

Gateway to the Earth



Science for the
next decade



**British
Geological Survey**

NATURAL ENVIRONMENT RESEARCH COUNCIL

Who we are

The British Geological Survey (BGS) is a world-leading geological survey focusing on public-good science for government, and research to understand earth and environmental processes.

We have:

- an annual budget of £50 million, and around 50% of this comes from the Natural Environment Research Council (NERC)
- 520 scientists working with more than 40 universities and institutes
- 120 staff working in science support roles (knowledge exchange, outreach, information technology)
- 150 current private-sector customers
- 20 unique science laboratories
- NERC and national science facilities including the isotope geosciences, radiocarbon, and geophysics and geodesy facilities

Examples of our excellent science:

- more than 90% of impact cases in a recent NERC research review were classed as outstanding or very considerable and 78% of our research was classed as internationally recognised or better
- 250 peer-reviewed papers were published by our staff in 2012
- there was a 75% increase in the number of peer-reviewed papers published in the 4 years to 2012, with 250 000 downloads annually from our research archive



Our vision . . . is to be a global geological survey, working with new technology and data to understand and predict the geological processes that matter to people's lives and livelihoods.

BGS will harness new technology to instrument the Earth so that we understand how geological processes act in real time. We will use our new understanding and existing research capability to rise to challenges across the world, and help society to:

- use its natural resources responsibly
- manage environmental change
- be resilient to environmental hazards

BGS will make this happen by:

- nurturing our people
- developing our partnerships with universities, institutes and businesses
- playing to our core strengths in 3D geology and the national geological database
- remaining a trusted, independent voice for the geological sciences in the UK and abroad

This document sets out our strategic direction.



What we'll do

Instrumenting the Earth

In the past, geological surveys concentrated on the solid subsurface but in the decades to come we will need to monitor processes below ground in real time.

Weather and river water quality are already monitored continually, and some geological processes (volcanoes and earthquakes) are monitored in real time, but deeper subsurface processes are monitored episodically, if at all. Our future use of the subsurface – for groundwater, energy and waste disposal – depends on improving our understanding of subsurface processes. This will make us better at managing these activities safely and sustainably. It will require much greater effort in subsurface monitoring, essentially 'instrumenting the Earth'.

This approach implies a step change in the way that BGS ingests, processes and serves data. We will need more processing power for the 'big data' we will generate, and a clear line of sight between collection, interpretation and modelling. This

will benefit our own scientists and the global scientific community.

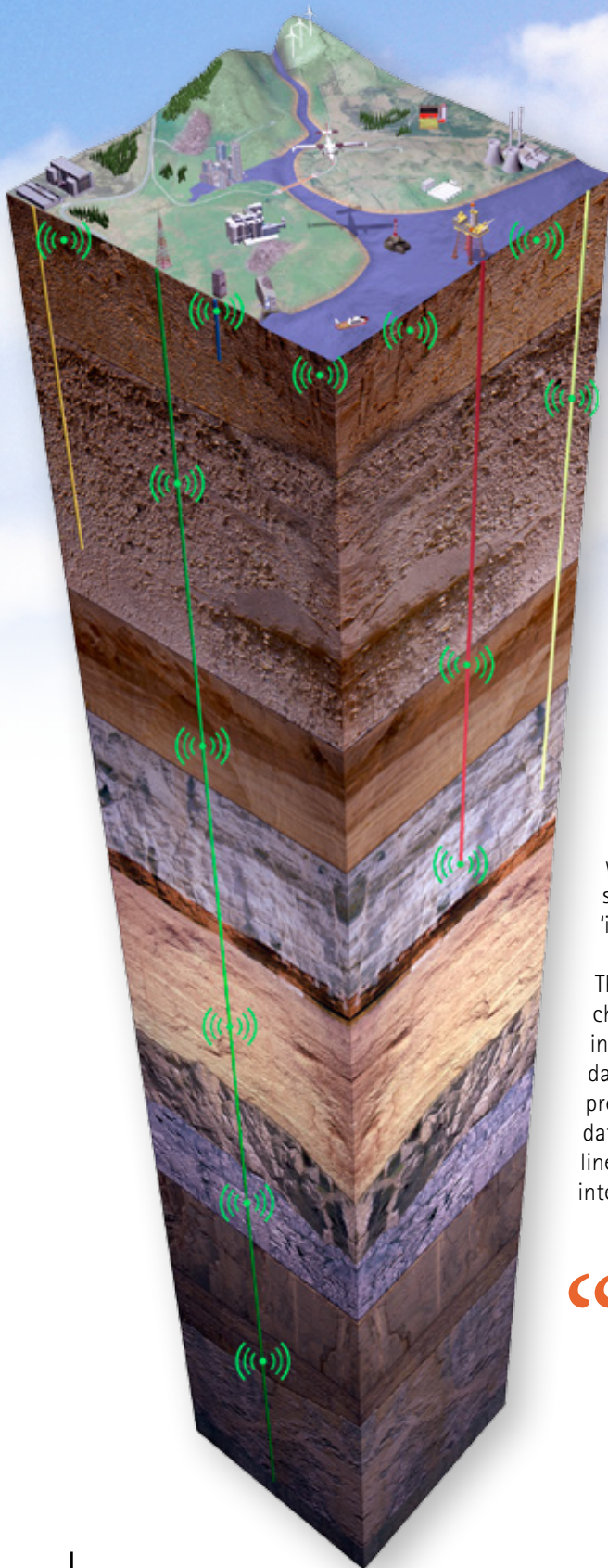
The National Geological Model

Instrumenting the Earth will need a 3D model. In the next decade BGS will complete the National Geological Model and start to take it offshore. The model will underpin our understanding of the subsurface onshore for groundwater, radioactive waste disposal and shale gas. Offshore, it will support our work on oil and gas, and on carbon capture and storage.

