

## **Geological Society, East Midlands Regional Group**

### **Report of Meetings January 2000 to March.**

*by Geoffrey Jago*

All meetings were held at British Geological Survey, Keyworth at 7.00 p.m. The committee of the East Midland Regional Group extends its sincere thanks to British Geological Survey at Keyworth, Nottingham for their help in providing lecture rooms for most of our meetings.

#### **Land Contamination Risks**

It was at BGS that the first of these in the new millennium was held on 12th January, 2000 when Dr. Paul Nathanail, Senior Lecturer in the Land Quality Management Department of Nottingham University, spoke on "Land Contamination Risks and their Evaluation".

Land which has been contaminated, most commonly by past industrial activity, often poses a major problem to local authorities, vested with the responsibility to examine the whole of their area. This is likely to be done by examining existing records rather than by field studies. The designation of such land lies with the Planning authorities; but at the time of the meeting much remained in the field of elucidation.

A model currently proposed is Contaminated Land Exposure Assessment (CLEA) but this does not cover all hazardous substances and its software awaits completion. With local authorities not bound to use a specified risk-assessment model, each adopts its preferred system.

A new guidance document, presenting a measure of standardisation to assist authorities in laying down strategies for tackling each problem, was expected to be published within six months of the date of the meeting.

Since it is vital that the language used is clearly understood by all involved in land assessment work, an important part of the talk dealt with definitions of terms. For example, the risks associated with contaminated land vary from insignificant to very hazardous, so "Risk" can be defined by assigning factors for "Probability" and "Magnitude" and multiplying the two. "Pollutant Linkage" gives the relationship between "Contaminant", "Pathway" and "Receptor". Unless all three are present such land is not classed as contaminated.

"Controlled Waters" means almost all natural waters. Of these, twelve specifically recognised and named rock formations have been defined as water-containing resources. Another important aspect discussed was the problems that local authorities have with the assessment of best practicable techniques of remediation.

Dr. Nathanail's talk, as comprehensive as it was interesting, presented a far wider ranging exposition of a complex subject than this space provides; but it may provide a trigger to further reading. Here Nottingham University is in a position to help.

A vote of thanks was given by Martin Culshaw.

#### **The Evolution of Lower Paleozoic Geography**

On 8th February, 2000 we were honoured to play host to Dr. L. Robin M. Cocks. An authority on Brachiopoda and Lower Paleozoic rocks who has spent his main career as Keeper of Palaeontology at the Natural History Museum, Dr. Cocks was at the time the 1999-2000 President of the Geological Society.

Dr. Cocks began the meeting by describing the current activities being undertaken by the Council and working groups of the Society.

Moving on to the subject of his talk, he showed a map of the latest interpretation of the positions of the ancient land masses of Pangaea in Ordovician times. In 1972 two interpretations had been proposed (one each for the

Ordovician and the Silurian) which were merged after cooperative study. Three main continents existed: Laurasia, Baltica and Gondwana. The last-named covered the south Pole and the three continents were separated by the Tournquist and Iapetus oceans. During Ordovician times Baltica rotated by 90 degrees. The Ural mountains are regarded as the eastern part of Baltica where lower Ordovician brachiopoda and trilobites lived. Although the Urals are linear, Baltica was not so limited, being changed by later earth movements. One margin of Baltica lay along a line from the Denmark-German border to the Black Sea.

At Yaman Kasy in the Urals sulphidised fossils have been found, thought to have been associated with black smokers on the sea bed. Armorican quartzites in Libya yielded large brachiopoda and trilobites from Gondwana, while photographs of bivalve molluscs illustrated distinct differences between equivalents living in Laurasia and Baltica. Work on brachiopoda alone now occupies the time of 200 geologists worldwide.

Also stressing the continuing importance of palaeontology, Tim Pharaoh gave the vote of thanks

### **Geoarchaeology**

When identifying stone items of ancient origin it is important to trace the sources of the materials. Should you be visiting the Sistine Chapel and notice the floor tiles carved from a hard red-brown material with small white angular crystals, you can identify the rock as "Imperial Porphyry" while modestly polishing your nails on your tee shirt. This is just one of the items of information to which we are indebted to Dr. Olwen Williams-Thorpe who spoke to us on "The best methods of tracing the sources of archaeological stone artifacts without upsetting museum curators" on 16th March, 2000 at BGS.

Dr. Williams-Thorpe's work covers the fascinating margin where geology and archaeology overlap; and her experience includes studies of a range of ancient sites in Britain and around the Mediterranean. She has examined artifacts ranging in size from Stonehenge and Roman buildings down to three-inch stone age axe-heads. Her studies of Roman building stones have extended to Tunisia, Egypt, Greece, Turkey and Italy. It has been found possible to identify five or six widely separated quarries around the Mediterranean which produced most of the architectural pillars for a wide area in time of the Caesars. The attractive "Imperial Porphyry" was a principal rock used by the Romans.

Until recently, for artifact analysis to proceed, it was necessary to remove some material from the object, a process manifesting some nervousness on the part of museum curators; but now non-invasive techniques can be used at least in part, thus allowing more access to valuable articles. Three non-destructive methods are used: magnetic susceptibility (magsus), gamma ray and x-ray fluorescence. Magsus and gamma equipment is hand-held and designed for reading from flat surfaces, while x-ray fluorescence machines, using mercury iodide detectors, are larger but portable. The gamma ray method can provide information from a 40 or 50 gram sample. Using a sodium iodide crystal as detector, it reads and quantifies emissions from uranium, potassium and thorium. Care has to be taken to separate the sample from other nearby artifacts which could give erroneous readings, but all the methods give very satisfactory results.

