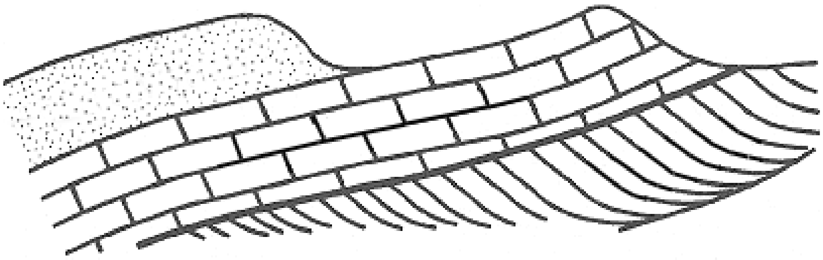
Farnham Geological Society

[www.farnhamgeosoc.org.uk]

Farnhamia farnhamensis



A local group within the GA

Vol. 7 No.2

Newsletter

June 2004

INSIDE THIS ISSUE

In the February newsletter the question of mounting displays of our rock specimens was raised. At our last committee meeting it was agreed that the exhibition to be shown at the Churt Fete on Saturday 12th June will be transferred to Church House for our July Members' Evening when we will be joined by members from the Hereford Society.

Our membership now stands at 131 and it is very pleasing to note that, excluding our more distant associate members, we regularly achieve over 70% attendance at our lecture meetings, a fact that has been commented on by several of our speakers who, we assume, are usually asked to address smaller gatherings.

The committee had agreed to have a table at the GA Reunion weekend in Cardiff on 5th-7th November. The theme for our presentation will be visits we have made to volcanic areas over the past 35 years. This meeting should be fun and members are encouraged to join those of us already going.

As already reported at the April meeting, Melene Barnes, our oldest member at 96, died recently. She had been a member for many years and continued to go on field trips well into her eighties. Nineteen members of the Society attended her funeral in Churt. Finally there is a short article in this issue relating to fellow geological societies operating in this part of England. We do have details of their planned activities for anyone interested.

Peter Cotton

COMMITTEE

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FGS monthly meetings and field trips - 2004

Jan 9	AGM followed by John Price, Astronomical Association
	The anthropic cosmological principle
Feb 13	Dr David Norbury, CL Associates, Wokingham
	Failures in engineering geology
Mar 12	Prof. Dorrik Stow, University of Southampton
	Into the abyss; Oil resources for the 21st Century
Apr 9	Dr Michael Kucera, Royal Holloway College
	Deep sea sediments: archive of climate change & plankton evolution
May 14	Prof. Michael Tooley, University of Durham
	Predicting sea-level changes
June 11	Prof. Cindy Ebinger, Royal Holloway College
	The East African rift: how to break a continent
July 9	***Members evening & presentations***
Aug 13	Summer break - no meeting
Sept 10	Prof. Richard Selley, Imperial College
	The geology of British vineyards
Oct 8	Andrew Davis, Mott McDonald (Consultants)
	Geological aspects of the A3 Hindhead scheme
Oct 15	**Society dinner**
Nov 12	Dr Steve Toothill, Ashstead Geological Society
	A View of Geology through seismic data
Dec 10	Dr Ian Jarvis, Kingston University
	20Ma of disasters - do deep-sea muds hold the key?
Jan 14	AGM 2005

Proposed Field Trips 2004

1-17 September - US & Canadian Rockies

11 September - Dorking vineyard

5 - 7 November - GA meeting in Cardiff

Possible future trips: October? 2005 - Tunisia

2006: France (Languedoc region)

Society dinner - Friday 15th October 2004

This year's annual dinner will be held at the *Farnham House Hotel* on **Friday 15 October**. The price of the 3 course meal, including coffee/tea, will be ~£18.00, a lower than inflation increase on last years excellent fare. Detailed arrangements will be announced at future monthly meetings, but the format will be the same as in previous years, that is, pre-selection from a choice of 4 dishes per course. A list will be posted for members wishing to attend to add their names to at the June, July and September monthly meetings; anyone who wishes to attend the dinner but cannot get to any of these meetings should let me have their name **no later than 10th September.**

Michael Weaver - Tel: 01252 - 614453

The anthropic cosmological principle

Summary of January 2004 lecture given by John Price, member of the Society and of the Astronomical

The somewhat forbidding title of this lecture concerns the theory that intelligent life on Planet Earth was preceded by many cataclysmic, chance events which could easily have produced a cosmological scenario that would have made it impossible for the evolutionary processes of life to take place. In other words the pathway of evolution leading to Homo sapiens was not inevitable, and so we are lucky to be here.

In the 20th century the development of nuclear physics revealed that the fundamental forces of nature had values that were critical to the evolution of life. It seemed that crucial nuclear reactions, such as the synthesis of carbon in stars, depended upon “finely tuned” properties of the nuclei involved. The production of all the elements from carbon upward depends in a most critical way on the nuclear energy levels of helium, beryllium, carbon and oxygen. If the fundamental nuclear forces had been different by a few percent carbon would not have formed and life could not have evolved. This is a statement of the anthropic principle along the lines that “nature is this way because if it weren’t we would not be here to observe it.”

