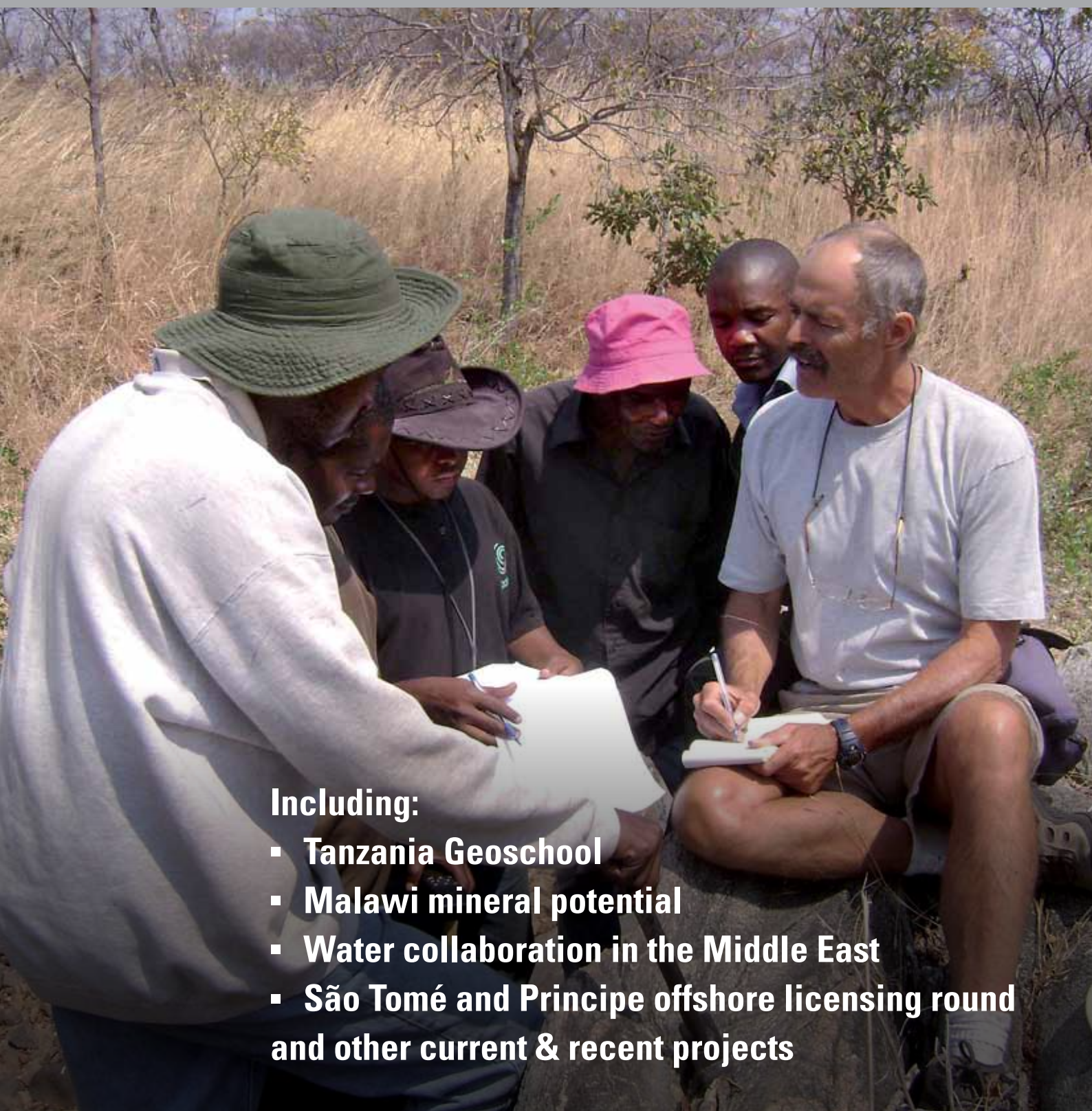




British
Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

BCGS International Activities



Including:

- **Tanzania Geoschool**
 - **Malawi mineral potential**
 - **Water collaboration in the Middle East**
 - **São Tomé and Príncipe offshore licensing round**
- and other current & recent projects**

International work by the British Geological Survey

BGS International



*Bill McCourt, Head of
BGS International*

Through working in over 100 countries during the last 45 years the British Geological Survey (BGS) has become a leading international provider of applied geoscience services. We undertake an extensive programme of international research, surveying and monitoring, including major institutional strengthening and capacity building programmes throughout the developing world and especially in Africa.

The programme is managed by BGS International under a team of experienced managers who draw on specialists from across the organisation to undertake multi-disciplinary, mainly commercial contracts. In addition, we have well-established links with independent experts, commercial consultants, universities and private sector organisations that can provide relevant expertise not available in-house.

