AGSO

Third National Forum on GIS in the Geosciences

Forum Proceedings

AGSO Record 1997/36

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

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Third National Forum

on

GIS in the Geosciences

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Forum Proceedings

AGSO RECORD 1997/36

Australian Geological Survey Organisation

DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY

Minister for Primary Industries and Energy: Hon. J. Anderson, M.P.
Minister for Resources and Energy: Senator the Hon. W.R. Parer
Secretary: Paul Barratt

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Executive Director: Neil Williams

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Preface

The 3rd National Forum on GIS in the Geosciences built on two previously successful Forums, the first of which was held in 1992. The concept arose in response to a need to establish standards for the application of computer assisted cartography and GIS in geo-thematic mapping that would facilitate information exchange across the geoscience industry. Clearly, things have moved on to the point where functioning within the GIS mapping environment is a daily part of our lives. However, the developers continue to push the boundaries of the existing technology beyond our comfort zone, to the new paradigms of 'data mining', artificial intelligence and the like.

The applications appear to be developing faster than the momentum for creating working standards, so it is essential that we continue to conduct forums such as this. Sharing the knowledge and establishing common working units is fundamental to data integration and efficient information exchange. In his opening address, the Minister for Resources and Energy, Senator Warwick Parer, talked about the three essentials necessary for Australian geoscience to continue its excellent contribution to Australia's health and well-being. They are cooperation, innovation and information access, the key ingredients that will optimise the process of building comprehensive geo-referenced information assets.

These proceedings epitomise those three essentials, but, most importantly, they represent a sharing of the knowledge and the developments in GIS that are taking place in government, industry and universities. They will be an invaluable reference source for some time to come and an important benchmark against which to measure progress.

On behalf of AGSO I thank the authors and the presenters of papers, for without their contribution there would no Forum.

Acknowledgments:
The patrons of this Forum were the Government Geoscience Database Policy Advisory Committee (GGDPAC) and the Chief Government Geological Cartographers. Both these committees were established by the Chief Government Geologists, who in turn report to the Australia and New Zealand Minerals and Energy Council (ANZMEC) - a peak States/Federal Ministerial Council.

My thanks to the organising committee and staff whose effort and professionalism contributed to the overall success of the Forum and workshops.

Editor's comment:

Please note that only papers that were provided by 9 May 1997 are included in this Record. Authors were requested to submit papers in digital form according to prescribed guidelines and no editing has been performed on their content. The content of the papers in this Record reflects the opinions of the authors and may or may not represent the views of AGSO.

Ian O'Donnell
Forum Convener

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GIS techniques for handling geoscience data within New South Wales Department of Mineral Resources

Peter Lewis and John Fryer, Geological Survey of New South Wales

Abstract

The changes evident in the way companies conduct exploration are also noticeable in the changing work processes of government survey organisations. This is particularly evident in the way they now process information and apply GIS technology. In the New South Wales Department of Mineral Resources (NSWDMR) this change is evident in three areas.

- Data management issues and the integration with GIS functionality, national and international standards.
- GIS use in core business areas, data capture, map generation and cartography, spatial analysis, resources, land use and title management.
- Presentation of data: as single theme GIS coverages and the packaging of data as multi-theme GIS CDRom products.

The NSWDMR has undergone major changes in recent years in order to manage and process the information they hold. The scale of the problem has forced the Department to adopt improved work processes, data standards and models. Several programs are operating to aid data acquisition and retrieval, namely the digital imaging of documents in the GS System **(DIGS)** and the **Discovery 2000** Minerals and Petroleum Programs. Planning has started on other programs to improve work practices and related IT issues in geoscience, titles, mining engineering and communications. Scoping studies have been completed for the Geological Survey **(CoGENT)** and Mines Inspection Branches**(COMET)** and the work has begun to revise the IT environment of the Titles Group **(TAS).**

Introduction

A major initiative is underway within the Department to ensure that information is treated as a valuable resource and handled efficiently. This paper will summarise the IT/Data/GIS projects in place and the programs planned for the immediate future. Its focus will be on the Geological Survey with references to activities in other branches.

There have been several reviews of IT strategy with initial documentation in 1992 (Information Systems Strategy), subsequently updated in 1994. Originally the scheme considered the problem at a corporate level. This strategic plan was followed up and the infrastructure is now in place to tackle projects at both a corporate and branch level. Senior management identified the Titles Administration area for immediate attention followed by the Geological Survey, Mines Inspection and Administration/Policy. The structure of the Department was altered in 1993-4 and this caused some delays in implementing these IT/GIS projects.

Funding of $5 million for these projects is sourced from State government capital funds made available to departments for improvements the capture and storage of information.

The implementation of GIS technology and database development was initially accelerated in 1992 by the Minerals Audit Project and given a further boost since 1994 with funding from the

Discovery 2000 Exploration Initiative. These activities have led to rapid advances in the application of GIS technology , data retrieval (DIGS Project), data capture/handling and release of products (e.g. multitheme geoscience data packages on CD).

Departmental Information Systems Initiatives 1996 -1998

TAS2	Conversion and redesign of the Titles Administration Branch Started 1996, scheduled for completion 1998.
CoGENT	Development of a common geoscience environment. Scoping study complete, scheduled start date June 1997.
COMET	Upgrade of data systems in use for Mines Inspection. Scoping study under way.
DIGS	Digital conversion of company reports and other GS reports 1994-99. Systems in final acceptance testing, conversion underway.

Current Status of Database and GIS in the Geological Survey

Note: The NSWGS was restructured in 1995, see figure below. It has been expanded to include the Cartographic/Information and the Coal & Petroleum groups.

Databases:

Tables have been established for many of the important activities in the Geological Survey. Several data themes are modelled relational databases with common authority and lookup tables. These datasets are linked by a Sites table, they include;

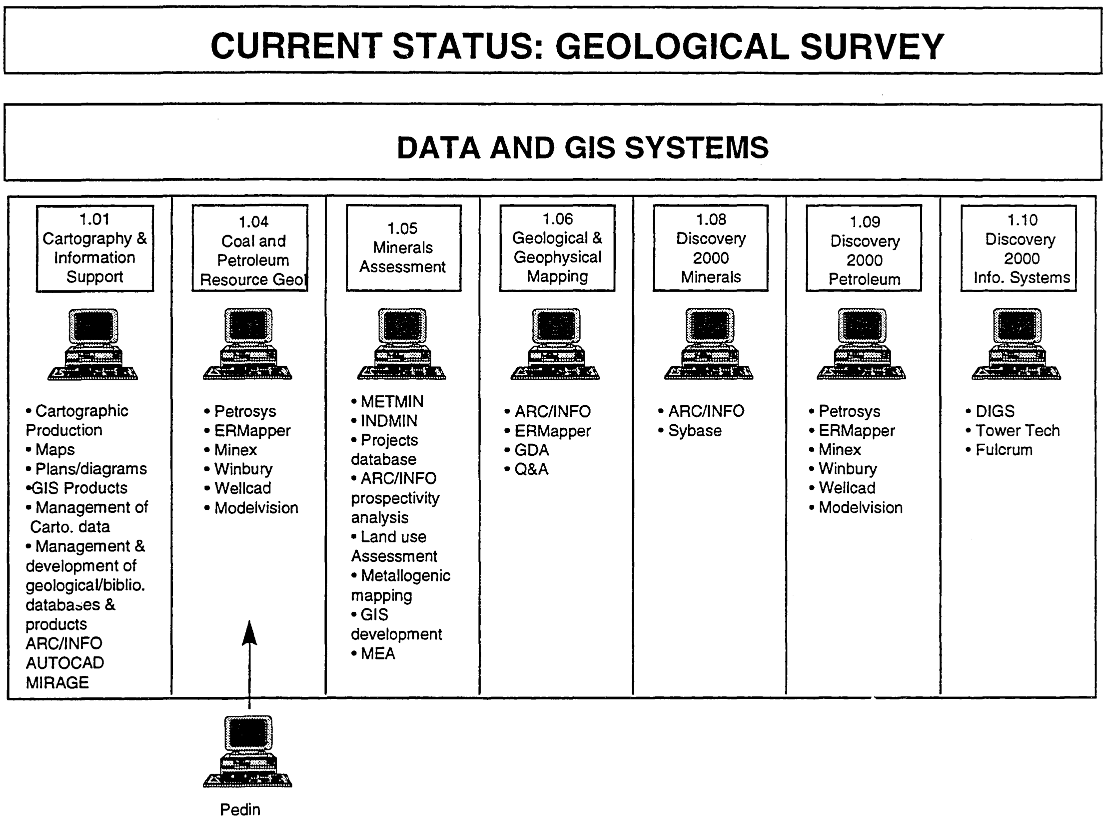
Outcrop	dynamic
Petrology	70,000 records
Whole rock geochemistry	est. 2000 records
Grab geochemistry	incomplete
Stream sediment geochemistry	170,000 records
summary drill information	incomplete
Metallic deposits (MetMin)	7000 records
Industrial deposits (IndMin)	?2000 records

These tables were modelled as part of a Discovery 2000 project and are in near final form. Where possible they conform to "common" structures and lookup tables. The Department is a member of the GEODATA and GGDPAC Committees attempting to establish a common approach to data management/description and data capture.

Other structured datasets include Pedin (data on petroleum drilling).

Most other data is maintained in single table form, commonly in MS Access on PC's, often in isolated storage.

GIS Activities



a) Geological Mapping. Increasing use of ERMapper and ArcView as tools to aid map compilation. Data stored as spatially located records in the Outcrop and related databases.

b) Cartography, A mix of AutoCad, ArcInfo, (ArcScan, ArcView), MapInfo, Mirage tools.

c) Geophysics. ERMapper, Geosoft, Modelvision etc.

d) Mineral resource studies. Increasing use of ArcInfo and ArcView (MapInfo) tools. Note spatial analysis conducted using GRID module of ArcInfo.

e) Coal & Petroleum. Image processing by ERMapper, 3D modelling using Minex software. Minor use of GIS viewers e.g. ArcView.

f) DIGS. See description below.

g) Discovery 2000. Image processing, interpretation using ArcInfo, ERMapper, ERDAS, Geosoft, ArcView and MapInfo. Customisation and packaging of datasets in MapInfo and ArcView. (see also paper by Fleming and Clare, this volume).

Project Descriptions and Significant Issues

1. DIGS

    Digital Imaging of the Geological Survey (GS) Report System.

The DIGS project has been well documented and a more complete description is available in Brookes 1995 . It is essentially a project to create a digital record of company exploration reports, text and maps. The project details included the capture, storage, retrieval and viewing of data at head office, in the regional offices and via the Internet. It involves the scanning of an estimated one million documents and plans and the storage of around 3 terrabytes of data.

Scanning is carried out by an on site bureau run by the primary contractor, Ikon. The primary contractor for system development is Tower Technology. The system is in its final phases of acceptance testing. Prior to scanning the documents are indexed and bar coded. Completion of data conversion (scanning) is scheduled for 1999. It is planned that 35% of material will be migrated by June 1997.

The major issues for DIGS have been retrieval speed, data structure, hardcopy products, and data delivery, particularly of colour originals. Research into the compression of raster files as JPEG files has resulted in acceptable hardcopy imagery and refresh speeds for screen display from reasonable file sizes (2-4 Mb).

DIGS (plus MEA group and Discovery2000) are also concerned with issues relating to the format of company reports and handling data in digital format. The matter is the subject of ongoing discussion in the NSWGS and by GGDPAC.

2. TAS2

Titles Administration System

The TAS1 project covered the scoping exercise and tender procedures for the conversion of Titles Administration to an Oracle - ArcInfo - ArcView system. TAS2 refers to the contract for the work. The job was awarded to Geographic Business Solutions (GBS), a subsidiary company to ESRI Australia.

In addition to data modelling, data conversion and data enquiry/reporting/delivery mechanisms the job entailed an analysis of work processes. The aim being to allow the file handler to be a one stop shop in processing the title application.

3. CoGENT

Common Geoscience Environment

CoGENT is the second project of branch level business and data process revision to be initiated as part of the Information Systems Strategy. There are three main aims to the exercise:

1. To identify all datasets, complete a data inventory, establish a clearinghouse system of metadata and complete development of internal and external enquiry mechanisms.
2. Complete the establishment of data tables, with proper documentation, data manager, data custodian and rules. Conduct progressive conversion of data into the new tables.
3. Conduct a workflow analysis of the geological mapping and map production cycle from data collection through the iterative compilation phase to cartographic input and production of both digital and hardcopy products.

A scoping study has been completed and a tender document is being prepared. If there are no unforeseen delays the project should start by July 1997 and be finished within a year. The system to be established will be based on an Oracle database and ESRI GIS tools (ArcInfo and ArcView). However there are a number of issues to be considered, as listed below:

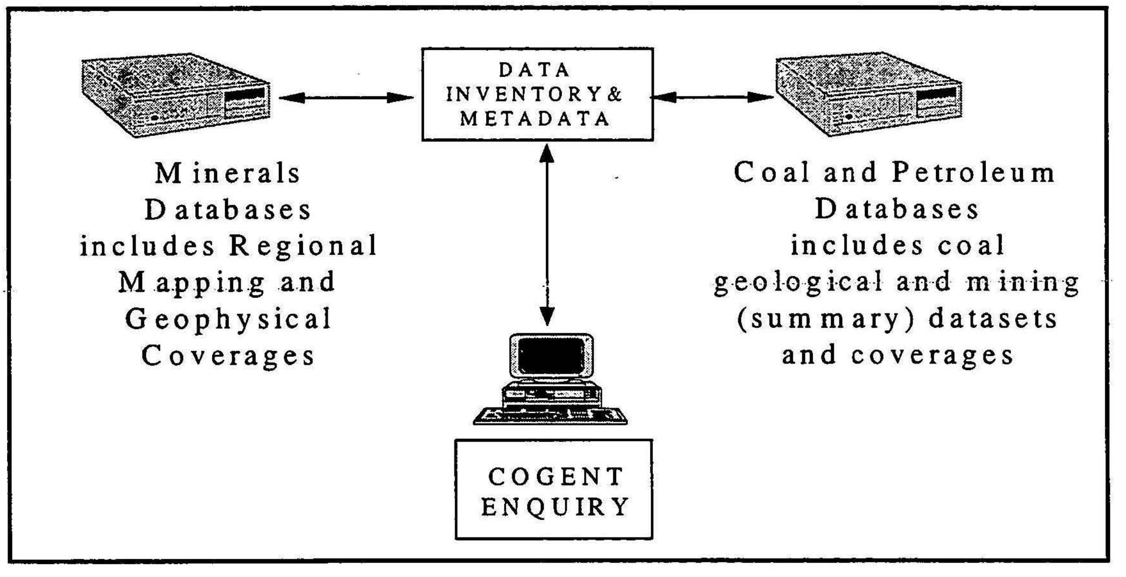
- a range of platforms (Sun, DEC, PC)
- several graphics/drawing systems, AutoCad, ERMapper, ArcInfo, MapInfo, ERDAS, CorelDraw etc.

- head office and regional office locations
- separate datasets, some normalised relational tables, others single tables
- corporate ('finished') and project data

The majority of problems can be overcome by setting up a layer of properly documented metadata tables drawing information from all sources of corporate data. Standards will be set at a high level and include data quality statements (similar to ANZLIC specifications).

The system can be made flexible and if well designed can be amended if necessary without jeopardising the integrity of a fully relational system. The lean metadata tables can be searched quickly and should allow the enquirer to 'bore down ' to the primary tables, if privileges allow.

Rules can be set at a Departmental level and it anticipated that the tables would become part of a Departmental enquiry system. The tables would permit the use of third party tools for browsing and development.



Most of the data will be spatially located and it is envisaged that some form of GIS viewer such as MapObjects could be used to browse the information spatially, on screen. Another possibilty to be explored is the use of a Spatial Database Engine to create a common format and link for all spatially located material.

Workflow Analysis

Map production is the principal business processes of the geological survey. Under the pressures to produce map products with fewer staff it is essential that the most efficient business processing is applied. The current study will attempt to find a suitable method to optimise data capture in the field, map compilation and map production.

In the process the roles of the geologist and cartographer should better defined.

Other issues to be confronted include; the release of interim products, 'on-demand' plotting, possible customisation of products, a range of formats (ArcView, MapInfo etc..), tracking work in progress (version control), change from large print runs to much smaller in-house plotting runs.

GIS IN THE GSV

Recent advances in GIS in the Geological Survey of Victoria

Roger Buckley
Manager Mineral Resources
Geological Survey of Victoria

The improved GIS capability of the Geological Survey of Victoria (GSV) has been an important aspect of making quality regional data sets readily accessible to our clients.

Victorian Initiative for Minerals & Petroleum

As part of the 3 year, $16.5 million Victorian Initiative for Minerals & Petroleum (VIMP) program, the GSV has substantially completed major data acquisition projects with the aim of encouraging mineral exploration and mining development in the State. The program has concentrated on under explored areas of Victoria that are considered prospective for a variety of commodities. These Initiative Areas are the mineral prospective Eastern Highlands area and the North Western Plains area as well as the petroleum prospective Otway Basin in western Victoria.

The main components of the program are:

- Geophysics - consisting of airborne magnetics and radiometrics as well as gravity and seismic surveys;
- Drilling - ground truthing geophysical interpretations of bedrock under thin cover of Murray Basin sediments;
- Geological mapping - producing quality 1:50 000 scale geological maps;
- Mine and geochemical database compilations.

This data can then be presented in an integrated, user friendly GIS format.

The initial 3 year program is almost complete and you must ask the question "Is VIMP working?" We believe the answer is yes. Quality regional data sets such as the extensive, 200m line spaced airborne geophysical coverage as well as the detailed geological mapping provide the exploration industry with excellent tools to reassess areas for their mineral potential and hence target their exploration effort. This combined with a revamped Mines Act and a customer focused Department has contributed to a tripling of exploration expenditure from $12 million in 1992/93 to over $42 million in 1995/96. The area of the State under Exploration Licence (EL) or application has also increased dramatically, from 25% in April 1994 to 46% in March 1997. This is almost a doubling in just under 3 years. Many of the ELs, especially in the north west of the State are due directly to the availability of VIMP data.

GIS data sets

So which areas do these GIS data sets cover? To date, the GSV has released 4 data sets covering the VIMP initiative areas of Glenelg in western Victoria, Tallangatta and Bairnsdale 1:250 000 mapsheets in eastern Victoria and the Dunolly 1:100 000 mapsheet in Central Victoria (see Fig. 1). Additional GIS data sets for eastern and central Victoria are planned for release later this year.

Typical themes that are available in these data sets include:

- Geophysics - magnetic, radiometric, gravity and digital terrain model colour images;
- Geology - 1:250 000 scale regional geological maps together with more detailed 1:50 000 scale geological maps;
- Mineral deposits - prospects identified by modern exploration and historical and current mines;
- Geochemistry - all stream sediment and soil sample data collected from relinquished ELs;

- Tenement data - current and relinquished Exploration and Mining Licences with a summary of work programs;
- Borehole data - as derived from the Department's corporate GEDIS database;
- Land use - National Parks, reserved and unreserved Crown Land;
- Cultural features - such as roads, towns, mapsheet boundaries.

The GIS data set covering the Bairnsdale 1:250 000 mapsheet is a good example of the type of data available.

Geophysics is an important data set and a comparison between the new GSV airborne magnetic data and the old 1500m spaced AGSO data in the south of the mapsheet highlights the detail available in the new data. By overlying the major faults and known mineral deposits on the magnetic image, mineralised areas and structures can be easily identified and possible extensions to these inferred. Each of the mineral deposits is fully attributed with such information as name, location, production, geology, mining information and scanned mine plans or sections from the Department's microfiche collection. An expanded database version of the mineral deposits information is also available which makes it a powerful tool to query and select sites as required.

Regional geology maps are an essential exploration tool, and the GIS digital versions contain information on the Group, Formation name, age, lithology and geophysical characteristics of each of the rock units.

Some of the VIMP areas have been subject to detailed geological mapping which has produced hard copy maps at 1:50 000 scale. All the information on these maps, including structural information such as dips and strikes, plunges of folds, orientation of cleavage, joints etc, and detailed geological information such as the outline of thin dykes, shear zones and quartz reefs are presented in the GIS.

The Geological Survey has used contractors Terra Search to compile the stream sediment and soil sample data from all the expired Exploration Licences in the area. There are over 17 000 stream sediment samples on the Bairnsdale sheet, most of them in the east of the mapsheet (see Fig. 2). The distribution of BLEG samples is much more limited and just from a simple plot of location of all stream sediment samples, it is obvious that there are large areas of virgin, unexplored country in the Bairnsdale 1:250 000 mapsheet. This is surprising given the detailed patchwork of ELs that have covered the mapsheet over the last 30 years. The mineral potential of these unexplored areas can now be reassessed in the light of the new geophysical and mapping data. It is a relatively simple matter to normalise different geochemical surveys and colour code the samples for assay results for specific elements. In this way, anomalies are easily identified. The attributes for each sample site include location, sample type, company and EL, assay results, detection limits, analytical methods and laboratory used. This data is available in Terra Search's *Explorer* database format as well as in GIS format, enabling easy searching and selecting of specific data sets.

In much the same way, over 63 000 soil samples on the Bairnsdale sheet have been located to AMG coordinates. These samples have similar attributes to the stream sediment samples and can be queried in a similar way.

GIS in action

Collecting data is a noble cause, one which Governments spend a lot of time doing and it could keep me in a job for several years, but how can this be applied to the mineral exploration industry?

A typical example of how GIS data sets can be used to more efficiently and effectively target exploration is the EL 3012 program. This is just a typical example and I'm not trying to target the company in any way. This EL is on the Bairnsdale 1:250 000 mapsheet and was granted to CRA Exploration in 1988, well before the VIMP program was born.

The process CRA Exploration used in exploring the EL area was fairly typical of the industry in its methodology.

1. Reviewed literature, summarised regional geology and mineral deposits and I'm sure produced a very well written report. We have that same data available at the touch of a finger in the GIS.
2. Compiled previous geochemical data from relinquished EL's from the microfiche reports in the Departmental library in Melbourne. This is a time consuming process which has to be repeated for each company that looks at a specific area. Again, we have that same data readily available in the GIS.
3. Airborne geophysics survey conducted and images produced. Again, we have that same data available in the GIS.

These layers of information were compiled onto hardcopy maps and overlaid with each other using a light table. After much fiddling with scales and much thought provoking discussion I'm sure, several prospective area were identified and further investigated. In this case, the investigations revealed the Dogwood chalcocite Cu prospect with a best drill intersection of 24m @ 0.8% Cu. Whilst this is an ore grade intersection, the total resource was quite small by CRA standards.

This initial review and data compilation process is typical of many exploration programs. In this case, it took the company 1 year and many thousands of dollars. Now we have this data available relatively cheaply in a GIS format allowing several layers to be viewed and queried simultaneously. This saves the company time and money, allowing additional resources to be devoted to the business end of drilling and outlining ore bodies. The GIS also has the advantages of providing a comprehensive data set compiled to a uniform standard as well as providing an excellent platform for the company to add and interpret its own exploration data.

Whilst the future of the VIMP program beyond June 1997 is uncertain, we are hopeful that Jeff Kennett can see the benefit to the exploration and mining industry and continue the initiative funding. GSV will then be able to continue the production of quality GIS data sets into the next century.

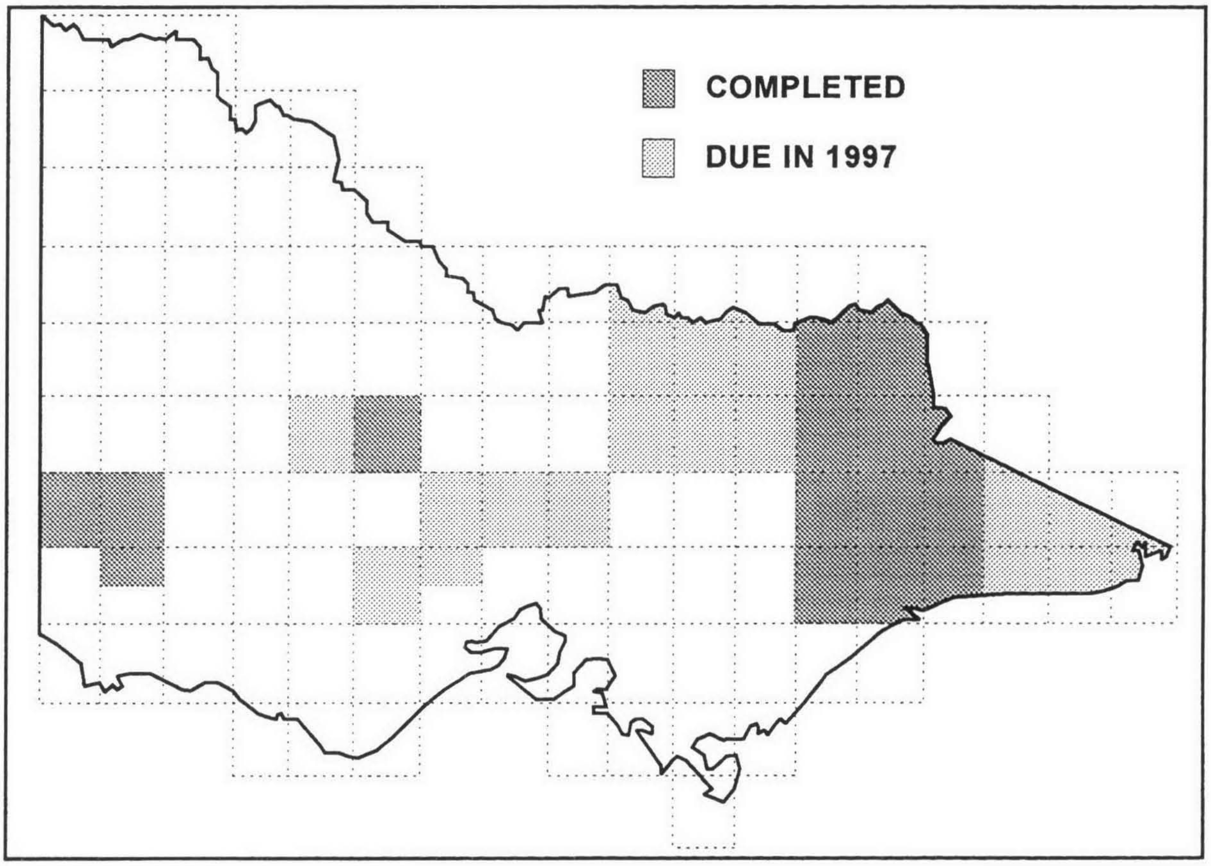


FIGURE 1: Victorian GIS data sets.

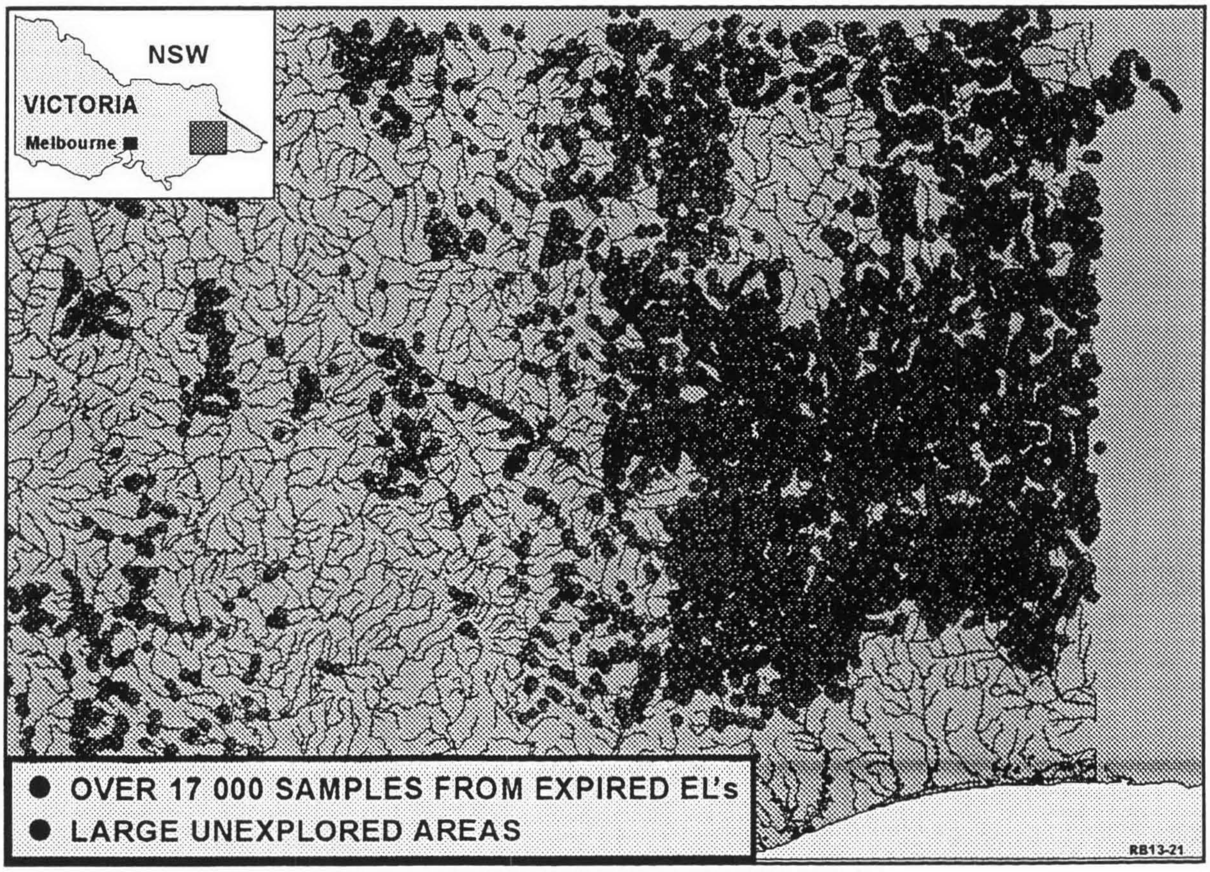


FIGURE 2: Stream sediment sample locations, Bairnsdale 1:250 000 mapsheet.

GIS INITIATIVES: MINERAL RESOURCES TASMANIA

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Introduction

Recent developments at Mineral Resources Tasmania (MRT) have centred upon consolidating the digital capture of geological maps and commencing development of a textural database to manage the continually increasing amount of digital scientific and tenement management data. In the period leading up to the Second National Forum on GIS in Geosciences significant advances were made in implementing Arc/Info as a GIS for geological mapping. While this phase has been successful it only forms part of a complete geoscience information management system. From this position Project TIGER (Tasmanian Information on Geoscience and Information Resources) was commenced and will construct the remainder of an integrated information management system.

Activities under the objectives of Project TIGER have included entry of stream sediment and whole rock geochemistry data, creation of a spatial index for the TASXPLOR bibliographic database of company reports and research into a feasibility study for further funding of TIGER.

Current digital data sets

The state is now covered by 1:250,000 scale digital geology. This is available in 4 tiles or as a seamless data set.

The program of 1:25,000 geological compilation has continued in areas of known high mineral potential or perceived high potential for mineralisation. To date 31 out of 451 1:25,000 scale geology tiles have been completed. All 1:25,000 tiles are delivered as a package of 6 themes; geology polygons, structural measurement locations, open file stream sediment geochemistry, whole rock geochemistry, drilling locations and mineral deposit locations.

Recently the Launceston Urban Mapping Project which was funded with the cooperation of local government was completed. This is a set of geology and land stability maps covering the greater Launceston area at 1:10,000 scale. The package includes Engineering Geology with a comprehensive legend of engineering properties and a Land Stability Zonation theme which was produced from a synthesis of slope conditions and geological investigation.

Current mineral tenement boundaries are available on disk by request or by subscription on a monthly or quarterly basis.

GIS developments

TASXPLOR, the bibliographic data base of company reports held by MRT is a listing managed by an in house Fortran program. The data set is a comprehensive index which contains many keywords, a brief summary and coded classifications of exploration activity documented in the report. The only spatial index for the data base is a reference to the 1:50 000 map sheet number. This has proved to be far too wide to make effective spatial searches.

Introduction of the Arc/Info regions data model permitted the development of a much more precise spatial index. This data model allows overlapping polygons or isolated island polygons to belong to a region subclass in a polygon coverage. A total of 19 subclasses have been defined based on the most frequent exploration activity classifications held in TASXPLOR. An additional, 20th subclass labelled 'Other' contains all activity that doesn't fall within the other 19 subclasses. If a particular activity is found to have a high frequency in the Other subclass it can be transferred to its own subclass. Each subclass or region is attributed with the index number (Tasmanian Company Report Number, TCR No) of the company report to which it refers. The current subclasses are:

- Geological mapping
- Remote Sensing
- Drilling
- Ground magnetics
- Airborne magnetics
- Ground electromagnetics
- Airborne electromagnetics
- Ground radiometrics
- Airborne radiometrics
- Induced polarisation, self potential, resistivity
- Gravity
- Seismic refraction
- Seismic reflection
- Stream sediment geochemistry
- Soil geochemistry
- Rock chip geochemistry
- Surveyed grid lines
- Access tracks, (vehicular or walking)
- Site rehabilitation
- Other

When opening the TASXPLOR regions coverage in Arcview each subclass is represented as a theme in the table of contents. By linking the TASXPLOR listing to subclasses using TCR No as the key field the bibliographic details of any exploration activity subclass can be displayed.

Due to interest from external clients a preliminary release of this data will be made and comments invited. The preliminary data release will include all open file reports from March 1997 back to mid 1987.

Feasibility Study

In early 1995 Phase 1 of Project TIGER developed a stand alone prototype of an integrated geoscience information resource in the form of a public access inquiry system. This was designed to demonstrate what an integrated information system could do using existing data sets. Rapid developments in communications, such as the World Wide Web, since this time means that several new opportunities are now available to give external clients online access to MRT information.

Phase 2 of Project TIGER has involved the back capture of data. This commenced with Phase 1 and is creating a comprehensive ground water, stream sediment and whole rock geochemistry data base for the State. The development of the TASXPLOR spatial index has been a more recent development under Phase 2. Phase 2 is not complete and requires ongoing funding to complete the back capture of data and keep the data sets up to date.

Phase 3 is the development of an integrated spatial and textural database management system. This will involve creating a CA-Ingres/Arcstorm database to hold data which is now spread across a wide variety of applications and platforms. The benefits will be a robust warehouse for MRT data from which a diverse array of information products can be distributed.

A feasibility study for Phase 3 commenced with a questionnaire that was circulated in February 1996 to get feed back from external clients on aspects of MRT information and delivery. This was done to identify areas of lowest and highest need for allocating scarce resources on further development of the information management system. Respondents were asked to rank the relative importance of current information products. In addition several questions were asked on the type of media and mode of delivery preferred. Respondents were grouped into categories to aid interpretation of results (see Table 1). From 120 questionnaires circulated 78 were returned, a response rate of 65%.

STAKE HOLDER GROUP	RESPONSES	COMMENTS
Mining and petroleum industry	38	Mostly mining and consultants, only 4 energy companies replied
Other industry	17	Mostly local engineering and environmental consultants
State Government	8	Resource & land management agencies
Local Government	8	
Federal Government	4	AGSO, National Library, BRS
Research/education	3	University of Tas, CSIRO-Forestry
TOTAL	78	

Table 1 Summary of responses by external stake holder groups

The survey is a good indicator of industry needs as this group had the highest representation by far. Conversely, the Federal Government and Research groups are poorly represented and the results should be treated with caution. Results from the survey are summarised in Figure 1 and Figure 2. Information has been categorised into geological, which is geological maps of the 1:25 000, 1:250 000 and 1:500 000 series, and other specialised products. Tenement is boundaries of mineral tenements and tenement holder listings. Engineering is the engineering geology and groundwater maps. Point data bases refers to GIS data sets of stream sediment geochemistry, whole rock geochemistry, drill hole locations and mineral deposit locations. The y axis of each graph in the figures is the average normalised rank for each stakeholder group.

The pattern of relative levels of importance of information product types amongst stake holder groups is largely as expected. Overall geological maps are the most valued output. The importance of other information types is largely dictated by the type of business the client is involved in. Industry is interested in scientific information from point location databases where as State Government has more of a land management role and values tenement information more.

Respondents were asked to rank the modes of information delivery (Figure 2). One option was a Public Access Inquiry System such as the prototype described above which would be accessed in the MRT office in Hobart. The remaining options were mail order of printed and digital products on magnetic media, data packaged onto CD-ROM or remote transfer such as ftp. Currently most MRT products are delivered by mail order on magnetic media.

The PAIS interface was the least preferred by all groups. CD-ROM packages and the current mail order of data sets are the most popular across all groups. The ranking of remote transfer varies widely between groups, and largely reflects access to the Internet which is now seen as a common and practical transfer protocol.

Summary

Tasmania is covered by 1:250 000 digital geology and compilation of a 1:25 000 series is progressing.

A spatial index to the TASXPLOR bibliographic database has been developed and back capture of exploration activity areas is in progress.

A questionnaire circulated to clients who have used MRT information products has highlighted areas which need further development. Many Local Government bodies and consultants indicated that the engineering geology map products did not cover enough area and 1:25 000 geological maps did not meet their needs. Smaller scale engineering geology maps of urban areas with comprehensive engineering properties are required. The Launceston Urban Mapping project is a good example of this. Land management issues have come to the forefront in recent times which is creating increasing demand for environmental and engineering information.

Hard copy output of maps is still a widely preferred mode of information packaging, however CD-ROM is a popular digital alternative. Preference for remote transfer of data varies between groups according to their access and use of the Internet. Government based organisations have the Internet embedded into their business and a strong preference for this mode of delivery. In contrast, industry take up of the Internet is slower due to a wider geographic spread of people in remote areas. The acceptance of the Internet should improve as companies improve their internal distribution of digital data. This will promote transfer of information from government agency to a head office distribution point. All groups expressed a strong interest in browsing meta data and indexes via the Internet.

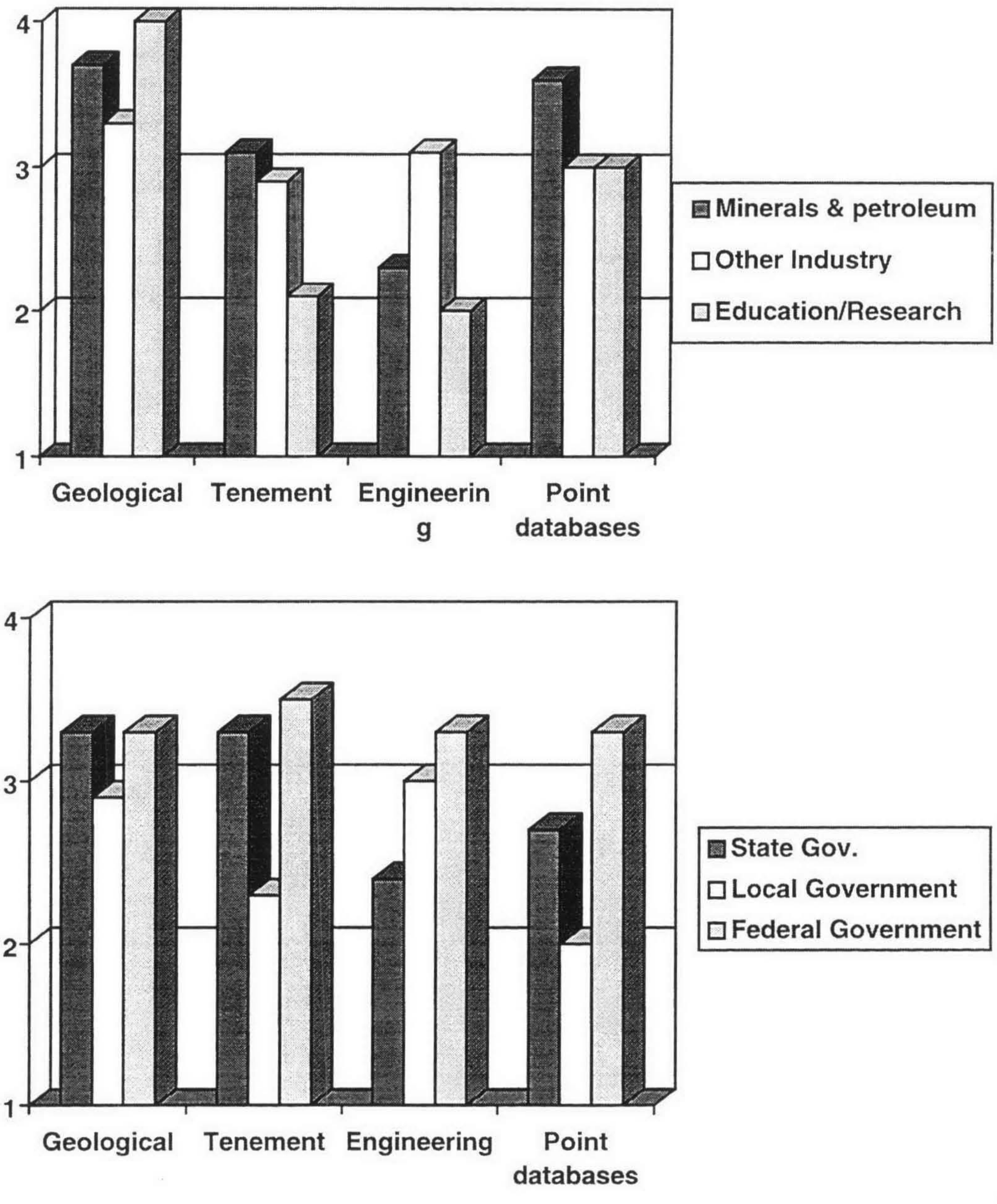

Figure 1. Average normalised rank of importance of MRT information product types amongst stakeholder groups.

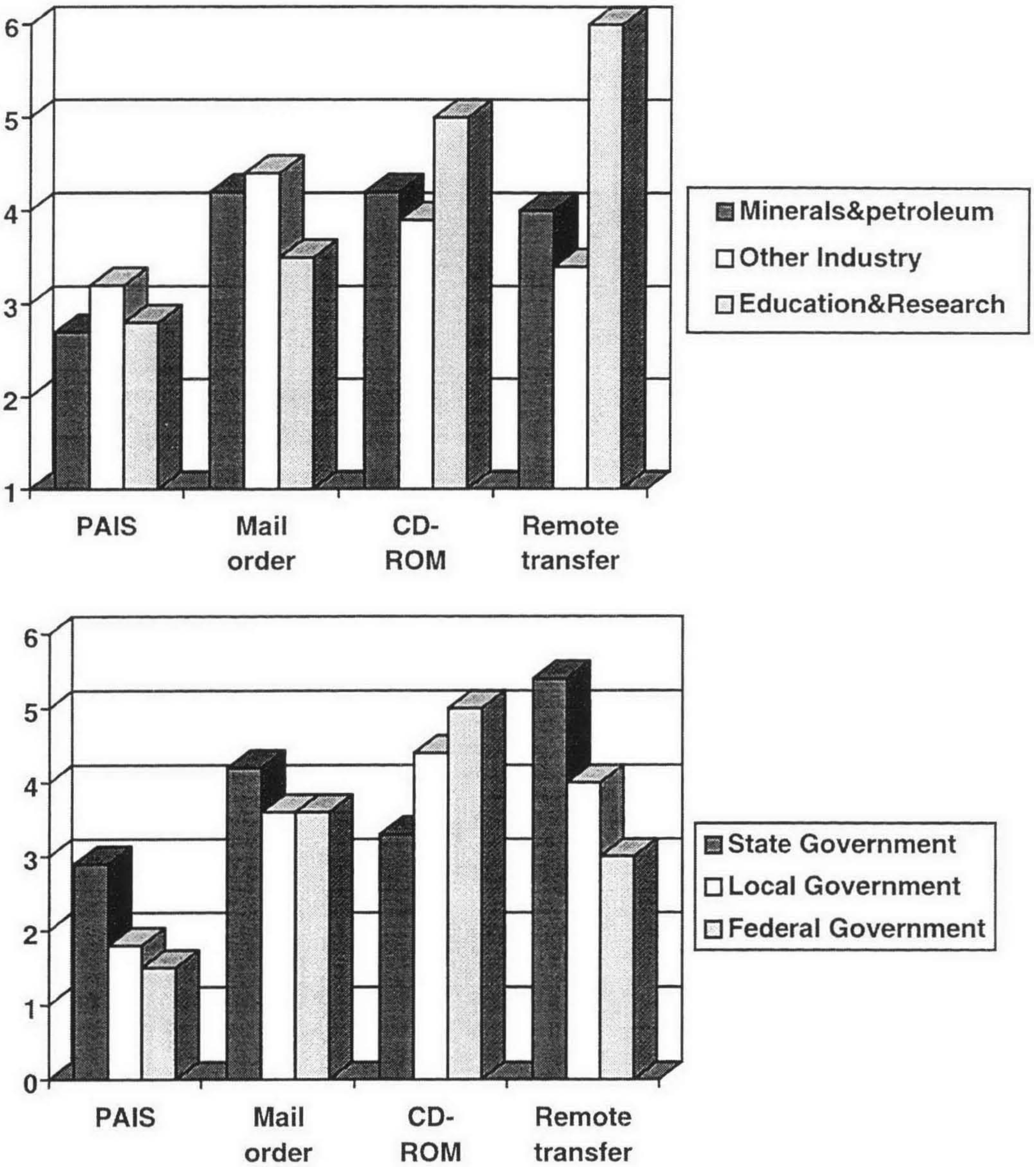

Figure 2. Average normalised rank of the mode of delivery of information products between stakeholder groups.

What's New at Mines and Energy Resources South Australia

Neil Sandercock
Geographic Information Systems Group

ABSTRACT

MESA has been compiling and maintaining spatial geoscientific and related datasets for many years now. Much of the usefulness of these datasets relies upon them being state-wide in extent, having reliable spatial relationships and being up-to-date. In this way, scenarios can be modelled using the datasets in combination to present results which were previously either exceptionally time-consuming or simply not feasible to attain. With the collection of datasets MESA now has, it has been possible to compile several new interpretive data layers that can make the data package considerably more powerful. MESA now has available datasets including imagery (total magnetic intensity, first vertical derivative magnetics and gravity), drillholes with stratigraphy, geochemistry and petrology, geochronology, known mineral occurrences, lithology, structural observations, basement outcrop and solid geology interpretation. Supplementary datasets that have recently been compiled or acquired include historical tenements dating back to 1930, detailed culture and drainage patterns, environmentally sensitive area such as parks and reserves, AUSLIG's 9-second terrain grids, cadastral and land ownership details and native title claims. New detailed data packages have been released for the Southern, Northern and Western Gawler Craton and the Curnamona Province. Our Groundwater Division has recently produced a CD-ROM package containing groundwater resource information at regional scale.

Dissemination of MESA's considerable data holdings to the exploration industry has always a priority. Naturally this now extends to the medium of the Internet. MESA has recently gained a presence on the World Wide Web and is looking closely at the rapidly evolving technology that enables the publishing of intelligent map data on a Web page. The ability to publish large, complex datasets at very reasonable cost to interested parties throughout the world certainly promises exciting and challenging times ahead.

PRESENT GIS INITIATIVES AND THE FUTURE DIRECTION WITHIN THE GEOLOGICAL SURVEY of WESTERN AUSTRALIA

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ABSTRACT

In the past six years the Geological Survey of Western Australia (GSWA) has used a project approach to implement GIS within the organisation. This approach has proved successfully with a number of large GIS projects having been completed. It does, however, have some disadvantages, particularly in data sharing.

In order for the information to be of maximum value to Industry and the GSWA, the spatial and attribute data must be readily accessible. Thus, the strategy is to move from a project based GIS to an enterprise model. As such, the GSWA has recognised a need to further extend its GIS capabilities throughout the organisation using desk-top mapping tools.

The spatial and attribute data will be integrated at the systems level and incorporated into the existing information system. This has caused the GSWA to refining its approach to data management and sharing.

INTRODUCTION

Geographic Information System (GIS) has been operational in the Department of Minerals and Energy, Western Australia (DME) for the past six years following a pilot project conducted in 1990 (Gozzard and Bandy 1991). During this time a number of projects in the Geological Survey of Western Australia (GSWA) have been successfully completed.

However, factors such as changing client needs, greater integration of data and new technologies are having an impact on the organisational and operational structures within the GSWA. As a result, the past year has been a time of consolidation and a time of review. Our current strategies have been re-examined. Where necessary new strategies are being developed to provide for greater flexibility to meet these changes.

PRESENT GIS INITIATIVES

ARC/INFO

Two important strategies were adopted at the time of establishing a GIS facility with GSWA. Firstly, the recognition that the GIS be 'project' driven and secondly, the need to disseminate GIS functionality to the geoscientists.

Arguably the first, the project driven approach, was the most important and lead to the initial recognition of what could be achieved.

Advantages

- Tangible results were produced in a shorter time frame
- Lower initial costs

- Reduced maintenance of acquired data

Disadvantages

- Limited data sharing as what was acquired for one project may have little interest with another
- Limited access to GIS tools as it was a 'centralised' system
- Reduced ability to modify our processes

The second strategy, dissemination of GIS functionality, has only been achieved to a limited extent in the past due to the nature of the project based operation and the conservative nature of the geoscientists.

More recently there has been a move towards an enterprise based system. New strategies have been adopted and the initial implementation commenced.

Some examples of how the analysis and cartographic functions of Arc/Info are being used in project driven programs within GSWA are:

Regional Geochemical Mapping Series

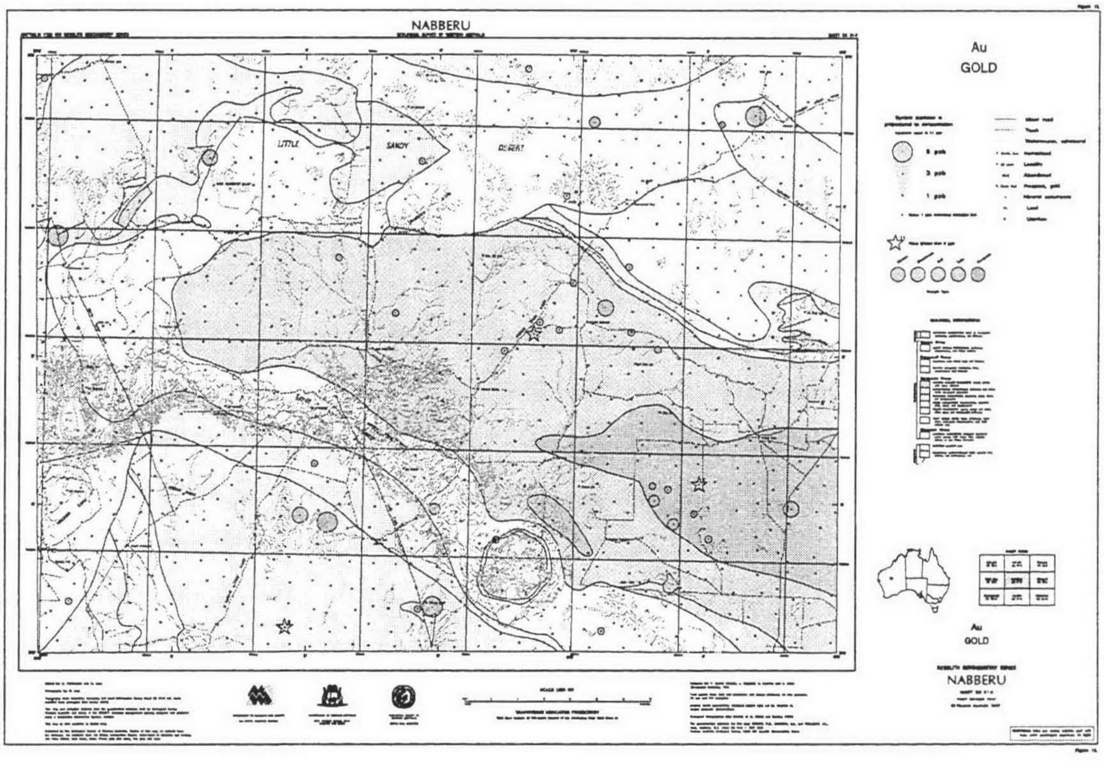

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Figure 1

Figure 1 demonstrates how at each sample point the shape, size and colour of a symbol is determined by one or more of the attribute values associated with the chemical analysis at that point.

Image Maps

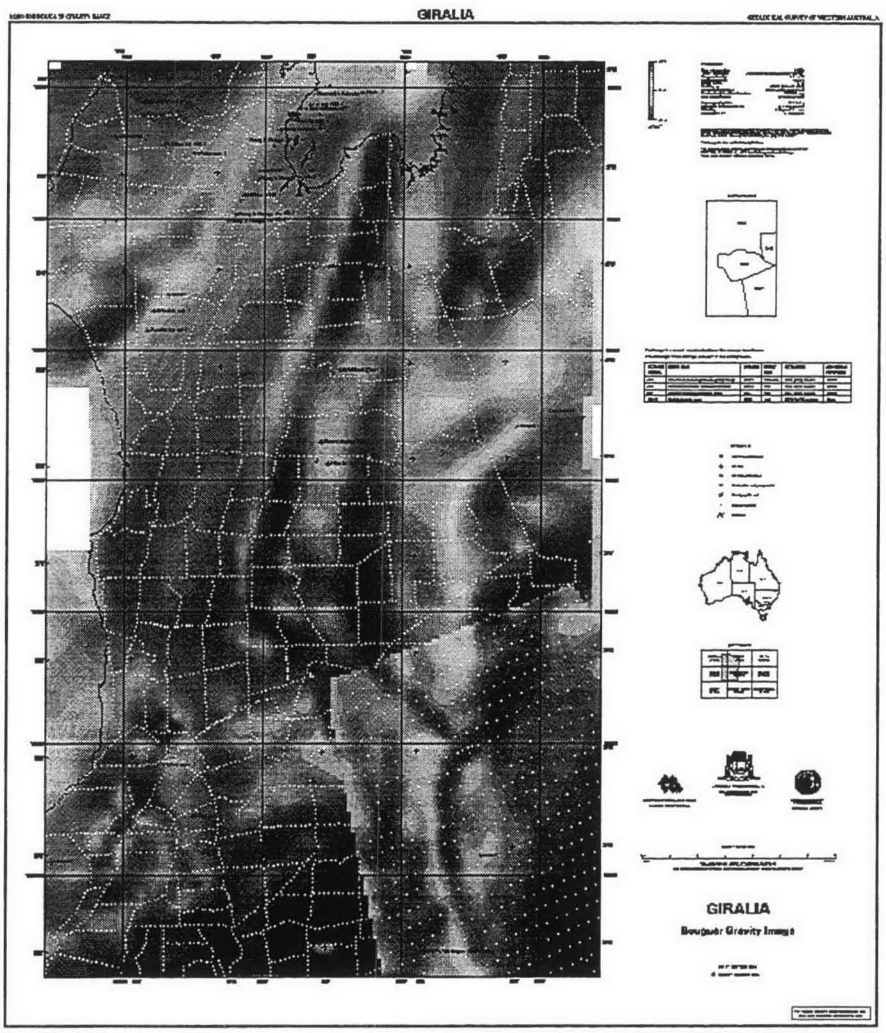

Figure 2

Using the dynamic linking facility of the ER Mapper image processing package, Arc/Info coverages are overlaid onto an ER Mapper image window by sending AML commands to Arc/Info. In the example shown in figure 2 the grid, well symbols, well names and map marginal information are generated through Arc/Info.

ARCVIEW

The need to provide desk-top application systems for data integration and visualisation has never been so great. As mentioned previously, one important long term strategy was to disseminate the GIS technologies to our clients within their own work domains. This will result in a better service to the client and a more efficient use of the data..

In early 1994 DME adopted ArcView as its strategic platform for desk-top GIS. ArcView will provide the foundation of the enterprise wide GIS model. This technology is crucial in integrating data from a variety of sources and providing users with access to the data and the tools.

ADVANTAGES

- Greater data sharing
- Greater access to GIS tools
- Ability to modify and improve work processes

DISADVANTAGES

- Higher costs in data acquisition as it must meet a greater range of needs
- Increased maintenance of data

Examples of this type of application within GSWA are:

Regional Forest Assessment Project

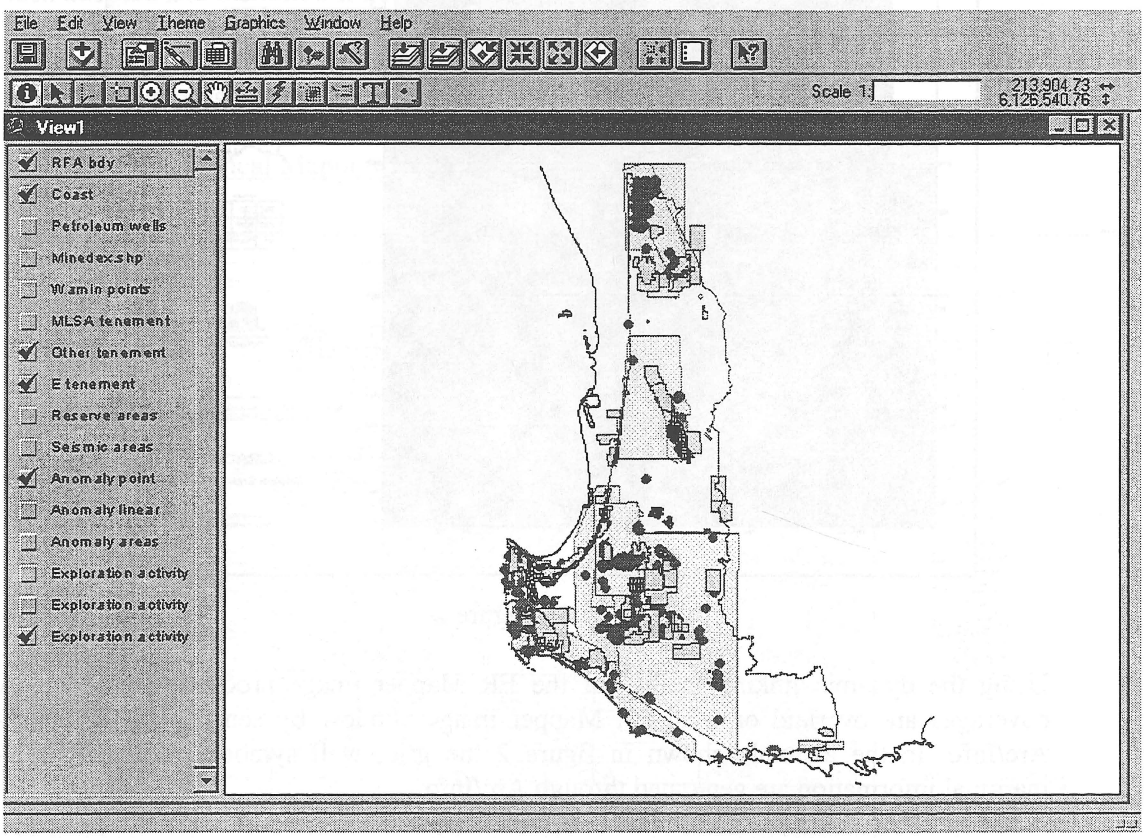

Figure 3

The Regional Forest Assessment Project is an example where the GIS core group acquired and validated data from various sources and scales, while the geoscientists were able to visualise and analyse the data at the desk-top level (see figure 3).

DATABASES

Recent mapping initiatives have generated a large increase in the volume of data acquired in digital form by the GSWA. These data resided on a number of databases on various platforms. The need for improved data integration and sharing of spatial and aspatial data to gain the maximum benefit to GSWA and, in turn, to Industry became important issues.

A review of the existing databases within GSWA was conducted and a strategy for the development and implementation of a GSWA corporate spatial information system was developed (Gozzard 1995).

The resulting logical data model and physical databases hold all corporate data and structured in such a way to allow easier integration with GSWA's mapping systems. The data models, are largely based on the Australian Geological Survey Office (AGSO) models, for example, WAROX (see figure 4) is based on the OZROX database.

Initially the databases and input forms were built using Microsoft Access. This provided the users to test the logical model. Following valuable feedback from the users, modifications to the tables were made. These databases are now being developed using Oracle.