Turning back to early views about the nature of the cosmos, we know from records of ancient civilizations, whether in the term of artefacts, or written records, that the understanding of the relative positions of heavenly bodies and their observed motions has gone through many phases. Aristotle and other thinkers of Ancient Greece had the earth at the centre of the universe and this view held for 1500 years until fresh scientific evidence produced by Copernicus and Galileo established that it was the sun at the centre. It must be observed that religious thinking about these fundamental matters has often appeared to be so conservative that scientific discoveries have been hotly disputed. Such remarkable attitudes have been seen in more recent centuries as for example Bishop Usher’s utterance in the 18th century that Earth was created in 4004BC.

We now know that we live in a galaxy of 100 – 400 billion stars and that the number of galaxies is of the same order. Our observations have taken us to the boundaries of the observable universe. Humanity seems such an insignificant speck in this vast cosmological scene, but the anthropic principle predicts that we are the only life in the galaxy, if not the universe. On the other hand, if intelligent extra-terrestrials could be found within 100 light years of us, it would mean that the galaxy is teeming with life and the anthropic principle would collapse.

Peter Cotton

Failures in engineering geology

Summary of Society's February 2004 lecture given by David Norbury of CL Associates

Three examples of engineering geological failures were described by David Norbury. Firstly, a landslip area north of Berwick on Tweed. Here fissures became established beneath the main railway line near Lamberton. A site investigation in this area established a faulted zone between Silurian and Devonian rocks. This zone built up a raised water table such that a head of water under pressure opened up fissures in the cliff area below the railway line. The remedial works included moving the tracks southwards away from the disturbed area, and diverting the groundwater from the cliff face below the railway.

Secondly, the Carsington Dam failure. This dam, built in Derbyshire, collapsed shortly before being completed. The material forming the dam was sampled by using a stringent system in the area of failure, to confirm the problem. The failure was attributed to solifluction of the fill, caused by the incorporation of ‘yellow clay’- a head deposit. The solifluction ultimately caused a toe failure. The dam was rebuilt using modified materials. Subsequently minor problems were judged not to be the major cause of failure, such as sulphate growth on the slickensides of the shear failure planes in the shale fill, and chemical degradation of the limestone used as a drainage layer.

Lastly, the failure of the tunnel lining at Heathrow. The construction of the underground station for the railway line to Paddington Station was built in London Clay. Tunnels were built in close proximity as the access and running tunnels. Shotcrete and reinforcement was used for the first time as tunnel lining in the soft ground. Previously it had only been used in rock. During remedial works the shotcrete lining failed, the clay moved and hence other linings collapsed. The void was filled with concrete in order to stabilise the area, and then a large shaft was sunk. Within this shaft the tunnels were rebuilt in a traditional way, using precast lining.

David Stephens

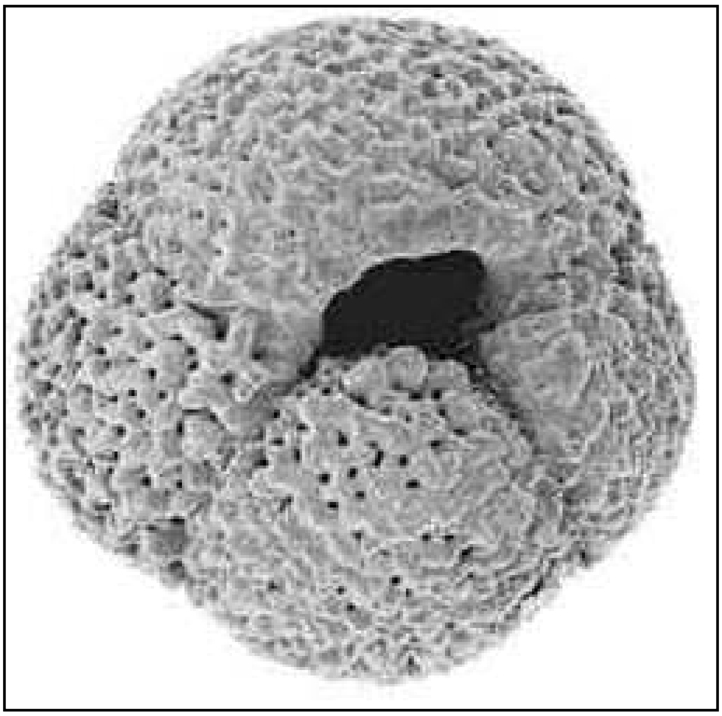
Deep sea sediments: archive of climate change and plankton evolution

Summary of Society's April 2004 lecture given by Dr Michal Kucera, Royal Holloway, University of

The bottom of oceanic basins is covered by an unusual collection of sediments. Isolated from continental clastic sources, the basin floor receives most of its sediment load in the form of mineralised shells of microscopic marine plankton. Among the most conspicuous ones are planktonic foraminifera, a group of protists (amoebas) which produce ornate calcite shells made by sequential addition of chambers. The deep-sea sedimentary record is uniquely complete and undisturbed and the microfossils that make up the bulk of the sediment faithfully record the history of the plankton living in the surface ocean. Thanks to the activities of international collaborative projects, such as the Ocean Drilling Programme, the technology for routine deep-sea sediment drilling has been developed and the sediment archive is made available to researchers in participating countries (including the UK).

