British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

BGS Global Geoscience

Including:

- **Glacier observatory in Iceland**
- **Urban geology in 3D for Abu Dhabi**
- **Groundwater in Africa**
- **Worldwide volcanology activities**

International work by the British Geological Survey

BGS Global Geoscience

Dr Martin Smith, Science Director, BGS Global Geoscience

BGS's international geological activities, now renamed as BGS Global Geoscience, have been a cornerstone of BGS work for more than a century. As the recently appointed Science Director for BGS Global Geoscience, this magazine provides a welcome opportunity to introduce myself and to highlight the continuing breadth of BGS overseas applied research and survey.

Since I last worked overseas in the late 1990s, BGS's work on the international stage has witnessed significant change. Traditional overseas placements funded by UK aid gave way in the 2000s to large, mainly World Bank funded, non-residential mapping projects. Over time, increased competition and the price sensitivities became ever more telling and it was increasingly apparent that if BGS was to remain active in this area we would need to review the appropriateness of our business model. As a consequence of this review, in 2010 BGS set up a spin-out company (International Geoscience Services Ltd – currently trading a BGSi).

Thus, as traditional international mapping surveys have declined, our focus has shifted from traditional survey work to developing research and scientific applications. For example, the United Arab Emirates survey, which commenced 10 years ago as a mapping programme, now funds more applied research focused on urban and developmental resource issues.

Responding to global science and environmental drivers, the current BGS science strategy (2009–2014) gives priority to activities that increase our understanding of environmental processes particularly in developing countries. Exchanging know-how, building capacity for alleviation of resource poverty, and living with environmental hazards, are key. With these visions in mind, throughout 2011 to 2012, BGS has pursued the range of project activities described herein. They focus on water and mineral resources, volcano and tsunami- related geohazards research, new monitoring activities combining ice and fire in Iceland, and expanding our geomagnetic network in South Georgia.

For survey research to have measurable impact requires a fresh approach. Our vision for the future is, therefore, of a co-ordinated and integrated combination of skills, data and expertise to deliver not just maps but modern geoscience databases. They will underpin the modelling and prediction of resource abstraction (especially water), subsurface storage, and the monitoring of climate change impacts across national boundaries. Urbanisation is another key area that lends itself to such an approach. Expanding modern cities in both developing and developed countries affect the surrounding environment and create an ever-increasing demand for resources from the subsurface. BGS expertise in 3D geology and in handling large volumes of data, gained over many years working on UK cities, has applications to many modern cities in south-east Asia, the Middle East and globally.

I believe that this multi-disciplinary approach will drive a new generation of BGS international work and lead to improved integration of geology with the social and economic sciences to benefit planning and development and deliver a visible impact on the global community.

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Mapping the birth of Africa's new ocean

The Afar Depression is a triple plate junction in northern Ethiopia and the only place on Earth where we can directly observe active rifting of thick continental crust. Current understanding of the processes and controls involved in the break-up of continents and the generation of new oceanic crust is limited, for the simple reason that these processes operate on geological timescales that are rarely amenable to human observation.

Interest in the Afar Depression region was reinvigorated by a rifting event which began in 2005. A fissure, six metres wide and 500 metres long, opened as a 60 km-long dyke was injected into the shallow crust. Injection of dykes, seismic swarms and periodic volcanism at six to nine month intervals has occurred in this active area (the Dabbahu – Manda Hararo rift segment) for the last five years. Afar offers a unique opportunity to study the spatial and temporal evolution of rifting processes in the Earth's crust — similar to rifting on the ocean floor beneath the Atlantic. Volcanism in Afar has been episodic since the onset of the rifting that generated the Ethiopian Trap basalts approximately 26 million years ago, and which now form the rift walls. The rift floor consists of central volcanoes and rift basalts that erupted within the last four million years.

BGS is a project partner in the NERC-funded Afar Rift Consortium to research the creation of magma from deep within the Earth, studying how it migrates and evolves as it rises towards the surface, the character of the resulting volcanic eruptions and faulting, and the timescales over which these processes occur. Our geological mapping provides an overview of the changes in style, location and composition of volcanism and the development of structure over time.

The key to deciphering the complex geological history of the Afar region is to combine interpretation of high-resolution satellite and airborne remote sensing imagery and digital elevation models with observations made in the field, geochemistry and high-precision ^{40}Ar-^{39}Ar ages. This work is enabling us to characterise the magmatic evolution and volcanic history of this part of the East African Rift.

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Worldwide volcanology activities

BGS is leading and contributing to several international projects which aim to:

- improve understanding of tectonic, magmatic, volcanic and atmospheric processes
- identify, assess and monitor volcanic hazards
- mitigate volcanic risk
- respond effectively to volcanic eruptions
- increase societal resilience to volcanic eruptions

Global Volcano Model (GVM)

The BGS and the University of Bristol are project leaders (with Natural Environment Research Council (NERC) funding) of the growing GVM collaboration network which includes many international initiatives in volcanology. The GVM project will develop an integrated database system on volcanic hazards, vulnerability and exposure. This will be globally accessible and the volcanological community will form a partnership to develop the database system. New international metadata standards will reduce ambiguity in the use of global volcanic datasets and we will:

- establish methodologies for analysis to inform risk assessment
- develop complementary volcanic hazards models
- create hazard and risk assessment tools.

This research will provide the scientific basis for mitigation strategies, land-use planning, evacuation plans and management of volcanic emergencies.

For further information, please see http://www.globalvolcanomodel.org/

European Volcano Observatory Space Services (EVOSS)

EVOSS is a consortium project to develop products based on Earth Observation data to optimise volcano monitoring capacity in Europe, Africa and the Lesser Antilles. The products allow users to monitor SO_2, ash, thermal anomalies and ground deformation at any volcano worldwide in close to real time. The data and products will be delivered through the 'Virtual Volcano Observatory' web portal when there has been evidence of unrest at a volcano or an eruption has begun. Products will be derived from different sensors so users can check different data sources against each other. Derived products such as sulphate aerosol lifetime are also being developed which are useful for assessing distal impacts and there is a plan to link to numerical modelling of different types of eruption to facilitate real-time assessment of eruption rate and particle size distribution.

The initiative is EU FP7-funded and led by IPGP, France. We intend the EVOSS project to be sustainable and have a global scope.

For further information, please see www.evoss.eu

VANAHEIM

The VANAHEIM project combines detailed observational data of the Eyjafjallajökull eruption from ground, air and space-based platforms with very high-resolution numerical modelling to achieve more accurate and validated dispersion predictions. Modelling of the dynamics of volcanic plumes and effects of meterological conditions will enhance our capability to predict the dispersion of ash, gas and aerosol clouds, prepare the UK for future observations and forecasting and facilitate planning for the potential impacts of future eruptions. This is a NERC-funded consortium led by Leeds University.

Strengthening resilience in volcanic areas (STREVA)

STREVA is a consortium which aims to increase resilience to volcanic risk in the Caribbean and northern Andes region. To minimise the social

and economic disruption of volcanic eruptions, the resilience of people and systems needs to be strengthened. This demands a detailed understanding of a number of dynamic factors that characterise disaster risk:

- the nature of the hazard itself
- the exposure and vulnerability of people and assets
- the set of capacities in place to reduce, prepare for and recover from the impact.

The project will begin with forensic analyses of recent eruptions at three volcanoes in Montserrat, Columbia and Ecuador to identify the ways in which risk factors interact and can be characterised, analysed and monitored.

The consortium is NERC-funded, led by the University of East Anglia.

FUTUREVOLC

FUTUREVOLC aims to coordinate ground-, air- and space-based volcano monitoring and analysis in Iceland and improve communication between scientists, civil protection and authorities.

The project, which started in September 2012, will establish new methods for near real-time integration and analysis of datasets and develop instrumentation to allow improved understanding of physical processes ranging from deep magma transport through eruption dynamics to plume dispersion and deposition of eruptive products.

This EU FP7-funded project is led by the University of Iceland and involves 28 European partners including BGS, the University of Cambridge, the UK Met Office and the University of Bristol.

BGS volcanology

As well as participating in the major co-funded projects described above, BGS also supports smaller volcanology projects worldwide including PhD studentships in Chile, Mexico, Montserrat, Ecuador, Kenya, Ethiopia and Tristan da Cunha. These research projects serve to improve our understanding of volcanic processes as well as hazards and risk and the knowledge obtained from different sites can be applied elsewhere.

