The application of mineral information management and delivery systems in the sustainable management of mineral resources.

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Abstract

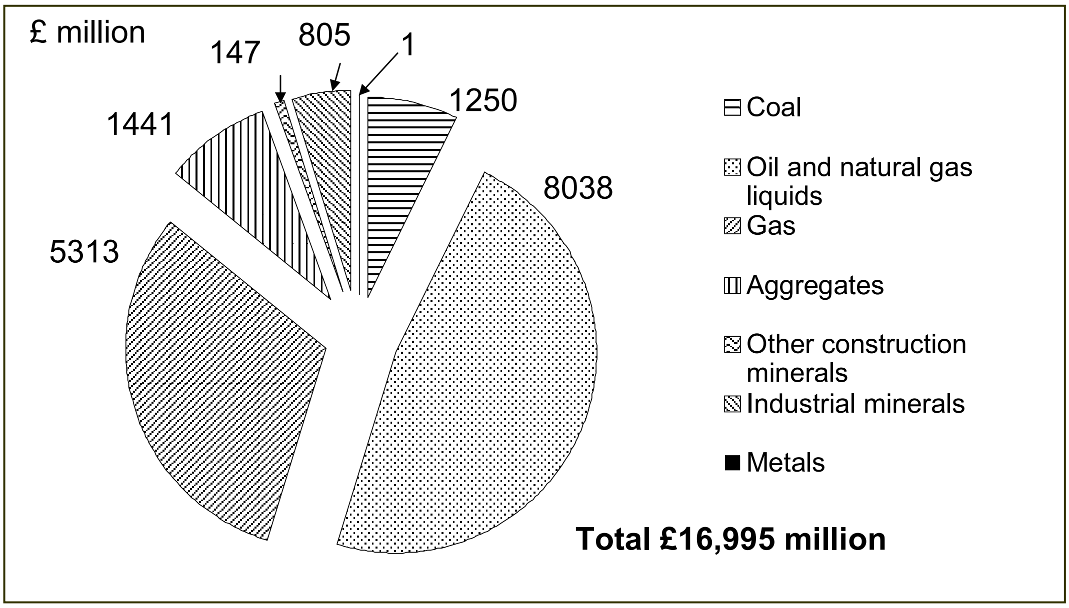
Changes in political, social, regulatory and technological factors will shape the interfaces between the minerals industry, government and the public, resulting in changing requirements for information, knowledge and policy related to the sustainable management of mineral resources. This provides a new challenge to review the current and future needs for such information, its collection, analysis, and publication. In the last decade, there has been a large shift in the way that land and mineral-resource information is collected, analysed and presented. Resource information is now collected quickly, using advanced digitizing, scanning and vectorizing routines. Geographical Information Systems and integrated database technologies allow rapid analysis of such data, which can then be published in map or table form instantly to a global audience via internet technologies.

Despite the availability of these technologies, the management and stewardship of mineral resources is a substantial responsibility. Planning decisions to permit mineral working are based upon integrating a variety of data from government policies, up-to-date land-resource information and related economic and social factors. Data and information gathered from such a variety of sources needs to move, in a seamless way, from the domain of the information provider to the users of the information. The ability to answer the right questions at the right time is central to a more efficient planning system. The British Geological Survey is currently in the process of gathering such information from a variety of projects. The Minerals Information System has been designed to gather and store resource information and make it available quickly to a variety of users. This paper will demonstrate how the system may be utilized.

Introduction

The sustainable development of Britain's economy is dependent upon adequate supplies of a wide range of mineral raw materials obtained from the natural environment, whether at home or overseas. Indigenous mineral resources represent valuable national assets, or capital, and their extraction and, more importantly, use make a major contribution to economic growth, the infrastructure of our society and the quality of life of individuals (Figure. 1).

Figure 1. UK: Value of mineral production 1998 (British Geological Survey, 2000).



Whilst energy minerals dominate the value of mineral production, non-metallic minerals, and particularly aggregates, are produced in large quantities and it is their extraction that is often the focus of public concern and opposition. Mineral extraction almost always leads to some adverse environmental impact. In a densely populated island like Britain, mineral working causes conflict, at least temporarily, with other desirable aims of society, both by loss or change to valued landscapes, habitats and archaeological features and by impact on people's lives. However, minerals are of no value unless they are worked, for it is only then that the capital they represent is released and wealth and employment is created. The issue is one of balance: how to weigh the need for essential minerals with effective protection of the environment. This issue is at the heart of sustainable development and can only be addressed by utilizing accurate, up-to-date mineral, land-use and related information. Access to such information is essential to developing and making sound planning and policy decisions.