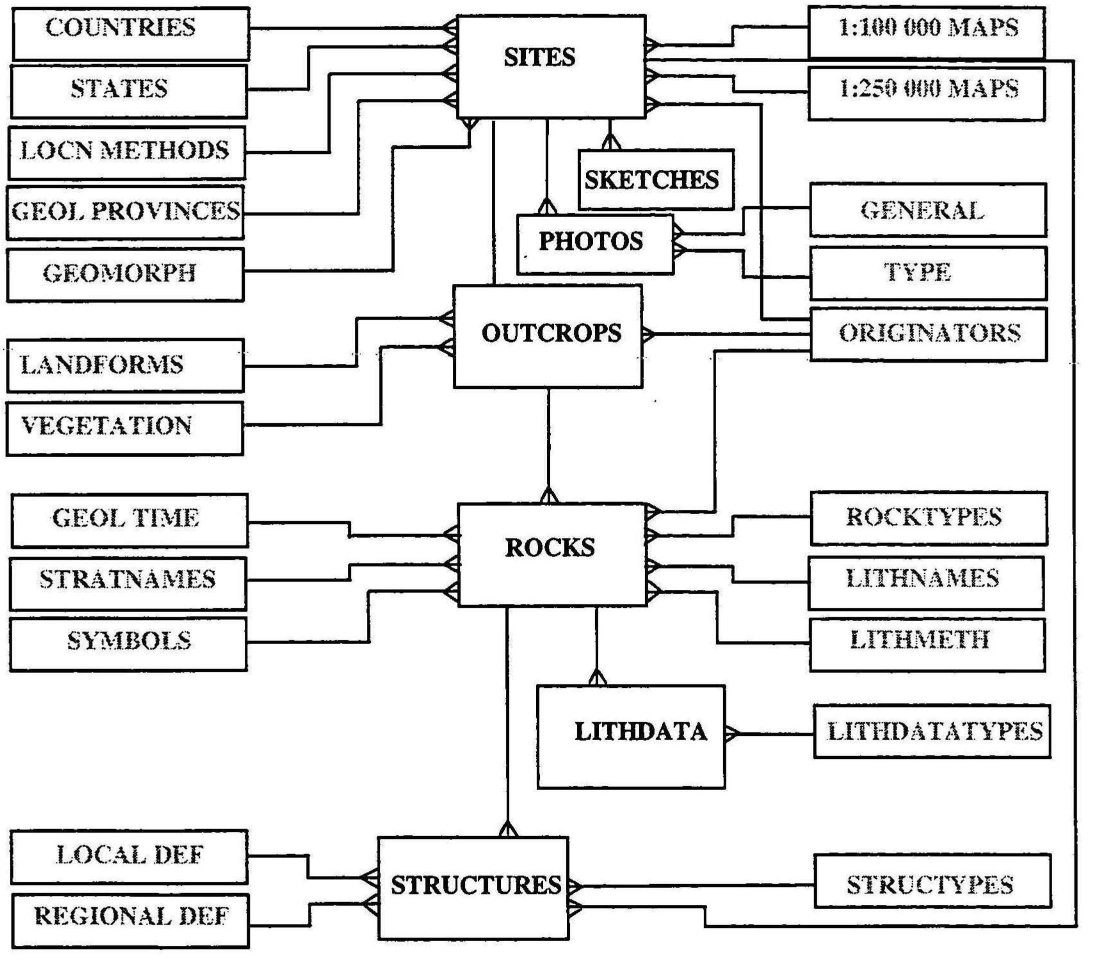

Figure 4 - WAROX Relationship Model

Strategies are being implemented to strengthen and expand the database support infrastructure. Data management practises such as data dictionaries, documentation, standards, backup and recovery are being improved to meet more demanding needs.

FUTURE DIRECTION

It is difficult to provide an accurate prediction of the future, however the following topics are presented to provide a context within which to see the direction GSWA is heading over the next two years.

Product

- GSWA continue to provide high quality offset printed maps but there will be an increased use in the number of high cartographic quality four colour maps produced on ink jet plotters.
- Industry and GSWA staff are provided electronic access to GSWA corporate databases and information products through Web browser interfaces.
- A significant number of new products are designed specifically as digital information products integrating data from a number of GSWA sources (see figure 5)
- Geoscientific information products integrate with other Departmental digital products (e.g. geoscience information on CD-ROM that can be integrated with Tengraph software and data)

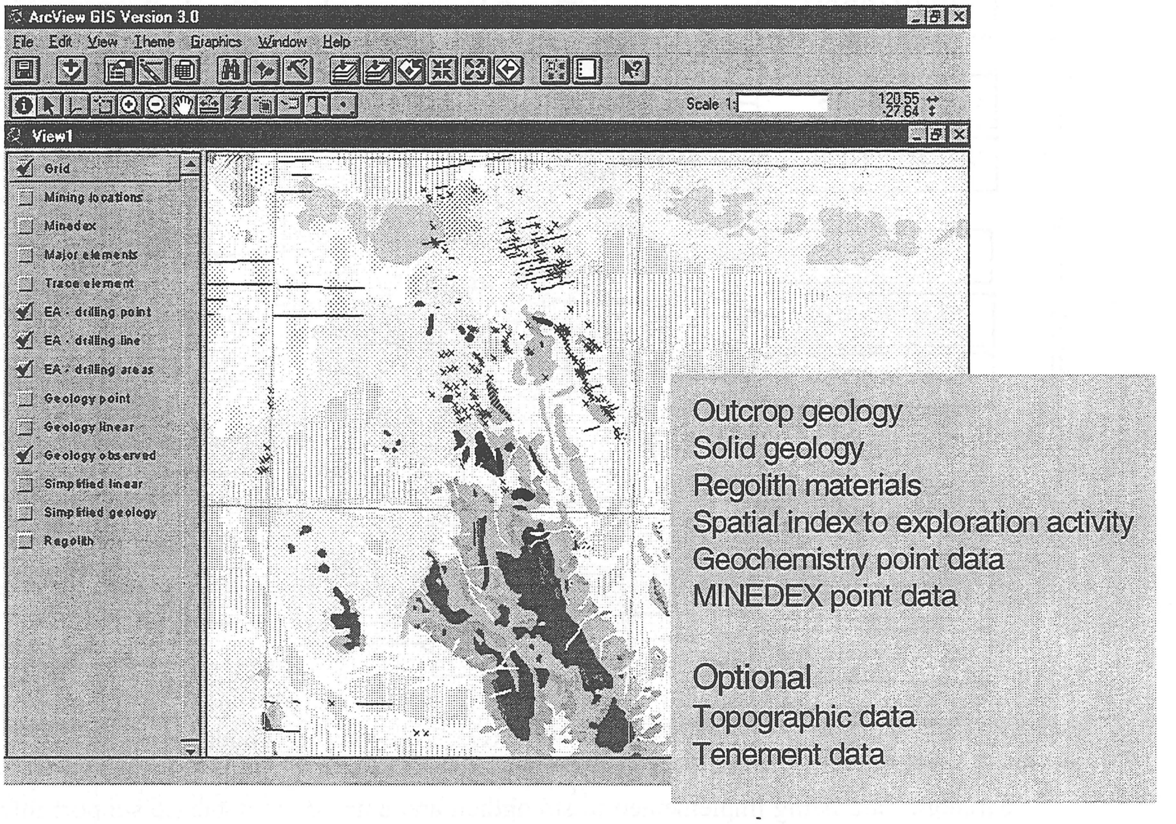

Figure 5 - Sir Samuel Geological Data Package

Databases

- GSWA's data are held in a corporate warehouse available to clients irrespective of data type, application software or access method

- Geoscientists, cartographers and other support staff will be using uniform graphical interfaces on their workstations to give on-line access to corporate databases

- Field data are captured electronically and down loaded directly into corporate databases using notebooks, GPS, images, cellular telephones and satellite telecommunications

Integration and Data Sharing

- Enterprise model approach where spatial and aspatial data are disseminated using ArcView via the distributed network system

- Corporate databases in GSWA are related, providing a wider range of geoscientific data to be available to users, particularly across the Department.

- GSWA geoscience staff are using desk-top mapping, image processing and GIS applications on PCs for spatial data analysis and editing.

- Further implementation of data archiving and transfer standards on provision of data and information products.

Infrastructure

- The installation of a high performance, wide band width local area networks (LAN) to support transfer of large files.

- Greater use of telecommunications (cellular telephones and satellites) to exchange data with geologists in the field.

- Geologists will use high power notebooks for running a number of mapping and scientific packages in the field.

- Increased education and training programs.

- Review of new products, such as, SDE, Map Objects and Data Publisher.

- Move away from UNIX to Windows NT based systems.

CONCLUSION

Within a few years, based on the international trends, the GSWA can expect the process of data acquisition, creation, presentation and dissemination of information to be radically transformed.

To become a benchmark within the geoscientific community, the GSWA must be able to identify and adopt the most advantageous emerging technologies with the capacity to efficiently and effectively enhance its core business.

The GSWA has just commenced to act and prepare itself but it must be said that the GSWA is well positioned to respond to these challenges in a measured and timely fashion.

Current and Future GIS based initiatives at the Queensland Department of Mines and Energy

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ABSTRACT

The Queensland Department of Mines and Energy has taken a **corporate** approach to the capture, management and access of its information, and the linking of its information systems. Client expectations have shifted to requirements for digital access to a greater range of existing data, with the catalyst being the widespread use of PC based GIS software.

Within the corporate Minerals and Energy Resources Location and Information Network (MERLIN), tenure data are stored in the Mining Tenures Data Base (MTDB) and geoscientific data in the Geoscience and Resource Data Base (GRDB). Data transactions with MERLIN are controlled through an ARC/INFO developed interface and Oracle forms and reports. In addition, PC based GIS software has been implemented on the Department's network. The Department's current GIS application focus is in the Graphical Services Unit and Information Technology Branch.

The Geological Survey Division is increasing its exposure to GIS to provide geoscientists with the tools to carry out data manipulation and analysis, and mineral prospectivity and resource potential modelling. The Resource Development Division will apply GIS tools to its land use decision making, and resource management and protection roles. To support this, a range of services and initiatives is being implemented to allow greater access to established graphic and attribute data sets, without compromising the integrity of the established corporate data regime and custodial relationships. The outcomes will enhance the GIS support roles currently undertaken in the Department.

The Department's expanded GIS initiatives will impact on the GEOMAP 2005 Program, continuing the development of geoscientifically focused information systems that capture and distribute the maximum benefits of this second generation geological mapping program.

These initiatives will be advantageous, enhancing the ability of the Geological Survey to identify areas of mineral resource prospectivity, and enabling better informed land use planning decisions. This enhanced prospectivity should translate into increased mineral exploration with the potential pay off of new mineral resource discoveries.

INTRODUCTION

State Government minerals and energy agencies:

- set and administer the industry's regulatory environment
- are custodians of exploration data from statutory reporting
- collect regional scale geological information to update geological knowledge and mineral prospectivity
- disseminate geoscientific information to industry

Information systems have clearly been of benefit in dealing with the ever accruing volume of minerals and energy related data, with the development of Geographic Information Systems (GIS) presenting resource managers and geoscientists with an exemplary opportunity for displaying and analysing the spatial data.

Maguire 1991 succinctly describes how GIS is relevant. *"The key features which differentiate GIS from other information systems are the general focus on spatial entities and relationships, together with specific attention to spatial, analytical and modelling operations".* GIS has a role in the quest for mineral resource discovery however that role is predicated on the ready availability of reliable, accurate and timely data, especially the geological data pool for which the Government is responsible.

The Queensland Department of Mines and Energy (DME) is focused on unlocking the full downstream benefits of the State's contained mineral wealth. It applies GIS based initiatives to these agency activities and is currently implementing additional initiatives to benefit its internal and industry based clients.

CURRENT GIS BASED ACTIVITIES

The MERLIN System

The DME has taken a **corporate** approach to the capture and management of its information and the linking of its information systems. *"MERLIN is a concept where all non-confidential departmental mineral and energy resource information is accessible through a computerised interface"* (Baisden, 1995). It is a data warehouse with 32 separate systems providing Departmental officers with a structured environment in which to capture, manipulate and display all tenure and geoscientific data. Within MERLIN's Oracle database, tenure data are stored in the Mining Tenures Data Base (MTDB) and geoscientific data in the Geoscience and Resource Data Base (GRDB). The GRDB contains data sub systems for:

- Boreholes
- Surface Geology
- Seismic Surveys (metadata level)
- Aerial Geophysical Surveys (metadata level)
- Exploration Report Management System (ERMS)

with structured data capture ongoing. The Geological Survey Division's Airdata Project manages aerial geophysical, gravity and remote sensing data sets in Intrepid and ER Mapper software, independent of MERLIN while petroleum seismic data sets are managed through the Pacific Resource Information Centre (PRINCE).

MERLIN is networked through head and regional offices with access levels defined by area of jurisdiction. Database transactions are automated through Oracle Forms and Browser interfaces, while map data is captured or generated through ARC/INFO. Graphical data transactions are controlled through an in-house programmed ARCPLOT interface while. ArcView and MapInfo are available on the departmental network but not configured to the MERLIN system. A framework of system component and data custodians has been established to maintain operational integrity.

MERLIN support is delivered through the Information Technology Branch and Information Management Unit with their activities orientated towards

- MERLIN system enhancements
- MTDB and GRDB structural issues and the MERLIN ARC/INFO interface
- GIS software licensing and upgrade, and new GIS system developments

- brokering new MERLIN data proposals
- responding to ad hoc MERLIN queries

Both groups have core practical GIS experience and both are heavily involved in the current MERLIN redevelopment.

A range of MERLIN digital graphical and attribute data products is available. Graphical products include:

- Queensland, regional and 100 000 scale geological maps as tagged and polygonised vectors in ARC/INFO export format
- raster images of the State's 1:250 000 geological maps
- exploration tenure data in dxf format (QSET)

and individual clients can negotiate to have digital map products formatted to their GIS needs. Digital geophysical data products are catered for independent of MERLIN, and are available as:

- Intrepid binary or flat ASCII file for airborne geophysical data
- ASCII file in AGSO format for regional gravity data

The Department is also associated with the Queensland Land Information Strategy (QLIS) initiative under the Natural Resource Theme. The associated data link aims to be independent of vendor hardware and software and has been successfully trialed between MERLIN tenures and the Queensland Department of Natural Resources Basic Land Information Network (BLIN).

THE USER ENVIRONMENT

In essence MERLIN operates as the Department's corporate geographic information system, providing ready access to all georeferenced data (Whitaker and Baisden, 1994). The interface is configured with a series of drop down menus, providing a diverse range of internal users with layer display and query focused access to:

- all tenure types
- sterile and constrained land and native title
- topographic and cadastral maps
- State, regional and compilation scale geological maps
- geological site data in the GRDB

The display mode operates on a global level for the designated layer at a range of fixed scales, with the flexibility to add combinations of other layers as background displays. Feature enquiries are conducted through point and click or bounding polygon operations with data output to screen views and hard coded attribute reports. There is currently no facility to

- join and query resultant layers
- conduct and display filtered queries
- display Oracle browser views

MERLIN's public interface is MTDB focused allowing users to manage all tenure related transactions from application to relinquishment and industry clients can track tenure developments through counter enquiries and hard copy map and reports. MERLIN's GRDB functionality is focused in-house allowing users to enter data in consultation with sub system custodians.

Historical tenure relationships can be established for areas to assist with exploration data compilation with the enquiry generating list's of related company reports. Report summaries may then be accessed through MINLIB, the Department's on line library information system.

Graphical Services Unit

Graphical Services is responsible for digital mapping services, MERLIN geological layer update and maintenance, and all digital and hard copy geological map production for the Department's internal and external clients. The Unit has an invaluable range of core ARC/INFO skills from an extended association with the implementation of GIS.

The Graphics Unit has developed spatial data capture standards and innovative, automated programs to streamline the digital geological map development cycle right up to four colour map production. In addition, metadata formats are currently being developed for all digital maps. Map compilation is an arc driven process creating a master arc cover that is remanipulated to create polygon or other specific arc feature covers. Point data capture is also partially automated with special attention to generating structural symbology.

One of the Unit's key support roles is in the Geological Survey Division's geological mapping projects. Graphics officers work with project geoscientists, building digital geological compilation maps up to the 1:100 000 presentation scale as well as providing extensive technical support through to final geological map production. They are also setting up map based ArcView and MapInfo environments to allow project geoscientists to work digitally with all relevant map themes and to keep track of the geological map compilation process.

The Unit's current major project is developing annotation layers at four display scales for GEODATA 250 maps to create significantly enhanced digital topographic base maps for MERLIN display.

Geological Survey Division

The Queensland Department of Mines and Energy has implemented broad scale geological data capture initiatives through the Geophysical Data Initiative (GDI) and GEOMAP 2005 program. The GDI provides high quality aeromagnetic and radiometric data to underpin GEOMAP 2005 mapping and exploration client needs. GEOMAP 2005's primary objective is to update geological mapping of potentially mineralised areas of Queensland and the work programs will generate significant volumes of new data. Consequently, the Survey is both the largest contributor of raw data to the GRDB and largest potential user of this digital data, along with geophysical and remote sensing data sets.

MERLIN's operational mode places constraints on geoscientists ability to fully analyse the digital data prompting the Survey's move into ArcView and MapInfo. This recent move has enabled project teams with the analytical tools to carry out data manipulation and analysis, and support mineral prospectivity and resource potential modelling. In addition, the Airdata Project directly support's GEOMAP 2005 mapping projects with digital geophysical and remote sensing images, and digital based interpretations, via ER Mapper and its Arc/Info dynamic link.

Advanced mapping projects will be encouraged to focus outputs around GIS data sets as well as geological maps, while new projects will endeavour to set up GIS based data environments from the outset. This approach will endeavour to meet geoscience client expectations for access to a greater range of existing data in digital GIS formats.

Resource Management

The Department's Resource Development Division oversees resource and land use management for the State's minerals and energy sector. The Division's Coal Resources and Petroleum Branches are currently formulating policy and developing strategies to facilitate the development of the State's coal seam gas reserves, as there are some cases where economic coal resources are coincident. To assist the process coincident tenures and coal resource data attribute relationships were established at a defined date through querying MERLIN's MTDB, and by capturing a graphical snapshot of the State's energy tenures as a series of ArcView shape files.

The data attribute files were massaged and updated with additional data attributes in Microsoft Access to produce coincident tenure reports. ArcView's query capabilities were used on the shape files to establish graphic based relationships and to

- define coincident coal tenure and related attributes by tenure type
- define currently excised coal tenure
- define coincident tenured or untenured coal resources by category
- define each petroleum company's tenure and the coincident coal tenures
- output maps and data for reports, for each petroleum company's tenure

The project demonstrated how corporate data could be used externally to develop quick solutions using analytical GIS tools not available in the MERLIN environment. With further development, the project may serve as a pilot for future Departmental geoscientific and other land use related projects.

NEW GIS BASED INITIATIVES

Evolving client needs have dictated that MERLIN system architecture and functionality be more dynamic and the Department is now enhancing the system reach with a range of new measures:

- MERLIN Redevlopment Project
- project GIS environment
- additional data layers to enhance internal operations
- new digital product initiatives

MERLIN Redevlopment Project

The most significant changes are occurring in the MERLIN interfaces. The current Oracle Forms and Reports components for MTDB and GRDB are being synchronised and upgraded to Oracle's Developer 2000 GUI mode. The changes provide user data interfaces with Windows based functionality making data transactions significantly easier. The Oracle Browser interface is also being enhanced to improve its functionality. The Oracle based changes coupled with a corporate data structure and the current GIS architecture, place the Department in a strategic position to implement SDE in a fully secure environment. The use of MapObjects as an obvious external vehicle for the ARC/INFO and ArcView environment is also under consideration especially in view of the move to establish Departmental internet and intranet infrastructure. At the same time, graphical layer data entry and maintenance interfaces for layers other than geology are being configured to ARCTOOLS mode.

The ARCTOOLS interfaces have region, arc or point tools depending on the layer feature type, accompanied by a range of attribute data transfer modes including GPS file format uploads.

The mode offers fully flexible data edit sessions for tenure processing maximising control over lease meets and bounds, and access transactions. Final lease layouts will be built as regions instead of the current arc mode, introducing greater GIS functionality to these features. Associated tenure layers such as Charting will be easier to update as field officers can enter or update feature and feature attribute data on returning from field duties. The improved graphics functionality will bring substantial productivity gains for users particularly field and environmental officers, and mines inspectors, and dovetails neatly with new graphical data extraction programs.

AML programs have been developed by IT Branch to extract customised views of MERLIN graphics and their hard coded attributes, as ArcView shape files. The output will be written to a Project GIS environment where users can incorporate that data into their ArcView based work projects. The benefits are direct digital access to corporate data without compromising system integrity and will deliver across the board flexibility to regional offices, resource management, geoscientific mapping and environmental compliance. In the future, consideration may be given to extending the extract facility to the Department's external clients as it has the potential to supply digital data in a ready to use format.

While GIS implementation opportunities will be most apparent in the Geological Survey Division the increased availability of digital maps and data from MERLIN, and other external agencies, makes land use and resource assessment in an ArcView project environment a logical progression. This approach will dovetail with the widespread use of GIS in other Government agencies.

Project GIS Environment

A separate workspace outside MERLIN is being established for internal users to take full advantage of corporate data and ArcView. The Project GIS environment is being allocated 8 Gb of disk space as three additional drives on the Department's network and is not meant to duplicate MERLIN. Users will work unencumbered, with graphics and hard coded attribute data extracted from MERLIN, and be able to add other relevant raster and vector data sets and data tables. To minimise data duplication, core graphic datasets may be established in a read only directory with the potential to have direct ArcView read access to MERLIN graphics and Oracle to be tested in the future. New data sets may be created but will have to pass through the custodial protocols before being loaded into MERLIN.

This innovation coupled with data extract functions being established in the MERLIN interface, and Oracle Data Browser will deliver internal users significant analytical and visualisation benefits. Geological Survey mapping projects have the most to gain while groups such as Land Use Planning will discover that working projects such as regional forest assessment and conflicting land use assessment can now be managed in an ArcView project environment.

Additional Data Layers and New Product Initiatives

New map layers showing the distribution of Queensland's coal resources, and the State's mine workings, are under development for MERLIN graphics. The mine workings layer will offer considerable benefits to Environmental Compliance Division officers while the coal resources layer will play an important role in the new coal seam gas regime. The Department is also looking to maximise its new geological data initiatives and improve exploration and resource assessment.

Digital geoscience data products are being reviewed, paying attention to the established corporate system and the needs of the Geological Survey's clients. Two possible ways of packaging and distributing GIS ready geological data sets are being considered:

- licence agreements with GIS bureau
- in house developed CD packages formatted for GIS platforms

Client requirements and the availability of Departmental resources will influence the final decision and regardless of the outcome, the Department has a substantial range of digital map themes amenable to distribution in value added GIS formats.

The planned release in late 1997 of the digital seamless geological map for part of the GEOMAP 2005 Southeast Queensland Project area, will act as a pilot for future GIS formatted product releases. This map is being created by the project's graphics officer in consultation with geoscientists, through seamless integration of new and current 100 000 geological mapping with the process working through a range of tasks, addressing unit boundary and nomenclature continuity issues along the way. The map is also being focused towards an ability to be reconfigured into its 100 000 map sheets and differing geological data themes, and to have a range of geological point data files included to provide further analytical capability.

CONCLUSION

At inception MERLIN's key features were

- corporate, client and regional focus
- market orientation
- flexibility
- MIS to assist compliance with Government policy
- enhance access to strategic databases between State agencies

(After Whitaker et al 1991)

The Department of Mines and Energy will ensure that these features remain relevant by investing is up to date enhancements to the system's architecture. The primary emphasis is on core business and client needs, and the benefits will translate into more flexible work practices, better availability of digital data products and increased client satisfaction. On GIS implementation,. the Department's corporate data and system architecture has left it well positioned to take advantage of new and emerging GIS strategies. The greatest impact will be visible in the Geological Survey Division's core business and will be reflected in the intellectual capital invested in geologically based GIS initiatives.

These initiatives will be advantageous, progressing second generation geological mapping towards assessing mineral resource prospectivity. The ability to significantly enhance Queensland's minerals and energy prospectivity through timely tenures administration and appropriate, digital, geological data transactions, will encourage greater exploration, increasing the potential for new mineral resource discoveries.

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GIS initiatives in AGSO

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INTRODUCTION

AGSO is Australia's national geological research and survey agency and is part of the Commonwealth Department of Primary Industries and Energy (DPIE). Employing ~200 geoscientists, AGSO is one of the largest geoscientific organisations in Australia. Our business is to provide geoscientific maps, research and information to support sustainable development of Australia's mineral and petroleum industries, management of its land and groundwater resources, management of the Australian Ocean Territory, and the identification and mitigation of geological hazards. We operate within the framework of DPIE's mission and as a national survey complementing the roles of State and other Commonwealth agencies.

AGSO's programs are determined by Government within the framework of the DPIE's Mission and Key Result Areas. They are the:

- Australian Ocean Territory Mapping Program;
- National Geoscience Mapping Accord;
- Land and Water Program;
- Geohazards Program.

Priorities within programs are determined by clients needs, consistent with AGSO's national responsibilities, and in consultation with partners and other stakeholders. AGSO's science is based on the provision of spatially referenced geoscience information and builds information systems to facilitate decision making using geoscientific principles and uses information technology to exploit the capital of available geoscience data.

As a result of a recent restructure, AGSO is now divided into 5 main divisions: Minerals, Petroleum and Marine, Geohazards, Land and Water Resources (GLAW), Research and Development, and Science and Survey Support (Figure 1).

As digital data has been an integral part of these divisions and their predecessors for at least the last 30 years, AGSO has built up vast amounts of digital data in the form of data bases, geophysical data, digital maps etc. The trend has been to convert this data into information within a Geographic Information System (GIS). GIS now underpins all aspects of a project from the initial data capture phase, through the analysis and integration phase to outputting products to the clients in the form of fully integrated GIS packages. Throughout AGSO, a variety of tools are used: GIS systems include Arc/Info, ARCVIEW, MapInfo, Petroseis, Schlumberger GeoQuest, INTEGRAPH, Image analysis ERMAPPER, ERDAS IMAGE and IIS. Most point information is stored within the AGSO corporate ORACLE data base system.

In this paper we hope to outline how data are collected and managed within AGSO as a whole and outline some of the various GIS initiatives within each of the major divisions of AGSO. We will also discuss some future directions.

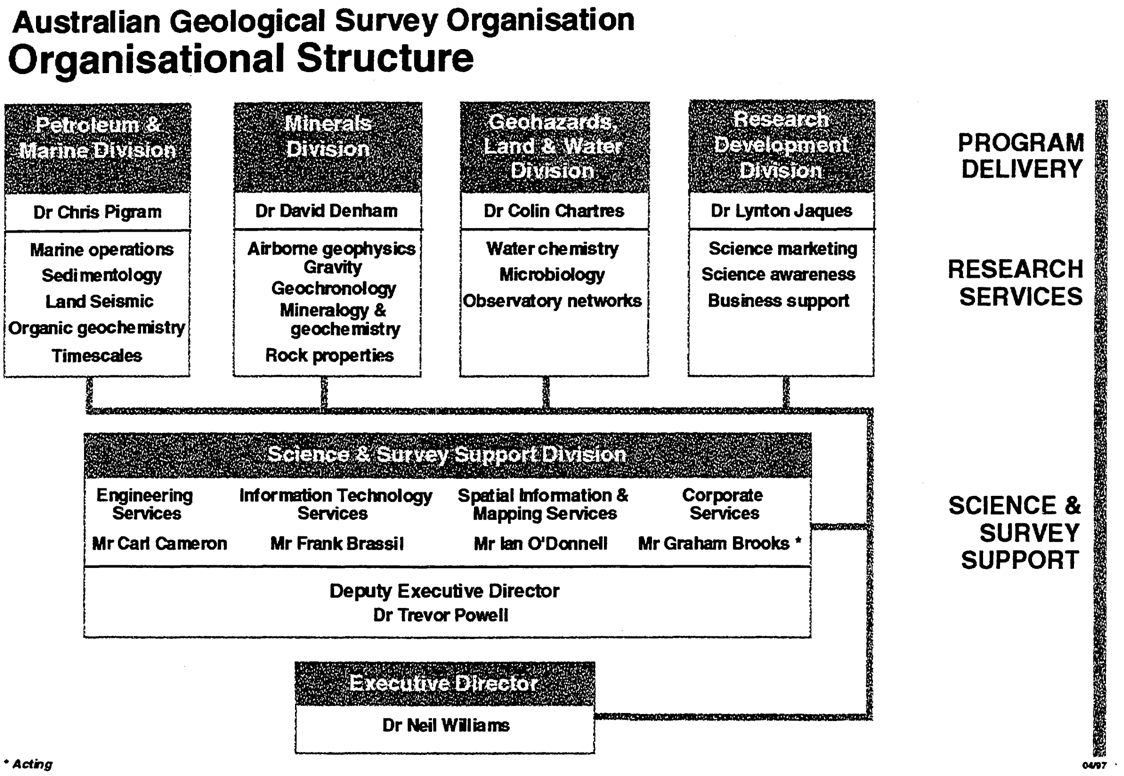

Figure 1: The Current AGSO structure

DATA MANAGEMENT WITHIN AGSO AS AN ENTITY

Because of the vast amounts of digital information stored by AGSO, data management is becoming critical issue in the 1990's. Historically, with the advent of PC's in the late 1970's AGSO like many organisations, drifted away from major corporate data systems housed on mainframe computers to almost personal data bases held on individual PC's. Many scientists preferred this system as it gave them perceived flexibility and more importantly enabled them to work independently of the mainframe 'experts'. However, the PC environment offered little security of data and with early systems backups were almost non-existent. In the PC environment, the users were very vulnerable to changes in the availability of hardware and software and if production of one or both ceased, then the data stored within a particular system could become unreadable. PC based systems also severely restricted the ability to combine large data sets from individual scientists. Further, the PC systems tended to be tailored to the needs of the individual scientists and corporate standards were difficult to impose.

In order to address these fundamental issues AGSO is rapidly moving to an internal data management system which combines the flexibility of the PC systems with the greater rigour that a mainframe system can offer (Figure 2). Right from the initiation phase individual projects are encouraged to store their data in National Data sets which are developed, maintained and archived corporately. For manipulation and interpretation the data are then ported from the corporate systems into the Project environment to be utilised in varying systems depending on the needs of the individual project. Storing all primary data within the corporate system from the commencement of a project has two main advantages: firstly, the overheads on archiving data at the end of the project are non-existent and secondly, the corporate archive is in reality an active data base. An example of this is the AGSO ROCKCHEM data base which contains all whole-rock geochemical data collected by AGSO since 1968 (Hazell et al., 1995). Although this data base has been through many iterations (e.g., Wyborn and Ryburn, 1989, Sheraton et al., 1991, Hazell et al., 1995) at each major change to the data base structure and/or hardware, all data are translated into the new structure and the data are continually available to all external and internal clients for various project based work. Further security is offered in that as corporate databases are generally tied to large hardware and software systems which tend to be less likely to be superseded than smaller PC-based systems.

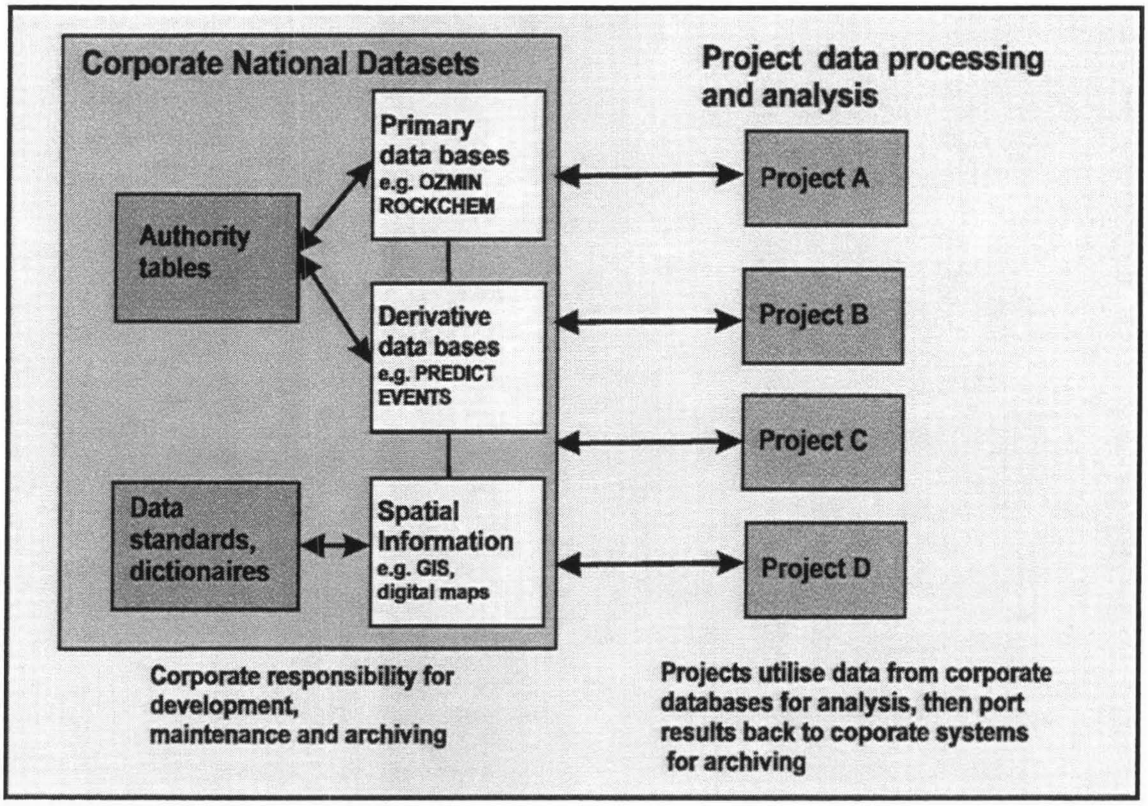

Figure 2. The Internal Data Management Model within AGSO.

Within the corporate data systems every effort is being made to ensure that data captured by the individual project at any locality in Australia can be incorporated and analysed on varying scales from detailed 1:10 000 scale projects to national scale data syntheses. Corporate data bases are developed with the national overview in mind, and are not tailored for specific persons or individual projects. The development of such large data systems requires comprehensive quality control/quality assurance systems and strict adherence to corporate data structures and data standards. These standards have evolved over many years as their need for managing the vast amounts and varying types of geoscientific data that are held by AGSO becomes increasingly appreciated. Many of AGSO's data standards and authority tables are now available, some on the WWW for general use within the geological community.

When a project is ready to release data to the clients, the data pass through a series of corporate quality control and quality assurance systems and then are translated into various packages depending on client needs (Figure 3). The same data is also passed back into the corporate National Digital data sets for archiving and maintaining. Once the data are housed within the corporate data systems every effort is made to keep the data viable and actively available for other projects which often use this data for purposes way beyond what the original collector of the information ever considered. These raw (or primary) data sets are also available to the general public (eg., the whole-rock geochemical database, ROCKCHEM, and the organic geochemistry database ORGCHEM). Several specialised industry-funded projects are directly analysing data within the AGSO corporate systems (eg. Proterozoic Granites Project).

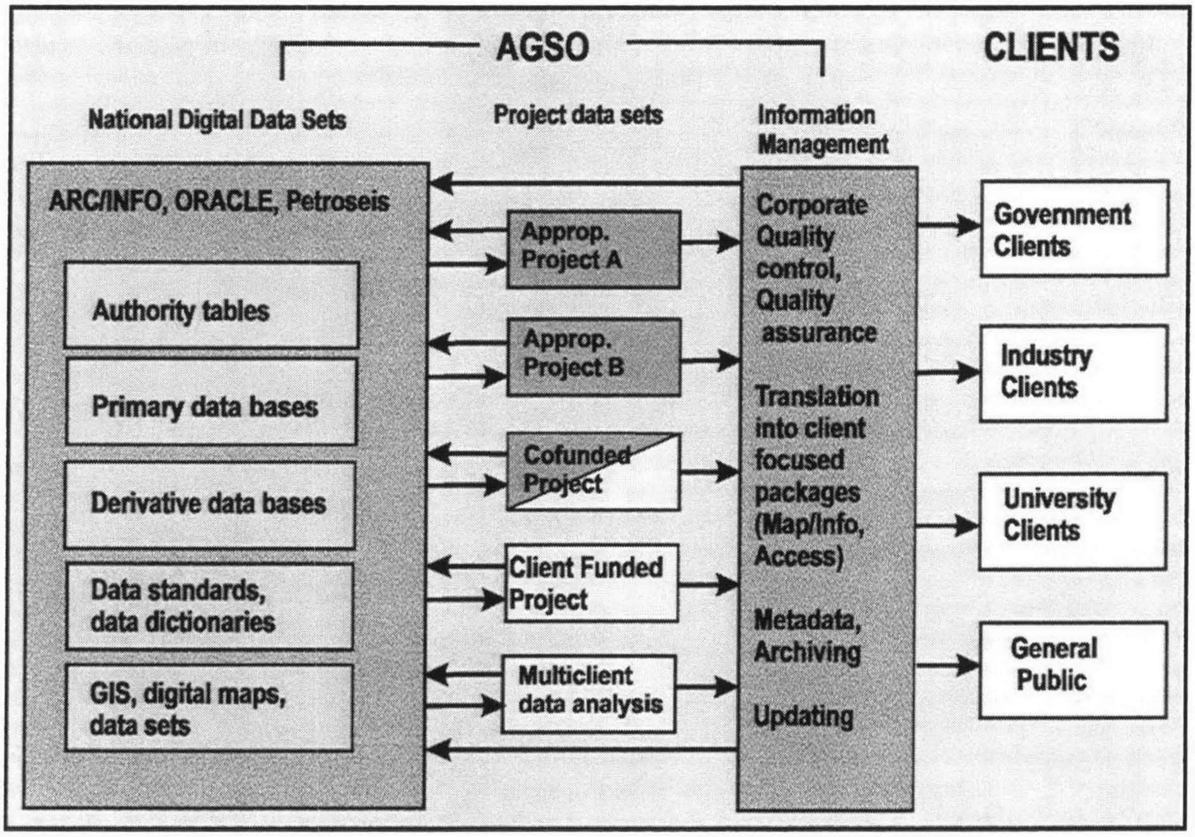

Figure 3. The External Client Interface Model for AGSO data.

DATA MANAGEMENT WITHIN THE INDIVIDUAL DIVISIONS OF AGSO

As each division has its own historic data collection, differing clients and data types, the initiatives in each will be discussed individually.

Geohazards, Land and Water Resources Division (GLAW)

This division contains the groundwater group, land degradation projects, the Cities project, and the geomagnetic and seismic observatories. GLAW probably has the most diverse group of clients of any division in AGSO. In the hydrological area, increasingly GLAW is providing decision support for client groups as diverse as the Central Lands Council, the Murray Darling Basin Commission, CSIRO, Liverpool Plains Catchment Management Committee, State and Territory Agencies (Geological Surveys, water resources commissions, and conservation and Land Management Groups), remote aboriginal communities, and rural and urban communities. The Geohazards Group is providing decision support to emergency planners at State and local level, urban planners, urban regulatory bodies, the insurance industry, and Rabaul Provincial Disaster Committees.

GIS technology is fundamental to the success of projects within GLAW, with many having a GIS database as an integral part of project output. In GLAW the main GIS components used are data analysis, image processing and visualisation. Techniques in data analysis include using point sample data to interrogate remote sensing data sets, whilst in multilayer analyses, various different remotely sensed data sets (NOAA, LANDSAT, gamma-ray spectrometrics, radar etc) are routinely used in combination with digital elevation models, geology and soils to derived land management information.

Developments in image processing have involved deriving algorithms for information extraction such as spectral unmixing of vegetation and mineral components (both from solar reflectance remote sensing data). Spectral analysis of remotely sensed data from offshore environments is being used for substrate mapping in shallow marine environments. Modelling has also been utilised to generate classes representing soil properties such as acid sulphate soil potential and activity from radiometric, elevation and multispectral data.

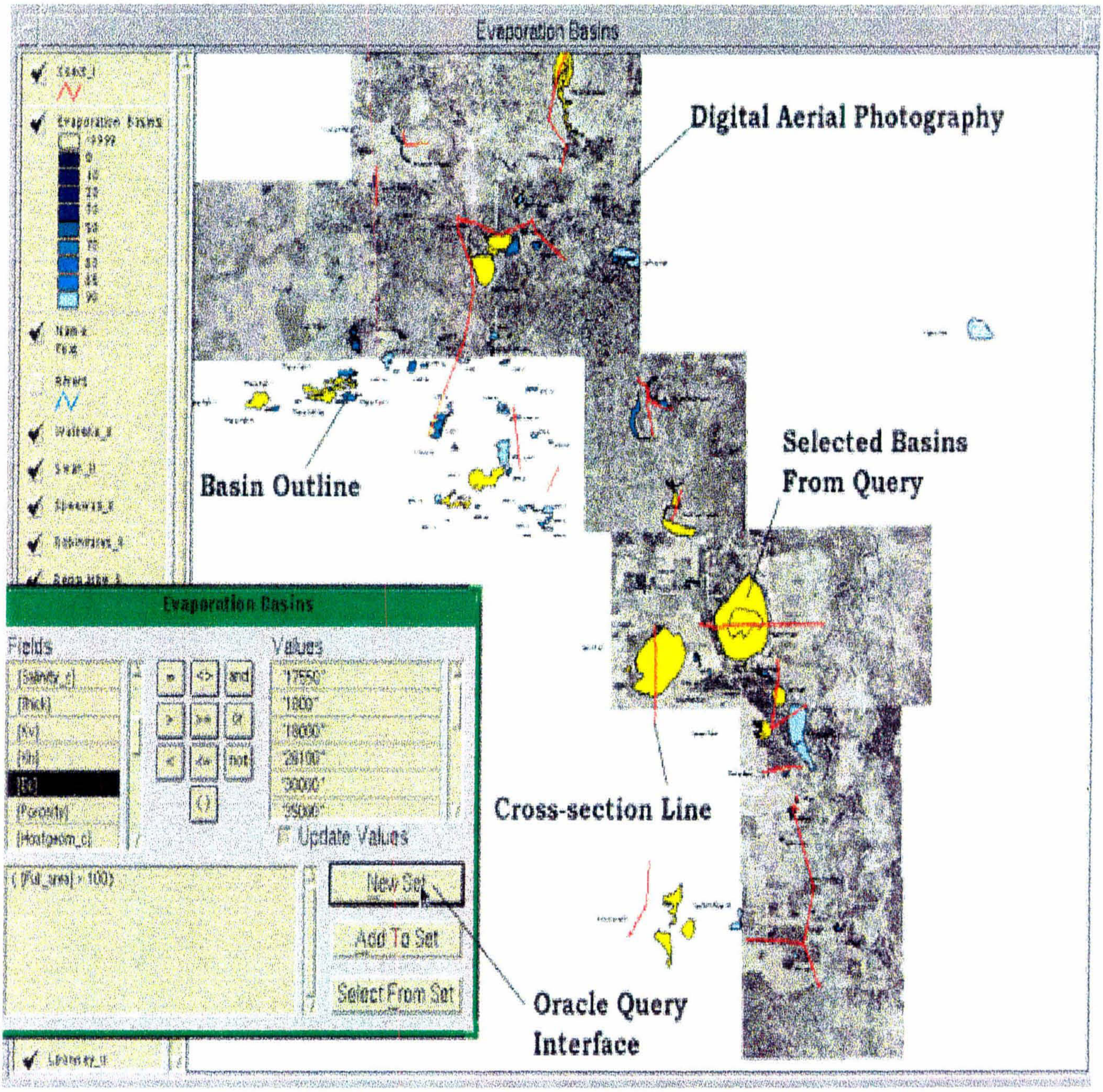

Figure 4. ARCVIEW Interface to the Murray Basin Disposal by Evaporation Resource (MurDER)

Current GIS projects in GLAW include using GIS for compilation and production of Quaternary and Bedrock geology and in the compilation of ground water maps. These include themes such as groundwater salinity, aquifer yield, depth to water table and potentiometry. Through the application of GIS to water analysis it is now possible to interrogate borehole data through links to relational data bases thus allowing spatial statistical analysis of water quality. Groundwater modelling has allowed the evaluation of management scenarios whilst a groundwater monitoring network allows data to be statistically analysed and viewed within a GIS environment. From this approach a Regional Natural Resource Management Issues Analysis has been developed to assess the availability of safe drinking water, and the impact of salinity, irrigation development and land clearing. In addition two information packages that have been developed for client groups: MurDER (Murray Basin Disposal by Evaporation Resource (a basin salt disposal information package) (Figure 4) whilst on the World Wide Web, an interactive package on the Murray Basin hydrogeology is available (Figure 5).

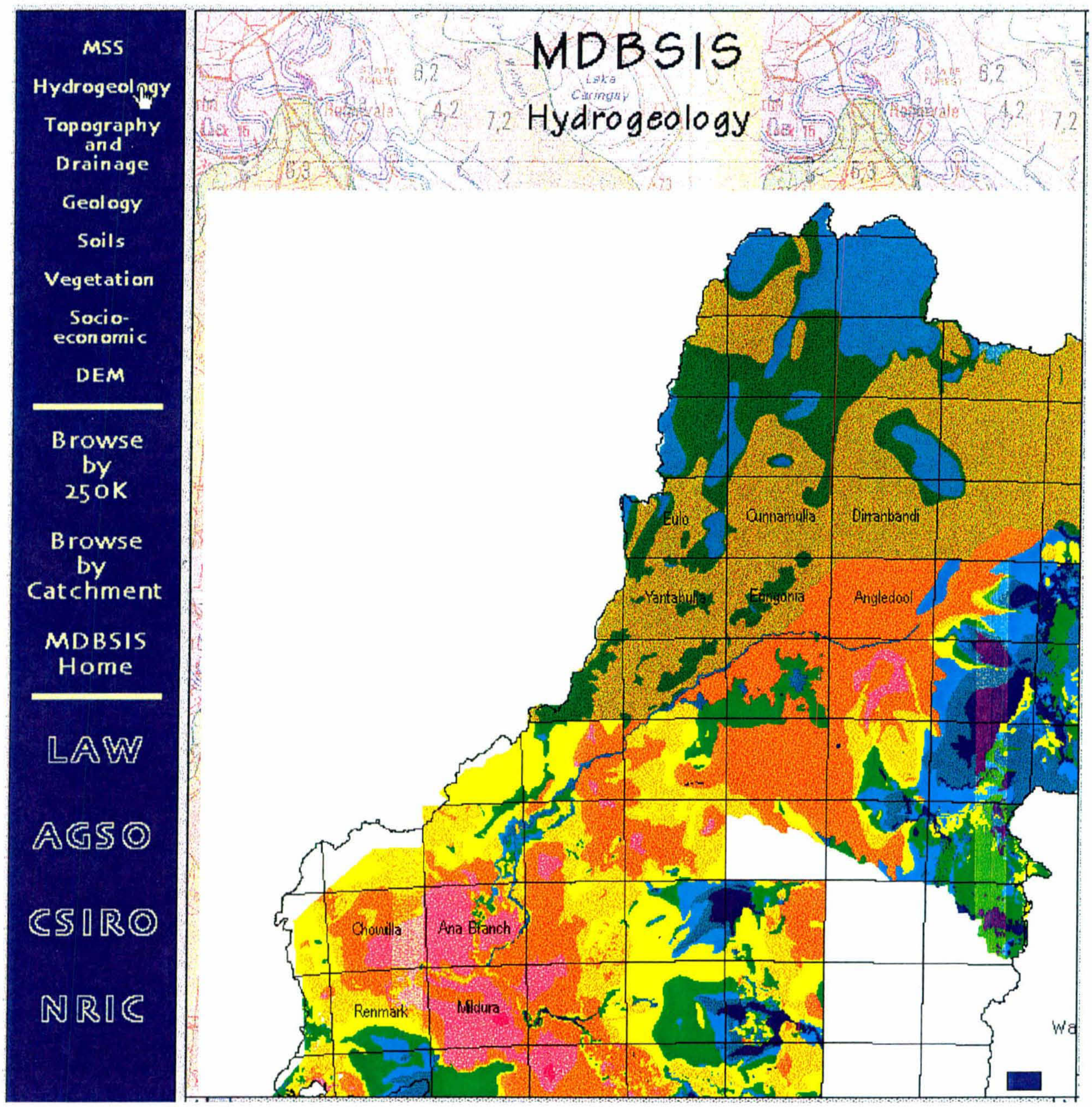

Figure 5. Murray-Darling Basin Soil Information Strategy WWW Interface.

A major project utilising GIS technology has been the **Murray Darling Basin (MDB) Project**. The Soils Information Strategy is a component of this project. Thirty years of soil related MDB data, was integrated with remotely sensed data and other existing data using GIS for effective soil mapping. Methods have been developed to map soil related units in areas where soil mapping is sparse or absent to provide spatially referenced data for key soil properties: it has also been possible to provide a synoptic overview of the MDB soil resources.

In the **Geohazards** group there have been several new initiatives including the development of a Volcanics-hazard Mapping and Information system, established to provide modelling and visualisation of expected distribution of affected areas for different types and levels of volcanic hazards and to produce hazards maps. In the Cities project, GIS is used to analyse hazards, particularly earthquakes and landslides affecting urban areas. The Cities project is developing decision support tools to assess and reduce the vulnerability of Australian Urban Communities to geological hazards. Specific projects to date include using a risk management approach, vulnerability assessment methods have been developed under the Tropical Cyclone Coastal Impact Program, coordinated by the Bureau of Meteorology. Urban earthquake zonation was undertaken for Launceston, Newcastle, Adelaide City and a pilot area in Sydney. Studies on vulnerability to earthquakes, landslides, storm surge and flooding were undertaken in Cairns, Gladstone and Mackay in 1996/97, whilst studies for Brisbane, the Gold Coast and the Sunshine coast will be done in 1997/98. Parallel studies are also planned for Sydney, Adelaide, Launceston and Newcastle.

Petroleum and Marine Division (PMD):

This division has responsibility for all marine geoscience research including gathering and analysing data in support of Australia's marine jurisdictional claims (Law of the Sea), provision of information in support of the Acreage release program for petroleum exploration and investigation of urban impacts on near shore and estuarine environments. Key client groups include the Commonwealth Government (Law of the Sea), the offshore petroleum exploration industries, and State and Territory authorities. It could be said that the Petroleum & Marine Division was a relatively late comer to GIS technology. However, in recent years this situation has changed dramatically, with the technology playing a crucial part in most projects and will be essential to the preparation and presentation of project results.

Commercially recognised GIS packages such as Arc/Info and MapInfo provide essentially 2-D visualisations of the many forms of geoscience data sets and most GIS packages are geared to portraying data in plan view. Very few commercial GIS packages are equipped to effectively handle seismic data and well log data and for this reason, PMD has had to embrace several different GIS systems to undertake specific tasks in project work and the main packages used are Petroseis or Schlumberger GeoQuest. Two projects which have involved extensive use of GIS include Law of the Sea and the Mount Isa Seismic Transect.

The **Law of the Sea (LoS) Project** under the new Australia's Offshore Territory Mapping Program (AOTMP) is aimed at building a comprehensive data base on physiography and sediment thickness around Australia. This program has been initiated to substantiate and maximise Australia's claim for ocean territories under the United Nations Convention on the Law of the Sea (UNCLOS). The areas claimable under UNCLOS, referred to as Legal Continental Shelf (LCS), include the Exclusive Economic Zone (EEZ) and some areas beyond the EEZ defined by a series of rules stated in the Convention (Figure 6). Most of the objectives of this program can be met by traditional GIS methods and software, such as ArcInfo and ArcView. A database of all Australian maritime boundaries including the type of boundary and its current status (signed, agreed, negotiated) has been build in ArcInfo. ArcView is being used to perform complex queries about Australian ocean territories.

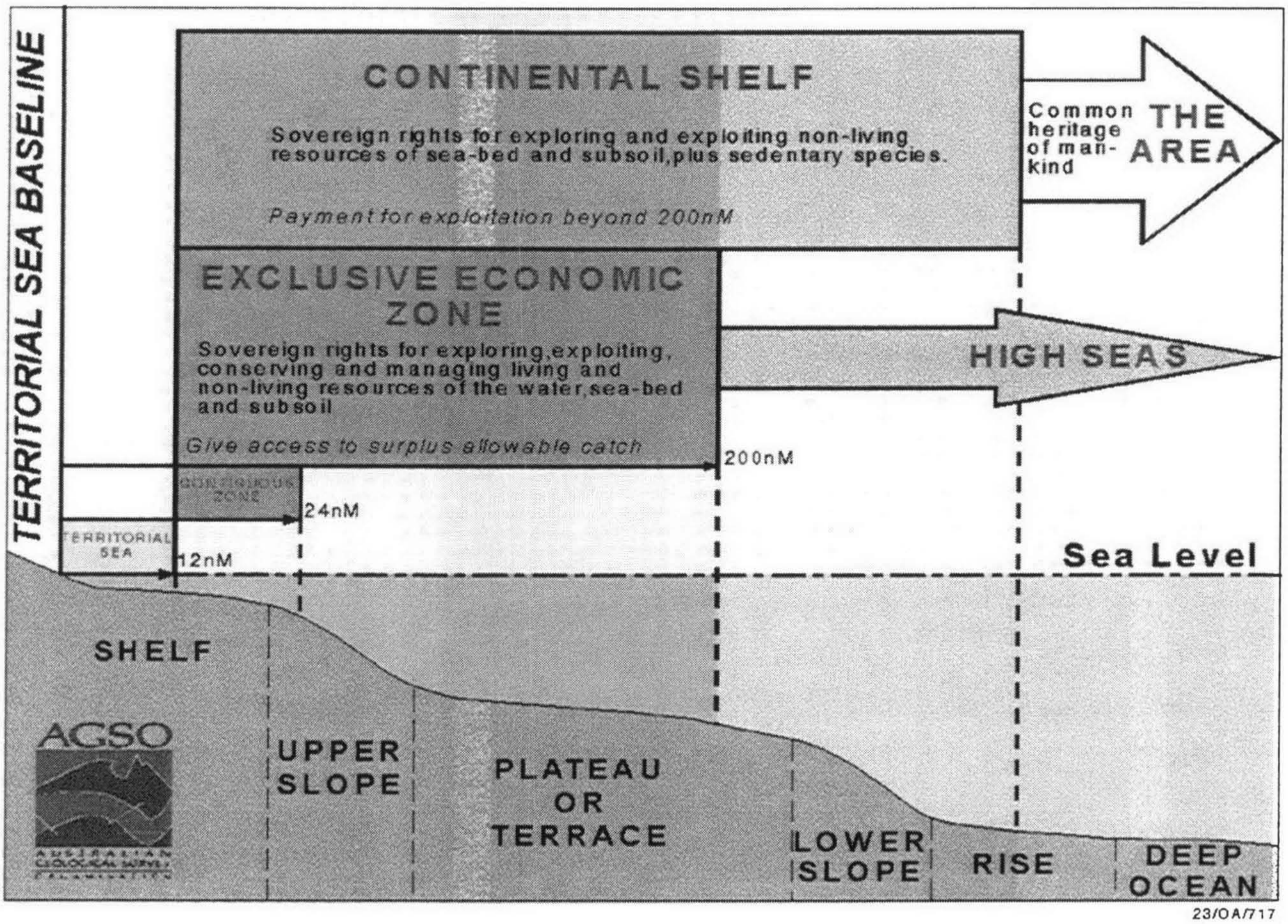

Figure 6. The various components of the continental margin as defined by the United Nations Convention on the Law of the Sea, and used in the GIS analysis to define the areas for Australia's claim for Ocean Territories.

To underpin Australia's claim for Legal Continental Shelf in areas extending beyond the EEZ, the Law of the Sea project is building a foot-of-slope (FoS) database. This database consists of FoS points picked from existing bathymetric and seismic profiles as well as those from new data acquired on LOS surveys. GIS analysis plays a crucial role in the survey planning. The first stage of the process includes analysis of the bathymetric and seismic data to identify foot-of-slope locations and thereby populate the FoS database (Figure 7). Next, the outer limit of claimable areas - the cut-off boundary - is computed. It consists of portions of 2500 m +100 nautical miles (nM) and 350 nM from the baseline, depending which one is further offshore (Figure 8). Then the identified FoS picks are used to compute the Hedberg Line (60 nM from the FoS). The areas between the Hedberg Line and the cut-off boundary indicate where more work could be required to extend the Australian claim (Figure 8). Some of the large gaps between the Hedberg Line and the cut-off boundary are caused by gaps between existing FoS points. These areas are being addressed using the safe minimum approach adopted by AGSO - FoS points should be no more than 30 nM apart. New data acquisition lines are planned to close off these gaps. The next step is to assess the position of the FoS between existing FoS picks and to compute a predicted Hedberg Line, using the satellite gravity image. Comparison between the Hedberg Line computed from known FoS points and the one computed from the predicted line provides a very good indication where additional survey lines could extend Australia's claim (Figure 9). Finally, areas

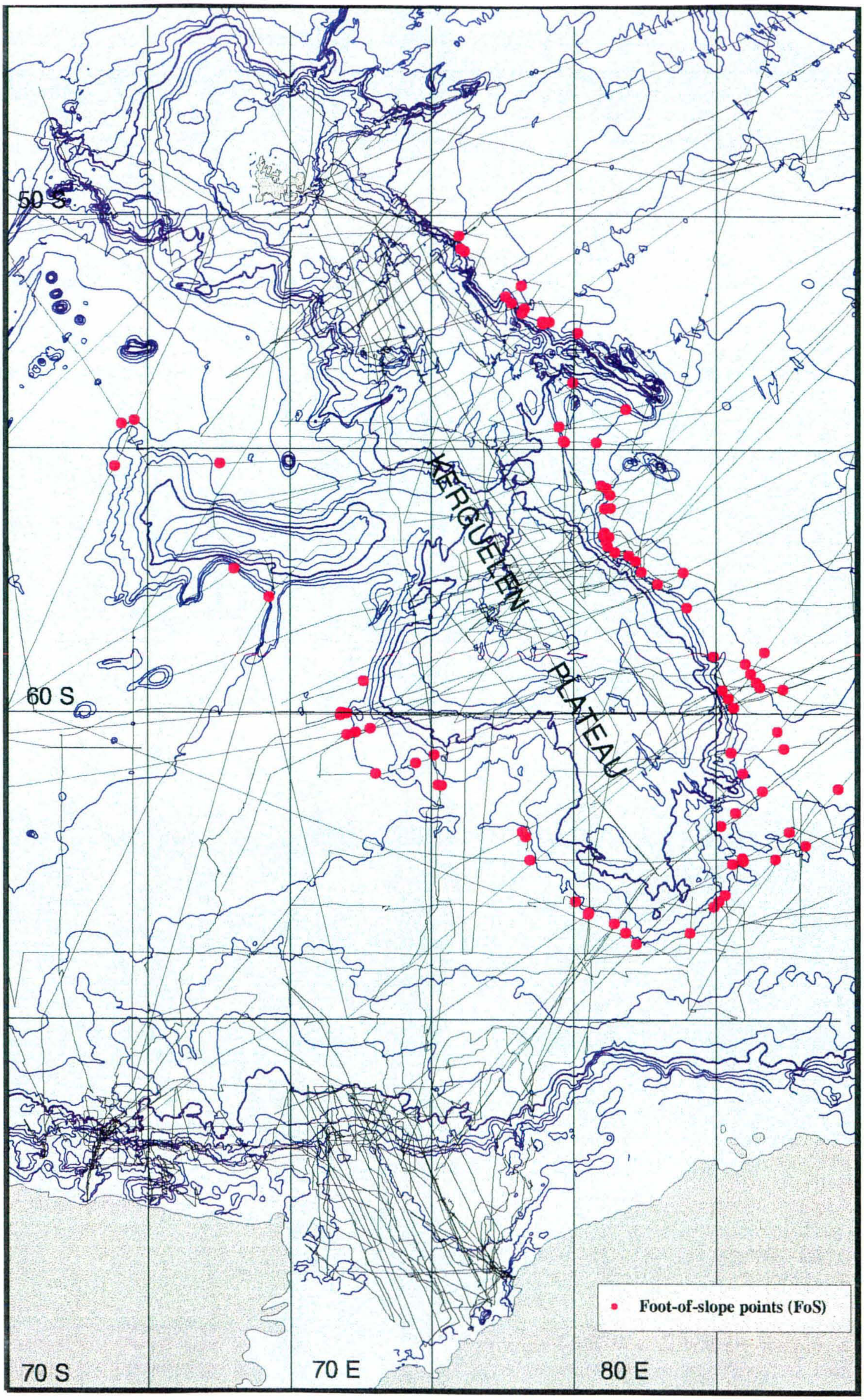

Figure 7. Foot of slope points identified from bathymetric and seismic data.

