

# HMSNEWS

Historical Metallurgy Society

45

Summer 2000

## Forthcoming Events

### HMS Conference 2000

This year's Millennium Conference will be held in **The Tank Museum Bovington** Dorset (OS Landranger map sheet 194, grid reference 831883) from 1600 hrs on Friday 22 September to 1630 hrs on Sunday 24 September. The theme will be armour and its defeat, but it will not be confined to C20th armoured fighting vehicles. A provisional programme and booking form is included with this mailing of HMSNews. The Museum's Curator will give a short history of the development of the tank, other speakers will address the development of armour plate and its defeat, the Conference will include a guided tour of the exhibits. Accommodation and meals will be provided in the Officers' Mess at the neighbouring Royal Armoured Corps Centre by kind permission of the Director the Royal Armoured Corps. Bovington is well served by trains to Wool railway station, lies in very beautiful and archaeologically significant countryside inland from Lulworth Cove and between Dorchester and Poole. Further papers are sought by the organiser. As ever places will be limited.

**Verein Deutscher Eisenhüttenleute** are organising an excursion to England from Sept. 6th to 10th visiting Coalbrookdale Ironbridge Gorge Museum, Abbeylea Industrial Hamlet and Kelham Island Museum. They will take dinner in the Cutlers Hall in Sheffield. For particulars contact V.D.E. Herm Dipl-Ing-, M. Toncourt Sohnstrabe 65. 40237 Düsseldorf.

**Newcomen Society Meeting**, at the Science Museum, London 19th–21st September "**Engineering the Millennium**" No bookings after Sept. 11th. For particulars apply to the Executive Secretary, The Newcomen Society, The Science Museum, South Kensington, London SW 7 2DD.

**World-wide congress on Mining and Geological Heritage in the setting of the tenable development.** Fifth scientific session. Linares 20-21-22 October Convoled by the Spanish Society for the Protection of Mining and Geological Heritage. In Escuela Universitaria politecnica de Linares. Contact La Caixa, Mignel Angel 33, 28003 - Madrid.

**Finds Research Group** "The 14th century" Monday 23rd October at the Society of Antiquaries, London. Includes Base Metalwork by Geoff Egan and Technology by Justine Bayley. For further information contact Geoff Egan, Museum of London Specialist Services, 46 Eagle Wharf Road, London N1 7ED Tel: 020 7490 8447.

A Conference on "**The History of European Wide Strip Mills**" will be held on 27th and 28th of April 2001 at the University of Manchester. It aims to put on record the importance of the wide strip mill as a pivotal technology that supported the out-burst of European economic growth in the range of industries after the Second World War. Strip mills — like the railways in the 19th c. or the internet now — were an 'enabling technology' that allowed other manufacturing to flourish. A wide range of industries from cars to consumer durables, from canned food and drink to metal goods grew on the back of strip mill development in the U.K. France, Italy, the Netherlands and Germany. We do not think that strip mills have been given the recognition they deserve. We are keen to run a conference now, while many of the European mill builders are around to tell their story. The **Programme** includes *A technical history of the wide strip mills from Generation 1 to Generation 5. The development of wide strip mills in Europe and the Marshall Plan. The wide strip mill - an operator's perspective. The impact of wide strip mills on consumer industries. The key installations in Europe: South Wales, Toronto, Bremen, Fos-sur Me., etc.* A registration fee will be charged to cover conference costs.

Please contact the Conference Organiser Ruggero Ranieri (R-Ranieri@man.ac.uk) or at University of Manchester, Department of History, Oxford Road, Manchester M 13 9PL.

### AGM 2000

This year's AGM was held at the Riverside Inn close to the Saltford Brass Works in Bristol.

30 members and their guests met in very commodious surroundings for the 21st AGM. We elected a new President and two new Ordinary Members of Council. The accounts and the directors report have been circulated.