Going global

Resources, environmental change and hazards are global challenges, and so BGS needs to think globally. We will work with European platforms on the sensing and prediction of hazards and reach out by providing a global geological data warehouse and geological research to other nations.

“ In the next decade BGS will research the interactions between subsurface flows and the solid rock matrix at timescales consistent with human usage of the subsurface. ”





For example ...

Sustainable global cities

Out of sight . . . out of mind – the subsurface rarely, if ever, makes an appearance in the long-term planning of the world's cities. With urbanisation comes increased pressure on space and resources and, increasingly, underground development. This means that understanding the subsurface beneath our cities is a key focus for modern geological surveys. In the same way that air quality is used as a measure of the health of a city above ground, we now need instrumentation and real-time monitoring to measure the health and environmental impact of the urban footprint.

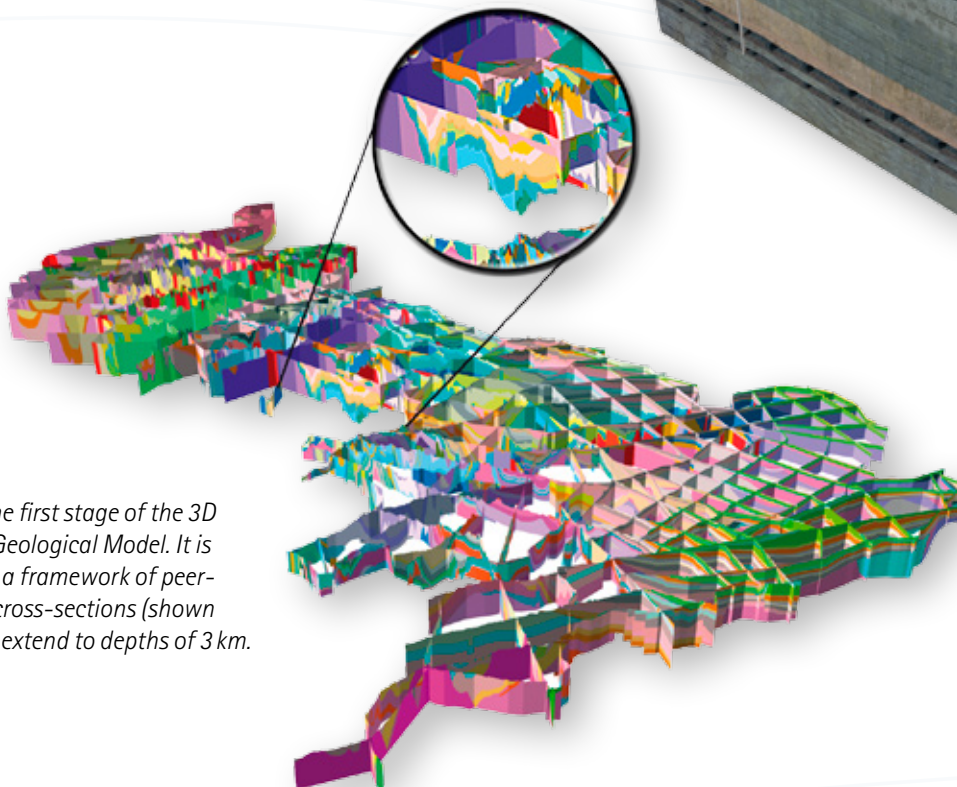
BGS will develop observatories in cities to monitor underground processes while linking these with what happens at the surface. The first, an observatory for the Thames catchment and London, is already starting.

In the next few years we will be working with planners in the Middle East and Asia to develop sustainable cities there.



In the future we will need to manage the subsurface under modern cities.

