the period 1747-1803, and the early use of gunpowder in iron mining. Roasting of magnetite ores was done to reduce the sulphur content. L Salvi followed with a talk on iron smelting using the Catalan process in Apulia. G Forni spoke on the diffusion of iron working over Europe making reference to the rock drawings of the Valle Camonica which clearly show ploughs with iron shares.

On Saturday 15th October we made a trip up the valleys to see museums, mines and smelters as well as a modern steel-mill rolling reinforcing bars from concast billets. The iron blast furnace at Desso had been used well into this century. It had extensive charcoal storage, a square roasting kiln, and had used high grade ore from local mines. At Schilpario, higher up the valley, was a small ethnic museum showing weaving looms and agricultural tools. Even higher up was one of the mines that supplied ore to Desso. On our return to Bienno we visited a working hammer-forge making edge tools, especially shovels and spades. The water wheels, supplied with more than sufficient water from leats from the hills above, were of the Bulgarian Samokov type in which water was directed on to the iron wheels through a vertical pipe. Thus the wheels were more like impulse turbines rather than the normal water wheel which is turned by the weight of water in the buckets. These wheels were no more than 2 metres in diameter and ran at a speed of 30 rpm. Instead of cams, 4 short bars were placed longitudinally on the shaft operating the tails of the helves. The frames were of stone and the rest of the hammer, hursts and bearings were normal. Although clearly of an old traditional design these units were quite capable of doing the job they were doing efficiently and it would have been difficult to find modern equipment capable of replacing them. One wonders how widely this type of water wheel was used on the north side of the Mediterranean and what its origins were.

The next morning was again devoted to more lectures many of them not related to things Italian but most interesting. R Vergani talked about the industrial hinterland of Venice centred on the town of Belluno in the 12th to 18th centuries. This was followed by M Matteoli on Corsican bloomeries, which as the 19th century metallurgist, John Percy, pointed out have a rather different method of working from their Catalan counterparts, and Riccardo Francovich spoke on the structure of the medieval Tuscan iron industry.

Having opened the technical sessions, R F Tylecote was called upon to close them by giving his impressions. The first was that of crossing the alps from Switzerland and being greeted by torrential rain — not for the first time. Of course rain means water and water means power and if it were not for this rain northern Italy would never have developed in the way it has. The second impression was on the immensity of the hospitality and the warmth of the people. The Commune of Valle Camonica and its individual towns had been determined to make this a great occasion and had succeeded admirably. We owe them our most hearty thanks. The speakers too had done their bit and we can truly say that we have all learnt a lot about the early days of Italian industry. One must congratulate the Iron Committee and its organisers for providing one of the most exciting conferences yet.

Conference of the Archaeology Committee of the Society

Muck to Metal; how metallurgy helps the archaeologist.

A one-day conference was held at the British Academy on 23rd November with about 80 people present. It was introduced by Dr Bob Smith of the Tower Armouries. In the chair was Richard Hall of the York Archaeological Trust. The morning session included papers by Dr Gerry McDonnell on the processes involved, Dr Henry Cleere on iron-working structures, Dr Chris Salter on iron-working slags and Dr Brian Scott on the artifacts.

The afternoon session was chaired by Dr Jim Charles and opened with Dr Liz Slater on copper-based ores to artifacts, followed by Justine Bayley on residues, crucibles and moulds, and Dr Paul Craddock on metal artifacts and analysis. After a discussion the proceedings were brought to a close by Prof Jack Nutting.

More meetings of this kind are planned for the near future.

Book reviews

Martha Goodway and J Scott Odell
The Historical Harpsichord, Volume 11; The Metallurgy of 17th and 18th Century Music Wire
Pendragon Press, Stuyvesant, New York, 1987, A5 hardback pp. 143 incl. index. Price £32.00

Martha Goodway has been interested in harpsichords for a long time and it is not surprising that as a metallurgist she should take an interest in its materials of construction. Restorers of old instruments which have been restrung many times have found pieces of old wire embedded in softwood at the bases of some of the hitchpins (pegs). Examination of these wires showed that they were consistently made of high phosphorus iron and it became quite clear that this had been selected for its higher tensile strength.

Modern materials are now known to have altered the tone of the old instruments and phosphorus iron is making a comeback. Perhaps one should say in more than one field, as rephosphorised low carbon mild steel is being considered for many other uses.

The book starts with a study of the early wire which is followed by a study of early iron wire-drawing and wire-making processes including fining. The chapter on alloy compositions not only discusses iron wire with 0.1 - 0.15% P but also brass wire which was found to contain from 7 to 30% Zn. No hardnesses are given here but these come later.