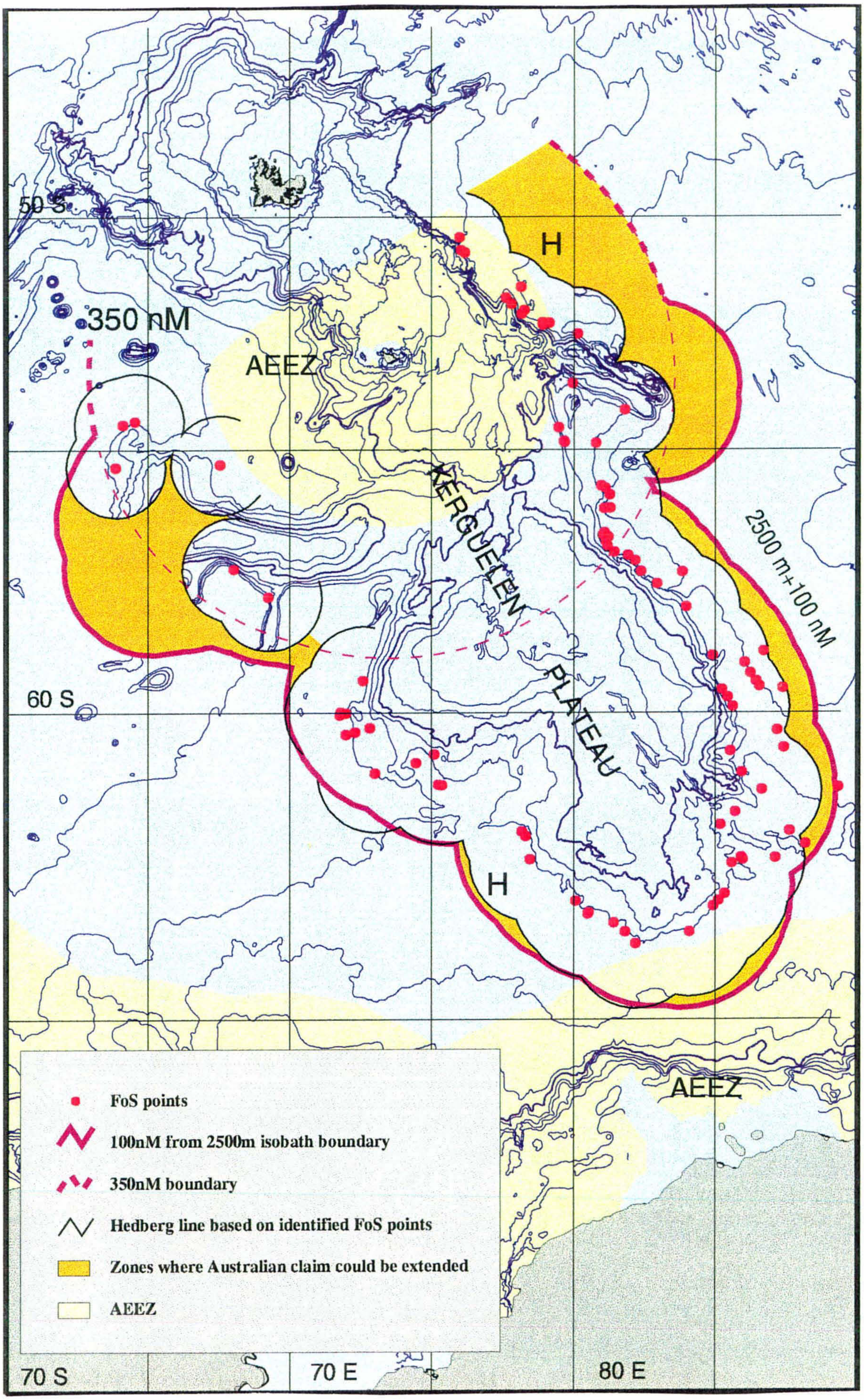

Figure 8. Identifying potential areas for extending the Australian Claim

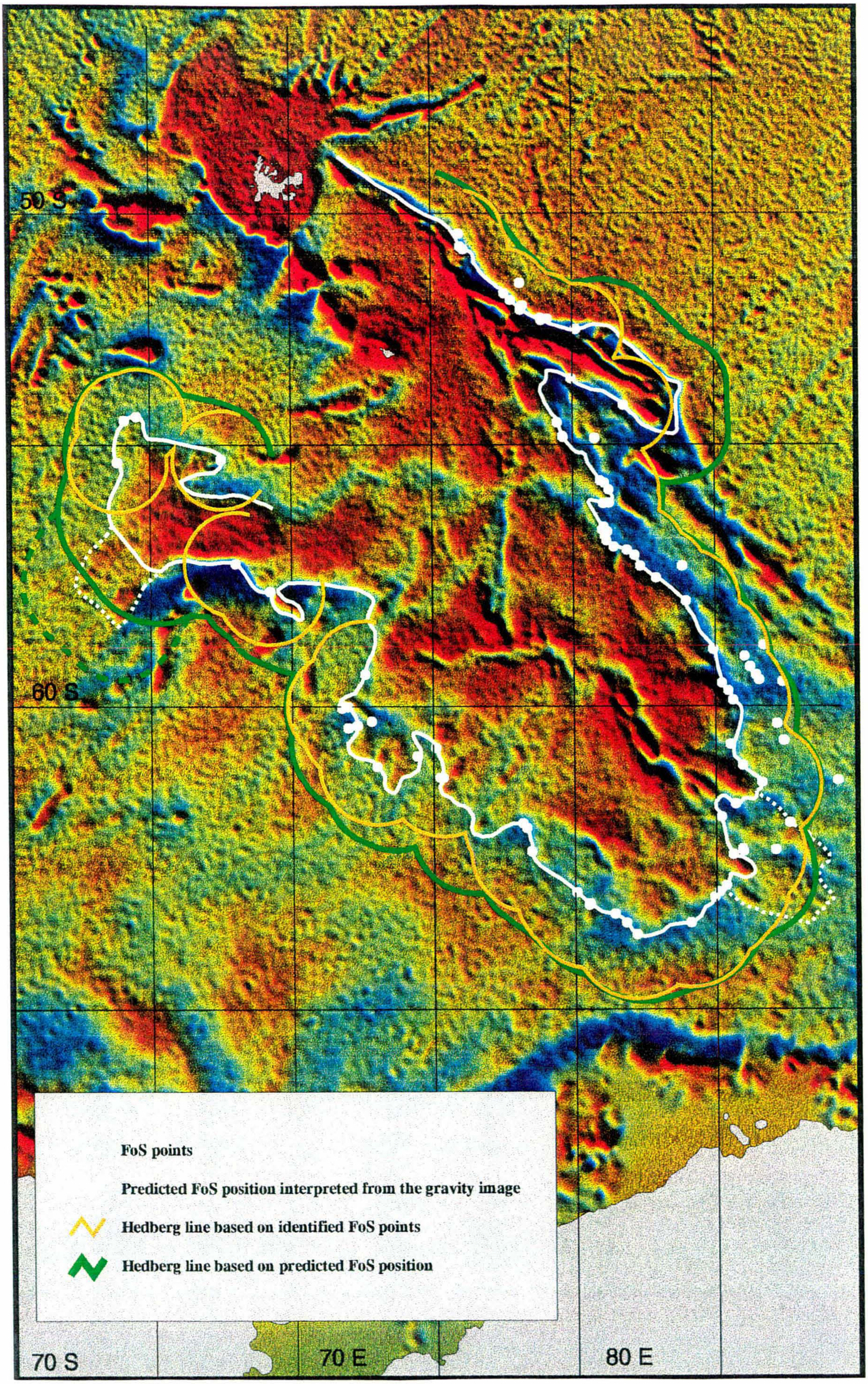

Figure 9. Gravity Satellite Image with identified and extrapolated position of the foot of slope. Comparison between the Hedberg Line computed from FoS points and from the predicted FoS line.

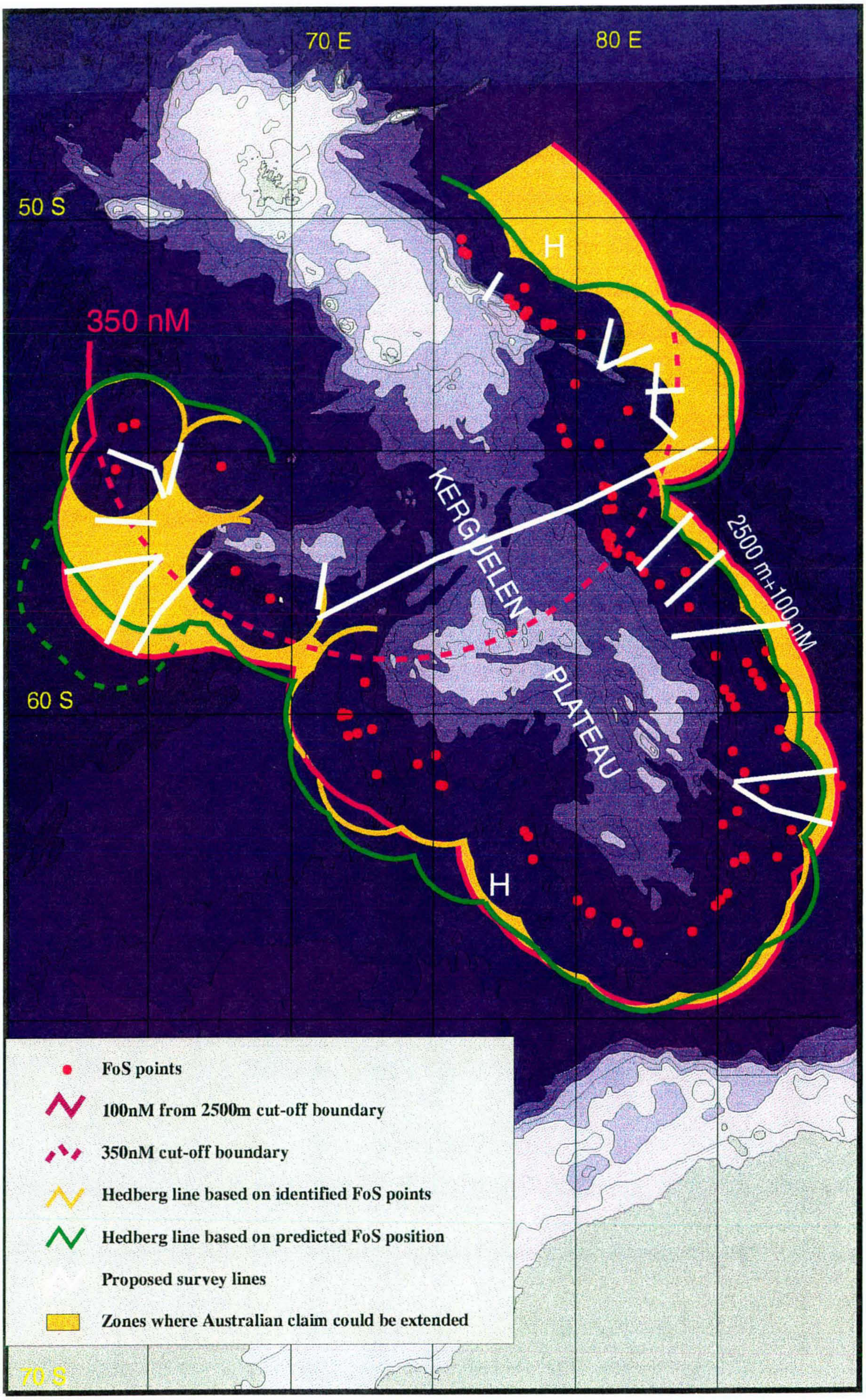

Figure 10. Proposed surveys lines for the Kerguelen Plateau area.

between the Hedberg Line and the cut-off boundaries are assessed for the sediment thickness criterion. If available seismic data indicate that there is significant sediment thickness beyond the Hedberg Line, then new survey lines are planned accordingly (Figure 10).

The LOS project is also building a bathymetric database for the Australian LCS. It includes data collected in all the AGSO surveys and foreign surveys that contributed data to the world data bank. It also contains Landsat imagery and digitised bathymetric maps. A few swath-mapping data sets have recently been added to the database. These very detailed data sets will be invaluable for the management of Australian ocean territories. With time, more swath-mapping data will be added to the database. All bathymetric data will be stored in the ORACLE database (OZMAR) and subsets of the database will be brought into the GIS for queries and integration with other data sets.

The challenges of the next few years lie with incorporating the 3rd dimension into our GIS. We plan to build a system that would integrate spatial information (bathymetry, gravity, navigation, well location, etc) with ready access on demand to bathymetric profiles and seismic sections. Creation of such a comprehensive GIS for Australian marine jurisdictional zones will be crucial for both the process of justifying Australia's claim and for managing its vast but as yet largely unknown resources.

In the **Mount Isa Seismic Transect Project** an attempt was made to develop a genuine 3-D model of the Inlier. This proved difficult. Although interactive 3-D packages have been developed for visualising large amounts of detailed 3-D geoscience data (eg., drilling, open pit, seismic and underground mining), use of data from these packages consisted of a simplified form of 3-D display by linking data to point or line locations on the earth's surface. Developing truly predictive 3-D geoscientific GIS in regions where a network of subsurface data is not available is a challenge, as many aspects of geoscience data are extremely variable and rarely form mathematically predicable patterns in the subsurface, particularly in regions of complex folding and faulting such as at Mount Isa. The project succeeded in creating a 2.5D cross section by 'warping' lithology mapping over seismic sections in ArcView. From this 2.5D integration it was possible to determine which major faults as imaged in the seismic section controlled the major deposits in the Mount Isa Inlier. It was quite clear that all major deposits were located along inclined faults: the vertical faults had no significant deposits along their length.

Science and Survey Support Division

Spatial Information and Mapping Services (SIMS) has recently been established from the now defunct Cartographic Services Unit and Information Systems Branch to coordinate and complement the provision of spatially referenced geoscience information in AGSO. SIMS has responsibility for corporate databases, image processing, cartography, soft photogrammetry, @ngis - the Australian Geoscience Information System, AGSO's Web site, and corporate data management, and thus plays an important role in most of AGSO's GIS activities. Key clients of SIMS include AGSO programs/projects, other Commonwealth and State organisations, and industry. External customers are charged a fee for service. Current GIS-related work includes the development of systems for metadata and data/product catalogues for both internal and external use; production of maps and datasets; refinement of standard Arc/Info symbols, colours and patterns; improvements to data dictionaries; promotion and development of @ngis; testing of digital photogrammetry software; training of South African GIS technicians; and development of a strategy for the corporate management of GIS in AGSO. Digital datasets completed or nearing completion include NTData geology (Figure 11), Southern Tasman Fold Belt Structure/Tectonism, Australian Crustal Elements, Australian 1:2.5M Geology. SIMS map products continue to receive accolades, taking out awards at the International Cartographic Conference, ESRI and Integraph international user group conferences, and the Australian Mapping Sciences conference.

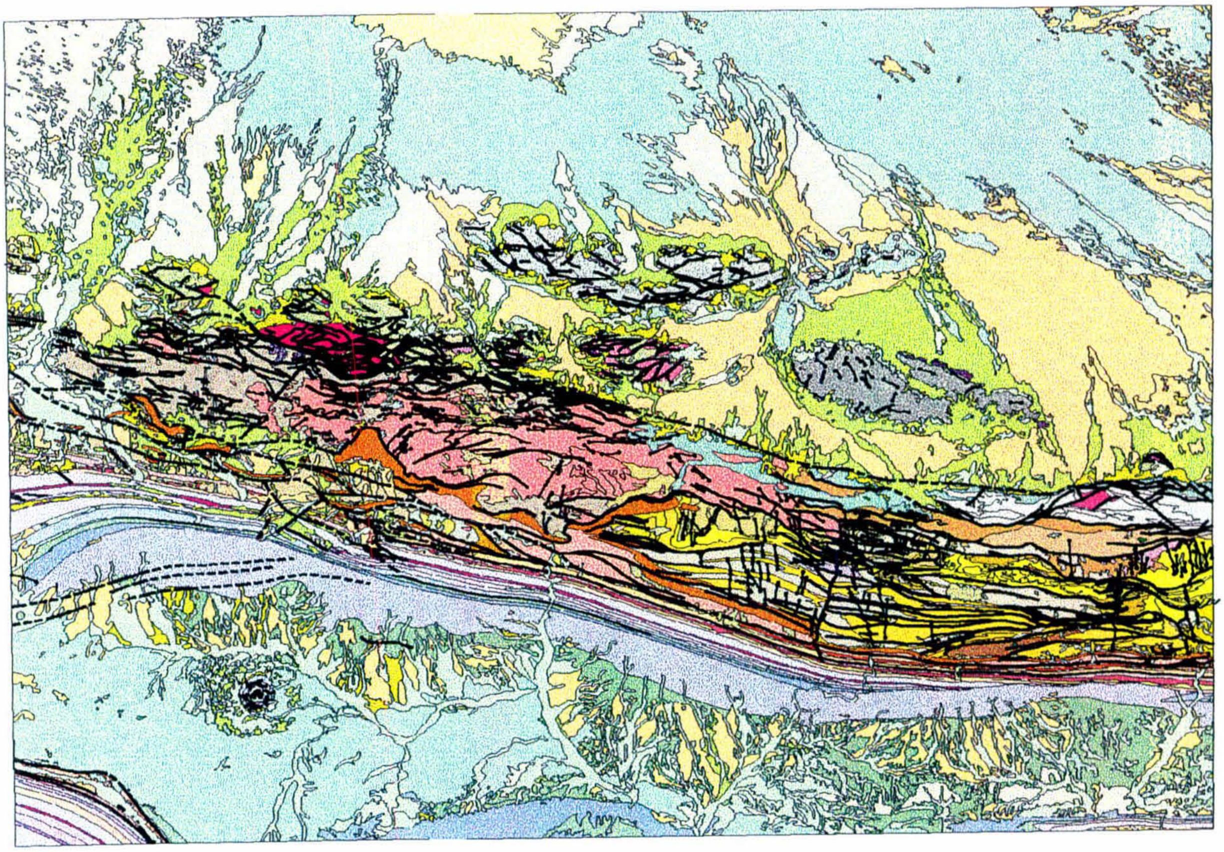

Figure 11. Diagram showing data from the NTData geology data set (Hermannsburg tile) which is sourced from the Australian 1:250 00 geological map series. Further information on NTData can be found on the Web at http://www.agso.gov.au/information/publications/ntdata/ntmain.html.

SIMS has responsibility for all ORACLE databases within AGSO, including OZROX, OZCHRON, ROCKCHEM, and STRATDAT. Each of these databases has been developed to have the capacity to integrate data on a national scale, and all have the ability for the data to be extracted and used on national, regional and detailed scale projects. Most of the databases are linked via a sites table thus ensuring that where diverse information types are taken from one site, the location information is stored once and once only, with observations stored in a series of linked data bases (Figure 12).

AGSO is also providing a state of the art link between the WWW and its Arc/Info GIS. From a simple interface, a user can initiate sophisticated GIS processing and produce thematically-rich maps tailored to specific requirements. These maps can be customised in terms of theme, scale, content and colour and viewed in real-time by a remote WWW user and printed out if required. Already users can produce maps of groundwater-related themes for the Murray Basin.

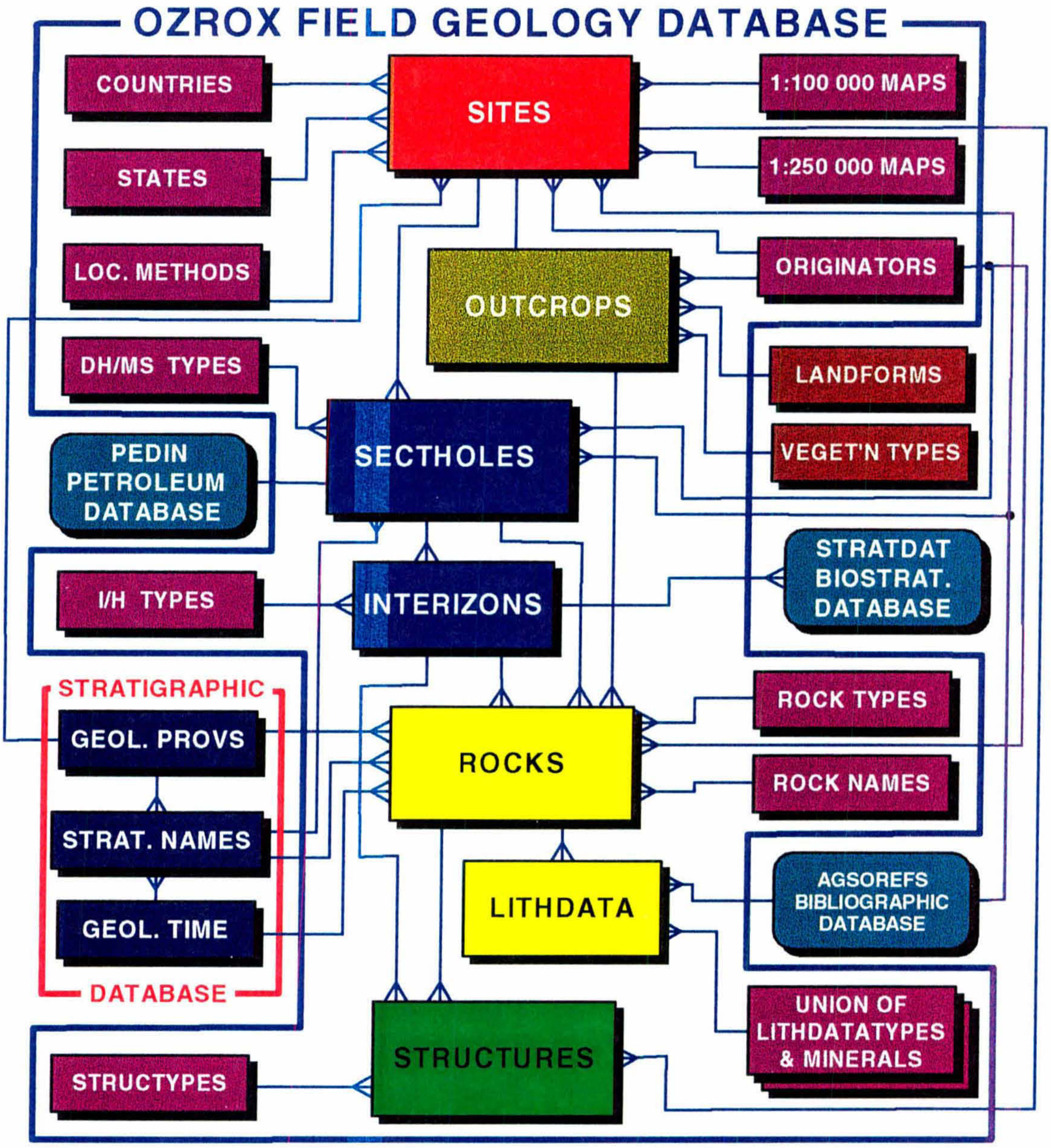

Figure 12. A table-relationship diagram showing the structure of the OZROX field geology database and related data structures. Square boxes indicate tables, rounded boxes databases, and 'crows feet' the many end of one-to-many links between the objects.

Minerals Division.

The Minerals Division includes the airborne geophysical, gravity, geochronology, regional mapping and geochemical laboratories groups. Its key clients are the Australian Minerals Industry groups and several major multiclient GIS projects have been cofunded by various industry sponsors. Although it has been relatively easy to produce GIS packages by integration of LANDSAT TM data and geophysical images, one of the major stumbling blocks has been the effective integration of field observations (so crucial to any mapping project) as searchable attributes within a digital GIS. In collaboration with SIMS a series of ORACLE data bases have been developed to store almost any type of field observations: these are now regularly integrated into the digital maps. As a matter of routine in the NGMA, digital data sets are compiled and interpreted prior to fieldwork. In several projects, a solid geology map has been constructed through on-screen interpretation of digitised published maps, Landsat TM, digital elevation, airborne radiometric and gravity data sets. As fieldwork proceeds, outcrop mapping and airphoto interpretation are integrated into the existing digital data sets. More specific highlights of GIS and GIS-related developments within the minerals division are as follows;

The **Bathurst GIS,** a recently released a GIS package on CD covering the Bathurst 1:250,000 sheet area (Raymond and MacRae, 1997, MacRae et al., 1997) was a product of the Lachlan Fold Belt National Geoscience Mapping Accord (NGMA) joint project between AGSO and the NSW Department of Mineral Resources. The package is based around a digital geology map compiled from new 1:25,000 and 1:50,000 mapping, and includes additional layers such as interpreted Palaeozoic solid geology with an extensive geological attribute table, buffered structures and intrusive bodies and a whole rock geochemistry compilation. Point data sets in the package include mineral occurrences; outcrop, petrological and fossil descriptions; structural and geochronological data; and a digital photographic database of over 130 scanned and annotated images. GIS analysis of this data package will provide a valuable new tool for mineral exploration in the central west of NSW, where recent discoveries at Cadia Hill, Lewis Ponds and Discovery Ridge have highlighted the potential for diverse styles of mineralisation in the Lachlan Fold Belt. It is envisaged that similar GIS packages will be developed for Dubbo and Forbes 1:250 000 sheet areas after completion of the field mapping program.

The **GIS of the North Australian Basins Resource Evaluation (NABRE) Project** consists of 58 1:250000 geology map sheets of the NT and parts of WA (Martin et al., 1997). In QLD the Mount. Isa 1:100000 digital data set is integrated. This comprises AGSO's largest regional geology GIS coverage. The GIS uses geophysical raster data (gravity and magnetics) as backdrops for the vector geology coverage's, and it is hoped to hotlink to seismic and well log data. Eventually data links will be established to the OZCHRON, MINLOC, and ROCKCHEM databases. The GIS will be used to perform regional spatial analysis using all the data sets listed above, as well as domain analysis, time series analysis, complex data analysis and correlation between the geophysical data and the geology coverage. Eventually, it is hoped to do 3-D modelling using AVS.

For the **Metallogeny of Australian Proterozoic Granites Project**, 20 minerals companies sponsored AGSO to build a national data set of all Australian Proterozoic Granites and their environs to better understand the regional controls on granite-related mineralisation. This data set was built using fairly rigid data structures and standards so that factors found to control mineralisation around granites in the better known provinces could be digitally applied in areas not known to have mineralisation.

Several major **regional map compilation projects** have been undertaken of existing data (eg., Mount Isa, data set which compiled 32 1:100 000 digital maps and the Granites-Tanami data set which compiled 15 1:250 000 digital maps). In both these projects rigid data structures were developed to ensure that a 'seamless coverage' was generated in which a common map legend and shade set were developed. Where boundaries between individual map sheets did not join the original air photos were obtained from archives and the boundaries reinterpreted. In the Mount Isa 1:100 000 map project (which was sponsored by 7 minerals companies) some 3500 field observation points were integrated into the data set to ensure that all polygon labels and boundaries were correct. An additional innovation in the Mount Isa data set was the unique coding of all faults within the complete data set to facilitate metallogenic analysis.

The development of the **AGSO FieldPad** (Hazell, et al, 1996; Blewett and Hazell, 1997; Hazell and Blewett,1997) has resulted from the recognition by AGSO of the value of reliable, standardised digital field data/observations for GIS. Structured notebooks (Ryburn, et al, 1993; Blewett, 1993; Ryburn, et al, 1995) were developed several years ago to record field data in a standardised and structured manner. Standardised and structured descriptions are necessary for the successful retrieval of data from the corporate field database system, OZROX. These notebooks are now being superseded by palmtop computers for data entry. Running on an Apple Newton, the AGSO FieldPad is a digital field notebook system for capturing field observations including sketches digitally at the outcrop (Figure 13). The design of the Fieldpad matches AGSO's OZROX field database, allowing direct transfer of field descriptions into OZROX. One of the main objectives for developing the digital field notebook system was to eliminate the numerous transcription errors that inevitably found their way into the corporate data base systems as data was typed in from the field notebooks.

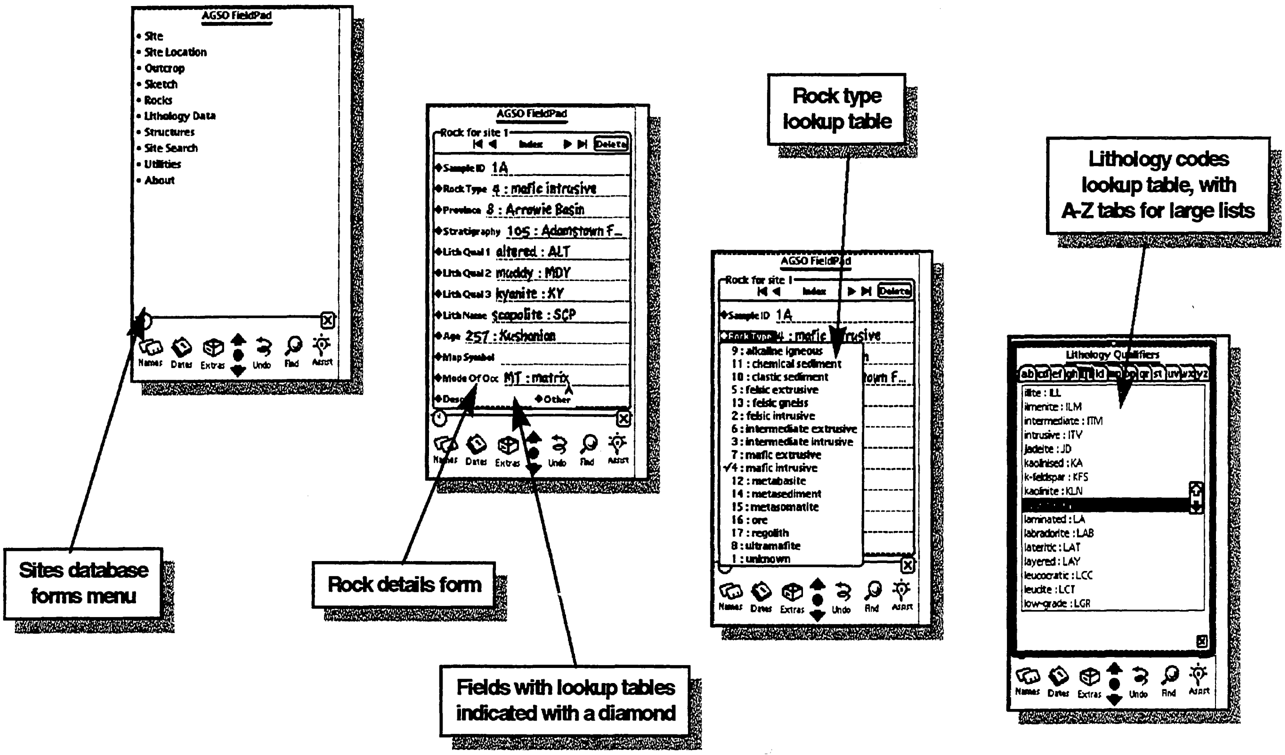

Figure 13. Example screens from the AGSO FieldPad. Most data entry is achieved through selecting values from lookup tables.

In the **Regolith Group**, GIS modelling functionality has been used to integrate airborne gamma-ray imagery with ancillary digital data, including geology, landforms and slope classes (based on geomorphic thresholds). Modelled raster maps generated from this approach have the potential to complement existing terrain evaluation methods by improving the efficiency, speed and, in places, accuracy of regolith/soil mapping.

GIS INITIATIVES IN AGSO AS A WHOLE: FUTURE DEVELOPMENTS

Despite all the development that has gone on, limitations are being reached in data analysis of data sets both within projects and across projects within AGSO in part because of lack of standardisation of data dictionaries and data sets. As a result AGSO is in the process of revisiting all of its data standards for GIS digital data. This revision will attempt to standardise attribute definitions and data compilation standards across a broader range of AGSO activities than the mineral province mapping that has dominated the development of GIS standards until now. It is hoped that AGSO's data standards can be published on the Internet on our home page to allow the widest possible exposure for these standards.

The key future developments for ASGO is to truly integrate all of its data sets from the individual divisions and to ensure that across AGSO information on any item is stored once and once only and then copied into other data sets. As a new initiative AGSO has compiled all national scale GIS data sets into a single GIS. All data sets are now available for viewing on the WWW and it is hoped to release this national scale GIS as a hard copy atlas and an interactive CD-ROM.

ACKNOWLEDGEMENTS

Many thanks to those who have contributed to the GIS projects in AGSO listed in this paper (and to many others that have been completed or are currently in progress). This paper is published with the permission of the Executive Director of AGSO.

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The National Geoscience Information System: linking spatial data to the World Wide Web.

Jonathon Root and Prame Chopra, AGSO

Abstract

The Internet promises spatial data providers an unprecedented opportunity to make their data widely available in forms most useful to data users. For a number of reasons however, most data providers have been slow to take up the technology. In particular, limited bandwidth, licence arrangements for server-side applications, and concerns over data security and online commerce have affected the way spatial data are used over the Internet.

Under the National Geoscience Information System Program, AGSO has taken a staged approach to implementing online spatial data services. Static maps, image maps, online databases, GIS and simple dataset mapping tools have all been used and each has proved effective, although limited by the issues raised above.

Two key components of AGSO's current online system are a GIS based on Arc/Info (http://www.agso.gov.au/map/mb_make_map.html), and a dataset mapping tool, the @ngis Data Locator (http://www.agso.gov.au/ngis/locator.html). The GIS is a powerful solution for providing data over the World Wide Web: it delivers a high level of detail and extensive user-controlled customisation of the output. Bandwidth limitations and licensing requirements do, however, place some limits on its functionality. On the other hand, low bandwidth solutions, such as the Data Locator, allow users to map large volumes of data easily, but the level of detail and customisation is low. AGSO is overcoming these Internet limitations by combining a variety of online tools to satisfy web users in the short term while leaving the way open for new services as Internet infrastructures improve.

As bandwidth, commerce, security and licensing issues are resolved, fully interactive systems with GIS interfaces linked to relational or object-oriented databases will allow thin clients to access AGSO datasets in a flexible manner. Users will be able to create maps and datasets to suite their individual needs, greatly enhancing the usefulness and accessibility of AGSO's significant national geoscience datasets.

Introduction

The last fifteen to twenty years have seen an almost exponential increase in the volume of digital geoscience data available in Australia. These data have accumulated as a result of the work of government at all levels, private sector firms and educational institutions who have both collected new data sets and digitised existing ones.

With the increased volumes of data has come the problem of management; developing efficient methods of storage and extraction, methods of processing, integration and interpretation and methods of presentation. The development and wide acceptance of relational databases, and emerging object oriented systems, image processing, and GIS have gone a long way to solving these problems but have led in many cases to inefficient and costly duplication of datasets.

With the emergence of Internet technologies in the early 1990s has come the opportunity to utilise data more efficiently through the concept of data custodians and online access to data. This overcomes problems of data duplication, quality control and currency. Present limitations of the Internet, particularly in terms of bandwidth and security, constrain the way this can be done and require data providers to make choices as to how they allow access to their data.

Ultimately, when security, bandwidth and commercial considerations have been resolved, online Internet and intranet based systems will be similar to current LAN and WAN based systems in terms of functionality and structure. In the meantime a number of technologies have emerged to fill the gap between the industry's current network based systems and the thin-client Internet based systems of the future.

The Nature of the Web: Advantages and Constraints

The World Wide Web (WWW) is a rich information system built upon the global computer network known as the Internet. The WWW originated from the efforts of scientists working in the field of nuclear physics who sought to establish a means of data exchange and data sharing through the Internet for scientists working in their field. The WWW has spread far from its original scope, so much so that it now involves every facet of human communication. The growth of the WWW has been phenomenal both in terms of the numbers of people regularly using it (e.g. an estimate of 30 million users in February 1996) and in terms of the numbers of sites offering information to these users (e.g. 16 million website addresses in January 1997 - http://www.nw.com/zone/WWW/report.html). Figure One shows the growth in Internet host addresses since 1981.

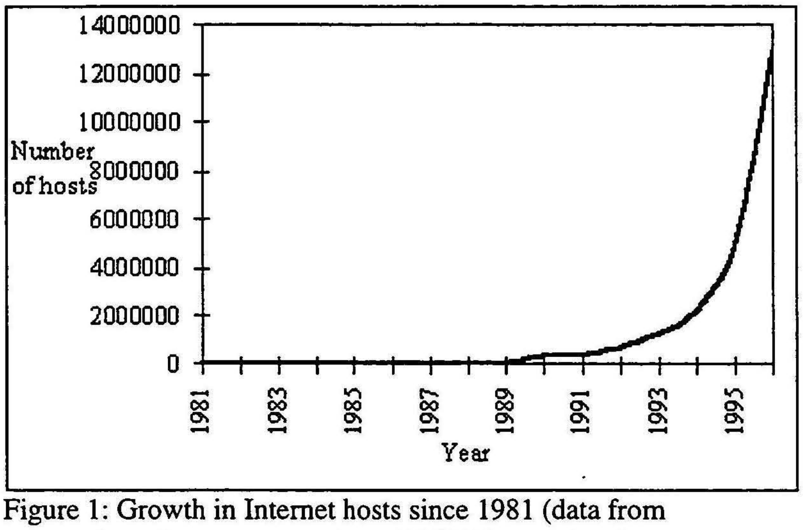

Figure 1: Growth in Internet hosts since 1981 (data from http://www.nw.com/zone/WWW/report.html)

The remarkable growth of the WWW has been underpinned by a number of factors:

- the rise to dominance of the graphical user interface (GUI) in computing. The GUI environment permits the construction of sophisticated displays incorporating the elements of what has become known as "desktop publishing" (i.e. elaborate text presentation integrated with rich graphics).

- the world-wide growth of the Internet and the general acceptance of its underlying protocols governing the communication between computers (TCP/IP).

- the early adoption of an internationally agreed standard controlling the display of text and data within the WWW. This standard, known as Hypertext Markup Language (HTML), is something of a rapidly moving feast in that new versions are continually being discussed and implemented. Further standards are also being introduced to augment HTML. Examples include Virtual Reality Markup Language (VRML) for the interactive display of 3 dimensional space and Java, a C++ like programming language used for the building of "WWW applets." The rapidity with which these standards have been implemented is in itself a measure of how quickly the whole WWW system has been growing. The most important consequence of the implementation of the standards has been to make the WWW platform-independent. Computers serving information and those browsing it can be of any architecture between a unix mainframe and a desktop PC.

- the de-centralised nature of the WWW. Because the WWW is modelled on a peer-to-peer communication model in which computers communicate directly rather than through a centralised computer or groups of such computers, the growth of the WWW has been almost biological in form. Information content is added to the myriads of WWW servers in a more or less spontaneous fashion and the resulting pool of information that is available to WWW users is incredibly rich and diverse. Without centralised control, it is also easier for data providers to keep their data up-to-date. The experience to date has been that the growth of the web has been "data driven." The more data added, the greater the allure for potential users to browse the WWW and hence the greater the perceived advantage of organisations to participate.

The growth of the WWW and of individual sites serving information to the WWW has inevitably been constrained by a whole range of technical, economic and legal factors:

- Bandwidth: this term comes from the telecommunications industry and measures the capacity of the telecommunications network to carry the messages and data between computers participating in the WWW. Bandwidth has always been the greatest technical impediment to the WWW.

  In Australia, the main telecommunications "backbone" for the Internet and WWW operates at a bandwidth of 2 Megabits per second. For computers connected to this "backbone" by segments with similar or higher bandwidths, up to a maximum of 2 Megabits per second may be transferred. To put this into perspective, a modest image on a WWW page of 100 kilobytes (=800 kilobits or 0.8 Megabits) could in principle be transferred in less than ½ second if there were no delays in the computer sending and the computer receiving the image data. However, if either computer were connected to the backbone by a segment with a smaller bandwidth then it would be this segment which would control the data transfer speed. Thus even for the best currently available modems on standard phone lines (i.e. 33.6 kilobits/second) the transfer would still take at least 24 seconds. Obviously, when the data to be transferred is much greater in volume (as it often is), the waits for the user become very much longer.

- Cost: The costs of setting up and maintaining WWW servers to provide information to the WWW can be considered in two categories: the set-up costs of purchasing a computer and its Internet link to connect to the WWW, and the cost of developing and maintaining the information content that is going to be served. Of these two categories of costs, the former is easy to quantify and is largely an "up-front" cost, while the latter is likely to be on-going. If a site aims to serve substantial amounts of material to the WWW, the development and maintenance costs will soon predominate.
  The initial development costs include the tasks of organising the data that is going to be served on the WWW. At a simple level, this might involve the conversion of existing documents (e.g. annual reports) into HTML and graphics (e.g. organisational charts and

project highlights) into compatible computer graphics files (e.g. GIF or JPEG formats). For WWW sites such as those of mainstream data providers (e.g. AGSO), the underlying data structures used to store the entire corporate data base and the formats in which these data should be stored, may have to be revised before the data can be presented on the WWW in the logical and consistent fashion that WWW users require.

- Security: When a computer is connected to an external network like the Internet, it becomes possible for its contents to be read, copied, modified or erased by "hackers." If the target of the "hackers" is the HTML and images being served by a WWW server, the result will perhaps be irritating, or embarrassing as in the case of the US Central Intelligence Agency's home page which was changed by a hacker to read "Welcome to the Central Stupidity Agency." However, if the hacker gains access to other computers in the organisation through the WWW server machine, the results can be catastrophic especially if these computers hold sensitive material or corporate databases.
  A common response to this security issue is to install an internet firewall which filters the traffic taking place between an organisation's computers and the outside Internet environment (including the WWW).

- Authentication: This issue is an extension of the security and commercial issues associated with use of the web. It stems from the fact that it is often difficult to ensure the identity of a client, and, similarly, it is often difficult for the client to ensure the identity of the server. Both of these are necessary if users are to have confidence that they are receiving the correct data and organisations are to be confident that only authorised clients are accessing their data.

  A number of tools are available to ensure authentication. Double encryption, where data is encrypted using encryption keys belonging to both the provider and the client, is one such tool. Improved HTTP protocols are also likely to help stamp out impersonators and eavesdroppers.

Tools Available for Linking Spatial Data to the WWW

There are a wide range of tools available to spatial data custodians for linking their data to the WWW. The appropriateness of each tool will depend on the nature of the dataset but in general it is best to use a combination. Table One details some of the principal tools available, together with their strengths and weaknesses.

As Internet technologies evolve, many current problems will be overcome and new ones will emerge. Bandwidth (and hence the volume of transmitted data) is likely to remain a key issue. Hence decisions such as whether tools are developed to run on the client-side (via JAVA-style applets) or on the server side will devolve to comparing the client-side processing time and download time of the applet with the server side processing time and download time for the final product. Issues such as server load should also be considered as data providers bring more content online and increase the functionality of their online services.

WWW content	Comments
Text description (metadata)	This is perhaps the most common type of information available on the WWW at present. It is simple to set up and requires nothing more than basic HTML. It is very low resolution, however, being information rich but data poor. It is not interactive.
Online database	This is an interactive, data rich solution but requires some technical expertise to implement and may be expensive if the database is relational or object oriented. Relational databases are often slow to extract spatial data. Online databases may include image databases which are a useful solution to presenting high volumes of pre-prepared images
Static image	This is another common solution. It is not interactive but allows spatial representation of datasets. There is some maintenance cost associated with this solution as images must be recreated every time a data set changes. Plug-ins are available which allow zoom & pan of static images which can enhance the functionality of this solution
Imagemap	This is a more interactive version of the static image solution. Users can click on a static map and return further information about a particular point or area, in the form of a higher resolution image, static text, or data extracted from a database. This is a moderately interactive solution but suffers from the same problems of maintenance as the static image solution.
Raster overlays	Tools are available which allow combinations of pre-prepared images to be overlain. This allows a pseudo online GIS functionality but suffers from the cost of creating the pre-prepared images and has limited interactive capability.
Data map	This type of tool allows "on-the-fly" image creation from databases giving rapid spatial representation of datasets. Depending on how such tools are configured they can be an efficient enhancement to online databases. Their functionality is limited however, and they are at best a low resolution solution.
GIS	An online GIS is an ideal solution as it bundles the functionality of all of the above tools. There are technical problems associated with such applications, in terms of developing browser based interfaces and limiting the volume of data transmitted over the web. A more detailed discussion of this type of tool is given by Chopra (1996).
VRML	VRML has the potential to allow online representation of spatial data sets in 3 dimensions.

Table One: Some current tools for linking spatial data to the WWW.

Examples from AGSO's website

Static text, images and imagemaps

A large amount of spatial data is represented on the AGSO website via text descriptions or tables (Figure 2). Figure 3 demonstrates the use of static images and clickable imagemaps. In this example users can click on their area of interest on a clickable map of Australia (showing the locations of ROCKCHEM database samples) to access a higher resolution sample location map.

Data description:

This database contains 2093 samples from the Lachlan Fold Belt. These can be divided into five major groups:

- 568 analyses of mainly igneous rocks collected during AGSO 1:100 000 mapping in the vicinity of Canberra. The samples are mostly from the Tantangara, Brindabella, Canberra and Araluen 1:100 000 sheet areas, but some come from adjacent areas and are thought to be related to rock suites from these sheet areas.
- 406 analyses of rocks collected by Wyatt et al. (1984) in a regional study by AGSO of geophysical rock properties of the Lachlan Fold Belt. The samples include a wide variety of mainly igneous rocks from all over the NSW sector of the Lachlan Fold Belt.
- 223 analyses of rocks collected during a detailed CSIRO study of alteration and mineralisation around the Woodlawn mine by Petersen et al. (1977).

Appendix - Listings of the components of the Pilbara Block database

Pilbara Block Samples assigned to Groups

STRATNAME	COUNT (STRATNAME)
Andover Complex	209
Gorge Creek Group	104
Munni Munni Complex	126
Radio Hill Complex	75
Warrawoona Group	630
Whim Creek Group	33
sum	1177

Pilbara Block Samples assigned to Subgroups

STRATNAME	COUNT (STRATNAME)
Salgash Subgroup	178

Figure 2: Text and tabular descriptions of spatial datasets taken from AGSO's ROCKCHEM database web page (http://www.agso.gov.au/geochemistry/rockchem/)

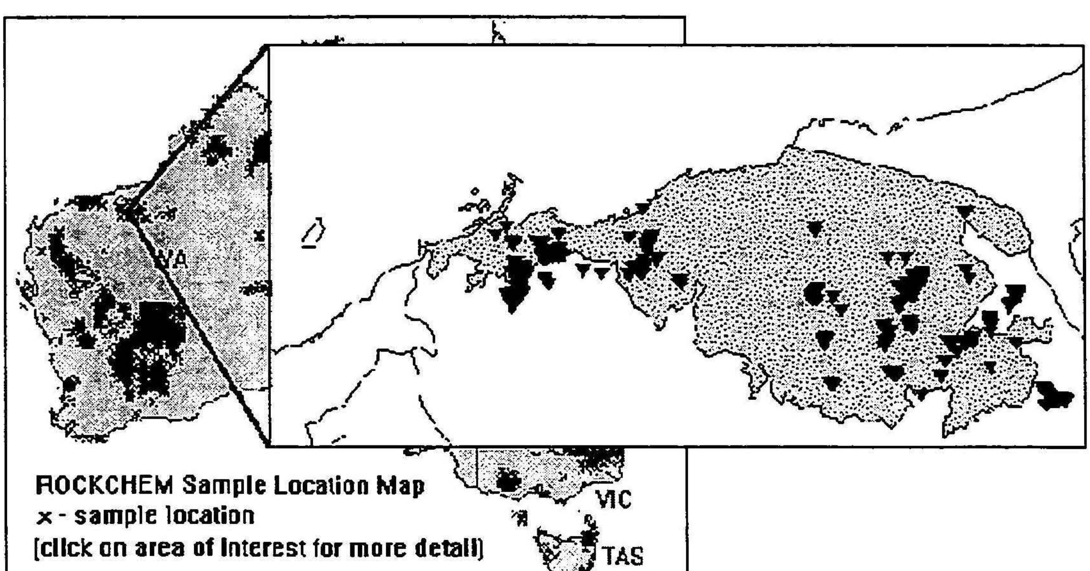

Figure 3: A clickable imagemap from the ROCKCHEM web pages, allowing zoom to a higher resolution static image (http://www.agso.gov.au/geochemistry/rockchem/).

Online Databases

AGSO has a number of online databases. Users make queries via an HTML forms interface, queries are parsed by a C script and the data returned from production Oracle databases via SQR. Figure 4 shows a typical browser form for querying an online database. The use of look-up tables and text boxes allows users to customise their query. Results are returned as an HTML file.

Online GIS

AGSO's online GIS allows users to create maps relating to the groundwater resources of the Murray Basin. The system uses Arc/Info to produce its maps. Users view a sample image and then select options from a forms based browser interface (Figure 5). The resulting request is parsed by a C program residing in the web server's CGI bin and an Arc/Info session is invoked via a Bourne shell. An AML is used to generate map output from the query and this is passed to a Ghostscript interpreter for conversion to GIF format. It is then combined with appropriate HTML and returned to the client (Figure 6).

Internet GIS systems such as that described here suffer from the relatively simple interfaces required when using HTML forms and single queries to generate output. In the future, technologies such as JAVA and cookies will allow more complex interfaces and sequential querying, greatly enhancing the functionality of these systems.

Data Map

Figure 7 demonstrates a simple tool used to map datasets on AGSO's @ngis site (http://www.agso.gov.au/ngis/). This tool, the Data Locator, was developed under the Australian National Geoscience Information System Program (see Berman & Root 1996). It uses simple C programs to generate GIF files on-the-fly from flat file databases of a range of point, line or polygon datasets. Functionality is limited to scroll and zoom but it has the advantage of being relatively quick and allows users to burrow down to metadata about individual survey points or polygons.

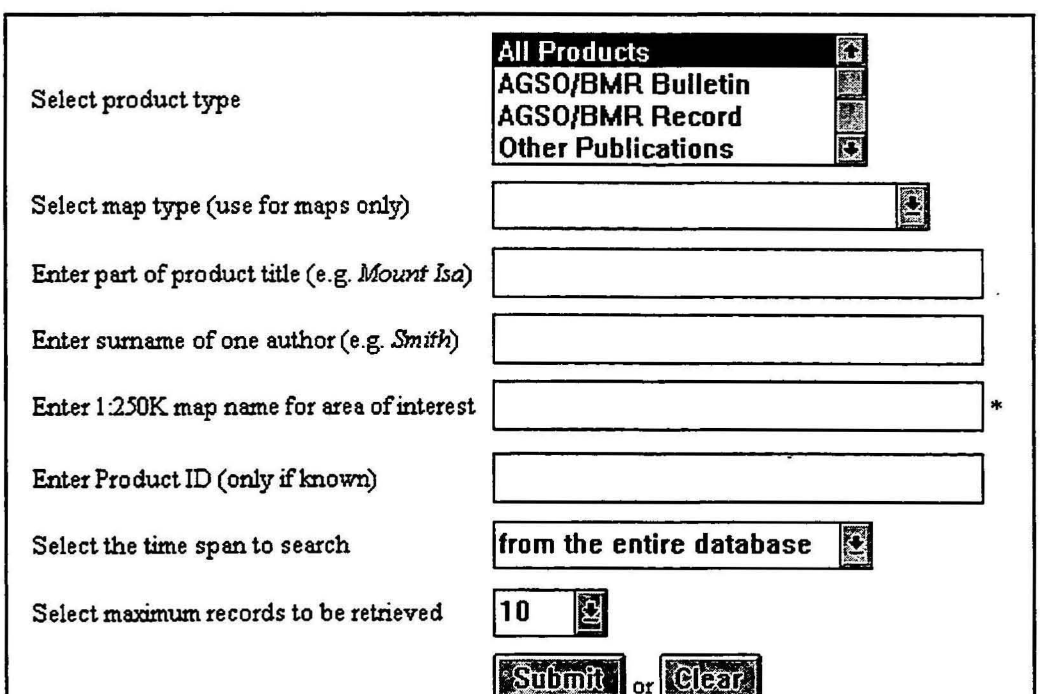
Select product type
All Products
AGSO/BMR Bulletin
AGSO/BMR Record
Other Publications
Select map type (use for maps only)
Enter part of product title (e.g. *Mount Isa*)
Enter surname of one author (e.g. *Smith*)
Enter 1:250K map name for area of interest *
Enter Product ID (only if known)
Select the time span to search
from the entire database
Select maximum records to be retrieved
10
Submit or Clear

Figure 4: Query form for AGSO's online products database (http://www.agso.gov.au/).

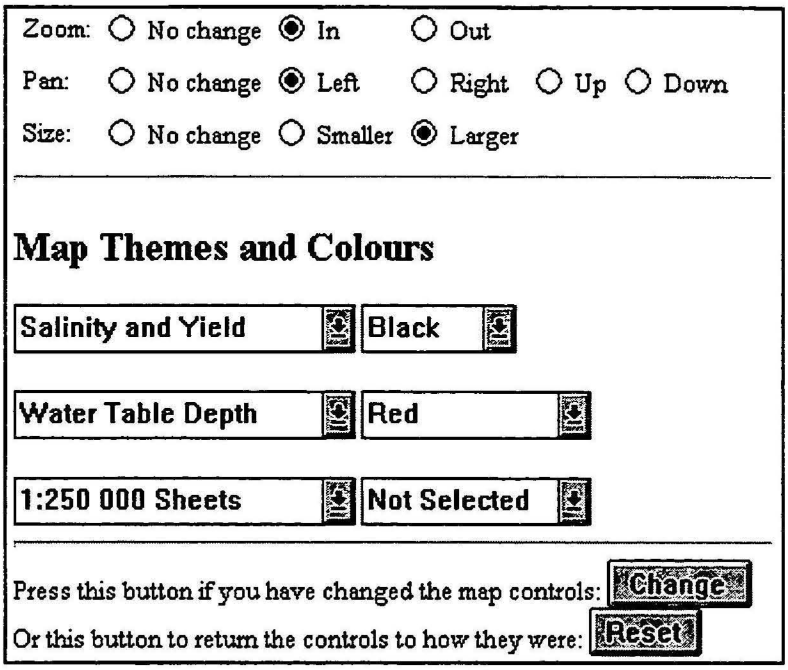

Figure 5. HTML forms interface from the AGSO Murray Basin GIS. (http://www.agso.gov.au/map/mb_make_map.html)

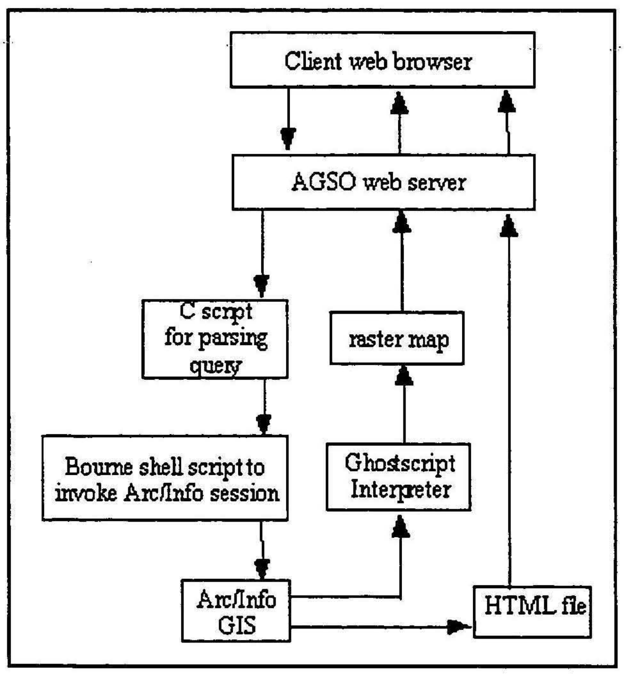

Figure 6: Flow diagram of AGSO's Murray Basin WWW GIS (after Chopra 1996).

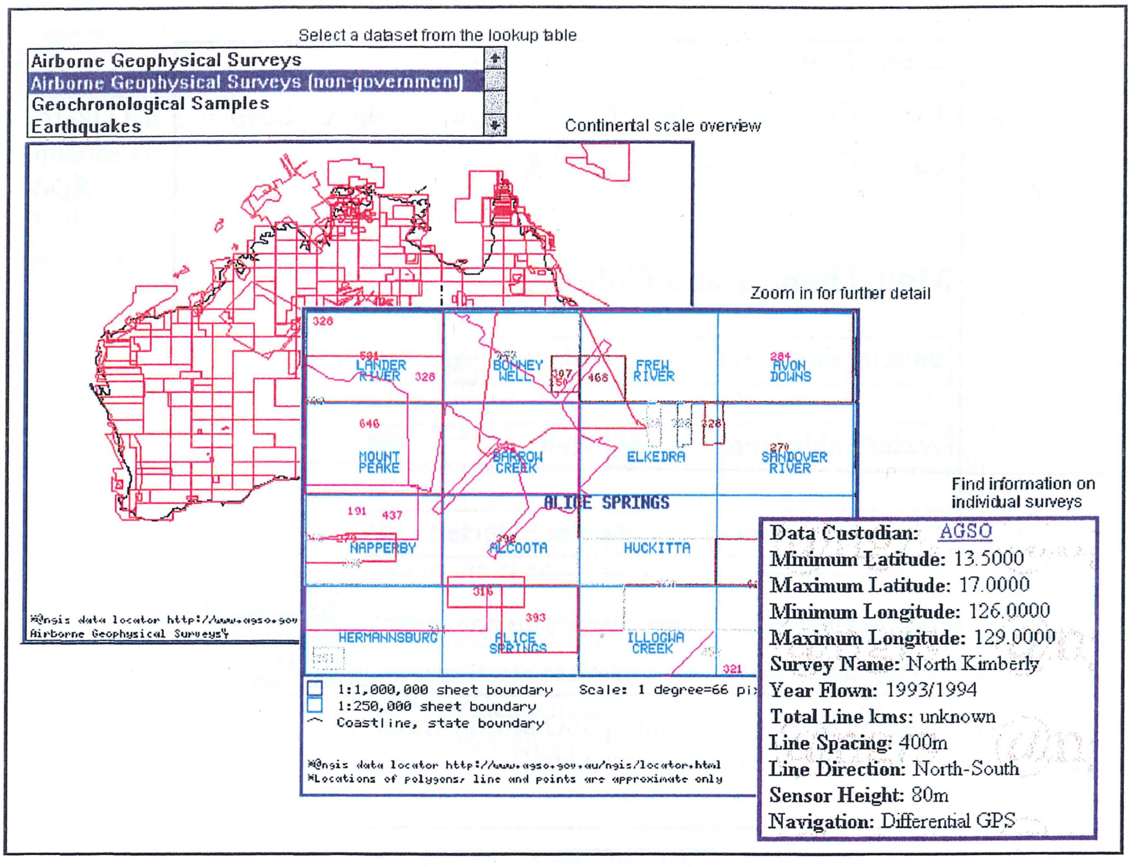

Figure 7: An example from the @ngis Data Locator.

Future Directions

The use of simple tools such as the data locator, which are low resolution and hence (generally) require less bandwidth, can allow users to refine their data requirements to the stage where higher resolution tools can be used without running up against the web's bandwidth barrier. In the short term, developments are likely to take this approach; identifying precisely how much data users require and delivering only that data. User frustration over slow download times on the Net stem more often from being forced to acquire more than they need (and often data they don't want but don't know until they've downloaded it), than from it taking a little extra time to get exactly what they want.

Ultimately however, Internet based applications will be almost identical to applications running on internal networks. Improved bandwidth, compression algorithms and switching technologies, better modems, client side applets, cookies, fire-walls, reverse proxy servers, cyber-cash and browser plug-ins are all moving to overcome the problems of bandwidth, security, ephemeral communications and issues associated with online commerce.

What may take longer is the change needed in the way data custodians think about their data, and the way clients use data. It is no secret that the technologies which underpinned the Industrial Revolution predated the revolution itself by at least thirty years (Marglin 1974, 30). Changes in work processes were the key to taking advantage of those technologies. Likewise, the technologies which will underpin the Information Revolution are beginning to appear, but significant changes in the way we use and think about data and information will be required as the Information Revolution begins.

For truly distributed, Internet-based data and information systems to emerge there will need to be considerable improvements in the way data is managed, in the quality control applied to datasets, and in the use of standards. Organisations will move away from valuing the ownership of data as a commercial advantage towards valuing the use to which data is put.

Conclusions

The Internet allows data providers the opportunity to greatly reduce their publishing costs, and has the potential to increase the efficiency of data delivery to clients. It affords data users the opportunity to more readily locate and obtain data. Accessing data online can reduce unnecessary duplication and lead to significant reductions in data management costs for non-custodial users.

