poisoning from it would follow.

At source its danger would be minimal if modern experience is a guide, for galena, the principal lead ore of the ancient world, is relatively non-toxic. McCord, in his history of lead mining in America says that there were few cases of lead poisoning from the early workings when galena was mined. When lead carbonate was worked in Utah after 1870, however, it became an all too common hazard.[32] Similarly, a more recent investigation of men exposed to galena dust revealed few indications of lead intoxication amongst them.[33] The galena mines gave off sulphur dioxide, however, and on this account Pliny warned that the 'exhalations from silver mines [i.e. galena mines] are dangerous to all animals.'[34] Once the ore was smelted, however, its dangers were apparent. McCord quotes Durant as saying of the Athenian silver mine,[35] 'Laurium pays the price of the wealth it produces, as mining always pays the price for metal industry; plants and men wither and die from the furnace fumes, and the vicinity of the works becomes a scene of desolation.'[36]

The fumes given off from heated lead were well known to be poisonous. Both Vitruvius and Pliny gave warning of the danger. Describing the production of white lead, Vitruvius says, 'At Rhodes they place a layer of chips in a large vessel, and pouring vinegar, they then put lumps of lead on top. The vessel is covered with a lid lest the vapour which is enclosed should escape.'[37]

Pliny is more dramatic: 'For medicinal purposes lead is melted in earthen vessels, a layer of finely powdered sulphur being put underneath it; on this thin plates are laid and covered with sulphur and stirred with an iron rod. Whilst it is being melted, the breathing passages should be protected . . . otherwise the noxious and deadly vapour of the lead furnace is inhaled; it is hurtful to dogs with special rapidity.'[38]

Vitruvius was also at pains to point out that water found near mines was not free from hurtful effects. 'When gold, silver, iron, copper and lead and the like are mined, abundant springs are found, but mostly impure . . . When the water is taken into the body, and . . . reaches the muscles and joints, it hardens them by expansion. Therefore the muscles swelling with expansion are contracted in length. In this way men suffer from cramps or gout, because they have the pores of the vessels saturated with hard, thick and cold particles.'[39]

He was also critical of the custom of using lead for water systems. Not only were earthenware pipes considerably cheaper and easier to repair than those made of lead, but

> water is much more wholesome from earthenware than from lead pipes. For it seems to be made

injurious by lead because cerusse is produced by it; and this is said to be harmful to the human body. Thus if what is produced by anything is injurious, it is not doubtful but that the thing is unwholesome in itself.

We may take example by the workers in lead who have complexions affected by pallor. For when, in casting, the lead receives the current of air, the fumes from it occupy the members of the body and rob the limbs of the virtues of the blood. Therefore it seems that water should not be brought in lead pipes if we desire to have it wholesome.[40]

In this passage Vitruvius seems to be describing lead palsy, just as Pliny had done earlier, albeit in an indirect way. The credit for the first direct clinical account of lead poisoning has in recent times been accorded to Hippocrates. It is an opinion which has grown more firmly held with the passage of time. Alderson[41] states that Hippocrates made cursory remarks which included, but did not specify, the particular effects of lead, but Legge and Goadby state that he was apparently acquainted with lead colic.[42] Aub and his colleagues were still more specific—even to the date—saying that 'Hippocrates (370 B.C.) was probably the first of the ancients to recognise lead as a cause of symptoms, at least he describes a severe attack of colic in a man who extracted metals.'[43] This opinion has been followed by many writers since, and has become accepted dogma.[44]

Since none of the authors cited has given reference to the passage in Hippocrates on which they base their conclusions it is difficult to substantiate them. Hardy, writing in 1778,[45] does provide a case from the VIIth Book of the Epidemics which he supposes to have been one of lead colic, but it is hard to see how he formed this opinion for there is nothing to suggest colic in the case report. 'Nicoxenus in Olynthus seems to have broken out in a sweat on the seventh day. He afterwards took soup, wine and grapes dried in the sun. These were the following effects on the seventeenth day: he was burning, the tongue was hot, and there was little strength in the limbs and a terrible feebleness of body; the voice was impeded but the faculty of hearing was distinct. The temples were collapsed and the eyes hollow, his feet were feeble and weak. There was distension of the spleen.'