After the AGM Joan Day spoke about the history of the site, and of the Bristol copper industry. Copper was made in Bristol in the seventeenth century and brass in the early 18th century. Originally the brass was made by the cementation process from copper and calamine but when the Champion zinc refining process was introduced it was made by

alloying copper and zinc. The works at Salford was one of a series that were built in the Avon valley in the eighteenth century. It was a rolling and battery mill but very little of the machinery survives. The earliest process was hammering a block of brass into sheet and then "battering" the sheet into holloware. Water powered rolling mills soon replaced the hammers for reducing the ingots to sheet. All the working was at room temperature and the metal soon work hardened and had to be annealed. The most important survival at Salford is an annealing furnace, one of four originally at work. This was found in a ruinous state and a great deal of work was needed to rescue it. It is now well conserved. Muffle furnaces such as this were developed in Bristol so that coal could be used for annealing without spoiling the work. There is no other furnace of this type standing above foundation level. The site was water powered to the end and there are the remains of the water wheels but only one has been restored. The battery stopped work in 1908 but the rolling mill continued until 1925.

After an excellent lunch we walked to the Mill, which had been opened especially for us. There were a number of interesting exhibits but none of the iron machinery has escaped the scrap man. Not having given too much thought to powering rolling mills with two water wheels the distance between the axles of the water wheels was a surprise. This must have been to allow space for the gearing to reverse the rotation of one of the rolls. I have not seen any illustration that shows this. The visit concluded with thanks to the organisers and volunteers.

#### **Council for 2000–1**

President	Geoff Lucas
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Members	Peter Claughton, Paul Cort, David Cranstone, Roger Doonan, Kathy Eremin, Vanessa Fell, Duncan Hook, Peter Northover, Matt Ponting, Thilo Rehren, Tim Smith

Peter Hutchison

#### **Early American Iron.**

James H. Brothers is researching the colonial ironworks of Virginia. He seeks information on the following:

1. Information on the two ironmasters hired by the Virginia Company — John Berkeley (see HMS Journal 31:1) and Capt Bluett. And the men who went with them.
2. Who operated the 1630-40 bloomery just discovered at Jamestown? Are there any documents relating to the sale of Virginia iron other than John Smith's comment in 1608 that "our best commoditie was Yron which we made into little chissels."
3. In 1608, CPT John Smith reported that he had sent to London "two barrels of stones, and such as I take to be good Iron ore at the least." Who assayed the ore?

4. Prior to Falling Creek there was talk of recruiting ironworkers in 1609-12. In a February 20, 1610 letter from the Council of Virginia to Lord Saandwich there was included a list of "The Trades-men to be sent into Virginia under the comaunde of Sir Thomas Gates." The list includes — Millwrights for Iron Mills 2. Iron Miners 4. Iron Finers 2. Iron founders 2. Hammermen, for Iron Works 2. Colliers for Charcole 2. Were these men recruited and from where? Did they accompan Gates and if so on which voyage (1610 or 1611)? If they arrived in Virginia, what did they do and where?
5. In 1612 Sir Thomas Dale wrote "of a goodly Iron Myne, and Capt Newport hath brought home of that mettell so sufficient a tryall, as there hath been made 16. or 17. tonne of Iron." The iron was sold to the East India Company for £4 per ton. Where was it smelted? If anyone is able to help in any way contact James Brothers IV 11719 Heathmere Cres. Midlothian, VA 23113-2419. e-mailjhbiv@erols.com.

## **ARCHAEOLOGICAL METALLURGY**

### **Fatimid metalworker's hoard**

A rescue excavation on the outskirts of **Tiberias** on the shores of the Sea of Galilee in northern **Israel**, undertaken by the **Hebrew University of Jerusalem** in 1998, yielded an important metalworking assemblage. Beneath the floor of an early Islamic building — dated by pottery to the Fatimid period, were found three massive terracotta storage vessels full of a unique assortment of copper-alloy artefacts. **Dr. Matthew Ponting in the Department of Archaeology, University of Nottingham** is currently undertaking a programme of scientific analyses of this material.

The 800 or so artefacts represent the largest assemblage of Fatimid metalwork anywhere — and exceed the total combined holdings of the world's museums. A group of 58 Byzantine coins found in one of the storage vessels provides a terminus post quem for the deposition of the hoard of 1078. This suggests that the hoard was buried sometime before Tancred's capture of Tiberias in 1099. It is known that the local non-Christian population fled to Damascus immediately before this, news of the Crusaders' treatment of both Arabs and Jews having preceded them.

The hoard represents the stock-in-trade of a Fatimid Moslem artisan's workshop and includes over 200kg of scrap for recycling and "process waste" as well as finished vessels. Parallels for some of the vessels have been found from Nishapur in Persia (Iran) and the Islamic inscriptions on some vessels proclaim the cultural affiliation. The scientific examination of

this material presents a unique opportunity to study Early Islamic metalwork in depth and at a level of detail not previously possible. Already several different alloy categories are apparent; copper, brass and gun-metal, together with an exciting class of high-tin bronzes that only have contemporary parallels in India.

