Geological Map Database – A Practitioner's Guide to Delivering the Information

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INTRODUCTION

The British Geological Survey (BGS) has been practicing geological mapping since 1835. One would think that we should be getting quite good at it by now. The simplistic view is that the geology doesn't change, or at least not very quickly, so why is the job not done? There are two related answers to that question. The first is that our understanding is continually improving, so that we can know more about any given area. The second is that the demands upon the outputs of geological surveying are ever increasing. In his Presidential Address to the Geological Society of London in 1836, Sir Charles Lyell explained the process of setting up the world's first national geological survey "to cover the cost of geologically coloring the topographical maps of the trigonometrical Survey." He said: "…we drew up a joint report in which we endeavoured to state fully our opinion as to the great advantages which must accrue from such an undertaking not only as calculated to promote geological science, which would alone be a sufficient objective, but also as a work of great practical utility bearing on agriculture, mining, road-making, the formation of canals and railroads and other branches of national industry".

Those demands have now grown considerably as the number and variety of the branches of national industry has grown and developed. Roger Tym & Partners estimated in November 2003 that: "the total value added of national output to which BGS contributes for 2001 lies in the range of $64 billion – $116 billion, representing around 5%–8% of total UK output (GVA). This is of course orders of magnitude greater than BGS's annual turnover of approximately $75 million."

The aims of BGS geological mapping are stated in Walton and Lee (2001). They said: "the key objectives of the programme are to (i) deliver high quality detailed information on bedrock and superficial geology of the UK landmass as digital, map-based and text data, (ii) provide increased information on Quaternary and other superficial deposits, (iii) provide increased understanding of three-dimensional structure and process, (iv) deliver the near-surface component of the Digital Geoscience Spatial Model (DGSM) and (v) deliver the remaining 'sheets' in the current programme for incorporation into the Digital Geological Map of Great Britain (DiGMapGB)."

To achieve these stated aims, BGS has been progressively developing the key components of a geological mapping system (Figure 1). This multi-component system has been developed by a large team of scientists and developers (see Acknowledgements). The key components of the system, which are described below, are as follows:

- BGS-geoIDS and the associated databases and data stores in which BGS information is managed
- NGDC
- SIGMA
- LithoFrame
- Internal Discovery
- Internet
- DiGMapGB
- GeoSure

BGS GEOSCIENCE INTEGRATED DATABASE SYSTEM (BGS-GEOIDS)

BGS is the custodian of a wealth of geoscience information that has been collected by its own scientists or deposited by industry under various government statutes and voluntary agreement. Acquisition of this information has been continuous since the Survey's formation in 1835, and material created prior to this date is also stored in its archives. The range of information types includes materials (such as rocks, fossils, minerals, and borehole core), paper records, microfiche, reports, digital databases, digi-