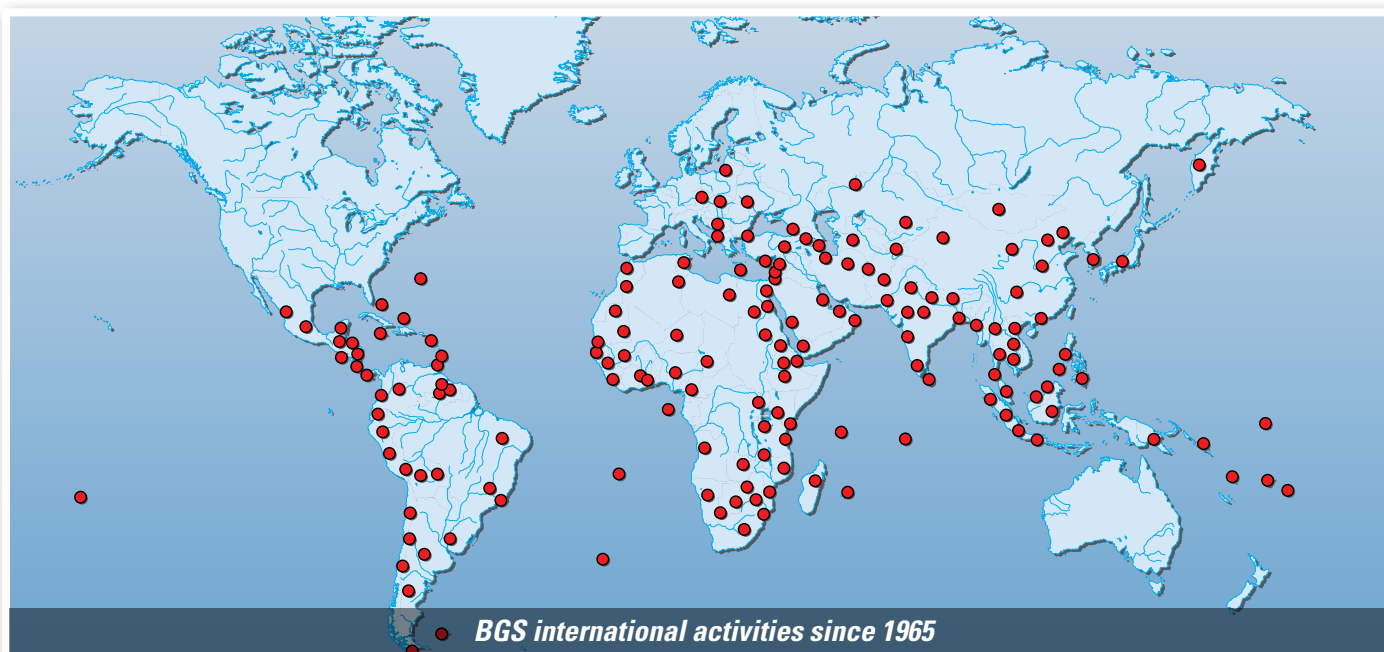
We have worked for many of the principal international development agencies including the Department for International Development (DFID), the European Union, and the World Bank; as well as national governments such as Hong Kong, Botswana and the United Arab Emirates.

Our international activities are mainly directed toward development issues such as sustainable resource development, protection of people and the natural environment, quality of life and poverty alleviation. Many of these have been long-term residential projects involving working closely with governmental counterpart organisations through capacity building and institutional strengthening. We have assisted governments in formulating and undertaking their national geoscientific mapping programmes and the development of 'fit-for-purpose'

multi-disciplinary geoscience policy. Our depth of experience has produced an unrivalled understanding of the scientific, logistic, managerial and cultural requirements necessary for the successful design, management and implementation of multi-disciplinary geothematic projects.

Ongoing international work includes projects in Papua New Guinea, Nigeria, the UAE, Ethiopia, China, the Falkland Islands, Malawi and Tanzania. The latter builds on our long history of international geological mapping and the related transfer of knowledge and skills in developing countries and was undertaken under the BGS Geoschool initiative. This magazine includes examples of recent and current projects, including the Tanzania Geoschool (page 19), that we hope you will find interesting and welcome your enquiries.

Bill McCourt, January 2010.



Airborne and geological surveys support mineral exploration in Ghana

The BGS, in conjunction with Fugro Airborne Surveys Pty Ltd, has completed an EU-funded project to combine newly acquired airborne geophysical and satellite image data with enhanced geological mapping for the Volta River and Keta Basins of Ghana; an area comprising some 98 000 km²—more than one third of the country. The BGS input, financed by the 8th European Development Fund, amounted to approximately one million Euros. The project was part of the larger Mining Sector Support Programme whose objective is to sustain the sector's economic performance, alleviate poverty by increasing employment, and mitigate the negative environmental impacts of mining.

Between November 2006 and March 2009 we were subcontracted by [Fugro Airborne Surveys Pty Ltd](#) to undertake ground reconnaissance mapping of the Volta and Keta basins. An important aspect of the fieldwork undertaken by the BGS was the provision of on-the-job training to Ghanaian geologists from the [Geological Survey Department](#). Formal courses in mapping

technologies, remote sensing and geophysics were also provided in addition to the field-based work programmes.

Fugro AS conducted the airborne surveys while our role included the provision of optical and microwave satellite imagery, developing a Digital Terrain Model and conducting a differential GPS survey. New products, including topographic and preliminary geological maps



were produced to assist mineral exploration companies target areas for more detailed work. Particular attention was focused on the potential for locating deposits of gold, uranium, phosphate and diamonds, and mineral prospectivity models and maps were produced for each of these commodities.

Outputs from the BGS project include:

- 48 geological maps
- 48 topographic maps
- processed satellite imagery
- training manuals
- differential GPS survey

- fully attributed GIS
- a series of abstracts
- an excursion guide ([Voltaian Basin Workshop Proceedings, Geological Survey of Denmark, 2008](#))
- final technical report

Exploration and mining companies are using these products with a view to undertaking more detailed assessment of the region's mineral potential. The geological maps are being integrated into the revised the national geological map of Ghana at a scale of 1:6 000 000. ■





Madagascar geological and mineral occurrence mapping

The BGS, in conjunction with the US Geological Survey, has completed a major World Bank-funded, multi-thematic geological mapping project in northern and east-central Madagascar. This three-year project, which produced hundreds of digital maps and a final report, is the largest international geoscience project the BGS has managed.

Madagascar is rich in economic minerals. Chromite and graphite are the main export products along with less well-regulated appreciable quantities of gold, precious and semi-precious gemstones. Major lateritic Ni-Co and ilmenite sands projects are currently under development.

We examined a large variety of ore deposits including gold, chromite, nickel-cobalt, base metals, graphite and other industrial minerals. We achieved some success in defining the

mineral potential and controls on gold mineralisation.

The field work presented many challenges including the negotiating jungle trails, deeply rutted muddy tracks and impassable bridges in both mountainous rain forest and marginal savannah. Despite this, during seven field campaigns we undertook a drainage geochemical sampling programme, which involved the collection of over 20 000 samples and the training of Malagasy students and

Project outputs:

- 98 geological map sheets at a scale of 1:100 000 covering an area of around 130 000 km²
- 1 panned heavy mineral and 23 single-element 1:200 000-scale geochemical maps for each of the 19 sheets covering the areas geologically mapped at a scale of 1:100 000
- one set of 24 geochemical maps of the reconnaissance area at a scale of 1:850 000
- a series of thematic maps (1:500 000 scale) covering the entire BGS-USGS project area, depicting geology, tectonic structure, mineral occurrence and potential, geomorphology, and hydrogeology
- a GIS database, including all geology and minerals information
- a 1400-page report describing the results of the mapping project

counterparts from the Ministry of Energy and Mines.