There are two main areas where the excellent record of marine microfossils comes to prominence: the study of plankton evolution and climate change. Detailed investigation of the shape of tiny shells of planktonic foraminifera allows researchers to examine how plankton species evolve, how long this process takes and what causes the evolution. By comparing species divergences dated in the fossil record with DNA data, it is possible to calculate the rate of gene mutation and assign dates to the divergences among cryptic species – species that are genetically different but their shells appear identical. Each species of planktonic foraminifer thrives at a different temperature making it possible to devise mathematical formulas relating ocean temperatures to abundances of species. Such formulae can then be applied on fossil samples in order to reconstruct temperatures in the past. What are such reconstructions good for? Tiny as they may seem, planktonic foraminifera play an important role in providing ocean temperature reconstructions in critical intervals of recent earth history, such as the last ice age, that are used to validate climate models (i.e. assess which models may work better in reconstructing climates different from that of today).

These are the same models that are being used to predict future climate change and influence the decision of governments, banks, insurances and planning authorities.



Scanning electron image of the shell of a planktonic foraminifer Neogloboquadrina pachyderma from the Quaternary deep-sea sediments in the Northeast Pacific Ocean. The shell measures approximately 0.2 mm across. Photo M. Kucera.

Mical Kucera

The Wealden iron industry

Iron is one of the most abundant minerals found in the earth’s crust in the form of ferric and ferrous oxide and magnetite. It has been exploited by man since Neolithic times, It is as well to point out at the beginning of this article that the terms commonly used in archaeology to subdivide the Neolithic peoples into Stone, Bronze and Iron Ages are inaccurate when considering the time at which iron was first being worked which in many countries was before bronze. The earliest processes used for fashioning small iron objects were less complicated than for bronze and so bronze achieved the cachet of a superior material and did in fact have many advantages over the soft iron then produced. It is on record that in the struggle of the Barbarians with the Romans, the former had to pause in battle to straighten their iron swords whilst the Romans pushed on with their heavy bronze weapons. By 1200 BC iron working had extended over much of the Middle East and into Europe.

The Wealden Iron Industry

It was probably the Celtic people who brought the techniques of iron manufacture to Britain in about 700 BC but it was not in plentiful supply for another two centuries. The region of the Weald, and in particular the areas now situated in Kent and East Sussex, was ideal for the small scale production of iron at this stage with its abundance of forests for providing charcoal and the relative ease of extracting ore from the Wadhurst Clay Beds, the Wealden Clay and some of the Lower Greensand Beds particularly in Surrey.

When the Romans occupied Britain from 43 AD they found an established, though still small and scattered, iron industry particularly in Kent. During the course of their occupation its importance increased to an extent sufficient to justify the building of a road across the Weald for commercial rather than military reasons in order to transport iron to the area round Rochester and Maidstone for possible use by the Roman navy, or for exporting it. Also at this time the original technique for producing iron was being improved. The earliest system was a small furnace built of clay into which iron ore was introduced on top of burning charcoal and this produced a small amount of wrought iron called a bloom. The whole device was called a bloomery and the Romans developed taller furnaces into which successive layers of charcoal and ore could be introduced through a hole in the top of the bloomery whilst the furnace was being fired. The process still relied on manually operated bellows to provide the air blast required for continuous operation. Manually operated bellows continued in use during the period after the Romans departed and it was not until the thirteenth century that water power was used both for driving the bellows and for powering the hammers used for the forging process that was needed to remove the slag by hammering and re-heating. Water for use in driving the industry's machinery was obtained in the Weald by damming smaller rivers to form ponds. These were known as hammer ponds (*see photo*) and they are today the only lasting monuments to the old iron industry. Some of them were very large because they needed to hold sufficient water throughout the year to keep the operation running. Even so, some of the smaller units could only be worked seasonally.

Turning now to the extraction of the iron ore from the Wealden Beds, it was accomplished either by open-cast quarrying or by sinking "bell pits" measuring some 6 feet in diameter at the top and widening towards the bottom at depths of up to 20 feet. The iron content of the ore varied considerably but it was mostly low-grade siderite from the Wadhurst Clay. In other parts of Britain where ore is found in carboniferous strata it is usually hematite which can produce much higher iron yields such as in the old workings in West Cumbria where an average of 40% iron was extracted. As will be seen later in this article the low iron content of Wealden ore was one of several reasons why the Wealden iron industry closed in the 18th century.