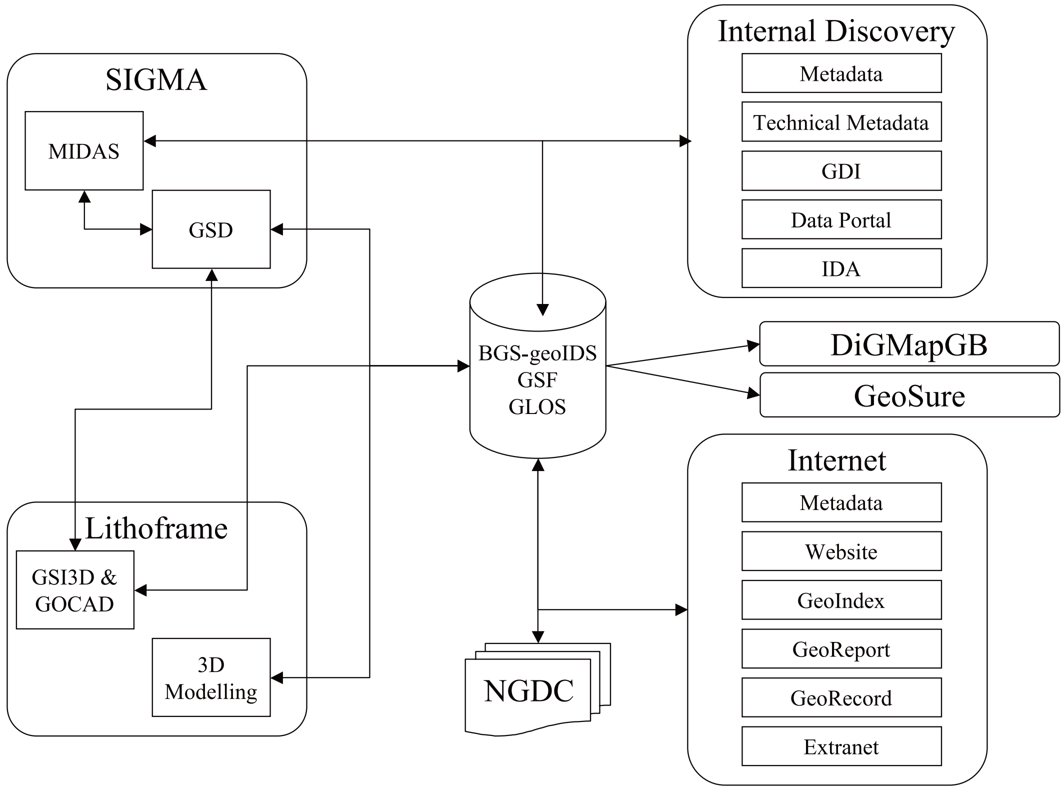

Figure 1. Geological Mapping Implementation (BGS-geoIDS – BGS Geoscience Integrated Database System; GDI – Geoscience Data Index; GLOS – Geoscience Large Object Store; GSD – Geoscience Spatial Database; GSF – Geoscience Spatial Framework; GSI3D – Geological Surveying and Investigation in 3D; IDA – Intranet Data Access; MIDAS – Mobile Integrated Data Acquisition System; NGDC – National Geoscience Data Centre; SIGMA – System for Integrated Geospatial Mapping).

tal files, digital models, etc. A range of systems and tools has been developed to manage these information assets in a holistic manner.

Peebler (1996) made the following observation: "Lack of basic data integration costs the average E&P professional a considerable amount of time. According to various estimates geoscientists and engineers spend from 20% to 30% of their total project time searching for, loading and formatting data."

Similarly, Adam Dobson (*Pers Comm*: 2002), representing Shell, a major international oil company, said that an internal audit undertaken in 2002 showed that, for new frontiers areas, staff spent their time as follows:

- Finding data – 53%
- Archiving data – 9%
- Documenting the data – 15%
- Interpreting (adding value) – 23%

On the basis of this audit Shell set a target of reducing the time spent finding data to 30% and increasing the adding-value time to 46%.

Several years earlier the BGS-geoIDS Project had been established to resolve a number of similar problems. BGS recognized that it held a wealth of valuable and important data, but that this resource was largely inaccessible to staff. Some of the data might be held and managed in well designed databases, but these were isolated "islands of excellence." There was little interoperability between these islands, so that routine integration and onward use or enhancement of the data were rarely straightforward. There were few corporate standards, and the local standards that did exist were not shared between databanks. BGS had no maintained metadata, so most BGS staff had no idea what data were held corporately, how these data might be used, or what their quality was. Finally, there were no corporate application standards, so data were accessed through the use of a multitude of different tools that had been built with no consistent design standards and no thought for future interoperability.

Key drivers recognized in planning and undertaking the BGS-geoIDS work were the opportunities to

- reduce staff effort in finding data,

- make quality-assured data available to staff and customers,
- encourage and facilitate collaboration across BGS,
- improve access to the unique BGS information base,
- keep BGS at the forefront of the development of digital geoscience systems,
- inform and support management decisions,
- create and implement corporate standards and establish best practice

The BGS-geoIDS Project produced a range of deliverables, including a Corporate Data Policy, a system for data management planning, metadata at various levels, a documented corporate data model, an application standard implemented through an Intranet data access tool, and the adoption of BGS-wide best practice. Above all, the Project imposed a significant culture change within BGS, transforming data from being personal property to being corporate property.