The field studies, in combination with an extensive programme of isotopic age dating and thermobarometric



determinations, have significantly added to our understanding of the complex tectonic history of the region.

Eugene O'Connor, Manager of Francophone Africa projects at BGS, said *'This is the single largest international geoscience project we have been involved in. And in addition to the project deliverables, this work has generated numerous scientific*

papers in many journals'. One of the project area managers, Peter Pitfield, has contributed to research on a mini-series that the BBC is producing on the ecology of Madagascar.

Copies of the various datasets may be obtained from the [Ministry of Energy and Mines](#), Madagascar. ■

Promoting Malawi's mineral potential

The BGS has produced updated geological and mineral resource maps for Malawi at a scale of 1:1 million and a series of brochures on the mineral potential for use by mineral exploration companies in a project lasting only three months.

A geological map was used as a backdrop to accompanying mineral resource and magnetic anomaly maps, together with a series of four geology-based prospectivity brochures. These materials were prepared by the BGS with financial support from the [Department for International Development \(DFID\)](#). The work is intended to be part of a longer term capacity building relationship with [Malawi's Geological Survey Department \(GSD\)](#).

David Ovadia and Bill McCourt of the BGS visited Malawi in October 2008 to obtain agreement from the local DFID area manager for the go-ahead of Phase 1 of the project. The GSD national mineral resource and occurrences map (published in

1990) and aeromagnetic data were brought back to the UK to compile some derivative digital products. A follow-up visit was made in November by Peter Pitfield to liaise with the commercial mining sector and to obtain up-to-date information and illustrative material for the brochures.

We digitised and edited the existing 1:1 million-scale national geological map, produced a revised legend consistent with modern regional lithostratigraphic schemes and added cross-section. The mineral occurrences were taken from the 1990 mineral resources map and augmented with more recently developed mineral prospects.

The geological and mineral occurrence maps were



Drilling activity, Kanyika deposit, Malawi

completed in November 2008 and the Principal Researcher, Peter Pitfield presented draft copies to Dr Leonard Kalindekafe, Director of the GSD. Peter explained *'the new maps and exploration activity show that Malawi, far from being poor in mineral wealth, has lots of potential'*.

Landsat, gravity and airborne radiometric, aeromagnetic and



electromagnetic data are also available. The aerogeophysical data indicate that the maps need updating in the west–central part of the country where the African surface is best developed. These data have not been used but there is potential for their application in a second phase.

The brochures and maps were launched at Indaba in February 2009 by Ted Kalebe, Malawi's Minister of Energy and Mines. Dr Kalindekafu commented 'We are very supportive of this work

by BGS. It will help investment in Malawi'.

The maps and brochures, which describe the mineral deposits associated with different geological settings, are available from the Geological Survey Department in Zomba, Malawi, or by contacting BGS through enquiries@bgs.ac.uk. You can also download the brochures from our web site: www.bgs.ac.uk ■

Nigeria plans to diversify its minerals industry

The BGS

is currently undertaking a national programme of geochemical mapping and training in Nigeria to help identify mineral potential and assist in environmental management.

Nigeria is a hydrocarbons-based economy. The Nigerian government would like to diversify their mineral extraction industry—there is mineral potential but, at present, there is insufficient baseline data to attract the interest of investors. In addition to using the national geochemical maps for resource exploration, Nigerian decision-makers will use the data to underpin decisions relating to the environment, health, and land use and rehabilitation.

The Nigeria geochemical mapping project, worth £2.2 million, is funded by the World Bank through the Nigerian Sustainable Management of Mineral Resources Project (SMMRP). Our two-year project, which commenced in October 2008, provides technical assistance to the Nigerian Geological Survey Agency (NGSA) to carry out a national programme of geochemical mapping of the



surface environment for over 50 chemical elements. BGS is the main client but some of the work has been sub-contracted to the Geological Survey of Finland (GTK). The project will provide extensive training in the methods and techniques of regional geochemical mapping to the NGSA, and advise on the necessary infra-structure such as the requirement for

a dedicated geochemical laboratory.

To give an indication of the scale of the work programme, the Global Reference Network (GRN) for geochemical mapping comprises approximately 5000 cells. Each cell is 25 600 km² in area and 35 of these are completely (and nine partly) in Nigeria. The recent geochemical mapping of Northern Ireland

(part of the Tellus project) mapped an area just over half the size of one GRN cell. NGSA selected two field areas for geochemical mapping — a GRN cell to the north-west of Abuja and another in south-west Nigeria to the north of Lagos.

In January 2009, specialists from BGS and GTK ran a workshop on geochemical mapping techniques in Kaduna, Nigeria. The workshop was opened by representatives of the Kaduna State Governor and Mrs Deziani Alison Madueke, Minister of Mines and Steel Development.

More than 50 people attended, including staff from NGSA and Nigerian universities. During the course of the week, participants were trained in practical sampling techniques, digital mapping, and analysis of geochemical data. Feedback was very positive. One trainee commented *'Very enlightening. Cannot wait to do it hands-on in the field and see the outcome, which I believe will change the mining sector in this country'*.

The workshop was followed by a field orientation exercise using stream sediment sampling in the Minna area of Nigeria. Some NGSA staff were also trained in the UK on sample preparation and laboratory techniques, aspects of



economic geology, and data processing at the BGS. Part of this training included an attachment to the 'London Earth' G-Base geochemical sampling team in the summer of 2009.

Progress of our work will be monitored by the World Bank and the results will be presented as geochemical maps and a series of 26 reports, each tied to a particular phase of the project. To date, we have completed four reports — recommendations for software and equipment, a work plan, UK training report and a report on the Kaduna Workshop. We are now preparing a geochemical mapping procedures manual and reporting on



a geochemistry laboratory audit done by BGS staff in Nigeria.

Towards the end of the project our field geochemists will give assistance to NGSA staff as they commence their work on completing the remaining GRN cells that cover the country. ■



Training in sampling techniques

Support for the mining sector in Papua New Guinea



Mineral exploration and mining are vital to the economy of Papua New Guinea but this has been declining in recent years. BGS is involved in a multi-project, EU-funded programme to stimulate interest from mining and exploration companies.