A vote of thanks was given by Ian Penn.

### **Himalayan Geology**

When continents drift around without intelligible direction, collisions are inevitable, a characteristic they share with modern-day vehicles. The Himalayas stand monument to a big crunch as the Indian plate shunts into Asia. On 12th April, 2000 Professor Randolph Parrish of National Environment Research Council's Isotope Geosciences Laboratory at BGS spoke on the geology of the world's highest mountain range. Stretching from northern Pakistan eastwards to Indo China the Himalayas are the most prominent topographical feature on Earth.

Professor Parrish showed us many outstanding aerial photographs of the landscape: the peaks from the south and exhilarating valleys. To the north of the mountains lies the large plateau of Tibet, while to the south an abrupt change bounds the flat foreground.

The northward journey of the Indian plate has been mapped by magnetic anomalies which show that it began over 80my. ago with the first contact being made about 50my. The crunch continues with convergence of India with Asia at 40 to 60mm. per year.

A number of controversies and uncertainties remain in respect of the structure and deep geology of the Himalayas. There are four major fault systems on the Indo-Gangetic plain, all roughly parallel with the mountain range. The southernmost Main Boundary Thrust separates Precambrian rocks from Pliocene and Miocene. Next to the north is the Main Central Thrust and then the South Tibetan Detachment System with Paleozoic/ Mesozoic rocks to north. These predominantly sedimentary sequences were deposited on India. Next northerly lies the Indus-Tsangpo Suture Zone. All these major structures and their associated rocks extend from east to west along the range without a great deal of variation.

Granite is found across the Main Central Thrust, some of which suffered shear strain under high temperatures which reduced the crystal size. Kyanite, which can only form under very high pressure, is present in these granites.

At Anapurna the tectonic evidence points to two thrust events alternating with two eras of normal faulting. A major and very extensive normal fault, the South Tibetan Fault, dips at only 15 degrees and forms the base of the Ordovician. The very top of Everest is composed of Ordovician limestone lying on this fault. The notably shallow angle is the subject of some speculation and many authorities believe that rotation must have played a part in forming the structure despite the fact that no evidence of this has been observed. Younger rocks almost always sit on older strata and rocks of some time periods must be missing. Fault angles of 10 to 40 degrees occur, with occasional overturning.

In Tibet, responding to the spreading of the Tibet plateau, young normal faults trend in a direction close to north-south and appear to end near the mountains.

Over the last 60my the Himalayas have changed the Indian climate, giving rise to the monsoons which are the result of southerly winds of warm moist air driven to precipitation onto the high ground. This weathering has caused very rapid erosion and deposition into the sea both to the west and east of India.

A vote of thanks was given by John Carney.

*Report by Geoffrey Jago*

## **Oil & Gas in Central Asia**

On 17 May Dr. Robert Gatliff spoke on the Petroleum Geology of the Caspian region.

The Caspian Sea area is a complex of micro-continents, island arcs and associated basinal sediments accreted by northwards movement into the Eurasian plate. Three main petroleum basins are present; the north or Pre-Caspian, Amu Daria in the central area and the South Caspian, which mirror the direction in which the reservoir rocks young.

The area has a long history of exploration starting at the end of the nineteenth century when oil seeps in Azerbaijan were exploited. Development halted after the Russian Revolution until post World War II when the first offshore well was built in 1949. Since the mid- 1990's BGS Petroleum group and others have been reassessing 5 fields offshore of Azerbaijan for much needed western investment and development. The region is remote and the poor infrastructure and large safety problems have so far limited interest.

In the North Caspian area, early plays were found in Devonian clastics above salt diapirs and later below them with the advent of better quality seismic data.

Amu Daria in Turkmenistan has similarities with the North Sea basin; Jurassic black shale source rocks (at about 8km depth) produced gas which filled higher Jurassic and Cretaceous clastic reservoirs.

In the South Caspian area, nearly 20km of sediments with organic rich muds accumulated in the mid-Jurassic Caucasus Basin, over possible oceanic crust. Following early Cretaceous back-arc spreading, obduction occurred in the mid-Pliocene forming the Caucasus Mountains.

As sea level dropped, three main rivers including the Volga, deposited vast deltaic sequences across the basin. Although the source rocks are deep at 7km, the geothermal gradient is small at 10-12 degrees centigrade per kilometre and the source rocks still exist within the window of oil generation. Contrast this with the Kimmeridge Clay in the North Sea which is mature at 3km depth.

On the western side of the basin, anticlines are associated with deep sourced mud volcanoes, possibly driven by gases from overpressured sediments. Some fields such as Oily Rocks are developed using onshore oil technology in the shallow waters just offshore. The field consists of many simple wells drilled from a number of platforms connected by now rickety causeways. No seismic data were used but the complex fault pattern has been mapped using the wells which tap into 26 stacked reservoirs down the flanks of one of the mud volcanoes. Thicker sands often have smaller oil columns due to the lack of fault sealing in comparison to the thinner ones. In many reservoirs, the unusual situation of brines up dip of oil occurs, which is thought to be derived from the waters expelled at the time of the mud volcano formation.

Many similar fields exist and some have been found using LANDSAT imagery to trace what appear to be separate oil slicks back to a single sea bed seep.