### **Archaeological and documentary evidence for a late medieval/early post medieval Welsh ironworks**

Tim Young has sent details of a major ironworking site that has been revealed by geophysical surveying near **Miskin** (Rhondda Cynon Taf, **Glamorgan**). Recent finds of slag in the bank of the Ely had confirmed the location of a site first recorded by the Geological Survey around 1900. A full survey was subsequently undertaken by **Cardiff University Archaeology Section** in April 2000. The site is not dated directly yet, but the layout strongly suggests a late medieval to early post-medieval date.

The ironworks lies on the floodplain of the Ely, with smelting furnaces on the steep slopes to the west. The dump complex has an overall elliptical shape, approximately 120m by 80m. Where visible in section in the river bank, the dump is seen to be about 1.5m thick. The site survived as prominent earthwork features until the early 1950s, when the site was "improved". There are two clear furnace sites (each with gradiometer anomalies of up to 1700nT), with a possible third to the south. The smelting slag dumps lie on the floodplain below the furnaces and also in an elongate belt stretching across an old ox-bow lake towards the present channel. It seems likely that this spread of slag represents a dam, with the spring-fed ox-bow supplying power to a forge. The smithing slags are concentrated along a topographic and geo-physical feature, interpreted as a leat, below this dam. The geophysical data suggest at least two hearths on the east side of the leat.

The site lies immediately outside the former deer park of Cloune, which was the site of iron-mining from 1531. The first year of this operation is described in surviving accounts, which detail the production of 2 blooms per day, with smeltings lasting 6-7 hours, in a furnace manually blown by a team of 4 blowers, who also doubled-up as bloom-smiths. A subsequent grant in 1540 records the right for building iron mills in, and within three miles of,

Cloune Park for 21 years, including the right to employ water power. It seems likely that the new site belongs to the period of this grant and it probably operated at the same time as other iron mills at Mwyndy and Rhiwseason, also within the three mile zone. At the Mwyndy site at least, a reversion to agricultural use seems indicated by a rental of 1570, by which time the external investment seems to have been focussed on the first of the regions blast furnaces in the Taff Valley, some 8km to the east. If these interpretations are correct, then the site is significant in preserving a short-lived 16th century bloomery iron mill, which did not develop into a finery forge, as so often happened elsewhere.

As a bonus, the geophysical survey also located rectilinear ditched enclosures, apparently associated with a spread of bloomery tap slag, bloom smithing slags and Roman pottery, on the hilltop above the later site. Future fieldwork will aim to clarify the dating and preservation of both sites, and laboratory work during the coming months will investigate the 16th century slags.

### **Norse iron smelting in Cumbria**

A six week season of field work will begin for the **SMELT/Low Birker** project on 28 June 2000, building upon the discoveries of the first three years of active data recovery. The site, located at NY 185004 is a Norse era iron production and settlement complex. Located within the Lake District National Park and largely in formerly coppiced woodland, the archaeological remains have had minimal disturbance.

From a metallurgical point of view, the most interesting results from the first three years of work are an extensive array of large, tall shaft furnace remains. By the end of the 1999 field season excavation, geo-physical survey, and test pitting had identified 12 furnace locations, each containing the remains of 8-10 furnace bases, in the main production area. An additional 8-10 furnace locations have been identified in the surrounding area. The furnaces so far investigated have a normal egg shape averaging 120 cm from back wall to throat and 105 cm across. The unusually thin bases (3-5 cm) are attributed to the rocky subsoil in the area, which largely eliminates the need for a significant foundation, the walls are a more "typical" 30-33 cm thick and some remains show repeated

relining with lute slurry. Along with the furnace bases, the remains of significant stone furnace shelters have been located. Slag deposits, iron ore mines, charcoal dumps and charcoal burning pits are all within 200 meters of the main production area.