Mineral extraction plays a significant role in the economy of Papua New Guinea (PNG). In the late 1990s, minerals comprised around 70 per cent of the country's exports and played a significant role in its economy. However, at around that time, a downturn in mineral exploration worldwide had a marked effect on PNG: the El Niño drought

and a fall in metal prices, in addition to the complex issues related to working in the PNG mining sector, further discouraged investors.

Against this background of falling revenue from mining, in 1997 the Government of Papua New Guinea applied for support under the eighth European Development Fund special financing facility. In 2000–01, a comprehensive eligibility study recommended a €50 million, Mining Sector Support Programme (MSSP) comprising 10 projects:

- formulation of a Mining Waste Management Policy
- independent evaluations of deep-sea mine tailings placement in PNG
- construction of a new Mining Haus for the Mineral Resource Authority (MRA)
- small-scale mining training centres and a women's development centre
- airborne geophysical survey of the PNG Highlands and Papuan Peninsula
- geological mapping and mineral potential assessment of the PNG Highlands
- geological and mineral resources information system
- hardware procurement
- promotion of the PNG mineral sector

- technical assistance to the Programme Management Unit

The MSSP objectives are to sustain the economy of PNG through its mineral production and exports, alleviate poverty locally through increased employment, and to mitigate the environmental impact of mining. The Programme, which is scheduled to run until the end of 2012, will develop institutional capacities to promote and regulate the minerals sector and encourage mineral exploration by private companies.

The BGS has a key role in the geological mapping and mineral potential assessment of the PNG Highlands. This commenced in April 2006 with a budget of €13.8 million. The purpose of this project, known as GEOMAP, is to provide the PNG Department of Mining with comprehensive, up-to-date geological and geochemical maps and data for the PNG Highlands, so reducing the risk for private exploration companies. To build capacity in the PNG geological survey, a key part of GEOMAP is the training of several geologists and technicians and their involvement throughout the project.

The PNG Highlands were mapped in the 1970s, and we are now revising these maps at the 1:100 000 scale. Traditional mapping is not practical in the time available due to the inhospitable terrain and difficult access. As a result we use targeted geological mapping, stream sediment sampling for geochemical and heavy mineral analysis, and interpretation of the recently acquired airborne



MRA trainees undertaking heavy mineral analysis

geophysics. Teams of geologists work out of remote villages during the field seasons and access to targeted areas is frequently by helicopter. We anticipate that this mapping will lead to new interpretations of this prospective region and the identification of targets of commercial interest.

Our partners in this project are the South African Council for Geosciences and the German exploration company, Deutsche Montan Technologie (DMT). DMT manages this project and provides the geologists who fill many of the long-term, residential positions. The BGS provides the project's Chief Geologist and Geochemist, also in residential posts. We also supply a series of specialists who visit PNG as short-term experts, providing input on applied mineralogy, geochemistry, geophysics, remote sensing and satellite imagery, geographic information systems and cartography. Local guides are employed during the field seasons, particularly to help teams sampling stream

sediments in areas of interest for gold exploration.

Staffing the GEOMAP project has been challenging, largely due to the difficult working conditions but exacerbated by in 2008 when the upturn of metal prices resulted in staff leaving to work for exploration companies. Potential replacement geologists, including new graduates from the University of PNG and consultants from Europe, became increasingly difficult to recruit due to the worldwide demand for experienced geologists by the mineral industry. As a consequence, the number of staff from the PNG geological survey is below the level required.

To date, eight draft maps have been released of the 18 that are planned. The project outputs will be disseminated using a database of geological and mineral resources information which will be available on the Department of Mining web site: www.mineral.gov.pg ■



Geological maps and mineral assessment for the UAE

Funded by the UAE Ministry of Energy, the BGS is undertaking a second phase of geological mapping that when completed will provide coverage of the entire country at the 1:100 000 scale. We will produce 30 maps and accompanying geological explanations. In addition new airborne magnetic data over the entire western part of the country, and gravity data over the mountains will be acquired by the project.

The project, with a gross value of £8 million will, in addition to other deliverables, produce the first large-scale geological maps (1:100 000 or greater) for the whole country. These maps will be launched by the Ministry of Energy in 2012. Satellite imagery is being incorporated into the project's dedicated

geographic information system (GIS) which will also be used to record occurrences of mineral resources. Many BGS scientists are involved in this project, undertaking field work in the winter months and producing digital maps, using the facilities at our UK headquarters, in the summer. We also work with university



geologists who provide specific expertise not available in-house, and have subcontracted private sector partners [Western Geco](#) for the seismic line interpretation and [Sander Geophysics](#) for the airborne geophysical surveys.

The scientific focus of the mapping will be on the Mio-Pliocene and Quaternary sediments, dating from up to 20 million years ago, which include a vertebrate fauna described in the 1980s and 1990s. Our mapping and palaeontological work will put these discoveries into a regional setting.

We will enhance the Quaternary chronological framework with dates obtained by [Aberystwyth University](#) which, combined with results from the mapping and other unpublished and published data, will contribute to a greater regional understanding of the evolution of the area over the last two million

years. These data will be supplemented by detailed work undertaken by [Oxford Brookes University](#) on Quaternary climatic fluctuation, from humid to hyper-arid, to help place evidence for human migration across Arabia in a geological context.

BGS is also supporting the development of a regional picture of deeper geological structures nationwide by integrating a network of onshore and offshore legacy seismic data, in conjunction with Western Geco, and onshore and offshore airborne magnetic and gravity data. This will result in the first nationwide regional overview of the deeper structures that controlled sedimentary basin development.

