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Minerals and Metals Heritage of India

National Institute of Advanced Studies
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MINERALS AND METALS HERITAGE OF INDIA

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Minerals and Metals Heritage of India

Introduction

The minerals and metals heritage of India covers a period of over ten thousand years and extends beyond the current national boundaries of the Republic of India. Until 1500 CE the superpowers of the world were China and India. Their civilizational hold on the imagination of mankind was built on their mastery of minerals and metals. With the dawn of the twenty first century, these two nations appear poised to recapture the earlier dominance after an interregnum of five centuries. Witness China emerging as the world's largest steel producer with over 500 million tons per annum and India racing to become the world's second largest producer. At an iconic level, Arcelor Mittal 'Orbit', a spiral steel sculpture designed by Indian born Anish Kapoor and commissioned by L N Mittal for the 2012 London Olympics (Figure 1), seems poised to rival the Eiffel tower in the public gaze.

Figure 1: Arcelor Mittal 'Orbit', Steel sculpture designed by Indian born Anish Kapoor and commissioned by L N Mittal for the 2012 London Olympics

The history of civilization is in many ways linked to the story of the use of metals in antiquity. Metals were extracted and utilized in the past in stages progressing usually from the use of native metal, to those metals which could be smelted easily from ores, to those which were more difficult to smelt. The commonly used eight metals in antiquity are gold, silver, copper, iron, tin, lead, zinc and mercury. This brief review illustrates some of the achievements of ancient Indian metallurgists. Metals are intertwined with minerals and mining. The present article builds on our earlier essays on this subject and also raises issues concerning Indian heritage that must engage our attention.

LITERARY EVIDENCE

The study of minerals and metals heritage of Europe is facilitated by the existence of many books. One must refer to Pliny (23- 79 CE) in his encyclopedic Natural History in 37 volumes. Foremost among the other historical texts is De Re Metallica in Latin by Georgius Agricola (1556 CE). His woodcuts bring home the then extant mining and metallurgical processes alive in a vivid fashion. The translation into English in 1912 by President Hoover (a mining engineer!) and his wife did an enormous service to highlight medieval mining and metallurgical processes. Cyril Stanley Smith translated several classics into English so that a reasonably complete view of European heritage is available. A Special Issue of Resonance in 2006 celebrates his contributions. The field of archaeometallurgy owes a special debt to the materials scientist Cyril Stanley Smith, a renaissance personality, who admirably brought together interests in aesthetics and materials science and thereby played a seminal role in enthusing many researchers in this direction.

But as far as writings on history of science go, it is Joseph Needham's monumental work and volumes on science and civilization that will long remain the model. In China meticulous records were maintained. But it was the painstaking and comprehensive compilations of Joseph Needham that brought the heritage of science and civilization in China to world attention.

An oft-heard lament is that India does not have the equivalent of Joseph Needham. This situation is being remedied now with the collective effort of several Indian scholars. They have shed further light by applying archaeological sciences. The Ministry of Culture, Government of India has constituted a committee with the

National Council of Science Museums as a hub for establishing ancient literary evidence with the evolution of Indian science and technology. Their Science Centre at Dharwad, Karnataka must be replicated across the length and breadth of India. The Indian National Academy of Engineering has a study group devoted to documenting Indian metallurgical heritage. Shivaprasad Khened has written about the need to propagate the knowledge of Indian scientific heritage. For a complete understanding of Indian heritage the reader is recommended to study the magisterial survey by A K Biswas and Sulekha Biswas.

In this context we need to appreciate two ancient Indian texts which normally may not attract our attention as pertaining to metals and mines. The Ashtadhyayi composed by Panini in the 5th century BCE is acknowledged as a masterpiece in linguistics. It established grammar with rigour and is often compared with what Euclid did for Geometry in his Elements. Biswas has emphasised that etymology can throw light on the minerals heritage of India. The names for some minerals in European languages were derived from Sanskrit. Corundum from Kuruvinda and Beryl from Vaidurya are examples. Kautilya's Arthasastra of 4th century BCE is often regarded as a manual in statecraft. It contains a great deal of information about mines and metals as well as gems and jewellery. Both these ancient texts predate the 300 BCE text De Lapidibus by Theophrastus of Greece and were in some ways more advanced.