Sustainable management of mineral resources

Sustainable development is a key concept that underpins the UK's planning system. The UK Government's strategy for sustainable development (Anon, 1999) stresses the importance of integrated policies in meeting four key objectives which need to be addressed equally. These are:

- Social progress, which recognizes the needs of everyone
- Effective protection of the environment
- Prudent use of natural resources
- Maintenance of high and stable levels of economic growth

Thus economic growth needs to take place in a way that ensures effective protection of the environment and prudent use of resources. Policies and the resulting regulatory decisions based upon these principles require an integrated and well-informed approach, so that the correct choices are made between working minerals and conserving environmental capital. Such choices are not easily made and require detailed information to arrive at the most sensible outcome. These judgements are made in Britain by the planning system, and it is this system that is central to the Government's strategy for sustainable development.

Mineral planning and the life cycle of mineral-bearing land

The planning system in Britain has a key role in contributing to the Government's strategy for sustainable development. It is the function of the planning system, through policy contained in the development plan and individual decisions, to regulate the development and use of land, including mineral working, in the public interest. The system thus needs to strike a balance between the essential need for minerals and the need to conserve and protect the environment and enhance quality of life. In order to achieve this the planning system must deliver the following objectives:

- A balance between the essential need for minerals and the protection of the environment
- Identification of areas of possible future mineral working
- Better use of primary minerals, by encouraging greater use of recycled and waste materials
- Restoration of mineral operations at the earliest opportunity for beneficial after use
- Avoidance of unnecessary sterilization of mineral resources

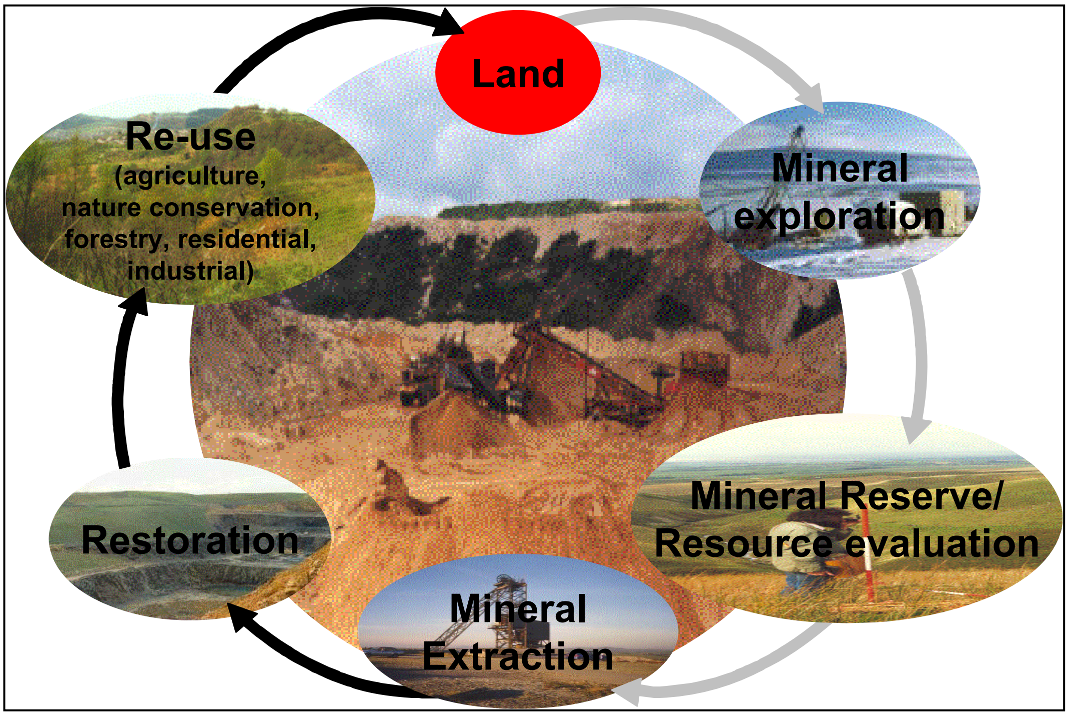
To achieve these objectives, policy and decision-makers require access to reliable and up-to-date information on the nature and extent of mineral resources, and the demand and rates of supply of minerals.