The iron wire was surprisingly clean with very little silicate slag and a little iron phosphide and oxide. Iron carbide was absent. It is claimed that this is due to the use of the Westphalian fining process and the first-tapped iron from the blast furnace, which produced an ultrapure iron. It is difficult to see exactly where the process differs from the Walloon process except that the finery also serves as a chafery i.e. it is a one-furnace process.

Physical properties such as creep are also considered since this determines the rate at which a string loses its tension. Thicker wires tend to have lower tensile strengths due to the fact that the thinner wires are higher drawn, i.e. have greater final deformation and hardness. The hardness of the brass wires varied from 152-255 HV 0.1, the finer wire naturally being the harder. Iron wires varied from 275 to 322 for much the same reason.

One interesting efect for the metallurgist is the so-called "brightening effect" where a string alters its tone during use due to a decrease in the damping capacity - the Koster effect. This is caused by relaxation due to low temperature diffusion of the more mobile elements, nitrogen and carbon in iron, and to a lesser extent, zinc in brass.

Obviously there is a wealth of interesting metallurgical information in this book. It is a classic example of how research on a simple piece of early materials science can involve the consideration of a wide range of physical properties. Music has always needed the metallurgist. This book shows some of the results of this cooperation in a very intriguing way. It is also a useful introduction to wire drawing and the properties of drawn wire.

R. F. Tylecote

J Cowgill, M de Neergaard and N Griffiths, Medieval finds from Excavations in London: Knives and Scabbards. *Museum of London, 1987, 169pp 23 tables, 107 figs, 25 plates. Price £10.95*

People expecting a rather dull catalogue of medieaval finds from excavation should be very pleasantly surprised when they open this very well thought out and produced book. It sets new standards on how groups of artefacts should be examined, discussed and presented, especially the excellent illustrations.

The book is the first of a series of projected volumes which are to present various types of medieval finds from excavations in the City of London over the past 15 years. In this work some 300 knives, 100 leather scabbards and 50 pairs of shears and scissors from 14 sites are dealt with.

These finds range in date from the mid-12th to the mid-15th centuries and the first two short sections of the book describe how the finds are divided into six chronological groups (plus one unstratified), and the basis by which groups of material from each site was dated.

The first half of the book covers the main ways in which the material was studied and gives the results and discussion to have emerged from these.

The largest section is entitled Manufacturing Techniques. It describes the forging of, decoration of, and makers marks found on the blades. This part of the book does not, however, incorporate (except by reference) the results of the metallographic examination of some of the blades. This should perhaps have been integrated into this section of the book rather than being relegated to an Appendix.

Plates 1 and 2 could have been better. Plate 1a is rather confusing and could probably have been omitted. Plates 1b and c illustrate differential corrosion better. In plate 2a it is the apparent weld line between the cutting edge and back of the blade that is the most interesting feature not the differential density of the radiograph which only shows the blade to be thinner towards the cutting edge. Plate 2b nicely illustrates how corrosion has followed and exaggerated weld or slag lines. It should be noted, however, that without prolonged (but slow) corrosion the effect would be largely undetectable on radiograph. The classic example is pattern-welding, some examples of which are quoted but, curiously, not illustrated among the plates. Non-ferrous inlays were also found on some blades dating from the 13th century onwards. Silver and brass were used in the 13th century examples while the later inlays are of gunmetal (copper-zinc-tin alloy), brass or tin.

Makers marks were found on 10 knives and 12 pairs of shears and these are illustrated. Surviving documentary evidence on the medieval guilds involved with the manufacture of knives and scabbards is discussed and the style and construction of scabbards and handles described and illustrated and the organic materials used to make these are identified.

Many of the scabbards were richly decorated and the methods and styles of decoration are described and various stamped motifs well illustrated. A separate section also describes and discusses the heraldic decoration found on the scabbards.

The appendix at the end of the first part of the book features reports on the metallographic examination of 10 knives and 5 shears and includes a general account of the types of iron and steel expected in blades of this kind. It is good to see technological reports on metalwork appearing in a book of this kind even if the metallographic details should have been integregated with the main section on manufacturing techniques.

The catalogue of all the objects examined forms the second half of the book. Each entry is concise and clear and appears to include all the information gained from

the different types of examination including technological details such as the possible presence of welds and the qualitative identification of the non ferrous metal parts . All the entries are illustrated, again to a very high standard and all relevant details are shown including cutlers marks which are shown at a larger scale.