In terms of historical evidence we face two problems. One is the inability to distinguish between mythology and history which bedevils our efforts. On the other hand the European domination over the past few centuries has led to a Eurocentric view which needs to be redressed. Michael Ashby has been gifted in marshalling information in the most graphic way through the use of Ashby Maps. In his article 'A Brief History of Materials' he credits Benjamin Huntsman with the invention and manufacture of crucible steel and William Champion with the extraction of zinc both in the mid 18th century!! However, both the making of crucible steel and extraction of zinc are among the major Indian accomplishments of antiquity. Fortunately the situation is improving, as more authors from across the globe participate in reconstructing the beginnings of the use of metals and alloys and taking into account innovations from across the world.

The Beginnings and the Stone Age

The diffusion of technology is crucial to human development. This was as true in the stone age as it is now. The stone tools are examples of a Palaeolithic technology called the Acheulian. It was invented in Africa by Homo erectus about 1.6m years ago and then spread to populations of erectus in other parts of the world. The speed of that spread, however, is unclear—or, rather, was unclear. In a paper in Science 2011 Shanti Pappu of the Sharma Centre for Heritage Education, in Chennai, and her colleagues have suggested that the humans carrying this technology from Africa reached India far faster than had been thought. The tools in question come from Athirampakkam, in Tamil Nadu, and have been dated to at least 1m years ago, probably 1.5m and possibly 1.6m (Figure 2). DNA analysis provides a genographic atlas to follow human migrations across continents. Dating techniques are giving us new scientific windows through which the past can be captured. The material history of India is undergoing revision.

Figure 2. Stone tools from Athirampakkam, Tamil Nadu dated to 1 m years (Courtesy : Shanthi Pappu)

As early as 7000 BCE, a Neolithic ceramic culture flourished in Mehrgarh in Balochistan. This was followed by the Indus Valley Civilization from 3300 BCE, ranked as one of the four great civilizations of antiquity along with those

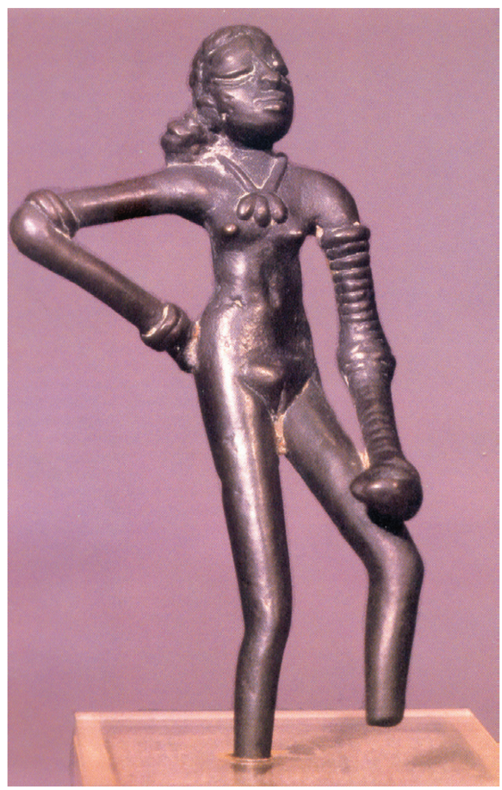

Figure 3. The celebrated statue of a dancing girl from Mohenjodaro (Courtesy : John Marr)

in Egypt, Mesopotamia and China. The artefacts from this period include the celebrated statue of a dancing girl (Figure 3) from Mohenjodaro from the Indus Valley. This is one of the earliest examples of bronze casting by the lost wax process.

GOLD

Early reference to gold is to be found in the Rig Veda Samhita. In all the sacrificial rites golden vessels were said to have been used. The Arthasastra refers to gold having "the colour of lotus, soft, lustrous and not producing any type of sound". The Harappan civilization had many gold objects such as those found at Mohenjodaro. Some analyses reported an admixture of gold with silver which might suggest that this gold originated in Kolar in Karnataka. Silappadikaram, the Tamil Classic by the prince Ilango Adigal, dated to the early Christian era is an epic that follows the twists of fate due the theft of golden anklets belonging to the heroine, Kannagi.