Mineral resources, by their very nature, can only be worked where they naturally occur, but extraction must also be subject to exacting environmental and development criteria. It is, therefore, necessary to identify and understand the spatial relationships between the distribution, nature and relative importance of mineral resources and the environmental constraints that may affect their extraction.

Over the past five years the British Geological Survey (BGS) has been developing a Minerals Information System (MINGOL) to integrate its minerals-related datasets with other environmentally-related information. These include the distribution of mineral and environmental resources and their relationship to one another, the rates of supply and demand for minerals, and the location and extent of mineral reserves within planning permissions, together with their rates of depletion.

The analysis of complex spatial and non-spatial datasets in an integrated manner forms the major part of a GIS's capabilities. Such an integrated Minerals Information System provides a key role in the continued understanding of and planning for the life cycle of mineral-bearing land (Figure 2). Tracking the life cycle of land through mineral development, extraction, restoration and afteruse allows us to build up a picture of how effective policies have been for the sustainable management of mineral-bearing land (Plant, Turner & Highley, 1998).

Figure 2. The life cycle of mineral-bearing land.



A Case Study: The Wareham Basin

The Palaeogene Wareham Basin of east Dorset is a location where the current conflict between the need for minerals and the desire to 'protect' and 'conserve' the environmental assets is particularly acute. The area contains perhaps the most diverse range of potentially conflicting resource development and management pressures in the country. The Basin is highly valued for its landscape and nature conservation importance. Very extensive areas are designated as Sites of Special Scientific Interest and a very large proportion of these are also of international nature-conservation importance, notably for both scarce dry and wet heathland, together with their associated ecosystems. In addition, a large part of the Dorset Area of Outstanding Natural Beauty (AONB) falls within the Basin. These areas are given special protection from development by planning policies. Extensive areas are also owned by the National Trust, there are many archaeological sites and large areas are used for military training. The area is important for tourism and adjoins the Poole-Bournemouth conurbation, one of the fastest growing areas in the country (Table 1). However, the area also has important mineral resources, notably ball clay but also sand and gravel, and it was against this background of conflict that the current project on the 'Mineral Resources of East Dorset' was undertaken by the BGS on behalf of the Department of the Environment, Transport and the Regions (DETR). This work is now nearing completion

(Bristow et al., in press; Highley et al., in press). The principal objectives of the study were to provide impartial and factual information on the distribution and quality of the mineral resources of the basin, particularly ball clay, and to relate these to the numerous planning constraints which might effect their extraction. The primary purpose of the work was to provide data that would assist the planning process.

Table 1. Constraints in the Wareham Basin.

Dorset Area of Outstanding Natural Beauty	Ramsar Sites
Sites of Special Scientific Interest	Conservation Areas
National Nature Reserves	National Trust Land
Special Areas of Conservation	Agricultural Land
Special Protection Areas	Purbeck Heritage Coast

Ball clays suitable for the manufacture of ceramic whiteware, such as wall and floor tiles, sanitaryware and tableware, have a limited occurrence, both nationally and internationally, and Britain is a leading producer and exporter. Ball clay has been produced in Dorset for over 300 years and the Wareham Basin is one of only three areas in Britain where commercial ball clay deposits occur , the others being the Bovey and Petrockstow basins in Devon. It accounts for about 20% of national output (about 200,000 t/y in 1999) and production has been increasing steadily in recent years due to a buoyant export market. Dorset clays are particularly noted for their high plasticity, and strength, and wall-tile and floor-tile manufacture is the largest tonnage market. The deposits were formerly worked by underground mining but this method of extraction has been in decline for many years and ceased entirely in 1999. All production is now by openpit methods.

Detailed mapping and the evaluation of a very large volume of borehole data, with associated geochemical data on the clays, have allowed the distribution and variation in the properties of the resources to be delimited in detail. Economically, the most important deposit is the Poole Formation, which consists of an alternating sequence of sands and clays. The sands are of regional importance for construction use. The clays host the important ball clay deposits. There are four host clays which are, in ascending sequence, the Creekmoor, Oakdale, Broadstone and Parkstone clays (Figure 3). The ball clays are laterally impersistent. The proportion of ball clay within a host clay varies, to a maximum of 25%. Ball clays are locally absent.

