FREE AT THE POINT OF USE – THE NEXT GENERATION OF BGS ONLINE RESOURCES

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ABSTRACT

The British Geological Survey (BGS) website is a treasure trove of geological data spanning the last 200 years. However, unearthing the gems of information and data you desire amongst the 5000 pages of web content is a quest that would have even Jack Sparrow trembling at the prospect. In this paper BGS industrial minerals geologist Clive Mitchell, navigates a path through the BGS website. The starting point is OpenGeoscience which is a free service that acts as the portal where visitors can view maps, download data, scans, photos and other information.

Geological maps are available through a series of online map viewers. The most popular being the Geology of Britain viewer, this is based on *BGS Geology* (formerly DigMapGB) which is the basis for all BGS geological maps for the UK. *BGS Geology* was initially created by the digitisation of BGS paper maps and is now maintained by straight to digital geological mapping. This viewer is a seamless and scalable map that can be queried to give a summary of the geological units being displayed. Further detailed geological data for these rock units is accessed via the BGS Lexicon. This is essentially the bible for UK geology covering all of the named rock units that appear on BGS maps and publications. The viewer and the lexicon are two of the top four most visited web pages on the BGS website. Other geological map viewers include onshore and offshore GeoIndex datasets for mineral resources, groundwater, soil properties and environmental baseline monitoring for shale gas sites. Fans of paper maps can access the entire archive of over 6000 maps published by the BGS from 1832 to 2015 via the BGS maps portal.

The starting point for onshore BGS geological data is the GeoIndex Onshore. This is a map-based index to onshore datasets collected by BGS or obtained from other sources. There are 156 available dataset layers that can be added covering: geology, boreholes, collections, hazards, geochemistry, geophysics, products, photographs, hydrogeology, minerals, environmental designations and surface (Ordnance Survey terrain data). There are 44 minerals layers including mineral occurrences, mines and quarries, building stones, and oil and gas licence areas. Certain data sets can be downloaded. These include 1:625k geological line work, geohazards, hydrogeological, geochemical and geophysical data sets. For example, the *BGS Geology* 625k geological map is available in a range of formats including ESRI (for ArcGIS) and MapInfo. More detailed geological line work is available as licenced data products.

Increasingly BGS maps and data are available via mobile devices. The most popular mobile application is iGeology, which is essentially the Geology of Britain viewer in app form. This app has been downloaded over 335,000 times with 90,000 active users (combined iOS and Android). It is largely responsible for the marked increase in visits to the BGS Lexicon. It is anticipated that most BGS geological data will be accessed via mobile devices in the near future with the prospect that demand from our user community will not only drive app development but also shape the future data priorities of the BGS.

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INTRODUCTION

Established in 1835, the British Geological Survey (BGS) is world's oldest geological survey. It now has a reputation as a world-leading survey and is an independent, not-for-profit public sector research organisation that is partly funded by public money and partly by commissioned and commercial research. Over the 190 years of its existence the BGS has created a wealth of geological data and information, most of which is now freely accessible and downloadable from the BGS website (www.bgs.ac.uk).

The first national scale geological map of Great Britain predates the BGS by 20 years and was produced by William Smith (Fig. 1). The map, produced in 1815, is a "Delineation of the strata of England and Wales with part of Scotland". It came in 15 sections, each with 6 panels and when combined measured eight feet long by six feet wide. It is widely referred to as the 'map that changed the world' and helped to shape the economic and scientific development of Britain. It was a significant resource used to locate the raw materials, such as iron ore, coal and limestone, that were vital for the continuation of the latter part of the industrial revolution.

Figure 1. William Smiths 1815 map "Delineation of the strata of England and Wales with part of Scotland"

This paper summarises the resources of maps, data and information produced by the BGS over the 200 years following William Smith that are available online and are of more interest to those in the UK minerals industry.

GEOLOGY OF BRITAIN

The starting point for a discovery of the online geological resources of the BGS is OpenGeoscience: www.bgs.ac.uk/opengeoscience/. This is a web portal for the free online services of the BGS where you can view maps, download data, scans, photos and other information. Data is made available where ever possible under the Open Government Licence which is designed for the royalty free use of public sector information as long as the source is acknowledged.