Subsequently, the DGSM (Digital Geoscience Spatial Model) Project extended the data management system to deal with digital 3D models and introduced the Geoscience Large Object Store (GLOS) to hold the full models in their proprietary software format with associated metadata. However, it was recognized that the various proprietary software formats were unlikely to remain unchanged and could not safely be used for archiving the models. Such models would probably have a life expectancy of less than 10 years. Thus, a second component was introduced, which "sampled" the model and produced a series of X, Y, Z coordinates for each stratigraphical horizon represented in the model. As this information is stored as a simple digital file, it is more suitable for long-term preservation.

NATIONAL GEOSCIENCE DATA CENTRE (NGDC)

www.bgs.ac.uk/ngdc

All BGS corporate data are managed through the National Geoscience Data Centre, which is the Natural Environment Research Council (NERC) designated center for geoscience data and information management, and which has five main elements:

- National Geoscience Records Centre
- National Geoscience Materials Collection
- National Hydrocarbons Data Archive
- NGDC Earth Science Academic Archive
- NGDC Digital Data Management

The top level aim of the NGDC is to manage all BGS data and information in accordance with the NERC and BGS Data Policies. NGDC staff members manage a wide range of information types, aiming to preserve them for use by future generations. Thus, the environments in which the collections are held are monitored carefully, and action is taken to manage environments where conditions fall outside accepted norms. For example, localised high humidity in a room holding a palaeontological collection triggered an investigation that discovered a fractured rain waste pipe on the exterior of the building. A robust metadata system is recognized as being indispensable, and an active program of metadata management is operated within the NGDC. Where appropriate, digital indexes are created and maintained as aids for finding individual records or specimens.

Overall, the NGDC activities attempt to strengthen users' confidence by creating and maintaining validated and verified datasets to agreed standards, and providing tools that enable geoscientists and others who need geoscientific insight, both inside and outside BGS, to use BGS information with confidence.

SYSTEM FOR INTEGRATED GEOSPATIAL MAPPING (SIGMA)

http://www.bgs.ac.uk/scripts/downloads/start.cfm?id=381

Once the key elements of information that underpin geological mapping are in place and tools have been provided to facilitate access, it becomes possible to build a digital geological workflow that starts with digital field capture, progresses through digital map compilation, and passes into a digital map production and management system. The project that specified and developed this process is called SIGMA. The project has two key elements, the first being the MIDAS system (Mobile Integrated Data Acquisition System), the second the Geoscience Spatial Database (GSD).

Mobile Integrated Data Acquisition System (MIDAS)

Designed to allow use in the field, each MIDAS setup is mounted on a weather proof, robust, impact-resistant computer. It is based on standard ESRI software that has been customized to meet the project's specific requirements. The field geologist's base map and an analysis of existing information are loaded onto the computer, and the GIS provides digital field slip functionality. A global positioning system is used to locate the sites of observations, and forms are called up to support the population of a Microsoft Access Database with a range of information.

Geoscience Spatial Database (GSD)

Once the geologist returns from the field, the GSD is used to compile the geological map from existing information and from the data captured by the MIDAS system. The product is a traditional geological standard map that is created and managed in the digital environment along with its accompanying digital databases. This suite of information is then passed into the cartographic map production system for final delivery in the form of the DiGMapGB product or as printed maps.

LITHOFRAME

http://www.bgs.ac.uk/scripts/downloads/start.cfm?id=535

Merger of aspects of the data captured by the digital geological mapping workflow with appropriate digital information managed by the NGDC permits the creation of three-dimensional models of the geology of the whole or part of Great Britain. For example, the BGS receives approximately 50,000 borehole logs a year from industry. These range from shallow construction industry boreholes to deep energy exploration boreholes. The borehole logs are scanned and the metadata entered into the appropriate database by the NGDC registration team. The borehole logs are then available for use, on every desktop in the BGS, and can be accessed through a range of application and GIS tools. Two principal tools are used to undertake the modeling. The first is GSI3D, which is used for modeling superficial deposits, and the second is GoCAD, which is used for bedrock modeling. LithoFrame models are prepared at various resolutions:

- LithoFrame – shows the most significant stratigraphical divisions and major faults
- LithoFrame250 – prepared for stratigraphical groups
- LithoFrame50 – modelled at the formation level
- LithoFrame10 – focuses on well-characterized and relatively shallow superficial deposits