The Creekmoor Clay is the most important host clay, supplying most of the high-quality ball clays and accounting for some 55% of total output. Workable deposits are confined to the southern part of the basin, entirely within the Dorset AONB, and are very severely constrained by nature conservation designations (Sites of Special Scientific Interest and National Nature Reserves). This has inevitably led to a conflict of interest between resource extraction and protection of the environment.

Data for the project was gathered from a wide variety of sources. BGS mapping at 1:10,000 scale was used to create a digital geological base and a borehole database, containing several thousand records obtained mainly from industry, was created and proved invaluable in plotting variations in ball clay quality throughout the Basin.

Constraint information was acquired from various sources, including English Nature, the Countryside Agency, English Heritage, the Ministry of Defence and MAFF. Information on mineral planning permissions, preferred areas and areas of search for various mineral commodities was obtained from Dorset County Council. The BGS BRITPITS database supplied the location of active mineral operations.

Figure 3. GIS output from MINGOL: the extent of the ball clay host rocks in the Wareham Basin. (© Crown copyright. All rights reserved).

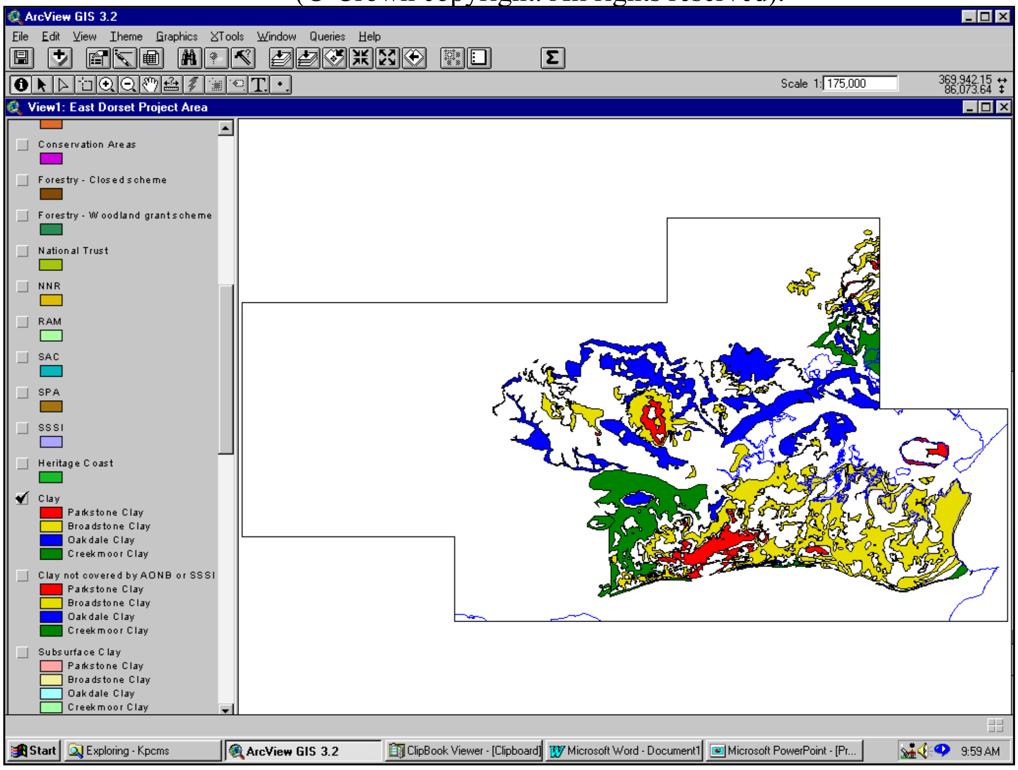
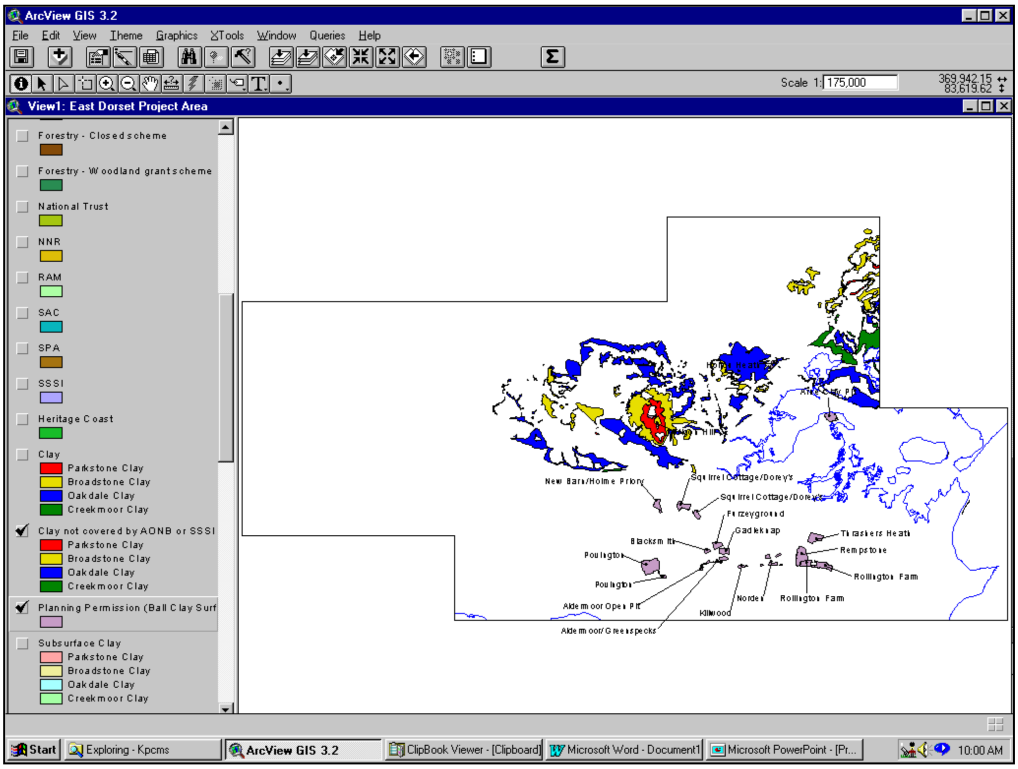