Work at Low Birker is undertaken under the direction of **Carl Blair** of **Michigan Technological University** with collaborating scholars and students from 5 American and British Universities. The site is open to the public and visitors are welcome (Thurs. morning to Tues. noon). At least 20 years of additional work is planned in the Esk Valley. Enquiries to: [ceblair@mtu.edu](mailto:ceblair@mtu.edu)

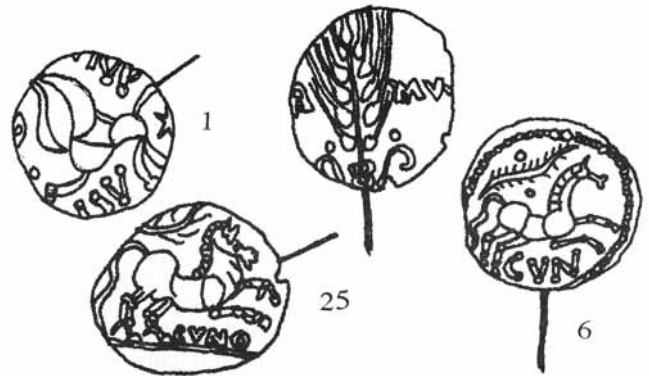
### Investigation of an Iron Age gold coin hoard

The Silsden hoard is an exciting and unique find of 27 late Iron Age coins and a Roman iron finger ring discovered by Jeff Walbank, a metal detectorist, in 1998 in a field near **Silsden, West Yorkshire**. An integrated technological, numismatic and archaeological investigation of the hoard was carried out by **Megan Dennis** within the **Archaeometallurgy Research Group in the Department of Archaeological Sciences at the University of Bradford**.

X-ray fluorescence analysis, combined with specific gravity measurements, and visual and metrological (weight) assessments identified several interesting factors. The coins are made of gold alloyed with silver and copper; but seem to show more variation in copper content than has been previously interpreted (Van Arsdell, 1989). The study reinforced the general chronology identified by Cowell (1992) and Northover (1992) of increased copper contents of the latest British Iron Age coins. The increasing copper content of the Corieltauvian coins in the hoard (stylistically identified as IISVP RASV and VOLISIOS DVMNOVELLAVNVS) has been interpreted as being caused by the recycling of older issues and gradual debasement by the addition of copper. This suggests that these coins are also late in the British sequence, something that has been supported by recent reinterpretations that have linked the IISVP RASV types with the late Icenian ESVPRASVO coins which were minted in the second half of the first century AD.

Investigation of the relationships between upper and lower designs has also shown that the latest stages of coin production are characterised by the use of a

fixed upper and lower die that results in a constant relationship between the two designs. The study also raised methodological questions and revealed the need for further archaeological investigation of the immediate area where the hoard was discovered. The assessment of the hoard has successfully demonstrated that archaeology and science need to be integrated to reveal more about our technological and cultural past. It is hoped a full report on the research will be published soon.



*Coin 1 obverse IISVP RASV Coin 25 reverse Classic Cunobelin Coin 25 obverse Classic Cunobelin Coin 6 reverse Linear Cunobelin.*

### References.

- Cowell, M. (1992) 'An Analytical Survey of the British Celtic Coinage' in Mays, M. (ed.) (1992) *Celtic Coins: Britain and Beyond BAR Research Series 22*, 207-233
- Northover, J.P. (1992) 'Material Issues in Celtic Coinage' in Mays, M. (1992) *Celtic Coins: Britain and Beyond BAR Research 22*, 235-299
- Zograph A.N. (1977) *Ancient Coinage Part 1: the general problems of Ancient Numismatics* (trans Bartlett Wells, H.) *BAR Supplementary Series 33* (1), 43. Figure 14. (See illustration).

### Indian armour - earliest evidence of zinc plating

As part of her BSc in Archaeological Sciences at **University of Bradford**, **Helen Bowstead Sallybrass** has been working at the **Royal Armouries, Leeds**. The main project has been looking at a collection of 17th century Indian mail and plate armour formerly from the armouries in Bikanir. Initial examination of this material appears to show that much of it has been zinc plated in some way, making it the earliest known evidence of galvanising. It is hoped to publish the full results of this work in the near future.

### Medieval Uzbekistan steel production

Various aspects of crucible steel making have recently enjoyed good publication coverage, especially the Indian evidence and the finds from Merv in Turkmenistan. **Thilo Rehren** also wishes to

draw the readers attention to a major crucible steel making region in eastern **Uzbekistan**, in the **Ferghana valley**. Over a period from about the 9th to the 12th century AD, vast quantities of steel ingots were smelted at Akhsiket, and several other sites. The specific feature of this tradition is the occurrence of a solid cake of crucible slag, typically about 200 g, on top of a steel ingot which probably weighed about 3 to 4 kg. This massive crucible slag cake is in stark contrast to all other known crucible steel processes, which produce little slag. The difference is explained by a different charge composition, including significant amounts of ore or slag in the Ferghana case, rather than relatively pure metal, as elsewhere.

