



British  
Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL



2012–13

# Annual Science Review





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# British Geological Survey Annual Science Review 2012–13

The British Geological Survey (BGS) is part of the Natural Environment Research Council and is its principal supplier of national capability in geoscience.

We advance understanding of the structure, properties and processes of the solid Earth system through interdisciplinary surveys, monitoring, modelling and research for the benefit of society.

We are the UK's premier provider of objective and authoritative geoscientific data, information and knowledge for creating wealth, using natural resources sustainably, reducing risk and living with the impacts of environmental change.

## **Our vision**

To be the world's leading centre for geoscience impact.

Some research reported here may not yet have been peer-reviewed or published.



# The Natural Environment Research Council

The Natural Environment Research Council (NERC) is the largest funder of environmental science in the UK. It invests public money in cutting-edge research, training and knowledge transfer in the environmental sciences. NERC scientists study and monitor the whole planet, from pole to pole, and from the deep Earth and oceans to the edge of space. They address and respond to critical issues such as environmental hazards, resource security and environmental change. Through collaboration with other scientific disciplines, with UK business and with policy-makers, the NERC provides the knowledge and skills to support sustainable economic growth and public wellbeing — reducing risks to health, infrastructure, supply chains and our changing environment.

The BGS's programme is closely aligned with the NERC's strategic goals, which are to deliver world-leading environmental research at the frontiers of knowledge:

- Enabling society to respond urgently to global climate change and the increasing pressures on natural resources.
- Contributing to UK leadership in predicting the regional and local impacts of environmental change over timescales from days to decades.
- Creating and supporting vibrant, integrated research communities.

With its researchers and stakeholders, the NERC develops the priorities that provide a focus for the marine, polar, atmospheric, geological, terrestrial and freshwater science communities. This research is often multidisciplinary and carried out in collaboration with national and international partners.

The NERC runs a fleet of research ships and scientific aircraft, maintains bases in some of the world's most hostile environments, and invests in satellite technology to monitor environmental change on a global scale.

The NERC is committed to developing UK and international capability across the environmental sciences. It funds centres and universities to carry out research and to train and support a world-class community of environmental scientists.

Visit [www.nerc.ac.uk](http://www.nerc.ac.uk) for more details.

# Contents

Introduction	6
Beyond the map	9
Our dynamic environment	14
A resilient society	18
Building a natural resource base	23
Sharing our research	28
Awards	31

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# Introduction

## Executive Director John N Ludden

Geologists are trained to think in three dimensions — or four dimensions, including time. Geological maps are, in fact, a two-dimensional representation that a good geologist can convert to a three-dimensional picture in their mind's eye, even as far as imagining ancient river beds and mountain ranges. New technologies increasingly allow us not just to imagine but to depict all three — or four — dimensions and, more importantly, we can add key properties such as porosity, fluid flow rate, or degree of compaction to enhance our shared understanding of the geology. However, we need to understand the limitations of the geological models we construct and communicate the uncertainties to our stakeholders, particularly those involved in making sensitive decisions.

*Beyond the map* on page 9 outlines progress with our geological model for the UK. This 'cut-out' model is underpinned by a wealth of geophysical and borehole information, along with the knowledge both of our own geologists and our collaborators. Translating the information into research and decision-making tools is our core role, though only every now and then does the need for this underpinning role for the UK economy become apparent to the public and government. The release of an estimate of the shale gas resource for northern England in June 2013 ([www.bgs.ac.uk/shalegas](http://www.bgs.ac.uk/shalegas)) resulted from an intensive study, funded in part by the Department of Energy and Climate Change during 2012/13. The estimated resource is large, with the median value being 1300 trillion cubic feet; it needs to be proven through exploratory drilling before the reserves of recoverable gas can be estimated, based on engineering

tests and an understanding of where the sweet spots that yield gas are located. This will be a long process and will need to be closely monitored and re-evaluated along with the environmental consequences of developing the industry.

The key role of monitoring, measuring and modelling the subsurface will be the hallmark of the BGS's science for the next decade. We must be able to model the geology of the subsurface at timescales consistent with a human lifetime because it is not only the source of many of our resources but also where we will sequester carbon dioxide, dispose of radioactive waste and store gas and other energy resources.

We live on a dynamic planet and our global reach in monitoring programmes ranges from our own shores across the globe. The UK's weather in 2012 was unusually wet, and as one would expect, a year of numerous landslides — in some months as many as five times the average. Although unfortunate, these events allow us to calibrate the earth system and design for a wetter world, and this research will be equally applicable in regions outside of the UK. At the opposite extreme is the understanding of water resources in times of drought, both in highly urbanised areas such as the London Basin and across Africa; our expertise in groundwater studies led to a significant increase in research funding in 2012/13. We have added significant monitoring capability to the Iceland Observatory this year and while volcanic activity is quieter, we are in a significantly better position to monitor future events and have developed expertise in seismology, the dispersion of volcanic gases and communication of hazards to key agencies through numerous research contracts with the NERC, EU and others.

The UK and international resource base is increasingly at the fore of our work. This involves not only the unconventional gas resource mentioned above, but also geothermal energy and gas combustion with carbon capture and storage, as well as mineral resource studies in technology metals and minerals in the UK continental shelf. The pressure to use these resources must be weighed against the environmental costs and the BGS provides the best available information to the resource extraction companies as it does to NGOs and the public.

The BGS has led the world in managing data and we are constantly innovating in broadening access to information through modern technology. The challenge now is to integrate the geological data with other environmental and social sciences data in order to provide the public with well-reasoned responses to enquiry. To facilitate this we have



Mike Stephenson.



Denis Peach.

created a 'Geoscience in Society' research team to respond to societal questions related to our science.

At the end of the 2012/13 financial year, we employed 516 scientists working with more than 40 universities and institutes, and 120 staff supporting our scientific objectives. We opened the renovated head office in Keyworth, Nottinghamshire (431 staff) and agreed with Heriot-Watt University to relocate our Edinburgh office (174 staff) to a new joint facility on their campus. We maintained our regional sites (58 staff) in Cardiff, Wallingford and Belfast, our London office at the Natural History Museum, and our global observatory system; the latter was further enhanced in Iceland and also in the southern Atlantic.

Our budget in 2012/13 was £43.2 m plus a capital allocation of £747 k. Funding from the NERC comprised an allocation of £20.8 m plus competitively won research funds and service level agreements totalling £3.6 m. Funding from external sources totalled £18.8 m and included £1.8 m from the EU, £2.9 m from other government departments, £3.5 m from royalties, licensing and sales income, and £10.6 m of research income from the private sector.

During the year we worked with more than 150 private sector customers, most often in consortia with other surveys. The impact of our work was recognised in the results of the NERC research review prepared in 2012/13, in which 92% of our reports were recognised as excellent or outstanding.

In addition to our bespoke science laboratories in geochemistry, rock properties, geological visualisation and others, at the start of the 2013/14 financial year we took on the management of the NERC Earth Sector Services and Facilities which may be grouped as follows:

- NERC isotope geoscience facility, encompassing five isotope laboratories in Keyworth, Glasgow and Edinburgh;

- a radiocarbon facility including laboratories at Oxford and East Kilbride; and
- a geophysics and geodesy group, including the UK terrestrial and marine equipment pools, SeisUK, the Herstmonceux laser ranging facility and the UK GIS network (BigF).

While we will keep involvement in these facilities at arm's length, this further strengthens our integration with the UK university sector and in 2012/13 the BGS–University Funding Initiative supported 77 Ph.D. studentships in 35 universities and strengthened thematic research and national capability partnerships. These partnerships include:

- the Critical Metal Alliance with Exeter University/ Camborne School of Mines;
- the Nottingham Centre for Carbon Capture and Storage, Scottish Carbon Capture & Storage, and the UK Carbon Capture and Storage Research Centre;
- research into subsurface contaminants with Lancaster University;
- research into rock physics with the University of Leicester; and
- the NERC Isotope Geosciences Laboratory with the University of Leicester.

Other partnerships are in development.

The BGS intends to increase its score in research output assessments. We have achieved a 75% increase over four years in peer-reviewed papers to 245 in 2012 and the BGS scores as well as an international university in key areas where, as a survey, we can add research value.

Finally, at the end of the 2012/13 financial year Denis Peach stepped down as Chief Scientist and he retired from the BGS in June. He will remain as a research fellow within the BGS and I sincerely thank him for his contributions over the past seven years (<http://britgeosurvey.blogspot.co.uk/2013/05/denis-peach-bgs-chief-scientist.html>). Denis was replaced by Mike Stephenson who fills the role of Director of Science and Technology. Our current organisational structure is shown towards the end of this annual review.

I sincerely thank all of the BGS staff for their excellent work and our collaborators and stakeholders for their support during the year. We are in a strong position to rebuild as the economy grows, now that we have reshaped the workforce.



*Fagnfoss, Iceland.*



# Beyond the map

## New research is providing a more complete picture of the ground beneath our feet

### GB3D — adding the third dimension

In December 2012 the geological map of Great Britain was extended into the third dimension with the release of GB3D, shown as a network of cross-sections through the Earth's crust.

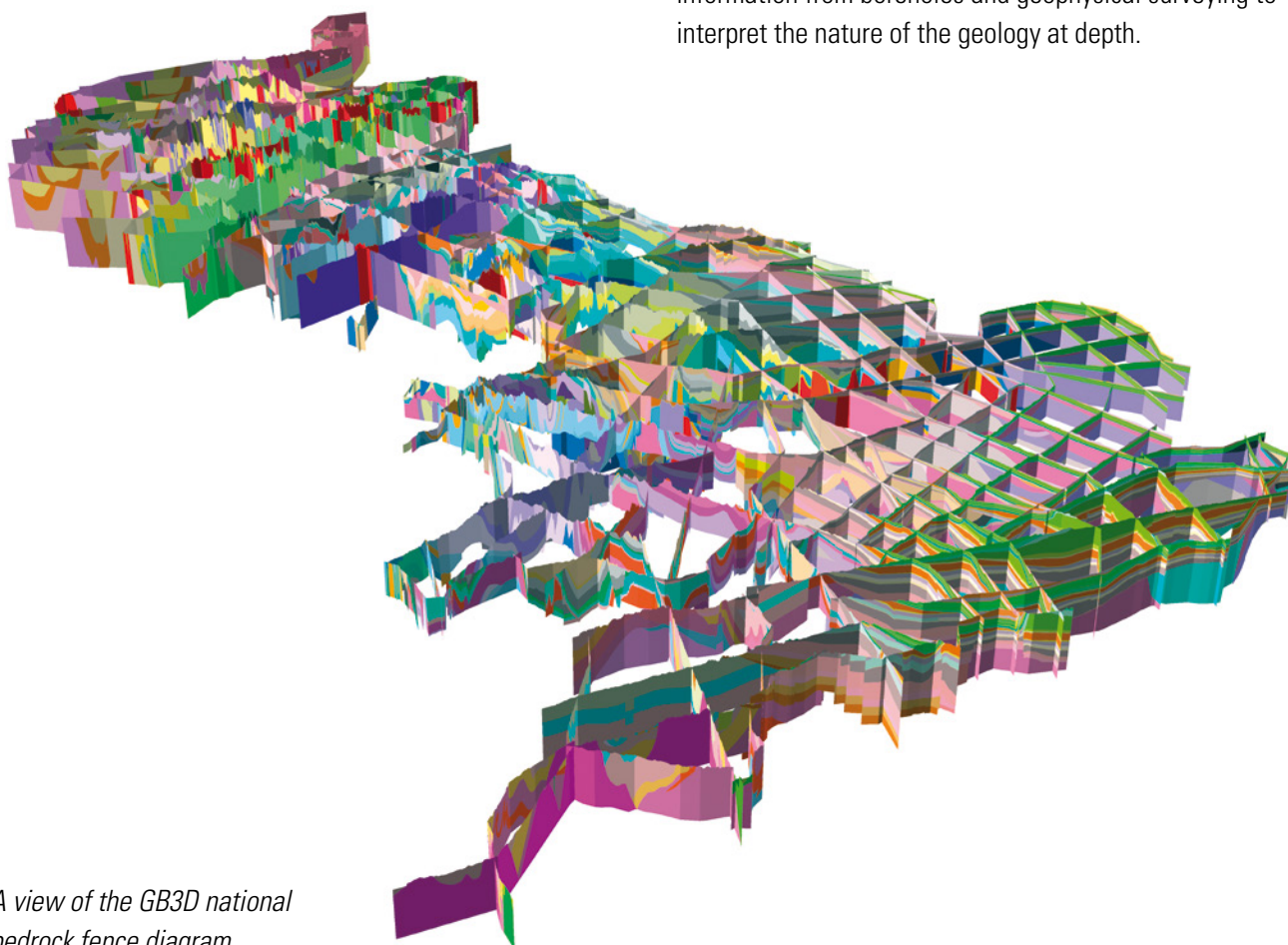
This new digital model provides a novel way to visualise the relationship of geology to landscape or resources such as water, oil, minerals, coal and gas on a national scale. It is also a useful tool in teaching and for explaining complex geological relationships to non-specialists.

