GEOLOGICAL INFORMATION SYSTEMS IN ACTION

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Abstract

During the early 1900's the British Geological Survey developed and implemented a digital mapping system utilising GIS technology. This system enables the generation of a variety of products from a geological database containing spatial and relational data. Output includes high quality map products and digital datasets derived from the database. The latter can be incorporated into other digital systems for use in geological manipulation, such as the surface modelling. This allows the data collectors to visualise their data in different formats and to combine geology with other types of information, to create new datasets and facilitates the visualisation of varied and diverse data within a single system.

During the past 4 years, the methodologies developed for the Digital Map Production System (DMPS) have been applied to several geoscience projects. These projects include i) the adaption of the BGS system for geoscientific programmes in other organisations and ii) the development of PC GIS for low cost, user friendly manipulation of geoscientific data.

Where high quality map production and efficient management of large datasets have been required, the GIS/database design has been modified and system analogues to the DMPS built for the UK and overseas applications. The basic design has been customised to fit the requirements of other organisations, creating geosciences dataset management systems to suit the specific data and investigation needs.

Transfer of geological data into PC-based GIS has enabled geoscientists, with minimal GIS expertise, to view and manipulate their own data. This gives those with the greatest knowledge of that data the power to analyse it in digital system. The relative low cost of PC systems has allowed methods and procedures developed for the BGS DMPS to be customized, more widely used and applied to requirements for digital data management in developing countries.

Introduction

Since 1988, extensive BGS investigations have taken place into the use of GIS managing and manipulating geoscience datasets. Methods and systems adopted were initially constrained by the limited software available and its inability to cope with geological requirements. Most early developments originated form map-based or table-based (database) datasets. For example, a digital map production system (MPS) was developed using Intergraph™ software linked to ORACLE™ databases, which enabled the formulation of complex queries and generation of high quality map output (1). This system was designed to meet geological and cartographic requirements. ArcInfo™ was used to develop systems that were-less map orientated, such as an index to BGS's data holdings (2) linked to ORACLE™. This allows complex queries with built-in automatic, scale-controlled display functions, but requires less sophisticated output capabilities.

Over the years the functionalities of many GIS software packages have become increasingly similar and more wide ranging. Additionally, the move from almost exclusively UNIX-based software to Windows NT and PC-based GIS has made these systems more readily available to potential users. During this time:

- Software and required hardware costs have decreased markedly.
- User familiarity with operating systems has increased.
- More user-friendly interfaces have been developed.
- Perception of the required expertise to run these systems has changed.

Within BGS and the international geosciences community in general, the application of GIS to 'real' problems is now established. Use of GIS was often considered inappropriate before geoscientists saw systems working and supplying analysis of data for their needs. There has been a marked change of attitude in the last 2 years. Geological survey investigations are traditionally map-orientated and require information from numerous, commonly analogue, data sources. Digital systems, and specifically GIS, have become used increasingly for surveying projects and the final output or some recent BGS studies has been granted from, or provided in, GIS format.

GIS developments in BS in the early 1990's were carried out by GIS specialists, building systems to be used by GIS specialists for data manipulation on behalf of geoscientists. As the profile of GIS widened and the functionality of the systems available in the BGS become more widely known, system requirements within the BGS began to change. The functionality of existing software systems generally fitted this new requirement, but there was a growing desire among geoscientists to use GIS themselves, to manipulate their own data and produce useful output. Geology is a 3D science and geoscientists are using modelling software increasingly to visualize their data model, for example, geological surfaces, geochemical concentrations and geophysical parameters. To integrate surface models with database and GIS data successfully, geoscientists often required assistance form Information Technology (IT) specialists, but they did not want to be totally reliant on GIS and other IT specialists to utilise these systems and transfer data between them. It became apparent that although certain transactions require trained experts, others could be performed by non-specialists on less complex systems, such as PC-based GIS.

As part of long-term GIS research and development within the BGS, the 'next step' after implementing large scale GIS was investigation of PC-based systems. In 1995 a user requirement and specification for PC-based GIS were constructed, in consultation with geoscientists, which identified both in-house and external requirements (3). Three main requirements of PC-based GIS were identified:

- A low cost presentation.
- A simple system that could be used by geoscientists
- An off-the-shelf' GIS for external customers.

Subsequently, software reviews were carried out and the MapInfo™ PC system was chosen for its compatibility with existing systems, ease of use and functionality. A pilot was initiated to ensure that the first requirement could be met and to review the system thoroughly before it was applied to active projects. The popularity of a PC-based GIS quickly became apparent and the trial became an integral part of several geological projects. Work then began on developing the system for use in [projects constrained by very low budgets, but requiring integration of non-geoscience and geological data, such as some projects for local government and developing countries. The work was planned to provide a basic building block for further projects and to initiate the development of a wider range of applications to use geoscience with GIS and GIS for geosciences. The value of this system for projects is clearly evident where low-cost, easy to learn and easy to maintain systems are essential.