Figure 4. GIS output from MINGOL: the extent of the ball clay host rocks not covered by environmental constraints. (Surface ball clay planning permissions are also shown). (© Crown copyright. All rights reserved).



To facilitate the integration and interpretation of the large amounts of spatially-related data collected, a Geographical Information System has been designed using ESRI's ArcView® (ESRI, 1996) software. This has enabled rapid analysis of a wide variety of questions. For example, 'What is the total area of any particular dataset, such as the total area of a specific ball clay host clay, all SSSIs, mineral planning permissions by commodity, Ministry of Defence land, or high-grade agricultural land?' Then the datasets may be combined and analysed further. For example, 'What is the area of the Creekmoor Clay not covered by major environmental constraint areas, such as the AONB and /or SSSIs (Figure 4)?' In fact only 13% of the Creekmoor Clay outcrop is not covered by these constraints and this occurs in the north-east of the Basin where the clay is known to be of inferior quality. Figure 4 clearly illustrates this point by showing the extent of only those resources not covered by the major constraints in relation to surface planning permissions for ball clay extraction, which almost entirely fall within one constraint or another. The system allows the basic, but essential, information to be displayed and analysed and thus to contribute intelligently to the debate over allowing certain activities to coexist on the same or adjacent areas of land. Mineral resource extraction, tourism, preservation or conservation of the environment, military activities can all have an actual or perceived value placed upon them, so that decisions can be made in the light of the best possible information.

