Programme for HMS Research in Progress Meeting
10th October 2013
Department of Archaeology, University of Exeter

	09:15-09:45	**Reception Tea/Coffee at the Archaeology Department, Laver Building**
	09:45-10:00	**Move to Xfi Conference Room 1 for the meeting**
Session 1	**10:00-12:00**	**Student Presentations: 6 papers of twenty minutes each (15 min presentation + 5 min discussion)**
	10:00-10:20	E. Giovanna Fregni: ***Minimum tools required: a system for organising bronze age metal-smithing tools***
Chair:	10:20-10:40	Tathagata Neogi: ***Forging tools, building relations: the social contexts of iron-working in South India***
Dr. Tim Young	10:40-11:00	Angela Wickenden: ***Mine tailings and slimes project***
	11:00-11:20	Steffan Klemenic: ***An experimental investigation into the means by which rivet-holes were made in the tangs of bronze swords, with a focus on artefactual evidence from Great Britain and Ireland***
	11:20-11:40	Kathryn Bonnet: ***Iron Age technology in Thailand: the manufacture and use of a protohistoric tool from Ban Don Ta Phet***
	11:40-12:00	Brice Girbal: ***The Legend of Wootz: research in progress on the south Indian crucible steel industry***
	12:00-13:30	**Lunch**
Session 2	**13:30-15:30**	**Presentations of researchers other than students: 7 papers of twenty minutes (15 min presentation + 5 min discussion)**
	13:30-13:50	Steve Grudgings: ***The sources and applications of the specialised iron and steel used to build Newcomen engine in 1751 – an insight into the skills and specialisations of some of the early artisan engineers***
Chair:	13:50-14:10	Chris McKay: ***A Pound of wyre***
TBA	14:10-14:30	Tim Young: ***Another piece (or two) in the jigsaw? refining slags from Ynysfach Ironworks***
	14:30-14:50	Steve Grudgings: ***The early boilers, how were they made and why they failed so frequently – an exploration of the practical obstacles these pioneering metalworkers had to overcome***
	14:50-15:10	Roger Hutchins: ***Tin extraction routes on Dartmoor***
	15:10-15:30	Neil Philips: ***The early Angidy works***
	15:30-15:50	Peter King: ***Charcoal consumption by the iron industry in modern England and Wales***
	15:50-16:15	**Tea/Coffee**
	16:15-17:00	**Discussions and Student Award**

Venue Information

For Tea/Coffee Reception:
Department of Archaeology
Laver Building
(No. 22 on the attached map)
University of Exeter
Streatham Campus
North Park Road
Exeter
EX4 4QE

For Presentations and Lunch:
Conference Room 1
Xfi Centre for Finance and Investment
(No. 84 on the attached map)
University of Exeter Business School
Streatham Court
Rennes Drive
Exeter
EX4 4ST

NOTE: Parking in the university is at a premium**.** It is recommended that those driving to the university arrive not later than 9 am for the convenience of parking in the Visitor Car Park of the university (see Streatham campus map attached).

Getting to the University

On foot

The University is within easy walking distance of Exeter city centre. The city centre map shows the location of the Streatham Campus and the St Luke's Campus, plus routes between the campuses and Exeter St David's and Exeter Central train stations, all within walking distance.

By bus/coach

The Streatham Campus is served by the D and H bus routes. The **D** bus route includes Digby, St Luke's Campus, the City Centre and Streatham Campus. The **H** bus route includes the RD&E hospital, St Luke's Campus, the City Centre, St David's station, Cowley Bridge and Streatham Campus.

National Express coaches (08705 808080) call at Exeter Coach Station. The Coach Station is a short walk to the High Street where you can catch the local D bus which will take you to the Streatham Campus.

By rail

Exeter has two railway stations - Exeter St David's (main station) and Central. Exeter St David's Station is approximately 10 minutes walk from the Streatham Campus and taxis are available. The average journey time from London Paddington is 2 hours 30 minutes to Exeter. See Streatham Campus map for the walking route.

Use National Rail Enquiries to plan your route. For passenger information telephone 08457 484950.

By car

The M4/M5 links Exeter directly to London, the Midlands, South Wales and the North including Scotland. The average journey time from either London or the Midlands is 3 hours. Download our detailed directions to the Streatham Campus by car.