Geological Surveying and Investigation in 3D (GSI-3D)

http://www.bgs.ac.uk/science/3Dmodelling/gsi3d.html

The GSI-3D software tool and methodology has been developed over the last decade by Dr Hans-Georg Sobisch of INSIGHT Geological Software Systems GmbH, based in Cologne. During the past 3 years, BGS has acted as a test bed for the accelerated development of the tool and methodology. GSI-3D utilizes a Digital Terrain Model, surface geological linework, and downhole borehole data to enable the geologist to construct cross sections by correlating boreholes and the outcrops to produce a geological fence diagram. Mathematical interpolation between the nodes along the drawn sections and the limits of the units produces a solid model comprising a stack of triangulated objects, each of which correspond to one of the geological units present. Geologists draw their sections based on facts such as borehole logs correlated by intuition – the shape "looks right" to a geologist. This "looks right" element draws on each geologist's wealth of understanding of earth processes, examination of exposures, and theoretical knowledge gathered during a career in geology.

GoCAD

http://www.gocad.org/www/

GoCAD is the tool used in BGS for modeling bedrock geology, as it has additional features, such as fault and fold handling capabilities, which GSI-3D lacks. The GoCAD Research Program is run by the Computer Science Group of the National School of Geology in Nancy, France. This project is currently undertaken in collaboration with the Institut National Polytechnique de Lorraine and the Centre de Recherches Petrographiques et Geochimiques, France. The aim of the research program is to develop a new computer-aided approach for the modeling of geological objects. This approach is specifically adapted to geophysical, geological, and reservoir engineering applications.

KNOWLEDGE DELIVERY

The knowledge created during the geological mapping process is delivered through a range of products and services that are available from the BGS (see "Internal Discovery" and "Internet", in Figure 1). These include not only the geological map itself but also the elements of data that were used to develop the map. These products include:

- The BGS Website
- The BGS Intranet
- Discovery Metadata
- GeoIndex
- GeoReport
- GeoRecord
- DiGMapGB
- GeoSure

Website

http://www.bgs.ac.uk/

The award winning BGS website is accessed extensively by a wide range of users. It caters specifically to the needs of various groups, ranging from children to professional geoscientists. Its aim is to inform users about BGS activities and provide them with access to information and data. The site offers well over 900 downloads, a number set to rise to well over 10,000 in the near future. There is access to a range of definitive data sources. For example the four BGS Rock Classification Scheme (RCS) reports are available from http://www.bgs.ac.uk/bgsrcs/home.html. The BGS Rock Classification Database can be accessed and searched using a web-based form at http://www.bgs.ac.uk/bgsrcs/searchrcs.html, and the data that it holds can be downloaded in spreadsheet format at http://www.bgs.ac.uk/data/dictionaries.html.

Intranet

In parallel to the BGS Website, there is a comprehensive Intranet that provides information and data to BGS staff. Intranet information and data suites are normally more comprehensive than their Internet equivalents.

Discovery Metadata

www.bgs.ac.uk/metadata

Published BGS discovery metadata can be accessed as part of the main BGS Website. A profile of ISO19115 is used to describe each dataset at a level that is appropriate for a user to assess whether the data contained in the dataset are appropriate for their needs and to allow recognition of data limitations. The full record is posted on the Internet, and the tools to manage the underpinning Oracle database are on the Intranet.

Technical Metadata

The BGS Technical Metadata, which describe the numerous components to the BGS Oracle database system, are only available on the Intranet. The information provided includes details of databanks, tables, views, indexes, synonyms, etc., and the system as a whole contains some of BGS's most critical digital data.

As the Technical Metadata system is complex, it is actively maintained to help users. The system extends Oracle's own data dictionary and is designed to help those with a basic understanding of Oracle to navigate the objects that make up the BGS Data Architecture. Its application front-end also provides "Best Practice Guidelines for Oracle Development," procedures for changing the structure of database objects and some documentation on data models.

GeoIndex

http://www.bgs.ac.uk/geoindex/home.html

The GeoIndex provides detailed metadata about selected datasets. Using a web-based GIS, it shows the locations of data points within each featured dataset and provides basic information about each data point. For example, the sites of geochemical stream sediment samples are shown in the GIS along with a list of elements analyzed in each sample.