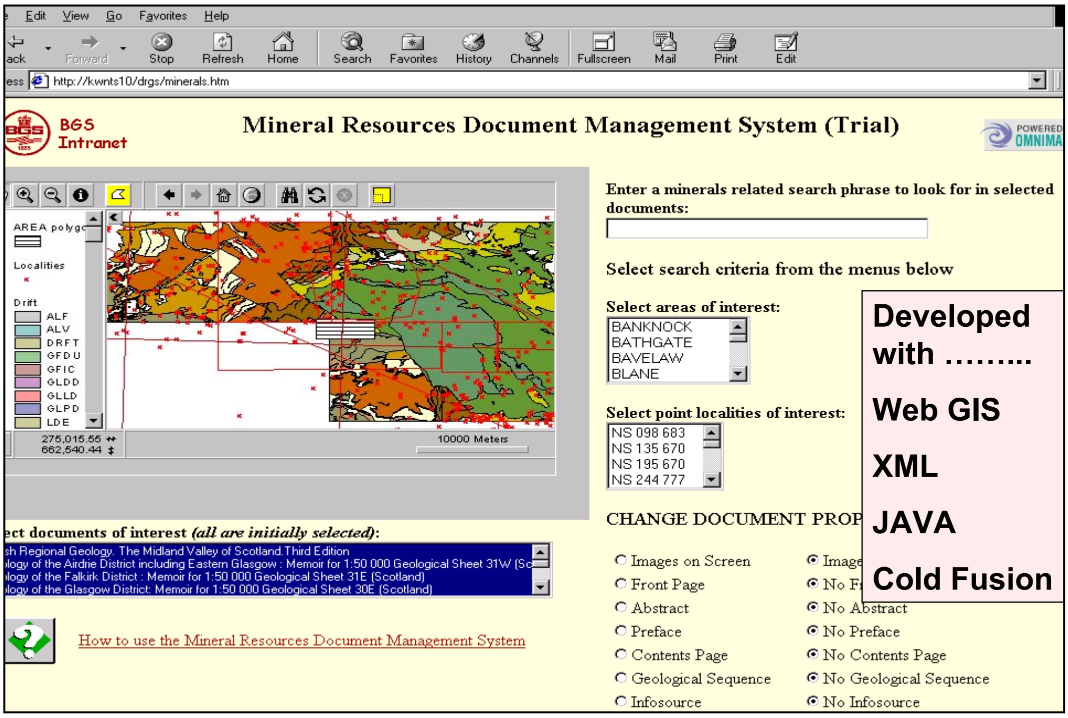
An extension of this work will assist mineral planning at national, regional and local level. It will allow rates of mineral resource depletion to be measured and highlight those resources under greatest pressure. Moreover it could be a powerful tool for monitoring and evaluating the extent that former mineral workings have been restored to beneficial afteruse, including their contribution to habitat re-creation and biodiversity through their subsequent designation as sites of nature conservation importance. It is only by monitoring the life cycle of land through historical and current land use information that progress towards sustainable development objectives can be fully evaluated.

Future minerals information management and delivery

The BGS has a long tradition of collecting and publishing relevant information on minerals both for the UK and globally. This activity will continue into the future. However, it is keen to improve the synthesis, organization and re-distribution of minerals information to a wider audience. The BGS is investing in and developing some new technologies, such as knowledge management, to achieve this goal. The integration of GIS technology with document-management systems and world-wide-web (WWW) delivery allows the organization and classification of such information so that it can be delivered rapidly and widely.

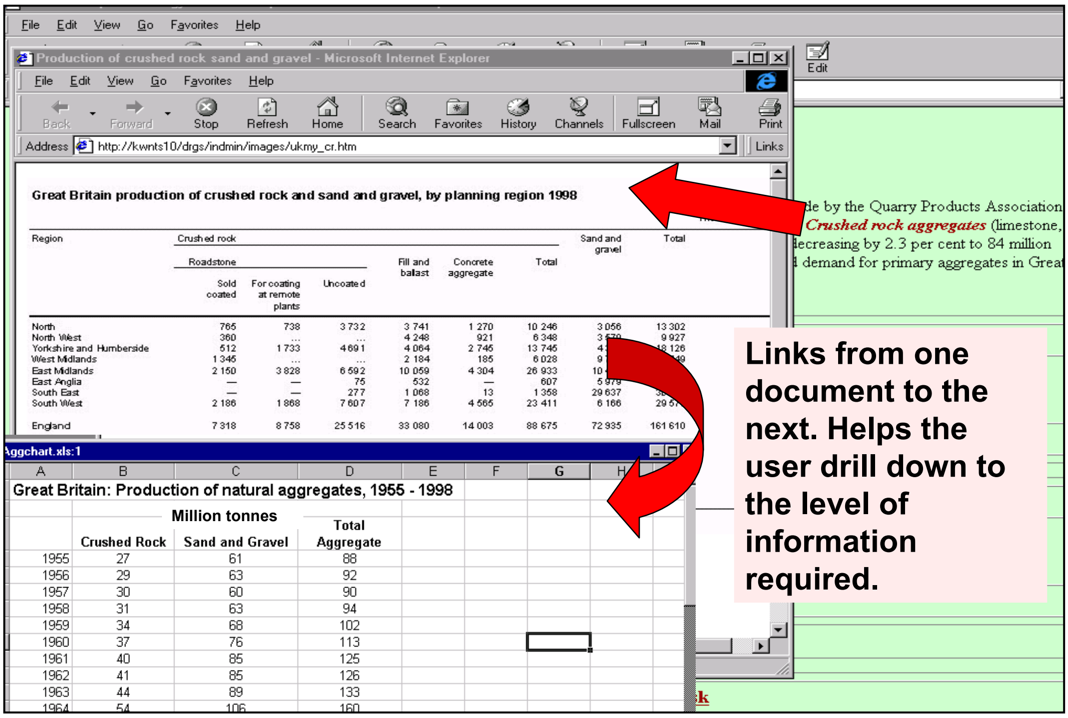
A web-based application has been developed to enable the user to query and interact with the map data, documents, images, statistics and analyses (Figure 5). This application permits both spatial querying (through web-based GIS) and attribute querying (through the use of on-line forms).