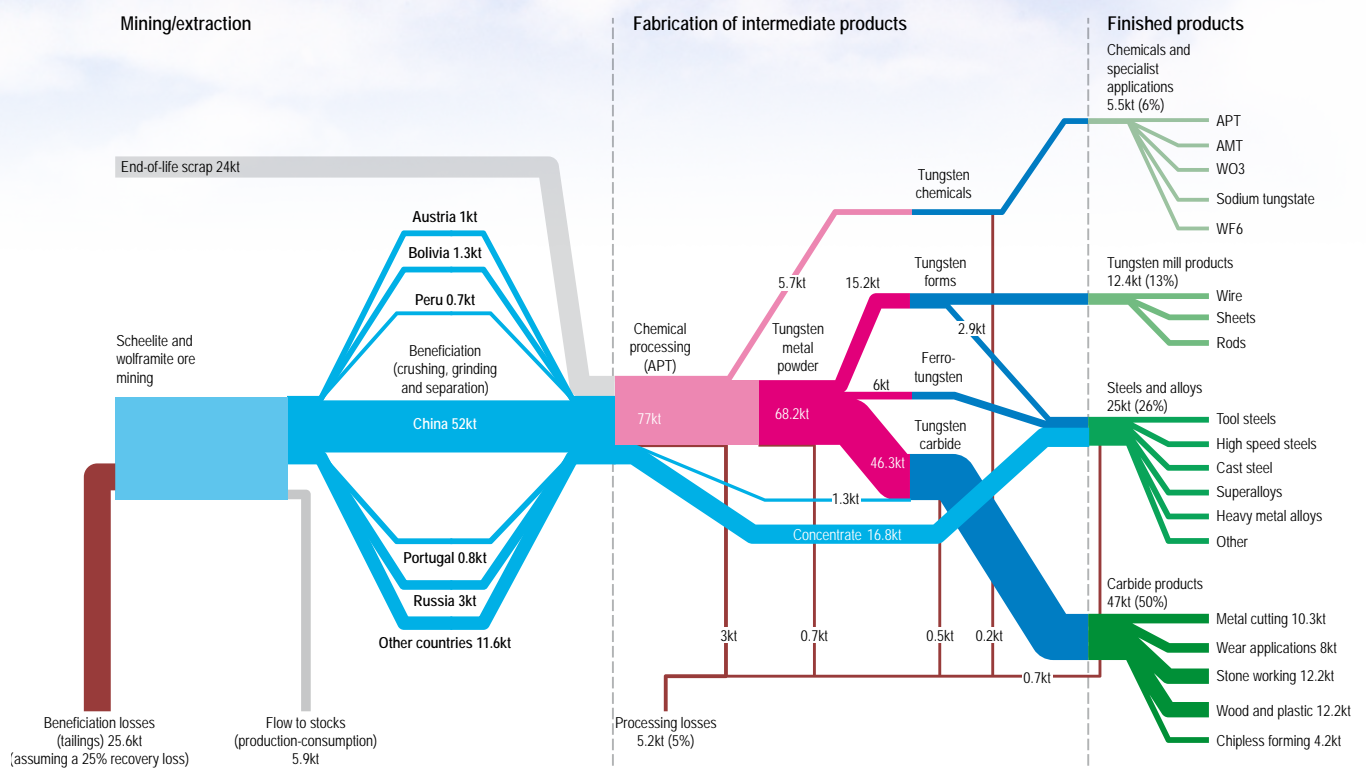
GB3D is the first stage of the 3D National Geological Model. It is built from a framework of peer-reviewed cross-sections (shown here) that extend to depths of 3 km.



What we'll do

Use our natural resources responsibly

Global population growth and changing lifestyles are increasing the demand for energy, water and raw materials. Political and economic instability can make things worse, creating price volatility, shortages and conflict. BGS will continue to research resource security, evaluation and extraction whether it be groundwater or shale gas. We will also research energy storage and geological disposal, for example of radioactive waste and CO₂. In the long run, BGS science aims to ensure that we get the most out of our resources without harming the environment.



This 'Sankey diagram' illustrates the flow of tungsten through the modern industrial world, but could be used to illustrate the origin and fate of any precious resource. BGS and Cambridge University are researching the 'flows' of metals in the natural and human environment to promote more efficient management. Diagram courtesy of Cambridge University.



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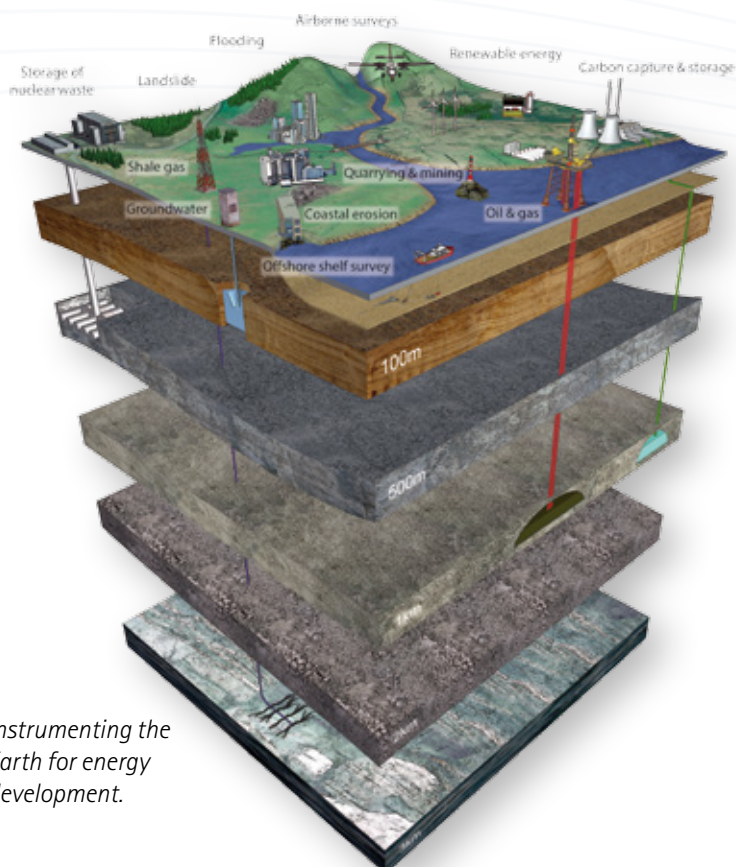
For example ...