Conventional, two-dimensional geological maps, showing the rocks found at the surface, typically include one or two vertical cross-sections: virtual 'slices' through the Earth's

crust that illustrate the relationship of different strata deep beneath the surface.

The GB3D digital geological model links together cross-sections of the geology beneath Great Britain to create a 'fence diagram'. The resulting fence diagram may be rotated or tilted on-screen and users can zoom in to examine a geological layer at any point of interest.

GB3D will help users to visualise the structure of rock strata beneath the surface at county, regional and national scale. This is particularly useful for scientists modelling the flow and storage of water between aquifers. The individual cross-sections are created using geological modelling software called GSI3D, which has been developed by the BGS in partnership with INSIGHT GmbH. GSI3D uses information from boreholes and geophysical surveying to interpret the nature of the geology at depth.



*A view of the GB3D national bedrock fence diagram.*



*EMODNET brings together datasets on geology, hydrography, biology, chemistry, physical properties and habitat mapping from the European seas.*

## Mapping Europe's seas: EMODNET-Geology

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 provide 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:

- rates of accumulation or sedimentation
- sea-floor geology (including age, lithology and origin)
- geological boundaries and faults
- rates 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 brings together information on hydrography, biology, chemistry, physical properties and habitat mapping from the European seas. In the preparatory phase, which ran from July 2009 to the summer of 2012, the areas covered were 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 outputs have been delivered through the World Wide Web using the multilingual portal developed for the OneGeology-Europe (1GE) project. Existing metadata will continue to be stored on the EU-SEASED website, currently being developed and upgraded under the EC-funded GeoSeas project.

For more information see: [www.onegeology-europe.org](http://www.onegeology-europe.org) and [www.geo-seas.eu](http://www.geo-seas.eu)

## Contaminated soils — what are the risks?

Research shows that, on average, we ingest 100 milligrams of soil from our local surroundings every day. Soil contains a number of chemical elements that are harmful to human health; the two of most concern in the UK are arsenic and lead.

Whether contaminated soils pose a human health risk depends on the potential of the contaminant to leave the soil and enter the bloodstream. There is thus a clear need for a practical methodology that measures the fraction of a given contaminant in the soil that, if ingested, will be soluble in the human body and available for absorption. This fraction is known as the bioaccessible fraction.

Using archived soil samples from our Geochemical Baseline of the Environment (GBASE) programme, we have developed a methodology that combines data on bioaccessibility, soil geochemistry and the geology of the soil's parent material to map the bioaccessibility of arsenic, lead and cadmium in England and Wales. The methodology is gaining wide acceptance in Europe as a standard procedure, and our research project on the development of a bioaccessibility test to aid in human health risk assessment and brownfield land reclamation (commissioned by National Grid: Gas) won an award for innovation at the Parsons Brinckerhoff 2012 awards ceremony.

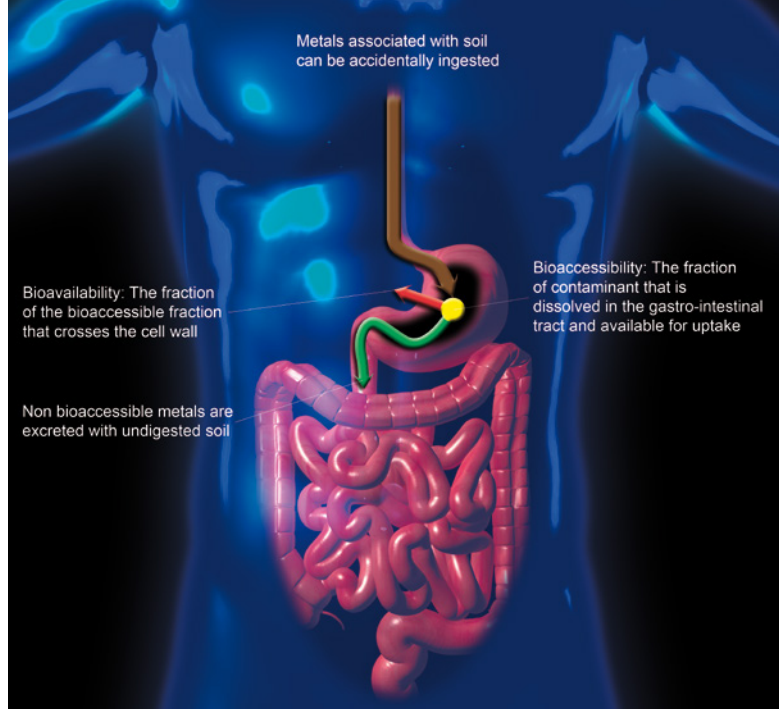
We have also analysed a comprehensive geochemical dataset for soils from Northern Ireland provided by the Tellus Survey project, combined with supplementary bioaccessibility test results from selected soil samples. This geostatistical analysis has highlighted where individual element concentrations exceeded generic assessment criteria and may reflect an unacceptable risk to human health.

Our tests have shown that, for some soil parent materials associated with elevated levels of potentially toxic elements (PTEs), the bioaccessible fraction from oral ingestion is relatively low. In contrast, the bioaccessible fraction from oral ingestion was measured to be relatively high in other soil parent materials with moderate total PTE concentrations. These findings have implications when assessing the risk to human health from specific PTEs on a regional basis. Our research has resulted in a new spatial dataset giving PTE values for the whole of Northern Ireland. This dataset will help the regulatory authorities to develop land-use strategies by helping to establish the average levels of PTEs in the soil below which long-term health risks are likely to be minimal, known as Soil Guideline Values.

## Britain in a bottle

We have carried out a survey of the inorganic chemistry of bottled natural mineral waters and spring waters from across the British Isles. During the survey we analysed 85 samples from 67 groundwater sources representing a diverse range of aquifer rock types. Analyses included the major ions and a wide range of trace elements.

While chemical analyses of water samples from domestic mains supplies in the UK are published widely online and often include a comprehensive list of analytes, reliable analyses of the chemistry of bottled water are harder to find.



*The fraction of any ingested soil contaminant that is available for absorption is the bioaccessible fraction.*

And although most manufacturers supply representative major-ion data on the labels, trace elements are usually excluded.

Our key findings were:

- The concentrations of the inorganic constituents analysed were well within the limits for compliance with European and national standards for bottled waters.
- A small number of samples had relatively high uranium concentrations (10–13 micrograms per litre), though none exceeded the current provisional World Health



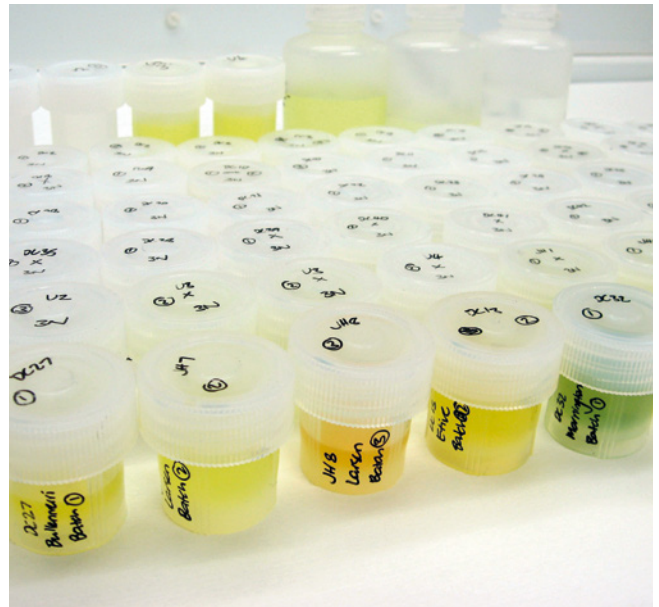
Organisation guideline value for uranium in drinking water (30 micrograms per litre) and no European limit currently exists for uranium in bottled water.

- The concentrations of antimony were higher in water samples from PET (plastic) bottles compared to those in glass containers or to raw groundwater samples from the corresponding aquifers. The higher values probably derived from contamination from the PET bottles. In no cases, however, did concentrations approach the limit for antimony in natural mineral waters or water intended for human consumption (5 micrograms per litre).
- In comparison with raw groundwaters from equivalent aquifers in Britain, the bottled waters had lower overall concentrations of aluminium, cadmium, copper, iron, manganese, lead, and zinc. This is consistent with loss by processing before bottling (e.g. by aeration, settling, filtration); the choice of material used for pipework at the bottling plants may be an additional factor.

Our results suggest that, for the most part, the major ions in the bottled waters appear representative of the groundwater in their host aquifers. However, many of the trace elements appear to have been modified significantly from natural compositions found underground as a result of processing.

## Calibrating deep time

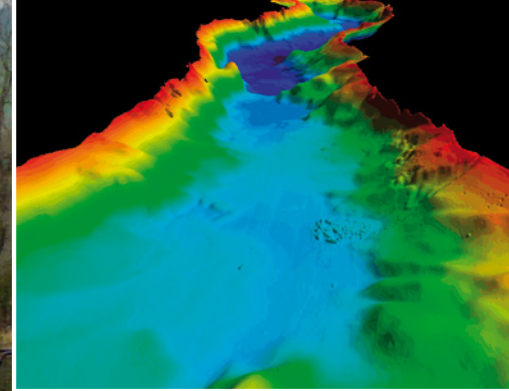
Geochronology at the BGS is focused on a wide range of important geological processes that help us understand the evolution of the Earth, past present and future.



EARTHTIME is an international initiative to improve the tools for quantifying geological time. The methods for dating rocks and minerals are being refined to produce the highest resolution results that can be applied to a range of geological topics.

Quantifying geological time has become a key tool for understanding the geological archives, whether the topic of interest is the stratigraphical record of the evolution of life, the discovery of mineral and energy resources, or studying the Earth's environments from several hundred thousand years ago. This understanding provides the context for anthropogenic climate change. Radio-isotopic dating methods have been used to define the age of our Solar System (about





*Inset: Multibeam data from the North Basin of Windermere (looking north). Red colours indicate shallow areas and blue colours indicate deep water.*

*The RV White Ribbon on Lake Windermere during fieldwork in September 2012.*

4.567 billion years), 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 Geosciences Laboratory (NIGL) plays a lead role in the EARTHTIME initiative. This has involved carrying out 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, providing maximum insight into the processes studied.

For more information see: [www.earth-time.org](http://www.earth-time.org)

## The unseen landscape of Lake Windermere

In collaboration with the University of Southampton and the Environment Agency we have funded a research project to investigate modern and glacial environments and processes in Lake Windermere.

A multibeam bathymetric survey of the lake was undertaken in September 2010 on the BGS research vessel RV *White Ribbon*. The multibeam echo-sounder transmits sound energy and analyses the return signal (echo) that has bounced off the lake bed. The time for the acoustic signal to travel to the lake bed and back to the receiver is measured

and used to generate a 'landscape' map of the lake bed. This map shows a number of debris flows, the largest of which is found in the North Basin and extends 450 metres into the lake to a depth of around 45 metres. Potential trigger mechanisms of the debris flows in Windermere include river inputs, hill slope runoff processes, and human activity, such as dredging.

We plan to produce an updated bathymetric chart using the 2012 survey data combined with a survey chart from 1937. The new data will provide a number of enhancements, including more detail in the shallow parts of the lake. The new chart will be a useful resource for local communities, National Park lake wardens and other lake users.