Joint research at the **Institute of Archaeology, University College, London** and the **Archaeological Institute of the Republic of Uzbekistan's Academy of Science in Tashkent** is in progress. This will analyse the slags further (see Papachristou & Swertschkow 1993 in *Der Anschnitt* vol. 45, p. 122- 131 for an initial publication) and identify the nature of the charge and the smelting process. Mass balance calculations, based on volume ratios in the crucible and possible slag-forming reactions, tentatively indicate a slag-rich bloomery iron charge mixed with charcoal (Rehren & Papakhristu in *Metalla* (Bochum), forthcoming, vol. 6 or 7).

### **New MSc in technology and analysis of archaeological materials**

This new one-year programme at the **Institute of Archaeology, University College London** offers an introduction to the scientific study of a broad range of materials typically found in archaeological excavations and museum collections. It is designed for graduates in archaeology with a strong interest in scientific methods. It is also suitable for conservators and others concerned with archaeological collections, and for science graduates who have, or are willing to acquire, a good understanding of archaeology.

The programme provides an overview of the role of materials in past societies, enabling the student to understand and interpret scientific data derived from the investigation of these materials. Students may choose to specialise in the analysis of materials such as metals, ceramics, glass, lithics etc. The Institute's own analytical equipment and facilities includes

optical and electron microscopy. X-ray radiography, image processing; bulk and spot analysis by AAS, XRF and microprobe; phase identification by XRD and FTIR. A specialisation in metals will address mining, smelting and refining of raw and primary materials as well as the making and investigation of metal objects and their corrosion phenomena.

Details: [www.ucl.ac.uk/archaeology](http://www.ucl.ac.uk/archaeology) or by contacting the programme co-ordinator, Thilo Rehren at [th.rehren@ucl.ac.uk](mailto:th.rehren@ucl.ac.uk).

### **Cistercian Iron Smithing**

**Gerry McDonnell** of **Bradford University** has been awarded a British Academy Grant to continue research on the iron industry of **Rievaulx Abbey**. This year will concentrate on location of smithies used to provide tools for the large monastic quarries in Bilsdale. The aim is to undertake detailed geo-physical surveys of the smithy sites and recover samples of residues and artefacts to examine the technology of Cistercian smithing.

### **Back garden experimental bloomery smelting**

In 1996 **John Anstee** achieved one aim of his long interest in early ironwork, by building a bloomery shaft furnace of Iron Age/Romano-British type in his back garden. It stood 120cm tall with an external diameter of 76cm and internal diameter of 25cm. The inner wall of rubble sandstone set in clay was separated from the exterior case by 8cm of sand. A fire- clay tuyère of 25cm internal diameter was blown by an electrically-powered, wooden piston bellows delivering between 250 and 500 litres of air per minute. Haematite ore was crushed small and mixed 1:1 by weight with hardwood charcoal and smelting times ranged between 6 and 7 1/2 hours. Of five experiments, the first three successfully produced blooms weighing between 6.5 and 8.25kg, containing about 40% metal which varies between soft iron and 0.8% carbon steel.

As a result of the work, John reached a number of conclusions:

Firstly, he is not in sympathy with the belief that small shafts were shifted bodily over newly dug basal hollows. The experimental shaft weighed about 850kg and would fall apart if moved. Secondly, with fuel consumption at 2-3kg/hour, and despite high consumption during later smithing, the high burning rates postulated by some practitioners can be reduced from the 100kg fuel for each kg of

artefact suggested. Finally, the importance of “tricks of the trade”, well known in antiquity, should be recognised by those attempting reconstruction iron smelting today.

### **Forest of Dean site request**

**Gloucestershire County Council** are starting a project to ensure their Sites and Monuments records are up to date for the Forest of Dean. They have asked whether any HMS members know of work which, either because it has not been published or for any other reason, may not have come to the attention of the Gloucestershire Archaeological Service. If they do would they please contact the Hon Secretary, Peter Hutchinson for further details: Peter Hutchison, 22, Easterfield Drive, Southgate, Swansea SA3 2 DB Tel. 01792 233 223 email hon-sec@hist-met.org

### **Metallography/phosphoric iron references**

Three papers have been published arising from **Johnny Stewart's** PhD at **Cambridge University** (see *HMSNews* Spring 98). The papers detail metallurgical investigations of phosphoric iron, and analyses of archaeological material.