Other work we are undertaking includes:

- assessment of the limestone resources, particularly the

potential for high quality limestone and dolomite

- assessment of the non-limestone hard rock resources to help determine the location of future environmentally sensitive quarrying operations, and possible additional uses for the rocks
- investigation into the origin of linear magnetic anomalies parallel to the mountain front in the north-east of the country
- assessment of the distribution and economics of platinum group elements in the ophiolite sequence in the Hajar Mountains

Richard Ellison, the project manager, was invited to make a presentation to the inaugural meeting of the Emirates Forum for Geotechnical Engineers. Major international engineering consultancies working in UAE have already shown considerable interest in this work. ■

Avoiding the use of mercury in gold extraction

Mercury amalgamation is the most widespread method employed by artisanal and small-scale gold miners to separate gold that occurs in a very fine-grained state. Most of this mercury escapes into the environment where it poses a significant hazard to the health of miners and their families. In March 2007, the BGS completed a project aimed at developing an alternative gold extraction process that avoids the use of mercury.

In order to establish the practices and attitudes of artisanal and small-scale miners we visited all the principal alluvial and hard-rock gold mining districts in Ghana. We carried out a characterisation survey on gold samples, particularly with respect to grain size distribution, which is a significant factor in the gold recovery process. We used these results to define the mineral processing problems and to identify which

alternative gold separation technologies should be tried. Laboratory tests have shown that direct smelting recovers finely divided gold from black sand concentrates with an efficiency of over 99 per cent. This is significantly greater than amalgamation where the efficiency is estimated at 90 per cent recovery. A simple furnace for gold smelting was designed, and field trials conducted at the University of Mines and Technology, Tarkwa, and at

mining sites. The results show that direct smelting is a viable alternative to amalgamation for the recovery of gold from these concentrates.

Eugene O'Connor, Manager, of Francophone Africa projects at BGS, commented '*This pilot study is a good example of what can be achieved in other gold-producing regions of West Africa and areas of South America*'. One of the outputs from this project is an operator's manual for direct smelting of gold-bearing concentrates in small-scale operations.

This project, based in Ghana, formed part of a European Development Fund Mining Sector Support Programme and was undertaken in collaboration with Wardell Armstrong and the University of Mines and Technology at Tarkwa, Ghana, under the supervision of the Ghana Minerals Commission. ■



Gold-smelting furnaces under construction

Drought management plan for the Limpopo Basin, southern Africa

The development and management of water resources in SADC Member States has traditionally focused on surface waters. However, increasing aridity and limited surface resources has led to greater dependency on the use of groundwater for both domestic and commercial needs. With this in mind, SADC has developed a Groundwater Management Programme to promote the sustainable development of groundwater at a regional level and to help villages get the best from their systems.

This project aims to develop a groundwater drought management plan in the Limpopo Basin — which includes Botswana, Mozambique, South Africa and Zimbabwe — to obtain empirical information that can be replicated elsewhere in the SADC region. The consultancy is being led by Wellfield Consulting Services and includes the BGS and the Council for Scientific and Industrial Research. Our team,

which includes geologists, engineers and socio-economists, is designing and piloting physical interventions for mitigating against groundwater drought within the Limpopo Basin. These interventions include the installation of dams across sand rivers that promote recharge of surface flow into shallow weathered rock systems. Water abstracted from shallow wells installed within these systems will be

used for the cultivation of small acreages of crops, even during prolonged drought periods. We are collecting, analysing and reviewing all available background data on the region and a field programme to characterise the pilot study areas is also underway. We will test a number of drought alleviation measures under differing environments.

This project, funded by the World Bank's Global Environmental Fund, was completed in September 2009. Workshops organised by the project core team in consultation with the SADC Project Management Unit and involving regional stakeholders as well as SADC country representatives will be conducted in order to reach a consensus on possible 'drought-proofing' measures that may be developed into a basin-wide, and eventually SADC-wide, strategy. ■



Groundwater resource mapping in Uganda

The BGS was sub-contracted through COWI (a Danish consultancy) to assist the Ugandan Directorate of Water Resource Management with the planning and implementation of groundwater resource mapping in central and south-western Uganda. Funding was provided by the Danish International Development Agency as part of their comprehensive Water Sector Programme Support to Uganda.

Two BGS experts, Jeff Davies and Rose Hargreaves, supervised the production of water resource maps for 16 districts — eight in south-central Uganda, north

of Kampala, and eight in the south-west of the country. Six maps were produced for each of these districts. We provided specific advice on data gathering,

collation, interpretation and classification. The BGS advised on how to populate and use a geographic information system (GIS), how to assure the quality, and

assisted in the dissemination of maps and reports. These maps will guide efficient and cost-effective groundwater resource planning and development.

The European Commission subsequently became involved with the project and is now providing funding to complete the groundwater mapping of the remainder of the country, which includes a further 48 districts. ■



Maps and water supply in Ethiopia data → information → knowledge → wisdom

To plan and develop successful, reliable new water supplies it is vital to use the best available evidence. BGS scientists are working with the RiPPLE programme in Ethiopia to develop maps that make data more user friendly, helping to translate that data into information, knowledge and ultimately wisdom. The question we are addressing is: 'Do maps improve water supplies?'

Water supply and sanitation (WASH) are enormous challenges in Ethiopia, a country that has been at the bottom of international league tables for safe water and sanitation for many years. The Ethiopian government has launched an ambitious Universal Access Plan to ensure access to safe water and sanitation for all by 2012, and government departments and donor organisations are working together to achieve this.

BGS is a network partner in the [RiPPLE](#)¹ programme —

Research Inspired Policy and Practice Learning in Ethiopia and the Nile Region. RiPPLE aims to improve the water sector throughout this region by advancing evidence-based learning on water supply and sanitation and the translation of this into workable policies and everyday practice. Two of our scientists — Alan MacDonald and Brigid Ó Dochartaigh — have been working with RiPPLE to investigate how maps are currently being used to help improve water supplies in Ethiopia and how these maps

could be made even more useful.

Mapping involves collecting and interpreting the best possible spatial data and information, including, for example, geology, rainfall, existing infrastructure, and poverty distribution. Mapping can support decisions at all stages in projects and programmes. Within Ethiopia, we have evidence that maps can be an important part of the process of turning this raw

data into useful information and practical knowledge.

There are many practical challenges involved in making and using maps to improve water supplies: in particular data availability, data accessibility, poor data management, and the technical capacity required to manage the data and make successful maps. Alan MacDonald explains '*There is a great appetite for mapping in Ethiopia, but first we need to*



build the appropriate skills and capacity before maps can be used routinely and effectively by the people who matter’.