For more information see: [www.bgs.ac.uk/research/highlights/2012/lakeWindermere.html](http://www.bgs.ac.uk/research/highlights/2012/lakeWindermere.html)

## 3D modelling for CROSSRAIL

Using GSI3D software, we have outlined the ground conditions and presence of faulting in bedrock at the proposed CROSSRAIL underground station at Farringdon in London. This had not been possible to do via other commonly-used methods. The outcome, an improved understanding and recognition of a complex fault pattern, optimised future ground investigation and had a significant impact upon the assessment of risks for construction, design and, ultimately, on final costs.



*Icefall on Falljökull, Iceland.*

# Our dynamic environment

## How the world around us has changed, and is changing

### Glacier monitoring in Iceland

Our observatory at Virkisjökull in south-east Iceland was established to study the evolution of the glacier and surrounding landscape, including their responses to regional climate. The observatory began operating in 2009, and new equipment has been installed each year to monitor the key components of this glaciated catchment. These include climate, ice dynamics, landscape change, hydrology and groundwater.

Sensors at the site collect climate and seismic data continually, some of which are available through our website. Repeated high-resolution surveys reveal changes over time in the glacier and land surfaces, as well as the deposits beneath. The cutting-edge technologies we deploy are not used in such a combination anywhere else in the world. They provide unique insights into the processes of landscape formation and the responses of glacial systems to climate forcing.



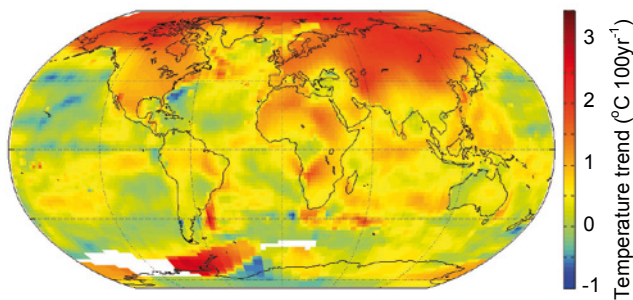
*Scanning the ice with ground penetrating radar on Falljökull, Iceland.*

### Warming on the Antarctic Peninsula

Rapid warming over the past 50 years on the Antarctic Peninsula is associated with the collapse of a number of ice shelves and accelerating glacier mass loss. In contrast, warming has been comparatively modest over West Antarctica and significant changes have not been observed over most of East Antarctica, suggesting that the palaeoclimates recorded in ice cores from these areas may not be representative of the climate history of the Antarctic Peninsula. The NERC Isotope Geosciences Laboratory at the BGS has measured deuterium isotope variations in ice cores from James Ross Island on the Peninsula to investigate how temperatures have varied. The results show that the

Antarctic Peninsula experienced a warm period in the early Holocene followed by stable temperatures from about 9200 to 2500 years ago that were similar to modern-day values. The development of ice shelves near James Ross Island in the late Holocene coincided with pronounced cooling from 2500 to 600 years ago. Although warming of the north-eastern Antarctic Peninsula began around 600 years ago, the high rate of warming over the past century is unusual (but not unprecedented) in the context of natural climate variability over the past two millennia. The connection shown here between past temperatures and the stability of ice shelves suggests that warming for several centuries rendered those shelves on the north-eastern Antarctic Peninsula vulnerable to collapse. Continued warming to temperatures that already exceed the stable conditions during most of the Holocene epoch is likely to cause ice-shelf instability to encroach farther southward along the Antarctic Peninsula.

This research is published as a paper [doi:10.1038/nature11391](https://doi.org/10.1038/nature11391)

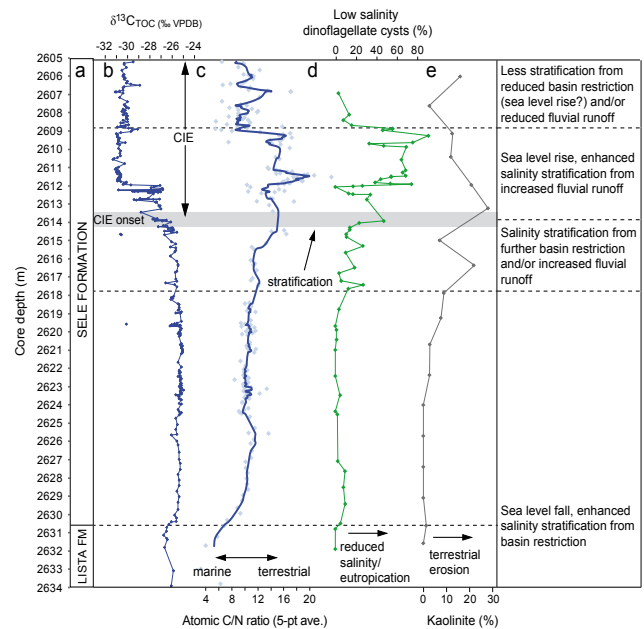


Temperature trends for the period 1958 to 2008 show the rapid regional warming of the Antarctic Peninsula.

## Climate change lessons from the past

One of the most extreme periods of climate change known to have occurred during the past 65 million years resulted in global temperatures rising by up to 8 degrees Celsius. This event is known as the Paleocene–Eocene Thermal Maximum (PETM) as it marks the boundary between the two epochs. It is preserved in the North Sea sedimentary record where rapid sedimentation has resulted in a highly expanded stratigraphical sequence. Scientists from our climate change research group and the NERC Isotope Geosciences Laboratory (NIGL) have shown that the PETM is documented in exceptional detail by variations in the value of  $\delta^{13}\text{C}$ , a measure of the stable carbon isotope ratio carbon-13:carbon-12 in preserved organic matter.

Pollens and spores analysed in the same samples have allowed us to a reconstruct, for the first time, possible



Geochemical, micropalaeontological, and sedimentological data for North Sea core 22/10a-4. (a) Lithological formations, (b) bulk total organic carbon (TOC)  $\delta^{13}\text{C}$ , (c) carbon/nitrogen ratio, (d) dinoflagellate cysts tolerant of low salinity and high nutrients as percentage of all dinoflagellate cysts with known salinity preference, and (e) percentage kaolinite.

changes in the vegetation on the landmass surrounding the North Sea during the PETM. These data demonstrate that about 1000 years before a marked carbon isotope excursion (CIE) the salinity gradient of seawater (the halocline) became more clearly stratified and that the amount of sediment eroded from the surrounding landmass increased. There may have been increased precipitation in response to warmer temperatures, a rise in sea level, and flooding of coastal areas. At the same time, terrestrial plant species are documented to have changed towards a more diverse angiosperm vegetation. The combination of isotope and fossil data record changes to ocean stratification and terrestrial environments well before the major release of carbon into the atmosphere, and this relative timing is telling us about the fundamental trigger mechanism that caused one of the most significant global warming events in the geological past.

This research is published as a paper [doi:10.1016/j.epsl.2012.08.011](https://doi.org/10.1016/j.epsl.2012.08.011)

## Will climate change cause more subsidence?

Our recent investigations into the factors that control the shrink–swell properties of clays has found that the preceding two years of rainfall has a strong influence on the ground saturation, and thus the potential for subsidence in our buildings.

Clay soils are found in many areas of the UK, but are most common in the London area and in south-east England. These soils are susceptible to shrinking and swelling according to the amount of water saturation. The resulting change in volume is one of the causes of subsidence, visible when cracks appear in buildings.

In order to map the areas of south-east England most likely to become vulnerable to subsidence, we have combined our GeoSure dataset with the UK Climate Projection scenarios for rainfall and temperature changes for the next century. The resulting maps show that areas with clay soils that shrink and swell with changes in moisture are going to become increasingly susceptible in the coming century and beyond. The research has established thresholds in rainfall values that suggest high, medium or low likelihood of shrinkage and subsidence occurring.

For more information see: [www.bgs.ac.uk/science/landUseAndDevelopment/shallow\\_geohazards/shrinkSwellClimateChange.html](http://www.bgs.ac.uk/science/landUseAndDevelopment/shallow_geohazards/shrinkSwellClimateChange.html)

## Water resources in times of drought

The drought of 2011/12 raised a number of important questions concerning water resources in the UK. In partnership with the Centre for Ecology and Hydrology, we maintain a national archive of hydrological data and that archive has provided the foundation for several scientific initiatives associated with water supply, including forecasts of drought development over 6- to 24-month periods.

We have developed an operational forecasting capability for key groundwater sites across major aquifers in England using our own groundwater model. The seasonal forecasts



for water resources over the next 24 months have been used by Defra's National Drought Management Group, and by Environment Agency operational teams. Although the 2012 drought broke, the techniques developed are already being refined for operational application in future hydrological outlook products.

Even before 2011/12, the economic impact of drought on European countries over the previous 30 years has been estimated at 100 billion euros, so modest improvements in forecasting water availability can have major impacts. Forecasting systems will be used by Defra, the regulators and water companies in planning for future drought events, and the modelling capability can be used to test climate change scenarios. These systems can also be applied to forecast flooding and related issues caused by rising groundwater levels during periods of abnormally high rainfall.

For more information see: [www.bgs.ac.uk/research/groundwater/waterResources/drought\\_overview.html](http://www.bgs.ac.uk/research/groundwater/waterResources/drought_overview.html)

*Shallow groundwater supply in rural Africa.*





## Security of drinking water in Africa

With support from the Department for International Development, we have completed a one-year research programme to improve understanding of the resilience of African groundwater to climate change and links to livelihoods. Groundwater provides most of the domestic water in rural Africa and supports poverty reduction through irrigation.

Reliance on groundwater is likely to increase in Africa as rainfall becomes more variable and demand for water grows. The project has improved our understanding of the impacts of climate change on groundwater resources and local demand by strengthening the evidence base linking climate change, climate variability, aquifer resilience and livelihood vulnerability.

Project outputs have included an aquifer resilience map for Africa based on geology, hydrogeological maps and interpretation of new data. The project has also developed policy recommendations for assessing how groundwater can support adaptation and build resilience to climate change.

Quantitative maps of groundwater productivity, storage, and depth to groundwater in Africa can be downloaded from our website. The quantitative maps are the first produced for Africa and are underpinned by dedicated case studies and systematic reviews of the data and literature. They are designed to show information at the continental or regional scale (nominally at a scale of 1:20M).

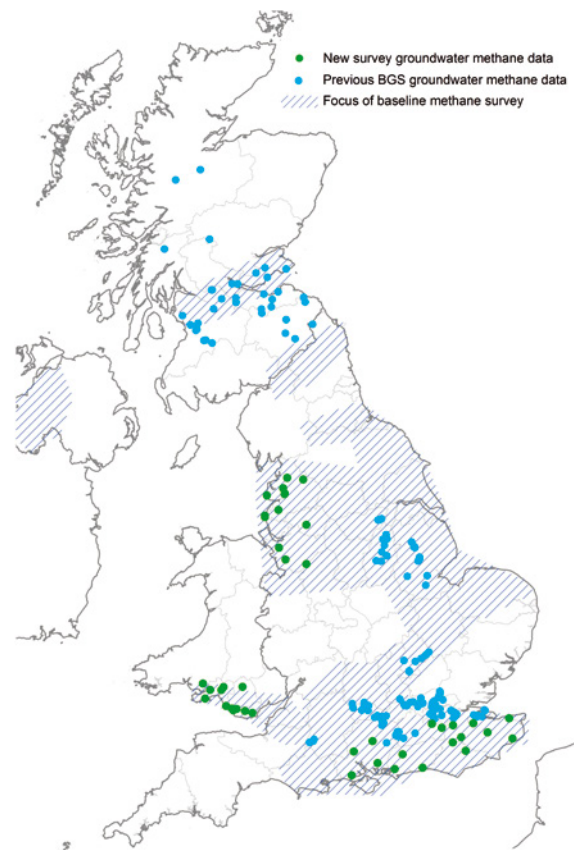
For more information see: [www.bgs.ac.uk/research/groundwater/international/africangroundwater/home.html](http://www.bgs.ac.uk/research/groundwater/international/africangroundwater/home.html)

## Methane in groundwater — a baseline survey for monitoring shale gas extraction

Methane is an important greenhouse gas and a common trace component of groundwater. Since the 1980s we have been studying:

- the sources of methane in the subsurface;
- the hydrogeochemical controls on the fate and behaviour of methane; and
- the potential for methane emissions from groundwaters.

Evidence from the USA reveals high methane concentrations in certain aquifers in some of the areas where shales are being commercially exploited for gas, although there is considerable uncertainty and argument both over the source(s) of methane and how it entered the aquifers.