Please note that from 4 February 2013 the Stocker Road entrance allows access to Car Parks A, B and D, the Business School and the Innovation Centre only. All other traffic including that for the Visitor Car Park must use the Streatham Drive entrance.

ABSTRACTS

MINIMUM TOOLS REQUIRED: A SYSTEM FOR ORGANISING BRONZE AGE METALSMITHING TOOLS

E. Giovanna Fregni
University of Sheffield
gfregni@comcast.net

A problem facing archaeologists is that only a fraction of the tools necessary to make metal objects have been recovered. Tools are often not recognised for their place in the metalsmithing chaîne opératoire, and little research has been done in organising the craft using the tools found in Bronze Age contexts.

In order to understand what would constitute the necessary materials and tools to equip a Bronze Age metal toolkit, an inventory was made of known metalworking tools from the archaeological record. This was cross-referenced to contemporary tools, the tools and materials used in modern workshops, and descriptions from ethnographic literature. This catalogue, along with an understanding of the chaîne opératoire for creating metal objects, provide the components for establishing a system that will yield a clearer image of the organisation of the metalworker's craft.

By organising metalsmithing tools, more precise interpretations can be made of assemblages, such as founders' hoards. Thus recognising the tools and their function, statements can be made about how these tools were used and the processes by which metal objects were made in the Bronze Age.

FORGING TOOLS, BUILDING RELATIONS: THE SOCIAL CONTEXTS OF IRON-WORKING IN SOUTH INDIA

Tathagata Neogi
University of Exeter
tn241@exeter.ac.uk

While archaeological excavations and surveys in south India has recovered and documented a significant number of iron tools backed by evidences of iron smelting in archaeological record and presence of a thriving iron-working community through inscriptional records, there has been a significant gap in understanding the socio-cultural context of iron-working (smelting and blacksmithing) in south India, if not South Asia. The extant traditional blacksmith community in northern Telangana and the erstwhile indigenous iron smelting communities of associated forest tracts of Central India provide an excellent opportunity to conduct detailed ethnoarchaeological research to unravel and understand the social and cultural aspects of iron production in the region. The present research in progress is expected to provide pioneering insights about *chaîne operatoire* and organisation of production, technological choices and styles, levels of craft specialization, intra and inter community social relations and trade network. From a material culture point of view, the study will focus on tool typologies, tool use and trace object biographies from manufacture to discard. This research is to address the existing gaps in knowledge in terms of iron-working communities and complement existing archaeometallurgical record with ethnographic data for a holistic understanding of iron-working in antiquity in the Indian Sub-continent.

MINE TAILINGS AND SLIMES PROJECT

Angela Wickenden
University of Exeter
wickenden66@msn.com

Tailings are a human made material left as industrial waste. With this research I intend to make vessels which will contain embodied meanings of archaeology, industrial archaeology, history, science, ideas of sustainability, art and craft, ceramics, the extractive industries of Cornwall and metallurgy.
I have been a practicing potter since 2006, after I graduated with an Applied Arts degree. 1n 2012 I was introduced by an ex mine engineer to the post industrial waste from Cornish tin and copper mines, known as tailings and slimes.. Initially, at the 19th century Mulberry Mine Lanlivet, near Bodmin, I dug out gravelly substance that are tailings and it became apparent that I could use this material to grog my clay to make it more refractory. Then we dug out some slimes from a small 19th century tin mine called Wheal Merthe, near Hayle, St Ives. The difference between the tailings and slimes, I believe, is particle size. This has yet to be confirmed by microscopy. It was immediately obvious to me, without any scientific testing, that the slimes were incredibly plastic, resembled clay and have subsequently proved to be plastic enough to throw pots with.

Samples I have fired are a spade full of slimes with organic material left in. One test tiles and cylinders, thrown on the wheel are almost like a porcelain in hardness and appear to vitrify at 1000 degrees Celsius. Porcelain has a maturation/vitrification temperature of 1200-1300 plus.

My final aim with this project is artistic. I aim to make a range of vessels from slimes from different mines, aim to have the slimes analysed with an XRF machine (I will be searching for funding for this later on this year). These pots will not be functional- they will be purely sculptural but contain meaning other than that they are ceramic. It is in these meanings where material culture studies/archaeology and art merge and according to Victor Buchli it is at these interfaces where new meanings emerge.