From the 15th century, the iron industry of the Weald grew rapidly and, in line with this, a new type of furnace called a blast furnace, was introduced from the continent which allowed much greater output of iron in the form of cast iron. This was made by smelting iron ore with charcoal fuel in the blast furnace which attained sufficiently high temperatures to produce molten iron which was tapped at intervals of several hours and run into a series of long channels made in a bed of sand with smaller channels running at right angles like a comb. Here it cooled and was broken up, originally to undergo further heating to extract carbon and produce wrought iron. A fanciful resemblance of this comb to a sow with its litter gave rise to the name of pig iron. The first blast furnace in England was created at Newbridge in Sussex in 1496. Then in 1543 at Buxted a blast furnace was used for casting cannons and cannon balls. This set the scene for a virtual monopoly in gun-casting in the Weald at a time when the Tudors were involved in hostilities with France and Spain and required considerable amounts of munitions. By the year 1560 the Weald was Britain's biggest iron-producing area but by this time the iron industry in Staffordshire, South Wales, the Forest of Dean and in the northern counties was growing apace. Nevertheless the Weald retained its hold on armaments manufacture throughout the 16th and 17th centuries.

There was clearly much wealth being accumulated by the big iron-masters and owners of estates where iron was being mined and woods coppiced for fuel. This led to the building of large houses for the iron-masters in Kent and Sussex and also substantial residences for the managers of the operations which surpassed the size of many of the existing manor houses. Being so close to London the city financiers would also have been involved in this bonanza. The Weald could clearly be said to have been in the vanguard of the industrial revolution which a century later was based in the north country. As well as the aspect of personal wealth creation it should be noted that the development of the Iron Age economy in Britain over the previous two millennia had made possible the whole material success of civilisation. In the 21st century we so take for granted the use of iron in supporting our life style that it is difficult to realise how, before iron was exploited in quantity, the development of western civilisation was severely restricted.

We now come to the latter part of the 17th century and into the 18th century when the collapse of the Wealden iron industry began. In 1709 at Coalbrookdale in Staffordshire Abraham Darby discovered how to replace charcoal with pit coal in the operation of a blast furnace. This process began to take over in the manufacture of iron and new ironworks based near to the coal fields in the North, Scotland and South Wales were rapidly developed. This obviously had serious consequences for the Wealden iron industry which suffered from high costs of its charcoal fuel whose price was also being pushed up by increased demand from the hop producers. It seems probable, however, that the final blow to the Wealden industry was the award of valuable naval contracts to the great Carron Ironworks in Scotland that was being operated at a high degree of efficiency without all the high costs in the Weald. There is no doubt that towards the end of the 18th century all the adverse factors faced by the Weald iron-masters spelled out doom. Consider what these were:

i) High cost of charcoal versus pit coal
ii) High transport costs
iii) Relatively low grade ore
iv) Few economies of scale
v) Cheap imports, particularly into the major London market of the Weald
vi) A remarkably low rainfall compared with the previous periods that caused the small streams feeding the hammer ponds to dry up.

Epitaph - by Ernest Straker

So ended, after some 300 years of life, one of the most important industries of these islands. In its prime it had employed a notable proportion of the inhabitants and was not only a means of prosperity to the countryside but a source of strength to the nation.

Little, save some of the ponds, remains to be seen today; many a once busy site is hardly to be distinguished in the dense tangle of brushwood and bracken that has overgrown it. The buildings have gone, almost every stick and stone has been utilised elsewhere. The great bays are crowded with noble trees of many years growth and the once threatened woods have come into their own once more.

Peter Cotton

Newspaper snippet - Scottish fossil is first known land creature

A fossil discovered on the beach at Cowie Harbour, near Stonehaven in Scotland, has been confirmed as the earliest known creature to live on land. The fossilised millipede, which is less than half an inch long, is about 420 million years old, some 20 million years older than what had previously been believed to be the oldest breathing animal - a spider-like creature chiselled out of the chert at Rhynie, also in Aberdeenshire.

Victoria Mitchell, The Independent, Monday 26 January, 2004

An early industrial revolution

Perhaps we all thought '**<u>the</u>**' Industrial Revolution happened in the 19th century ! Well the first major revolution in '*industry*' was after the start of the 2nd millennium BC, at about 1860 BC to be more precise. That it when it is thought mining first started at the Great Orme Copper Mines, early in what we now call the Bronze Age. How did copper arise at a spot just north of Llandudno ?

Geology and Mineralogy

During the Carboniferous period, 340 – 280 ma, North Wales lay beneath a shallow tropical sea, in which skeletons and shells of dead marine creatures fell to the sea floor eventually forming beds of limestone hundreds of feet thick. The limestone came under pressure from earth movements and cracks and fissures were created through which over millions of years minerals and gases were carried to the surface dissolving the limestone to create cavities for the copper minerals to solidify in and form copper ore. The chemical change in the limestone brought about the formation of Magnesian Limestone (Dolomite) which was softer than the limestone and was therefore easier to work when those early miners began working the copper ore.

Entrance to mine

Manufacture

Copper is a relatively soft metal and not at all suitable for tool making but the clever Bronze Age smiths discovered, probably by trial and error, that by adding 10% tin to 90 % copper an alloy (called Bronze) was formed. The nearest tin mines were in Cornwall, a return trip of some 500 miles, so because of the difficulties in mining both copper and tin, Bronze became a very valuable commodity.

While Bronze may have been used for ornamental purposes the main use was in the manufacture of axes. During work for a Masters Degree in 1995, archaeologist Mark Randall, from UCL, calculated that over 1,700 tons of copper ore was extracted from the Great Orme mine during the Bronze Age. This would enable the manufacture of over 10, 000, 000 axes.