The traditional paper-based map production of the BGS has changed dramatically over the last 20 years. Paper maps are still available but are now typically 'print on demand' based on their digital equivalents. The currently understood geology of Great Britain is based on the **Digital Geological map of GB**, which is usually known by its shorthand '*BGS Geology*'. This is produced at various scales from 1:10,000 to 1:625,000 and includes bedrock and superficial geology, mass movement (mostly landslips), artificial ground (modified by man) and linear features (such as coal seams, faults, folds and veins). The best coverage of Great Britain is at the 1:50,000 scale (99% coverage), known as *BGS Geology* 50k. Geological line work is currently licenced per square kilometre but is free to view online via the BGS web map viewers or for users to view within their own GIS software via a Web Map Service (WMS).

Geological mapping is carried out by the BGS using ruggedized tablet computers (Fig. 2) with information added using the BGS-SIGMA*mobile* digital data capture software (freely available to download from www.bgs.ac.uk/research/sigma/home.html and is run using standard ArcGIS software, ArcGIS 10.1 and 10.3).

Figure 2. BGS geologist mapping using a ruggedized field tablet computer in the Scottish Highlands.

All of the paper maps produced by the BGS from the 1830s up to 2015 are available to view via the **BGS Maps Portal**: www.bgs.ac.uk/data/maps/. This includes high resolution scanned images of 6000 maps and cross sections, with the oldest map being that of Weston Super Mare by Henry Thomas De la Beche in 1834 and the latest paper map being the 1:50,000 map sheet 118 for Nefyn and part of Caernarfon in 2015.

There are many options to view the current geological line work of Britain. The **Geology of Britain viewer** (http://mapapps.bgs.ac.uk/geologyofbritain/home.html) is the simplest option with the geology presented at 1:625,000 for the national view and at 1:50,000 when the map is displayed at the local view (Fig. 3). The map can be used to view bedrock and superficial geology, 3D models to create virtual boreholes and cross sections, scans of borehole records and a timeline of earthquake activity. The geological units displayed can be queried to display a summary description of the bedrock and superficial geology with an option for further details that leads to the 'BGS Lexicon'. Currently there is a beta-version of the Geology of Britain viewer that integrates the National Geological Model. This displays the BGS National Bedrock Fence Diagram allowing a 3D view of the subsurface geology of Great Britain. The geology of the UK can be draped over digital terrain models using varying degrees of vertical exaggeration.

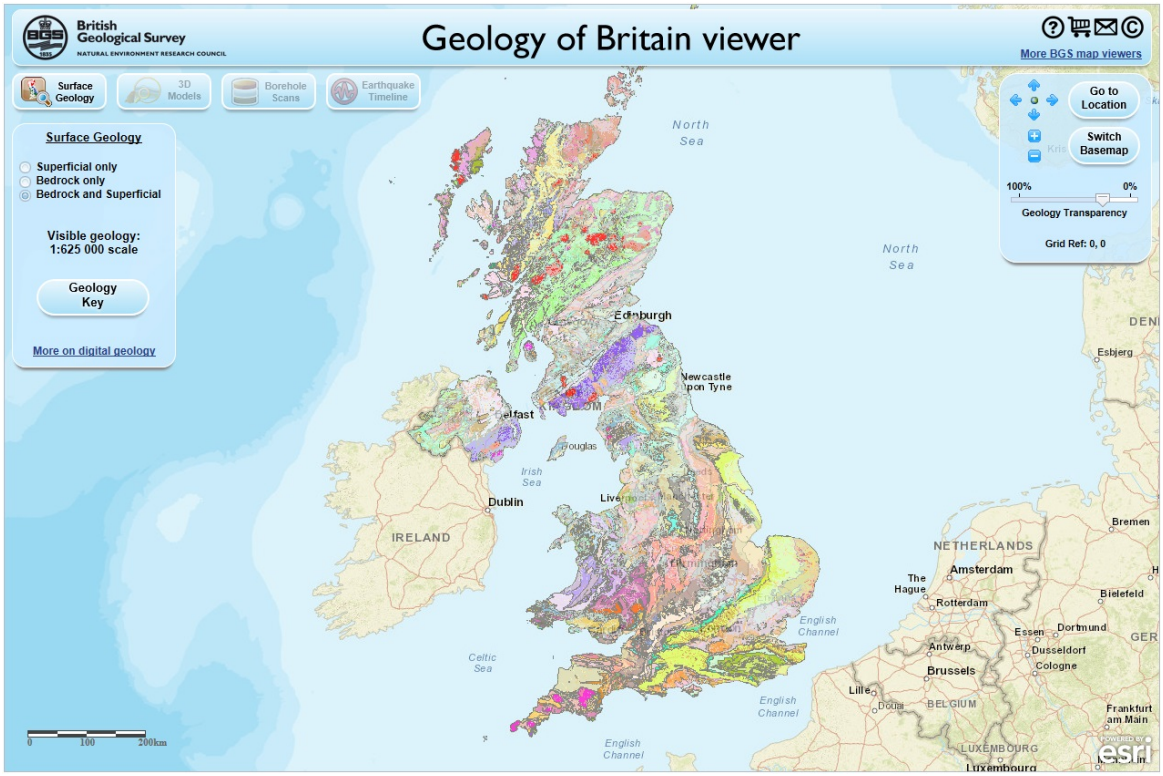

Figure 3. The Geology of Britain viewer.