Alf Whittaker gave the vote of thanks

References to follow up:

[http://www.eastoil.com/caspia/Caspian\\_Sea.html](http://www.eastoil.com/caspia/Caspian_Sea.html) for seismic data, maps, reports etc;

<http://washingtonpost.com/wp-srv/inatl/europe/caspian100598.htm> for a sideline on politics in the region;

<http://www.pesgb.org.uk/caspian.htm> for geological abstracts from PESGB 1997 conference.

*Report by Andrew Brewster*

## **Coal & Minerals Mapping in the UK**

On 7th June 2000 at Nottingham University's Pope Building our Group attended a Joint Meeting with the above title which had been convened by the North Nottinghamshire Branch of the Institution of Mining and Metallurgy. The two speakers were David Highley and Graham Chapman, Economic Geologists in the Onshore Minerals and Energy Resources Programme of BGS, their subjects being, respectively, recent examples of mineral mapping in Britain by BGS and the Coal Resources Map of Britain (CRMoB) which is published jointly by BGS and the Coal Authority.

In addition to the purely geological study, environmental factors become increasingly important and BGS work in Britain has been driven by mineral planning of which the Minerals Local Plan produced by local authorities is a major work of reference. Qualifying information obtained on economic minerals are considerable environmental restrictions to the exploitation of minerals including National Parks, Sites of Special Scientific Interest, Areas of Natural Beauty, Ministry of Defence land and high grade agricultural land. Hence the CRMoB includes information relevant to environmental constraints.

As an example of a relevant study, David Highley spoke on the mineral resources of east Dorset where BGS are coming to the end of a three year scrutiny into the district around Wareham.

The Tertiary strata are of Paleogene age (Lower Eocene). This locality includes the Wych Farm oilfield and contains valuable sources of ball clay and sand for construction. North and south Devon and Dorset are all producers of ball clays which are globally quite rare, Britain being a leading exporter. They are fine grained highly plastic sedimentary clays with very low iron and carbon content, burning to a white colour. Kaolinite is a

key component, with illite and quartz also present. Carbon must be less than 0.3% and preferably below 0.25%. Typical analyses are SiO<sub>2</sub> 53-65%, FeO 3%, Kaolin 32-52%. Ball clays provide a unique plasticity to clay bodies and are used in tableware, enamels, floor and wall tiles and refractories.

In the Wareham district there are four major beds of ball clays known as the Parkstone, Broadstone, Oakdale and Creekmoor clays. Brilliantly clear geological maps illustrated the talk, produced by a lap-top computer and video projector. The occurrences of the clay beds were described, and photographs of exposures also displayed.

Consultation areas for clays have been set up, the clay industry being informed of any proposed development which may sterilise clay reserves. Much thought is being devoted to methods of improving restoration of exhausted clay pits in Dorset where high acreages of natural heathland survive.

In addition to their work in Dorset, BGS are also seeking to cover many other areas of England & Wales.

Graham Chapman then provided information on the CRMoB which is the first official map of coal resources produced since 1945. We were told that since 1780 the total production of coal in Britain has been 26.3 billion tonnes.

CRMoB is primarily a digital operation, and its purposes relate to resource development, energy policy, land-use planning, the avoidance of resource sterilisation, hazard indication, environmental assessment, property conveyancing, insurance work and education.

The Coal Authority is responsible for coal licensing and for maintaining a database of boreholes and maps as well as providing a depth and breadth of expertise. BGS maintains the national geological archives and a unique dataset of geological maps. The Coal Authority's input to the map includes the choice of geological boundaries, depth from surface criteria, licence information for mine location, topographical base requirements and trouble shooting. BGS's input to the map includes the 1/50000 scale geological linework, shallow borehole map insets, deep borehole map insets, international mineral resource concepts and a coal bed methane study.

Dr. Chapman displayed and explained various insets of the CRMoB. One such showed the vast concealed coalfield extending eastwards from the exposed Notts-Yorks coalfield under a large area of the North Sea east of Lincolnshire and Yorkshire and northeast of Norfolk where enormous volumes of coal are present at depth.

Using the laptop controlling the video projector, Tim Coleman demonstrated the easy access to the map information. A specific class of intelligence can be made to appear instantly on the map by clicking on a box in the legend; and display to great detail is possible by zooming in.

A vote of thanks was given by Martin Culshaw who said that while BGS had spent 150 years making maps, their presentation by computers in the last 15 years has undergone revolutionary change. Professional people have the responsibility to present the facts they discover to the general public. Whereas at one time profitable production was virtually the only restraint to working, in recent years the environmental aspects become increasingly important. Today's lecture shows how many classes of information, both technical and those important to environmental factors can be presented on one map.

*Report by Geoffrey Jago*

### **Aspects of Charnian Geology**

Under grey but dry skies on the evening of 5th July, 2000 a large gathering met in Charnwood Forest, Leicestershire for our field excursion to study Precambrian geology. Of all items, fossils were certainly not expected, but read on. Leading the excursion were John Carney and Tim Pharaoh of British Geological Survey, experts on the geology of this area. Time allowed us to visit several inspiring exposures of some of the most ancient rocks in England at Calvary Rock, Ratchet Hill, Mount St. Bernard and Beacon Hill. Casting our minds back 600,000 millennia a picture was evoked of an arc of volcanic islands not unlike those in the present-day

Leeward Islands where the recent production of acid lavas at Montserrat was the subject of our Group's meeting in November 1999.