It has been stated that the Indian conquest of South Asian regions in the distant past was driven by the desire for gold. The tradition of mining gold started at least as early as the first millennium BCE. The Champion reef at the Kolar gold fields is believed to have been mined to a depth of 50 m during the Gupta period in the fifth century. In antiquity gold would usually have been collected by panning alluvial sands from placer deposits. However India has the distinction that the deepest ancient mines in the world for gold come from the Maski region of Karnataka with carbon dates from the mid 1st millennium BCE. The metal was continued to be mined by the eleventh century kings of South India, the Vijayanagara emperors from 1336 to 1560 and later by Tipu Sultan. Renewed interest in the Kolar Goldfields occurred towards the end of the nineteenth century. The ancient gold workings, which may be 200 years old and the workings of Tipu Sultan were located by Captain Warren in 1802 and started in 1864 by Michael F. Lavelle. John Taylor & Company did much of the prospecting. The Kolar and Hutti gold mines have been under continuous, if somewhat chequered, development.

It is interesting to report that in the seventeenth century during the Edo era Japan became a world leader in the production of gold from the mines in Sado Island. The gold was minted as Koban coins. Since Japan allowed trading privileges only to the Dutch East India Company, it bought Japanese gold and brought it to the Indian ports in the Coromandel Coast and traded it for Indian textiles. Indian textiles and the indigo dye mark another glorious chapter in India's materials heritage and need to be recounted on another occasion. The Japanese Cultural Ministry is making efforts to have the Sado mining complex inscribed as a World Heritage Mining Site. They are planning to visit the Kolar Gold Field to make comparisons. Surely, the Kolar Gold mines with its illustrious history has excellent reasons for being inscribed in the UNESCO list. While India has many sites including the Taj Mahal and the Hampi group of monuments, it has not given attention to illustrating its rich mining heritage in a similar way. Perhaps the International Minerals Congress can help raise Indian awareness in this context.

COPPER

Early copper artifacts of about the sixth millennium BC are reported from the pre-Indus Valley sites of Baluchistan in the northwestern part of the Indian subcontinent close to the Iranian border. There is also some evidence for smelting furnaces from the Harappan civilizations of the northwestern part of the Indian subcontinent. There is fairly extensive evidence for the ancient mining of copper ores in Baleshwar from the Khetri region of Rajasthan in northwestern India dating to about the 3rd-2nd millennium BCE.

MERCURY

Mercury is a metal that has been of great alchemical importance in ancient times. In ancient China there is evidence that mercury was used by the latter half of the first millennium BCE, while mercury metal is reported from Hellenistic Greece. Mercury is a volatile metal which is easily produced by heating cinnabar followed by downward distillation of the mercury vapour. Some of the earliest literary references to the use of mercury distillation come from Indian treatises such as the Arthasastra of Kautilya. Some evidence for mercury distillation is reported from the ancient Roman world. In India, vermilion or cinnabar i.e. mercuric sulphide has had great ritual significance, typically having been used to make the red bindi or dot on the forehead usually associated with Hinduism.

LEAD

In ancient Predynastic Egypt (ca 4000-3000 BCE) galena or lead sulphide was used in the manufacture of kohl or eyeliner and indeed a striking feature of Egyptian art is the beautiful and exaggerated lining of the eyes. Stone palettes for grinding kohl are found in ancient Egypt along with artifacts of lead indicating that lead was one of the earliest metals to be smelted since lead ore is easily reduced and does not require very high temperatures. Lead was commonly alloyed with copper and bronze for making castings. In De Re Metallica by Agricola, the Westphalian process of smelting lead ore is described where lead ore is smelted in an open hearth. The mineral-rich Aravalli region of Rajasthan was one of the important early lead mining regions in antiquity.

ZINC

The earliest firm evidence for the production of metallic zinc is from India. Of the metals used in antiquity, zinc is one of the most difficult to smelt since zinc volatalises at about the same temperature of around 1000^{0}C that is needed to smelt zinc ore. As a result it would form as a vapour in the furnace which would immediately get reoxidised and hence lost. Hence metallic zinc is seldom reported in antiquity. However in India there is unique evidence for the extensive and semi-industrial production of metallic zinc at the Zawar area of Rajasthan. The Rasaratnakara, a text ascribed to the great Indian scientist Nagarjuna, of the early Christian era describes this method of production of zinc. Rasa Rasaratnasamuccaya, a 13th century text gives details of the distillation process by tiryakpatanayantra (distillation by descending). This ingenious method was devised of downward distillation of the zinc vapour formed after smelting zinc ore using specifically designed retorts with condensers and furnaces, so that the smelted zinc vapour could be drastically cooled down to get a melt that could solidify to zinc metal. The collaboration among Hindustan Zinc Limited, M S University of Baroda and the British Museum has highlighted that 100,000 tons of zinc were produced from the 13th to the 18th century CE (Figure 4). This industrial scale production commands our admiration, as it predates