The few small points of criticism not withstanding, this is an excellent publication which sets a very high standard which it is hoped that future volumes in the series will maintain.

Brian Gilmour

La métallurgie du fer dans les Ardennes (XVIe-XIXe) Cahiers de l'Inventaire II, ***Inventaire General des Monuments et des Richesses Artistiques de la France, Paris, 1987, Fr. 120. Paperback, pp. 111, 97 illustrations.***

In the French contribution to the Colloquium held at Cologne in 1974 under the title *Schwerpunkte der Eisengewinnung und Verarbeitung in Europa 1500-1650,* Pierre Léon lamented the almost total lack of worthwhile local studies of the French iron industry. He rightly saw that the only way the pioneering work of Betrand Gille, for the understanding of the development of the French iron industry, could be carried forward was through the evaluation of an ensemble of such local studies. What local studies existed were usually the work of antiquaries who barely understood the technologies involved. Pierre Léon held out the hope that, based on the Centre de Recherches de l'Histoire de la Sidérurgie at the Musée du Fer, Jarville, near Nancy, such local studies would be forthcoming. But for a further ten years the situation remained little changed and the publication in 1981 of *La Grande Forge* by Christian Sütterlin came like a bolt from the blue. This splendidly illustrated work drew attention to the wealth of archaeological material which survives, or until very recently survived, in France. The era of the charcoal blast furnace had persisted until particularly late in rural areas, and it is ironic indeed, that given this marvellous industrial heritage, France should almost completely lack the means to explain and evaluate it.

However, in 1984 the first detailed and scholarly study of ironworks in a particular area was published under the auspices of the Inventaire Général. *Les forges du pays de Chateaubriant* concentrated on a small area of Brittany and was a model of what such a study should be. The 295 pages of text were supported by 490 footnotes, 31 Annexes, some of which were statistical tables and the last of them a glossary, and 195 illustrations. The illustrations included numerous maps from archival sources and elsewhere, engravings and photographs reproduced from books, as well as specially prepared photographs, many in colour and some taken from the air. Such topics as charcoal supply and water management were given particular attention. The whole was rounded off with genealogical tables and indexes of persons and place-names. However, it was obvious that though this work was quite exemplary, we should have to wait for quite some time before the accumulation of such studies would have much impact on the picture of ironworking in France as a whole; the present publication comes as an answer to that objection.

Covering the whole department of the Ardennes, this work does not provide a more or less complete and exhaustive study of a particular area. It does however, take the first steps along the way and like Straker's work on the Weald, it will be the basis on which all subsequent research will depend. And this work has the advantage of being about an area of much greater historical interest for the industry than the Chateaubriant. In the introductory chapter, J F Belhoste describes its importance not only as an intermediary between the industrial regions of the Netherlands and northern Italy, briefly almost achieving unity with its neighbours in the 15th century under the dukes of Burgundy and then for a space of twenty years in the Republican and Napoleonic periods actually doing so. The contrast between this regime of open and untramelled trading and the more (Restoration) or less (18th century) systematically protectionist eras which followed and preceded it had dramatic effects on the industry. This was particularly the case after 1815, when only extreme protectionist measures prevented the iron industry being overwhelmed by a flood of cheap English imports. Behind the tariff barriers, English puddling and rolling techniques were gradually adopted, production costs were lowered and the industry again made viable, until the second half of the century, when the blast furnace virtually disappeared. It was replaced by a foundry industry based on imports of foreign, largely Belgian, pig iron.

The chapters describing developments in more detail are by Louis André. He rightly concentrates on the 16th century, which saw the widespread adoption of the blast furnace, and the first half of the 19th century, which saw the restructuring of the industry. The first written mention of a blast furnace comes rather late, in 1518. This is surprising in an area located between Wallonia, which knew the indirect process by around 1450, and Lorraine, where Rolf Sprandel noted 'hault fournelz' and 'affineries' in a works near Toul in 1445. The importance of the ironmaster Jean Regnesson in central Ardennes is stressed and it is interesting to learn the Goffin family from Franchimont was active in the Sedan area by 1536. But probably the use of an 'instrument a fendre fer' by Jean David at the forge of Linchamps in 1579 is the volume's real surprise, and just in case any doubting Thomas objects that this wording is far too imprecise to be construed as the earliest known reference to a slitting mill, they had better take a long look at the illustration on page 14, which comes from a book by Errard de Bar-le-Duc published at Nancy in 1584. However, André's suggestion that the phrase 'affiner et esteindre fer' in 1573 at the forge of Nouzon might refer to the same process is surely mistaken. This is a reference to the 'drawing out' of iron into bars under the hammer — Pierre den Dooven cites at least four references to *fer*