A range of tools are available for linking spatial data to the WWW. With judicious use of combinations of these tools, data providers can overcome the bandwidth problems currently limiting the use of Internet technologies. In general, data providers should consider an incremental approach to implementing such systems, starting with the simpler static tools and moving where possible to more interactive and dynamic methods of representing data as their level of WWW expertise increases. Feedback from users should be an important guide to the pace of this development and to its form and content.

The rapid developments which characterise the growth of Internet technologies are a double edged sword. They bring the promise of new opportunities for data providers but may also tend to marginalise those who established an early presence. "Old ware" dates very quickly in this new communications medium. Dynamic, online information systems offer a practical, data-rich solution to this dilemma. Thus, while there has been some opportunity for more circumspect data providers to "leap-frog" the early starters, those wanting to establish a presence in the rapidly expanding WWW should begin to seriously consider their options now.

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The Stratigraphic Index of Australia: is it a national treasure or a dinosaur ??

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Abstract
The Stratigraphic Index of Australia (STRATINDEX) was started in 1949. It provides a unique coding for all formally registered geological units in Australia. Considered a dinosaur by many, and as having no place in 'modern' geological research, the STRATINDEX database is coming into its own in the digital age. For many digital databases and digital geological maps it acts as an authority table with the potential to automatically provide information on parentage, age and province of any geological unit that has been registered. The STRATINDEX also stores information on literature references where the units have been discussed and is the repository for all definition descriptions of all units. In order to ensure that all geological units on Australian maps and publications can be uniquely coded the STRATINDEX is being modified to store information on granite suites, sequence stratigraphy, and unnamed units on geological maps. The STRATINDEX is not yet perfect. Much information is still stored on cards and has not been translated into the digital database.

Just what is the STRATINDEX ?
The Australian Stratigraphic Index was started in 1949, as a co-operative effort of BMR, the State Geological Surveys and the universities, to produce the Australian volumes of the International Stratigraphic Lexicon (the Macquarie Dictionary defines a lexicon as the total stock of words in a language). At the same time, the STRATINDEX complemented the first Australian Code of Stratigraphic Nomenclature which was initiated in 1946 by the Australian and New Zealand Association for the Advancement of Science (ANZAAS) and followed up by the Geological Society of Australia. The aim of the STRATINDEX and the Code was to provide a system which guaranteed that all geological names used in the Australian Geological literature and on published maps were formally registered and properly defined. The STRATINDEX continues to provide a lexicon of all geological unit names and has traditionally been used for establishing unique new names and researching the historical use of existing names.

What is the key information contained ?
For each stratigraphic name, information is stored on currency, status of unit description and location (State). If known, location (map sheet), geological province, age, thickness, parentage and lineage data is also recorded (see Figure 1). Misspelt, superseded and obsolete names are systematically recorded and maintained within STRATINDEX and are marked with replacement names as soon as these are identified.

For those units with a definition card, extra information is available on type section location, unit description including full lithological description, geographical distribution, relationships with other units, age (and evidence for the age) and other relevant information. The derivation of the name is also recorded as well as synonymy and previous usage of the name. For sedimentary units a detailed measured section may also be included.

All published references to each stratigraphic name are also recorded, along with an indication of the amount of description (see Figure 1). For each reference information is also recorded in STRATINDEX on the State/Territory, geographical place names, 1:100 000 and 1:250 000 map sheet areas and geological provinces covered by the publication.

12978 **Y** Mount Norna Quartzite QLD ***Type state***: QLD
Entered: 01-JAN-88 by GEODX ***Status***: Defined
Defined in Geodx reference: 79/19701
First published in Geodx reference: 79/04754
Definition card: Y *Stratname category*: Unknown or process pending
Rank: Formation, beds
Previously known as: Mount Norna quartzite
Modified: 05-SEP-95 by STRATA
Comments: Type section follows Weatherly Creek on the east side of Snake Creek Anticline, Cloncurry 1:100,000 map sheet.
Age: Palaeoproterozoic - Palaeoproterozoic
Geological province: Mount Isa Inlier
Section/drill hole number: 7064
Maximum thickness (m): 2150
Parent unit: Soldiers Cap Group
Overlying unit: Toole Creek Volcanics conformity
Underlying unit: Llewellyn Creek Formation conformity

Geodx No.	Usage	Status	Comments
79/04754	P17	Mentioned	
79/19701	P601	Defined	
82/22378	P81	Briefly described	
84/24309	Map legend	Mentioned	
90/26900	Table 1 P492	Fully described	
J0102/04	P601	Defined	Name for Weatherly Creek Quartzite.

References from Geodx

90/26900 Beardsmore T.J. Newbery S.P. Laing W.P. 1988
The Maronan Supergroup: An inferred early volcanosedimentary rift sequence in the Mount Isa Inlier, and its implications for ensialic rifting in the Middle Proterozoic of northwest Queensland.
Precambrian Research
40/41 P487-507

Figure 1. Example of range of data available in the three sections of a stratigraphic names report.

How is the information stored ?

As the STRATINDEX was established well before the digital age, a series of card file indexes were used initially to cross reference stratigraphic names, published references, sheet area, basin and subject. State lexicons were also published between 1958 and 1966, an index volume for mainland Australia in 1975. An Antarctic Lexicon was finally published in 1983. The card file system was closed in 1979 and the Stratigraphic Index went digital. It has been upgrading and improving ever since, although most of the pre-1969 data is still only on cards.

The modern data is currently stored on AGSO's ORACLE Relational Database Management System (Lenz, et al, 1996). Most of the information stored in the STRATINDEX Database is accessible to the public through AGSO's WWW Geology pages. Within AGSO, more flexible access is available through a series of menus, forms and reports (see examples shown in Figures 2, 3, 4, 1). Figure 4 also illustrates the extent of geographical information that is stored for each reference. This geographical information enables searches to be made for references on a particular location or map sheet and in turn back to Stratigraphic names within a particular geographical area. Validation triggers and pick lists (Figure 5) operate on many fields to assist with accurate data entry and make searching easier.

In the last two years, definition information has also been stored digitally, but is not yet in a properly accessible database. So far no attempt has been made to convert existing definition cards to digital format, but much of the information can at least be found in published references.

Does it have any value in the digital age ?

The STRATINDEX is becoming increasingly recognised as a powerful digital data set which has the capacity to both enhance and validate any digital database or digital map. Because it provides a unique coding for all stratigraphic units in Australia, it has the ability to act as an authority table in providing, automatically in digital form, the name that is current and the correct spelling of that name. Further, as the STRATINDEX also provides the parentage of any unit, the geological province and the age, additional information can automatically be added to any digital data set.

In reality, the STRATINDEX has already proved to be a backbone to several GIS packages developed in AGSO, particularly those that are compiling more than one 1:250 000 or 1:100 000 scale map sheets into a single seamless coverage. Within the Australian Mineral Systems Project of AGSO the STRATINDEX has been used for the following purposes:

1) *To provide a unique numerical coding for all Australian geological units.*
Traditionally in a geological map, map symbols, which are essentially 3 or 4 letter mnemonic codes, are used to provide a unique abbreviated symbol for a unit on a map face. Rarely, when a mapping project compiled a series of paper maps over an entire region, was an attempt made to ensure that the letter coding was unique throughout all maps of the region. In addition, map

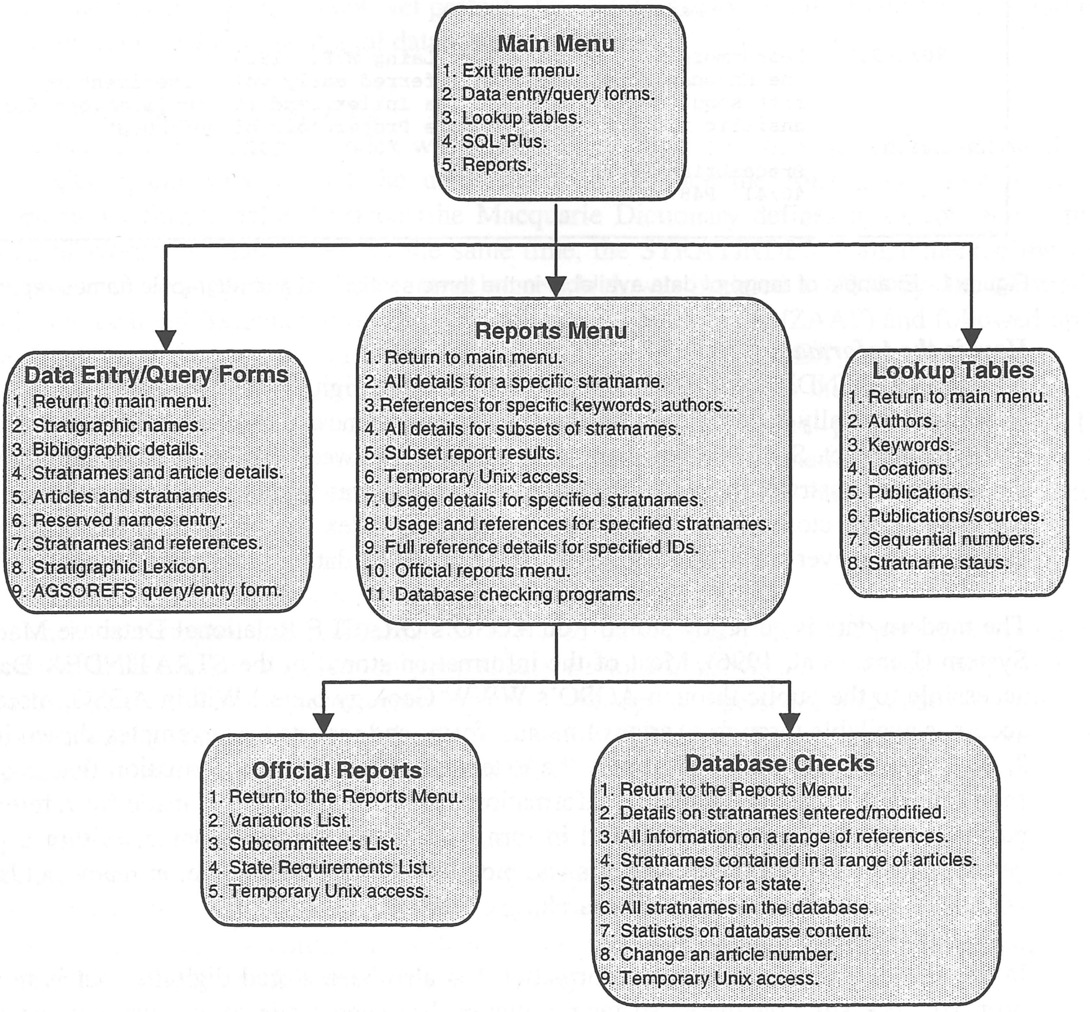

Figure 2. The three levels of the Stratigraphic Names Database Menu.

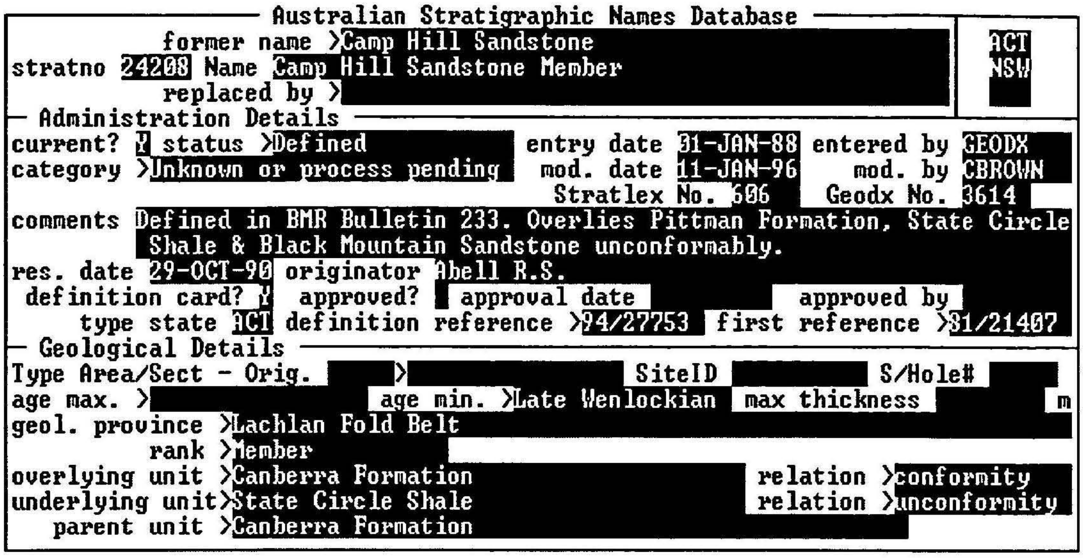

Figure 3. The Stratigraphic Names Form.

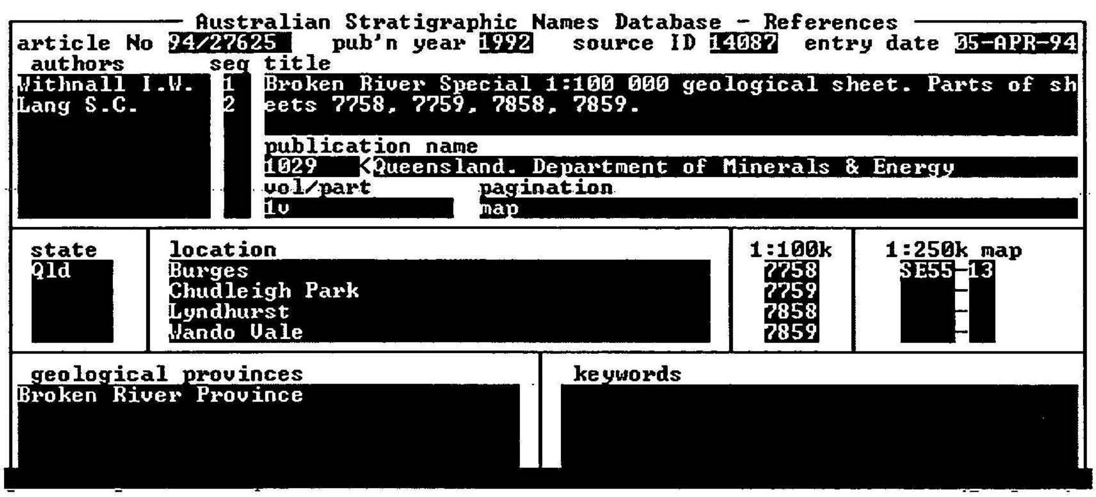

Figure 4. The Bibliographic Details Form.

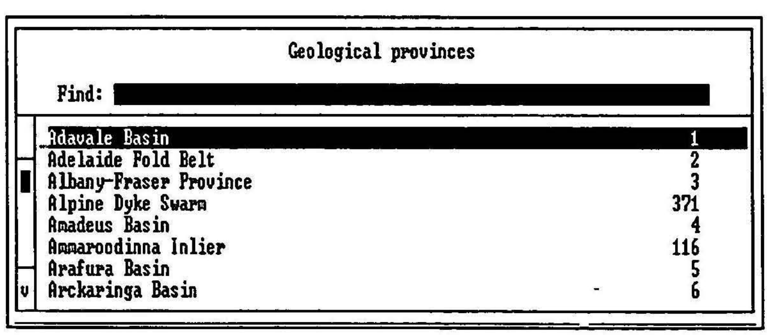

Figure 5. Part of a Pick List

symbols were rarely consistent between maps of different scales, even for the same area. This lack of a unique coding system has been a major inhibitor to compiling seamless digital coverages comprised of more than one map.

The power of digital maps is that they can be compiled as a seamless coverage, and in fact a seamless digital coverage of Australia at 1:250 000 scale is an achievable objective. Also data sets produced at different scales and levels of complexity can readily be combined. However, at the start of the AGSO Mount Isa 1:100 000 (which compiled 32 1:100 000 maps) and the Tanami 1:250 000 (which complied 15 1:250 000 maps) digital maps projects, it was quickly realised that the letter codes within these regions were not unique. As the aim of both these projects were to create a seamless coverage, unless a unique coding could be provided this coverage would not be 'seamless'. The number of units in the Mount Isa Inlier prohibited developing a unique letter coding. However using the numeric code (stratno) provided by the STRATINDEX automatically provided a unique code for all units across all 32 1:100 000 map sheets.

The onus therefore is now on those who produce digital maps at any scale to ensure that all units, even down to the member level are registered with the STRATINDEX. Further, at the start of any regional mapping project it is advisable to **compile a centralised list** from the STRATINDEX of all existing units within the proposed mapping area, and for the duration of the project to keep adding to this centralised list as new units are added to the digital data set, or existing ones are changed or even dropped. This centralised list will ensure that all units within the project area, both existing and proposed, will always have a unique code.

2. To provide a means of speeding up digital map compilation, particularly in major 'seamless coverage' compilations

In building a digital geological map it is common have items such as the Formation Name, Group Name, Member Name and age of the unit as attributes to the polygons. These items are already stored within the STRATINDEX data base. By embedding the STRATINDEX code (stratno) as one of the few essential attributes in the polygon attribute table (.pat), and then developing the main geological attributes in a data base system based on the STRATINDEX code, external to the GIS, the time spent building the polygon coverage is greatly shortened. The information developed in a data base environment external to the coverage is much easier to manage, attributes can be validated by authority tables as they are added, and the primary data exists in the one place only and is not duplicated across several .pat files attached to multiple coverages. The expanded attribute file is then merged with the completed polygon coverage for the GIS analysis phase.

Thus by embedding the STRATINDEX code in the .pat, it enables a much shortened .pat file to be used in the compilation phase, which in turn speeds up the building of the file.

3. To provide a rapid mechanism for validating (if not providing) information required in the legend on any geological map or in any data base (e.g., age, parentage etc).

Many project databases and digital geological maps record information that is also stored as part of the STRATINDEX data base, in particular the parentage (Member, Formation, Subgroup, Group, Supergroup) and age. Getting the spelling and parentage of each of the units for each individual entry in any database correct can be an editorial nightmare. By simply storing the STRATINDEX code in any database or digital geological map which requires such information, and then linking to the STRATINDEX, this information can automatically be imported into the digital data set, and because it has already been validated within the STRATINDEX database, the information does not require further editing .

4. To provide a mechanism for rapidly updating any previously released or archived digital data set.

By ensuring that the STRATINDEX stores the latest information on parentage, and in particular age, of any unit, the STRATINDEX code can be used to fairly automatically update existing or archived data in a map or project database. For example, in areas where new geochronological determinations significantly change the interpreted ages of units in existing data sets, then by ensuring that the STRATINDEX stores the latest age information (by directly linking to geochronological databases such as OZCHRON), the new age information can readily be incorporated into any existing data set which is directly linked into the STRATINDEX.

5. To provide a much more comprehensive map 'legend'
Traditionally the amount of information that can be stored in the legend of a geological map has been restricted by the physical dimensions of a map, which in turn means that only a few words can be used to describe the dominant rock types present in each unit. However, in a truly digital map, which has the STRATINDEX code embedded in the legend, all existing digital information within the current STRATINDEX can be linked into the legend of the map. When the definition cards are fully digital, these, as well as the bibliographic references, and also any other database which uses the STRATINDEX code (e.g., outcrop description information in the OZROX field database (Ryburn, et al, 1995)), will also be accessible as information attributed as part of the 'map' legend.

6. To provide a means of readily generating additional maps (e.g., age maps, province maps).
Once the digital map is attributed with the STRATINDEX code and the relevant information is transferred to the polygon attribute table of the digital map, it is then possible to easily generate additional maps. The two most obvious ones are age maps and province maps which are readily created by simply coding the map on the age or province attribute.

7. To provide a mechanism for generalising maps and for easily generating small scale maps, whilst still preserving the precise geographic integrity of the bounding units.
Because the STRATINDEX can provide the parentage of all units from Member through to Formation, Subgroup, Group and Supergroup, it also provides a simple means of generating small scale maps. If all units in a digital map are coded with the STRATINDEX number, then the map can be plotted at the most detailed level of stratigraphy (*ie.*, Member status) for 1:10 000 scale maps. The same data can then be easily generalised and plotted at 1:500 000 scale by simply coding the map on the highest level of stratigraphy (*ie*, Group or Supergroup status) and then dissolving all internal boundaries (Figure 6). This methodology preserves the geographic integrity of the main bounding units between groups and thus ensures that maps from the same area at different scales can then be overlain on top of one another.

Most commercial GIS packages have a function that allows for changing to larger scale maps as the data are zoomed in to greater detail. Usually the large and small scale maps of the same area have been generated at totally different times, or else the small scale map has been generated by either manually and/or digitally generalising the larger scale map (*e.g.*, the regional 1:500 000 scale map has been developed by generalising 1:100 000 data). With this method, the geological boundaries of all the units do not have the same precise geographic coordinates. However, by using the STRATINDEX to combine units into groups, geological boundaries between major groups preserve the same geographic coordinates. Thus within a GIS package, when 'zooming in' to look at an area in more detail, these boundaries do not change coordinates.

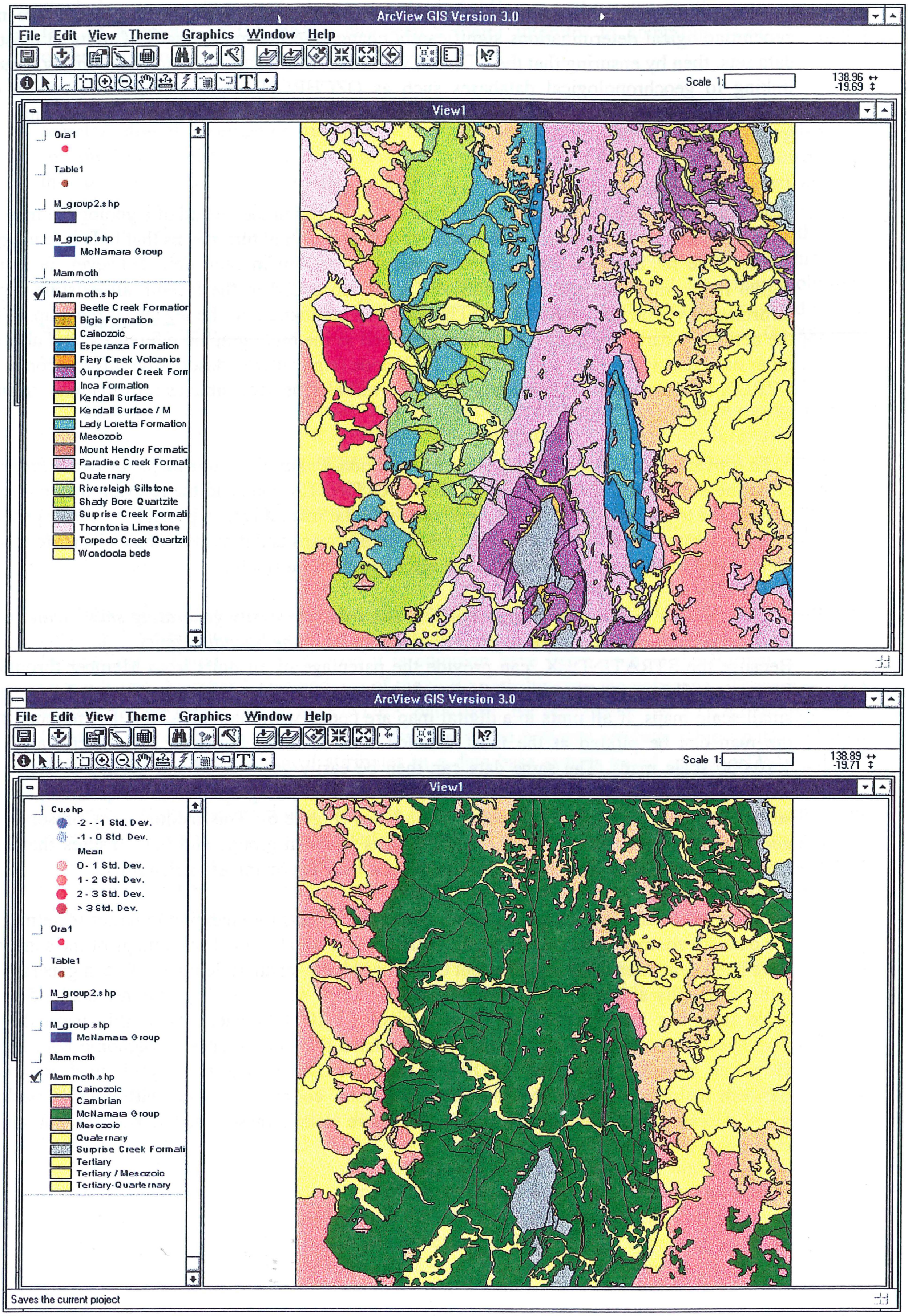

Figure 6. Same map plotted a) in detail at Member level, and b) generalised using Group and Supergroup

8. To provide a common element for transferring polygon attribute information pertaining to a defined geological unit from one digital map to another, regardless of scale.
Various methodologies have been developed for getting geological information that is usually provided only in reports and map commentaries into searchable attributes attached to the relevant polygons. One such methodology, described by Wyborn *et al.* (1995), involves simply generating a spreadsheet in EXCEL or as a table in a relational database such as ACCESS or PARADOX in which individual attributes (*e.g.*, dominant rock type, mineralogy, environment of deposition, types of mineral deposits) are stored in individual columns. These are then linked to the map using a map symbol code which is unique for each map or package. The disadvantage of this method is that the information is then attached only to the particular map or package that was developed for a specific purpose. However, if the table of additional attributes also incorporates the STRATINDEX code for each unit, then because the STRATINDEX code is unique for all of Australia, the information can be readily transferred to any other maps that are also coded with the STRATINDEX code. These maps can be of any scale. This methodology also allows the rapid transfer of any information on a public domain map to the confidential or proprietary maps of any company.

This methodology also ensures that the voluminous amounts of relevant information that is usually only available in accompanying hard copy reports or as scanned text attached to the digital map can become searchable attributes attached to each of the relevant polygons. This vastly enhances the useability of the map and any other data sets that the information can be linked into via the STRATINDEX code.

9. To provide a national standard facilitating the transfer of digital data between and within organisations.
In reality, the Stratigraphic Index of Australia, by providing a unique coding for all geological unit names in Australia, automatically becomes a national standard and a national authority table which facilitates transfer of data between and within organisations.

Can I only register formal lithostratigraphic names ?
Despite misconceptions that it only handles sedimentary units defined on lithostratigraphic principles, the STRATINDEX has always recorded igneous unit names and now handles parentage for these units (defined on the basis of chemistry in terms of suite and supersuite), and can also record unnamed units from published geological maps. We are also considering how to accommodate sedimentary rocks defined on sequence stratigraphic principles in the STRATINDEX. Its horizons are rapidly expanding and perhaps the name should be changed to the Australian Geological Names register ?

What are the limitations of the Australian Stratigraphic Index ?
Currently the main limitation is the number of geologists who think that in the digital age it is totally irrelevant and 'old hat' !! Conversely, those who see its potential value in digital data sets have given invaluable assistance by checking and providing additional data to update current entries. Having done this, they can then take full advantage of the capabilities of the data base in their own GIS package. Please note: constructive criticism and help is always welcomed **and we accept that in its current format the data base is not perfect and that many attributes are not completely filled in for all units throughout Australia.**

Perhaps in reality the greatest limitation is the information explosion in the geological literature combined with an increasing number of geologists that wish to access the various types of information stored within the STRATINDEX database. Technology has changed the way inquiries can be handled, but with an average of more than 11 inquiries a day just to our WWW access, that is just as well. Many other inquiries still need to be dealt with more personally. Some of the recent special new Government Geological Survey initiatives, such as the NGMA, first create an explosion of inquiries, then later, publications. Technology has not yet reduced the work involved in indexing publications, but it has made them much easier to produce (in particular the cut and paste function!). Also, although data entry techniques have changed and improved, the pressure to record extra data for extra purposes, has proved irresistible. The overall workload has resulted in a serious indexing backlog of new material, and the continued existence of the card file for most of the pre-1969 data. Despite the increase in the amount of information both to be stored within the database and to be accessed from the database, staffing levels have not increased. When the data base was established, as card files and State Lexicons, permanent staff were appointed in several State Surveys, and in Canberra. Over the years nearly all these positions have evaporated.

None-the-less, a number of temporary staff have been employed to address the indexing backlog problems over the years, whenever funding is available. It is also hoped that by converting as much of the database into digital format as is possible, then the database itself can be more efficiently run. By the end of 1997 we are optimistic that the current temporary staff will make major inroads on the indexing backlog and also in transferring a significant proportion of the 44 filing drawers of reference cards into the digital database. We also plan to provide a digital registration card for new units at our WWW site.

The next major step will be to enter the full definition cards into a properly structured digital database. These definition cards are a major resource on Australian geology as they contain comprehensive descriptions of defined units including the coordinates of the type locality, the geographical distribution of the unit, a very detailed lithological description, the age, a summary of rock relationships and key references: for sedimentary units a measured section of the type area may be included as well as thickness measurements. The information on these definition cards could be stored as simple word processor files or as HTML. However, the ultimate aim is to have all of the information contained on these cards stored in an effective structured digital database in which all these items are stored as searchable attributes that are fully validated by authority tables (ie., a minimum of free text fields). Designing such a data base will not be a trivial task, neither will entering all of the information on the definition cards. However, once all type descriptions are effectively digitally recorded, it should be possible, in conjunction with the new digital geological map of Australia, to search and locate all known occurrences of graphitic shales, or hematitic sandstones or whatever other groupings of geological units might be of interest to the exploration geologist.

Where can I obtain data from it ?

AGSO's World Wide Web pages are a good place to start. From the home page (URL http://www.agso.gov.au), move on to the Geology page and then choose the option - The Australian Stratigraphic Names Database *online querying.* If you need further information, or don't have WWW access, or can provide further information to accurately update the data base please contact Cathy Brown (email: cbrown@agso.gov.au, phone: 06 249 9535, fax: 06 249 9971 or write to the Australian Geological Survey Organisation, GPO Box 378, Canberra ACT 2601). The data base can also be purchased as either a complete Australia wide listing of all current names, or as a listing of all names used within a particular state: contact the AGSO sales centre.

Acknowledgments.

Many thanks are due to the quiet 'backroom' brigade who faithfully recorded information in the Australian Stratigraphic Index over the last 46 years to make it the 'National Treasure' it is being increasingly recognised as. This paper is published with the permission of the Executive Director, AGSO.

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PROJECT VERSUS CORPORATE INFORMATION AND THE ELECTRONIC PUBLICATION DILEMMA

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The increasing emphasis on project management and the inexorable change to electronic representation of information are creating headaches for information providers like AGSO. Projects must do more than just produce static electronic products. They must endeavour to get their information into standards-based systems that remain on line and up to date with respect to data models and technology. 'Publish or perish' is rapidly becoming 'go on line or perish', but corporate support is still needed to maintain databases, Web sites and standards. Projects cannot hope to do it all on their own.

Introduction

Most people who have worked for large (say >100 people) organisations in government or private enterprise will appreciate there is often a tension between corporate objectives and the immediate goals of workgroups or projects. The project is quite rightly focussed on short-term goals and getting products out the door on time and within budget. For most projects the best route between A and B is a straight line. The corporation may be concerned with longer-term strategic goals — with quality, image, standards, risk, security and style. It will often impose its corporate requirements on the project. The straight line is bent a bit. In any given situations there is usually a balance between the two sets of requirements that keeps everyone happy and the companies prosperous.

Sometimes, though, the pendulum oscillates wildly from one extreme to the other, from extreme centralisation to complete devolution. We have seen a little of this in government in recent years, and the Howard government is now trying to outsource everything that is not securely tied down. On the computing and information side, the centralised computing of the sixties and seventies gave way in the eighties to the distributed, do-it-yourself computing of the PC. To some extent that trend has been reversed with the rise of the Internet and Web, and the need to coordinate Email and other corporate information resources. GIS, on the other hand, has largely (but with numerous exceptions) been a project tool that has only recently begun to take on corporate overtones.

With the onset of the information revolution and the inevitable change from paper-based information systems to online electronic methods, signs of stress are beginning to appear in what were previously finely tuned balances between the project and corporate perspectives. As was recently spotlighted in an article in Business Review Weekly (Plunkett, 1997) as "Internet Apathy", Australian management, by and large, is not switched on to the implications of this revolution, and how radical are the changes it will bring. This paper examines some of the ramifications of this revolution and how it will affect information organisations like AGSO.

The Paper Information Cycle

Not so long ago the products of an information factory like AGSO were mostly on paper — except for the odd audio-visual presentation, like the one this paper is being written for. Paper products included published and unpublished reports, maps, articles, monographs, etc, that were sold or given away and ended up in libraries, company archives and peoples' private bookshelves. Published reports, articles and maps went through a well-established process of peer review, editing and general quality control before being released to the public. It was ultimately a corporate responsibility to ensure that all products were up to scratch and reflected the prestige that the organisation liked to think it deserved. In AGSO, all publications were vetted by the Director before being released.

In the paper information cycle the products are static — frozen at a particular point in time. Even annual reports are static in that sense. Products may sell well when they first appear, but sales tend to drop off asymptotically with time. Notwithstanding, some paper products, like maps and Bulletins, remained a valuable source of information for a long time. Large numbers were printed and stocks were kept for many years. This resulted in considerable warehousing costs, and AGSO has had to thin its stocks of old publications.

Nevertheless, most paper products can still be found in libraries and archives around the country. If one is prepared to try hard enough, almost anything ever produced can still be found. When it comes to mineral exploration data, companies spend many millions of dollars searching for information in the still largely paper-based archives kept by State geological surveys and mines departments (Porter, 1992).

I suppose there is an ultimate death for all paper products, hastened in some cases by acid paper, but most Australian paper products have not yet reached this point. Before this becomes a widespread problem one would hope that most of the important paper products are transferred to some other medium, such as microfiche and magnetic disc. The electronic capture of state exploration archives has already begun (Brookes, 1995, Beams, 1997).

The Electronic Information Cycle

The problem with trying to describe the electronic information cycle is that nowhere is this cycle well developed and mature. In fact it may not really be a cycle at all, but rather a linear process stretching off into infinity. We are all in the middle of trying to change from a paper based regime to an online world being brought about by the information revolution. Although the ultimate shape of a post information-revolution world is not yet absolutely clear, the major directions in which we are moving are now reasonably well understood. Just as most of the mechanical devices used in the modern automobile were already known by the turn of the 20th century, most of the technology required by the online revolution is probably now with us. No doubt this technology will be greatly refined and developed over the coming decades. We are right in the thick of a period of rapid evolution. Things may stabilise a bit in a decade or so.

For the geoscientist the old adage about 'publish or perish' will still hold post information revolution, but will be modified to 'go online or perish'. Not only will geoscientists have to place their reports, papers and maps on line, but they will also have to make ***all*** their basic data permanently available via the Information Superhighway (but not necessarily free!). In the case of confidential company information, substitute the word 'Intranet' for Information Super-Highway. The Information Superhighway currently means the Internet, mainly the World Wide Web (see Fig. 1), but also the private Intranet part that hides behind the organisational 'firewall'. Not everything needs to be instantly online — voluminous material like GIS, seismic and airborne geophysical data can be made available via overnight Email — but almost everything the geoscientist now produces can be transmitted electronically. The solutions to problems of data encryption and secure commercial transactions on the Web are already to hand, but not yet widely adopted. They will become commonplace over the next few years.

Although the medium is changing the basic processes are not. We still need intellectual property rights, peer review, editing, graphic design, quality control, production scheduling, marketing, etc, but now the whole production line can be fully automated, with project management, data management, metadatabases, groupware, change control, messaging, Email, scheduling and publication software all capable of being brought to bear. No longer can reviewers, editors or publishers sit on a product for too long — automated systems can be instructed to bypass them if they take too long, leaving a black mark in the process!

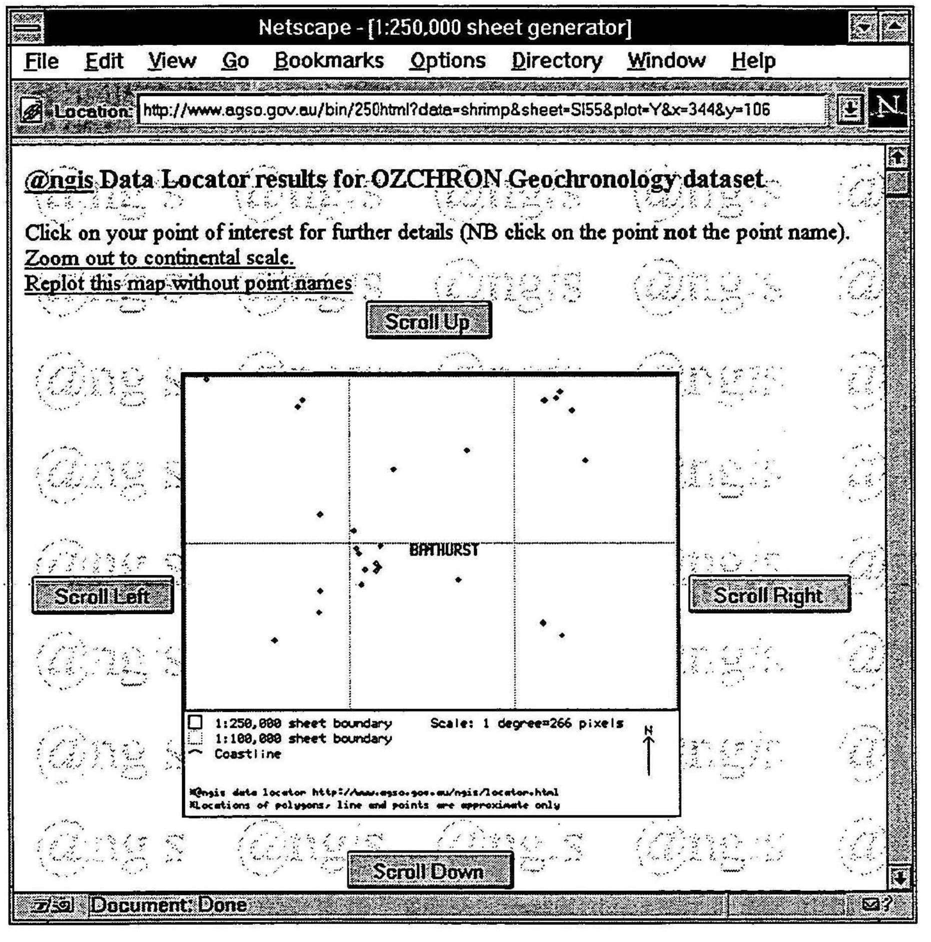

Figure 1. Points from the OZMIN geochronology database plotted on the Web by the @ngis Data Locator (Root, 1997). The Bathurst 1:250 000 sheet is shown. Sample information may be obtained by clicking on individual points.

There is, however, one class of product that has no paper-based equivalent, and that is the evergreen database — the corporate, state or national database that is always online and always up to date. This does not fit the static product cycle, in that usage or sales of data should normally stay constant or increase. With the advent of the Web, such databases are enjoying a new lease of life, and their importance will continue to increase for some time to come. Geoscientists are contributing more and more data or metadata to such databases.

No doubt some will find this all a bit hard to swallow, in view of the current state of corporate networks and the Web. However, I am sticking to my guns on this one, as ultimately the economics of going completely on line will win hands down. The logic of it all is already beginning to become apparent to a great many people. The experience will follow. That is not to say we don't have any immediate problems — we have plenty.

The *Status Quo*

Right now we appear to have the worst of both worlds and a bloated infrastructure required to support both the old and new cycles. Paper-based methods are still with us, but feeling the pinch from reduced resources. The corporate infrastructure required to support the paper information cycle is being cut back — editorial and library staff reduced, publications, marketing and sales outsourced and AGSO's Journal amalgamated with the Australian Journal of Earth Sciences. At the same time, the resources needed to support the electronic information cycle are insufficient, or not yet synergistic enough, to cope with the demand for computing and online services. Geoscience information is extremely diverse, and requires a much wider range of systems and software that one would normally find in a bank or government policy area.

We are still struggling with proprietary software systems, including GIS, that generate massive amounts of data that are difficult to integrate properly with standards-based online systems. Such data often languishes on tape, gradually loosing its magnetic signature and rapidly becoming obsolete with respect to the latest software. Unattended, such tapes can become useless in just 5 years. Such data should ideally be converted to national of corporate standards and then placed in a database system that will automatically keep it up to date, on line and backed up. Such systems can be disc-based, or even tape cartridge silos with the data automatically cycled to prevent loss of signal. Unfortunately AGSO's first attempt at a mass storage system based on the UNIX filing system has officially been declared a failure.

We are still using the UNIX filing system at the level of the UNIX operating system to try to solve our data management problems. UNIX was invented nearly 30 years ago and is now totally inadequate on its own for the sort of data management problems we now face. Database management systems (DBMSs) were developed precisely to solve data management problems that the basic operating systems could not handle, and they now support a wide variety of data types, including those required by GIS. ESRI's Spatial Database Engine, which runs on Oracle 7, would allow us to place standard national GIS datasets, such as 1:250 000 geology, permanently on line. In a similar vein, the New South Wales Land Information Centre has recently adopted Informix's Universal Server to manage their diverse datasets. Web and Intranet servers in organisations like AGSO need document-cum-image servers and publication software to manage their static Web publication requirements. All we have at present is the basic Oracle 7 relational DBMS, and a home-grown AEGIS change control system for Web development that operates at the UNIX command level.

Project versus Corporate Information in AGSO

The current trend in AGSO is to devolve as much as possible to the project. Project management is now heavily emphasised and considerable resources are being put into a custom-developed project management information system (PMIS) that is not yet operational. The service areas of the organisation, including the areas with information management expertise, are the providers to the purchaser projects, or the projects may buy the services they need from outside the organisation. Projects are supposed to be totally client focussed. Some projects, particularly in the petroleum area, are focussed exclusively on large commercial clients. Cost recovery is thereby maximised.

On the other hand, AGSO's computing facilities are being centralised to a greater extent than before, with considerable control on purchasing and on most things to do with the network, disc resources and multiuser systems. A 'call centre' (help desk) has been instituted. Some of these areas could conceivably be outsourced in the future. This reassertion of corporate control on computing systems appears to be partly a reaction to recent infrastructure failures, particularly in UNIX networks. It does not yet extend much to information management, and most projects seem to be free to adopt the information management systems, standards and strategies they see fit. This is rather like fixing the plumbing, and then not ensuring that everyone washes! To be fair, Arc/Info is used by many projects and Oracle is tolerated by some.

When it comes to information management the prevailing attitude seems to be that the projects can look after their own standards and quality. As on the assembly line where quality circles are solving quality control problems, so too can projects, by focussing on the problem at hand, achieve best practice. Unfortunately this analogy does not really hold, as the main problems in data management can only be solved by all parties getting together and agreeing on optimal semantic data models and transfer standards. This is a difficult and time consuming process — one that is not well understood by many managers or geoscientists. It should take place in a wider context than most individual projects encompass (see the description of POSC below).

At the same time as this rather gloomy scenario is unfolding, there have been some recent success stories in AGSO. At the instigation of the former Chief of Environmental Geoscience and Groundwater, projects involved with hydrogeology and water quality came together to develop a data model covering all things to do with water, including borehole and surface sources and laboratory analytical data. This has now been translated into the GWATER relational database, with an attractive and functional front end and the potential to keep all water data online forever. Similarly, the recent OZMAR database, which was developed for AGSO's Law-of-the Sea Project, has the potential to manage most of AGSO's huge volume of marine geoscience data. In this case we have reached the limit of our current physical resources, and its future will depend on money for faster systems, more RAID disc storage and, of course, the support of management in the appropriate areas of AGSO.

The problem we face with a totally project-oriented approach to data management is that long-term management and preservation of information is at risk. Projects are of limited duration — typically two to four years — and all resources are focussed on getting products out the door on time and within budget. Unless corporate data-management considerations are adequately scoped and resourced at the time a project is formulated there is a grave danger that the data generated will simply vanish into thin air once a project has finished. It is no longer good enough simply to hand over a bunch of tapes and floppy disks at the end of a project and say "Here, you look after these". There is a good chance that after a few years no one will be able to relocate and run the older software required to access the files, even if the medium is still readable. Data collected by an earlier AGSO coal project was put into the 'Status' free-text database running on a PC. When the time came to transfer the data to an Oracle relational database the discs could not be found, let alone translated. Only hard copy remains. Arc/Info tapes may be longer lived, but even here we face the problems common to all static products. We must endeavour to get our data into systems that are automatically kept up to date and permanently on line. Automated tape archives (silos) are not necessarily the full answer.

Unless corporate infrastructure is adequately resourced, there is a risk projects will go their own way with respect to information management. Traditionally, AGSO projects have tended to think they can handle all the prerequisites to producing a product — a sort of 'cult of amateurism'. GIS for example, was started as a project initiative and there is still not much corporate oversight of GIS in AGSO. There is also a danger that Web development may become fragmented if not adequately resourced. Individuals or projects, frustrated with the difficulty of getting material on the regimented corporate Web site, may be tempted to set up 'bedroom' Web sites outside the corporate firewall. They will then want to purchase ISDN phone lines into their bedrooms with project funds! A jack of all trades is a master of none, and geoscientists have to realise they are not necessarily experts in information management. Scientists, on the whole, are not renowned for their interest in information management as a subject — a greater depth of knowledge can commonly be found in a commercial business environment. On the other hand, geoscientist are often more knowledgable than most other scientists, due to the sheer volume and diversity of the data in which they have to deal.

Standards-Based Information Management

Part of the answer to the problems just outlined is to adopt, as far as possible, standards-based solutions to our information requirements (Berman *et al.*, 1995). In many cases the standards already exist at the national or international level. Witness the new ANZLIC (1996) metadata standard and the Spatial Data Transfer Standard (SDTS) for spatial land information (Hume & Miller, 1995b). However, cooperation between projects is still very much needed to establish the terms and domains to be used in the local database. In other cases, as in the water database described above, the affected projects and work groups should get together and develop a corporate data model that is satisfactory to all parties. In some cases, as in the Law-of-the-Sea Projects, one project may be responsible for a national data model. Database infrastructures should be developed corporately in close collaboration with the projects and people involved. Sufficient resources are needed to develop an attractive and functional front end to such databases, including any Web interfaces and online sales mechanisms. The data entered into the database can be considered permanently on line, as any future changes to the data model and software will almost certainly carry with them the existing data.

An important instance where the adoption of standards-based information management appears to be having a huge impact is in the non-profit Petrotechnical Open Software Consortium (POSC) set up by the exploration and production arms of the petroleum industry (du Castel & McLellan, 1995). POSC was started in 1990 by BP, Mobil, Elf, Texaco, and Chevron to try to rationalise the multitude of data models, systems and software then in force in the industry. On their account the lack of integration of data and systems was costing the companies hundreds of millions of dollars. The data models and other standards they have come up with, although enormously complex in themselves, already seem to be reaping a big harvest. According to the POSC business model promoted on the POSC Web site (http:/www.posc.org/), their standards-based solutions are now reducing the price of oil by between $1.00 and $3.00 US per barrel compared to the price that would have applied without the adoption of POSC standards. If these figures are to believed, the POSC standards should save a total of about one billion dollars US on the cost of production from Australia's recent discoveries in the Timor Sea — estimated to be 500 million barrels.

Now contrast this with the efforts to date by the Australian mineral industry to set standards. The AMIRA Geoscience Data Model project (Hume & Miller, 1995a & c, Hume 1997) has been motivated by similar admirable sentiments to those applying to the POSC consortium, but the resources put into it to date pale into insignificance in comparison with the POSC effort, and the time table seems to stretch out to infinity. Admittedly, the Australian mineral industry is a lot smaller than the combined wealth of the world major oil companies, but I would have thought that the standards issue would have been well worth the expenditure of a few millions of dollars. The potential returns are enormous. Similarly, the current GGDPAC (Government Geoscience Database Advisory Committee) initiative to standardise the electronic reporting of mineral exploration activities to the state government authorities has the potential to save the country hundreds of millions of dollars — perhaps billions — if carried out in the right way (see draft guidelines at *http://www.dme.nt.gov.au/library/ggdpac96.html#INTR*). Unfortunately the importance and urgency of the task does not seem to be filtering through to the right people. Another area where Australian politicians and bureaucrats do not yet seem to have woken up to the economic benefits is the Australian Spatial Data Infrastructure (ASDI) initiative (Nairn, 1997). In the United States the NSDI, on which ASDI is modelled, was launched by the President. The business case on the POSC Web site (http://www.posc. org/) has the sorts of arguments, approach and language that might be of use to convince people in high places.

Some Suggested Solutions

Efforts are currently underway in AGSO's Spatial Information and Mapping (SIMS) group to try to do something about the long term storage of Arc/Info coverages. Corporate standards are being established for GIS metadata, so that coverages are not put away without essential accompanying information about what the information is and how it was obtained. However, because of the obsolescence problem that applies to nearly all static electronic data sets, these measures are insufficient on their own. We are eventually going to need standards-based online methods of dealing with spatial data, so that standard datasets like the 1:250 000 geological coverage of Australia can be kept permanently on line and up to date. For this to happen we are likely to need a corporate spatial database system like ESRI's Spatial Database Engine, or Informix Software's Universal Server. As with the corporate relational databases, the metadata should be built into in the design of these spatial databases. The sensible way to tackle this initiative would be to start with a pilot project, and build up the effort slowly as experience is obtained and the technology matures.

Web publication of reports and articles is going to require some sort of document-cum-image server, combined with an automated corporate publication system. The present practice of painfully hand coding HTML documents and placing them and numerous separate GIF files into UNIX directories via a home-grown, command-driven change control system should give way to easier ways of placing documents on the Web. I believe there are already a number of commercial systems for handling exactly these sorts of requirements, as well as production of hard copy. Ideally, such a system should allow WinWord documents (or similar), including illustrations, to be sent on their way for peer review, editing, sign-off and final integration into the Intranet and/or external Web site. Whether the documents are held in WinWord format, Adobe Acrobat (PDF), HTML, or SGML is largely immaterial, as long as they are capable of being easily converted to any future standard that may become dominant.

The development of standards-based data models, as has already been described for groundwater and water quality, is clearly a very worthwhile exercise wherever it is possible. It leads to databases that are cross-project, long lived, evolving and easily integrated with the Web and probable future methods of automated marketing, distribution and sales. In some cases the standards being followed are developed in house, but in other cases we may follow some pre-existing national or international standard. Databases developed in house may later have to be refined to match external standards. In any event, cross-project cooperation is usually needed, or even projects specifically created to set up or modify the required corporate databases. For the maintenance of databases such as the Australian Stratigraphic Names Database a project is probably not the right setting. This is an ongoing service that is more in the nature of a library or information service, and such services should never be thought of as purely short term, start-and-end projects. With the automation of data sales via the Web just around the corner, such services could conceivably be self supporting (or even outsourced!).

For efficient, online management of a wide variety of data types, including GIS, images, video, documents, metadata and structured relational data, geoscience information organisations such as AGSO are ultimately going to require the services of a 'Universal Server' — such as the Informix Universal Server already mentioned, or Oracle's Universal Server based on Oracle version 8. Such severs are now being designed to deliver all types of data — both relational and object oriented — over the corporate Intranet or external Web server. Furthermore, the server provides the wherewithal to display and manipulate the data as well as the data themselves. It obviates the need for large amounts of software on the user's PC or Workstation. This is the so-called 'thin client' solution which is supposed to provide much cheaper solutions than are currently available. Let's hope it does!

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GIS ANALYSIS OF THE EFFECTS OF FOREST BIOMASS ON GAMMA-RADIOMETRIC IMAGES

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Abstract

This work relates to the interpretation of a geophysical survey in the Tumut area in New South Wales and has important implications for gamma-radiometrics interpretation in other areas. The study uses GIS layers (forest types, forest age, geology and elevation data) and Arc/Info functions to determine the gamma-ray responses for a unique forest type and age class. The use of the GIS was essential for 1) the analysis of spatial vector and raster data and 2) collecting statistics on large amounts of data. To reduce the variation due to gamma-ray source materials, specific geology and landscape parameters were also used to segregate the data. Only areas designated as granite bedrock were used and these areas were further subdivided into classes based on 1) values of slope and 2) the results of an algorithm designed to remove the attenuating materials. In pine areas, old forests reduce the gamma response by 13.5-20%. In native forest, Landsat TM was used to mask cleared areas versus dense forest for statistical analysis. In these areas, gamma-rays were reduced by 14.1-21.9%. The increase in gamma attenuation relative to pines is thought to be due to the nature of leaf litter in native forests. Results can be used to calculate relative attenuation coefficients which are compared with theoretical values. The study shows that a GIS can be a powerful tool for deriving information from the analysis of multi-layer spatial data sets.

Introduction

Airborne gamma-ray spectrometry (AGS) has been used for many years to measure the natural radioactivity of potassium, thorium and uranium, or rather the gamma-emitting isotopes in their decay series. The gamma radiation can only travel limited distances through both the air and soil or rock due to it's extremely short wavelength. These are in the range of 100m and 1m respectively (Griffiths & King, 1981). Airborne or hand held spectrometers measure the absorption of a γ ray photon by the emission of a flash of visible light. The scintillation is converted into an electrical pulse by a photomultiplier device. Although a range of energies are recorded, it is still common practice that only the energy windows for potassium (K), thorium (Th), uranium (U) and total count (TC) are used. Table 1 shows the typical data channels for an acquisition system.

Table 1. Data channels for an airborne gamma survey.

Channel/Element analysed	Isotope sensed	Gamma-ray energy (MeV)	Wavelength (nanometres)	Energy Window (MeV)
1. Potassium	40K	1.46	$8.50 * 10^{-4}$	1.37 - 1.57
2. Uranium	214Bi	1.76	$7.05 * 10^{-4}$	1.66 - 1.86
3. Thorium	208Th	2.62	$4.74 * 10^{-4}$	2.41 - 2.81
4. Total Count				0.40 - 3.00

Little practical research appears to have been done on the effects of vegetation on airborne gamma ray measurements. One study was performed by Glynn et al. (1988) looking at the problems arising from gamma ray measurements taken over forests covered in deep snow. Another (Kogan et al., 1969) reports that up to 15% of the potassium signal reaching the sensor comes from the biomass. Lavreau et al. (1991) recognise that moisture and dense vegetation effectively screen airborne data and this needs to be considered in the processing sequence.

Lavreau et al. go on further to say that satellite imagery can be of assistance by using it to calculate water/vegetation index images and using this to then correct the gamma data.

A helicopter survey over the Bago-Maragle region of NSW (Figure 1) in February 1996 resulted in a high quality AGS data set. The survey was flown at 80m and the spacing between flight lines was 200m. The region consists of steep hills with highland plains and is extensively covered with both native forests and pine plantations - some of a historical nature. In Bago-Maragle the State Forests of New South Wales (SFNSW) has plantations of radiata pine ranging from 1922 up to 1996 for the year they were planted in. SFNSW also produced the forest age class GIS coverage that was used in this study. The object of this study is to attempt to measure the impact that vegetation biomass, in particular radiata pine and native forest, predominantly eucalypt, has on gamma ray data collected by airborne methods. An estimation of how much the vegetation affects the signal may be used in future surveys to assist in interpretation and potentially correct the data. For this forum, another aim was to demonstrate the versatility of the GIS for analysing multi-layer information.

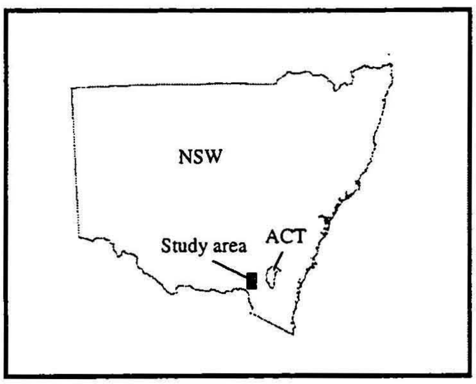


Figure 1. Location of the study area.

Methods

The data used for this survey consisted of four bands of airborne collected radiometric data; potassium (K), thorium (Th), uranium (U) and total count (TC), and an arc/info forestry coverage that includes both the species type and year that the plantations were planted. These layers were imported into both Ermapper and Arc/Info as required, usually using the arc commands either *gridfloat* or *floatgrid* depending on the initial format of the data.

To reduce variations in the data to be used, many sources of potential interference or variance were removed. This included only using data that was collected over the Green Hills Granite (includes New Maragle Granite) as identified on the Wagga Wagga 1:250,000 metallogenic map (Degeling, 1977). Likewise, only data that was covered by radiata pine with known planting dates were used.

An initial problem with the project became apparent due to the lack of a digital geology coverage covering the Bago region. The only map available was the Wagga Wagga 1:250,000 metallogenic map and this was not considered detailed enough to accurately identify granitic geology in the area. The problem was solved by using the K and magnetics images to define the granite/basalt boundary. Basalt has a low K value and a relatively high magnetics value compared to the surrounding granite. Areas containing geology other than granite or basalt were grouped in the northwest and south of the survey area so were also relatively easy to identify. Areas where non-granitic geology occurred were assigned a null value.

Layers imported into GRID included;

- granite mask (edited K image)

- radiata pine year of planting coverage - a layer that shows where radiata pines occur in the Bago region and in what year they were planted.
- K, U, Th, TC - 4 separate gamma radiometric layers that cover the Bago study region.
- DEM - Digital Elevation Model.

The granite mask was then imported into Arc/Info GRID and used to mask out all non-granitic areas on the 4 gamma data sets. This was performed by using a series of *con* and *setnull* statements in GRID. For example; *new_grid1 = con(mask, k_grid, -9999)* and then *new_grid2 = setnull(new_grid1 == -9999, new_grid1)*. A similar process using the radiata coverage was then used to mask out non radiata pine areas.

Classification by slope

To reduce the influence of soil variation in the various age classes two methods of dividing the data into classes were considered:

- percentage of slope
- mathematical removal of screening effects (attenuation modelling).

These are discussed in further detail below.

To produce the percentage-of-slope grids the *slope* function in GRID was applied to the DEM to create a grid representing percentage of slope for example; *slope_grid = slope(dem_in, percentrise*. The new grid was then used in conditional (*con*) statements to create 3 slope categories. They are: slope ≤ 10%, 10% < slope ≤ 20% and 20% < slope ≤ 30%. Values outside of these gates were assigned a null value using the function *setnull* in GRID as outlined above. Other slope classes were considered, for example, Soil Conservation Agency of NSW classifications (McDonald et al., 1990). Their classes appear more suited to flatter terrain than the steep terrain of the Bago/Maragle region. The *con* and *setnull* functions in GRID were then used to create further grids that contained K, U, Th and TC values only where granite and radiata pines occur.

The GRID function *zonalstats* was then used to classify these newly created gamma data grids according to the year in which the radiata pines covering the area were planted. The mean was calculated using the *zonalstats moment* option. For example; k_stats = zonalstats(age_grid, k_grid, moment). The result was a table in INFO that listed the year planted, mean gamma ray count for that year, standard deviation and number of values (or pixels overlain by a particular section of the coverage) for that year. All of the tables were then imported to a spreadsheet.

Attenuation modelling

This is a method developed for removing attenuation effects in multiband imagery. The technique applied to gamma-ray data (Bierwirth, 1994) was adapted from work originally aimed at removing water depth effects from optical remote sensing imagery (Bierwirth et al, 1993). The idea was that an image could be derived where attenuation (ie. vegetation) effects were largely removed and variations in parent materials remained. This image then could be used to reduce the "noise" associated with geological and soil factors.

The absorption of gamma-ray photons by an attenuating medium is given by:

$$I_{ri} = I_{0i}\, e^{-u_i r} \qquad (1)$$

where I_{0i} is the intensity of gamma-rays emanating from a covered source in wavelength i and I_{ri} is the intensity after a distance r has been traversed through material with a linear absorption coefficient, u. By averaging over all wavelengths available, the depth of attenuating cover, r, can be represented by:

$$r = \sum_{i=1}^{N} \frac{\ln I_{ri}}{-u_i N} - \sum_{i=1}^{N} \frac{\ln I_{0i}}{-u_i N} \quad (2)$$

where N is the number of wavelengths. The second term is set to a constant, zero in fact. This is roughly equivalent to assuming that the average intensity of radiation sources is the same and that variations in the amplitude of the spectrum is due to attenuating cover. The derived attenuating thickness (r) can be calculated using band values (I_{ri}) and attenuation coefficients (u_i) derived for the appropriate density (Grasty, 1979). The value for overburden depth can then be substituted into equation 1 to derive the source intensity (I_{0i}) for each element and effectively remove attenuation effects. For example, the area of the K image before and after application of the algorithm is shown in Figure 2.