The first phase of work has ended and has clearly shown that maps are useful in Ethiopia. They provide vital evidence to support decisions and are a highly effective way to present and share knowledge. We conclude that mapping could be used to target major investments in

water and sanitation services much more effectively. Maps can also be a powerful tool for monitoring and evaluating the impact of investment. However, there is also a lack of basic information, such as on the distribution of groundwater resources, which severely hampers the efforts of water supply projects, and can result in money being wasted on drilling many dry wells. Alan

MacDonald says *‘There is considerable investment in Ethiopian water supplies at the moment — developing and using good new maps*

of available groundwater resources and infrastructure will help ensure that this money is not wasted’. ■

¹RiPPLE is a five-year research programme consortium funded by the UK’s Department for International Development (DFID). It aims to advance evidence-based learning on water supply and sanitation and focuses specifically on issues of planning, financing, delivery and sustainability and the links between sector improvements and pro-poor economic growth. This DFID programme started in November 2006.

More information on the RiPPLE project — the programme phases, the vision, the team, outputs and many other aspects — can be found at www.rippleethiopia.org.

Investigating groundwater pollution in Malta

The Maltese islands have some of the highest groundwater nitrate levels in Europe. To comply with the EU’s Water Framework Directive, the government must identify and control pollutant sources and work towards reducing the concentration of nitrate to acceptable levels. The BGS led a collaborative project to identify the source of this pollution and our scientists concluded that the most probable source is leaching of nitrate from cultivated soils and manure piles.

Malta has hot and dry summers and because surface water is scarce the islands are heavily dependent on groundwater extracted from many boreholes and by large pumping stations. There are two aquifers of coralline limestone separated by a less permeable clay-rich layer. Groundwater quality in the shallow aquifer can be poor with high nitrate and bacterial concentrations. Water flows to the lower aquifer quickly through fissures and also over many years through the small

pores in the limestone. This means that the full impact of pollution today may not be seen in groundwater for many years or decades — even if all nitrate-producing activities could be stopped immediately.

Marianne Stuart, a BGS hydrogeologist, led an EU-funded project, working with the [NERC Isotope Geosciences Laboratory](#), in collaboration with the [Malta Resources Authority](#), to identify the sources of the pollution. The various likely sources were considered — leaching of

fertilised agriculture; seepage from some old sections of the sewerage system that are unlined; and animal farming practices including spreading cattle manure and dumping pig slurry. A range of indicators were used to provide clues about the source of pollution, including nitrate stable isotopes, dissolved organic carbon, fluorescence, and coliform bacteria.

In her conclusions, Marianne explained *‘the groundwater system is very*

complex and there is no unequivocal answer. It seems that fertiliser and sewage-derived nitrogen are not major contributors to groundwater nitrate and that the most probable source is leaching of nitrate from cultivated soils and possibly from manure piles’.

The results of this project are helping the Maltese government to develop effective methods for reducing groundwater nitrate. ■



Typical complex land use in western Malta

BGS provide forum for collaboration in the Middle East

The neighbouring countries of Jordan, Israel and the Palestinian Territories are sharing technical expertise in order to improve management of shared groundwater resources. In this arid region water supply is heavily dependent on groundwater, but much of the available groundwater is located in transboundary geological formations which lie across the international borders. The impact of decisions in one country can have effects on the supply and quality of groundwater in the neighbouring countries, so collaboration is vitally important. Through OASIS¹, BGS has been involved in a three-year technical aid project to assist the parties in working together on common approaches to solving regional pollution problems.

Under the auspices of the multilateral Executive Action Team (EXACT) framework DFID have funded a three-year project to extend the dialogue between Israelis, Jordanians and Palestinians on the subject of water pollution monitoring and water resource protection. The project team is made up of technical representatives from the water authorities of each of the three countries with Professor Eliahu Rosenthal, of Tel Aviv University, as project manager and John Chilton and Chris Milne from BGS as project technical advisers.

The team identified several types of water management problems affecting all three core partners. Study areas

typifying these problems were then selected from across the region: a site with historical industrial contamination in Israel, two urban waste water sites in Jordan, and locations with agricultural problems and untreated sanitation in the West Bank and Gaza.

The team agreed strategies for monitoring water quality at the study areas and shared their progress at a series of workshops, where they discussed the results and agreed the next phase of work for each partner. There was also an extensive training programme based on their identified needs, which included teaching workshops, exchange visits and external professional courses.

Working together on this project has built trust and relationships at a professional level between the partners. The project has been lauded as being politically very successful, avoiding some of the hurdles which have dogged other projects in the region, and has produced active technical collaborations

between Palestine, Israel and Jordan, with consistency in groundwater monitoring and agreed strategies for dealing with problems. This has laid the foundations for moving beyond technical cooperation towards political cooperation on control of pollution between government agencies from the different partners. In a rare joint communiqué, senior representatives of the Israeli Foreign Ministry, Jordanian Ministry of Water and Irrigation and the Palestinian Authority wrote to thank DFID for their support, highlighting practical benefits *'for the people living [locally] and using the water'* and remarking that *'special consideration should be given to the excellent work of the British professional advisers who contributed enormously to the progress of the project'*. ■

BGS scientist demonstrating groundwater quality monitoring techniques during project workshop



¹OASIS is a resource centre specialising in water resources and related issues including policy formulation, economics and law, water use in agriculture and industry, monitoring, floods, droughts and transboundary issues. It is managed by the Centre for Ecology and Hydrology (CEH), BGS and Hydraulics Research Wallingford and the network of partners includes over 20 expert organisations. OASIS works with DFID and partners to deliver their contribution to the Millennium Development Goals.

Funding for this project was provided by DFID who, in turn, were supported by the Foreign and Commonwealth Office's Global Conflict Prevention Pool.

Falklands oil exploration progress



Although a decade has passed since the last drilling activity in the Falklands, companies are now gearing up for the next phase of exploration.

Several companies, ranging from small Alternative Investment Market (AIM) listed players to world leaders such as BHP Billiton, are involved in oil exploration in the seas off the Falkland Islands. They have invested around US\$200 million in exploration, mainly on 2D and 3D seismic surveys over the past five years. Six wells have been drilled, and minor quantities of

sub-commercial oil have been found, but the last drilling activity was in 1998. Several companies now plan to drill to the north and south-east of the Falkland Islands and we anticipate this work will start in 2010.