XRF analysis can show the elemental breakdown of tailings. The Wheal Merth tailings have a high tin content of 2 %(pers comm). I have no similar breakdown for Wheal Andrew or Tolgus Tin tailings. Interestingly, according to Quivick(2007) all cassiterite, tin ore, consistently contains arsenic, among other minerals. Therefore, these pots will have no food safety standards and will be non-functional.

Tailings have a huge environmental impact not least due to heavy metal contamination and the disposal of tailings and slimes for mining companies presents huge environmental problems, making some mining projects economically unworkable. This project will explore the possibility of using tailings for initially an artistic purpose. However, being able to make a ceramic material may offer a solution for the reuse of these materials.

AN EXPERIMENTAL INVESTIGATION INTO THE MEANS BY WHICH RIVET-HOLES WERE MADE IN THE TANGS OF BRONZE SWORDS, WITH A FOCUS ON ARTEFACTUAL EVIDENCE FROM GREAT BRITAIN AND IRELAND

Steffan Klemenic
University of Exeter
sk328@exeter.ac.uk

This presentation covers the findings of a masters dissertation, involving an attempt by experimental means to investigate possible methods by which the rivet holes were made in the tangs of bronze swords. Moulds were made to produce differing degrees of indentations to assist perforation and the efficiency and utility of mould types were considered. A series of 10% tin bronze plates of the same thickness as the hilts of bronze swords were made, and various methods were tested based on the suggestions of previous authors. Holes were formed using drills and punches of antler, bone, bronze, copper and flint.

This study found that many of the suggestions given by previous authors as to how the rivet-holes were made were flawed, and that in many cases the tool type had no impression on the bronze whatsoever. Antler, bronze and copper punches were used to good effect, and a flint drill showed signs of working at a later stage. Results suggest that cast-in indentations were essential to the success of the perforation and may have been one of the key aspects of this technology. These results are reflected in archaeologically found moulds that show cast-in indentations. The work provides a useful data set that has the potential to be built on with further work to achieve a more complete understanding of sword finishing techniques.

IRON AGE TECHNOLOGY IN THAILAND: THE MANUFACTURE AND USE OF A PROTOHISTORIC TOOL FROM BAN DON TA PHET

Kathryn Bonnet
University of Exeter
krb209@exeter.ac.uk

This project examines iron implements, labeled as billhooks, found in the protohistoric burial site of Ban Don Ta Phet located in Central Thailand. The site dates from early 4th century B.C.E or early 3rd century B.C.E. and excavations from this site discovered one of the largest iron tool assemblages in Thailand. Using experimental archaeology the billhooks are recreated leading to inferences regarding the technology and skill of the blacksmiths of Iron Age Southeast Asia. The recreated billhooks are also studied to understand a possible use for the tool.

An overview of the background information on the billhooks is given followed by the methodology of the study. The succeeding information focuses on the forging of the tools and subsequent use of the tools. These include details about the forge work carried out in two different locations, one in England, another in Sri Lanka. This is followed by a discussion of the skills needed to forge the tools and possible function of the iron implements.

THE LEGEND OF *WOOTZ*: RESEARCH IN PROGRESS ON THE SOUTH INDIAN CRUCIBLE STEEL INDUSTRY

Brice Girbal
University of Exeter
bmg205@exeter.ac.uk

The presentation will introduce my doctoral research on ancient iron and steel production in Northern Telangana which encompasses four districts; Karimnagar, Warangal, Nizamabad and Adilabad. The main aim is to understand the nature of iron production technologies and their development over time within the study area, in order to establish the reality of the technologies that made the production of high-carbon steels in crucibles (*wootz*) possible. The focus of the research is primarily on the assessment and analysis of the archaeological material collected during the UKIERI funded Pioneering Metallurgy survey which took place in 2010. The archaeological material primarily consists of the metallurgical waste associated with iron and crucible steel production; slags, furnace lining, tuyeres, crucibles, ores and iron. The research has two main phases. The first is to visually assess the material giving clues on the type of technologies present while in the second phase they will be subject to scientific (chemical and micro-structural) analyses which should inform on the type of natural resources (ingredients) exploited as well as some of the running parameters of the different technologies. This study should therefore enable the identification and to some extent the re-construction of the ancient metallurgical technologies in Telangana.