Geoscience Data Index (GDI)

The intranet version of the GeoIndex is the Geoscience Data Index (GDI). It is built in ESRI's ArcGIS and allows BGS staff to discover the availability of spatially-referenced information, drill down to it, and gain access to it. It allows a rapid assessment to be made of information and data that are available for any given location within Great Britain.

Data Portal

The BGS Data Portal is an Intranet tool that allows access to the datasets and information to support 3D modeling. Its functionality overlaps partially with that of the GDI and the two applications will eventually be merged.

Intranet Data Access

Intranet Data Access (IDA) is an Intranet tool available to BGS staff to facilitate access to BGS Oracle databases through a user-friendly forms interface. The interface has been developed using Adobe's ColdFusion, and its components have been developed to a standard design template so that users are presented with a consistent look and feel across the application. Examples of the databases that can be accessed include:

- Borehole locations
- Borehole lithology
- Borehole materials (samples collected from boreholes)
- Geophysical log index
- Geological maps and field slips
- Palaeosaurus (paleontology specimen data)
- Britrocks (rock specimens)

GeoReport

http://shop.bgs.ac.uk/georeports/

If you are investigating land or property, GeoReports could save you time and money. GeoReports will:

- tell you about the condition of the ground—its geology, hydrogeology and any related hazards (such as subsidence or radon potential),
- let you know what information about your site might already be held in the national geological archive,
- provide cost-effective access to expert advice from BGS scientists who know about your local area.

There are a wide range of GeoReports that are available from the BGS Internet site, including:

- Building stone assessments
- Data listings
- Geological assessments
- Geological map extracts
- Ground source heat pump
- Ground stability
- Radon protection
- Water borehole prognosis

GeoRecord

http://www.bgs.ac.uk/boreholes/home.html

The BGS provides a comprehensive range of scanned documents, including:

- Borehole records
- Site investigation reports
- Technical reports
- Mine records

DIGMAPGB

http://www.bgs.ac.uk/products/digitalmaps/home.html

BGS maps are increasingly being offered digitally, either as raster images or as vector data, in a variety of formats and structured into themes. This allows them to be used in Geographical Information Systems (GIS) where they can be integrated with other types of spatial data to provide powerful aids to problem solving in many earth science situations. Map data are available at a range of resolutions, from small to large scale, and they cover many aspects of the geological and related sciences.

Layers include:

- Superficial deposits
- Artificial ground
- Mass movement
- Thickness of superficial deposits
- Bedrock geology
- Elevation of bedrock

GEOSURE

http://www.bgs.ac.uk/products/geosure/home.html

Hazards that go unrecognized by developers, householders, or local government may lead to financial loss, which can be avoided. The cost of arresting or repairing a ground failure is far greater than the cost of prevention.

Understanding geology is vital when determining the stability (and thus the value) of land and property, and ensuring the safety of its occupiers. The GeoSure datasets from the British Geological Survey provide information about potential ground movement or subsidence in a helpful and user-friendly format. The datasets can help inform planning decisions and indicate potential causes of subsidence:

- Soluble rocks (dissolution)
- Shrink-swell clays
- Landslides (slope instability)
- Compressible ground
- Running sands
- Collapsible deposits

As well as being able to license any of these datasets in digital form, the BGS provides a report generation service GeoReport, whereby reports can be produced giving details of six ground stability issues for specified areas or properties.

CONCLUSION

The BGS has aspired to develop a digital workflow for its data and information acquisition, management, manipulation, and delivery. This aspiration is now approaching fulfillment. Tools that have been developed will allow digital capture of field mapping data and support its enhancement right through to its digital delivery.

Digital information created by the process is being managed systematically across the entire organization in a manner that allows its rapid discovery, retrieval, and exploitation.

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- Richard Hughes, Programme Manager for Information Delivery
- Ian Jackson, Programme Director for Information
- David Lowe, Geoscience Data Manager
- Hans-Georg Sobisch of INSIGHT Geological Software Systems
- Martin Nayembil, Data Architect
- Rob Pedley, Application Architect
- Jenny Walsby, Programme Manager for Information Products

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