BGS has a long-term commercial contract with the Falkland Islands Government. Our role is to bring in companies and to manage the

licensing rounds and offshore activity programme. This aims to create inward investment for the Falklands and we manage this so the Government and people of the Falkland Islands obtain the best return.

BGS hosts a web site for the Falkland Islands' Department of Mineral Resources where you will find news and other information: www.falklands-oil.com ■

First offshore licensing round for São Tomé and Príncipe

In 2007, BGS undertook a six-month project in São Tomé and Príncipe to provide advice on petroleum exploration and economic modelling in the Exclusive Economic Zone (EEZ). Our partners were Aberdeen University Petroleum Economic Consultants (AUPEC) and we worked with the country's National Petroleum Agency to produce reports, an economic model and a GIS. It seems likely that there are some large prospects and we now await São Tomé's first offshore licensing round.

we identified licence block areas, potential fields, and the possible economic reserve of oil and gas.

The results of our prospectivity study fed into AUPEC's economic model. Their report includes an outline for future contract terms for exploration and production licences, based, in part, on comparisons with other countries in the area. The final project report includes information on the regional petroleum geology, maps of the subsurface structure and summary information for a range of prospects. The results were also provided in a GIS format.

Several potentially very large prospects have been identified. Further exploration will probably focus initially

on further analysis of existing data and the acquisition and interpretation of additional 2D or 3D seismic data.

This work was carried out for the Projecto de Assistência Técnica Reforço da Capacidade de Governação (PATRCG), on behalf of the government. Funding was provided by the World Bank. ■



BGS took all existing offshore data including seismic, magnetic and gravity surveys, oil seep analyses, well data and regional geology, and carried out review and prospectivity summaries. We re-interpreted information from earlier studies to fit current geological knowledge and, using this data,





BGS scientists using GeoVisionary software developed jointly by Virtualis and the British Geological Survey

Supporting petroleum exploration in Tajikistan using 3D Visualisation

In 2008 the BGS was commissioned by Tethys Petroleum Limited to produce a 3D interpretation and visualisation model of a part of the Tajik–Afghan Basin in south-west Tajikistan to assist them with their regional exploration programme.

The remit of the project was to verify remote sensing interpretations, assess the level of confidence that can be applied to existing geological maps and sections, undertake field reconnaissance studies and build a 3D digital model of the geological structure of the basin as a means to increase the geological understanding of this prospective area, covering some 40 000 km², prior to a phase of exploratory drilling.

The BGS used GeoVisionary software in conjunction with SRTM DTM, satellite imagery and pre-existing geological maps and interpretations of the area, including seismic data and well logs, to produce a three-dimensional visualisation of the Tajik Basin. Geological cross sections were constructed using borehole and seismic data where possible. Finally, a field visit was undertaken to assess the quality of the

interpretation and 3D model in order to identify and evaluate target areas as potential hydrocarbon traps for follow up exploration. The ability to visualise the geological model of the Tajik Basin in this way means that geologists from Tethys are now able to plan their field campaigns and seismic acquisition programme with much greater rapidity and effectiveness.

The results of the project were co-presented with Tethys Petroleum in the 3D visualisation theatre at the November 2008 PETEX conference and exhibition in London. ■



EU-China collaboration of carbon capture and storage

In collaboration with our EU and Chinese partners, BGS scientists are working to evaluate potential for geological storage of carbon dioxide in selected regions of north-east China. This work, which we undertake as partners in the Cooperation Action within Carbon Capture and Storage China-EU project (COACH) and the Near-Zero Emissions from Coal (NZE) project, commenced in 2007.

China is the world's largest carbon dioxide emitter. In parts of the country, coal power generation is increasing rapidly to meet the demands of increasing industrial output and construction. China's carbon dioxide emissions are predicted to double by 2030, yet per capita emissions will remain below average. Continuing economic growth is coupled with increasing energy demand but carbon capture and storage (CCS) will enable this to happen without long term harm to the environment.

Recent work with our Chinese project partners focused on producing an inventory of geological formations which are potential storage sites for carbon dioxide. These sites include pore space in sandstones, oilfields, and unmineable coal seams. Injecting carbon dioxide into oilfields could potentially improve recovery. Injecting carbon dioxide into coal seams could be coupled with methane recovery. The potential volume of space in these rock reservoirs has been

calculated, taking into account such factors as porosity and permeability.

Interim storage assessments were presented at a joint NZEC-COACH-GeoCapacity workshop, hosted at the BGS in February 2009 and final results were presented in Beijing at the end of October 2009 by all project partners. These results suggest a large capacity in the aquifers but more detailed study is required to thoroughly characterise these potential storage 'containers'. The nearby oilfields have generally

smaller potential capacities and are compartmentalised by lithological and structural features, however, there are already experimental CO₂-enhanced oil recovery projects being undertaken in China, which could potentially be tied in with proposed storage sites. Future work will involve more detailed study of the site selected for the next phase of working towards a demonstration in China and eventually full-scale deployment including:

- surveying specific sites
- drilling injection wells
- pilots in China testing feasibility of storage and monitoring techniques at selected sites and in selected formations
- establishing a CCS demonstration plant in China by 2014 (phase 2 and 3 of the China-EU Near Zero Emissions from Coal initiative, depends on

funding and other factors)

- contributing to development of the regulatory and legal framework though scientific support of Chinese scientists and policymakers

The BGS has also undertaken capacity building activities in China, through the COACH project. We provided ArcGIS software training to Tsinghua University in 2008 and assisted in the organisation of, and presented on, aspects of geological storage at the 'COACH CCS schools' held in Hangzhou (April 2009) and Beijing (October 2009).