Surrounded by Triassic strata and in an anticlinal structure trending NW-SE the ancient rocks fall in the late Precambrian, with the Cambrian Swithland and Brand Hills formations nearby. John Carney explained his work in exploring the genetic associations between the Charnian Supergroup and the Whitwick Volcanic Complex. At the time of formation, a subduction zone lay alongside the continent of Gondwana producing a volcanic arc which allowed viscous acid lavas to burst upwards. It is postulated that the Whitwick rocks are the solidified remains of feeder bodies which produced the lava aprons of the upper Charnian.

At Calvary Rock we examined an exposure of the Cademan Volcanic Breccia (Charnian), a breccia of 100mm to 500mm blocks of dacite in a mixed matrix of finer similar material. The owners, Aggregate Industries (Bardon) and their grazier Mrs. Woolliscroft, kindly allowed us access to Ratchet Hill to examine four exposures. The Sharpley Porphyritic Dacite (the feeder component in the Whitwick Complex) was compared with its contemporary in the Charnian: the Swannymote Breccia; and the Grimley Andesite (Whitwick Complex) was examined in comparison with its correlative Cademan Volcanic Breccia in the Charnian.

Near our meeting point, the building stones of the impressive Mount St. Bernard Abbey presented first class examples of the Peldar Dacite Breccia (Whitwick Complex) which formed a cryptodome beside the Grimley Andesite feeder.

The famous local landmark, Beacon Hill, provided our final locality. In contrast to the other volcanic rocks, the Beacon Hill Formation (Charnian) is largely sedimentary, beginning life as fine grained sandstones, siltstones and mudstones derived mostly from volcanic material. Of especially intriguing interest at the end of a most inspiring visit, we were shown what is probably one of the most ancient fossils: a disc-like structure thought to be the attaching foot of a frond of algae.

A full illustrated account by John Carney and Tim Pharaoh is published by NERC as British Geological Survey Technical Report WA/00/52

*Report by Geoffrey Jago*

### **Geology and Life As Seen Through a Salt Crystal**

Could Tom Shepherd's last talk to our Group have been as long as six years ago? Memory of his presentation on mineral surveys, of gold mining by the Romans in Spain and of his research into micro-inclusions in the quartz of gold-bearing veins remains fresh in memory.

On 21st September 2000, Dr. Shepherd gave an account of his current research which again includes the study of micro-inclusions, of how he and his colleagues have turned their proven skills of distilling information from tiny gas or liquid inclusions, this time in salt crystals. His tour took us from Cheshire to Catalonia, the East African Rift Valley and finally to Europa, orbiting Jupiter.

Plato described salt as "a substance near to the gods" and we all contain about half a pound of the stuff. From the oldest times common salt has been valued, used in trade and recovered, the oldest recorded mine for salt lying in Austria.

Destined chiefly for the chemical industry, 182 million tonnes are extracted annually from the Permo-Trias of the Cheshire basin, mostly by brine pumping; but reserves will last a few years yet. 28 cubic miles remain.

Layered salt deposits and salt domes occur in rocks of all ages from Cambrian to Miocene. On the surface, common and other salts are extracted by solar ponds from saline lakes and from the sea.

Salt domes are deposits which have been tectonically loaded leading to upwarps by plastic flow into overlying strata. No salt domes occur onshore in the UK, but we were shown a picture of an impressive dome surface

exposure comprising a huge face of salt with vertical stratification at Cardona, near Barcelona. Within the dome, sylvite (KCl) is mined from tunnels where curious salt stalactites form, angled by airflow effects.

Dr. Shepherd described how close examination was made of naturally grown salt crystals of ages ranging from Cambrian (550 Ma) to Miocene. These revealed that many crystals contained brine inclusions which are unique samples of ancient oceans. Changes in salinity of the oceans over time has long been the subject of discussion but this work indicates that ocean salinity changes have definitely taken place. Access to these inclusions was by laser drilling and vaporisation analysis. These and other techniques indicate historic cation changes. Today, it is known that sea salinity is affected not only by stream run-off but by hydrothermal brine discharges (black smokers) from mid-ocean ridges.

An associated study of sedimentary carbonate fluctuations in rocks examined the crystals of lime-skeletoned plankton. Some contained calcite and others aragonite - both calcium carbonate but of disparate crystal structures. It appears that sea conditions control which mineral is formed. For example, organic lime in the Great Barrier Reef is mostly aragonite. It was found that sea-borne magnesium caused systematic swings between the two crystal forms. Sandberg postulated a calcite / aragonite alternation in the sea over time. Nucleation fields depend upon the ratio of Mg/Ca in solution. A graph displayed of the changes of Ca and Mg content from Cambrian ages indicated a Ca / Mg balance symmetrical about 30 millimol per litre of calcium.

Over long periods creatures either adapt to changing conditions, or die out. This may be the main reason for changes in reef builders. One studied fossil species of plankton seemed to suffer "carbonate osteoporosis" by adapting as magnesium level rose, only to die out when this level rose too high.

Studies also led to Lake Magaldi in the East African Rift Valley which is a soda lake. Solar evaporation ponds are constructed to recover trona, a mixture of sodium carbonate and sodium bicarbonate which is a base material in the production of soda-ash. This brine contains more than 10 % w/w of salts and is stained pink not by iron but by a pigment provided by bacteria which can exist only in extreme saline conditions. Those present were able to examine a sample.