Mining and Dating the Ore Mining

The softer ores could be mined using stone hammers to break up the rock, as the 2.500 stone hammers so far found in the mine indicate. These range in size from 4lbs to 64lbs, probably hand held, as most show signs of battering at one end with the rest smooth. Bone tools were then used to scrape away the loose rock, as indicated by the 30,000 bones found, many showing evidence of one end being rounded through use.

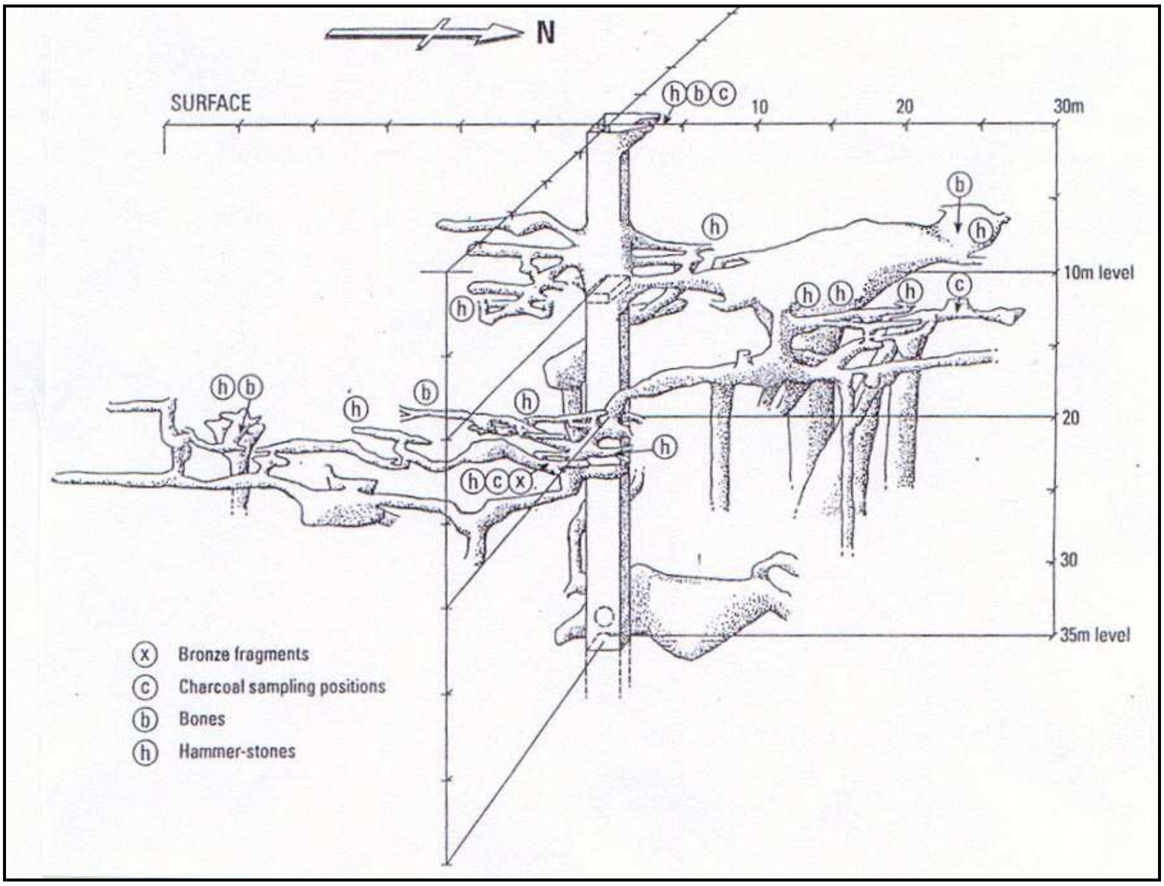


Diagram of the 4 miles of tunnels surveyed so far

When the rock was too hard for the miners to work they resorted to Firesetting, where a fire was lit against the rock, which expanded, then left to cool. When the rock had cooled it contracted, causing cracking which was then exploited. Evidence of Fire-setting has been found down to a depth of 220 feet below ground, suggesting a sophisticated method of fire control was used.

It is the charcoal left over from this activity that allowed the modern method of Carbon 14 dating to be used which shows that activity took place in the mine from 1860 – 600 BC. Though it is now known that mining took place during the Roman occupation and between 1692 – 1881 AD.

Modern Ideas on past Copper Mining

Until the 1970’s it was believed that copper mines were rare and worked by shallow surface mining. Recent research has shown there are 5 distinct prehistoric mining area in Mid-Wales alone and abundant evidence for copper mining elsewhere in Western Britain and Ireland.

Some idea of the scale of the Great Orme yield can be judged by estimates that other mines in Mid-Wales produced 6 –10 tons of copper between 1800 – 1500 BC; the Irish mines 3 – 4 tons over 200 years while the Great Orme mine is thought to have produced 175 – 238 tons.