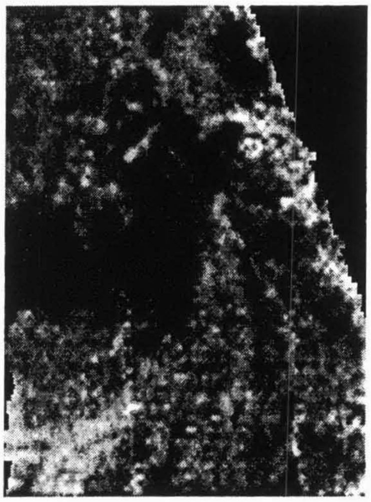
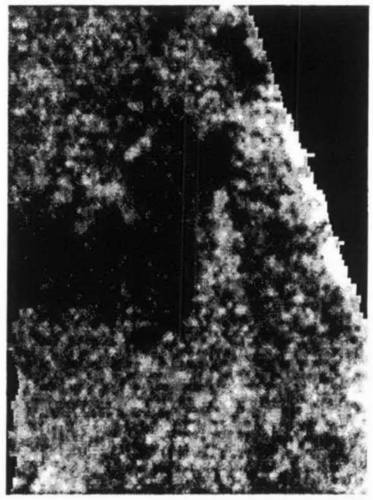
(a)  (b) 

Figure 2. Airborne K data before and after attenuation modelling. The powerlines (pale linear features) that are visible in (a) are not visible in (b) due to the effects of the surrounding vegetation having been removed.

The data set produced by the attenuation modelling was used to create 4 divisions of the gamma data according to how much it had been attenuated during the modelling stage. The *con*, *setnull* and *zonalstats* functions were used in GRID to produce a spreadsheet of the mean gamma data classified according to the attenuated values and the radiata pine year of planting.

The data in the spreadsheets were further edited. This consisted of removing data prior to 1960. Data prior to 1960 was removed because radiata pine trees are normally harvested after 25 - 30 years (pers. comm. Bob Gay SFNSW) and also because the data was relatively sparse in the number of counts in age classes prior to 1960. Analysis was also performed on the gamma ray data where a powerline clearing goes through native forest. Mean values were determined for powerline areas and adjacent forest. Results of this analysis are presented later.

Results and analysis

Line graphs were created to give a visual representation of the year of planting versus the gamma ray signal for unclassified slope (Fig 3a-d) and attenuation ratio classes (Fig 4a-c).

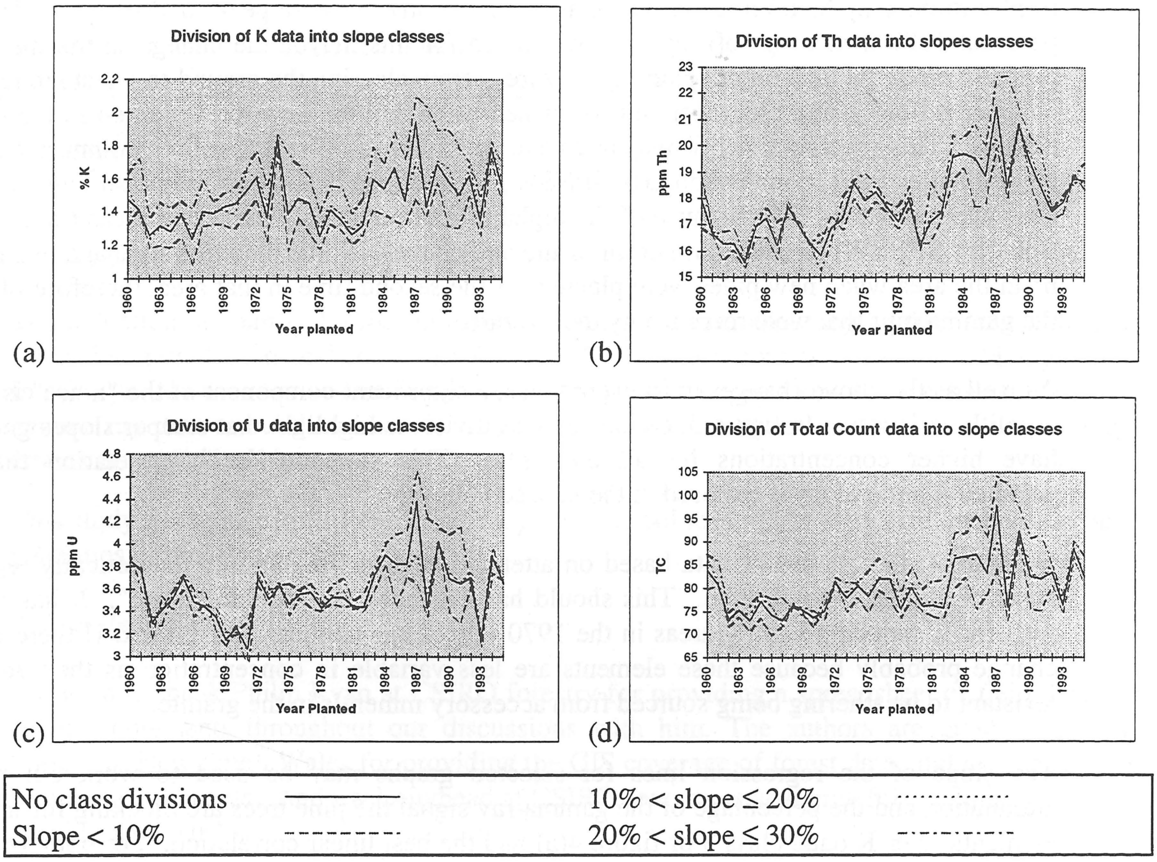


Figure 3. Mean gamma-element concentrations for vegetation age class and various slope classes (a) K (b) Th (c) U (d) total count.

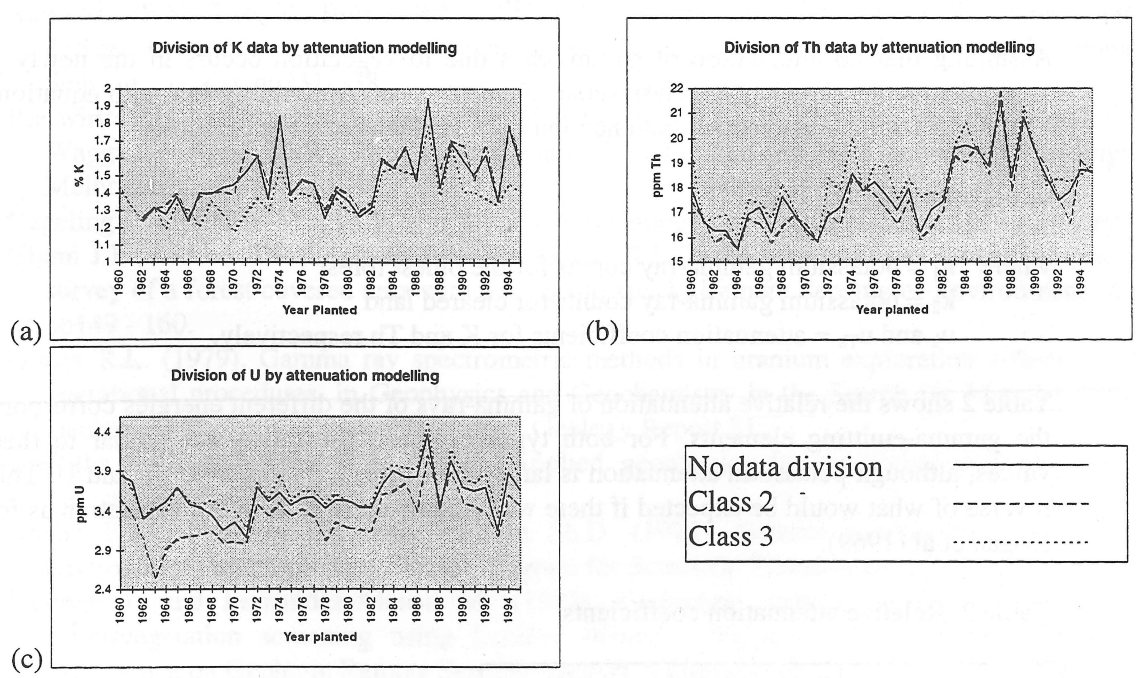


Figure 4. Gamma data, K (a), Th (b) and U (c), plotted for classes defined by data ranges in corrected (by attenuation modelling) K, Th and U images. Only classes 2 and 3 of 4 classes are shown here because classes 1 and 4 are open ended and subject to low and high extremes of data respectively.

Discussion

All the graphs (Figures 3a-d) showed a general increase in the gamma ray value from 1960 to 1995. There is also however numerous high and low values throughout that time period. Explanations may be offered for the occurrence of some of these peaks and troughs. The data peaks at 1987 then drops off again. The reason for this maybe the change in the method of preparation of the land before planting new trees from clearing the ground to a technique called chopper rolling where old vegetation is pushed aside and the new trees planted in the cleared furrows. This vegetation debris may attenuate gamma-rays. Chopper rolling commenced in the early nineties (pers. comm. Bob Gay SFNSW). Variations in the data may also have occurred after approximately 1978 because of the replanting of previously harvested areas (pers. comm. Bob Gay SFNSW) in some but not all of the age classes. Some pine tree remnants would still be in the area when new pines were planted for the second time in that area, therefore blocking the gamma rays that were recorded by the aircraft.

As well as the above changes in forest practise, a significant component of the "noise" is due to regolith variations. In figure 3, the slope class divisions highlight that steeper slopes generally have higher concentrations for all elements. This supports the interpretation that less weathered mineralogy is exposed in the incised valleys.

In figure 4, the classes of data based on attenuation modelling should theoretically represent areas of similar regolith type. This should have reduced the regolith "noise". It has worked well for K reducing high K areas in the 1970 - 1974 age classes. For Th and U there is little change probably because these elements are less variable in concentration as they are more resistant to weathering being sourced from accessory minerals in the granite.

The slope of the regression lines for selected graphs may be used to work out relative attenuation and the percentage of the gamma-ray signal the pine trees are blocking for different elements. For K data, class 3 of figure 4(a) had the best linear correlation. For both Th and U the original graphs (solid lines) were used.

Deriving relative vegetation attenuation-coefficients

Assuming that no attenuation of gamma-rays due to vegetation occurs in the newly planted areas, the graphs showing age class versus element concentration together with equation 1, can be used to calculate the ratios of attenuation between elements. For example:

$$u_k/u_{Th} = \ln(k_1/k_2)/\ln(Th_1/Th_2)$$

where k_1 = potassium gamma-ray counts for the oldest forest
k_2 = potassium gamma-ray counts for cleared land
u_k and u_{Th} = attenuation coefficients for K and Th respectively.

Table 2 shows the relative attenuation of gamma-rays of the different energies corresponding to the gamma-emitting elements. For both types of forest the ratios are similar to theoretical values, although potassium attenuation is larger than expected relative to Th and U. This is the reverse of what would be expected if there was a component of K in the vegetation as found by Kogan et al (1969).

Table 2. Relative attenuation coefficients

	u_k/u_{Th}	u_{Th}/u_u	u_u/u_k
Pine Forest	1.48	1.05	0.65
Native Forest	1.63	0.85	0.72
Theoretical-1	1.34	0.82	0.91

Table 3 gives the results of gamma signal reduction from cleared land to dense forest. This is highly significant information for the interpretation of gamma-element images particularly when subtle variations in ground concentrations overlap with variable vegetation density. The slightly higher values for native forest is thought to be due to thicker, wetter leaf litter.

Table 3. Percent reduction of gamma-ray counts

	K	Th	U
Pine Forest	20.0	14.0	13.5
Native Forest	21.9	14.1	16.4

Conclusions

The reduction in counts of airborne gamma-ray data is significant ranging from 13.5% to 20% for radiata pine forests and from 14.1% to 21.9% for native forests in the Bago-Maragle area. In surveys flown over forested areas this has important implications for the interpretation of gamma ray data as subtle variations may be misinterpreted because of the variable screening effects of vegetation biomass.

This study has demonstrated that GIS is a powerful tool to perform statistical analysis on large quantities of multi-layer data.

Acknowledgments

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The Western Water Study GIS, an aid to groundwater assessment and prospecting on Aboriginal land in central Australia.

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Abstract: The Western Water Study is a collaborative project between the Central Land Council, Northern Territory Department of Lands, Planning and Environment and the Australian Geological Survey Organisation. The study area overlies 68 000 km^2 of central Australia. The main objective of this study is to improve access to groundwater information for Aboriginal people on their land. To this end available geological, geographical and hydrogeological data have been incorporated into an ArcView GIS package. This package provides a tool for hydrogeological map compilation as ready access and manipulation of groundwater data is possible. Avenue script developed for this project by Robyn Gallagher (GISolutions) allows for the linking of the one-to-many data configuration found in the spatial and depth domains common to water bore data sets. Consequently bore data can be interrogated for geological, hydrogeological and hydrochemical analysis tasks. These tasks can be orientated to help local councils and community groups assess groundwater management issues. Supplementary data from exploration drilling and specific water quality sampling conducted for this project can be readily included in this package. Much of the GIS analysis work so far has been targeted at investigating the distribution of water quality variables throughout the study area. The database ARC format of this package allows the Central Land Council to customise groundwater spatial analysis tasks as the need arises on Aboriginal land using either ArcView or ArcInfo and also provides a template for future expansion of this groundwater GIS in the Northern Territory.

INTRODUCTION

The Western Water Study (WWS) covers 58 000km^2 of Aboriginal land and 10 000 km^2 of pastoral land in the south west of the Northern Territory (Fig. 1) comprising four 1;250 000 map sheets (Fig. 2). This arid region has several major Aboriginal communities, numerous Aboriginal outstations and two pastoral homesteads. All these settlements rely on groundwater supplies. Previous groundwater studies have usually been orientated at local sites such as community borefield development or individual stock or outstation bore programs. Much of the data generated by this work has previously been held as paper records by the Water Resources Division of the Northern Territory DLPE. In an attempt to bring data relevant to groundwater studies into one package this collaborative work between the AGSO, DLPE, CLC and Aboriginal communities was undertaken. The main objective of this work is to improve access to groundwater information, currently held by various agencies, for Aboriginal people on their land. Other interested parties such as government planning agencies can also be expected to benefit. Consultations with Aboriginal people on water issues were also conducted for this project (Toyne et al. 1997). The premise that the availability of clean, dependable supplies of water is a vital step towards health improvement for Aboriginal communities (e.g. Water, 1994) has focussed much of the work undertaken for this project. A portion of this work has been funded by the Aboriginal and Torres Strait Islander Commission on the understanding this work will serve as a pilot for further groundwater studies on Aboriginal and Torres Strait Islander lands.

Incorporating the groundwater data into a Geographical Information System (GIS) was chosen at the outset to meet some of the project aims (Jacobson et al., 1995). As in many GIS projects considerable effort has been required to get relevant data into a suitable digital format (e.g. Wyborn et al., 1995). Much effort was also expended in linking data sets held by the collaborative partners. The GIS package has been set up in ArcView, a commercial GIS program that is used by the CLC, DLPE and AGSO. The data sets for this package are written to a Compact Disc in an ArcView project format that can be run direct from the disc (Woodcock and Gallagher, 1996). The package has layers of processed remotely sensed data, geological data, topographical features, and cadastral data. These data sets complement the groundwater database compiled from Northern Territory records. An outline of these data sets is given below.

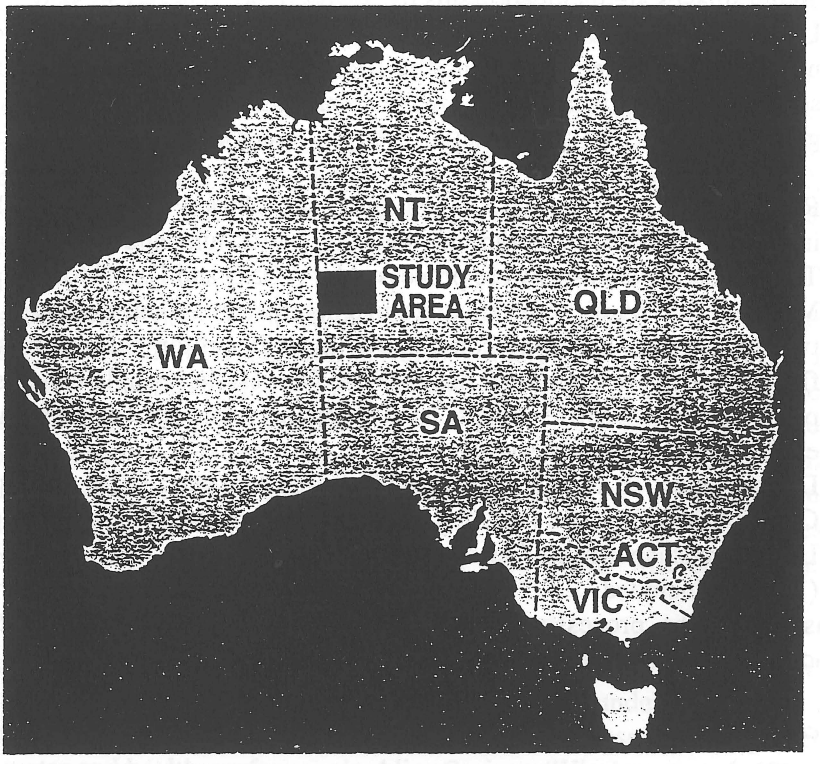

Figure 1. Location of the Western Water Study area, 68 000 Km^2 of the Northern Territory.

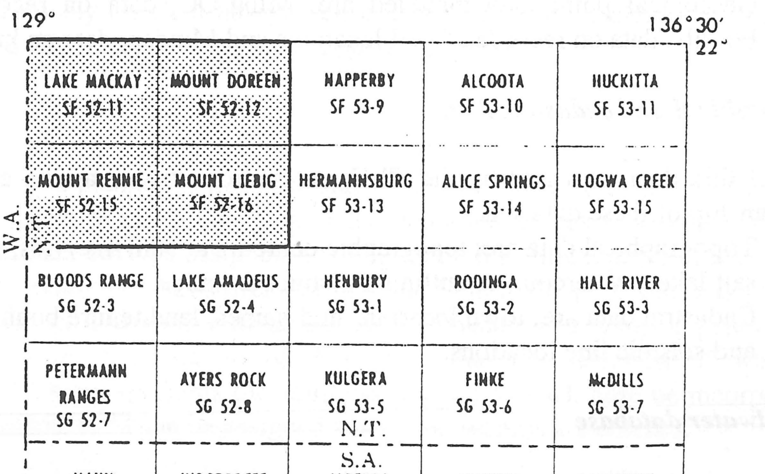

Figure 2. Diagram highlighting the 1:250 000 map sheets covered by the Western Water Study.

Imagery

The following images are included in this package:

a) Landsat thematic mapper (TM): Two TM scenes that have been processed by AGSO using the pixel unmixing method of Bierwirth (1990) are included. One scene is a grey scale calibrated "Iron Oxide" image to highlight drainage lines and the other is a red green blue (RGB) scene that has been processed to reduce the masking effect of vegetation cover.

b) Radiometrics over the Mt Doreen and Lake Mackay sheets (half the study area) are included. Total count, uranium, thorium, potassium and RGB images are included. These existing data sets were processed by AGSO and DLPE for the project.

c) Magnetics: 1965 airborne fluxgate magnetometer vertical field data over the southern two map sheets has been combined with 1976 proton magnetometer total field data flown over the two northern map sheets. The resultant single band pseudocolour image processed by DLPE represents total magnetic intensity with the magnetic field of the earth removed over the study area.

d) Digital elevation model (DEM): This image has been taken from the Australia wide GEODATA DEM - 9S (AUSLIG) and is stored as a .bil file.

e) Lineaments: an image file of lineaments interpreted from the TM data by English (1997) is included.

A discussion of the processing conducted on TM images for the WWS is presented by Woodcock and Bierwirth (in prep.)

Geological data

The existing 1:250 000 AGSO geology maps have been digitised as a separate project for the CLC. These data along with AGSO geological point data were made available for this project. The following geological data sets are included in the package.

a) 1:250 000 geological mapping polygons over the four sheets. A look up pallet to colour these polygons with the standard AGSO scheme or customised schemes such as Palaeozoic and Tertiary two colour scenes exist. Structural lines and symbol data are also included.

b) Geological point data included are: MINLOC, data on recorded mineral deposits; Fossils, data on recorded fossil locations and Mindep, data on known mine sites.

Topographical and cadastral data

Much of this data was held by the CLC and sourced from various agencies responsible for custodianship of these data sets:

a) Topographical data are; topographic contours at 50m intervals, surface water bodies i.e. salt lakes, watercourses outlining distinct drainage.

b) Cadastral data are; town locations and names, land tenure boundaries and names, roads and seismic line locations.

Groundwater database

Groundwater data from 868 bores are held in this package. There are over 40 data fields to describe each bore. Linked tables giving down hole data on bore construction, yields and lithology also exist. Water quality data may include several records for different depths and dates. This is a one-to-many data format. At the start of this project the DLPE database was incomplete. AGSO and DLPE staff spent much time interpreting, entering and editing to complete the database. Files with a unique identifier (bore number) were then extracted in an ArcView compatible DBF format for this package.

THE PACKAGE

Robyn Gallagher of GISolutions was commissioned to advise on the necessary data formats required by the collaborative partners to ensure an ArcView 2 GIS package could be made. Once the data were collated a CD-ROM package was created (Woodcock and Gallagher, 1996) to be run with ArcView. Robyn Gallagher was again commissioned to create customised tools to view the boredata and associated themes within the package. This utility is of significance as the methodology developed should be applicable in many other GIS applications. The data model, customised tools and associated Avenue scripts developed are reported elsewhere by Gallagher (1996).

Once the groundwater data of the study area was incorporated into the package use of the customised tools helped in the creation of various interpretive geological and hydrogeological maps. The "draw a cross section" facility was most helpful in the construction of a Tertiary geology map (Lau, in prep.) as downhole data that previously required access to many different paper records could be viewed graphically at the push of a button. Similarly maps of potentiometric surface, salinity and geological isopachs were readily constructed by use of customised tools that allow any bore attribute to be labelled at each bores location. The derivative data sets constructed with the aid of these tools will be included into updated versions of the package.

A preliminary use of the data set allowed an analysis of the availability of water supplies to stranded travellers on major roads in the study area to be undertaken using ArcView 2. To simply demonstrate GIS capabilities this analysis was presented in poster format at an Aboriginal water and health conference in Alice Springs (Wischusen et al. 1996).

The "shopfront" data query capabilities of this package where, at the push of a button, a diagram displaying lithology, construction details, water cuts, water level and elevation data of a bore appears, have proved popular with all users. Ongoing use of the package provides valuable feedback on data integrity which helps identify data sets that DLPE need to clean for updated versions of the package and for any future GIS development in the Northern Territory. As all the links and functions of the package depend on file name only this "test drive" before all data were rigorously checked has proven a useful exercise to clean data prior to running more complicated GIS analysis tasks on an updated package.

ANALYSIS

The first analysis task planned is to create statistical data sets of the various stratigraphic units drilled in the Western Water Study area. This tabulation of basic drilling and water quality statistics requires each bore be assigned a stratigraphic unit that aquifer characteristics can be attributed to. The creation of an aquifer stratigraphic field in the bore data sets will be achieved by processing data in a relational database and by manual checking of paper records when necessary. It is a recommendation of this study that the selection of which downhole stratigraphic unit(s) best represents the aquifer(s) tapped by each bore be incorporated into the DLPE database so this field can be assigned when new records are entered.

Once statistical data sets are created for each stratigraphic unit valuable predictive information on expected drilling conditions and water quality are potentially available. Incorporating drilling statistics from outside the study area will help assess units where drilling data are sparse. It is expected that the compilation of these statistics will provide a guide to groundwater prospectivity over the study area in that stratigraphic units can be rated. It is also planned to provide help text windows outlining the general strategies employed by DLPE hydrogeologists when selecting boresites in the different terrains and how the data sets within the package may be used to enhance drilling success.

The collection of data sets in this package creates the opportunity for GIS modelling methods to be used for groundwater studies in this region. A common approach to enhance the success of drilling programs in the past has been to integrate remotely sensed data and fracture/lineament trace analysis with other spatial data sets (e.g. Gustafsson,1993; Teeuw, 1995; Sander et al., 1996). While these techniques might be applicable in some regions of the study area, the lack of a digitised lineament coverage, varying geological terrain and sparsity of drill hole data led English (1997) to note that such methods are not readily applicable with the current data set. Weights of evidence and fuzzy logic techniques as outlined by Bonham-Carter (1994) may also suffer from a lack of suitable data, however the desirability of producing maps of groundwater prospectivity from GIS modelling may inspire a future study.

CONCLUSIONS

This project has produced a functioning groundwater GIS operating in ArcView. Ready access to groundwater data is now possible for any of the collaborative partners and their clients. The integration of many data sets into one package has aided the understanding of groundwater in the study area. This facility has the potential to help Aboriginal people understand and manage groundwater resource issues on their land. The linking of generic bore data sets in the package and customised bore query tools (Gallagher, 1996) provide a template for the expansion of this GIS to other parts of the Northern Territory (i.e. given the data, this package will operate without modification anywhere in the NT).

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Accurate and efficient capturing of field data for integration into a GIS - a digital field notepad system.

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Abstract

The minerals industry spends vast amounts of money sending geoscientists into the field to make direct physical observations. These observations are valuable not only because of cost but also because they are the key to understanding the geological evolution of an area. Traditional methods of recording field data result in a large amount of data being unsuitable for use in modern digital data analysis packages. Structured digital databases and GIS now give us the tools to utilise the large amount of data that can be obtained at the outcrop. This data can readily be integrated with other data sets. Transferring field descriptions from traditional free-hand notebooks into a digital system is very time consuming, inefficient and prone to error. AGSO in conjunction with Resource Industry Associates has developed the AGSO FieldPad running on an Apple Newton Personal Digital Assistant. The AGSO FieldPad captures field descriptions and sketches digitally, links to a GPS and can display georeferenced vector maps with a real time GPS position.

Introduction

The integration, analysis and modelling of geological information within Geographic Information Systems (GIS), statistical data analysis packages and 3 dimensional CAD packages is becoming more and more an integral part of the work of geoscientists. As such the requirement to have geoscientific data in a digital form is becoming more imperative. The mineral exploration industry has been somewhat slower than other areas of the geosciences in adapting digital data to its exploration requirements (Wyborn et al, 1996). Part of the reason for this is that the minerals industry is often focused in more geologically complex terranes and much more emphasis is placed on direct observation of field features (Archibald et al, 1997). Until now it has been difficult and time consuming to capture direct field observations in a format that can in the first place, be easily interrogated and, secondly integrated with other data sets. The advent of GIS has given mineral explorationists a sophisticated tool to integrate diverse data sets including geophysics with direct ground observations. A GIS is the ideal tool to allow geoscientists to visualise the large amount of raw field observations, and then to interpret them in a variety of ways. To be able to do this effectively however, field data needs to be digital, properly structured and validated, and it should be captured in a standard format, and if possible accessible across an organisation, ie., it should be stored within a relational database (Wyborn et al, 1994; Ryburn, 1996). The data capture and archiving process needs to be cost effective. Therefore field observations need to be captured digitally at the point of observation. This paper describes a system developed by AGSO and Resource Industry Associates on the Apple Newton Personal Digital Assistant to capture field observations digitally at the field site.

Collecting Field observations

A huge amount of information can be captured at the outcrop level by geoscientists. This information is often the key to interpreting and understanding the geology of a particular area. Unfortunately much information is lost at the outcrop where the geoscientist, intent only on his/her own perceived end purpose for the data or the current model that is in vogue, often synthesises or summarises the features observed at a site. This is only natural as the mass of information is often too much to be adequately handled by the geoscientist when developing a geological model for an area or compiling a map, particularly when working to tight schedules. As a consequence a lot of interpretation occurs at the outcrop and many of the raw facts of the site may not be recorded. These facts however are important. Features which the geoscientist did not consider important at the time may later be recognised as important. The geological model driving the exploration or mapping team may change making earlier interpretations invalid. If the raw observations have been recorded then the field descriptions can be reinterpreted in the light of the new model. Also, someone else working on the project with different expertise may recognise features that are important. For example, the degree of weathering at a site may be useful to the person interpreting airborne radiometrics or the regolith expert attempting to understand surface geochemical dispersion patterns.

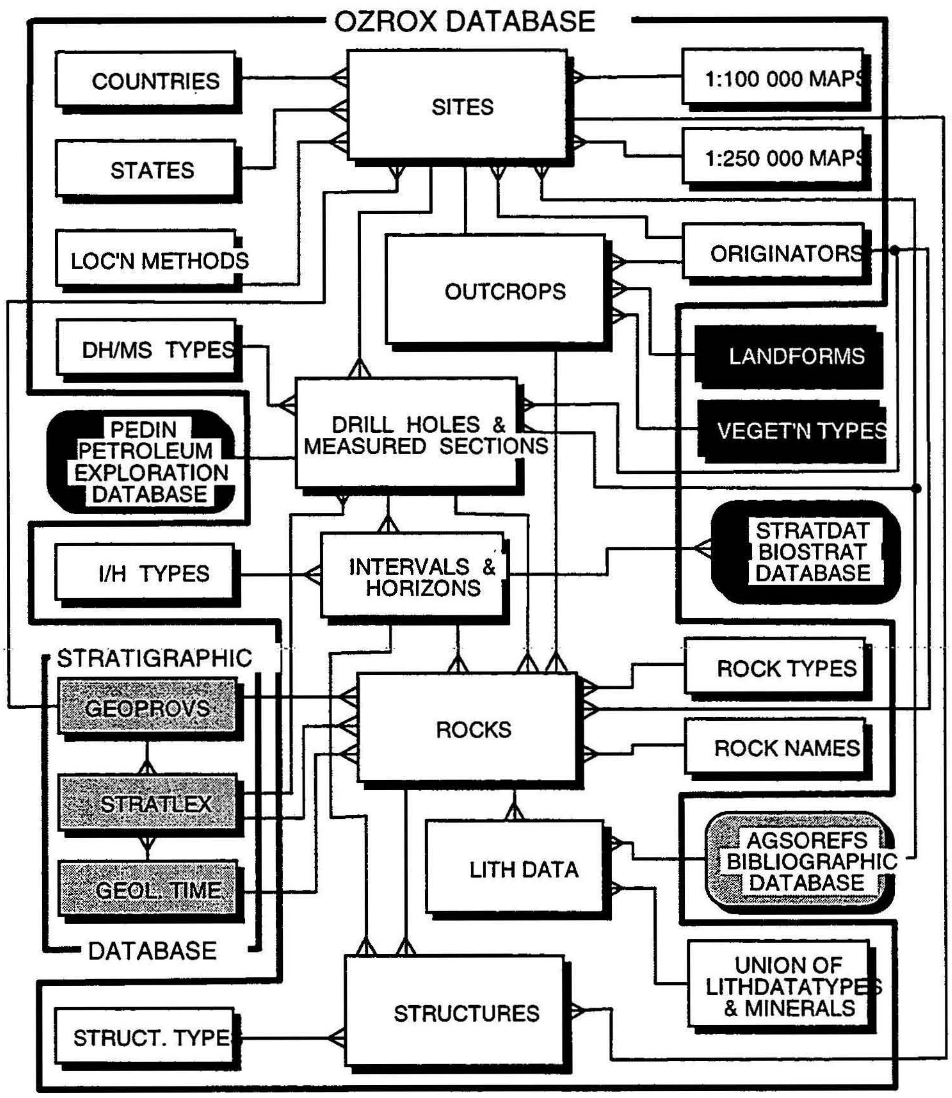

Figure 1. A schematic diagram of the OZROX database showing the relationship between component tables and some other AGSO field databases. The "crows" feet on the lines joining tables indicate the many side of many-to-one links.

Further data are lost through the filtering process of producing the map and report. While no one doubts the scientific value of a map, it is still a summary of the field mapping process and based on a geoscientist's interpretation and requirements at the time it was produced. Also, only so much information can be adequately displayed on a 2-dimensional piece of paper. Reports are necessarily a summary of the important features of all the geological observations made by the project and it is not possible or feasible to retain all of the raw field observations, and even if it were, seeking out the information stored in this format is tedious and time consuming.

To make field data accessible and retrievable it needs to be captured and stored in a structured and standardised format (Withnall et al, 1992). The data also needs to be digital. Attempts have been made in the past, with varying degrees of success, to capture and store field observations in a structured and standardised format usually using printed pro-forma paper forms. Inevitably these systems failed after a time because of the difficulties in sifting through reams of paper forms looking for common themes. Although geoscientists may have studiously filled in the forms at the start they soon lost interest when they saw that the data collected were not being used, or used only at a very superficial level.

OZROX - AGSO's Field Geological database

At the commencement of the National Geoscience Mapping Accord (NGMA) in 1990, AGSO recognised the benefits in making the information recorded by field geoscientists accessible to automated methods of data manipulation and presentation by storing field observations digitally (Blewett & Ryburn, 1992; Blewett, 1993). The OZROX field site database (Ryburn, et al, 1993; Ryburn, et al, 1995) was set up using the Oracle Relational Data Base Management System to store field observations in a structured format so that data could be readily retrieved for data analysis in packages such as GIS (Figure 1). Important in designing OZROX was the requirement to maintain standards through validation of data on entry. OZROX was designed using experience gained from the earlier PETCHEM whole rock geochemistry database (Wyborn and Ryburn, 1989) and the Geological Survey of Queensland's Regional Mapping Field Data Management System REGMAP (Lang et al, 1990).

OZROX is tightly structured with most fields controlled by authority tables of standard values to ensure that the database can be successfully interrogated. Experience from the PETCHEM database showed that the integrity of the data in the database could only be maintained by generous use of authority tables. The uncontrolled free-text fields in PETCHEM were virtually impossible to interrogate successfully due to an abundance of spelling mistakes and attributes being recorded in the wrong fields. Another improvement built into OZROX was the use of mandatory fields which ensure information which is considered fundamental is recorded. For example information required for assessing the spatially accuracy of field locations is essential if the data is to be used within a GIS (Wyborn et al, 1994; Hazell and Wyborn, 1995). These fields must include:

1. location in either AMG or latitude and longitude and if recorded as AMG then the map sheet or zone number must also be recorded.
2. the method of location ie., whether a GPS was used and if so what datum the GPS was set on (Hazell et al, 1996).
3. an estimated accuracy so that GIS users will know at what scales the location is valid.

Structured Field notebooks

When geoscientists within AGSO began storing their field data in the OZROX database it became apparent that translating field data from their traditional free-hand notebooks into the database structure was very inefficient. Transferring field descriptions from an unstructured free-hand field notebook into a structured database system takes approximately 2.5 times longer than entering the descriptions from a structured field notebook. If the data are not entered by the geoscientist who collected it then it is also prone to significant error and loss of information. Recording data in a structured format requires information to be categorised and data types to be clearly separated e.g., interpretation from fact. For a person other than the data collector to categorise unstructured field observations and separate interpretative observations from factual ones is extremely difficult.

As well as vastly speeding data entry and reducing the error rate, structured notebooks prompt geoscientists in the field to be more complete in their observations. Location information, which are essential if the data are to be used in a GIS, are less likely to be forgotten. Geoscientists are also prompted for information that may be outside of their own immediate area of interest, but of use to others in the project. Less synthesising takes place at the outcrop and more factual information is recorded. The geoscientist is also forced to make a decision on how to categorise the observations. Within a digital environment it is, at least in the first instance, not so important to categorise something correctly as to ensure that all "like" things are categorised the same. As long as this is done all "like" information can be retrieved and analysed. For example a field team may not be sure of the correct name of a particular rock but as long as all members of the team decide to call it the same thing then it easy, at a later date, to do a global update once the correct lithology is decided.

Even using structured field notebooks, transferring field observations from paper to a digital database is very time consuming and prone to error. The geoscientists who collect the data are the best people to enter it into the database. They understand the observations and can resolve ambiguities, particularly those due to poor hand writing. The geoscientists can also enhance their descriptions based on later observations.

In the real world, however, geoscientists are often too busy to enter their own site information. Some geoscientists estimate that 75% of the time spent in the field is required to enter their field data. This problem is compounded by the fact that many geoscientists work a seven day week in the field. Therefore a month in the field equates to a month in the office entering data. This calls into question the cost effectiveness of having geoscientists entering field data.

Therefore notebooks are often given to non-geoscientists to enter in the belief that this will save time. Usually it doesn't, because of the need to check what has been entered. If this checking process is not done, major problems with incomplete or the low quality data often arise when the project is attempting to use the data within a GIS or other data analysis package. The end result of this is that more time is needed to correct the data to make it useable. In the worst cases incomplete or poor quality data can result in a failure to meet the project targets.

Capturing data digitally at the outcrop

It is obvious therefore that the step of converting field observations from analogue to digital should be removed. Observations should be recorded digitally at the outcrop for subsequent transfer to the corporate database. The data are handled only once, removing the risk of transcription errors and they are also immediately available for use within any digital data analysis package, either in the field or back at the office.

In designing a digital field data recorder AGSO had several requirements:

1. The internal data structure, codes and attributes had to match the corporate field site database OZROX. By matching the corporate database structure the transfer of data is much quicker and simpler because there is no need to combine, edit or split attributes in order to fit them into the corporate database structure. Also by entering data into the same fields which are controlled by the same lookup tables as in the OZROX database validation occurs at the point of data collection.
2. The ability to record field sketches was very important. We had to be able to do almost everything that could be done on paper.
3. Pop-up lists of database attributes were required so that the geoscientist can quickly and easily select values. By restricting data entry as much as possible to selections from pop-up lists data integrity is tightly controlled (Figure 2).
4. The system had to be able to accommodate all codes and attributes available on the OZROX database so that all possibilities that could be encountered by a geoscientist were covered.
5. In addition to the tightly controlled fields which used pop-up lists, some free-text fields were required. These free-text fields had to be able to accept and interpret hand writing rather than entry from a keyboard. Small pocket computers with field data capture capabilities have been around for some time (Mitchell, 1992). However data entry into these systems is via a keyboard. AGSO had looked at these systems in the early 1990s but found them impractical as most geoscientists are inaccurate or slow typists
6. Finally the machine chosen needed to be robust, simple and fast to use as well as light and easy to carry.

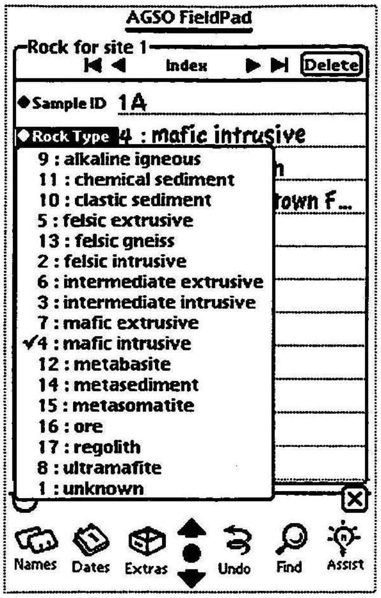

Figure 2. A screen from the AGSO FieldPad showing a pop-up list of values

The Apple Newton PDA

AGSO was introduced to the Apple Newton Personal Digital Assistant (PDA) by Resource Industry Associates (RIA). The Newton PDA seemed to meet all our requirements so AGSO entered into a development project where RIA programmed AGSO's field database structure into the Newton complete with pull-down lists of authority tables. This application is called the AGSO FieldPad digital field notebook (Blewett and Hazell, 1996, Hazell et al, 1996).

The Newton PDA is very easy to use. A pen is used to control the Newton and data are entered via a touch-sensitive screen. The Newton's text recognition software enables geoscientists to enter their descriptions free-hand into the available free-text fields. Other advantages that came with the Newton were:

1. RIA's MapPad software, which provides for georeferenced vector maps to be displayed and linked to a GPS to show location (Figure 3). Vector maps that can be displayed include topography, geology or even geophysical interpretation maps. By having a real-time link to a GPS geoscientists can locate themselves using the digital topographic map or navigate to any features of interest recognised on the geology or geophysical interpretation map. Vector maps are very easy to create using an add-on module to RIA's Terrascan software. Standard .DXF files can be easily converted to a format suitable for the Newton. A 4 Mb DXF file will reduce to a 0.5 Mb file for loading into the Newton.
2. Positions are saved directly from the GPS, obviating transcription errors.
3. The geoscientist can draw a field sketch directly into the Newton (Figure 4). The sketch is then stored digitally, along with the rest of the field description, and can be loaded into a database and displayed anytime by querying the database.
4. The Newton is a fully programmable computer allowing for any number of applications to be developed for it.
5. A large range of off-the-shelf software is also available which can extend the Newton's functions.
6. The Newton was originally developed as a PDA, consequently it has other features which make it a useful adjunct to the field geoscientist. Personal organiser software such as diaries, notebooks and address books are available for the Newton. It is also fax and email capable, giving geoscientists the capacity to send and receive faxes and email in the field.

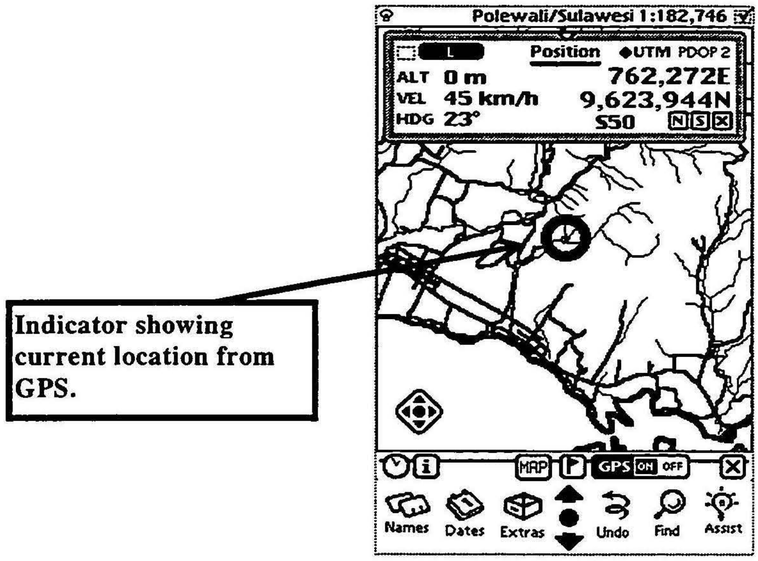

Figure 3. Georeferenced vector maps linked with a GPS provide for real time navigation.

Is using a digital field notebook all rosey?

While the Newton has obvious benefits there are also some difficulties to over come with using the new technology. Probably the greatest difficulty with using a digital field notebook is just getting used to it. Compared to paper a digital notebook can seem constrictive. It takes a little time to get used to writing onto a screen and the character recognition also lags a little behind the scribe, which can be disconcerting. The Newtons character recognition is excellent and it can also be "trained" until its recognition level is faultless. The system at present running on the Newton 120 is a little slow. It takes a little time to refresh a screen and to display the pop-up lists of the larger lookup tables. The current speed of operation is however only a temporary impediment, as technology improves and faster machines are developed this will no longer be a factor. The new Newton 2000 which has just been released increases the speed of the Newton's processor from 20MHz to 160MHz. Internal memory has been increased from 2Mb to 4Mb. From reports that we have received so far they are very fast, and operating speed is almost no longer an issue.

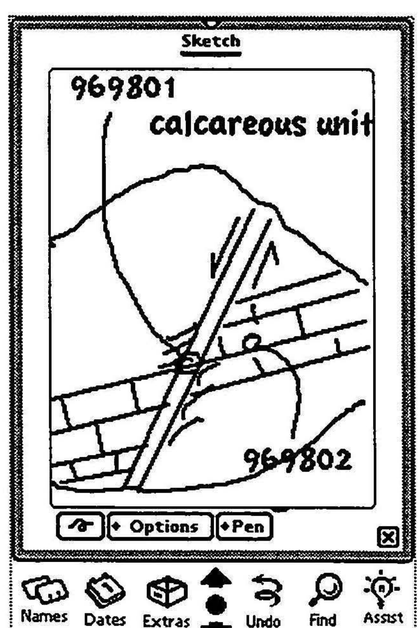

Figure 4. Example of field sketch from AGSO FieldPad.

However, hardware issues aside, perhaps the most difficult aspect of using a digital field notebook with structured data entry is the requirement for geoscientists to change the way they observe and record geological field information. Instead of recording their observations at a site in freehand 'text strings', they need to think in a structured manner and record the individual features of an outcrop as individual 'codable' items. Even though the initial response of some geoscientists is that they cannot record all of the information that they observe at a site in a structured format, we have yet to find a situation where it can't be done. For AGSO geoscientists who have been using the paper structured field notebooks the transition to a digital system should be easy.

Conclusion

The AGSO FieldPad software operating on the Apple Newton PDA greatly improves the efficiency of capturing geoscientific field data, particularly outcrop descriptions. The removal of double handling of the data provides a great time and cost saving. It also removes errors, which are part of the data entry process, and provides structured and validated data that can be successfully interrogated and integrated with other geoscientific data sets.

Sophisticated data analysis software is no longer limited to the office. Small powerful computers running the latest in GIS or image processing software can be easily taken into the field. A geoscientist using a digital field notebook will have the day's field descriptions available in digital form and be able to integrate and combine them with other data sets, including the field descriptions of his colleagues on his GIS or image processing system in the field camp. With all the data available on the desktop the day's work can be assessed and the next day's work can be planned.

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GEODATA - GIS Data for Australia

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ABSTRACT: *TOPO-250K was the first of the Australian Surveying and Land Information Group (AUSLIG)'s GEODATA digital data products. This GIS ready vector data was derived from 1:250 000 scale base maps and covers all of Australia. The structure, quality and documentation of TOPO-250K has set a new standard for GIS data and received national and international praise.*

This paper provides a brief history and describes the future plans for GEODATA. The intention is to pass on some important lessons learnt from our experience in the capture and maintenance of digital data.

INTRODUCTION (ABOUT AUSLIG)

The Australian Surveying and Land Information Group (AUSLIG) is the national land information agency of Australia. Its charter includes:-

- coordination of national land information programs,
- lead Commonwealth responsibility for Australia's National Spatial Data Infrastructure,
- remote sensing,
- geodesy,
- maritime boundaries program, and,
- ongoing revision of the national topographic map series of Australia.

This program of map revision involves both paper maps and high quality mapping data (GEODATA) suitable for use in geographic information systems (GIS). This paper describes AUSLIG's GEODATA products including characteristics, history, and future with particular reference to TOPO-250K vector data. In conclusion, some of the lessons learnt from our experiences with GIS data are described.

WHAT IS GEODATA?

GEODATA is a term which refers to AUSLIG's suite of GIS ready digital spatial data products. All GEODATA products incorporate the following important characteristics:

Customer Focus

Seminars, questionnaires, interviews and 'beta testing' provide the vital feedback needed to ensure that each GEODATA product is useful in the widest range of applications.

GIS Compatibility

GEODATA products are specifically designed for GIS applications. For vector products, this means the adoption of a suitable data model and exacting standards for topological integrity.

National Consistency

Each GEODATA product adheres to a consistent, national specification. As a consequence, each product offers consistency in the treatment of features and attributes, the criteria for feature selection, the positional and attribute accuracy, and the data point density.

Assured Quality
AUSLIG has implemented rigorous production procedures to assure superior quality for all GEODATA products. All products undergo independent quality assurance, including tests on vital aspects such as topological integrity, completeness, and positional and attribute accuracy.

Comprehensive Documentation
Comprehensive, user friendly documentation accompanies all GEODATA products, allowing the users to determine whether a particular product is suitable for their application.

Choice
GEODATA products are available in a variety of vendor formats and industry standard media.

Maintenance
Through timely revisions and upgrades, all GEODATA products remain up-to-date and relevant to changing customer requirements.

TOPO -250K

The GEODATA product derived from the national coverage of 1:250 000 scale topographic maps is known as TOPO-250K. Version 1 of this data are provided in three themes covering hydrography, infrastructure and relief.

History
In early 1991 AUSLIG recognised the need for a national digital topographic database and applied to the Department of Finance for development funding. AUSLIG was granted funds additional to those it already received on the condition the project was complete by July 1994. The data were to be derived from the 546 maps of the national 1:250K map series, and to be of a quality suitable for inclusion in geographic information systems (GIS).

By June 1991 work was under way developing an implementation strategy and product specification. Workshops, with input from users, were held on the strategy and specification in June, July and September 1991. Production began in November 1991 with the extraction and copying of 1:250K repromat in preparation for scanning.

By mid 1992 the data specification was complete. The specification set out the minimum quality standard of the data, the data's feature content, topological structure and the rules to be used in the collection of the data.

The first tile passed AUSLIG's Validation and Testing (VAT) unit in December 1992, some thirteen months after production commenced, and only 18 months short of the deadline for the completion of all 540 tiles. By July 1993, less than twelve months before the deadline, throughput had increased but more than 400 tiles still remained to be passed by the VAT cell. Nevertheless the TOPO–250K project was completed in July 1994, on time and within budget and all 540 tiles were available to the public.

The feedback from the Australian public and internationally about TOPO–250K has been very complimentary and the product is seen by many to set a standard for digital GIS data, in particular in regard to specifications, data quality and accompanying documentation.

Characteristics
Some of the characteristics which established TOPO-250K as an exemplary GIS product are:-

- *Unique Feature Identifiers*

Each entity in TOPO-250K has a unique attribute code, known as *a unique feature identifier* (UFI). This can be used to maintain a historical log of the data and to allow 'change only' updates of the database.

- *Data Quality Pointers*

GEODATA has detailed information on data quality based on the concept of 'truth in labelling'. In accordance with this, each entity has a data quality pointer which links the entity to a table providing quality information such as feature and attribute reliability dates and positional accuracy.

- *Validation and Testing (VAT).*

TOPO-250K data were subject to a rigorous quality validation program, run after initial production was completed. The program used statistically based testing routines that ensured, to a given confidence level and error tolerance, TOPO-250K complied with the data specification and user requirements. Numerous testing methods were used including the running of UNIX scripts that automatically isolated errors in GeoVision GINA files, the running of ARC/INFO AML programs that automatically isolated errors in ARC/INFO coverages, manual scanning of paper plots, and manual on-screen scanning and querying of ARC/INFO coverages.

OTHER GEODATA PRODUCTS

TOPO-10M

The TOPO-10M product is a digital vector data version of AUSLIG's 1:10 million scale map series. As a GEODATA product TOPO-10m has structure and documentation at a standard similar to TOPO-250K.

COAST-100K

The COAST-100K is another well structured and documented GEODATA product comprising a vector coastline of Australia based on 1:100 000 scale map information. Both the TOPO-10M and the COAST-100K have extensive user guide documentation and are fully structured GIS data.

9" DEM

The 9 Second Digital Elevation Model (DEM) of Australia is a recently released GEODATA product and a result of a joint cooperative project between AUSLIG, AGSO, ANU, and Australian Heritage Commission. AUSLIG and AGSO data were combined to produce more than 120 million elevation points on a grid of 9 seconds in latitude and longitude (equivalent to approximately 250 meter squares). This data are available on CD-ROM with software which allows users to download the whole of Australia or smaller areas as required.

FUTURE

The 1996 Federal Government budget decision, while requiring AUSLIG to market test outsourcing of Public Interest programs, endorsed AUSLIG's responsibility to the Government for managing the current programs and providing expert advice on land information issues. In accordance with this charter, AUSLIG is currently pursuing the GEODATA concept with the following initiatives.

TOPO-250K Maintenance

AUSLIG is committed to maintaining the Version 1 TOPO-250K data and this is now possible via incremental, or change only, updates. Effectively, incremental updates involves the supply of a 'delete' coverage and a 'change' coverage rather than resupply of the entire tile. By deleting features identified in the delete coverage and adding or amending features identified in the change coverage, users can update their data without needing to reload the entire data set. This is a big advantage for users who may have made alterations or additions to the base data for their own purposes.

TOPO-250K Version 2

The Version 2 of TOPO-250K will have more than three times the number of features found in the Version 1 data. In fact Version 2 data will have almost all the features found on the paper maps. This will include features such as:-

- Vegetation
- Buildings
- Utilities (fences, mines, dams, etc.)
- Powerlines
- Pipelines
- Offshore reefs
- Marine (boat ramps etc.)
- Survey marks
- Relief areas (distorted surfaces, sand dunes, rocky outcrops, etc)
- Contours
- Morphology (caves, cliffs, pinnacles, etc.)
- Reserve areas (Nature, Nat. park, Defence, Aboriginal, etc.)
- Additional features in road and drainage coverages.

Version 2 data will be on the new GDA94 datum which is a geocentric (earth centred) datum more suited to navigation and compatible with international standards. However the change of datum will make incremental updates between Version 1 and Version 2 data impractical.

RASTER-250K

Due for release later this year, the RASTER-250K product is a digital colour representation of the 1:250 000 scale paper maps. Scanned at 150 (DPI) Dots Per Inch (approximately 170 microns) and with 8 bit (256) colour, the whole of Australia will be available on seven CD ROMs. The whole of each map will be provided including surrounding information and including legends, scale bar and grid information. This will ensure the data can be used by a wide variety of users from GIS professionals to the general public.

TOPO-2.5M

Also due for release later this year, the 1: 2.5 million scale digital vector data of Australia, is intended for users requiring less detail, and therefore smaller file sizes, than provided by TOPO-250K. This product is being derived by digitising original 1:2.5 million repromat information and also by generalising TOPO-250K data.

LESSONS

The success of the TOPO-250K product and the positive feedback from users has inspired the continuation of the GEODATA concept for GIS-ready spatial data. The following recommendations are made for other data providers based on our experience with these products.

Market Research

Extensive market research is vital to ensure that products meet the strongest demands. In every business there is a common perception that 'we know what is needed and wanted' however our experience has shown that market research changes that perception and results in a far more focused and valuable approach to product delivery.

Documentation

The TOPO-250K documentation has been very well received within the GIS community and the user guide purchased in many cases purely for reference purposes. Comprehensive documentation gives users confidence in the strengths and limitations of the data.
Detailed documentation is also an advantage to the data provider as well as the user. Much of the knowledge of a product is easily lost over time with staff changes and careful documentation is essential to ensure efficient hand-over of projects.

Validation and Testing (VAT)

AUSLIG established a separate VAT group at the beginning of the TOPO-250K project and this proved to be vital to the success of the product. By providing independent checking, consistency was ensured even though data capture was being performed by different units, and in different offices. The VAT centre also created an atmosphere of competition with the challenge to get the most tiles through VAT becoming an incentive to production.

Distribution

Changes in technology have improved the methods of distribution available to data providers. The 9" DEM is an example of an innovative approach to distribution with all Australia's data on one CD and with users accessing via a password. By limiting the number of formats to those readily acceptable by the majority of GIS systems, and also restricting media to just CD ROM, the cost of distribution, and therefore the price of the product, is greatly reduced. It is our intention to continue to improve methods of distribution, to reduce costs and increase distribution.

CONCLUSION

The TOPO-250K product, and the concept of GEODATA has been a great success for AUSLIG. The success stems from effectively researching market needs and expectations, establishing independent validation and testing, and thoroughly documenting history and quality of the data. Our experience has shown that the cost and time associated with these activities is repaid through data sales and future efficiencies in revision and enhancement.

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AUSTRALIAN SPATIAL DATA INFRASTRUCTURE (ASDI)

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ABSTRACT: Data are of primary consideration in any GIS project. The knowledge and availability of data as well as access to the relevant data can make an immense difference to the viability and cost of undertaking GIS projects.

The concept of a national spatial data infrastructure is not new and most people working in the GIS field would be aware of the efforts being made in the US to implement a NSDI.

This paper explains the concepts of the Australian Spatial Data Infrastructure (ASDI) and draws some comparisons and likely differences between the implementations of spatial data infrastructures in Australia and the United States.

The paper also provides a brief snapshot of where Australia is currently at with the implementation of the ASDI, particularly at the Commonwealth level.

Introduction

The concept of a national infrastructure is not new. The major road and telecommunications networks, and basic health and education facilities have been funded by government to ensure that consistent infrastructure is developed in the national interest.

It is a role of government to ensure that there is a common, consistent infrastructure upon which a range of government, private sector and community activities can take place. Recently, national competition policies have highlighted the need for access to government funded infrastructure as a basis for developing competitive private sector value adding services.

Geospatial data can also be considered as infrastructure, necessary to support the nation's economic growth and its social and environmental interests.

What is the Australian Spatial Data Infrastructure?

The spatial data infrastructure model as promoted by the Australia New Zealand Land Information Council (ANZLIC) comprises four core components that are linked as follows:

- An institutional framework that defines the policy and administrative arrangements required to implement and maintain the infrastructure.
- Fundamental datasets that are produced within the institutional framework and fully comply with the technical standards.
- Technical standards that define the technical characteristics of the fundamental data.
- A distribution network (sometimes referred to as clearinghouse) to provide the means by which datasets are made available to the community in accordance with agreed policy and to the agreed technical standards.

The Australian Spatial Data Infrastructure (ASDI) will most likely comprise a distributed network of databases. Under this model, each database would be managed by custodians, perhaps at the jurisdictional level, with the expertise and incentive to maintain the database to the standard required by the community. The custodian would be obliged to undertake certain agreed responsibilities.

The ASDI implementation is still open for input and a discussion paper is available from ANZLIC. The intention is to review comments and submissions received by July and produce a policy paper for putting to government in all jurisdictions by the end of 1997.

Progress in the United States of America

Background

The United States Government has recognised the management of geospatial data as an important national issue. On 13 April 1994 President Clinton made an Executive Order on "Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure."

The U.S. Government established the Federal Geographic Data Committee (FGDC), chaired by the Secretary of the Department of Interior. All Departments with an interest in the NSDI are encouraged to participate with a senior, policy level representative.

The FGDC was tasked with specific responsibilities and targets and was instructed to involve State, Local and tribal governments in the developments and initiatives outlined in the Executive Order. The expertise of academia, the private sector, professional societies is also to be utilised where appropriate.

Specific objectives outlined in the Executive Order include:

- Development of a National Geospatial Data Clearinghouse. This is defined as a distributed network of geospatial data producers, managers, and users linked electronically. Under the clearinghouse various tasks have been defined, such as;
  - ⇒ agencies producing and making available electronically standardised documentation of data.
  - ⇒ producing a plan outlining how geospatial data will be made available to the public.
  - ⇒ agency utilisation of the clearinghouse to check on data availability before expending funds collecting or producing new geospatial data.
  - ⇒ provision of funding by the Dept. of Interior to assist with the development of the clearinghouse concept.

- Data Standards Activities. These objectives refer to the identification, use and development where needed of appropriate standards to ensure compatibility of geospatial data.
- National Digital Geospatial Data Framework. This "framework" includes transportation, hydrology and boundary elements required to support the decennial census of 2000. The framework should be completed by January 1998.
- Partnerships for Data Acquisition. This involves producing strategies to maximise the participatory efforts of State, local and tribal governments, the private sector and other non federal organisations to share costs and improve efficiencies of acquiring geospatial data.

Progress to Date

The FGDC, with its high level government representation and support has taken a very proactive role in the promotion and implementation of the NSDI. Progress has been made in a number of areas, particularly in the area of promotion of the idea of data sharing and collaboration. FGDC maintains a comprehensive home page on the Internet to share information.

Doug Nebert, the FGDC Clearinghouse coordinator recently visited Canberra and I was able to get a good understanding of the direction being taken. FGDC have started to establish a distributed database of servers that contain metadata. Currently there are 17 servers connected and users can conduct parallel searches of these servers by accessing the FGDC site. These servers are "registered" by FGDC and consist mostly of State Government agencies at this stage. Searches are conducted using the Web as a medium, however standard search and retrieval protocols such as Z39.50 are used. Electronic payment using credit card facilities over the web is now starting to occur.

The Clearinghouse is an ideal way of advertising the data an organisation has available and also any intentions to undertake data acquisition projects. This knowledge of planned activities can give organisations the chance to pool resources rather than duplicating activities.