The **BGS Lexicon** (www.bgs.ac.uk/lexicon/) is a database of over 10,000 named rock units and provides the definitions for all terms that appear on BGS maps and publications. It is a dynamic database that represents the current BGS interpretation, new entries are added and existing entries are updated regularly.

The **GeoIndex** (www.bgs.ac.uk/geoindex/) is the option most suitable for professional users to view the current geology of Britain. This is a fairly sophisticated map-based index of BGS datasets. There are two versions, the Onshore GeoIndex and the Offshore GeoIndex. The Onshore GeoIndex enables access to approximately 160 data sets that can be displayed onto a web map of Britain. The data sets are grouped by theme into geology, boreholes,

collections, hazards, geochemistry, geophysics, products, photographs, hydrogeology, minerals, environmental designations and surface (such as digital terrain models). There are 44 mineral data sets that include mineral occurrences, resources, planning permissions, licence areas, hydrocarbon wells, historic and active sites. The most popular GeoIndex data set is the borehole scans with the option to display scanned records for boreholes across the country. The Offshore GeoIndex enables access to datasets including geophysical surveys, Oil & Gas Authority surveys, magnetic and gravity anomaly maps, and BGS marine maps and reports.

> *"… the more boreholes that we release, the more they are accessed and the more the industry look at them and think they should donate their own records. This then gets into a virtuous cycle of more access and more donations. The benefits outweigh the disincentives, which results in companies saving a fortune on drilling new boreholes."*
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> **Gerry Wildman, BGS Data and Science Services Manager**

The current geology of the UK can be also accessed via the smartphone application ('app') iGeology: www.bgs.ac.uk/igeology/. This app pulls in the geological map data as required from *BGS Geology*. It can be queried to give a summary of the information for the bedrock and superficial units displayed with a link to the lexicon. The latest version allows users to act as citizen scientists by uploading their own geological observations and photos which can be viewed in a photo feed. Data layers can be accessed for scanned borehole logs, linear features, reports on geological hazards and an overlay of the 1815 map produced by William Smith. The app is free to download onto iPhone and Android phones and has been downloaded over 335,000 times. Other apps from the BGS include mySoil and myVolcano.

> *"(The current version of the iGeology app has) much more focus on crowdsourcing and making users more aware of being involved in the submission of data. Ideally we would like it to be a way for trained, qualified users being able to validate and look at BGS maps and data as we can only stretch our resources so far across the country."*
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> **Steve Richardson, BGS Geospatial Applications Developer**

MINERALSUK

The online resources produced by the BGS Centre for Sustainable Mineral Development are hosted by MineralsUK: www.mineralsuk.com. This is the portal for information on mineral resources, mineral planning, policy and legislation, sustainable development, statistics and exploration. Products freely available to download include the Directory of Mines and Quarries, the United Kingdom Minerals Yearbook, as well as European and World mineral statistics, mineral planning factsheets, mineral commodity profiles and the Risk List which details the supply risk for elements of economic value.

Over the last 15 years or so, the BGS has embarked on a systematic data mining programme to scan and capture the largely paper based maps, reports and data that it holds in its archives. These have been added to the online resources available to download from the BGS. Those relevant to the UK minerals industry have proven to be popular and sought after, frequently topping the 'downloads charts' for the BGS. These include the following:

- **World Mineral statistics**: world mineral statistics have been produced consistently by the BGS for more than 100 years; the first was the 'Mineral statistics of the British Empire and Foreign Countries 1913 to 1922'. www.bgs.ac.uk/mineralksuk/statistics/home.html