(With acknowledgements to The Great Orme Mines and Cath Clemesha for literature and information, and to Francis Pryor's book "Britain BC" for descriptions)

Colin Brash

From the archives - FGS Journal, July 1982, pp 22 - 26

Copper and its minerals **by Colin Wilson**

This paper, first published in the FGS Journal in July 1982, is intended to give a brief introduction to copper and some of the more interesting copper minerals. Man's use of the metal together with the formation of some minerals are considered and the more physical characteristics and points of identification are enumerated.

Copper in History

Copper in its native form was one of the earliest metals known to Man, and due in part to the ease with which it can be worked, it was probably being fashioned into simple implements as early as the late Stone Age. At the same time its distinctive colour, ranging from salmon-pink when pure to reddish bronze when contaminated, made it particularly attractive for purely decorative and ornamental work. By about 5000 BC the techniques of work hardening, annealing and casting had become well developed and the range of articles being produced had expanded to include more imaginative tools, weapons, nails, tubes, ornaments and statues. Soon after this time, smelting of copper minerals to give relatively pure metal had been established and the amount of available workable material thereby increased. The process was probably discovered by accident during the glazing of ceramics using oxidised copper deposits at high temperature.

Copper combines easily with a number of other metals to form a series of different alloys. One such is bronze, and whilst the earliest examples occurred naturally in Middle Eastern mineral deposits, by 3500 BC a standard tin/copper alloy had been developed. This was both harder than copper and easier to cast, leading to improved weapons and finer ornamental items. Whilst the Romans were spreading these techniques and ideas throughout their Empire, similar usage of these materials was being made in Britain, China and South America. During the millennium following the end of the Bronze Age and the start of the Iron Age, copper and its alloys continued to be used wherever a combination of strength and durability was required. Typical applications would be the casting of bronze church bells, doors, and latterly cannon, and of copper-based wire, pins, printing plates and sheathing for ships.

At the end of the 18th century, the Industrial Revolution gave an upsurge to demand for coal and iron as the machine age began and this led to a corresponding rise in demand for copper. For a short period, Great Britain was the world's largest producer until the high grade deposits of Cornwall and North Wales were exhausted, after which production in North and South America became dominant. The rapid development of the Electrical Engineering Industry over the last one hundred and fifty years has had by far the greatest influence on the increase in demand for copper. The chief use is as an electrical conductor and this accounts for roughly half the total consumption. Other industrial users include the building and construction industry, the car and agricultural industries.

The name -'Copper' and its symbol

The Ancient Romans obtained supplies of copper from Cyprus where it was known as *'aes cyprium'*. From this the Latin name Cyprus was derived, hence the word copper and chemical symbol '*Cu*'. The copper symbol is taken from the Egyptian hieroglyph for both copper and eternal life, the ankh. As desirability is a major feature of copper the symbol is used for the metal itself.

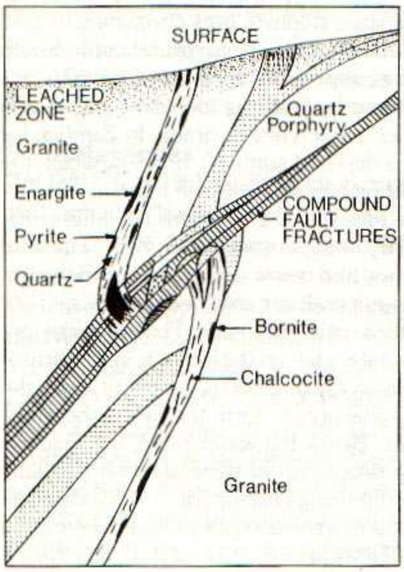
Copper ores and their occurrence

Copper ore bodies are widely, though not uniformly, distributed throughout the world. They are found in practically every type of ore deposit and are associated with every metallic and rock forming mineral. There are five major mining areas for copper and its ores - the Rocky Mountains and Great Basin area of the USA; the

Western slopes of the Andes in Chile and Peru; Central Africa; Central Canada and Northern Michigan; and the Soviet Union.

Many mineral deposits are found as tabular or sheet-like bodies intruded into joints or fissures in the host rock. The physical characteristics of these veins are dependent upon the type of fissure and surrounding rock. This mineralization is generally the result of deposition from a hydrothermal process associated with igneous activity. High temperature solutions containing sulphur and copper intrude into the fissures in the host rock, or in some cases, replace the rock completely. On cooling, the minerals are deposited out as vein-stuff. Butte, in Montana, one of the most productive regions in the world, has such well defined veins. The only native copper deposits of note are found in the Lake Superior district. The ores are either amygdaloid or conglomerate containing copper grains ranging in size up to large nuggets and beyond. The largest recorded single mass of metal weighed 420 tons.