Figure 5. BGS proto-type WWW based Minerals Information System.



The application allows users to specify an area of interest by using the web-GIS and select their datasets of interest. Users can further refine their requirements by selecting attributes presented in a series of additional on-line forms. The details available for selection in these forms change dynamically to display only the options relevant to the area of interest and datasets chosen using the GIS. Having selected the required area of interest and datasets of interest using the on-line GIS and further refined their requirements using the on-line forms, users can submit their query. This action passes the criteria selected by the user via a query engine to the data within the system. The user accesses this information by means of a query engine. This program parses the selected documents, extracts the text of interest and returns it as a single web page. The search variables (i.e., the information to be extracted) are passed to the query engine by means of a ColdFusion® interface. ColdFusion® is a rapid application development system, used to create dynamic web sites, marrying together browser, server and database technologies (Allaire). The information retrieved by this query is returned to the user. This might include text, images, statistical analysis or any other information held in the system. The information retrieved is presented to the user in such a way that they can drill down to find more detailed information or sideways to obtain related information on similar topics (Figure 6). The user has control over the information that is brought back and how it is displayed. Details retrieved from the system are tailored to meet the individual needs of each user. It is this flexible presentation of information that is the key to the success of such a system.

Figure 6. Active links allow the user to drill down through the mineral information.



Extensible Markup Language (XML) is used to provide the user with the context-oriented interface to the document (text-based) information. XML allows documents to be encoded with various types of information (Leventhal, Lewis & Fuchs, 1998). Three broad types of information (contextual, meta and descriptive information) can be defined using the XML. Contextual information is that which defines the relative order of a block of text (e.g. whether the text is a heading, a chapter, a section, a subsection, an abstract, or a set of references). Meta information is that which holds information about the document (e.g. who authored it, who published it, who supplies it, how often it is updated, when it was published, or what type of document it is). Descriptive information, is that which describes what a block of text is about (e.g. which minerals are mentioned, which stratigraphy is referenced, or the spatial constraints). The GIS functionality of the system has been achieved through Java customization of ESRI's ArcViewIMS® (ESRI, 1996). This will be updated to ArcIMS® in the future. The communication between the GIS and the on-line attribute forms and the passing of parameters from the front end user interface to the back end XML processing scripts is achieved using Allaire's ColdFusion®. The XML scripting and presentation of results to the user is carried out using OmniMark® (OmniMark, 2000).

Conclusions

Successful and sustainable management of Britain's mineral resources requires the integration of a wide range of land-use and related information. Mineral resources can only be worked in Britain, with very careful attention to the need for development, set in context against the scale and longevity of environmental disturbance. Issues that arise from such debate require accurate and up-to-date information and knowledge tailored to inform all parties. The development of efficient systems for combining, analysing and delivering such information will become an increasingly important element in ensuring that balanced choices are made in the future.

The British Geological Survey is now embracing new technologies within knowledge management, providing mechanisms to locate, organize and use information and expertise. The BGS information system is one of the first knowledge management tools to integrate GIS, XML and WWW technologies to provide data and information. In the past, knowledge on mineral resources was held in individual systems or silos, which were efficient in creation and processing but failed to attract added value because of their isolation and lack of integration. The pilot system described in this paper has been designed to overcome these barriers, adding value by classifying its information using an intuitive taxonomy, allowing users to quickly find what they are looking for.

Acknowledgements

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