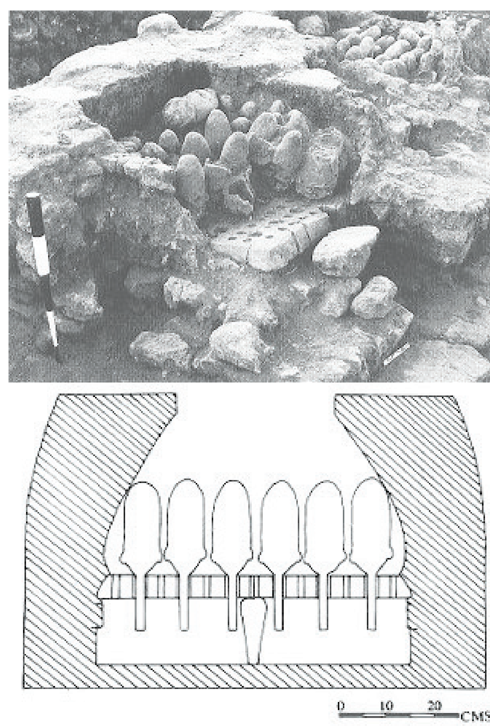

Figure 4. Zinc retorts from Zawar Zinc Mines - an ASM Historical Landmark (Courtesy :Paul Craddock)

the Industrial Revolution in Europe. ASM International has recognized the Zawar Zinc Mines as a Historical Landmark .

In Europe, the production of metallic zinc was virtually unknown until William Champion first established commercial zinc smelting operations in Bristol in the 1740's following which it was industrially produced. Interestingly the method of production adopted by downward distillation bears a strong resemblance to the Zawar process and it has been pointed out that Champion's process was very likely inspired by the Zawar process which would have been made known to the British during the forays of the East India Company as pointed out by Paul Craddock.

Another remarkable artistic innovation by Indian metalworkers of the past was the use of zinc in making highly elegant bidri ware, an inlayed zinc alloy with a small amount of copper, which came into vogue under the Muslim rulers of the Bidar province in the Hyderabad region from about the 14th century CE. Several impressive vessels, ewers, pitchers, vessels and huqqa bases were made of bidri ware with patterns influenced by the fine geometric and floral patterns and inlayed metal work of the Islamic world where decorative metalwork reached some its most exquisite heights. Glass-based enamelling of metalware also reached high perfection under Moghul influence such as the huqqa base in Figure 5 and drew upon the expertise of the Islamic world in glass making.

Figure 5. Enamelled Huqqa base, National Museum, New Delhi

BRONZES

Some of the most beautiful and well executed bronze castings in the world are the icons (Figure 6) from the Chola period in the Thanjavur area of south India (ca 10th century CE). Whereas the Greeks made life sized statuary bronzes already by the late 1st millennium BCE, and the Chinese made very large early castings of ceremonial vessels and such like, such large bronzes

Figure 6. Nataraja icon of the Chola period from Thanjavur district, Tamil Nadu

came into vogue in India only by the 1st millennium CE. South Indian bronzes were mostly solid cast whereas images from Southeast Asia are mostly hollow cast. The Nataraja bronze of the dancing Hindu God Siva, has been hailed as a remarkable synthesis of art and religion by writers such as Coomaraswamy and is coveted by museums around the world. The making of such icons still survives in Tanjavur district as documented by scholars including M V Krishnan, S Srinivasan, Baldev Raj, C Rajagopalan and C V Sundaram. Special mention may be made of the book, Masters of Fire, by Thomas Levy and the Sthapathis. It gives a lively and colourful anthropological account of the unbroken traditions over centuries of the hereditary bronze casters of South India through the family of Devasenapathy, who owns Sri Jayam industries. Srinivasan (1996) has provided insights in terms of tradition and continuity. Using archaeometric studies including lead isotope analysis, Srinivasan has argued that the Nataraja bronze may have already been in vogue in the 8th-9th century CE Pallava period.