*Methane in UK groundwater: preliminary survey.*

The need for a baseline study in the UK was recognised in a report on shale gas extraction published jointly by the Royal Society and Royal Academy of Engineering in June 2012<sup>1</sup>.

Our current survey began in 2012, with sampling in aquifers in the following areas:

- Lancashire and Cheshire;
- South Wales; and
- Hampshire, Sussex and Kent.

The work will continue with sampling in Northern Ireland, Northumberland and Yorkshire. These areas have been selected because they are situated above potential shale gas resources.

We are building on previous studies and measuring the methane concentrations and other chemical parameters in groundwater in a range of aquifers before any shale gas development begins. Any future environmental changes can be assessed against the baseline data, and will enable informed management decisions to be taken.

For more information see: [www.bgs.ac.uk/research/groundwater/quality/methane\\_baseline\\_survey.html](http://www.bgs.ac.uk/research/groundwater/quality/methane_baseline_survey.html)

<sup>1</sup> The report can be downloaded from: [www.raeng.org.uk/shale](http://www.raeng.org.uk/shale)



*Flank eruption of Eyjafjallajökull in March 2010, which preceded the much larger ash-rich eruption of April and May.*

# A resilient society

## Understanding the risks from natural hazards

### Volcano watching: FUTUREVOLC

The FUTUREVOLC project coordinates information from the monitoring and analyses of volcanoes in Iceland and aims to improve communication between scientists, civil protection and authorities. Observations are carried out from the ground, air, and space.

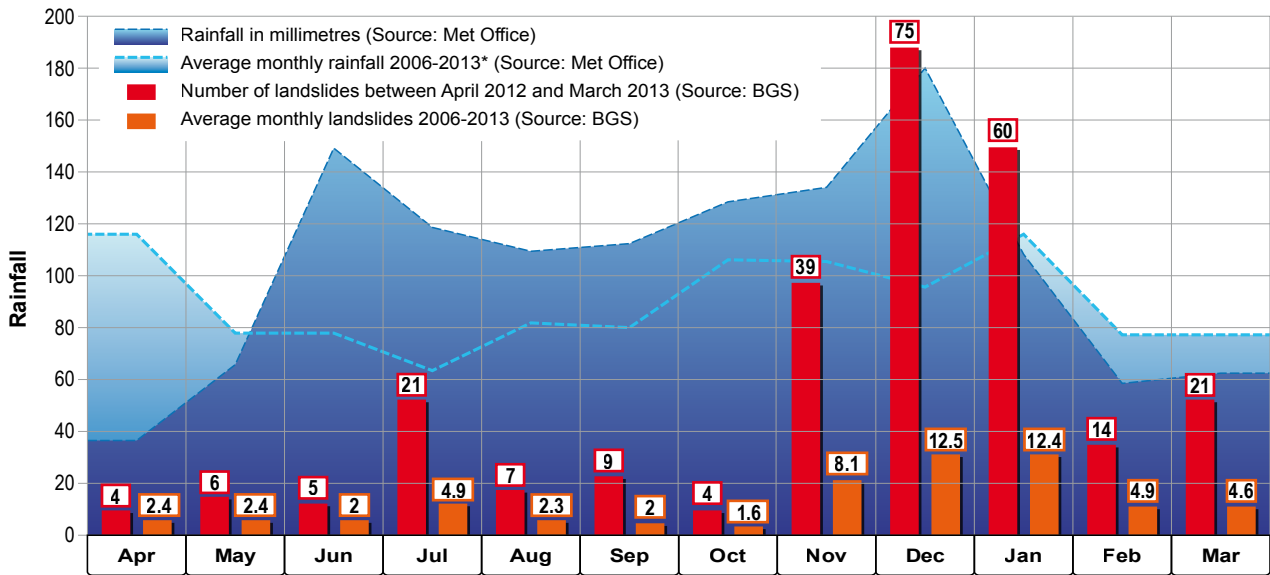
Project partners will establish new methods for near real-time integration and analysis of datasets and develop instrumentation to improve our understanding of a range of physical processes, from deep magma transport through eruption dynamics to plume dispersion and the deposition of eruptive products.

FUTUREVOLC, which started in September 2012, is an EU FP7-funded project, led by the University of Iceland.

It involves 28 European partners including the BGS, the University of Cambridge, the UK Met Office and the University of Bristol.

### A year of landslides

The unusually high rainfall recorded across the UK in 2012 coincided with a sharp increase in the number of landslides reported in the media. For example, 21 landslides were reported in July 2012, four times the long-term average for the time of year. The figures for November and December were 39 and 75, several times the long-term averages for those months. Our Landslides team are investigating the extent to which the rise in reports reflects a genuine increase in the incidence of landslide events, or is partly the result of higher awareness and reporting via social media.



\* Data as of 15 August 2013

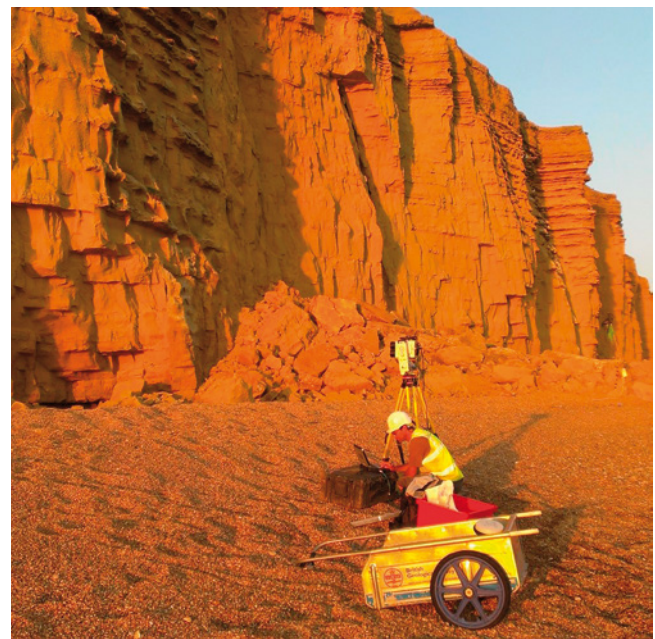
*In the UK, 2012 was a year of unusually high rainfall and large numbers of recorded landslides.*

The BGS Landslide Response Team dealt with many incidents during the year, including the following examples which were widely reported in the national media.

On 24 July 2012 a large rock fall was reported at Burton Bradstock, Dorset. About 400 tons of rock had fallen and, tragically, a 22-year-old woman had died. The Response Team carried out an investigation, including a LiDAR survey, the following day. The survey data are logged in the BGS National Landslide Database (reference NLD 18684/1).

The failure was controlled and constrained by a combination of factors including:

- Discontinuities within the cliff.
- Weathering.
- Erosion of the base of the cliff (undercutting).
- High rainfall that had increased the amount of water present in the rocks forming the cliff and weakened the Bridport Sand Formation.



*Rock fall at Burton Bradstock.*

On 12 February 2013 a landslide occurred in a spoil heap at Hatfield Main Colliery which distorted a large section of track

along the lines connecting Doncaster to Goole and Scunthorpe. Train services in the region were significantly affected and this section of the line had to be closed.

*Landslide at Hatfield Main Colliery.*





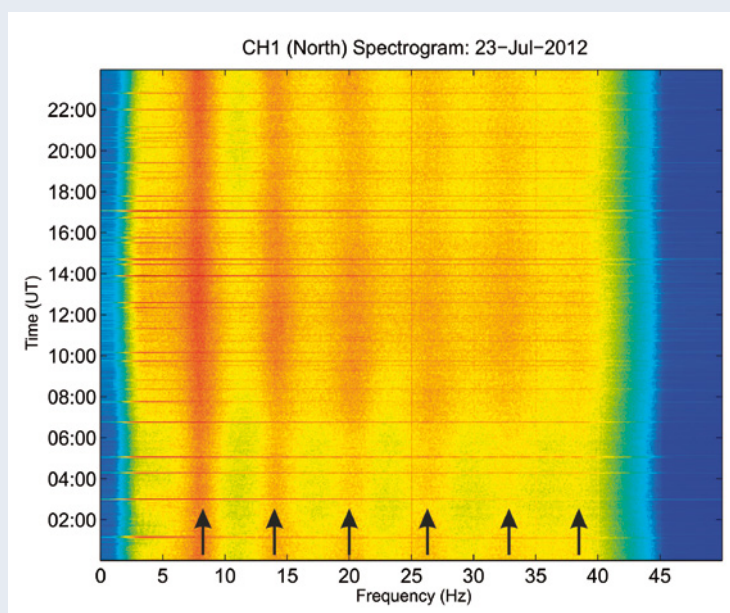
Members of the Geomagnetism team link an induction coil to a nearby break-out box and digitiser at Eskdalemuir. The induction coil is placed on a levelled bed of gravel.

## High frequency magnetometers

In June 2012, our Geomagnetism team installed two high frequency induction coil magnetometers in an empty field at Eskdalemuir Geophysical Observatory in the Scottish Borders. A high frequency induction coil magnetometer comprises two coils of insulated copper wire wound around an iron core. This instrument permits us to measure the very rapid changes of the magnetic field at frequencies

between 0.1 and 1000 times per second. This part of the electromagnetic spectrum is called the Extremely Low Frequency range.

The Eskdalemuir Geophysical Observatory is an electromagnetically quiet region of the UK. The coils are protected by a wooden covering and are linked to the internet via a computer system in the seismic vault about 100 metres away. A small breakout box and digitiser lie



Spectrogram of the 100Hz data from the north-pointing induction coil magnetometer for 23 July 2012. Arrows indicate the diffuse 'Schumann' resonances, a natural set of spectral peaks in the ELF electromagnetic field spectrum, caused by lightning discharges. The strong signal at 25Hz is a harmonic of the UK's power grid. Note the diminished intensity between midnight and 08.00. This is due to the lack of thunderstorm activity over Africa and North/South America at this time. Later in the day, the heat generated by the sun shining on the landmasses in the equatorial land regions begins to trigger thunderstorms. The increase in lightning activity is recorded by stronger Schumann resonances.



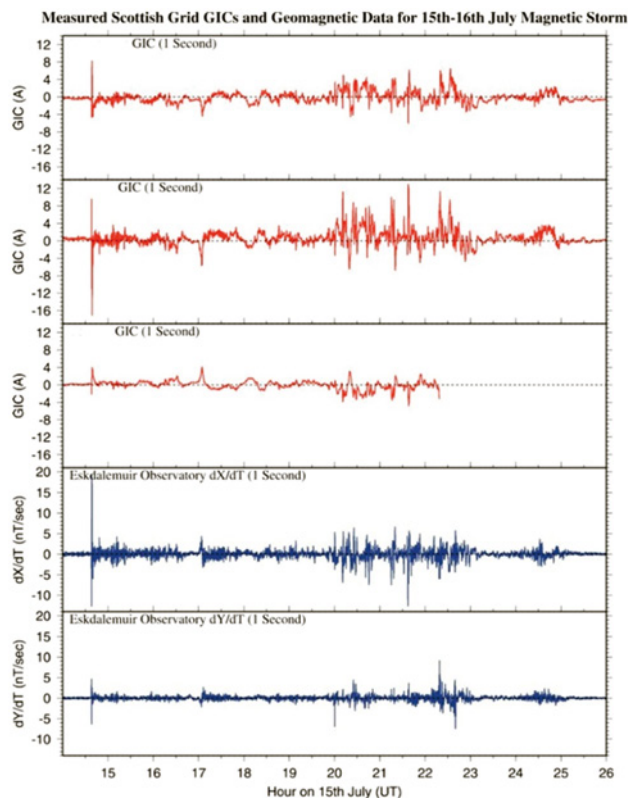
*Eskdalemuir, one of our three geomagnetic observatories in the UK that provide high quality, near-real-time data for both academic and commercial users.*

close to the coils. The data from the induction coils are returned on an hourly basis to our Edinburgh office.

This new research project should produce a new dataset for monitoring global lightning storms and related ionospheric phenomena.