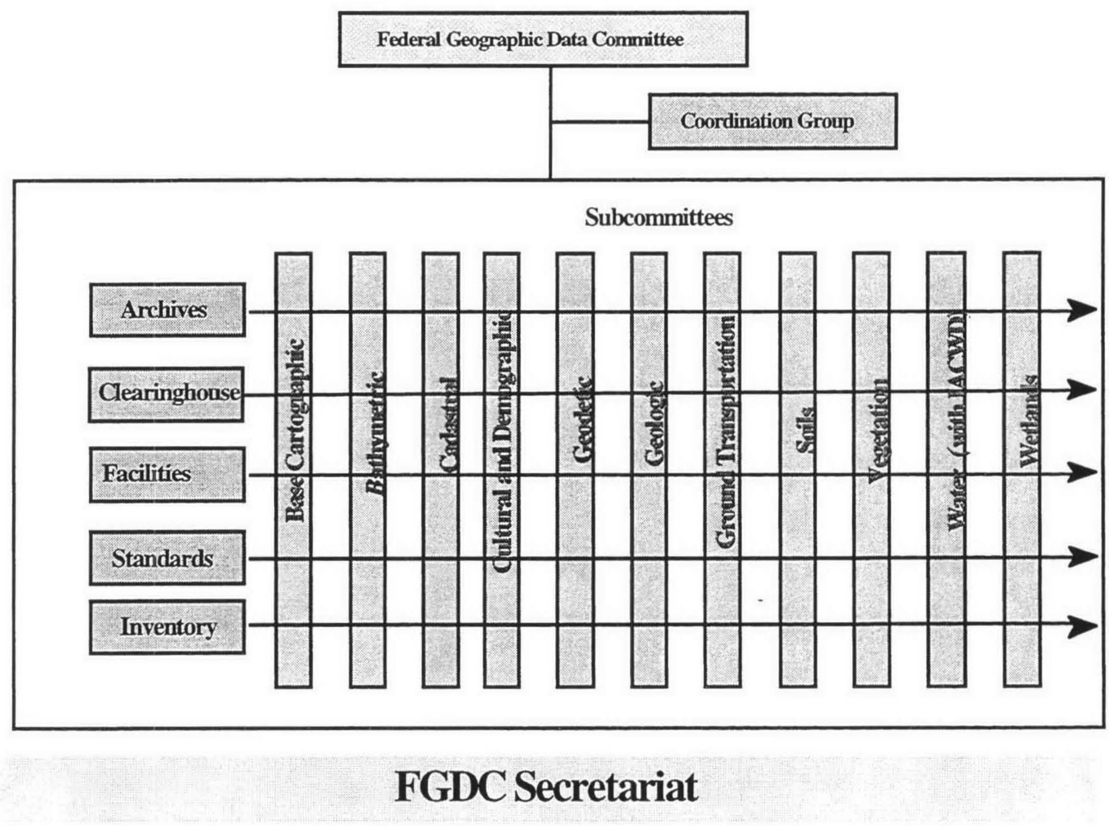
Thematic Sub-committees have been established to develop standards for data collection and content, data presentation and data management including developing "Framework" datasets.

The Framework concept is based on cooperative development of "wall to wall" coverage of the nation for a particular theme to a least common denominator standard agreed by participants.

Themes where sub-committees have been established include Base Cartographic Data, Bathymetric, Cadastral, Cultural and Demographic, Geodetic Control, Geology, Ground Transportation, International Boundaries and Sovereignty, Soils, Vegetation, Water and Wetlands. Hydrography, Vegetation, wetlands and transportation appear to be the most developed national Framework datasets at this stage.

Working groups have been set up covering archives, clearinghouse, facilities, standards and framework.

Figure 1. Organisation of the FGDC



A partnership programme has been established to encourage cooperation between Federal and State coordinating councils and with other groups in the development of the NSDI. Nine State councils have been recognised so far under this programme.

Finally, the FGDC administer a funding program, known as the Competitive Cooperative Agreements Programme that funds approximately $1 million pa on NSDI related projects (up to a maximum of $25,000 per project). The programme is intended to encourage resource sharing projects between and amongst the public and private sector through the use of technology, networking, and enhanced inter-agency coordination efforts.

Most Federal agencies and many State and Local governments are currently disseminating data through the Internet. Many thousands of files are being accessed in this manner. The U.S. Fish and Wildlife Service reported that in the first month of operation, approximately 29,000 digital maps from the National Wetlands Inventory were retrieved. The USGS distributed 40,000 digital files during the first 3 months of Internet distribution.

The conclusion provided by Barbara S Poore of the FGDC in the US report to the 14th United Nations Regional Cartographic Conference for Asia and the Pacific was that:

"Efforts so far to develop the NSDI have focussed on the very specific problems such as: Who has the data? How can the data sets be accessed? Are these data suitable for my application? Future efforts will depend on the community's ability on the many institutional, policy economic and technical issues. These challenges will only be overcome and the NSDI developed through the creation of partnerships, placing responsibility for data creation at local levels, and collaborating to resolve issues."

Implementation Progress in Australia

Although the final configuration is still to be determined, Australia has already made significant progress towards a spatial data infrastructure in a number of areas. These include:

<u>Coordination and national policy</u>.

> ANZLIC, comprising membership from Commonwealth, States, Territories and New Zealand, has been operating since early 1980's and is the peak intergovernmental council providing leadership, coordination and priority setting for the implementation of the ASDI.
>
> States and Territories have their own jurisdictional councils that provide strong coordination mechanisms. The Western Australian Land Information System (WALIS) has been particularly active for over a decade.
>
> ANZLIC has sponsored or undertaken work related to the ASDI including a national agreement on the transfer of spatial information, guidelines on rural street addressing, development of Metadata guidelines, commissioning a study of economic benefits arising from the acquisition and maintenance of the nation's land and geographic information, standards for land use codes and the discussion paper on the ASDI.
>
> Coordinating and policy bodies such as the Australian and New Zealand Minerals and Energy Council (ANZMEC), The Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) and the Australian Local Government Association (ALGA) also provide a mechanism for interagency coordination and cooperation.
>
> The Commonwealth established the Commonwealth Spatial Data Committee 1n 1992 which has membership from Commonwealth agencies with an interest in geospatial data. The CSDC has amongst other activities, produced custodianship guidelines, promoted the publication of metadata by Commonwealth agencies and developed the Commonwealth Public Interest Spatial Data Transfer Policy. There are currently 3 working groups, the

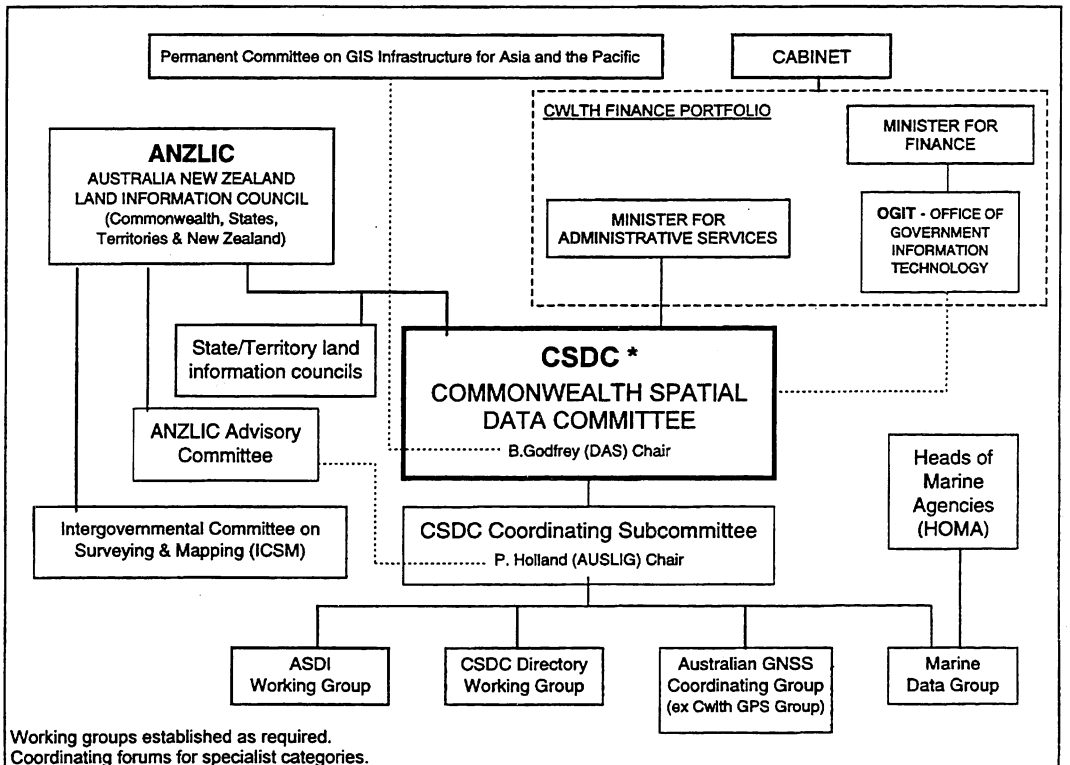
Directory working group, the Spatial Data Infrastructure working group and the Commonwealth GPS Group.

AUSLIG has been given the responsibility for providing a Commonwealth focus for the development of the ASDI and is currently developing a Commonwealth policy position in conjunction with members of CSDC.

The Marine Data Group is concentrating on data issues specific to the marine environment.

One of the main issues facing the Spatial Data Infrastructure working group is determining which national datasets are most important to the Commonwealth to meet their requirements. Another is how Commonwealth policy can best ensure that these datasets are developed, maintained and made readily accessible, including whether Federal funding may be required to stimulate development of the ASDI.

Figure 2. Spatial Data Coordination Arrangements for the Commonwealth



* CSDC membership: Dept of Administrative Services, Dept of the Environment, Sport & Territories, Dept of Primary Industries & Energy, CSIRO, Dept of Industry, Science & Tourism, Dept of Defence, Dept of Finance, Bureau of Meteorology, Australian Bureau of Statistics, Murray Darling Basin Commission, National Native Title Tribunal

Corresponding members:
Attorney General's Dept, Aboriginal & Torres Strait Islander Commission, Australian Archives

Fundamental datasets.

Australia is in a fortunate position to have a single nationally consistent geodetic datum that can be used as a basis for coordinates. A new geodetic datum, the Geodetic Datum of Australia (GDA), which is a geocentric datum compatible with GPS became available from the end of 1994 and the Intergovernmental Committee on Surveying and Mapping (ICSM) has recommended it's Australia wide adoption by 2000.

AUSLIG GEODATA products offer nationally consistent coverage of topographic information in GIS ready formats.

The PSMA database, produced to assist with census mapping for the 1996 population census also provides a good case study of intergovernmental cooperation between the Commonwealth, States and Territories.

In the Geoscience area, the National Geoscience Mapping Accord was established to address one aspect of the deficiencies seen with a critical scientific dataset.

Standards.

The Spatial Data Transfer Standard (SDTS) was published as a standard in January 1995 as AS/NZS 4270 and although slow to be adopted nationally offers one potential solution to the problem of transferring and archiving geospatial data.

Standards for Metadata, land use codes and street addressing, although not yet published Australian standards, are available for use.

ANZLIC plans to conduct a census of geospatial standards to determine areas where effort is required and to identify existing standards that might be more widely adopted.

Data Access.

The main progress here has been publication of the ANZLIC Metadata Guidelines which provide a vision for a national spatial data directory system and identify a core set of metadata that all jurisdictions have committed to record. The Commonwealth, through the National Resources Information Centre (NRIC), has undertaken to implement a national directory with input from all Commonwealth agencies and the States and Territories. A new directory has been designed and is being populated by Commonwealth agencies. It will go live when there are sufficient metadata in it. Meanwhile, some Commonwealth agencies, such as AUSLIG, AGSO, ABS and ERIN, are publishing their own metadata on their Internet home pages.

Most State and Territory land information councils have implemented metadata directories.

Comparison between the United States and Australian models

Although the Australian Spatial Data Infrastructure model is still under consideration it is possible to make some observations as to likely similarities and differences. The first obvious difference is that the population density and size of the economy in America is roughly twenty times that of Australia. The money spent on infrastructure will obviously be much greater than in Australia. Consequently the resolution of datasets covering Australia will probably be less than for America.

Another observation is that in America there is no equivalent of ANZLIC ie. a coordination council with representation from Federal and all State and Territory Governments. While the FGDC relies on interest and cooperation from various governments, and there has been a significant level of participation by State agencies, Australia has an established structure of coordinating mechanisms that enjoy the support of all jurisdictions. Australia can reasonably hope to achieve better overall coordination and consistency in its policies as a result.

ANZLIC's proposal to determine "sponsors" for various themes potentially places a lot of responsibility on the national sponsors. However, at the February 1997 ANZLIC Council meeting in Hobart it appeared that there is an expectation by Council that the ASDI will strongly reflect the jurisdiction structure of ANZLIC. This probably means that custodianship will be controlled at the jurisdiction level and that the role of sponsors will be to coordinate custodians across jurisdictions, within their theme, to ensure that all are contributing towards a nationally consistent layer of data. The national spatial data directory system that ANZLIC outlines in its Metadata Guidelines, will also reflect this jurisdictional structure with jurisdiction level directories becoming part of a national network of directories providing access to the whole ASDI.

In the United States there is a policy that data produced by federal government agencies is not subject to copyright, whilst in Australia government copyright is protected and commercial exploitation of government copyrighted data is subject to control through licensing arrangements . This difference in policy will have an impact on distribution arrangements.

Despite these differences there are many similarities between the proposed Australian and the American NSDI. The fundamental concepts are the same and we can learn much from the experience to date of the implementation of the NSDI in America.

Conclusion

The successful implementation of the ASDI will offer many benefits to users of geospatial information in Australia. There is a groundswell of support for the concept amongst government, industry and professional associations.

Valuable lessons can be learnt from the experiences to date in America but above all there must be an inclusive, cooperative approach taken between the different levels of government, industry and users to achieve the potential benefits offered by the ASDI.

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OUTCOMES FROM THE INDUSTRY FEEDBACK SESSION

The Industry 'feedback' session was chaired by Dr Lesley Wyborn and included representatives from the State/Territory geological surveys as well as AGSO. Approximately 60 delegates to the Forum participated in the session.

1. Some industry representatives indicated that they were waiting for a lead from Government on the transfer from AGD to GDA. Ian O'Donnell indicated that the Chief Government Cartographers have recommended that CGGC consider a uniform change over.
   -AUSLIG's revised GEODATA 1:250K, soon to be released, will be based on the new datum
   -It was also noted that software vendors need to incorporate the new spheroid option in their software upgrades.

2. Some industry representatives requested that the surveys support MapInfo and ARCVIEW to the same level that we support ARC/INFO

3. More emphasis has to be placed on data quality

4. Clients of our data would appreciate the inclusion of colour tables where applicable.

5. There was some discussion about metadata standards. AGSO indicated that it will be working, without question, to the ANZLIC Metadata standards which will ensure compliance in an Australian Spatial Data Infrastructure (ASDI) environment.

6. Companies indicated they want AGSO and the Surveys to standardise on codes and data structures within GIS

MAKING GIS 'GEO-FRIENDLY'

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One of the greatest challenges for us in BHP Minerals Exploration has been to make the GIS environment 'GEO-FRIENDLY'. In simple terms this means making data easy to find and to use for our explorers and technical staff. I cannot emphasise enough that it has required us to maintain an 'end-user' perspective at all times - to focus on how they are going to want to use the data.

The core issue in making GIS 'geo-friendly' is data management. It is critical that explorers are able to use information effectively, otherwise there is little point in having it. This means ensuring that data is easy to find; readily accessible; relevant; accurate; consistent; and up-to-date for our explorers to view and manipulate.

The quality of digital data from suppliers is at best varied. There is little consistency between suppliers and sometimes even from the same supplier. Each dataset needs to be managed separately. Some suppliers use codes for attributes, which are at best cryptic. The end-user has no idea what they mean, and often data administrators have no idea what they mean because the tables to de-code them are not routinely provided with the digital data. These sorts of problems make the data difficult to use and ultimately decreases its value and does not make it 'geo-friendly'.

BHP Minerals Exploration has been involved with GIS for 6-8 years, using both ArcInfo and ArcView on a UNiX platform. Initially, we started building an in-house GIS front-end (in ArcInfo) for querying and manipulation of our databases and datasets. This was discontinued when ArcView, the user-friendly spatial querying front-end for ArcInfo, was released. This was found to be more robust and easier to use. Since that time we have concentrated on managing our GIS data and environment to ensure that it is 'geo-friendly'. Considerable effort has been spent to ensure that all our spatial data has been made into GIS coverages and now there are over 4500 coverages to manage.

The term 'geo-friendly' probably conjures up many ideas. I will present what it has meant in the BHP Minerals Exploration GIS environment - What it means to us; How we try to manage our data for our explorers; and what data suppliers can do for us the GIS community. I will focus on the following concepts and provide you with examples to show what enhancements we have made to the GIS environment to make it more 'geo-friendly'.

1. Standard Directory Structures

We have adopted a standard directory structure for GIS data in both our Australian exploration offices. All GIS data is located under a directory called gis/data on dedicated GIS host machines in each office. Here it is divided into directories on the basis of geographical areas such as regions, states and countries.

Each of these geographical directories contains a standard set of sub-directories based on data type e.g. Geochem, Geology, Geophysics, Other, Tenement, and Topo. All our master GIS datasets are located in these sub-directories. Users can readily identify where to go for the type of information relevant to them from this one-stop-shop.

2. Standard Coverage Naming Conventions

A 13 character naming convention has been adopted for all GIS coverages under gis/data. This is the maximum number of characters allowable for coverages in Unix ArcInfo. The format for naming is: aaaabbccc.ddd and from this explorers can readily determine the following:

Area (mapsheet or region) covered by the coverage (aaaa)
Scale of data source (bb)
Type of data (ccc)
Projection of the coverage (ddd)

3. Read, Write and Edit Protection for Master Datasets

In our UNiX environment we have established a group called 'data' with read, write and execute permissions for all the strategic GIS data under gis/data. A select number of staff belong to this group. Explorers (the end-users) are not included. This ensures that only those with group 'data' permissions can move, alter, rename or delete coverages under the gis/data directory. Along with regular backups, this provides a high level of security for the data.

Each explorer has their own sub-directory or working directory where copies of digital data can be modified.

4. Metadata

There were 2 main reasons for metadata development: (1) to record data about each coverage e.g.. source, version information, data format, projection, quality, and descriptor keywords; and (2) to greatly improve explorers awareness of what digital data we hold in the gis/data directory.

Our needs were for a simple, user-friendly, GUI interface that provided explorers with pointers to relevant information. A metadata system, based on ArcInfo's info file format, was developed for our point, line, polygon and region coverages. Karl Warschau will be presenting more on this later today.

5. Concatenation of Coverages

This means combining many different (but similar) data types into a single coverage for easier management.

The AGSO 1:100,000 Mt Isa digital geology is a perfect example. For each of the 32 mapsheets there were up to 22 separate layers. This meant a total of 704 coverages to manage - a difficult task for the data administrator as well as the explorer. All the topographic and structurally-related layers were amalgamated into TOPO (anno, culture, frame, hydr, grid and graticule) and STRUCTURE (bedding, cleavage, faults, folds, foliation, joints, linears, lineation, minor folds, trends, and veins and dykes) respectively, thus reducing the number down to a manageable 192 coverages.

6. Concatenation of Attributes

This means amalgamating similar fields in a coverage into one. A typical example is Minocc (mineral occurrence data) where we have concatenated four fields, Commod1, Commod2, Commod3 and Commod4, into a single one called Commodity. The integrity (order of commodities) has been kept in tact so that explorers can readily identify the importance of a specific commodity whilst making searching much easier.

7. Expanding Codes

Data supplied as codes are frustrating to use in the GIS environment. Explorers are rarely cognisant of their meaning rendering the data ineffective. Where the data supplier is able to provide a simple ascii file, in the format: code, description, a simple AML adds a description field which is more meaningful to the end-user. AGSO's list of bmr_codes (now agso_code) is a candidate for this treatment e.g. 351 for thrust fault or 541 for anticline etc. Fortunately, the codes remain the same from mapsheet to mapsheet. These lists of codes and descriptions should be a deliverable with the digital data if suppliers insist on using codes.

8. Adding Fields

Minimal attributes are often supplied with digital data e.g. one attribute attached to a point, line, or polygon. Quite often there is additional information readily available (hardcopy maps and reports) which can be added. The digital Geology of Australia (1976) at 1:2,500,000 is an example where the polygons only have the geocode attached. Additional information from the hardcopy map such as Age and Description are available. By this simple addition, explorers are able to query more effectively e.g. Age = Permian and Description = *granite* whilst adding value to the dataset.

9. Adding Value to Datasets by the Union Process

By the process of union, the attributes from one coverage can be added to another, but only where their spatial extents overlap. The union of geology and geochemistry is probably the most useful, where the attribute information from the geology coverage is added to the point geochem data. This enables geologists and geochemists to analyse geochemical data more critically, taking into account the lithology of the country rock. More rigorous analysis of background geochem values can be then be undertaken.

10. Other Issues

- We aim to standardise all our strategic GIS coverages into the geographic coordinate system using the Australian National Spheroid. This will provide greater flexibility because of the ability of ArcView to project on the fly.
- We aim to have both AMG and geographic coordinates attached to all coverages.
- Another principle which we try to adhere to is to ensure that all attribute information is attached to each coverage. Linking of tables to coverages are fraught with data management problems.
- We are strong advocates for having structural and geological boundary information in separate coverages. This ensures effective GIS analysis.
- There are not enough quality control checks put in place by data providers, which suggest the lack of data dictionaries for data entry and lack of rigorous checks once completed eg.
    - Numeric fields with characters in them

- Numeric fields that should be 8 digits long containing other variations
- No reference control on simple things like mapsheet numbers e.g SH5402 or SH-5402 or SH/5402 or SH542
- AMG coordinates to five decimal places (obviously irrelevant)

- There needs to be more importance placed on the definitions of attributes, especially fields that could be numeric. Are end-users going to want to ask a question such as: I want all X = 1234 or Y < 200 etc.

Conclusion

The 'End-User' perspective is a critical part of the whole GIS process. This is where the real power of GIS is realised and hence the value of data supplied to us. If we want quality decisions from GIS we need to be provided with quality data. There is room for improvement for data suppliers to be more rigorous in their quality control checks and planning of attributes so that they focus more on the 'End-User'.

I hope that you can relate to some of the trials and tribulations that we have sustained in order to make our GIS environment more 'geo-friendly'.

Converting word-based seabed sediment descriptions to numerics using a fuzzy parser

New software converts word-based geological data into numerics for use in GIS and Numerical Modelling. The first application has produced detailed seabed materials maps for the Australian EEZ

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An overwhelming amount of data on seabed materials is in the form of word-based descriptions. With the rapid growth of mapping systems, relational databases and numerical modelling tools, a strong need has arisen for ways to transform that data into numerics which are much better suited to computerised display and analysis systems. A new technique for doing this draws on the concepts and processes of parsing, thesaurus, syntax and fuzzy set theory.

Word based data
Seafloor materials have been described linguistically rather than numerically for good reason - they are extremely complex in their composition, structure and properties. Composition, for example, involves chemistry and grain type; grain type is complex in itself, embracing mineral composition, grain structure, alteration, shape and origin.

A large number of numbers is needed in order to describe a sediment effectively. In practice sedimentologists make a compromise and precision is traded for brevity. Descriptions are made which convey characteristics to a given level of accuracy by assigning each sample to a number of sediment classifications , like "muddy", "phosphatic" or "cemented". It is worth noting that even in new acoustic seafloor classification systems outputs are provided as descriptive word data.

Offshore scientists and surveyors look set to continue using word-based descriptions, not only for brevity, but because the investments in equipment and time for detailed numerical measurement of seabed properties over large regions are unlikely to occur. A vast store of descriptive seafloor data has been amassed over the decades and continues to be amassed. Considering the urgent need for seafloor datasets to support decisions in environmental management, offshore industry and fisheries, we need to use all this data

How can word-based data be used in modern computational mapping and modelling systems that prefer numerical types of data? Some GIS and RDB systems do handle word data but not flexibly. Classically, it is done by keyword or synonym searches and the results may be ranked by frequency of occurrence (as in World Wide Web searches).

New approach
These standard techniques do not recognise meanings / inferences which occur in word-based data and are obvious and important to a sedimentologist - for instance that a "bryozoan sand" is physically a gravelly sand composed of low sphericity, highly porous and crushable carbonate grains. Neither do they make use of abundance weightings built into the terms and description syntax such as terms like "slightly" or "abundant".

Our approach allows the implied and explicit meanings in word-based descriptions to be used. The method combines a parser, a thesaurus, syntax recognition, some symbology in the database and also fuzzy set theory. It is probably widely applicable in word-rich geological and ecological sciences.

Most sediment descriptions contain constructions like: ... *[quantity] (modifier) object* ... . In the example, "slightly muddy relict bryozoan sand with rare green shark teeth" we recognize 4 objects and their modifiers: *[slight] ( ) mud, [ ] (relict) bryozoa, [ ] ( ) sand, [rare] (green) shark_teeth*. In this way the description is analogous to a linear equation of the form: $n * a x + m * b y + ... = total$.

Recognition of the objects, modifiers and quantities is assisted using a simple and easily implemented symbology in the database: for example, "rare/ A" and "A /rare" signify that A is rare; "coarse-" and "soupy-" are modifiers; also terms like "bryozoan sand" can be welded into one, "bryozoan_sand", here so that instances of compositionally ambiguous "sand" are minimised.

The objects, modifiers and quantifiers are identified during parsing by reference to a look-table which is both a dictionary and thesaurus. Synonyms - words or numerics - can be assigned from the table. For example "beachrock" is simply "rock" in terms of texture, "carbonate" in composition and "weakly cemented" in consolidation. Synonyms also allow a table of grain type abundances to be created so a GIS can display geographic abundance patterns of sediment constituents - such as heavy minerals, bryozoa or phosphate.

Many objects (with their modifiers) have a characteristic grain size and composition. "Bryozoa" for example are 100% carbonate and about -1phi in average grainsize. From a description a weighted sum is formed of the carbonate, grainsize and other attributes of each object where that data is available (an 'unknown' component is also accumulated and is used to accept/reject a parsing). Weightings can be derived from quantity factors internal to the term (e.g., "marl" ~50% carbonate) and/or attached in syntax as in the case of terms like "/rare". Where a syntax obeys a rule of most or least significant component last, objects are (gaussian) weighted according to their number and position in the description.

The software also handles petrological grain count data but differently than for descriptions.

Outputs
The end result of the parsing operation is a tabulated set of numerical aliases - approximations - for the description: component abundances, average grainsize, gravel:sand:mud ratio, carbonate percent, indexes of rock and weed abundance and other outputs which are very well suited to use in GIS and modelling systems.

Successfully parsed results are output to tables separate from those reporting actual measured grainsizes, etc. The accuracy of the parser is then tested using samples/locations having available both described and measured data. The results (Fig. 1) show a statistically good correspondence with R^2=0.77 on a linear fit and the difference $<\pm2$ phi in 96% cases. For context, grainsizes of repeated samplings within a m^2 area of seabed often vary by 2phi.

The reliability performance of each parsing is monitored; if the unknowns exceed a set limit (usually 10%) then no result is returned. If a word does not occur in the dictionary the parsing is aborted. Parser performance could be improved further. Separate adjustments could be made for individual datasets, regions or facies. As more combined numeric / descriptive data comes to hand the power of the 'calibrating / teaching' dataset will grow.

Applications
Having produced numerical data from the text descriptions, and combining that with actual measurements of parameters like grainsize, it is possible - even for sparsely researched offshore Australia - to make relatively detailed maps of offshore soil types. Significantly, the use of the text-based descriptive data has most impact on the coverages in inshore zones where the call for data to assist environmental management and engineering feasibility studies are most frequent.

A key demonstration product from the parsing process is the mapping of average grainsizes for the Australian maritime area (Fig. 2). This mapping and others like it is now finding wide application in studies of seabed stability, naval acoustics, biological habitat diversity, nutrient budgets and the ground truthing of seabed swath mapping. As more data is added resolution and reliability of the data will increase.

Fuzzy Facies Recognition

The concept of Fuzzy Membership is invaluable as a tool for handling the linguistics of sediment descriptions. At a basic level, Fuzzy Set Theory provides a formalism for handling the component weightings within the sediment descriptions; for example, word-described grainsize classes are classic fuzzy set elements with distinct membership functions.

After the parsing Fuzzy Set Theory plays a strong role in sediment facies recognition - a most important step in dividing the offshore into zones where different processes act. A sediment facies is first defined with memberships attached, again using the [quantity] (modifier) object structure - for example, "[0.5] () mud AND [0.5] () Halimeda" for the mud-Halimeda facies. A sediment's membership of the facies is the sum of the minima of memberships (abundances) of each component - i.e., of the mud and the oatmeal-like alga Halimeda. Fuzzy OR and other fuzzy functions like CONCENTRATION can be used.

In this way each sample in the offshore database can be assigned a membership of each conceivable facies and GIS mappings of the intensity of a facies can be mapped around Australia (Fig. 3).

Summary

Word-based sediment descriptions dominate our data holdings on offshore soil types and a new method of comprehensively bringing them into numerical formats for use in GIS and numerical modelling is now available.

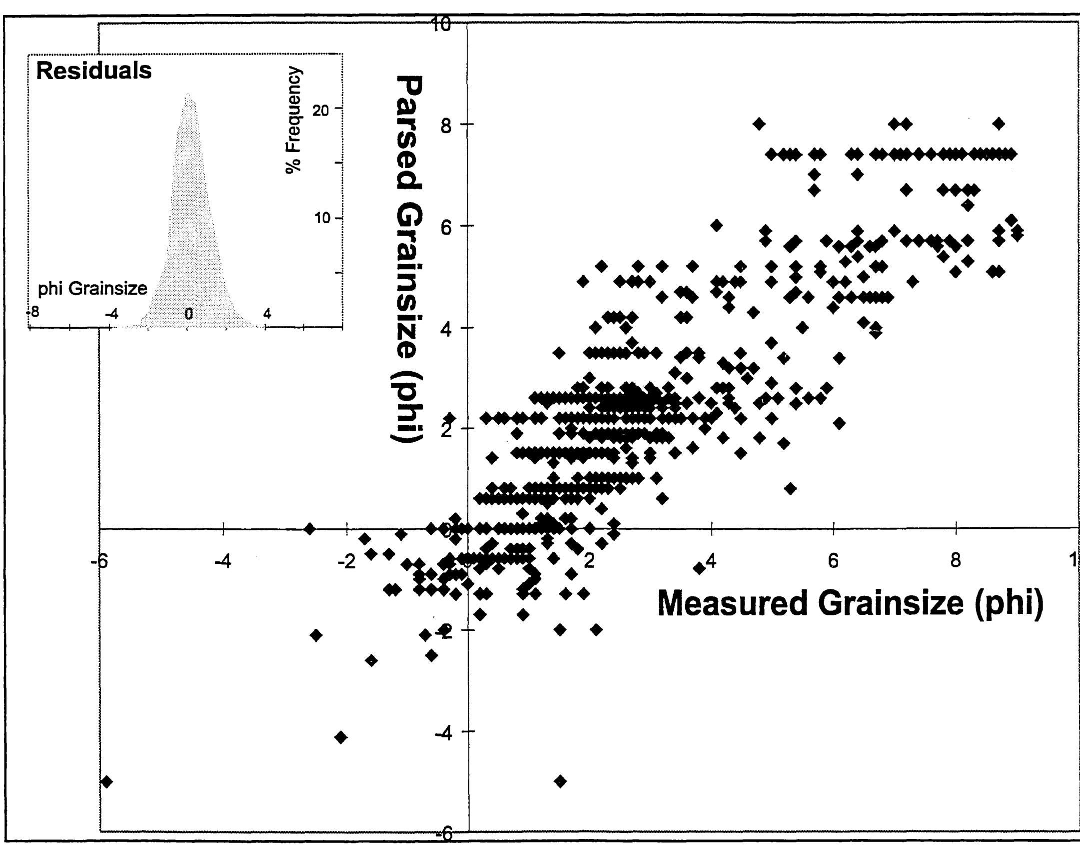

Figure 1: Parsed vs measured grainsizes for samples where both word and numerica data available.

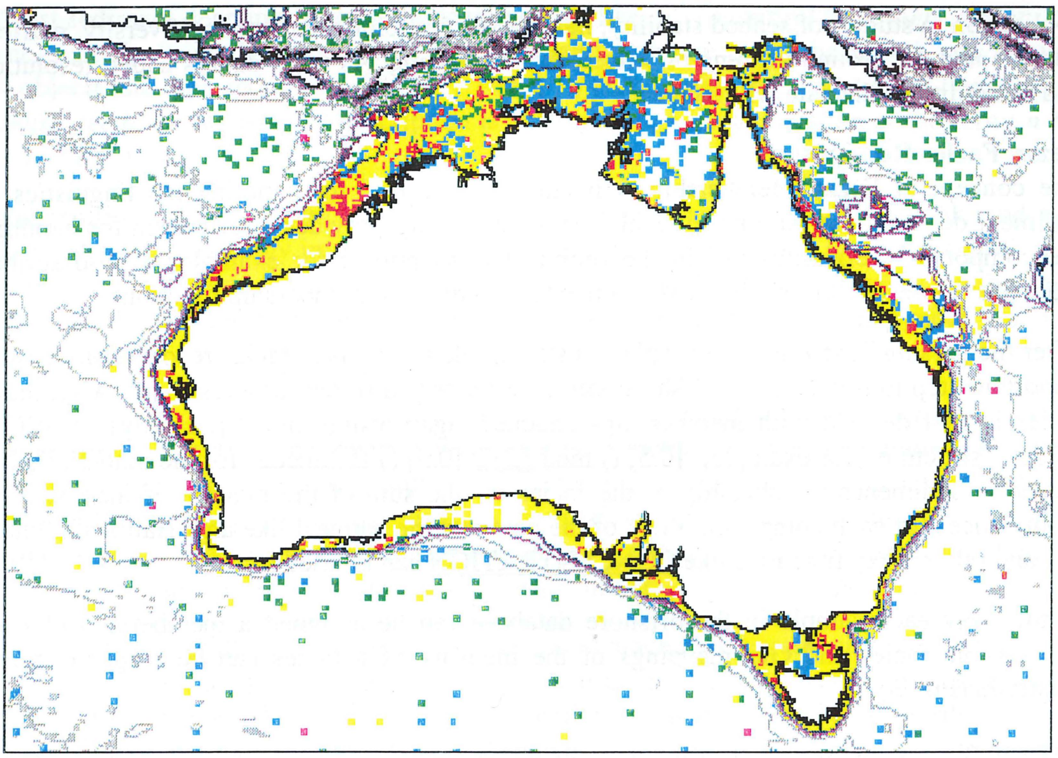

Figure 2: Grainsizes of Australian offshore sediments (red to blue -6 to 6 phi)

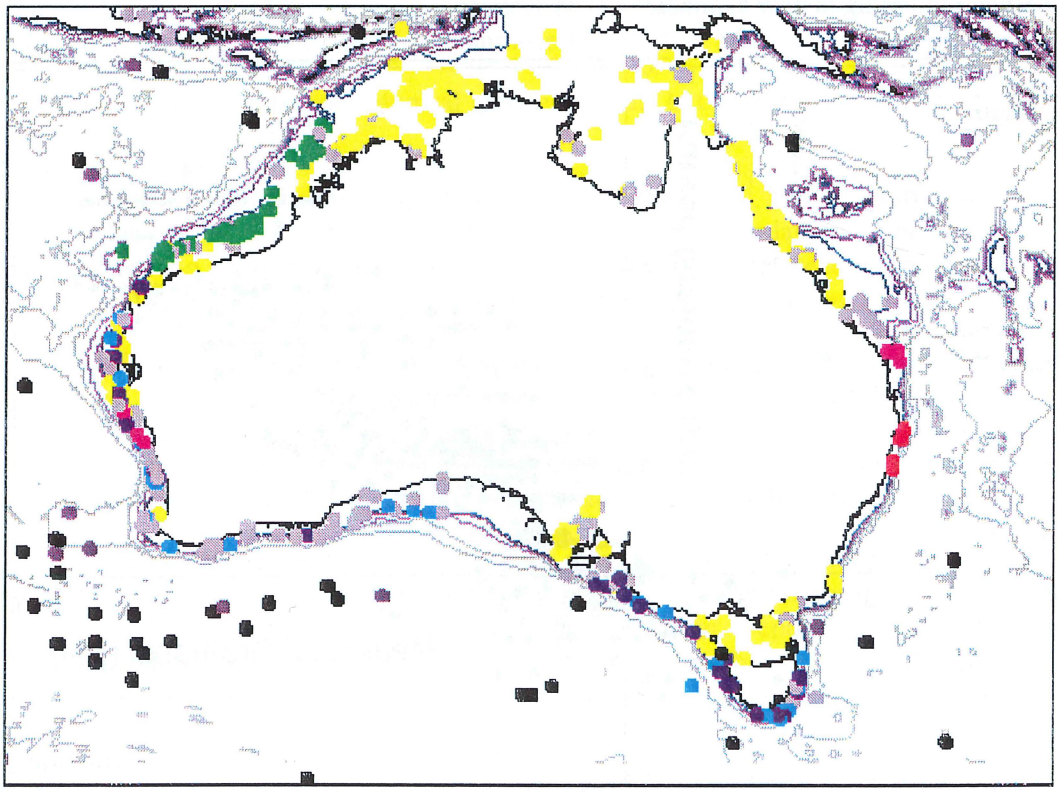

Figure 3: Some important sediment facies of the Australian EEZ (blue-grey bryozoan, purple rhodolith, green oolith, yellow shell, red phosphates, black Mn nodules/crusts)

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Integrating affordable GIS with exploration data analysis requirements - a development history

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ABSTRACT

New integrated exploration software systems now becoming popular are built upon desktop GIS systems with the addition of specific methods and tools required by geoscientists. These new systems contrast with traditional exploration data analysis and display software packages which have typically evolved from minesite data processing or CAD packages and which lack the important spatial database framework of a GIS.

The development of integrated exploration-GIS software has been spurred on by the availability of relatively low-cost/high-functionality desktop GIS and the needs enunciated by forward thinking geoscientists in some of Australia's larger mineral exploration companies. The resulting software has evolved rapidly, with significant input from users, to the point where many companies now favour these hybrid GIS solutions above the traditional exploration packages for much of their exploration data integration, visualization and presentation requirements.

The development history of ***Discover***, an exploration-oriented GIS add-on, illustrates the way that these integrated exploration-GIS software packages have developed to address industry needs and take advantage of changing technology.

ACKNOWLEDGEMENTS
Stephen Winter (Encom), David Gamble (Acacia) , Robyn Hee (CRAE), Nigel Radford and Gordon Barnes (Normandy Exploration), Nigel Hall (CRAE), Clive Willman (GSV).....

INTRODUCTION
The previous situation
The current GIS packages
Introducing Discover

PERCEIVED NEEDS
User input
How did we see the project developing

HISTORICAL DEVELOPMENT (1992 - PRESENT)
Internal development priorities (surfaces, object editing, ...)
Externally driven devlopment (EL applications, cross-sections, graphmap)

CURRENT SITUATION
Still only 2d
Starting to integrate vectors and rasters - aided by improvements (eg AV, ER-Mapper....). Data accessibility - variety of databases - plus new exploration specific databases (explorer, ...)

The reasons that these systems have acheived popularity is due to ease in accessing data (ability to store data in popular formats), ease in integrating data (ability to combine eg. an AGSO digital map with local mapping, with AUSLIG topography, with regional sampling program, tenements database, DTM etc.) ease of use (standard windows interface) and ease of presenting data (presentation quality output available on standard windows output devices). The exploration add-ons have added to that x-sections, gridding and contouring, automated map production, and ......

Future trends will see development of desktop GIS software to allow data storage in a variety of industry standard databases, with improving presentation tools and 3d visualization.

FUTURE TRENDS
Fully integrated vector and rasters to allow integrated analysis of exploration datasets.
Improved cartographic tools will allow production of better maps within the package, reducing the need to go to CAD.

3D will start to become used, as developments in hardware/software (OpenGL for Win32) make it affordable. Extending the exploration-oriented GIS into this domain will be a considerable challenge.

RECENT APPLICATONS AND RESEARCH INTO MINERAL PROSPECTIVITY MAPPING USING GIS

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CSA Australia

INTRODUCTION

Mineral exploration is a task that involves the **collection, analysis, and integration** of data from a variety of sources, generally at small scale over sizeable areas and progressing to large scales over relatively small areas, with the objective of **defining locations** likely to host mineral deposits.

WHAT IS MINERAL PROSPECTIVITY MAPPING?

Traditionally, the integration of exploration data sets to investigate overlap relationships between anomalies was done manually with the aid of a light table. This process was highly subjective, labour-intensive, and almost impossible to repeat without getting different results. With the availability of relatively inexpensive, high-powered computing workstations and GIS, the efficiency with which this process can be carried out has improved dramatically. **Computer based mineral prospectivity mapping** allows the geologist to make the evaluation process more thorough, analytical, repeatable and less subjective than strictly manual methods. Improved statistical and expert-system methods applied for integrating data sets allow computer-generated analyses to mimic and/or improve upon the performance of experienced exploration geologists due to the ability to integrate multiple data sets simultaneously.

However, mineral prospectivity mapping does not remove geologists, geophysicists and geochemists from the exploration process. **Mineral prospectivity mapping is simply part of an overall exploration process.** Its benefit lies in its ability to enhance and organise data into a coherent model and to make the analysis of exploration data sets more efficient and quantitative than what the exploration team already does intuitively.

TYPICAL MINERAL PROSPECTIVITY MAPPING GIS OBJECTIVES

Typical objectives of a mineral prospectivity GIS mapping project would be to:

- establish a digital, geographically-registered database of proprietary exploration data sets,
- develop and apply quantitative methods for characterising each data set, for studying their inter-relationships, and for combining them to estimate mineral potential, and
- generate maps showing areas of favourability for new deposits using a variety of assumptions and integration models.

MINERAL PROSPECTIVITY MAPPING GIS BASED MODELS

Exploration for different mineral deposit types require different models and usually uses different data sets. Therefore, different data integration and analysis techniques are required to resolve problems of variable complexity.

In some cases there is a wealth of information and data and a data-driven approach is applicable. In other cases the information available has to be derived from remotely sensed and geophysical data and the models are limited to the geoscientists conceptual ideas about what could be important. In these cases, a data-driven model is impossible to apply and one is forced to use either simple ranking or a knowledge-based system within the GIS modeling.

Target modelling that falls in the data-driven style include the exploration for nickel sulphides and laterites and lode gold in the Archaean Craton of Western Australia. Here it is possible to test such hypothesis as the relevance of :

- faults (type, direction, splays, and flexures) to known gold and base metal deposits (lateritic and lode);
- East-West Proterozoic dykes to gold;
- all dykes and impervious barriers to nickel laterite deposits;
- the importance of granite types and their proximity;

Target models that do not fall in the data-driven style, are areas of Australia (and overseas), where no known or few mineral deposits are known to exist. In such areas the geological model or the geoscientist's experience and expertise are fundamental to designing a GIS targeting model that is relevant to the exploration problem. Here it is possible to use sophisticated knowledge driven models but often simple Boolean and/or Fuzzy Logic models are adequate. Even these latter allow interesting correlations to be made and may highlight new geological aspects that were not previously known or considered. Often a requirement in such areas is the interpretation of remotely sensed data (Landsat, SPOT, radar) and geophysical data (aeromagnetic, radiometrics, gravity). Constructing these as digital data sets allows for the ultimate integration in the GIS.

In addition true GIS modelling for mineral exploration targeting needs to be cognisant of the geological model that describes the ore body or mineralisation sought. Alteration style and recognition are just as and probably more important than what the data may appear to be telling one or what the geoscientist observes or reasons. To include such factors may require the use of AI and neural networks. However, it has been the writer's experience that often the simplest solution works the best. Perhaps the simple data driven approach is most useful as a first-pass. More complicated GIS modelling for exploration targeting can be used where better data or geological model constraints are recognised. An understanding of the data and its limitations are vital to be useful in GIS modelling. However, the reciprocal may also be true, that is, that the use of GIS leads one to a better understanding of the data.

MINERAL PROSPECTIVITY MAPPING RESEARCH AND APPLICATIONS

Mineral Prospectivity Mapping is frequently used to define targets as part of the exploration process in search for:

- Nickel laterite deposits,
- Nickel sulphide deposits,
- Lode gold deposits,
- Lateritic gold deposits,
- Diamondiferous kimberlites,
- Pb/Zn deposits.

Lead in Australia

An examination of the BRS MINRES database for lead in Australia reveals an outstanding correlation to such simple elements as the tectonic cratonic boundaries and major mapped faults of the Australian continent. For example, 41 of 73 lead deposits fall within 40 kilometres of these tectonic boundaries. Such as area represents 2,696 square kilometres compared to the total area of Australia of 7,506,564 square kilometres. Thus, 56% of the deposits fall in 3.5%

of the total area. This is a quite outstanding reduction in the area selection process and can be further reduced with the introduction of other elements such as faults and buried geology.

Nickel

In a study of nickel and nickel laterite deposits on the Sir Samuel, W.A. 1:250,000 map sheet, 10 of 12 known deposits occur in a 40 metre elevation interval in the Digital Elevation Model (DEM) for the Sir Samuel 1:250,000 sheet. This represents a reduction in total area for the sheet from 16,431 to 3,992 square kilometres for a success of 10 from 12 deposits. This correlation of lateritic nickel deposits to a specific elevation interval has also been confirmed over six 1:250,000 sheets in the Kalgoorlie region. Clearly this is an association that is of interest and could be useful for the discovery of other deposits in the area.

Other criteria tested in the Kalgoorlie region and found to be important are faults and dykes, both of which, probably acted as impervious barriers to fluid flow either in the geomorphological formation of the lateritic profile or to the creation of the nickel laterite deposit itself.

Other criteria illustrated tested for nickel deposits on the Sir Samuel, W.A. sheet are major faults derived from the GSWA aeromagnetic features map. A weights of evidence analysis indicates 10 of 12 deposits fall within 800 metres of major faults. A polygon coverage of buffered faults to 800 metres represents an area reduction of 2,803 square kilometres from a total area of 16,431 square kilometres.

A lineament interpretation of the same area done by Dr EST O'Driscoll reveals a high correlation with nickel deposits within 1,500 metres of his WNW lineaments. On the Sir Samuel sheet area 8 of 12 deposits fall within the buffered corridors.

Gold and Kimberlites in Tanzania

As discussed previously, in areas where less geological and exploration data is available such as in many overseas countries, a critical part of the GIS pre-processing may involve processing and interpretation of remotely sensed data. Such as example is the lineament analysis of a Landsat TM scene for the Lake Victoria area in Tanzania. Here, flat WNW lineament zones show an outstanding correlation to clusters of known kimberlite pipes when projected to the ESE. In addition, ENE lineaments show a high correlation to known gold deposits particularly where they intersect NNE and NNW trends or zones. Such pattern directions can also be seen in detailed aeromagnetic surveys flown over prospect areas in the area. Although not yet analysed statistically with the GIS, this is the next step.

Gold in Indonesia

A similar interpretation of a Radarsat mosaic of Borne/Kalimantan reveals a fundamental crustal zone that runs through a number of major gold deposits such as Busang. Where these zones cut orthogonal lineament zones appears to be the loci for several major deposits (Busang and others). Work in this area and the compilation of other data sets into a GIS is continuing.

BENEFITS OF MINERAL PROSPECTIVITY MAPPING WITH GIS

Using GIS for Mineral Prospectivity Mapping leads to huge increases in the understanding of both the geological data available but also the geological model itself. Thus, using a GIS for Mineral Prospectivity Mapping, greatly increases the flexibility of such geological models and the inherent handling of the data itself.

If the data is handled more than once, there are enormous gains in productivity. Thus, it is much more cost effective to use a GIS than to try to handle the data manually.

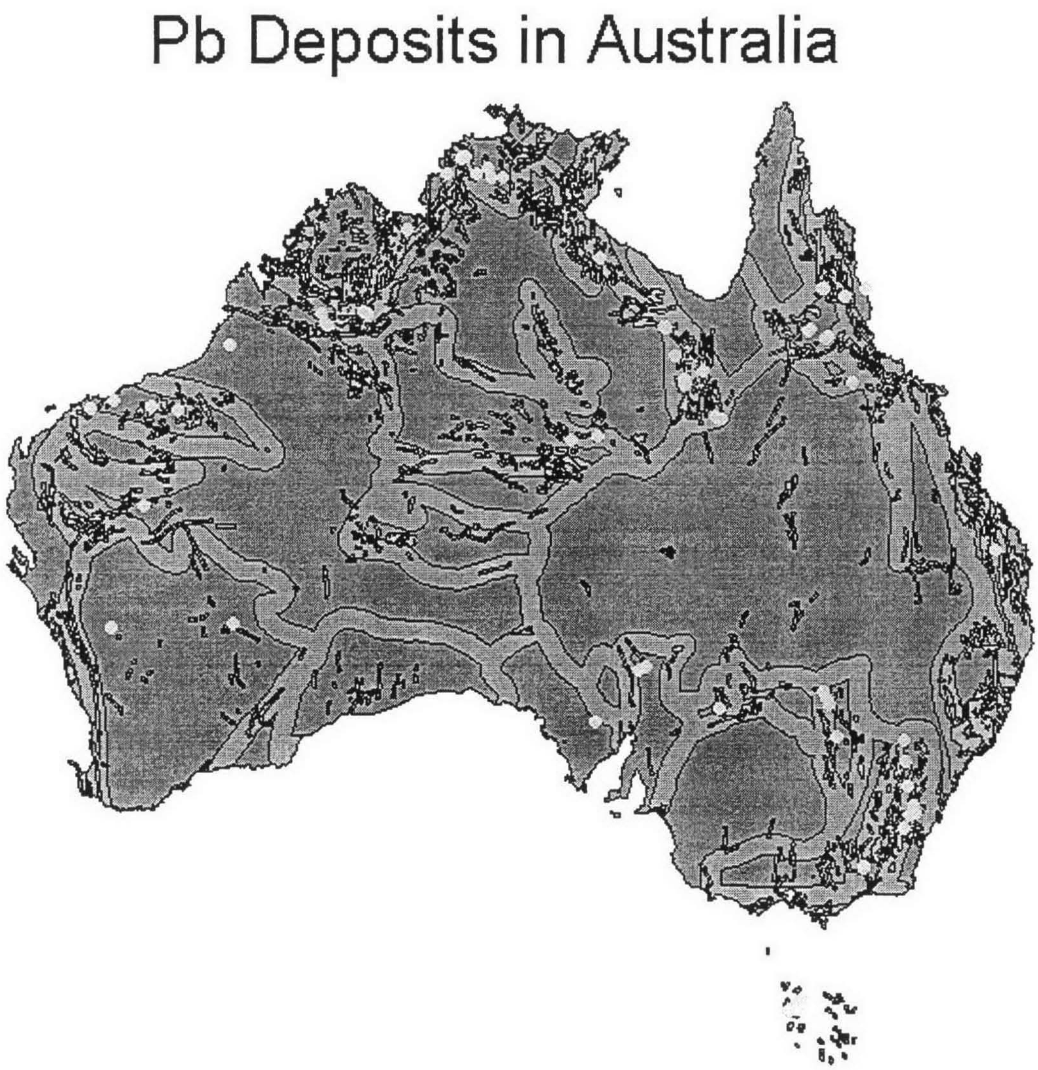
Mineral Prospectivity Mapping using a GIS means the results are less subjective and therefore more repeatable. MPM is more quantitative both in terms of simple and complex GIS modelling.

Last but not least, using a GIS for MPM forces the construction of a highly organised digital data base that can be used over and over for many years into the future.

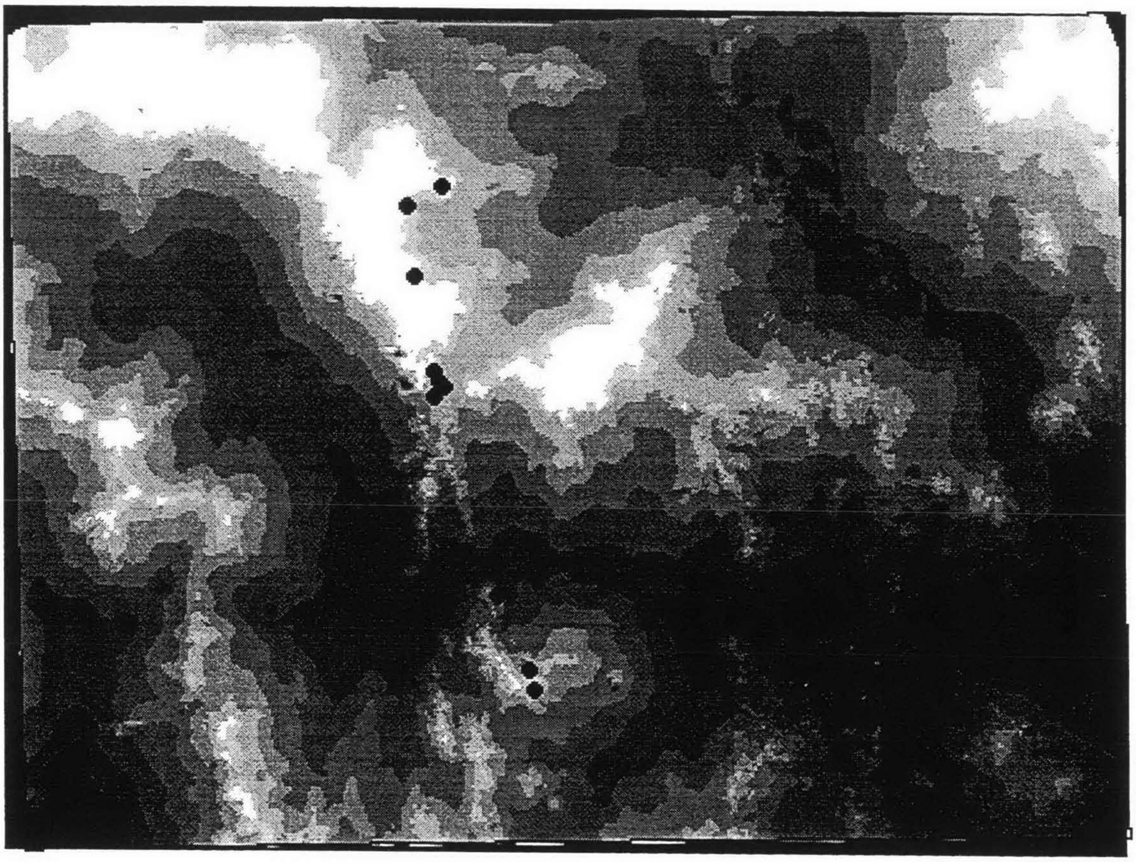
CONCLUSIONS

How many of the correlations described above would have been made if the data had not been processed and examined using a GIS? Therefore, despite the need for intelligent GIS modelling techniques such as AI, knowledge based and neural network GIS models, significant relationships can be made and understood using simple GIS analysis techniques!

Application and research into applying a variety of GIS Mineral Prospectivity Mapping techniques is continuing on a large number of geological problems and environments in Australia, SE Asia and Malaysia/Indonesia.

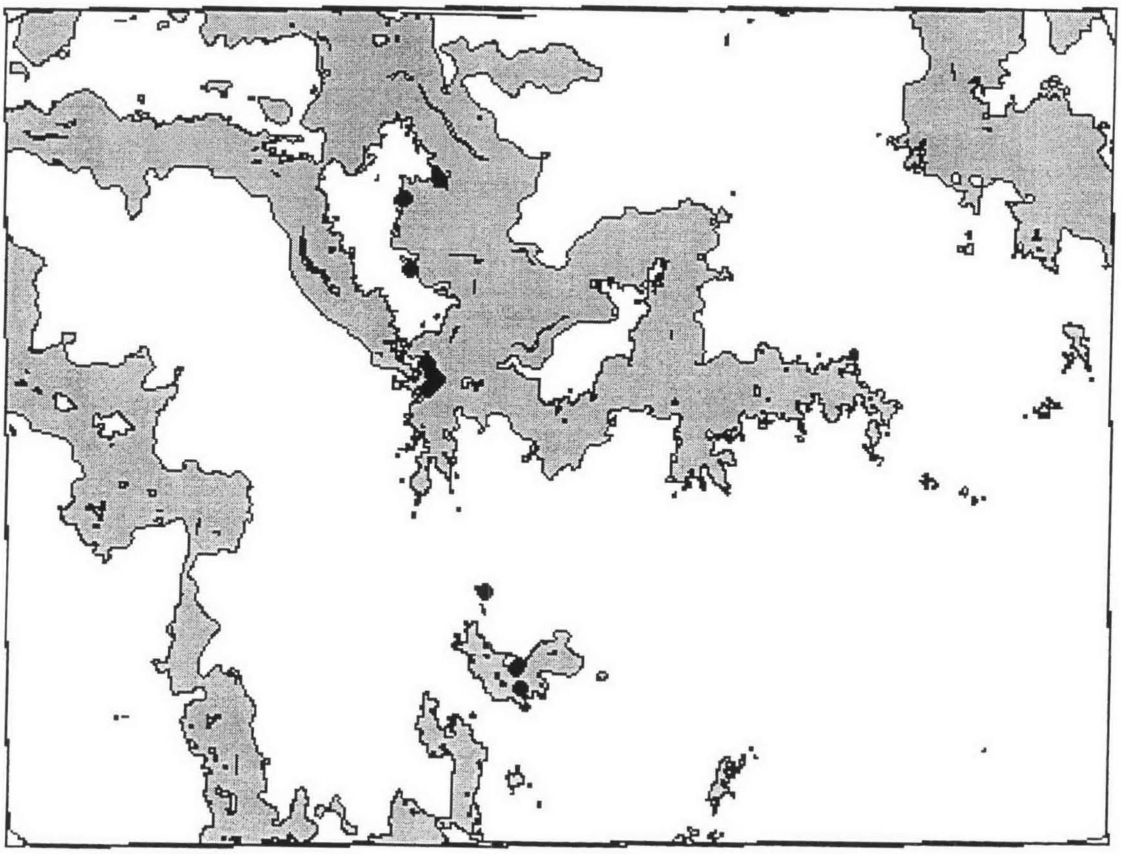


Sir Samuel, W.A.
Elevation
(derived from AUSLIG Spot Heights)



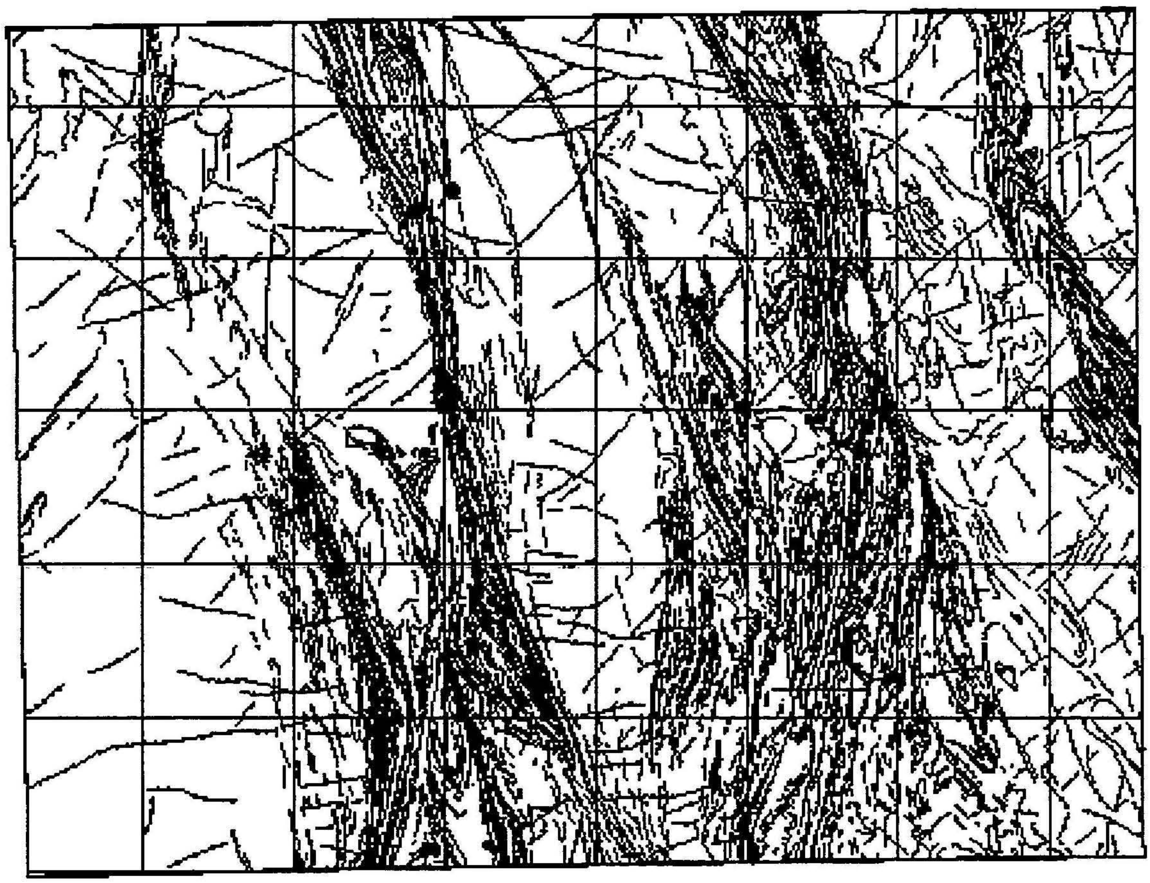
Sir Samuel, W.A.