The most extensive deposits worked in the present day are colloquially known as 'porphyry coppers', these are low-grade disseminated sulphide ores containing usually not more than one or two per cent of the metal. Such deposits are found in the South Western United States and in Chile and Peru. The copper-belt deposits of Central Africa resemble the porphyry coppers except that these bedded ore deposits are usually sharply delimited by barren rock walls and are of a much higher grade. In Zambia, for example, oxide mineralization extends down to a depth of some 50m, below which the leached secondary oxide changes to widespread high grade sulphide mineralization. With few exceptions, copper-hearing veins (see FIG. 1/2) are economically interesting only if the ore has been concentrated by secondary or supergene enrichment. The level of the water table is significant, as above it oxidation and below it secondary enrichment are the dominant processes. The primary copper minerals are oxidised and leached out near the surface by the action of low temperature meteoric water. The sulphides are converted to soluble sulphates and a residual limonite is left on the surface, in the form of a reddish brown gossan or 'iron hat'. Lower down in the oxidised enrichment zone, the descending sulphate solutions react with the original ores to form the two carbonates, malachite and azurite; cuprite and native copper. Below the water table, the reaction between the oxysalts and primary ores gives a deposition of minerals with a greatly increased mineral content. For example, a vein containing chalcopyrite (34.5% Cu) may be enriched by either deposition of bornite, or by more chalcopyrite and even by the conversion of the latter mineral to chalcocite (79.8% Cu).



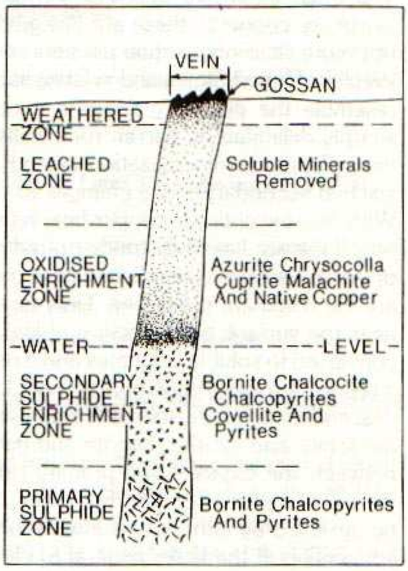


FIG. 1 Diagrammatic cross section through the Anaconda (Butte, Montana) copper deposit. Adapted from CDA publication No. 46 (1967).

FIG. 2 Supergene enrichment in a typical copper lode.

Beneath this secondary sulphide enrichment (or 'chalcocite') zone, the vein is in its primary condition where the mineral content is usually at too low a concentration to allow economic working. In and regions with a maritime climate, wind-blown sodium chloride may combine with the copper to form atacamite and brochantite, both important sources of ore at Chuquicamota, Chile.

Some Common Copper Minerals

In the following section, a brief descriptive narrative is given for chalcopyrite, the chief primary ore of copper. Also included are malachite, an important and decorative carbonate and cuprite, a copper-rich oxide ore. The three sulphides bornite, covellite and dioptase complete the range of major copper minerals, the last named being particularly decorative.

(a) Chalcopyrite (Copper pyrites or 'Fools' gold) $CuFeS_2$

Geographically the most widely distributed copper mineral, this sulphide of copper and iron is one of the most important sources of the metal. It occurs as a primary mineral in hydrothermal vein and replacement deposits and is associated with pyrites, cassiterite, sphalerite, galena and various gangue materials. In the porphyry copper deposits it is disseminated with bornite and pyrites, and is also found in pegmatite dykes and contact metamorphic deposits.

The common form is usually in compact masses. Occasionally it is found in small tetrahedral crystals of the tetragonal system, resembling cubes or wedges, which may be twinned. The distinctive features of chalcopyrite, include its brass yellow colour (often tarnished to bronze or iridescence), metallic lustre, and greenish black streak. It is distinguished from pyrites by its deeper yellow colour and inferior hardness (H 3½- 4); and from gold by its superior hardness and brittleness. It is soluble in nitric acid, and of medium weight (SG 4.1 - 4.3).

The theoretical composition is about 34.6% copper but this figure may be as low as 2% or less in terms of rock concentration. Even such low grade ores can be recovered economically under favourable conditions. The mineral is unsuitable for cutting. The name is derived from the Greek word meaning brass and from pyrites.

(b) Malachite $Cu_2C0_3(OH)_2$

The most abundant oxidised copper ore, this hydrated carbonate usually occurs in copper veins associated with limestone. Although crystallizing in the monoclinic system, it commonly occurs as radiating aggregates with botryoidal surfaces and may sometimes be pseudomorphic after azurite. On cutting and polishing, the characteristic concentric bands of blackish green colour are particularly distinctive. It possesses a medium hardness and weight (H 3½ - 4; SG 4) and displays a light green streak with a variable lustre. It was the source of much of the copper mined in ancient times, probably because of its conspicuous appearance in outcrops. The pure mineral contains 57.7% copper but because of its high colouring power and solubility it often stains and encrusts large areas of worthless rock disguising it as a valuable mineral. When found in large solid masses its worth is not only as a mineral ore, but also as a semi-precious stone taking a high polish. It is used for jewellery, table top veneers, vases and other works of art - particularly in the USSR. In smaller pieces, cutting is generally as a cabochon, beads or in flat pieces. The name is derived from the Greek word for mallows, a wild green plant of the genus *Malva*.