## Generation of 100-year geomagnetically induced current scenarios

The BGS has undertaken work to explore 100-year extreme geoelectric field and geomagnetically induced current (GIC) scenarios, taking into account key geophysical factors associated with the geomagnetic induction process. BGS derived explicit geoelectric field temporal profiles as a function of ground conductivity and geomagnetic latitude, and demonstrated how the extreme geoelectric field scenarios can be mapped into GIC. Generated statistics indicate 20 V/km and 5 V/km 100-year maximum 10-s geoelectric field amplitudes at high-latitude locations, respectively for poorly conducting and well-conducting ground structures. This work, together with other extreme space weather event studies, informs assessments by government and industry of the space weather risks to power grids.



*Measured geomagnetically induced currents (GIC) in Scottish Power's Grid and the geomagnetic rate of change for the same time period.*

## Space weather service for National Grid

We now provide a space weather monitoring service to alert the National Grid to the possibility of geomagnetically induced currents (GIC) in the power network. This forecast service is integrated with the Met Office through the Natural Hazards Partnership and links are being made with

*The Northern Lights, or aurora borealis, are a result of geomagnetic storms, periods when the Earth's magnetic field changes very quickly and strong electric currents flow high in the atmosphere.*



the US Space Weather Prediction Centre. The geomagnetic data are supplied by highly reliable links from BGS in Edinburgh and, as an independent backup, directly from the UK observatories. We use the hourly standard deviation (HSD) in the horizontal magnetic components to detect those rapid variations that drive surface electric fields across the UK and hence geomagnetically induced currents in the power grid. The grid operators use this HSD index, as part of their wider environmental and system data collection, to ensure the power grid continues to operate safely.

For more information see: [www.geomag.bgs.ac.uk/research/space\\_weather/sw\\_partners.html#GIC](http://www.geomag.bgs.ac.uk/research/space_weather/sw_partners.html#GIC)

### Secure storage for radwaste: understanding gas flow through clay

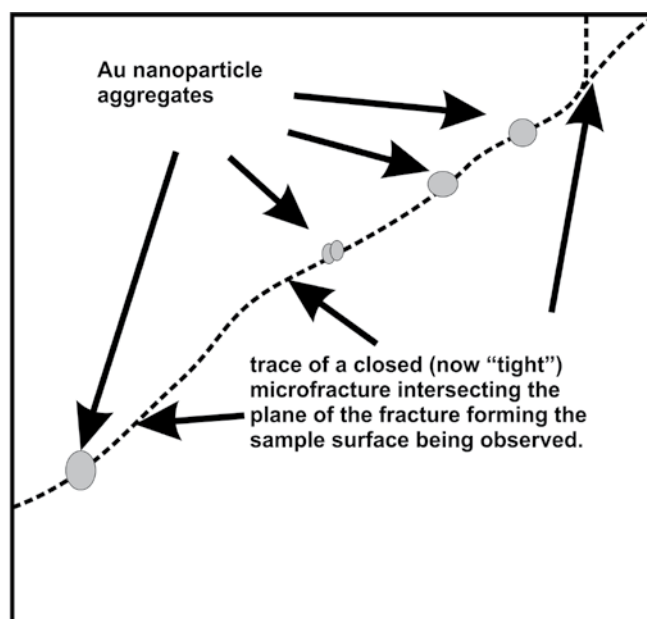
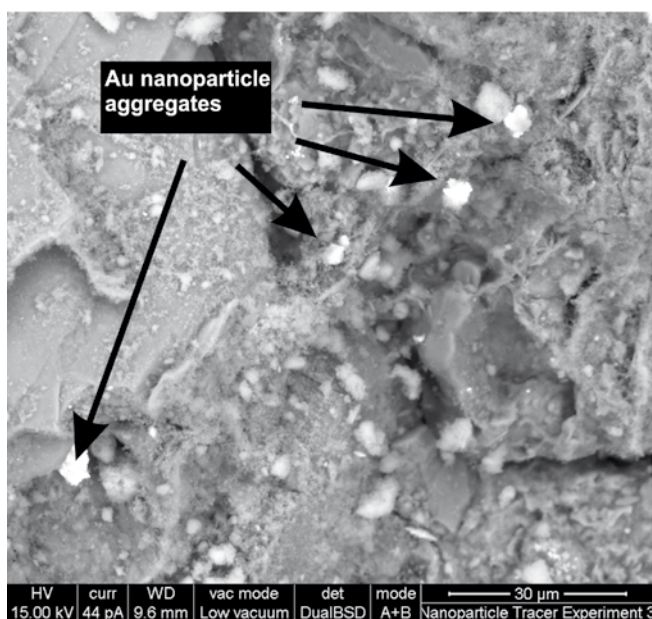
Corrosion, water radiolysis and microbial degradation will cause the generation of gas within repositories designed for the geological disposal of high-level radioactive waste. It is therefore crucial in designing such facilities that the mechanisms that allow gas migration through repository materials, whether engineered barriers or clay-based host rocks, are well understood.

We have developed a novel technique involving the injection into clay samples of nanoparticles entrained in helium gas. This provides a novel diagnostic tool for identifying the pathways through which gas has flowed. Results



*Investigating gas flow through clay samples in the Transport Properties Research Laboratory at Keyworth.*

using this technique have provided conclusive evidence of the processes governing multiphase flow in a candidate host rock for the national radioactive waste programme in Belgium and support robust assessments of how this material would perform within a repository setting.



*Gold nanoparticles (Au) entrained in helium gas have been injected into clay samples. Under the scanning electron microscope the gold particles highlight the trace of microfractures through which the gas flowed during the experiment.*

# Building a natural resource base

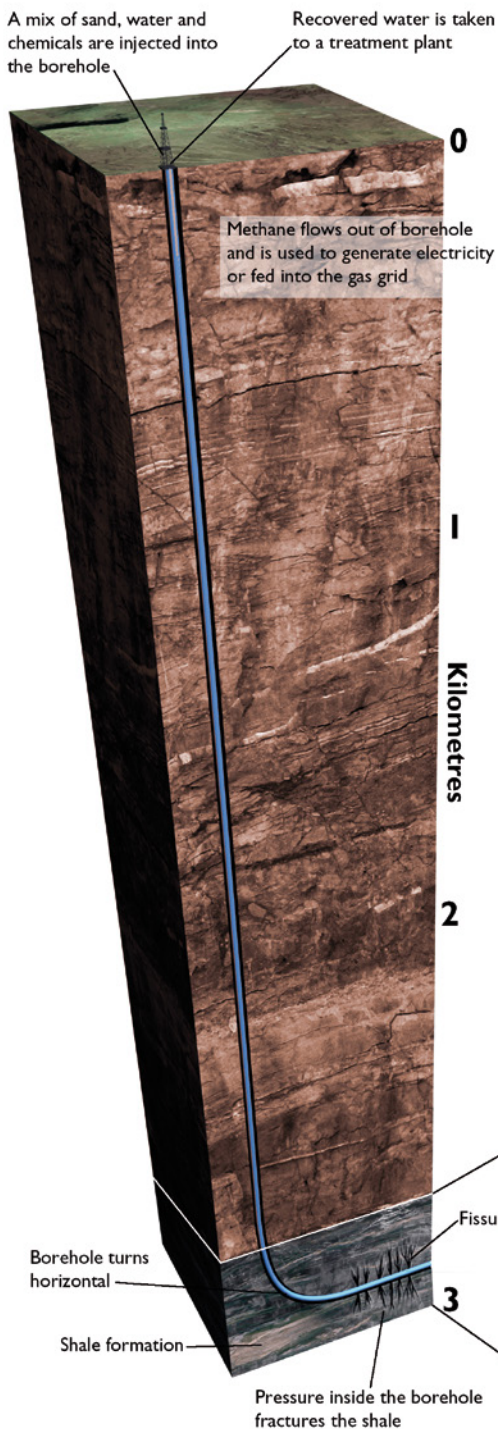
## Minerals and energy for society

### Fracking and earthquake hazard

During 2012 the BGS co-authored a report published by the Department of Energy and Climate Change (DECC) into the

magnitude 2.3 ML and 1.5 ML earthquakes recorded near Blackpool in April and May 2011. The report concludes that the earthquakes were induced by hydraulic fracture treatments during exploration by Cuadrilla Resources Ltd of a shale gas reservoir in the Bowland basin at the Preese Hall well.

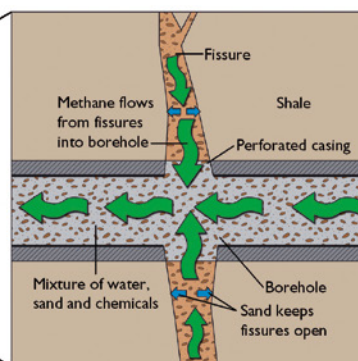
As a result of the earthquakes, operations were suspended and Cuadrilla commissioned a number of studies into the relationship between the earthquakes and their operations. The DECC report also concludes that further small earthquakes cannot be ruled out. However, the risk from these earthquakes is low, and structural damage is extremely unlikely. The report recommends a number of measures to reduce the likelihood of earthquakes associated with hydraulic fracturing in future.



### Burying greenhouse gases

The Energy Technologies Institute (ETI) has agreed a licence with the BGS and The Crown Estate to host and steward the development of an online database of the potential capacity for carbon dioxide (CO<sub>2</sub>) storage that has been mapped offshore UK. The ETI is a public-private partnership of global energy and engineering companies: BP, Caterpillar, EDF, E.ON, Rolls-Royce, Shell and the UK government.

The UK is potentially well served with offshore CO<sub>2</sub> storage and although various estimates have been made of the total amount available, these figures vary widely. The



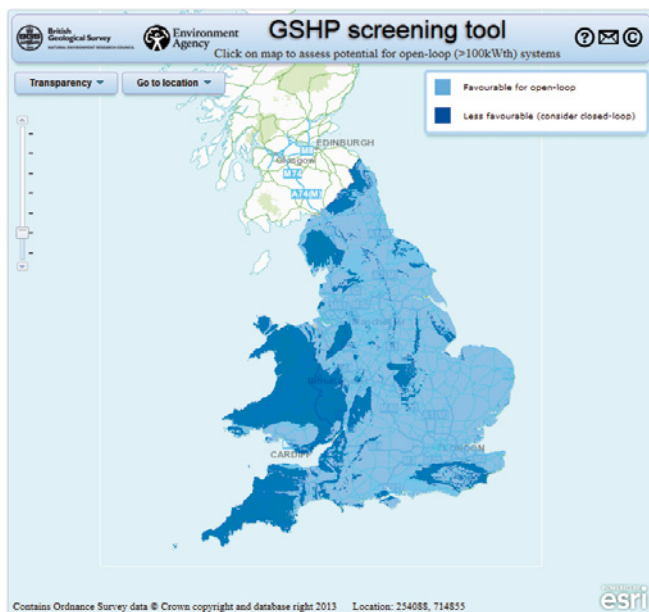
*Hydraulic fracturing or 'fracking' involves the injection of sand and chemicals at high pressures, causing networks of fractures to open. The sand particles hold the cracks open to allow gas to flow out.*

web-enabled database is the first of its type anywhere in the world and contains geological data, storage estimates, risk assessments and economics for nearly 600 potential CO<sub>2</sub> storage units utilising depleted oil and gas reservoirs and saline aquifers around the UK. It will enable interested stakeholders to access information about the storage resource and to make more informed decisions related to the roll-out of carbon capture and storage.

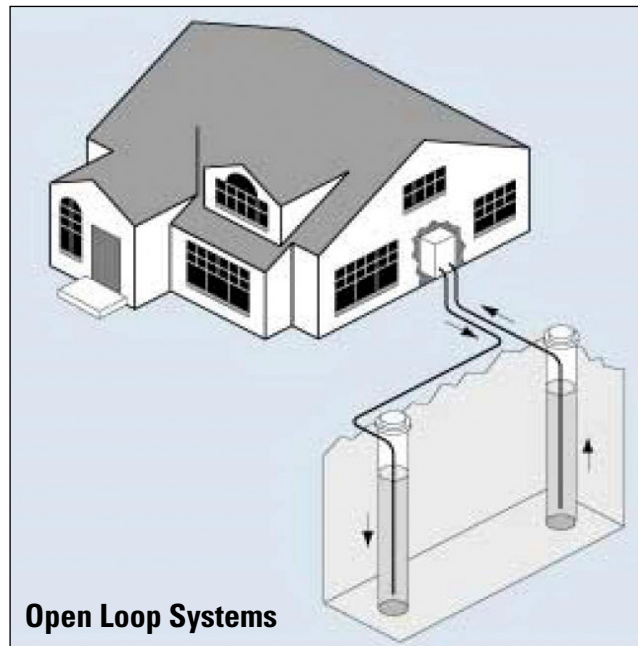
As part of the licence agreement, The Crown Estate and the BGS have together committed £1 million to develop the content of the database and to provide users with a dedicated hosting service.