We're working alongside the Icelandic Meterological Office (IMO; the operational volcano observatory in Iceland), the University of Iceland, the UK Met Office (London Volcanic Ash Advisory Centre for the UK and North Atlantic) and others (see above) to improve:

- early warning of volcanic eruptions
- communications during eruptions
- modelling of ash, gas and aerosol dispersion from volcanoes in Iceland

We conduct this work in an operational response capacity during volcanic unrest and eruptions, and support long-term planning in the UK during periods of quiescence.

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African rare earth elements research

Rare earth elements (REE) have numerous uses, including the manufacture of permanent magnets, which are used for many new high-tech and environmentally friendly technologies. REEs have been identified as 'critical' metals by a number of countries due to their growing economic importance and high risk of supply shortage. The search for new and geographically diverse sources has therefore gained momentum in recent years.

BGS's work on two projects in Africa has involved both exploring for deposits which could represent alternative supplies, and improving our understanding of the processes that concentrate critical metals in geological environments in order to guide mineral exploration.

In Nigeria, stream sediment data from the Minna area (central Nigeria) indicated highly anomalous values for a number of critical metals including REE. BGS geologists Paul Lusty, Kathryn Goodenough and Roger Key spent two weeks with the Nigerian Geological Survey Agency (NGSA) following up these geochemical anomalies and studying and sampling the main rock types, principally granitoids. Whilst the REE contents of the rocks were not economically significant, the values obtained are scientifically interesting and provide evidence for the geological processes associated with REE concentration. Our work in Nigeria was funded by the World Bank and comprised a two-year project in which BGS and the Geological Survey of Finland provided technical assistance to the NGSA to carry out a national programme of geochemical mapping.

BGS is also collaborating with the Geological Survey of Botswana to assess the potential for REE mineralisation associated with igneous rocks in the east of the country. Although results are variable, significant REE enrichment is associated with a syenite body in south-eastern Botswana. Whilst the concentrations are of limited economic interest, the work provides further insight into the geological processes responsible for REE mineralisation associated with alkaline igneous rocks, which is valuable for targeting new deposits.

For further information please see http://www.bgs.ac.uk/mineralsuk/statistics/mineralProfiles.html

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Cockle-shell construction: designing a geological laboratory for The Gambia

Gambia is the smallest country in mainland Africa where it is situated on the west coast surrounded by Senegal. It is a developing country where three quarters of the population live on less than one US dollar a day and depend on subsistence farming for their livelihoods. International assistance focuses on supporting the national poverty reduction strategy which includes economic growth and enhancing the capacity and output of the productive sector.

The top priority of the Geological Department of The Gambia is the provision of information on mineral resources suitable for infrastructure development.

The main demand for construction material is in the Greater Banjul Area (GBA) especially in and around the communities of Bakau, Brikama, Brufut, Serrekunda and Sukuta. The Geological Department intends, with the assistance of the BGS, to establish a geological laboratory (GeoLab) that will provide technical information on the indigenous mineral resources. The most significant of these are silica sand, heavy mineral sand, kaolin, brick clay, laterite and cockle shells, which are limited to the Upper Tertiary and Quaternary sedimentary sequences.

BGS industrial minerals specialist, Clive Mitchell, has been working with the Geological Department in Banjul on a laboratory development plan. The

proposed GeoLab will have the capacity for the testing of brick and ceramic clay, building sand, cockle shells, construction aggregate, heavy mineral sand and imported mineral products. This laboratory will enable the use of indigenous mineral resources within The Gambia and will help to reduce the reliance on imported materials. This will conserve the foreign exchange reserves and in the longer term may even help to strengthen The Gambian export market for mineral products.

For further information please see http://nora.nerc.ac.uk/view/author/2827.html

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Soil mineralogy training for Bhutan

A team from the BGS Mineralogy and Petrology Facility led by Simon Kemp recently played host to Jamyang, Chief Chemist at the Soil and Plant Analytical Laboratory, Ministry of Agriculture, Bhutan. Jamyang attended the Keyworth laboratories for an intensive three-week BGS GeoSchool training programme entitled 'X-ray diffraction analysis of clay minerals'. The training was requested ahead of a proposed, large-scale investment in new X-ray diffraction and scanning electron microscope systems at the Soil and Plant Analytical Laboratory, the first such installations anywhere in Bhutan.

Although the course was principally based around sample preparation, X-ray diffraction analysis and interpretation of derived data, Jamyang was also introduced to the full range of mineralogical techniques available in the facility including optical and scanning electron microscopy, surface area, thermal analysis, heavy-mineral and particle-size analyses. Analysis of two Bhutanese soil samples carried out during the training course immediately offered explanations for their problematic behaviour and illustrated the benefit of mineralogical analysis to Bhutanese agriculture. Following discussions with BGS soil scientists, possible soil treatment scenarios were devised.

BGS has offered continued support and assistance to the Ministry of Agriculture and hopes to extend co-operation between the two organisations.

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Addressing **hidden hunger** in **sub-Saharan Africa**

Mineral malnutrition often referred to as 'hidden hunger' affects approximately four billion people worldwide and is widespread in sub-Saharan Africa (SSA) due to environmental, poverty and cultural factors. Even where staple food is plentiful, 'hidden hunger' pervades due to chronic micronutrient deficiencies (e.g. zinc, selenium, iodine, calcium, iron). Effective intervention programmes can help to reduce extreme poverty and hunger; cognitive dysfunction and growth retardation; child and maternal mortality and disease susceptibility especially in women and children. A multinational research consortium led by a University of Nottingham (UoN)–BGS partnership and the government of Malawi undertook research over the last three years with the aim of building a policy framework to link biogeochemical cycles of dietary minerals and poverty alleviation in SSA. The project initially focussed on deficiencies in the minerals iodine, selenium and zinc in Malawi. Through data integration, feasibility studies, networking and capacity-building we addressed three target themes: biogeochemistry, nutrition, and economics.

Biogeochemistry: we developed a GIS (ArcGIS) framework linking soil and land-use data which has been published in an open-access journal. We incorporated new geochemical data for soils and vegetation from an aligned project (UoN) and other spatial data (e.g. Malawi Ministry of Agriculture). Through integration of soil types in GIS, we have found that the population selenium intake from maize is typically 6–7 µg selenium per day — only 10 per cent of the dietary requirements. Since maize provides the majority of dietary energy to the rural poor of SSA, this study revealed for the first time that chronic Se deficiency is endemic for the majority of the rural population and is largely influenced by input from soil to crops.

Nutrition: a feasibility study including several villages investigated the spatial variation in iodine, selenium and zinc dietary intake and human nutritional status in Malawi. The data shows a strong link between the local soil geochemistry and the dietary intake and health status of the villages. This study is published in Scientific Reports http://www.nature.com/srep/2013/130312/srep01425/pdf/srep01425.pdf.

Economics: we developed a novel framework based on: modelling the soil-to-diet relationship using mineral/dietary-energy units; food choices and land use; quantifying relationship between disease burdens and poverty at population levels. Economic analyses were formalised using World Health Organisation disability adjusted life years (DALYS), which incorporated a willingness to pay for intervention. Such analyses provide a useful policy tool at national and regional scales. For example: despite limited data, a pilot analysis in Malawi estimated that the burden of disease due to Zn deficiency alone leads to a loss of almost 100 000 healthy life years (DALYs) per year and causes 3800 cases of infant mortality. This represents an economic loss to Malawi of more than 1% GDP per year. Economic analyses for iodine, selenium and other elements requires more data.

This work was funded via a research grant from the Ecosystem Service Poverty Alleviation programme by UK DFID-NERC (NE/I003347/1), as well as BGS and UoN. However, major knowledge gaps still exist. Further sampling is required to better understand the potential for soil types to deliver nutrients to humans via crops. Building local capacity will ensure improved impact, particularly in data integration of soil–agronomy–health status data, with socio-economic metrics to measure current mineral supply and estimate the cost of intervention e.g. addition of minerals to fertilisers. Overall, scalable geochemistry data can underpin a policy framework to ensure the delivery of essential minerals in the correct locations, to address 'hidden hunger' on a population scale.