(c) Cuprite (Red Oxide of copper) (Cu_20)

Cuprite, a cuprous oxide, is rarer than the other oxidised ores but because of its high copper content (88.8%) it is of greater value. It occurs as a supergene mineral in the upper zones of more oxidised copper ore deposits and is associated with limonite, native copper, malachite, azurite and chrysocolla. This cubic mineral crystallises as eight or twelve-sided crystals, but can occasionally occur in a reddish brown fibrous habit, know as chalcotrichite ('plush copper'). The colour varies from shades of deep red through brownish red and purple to almost black, and in the translucent crystal form shows a ruby red colour for which it is called 'ruby ore'., It is hard and heavy (H 3½ - 4; SG 5). Cuprite is distinguished by its crystal form, high submetallic to adamantine lustre, brownish red streak and association with limonite. It is used as a minor ore of copper, is unsuitable for cutting and is named after the Latin for copper - *cuprum*.

(d) Bornite (Erubescite) $CuFeS_4$

Bornite is a sulphide of copper and iron with a variable copper content, say 55.5%. It is fairly common but occurs usually in subordinate amounts, in association with other sulphides in hypogene deposits. Less frequently, it is found as a supergene mineral in the upper zones of the copper vein. It crystallises in the cubic system, commonly as cubes or eight-sided octohedra, but is usually in a massive form. It is heavy and of medium hardness (H ½ - 2, SG 4.5 - 4.76), the freshly broken surface has a copper-red to bluish- brown colour (horseflesh ore) which tarnishes to variegated blues and purples. This accounts for its name of 'peacock ore'. It has a metallic lustre and greyish-black streak. Bornite is distinguished by its characteristic bronze colour on a fresh fracture and by its purplish tarnish. It is altered readily to chalcocite and covellite. Although an important ore of copper, it is not suitable for cutting. Bornite was named after the German mineralogist Von Born (1742-1791).

(e) Covellite (Covelline) (CuS)

The cupric sulphide (66.4% copper) is chemically less stable than the cuprous sulphide chalcocite. Whilst found in hydrothermal veins, it is more common in the secondary enrichment zone in association with other copper minerals, primarily chalcocite, bornite, chalcopyrite, enargite, from which it is derived by alteration. Primary covellite is known but uncommon. Although a hexagonal crystal, the tabular crystals are rare and it usually occurs as flexible plates or foliated massive in the form of coatings or disseminations through other copper minerals. The striking deep indigo to blue-black colour, which when moistened turns to an easily recognisable purple, is characteristic. Its streak is lead grey to black, hardness 11/2 - 2 and specific gravity 4.6 - 4.76. It is distinguished from bornite by its cleavage and from chalcocite by its colour. A relatively rare ore mineral, except at Butte, Montana, it is used as a minor ore of copper and was named after N.Covelli (1790-1829), the discoverer of the Vesuvian covellite.

(f) Dioptase (Emerald Copper) $Cu_6(Si_6O_{18})\ 6H_2O$

An uncommon mineral found in the oxidised parts of copper sulphide deposits, in calcite veins and druses. Dioptase is a rhombohedral cyclosilicate occurring in well-defined short prismatic crystals of the trigonal system, in crystalline aggregates, or massive form. Its distinguishing features are an emerald green colour, translucent crystals and association with copper minerals. Hardness and weight are medium (H. 5.0; SG 3.3), its lustre vitreous, and its streak green to greyish blue.

This mineral is too rare to be of use as a copper ore, and it is valued as a semi-precious stone. The best specimens are found in the Tsumeb Mine, South West Africa. It may be faceted, cabochon-cut or tumbled. The name is derived from the Greek words meaning 'through' and 'to see', since the cleavage was first observed by looking through the crystals.

A Last Word

Copper minerals have always been much valued by mineral collectors and lapidarists for their colourful beauty. Their bright colours belie their crucial economic value to many Third World countries today. Copper has so many uses in modern industry that its future on the world metal markets seems assured.

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Hydrocarbon reservoirs - present and future exploration

Summary of Society's March lecture given by Prof. Dorrick Stow of Southampton University

Professor Stow opened his talk with a global view of energy resources and described the dramatic increase in demand for hydrocarbons both for power and chemical applications such as plastics. The growth in the economy of China was particularly significant. To meet this increasing demand, oil companies are increasingly exploring deep seas where improvements in drilling technology enable hitherto 'untapable' reservoirs to be worked.

Over 1000 hydrocarbon reservoirs have been discovered world-wide in turbidites and associated deep-water facies. Professor Stow showed many slides of on-shore turbidites, particularly in the Californian Borderland basins, where massive blocks of sandstone act as reservoirs. In the North Sea, inshore reservoirs are being worked but Tertiary depositional fans exist in deeper water and in earlier drilling, the oil companies went straight through these turbidite layers without discovering oil!

A world map showed many important recent discoveries in truly deep water beneath present day slopes off NW Scotland, W Africa, Brazil, N Alaska and the Gulf of Mexico where depths of up to 3 km are being reached. Other locations have been worked where the oil exists in frozen conditions and also in association with salt domes. <see article in February Newsletter on Salt where Spindletop Dome in Texas has been a major source of oil>

Professor Stow finished his talk by mentioning other possible sources of energy when the hydrocarbon resources go into major decline in about 20 years time. These include solar power, hydroelectricity, wind farms, geothermal and nuclear, particularly from fusion power through breeder reactors.

Peter Cotton