All share the following details: Stewart, JW, Charles, JA, Wallach, ER, 2000 Iron-phosphorus-carbon system. *Materials Science and Technology* March 2000, Vol 16.

Part 1 - Mechanical properties of low carbon iron-phosphorus alloys, pp275-282

Part 2 - Metallographic Behaviour of Oberhoffer's reagent, pp 283 - 290

Part 3 - Metallography of low carbon iron - phosphorus alloys

### **Medieval Arrowheads**

Finally a conundrum of my own . . .

A recent series of analyses of medieval military arrowheads from the collection of the **Royal Armouries** have shown a majority of these have surfaces enriched with substantial traces of copper, sometimes associated with lower levels of zinc, tin or lead. Although a similar observation had previously been made during post-excavation examination of arrow or crossbow quarrel heads from the site of **Holm Castle** near **Tewkesbury**, the widespread nature of this phenomenon does not appear to have been realised.

Two problems remain to be answered: Firstly, how was the copper “plating” carried out? The coatings are very slight — sometime visible on particularly well-preserved river finds, certainly not massive, as are found on medieval locks which have had the surfaces brazed at high temperature. Secondly, why bother to plate arrowheads which were clearly produced in very large

numbers and not necessarily retrieved for re-use? A possible advantage might be in limiting corrosion when the heads were stored for long periods in barrels - though it is hard to see that this would be easier or cheaper than waxing or oiling. An alternative suggestion is that the arrow shafts were dipped in copper sulphate solution, to preserve the fletchings against decay and insect attack. It may be that through electrolytic action some copper was deposited on the surface of the iron. Statistical examination of the data shows that the presence of copper is dependant on two factors; purpose and condition. Non-military heads are less likely to show traces of copper, also arrowheads in better condition are more likely to show the presence of copper.

Answers on a postcard . . . and contributions to next issue 1 Nov. to:

David Starley, Royal Armouries, Armouries Drive, Leeds LS10 1LT. UK.

Tel. (0113) 2201919, Fax (0113) 220 1917

email david.starley@armouries.org.uk

### **Chalybean\* Steel — ancient high-nickel iron, usually regarded as Meteoritic.**

By Jerzy Piaskowski

*The Chalybes, an ancient nation from Asia Minor famous for their skill in working iron. The following paper has been sent as a follow-up from that of Paul Craddock “Metal from Heaven” in HMSNews 42.*

*Editor*

In the paper “Metal from Heaven — A Bolt from the Blue” (Craddock 1999) was discussed the problem of meteoritic origin of the iron on the Earth. Based on the high nickel content in the earliest iron implements, similar to the concentration of this element in iron meteorites Zimmer in 1916 accepted the theory that the first iron on earth was of meteoritic origin. The most comprehensive summary of the earliest iron (Waldbaum 1980) showed that it was found in the Near East countries, and specially in ancient Greece (Varoufakis 1980).

However, the paper mentioned above has omitted the author's theory that high-nickel steel (or iron) was smelted by the metallurgists and it was Chalybean steel, it was presented in Toronto and later in Washington (Piaskowski 1979, 1982).

This steel was frequently mentioned by ancient Greek and Roman authors as Aischylos, Appolinus Rhodius, Strabo, Vergilius Flaccus, Dionysius (Piaskowski 1988). Xenophon, (*Anabasis* V:5:1)

stated that Chalybean steel was “difficult in working”, and Euripides (Alcestis 980) mentioned its “high strength”. Ammianus Marcellinus (*Historiae* XXXII, 8, 21) supposed that it was first iron smelted from the ore. The process of Chalybean steel smelting was very precisely presented in treatise *De mirabilibus auscultationibus* 48, attributed to Aristotle, as follows:

“It is said that the way of manufacturing Chalybean and Amisenian iron is very particular. And thus, they said that it is made of sand deposited by the river. Some say that this sand is just washed and melted in a furnace, whereas others state that the sediment is washed several times and roasted; after that a stone Pyrimachos is added to it; they said that there are plenty of these stones in the surroundings. This iron is said to look much more beautiful than the other types of iron; if not for the fact that it is roasted (smelted - J.P.) in a single furnace it seems that it would not, in the least, be different from silver. They say that not only does this iron not get rusty, but it is not great of its yield.”