THE SOURCES AND APPLICATIONS OF THE SPECIALISED IRON AND STEEL USED TO BUILD NEWCOMEN ENGINE IN 1751 – AN INSIGHT INTO THE SKILLS AND SPECIALISATIONS OF SOME OF THE EARLY ARTISAN ENGINEERS

Steve Grudgings
steve.grudgings@btinternet.com

The first successful installation of an atmospheric in 1712 by Thomas Newcomen at Dudley marked two key points of interest to historical metallurgists:

- Firstly the use of fire as a captive energy source with all its implications for the development of metallurgy
- Secondly the point at which large mechanisms built with an increasing proportion of iron components started to be built and used on a regular and repeatable basis

The detailed records of materials used to construct the 42" Newcomen Engine commissioned by Jarrit Smith at Coalpit Heath near Bristol in 1751 provides a fascinating insight into the specialised market for Iron and Steel that was already established by this time.

What is particularly interesting is the obvious knowledge that the artisan builders of these very early heat engines had of the performance characteristics of the various types of iron and steel and how to design and assemble the interlocking set of components needed to make them work reliably. The materials purchased cover the whole range of iron and steel available at the time and include:

- Wrought iron plates
- Bored and plain castings
- Bar iron of two separate types
- Wire Rods
- Blister Steel
- German Steel

These materials were ordered by Charles Palmer the engine wright, the builder of this engine and whilst the applications of the castings and the wrought iron plates are clear, what was the application of the other materials and how did Palmer acquire the knowledge to enable him to specify the materials and their quantities so precisely.

This account briefly describes these materials, suggests their likely sources, identifies their characteristics, postulates how they were combined for optimum effect and examines what insights this gives us into the early development of the engineering professions.

A POUND OF WYRE

Chris McKay
01258 840501
chris.mckay@tesco.net

The church of St Cuthberga, Wimborne Minster has an almost complete set of accounts starting around 1400 and running to the present day. A turret clock was in the church from 1409; this drove an astronomical dial and at a later date a chime and a jack were added. In the accounts work carried out, repairs, alterations and

maintenance were documented. The paper presents a speculative assessment of the various account entries that relate to iron, brass and wire. What the materials were used for and the quantities and prices involved have led to some qualified deductions that are presented along with the reasoning.

Background

The source information is in a book 'Clocks and Clockmakers in Dorset' by Tribe and Whatmore, Tribe produced an appendix in the book on the Minster clock transcribed from the original accounts.

I call myself a horological historian and have presented a lecture on the Minster clock to the Friends of the Priests House Museum in Wimborne. Currently I look after and maintain the Minster clock my main interest is in turret clocks, if you look at my website you will get a bit more information about myself.

http://homepages.tesco.net/chris.mckay/

ANOTHER PIECE (OR TWO) IN THE JIGSAW? REFINING SLAGS FROM YNYSFACH IRONWORKS

Tim Young
tim.young@geoarch.co.uk

The numerous processes involved in the conversion of cast iron to wrought iron at various times between the 16th and 19th centuries remain understood only very poorly and the identification of their residues is extremely problematic. One particularly poorly understood process has been refining. Cort's puddling process (patented in 1783-4) offered a much more direct approach to decarburising cast iron than the variants of the Potting and Stamping process (and its relatives) then in vogue. Richard Crawshay of the Cyfarthfa Ironworks, Merthyr Tydfil, was an early licensee of Cort's process in 1786, but initially failed to produce iron of acceptable quality when puddling grey cast iron from coke smelting. After much experimentation a solution was developed (perhaps by Samuel Homfray at Penydarren Ironworks), involving an intermediate stage of melting the grey pig iron in an oxidising environment, followed by quenching the molten iron in a water-cooled trough to produce 'finers metal', a white cast iron. This process was adopted rapidly and by 1791 Crawshay was fully committed to puddling. Rapid expansion of Cyfarthfa followed between 1792 and 1796. After 1796, the location of the large waterwheel powering the blowing engine for the Cyfartha furnaces prohibited easy expansion of the smelting operation, so a satellite works was constructed at Ynysfach in 1801, with two blast furnaces and two refineries to increase the feed of finers metal to the Cyfarthfa puddling works. After 1815, Cyfarthfa was restructured to permit expansion, with seven blast furnaces on that site by 1825, By the 1830s capacity was again stretched, so Ynysfach was expanded with two new blast furnaces and four new refineries. The Cyfarthfa/Ynysfach works were, however, managed in an increasingly conservative way. A lack of innovation caused them to fall behind their great rivals, Dowlais. The works closed in 1874, apparently using refining until the very end, despite pig-boiling replacing refining-plus-puddling in many newer works in South Wales. Eventually, a complete reconstruction of the Cyfarthfa works reopened as a steelworks in 1882; Ynysfach did not reopen.