Energy test bed

Geology is very important to Britain's energy — not just because we get oil and gas from the ground — but because we sometimes need to dispose of the waste products of the energy industry underground, like radioactive waste and CO₂. But the regulator, the government, business and the public need to be reassured that these activities are feasible and safe, so we need to understand subsurface processes better. BGS will do this by developing new monitoring and modelling systems as part of our ambitious 'energy test bed' concept.

The energy test bed will involve seismic and groundwater monitoring, borehole sensors, and techniques such as electrical resistivity tomography, remote sensing and surface gas testing.

We will start by instrumenting areas likely to experience underground energy development in the near future, working with partners in universities, and with businesses and the regulator.



Instrumenting the Earth for energy development.

Unlocking groundwater in Africa

Over 300 million people living in Africa don't yet have access to safe, clean drinking water. Wells are likely to provide much of that water in the future so we need to know how much there is and how vulnerable it will be to climate change. Through work led by BGS and supported by the Department for International Development and NERC, the amount of groundwater across Africa has been mapped in detail for the first time. These maps will help in the future sustainable use and management of African groundwater.

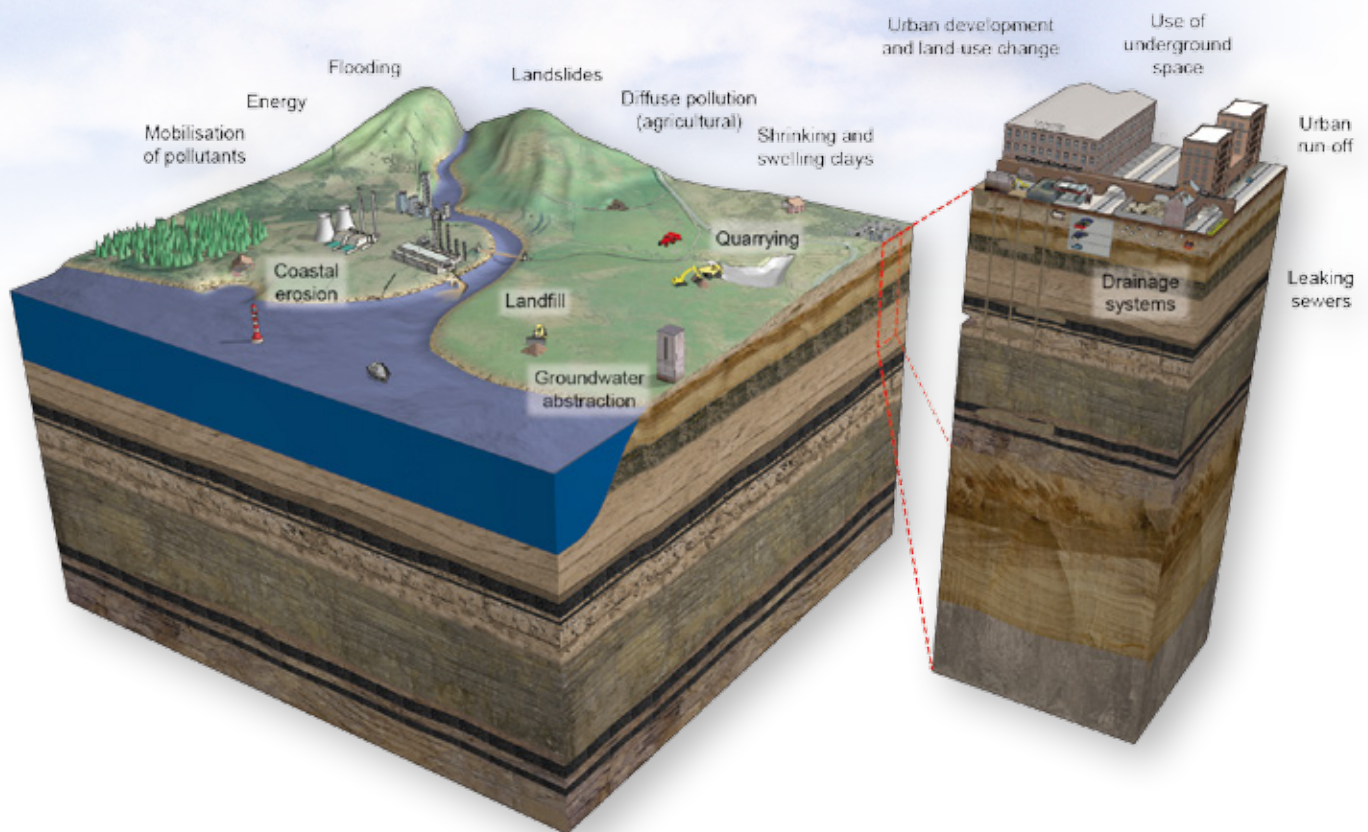
“This research ... could have a profound effect on some of the world's poorest people, helping them become less vulnerable to drought and to adapt to the impact of climate change. . .”

Andrew Mitchell — former Secretary of State for International Development

What we'll do

Manage environmental change

Environmental change is speeding up as a result of climate warming and population growth. BGS specialises in long-term monitoring and observation to detect change that may not be visible from day to day. Our analysis looks for tipping points and feedback, and in the future we will build computer models that will help us to predict environmental change and so protect lives and property in a timely and economical way.



Environmental change in the shallow subsurface.

“ We specialise in long-term monitoring and observation to detect change that may not be visible from day to day. ”



For example ...