stendu in Franchimont, all from around 1510. It is also a shame that in a work concentrating on the Ardennes, figures for the transport of iron on the Meuse around mid-century are taken from a secondary source which apparently cites the figures for the years 1548/9 and 1560/1 only, when such figures are available for a dozen years. This section is concluded with long extracts from three legal instruments, which are older than all 78 texts forming the appendix to Yernaux's work on the Liège ironworks. Such documents are precious indeed. The first defines the *fondée* to be used at La Folie furnace in 1544 as consisting of five days instead of the 6 day foundry of English practice. The second involves a wood agreement of 1510 and the last is the 1579 lease of the forge at Linchamps, with its mention of the slitting mill.

The inventory of the sites comes next — more than 100 of them. But it appears not to cover all the 16th century sites shown on André's map. Since the ironworks of Thiérache extend far into Belgium, the line had to be drawn somewhere, but the sites in the departments of the Nord and the Aisne are so few as to be unlikely to figure in separate studies. If I may be allowed a further niggle here, it is not always easy to pick up in the inventory ironworks mentioned in the text. For instance, in order to locate La Folie it is first necessary to turn to Louis André's admirable map, which indicates it is possible to find it under 'Baalons'.

M Andre's second chapter illustrates the restructuring that followed 1815, by concentrating on two complexes which experienced very different fates. That of Jean-Nicholas Gendarme is the story of the astute direction of a small family firm, until it became the most powerful concern in the Ardennes. Gendarme was careful not to be first in the field in adopting new techniques, but to time his moves carefully, profiting from others' mistakes. His master-stroke was the purchase of the huge Forest of Mazarin in 1820, which enabled him to 'play the market' for charcoal as he chose, without himself being dependent on it. In contrast, François Devillez-Bodson was not a prime example of prudence and caution. Though turning a modest profit at his early death in 1829, his large concern was found to have massive debts and to be under-capitalized, despite advances from the Parisian banker Poupillier. Shortly before his death Devillez had gone into partnership with, among others, the Parisian bank of Seilliere. After liquidation, Seilliere took over the ironworks and the brother of one of the banker's partners, Eugene Schneider, became their manager. This concern was basically sound and it has now continued making increasing profits, though never on the scale achieved by Gendarme. On the other hand, on Gendarme's death in 1845, his ironworks were split up and lost their former importance.

The work is rounded off by a series of studies which are in effect appeals for a more enlightened approach to the conservation of what vestiges of the Ardennes ironworks still remain. Patrice Bertand, in *Une architecture pour les forges,* shows how slender are the resources, both graphic and archaeological, on which we depend for understanding the layout of the ironworks of the 16th and 17th centuries, whilst, though for statutory reasons there are many plans for projected works from 1810 onwards, the number of sites actually available for study continues to diminish alarmingly. He devotes a separate chapter to *La forge et la fabrique royale de Nouzon,* the forge going back to 1541 and the royal armament factory to 1675. Here we have a whole industrial complex — where the similarity of the workmen's cottages to their British equivalents leaps to the eye — which is steadily being allowed to collapse, the calls for conservation made over the last 20 years having fallen on deaf ears. Lastly he devotes a few pages to other architectural features of *Le canton de Nouzonville.* In between comes a small piece by Louis André which directs attention to the secondary metal trades, such as the nail makers, armourers and others. A statistical table from the period 1840-44 shows the merchant nailers of the Charleville area to have given employment to 80,000 persons, whilst maps of the distribution of workers and clients, the latter apparently extending as far afield as Dunkirk, Caen and Bordeaux, demonstrate the field of activity of just one of these merchants in 1803, and suggest the interest and rewards of further research.

This publication should achieve the objective of the Inventaire Général in arousing more interest in, and greater awareness of, the French industrial heritage, together with an appreciation of the need for further research and for a more enlightened attitude to conservation. But I hope I have shown that it does rather more than that, and the French should be envied for having a government body prepared to put its money where its mouth is. As usual with these publications, the illustrations are drawn from an amazing variety of sources and their quality is quite outstanding. What could be more evocative than the photograph of the ruined 16th century blast furnace of Moraypré, set in its woodland glade at Haybes, the excavation of which is called for? The insects and smells of the spot seem to surge off the page,

B G Awty

H I Dutton. "The Patent System and Inventive Activity during the Industrial Revolution 1750-1852".
Manchester University Press, 208 pages 10 tables. Price £32.50

This is a balanced history of the trials and tribulations of inventors, manufacturers, merchants, and a host of Crown servants all trying to earn more than a crust from the inventive process via a patent system that was not user friendly. The arguments and lobbying that lead to improvement are fully discussed.