Project partners included: UoN-BGS, University of East Anglia, IFPRI (USA), University of Sabanci, University of Adelaide, University of Otago, University of Malawi, University of Zambia, Ministry's of Agriculture & Health, Office for the President and Cabinet (Malawi).

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East African Orogen project

The East African Orogen project is a collaboration between BGS, the University of Bergen, Norway, and the Geological Surveys of Mozambique and Tanzania. It began in 2004 with the BGS–Geological Survey of Norway Consortium which completed a World Bank geological mapping project in north-east Mozambique and continued in 2006 to 2009 with work in Madagascar. The study is focused on one of the largest and most complex mountain belts on Earth. It stretched over 8000 km from Arabia to East Africa, Madagascar and Antarctica when, between about 700 and 500 million years ago, these areas were part of the Gondwana supercontinent.

The purpose of the project is to understand a massive ancient orogen in order to stimulate economic interest (e.g. the mineral sector) and to develop geological research in Africa particularly amongst its young geologists.

Our work has focused on the salt domes of the UAE and Oman, the granites of Madagascar and the ancient metamorphic rocks of Tanzania, Mozambique and East Antarctica and it has involved geological mapping, geochronology, geochemistry and geophysics. There is an important training and research component and the present focus is on the Tanzanian segment of the belt in collaboration with the Geological Survey of Tanzania. It is hoped that the impending World Bank geological mapping project in Tanzania will add further impetus to the project over the next few years.

The project has led to many articles in high-impact international earth science journals.

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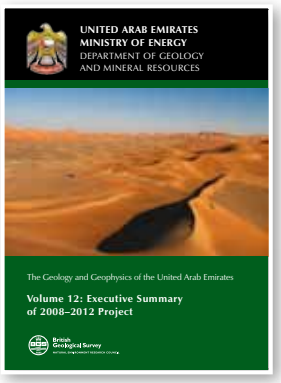
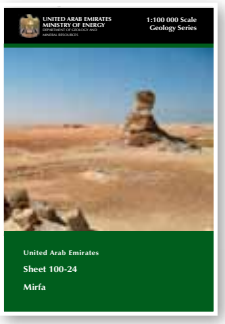
The **sands** of **time**

The Ministry of Energy of the United Arab Emirates (UAE) commissioned the BGS to map and interpret the geology and geophysics of the country over a 10-year period up to 2012. The research has resulted in completion of the geological mapping of the UAE, making it one of the best-surveyed countries in the world. Many countries worldwide are working towards a national, fully attributed, digital geological dataset, but the UAE and the UK are the only countries that have completed this task so far.

The UAE is now looking to widen its natural resource base away from hydrocarbons, and as a result of the BGS project, the background information is now in place for more detailed investigations into development of the high-purity limestone, and the dimension stone industries. In addition, the areas most suitable for exploitation of the best quality hard rock resources have been identified.

Seismic data, brought together for this project, when combined with airborne gravity and magnetic surveys, provides a valuable overview of the deeper geological structure of the country and a framework to illustrate the geology of the entire country in three dimensions.





Studies carried out on the UAE salt domes, the sedimentary successions in northern Oman, and the dating of selected rock units, have considerably advanced understanding of the geological evolution of the country. For example the age of the basement rocks brought up in the salt domes has been established for the first time. Dating of the Quaternary dunes and alluvial fan sediments has shown that some of them were deposited, cemented and stabilised during specific intervals between about 120 000 and 10 000 years ago, linked to changes in climate associated with fluctuations in the Indian Ocean monsoon. Furthermore, heavy mineral analysis coupled with the dating of individual sand grains has shown that the sand itself originated in the interior of the Arabian Peninsula and was redeposited many times before being incorporated into the dunes that dominate the west and central parts of the country.

The work is published in a six volume report, along with 27 maps and accompanying sheet explanations.

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Urban geology in 3D for Abu Dhabi

Abu Dhabi, located on the Gulf Coast of the United Arab Emirates (UAE), has a 20-year development master plan.

To provide government, planners, developers and contractors with sound background information about ground conditions, BGS has created a 3D geological model of the Abu Dhabi urban area, part of Abu Dhabi Emirate and the capital of the UAE. The work was funded by the UAE Federal Ministry of Energy, Department of Geology and Mineral Resources and the geological model was created using exiting ground investigation data provided by private and public sector organisations and agencies. It shows the distribution, thickness and elevation of rock units beneath the Abu Dhabi urban area. This model provides a geological framework for sustainable land-use planning, urban development and hazard assessment. The mapping provides a good record of Quaternary climate change over the last 200 000 years and will help archaeologists understand the impacts of climate change on human populations through time. The results of the work are published in a report with accompanying digital GIS and 3D data and background to the project is available at http://www.bgs.ac.uk/research/highlights/2010/uae_mapping.html

Contact Simon Price
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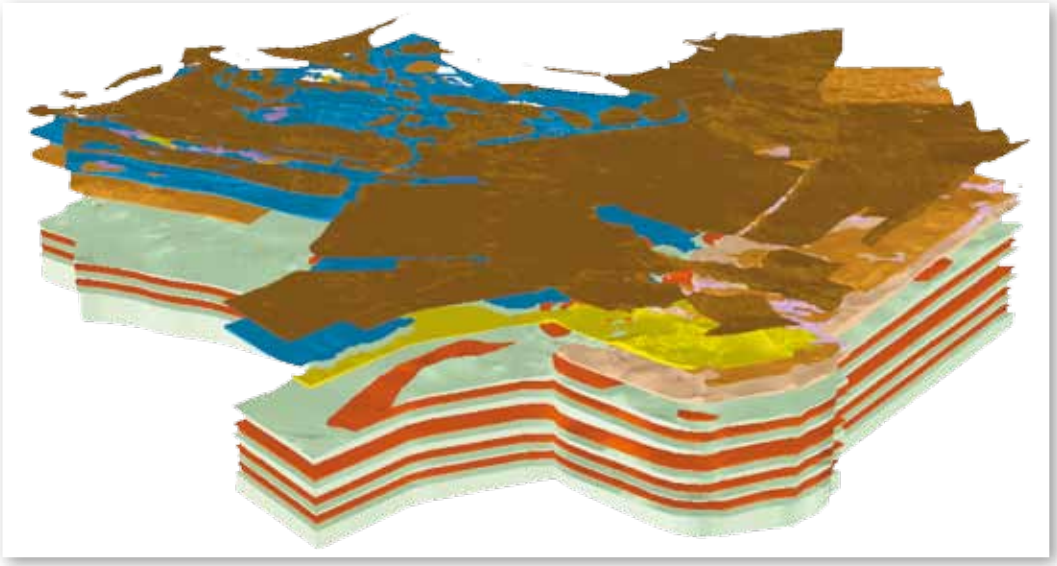
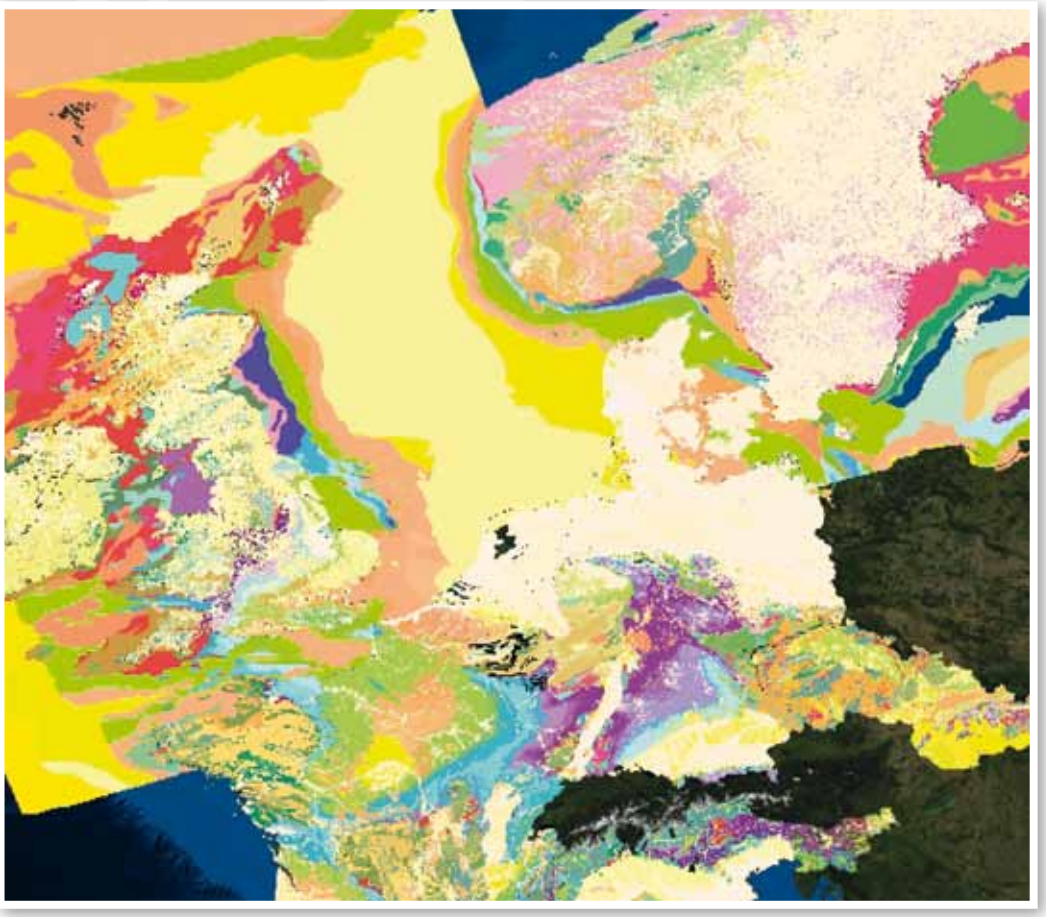