## Ground source heat pumps (GSHP): Open or closed?

In collaboration with the Environment Agency, we have developed a web-based tool for assessing the suitability of conditions for installing open-loop ground source heat pumps (GSHP). Ground source heat pump systems exploit the temperature difference between above-ground (air) temperatures and below-ground (including groundwater) temperatures for heating or cooling demands. In open-loop systems, groundwater is abstracted at ambient temperature from the ground, passed through a heat pump before being reinjected back into the ground or discharged at the surface. However, they rely on certain hydrogeological and economic conditions.



The open-loop GSHP screening tool maps the potential for open-loop GSHP installations in England and Wales at the 1:250 000 scale.



Ground source heat pump (GSHP) systems exploit the temperature difference between above-ground (air) temperatures and below-ground (including groundwater) temperatures for heating or cooling demands.

The tool maps the potential for open-loop GSHP installations in England and Wales at the 1:250 000 scale. These installations are suitable for buildings with heating or cooling demands of 100kW or more. The tool considers the hydrogeological and economic factors, including the presence and productivity of an aquifer and the depth of abstraction, as well as potential restrictions, such as whether the location of a proposed installation falls within protection zones.

For more map information see: [www.bgs.ac.uk/research/energy/geothermal/gshp.html](http://www.bgs.ac.uk/research/energy/geothermal/gshp.html)

## Heating for Glasgow

With Glasgow City Council we are exploring the use of heat energy from the ground to warm Glasgow's homes and communities. Collapsed mine workings provide conduits for extracting groundwater from the rock, together with a much smaller amount of mine water. Heat pumps can be used to 'concentrate' heat energy from water in the mines, raising it to a useful temperature for heating buildings.

Our research is identifying which parts of Glasgow offer the best prospects for exploiting this type of energy, by investigating the potential heat within mine waters, superficial deposits and bedrock aquifers beneath the city. We estimate that an annual contribution of 20 gigawatt-hours





*View to the north-west along the river Clyde from the Glasgow Science Centre. The heat from Glasgow's minewaters could provide the city with a low-carbon source of energy for at least 100 years.*

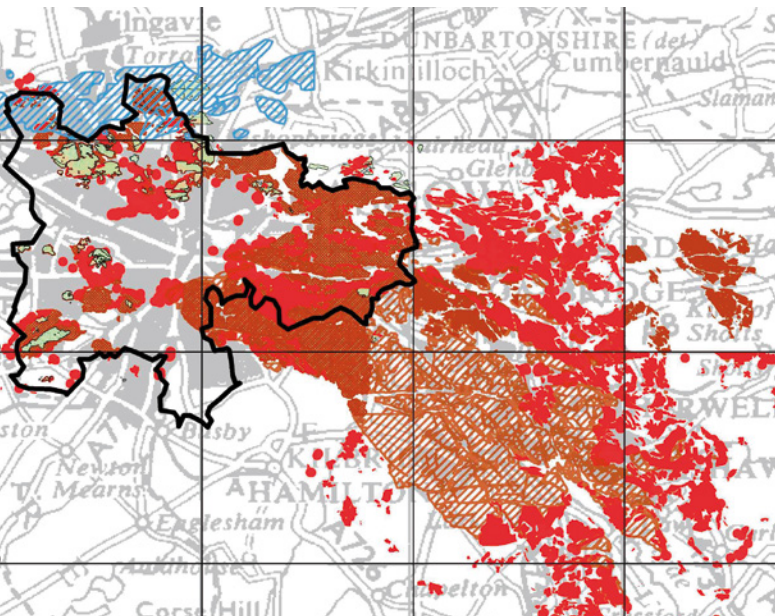
per square kilometre from ground source heat could provide at least 40% of Glasgow's heating demand, representing a low-cost source of energy for at least 100 years.

For more information see: [www.bgs.ac.uk/research/energy/geothermal/expertiseHeatEnergyGlasgow.html](http://www.bgs.ac.uk/research/energy/geothermal/expertiseHeatEnergyGlasgow.html)

## Technology metals at risk

The BGS Risk List 2012 ranks the threats to the global supply of those metals and other elements which are vital to our modern economy. The list highlights high-technology, 'critical' metals such as rare earths, tungsten and antimony

*Brown areas indicate where mining is known to have taken place beneath Glasgow. Red areas show the likely extent of shallow mining.*



where production and resources are concentrated in a few countries and so are at greater risk of supply disruption.

The Risk List 2012 will help to focus future exploration activity, as well as research on greener production technologies and more cost-effective recycling. Increasing global demand for metals and minerals leads to greater competition for resources, yet the supply of many metals and other elements used in high-technology products such as batteries, magnets, mobile phones and PCs is 'at risk'. Policy-makers, industrialists and consumers are increasingly concerned about the risk to the supply of these critical materials.

The Risk List 2012 provides an assessment of the relative risk to supply of 41 elements or element groups based on their abundance, production and reserves, as well as the political risks in producing countries. A new feature of the Risk List for 2012 is that the recycling rate of availability of substitutes for these critical elements are considered in analysing the risks to future supplies.

## Exploring low carbon energy sources: BritGeothermal

BritGeothermal is a partnership providing a mechanism for technical collaboration and co-operation in geothermal research within the UK. The initial partners are the BGS, the University of Glasgow, the University of Durham and the University of Newcastle. It is hoped that others will join as research projects develop.

BritGeothermal fosters better understanding of the UK's geothermal resources and their exploitation with the ultimate aim that geothermal energy should become part of the energy mix.

Its principal objectives are to:

- create a virtual geothermal research centre;
- actively collaborate and co-operate in geothermal research;
- seek out new sources of funding for geothermal research;
- create a common portal for the promotion and communication of geothermal research; and
- provide a unified voice in championing geothermal energy to government and commerce

A number of research projects are already underway, including:



*The Science Central Project borehole, drilled in central Newcastle in the summer of 2011.*

- The Science Central borehole in the centre of Newcastle, which at 1800 metres is the deepest geothermal well drilled for nearly 30 years. Temperatures of 73°C indicate a geothermal gradient of 36°C per kilometre, well above

the UK average. Research is continuing on the potential yield of the reservoirs and the origins of the geothermal waters.

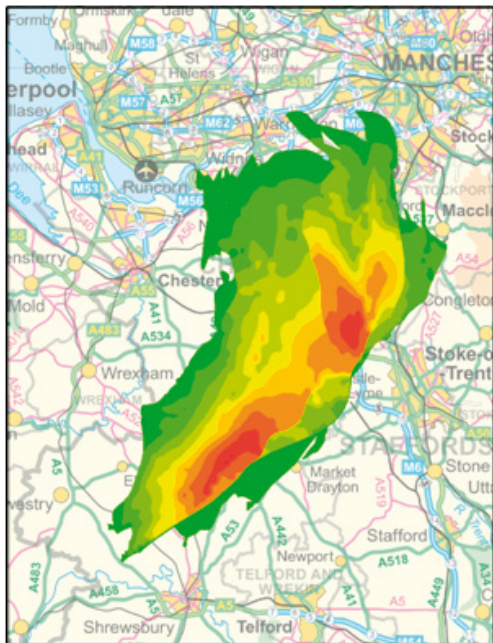
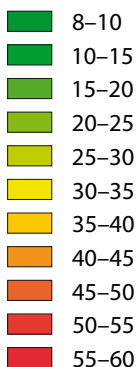
- Detailed investigations of hot sedimentary aquifers (HSAs), examining new data from hydrocarbon wells and synergies between the onshore and offshore.
- Determining the geothermal potential of old mine workings and how this large resource can be practically exploited.
- New algorithms and datasets for correcting heat flow for palaeoclimate and topography that will enable more accurate predictions of temperature at depth.

## Minerals in Northern Ireland

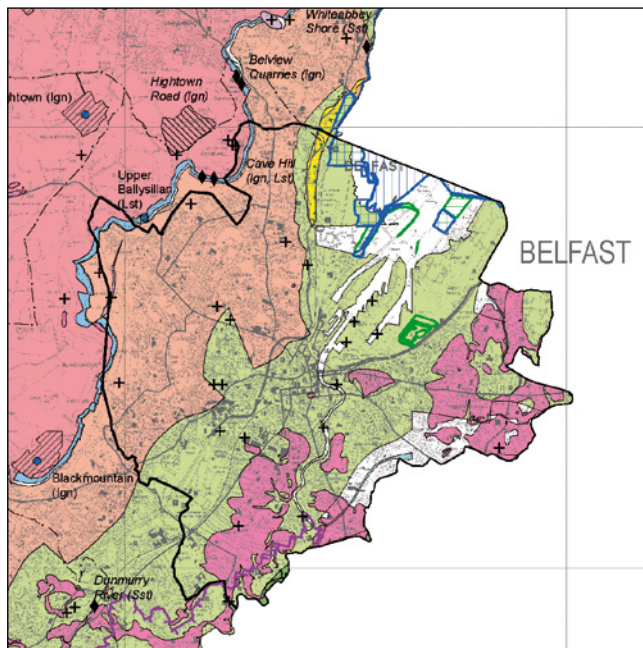
Effective planning for the sustainable development of mineral resources requires knowledge of both their extent and location. The BGS and GSNI published a new Mineral Resources Map of Northern Ireland, commissioned by the NI Department of the Environment, in 2012. This is the first modern, comprehensive and consistent mineral resource assessment for Northern Ireland and it confirmed the province's significant potential for mineral resources.

The map will be used by planners, industry and the wider community to make decisions on mineral extraction and protection of the environment. It allows all stakeholders to visualise the distribution of mineral resources and to relate them to other forms of land use, such as urban areas or

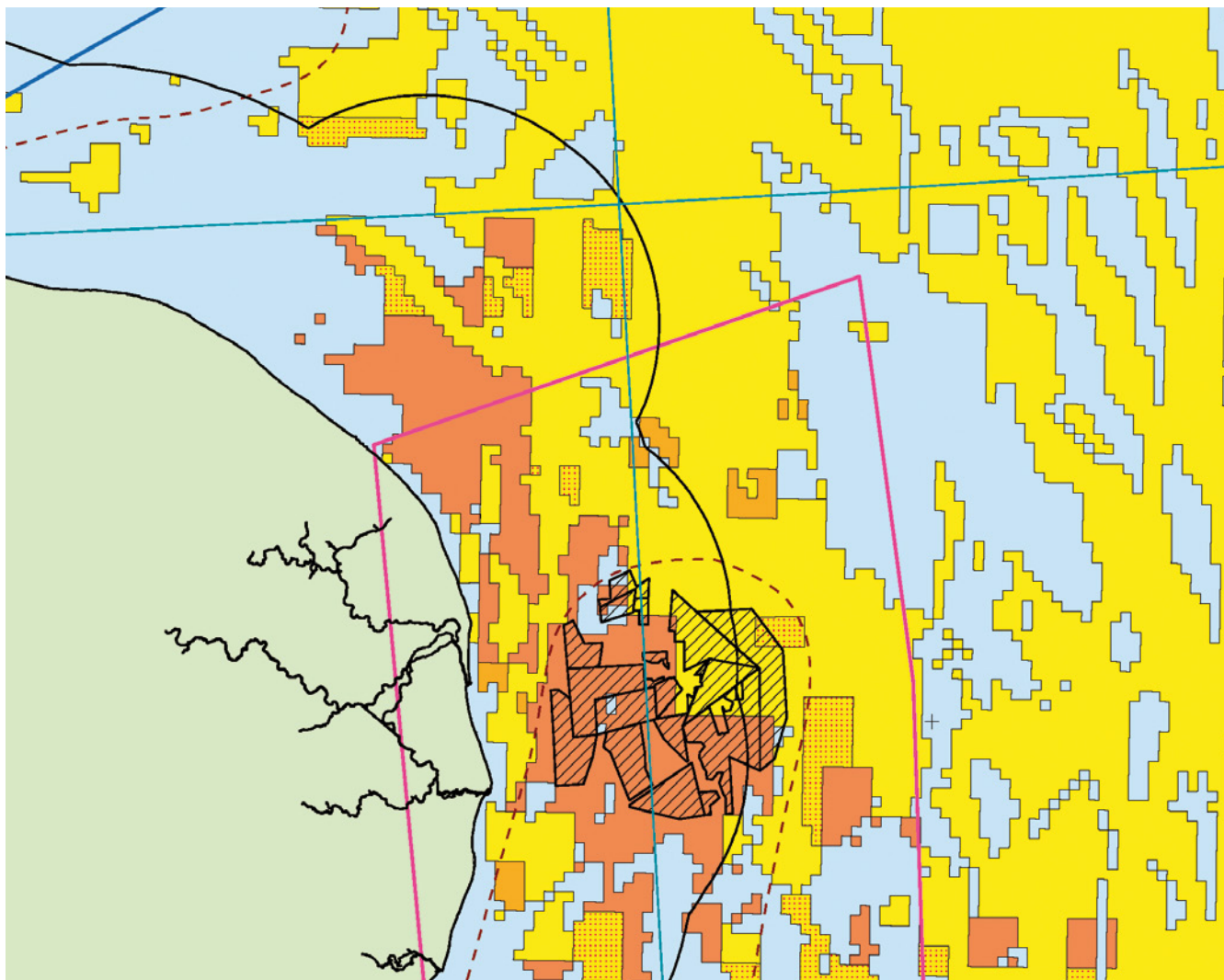
### Temp °C



*Calculated temperature model at the top of the Sherwood Sandstone in the Cheshire Basin.*



*Extract from the new Mineral Resources Map of Northern Ireland.*



*Marine mineral resource map, east coast, England (detail).*

nature conservation areas, or to factors such as transport infrastructure.