Climate change and groundwater levels

In future it will get warmer and rainfall patterns will change. Working with partners, BGS has assessed the potential impact of Met Office climate change projections on groundwater across the UK to 2080. We calibrated models to estimate the changes in groundwater levels under a range of possible climate scenarios. The outputs are being used to inform future government policy on sustainable water management and abstraction.

Modelling environmental change in the critical zone

As the world's climate and land-cover change, the critical zone (the zone where rock meets life) changes too. There may be landslides, and rates of soil erosion and river discharge may change. There may also be changes in the way that nutrients and contaminants flow underground. Melting glaciers may affect water availability and may cause floods. BGS is developing numerical models that assess the sensitivity of the critical zone to changes in climate and land cover, to help us understand, predict and forecast.



What we'll do

Be resilient to environmental hazards

Population increase and climate change will also affect the impact of environmental hazards on lives and livelihoods. BGS will take advantage of new technologies to improve satellite measurement and real-time monitoring of hazards including earthquakes, volcanoes, tsunamis, landslides, floods and subsidence. This data will allow us to assess, model and forecast hazards. If we can respond to events better and help to mitigate their effects, we will go a long way to improving our resilience to natural hazards.



Phases of the disaster risk-management cycle.

“ If we can respond to events better and help to mitigate their effects, we will go a long way to improving our resilience to natural hazards. ”



©Jupiter Images

For example ...

Planning for future volcanic eruptions in Iceland

In 2010, the Eyjafjallajökull ash cloud disrupted the aviation industry, with global losses of \$5 billion in the first week of the eruption. BGS played a key role in the UK Government's Scientific Advisory Group for Emergencies and in explaining the science to stakeholders including the Civil Aviation Authority, airport operators and airlines.

Today we are working with the UK and Icelandic authorities, and academic partners, to ensure that plans based on high-quality research are in place to respond to future Icelandic volcanic eruptions.

We are also developing scenarios as part of the UK National Risk Assessment including predicting the possible impacts of a future eruption, similar to the Icelandic Laki eruption of 1783 to 1784.

Coastal change

The impact of climate change will be felt most directly by coastal communities and infrastructure. It will modify sea levels, tidal ranges, tidal currents and waves. In partnership with the UK Environment Agency and others, BGS is making assessments of coastal vulnerability and building models of coastal change over decades and centuries into the future, applicable to coasts around the world.

Space weather

The Sun's radiation, particles and magnetic fields can have an effect on the Earth's magnetic field, disrupting power lines and communications. BGS is working with industry to help predict and prepare for major magnetic storms. Electrode systems at the UK magnetic observatories (Lerwick, Eskdalemuir and Hartland) monitor the surface electrical field created by geomagnetic field changes which are in turn driven by the Sun. These field measurements will augment our magnetic field monitoring and help us to identify geomagnetically induced currents, which are potentially damaging to the National Grid system.



Making it happen

The previous pages illustrate our ambitious programme to improve our understanding of the subsurface at timescales consistent with human usage. This will make us better at managing natural resources and environmental change, and make us more resilient to environmental hazards. We will make these things happen by nurturing our people and strengthening the research environment – and by partnerships with universities, business and other NERC centres. We will play to our core strengths in 3D geology and the national geological database, and we will work with technologists to make sure we are ahead of the game. We will also work with countries across the world, promoting responsible resource development and modern geological data storage.

Partnerships

BGS will team up with the best universities and institutes, and with business, to become the hub of modern British earth science research. We are already beginning this process with a number of strategic partnerships:

- geoscience campuses with Heriot-Watt and Nottingham universities
- surface and subsurface sensor systems with the Centre for

Ecology and Hydrology and the National Centre for Atmospheric Science

- improved earthquake monitoring across the UK with SeisUK
- minerals research with the University of Exeter's Camborne School of Mines
- subsurface groundwater modelling with Imperial College London and Lancaster University
- carbon capture and storage (CCS)

with the University of Nottingham and the Scottish CCS centre

- the Natural Hazards Partnership
- integration with key European national laboratories via the European Plate Observing System (EPOS)
- a 'European Geological Service' with other European geological survey organisations
- doctoral training partnerships with top UK universities.



BGS will work with NERC centres, UK universities, European national laboratories, and business and industry.



For example...

Partnerships in carbon capture and storage research

Carbon capture and storage (CCS) aims to capture and dispose of industrial CO₂ in deep rock formations. BGS is working with the University of Nottingham in the Nottingham Centre for Carbon Capture and Storage (NCCCS) and with Scottish universities in Scottish Carbon Capture and Storage (SCCS). These joint ventures bring together geologists, engineers, mathematicians, geographers and social scientists.

CCS might be big business in the North Sea in the near future. We are working with The Crown Estate and the Energy Technologies Institute to facilitate efficient leasing and licensing of offshore CO₂ storage. The website *CO₂Stored* is the first stage. It offers information on which structures might be able to hold CO₂. In the future we will develop 3D models for the subsurface of the North Sea so that we can manage stored CO₂ properly. Models like this will also allow better management of enhanced recovery of the remaining oil and gas in North Sea rocks.