- **Mineral Reconnaissance Programme** (MRP): the MRP carried out mineral exploration in the UK from the early 1970s to 1997. In total there are 145 reports and 16 data releases that provide geological, geochemical, geophysical, mineralogical and metallogenic information on prospective areas across the UK. www.bgs.ac.uk/mineralsuk/exploration/potential/mrp.html
- **Industrial Mineral Assessment Unit** (IMAU): from 1968 to 1990 the IMAU carried out surveys of the sand and gravel resources (Fig. 4) and industrial mineral resources including celestite, limestone and dolomite, conglomerate and hard rock of the UK. In total there are 158 reports and maps available to download. www.bgs.ac.uk/mineralsuk/mines/IMAU.html
- **Mineral resource maps and reports**: from the mid-1990s to 2012 the BGS produced mineral resource maps (1:100,000) and reports for all of the counties of England, Northern Ireland, Scotland and parts of south Wales, as well as six maps that cover the whole of Wales (and six maps for aggregate safeguarding in Wales). www.bgs.ac.uk/mineralsuk/planning/resource.html
- **Mineral Planning Factsheets**: from the mid-2000s the BGS has produced a series of mineral planning factsheets that cover economically important minerals extracted in Britain. They are primarily intended to inform the land-use planning process but have proven to be of much wider interest. www.bgs.ac.uk/mineralsuk/planning/mineralPlanningFactsheets.html
- **Directory of Mines and Quarries**: this directory provides information on all operational mineral sites in the UK including minerals worked, geological formations, location and operator. They are listed firstly by commodity, then by Mineral Planning Authority and thirdly by operator. www.bgs.ac.uk/mineralsuk/mines/dmq.html

Figure 4. Drilling rig used by the BGS for surveys of sand and gravel in the 1970s

BGS ONLINE IN THE FUTURE

In the near future, the semantic web will be the online experience. Rather than just delivering data the semantic web will enable computers to understand what the data means. This will allow users to ask questions and obtain intelligent responses based on an integration of all available online data. Data sets will be joined together using an Application Programming Interface (API). For example geological, mineralogical, geochemical and geophysical data could be integrated with non-geological data for a particular area or subject to create new understanding and interpretations.

> "Semantic web is linking of data to data in an intelligent way. The idea is that you would be able to ask a computer "How do I find gold?" and the computer will pull together an intelligent answer."
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> **James Passmore, BGS GIS & WWW expert**

Building Information Management (BIM) has become the norm for public sector funded construction and infrastructure projects. The BGS envisages that this will become accepted throughout industry. Subsurface data sets such as **BGS Civils** can be used with BIM applications. www.bgs.ac.uk/products/groundConditions/civilsBundleHome.html

Standardisation of data delivery will enable a greater degree of interoperability. This will ensure that geospatial data will be shared much more freely, saving time and money, and ideally enabling a greater degree of innovation. The Geospatial Commission (GC) is a step in this direction. It includes the BGS, Ordnance Survey, Land Registry, Valuation Office, Hydrographic Office and the Coal Authority. Currently the GC is developing a national geospatial strategy addressing key issues such as data licencing, interoperability and integration of third party data sets.

Models of the subsurface already exist for cities and countries. The National Geological Model of the UK is currently based on the National Bedrock Fence Diagram. The aim is to extend this and literally fill in the gaps between the cross sections to create an accurate, multi-scale geospatial model for the UK subsurface. In the future this will extend to continents and eventually the whole planet. The ideal would be a subsurface version of Google Earth.

> *"(In the future I envision) the integration of a wider range of data sets, real time data sets from citizens, real time monitoring of landslides, being able to deal with that volume of data, bring it back to computing infrastructure where scientists can find that data…. to fill the gaps between the traditional professional surveying."*
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> **Patrick Bell, BGS Information Systems Team Leader**

Low cost sensor networks to instrument the earth enable real-time subsurface monitoring that constantly takes the pulse of the planet. This may one day enable the realisation of true early warning systems for geological hazards such as landslides, earthquakes and volcanic eruptions. The Raspberry Shake is a small seismometer based on the Raspberry Pi mini-computer that costs about £300 which is a tenth of the cost of professional seismometers.

> *"We will move away from the 200 year old map which has been lovingly hand drafted by interpretation and opinion into something which is very much more data driven. It will be driven by satellite sensors, in the ground sensors, crowd sourced data from boreholes or ground sourced observations."*
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> **Russell Lawley, BGS Team Leader Baseline Products**

The virtual Earth already exists in the form of immersive virtual reality technology such as **GeoVisionary VR suite** at the BGS that enables the visualisation of the subsurface (www.bgs.ac.uk/research/environmentalModelling/3dVisualisation.html). This may in the future enable the visualisation of the potential environmental impact on the subsurface likely to be caused by planned developments such as transport infrastructure, industrial sites and the extraction of mineral resources.