No longer earthbound for a moment or two, we were shown pictures of Europa, a satellite of Jupiter, taken by the Galileo space probe. The surface is crisscrossed with lineations which in close-up resemble ice rafting; and infrared spectra denote ice. Europa is deduced to have a metal sulphide core covered by an ocean beneath the ice. Some areas are not ice but are salty, containing amongst other salts, sodium carbonate and magnesium sulphate. By these studies another area of enquiry opens. The next Mars probe plans to drill for samples.

From brine inclusions, not only in halite, the research described gave a wonderful insight into life in the oceans, including reef animals, down the epochs. The most rewarding ideas come from the interface between disciplines, in this case geology, geochemistry, paleontology and even molecular biology. We were told of further fascinating details of this work involving the recovery of fossil DNA from bacteria, but you must await publication.

To quote Falstaff, as he patronised the Lord Chief Justice, Dr. Shepherd gave us much more than "some relish of the saltiness of time."

A vote of thanks was given by his colleague Simon Chenery.

*Report by Geoffrey Jago*

## **The Geology of Brick-making**

In considering meeting subjects, our Group is alive to the need to maintain a balance between theory and application and in both we have been fortunate in our speakers, who have frequently provided us with latest state-of-the-art information.

Our meeting of 12 October 2000 was a good example when Dr. Andrew Smith, Head of Research and Technical Development at Hanson Brick plc spoke to us on the brick-making industry and its geology. He began

by observing that despite the ubiquity of bricks and the fact that most people live in brick houses, the brick industry employs only about six trained geologists.

The brick-making process is high-temperature, low-pressure metamorphism, the minimum aim being to convert clay and fluxes into a glass-bound ceramic. A good raw material contains sufficient clay minerals to enable the vitrification which glues a brick together. These minerals are primarily illite with some kaolin and minor chlorite and montmorillonite. Other constituents are principally quartz, feldspars, carbonates, sulphates and organics. Clay should vitrify between 950-1100°C, have a consistent fired colour and show a constant linear and volumetric shrinkage on firing. It should have low impurities with low sulphur, consistent carbon and no granular carbonates. Firing causes a densification of the body by migration of minerals and bonding. This process must form the ceramic glue, time and temperature transformations being fundamental. To obtain an optimum economic process, careful study is made of the phases that occur as clay changes to brick; and it is necessary to know when changes occur, how long each phase takes, the temperature of reaction and the environmental impact. Firing too hard too soon may result in the outer skin of a brick being sealed early on, causing the brick to bloat because gases cannot escape.

Selling criteria are cost, appearance and technical properties. Bricks have to follow the requirements of the customer. Colour is a vital element. This is affected by the calcium / iron ratio. Greater than 1.7 produces oranges 1.7 produces reds, less than 1.7 produces buffs, yellows and whites. Added manganese dioxide turns reds to brown. Reduction (low oxygen) firing makes red clays burn blue owing to reduction of iron oxides.

Of the source rocks, the Mercian Mudstone and Carboniferous mudstones are the biggest producers, with Jurassic mudstones next, followed by rocks from the Cretaceous. In a special category are the Etruria clays because their high kaolin and illite content with low sand grain size provide excellent glass formation; and these are sufficiently valuable for blending to warrant nationwide transport. Certain high kaolin fireclays are similarly prized.

Production of common bricks in the UK peaked in 1963, then declined. to an output which remained level from 1993 to the present. Nowadays three billion bricks a year are produced from about 8 million tonnes of clay. A typical works produces a million bricks a week, sufficient for 125 houses, at a brick cost per house of £1,200. Bricks cost no more than they did ten years ago.

The application determines the best brick to employ. Facing bricks, for example, while rarely used structurally, provide a pleasing cosmetic effect, while a common is the most economical preference for speedy access to jewellery in the High Street when appearance is less important. Construction methods are changing rapidly. In the last 50 years, owing to a move from solid wall to non-brick cavity wall construction, the production of load-bearing bricks has declined; but sales of facing bricks remain steady. Building now favours big mats with thin skins clad with good-looking facing bricks. In some cases the exterior is of 25 mm brick 'slips', fixed with adhesive before rendering. This is easily achieved and inexpensive; and in this way one fast-food restaurant was built, complete with prefabricated kitchen, in 48 hours.

Dr. Smith's interesting and well presented talk provided a comprehensive understanding of the many aspects of the brick industry.

Kip Jeffrey proposed the vote of thanks.

*Report by Geoffrey Jago*

The Work of the **Environment Agency in Groundwater Monitoring and Hydrogeology** was the subject of our meeting of 16th November 2000, held at at British Geological Survey, Notts. Dr. Rob Ward of the Environment Agency stood in for the advertised speaker, his colleague Jonathan Smith, who was unable to attend.

Groundwater protection is an important aspect of the work of the EA which publishes nationally the Groundwater Protection Policy (GPP), a document previously produced in 1992 by the National Rivers Authority. Applying risk- based principles, it sets out for the first time the Regulator's policy for the protection of groundwater and supports the implementation of statutory powers with respect to groundwater. In a series of

policy statements it sets out how the EA will respond to different potential impacts upon groundwater. As part of that policy the EA has developed two practical tools which are also available to others outside. These are Vulnerability Maps and Source Protection Zones.

### **Vulnerability of Groundwater**

All groundwater is affected by human activity including abstraction, and activities on the surface with potential for pollution. No rock is completely impermeable and human activity seriously affects groundwater quality. The degree of risk to water supply depends upon the natural characteristics of the sub-surface: the presence and nature of the soil, the nature of glacial drift, the underlying strata and the thickness of the unsaturated zone i.e. the depth to the water table.