The **EMODnet geology** project

The national geological survey organisations of the UK, Ireland, France, Belgium, The Netherlands, Germany, Denmark, Norway, Sweden, Finland, Estonia, Latvia and Poland, and the Lithuanian Institute of Geology and Geography, are working together to deliver the geological input to the European Commission's European Marine Observation and Data Network (EMODnet).



This consortium is bringing together datasets at a scale of 1:1 million including:

- rate of accumulation or sedimentation
- sea-floor geology (including age, lithology and origin)
- geological boundaries and faults
- rate of coastal erosion and sedimentation
- geological events and event probabilities (including information on submarine landslides, volcanic activity, earthquake epicentres)
- seismic profiles
- minerals (including aggregates, oil and gas)

In addition to geological information, EMODnet aims to bring together information on hydrography, biology, chemistry, physical properties and habitat mapping from the European seas. In the preparatory phase, the areas covered are the Baltic Sea, Greater North Sea and Celtic Sea. The next phase of EMODnet will be extended to include the other regional seas, and the resolution of the map compilations will be increased to a scale of 1:250 000. The EMODnet Geology Project started in July 2009 and ended in the summer of 2012.

The outputs have been delivered through the Web using the multilingual OneGeology-Europe portal, which was developed in the OneGeology-Europe (1GE) project (http://www.onegeology-europe.org/). Existing metadata will continue to be stored on the EU-SEASED website, currently being developed and upgraded under the EC-funded GeoSeas project (www.geo-seas.eu).

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International Ocean Discovery Program

The Integrated Ocean Drilling Program (IODP) will end in 2013. The next phase of the programme (2013–2023) is currently being considered for renewal by funding agencies in most of existing member countries. When the new programme is launched it will also have a new name, the International Ocean Discovery Program.

Europe expects to continue its major role in the programme as the European Consortium for Ocean Research Drilling (ECORD), working with partners in the USA, Japan and several other countries to provide scientists with access to drilling platforms that allow them to answer questions about issues of global importance. The science plan for the new programme addresses:

- climate change and ocean change: reading the past, informing the future
- biosphere frontiers: deep life and environmental forcing of evolution
- Earth connections: deep processes and their impact on Earth's surface
- Earth in motion: processes and hazards on human timescales

BGS will continue to act as the lead partner responsible for implementing mission-specific platform expeditions for IODP, working with partners at the universities of Bremen, Leicester, Aachen and Montpellier to form the ECORD Science Operator (ESO). Before the current programme ends, ESO will carry out the Baltic Sea Paleoenvironment Expedition to collect cores and other scientific measurements from seven sites in the Baltic Sea. The main aim will be to investigate the glacial/interglacial history of the region over the last 140 000 years.

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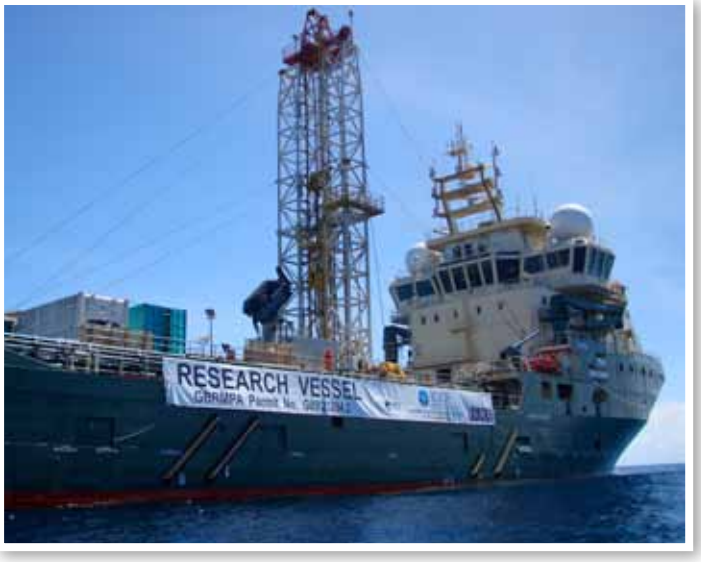

Groundwater research in the Ganga Basin, India

Over the past decades, the Indian subcontinent has undergone one of the largest environmental changes in human history. India's green revolution, besides the ubiquitous benefits, has resulted in large-scale changes in land cover and a significant increase in the exploitation of water resources, including the vast groundwater aquifers of the Gangetic plains. The pressure on water resources will increase in the near future. The population in Indian cities is expected to rise from 286 million in 2001 to 575 million by 2030. At the same time future climate changes, and particularly the reliance of water resources on the highly erratic rainfall patterns of the summer monsoon, pose significant risks to water supply. Since 80 per cent of India's rainfall occurs during the summer monsoon any change in its timing, intensity and duration caused by climate change could be seriously detrimental to water supply.

To assess this threat, BGS is undertaking research as part of the collaborative project 'Hydrometeorological feedbacks and changes in water storage and fluxes in Northern India'

The research is focusing on the Ganga Basin in northern India. This region is crucial for the socio-economic development of the country but also provides a unique case of a large-scale river system dominated by groundwater resources. We are investigating the following questions:

1. How do the large-scale, human-induced land-use changes and groundwater exploitation that have taken place in India modify the hydrological and climate system at the basin scale?
2. How can climate models be used with hydrological and water resources models to assess future changes in monsoonal rainfall and associated water resources and how certain are these?
3. Can large-scale modelling studies inform localised management decisions to improve water availability and security?

This research is funded by the Natural Environment Research Council's Changing Water Cycle programme and the Indian Ministry of Earth Sciences.

For further information please see:

Project summary:
http://paramo.cc.ic.ac.uk/india/

Funders

Changing Water Cycle:
http://www.nerc.ac.uk/research/programmes/cwc/

Indian Ministry of Earth Sciences:
http://dod.nic.in/

Partners

Imperial College:
http://www3.imperial.ac.uk/

University of Reading:
http://www.reading.ac.uk/

Indian Institute of Science:
http://www.iisc.ernet.in/

Indian Institute of Technology, Kanpur:
http://www.iitk.ac.in/

Indian Institute of Technology, Roorkee:
http://www.iitr.ac.in/

UNESCO:
http://www.unesco.org/new/en/

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The **Indian Hydrology Project II**

Water resources are immensely important to India's 1.2 billion inhabitants, but are facing multiple pressures. Rapid urbanisation and development, coupled with increased demands from the vital irrigation and power generation sectors make effective management and planning of water resources at regional and national level a priority. Over much of India rainfall is highly seasonal, with intense monsoon rains leading to flooding, followed by an extended dry season which makes water storage and effective groundwater exploitation vitally important.