It is possible that in the future the BGS would become a 'Geological Survey 4.0' driven by the convergence of current developments including:'

- **Web 4.0**, otherwise known as the 'internet of things', enabling a seamless connection and communication between machines, sensors and people.
- **Digital Twin**, a virtual copy of the Earth enriched with digital models and updated in real time by low-cost sensors.
- **Artificial Intelligence** (AI) and **Machine Learning**, where smart systems start to think like humans, making their own autonomous decisions, acting independently and learning through experience.

> *"(In the future) BGS will be the keeper of the national geological twin. Geology is and will probably mostly remain hidden. BGS will still need people, experts who will still need to work with geology in the real world. We will still need to drill despite advances in sensor technology – techniques will still need ground truthing."*
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> **Holger Kessler, BGS Modelling Systems Team Leader**

It could be imagined that the Geological Survey 4.0 would operate with sensor-equipped drones that telemeter their data in real time to an overarching geoscience AI that populates and maintains the digital twin of the planet, making minor decisions instantly and alerting the humans when appropriate. In this future there would be no maps but a seamless virtual model that integrates all data, not just the geology, but every aspect of the planet we live on.

CROWDSOURCING DATA

This vision of the Geological Survey 4.0 may be a long way in the future but the BGS is making progress towards it. In order to achieve this the BGS needs more data. As part of the drive for more data the BGS works with the ASK (Accessing Subsurface Knowledge) network which includes BGS stakeholders, industry partners, the AGS (Association of Geotechnical & Geoenvironmental Specialists) data standards community and the wider European data community.

The BGS is actively seeking subsurface data. Data sets can be donated via the BGS National Geological Record Centre (NGRC) through the digital data deposit portal: http://transfer.bgs.ac.uk/ingestion. Data submitted preferably should be in the AGS digital data transfer format (AGS3.1 or AGS4.0). Currently the BGS has received over two terabytes of donated data, such as borehole records and logs and site investigation reports and data (Fig. 5).

> *"It's a modern world so we like to take digital data rather than paper data but we never knowingly turn any data away it's just that we have to spend quite a bit of money cleaning up data. The future is going to be more digital anyway."*
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> **Russell Lawley, BGS Team Leader Baseline Products**

Figure 5. BGS server room storing its own and donated data.

The advantages of donating subsurface data to the BGS include the reduction in archival costs and the likelihood of data becoming irretrievable over time due to inaccessible formats or simply being lost. Donated data will help improve the understanding of UK geology and can be accessed once processed via the BGS GeoIndex.

> *"(For the) Selby map sheet we extensively used third party information to inform and improve our geological understanding from the deep geology right up to the surface. Mine plans, coal authority seismic and deep boreholes formed the basis for the BGS bedrock interpretation. The area is covered by up to tens of metres of surficial cover … the deeper geological information was crucial. The understanding of the near surface geology is largely constrained by the borehole data donated from a wide range of sources."*
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> **Jon Ford, Chief Geologist England**

CONCLUSIONS

For those embarking on a discovery of the online digital resources of the BGS, the place to start is the web link for OpenGeoscience on the BGS website homepage. This is the portal where visitors can view maps, download data, scans, photos and other information. All past maps and current geology can either be viewed as map scans or can be queried via the web map interfaces of the Geology of Britain viewer, the Onshore and Offshore GeoIndexes or on mobile devices using the app iGeology. It is anticipated that most BGS geological data will be accessed via mobile devices in the near future with the prospect that demand from our user community will not only drive app development but also shape the future data priorities of the BGS.

BGS minerals information is available via MineralsUK which provides information on mineral resources, mineral planning, policy and legislation, sustainable development, statistics and exploration. The most popular downloads from MineralsUK include mineral statistics stretching back over 100 years, the reports and maps from the MRP, IMAU and other mineral resource studies carried out over the last 20 years by the BGS (including Mineral Planning Factsheets and mineral resource maps).

The future of the geological survey will see a convergence of technological developments including 3D surface modelling, low-cost sensor networks, the internet of things, the creation of the digital twin of the world, artificial intelligence and machine learning. The role of the BGS geologist will be very different with much of the physical survey role taken up by smart technology, maybe only being called into service to solve the trickier geological complexities or act as the ultimate executive decision maker in a largely autonomous world.

Whatever the future brings the BGS will continue to maintain geological expertise and knowledge as part of its public service for the UK. In the meantime, the BGS will be happy to receive all donations of data on the subsurface to help improve its current understanding of UK geology for the benefit for society and the public good.

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