HIGH TIN BRONZES

The cast icons are single phase alpha. Further addition of tin poses some technical processing challenges. Enhanced strength, desirable colour changes and acoustic properties emerge but are offset by brittleness. In fact it was little appreciated that this alloy was used in the Indian tradition by devising novel processing techniques. High tin bronze containing 22 wt % Sn, heated to a temperature between 586 and 798^{0}C consists of alpha and beta phases for hot working. A higher temperature than 798^{0}C leads to peritectic melting and a lower temperature than 586^{0}C results in precipitation of Cu31Sn8. A close control of working temperature is essential. In 1995 Srinivasan and Glover studied these thermomechanical steps after hot forging followed by quenching resulting in a microstructure consisting of alpha phase and the martensitic beta phase from Iron Age examples and ongoing practices. R M Pillai and his colleagues have made notable contributions to the elucidation of these processes.

Continued addition of tin leads to a white colour delta phase and forms the basis for an intermetallic with specular properties. The Aranmula metal mirror is a fascinating art object. In this case a novel casting method was devised so that the brittle intermetallic can be cast as thin blank and then polished for high specular reflection (Figure 7). The tradition of bronze mirror is found in China, Korea, Japan and India. The interrelation among them in terms of composition, insights on heat treatment through thermographic study, artistic decorations and living tradition is being further investigated by the authors in association with Toyoma University, Japan.

Figure 7. inverted crucible cum mould for casting Aranmula metal mirror
(Courtesy : Sharada Srinivasan and Ian Glover)

DIAMOND

Diamond was a material that has a strong association with India's history. The word 'diamond' derives from the Greek work 'adamas' for invincible. Numerous Sanskrit texts refer to Vajra or diamond. Until the 18th century India seems to have been the only source of diamond and its mining would have been patronized under the Vijayanagara, Bijapur and Golconda kingdoms. Marco Polo mentions the fame of diamonds under the south Indian queen Rudramma. The renown of Indian diamonds is seen for example in the descriptions of the Great Mogul by Tavernier which weighted 240 carats. The Koh-i-Noor which weighed 101.6 carats and was originally part of Mughal emperor Shah Jahan's Peacock Throne, is now part of the British crown jewels.

IRON

Iron seems to have been used in India from about the late second millennium BCE and iron smelting and the use of iron was especially well established in the south Indian megalithic cultures of this period. The discovery of the Naikund Furnace dating to 700 BCE attests to early smelting of iron. Near the furnace arrowhead, chisels, fish hook and other iron objects have been found. Vibha Tripathi has shown that traditional iron smelting is still practiced by tribal communities such as the Agarias in Madhya Pradesh and Chattisgarh.

The forging of wrought iron seems to have reached its zenith in India in the first millennium AD. The earliest large forging is the famous iron pillar with a height of over 7 m and weight of about 6 tons at New Delhi ascribed to Chandragupta Vikramaditya 400-450 CE . The inscription of the Gupta period of the 4th century CE is in Brahmi script of Sanskrit (Figure 8).The pillar is believed to have been made by forging together a series of disc-shaped iron blooms.

Figure 8. Inscriptions in Brahmi-Sanskrit on the Delhi Iron Pillar
(Courtesy : R Balasubramaniam)

The first reports of the 1600 year old pillar are all recent by British soldiers and travellers in early 19th century. World interest was drawn, when exactly a century ago Sir Robert Hadfield drew attention to this engineering marvel. Its corrosion resistance was studied by the scientists at the National Metallurgical Laboratory. An exposition on the Rustless Wonder by T R Anantharaman ignited the interest of R Balasubramaniam. His seminal contributions showed that the absence of corrosion is linked to the composition, the high purity of the wrought iron and the phosphorus content and the distribution of slag. He studied every aspect of the pillar in loving detail. He wrote on the elegant Bell Capital at the top. He argued that the original location was in probably Udayagiri in Madhya Pradesh and the pillar was then shifted to Delhi. Its original location may have had an astronomical significance. Other iron objects meriting attention are the Dhar iron pillar and the beams in Konark Sun temple of 10 th century CE. The Indian Institute of Metals and the Indian National Academy of Engineering have suggested to ASM International that the Delhi Iron Pillar be recognised as a Historical Landmark with success.