Excavations by the Glamorgan-Gwent Archaeological Trust during development of the new Merthyr Learning Quarter investigated a boiler house, an engine house, a casting house of c. 1836 and, most importantly, almost the whole refinery building of the Ynysfach work, with both the c, 1836 extension and an earlier structure, probably that of c.1801. Although heavily robbed to below original floor level, all six bays of the building were investigated, with their furnace bases, trough bases, water systems and, in one case, the cast iron water trough itself, providing important constructional details not present in contemporary descriptions. Post-ex investigations are in progress.

The archaeometallurgical residues from refining include dense slag cakes and abundant particles similar to spheroidal hammerscale. These macro- and micro-residues form a coherent suite on the basis of chemical composition, but differ markedly in oxidation state (and therefore mineralogy). Preliminary interpretation of the analytical data suggests that the refining process had an important role in dephosphorisation as well as desiliconisation.

Positive identification of refining residues allows confident attribution of other slags as being puddling slags, probably dumped with other debris from the main Cyfarthfa site (including post-1882 steel-making slag, Bessemer convertor tuyères and probable silicomanganese slags) during the abandonment of the site.

THE EARLY BOILERS, HOW WERE THEY MADE AND WHY THEY FAILED SO FREQUENTLY – AN EXPLORATION OF THE PRACTICAL OBSTACLES THESE PIONEERING METALWORKERS HAD TO OVERCOME

Steve Grudgings
steve.grudgings@btinternet.com

The steam for the first Savory and Newcomen Engines was supplied by the first boilers and the men that made them and the materials they used were at the forefront of the materials sciences of the day. Their skills and knowledge provided a significant part of the foundation for modern engineering skills, particularly in two areas:

- The construction of large and technically complex vessels that were required to remain watertight under challenging and varied thermal conditions.
- The development of the tools, techniques and materials to enable such vessels to be constructed on a routine basis at the engine sites.

Records of the development of the skills and knowledge for both of these areas are notable by their absence and this brief paper examines some of the available information relating to the materials involved and speculates on the practical issues that the early boiler makers needed to overcome. The following topics will be (briefly) covered:

- The precedent technologies and expertise on which early boiler makers drew
- The settling of the form of the early boilers on the “Haystack” or “Balloon” patterns and its implications for the related metallurgy.
- Skills and expertise needed to manufacture the wrought iron plates that became the standard “building block” from which almost all boilers were built.
- The practicalities of transforming the flat wrought iron plates into the various shapes and sizes needed to make the haystack shape.
- The challenges of punching rivet holes in the plates, aligning them with their neighbours, holding them in position and finally exerting the required pressure on the rivets to ensure a good seal

Given the range of issues and the absence of archival data on these topics, the paper will focus on the challenges entailed.

TIN EXTRACTION ROUTES ON DARTMOOR

Roger B. Hutchins
rogerbhutchins@hotmail.com

Some of man's earliest scientific experiments were with metals. Mixing of various metals to make useful alloys was a scientific process. The perfection of Bronze, an alloy of tin and copper was probably the result of numerous experiments over many years.
Before the discovery of the tin & copper bronze, arsenic & copper bronze was found to be useful but dangerous for the metal workers who began to suffer from arsenic poisoning.

Copper was relatively common, but tin was hard to find. Dartmoor was the most productive source of tin in Europe.

Metal sources are not found in the most convenient of places, and Dartmoor tin is no exception. Even if the climate was drier in the Bronze Age, there would still have been a problem getting the material to the metal smiths, tool and weapon markets.