Two illustrations were displayed of extreme cases:

High vulnerability: no superficial deposits or drift, thin soil with a high water table, especially with a fractured limestone aquifer leading to rapid water flow.

Low vulnerability: Drift at surface and a thick clay soil, both acting as barriers to the downward movement of pollutants, with a low water table providing a thick unsaturated zone in which attenuation can take place.

For the vulnerability maps the EA has made three classifications of aquifers:

- major aquifer - fractured, giving significant yields of groundwater. Typically Trias sandstone and chalk
- minor aquifer - potentially fractured or porous media, perhaps shallow in nature - any aquifers less extensive than major ones which will give significant yields and provide supporting base flow to rivers.
- non-aquifer - low permeability formations with low yields. Drift is classified as a non-aquifer.

Used to support the groundwater protection policy, 53 vulnerability maps showing the three classified areas are published for the whole of England and Wales. The two higher classifications are subdivided into high, medium and low based upon the soil classification and the ability of the strata to attenuate pollutants. Because of the considerable variability in superficial deposits, drift is mapped separately and is shown only where it is thicker than five metres and of low permeability.

Dr Ward illustrated the interpretation of Vulnerability Maps with a displayed example covering an area west of London.

### **Source Protection Zones (SPZ)**

The second tool concerns Source Protection Zones which define those areas in proximity to abstraction activity such as springs, wells and boreholes. The EA has a published standard methodology for defining SPZs into three zones:-

- Zone I 50 day travel (an inner zone where a contaminant reaching the water table would take less than 50 days to reach an abstraction point.)
- Zone II 400 day travel (an outer zone where a contaminant reaching the water table would take less than 400 days to reach an abstraction point.)
- Zone III Source catchment. (eg. the total area of influence of pumping for a well - the discharge is equivalent to the recharge in the land surface.)

Where sufficient hydrogeological data are available, mathematical modelling is employed. Where less data are to hand the maps are based upon professional judgment and knowledge of the hydrogeology of the area. Map

examples of the shape of these zones were displayed, showing them to vary widely, often becoming complex where more than one abstraction point is present.

Groundwater protection policy is governed by a number of policy statements which set out the EA's position on how it will respond to proposals for various land-use activities and here vulnerability and SPZ information is of major relevance.

## **Tracer Testing in UK**

It is important to have confidence in the two tools but until recently it was not possible fully to validate them. Tracer Testing is one way that such validation can be carried out. This method is a valuable tool but its application in UK has not been widespread and its benefits should be stressed. About two years ago the EA and BGS collaborated to produce a guidance document to gather together a wide variety of methods of tracer testing in order to encourage improved application of the techniques. For illustration, three case studies were described.

### **Case Study 1**

A vulnerability map was displayed covering the study area in south Derbyshire and south Nottinghamshire. This research was described is unusual because it was carried out in order to validate vulnerability maps. Information was plotted of nitrate pollution diffused over a mainly rural area, principally from a background of monitoring points possessed by the EA. Here the nitrate, mostly derived from agriculture, was used as the tracer. The three data limits used were less than 20, between 20 and 40 and greater than 40 milligrammes per litre of nitrates. The hypothesis was that in the most vulnerable parts of the aquifer higher levels would be expected in groundwater because the nitrate had been applied for many years by agricultural practice and, in areas of low vulnerability, lower concentration could be expected. From mathematical study it was shown that this hypothesis was substantially correct. Further more detailed analysis was later undertaken which has formed the basis of the revision of methodology for the study of nitrate zones.

### **Case Study 2**

Correlation between vulnerability and groundwater contamination

As previously mentioned, the unsaturated zone is important in attenuating pollutants. A growing concern in the UK is the increasing pressure on land use in recent years, especially of livestock farming. There is scope for the acquisition of more information on micro bio-contaminants, a key issue being the rise of pollutants such as cryptosporidium. Furthermore, the Urban Waste Water Directive may trigger an increase in land-spreading of sewage effluent.

This study, undertaken by BGS, was an investigation into the transport of water in the unsaturated zone and its effectiveness in pollutant reduction. Biological contaminants cover a range of sizes, so non-harmful tracers with a range of similar magnitudes were used. The four tracers used were lithium bromide, non-toxic bacteriophage, microspheres of 6 microns and microspheres of 10 microns. Borrowed from the medical profession, microspheres, of a plastic latex material, are used to inject into the human body to monitor sizes of blood vessels. To help identify size, the microspheres used were dyed in differing fluorescent colours.

A 20 by 20 metre square of topsoil was removed to expose the underlying chalk and a borehole was drilled centrally to just below the water table, the thickness of the unsaturated zone being also 20 metres. This enabled water samples to be obtained just below the site; and other tests were carried out, including pumping, to determine the hydraulic qualities of the saturated zone. Sprinkled onto the exposed area of the chalk by watering can, the tracers were injected onto the rock surface and irrigated to help them on their way. Following this the exposed area was sheeted over to prevent any photo-chemical decay of the dyes in the microspheres. Monitoring of the unsaturated zone was then undertaken to determine proportions and arrival times at the water table, these being logged and tabulated. Next, two cored boreholes were drilled to study the area geologically and to sample the unsaturated zone for tracers. In many core samples no microspheres appeared, but in others

large amounts arrived, probably owing to fissures in the chalk. However the lithium solute diffused progressively into the chalk, indicating the rock's ability to attenuate contaminants.

Further work which BGS is currently undertaking for the EA is been carried out on the risks from cryptosporidium, sewage sludge disposal and the effect of cemeteries on the water table.