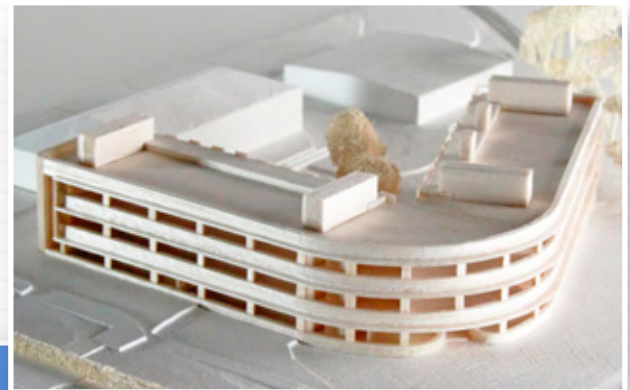


Sir Charles Lyell Centre

BGS is building the Sir Charles Lyell Centre as part of the relocation our Edinburgh office to Heriot-Watt University's Edinburgh campus. With a full complement of over 220 staff, the Centre will occupy a new, purpose-built complex providing office, research and communal space. The new research will cross the boundaries between geology, life science, computing, mathematics and engineering.

There will be incubator space for spin-out and spin-in companies looking to work with Heriot-Watt and BGS staff. The Centre will enhance Scotland's research base and support its innovation strategy by creating one of Europe's leading clusters in the earth and marine sciences.

Model of a design proposed by Page\Park Architects for the Sir Charles Lyell Centre.



Making it happen

Data

Data management will play a critical role in BGS in the next decade. The development of monitoring in real time will mean that we will need to ingest and process very large amounts of new data. The advent of open data and mobile platforms means that we will have to serve data and information in different ways. For example, there will be an increased focus on ad hoc data and information communities – like the ASK (Accessing Subsurface Knowledge) network in Glasgow. We will work with a broad

community to develop in-house skills to analyse data with high performance computers running models and decision-support tools. These tools will be used to communicate with decision-makers and resource-managers in non-technical language.

BGS has led open data initiatives, for example OpenGeoscience and iGeology, but this is a traditional data-provider model. In future we will enhance our web presence through much richer engagement

with the wider geoscientific community. We will use web and app tools to develop information-level community engagement and user-generated content. We will also forge partnerships with a wide range of organisations holding geoscience data to develop the concept of a global geoscience data warehouse.



Open access to BGS data will be a key objective in the next decade.



For example...

iGeology case study

iGeology (available for iPhone and Android) and its augmented-reality companion, iGeology 3D, are smartphone apps that provide mobile access to BGS mapping and other geological information in the field. Free to download, these apps put public data directly into the hands of the people who want to use them. Containing the equivalent of 500 traditional paper maps, iGeology has been downloaded over 150 000 times. Another app from BGS is mySoil, a collaboration with the Centre for Ecology and Hydrology, the European Commission Joint Research Centre and the Met Office to provide farmers, gardeners and land-use planners with improved access to soil information. Many more apps are in the pipeline.



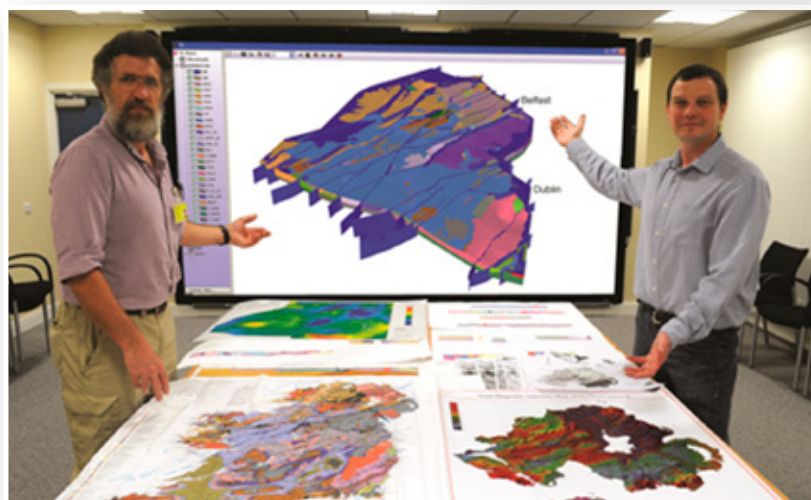
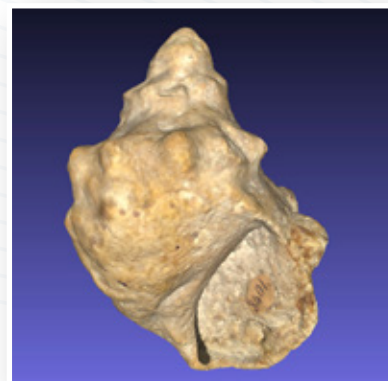
Tellus 3D models

The award-winning Northern Ireland Tellus Project and the current Tellus Border Project have collected vast geophysical and geochemical datasets and made them available to investigators and researchers. A new 3D model of Northern Ireland has been developed to provide the platform upon which the datasets can be fully exploited. The model is dynamic in that it can absorb new or legacy data, from outcrops, boreholes or remote sensing.

We will take the Tellus methodology to other parts of Britain and abroad, collecting geochemical and geophysical data and making 3D models to help us use our underground resources efficiently and sustainably. We started an airborne survey of the south-west of England in the summer of 2013.

3D images of fossils online

Every species of organism, whether living or fossil, has a type or reference specimen to define its characteristic features. These specimens are held in museums and collections around the world and must be available for experts to examine, but are also of interest to students and the public. BGS is making its best specimens available for study online as high-resolution 3D images and 3D digital models.