The tin needed to be transported to the coast for export, and an infrastructure had to be put in place for the supply of food for the mine workers and transport of the tin.

On Dartmoor are the "long reaves", which should not be confused with the early boundaries of the coaxial field systems. These long reaves were first considered to be Trackways, but since the publication of "the Dartmoor reaves investigating prehistoric land divisions", they became interpreted as boundaries.

As a Dartmoor guide I used this interpretation for twenty years even though it made little sense to me.

The problem was that at the time there was no alternative explanation. The old suggestion that the "Great Central Trackway" was a continuation of the fosse way was highly improbable, and the trackway theory was abandoned in favour of the boundary theory.

Any possibility that they could have been local trackways was now disguarded.

After many years of agonising, I realised that the long reaves appeared to connect rather than divide. At first I thought that could be simply raised pathways for pedestrian use. It was only when I realised the importance of pack animals for the transportation of heavy goods that I began to investigate the possibility that they were pack horse or donkey paths.

I found an organisation called "The South Pennine Packhorse Trails Trust", and a book by Titus Thornber, that made me realise the importance of creating a raised causeway across wet peatland.

Similar causeways were constructed in The Pennines, Yorkshire, Ireland and on Sedgemoor where the ground was too soft for heavily laden animals.

The Ordnance Survey maps have now labelled the long reaves as "Boundary Work", online sites seem to have accepted the boundary interpretation. Academic archaeologists and others have accepted that they are boundaries.

I suggest that there is little evidence for a boundary interpretation for the long reaves, and that evidence for a raised track system for use of pack animals makes reasonable sense and this possibility.

THE EARLY ANGIDY WORKS

Neil Philips
apac.philips@btinternet.com

1566 saw the formation of the Company of Mineral and battery Works, with a remit to perfect the process of brass wire making, using water power. The available infrastructure, minerals, labour force and power source directed their interest to the Angidy River which empties into the Wye at Tintern. Brass wire production was to prove unsuccessful so the company moved its interest to perfecting the process of iron wire production. The iron needed for wire making had to be ductile, a specialist process calling for, at the time, imported Osmund Iron.

As shortage for the import developed, a local source was looked for and Richard Hanbury, one of the members of the Company of Mineral and Batter Works took up the process and gained a monopoly of supply.

Legal disputes with Hanbury, throughout the later part of the 16th saw the supply to Tintern wire works dwindling, leading to its closure in 1595.

The solution was for Tintern to build its own furnace which it did; one is documented for 1629, position unknown at present.

The Angidy furnace of today is a much later construction; although listed on a survey map of 1763, it is documented in roughly the same configuration to present over the intervening Ordnance Survey mapping.

In the 1980s, Monmouthshire County Council exposed and consolidated the ruins of the site and opened it to the public. Unfortunately flooding prevented the site from being fully investigated.

In 2007, the site which was falling into severe decline underwent more consolidation work which led to my being involved in its archaeology.

In the previous year, I had undertaken a Desk Based assessment of the area for a proposed Hydro eclectic Scheme.

Familiarity with the area and access to the limited excavation work provoked questions as to the overall layout.

Neighbours adjacent to the site allowed, encouraged and funded further research leading to a detailed topographic survey and resistivity of their garden.

In 2010, a small excavation revealed two leats; a further excavation in 2011 revealed the corner of a large building.

As the 2013, season draws to an end we now have a large building, probably a forge with a 6m wheel pit and possibly the ghost of the battery frame.

All previously know structures are mapped from 1763 onwards. The newly discovered ones are not listed.

CHARCOAL CONSUMPTION BY THE IRON INDUSTRY IN EARLY MODERN ENGLAND AND WALES

Peter King
peterkingiron@blueyonder.co.uk

A new estimate of charcoal consumption by the iron industry suggests that (except in the Weald, which had no coal), charcoal consumption reached a plateau in about 1620, lasting for over 150 years. This reflects the sustainable limit of charcoal production in ironmaking regions. Some shrinkage of output occurred in areas remote from the manufacturing areas in periods when iron imports grew sharply: from Sweden in the mid-17*th* century and Russia in the 1730s and 1740s. The areas where iron production was most successful were those that had both coal for iron manufacture and iron ore.