A Web page "What's in your backyard" is published on the internet.

### **Case Study 3: Source Protection Zones**

A map was displayed of source protection zones in the chalk around Kilham, Yorkshire, where an abstraction well for public water supply is in use. The area contains a capture zone between two dry valleys where initial tracer tests showed high velocities of groundwater movement such as, in one instance, 480 metres per day over 900 metres. The results of the first tests enabled the planning of a much larger test sampling at many more points, and at the supply well itself. Because of the rapid flow, the tracers used were bacteriophages. The tracers were injected into observation boreholes in each of two catchments areas but none were detected in the abstraction well. However some did arrive further down-gradient at two of the springs. This demonstrated the complexity of the hydrogeological system compared with the simplicity of the model, and this is believed to be owing to the public supply system being superimposed on a natural flow system which is discharging further down-gradient into springs with their own capture system. While modelled zones are useful research tools in the study of water movement there are limitations in that they do not define 'true' capture zones; and models which assume porous flow do not account for complexities caused by fracturing. Another example of the application of tracer testing as a validation and understanding of the tools used, this has prompted a review of the methods used.

### **European Union Nitrate Directive**

The European Union Nitrate Directive was issued several years ago to reduce the impacts of agri-derived nitrate on both surface and underground waters; and there is an important requirement to identify and protect agricultural nitrate-vulnerable zones, reviewing at four-year intervals. Designated concentrations are those currently exceeding 50 mg/litre or which are likely to exceed that concentration by 2010. This led to the designation of the much publicised Nitrate Sensitive Areas, of which 72 were delineated, one being at Kilham. To examine whether benefits could be achieved, these areas were defined under a voluntary scheme introduced by Ministry of Agriculture Fisheries and Food to look at areas of changing agricultural practices and their impact on the environment. In Nitrate Sensitive Areas farmers were given compensation to take account of changes in working practices, whereas in the statutory Nitrate Vulnerable Zones no compensation was paid. The Nitrate Sensitive Areas scheme was abandoned about four years ago.

### **Tracer Testing**

In conclusion it can be stated that tracer tests have been found to comprise a very valuable tool, and are important in understanding the issues and the supporting policy and in identifying research needs. Tracer tests represent good practice and should be encouraged.

A vote of thanks was given by Andrew Brewster.

*Report by Geoffrey Jago*

### **Geoprophecy 2000 - What does the future hold for geology?**

This was the subject for EMR Group's meeting of December 6th 2000; but nothing was seen of psychics wearing star-studded robes and tall conical hats, nor the dealing of tarot cards nor even the close inspection of a polished quartz sphere. The information we heard was far more significant than any charlatan's spiel. In view of the accelerating changes of the twentieth century, it takes an especially brave person to make predictions to cover the first half of the twentyfirst; but we listened with interest to three. They were Professor Charles Curtis of Manchester University and ex-President of Geological Society, Dr. Tony Dore, Exploration Manager of Statoil

and Chairman of the Petroleum Group of Geological Society and Mr. Edmund Nickless, Executive Secretary of the Geological Society.

In preparing his talk, the initial speaker, Professor Curtis, first examined the changes of the last 50 years and considered how predictable they would have been to someone in 1950, secondly he looked at what developments might be expected by 2050 and thirdly, working on these predictions, he gave his views on what the geological profession should do about it.

Looking at the predictability and development of our time, with its speed and constraints and the driving forces that promote development in society, there is a need to map out a path ahead. To begin Professor Curtis re-read an authoritative statement by Arthur Holmes in 1944 on the subject of changes in geoscience. Interestingly, viewing the changes since 1944, as part of a rewrite in 1965, it concluded: "It is doubtful whether there will ever again be such a profusion of unexpected discoveries concentrated in so short an interval of time." Those discoveries included radiometric dating, ocean floor geoscience, continental drift, the structure of the Earth's crust, the rheology of salt domes and granite intrusions, climate change, ice age weathering, earth magnetism and heat flows and generation. All these were huge advances in that period and the interests of 1965 were similar to those of today. What was not predicted was the increase in specific areas of data gathering, the development of planetary geology from the lunar and fly-past missions, the development of geomicrobiological research into the origin of life and the realisation that the change from carbon dioxide to oxygen in the atmosphere was a consequence of life. What has controlled the speed of development in these areas and what constraints have applied? Technological developments have been a crucial factor. There have been great advances in drilling, geophysics, x-ray diffraction, mass spectrometry, remote sensing, space probes, oceanographic instrumentation and the increased sophistication of information technology. So geology has benefited from advances in technology, most of which have been outside our own geoscience.

Looking forward 50 years, Professor Curtis considers that we shall still be focusing on the processes that shape the Earth's surface but our store of knowledge about those processes will be greater and will have increased quantitatively. There is little doubt that there will be further development in instrumentation and information technology; and that geoscience will exploit those developments. In education, geoscience, while likely to remain in an academic minority, is an attractive pursuit and the profession should make sure that it remains that way. We shall only continue to attract substantial numbers of students if there are sufficient posts for them in industry. We have seen the number of posts wax and wane over the years. Society is likely to become increasingly dependent upon limited resources. There is an opportunity for geoscientists to demonstrate the quality of their skills and knowledge in the efficient exploitation of resources with minimal environmental impact. Geoscientists have to reach conclusions from very complex data, on material which is often incomplete and imperfect, and having reached those conclusions must act upon them. This may not be the case with other forms of training, yet the critical thing when graduates get out into the world around us, is that those are the skills which currently are required. It's about understanding risk and risk analysis. Within a short time, a virtue should be made of these typically geoscientific skills.