Major water supply, irrigation or hydroelectric schemes require massive investment, currently estimated at over 6 billion US$ per annum. Obtaining accurate hydrological data for decision-making is an important foundation for project planning. Under India's federal system, water resources are the responsibility of individual states, but central government agencies also play a role, especially in the largest infrastructure projects. The decentralised management of water resources led to some areas having little data, while in other areas state governments and national agencies maintained duplicate measuring facilities. It also made it hard for stakeholders to find and access the data they needed.

In the late 1990s the Government of India and the World Bank embarked on a major programme, the India Hydrology Project, to improve hydrological data collection — measuring river flows, groundwater levels and water quality across nine southern Indian states. The programme combined investments in new monitoring infrastructure, investments in laboratories and IT systems and institutional reform and training. In 2007 a second phase, the Indian Hydrology Project II, was started, to update the technologies and systems installed in the earlier phase, and to extend the project to four

new states. Since 2009 BGS and the Centre for Ecology and Hydrology (CEH) have provided technical experts to advise on several aspects of the new programme, from the specification of monitoring equipment to helping with a major upgrade of India's national hydrological databases.

Groundwater management in India has always had to balance the need to control exploitation to ensure long-term sustainability with the need to provide water to a growing population and agricultural sector. The results of the Hydrology Project are already being used to shape the future direction of management, putting information about their water resources directly in the hands of communities, so they can manage their own resource. Given the huge scale of the Indian water sector, and the large population who depend on its efficient management, the project is having an impact disproportionate to its own budget.

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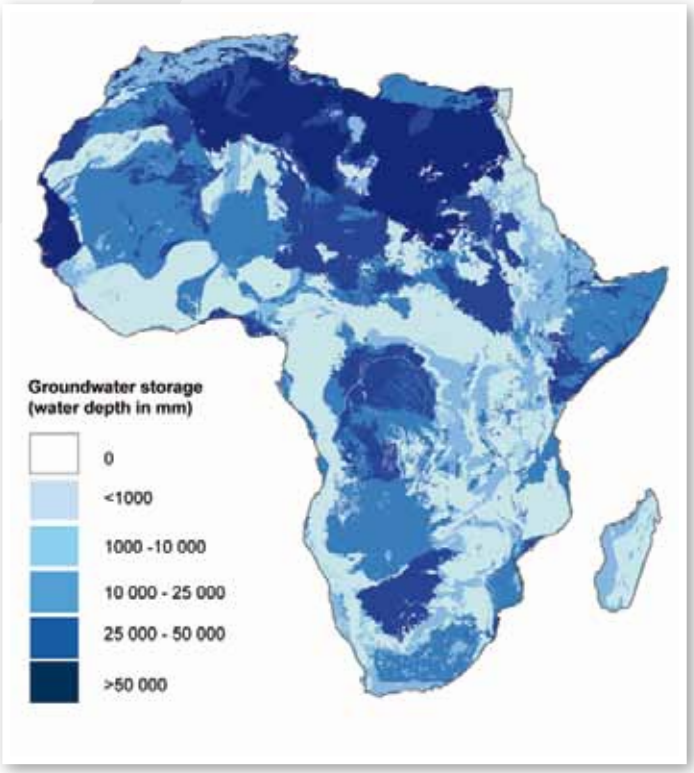
Groundwater in Africa

In Africa, groundwater is the major source of drinking water and its use for irrigation is forecast to increase substantially to combat growing food insecurity. Despite this, gathering information about groundwater resources has been a low priority with the result that groundwater resources are undervalued across the continent. To help address this knowledge gap, DFID funded a two-year research project to examine how groundwater in Africa can help people adapt to climate change. The research yielded significant results that were widely reported in the media.



The BGS-led project team brought together UK researchers from BGS, the Overseas Development Institute and University College London with African research institutions in Nigeria, Tanzania and Ethiopia. This interdisciplinary project team encompassed skills in international water resources, water policy and governance and water supply. The team produced, for the first time, a series of quantitative, continent-wide maps of aquifer storage and potential borehole yields based on an extensive review of available maps, publications and data. The maps indicate the wide variation in groundwater resources across the continent. We also carried out three field studies across five countries.

The team estimates that the total volume of water in aquifers underground is much larger than visible water resources: approximately 20 times the amount found on the surface in rivers and lakes. Although much of this water is locked away in aquifers in north Africa, in most environments there is generally sufficient groundwater to sustain a hand pump through several years of drought. Therefore, for much of Africa, carefully sited and constructed boreholes will be able to provide safe drinking water for those without it. However, the potential for boreholes that could sustain much higher yields for commercial irrigation or urban supply is much more limited. The large groundwater stores in the major sedimentary basins, which could accommodate high-yielding boreholes, are often far from population centres and associated with deep water levels and therefore very costly to develop.

Alan MacDonald, project leader and principal hydrogeologist at BGS, cautions 'We should not be distracted by the large aquifers below the Sahara and dreams of cross-continental pipelines. The priority must be to serve those who still have to take unsafe drinking water from ponds

and holes in dry river beds — and to do this sensibly and sustainably. We should get on with the job of getting drilling costs down and construction standards up and supporting and developing groundwater professionals in Africa. Then we can concentrate on helping communities, small towns and whole nations to sustainably develop and protect the groundwater under their feet.'

(Originally published in the New York Times.)

For further information please see:

Environment Research Letters article
http://iopscience.iop.org/1748-9326/7/2/024009

The BGS web pages, including link to final report
http://www.bgs.ac.uk/research/groundwater/international/africangroundwater/home.html

BBC article
http://www.bbc.co.uk/news/science-environment-17775211

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Australian Mesozoic geochronology

Reliable microfossil-based calibration of rock units is vital during the exploration and the production of oil and gas reserves to subdivide and correlate source rocks, reservoir rocks and cap rocks accurately in petroleum systems. BGS scientist Jim Riding has worked in Australia in an effort to improve the biostratigraphical resolution and calibration of the Jurassic and Early Cretaceous palynomorph (organic microfossil) biozones used in the north-west shelf of Australia, the principal hydrocarbon province down under. He described many new species of Jurassic dinoflagellate cysts which were subsequently used to define many new subzones in the standard Australasian Mesozoic biozonation. The majority of the key microfossil index taxa are not present outside this continent.

Jim and colleagues have also revised the geochronology of the Triassic and Jurassic biozones, which were not tied effectively to the standard geochronological scheme, largely based on type sections in the northern hemisphere. They discovered that some of the Mid Jurassic zones are significantly older than they were originally believed to be. For example, the *Wanaea indotata* Zone is now entirely assigned to the Bathonian rather than the Late Bathonian to Early Callovian. In addition, the Late Bajocian to Early Bathonian *Wanaea verrucosa* Biozone has been studied in considerable detail. Most recently, Jim has worked on the calibration of the Early Cretaceous biozones.

The vast majority of the Jurassic strata in onshore Australia are deltaic, but there is one prominent marine bed with abundant ammonites in Western Australia — the Newmarracarra Limestone. Strontium isotope ratios worked out by BGS have confirmed the ammonite-derived age of Early Bajocian (Mid Jurassic) age; a good example of the integration of biostratigraphy and chemostratigraphy.

This taxonomic work, the recalibration of the Triassic and Jurassic biozones and the chemostratigraphical tie-point has markedly improved the resolution and accuracy of the standard biozonation used by the oil industry in Australia and adjacent regions within the principal producing successions. This enhancement should impact on both hydrocarbon recovery levels and resource assessment, thereby helping the efficiency of the oil industry and enhancing government revenues.