Other research undertaken with partners in Northern Ireland confirms for the first time a correlation between rocks of the Tyrone Igneous Complex and Buchan's Mining Camp in Newfoundland which is rich in base metals. This correlation has immediate economic implications for the UK by increasing the mineral potential of this part of Northern Ireland and encouraging further investment through exploration.

For more information see: [www.bgs.ac.uk/mineralsuk/planning/resource.html](http://www.bgs.ac.uk/mineralsuk/planning/resource.html)

## Minerals in the UK continental shelf

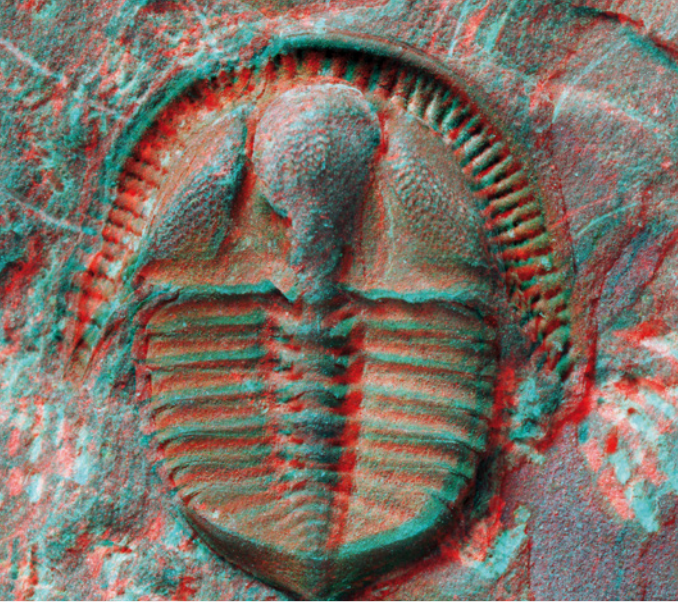
In 2011, The Crown Estate commissioned us to undertake a Mineral Resource Assessment of the UK continental shelf with the results being depicted as a series of maps.

The first area to be assessed encompasses areas off the east coast of England (East Coast Inshore and East Coast Offshore Marine Plan Areas) and the results have been published as a 1:500 000 scale map with an accompanying descriptive report.

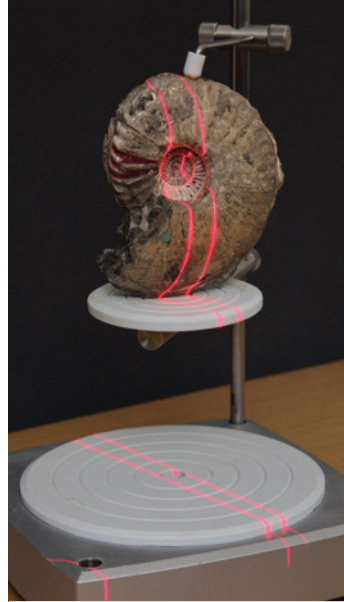
The marine mineral resource maps will provide a comprehensive, relevant and accessible information base so that planners, industry and members of the public can visualise the distribution of offshore minerals to a common standard and at a common scale.

There is increased pressure on marine space, which means it is important to ensure that natural resources are not needlessly sterilised by other forms of offshore development, leaving insufficient supplies for future generations.

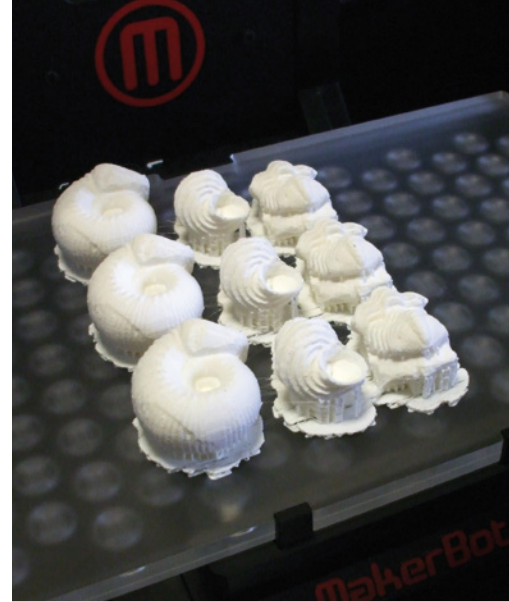
For more information see: [www.thecrownestate.co.uk/energy-infrastructure/aggregates/](http://www.thecrownestate.co.uk/energy-infrastructure/aggregates/)



Anaglyph image of a fossil trilobite.



An ammonite is scanned by laser.



Models in the online database replicated by 3D print technology.

# Sharing our research

## Broadening access to information through 21st century technologies

### GB/3D Type Fossils Online

GB/3D Type Fossils Online is an innovative project funded by JISC. Our project partners are the National Museum Cardiff; Cambridge University's Sedgwick Museum of Earth Sciences; Oxford University Natural History Museum and the Geological Curators Group (representing museums around the country). The databases of type fossils held in the project partners' collections are being combined into a single web portal, together with new high-resolution images, anaglyph stereo pairs and representative 3D digital models obtained from laser scanning selected fossils. The resulting web portal will speed up and improve the quality of research, offer many novel educational opportunities, and will improve techniques for digitising fossils. No digitisation of type fossils has been attempted on this scale before.

For more information see: [www.3d-fossils.ac.uk](http://www.3d-fossils.ac.uk)

### iGeology 3D and mySoil apps

The 3D version of our iGeology app is available, free, for mobile phones and tablets running the Android operating system and has been downloaded by over 5000 users. The application builds upon our web services and presents

users with geological map data apparently draped over the landscape in front of the mobile phone, a visualisation technique known as augmented reality. This modern approach provides a much more direct, visual experience of our geological data, with links to more traditional geology data summaries and products, and helps us reach more diverse user communities.

Our other new smartphone app, mySoil, was developed with the Centre for Ecology and Hydrology. Users can carry a soil

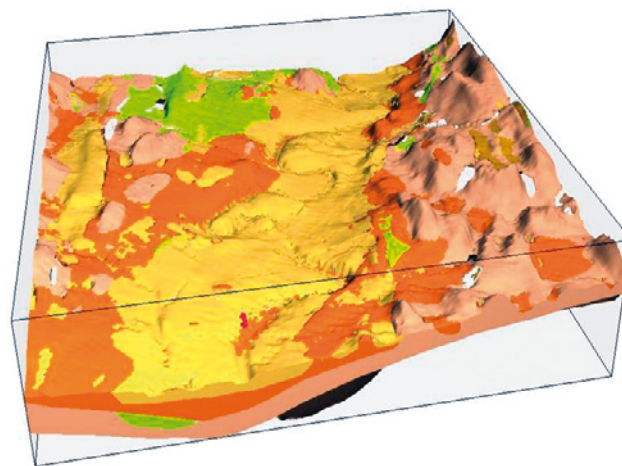


The iGeology 3D app combines 'live' pictures of the landscape with 3D views of the geological map.

properties map of Britain on their phone or tablet wherever they go, helping them learn about the soil beneath their feet. The free app is intended for anyone with an interest in the soil of Britain including gardeners and allotment holders; farmers, agricultural and horticultural specialists; school and college students; environmentalists; and land-use planners. Users are encouraged to upload information about the soil where they live, helping us to improve our knowledge about the properties of soils and the vegetation habitats provided both by experts and the general public.

For more information see: [www.bgs.ac.uk/iGeology/3d.html](http://www.bgs.ac.uk/iGeology/3d.html) and [www.bgs.ac.uk/mysoil/home.html](http://www.bgs.ac.uk/mysoil/home.html)

*Our new mySoil app provides users with information about their local soils and the opportunity to help crowd-source new data.*



*3D models are heavily dependent on high quality ground investigation data. Better data can reduce construction costs.*

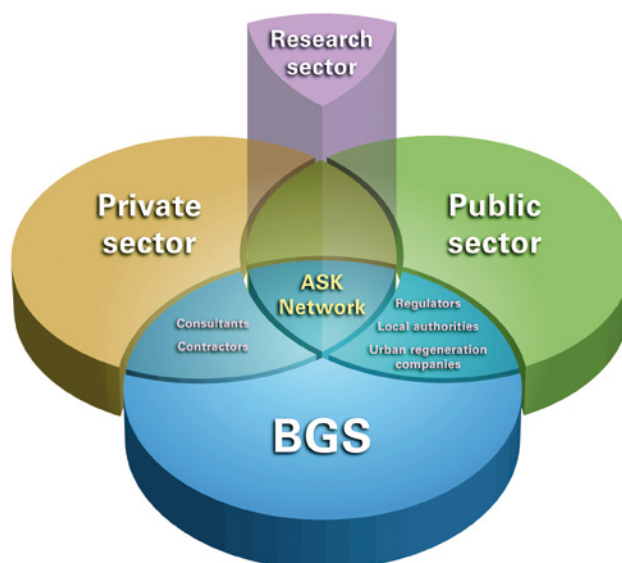
## ASK: all about the ground beneath Glasgow

The Accessing Subsurface Knowledge Network, or ASK, has been developed through a partnership with Glasgow City Council and with support from others in the public and private sectors. The purpose of the network is to build and share datasets about, and methods for investigating, the ground conditions beneath Glasgow. The network was launched on 16 November 2012 and aims to transform the ways in which partners exchange data and information and to promulgate best practices.

Knowledge of the subsurface is critical for successfully delivering construction and regeneration projects; a poor

## A system for planning electrical earthing

We have developed a methodology for predicting the optimum ground electrical earth for a rural substation on the electrical grid. It is based on a geographical information system and also provides estimates of the quantities of earthing materials (such as copper strip and rods) that will be required to achieve the earthing resistance. A parameterised near-surface model was developed comprising soil, superficial and bedrock geology. Extensive interpretation and modelling of near-surface electrical resistivity was undertaken to further attribute the model. The methods and procedures could be applied by any country with modern datasets for soil and geology. The work was funded by two of the UK District Network Operators who will incorporate the geographical information system into their earthing installation procedures.



*The ASK Network; showing the relationship between research, public and private sectors, and the BGS.*

understanding of ground conditions is widely recognised as the largest single cause of project delay as well as overspending. 3D models are heavily dependent on high quality ground investigation data. Network partners will develop more accurate models to support both public and private sector investment and, ultimately, to reduce construction costs.

The BGS has been at the forefront of developing 3D urban subsurface models in recent years to improve understanding of subsurface conditions and view the subsurface in its regional and local spatial context. Better reuse of subsurface data and knowledge will extend the capabilities of our models and increase their relevance to practical issues.