STEEL

India has been reputed for its iron and steel since Greek and Roman times with the earliest reported finds of high-carbon steels in the world coming from the early Christian era, while Greek accounts report the manufacture of steel in India by the crucible process. Wootz is the anglicized version of ukku in the languages of the states of Karnataka, and Andhra Pradesh, a term denoting steel. Literary accounts suggest that steel from the southern part of the Indian subcontinent was exported to Europe, China, the Arab world and the Middle East. In the 12th century the Arab Idrisi says 'The Hindus excel in the manufacture of iron. It is impossible to find anything to surpass the edge from Indian steel'. Cyril Stanley Smith recognized crucible steels among the four metallurgical accomplishments of antiquity. TMS listed wootz as Moment 7 in its compilation of 50 Great Moments in History of Materials (Figure 9).

Figure 9. Metal workers in south India develop crucible steel making "wootz" steel which becomes famous as "Damascus" sword steel hundreds of years later, inspiring artisans, blacksmiths, and metallurgists for many generations to come (Courtesy :TMS,USA)

Studies on Wootz indicate that it was an ultra-high carbon steel with between 1-2% carbon and was believed to have been used to fashion Damascus blades with a watered steel pattern. Experimental reconstructions by Wadsworth and Sherby in the 1980's have demonstrated that ultra-high carbon steels with about 1.5% C can be used to simulate blades and that these exhibit fascinating superplastic properties.

Wootz steel also played an important role in the development of metallurgy. Michael Faraday, the greatest experimenter of all times, tried to duplicate the steel by alloying iron with a variety of metallic additions including noble metals but failed. His failure had an unexpected and fortunate outcome as it marked the beginning of alloy steel making. Wootz has been a prime motivating force in the development of metallurgical science and the study of micro-structures. Although iron and steel had been used for thousands of years the role of carbon in steel as the dominant element was found only in 1774 by Tobern Bergman and was due to the efforts of Europeans to unravel the mysteries of Wootz. Similarly the textured Damascus steel was one of the earliest materials to be examined by the microscope. British, French and Russian metallography developed largely due to the quest to document this structure. Wootz was an 'advanced material' of the ancient world used in three continents for well over a millennium. Neither its geographic sway nor its historic dominance is likely to be equalled by advanced materials of our era.

There is an urgent need to substantiate Indian claims for supremacy by excavations to unearth furnaces and crucibles with proper dating. We narrate two of our ongoing efforts over the years in this direction. The South Indian site of Kadebakele is located on the northern bank of the Tungabhadra River in Koppal district of northern Karnataka. More than 60 hectares in area, occupation at the site spanned from the first millennium BCE Iron Age period into the first millennium as indicated by excavations by a collaborative team from the University of Chicago, University of Michigan, and Karnataka Department of Archaeology. Ferrous finds included projectiles, nails, rings and some slag specimens. Metallurgical studies are under way on some of the ferrous metals in collaboration with National Institute of Advanced Studies and Indian Institute of Science, Bangalore.

Deccan steel is famous and is seen at its best in Telangana region. Apart from accounts by Persian merchants, Daniel Havart of Dutch East India Company in the 17 th Century CE, Haji Hoysn from Ispahan in 1820, Henry W Voysey from 1820 to 1832, a serious study was made by Thelma Lowe. She demonstrated that the Deccan process used a crucible made of rice husks and led to an advanced ceramic composite that withstood the high temperatures encountered in melting steel. In recent times S Jaikishan has provided rich archaeometallurgical evidence for pre-industrial production of iron and steel. A major joint NIAS-Exeter University field expedition over 6 weeks was undertaken to the Telengana region of Andhra Pradesh in over Feb 2010 to early March 2010. Konasamudram in Telangana was a major centre for steel production centuries before Sheffield, Pittsburgh and Jamshedpur emerged. Figure 10 shows a large and elaborate courtyard house, where the 18th and 19th century trade in wootz is likely to have taken place. It is in urgent need of conservation as a heritage building. Also shown in the figure are crucibles. Over 120 sites were surveyed and samples were collected for archaeometallurgical study. A comprehensive database was compiled on the sites surveyed, the interviews conducted with the village blacksmiths, and morphology of surface sites with location information through GPS recordings. This database forms an important archive that could also be developed into a site gazetteer. Sampled materials were inventorised at NIAS and studied for macromorphology. Representative analytical investigations were undertaken to develop an appropriate methodology for the further study of the samples with insights from microscopic studies using techniques including CT scans, micro-structural analysis using electron probe microanalysis and texture analysis. This is another region that needs attention in terms of the world heritage of iron and steel and for preservation and recognition in terms of scientific heritage.