Some additional information on Chalybean steel was given by Aristotle *Meteorologica* 4,6:

“This is how the steel is made. The drops sink to the bottom and is purged away, when this had been done often and the metal is pure, we have the steel. The process is not repeated because the purification of the metal involves great loss of weight. But the iron that has the least dross is the better iron. The stone Pyrimachos too melts and forms into dross and becomes fluid; after having been in a fluid state it solidifies and becomes hard again.”

Chalybean (and Amisenian) steel was corrosion resistant, and it is not a fiction of Aristotle. Pliny (*Historia Naturalis* 10, 43) mentioned that early chain links of the bridge in the city of Zeugma, were not rusted, although new made pieces get rusty.

Historians of metallurgy did not explain either Chalybean and Amisenian steel nor both texts attributed to Aristotle. However, every metallurgist knows that there are only two alloying elements making the iron (or steel) corrosion-resistant: nickel and chromium. The latter could not be reproduced by ancient metallurgists. Thus corrosion-resistance may be only high nickel iron (or steel), austenitic i.e. well known in modern metallurgy — stainless steel, containing 8-20% Ni.

This steel is bright and really similar to silver and it was smelted in the bloomery (i.e. in one furnace). Silver was produced in antiquity (i.e. in Laurion, Greece) in two furnaces; in the first one was reduced the lead, containing silver from the ore containing both elements, in the second one the lead was oxidised and removed as the slag. The silver rested on the bottom of the hearth (cupellation process).

The manufacturing of Chalybean high nickel steel, was similarly explained using “sand deposited in the river and Pyrimachos, a stone added during the smelting process”. It was really “very particular”, not used for the smelting of any other iron alloys in antiquity.

After the theory was presented in the Smithsonian Institution, Washington, the specimen of “black sand deposit” found by the expedition of this Institution in the river about 10km west of Unye, Turkey, where the Chalybes lived in antiquity, was sent to our Foundry Research Institute in Krakow, Poland.

Chemical analyses of the grains, separated with the magnet showed that they are magnetite, very rich iron ore. It contained 58.2–64.9% Fe and less than 0.1% Ni and Co. The black sand particles mixed with powdered charcoal in a graphite crucible at the temperature 1250–1300°C in laboratory furnace held for 4h were produced some grains of reduced iron (Piaskowski 1982).

The stone Pyrimachos was identified thanks to the metallographic examinations of ancient implements made of high-nickel iron, found on the territory of Poland. Among 250 iron objects of Lusatian Culture (Hallstatt period, 800–400 B.C) four pieces were made of such an iron.

The edge of the socketed axe from Wietrzno-Bobka (Hallstatt period) was welded of five layers (Piaskowski 1960, 1963, Piaskowski and Bryniarska 1980). The outer layers on both external sites and central layer were made of low phosphorus, unevenly carburised iron (not containing Ni, Co, As). Electron micro-probe analysis revealed in both intermediate layers high nickel content, 8.9–17.8% Ni (in some areas even 39.1% Ni) 0.95% Co and 0.2-0.42% As (in some areas even 1.5% As).

Numerous very thin layers with 0.5–3.0% Ni, and ab. 0.2% Co were observed in a socketed axe from

Jezieryce, Silesia (Halstatt period) (Piaskowski 1963, Piaskowski and Bryniarska 1980). The same structure and analyses were observed in the socketed axe from Erkilstane, Sweden (Hansen and Modin 1973).

Two bracelets from the cemetery of Lusation Culture in Czestochowa-Radkow (Hallstatt period, 800-400 B.C.) were made of iron containing 18.3% Ni and 12.4% Ni (Zimmy 1965). Microprobe analyse of one bracelet revealed 17.4% Ni, ab. 0.58% Co and 0.5% As.

Thus the stone Pyrimachos was a compound of nickel, cobalt and arsenic, probably a sulphide, chloanite (FeNiCoAs)<sub>2</sub>. The deposits of this mineral were rather rare and not large (Piaskowski 1982; 1988; 1992; 1998). This is the reason why the smelting of Chalybean steel was very limited and stopped in antiquity quite quickly.