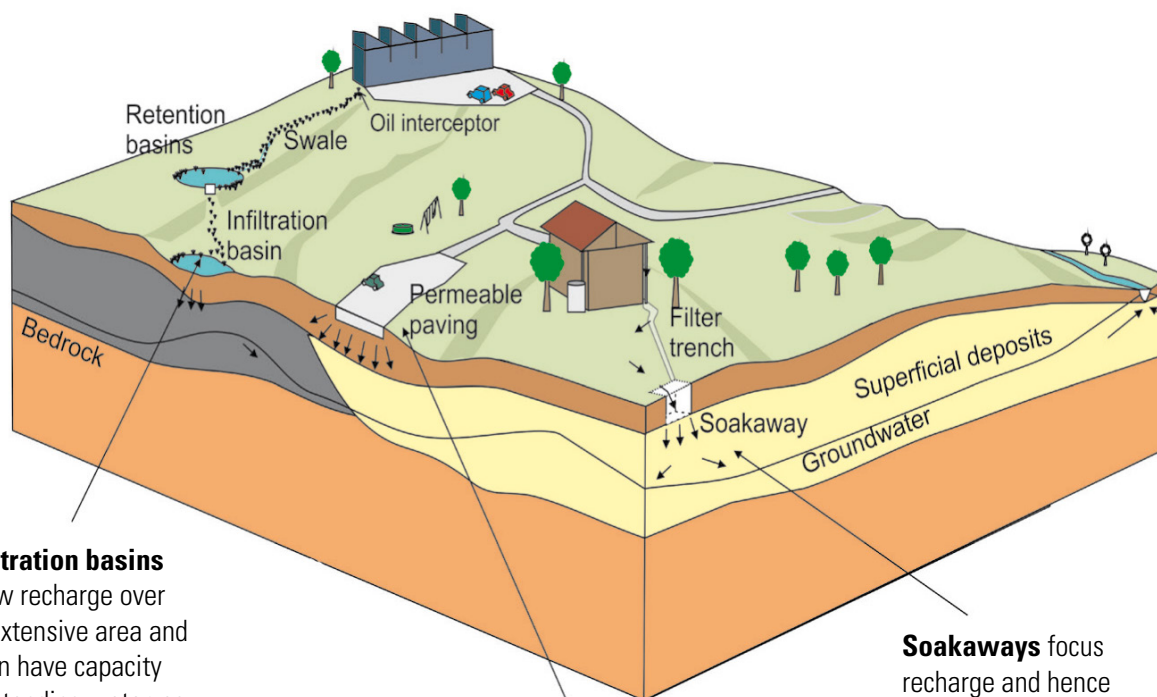
## Reducing flood risk: the national infiltration SuDS map

Using insights from studying the earth science factors that determine the infiltration of surface water into the ground we have proposed a nationally applicable method to

determine locations for surface water infiltration using sustainable drainage systems (SuDS).

The method identifies the locations using factors including permeability, groundwater level, the presence of contaminated soils, and susceptibility to ground stability hazards. The results of the investigation determine areas where infiltration can reduce surface water flooding, improve amenity value and prevent groundwater pollution.

Our location-based report series has been updated and now includes an Infiltration SuDS GeoReport. This report replaces the Infiltration-to-the-ground GeoReport and includes 24 map excerpts, reflecting the 24 layers of information within the Infiltration SuDS map national dataset. This report provides subsurface information required to design effective infiltration-to-the-ground sustainable drainage systems (SuDS) such as shallow soakaways, infiltration trenches and infiltration basins. It is aimed at the planning and construction industry, but may also help householders judge whether or not professional advice should be sought.



**Infiltration basins** allow recharge over an extensive area and often have capacity for standing water, so that they are suitable in poorly draining deposits.

**Permeable pavements** allow recharge over an extensive area, so that they are often suitable where drainage is insufficient for a soakaway.

**Soakaways** focus recharge and hence are only suitable in free-draining deposits.

*Sustainable drainage systems can reduce surface water flooding and prevent pollution of groundwater if properly planned.*

# Awards

The following staff received awards in recognition of their achievements during 2012/13

**Rachel Dearden.** 2013. Sustainable Drainage and Flood Management Initiative of the Year (<http://nora.nerc.ac.uk/500856/>).

**Anna Harrison, Matthew Harrison and Martin Culshaw.** 2013. Richardson Award — Geologists' Association (<http://nora.nerc.ac.uk/500418/>). Lloyd's Science of Risk Prize 2012; Climate Change; runner up (<http://nora.nerc.ac.uk/500417/>).

**Ricky Terrington.** Professor William R Dearman QJEGH Young Author for 2012 award (<http://nora.nerc.ac.uk/500420/>).

**John Powell.** 2012. John Phillips Medal; Yorkshire Geological Society (<http://nora.nerc.ac.uk/500415/>).

**John Rees.** Lloyds Science of Risk Prize 2012 (<http://nora.nerc.ac.uk/500354/>).

**Xiang Li.** 2012. Distinguished Achievement Award; Society of Exploration Geophysicists (<http://nora.nerc.ac.uk/500409/>).

**Marie Cowan.** Communications Excellence Awards 2012 (<http://nora.nerc.ac.uk/500423/>).

**Emma Bee.** 2012. Association of Geographic Information Geocommunity; best conference paper (<http://nora.nerc.ac.uk/500347/>).

**John Laxton.** 2012. IUGS Science Excellence Award for Geoscience Information (<http://nora.nerc.ac.uk/500348/>) and 2012 IUGS Science Excellence Award 2012 for Management and Application of Geoscience Information (<http://nora.nerc.ac.uk/500419/>).

**Katherine Royse, Lei Wang and Andrew Kingdon.** 2012. OpenMI Award (<http://nora.nerc.ac.uk/500401/>).

**Calum Ritchie.** British Cartographic Society Award 2012 (<http://nora.nerc.ac.uk/500346/>); Stanfords Award for Printed Mapping 2012 (<http://nora.nerc.ac.uk/500344/>); and Avenza Award for Electronic Mapping 2012 (<http://nora.nerc.ac.uk/500345/>).

**Edward Hough.** 2012. EAGE Honorable Recognition award (<http://nora.nerc.ac.uk/500412/>).

**Michael Watts and Barbara Palumbo-Roe.** SETAC 2012 Best Publication award in the category Chemical Analysis and Environmental Monitoring (<http://nora.nerc.ac.uk/500421/>).



*Anna Harrison accepting the Lloyd's Science of Risk Prize 2012 from CEO Dr Richard Ward.*

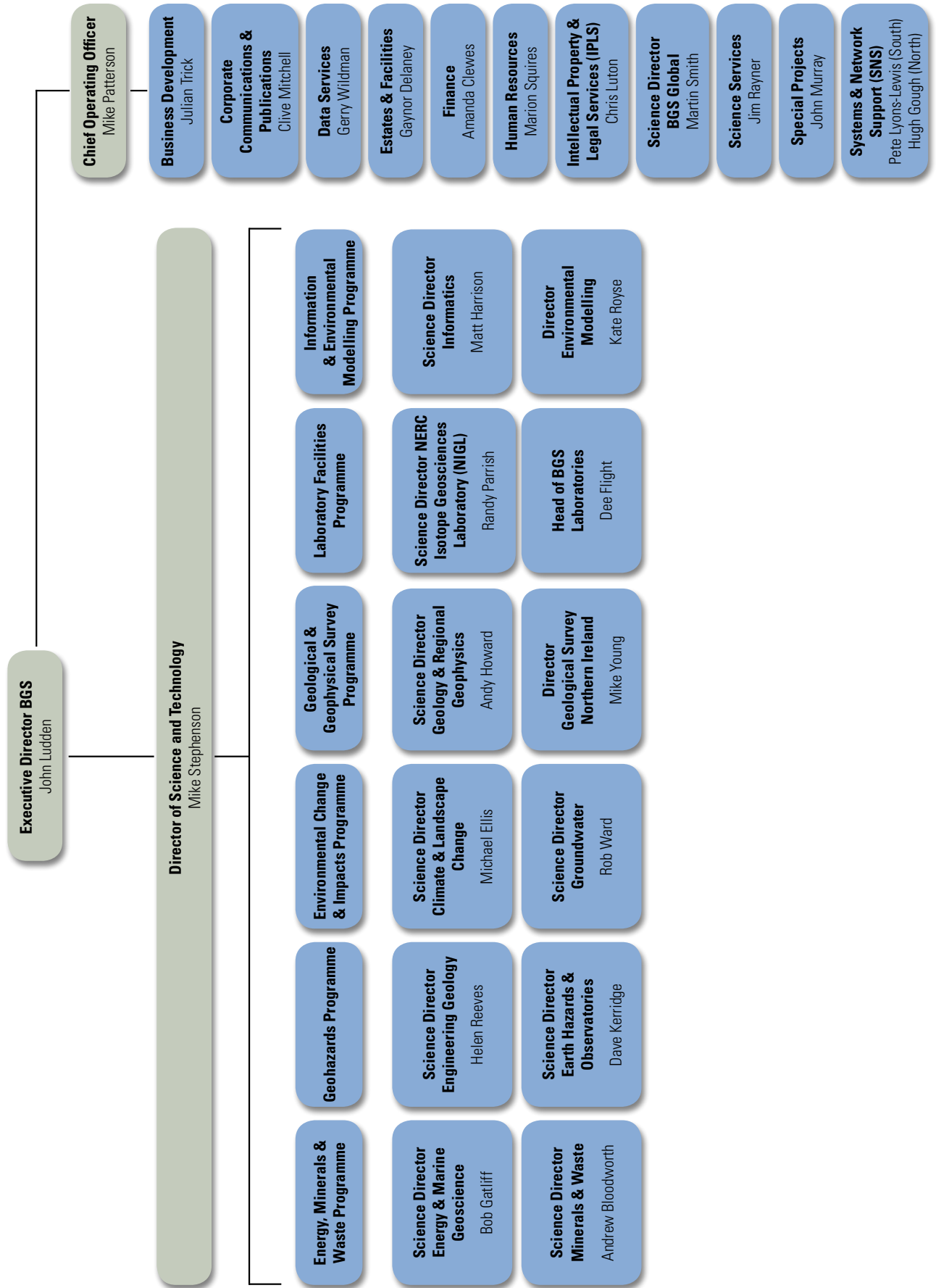


*John Laxton receives the IUGS Science Excellence Award in Geoscience Information at the International Geological Congress in Brisbane 2012.*



*President of the British Cartographic Society, Peter Jolly, presents Calum Ritchie with the BCS Award 2012.*

# BGS Management Organogram





# BGS and NERC offices



Environmental Science Centre,  
Keyworth, Nottingham,  
NG12 5GG  
☎ 0115 936 3100

Murchison House,  
West Mains Road,  
Edinburgh, EH9 3LA  
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Wallingford, OX10 8BB  
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☎ 020 7589 4090

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Greenmeadow Springs,  
Tongwynlais,  
Cardiff, CF15 7NE  
☎ 029 2052 1962

Geological Survey of Northern Ireland,  
Colby House,  
Stranmillis Court,  
Belfast, BT9 5BF  
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**NERC** SCIENCE OF THE ENVIRONMENT

Natural Environment Research Council,  
Polaris House,  
North Star Avenue, Swindon SN2 1EU  
☎ 01793 411500  
[www.nerc.ac.uk](http://www.nerc.ac.uk)

## NERC's research centres

British Antarctic Survey  
☎ 01223 221400  
[www.antarctica.ac.uk](http://www.antarctica.ac.uk)

Centre for Ecology and Hydrology  
☎ 01491 838800  
[www.ceh.ac.uk](http://www.ceh.ac.uk)

National Centre for Atmospheric  
Science  
☎ 0113 3436931  
[www.ncas.ac.uk](http://www.ncas.ac.uk)

National Centre for Earth Observation  
☎ 0118 378 6728/8317  
[www.nceo.ac.uk](http://www.nceo.ac.uk)

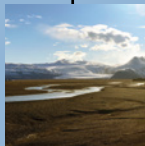
National Oceanography Centre  
☎ 0151 795 4800 (Liverpool)  
☎ 023 8059 6666 (Southampton)  
[www.noc.ac.uk](http://www.noc.ac.uk)



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**British Geological Survey**

NATURAL ENVIRONMENT RESEARCH COUNCIL



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