Reclassified Elevation



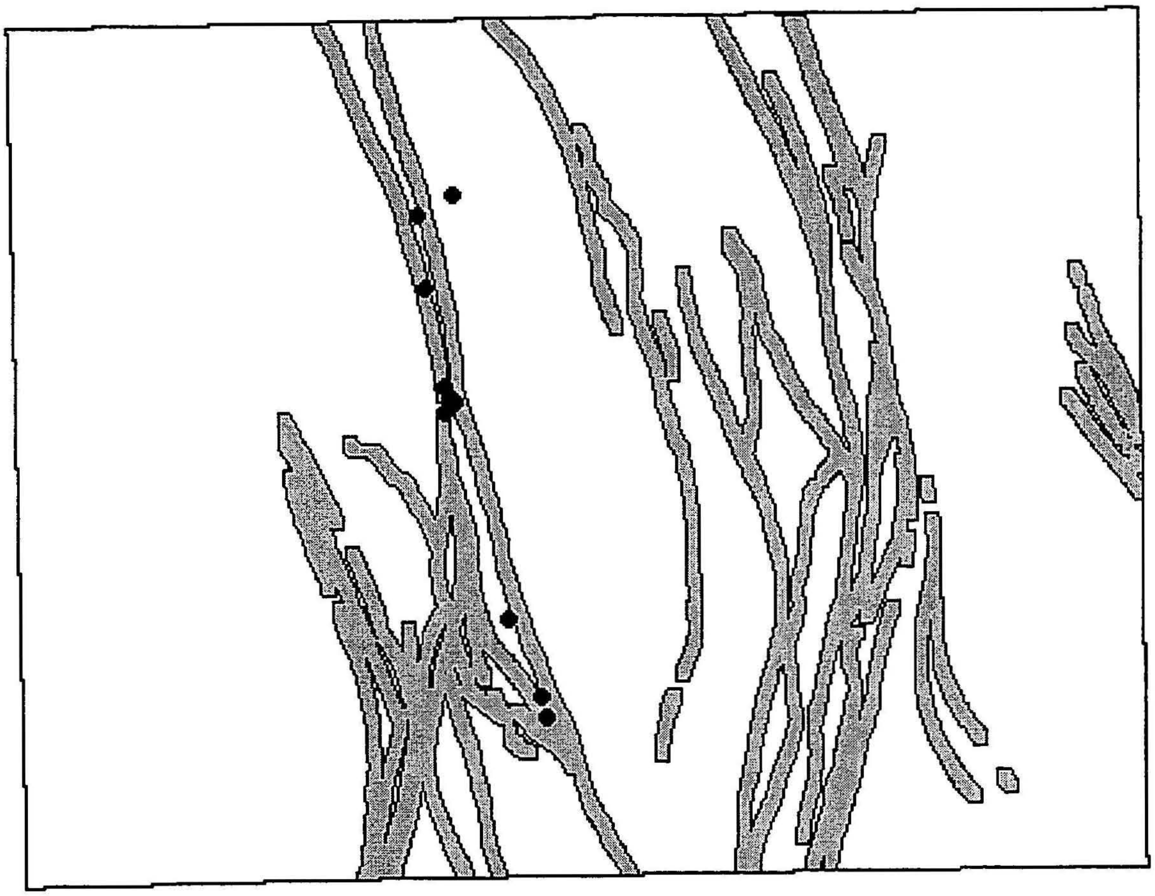
Sir Samuel, W.A.

(GSWA) Aeromagnetic Features Map



Sir Samuel, W.A.

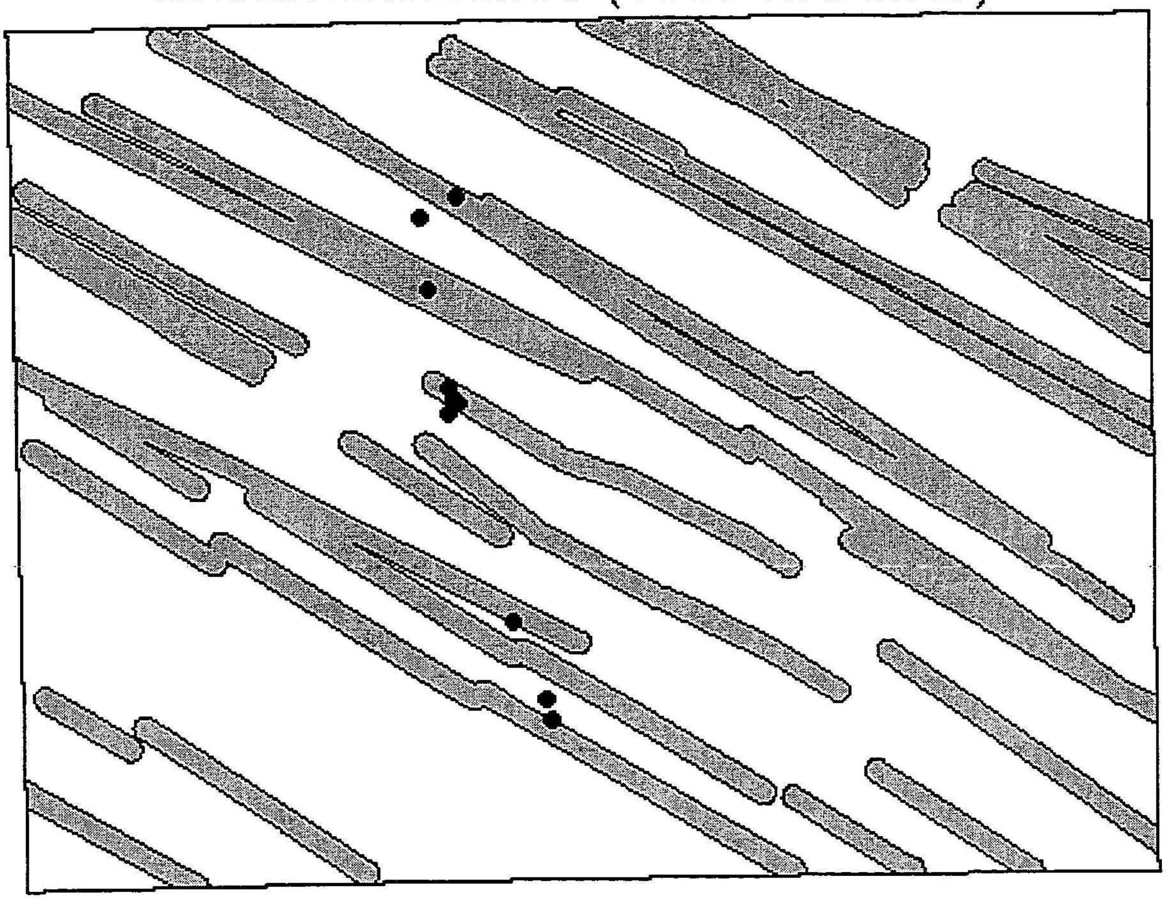
Major Faults (800 metre buffer)



Sir Samuel, W.A.

EST O'Driscoll WNW

Lineament Zones (1500 m buffer)



GIS DAY BY DAY

Harley Jones and Tim McGinnes

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ABSTRACT

North spends approximately $50 million dollars each year on exploration world wide. The greater portion of this funding ends up as digital data. Over the past 25 years North Exploration (formerly Geopeko) has been exploring in NSW. During this period vast areas have been explored by different geologists, methods, scales and using a multitude of codes.

In 1993 GIS was seen as a tool which would manage, use and analyse all our spatial data. Over the past four years, SDM (Spatial Data Management) has been developed and implemented at North's Exploration Base in Parkes NSW. The primary aim of this product was to improve the supply of digital exploration data to the geoscientists.

The final product is designed to supply data to the geoscientists, in a well managed structure, sound integrity, flexible to code/model changes and in a format which will allow high level queries to be undertaken by GIS users. It is the latter which will assist North Exploration in finding ore bodies .

In contrast to other systems it was not driven by emulating light tables, standard sheet coverage, cartographic excellence or replacing drafting personnel.

INTIAL CONCEPT- Directory Structure

In order to use our existing data in GIS, a directory and data structure had to be formulated. Geological mapping was the first discipline converted to GIS from a CAD environment.

Initially we followed the direction set by government bodies in having the directory structure relates to the standard NTS model, where data is collected in standard sheet areas.

This proved unworkable due to the following :-
- outcrops across edge joins
- areas mapped a number of times
- managing updates
- mapping at different scales

Exploration is based on Project and Prospect areas, this seemed the next logical choice for the structure.

Again this proved to be unsatisfactory:-
- areas mapped a number of times
- mapping at different scales
- multiple copies of data sets
- complicated unmanageable directory structure

CURRENT MODEL- Directory Structure

Each data set is considered as a separate identity and is described in a data base by a set of standard attributes. This is referred to as the catalog and supplies the foundation and structure for the system. The data is not separated into discipline or projects.

Only one data base exists for all data. This method allows different data sets of identical disciplines and over the same area to be managed and interrogated.

CATALOG

The catalog data base structure comprises the following fields-

BASE	Base Code (Corporate Offices World Wide)
TYPE	TO (Topography), GO (Geology), RE (Regolith) etc.
ID	Unique number
TITLE	Description
FORMAT	Format (Shape File, Coverage, TIFF File)
MINLAT	Minimum Latitude
MINLONG	Minimum Longitude
MAXLAT	Maximum Latitude
MAXLONG	Maximum Longitude
SCALE	
DATE	
AUTHOR	
METADATA	Metadata file completed (Y/N)
LOOKUP	Look up table to be used for the data set
STATUS	Status (Planned, In Work, Complete, Archived)
ARCHIVED	Location of data set when archived
IMAGEPRJ	Because Images are not held in latitude/longitude this is required.

Each data set is allocated a unique number from the catalog.

The individual data set names are a combination of the base code, type and ID fields (for example PKTO56 where PK= Parkes, TO= Topography and 56= the 56th Data set at Parkes). The ID numbering is consecutive regardless of discipline. For example GO55 (Geology) followed by TO56 (Topography) followed by ME57 (Metallogenic)

METADATA

A metadata form to describe both the data packages and data sets was created based on the U.S. Federal Geographic Data Committee "Content Standards for Digital Geospatial Metadata" 1994. The title of this paper is GIS Day by Day, if it was on metadata it would be hour by hour. The metadata form is a free flowing text file because to create a data base would not allow the flexibility for change as required.

SOURCE DATA MANAGEMENT

Source data for each data set is stored in a box which holds the original disks, copyright agreements, correspondence and is referenced by the catalog number.

When data packages are purchased they often contain a number of different data sets (topography, geology, point data, images etc). In line with the SDM structure, required data is stripped and becomes an individual data set. Not all information is stripped from the data package. It may already exist from another source, the information is questionable or is not needed.

CURRENT MODEL - Data Structure

Geological Mapping Case Study

The approach taken to capturing geological mapping is somewhat different to other organisations. After digitising, each geological outcrop is allocated a unique tag which is made up of the data set number (taken from the catalog) and a sequential number, resulting in tags of the form 55-1,55-2. This is in contrast to the usual method of each outcrop having the rock code as a tag.

A plan is printed showing the outcrop boundaries and the tag numbers. The geologist has a standard data base which has the SDM structure for geology -

TAG	Unique tag id
AGE1	Age - 1st Lithology
UNIT1	Unit
ROCK1	Rock
AGE2	Age - 2nd Lithology
UNIT2	Unit
ROCK2	Rock
AGE3	Age - 3rd Lithology
UNIT3	Unit
ROCK3	Rock
AUR	Combined Lithology

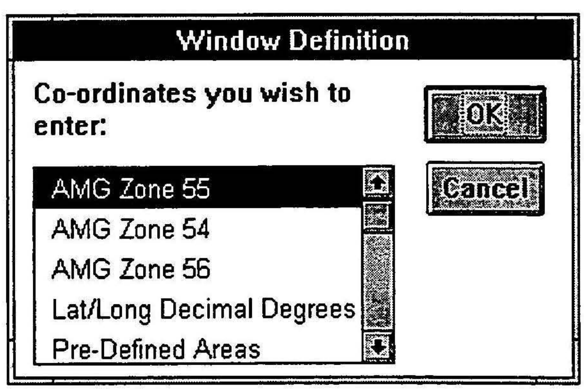
The structure is capable of holding three lithological types for each polygon. This provides flexibility in cases where the geologist cannot identify the exact lithology, or where lithologies overlay each other.

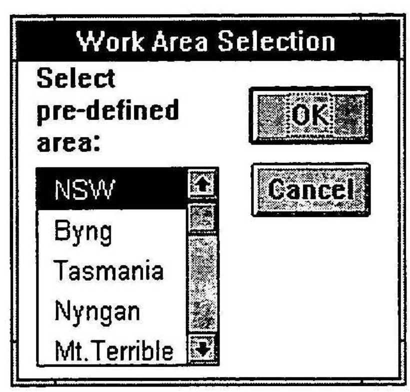
The tag is field is automatically loaded from the drawing file into the data base. The author fills out the geological code fields for each polygon.

SDM

By using Avenue scripts within ArcView SDM was created. This provides an easy to use interface to access the data sets without knowing their physical location.

To access the catalog the user first defines an area of interest. This is done by entering coordinates or choosing a predefined area.

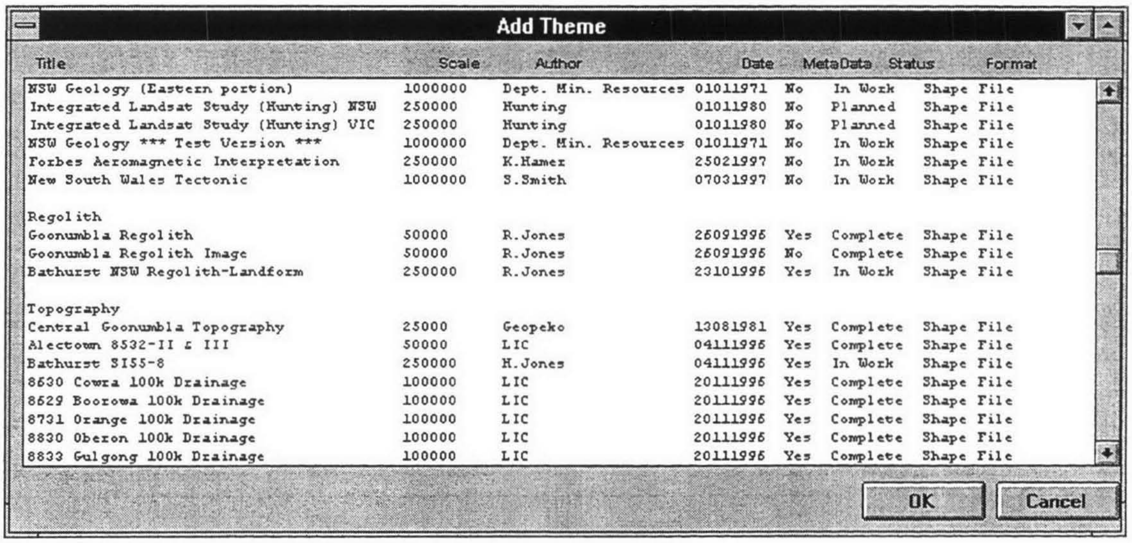




Once the area has been defined all data sets covering the area of interest are found, and a listing of the data sets is displayed. The information is not displayed as GO57 or TO58 but in the same format as the fields in the data base.

The advantage this method offers is that every data set from all disciplines and scales is shown without navigating a directory tree or knowing file names.

Data of similar disciplines are grouped together. The user selects all data sets of interest which are then loaded into the view window.

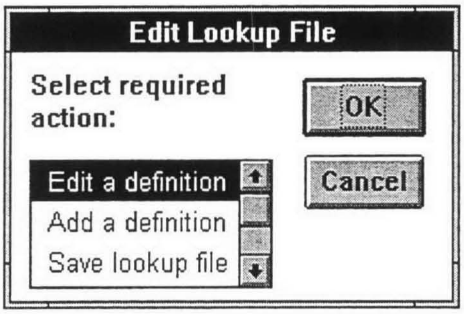


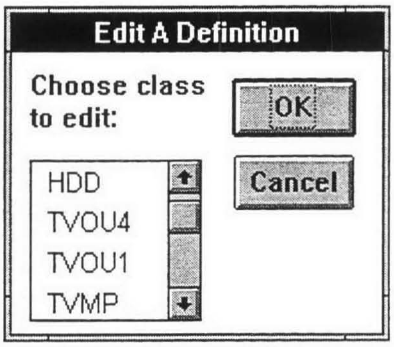
Title	Scale	Author	Date	MetaData	Status	Format
NSW Geology (Eastern portion)	1000000	Dept. Min. Resources	01011971	No	In Work	Shape File
Integrated Landsat Study (Hunting) NSW	250000	Hunting	01011980	No	Planned	Shape File
Integrated Landsat Study (Hunting) VIC	250000	Hunting	01011980	No	Planned	Shape File
NSW Geology *** Test Version ***	1000000	Dept. Min. Resources	01011971	No	In Work	Shape File
Forbes Aeromagnetic Interpretation	250000	K.Hamer	25021997	No	In Work	Shape File
New South Wales Tectonic	1000000	S.Smith	07031997	No	In Work	Shape File
Regolith						
Goonumbla Regolith	50000	R.Jones	26091996	Yes	Complete	Shape File
Goonumbla Regolith Image	50000	R.Jones	26091996	No	Complete	Shape File
Bathurst NSW Regolith-Landform	250000	R.Jones	23101996	Yes	In Work	Shape File
Topography						
Central Goonumbla Topography	25000	Geopeko	13081981	Yes	Complete	Shape File
Alectown 8532-II & III	50000	LIC	04111996	Yes	Complete	Shape File
Bathurst SI55-8	250000	H.Jones	04111996	Yes	In Work	Shape File
8630 Cowra 100k Drainage	100000	LIC	20111996	Yes	Complete	Shape File
8629 Boorowa 100k Drainage	100000	LIC	20111996	Yes	Complete	Shape File
8731 Orange 100k Drainage	100000	LIC	20111996	Yes	Complete	Shape File
8830 Oberon 100k Drainage	100000	LIC	20111996	Yes	Complete	Shape File
8833 Gulgong 100k Drainage	100000	LIC	20111996	Yes	Complete	Shape File

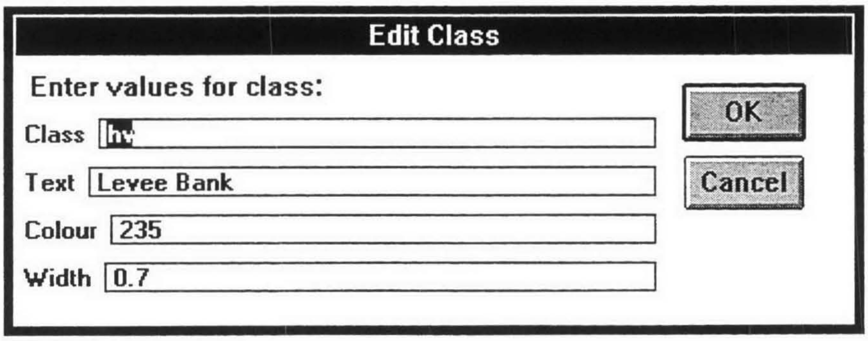
LOOKUP TABLES

When the data sets are loaded, SDM looks in the catalog for the appropriate look up tables. The themes are given symbology according to the look up table.

If during loading a attribute does not match the look up table then the process is halted. An option is available for the GIS Administrator to add or modify the attribute to the table.







By using the aliases method the look up table set up is only done once. The next time you purchase data from the same supplier if some attributes have been added or changed they will appear in the load process. It is then a simple case of adding the new attributes to the look up table.

Purchased topographic and geological data sets pose the most problems. North purchases topographic data from seven government bodies around Australia and the attribute for a 2 lane sealed main road varies from each supplier.

In the ever changing world of geology a code or description change can be done by changing the appropriate fields in the look up table. All geological coverages are instantly updated.

Geological look up tables also include the facility to order the legend by age creating a far more acceptable legend than the alphabetical one supplied by the software.

GRAPHIC OUTPUT

At the beginning of the paper the point was made that SDM was designed to supply digital data of high integrity in a well managed structure. Cartographic excellence was a minor part of the overall programme.

A set of basic options have been added to the standard software tools. These include -

- Title Block
- Work Area
- Grid
- Location Diagram

SUMMARY & OUTLOOK

The rigid directory and data structure of SDM is invisible to the user but the GIS Administrator now has a powerful tool to manage all digital exploration data. The addition of new data or code changes can take place on a Day by Day basis. This is the first time in Parkes that all Exploration Data has been available to all Geoscientists to analyse and we are already seeing interpreted data sets being created.

The challenge of the future is to support the geoscientist by developing more tools to aid in the interpretation process and ensure interpreted data sets are managed under the SDM umbrella.

ACKNOWLEDGEMENTS

North's geoscientists for their contribution towards coding and beta testing earlier versions.
Robyn Gallagher who's wealth of GIS knowledge has been called on to solve some issues.
Finally to Robin Nagorcka who supported and brought the authors back to reality and every day GIS on many occasions.

Coverage of GIS accessible mineral exploration data from the Prom to the Cape

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The historical problem: Underutilization of an enormous and valuable resource

All privately collected mineral exploration data in Australia eventually comes into the public domain in the form of the open file company report system administered by the various State Government mining instrumentalities.

This enormous resource consists of millions of surface and drill hole geochemical samples, geological and geographic observations. Until recently it resided in grossly fragmented hard copy or microfiche form with most sample data plotted on uncontrolled or unscaled maps, ie. totally inaccessible to modern GIS applications. Additional complexity is introduced with the myriad of combinations and permutations involved in geochemical sample collection and analytical techniques. We can confidently say that we are now well down the track of overcoming what many in the exploration industry and government have regarded as almost too big a problem to attempt to tackle.

The solution: Meticulous validation of locations combined with a comprehensive and uniform data management structure

The result: GIS accessible exploration data coverage now available for a large portion of Eastern and Northern Australia

Since 1993 several co-operative major research projects involving Terra Search, many of Australia's major mining and exploration companies, AMIRA, and the Queensland, NSW and Victorian Governments have resulted in GIS accessible open file exploration data now being available for a large portion of Eastern and Northern Australia.

Figure 1 and Table 1 show the March 1997 status for the major project areas covered to date. Figure 2 shows stream sediment samples as point data, clearly showing the extent of coverage in areas of outcropping basement geology.

Data capture methodology

All data have been painstakingly located onto controlled base maps and are now fully attributed in a standardised digital form, housed in Terra Search's research and developed **Explorer 3** relational data base management system (see Willis et al., 1997 this volume).

All regional samples are manually located, often at 1:25 000 or more detailed scales and digitized with AMG and Lat/Long coordinates referenced to AUSLIG digital 100K drainage. Figure 3 is an example of the Murrindal 8523 sheet in Victoria captured in this manner.

Our experience is that unless this attention to detail is applied to locational accuracy, further GIS analysis involving enhancing of geochem anomalies or integration of other data sets, will often be ineffective and lead to unsatisfactory results.

Common points from local grids are located with AMG coordinates and a grid transformation is carried out to convert all local coordinates to AMG. Screen and hard copy plotting and cross checking with the original hard copy maps are essential quality control steps.

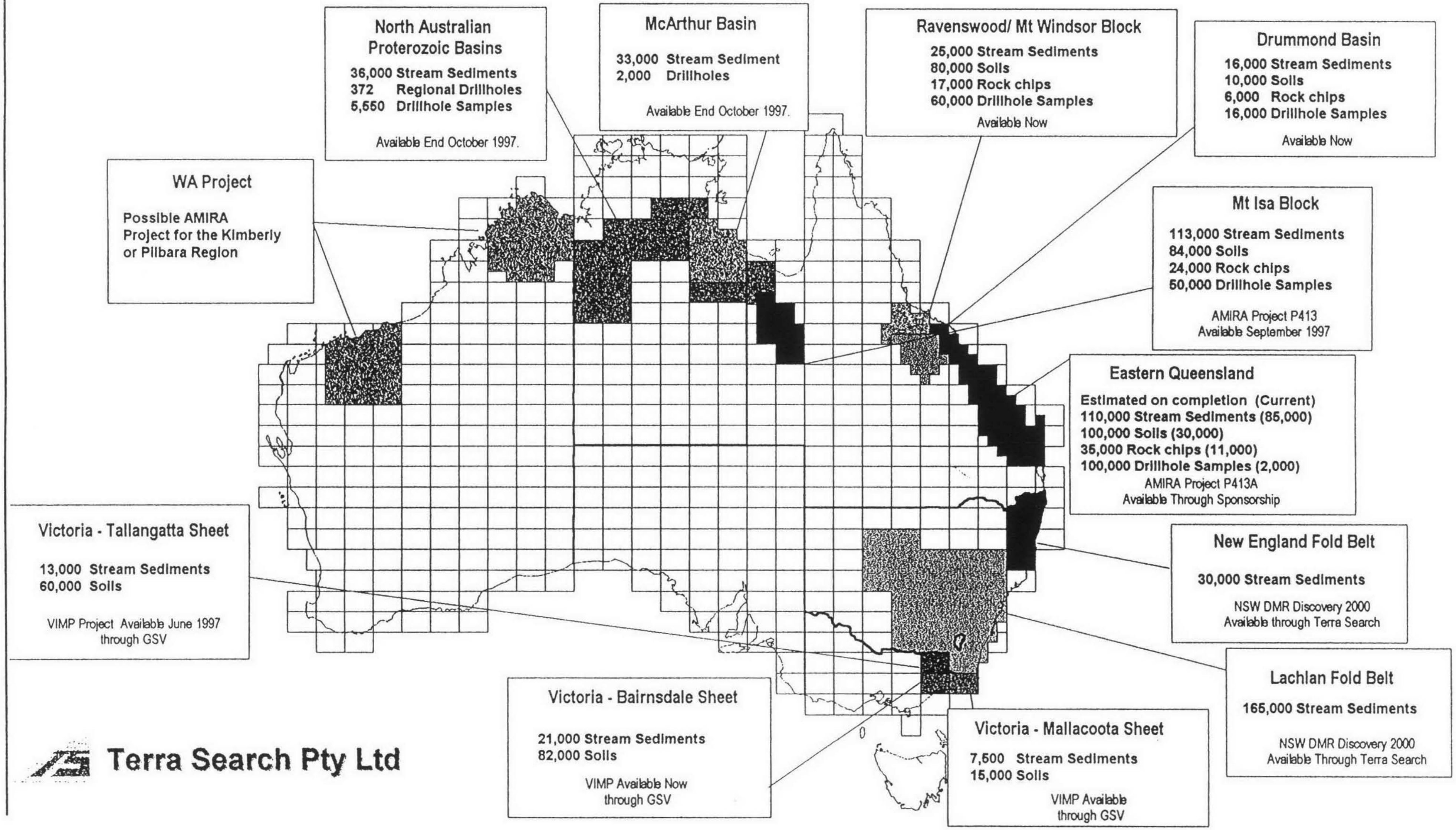
As described in Beams, (1995), after conversion to digital form, each sample sits in an interconnected framework accompanied by its essential attributes such as location information, sample collection methods, geochemical analytical techniques, assay data, lithological descriptions, geological relationships, with cross links into existing geoscientific and geographic data bases: eg. drainage bases, tenement information, regional geophysics, report bibliographies.

Project/ Mineral Province	*Research Partners*	*Total Samples*	*Stream Sediments*	*Soil*	*Rock Chip*	*Drillhole Samples*
			South Eastern Australia			
Lachlan Fold Belt	NSW DMR (Discovery 2000)	165 000	165 000			
Bairnsdale 1:250K	GSV (VIMP)	103 000	21 000	82 000		
Mallacoota 1:250K	GSV (VIMP)	23 000	7 000	16 000		
Tallangatta 1:250K	GSV (VIMP)	73 000	13 000	60 000		
			Eastern Australia			
New England Fold Belt	NSW DMR (Discovery 2000)	30 000	30 000			
Eastern Qld (P413A)	AMIRA 8 companies Qld DME	128 000	85 000	30 000	11 000	2 000
Drummond Basin	Company subscription	48 000	16 000	10 000	6 000	16 000
Ravenswood Block	Company subscription	182 000	25 000	80 000	17 000	60 000
			Northern Australia			
Mt Isa (P413)	AMIRA 15 companies Qld DME	271 000	113 000	84 000	24 000	50 000
North Australia Proterozoic	Company subscription	42 000	36 000			6 000
Macarthur Basin	Company subscription	35 000	33 000			2 000
GRAND TOTALS		**1 100 000**	**544 000**	**362 000**	**58 000**	**136 000**

Table 1. March 1997 status of open file data coverage for geochemical samples all in Explorer 3 format

Status of Open File Data Compilations as of March 1997

Over 1 Million samples fully attributed in Terra Search Explorer 3 Relational Database Format



For further information contact Townsville 077-725633 fax 077-723882, Perth 09-2779161 fax 09-2779163, Bathurst Phone/fax 063-325902 Email: terrasch @ ozemail.com.au

Figure 1

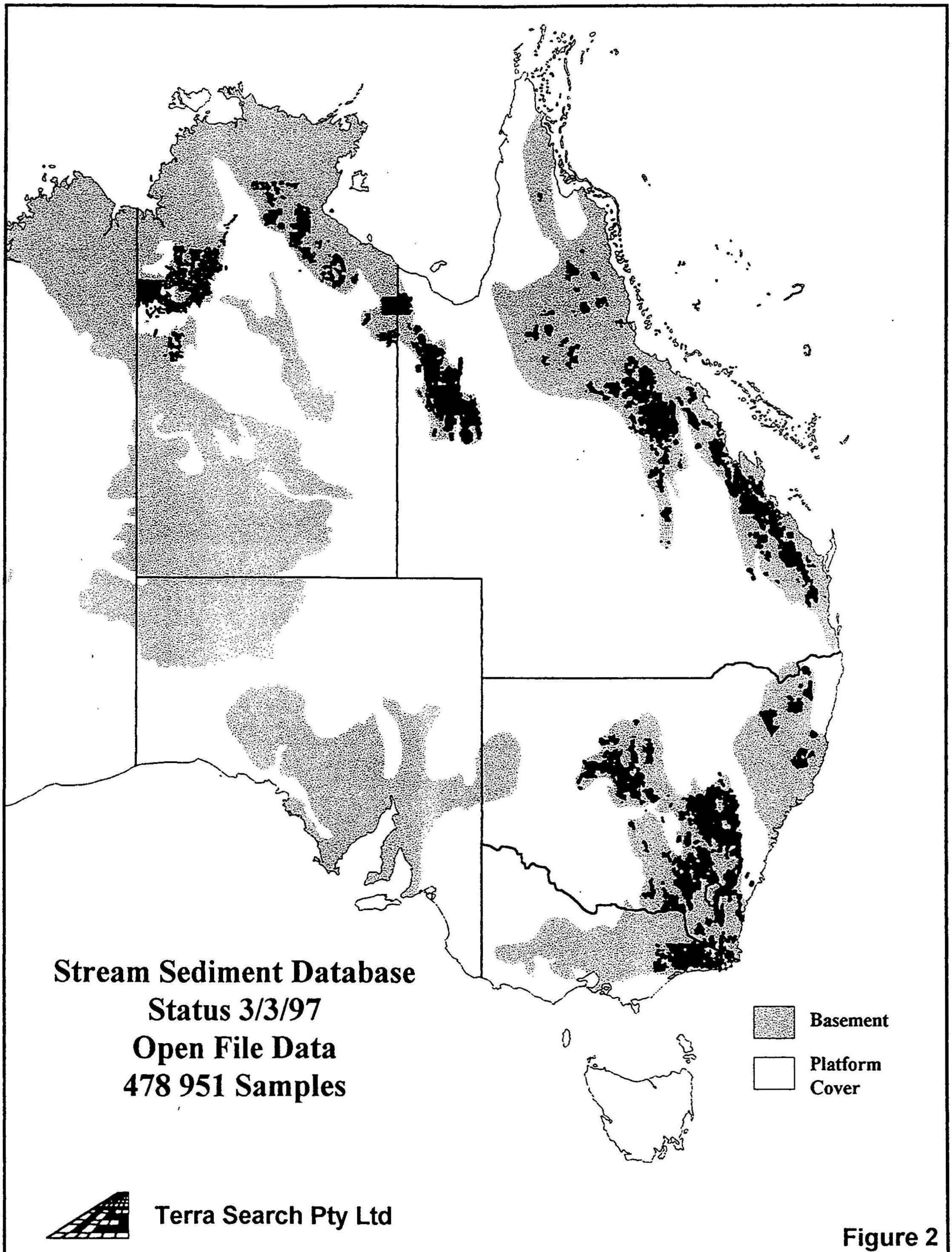
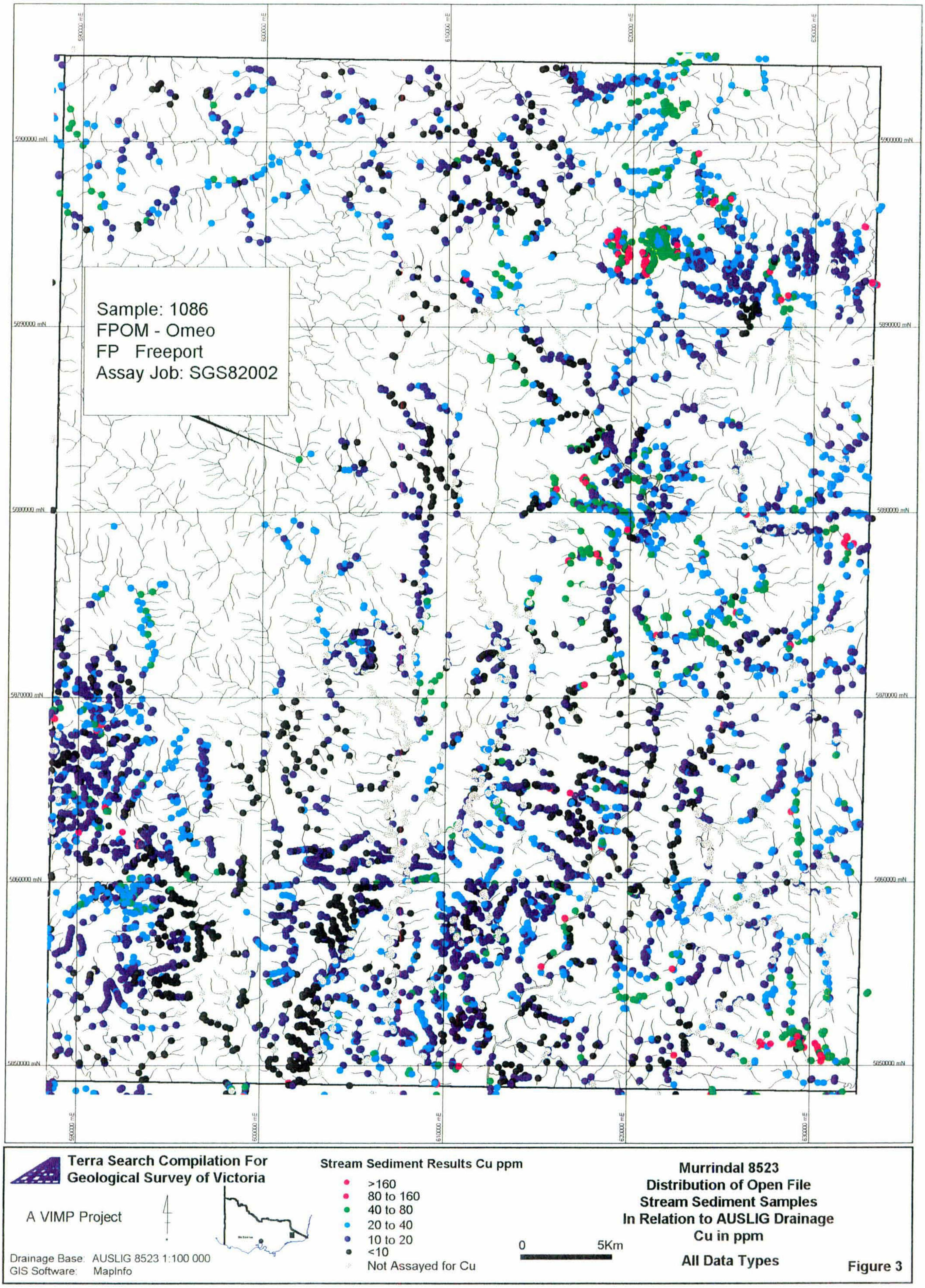

Stream Sediment Database
Status 3/3/97
Open File Data
478 951 Samples
Basement
Platform Cover
Terra Search Pty Ltd

Figure 2


Sample: 1086
FPOM - Omeo
FP Freeport
Assay Job: SGS82002
Terra Search Compilation For
Geological Survey of Victoria
A VIMP Project
Drainage Base: AUSLIG 8523 1:100 000
GIS Software: MapInfo
Stream Sediment Results Cu ppm
>160
80 to 160
40 to 80
20 to 40
10 to 20
<10
Not Assayed for Cu
0
5Km
Murrindal 8523
Distribution of Open File
Stream Sediment Samples
In Relation to AUSLIG Drainage
Cu in ppm
All Data Types
Figure 3

GIS analysis

The power of GIS means it is now possible to interrogate and visualise any one of the million plus data points from Eastern and Northern Australia, on any combination of attributes at scales ranging from mineral province down to prospect level.

Figures 4A to D are examples from Victoria where the same soil data set is interrogated and visualized respectively according to:

- Pb content
- Company which collected the data
- Analytical laboratory which completed the geochemical analysis
- Grid ID of the local grid

Figures 5A and B are further examples from the Mt Isa Block which respectively shows rock chip data interrogated according to mode of occurrence and then highlighting those samples which are outcropping veins containing detectable gold.

This style of analysis, where the most significant prospective criteria can be applied to a data set in a GIS environment is the goal of the end user explorationist. It can only be achieved if the data are located as accurate as practically possible and are accessible in a data base management system robust and flexible enough to house the enormous diversity of quantifiable attributes encountered in mineral exploration.

Further directions

It is envisaged that historical open file data from the whole of Eastern and Northern Australia will be available in Explorer 3 format over the next few years. Initial emphasis will be on regional surface geochemical surveys, followed by prospect scale drilling and geophysical coverage.

There has been considerable encouragement to extend the coverage to tackle the huge back log of exploration data in Western Australia, as well as offshore interest.

Adoption of a standard coding system for attributes such as lithology, minerals, geological units, etc. is essential to facilitate transfers of large GIS data sets between company and government institutions. Terra Search is working with AGSO to develop a uniform set of codes. AGSO are the obvious national custodians of the standard coding system.

Submittal of digital data to the various state instrumentalities administering the Mining Acts is the obvious goal of an industry requiring more and more GIS accessible data. Before this can occur there has to be widespread agreement of industry and government stakeholders of what attributes need to be quantified and how they should be stored and submitted.

Now that the industry is close to solving what up to now has been considered the intractable problem of the mountain of historical data, it would be a pity if it got buried in an avalanche of rapidly accumulating current project data frozen in a time warp of obsolete media.

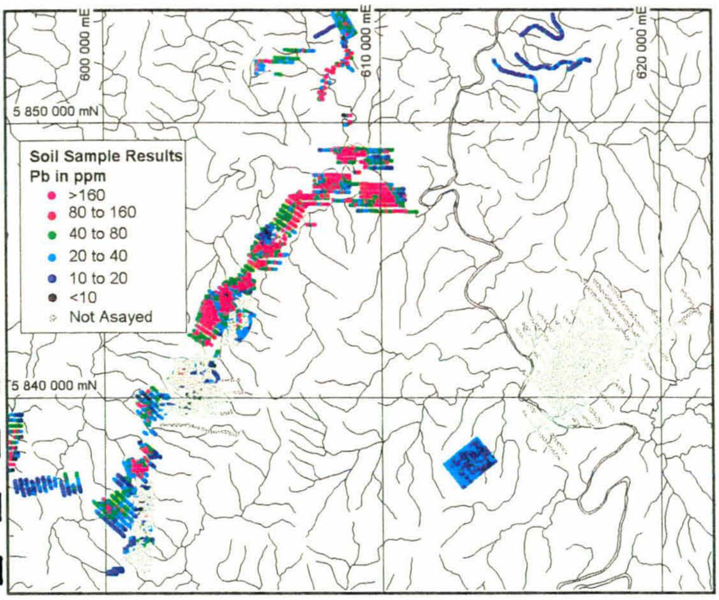
References

Beams, S.D., 1995. Exploration data management on a mineral province scale. *Proceedings of the Second National Forum on GIS in Geosciences, Australian Geological Survey Organisation Canberra, AGSO Record 1995/46.*

Willis, N.J., Jenkins, D.R. & Beams, S.D., 1997. The application of mineral province scale exploration data in the relational GIS environment. *Proceedings of the Third National Forum on GIS in Geosciences, Australian Geological Survey Organisation Canberra* (in press).

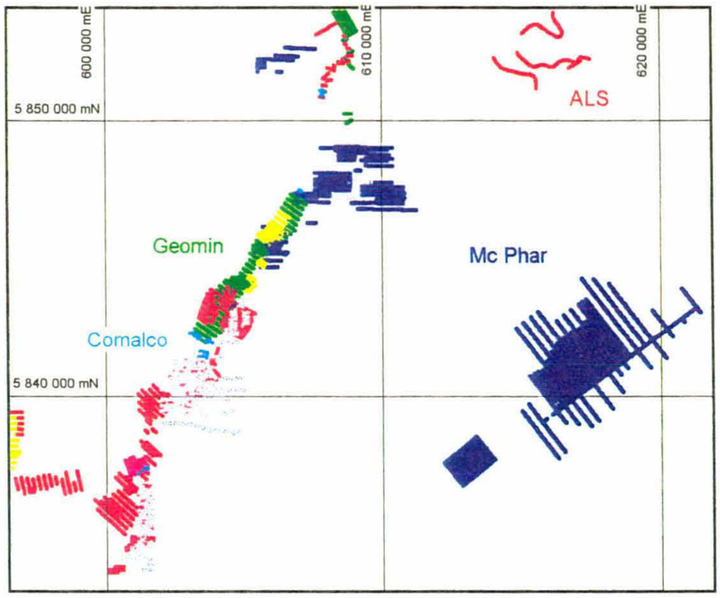
A

Murrindal/Orbost Distribution of Open File Soil Samples Colour Coded to Pb (ppm)



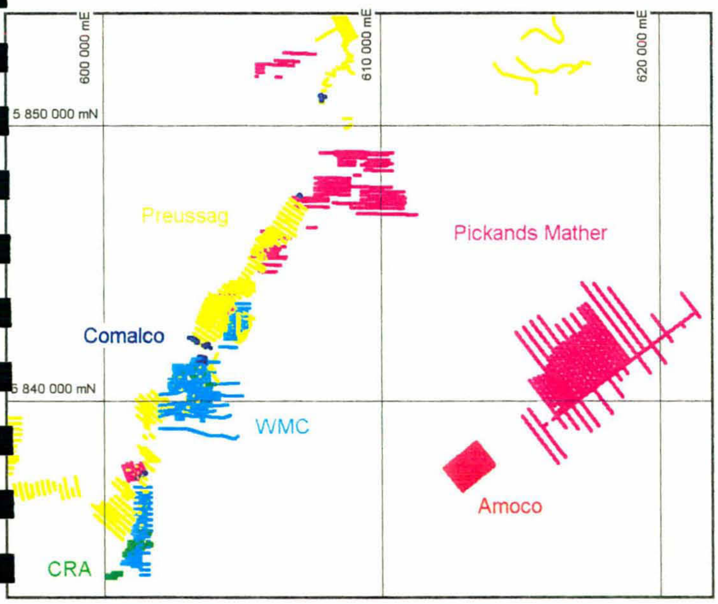
C

Soil Samples Coloured By Lab



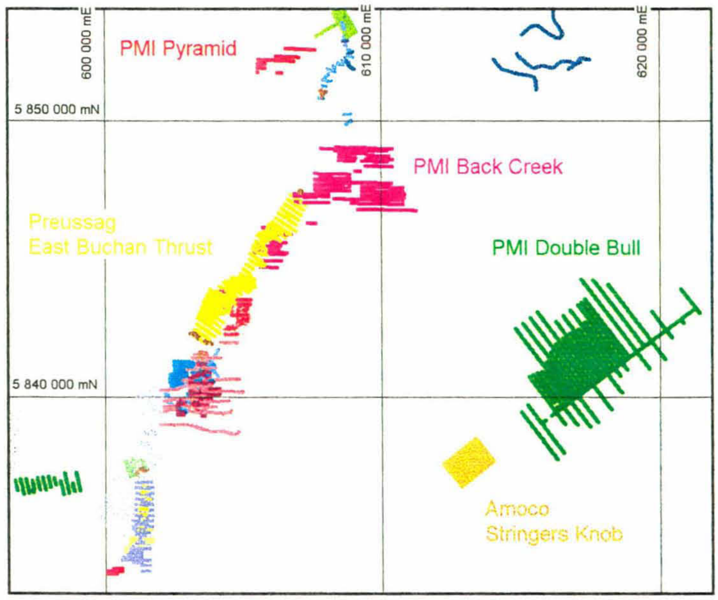
B

Soil Samples Coloured By Company Collecting



D

Soil Samples Coloured By Grid Id



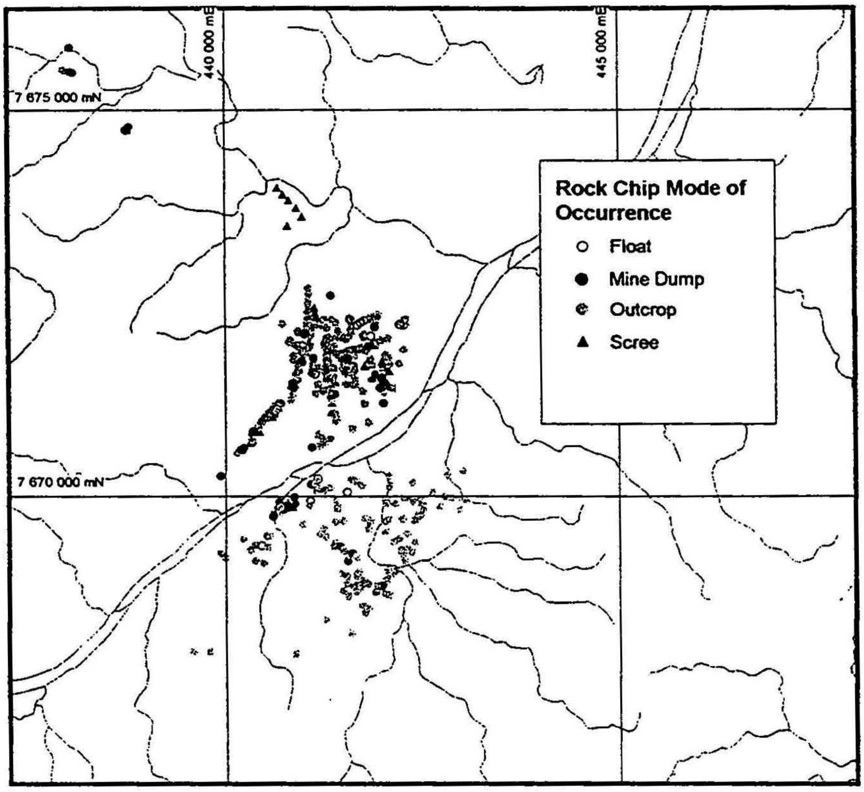
Terra Search Pty Ltd

Geological Survey of Victoria VIMP Project

Drainage Base: AUSLIG 8522, 8523 1:100 000
GIS Software: MapInfo

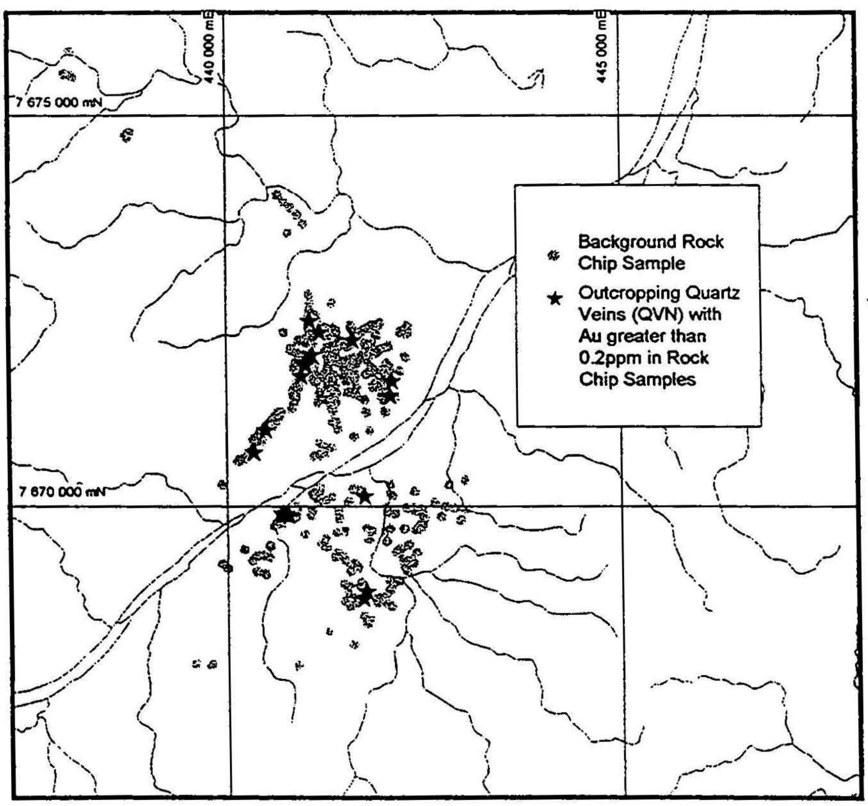
Buchan Area
East Gippsland Victoria
Soil Data Subsetted According to Various Attributes

Figure 4



A

Rock Chip Mode of Occurrence



B

Outcropping Quartz Veins With Anomalous Au

Terra Search Pty Ltd

Top Camp Area
Cloncurry River
Mt Isa Block
Rock Chip Data Highlighted According to Prospective Criteria

AMIRA P413 Data
Drainage Base: AUSLIG 6955 1:100 000
GIS Software: MapInfo

Figure 5

Delineating catchments of potential saline discharge zones, combining DEM and soils information

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A method for regional assessment of the distribution of saline outbreaks is demonstrated for the upper Burdekin river basin (68 000 km^2) in North Queensland, Australia. Soil map unit descriptions were used to determine likely recharge and discharge areas in the landscape. Analysis of the spatial association between surveyed electrical conductivity measurements and maps of estimated recharge and discharge areas were used to examine the landscape distribution of soluble salts in the region. Catchment areas feeding into discharge zones (different from catchments draining into streams) were identified by developing algorithms for measurement of non-Euclidean distance either uphill or downhill from a specified position. Most catchments showed a salt distribution where %TSS was large near the discharge areas and decreased rapidly with distance uphill from the discharge areas. However, in some catchments, local saline outbreaks were apparent at significant distances uphill from discharge areas. The possibility of geological sources of this salt was examined by comparing random point distributions with the location of saline points with distance downhill from geological units. The distribution of some saline outbreaks was consistent with the occurrence of Cambro-Ordovician volcanics and metasediments, upper Devonian-lower Carboniferous volcanics, and Triassic sediments.

Metadata principles - the first step in metadata management

Shawn Callahan and Brent Heuer
SNS consulting Group

Dataset managers recognise the importance of metadata for the effective management, utilisation and interpretation of organisational data assets. In many cases, however, these convictions are held in isolation within the organisation and getting a metadata system in place is usually an arduous process.

Why the resistance to invest in the long-term viability of these information assets? Why is there a tendency for metadata management to be subordinated by seemingly more important and urgent information management tasks? Effective dataset and metadata management is the cornerstone of a solid information management policy.

Some suggest the responsibility for information management in general has been wrongfully dumped by the CEO and delegated to the IT Director. This action has resulted in minimising the overall organisational support for information management initiatives. As we discuss, information and politics are inseparable in a knowledge-based society.

This paper suggests the reasons for the slow uptake of metadata as an integral component of an organisation's information strategy and then considers an approach that places metadata in context of a wider information management initiative. Specific principles are articulated to help guide the management and use of corporate data assets and an organisational structure proposed for the adoption of successful metadata development.

Geoscience Data Model, AMIRA Project P431

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ABSTRACT: A data model is being developed for geoscience data in Australia. This work is supported through the Australian Mineral Industries Research Association under their Project P431. The Geoscience Data Model is intended to provide a common basis for understanding geoscience data as it has been designed to encompass geoscience data models from State and Federal geological surveys.

The sponsors supporting this project have been predominantly from State and Federal geological survey organisations. The private industry sponsors are BHP and North though a wide range of private industry have expressed interest in the project.

The data models consist of a dictionary of geoscience terms and entity relationship diagrams. The entity relationship diagrams are a graphical way of representing the relationship between the geoscience features like boreholes and sample data.

Currently, data models have been created for the themes: geological data, geochemical data, drilling data and mineral resource/reserve data.

Whilst the data models allow an understanding of the data relationships they do not demonstrate the viability of the models. Consequently to test the data models in practice, examples of the data have been obtained from sponsors and these are being mapped into the geoscience data models using the Microsoft Access database. These example data sets will also make the data model easier to explain.

Introduction

The Geoscience Data Model project aims to develop an Australian standard data model to provide a common basis of understanding for geoscience data.

In the digital computing industry a standard data model will assist in the transfer of data between different computing systems. Importantly, it will provide a model to develop computer systems.

This common basis of understanding applies not only to digital data but also to text and graphic information.

The project is being undertaken by the Australasian Spatial Data Exchange Centre (AUSDEC) and has two objectives:

- to develop a data dictionary for geosciences, and
- to develop a data model for the geoscience data.

The project team consists of the project manager, Don Miller (Executive Director, AUSDEC) and the project consultants, Dr. John Parker (Principal, Geosurveys Australia) and Dr. Richard Hume, Principal Consultant, AUSDEC). The project aims to coordinate the tremendous store of experience and knowledge of disparate geoscience practitioners throughout Australia both in public and private practice.

Sponsors have been drawn together from all State and Federal geological surveys (one exception) and from private companies.

The project has been given strong support by the Government Geoscience Database Policy Advisory Committee, (GGDPAC).

AMIRA funded project Association
The Geoscience Data Model project is an Australian Mineral Industries Research (AMIRA) funded project and began in July 1994 with funding for three years. The Project completion is scheduled for the middle of 1997.

AMIRA projects are voluntarily funded by the AMIRA association members.

Sponsors
The project sponsors for the Geoscience Data Model Project are:

Australian Geological Survey Organisation,
BHP Exploration,
Department of Mineral Resources, NSW,
Department of Minerals and Energy, Qld,
Department of Mines & Energy, NT,
Geological Survey of Victoria,
Geological Survey of Western Australia,
North Exploration, and
South Australian Department of Mines and Energy.

These sponsors are predominantly from State and Federal geological survey organisations. It is unusual for AMIRA projects to be sponsored by this number of survey organisations.

Private industry had expressed a strong interest in the project but only BHP and North became sponsors. There was a feeling amongst some sponsors that government should be responsible for setting standards.

Themes
The geoscience area covers a wide thematic range and it was decided to limit the themes to break the project down into a number of manageable tasks. This ensured that products were being progressively developed so the project could be effectively managed.

The themes chosen by the sponsors for development were:
- Geology,
- Drilling,
- Geochemistry and
- Mineral Resource/Reserve.

Development of the data models

In view of the existence of a number of reasonably well documented databases developed by the project sponsors, in these selected theme areas, the project team first collected and collated the current models and dictionaries as supplied by the project sponsors. This created a generic model in these themes.

Terrasearch Pty Ltd, although not a project sponsor, also submitted their model for their Explorer II system for the management of geoscientific exploration data. Terrasearch developed this model under an earlier AMIRA project.

During the compilation of these various submissions into draft generic models it became clear that a number of elements were more or less common to many of the four themes being considered. Consequently, the project team created a number of "modules" for these common items. These can be considered as components of each of the themes. For example, some of the components are: Observation, Sample, Orientation, Fraction, Instrument, Site and Point Location.

The draft data models were recorded using a CASE tool for presentation, to simplify updating, and to provide some automated checking on the model.

In their review of the first draft models, the sponsors recommended the simplification of the presentation of the models to allow non-specialists to understand and adopt the models. There was overall agreement amongst the sponsors that the basic models developed were suitable as generic models and that each of the individual sponsor's models could be accommodated.

A number of experts in the four thematic areas were contacted by the project team in an attempt to obtain more industry consensus with the drafts as they developed. This did not prove to be successful because of the work commitments of the team members and consequently the project has primarily relied on the sponsor reviews.

Proving the data models

It became apparent during the reviews that there was a need to separately establish that the data models were practical because this could not be done with reviews of the data models alone. Both non specialist and specialists have difficulty in fully understanding the implications of data models.

A demonstration data set would clearly illustrate whether the models can be implemented and whether they could cover the wide range of existing data bases.

Consequently, it was decided to seek data in a well known area and the site chosen was Broken Hill.

A large data set has been prepared by the South Australian Department of Minerals and Energy for the Curnamona and Olary 1:250000 Map Sheet areas. These two sheets are adjacent to the Broken Hill and Menindee 1:250000 Map Sheets, data for which has been provided by the Department of Mineral Resources, NSW. In addition, a small company reporting data sets has been provided by Geological Survey of Western Australia. The Australian Geological Survey Organisation has also promised some data over this area. These data sets will provide an excellent coverage of the different data sets held by the project sponsors and will provide data for each of the four themes modelled.

Both the South Australian and New South Wales data sets have been reviewed to determine how the data element will map into the models.

The task being undertaken now is to populate test databases using the data.

The first task was to convert the data into Access tables. The SA dataset was in ASCII exported from an Oracle database and the NSW dataset was already in Access. The terms were separately defined either in hard copy or in the Access definitions themselves. Some information was available on how the tables were linked, ie the data models.

This conversion between models involves writing a considerable number of queries on the data tables to extract data into for the Geoscience Data Model tables

Publicising the models
It is planned to publicise the model through a number of workshops.

It is envisaged that these workshops will be one day in length, perhaps with one in the eastern states and one in Western Australia.

Immediate use for the Geoscience Data Model
The Government Geologists Database Policy Advisory Committee has a current project to define reporting to State geological surveys. The Geoscience Data Model could serve as the basis for that reporting.

BHP Minerals Exploration Approach to Metadata

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Abstract: The use of GIS as a tool, to assist geoscientists in data manipulation and management, has been vigorously adopted by BHP Minerals' Exploration Division in Australia. The Brisbane office manages over 4500 strategic ARC/INFO coverages. This large number of datasets and an expanding user base have resulted in an overwhelming need for comprehensive, yet user-friendly metadata.

Metadata is data about data. It can contain attributes like: content, projection, quality, source, references, etc.

The two main goals for our metadata system were to:

1. Record data about the data that we hold
2. Improve user awareness of what data we hold

A review of ARC/INFO's Document AML found it to be far more complicated than what we required. Our needs were for a simple, user-friendly, GUI based system that provided users with relevant information. We adopted ARC/INFO's INFO file format because it offered the advantage that our metadata tables automatically moved with the coverages if they were relocated, copied, deleted or renamed.

Staff were consulted about the attributes to be included in the metadata tables. A user-driven approach was a very important factor in the system's acceptance and success. A total of 46 attributes were selected for inclusion in our metadata. Of these 24 attributes were coverage defined and 22 were user defined. In summary, 28 fields are automatically generated and 11 are controlled by pop-down lists, leaving only 7 as free text / manual entry fields. This approach has the added benefit that metadata creation takes less than 1 minute per coverage to complete.

The most valuable feature of metadata for end-users is the ability to search for information by consistent, meaningful keywords, eg. geochemistry and whole rock analyses or magnetics and survey outlines.

The current version of our metadata system has been very successful in cataloguing all of our ARC/INFO coverages, resulting in the better management and appreciation of the strategic GIS data we hold. A future version will allow us to do the same for our image data as well.

The following add-ons have also been created to complement our current metadata system:

1. An ArcView button to show the metadata attributes for the selected themes
2. A Metadata coverage showing the extents of all the coverages we hold for Australia.
3. A Metadata coverage showing the extents of all the coverages we hold for the rest of the world.