Putting research in action

<u>The basic system</u>

The DMPS (4) provides a complex and wide ranging, high functionality geosciences data management system, that is capable of future expansion. Within the BGS to date, the purpose of the DMPS is to input, manage and manipulate geological land survey datasets; map data, database information and modelled surfaces. Data are selected from this system according to geological definition (e.g. a polygon of sandstone within the St Bees Sandstone Formation) and may be output as high quality cartographic products, in digital and hardcopy formats. Effort invested in the logical and physical design of the DMPS has ensured it can be modified to undertake tasks requiring larger and more diverse datasets. Examples of projects requiring such functionality are described below.

<u>Diverse Applications</u>

The Urban Environment Study (UES), an investigative project adopted Wolverhampton, UK as a test site, used the BGS DMPS structure as a basis for data management (5). A digital system was required to take data from various sources, link, interrogate and display them and produce the results as paper maps and as input to modelling software. GIS software met this requirement and the DMPS had an existing structure for geological data, which could be replicated and built upon, to incorporate all required datasets. As a result, a powerful UNIX system, which more than met the needs of the project, was put in place (at the time a simpler solution was not available)

Other organisations and projects for which the DMPS has been adapted and implemented UK Nirex Ltd (Nirex) and Proyecto do Desarrollo Minero y su Control Ambiental (PRODEMINCA: Project to Develop Mining and Control the Environment) in Equador. Both have adopted essentially geoscientific systems based on the DMPS design, retaining the functions of scientific data interrogation and high quality map production. In each case, the database and graphic data structure designed for DMPS were reassessed, and new data items identified e.g. mineral deposits, seismic line locations. The relationship between existing and ne data items were established, a new data model created and additional database tables and GIS features were designed and implemented.

The GIS developed for Nires was integrated with existing ORACLE™ digital geosciences database that was in active use by Nirex, and became part of their overall data management system. Selected database items had to be retrievable by GIS, thus geological attributes of previously cartographic datasets were added to the database. Additionally, provision was made for 'graphic only' datasets that required no database links and (in some cases) no GIS features. These would be output as maps or diagrams only, in contrast to the geologically orientated data, which would be used for complex interrogation and creation of new products. The original DMPS design was extended to include hydrogeological, geochemical and geophysical information and data extracted from 3D models (modelled surfaces and vertical cross-sections) since its implementation over 100 datasets have been input to the Nirex GIS and it has been used to analyse various scenarios and generate numerous map products. The data are interrogated and extracted for the Nirex community as working documents for research projects, for error checking, for identifying any additional data needs for further investigations and to generate information for public enquiries.

Examples of this include;

- Transfer of geological surface to generate new information to modelling packages for combination with new field information to generate new interpretations which are fed back in to the GIS.
- Combining datasets to identify new study areas. For example, surface geology 9to delimit peat0 has been overlain by existing spring and borehole locations to identify those areas to be sampled for additional geochemical information.

The system developed for PRODEMINCA (6) included an adaptation of the DMPS design to suit the demands of the project, the geology of Ecuador and to aloe the inclusion of large volumes of geochemical sample data. Geological mapping and geochemical sampling by BGS staff are currently in Ecuador and the first new datasets were recently reloaded in the system. A design (yet to be implemented) for PRODEMINCA has been devised for a larger project that will incorporate many datasets, including the information already being input to the geological, geochemical GIS. Information to be brought will include cadastral, environmental pollution, mining records, land use categories specifically nature reserves and urban areas) and hazard mapping assessments related to volcanic activity. This expands the basic DMPS deign from a purely geoscientific application to include administrative and ecological considerations. Development of this system is consistent with quality and integrity of the original design and the concepts upon which it is based.

Moving to PCs

Initial Investigations

Sophisticated systems, such as the DMP, were considered to be cumbersome and complex for infrequent, non-expert users. Furthermore, the DMPS is corporate system for managing the 1:10k scale geological map data and its associated datasets, one of the prime BGS data holdings. Granting direct access to this system to many non-expert geoscientists wishing to manipulate the data it holds could cause quality control problems, perhaps leading to the loss or corruption of data. Instead data required for use on a project basis could be extracted ad put in to a parallel system for manipulation, and such activity would not affect the validity of the approved and archived datasets. It is also evident that providing an exact copy of the DMPS would be prohibitively expensive in terms of software and training requirements and potential duplication of effort. The alternative was to provide lower cost and easier to use system(s) for general use, which were compatible with the DMPS.