Part 1 considers the changes from a 17th century patent system, which relied on a sketchy written specification of the invention leaving much "mystery" to be taught to apprentices, to the system after 1852, which recognised that a properly written description subjected to examination for novelty was essential to define an inventor's rights. In the period discussed

procrastinatory caveats became less effective in preventing grant of patents. Perceiving a better chance of patent protection, more inventors filed more patent applications: e.g. 7 patents granted in 1750 rising to 455 in 1851. Learned judges Mansfield (1778) & Buller (1785), for demanding a good specification and Lord Brougham, by Parliamentary achievement of examination and fees payable by instalments, much improved the system.

Part II discusses how inventors tried to exploit their patented inventions as the generally educated inventors of the 17th century were displaced in the 18th century by inventors who were actually engaged in the trade they sought to enhance. Chapter 7 lists prices at which inventions changed hands, e.g. D Mushet's 1835 patent to W Mushet for £15,000; D F Taylor's patent relating to a pin-making machine sold for £3,775 provided he made it work; £5 per horse power was an interesting royalty on use of a steam engine. Risk of bankruptcy deterred some inventors from manufacturing their inventions.

Little is said about the actual inventions but the bibliography tells one where to find out more. Those who do business in intellectual property might find the £32.50 well spent to get the explanation of the conclusion ". . . the imperfect patent system . . was probably most appropriate for the period of the industrial revolution".

R A Owen

Letters to the Editor

Phosphorus in low carbon iron

Dear Sir,
I will try to answer the questions raised by Martha Goodway and Robert Fisher in their paper on the influence of phosphorus on the properties of low-carbon steel/wrought iron.[1]

These questions were:
1. The phosphorus contents of the three iron wires from 1732-1782 — 0.1, 0.15 and 0.22% P - are conspicuously high. "Could this have been intentional?"

2. When carbon was not recognised as a constituent of iron "was decarburization the intended result?"

3. "How was this nearly complete decarburization achieved?"

Firstly, I would like to say that I think the results of the chemical analyses are not very exact if they are the result of microprobe analysis — as acknowledged to S S Brenner.

Secondly, for further consideration, it would be very necessary for me to know if the iron used to make these early wires, was produced by the direct/bloomery process, or by the indirect/finery process. Unfortunately I cannot tell because there are no microphotographs of the metal structures, and the silicon and manganese contents are missing in the paper.

So my answers would be:
1. It is possible that the phosphorus content in the wires has been intentional.
I found this problem when studying the phosphorus content of separate ferritic iron layers existing beside low phosphorus iron in knives from LUTOMIERSK 11[2], DANZIG 11[3] and TUM near LECZYCA 12 - 13[4 5 6], and in spearheads from LUTOMIERSK[2].
In all nine specimens the phosphorus content was in the range 0.23% to 0.45% P - arithmetical mean of 0.31%- analysed using the classical method, similar to the Goodway/Fisher results.
High phosphorus iron layered with low phosphorus iron was used to produce pattern welded knives, or other instruments, in Medieval times.[7] Iron containing more than about 0.4% could not be used because it would be too brittle, and also it could not be used for wire production. Ferritic iron, containing 0.15% P, I found in a Roman pattern-welded sword from WACHOCK about 3[8].
All the above mentioned implements were made from iron smelted in a bloomery.
The element phosphorus was discovered in 1677 but early smiths/metallurgists recognised it in metal during forging - its effect on plastic properties, strength, brittleness. They defined high phosphorus iron as "brittle iron"[9 10]. The influence of P on properties of iron and steel was invesigated by d'AMICO[11], in 1913, before Stead.

2. Decarburisation was the intended result because the production of low carbon/steel iron wire was quite easy. It was not a problem for early metallurgists. In the bloomery they obtained ferritic, uncarburised, iron directly from the ore. In the finery, it seems, it was easier to obtain full decarburised metal than to control middle carburisation.

3. So low decarburisation could be achieved without difficulty - but I am not sure that the analysis quoted is correct.

Sincerely yours,
Prof. Jerzy Piaskowski

References

1. **M Goodway and R M Fischer, Phosphorus in low carbon iron: its beneficial properties.** *Historical Metallurgy 1988,* 22 (1), 21-23.