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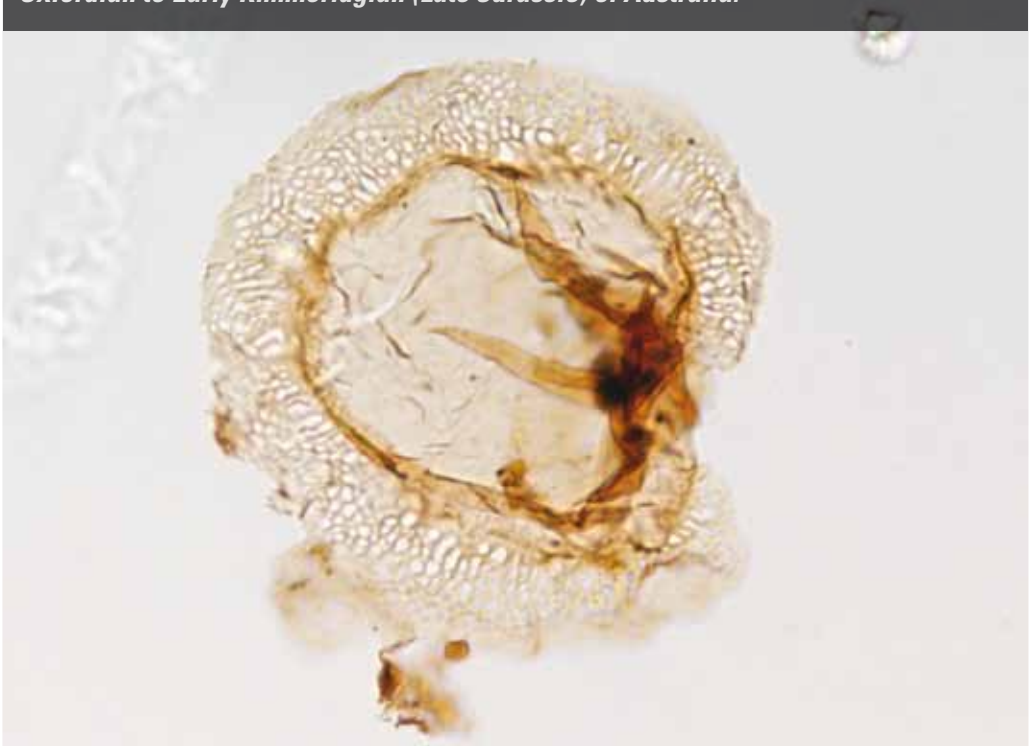
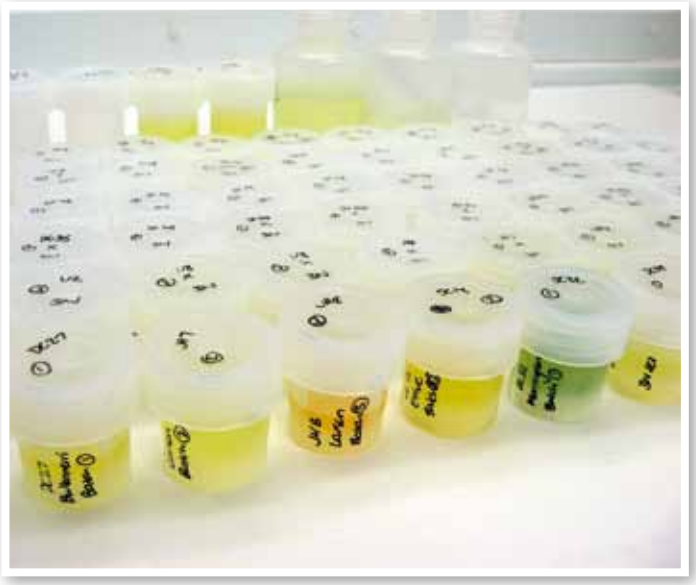
The dinoflagellate cyst* Wanaea clathrata *Cookson & Eisenack 1958. The diameter of this specimen is 100 µm. This distinctive species is a marker for the Late Oxfordian to Early Kimmeridgian (Late Jurassic) of Australia.



Calibrating Earth's time

EARTHTIME is an international initiative aimed at improving the tools for quantifying geological time. The methods for dating rocks and minerals are being refined to produce the highest resolution results, applied to a range of geological topics, from early animal evolution some six hundred million years ago to much more recent environmental change.



Quantifying geological time has become a key tool for understanding the geological archives, from the stratigraphical record of the evolution of life and environments, the discovery of mineral and energy resources, through to understanding environments from ten thousand years old to several hundred thousand years old. This understanding provides the context for anthropogenic climate change. Radio-isotopic dating methods have been used to define the age of the solar system (about 4.567 billion years ago), and also used to constrain the rates of sea-level change related to ice-sheet collapse since the Last Glacial Maximum (about 19 thousand years ago).

The NERC Isotope Geoscience laboratory (NIGL) plays a lead role in the EARTHTIME initiative (http://www.earth-time.org), an international effort aimed at improving radio-isotopic dating methods and their application. This has involved carrying out new calibration experiments, producing new reference materials and working with colleagues in laboratories across the globe. These efforts ensure that the dates produced by each laboratory, and by different methods or dating systems, can be compared without loss of precision, so maximum insight into processes studied can be gained. Geochronology at the BGS is focussed on a wide range of important geological processes that help us understand the evolution of the Earth, past present and future.

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King Edward Point geomagnetic observatory

South Georgia, located in a region sparsely populated by magnetic observatories and bordering the South Atlantic magnetic anomaly, is of specific interest for both global magnetic modelling and space-weather hazard.

Radiation belts are regions of the Earth's near-space environment where high-energy particles, mainly protons and electrons, are held captive and trapped by the Earth's magnetic field. The Earth is therefore protected by its magnetic field from radiation from space. One of the radiation belts, the smaller but very intense Van Allen Belt, makes its closest approach to the planet's surface in an area around Brazil and the South Atlantic.

At present, the global magnetic field is weakening and in the region of the South Atlantic this decrease is happening at a rate ten times faster than the norm. The accelerated weakening of the magnetic field in the South Atlantic, coupled with the close proximity of the Van Allen Belt to the surface of the Earth, results in this area being very poorly protected and, for a given altitude, radiation intensity is much higher than elsewhere. This region is known as the South Atlantic Anomaly.

There are no adverse effects on the surface of the planet, but the anomaly is very relevant to orbiting satellites, even in low Earth orbit (a few hundred kilometres). In the case of the Hubble Space Telescope, it does not take observations while passing through the South Atlantic Anomaly. On the International Space Station, flashes of light, thought to be the effect of radiation directly stimulating the retinas of astronauts, were a common experience when flying through the zone.

Satellite failure and loss of communication is much more common in this stronger radiation zone, resulting in operators of orbiting satellites endeavouring to avoid this area, which has become known as a 'Bermuda Triangle' for satellites. Those operators which have satellites that do have to travel in the region routinely shut them down, or switch them to 'safe mode' to avoid damage while passing over the Atlantic between Brazil and Africa.

In February 2011, with the co-operation of the British Antarctic Survey (BAS) and the government of South

Georgia, BGS completed the final phase of a project to re-establish a magnetic observatory on the southern Atlantic island of South Georgia. The geomagnetic field is now being continually monitored on the island for the first time in nearly thirty years.

Over nine days in early 2011, cabling, instruments, recorders and the absolute measuring hut were added to the groundwork completed in 2010 at the BAS research base at King Edward Point. We started recording on the 25th February — the first continuous magnetic measurements on the island since 1982.

Situated close to and using some of the foundations of the previous installation, which BAS operated until 1982, the new observatory has been designated the International Association of Geomagnetism and Aeronomy (IAGA) code KEP (for King Edward Point). A proprietary BGS acquisition system automatically samples a three-component fluxgate and a total-field proton magnetometer. The processed and recorded data are then transmitted to Edinburgh in near-real time using the BAS satellite network link. In addition, BAS staff make periodic, manual absolute vector measurements which are used to aid quality control.

The establishment of the King Edward Point Magnetic Observatory, located in a part of the world where ground observatories are sparse, will provide vital data for researchers studying this anomaly in order to:

- understand the rapid weakening of the magnetic field in the region

- help nullify the adverse affects on spacecraft
- further understand space weather in general.

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The **BGS glacier observatory** in **Iceland**

The BGS glacier observatory was established at Virkisjökull in southeast Iceland in 2009 to monitor and investigate the processes contributing to rapid glacier retreat. The project started with the installation of an automated weather station and one of the largest terrestrial LiDAR scans ever attempted by BGS. Since then the observatory science has grown each year, and now teams of scientists from disciplines across BGS travel to Virkisjökull several times a year to undertake projects that include high resolution landscape change, structural glaciology, glacier dynamics and seismicity, sedimentology, meltwater chemistry, and groundwater recharge and hydrology.

The driving aim behind the project is to understand how the dynamic processes within a glacial catchment vary over diurnal, seasonal and annual scales. The project therefore seeks to monitor and quantify the various components of the glacier catchment, and through high resolution observation determine the linkages and drivers within the system. This comprehensive approach is genuinely pioneering, and the suite of techniques are not being used anywhere else in the world.

