FROM 2D GEOLOGICAL MAPS TO MULTI-DIMENSIONAL MODELS OF ENVIRONMENTAL CHANGE IMPACTS – CHALLENGES AND ASPIRATIONS FOR NATIONAL GEOLOGICAL SURVEYS

Andrew S. Howard

British Geological Survey
Keyworth
Nottingham NG12 5GG
United Kingdom
mailto:ash@bgs.ac.uk

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GEOLOGICAL MAPS AS NATIONAL GEOSCIENCE KNOWLEDGE BASES

Geological Survey Organisations (GSOs) provide regional and national geoscience knowledge bases for effective decision-making on mitigating the impacts of natural hazards and environmental change, and on sustainable management of mineral, energy, water and land resources. Traditional geological maps have been the principal medium used to synthesise and communicate explicit knowledge on the stratigraphy, structure and composition of the Earth's surface and shallow subsurface. In the UK, the highly varied geology, high degree of urbanisation, long legacy of industrial development and a complex regulatory and planning framework created a requirement for high-resolution geological mapping at 1:10,000 scale. From the mid-1970s onwards, demand increased to produce thematic environmental geology maps and reports, aimed specifically at planners, regulators and developers (Smith and Ellison, 1999). The objective of these more sophisticated products was to unlock and communicate some of the additional, implicit knowledge on resources, hazards and constraints that are 'hidden' on a standard geological map. In the 1990s, GIS and decision-support systems began to replace these products (Culshaw, 2005). This drove the development of digital cartographic production systems to capture information from pre-existing paper geological maps (Jackson and Green, 2003), and the development by some surveys (including the British Geological Survey) of digital field data recording systems to facilitate a fully digital workflow from field observation to map, GIS and 3D model delivery (Howard et al, 2009).

FROM MAPS TO 3 DIMENSIONAL MODELS

Although geological and thematic maps have served the geoscience user community effectively for nearly 200 years, they have some basic deficiencies as a communication medium for explicit, spatially located 3D geological information (Loudon, 2000). In particular, the knowledge they convey is explicit in 2D, but largely implicit in 3 and 4D. The most serious knowledge gaps are in shallow superficial deposits, and at depth below major unconformities. These gaps coincide with those parts of the subsurface where information is in greatest demand from the modern user community. Shallow (less than 20 metre depth) 3D geological knowledge is required for a diverse range of applications, including engineering, waste management, environmental assessment, planning and environmental regulation and aggregate mineral exploration and exploitation (Culshaw, 2005). Deeper, spatially accurate geological information, once mainly required for exploration and management of hydrocarbon, coal, groundwater and metalliferous mineral resources, is now in increasing demand for newer technologies such as clean coal, underground gas storage, nuclear waste containment, and storage of carbon dioxide.

In the geosciences, combination of spatial and process models has been pioneered by the hydrocarbons, groundwater, nuclear waste management and contaminated land remediation industries, principally to model multi-phase fluid movement through reservoirs, repositories, artificial seals and containment rocks. Although many GSOs are now developing 3D geological models to communicate spatial geological knowledge, few users currently have the 3D information technology to utilise or query the models (Figure 1). Integration of spatial and process models remains in its infancy. Moreover, it is becoming increasingly apparent that, to meet future demands for understanding, modelling and predicting the impacts of environmental change, geoscience knowledge will need to be incorporated into more holistic environmental change impact models. These will be constructs of inter-operable, spatial environmental datasets and dynamic process models, and will cut across the interfaces between the geosphere, hydrosphere,

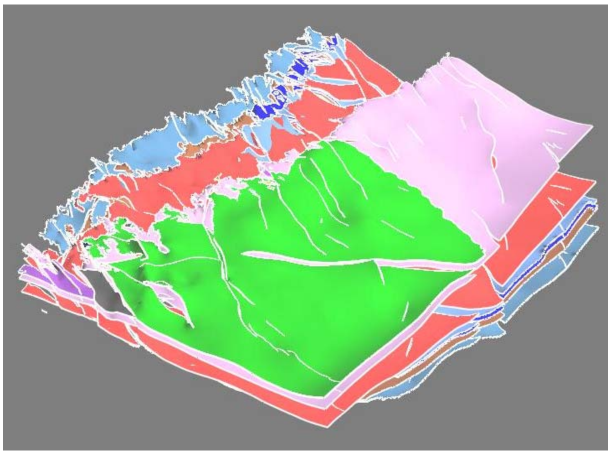

Figure 1. 3D geological model of part of central England. Approximate model dimensions 75km. x 30 km. x 0.4 km. The model was constructed to identify pathways for contamination of the underground public water supply by mine waters and by lower quality groundwater from minor aquifers. The model was essential to identify pathways but outputs were presented to the users as a simple 2D GIS.

biosphere and atmosphere. Their development will require unprecedented levels of interdisciplinary collaboration across the environmental sciences.

ENVIRONMENTAL CHANGE IMPACTS MODELS – CHALLENGES AND ASPIRATIONS

In the past, national geological mapping programmes in most countries have proceeded systematically, with the aims of completing map coverage to common standards and steadily improving accuracy and consistency. Uncertainties in interpretation have been concealed from users behind the aim to present, on a map, a single, defendable scientific interpretation. For spatial geological models the approach and prioritisation of effort is likely to be driven by new imperatives, in particular:

- The needs for interoperability and integration with other environmental datasets;
- The need for information on uncertainty in data and interpretations and on confidence and probability of predictions and scenarios, to enable risk-based decision-making by users;
- An understanding of the key sensitivities in environmental systems and the models that represent them, so that geoscience data collection and modelling can address the most important data variables and gaps in knowledge.

But, most importantly, future priorities will be driven by the pressing, trans-national and cross-disciplinary requirements for solutions to environmental change and future resource security. The geological models of the future will hang on consistent but low resolution trans-national 3D frameworks, and will employ interoperable spatial data models and standards. Compared to geological maps, their resolution, content and attributes will far more heterogeneous, confidence will be communicated and a range of alternative models and downstream predictive scenarios will be presented. To achieve these goals, the scientific, technical and cultural challenges will be considerable but rewarding.

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