Looking back on the last 40 years of geoscience and forward to the next 50 years in the oil industry, the second speaker, Dr. Dore, spoke on the geological ideas of importance to the oil industry and its technology and on oil and gas supply in the future. His central thesis was that the oil industry does not work on prophecy. - it works on multiple parallel hypotheses, some of which are dismissed while others take hold. The latter, paradigm shifts, represent fundamental changes in the way we think and look at challenges. Most revolutionary ideas, having been forecast for a long time, are only accepted when vital new evidence is provided. An example is the super continent cycle and ocean floor spreading which, although mooted early in the twentieth century, only became accepted in the early 1960s when details of magnetic anomalies and other breakthroughs were published. The extension of knowledge in the future can be expected to include subjects that are not fully understood at present such as earth structure, the nature of the mantle, the driving force of plate tectonics, hot spots and planetary geology.

Dr. Dore gave a brief history of seismic technology over the last 35 years during which, aided crucially by an exponential advance in computer technology, rapid changes took place. The primitive seismic survey techniques which led to the North Sea discoveries from 1966 were supplanted by 3-D seismic maps in the 1970s which became routine by 1981. By 1990 major regional 3-D surveys were undertaken which the oil companies initially regarded as too expensive; but by 1994 the accepted procedure was to commission 3-D

seismic surveys before drilling. By 1996, 3-D surveys grouped in time known as 4-D surveys, used to predict oil reservoir depletion, were becoming routine. Now 'no drilling without 3-D' is the norm.

An example was shown of an Amplitude Map of the Schiehallion Field, off Shetland, its colours giving clear visualisation of the structure of an oil reservoir including, as well as the main oil reserve, oil-water contact and channels.

A sill relationship map of a series of basalt flows at below-2,000 metre depth west of Shetland was also displayed, where even details of cinder cones on the basalt are discernible. Of the future, we have seen how working practice changed radically with the rise of microcomputers and then the internet. Automated oil-finding is almost with us with serious implications for petroleum geologists (but read on). It should be possible to get near-elimination of oil-drilling risk.

Remote working may become the norm indicating the death of the office, less travel and, as more people work from home, a return of the local community. Those doubting this should look to other industries where large proportions of the staff now work from home. As regards oil prices, attempts to predict them in the past have proved eminently inaccurate, especially in respect of 1983 when all pundits predicted a rise but the price fell radically. There are too many factors to take into account. Prophets use the cheap tricks which work only in the short term: firstly, everything will remain the way it is and secondly, present trends will continue. We know that the hydrocarbon age, on a millennial time scale, is just a blip. Since 1980 less oil has been found than is produced. A decline in oil production is predictable and there are various predictions as to when the mid-point will be reached. Some pundits say it is now, although one large company estimates 2010. Gas will last longer than oil but may have only a 50 to 100 year supply, sufficient for current generations but not for future planning; and, since much gas is remote, new solutions for its transport will be needed. Referring to possible lower employment prospects for petroleum geologists mentioned earlier, their chances are likely to look brighter when necessity drives the world to scour for diminishing resources. Nonetheless, as world demand increases fossil fuel shortages must be filled by other methods. Nuclear power is not without drawbacks and solar-, wave- and wind-power are limited. So fuel saving will become increasingly important. Right now the numbers of cars are increasing faster than the number of drivers and travel will be considerably restricted. Cyberspace and the remote office may give an answer.

Looking to sources of hydrocarbons other than oil, gas and coal, there is a reserve of methane hydrates, but, lying as they do under the oceans, they are currently far too expensive to extract; but one day they may be, when oil prices rise. Another much larger resource, the Athabaska oil sands, are not today economically recoverable.

Our third speaker, Ed Nickless, began by saying that, despite their assertions, governments are not good at predictions. In the regulation of Europe there is a lack of sound science for informed legislation. At meetings like those at Kyoto and The Hague there is a need for the long term view. In countries such as Korea the growth is almost exponential and such populations will seek their share of wealth which must be generated by trade. Resources, the availability of which become increasingly important, are ever more concentrated in the largest cities; and there is already evidence of resource wars. Will the world's population stop at 10 billion? For geoscience there are issues involved with industrialisation, resource availability and resource depletion. The mega-cities themselves present enormous challenges to us as geoscientists in terms of managing inflows and outflows of resources such as water supply, waste disposal and so on. There are vast issues of ground stability and, in coastal areas, danger of inundation. Then there are natural events like volcanoes, earthquakes and tsunamis. Despite assertions that the past is the key to predict the future, we can no longer use this hypothesis; but what we can do is be positive about our science and raise professionalism and the understanding of it. This is fundamental to the understanding of the issues described. If we do not, who else will do anything about it?

To be successful we must explain our contribution and it may well be that we shall have to answer the questions asked of us in a more intelligible way. We have to assume that we do not know best. We have to be honest and we have to talk about our services. We have to recognise that there are very real public concerns about risk and safety and the quality of advice. Science is not held in high regard at present and scientists in general may be to blame for this. Against this we have to react to a changing scene and be flexible. We have to recognise the contribution we can make to help resolve complex issues and be prepared to help.

Your correspondent anticipates with interest the review of these predictions, at a meeting place to be advised, in 2050.

A vote of thanks was given by Alf Whittaker.

*Report by Geoffrey Jago.*