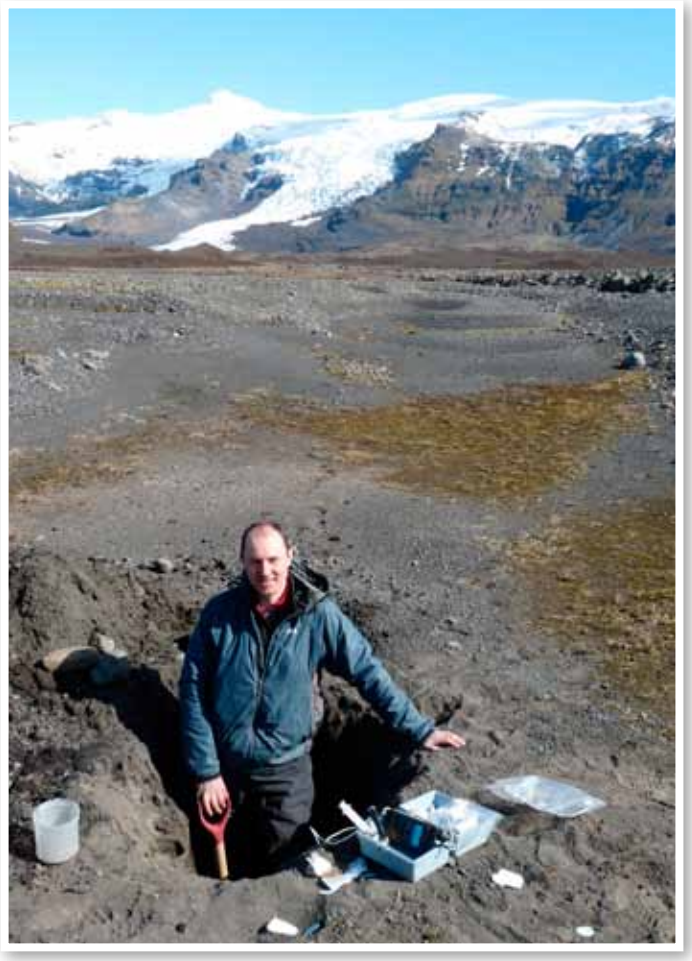
Changes in the dynamics of glaciated catchments are important to Iceland and its people, who face a future with less ice to attract tourists, and increased threats to infrastructure from flooding and landscape change. However critically the project will also provide data for other glaciated regions of the world undergoing similar changes, such as the European Alps, New Zealand and the North American Cascades. Perhaps more importantly for the global human population results of groundwater and hydrological studies at Virkisjökull are relevant to populations in semi arid regions, such as parts of Asia and South America, whose water supplies rely on glacial sources. Virkisjökull is being used by BGS Hydrogeologists as a model for deglaciating catchments supplying the Ganges Basin, where a population of millions depend on the glaciers high in the catchment for all of their water needs.

At Virkisjökull we now have equipment to constantly monitor many of the physical

components of the glacier and its catchment throughout the year. We have automated much of the data capture from weather stations, stream gauges, seismometers and GPS stations. Dedicated mobile data communication links are now established with many of the sensors at the site. This allows us to download data on demand and to make much of this data publicly available through the BGS website (see link below). We are also developing a strong working relationship with the Icelandic Meteorological Office, and our seismometers and some of our permanently installed GPS equipment are now integrated into their national network to boost their volcanic monitoring.

The BGS field teams are using geophysical surveys and structural mapping to explore how glacier decline is influenced, not only as one would expect, by local climatic conditions, but also by the glacier's internal structure. Our annual Terrestrial LiDAR scans, allied with sediment analysis, are providing insights into how the catchment evolves as the ice melts, and how the landscape responds once the glacier has gone. Meltwater chemistry analyses are revealing not only for how long and where water is stored and produced in the glacier, but also how we might start to understand more about the volcano beneath the ice. By studying the relationship between surface and groundwater hydrology of the catchment through our borehole network and high resolution stream gauging, we are able to determine the balance between water and snow inputs and outputs from the system, and how each of these affect groundwater recharge. Our NERC PhD student, based at the University of Dundee is investigating the linkages between glacier hydrology and the wider hydrology of the catchment. Finally we are monitoring the rate and composition of the ecology on site as the landscape adapts to glacier retreat. From this we are gaining insights into plant colonisation and soil formation, fundamental to the future of the landscape of Iceland, as ice-free areas most likely grow in size in the coming decades.

The project is representing BGS and NERC at the Royal Society Summer Science Exhibition in London between the 1st and 7th of July 2013. For more information on that exhibition and more detailed descriptions of the science, progress reports, newsletters and articles from the BGS glacier observatory, visit the project web site at http://www.bgs.ac.uk/research/glacierMonitoring/home.html, or contact Dr Jez Everest jdev@bgs.ac.uk.



Tsunami hazard research

The BGS has an established international reputation for tsunami hazard research both at sea and on land. We led the marine research that identified the cause of the 1998 Papua New Guinea tsunami that killed 2200 people. We carried out marine-based research into the 2004 Indian Ocean tsunami event, and in March 2011 when Japan was struck by a massive earthquake and tsunami, BGS scientists were part of the first international team to study the impacts.

The Japan earthquake was one of the largest ever recorded, but it did little damage. It was the tsunami that caused the greatest loss of life and building damage. At the final count 16 000 people are known to be dead and almost 3000 more are missing. Around 300 000 people were made homeless.

In May and June 2011 and February 2012, BGS scientists visited the tsunami-devastated region of north-east Japan to study the impact of the 11 March 2011 event. During the first visit we joined an international team studying sediments laid down by the tsunami. During the second and third visits we carried out further research on the sediments and, using satellite imagery, mapped the impact of the tsunami on the coast of northern Honshu.

This research will lead to a better understanding of the magnitude of past events, the timescales over which they occur and the impact of the tsunami on the coastal zone.

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Teaching tsunami and coastal geohazards

Two-thirds of the world's population live on coastal margins. This figure is projected to increase in the future so there is a growing global concern about the capacity of natural coastal environments to adapt to increasing levels of human impact. Furthermore, this increased impact is likely to be exacerbated by the effects of climate change, sea-level rise and flooding from tsunamis.

A new generation of scientists is needed to better understand the processes operating in the coastal zone, thus through knowledge exchange, BGS has developed focused training courses to impart essential knowledge to both practitioners and end users of the future. The courses can be adapted to any level from technical officer to postgraduate. They provide an overview of coastal environments and their susceptibility to natural hazards.

Coastal hazard assessment is complex because it is influenced by both marine and terrestrial processes that include rapid sediment evacuation downstream by steep-gradient streams, subsidence, cliff falls and coastal recession on the one hand, and storm surges and extreme flooding events (such as from tsunamis) on the other.

The courses provide an overview of coastal geological hazards including: coastal erosion, sea-level rise, major storms (includes storm surge and high winds), extreme seasonal high-wave events, volcanic and seismic activity and coastal stream flooding. They also provide an introduction on tsunami hazard and advanced lectures on tsunami sources and impact.

Contact Dave Tappin
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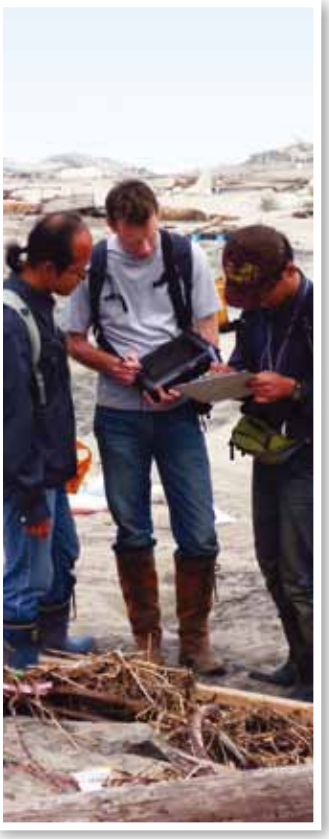

PanGeo — geohazard information for 52 European towns and cities

PanGeo is a three-year collaborative project involving the 27 EU national geological surveys. It started in February 2011 with the objective of enabling free and open access to geohazard information in support of global monitoring for environment and security (GMES, http://www.gmes.info/). It will provide an *INSPIRE- compliant, free, online geohazard information service for 52 of the largest towns and cities in Europe — roughly 13 per cent of the EU population.