#### References

- Craddock P 1999 Metal from Heaven - a bolt from the blue *HMSNews* 42, pp. 3-6.
- Hansson T. and Modin S.A., 1973. A Metallographic Examination of some iron Findings with a High Nickel and Cobalt Content. *Early Medieval Studies* 5, pp5 - 23.
- Piaskowski J 1960. An Interesting Example of Early Technology: a Socketed axe from Wietrzno-Bobrka in the Carpathians. *Journal of the Iron and Steel Institute* 194, 3. pp. 336-346.
- Piaskowski, J. Etude des plus interessantes techniques de fabrication des objets en fer employes an Pologne du VIII au II siecle ar. J.C. *Metaux-Corrosion Industries* pp. 455-456 and 282-298.
- Piaskowski, J. 1979 Is all early high-nickel iron meteoritic? Seminar on early Pyrotechnology. April 19 and 20, Smithsonian Institution, Washington, D.C. and National Bureau of Standards, Gaithersburg, Maryland p20.
- Piaskowski J., A Study of the Origin of the Ancient High-Nickel iron generally regarded as Meteoritic. *Early Pyrotechnology the evolution of the first Fire-using Industries* (Edited by T.A. Wertime and S.F. Wertime, Smithsonian Institution Press) Washington, pp. 237-243.
- Piaskowski J. The Earliest Iron in the World, *PAST Journal of the European Study Group on Physical, Chemical, Mathematical and Biological Techniques Applied to Archaeology* 21- II3, pp. 37-46.
- Piaskowski J 1992. Technical Studies on High Nickel Irons, with Special Reference to the Indonesian Kris, *Archeomaterials* 6,1 pp. 35-52.
- Piaskowski J. 1998. On the ancient Chalybean steel *Bulletin of the Metals Museum*, n, 10, pp. 65-67.
- Piaskowski J. Bryniarska J. Application of Microprobe Analyse to the examinations of Ancient Iron Objects, *Organon* 14, pp. 283-307.

Varoufakis G. 1982. The origin of the Mycenaean and Geometric iron on the Greek mainland and the Aegean Islands, [in] *Early Metallurgy in Cyprus 4000-5000 B.C.* ed. J.D. Muhly, et al. Pierides Foundation, Nicosia, pp315-324.

Waldbaum I.C. The first Archaeological Evidence for Iron and the transition to the Iron Age, [in] *The Coming of the Age of Iron* eds T.A. Wertime and J.D. Muhly, Yale, New Haven, pp 69- 98

Zimmer G.F. 1916 The use of Meteoritic Iron by Primitive Men, *Journal of the Iron and Steel Institute* 94, pp. 306-349.

Zimny J. 1965 *Mataloznawcze badania wyrobow zeiaznych z Czestochowy-Rakow* (Metallgraphic Examination of the Iron Implements from Czestochowa-Rakow) 1, pp 354-384.

#### Books

**The Cumbrian Industrialist.** ISBN: 0 9533 7991 4. Occasional Paper Vol 2. The Cumbria Industrial Society, c/o Graham Brooks, Coomara, Carleton, Carlisle, CA4 OBU. *Attempts to smelt metal with coal near Whitehaven before 1700.* Dr Blake Tyson. *Early activity, industrial injuries and the Poor Law. The case of Joseph Raven.* Anne Hillman. *Lime burning on Kendal Fell.* Tony Keates *Two engineering firms in a small county town: (Carlisle) A case study of what the engineers did and how they fared.* David George.

**West Street Trail Fareham's Millennium Sculptures,** by Eric Alexander. ISBN 0 9538279 0 9. The book (illustrated) follows the trail of the Henry Cort Millennium Project, which has placed a unique collection of wrought iron sculptures from all over Europe though the main streets of Fareham. Price £2.80 post free, from Wroughtware Publications 8a Chestnut Avenue, High Wycombe, Bucks HP11 1DJ. U.K.

Apology In HMSNews No 43 we gave a report of the Annual Conference in Cumbria 1999. It included a piece about the Millom iron and steel works given by Robson Davies on page 2. Part of this was amended in an apology in No 44 page 8. He now points out that the phrase "acid steelmaking for foundry use" should read "acid steel making and for foundry use." We regret this omission.

**The Hon. Editor Amina Chatwin,** The Coach House, Parabola Close, Cheltenham GL50 3AN. Tel 01242 525086 welcomes contributions for HMSNews by, the end of February, June 11th, and November 5th. If possible on Apple Mac or ascii.

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