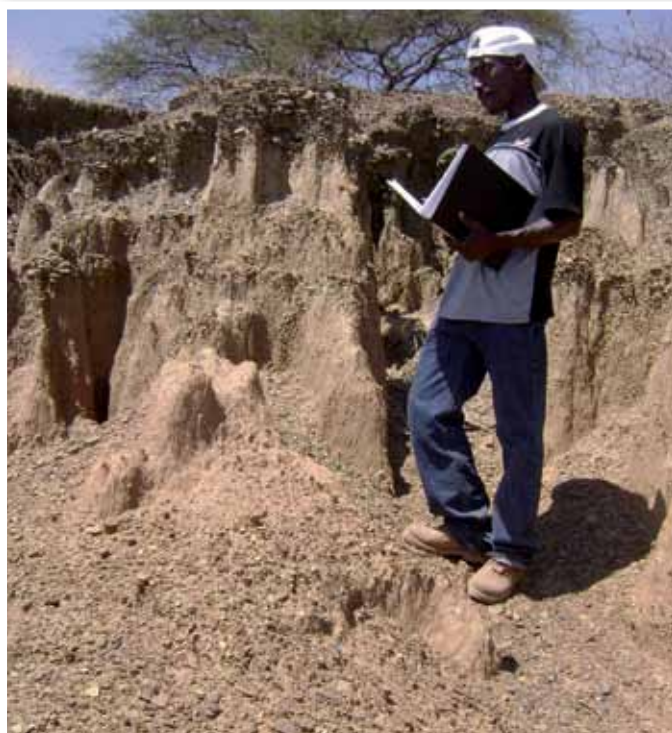
For more information and updates on the progress of this work, please visit the web sites of COACH (www.co2-coach.com) and NZEC (www.nzec.info/en/). To learn more about CCS visit our web pages at www.bgs.ac.uk/education/carboncapture. ■



View from CCTV tower, Beijing

Success of the Field Geoschool in Tanzania

In August–September 2009, the BGS ran a field ‘Geoschool’ in Tanzania to train six recent graduate geologists, newly-recruited to the Geological Survey of Tanzania (GST), in the skills of large-scale, regional geological mapping. During the three weeks fieldwork in south-west Tanzania, the participants worked hard, with very long hours in the field followed by evening study sessions. They produced a large-scale geological map for an area of 600 km² and gained the experience, knowledge and self-confidence to do similar work in the future.



the main points. During the fieldwork Bob gave many field talks on the background to the features being discussed. During the evenings, the students were encouraged to compile the day's field data on their topographic field slip maps and to keep a working legend of the units mapped, which was added to as new units were encountered.

Compilation of the data at 1:50 000 scale in such a complex geological terrane was difficult for the students, who had no prior fieldwork experience, but they produced a 1:50 000 scale geological map for an area covering more than 50 per cent of the published 1:125 000 geological sheet,

Chimala. It was consistent with the observations and remote sensing data, and represents a marked improvement on the published geological map of 1957.

During the last week, the geological report (sheet explanation) was written in Dodoma. To help with this, Bob explained the aims of such a report and how it should be structured. He wrote the background and introductory material, while each student provided the description of one of the main lithostratigraphic units.

Bob believes that the course was a great success, *‘It exceeded my expectations. While a four-week course cannot turn a newly-graduated geologist with no fieldwork experience into an expert mapper of high-grade basement rocks, I am sure that they now have the knowledge and self-confidence to undertake such work in the future’.*

The Tanzania Geoschool project was declared a major success by the CEO of the GST Professor (Dr) Abdul Karim Mruma at a ceremony in Dodoma to present certificates to the successful trainees. ■

The Geoschool was run by Bob Thomas, a BGS field geologist. To prepare his students for the fieldwork, Bob first led some practical exercises in map work at GST HQ in Dodoma, including preliminary interpretations of the published geological map of the area to be studied. This covered all aspects of the map, including lithostratigraphy, lithology, structure and tectonics,

geomorphology, legend layout, geological history and background in East African geology.

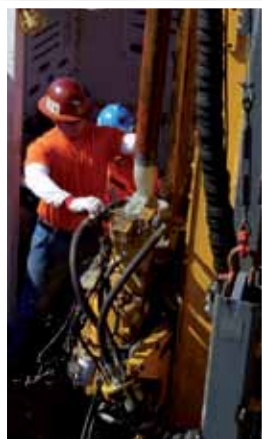
In the field, the students were split into three teams of two students. Bob used a BGS-SIGMAmobile mapping tablet computer to record all the field data. The students became attuned to working quickly and efficiently at outcrops and were able to gain an understanding of



Tanzanian geologists collecting age-dating sample

Subseafloor science

In addition to our work on international development projects, we also participate in international scientific research. The BGS co-ordinates the European Consortium for Ocean Research Drilling (ECORD) Science Operator group, which implements mission-specific platform operations for ECORD within the Integrated Ocean Drilling Programme (IODP). In this programme we have successfully managed major international drilling projects, including those in the Arctic, Tahiti and New Jersey continental margin.



C Cotterill©ECORD/IODP

The IODP is an international project which aims to address a wide range of societal issues as well as understanding more about the subsurface and dynamics of the Earth. The current project involves 10 years of research (2003–2013) into the Global Earth System and aims to:

- obtain records of past climate change
- study the deep biosphere
- establish sea floor laboratories to study submarine natural hazards such as earthquakes
- discover new energy resources
- understand how oceans develop

The IODP comprises USA, Japan and ECORD — which includes 16 European countries and Canada acting as a single agency. China, India, South Korea, Australia and New Zealand are also programme associates.

IODP's research is driven by the best science, proposed by scientists from all member countries. The top priorities are identified and teams of specialists are built to work on these projects and disseminate the results to peers and the public.

In addition to extending the range of skills and expertise in IODP, ECORD provides ships that can work in shallow seas, environmentally sensitive areas and areas where ice is present. ECORD has worked in the ice-covered seas of the Arctic, coral reefs in Tahiti and the shallow waters off New Jersey, USA, where the thick series of sediments was deposited 14–20 million years ago during a period of rapid climate change. Linked to the Tahiti project, ECORD will also implement an expedition to the Great Barrier Reef

to look at growth rings in dead coral as part of an investigation of oceanographic conditions and sea-level at the time that they were growing during the last 20 000 years—this is another part of the climate-change story.

The BGS manages the mission-specific platform operations for ECORD and provides 10–12 scientists and engineers to work on projects. The Natural Environment Research Council, the BGS's parent body, is a major financial contributor to ECORD.

For more information on the science, progress reports, newsletters and articles, visit the ECORD web site at www.ecord.org. ■



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