In the IIIrd Book of the Epidemics the following account is given of frequent and dangerous disorders affecting the belly. 'Painful colic and malignant flatulent colic also occurred; in these going to stool did not relieve the pains, the stools being such that much remained within the bowel after attempted evacuation. This condition responded only with difficulty to medicine, and in most cases purgatives did additional harm. Many of those with this complaint perished soon; others lasted rather longer.'[46]

The symptoms of colic and constipation occurring in endemic form are reminiscent of the descriptions of endemic lead colic to which mention will be given later, but it would be over zealous to suppose that they were —in fact—attributable to lead.

The first unquestioned clinical account of lead poisoning must be accredited to Nicander who wrote in the second century B.C. In his Alexipharmaca he describes in verse the symptoms arising from the ingestion of litharge and cerusse, including colic, constipation, palsy and a pallor which he fancifully likened to the dull colour of lead.[47] Dioscorides, in the first century A.D., described in his materia medica the ill-effects of litharge in graphic terms. 'The drinking of litharge causes oppression of the stomach, belly and intestines, with intense griping pains; . . . it suppresses the urine, while the body swells and acquires an unsightly leaden hue.'[48]

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The ancients were thus unquestionably aware of the dangerous character of lead and knew that it was poisonous when taken internally. Thus we find in Pliny, 'red-lead is a deadly poison and should not be used medicinally';[49] and, 'lead acetate is a deadly poison'.[50] Celsus also knew of its toxic effects for he prescribed as an antidote to poisoning by white lead 'mallow or walnut juice rubbed up in wine'.[51]

And yet the Romans and Greeks continued to expose themselves to the effects of a metal they knew to be harmful through their food and drink. The contamination of both was considerable. In an experiment, Hofmann[52] found that a litre of must took up 237 mgm of lead when boiled down with a plate of lead in it. A further experiment was conducted in which he treated Gebirgswein, Talwein and must according to the directions of Columella. He extracted 390 mgm of lead from the Gebirgswein, 582 mgm from the Talwein and 781 mgm from the must.[53]

This continual ingestion of lead from the diet resulted from time to time in epidemics of lead poisoning throughout the Roman world. Paul of Aegina described one such epidemic in the seventh century. He writes of a colic 'having taken its rise in the country of Italy, but raging also in many other regions of the Roman empire, like a pestilential contagion, which in many cases terminates in epilepsy, but in others in paralysis of the extremities, while the sensibility of them is preserved, and sometimes both these affections attacking together. And of those who fell into epilepsy the greater number died; but of the paralytics the most recovered, as their complaint proved a critical metastasis of the cause of the disorder.'[54]

This is the first account there is of the great outbreaks of lead colic which occurred sporadically throughout history and which were known variously as the colic of Poitou, the entrapado of Spain, the Huttenkatze of Germany, the bellain of Derbyshire, the dry bellyache of the Americas and the colic of Devonshire.

The circumstantial evidence is strong, therefore, to support the hypothesis that lead poisoning was pandemic in Rome as Kobert[55] and Hofmann[56] in particular have shown. The position of these authors has been this: there is frequent reference to symptoms—particularly colic and constipation—which are concomitants of poisoning with lead, amongst the Roman and Greek authors; lead was much used; therefore the symptoms were caused by lead.

Gilfillan[57] has carried the argument of these writers a stage further and advanced a theory that the Fall of Rome was the result of lead poisoning. He has laid particular emphasis on the declining birth rate amongst the aristocratic Romans, brought about by the subfertility of this class and the diminution of life span. Both these effects are blamed on poisoning with lead.