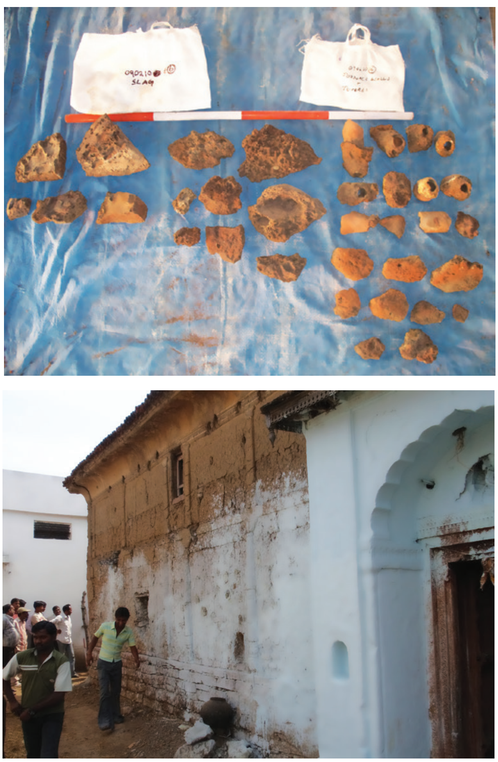

Figure 10. (a)Konasamundram: Large and elaborate courtyard house where the 18th and 19th century trade in wootz is took place. (b) Crucibles for making wootz steel from Telangana, Andhra Pradesh (Courtesy UKIERI Project between NIAS and Exeter University)

Geography as History

The geographic location of a region plays an important role in the evolution of culture and civilizations. The great civilizations of antiquity rose in river valleys. Jared Diamond has highlighted this in his book Guns, Germs and Steel and has contrasted the development of the large landmass of Eurasia in similar latitude with that of the Americas arguing that the latitude was the determining factor for the development of the former.

It is often stated that Afghanistan was at a crossroad of civilization. It led to successive waves of invasion from the Greek Alexander the Great to the Kushans of Central Asia. It was also a vital link on the silk Road to China. India has been involved in all these historic events. The development of Gandharan art is one example. At Bagram Indian ivory master pieces have been found.

In terms of trade routes we draw attention to the Indo-Roman trade linking Rome with Tamilakam. Kodumanal was a manufacturing and trading centre in Tamil Nadu in the 4th century BCE. It is mentioned as such in the Sangam literature of classical Tamil (circa 300 BCE-300 CE). The settlement was abandoned after the 3rd century CE. Excavations by K Rajan found decorative items such as semi-finished bangles and bracelets made from beryl, a crystalline mineral. A tiger-shaped copper object was studded with carnelians, sapphires and diamonds. There are sources of sapphire, beryl and quartz near Kodumanal, but carnelian, agate and lapis lazuli came from distant sources — as far away as Gujarat, Sri Lanka and Afghanistan. In addition to gems the ancient workers were masters of iron and steel.

A major recent success is the identification of ancient Muziri as Pattanam in present day Kerala. The Kerala Council of Historical Research has granted a major project to P Cherian. Pattanam was the first site in the Indian Ocean to yield archaeological evidence for Mediterranean, North African, West Asian and Chinese maritime contacts. The Natural History by Pliny the Elder refers to this site. Tamil Sangam literature refers to the trade in peppers with Rome, where Romans traded their gold for Indian spices calling them Black Gold. The ancient world was a globalised one, where Indian minerals, metals, spices and textiles were dominant

The study of the beginnings of the use of metals and alloys is the theme of the BUMA Conferences. BUMA VII was organized by us in 2009. It is hoped that in BUMA VIII scheduled for September 2013 in Nara, Japan Indian archaeologists and scientists will take active part and showcase Indian accomplishments in minerals and metals heritage. We also hope to generate a broader enthusiasm, whereby the education system in India could engage more fruitfully with a more field-based and museum-based awareness of heritage and also have a more creative engagement with crafts-based practitioners and related knowledge skills. This will motivate students to be engaged with the past in a way that can be beneficial for the future.

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