Each geological survey will provide a ground stability layer and accompanying interpretation. Following a design phase and the creation of a detailed methodology we are now producing geohazard information for PanGeo towns. Inputs to the creation of the ground stability layer include:

- satellite persistent scatterer interferometric synthetic aperture radar (InSAR) processing, providing measurements of terrain motion
- geological and geohazard information
- land-cover and land-use data contained within the GMES Land Theme's Urban Atlas

The five target user-groups for PanGeo services are:

- local authorities (planning and building development and control)
- local authorities (civil protection agencies)
- national geological surveys
- commercial business (conveyancing, insurance)
- the public

We hope that other towns will procure the PanGeo service as policy-makers, regulators, and the public will all benefit from this information. They will be able to:

- systematically assess geohazards in each of the 52 towns involved
- gain an understanding of the geohazards
- know who to talk to for more information
- statistically analyse and compare geohazard phenomena across EU countries
- better understand the socio-economic costs
- make better informed decisions, e.g. on civil defence, planning controls

The PanGeo team comprises 13 core partners, as well as all 27 EU national geological surveys. The core team partners are Fugro NPA Ltd (UK Project Coordinator), British Geological Survey (UK), Landmark Information Group (UK), Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek or TNO (Netherlands), Systèmes d'Information à Référence Spatiale or SIRS (France), Institute of Geomatics (Spain), Bureau de Recherches Géologiques et Minières or BRGM (France), EuroGeoSurveys (Belgium), AB Consulting Ltd (UK), European Federation of Geologists (Belgium), Tele-Rilevamento Europa (Italy), Altamira Information (Spain), Gamma Remote Sensing (Switzerland).

*INSPIRE — Infrastructure for spatial information in the European community

For further information please see www.pangeoproject.eu/

Contact Luke Bateson
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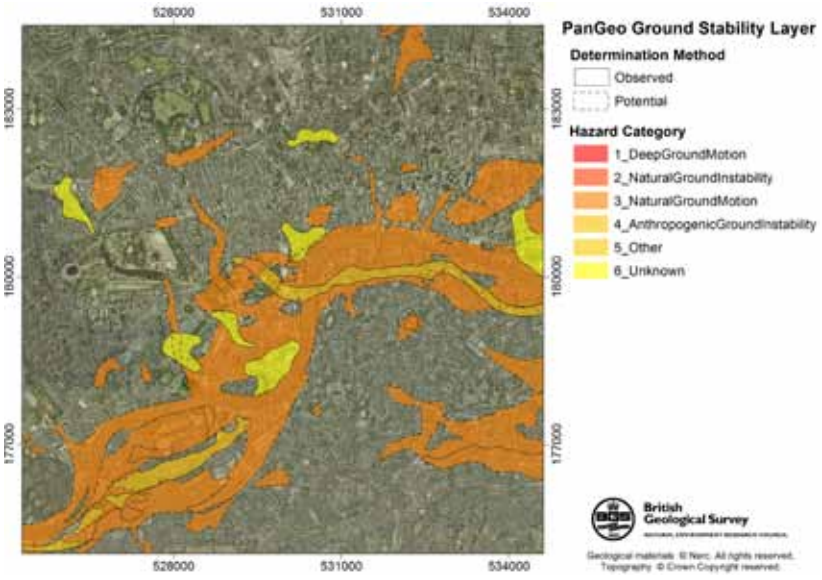

An example of the PanGeo Ground Stability Layer for the control area of London. Polygons are displayed according to their geohazard category. The boundary indicates if the hazard has been observed or if the area has the potential to become a hazard.

BGS International — a year on

In 2010, the BGS senior leadership team decided to spin out a company that would be more able to take international commercial projects forwards than could BGS itself, and the new company, International Geosciences Services Ltd (currently trading as BGS International (BGSi)), started trading in June–July 2011. It was not an easy decision, although it was very much in line with Government policy to spin out companies when it made sense to do so (a policy that arose from the Baker Report of 1999).

BGSi won some early business in Botswana, South Sudan and Nigeria. Peter Zawada joined the management team, comprising former BGS staff David Ovadia and Bill McCourt, and brought very valuable African contacts.

BGSi is owned partly by BGS (NERC), partly by the Rainbow Seed Fund, which in turn is owned by the Research Councils, and partly by David and Bill. That will soon change, as they bring in new investors to fund the planned expansion and diversification. John Ludden is a non-executive director on the Board.

The company's core business is to win and deliver large, World Bank-type projects in developing countries. So far, they have won almost every tender they have bid for, although many of them have a long lead time. This success is partly because they are selective in what they bid for, and partly thanks to low overheads which enable BGSi to compete very effectively with larger organisations.

Bill, Peter and David intend to build project teams comprising some current BGS staff, perhaps some retired or partially retired BGS staff and other high-quality staff from elsewhere.

Contact David Ovadia
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OneGeology-Global: a project update

OneGeology is an international initiative of the geological surveys of the world, with 117 participating countries. Thanks to the enthusiasm and support of these nations, the initiative has progressed rapidly towards its target — creating a dynamic geological map data of the world, available to everyone via the web. OneGeology has four basic objectives:

- improve the accessibility of geological map data
- exchange know-how and skills so that all nations can participate
- accelerate interoperability in the geosciences and the take-up of a new 'standard' (GeoSciML)
- use the global profile of OneGeology to increase awareness of the project and the relevance of the geosciences

There are currently 255 WMS (web mapping service) and 24 WFS (web features service) data layers being served through the portal. There are one or more layers for 55 nations, 20 continental or other large world regions and 11 smaller sub-national regions.

Recently...

The OneGeology annual meeting was successfully held in conjunction with the IGC conference in Brisbane in August 2012. Delegates could attend a number of presentations and keynotes as well as visit the OneGeology stand.

OneGeology received an award for 'Excellence in Geospatial Standards Implementation' from the Geospatial World Policy Awards. The award was presented to Ian Jackson, OneGeology Executive Secretariat, at the Geospatial World Forum 23–27 April 2012 in Amsterdam.

The 'OneGeology4Kids' pages, aimed at children under 10 years old, have added content and are translated into several languages. A translation into Russian is the latest addition.

New geodiversity web pages, in association with UNESCO and Geoparks, were released in December 2011. They explore geodiversity and the ways in which it is protected and celebrated around the world in the form of GeoParks and World Heritage Sites, linked in to the geological maps and the portal.

The proposal to incorporate OneGeology was a significant task during 2011–2012 resulting in the launch of a consortium. Although this process is time consuming, the aim is that it will provide stability and a formal structure for OneGeology, ensuring its future longevity and a more robust funding structure.

For further information please see www.onegeology.org

Contact onegeology@bgs.ac.uk

OTHER NEWS in 2012

- BGS and the Directorate General of Hydrocarbons, India, signed a memorandum of understanding in April.
- Jeremy Giles, BGS's Head of Information Management, visited Malaysia on 14–17 May to advise on strategic data management in connection with identifying suitable disposal sites for low-level waste and disused sealed radioactive sources.
- BGS coordinated the South Africa — EU Cooperation on Carbon Capture and Storage (SAfECCS) project from 2011 — 2013 with support from the South African Centre for CCS (SACCCS).This project promoted cooperation in the field of CCS (carbon capture and storage) between South African and European partners and provided essential data to support the proposed South African pilot CO_2 storage project. Project funding was provided by the European Commission in the form of a EuropeAid Grant (70%) and SACCCS (30%). The project reports will be available through www.sacccs.org.za soon.
- BGS has developed a strategic partnership with Coffey Mining, Brazil, to supply consultancy services, collaborative research, training and technology R&D to Vale Mining, Brazil — the largest iron ore mining company in the world. We are working with them to implement the BGS digital workflow, incorporating SIGMA, GeoVisionary and data management.
- BGS Volcanology contributed to the 'Anticipation of Geophysical Hazards' report for the Government Office for Science Foresight report on 'Reducing Risks of Future Disasters'.
- BGS is working for the Building and Construction Authority in Singapore an 18-month project to digitise the country's geological maps, prepare a lexicon database and a 3D geological model and provide training in GSI3D software.

Image courtesy of Lorraine Field.

For more information please contact:

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NATURAL ENVIRONMENT RESEARCH COUNCIL