From map to 3D model: the first geological model of Northern Ireland.

Making it happen

Technology

In the next few years much of BGS's science will be dependent on technology. Advances such as sensor networks, modelling and visualisation are changing the quantity and quality of scientific data. Increases in computing power, storage capacity and networking capabilities now allow this data to be processed and investigated.

Areas we will develop

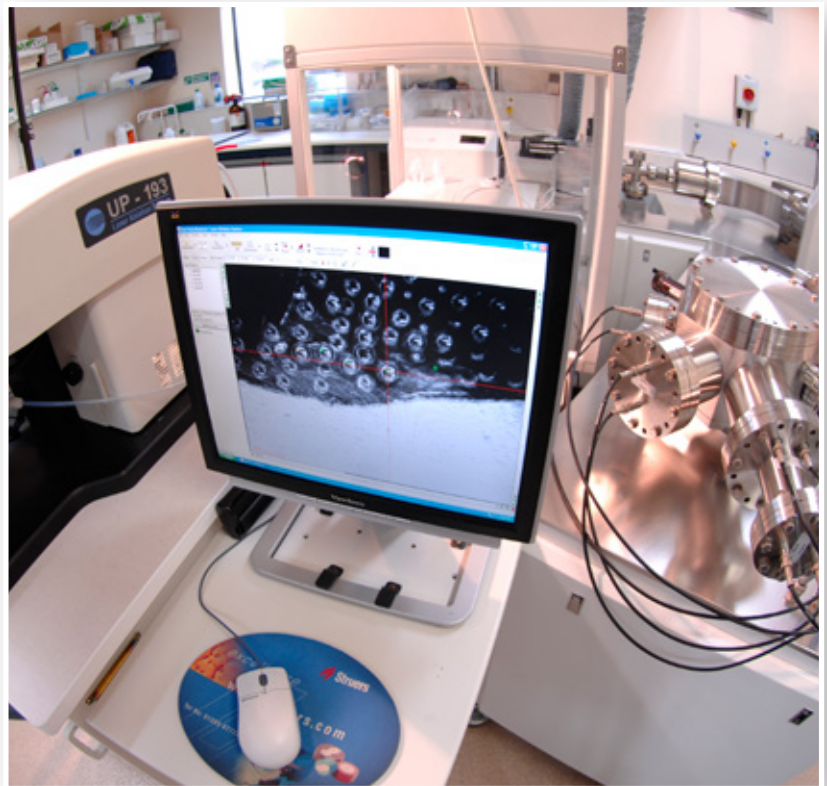
Nanotechnology is being used more and more in manufacturing, medicine and engineering. BGS is already using innovative nanotechnology in fluid flow studies (see right) and will develop it further in tandem with 3D imaging. BGS geomicrobiologists use microbes to track contaminant transport and now have the ability to use molecular techniques to monitor and predict geomicrobial processes. Our use of nucleic-acid base-sequencing will allow previously unrecognised ties between the biological and geological worlds. Advances in medical imaging are now being applied in engineering, materials science and the petroleum industry, for example computerised tomography (CT) and magnetic resonance imaging (MRI). BGS is at the cutting edge of seismic imaging for CO₂ in carbon capture and storage (CCS) and is a world leader in non-invasive geo-electrical imaging of the shallow subsurface. We will continue to work with technology companies to bring new techniques into geological surveying.

Rapid advances in lightweight wireless sensors will expand the efficiency and

accuracy of environmental monitoring creating a revolution in data collection, synthesis and analysis. BGS is developing the geological application of sensors, for example SENSOR NET, which consists of a network of soil moisture sensors in North Yorkshire.

We will develop real-time monitoring of organic contaminants and nitrate pollution and take sensor technology below the surface, making use of existing infrastructure, such as wells and boreholes.

We will continue to develop satellite and airborne remote sensing for hazard identification, as well as 3D visualisation for virtual field reconnaissance. We will develop new uses for remotely sensed data, for example monitoring CCS leakage and leaks of methane in the energy industry.





For example ...

Research-led seabed drilling

Studying the Earth beneath the sea requires specialised drilling and coring platforms.

With European partners, BGS will install 40 sea-floor borehole systems over the next 10 years. The sea-floor systems enable in-situ sampling, and recovery of pressurised samples to allow biological examination and accurate resource assessments for methane hydrates, deep hydrogen and minerals.