Whilst these hypotheses are persuasive there is, unfortunately, little objective evidence to substantiate them. Indeed, there has been little attempt to assess scientifically to what extent the peoples of antiquity absorbed the lead to which they were exposed. Kobert's student, Rosenblatt, analysed twenty-two bones gathered from various archaeological sites and found lead in four specimens from Carthage, two from before and two from after the Roman conquest of the city.[58] No quantification was possible, however, so although interesting, these results are of limited significance. Gilfillan stated that the results of lead estimations of forty bones were consistent with his theory, but presented no more details than this.[59] The only other piece of evidence in this meagre hoard is that of Specht and Fischer who estimated the amount of lead in a rib from the skeleton of Pope Clement II who died in 1047. The amount of lead they found was sufficient for them to propose that he had died of lead poisoning.[60]

None of this data helps materially in determining the extent of lead poisoning in Rome and until more has been done, assessments will depend on the interpretation placed on literary sources. It is indisputable that the Greeks and Romans knew lead to be poisonous and that they were familiar with the symptoms of plumbism. Clearly then they dissociated this hazard from the use of the metal in their cooking vessels, and it is beyond doubt that this resulted in lead becoming incorporated into their food and drink. How far beyond these bare statements it is safe to venture is difficult to say, but to suggest lead poisoning as the cause of the decay of Roman civilization may be exceeding the bounds. The civilization did decay, but all empires have a finite life. The decay of Rome is not unique and it is perhaps too facile to suppose it to have a unique cause. Indeed had Gibbon not unwittingly misled generations of readers to believe that this was a sudden event through the use of his phrase, the Fall of Rome, all-embracing theories might not be so much in vogue.[61]

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20. AITCHISON (n. 1), p. 154.
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23. A mixture of lead and silver.
24. PLINY (n. 22), XXIV, 48.
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26. COLUMELLA, *Rei rusticae*, XII, 20.
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H. A. WALDRON

A PALAEOPATHOLOGICAL RARITY IN A SKELETON OF ROMAN DATE

An extremely unusual skeleton has recently been found at Cirencester, Gloucestershire. It dates from the Romano-British period, about A.D. 150, and is one of some two hundred burials excavated at this site. It is the skeleton of a well-built man, in the 45–65 age range, and most of the bones have survived in excellent condition, apart from a few small elements of hands and feet.

The interest of the specimen lies in a number of abnormalities that are rarely encountered in ancient material. These consist of partial destruction of various joints and of small cavitations in the cortex of several long bones. In all, more than fifty of these lesions are present and they are widely scattered throughout the limbs.

There is a small hole, about 4 x 7 mm., in the medial side of the trochlea of the R. humerus and another, symmetrically pairing with it, in the L. humerus but this second one is about only 3 mm. in diameter and is less deep. Both ulnae and radii are also affected: the ulnae proximally and all four bones distally. The radial heads are slightly damaged by soil erosion and are difficult to assess but at least the L. radius seems to have had one of these lesions on it. In addition to this, both ulnae have small excavations on their dorsal borders about 55 mm. distal to the olecranon. The hands are incomplete: only 6 carpals, 9 metacarpals and 7 phalanges survive but this is enough to show that they were extensively diseased. Of the 22 bones, at least 15 are affected and most of the metacarpals and phalanges show well-marked cupping or little pits on, or closely adjacent to, their joint surfaces (fig. 1).

In the lower limbs the condition is more advanced. Small lesions occur on the anterior surface of both patellae. On the R. tibia there is a hole in the tuberosity measuring 18 x 10 mm. and 5 mm. deep. Large cavities are present in the R. ankle joint and have involved the medial and lateral aspects of the tibia, talus and also the calcaneus. Similar, but smaller, lesions are extensive among the tarsals and metatarsals of this foot, although the full extent of the disease cannot be known because of post-inhumation loss of some of the bones (figs. 2 and 3). The L. tibia, fibula and foot are more complete but show almost identical lesions. Of 7 tarsals, 5 metatarsals and 2 phalanges, every bone is extensively affected (figs. 4 and 5). Figure 6 shows the radiographic appearance of some isolated metacarpals, metatarsals and phalanges.

Visual inspection of these multiple defects, and especially their radiographic features, leaves no doubt that an abundant bony reaction occurred around them. They do not at all resemble any form of malignant invasion but strongly suggest that some more or less encapsulated or circumscribed lesion had pressed on and re-moulded the osseous tissue.

The sum of the evidence leaves little doubt about the diagnosis. This is a classic example of gout. The cup-shaped destruction on and around the joint surfaces would