An initial system requirement for PC GIS highlighted the need for compatibility with the existing BGS GIS and the ability to output data to other digital systems in various formats(3). ‘Simple is best’ and a phased approach to developments was put forward as being key to successful implementation ad use. There were some concerns as to whether PC systems would provide the ‘easy GIS’ that staff expected and whether extensive training would be required (as in the case with more sophisticated packages) Investigation of PC software revealed that a number of 'user-friendly' GIS compatible with BGS leading systems were available. Most BGS computer users are familiar with the Windows™ databases. It was decided that data used in a PC GIS should be held in a familiar format, both to make it more useable and to give the feeling if seamless progression into new technology. Introductory demonstrations and short courses would be of prime importance, followed by more in depth training once users were familiar with the system.

Making it available for geoscientists

The development of a PC GIS had three main objectives. The first was to provide a presentation system, to market BGS information and digital capabilities. It was important to demonstrate that BGS digital data could be viewed on a simple system without the need for complex software or a hefty (and hence expensive) workstation. This would allow the BGS staff to review and interrogate data in GIS with relative ease. A pilot project investigated the recommended software (MapInfo™) with the aim of providing the first objective and the user requirement as part of the study. The second and third objectives - to provide a simple system for geoscientists to use and provide and 'off the shelf' GIS for wider use - would follow.

However, demand for PC GIS was such that the pilot project evolved into developing a workstation system for Wolverhampton UES project. This route way followed because non-expert users wanted to manipulate their own data and did not want to rely on GIS specialists to provide assistance, which was necessary for the original more complex UES system. It transpired that many of the queries performed for UES did not require sophisticated software and having simple, direct access to their data enabled geoscientists to perform interactive 'ad hoc' queries.

During evolution of the initial PC system many aspects needed for the objective (as well as those needed for the first) were incorporated to meet project demands. The UES brought together many diverse datasets, including geology, geochemistry, land use, hydrogeology, topography, and mining information. The aim was to visualise and demonstrate the inter-relations of these data within an easy to use system; the data originating in Intergraph™ and ArcInfo™ GIS from paper records, ORACLE™ and ACCESS™ databases. The system design was developed and translated for the original Intergraph™ by a GIS expert, but was suitable for accessibility users of varying abilities, with limited GIS and MapInfo™ knowledge. Some basic software training was given and the interface was modified to suit users' initial needs. This has proven to be a very successful development with the geoscientist taking the concept further and adapting the interface to suit their changing needs.

Broadening the scope

The ideas used for GIS developments for the UES were quickly seen to be applicable to other projects, where geoscientists wanted to manipulate their data in a 'manageable' digital system. Additional interface modifications were made for subsequent projects, both to simplify some operations and to focus attention on others. It gave geoscientists the opportunity to perform their own GIS interrogations according to the needs of the particular projects, The low cost of the PC system, the ease by which basic commands could be grasped and data from numerous sources input, led to an expansion of applications. Projects with tight budget restrictions, as some of those for local government organisations and developing countries, can afford to implement PC GIS and users can now see how geoscience information may be made available in easily usable digital form.

There is a high demand for digital system implementation in some developing countries, but budgets are small and often the staff available to use the systems are few, with limited experience or are subject to high turnover. A relatively low-cost, user-friendly GIS provides an effective solution. Users achieve results quickly and are able to understand the application of GIS to their own objectives with little training. At present a PC GIS is being developed for geological survey work in Syria. This is building on the basic system used for the UES and incorporates future uses for PC GIS are:

- To modify the basic design and use it for coastal studies, integrating marine, coastline and onshore datasets.
- For other overseas projects where digital databases have been installed and users looking to visualise and manipulate their data in spatial context.
- To incorporate the third dimension, merging basic surface modelling capability with spatial interrogation.

Summary

Sophisticated GIS have been developed for managing complex datasets within large organisations and to provide in-depth interrogation of spatial information. The design and concepts of the DMPS (a corporate system) have been extrapolated to build both large, wide ranging GIS and simplified PC-based GIS, whilst retaining the original design concepts and compatibility between systems. A well designed product has been shown to be adaptable to incorporate a variety of geoscientific datasets and open to expansion to include other types of data, such as administrative, land use and environmental information and ultimately much more. Development of digital systems like this gives scientists the ability to manipulate their data more easily, increasing interrogation possibilities and potential output production.

The move to PC-based systems, allowing greater 'hands on' interaction with data, has increased the opportunity to test potential scenarios interactively. The PC GIS has been used and adapted by the geoscientists who know and understand the data and are now developing further applications of GIS for projects with a restricted and limited staff numbers expertise, where more sophisticated systems have prohibited such developments.

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