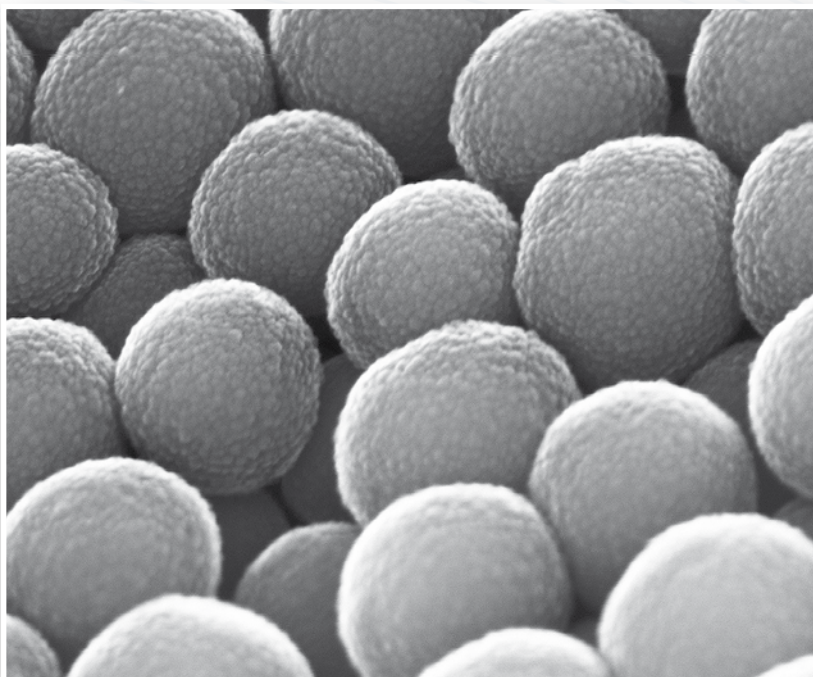


Seabed drilling will help us collect samples of new fuels such as methane hydrate.

Nanoparticles in fluid flow

How can you tell where a fluid has moved through a very low permeability rock like shale? The answer is to use nanoparticles. BGS has developed a new technique using gold and titanium nanoparticles to trace fluid flow. The nanoparticles are injected within a stream of helium into a rock sample under pressure. After the sample is depressurised, it is sliced and imaged with a scanning electron microscope to find the nanoparticles showing where

the fluid moved. As well as research into shale gas, the technique will help us understand how fluids might move in an underground radioactive waste repository.



Nanoparticles can be used to show how fluids move through rocks. The particles used are made of gold and rutile; the gold particles typically measure less than 100 nanometres.

Making it happen

Services and facilities

BGS represents the earth science sector in NERC and has laboratories, repositories, databases and equipment to carry out long-term strategic science, and to service the UK's science and business needs. Amongst these facilities are:

- the National Geological Repository which houses a unique collection of borehole cores, specimens, and subsurface information from onshore and offshore UK
- the NERC Isotope Geoscience Laboratory (NIGL), a world-leading laboratory for geochronology, pollution, hydrology, climate change, archaeology and forensic studies.

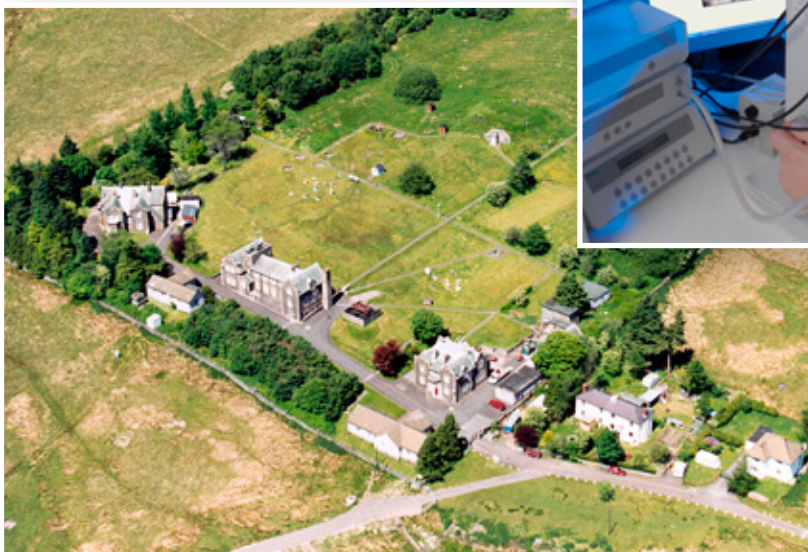
In the next five years we will build new laboratories to integrate specialised data further and work

with university partners to develop joint laboratory facilities.

We will integrate the earth science facilities of NERC – currently dispersed across BGS and universities – into a more coherent set of resources. We will link our geochemical and rock physics facilities with universities to build on our strengths.

We will expand the existing world-leading excellence in geochronology and stable and radiogenic isotopes

into Europe to improve technology and deliver the best capabilities in the world. In geochronology we will improve the accuracy of radio-isotopic dating of earth materials, for example through determining accurate values for the isotopic composition of uranium. We will also use innovative stable-isotope methods to analyse environmental change, for example large-scale shifts in the oceans which might affect future climate variability in Europe.



Eskdalemuir magnetic observatory in the Southern Uplands of Scotland.





Nurturing our people

Creating the right environment

We know that to sustain BGS as a world-class research geological survey we need to nurture our people. We will provide the best laboratories, working conditions and facilities. We will also provide the best opportunities for advancement through creative BGS research programmes and through working with world-class partners in universities and business.

We aim to have an inclusive and flexible environment for all of our employees. Our commitment to gender equality has been recognised in a pilot Athena SWAN awards process where BGS achieved the equivalent of a bronze award.

Measuring our success

It is important that the outputs of our research are measured. We will improve the reporting of our successes and connect our research outputs with impacts in the real world. We will follow our research from publication to policy, and measure its impact and benefit. We will also continue to increase the number and quality of our peer-reviewed outputs.

Integrity

BGS will continue to operate to the highest professional standards, emphasising impartiality, confidentiality, reliability, promptness, and value for money. We will also meet our obligations under the Freedom of Information Act 2000 and the Environmental Information Regulations of 2004.





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