Application of GIS to syn-sedimentary metallogeny - an example from the McArthur Basin

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The McArthur Basin contains a world-class, stratiform sediment-hosted base metal (SSHBM) deposit (HYC) which, because of its relatively undeformed and unmetamorphosed state, has been widely used as a basis for models of SSHBM mineralisation. Many of these models postulate ore deposition as a result of fluid flow within a rift-sag tectonic environment, although basin morphology is not well constrained by surface mapping due to very limited exposure of many of the deeper basin units. Analysis of the geometry of basins and bounding faults which may control mineralising fluid migration is a three-dimensional problem not well suited to conventional 2-D applications of GIS to metallogeny. This paper presents integration of 3-D information, derived from geophysical interpretation, with conventional 2-D geoscientific data sets in a metallogenic geographical information system (GIS), implemented in Arc/Info.

GEOPHYSICAL ANALYSIS

Rigorous quantitative analysis of Australian Geological Survey Organisation (AGSO) regional Bouguer gravity and magnetic data was employed to investigate the architecture of the McArthur Basin. Complementary interpretations of an interlocking array of 2-D gravity and magnetic profiles were undertaken by forward modelling constrained by application of the criteria of Leaman (1994). Picks of depth-to-top, depth-to-base and thickness were read from the 2-D profiles, and these were hand-contoured to produce structure and isochore contour maps of all major basin components. These maps reveal the gross morphology of the basin fill, its basement, and units which, while correlated with exposed rocks, are much more voluminous than hitherto suspected from their mapped exposure. Further details of some of the issues faced during interpretation may be found in Leaman (1996).

McARTHUR BASIN GIS

Geoscientific data

Geological data was captured in two separate layers at different scales and spatial extents. The more detailed data was acquired from a single 1:250 000 map sheet (Bauhinia Downs; Pietsch et al, 1991) by scanning of the original film separates. These vectors were then converted to a topologically correct polygon coverage using a combination of head-up digitising and direct editing of the scanned linework. The second geology layer, covering a much wider region, was manually digitised from paper copies of 1:500 000 and 1:1 000 000 geological compilations (Blake, 1987; Plumb, 1988). Other geological linework layers such as lineaments, strike lines and joints were constructed in similar fashion to the corresponding polygon layer. Faults were attributed in the geology polygon layer enabling them to be copied as a separate line layer.

Geological attributes were encoded in a hierarchical series of tables. The primary polygon attribute table contains only one numeric item, which serves as the primary key to two separate tables which contain stratigraphic and lithological data respectively. This information is encoded using alphabetic codes which relate in turn to a series of authority tables.

The mineral occurrences layer is a point coverage with attributes compiled from a number of literature sources, but principally from the Northern Territory Geological Survey database (B Roberts, pers. comm., 1995). Attributes include name, commodities present, deposit morphology, operating status and ore minerals.

Lithogeochemical data is included in the form of summary statistics keyed to the geology polygons. The lack of spatial attributes for individual samples is partly a deliberate degradation in response to confidentiality restrictions, however the data sets were of limited utility for spatial analysis in any case due to extremely clustered sampling (e.g. from drillholes).

Geophysical interpretation data

The isochore and structure contour maps referred to above were digitised as lines. TINs were constructed from the depth- or thickness-attributed arcs, and the results converted into a lattice using a bivariate fifth-order polynomial interpolation surface (QUINTIC option in Arc/Info). These grids were then used to represent the geophysical interpretations in the GIS, in lieu of raw gravity and magnetic data. The process of contouring and gridding, while inevitably leading to some smoothing of discontinuities, enabled more effective display and analysis of the geophysically derived structural information with respect to the other geoscientific data in the GIS.

ANALYSIS

A number of visualisation options were trialed in an effort to extract the maximum possible information from the combined geoscientific data, including representation of the geophysical data as pseudocolour or greyscale grids in plan view, or as DEMs with pseudocolour, sun-shaded, or fishnet drapes in isometric (3-D rendered) views. The fishnet DEM drape was found to be very effective in representing the 3-D structure while still enabling visualisation of geological data obtained from surface observations. Some insights gained from these displays are described below.

(Upper) McArthur Group

The upper McArthur Group was displayed in relation to its most prospective units, known mineral occurrences and major faults. The Group is largely truncated by the Tawallah Fault to the west, but extends beyond the Emu Fault to the east, though there are some indications of rapid thickness variation associated with the Emu Fault. The thick accumulation of McArthur Group sedimentary section south of HYC supports interpretations of transpressional or transtensional sub-basin development associated with the Emu Fault.

'Prospective units' were defined as all McArthur Group formations with a significant component of reducing lithologies. These were extracted from the GIS by selecting (using the lithological attribute table) all McArthur Group units with a proportion of carbonaceous or sulphidic lithologies exceeding 5% of the total volume of the unit. Only the Caranbirini Member, Reward Dolomite and Barney Creek Formation fulfil these criteria, and all known stratiform lead-zinc mineralisation is confined within these units. Most stratiform Pb-Zn deposits occur not in the centre of the thickest accumulations of McArthur Group, but rather on their periphery. This observation is consistent with genetic models which postulate bounding faults on grabens and half-grabens as favourable paths for migration of mineralising fluids.

(Mid-upper) Tawallah Group

Upper Tawallah Group igneous rocks vary in thickness up to more than 1200 m, though this thicker development of units correlated with the Settlement Creek and Gold Creek Volcanics is invariably confined to depths greater than 2 km. Conversely, outcrops of the upper Tawallah Group mafic units are clearly restricted to areas where their preserved thickness is relatively low, implying that these structurally elevated areas also experienced considerable uplift and erosion during basin development. Generally these predominantly mafic units underlie the McArthur Group at an average depth of around 2700 m. Many copper prospects occur in areas of greatest discontinuity separating thicker and thinner volumes of igneous accumulation. Similarly, many base metal deposits appear peripheral to more substantial developments of the upper Tawallah igneous units, again implying an association with long-lived basin bounding faults.

Flood volcanic rocks

An enormous volume of basalts underlies the entire greater McArthur/Mount Isa Basin region extending from the Urapunga Fault Zone past the Century Pb-Zn deposit in the south-east. The only exceptions are apparent onlaps onto the Murphy Inlier and a number of roughly east-west and approximately north-west-trending patches in the McArthur River region. The base of this basalt pile extends below 15 km depth, but averages around 6 km. There are few indications of a proto-Batten Trough, though a possible major north-south trending strike-slip fault is visible in the position of the present Emu Fault. This geometry can be interpreted as indicating north-south extension at this time. As with the upper Tawallah Group igneous units, these mafic volcanic rocks are much thinner where they outcrop as the Seigal Volcanics.

Lower volcanic rocks

A separate magnetic source has been delineated below the flood volcanic rocks, and is tentatively correlated with the Scrutton Volcanics. It averages 2.5 km in thickness, rising from a base depth of over 20 km in the west towards its exposed proposed equivalents on the Murphy Inlier and north-west of HYC in the Tawallah Range, near the eastern end of an elongated east-west uplift structure. Its base has a mean depth exceeding 8.5 km.

Granitoids

Granitoids of varying composition comprise much of the basement throughout the greater McArthur Basin region. Apart from their rise to exposure in the Murphy Inlier, the granitoids are generally deeper than 6 km, but their general relief exceeds 10 km. A number of younger plutons in the Batten Trough and south of the Murphy Inlier may penetrate basin units. The appearance of granitoids in the subsurface within a few tens of kilometres of the HYC deposit is an example of how prospectivity analysis based on (for example) buffering units in 2-D may be misleading.

CONCLUSIONS

Combination of rigorous geophysical analysis and GIS-supported display and integration with other data sets permits a new view of the McArthur Basin and its mineralisation. Though other authors have pointed out the need to incorporate gravity and magnetic datasets into metallogenic GIS (see, for example, Knox-Robinson et al., 1992; Wyborn et al., 1994), the three-dimensional utility of such data is not fully realised without the capacity to include quantitative interpretations based on these data in the GIS. Isometric views of structure contours and isochores enable easier visualisation of relationships between basin geometry, faults and mineral occurrences. Syngenetic/diagenetic mineralisation is not only spatially associated with faults mapped at the surface, but also with discontinuities in gross basin components interpreted as basin-bounding structures active during deposition.

Use of GIS to study or explore for ore deposits, particularly those which are syn- or early dia-genetic, is at best incomplete and at worst misleading without inclusion of 3-D geological information. Future work (Duffett, in prep.) will investigate techniques for quantifying relationships between structures in the 3-D subsurface data and ore deposits.

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The Search for wealth ...GIS applications in mineral exploration

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As part of the NSW Department of Mineral Resources' Discovery 2000 initiative, the latest Geoscience Database, covering the Cargelligo area in the State's central south west, has been completed, tailored for the exploration industry. Packages are produced in both ArcView and MapInfo and provide a first pass tool for project generation & selection of potential exploration targets. All data is produced to be easily converted into grid files for use in raster based GIS analysis.

The Cargelligo Geoscience Database is a multi-theme package aimed at incorporating new high resolution geophysical data with existing geological and exploration data sets. Data sets included are: magnetic, radiometric, DTM and Landsat TM imagery; geophysically derived contour data of gravity, magnetics and elevation; current geological mapping and mineral deposits; exploration licence and sample data; and detailed geographical reference data consisting of roads, rivers, rails, localities, local government areas and national parks.

Data has been compiled in ArcInfo and exported to the two PC based GIS packages. Likewise all point data was compiled in-house as a relational database within Microsoft Access and then exported as flat DBase files. Due to the specialist nature of the data, both GIS packages were customised to make data visualisation and manipulation easier for the end user.

The ultimate aim of the packages is to compile recent exploration oriented data sets into a spatial format for industry use with the emphasis on encouraging exploration in greenfield areas around the State. To date, response from industry has resulted in a 4-fold increase in exploration expenditure in the Discovery 2000 project areas.

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PRESENT STATE OF GIS AS AN EXPLORATION TOOL WITH IMPLICATIONS FOR FUTURE DEVELOPMENT

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ABSTRACT

Over the past five years or so, the use of Geographic Information Systems in geology has increased significantly. GIS has found a comfortable niche in the management and coordination of large exploration databases, especially with the recent availability of affordable and user-friendly desk-top software. Most attention has focused on the use of GIS to analyse exploration databases in an attempt to identify the most likely sites of undiscovered mineralisation. Research into mineral potential mapping carried out by the Geological Survey of Canada in the late 1980s was one of the first major geological uses of GIS and illustrated the enormous potential of this technology. Since then, several new prospectivity mapping methodologies have been developed with various degrees of success, using techniques such as Boolean and fuzzy logic, expert systems, and neural networks.

There are many problems and pit-falls that the un-initiated may encounter which will result in a poor, or even useless, prospectivity map. It is imperative that prospectivity mapping is not treated as a 'black-box' process, and that experienced geologists are consulted at each step of the assessment. The future use of GIS as a prospectivity mapping tool is dependent on several controlling factors, including the need for better geological data, the development of specialised GIS tools, and a change in emphasis with regards to the assessment philosophy.

INTRODUCTION

Major in-roads into geological applications of GIS were made about a decade ago with the pioneering mineral potential mapping work of the Geological Survey of Canada. Several factors, including expense, scarcity of digital data, and user-unfriendliness, prevented many mining and exploration companies from experimenting with this emergent technology. Consequently, most geological GIS research was initially restricted to universities and the larger exploration companies. Fortunately, the past few years have seen the demolition of the above-mentioned barriers, and almost any explorationist can afford to investigate the role of GIS for themselves. For those still unable, or unwilling, to personally experiment, there are an ever-increasing number of GIS consultants available for contract.

Attention has centred on the role of GIS for prospectivity mapping purposes, and this is not surprising. In many regions, the majority of easy-to-find deposits have been discovered, and modern exploration strategies require the simultaneous consideration of multiple datasets in an attempt to locate deposits obscured by surfical cover. To further complicate matters, non-geological datasets must also be considered in modern exploration programs. Such data include the locations of national parks, aboriginal sacred sites, water catchment areas, *etc*. The intrinsic ability of a GIS to store, manipulate, and analyse disparate spatial datasets for a particular area makes them a perfect decision making tool for the explorationist, and will aid the identification of areas that are the most prospective and accessible.

In this paper, the present state of GIS-based prospectivity mapping is discussed, and the research program of the Centre for Strategic Mineral Deposits (formally Key Centre) is introduced. This is followed by the identification of some problems which must be overcome if better prospectivity maps are to be constructed. Finally, a philosophy for prospectivity mapping is developed which, coupled with technological improvements, will lead to far superior prospectivity maps.

PRESENT STATE OF GIS-BASED EXPLORATION

GIS-based prospectivity analysis has progressed tremendously over the past five years primarily as a result of improved GIS technology and the increased availability of quality digital maps. Prospectivity analysis methodologies are broadly categorised into two types: empirical and conceptual. Empirical methodologies make use of known deposits in an attempt to identify favourable areas. Conceptual methodologies, on the other hand, assess a region based on deposit and genetic models, and consequently do not require the area to contain known deposits. Regardless of basic philosophy, the majority of methods aim to quantify proposed or identified thematic relationships, and ultimately integrate several of these into a single prospectivity map. Most research in GIS-based prospectivity mapping focuses on the latter step, and several methods have been developed; Boolean, algebraic, Bayesian, fuzzy logic, and neural networks. The kind of GIS available (*i.e.* vector vs raster) has, to some extent, influenced which method is used. The first two methods are best conducted within a vector GIS, but can be applied without great difficulty in a raster or quad-tree system. The latter three methods of integration are best conducted in a raster (or quad-tree) GIS, although can be applied in a vector system albeit with significant drop in performance. The five methods of integrating spatial relationships into a single prospectivity map are presented in Table 1.

Table 1. Common methods used to combine quantified spatial relationships into a single prospectivity map.

Method	*Data Type*	*Notes*
Boolean	Discrete	Thematic relationships are quantified as two-state maps displaying zones of either high ('1') or low ('0') favourability. Several quantified relationships are integrated by conducting a Boolean 'And' which will highlight only those areas which are favourable in all of the component maps. Alternatively, the component maps are combined, and a simple sum is calculated. In this case, for *n* input coverages, the resultant prospectivity map will have a maximum of $n+1$ states. The deficiency with this method is that all input coverages are treated equally, even though one of the identified relationships may be much stronger than the others.
Bayesian	Discrete	Thematic relationships are quantified as two-state maps displaying zones of either high or low favourability. These areas are assigned probabilistic weights based on the strength of the relationship. Bayes' law of conditional probability is then used to integrate several relationships into a single map. This method provides a probabilistic result, and takes into account the different 'strengths' of spatial relationships. However, the method is based upon statistical assumptions that cannot always be satisfied. Furthermore, deposit size is not incorporated in the analysis.
Algebraic	Discrete	The algebraic method is an extension of the Boolean method, and allows spatial relationships to be quantified into multiple states of favourability. Using an algebraic technique to combine relationships allows both relationship strength and deposit size to be incorporated.
Fuzzy logic	Continuous	Fuzzy logic is also related to the Boolean method, and in fact Boolean logic is actually a sub-set of fuzzy logic. In fuzzy logic, a spatial relationship is quantified as a continuous surface. A value of '0' implies complete disassociation (*i.e.* low significance) and a value of '1' implies complete association (*i.e.* high significance). A number of fuzzy logic operators can be used to integrate several relationships, including fuzzy

Method	*Data Type*	*Notes*
		equivalents of 'And' and 'Or'. The gamma function is a common operator used to combine datasets (Bonham-Carter, 1994).
Neural networks	Continuous	Artificial Neural Networks (ANNs) are not used to integrate previously defined spatial relationships into a single prospectivity map. Instead, ANNs are used as a classification tool. A database is constructed which contains items such as deposit size, distance to nearest fault, strike of nearest fault, local contact density, closest contact type, host rock, *etc.* This information, along with similar measurements for places known to be barren, are then processed by the ANN, which attempts to relate the inputs (*i.e.* the measurements) to the output (*i.e.* deposit size). Once trained, the ANN can be used to determine the favourability of any point in the study area. To date, there have been problems in getting ANNs to completely map inputs to the appropriate output. Research at the Centre for Strategic Mineral Deposits has only been able to get about 85% of the network trained. However, it is believed that the inclusion of a larger number of diverse datasets will enable an ANN to be fully trained.

GEOLOGICAL GIS RESEARCH AT UWA

The Centre for Strategic Mineral Deposits at The University of Western Australia has been actively engaged in GIS research since late 1989. The main focus of the GIS research program is the development of methodologies and GIS software tools to identify significant spatial relationships between mineral deposits and other geological features, and to integrate these into prospectivity maps. In addition, the enhancement of existing GIS to add functionality for a variety of visualisation and analytical purposes has been researched. With regards to prospectivity mapping, a multi-scalar approach is adopted, and individual research projects are conducted at all scales from global down to camp-scale.

On a global scale, a spatio-temporal database has been constructed for several commodity types which formed during the Phanerozoic, and a series of software modules have been written for the GIS Arc/Info, and more recently, ArcView, to manipulate and visualise these data. Equipped with a database of palaeomagnetically derived Apparent Polar Wandering Paths (APWPs), it is possible using the spatio-temporal database to reconstruct the relative location of the tectonic plates at any time throughout the Phanerozoic, and to display the location of known mineral provinces at the time of their formation. This ability effectively allows one to relate known mineral provinces to tectonic settings. This will aid the identification of prospective regions previously overlooked for a particular deposit type.

Moving down a scale, a research project was recently initiated to investigate world-wide Archaean gold prospectivity at a craton scale and to categorise the broad-scale features which control the overall prospectivity of a region. This research aims to answer the question as to why the Yilgarn is highly prospective with respect to the Pilbara, and why, within a single province, one greenstone belt is highly mineralised whereas an adjacent belt is not.

Regional-scale prospectivity mapping was the initial scale at which GIS technology was trialed, and resulted in the construction of gold prospectivity maps for the constituent provinces of the Yilgarn Block of Western Australia. Using predominantly an empirical methodology, several significant spatial relationships are identified between gold deposits and surrounding geological features. These have been integrated into prospectivity maps with a demonstrated predictive capability. For example, the prospectivity map for the Kalgoorlie-Kambalda Terrane, compiled using only geological map data, identified the highest prospectivity category as occupying only 0.3% of the greenstone belt. The area delineated contains in excess of 16% of known gold deposits and over 80% of known gold production and includes the giant deposits of the Golden Mile. Initial research was conducted using a vector GIS, with identified spatial relationships represented as discontinuous variables. Recently, a combined vector/raster approach has been adopted in which relationships are identified using the vector GIS and are quantified and integrated in a raster environment using fuzzy logic operators. This approach both increases the predictive capability of the resultant map, and provides a better visualisation of the spatial behaviour of prospectivity. Regional scale prospectivity analysis has been applied to other regions and commodities, including an investigation of lead-zinc mineralisation potential of the Lennard Shelf, Canning Basin (D'Ercole & Milton, 1996).

Finally, GIS-based prospectivity analysis is also conducted at a mine-camp scale. A three-dimensional model of the Wiluna gold district has been constructed, and two-dimensional GIS and three-dimensional mining and visualisation software are used to identify spatial controls on mineralisation and to identify factors which constrain the location of high-grade ore zones within the deposits. The ultimate aim of this research is to identify potential continuations of known ore bodies, and to identify likely areas of undiscovered mineralisation in the immediate vicinity.

CURRENT PROBLEMS

A number of problems need to be addressed in order for GIS-based prospectivity mapping to become a more exact and beneficial tool for explorationists. Current problems can be split into three general groups: technology, data, and processing.

Technology

Essentially, improved GIS technology will lead to better prospectivity mapping. Present and future methodologies will undoubtably require more advanced software manipulation tools. To date, one of the main problems with GIS has been the lack of tools with a geological emphasis. This has been partially remedied with the gradual development of software modules written using the various macro languages afforded by the majority of GISs. However, these macro languages are normally slow to execute, and often the commands available are at too high a level to be useful. Even basic GIS functions are often at too high-level, and may actually comprise a macro of several low-level commands which are not available to the user. For geological, and most other, purposes, present GISs could be made much more powerful simply by adopting an open-architecture strategy, and allowing users to access and manipulate the structure and contents of the spatial-data and topology databases at a low level. Unfortunately, the structure and construction of the spatial-data, and especially topology, databases is the key to a successful GIS. Consequently, it is understandable that GIS developers are unwilling to allow access at such a level. To this aim ESRI, who produce the GIS ARC/INFO, have developed the non-topological 'shape file' data structure which allows for some low-level interaction with spatial data without compromising their full data structures.

The next main leap for GIS will be the inclusion of the third dimension. Several prototype 3D-GISs have been developed in recent years, using vector, voxel (three-dimensional raster), or oct-tree (three-dimensional quad-tree) data structures. However, the potential usefulness of a true 3D-GIS for prospectivity mapping purposes is in some doubt. The main problem is the severe spatial anisotropy of district to regional-scale three-dimensional geological data. We can map surface geology to any degree of accuracy, but we can only infer the sub-surface geology by direct drilling or through various geophysical surveys. To date, 3D-GISs all treat data accuracy as being isotropic and this would be disastrous in any attempt to conduct a three-dimensional prospectivity analysis. Probably the best way to include sub-surface knowledge is to define suitable data structures and to enhance a conventional GIS into an interpolative 3D GIS. It is not beyond the capabilities of present GIS to incorporate sub-surface information. For example, Ichoku *et al.* (1994) wrote software for the automatic construction of geological cross-sections from suitably attributed GIS databases and digital elevation models. Also, at the Centre for Strategic Mineral Deposits, modules have been written for ArcView GIS to allow structural data to be analysed in a spatial context using computer-generated stereonets (Smith & Gardoll, *in press*; Knox-Robinson & Gardoll, *in press*).

Data

The success of all prospectivity mapping, regardless of whether it is GIS-based or not, ultimately rests on the kinds, quality, and format of available spatial and non-spatial datasets with which to conduct the analysis. The kinds of datasets required are dependent primarily on the type of deposit under investigation. For example, Archaean lode gold deposits are predominantly structurally controlled, with their location strongly controlled by the spatial interplay of contacts separating rocks of highly contrasting rheologies. Consequently, a geological map with a lithological base is required to identify suitable contacts. A geological map which has a stratigraphic base may result in important lithological contacts being overlooked.

Other difficulties stem from the co-registration of multiple datasets, and problems associated with incorporating Global Positioning Systems (GPS) data in a GIS. The main problem, which has much to do with current teaching strategies in GIS, is the relative lack of training in geodesy. Obvious errors arise when one attempts to overlay two maps which have different projections. However, errors when two maps of the same projection but different datum are overlain are easily overlooked. Consequently, the proliferation of GPS in geological field work is a major cause of concern with respect to the limited education in geodesy. GPSs are configured to a geocentric ellipsoid, such as the WGS84, and provide location in either latitude-longitude or Universal Transverse Mercator coordinates. Since 1966, Australia has used the Australian Geodetic Datum, which is based on the non-geocentric Australian National Spheroid. The difference in location between GPS-derived coordinates and those using the Australian Geodetic Datum is in the order of 200m. This difference is small enough that an inexperienced user could inadvertently mix data from these two sources. It is potentially disastrous for regional-scale prospectivity mapping, as an error in location of 200m could place a deposit on the wrong side of a lithological contact and thus greatly alter the prospectivity analysis. Hence, it is essential to ensure that both the datum and projection of the spatial data are suitably stored within the GIS. It is beyond the scope of this paper to further explain the concepts and problems associated with the reference spheroid. Details about the spheroids and datums used in Australia, and the push to introduce a geocentric datum by the year 2000 can be obtained from the AUSLIG web site[1].

Other data problems relate to the methodology used to construct a prospectivity map. For example, if an empirical methodology is used, one must be confident that the area has been subjected to reasonably even exploration. This normally requires the area to have been of interest historically. If, for example, the area is relatively unexplored and a company has used a particular genetic or deposit model to find all the deposits to date, then a prospectivity analysis may simply quantify this exploration strategy. Consequently, the resultant prospectivity map's ability to locate undiscovered deposits would be relatively low.

Processing

The manner in which spatial and non-spatial data are processed is reliant to a large extent on the GIS to be used and the methodology to be applied. A number of processing problems have been encountered, primarily as a result of poor database design and a lack of a geological knowledge on behalf of the GIS analyst. The key to good database design is the development of a structure that maximises its ability to be queried. Unfortunately, many GIS databases contain free-text fields of attribute information, or implement non-hierarchal codes that normally require multiple database searches per query. Another common occurrence, adopted by many GIS consultants, is to produce complex attribute databases employing several relationally or hierarchically linked tables. Although good database practice in terms of minimising data redundancy plus looks impressive, easy access to the data is often compromised. In most cases

[1] http://www.auslig.gov.au/geodesy/geodesy.htm

a single flat-file attribute database of suitably encoded information works best for prospectivity mapping purposes.

In the case of continent-scale to regional-scale prospectivity mapping, distortions introduced by the map projection must be taken into account. This simply involves using an appropriate projection for each type of measurement. For example, when calculating areas, an equal-area projection such as Albers should be used. Most high-end GIS easily transform map data from one projection to another, some now do it 'on-the-fly'. It is ironic that one needs to project data in a GIS to make various measurements. One would think a GIS should be able to manage data stored in geographic coordinates, without the need to project to a Cartesian coordinate system. By conducting measurements directly on the sphere, distortions in area, distance, and direction would be minimised.

FUTURE DIRECTIONS

Addressing the above-mentioned problems will result in better prospectivity maps. Better maps also result from using existing techniques and GIS-tools when a multi-scalar, multi-disciplinary approach is adopted. A multi-scalar approach is important especially when a conceptual methodology is applied to a region totally devoid of known deposits. A multi-scalar approach may simply involve an initial estimation of the likelihood that an area of interest will contain deposits through an investigation of the region's tectonic setting and subsequent comparison with known mineral fields. Prospectivity analysis will also benefit from a multidisciplinary approach, using all available data from geological, geophysical, and geochemical sources in the construction of the prospectivity map. The results of other exploration techniques, such as the location of low-mean-stress areas through stress mapping (Holyland *1990)*, can also be incorporated to further enhance the prospectivity analysis.

Perhaps the biggest mistake made by many GIS analysts is the belief that once a prospectivity map has been generated, then the analysis is complete. Once constructed, a prospectivity map must be tested for applicability by statistically comparing prospectivity categories with the location of a test-set of known deposits (or anomalies) which were not used to construct the map. If the map is useful, an inproportionate number of these deposits or anomalies should lie in high prospective areas. Even if the map proves to have a predictive capability, one should bear in mind that as many as 75% of highlighted targets may actually be false. This results from conducting a two-dimensional analysis on three-dimensional geological data, and the relative lack of knowledge about the behaviour of geology at depth. For example, consider a simplistic hypothetical case in which deposits are spatially constrained by faults and a particular kind of lithological contact (*e.g.* separating rocks of strongly contrasting rheologies). In this case, a prospectivity analysis will identify a proximity relationship between deposits and faults and deposits and the particular contacts. Integrating these two identified relationships into a single map will highlight areas proximal to both the faults and important contacts as being the most prospective. However, for a deposit to actually form, it may be a genetic requirement that the fault and contact must intersect. Assuming that the faults and contacts do not intersect at the surface, there are three possible geometries of which only one is favourable (Figure 1). Consequently, for exploration purposes, the product that most GIS-analysts consider to be a prospectivity map should be regarded as preliminary. Further assessment is required before money is spent investigating the targets. For example, in the above case, a follow-up investigation may select only those targets in proximity to known deposits, or which are in strike-continuation of known mineral fields.

Another area which will benefit GIS-based prospectivity mapping is shape analysis. The functionality afforded by most GISs is inherently short-sighted, and deals with nearest features or spatial inclusions. For prospectivity mapping purposes, the closest feature may not be the most important, and the shape of a particular feature may be more important than proximity to it. Hence, inclusion of GIS-modules to analyse and classify shapes will allow one to assess how deposits relate to their entire surroundings, and not just to their nearest neighbours. In turn, this

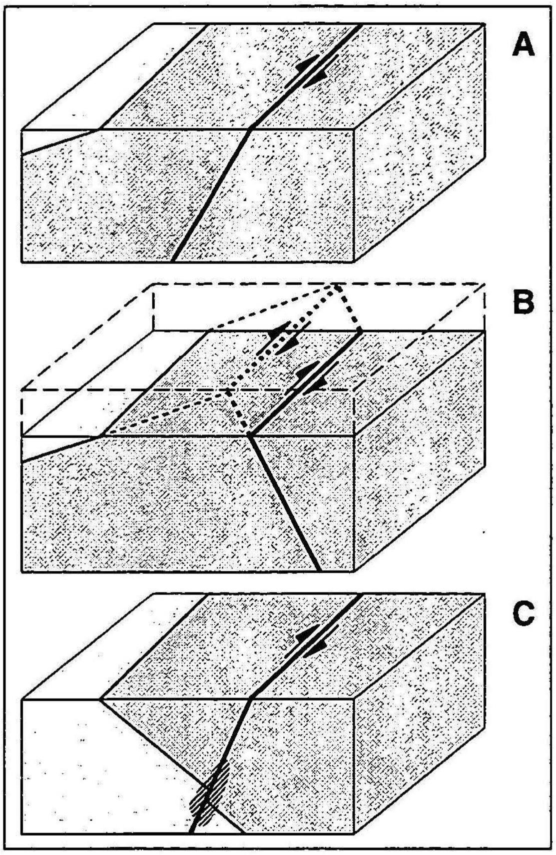

Figure 1. Three possible geometries of fault-plane / lithological-contact interaction. A) Contact and fault dip in the same direction and do not intersect at depth. B) Contact and fault dip in opposite directions, but diverge below surface. C) Contact and fault dip in opposite directions and converge below surface, with a deposit at the intersection.

will result in superior prospectivity maps. Pre-existing technology, such as neural-network-based optical character recognition, could be adapted to this aim.

CONCLUSIONS

Over the past decade it has become obvious that GIS presents a valuable tool for geoscientists that will become increasingly relevant as technology evolves. Much research has been conducted into the role of GIS as an exploration tool, and a number of methodologies have been developed which result in prospectivity maps with demonstrated predictive capability. However, a number of problems and deficiencies with present methodologies and technologies prevent the construction of even better GIS-based prospectivity maps. Perhaps one of the biggest potential pit-falls is the philosophy employed. Many researchers concentrate on the 'black-box' integration of spatial relationships into a single map using a variety of techniques. Prospectivity mapping is both a knowledge- and data-driven process. If the foundation data of the analysis are deficient, this will be apparent in the poor predictive capability of the resultant prospectivity map. With inadequate knowledge of deposit characteristics, the resultant map will be equally flawed. To this aim, the philosophy of prospectivity mapping needs to be refined. More emphasis must be placed on the identification of suitable data sources, the construction of effective GIS databases, and the identification and quantification of individual spatial relationships. The actual role of integrating multiple spatial relationships into a single prospectivity map should, to some extent, be de-emphasised. Most importantly, it is essential that GIS-based prospectivity analysis is not treated as a 'black-box' process and it is crucial that all steps of the process are verified by an experienced geologist.

However, treated with caution to ensure that scientific integrity is maintained, the future of GIS as an exploration tool appears attractive, especially with advancements in technology that are expected in the near future.

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Use of GIS to evaluate mineral potential in regional scale areas

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ABSTRACT: Two GIS based methods of spatial analysis (weights of evidence and fuzzy logic) are being used by the New South Wales Geological Survey to evaluate mineral potential in the central west of NSW. Preliminary assessments have been undertaken for Ordovician porphyry copper/gold and related mineralisation, and Silurian volcanic-hosted gold/base metal mineralisation styles on the Bathurst and Dubbo 1:250,000 sheets. Analyses were performed using ARC/INFO software.

Some 2638 mineral occurrences located in the central west of NSW (Bathurst, Dubbo, Narromine, Forbes, Cootamundra and Gilgandra 1:250,000 sheets) were grouped into 23 classes according to criteria including commodity, host rock age, host rock lithology, and mineralisation style. Summary tables of lithostratigraphic data were collated to facilitate selection of target rock units. Each geophysical data set (magnetics, gravity, radiometrics) underwent qualitative interpretation to produce layers delineating characteristic zones. Stream sediment geochemistry data, available for parts of the study area, were statistically analysed to determine anomalous values.

The analysis methods use a number of conditionally independent data sets. Up to nine data sets derived from geology, magnetics, radiometrics and geochemistry have been used in this study. However, there is a limit on the number of conditionally independent data layers that can be used, since modern geological mapping relies heavily on geophysical information to delineate rock units. Qualitative interpretation of geophysical layers is undertaken in order to limit conditional dependence between geology and geophysical layers.

Analysis of the Ordovician porphyry copper/gold model used nine data layers these being geology, mineral occurrences (337), buffered faults, buffered magnetic and gravity linears, magnetic zones, buffered anomalous gold and copper values, and a high potassium radiometric zone. The weights of evidence analysis showed several large areas with moderate to high prospectivity due to coincidence between the geology, magnetic zones, anomalous gold values and the high potassium radiometric zone. Some of these layers may be conditionally dependent. The fuzzy logic analysis produced a similar but less emphatic output because of the lower weighting given to some data sets in this analysis.

Analysis of the Silurian volcanic-hosted gold/base metal model used eight data layers: geology, mineral occurrences (213), buffered faults, buffered magnetic linears, magnetic zones, buffered anomalous gold, copper and lead values. Both analysis methods for the Silurian model delineated areas of moderate to low prospectivity. The weights of evidence method defined several restricted areas compared to the fuzzy logic method which showed much broader areas.

These methods of analysis offer a means of spatially relating data layers. However, regional scale analyses may suffer if any of the data sets is incomplete.

INTRODUCTION

The New South Wales Department of Mineral Resources has a program of evaluating the mineral potential of selected areas in the State (Suppel et al 1995). One previous such study was carried out in the State's Upper North East, as part of a broader Audit of Natural Resources of that region, undertaken under the auspices of the former Natural Resources Audit Council (Barnes et al 1996). Because of the nature of the data available at the time, methods used for that study were akin to a prospective tracts approach in which prospective areas are delineated by identifying coincident thematic signatures, and measures of prospectivity for particular styles of mineralisation are derived

In this paper, two spatial analysis methods, weights of evidence and fuzzy logic, are used to investigate the use of GIS in evaluating mineral potential in a regional scale area, the Bathurst and Dubbo 1:250,000 sheets in the central west of NSW. The data in a regional scale area, as in this case, is usually neither as detailed nor as complete as for smaller areas, and some accommodation is required in understanding the results obtained.

The mineralisation models used for this study were Ordovician porphyry copper/gold mineralisation and Silurian volcanogenic gold/base metal mineralisation.

GEOLOGICAL SETTING

The study area lies in the northeastern part of the Lachlan Fold Belt, a major geological province which occupies most of central and south eastern New South Wales.

The area has a complex geological history, summarised below. Three major tectonic structures controlled the early development of the region: the Molong Volcanic Rise, which extends north-south through the centre of the study area, the Cowra-Yass Trough which flanks the Molong Volcanic Rise on the west and the Hill End Trough which flanks the Rise on the east. Younger rocks intrude and overlie the rocks formed in these older structures.

The Molong Volcanic Rise formed during Ordovician to Early Silurian time (from about 490 to 435 million years ago). It is a thick accumulation of basaltic to andesitic lavas, associated intrusions and tuffs. This Ordovician volcanism occurred throughout the Central West and forms a major tectonic unit known as the Molong Volcanic Arc (figure 1). The volcanics and intrusives in the study area form the Molong segment of the Arc. Limestones are interbedded with the volcanics, indicating that periodically the Rise submerged to become a shallow marine platform. In the Ordovician, a thick sequence of deep water sediments was deposited adjacent to the Rise and throughout much of the Lachlan Fold Belt, particularly in the east and south.

The Cowra-Yass Trough contains a fairly continuous sequence of Silurian to Early Devonian sedimentary rocks with some felsic volcanic units. It is bordered on the west, in the western part of the study area, by the Quambone-Young Zone which consists mainly of a belt of granite and granodiorite plutons of Late Silurian and Early Devonian age.

The Hill End Trough contains a sequence of Middle Silurian to Middle Devonian sedimentary and volcanic rocks. Deposition along the western margin of the Trough, along the site of the earlier Molong Volcanic Rise, commenced with the eruption of submarine to subaerial felsic volcanics (the Mullions Range Volcanics) and formation of thick limestone reefs. These rocks are prominent in the eastern part of the study area.

Younger rocks formed in a variety of settings. In the west, felsic and subordinate mafic volcanic rocks formed in the Middle Devonian. They overlie the Cowra-Yass Trough sequence, forming a widespread sheet to the west and northwest of Manildra. In Late Devonian time a shelf formed on which there was widespread deposition of fluvial to shallow marine sediments. Structural remnants of these sequences are scattered throughout central New South Wales. Widespread eruption of basalt lavas occurred throughout eastern Australia in Tertiary time. In the study area, Tertiary volcanics occur to the south of Orange. The Canobolas Volcanic Complex formed 11-12 million years before present. Mount Canobolas forms the elevated central core to the complex, surrounded by less elevated areas of basaltic lavas which radiate outwards. Gravels, sands and clays found beneath basalts throughout the area also are of Tertiary age.

The major granitic intrusive bodies in the study area are:

- The Wyangala Batholith and Associated Intrusions (Early to Late Silurian); a group of intrusions concentrated at the southern end of the Molong Volcanic Rise.
- The Boggy Plain Supersuite (Early Devonian); granitic and granodioritic bodies intruding Silurian sequences of the Cowra-Yass Trough and in the adjacent Quambone-Young Zone, referred to above.
- The Bathurst Batholith and Associated Intrusions (Late Carboniferous); a group of granitic bodies in the Hill End Trough (and further to the east).

MINERALISATION

The Lachlan Fold Belt contains a wide range of deposits. The most important types are: porphyry, epithermal and skarn type copper, copper-gold, and gold deposits developed in

Ordovician basaltic and andesitic volcanics (shoshonites) and associated intrusives; base metal and gold deposits, with both volcanogenic (VMS) and thrust-related features, in Silurian felsic volcanic-sedimentary rock trough and basin sequences; tin, gold and smaller tungsten, molybdenum and base metal deposits in Silurian and Early Devonian granites; large gold and base metal deposits in Early Devonian turbiditic rocks in the Cobar region ("Cobar type" deposits), probably formed during deformation and closure of the Cobar Basin; and gold vein deposits in folded sedimentary rocks, for example at Hill End.

The Lachlan Fold Belt contains numerous significant mineral deposits. The number of important discoveries made in the 1980s and 1990s, particularly of porphyry related copper-gold and epithermal gold deposits, volcanogenic base metal deposits and "Cobar type" gold and base metal deposits, suggests good potential for the discovery of further deposits.

Copper and/or Gold in Ordovician Mafic Volcanics and related Intrusive rocks

In recent years, one of the success stories of the State's metalliferous mineral exploration has been the discovery and proving of porphyry and porphyry related gold and copper-gold deposits in central New South Wales. The largest of these are at Northparkes and Lake Cowal (to the west of the study area) and at Cadia Hill (in the study area). The deposits are related to Ordovician magmatism and occur in both volcanic and intrusive rocks which in the study area were formed in the Molong Volcanic Rise.

A major new mine is under construction at Cadia Hill by Newcrest Mining Limited. The project, located 20 km southwest of Orange, will be a very large open cut that will mine 17 Mt (million tonnes) of ore per year for 12 years to produce an average of 293,00 ounces of gold and 23,000 tonnes of copper per year. In December 1996, Newcrest announced very high grade drilling results from the Ridgeway prospect, 3 km northwest of Cadia Hill. This prospect has the potential to greatly increase the size and life of mining operations at Cadia.

In the same district, gold mining operations at Junction Reefs and Glendale have ceased, but resources have been delineated at Forest Reefs.

Elsewhere on the Molong Rise, encouraging results have been obtained from exploration at Cargo, Copper Hill and in the Kaiser mine area.

Some of the deposits grouped as deposits in Ordovician igneous rocks of the Molong Rise and as deposits in Ordovician non-igneous rocks are possibly related to younger intrusives. Examples are the Browns Creek gold-copper mine, where radiometric dating suggests that the mineralisation is Silurian in age, and possibly deposits in the Discovery Ridge area.

Silurian Volcanogenic Massive Sulphides

Another important deposit type is associated with felsic volcanic rocks and sedimentary rocks of Silurian age, especially along the western margin of the Hill End Trough. Deposits of this type contain copper, lead, zinc, silver and, commonly but not invariably, significant gold. They are referred to as volcanogenic massive sulphide (VMS) deposits. The most promising exploration results have been obtained in the Lewis Ponds - Mount Bulga - Icely area. Exploration of a substantial gold - base metal deposit at Lewis Ponds is continuing. Other target areas are centred on the Mount Lindsay copper deposit, near Clergate, and the Commonwealth mine, near Wellington.

METHODS OF ANALYSIS

Two methods, *Weights of Evidence* and *Fuzzy Logic* were chosen for use in the spatial analysis of metallic mineralisation types. These methods are described in Bonham-Carter (1994).

Weights of Evidence

The method proposed here is a version of the *Weights of Evidence* method, modified from that used by a team from the Geological Survey of Canada (Bonham-Carter, Agteberg and Wright 1990). It uses a combination of map patterns which are converted to probabilities using Bayesian statistics. In a simple case a binary pattern is employed. For such binary maps the areas of positive and negative weights is dependent on the presence or absence of occurrences within a pattern.

The method has a number of advantages in that it is data driven and it avoids subjective choice in weighting factors. Its disadvantages apply in areas which are underexplored because it treats lack of data as lack of "favourable" data.

It should be noted that weights are determined using the location of known mineral deposits. It is assumed that sufficient exploration has been carried out to "tune" the coefficients. This factor may require consideration and experimentation possibly involving training areas or the intuitive adjustment of weights to reflect personal judgement.

The binary map analysis entails the calculation of prior and posterior odds. Posterior odds can be calculated for combinations of patterns to create a "unique conditions map".

Appraisal of the Method

The weights of evidence method has a number of advantages and disadvantages.

Advantages

- The method is data driven and objective and avoids subjective choice in weighting factors.
- The model is easily programmed and easily combines multiple map patterns.

Disadvantages

- Input maps must be conditionally independent
- The value of prior and posterior probability is always underestimated as they rely on the number of response variables, in this case mineral deposits. In underexplored areas the number of undiscovered deposits could be significant. The method may not be suited to poorly explored areas, as lack of data is treated as lack of favourable conditions.

Fuzzy logic

This is a model driven approach which uses the estimation of possibility described as fuzzy logic (Lewis 1994). Membership of a fuzzy set (Zadeh 1965) is expressed as a continuous scale from 0 to 1. In the case of mineral deposit modelling, values of 0.1 to 0.9 are applied to an attribute as a measure of increasing possibility that the style of mineralisation may be present when the attribute is present (Suppel et al. 1995).

The flexible approach to numbering for membership allows for scalar or non scalar classes, the application of mathematical expressions to derive a membership function, or at the extreme end a subjective assessment of an attribute

Appraisal of the Method

Advantages

- The use of continuous values within a single map layer allows for a product that is more visually understandable.
- Changes in weighting to better reflect model conditions are easy to apply by use of a range of operators.

- Programming of macros to implement the method within a GIS is relatively simple to carry out and any changes are easy to implement

Disadvantages

- Reliance on expert opinion in a model driven method.
- This method also may not be suited to poorly explored areas, as lack of data is treated as lack of favourable conditions. However the weighting given to broader areas may lessen this disadvantage.

DATA COVERAGES

Mineral Occurrences

Metallic mineral occurrences for the Bathurst and Dubbo 1:250,000 sheets were selected from the Bathurst, Dubbo, Gilgandra, Narromine, Forbes and Cootamundra data set which was captured from a number of databases and edited to produce a single internally consistent data set. The entire data set consists of over 2638 metallic mineral occurrences.

A classification scheme designed specifically for use in the Central West study was devised based on a number of attributes of the data set, these being major commodity, age of host rocks, host rock lithology and type of deposit. The scheme shown in the table below.

code	explanation
a	Copper in Girilambone
b	Gold in Girilambone
c	Copper & copper-gold in Ordovician volcanics/intrusives
d	Platinum in Ordovician rocks
e	Copper in Ordovician non-igneous rocks
f	Gold veins in Ordovician non-igneous rocks
g	Gold related to serpentinite (ultramafic) rocks
h	Other occurrences in Ordovician rocks
i	Gold/base metals in Silurian volcanic sequences
j	Gold in Silurian non-volcanic sequences
k	Other occurrences in Silurian non-volcanic rocks
l	Gold/base metals in Early Devonian volcanic rocks
m	Gold in Early Devonian non-volcanic rocks
n	Other occurrences in Early Devonian non-volcanic rocks
o	Occurrences in rocks post Early Devonian-pre Late Carboniferous
p	Granite related W/Mo/Bi/base metals/Fe
q	Gold in granite
r	Copper in granite/granodiorite
s	Chromite in Cambrian
t	Other Cambrian occurrences
v	Chromite in Silurian rocks
w	Manganese occurrences
y	Placer, residual occurrences
z	other & unclassified commodities

Geology

A single contiguous digital coverage of the Bathurst and Dubbo 1:250,000 geological sheets was selected from a larger coverage derived from six 1:250,000 geological sheets (Bathurst, Dubbo, Gilgandra, Narromine, Forbes and Cootamundra). The coverage was produced from individual 1:250,000 sheets imported from several digital sources into Arc/Info GIS software.

The Bathurst 1:250,000 geology is a digital version (in ARC/INFO format) of the map produced by the Australian Geological Survey Organisation (AGSO) and NSW Department of Mineral Resources (DMR) in 1996. The Dubbo 1:250,000 geology is a digital version (in INFORMAP format) of the 1974 metallogenic map.

Lithostratigraphic information for the rock units on each 1:250,000 geological sheet was compiled into individual tables to form a database of lithological attributes. These tables were combined to produce a single attribute table for joining to the geological coverage using the letter symbol as the common key.

The rock unit attribute table comprises information on letter symbol, unit lithology, main lithology, formation or pluton name, group or suite name, age relationship code, old age and young age for the unit, lithology class, depositional environment, facies, volcanic attribute, granite number, and intrusive class.

The attribute codes provide a means of querying data sets to produce ordered subsets of data. For example, rock units in the geological coverage were queried by means of the age relationship code to produce a geological map which displays rock units by geological periods.

Faults

A fault coverage for the Bathurst and Dubbo 1:250,000 geological sheets was derived from the geological coverages. Fault traces on the coverage were buffered to 200 metres.

Magnetics and Gravity

The airborne magnetic data were those obtained by AGSO, DMR, and the geophysical company Geoterrex Pty Ltd. The gravity data was that contained in the Australian Gravity Database.

Qualitative analysis of the data was carried out to obtain sets of geophysical zones and sets of geophysical linears. In order to reduce the chance of the geophysical and geological coverages being conditionally dependent, care was taken to not carry out the analysis to an extent such that a geological interpretation map was produced for the geophysical coverages. The interpreted geophysical zones and linears were digitised using ARC/INFO software to produce separate ARC/INFO coverages showing interpreted magnetic and gravity zones and linears in the study area. Magnetic and gravity linears were buffered to 200 metres.

Radiometrics

The airborne radiometric data over the study area show variations which are due to the extent of soil cover, and in general, no consistent radiometric zones (for the purposes of analysis) could be interpreted. It was however possible to define one separate ARC/INFO coverage showing interpreted zones of high potassium radiometric values; these could be relatable to alteration within the Ordovician volcanic sequences.

Stream Sediment Geochemistry

Stream sediment geochemical analyses for the Bathurst and Dubbo 1:250,000 sheets were selected from a database developed under the Discovery 2000 exploration initiative (from exploration reports held by the DMR). These analyses were statistically assessed to determine mean and standard deviation for elements gold, copper, and lead in the Central West area (Bathurst, Dubbo, Gilgandra, Narromine, Forbes and Cootamundra).

Based on this statistical analysis, anomalous values were determined for the elements. In the absence of a drainage basin coverage for the study area, each anomalous data point was buffered at a radius of 2000 metres. The following table shows a summary of statistics on sample data for selected elements in the Central West of NSW.

element	sample type	no. of samples	mean	standard deviation	maximum value	minimum value	unit
Au	bleg	7179	6.37	67.87	3260	0.01	ppb
Cu	ss	31581	31.55	48.67	3300	1	ppm
Cu in Ordovician (Bathurst - Dubbo)	ss	7532	56.89	57.02	2350	1	ppm
Pb	ss	31006	23.48	68.68	10000	1	ppm
Zn	ss	31236	61.59	112.04	9700	1	ppm

MODELS OF MINERALISATION

Copper and/or Gold in Ordovician Mafic Volcanics and related Intrusive rocks

These deposits are developed in Ordovician shoshonitic basaltic and andesitic volcanics and associated intrusives on the Molong Volcanic Rise. Deposits in this group (mineralisation type 'c') are the porphyry, epithermal and skarn type copper, copper-gold, and gold deposits.

Silurian Volcanogenic Massive Sulphides

These deposits (type 'i') are associated with felsic volcanic rocks and sedimentary rocks of Silurian age, especially along the western margin of the Hill End Trough. Deposits of this type contain copper, lead, zinc, silver and, commonly but not invariably, significant gold. They are referred to as volcanogenic massive sulphide (VMS) deposits.

Geological and Geophysical Signatures for Mineralisation types 'c' and 'i'

The table below shows the attributes considered favourable for mineralisation types 'c' and 'i'

type	model	favourable host rocks	structures	Au	Cu	Pb	Zn	favourable aeromagnetic zones
c	Copper & copper-gold in Ordovician volcanics/intrusives	Ordovician mafic volcanics and related mafic intrusives	✔	✔	✔			✔
i	Gold/base metals in Silurian volcanic sequences	All Silurian rocks	✔	✔	✔	✔	✔	?

RESULTS

Ordovician Porphyry Copper Gold and related mineralisation

For the weights of evidence analysis the first step is to determine which of the elements of a coverage may be taken as favourable and which as not favourable for the particular style of mineralisation i.e. which features can be considered "prospective" for a particular mineralisation model.

For the porphyry copper/gold model, all Ordovician rocks (mafic volcanics as well as sedimentary) were considered "prospective", as were the buffered faults, magnetic linears, and anomalous gold and copper geochemical values. Three of the magnetic zones (zone 4, highs with striated appearance; zone 2, highs with blocky appearance; and zone 3, moderate highs with a pitted appearance) were considered as being "prospective".

The fuzzy values adopted for the same (porphyry copper/gold) model are shown - more "prospectivity" is allocated to the Ordovician mafic volcanics (above other Ordovician rocks and Silurian mafics); and so is more "prospectivity" allocated to magnetic zone 4 (above zones 2 and 3). In the fuzzy logic case, an additional "prospective" zone was defined by high potassium radiometric anomalies whicjh could reflect areas of more potassic rocks or areas of potential potassic alteration typical of porphyry mineralising systems. Fuzzy logic values are shown in the table below.

Ordovician Porphyry Copper/Gold mineralisation	
Feature or attribute	**Fuzzy value**
Ordovician mafic volcanics	0.7
Ordovician other rocks	0.5
Silurian mafic volcanics	0.4
Other rocks	0.2
magnetic zone 4 - highs with striated appearance	0.6
magnetic zone 2 - highs with blocky appearance	0.4
magnetic zone 3 - moderate highs with a pitted appearance	0.4
all other magnetic zones	0.2
potassium radiometric high zone	0.6
buffered Au	0.7
buffered Cu	0.7
buffered faults	0.4
buffered magnetic linears	0.3
buffered gravity linears	0.2

Silurian Volcanogenic Massive Sulphides

For the VMS model, all Silurian rocks (more felsic volcanics as well as sedimentary) were considered "prospective", as were the buffered faults, magnetic linears, and anomalous gold, copper and lead geochemical values. Only one magnetic zone (zone 5, magnetic lows with striated highs) was considered as being "prospective".

The application of the fuzzy values to the VMS model allows broadening the attribute base for the analysis -- Silurian volcanics are favoured above other Silurian rocks, and some "value" above background is given to magnetic zone 3 (moderate highs with a pitted appearance).

Silurian Volcanogenic Massive Sulphides	
Feature or attribute	**Fuzzy value**
Silurian volcanics	0.8
Silurian other rocks	0.5
Other rocks	0.2
magnetic zone 5 - magnetic lows with striated highs	0.6
magnetic zone 3 - moderate highs with a pitted appearance	0.4
all other magnetic zones	0.2
buffered Au	0.8
buffered Cu	0.8
buffered Pb	0.8
buffered faults	0.4
buffered magnetic linears	0.4

COMPARISON OF RESULTS

As seen in figure 1(a), for the VMS model, the weights of evidence result shows some very restricted areas of high potential - this is virtually wholly due to the two main attributes considered to be prospective (geology and magnetics) being totally separate in space, as would be expected since felsic volcanics would not be expected to have any magnetic expression. In a weights of evidence computation, this would (and does) result in zero prospectivity being indicated for a large part of the study area. The areas shown as prospective are but those rare areas where there is coincidence of two or more attributes.

By contrast, the fuzzy logic result - figure 1(b) - shows far more area to be prospective, a result of introducing a large area of magnetics (magnetic zone 3) as marginally prospective but overlapping "prospective" geology, thus reducing the area of zero prospectivity. The presence of faults and linears, and of geochemical anomalies, gives a graduation within the larger areas.

This comparison is also seen in the weights of evidence result for the porphyry copper/gold model - figure 1(c) - since in this case there is a large area of overlap between the main attributes of Ordovician mafic volcanics and magnetic highs (magnetic zones 4, 2 and 3), although the non-overlap between most of the anomalies in magnetic zone 2 and the favourable geology allows the elimination of those areas over the Carboniferous Bathurst Batholith and associated granitoids.

CONCLUSION

Each of the methods used here has certain advantages and disadvantages.

Other methods of analysis can also be used (Lewis 1994, Suppel et al 1995), most of which tend to be more knowledge-driven than data-driven. A possible advantage of the methods outlined here, is that results can be fairly intuitive and thus attributes can be "re-visited" to assess whether they should be considered favourable or not. This may lead the researcher to challenge the original assumptions about the mineralisation model and the relevance of each of the data sets. The calculation for the results is then a fairly well automated process and the methods commend themselves for their relative simplicity.

ACKNOWLEDGMENTS

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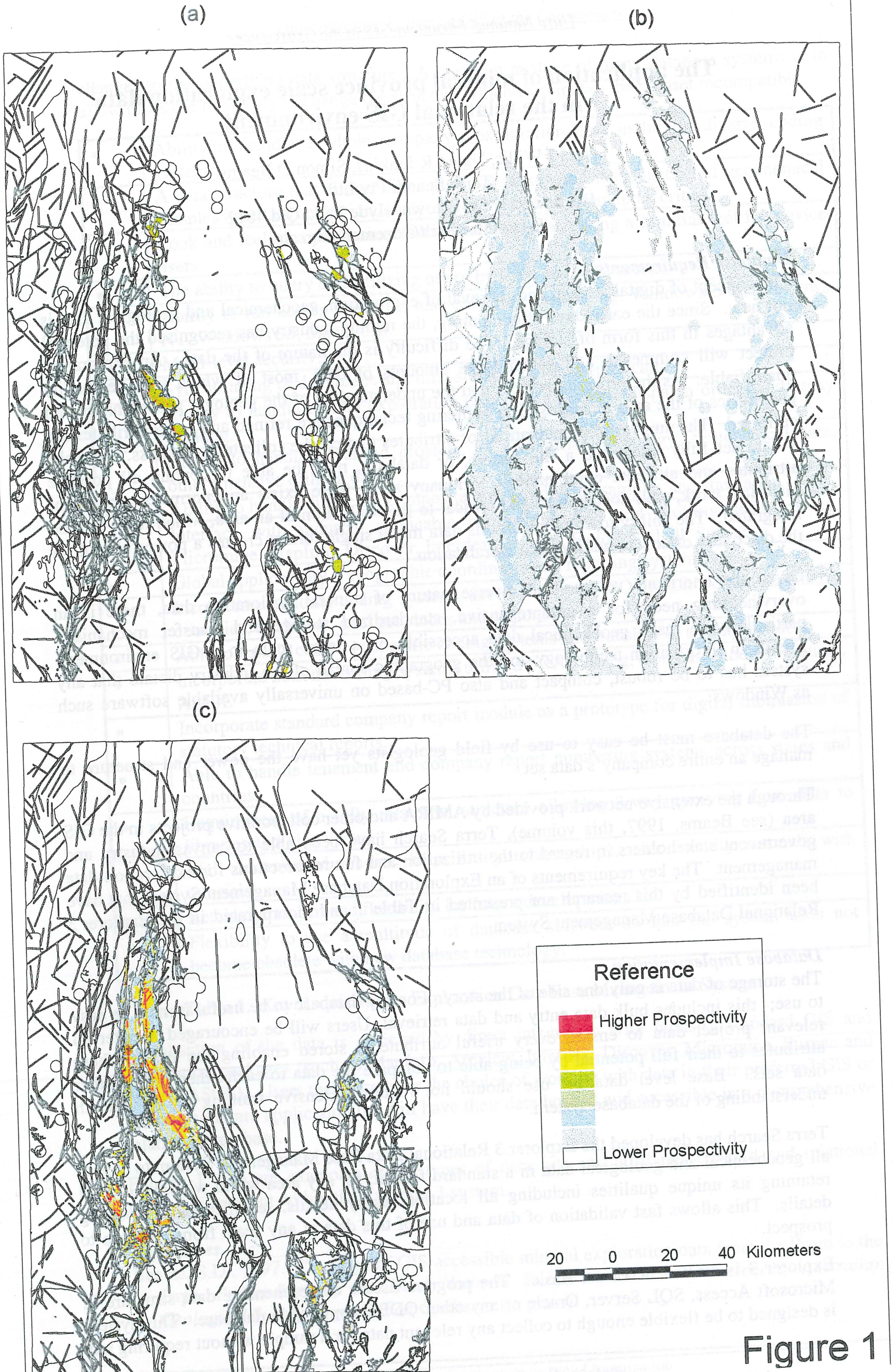
(a)
(b)
(c)
Reference
Higher Prospectivity
Lower Prospectivity
20 0 20 40 Kilometers

Figure 1

The application of mineral province scale exploration data in the relational GIS environment

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Database Requirements

The concept of digital storage and retrieval of exploration, geochemical and geological data is not new. Since the early days of computing, the mining industry has recognised the potential advantages in this form of storage. The difficulty is the nature of the data. An exploration project will commence and gather large amounts of data, most of which will be readily quantifiable. As the project advances and the understanding of the geology, geochemistry and geophysics of the area increases, data gathering techniques are refined and extra attributes are collected. The number of combinations of attributes that can be collected is endless. To make a data set fully integrable a file system, or database, must be able to contain all possible attributes and attribute combinations. In many areas there exists an enormous amount of historical work, well documented and critical to the evaluation of an area, which must also be integrated. The ability to combine all this data into a single format creates a powerful tool for the discovery of new or additional mineralisation.

Given the enormous volume and diverse nature of mineral exploration data, there is an overwhelming need for a comprehensive, standardized storage and transfer mechanism, particularly to make geochemical data accessible on a large scale in a GIS environment. Trends in information technology and the geographic spread of the industry dictate that any system has to be robust, compact and also PC-based on universally available software such as Windows.

The database must be easy to use by field geologists yet have the power and structure to manage an entire company's data set.

Through the extensive network provided by AMIRA and other collaborative projects in the GIS area (see Beams, 1997, this volume), Terra Search have been able to canvas industry and government stakeholders in regard to the utilization and future directions for exploration data management. The key requirements of an Exploration Database Management System that have been identified by this research are presented in Table 1 and incorporated in the Explorer 3 Relational Database Management System.

Database Implementation

The storage of data is only one side of the story. For any database to be useful it must be easy to use; this includes bulk data entry and data retrieval. Users will be encouraged to enter all relevant project data to ensure every useful attribute is stored enabling the use of these attributes to their full potential by being able to compare the data to each other and to other data sets. Base level database use should not require extensive training or an indepth understanding of the database system.

Terra Search has developed the Explorer 3 Relational Data Base Management System to collect all geochemical and geological data in a standard format, for any area world wide, while still retaining its unique qualities including all location, assay details, tenement and reporting details. This allows fast validation of data and use of this data at any scale from province to prospect.

Explorer 3 is written in Visual Basic. The program uses a comprehensive data structure in Microsoft Access, SQL Server, Oracle or any other ODBC compatible database. This system is designed to be flexible enough to collect any relevant data for a sample without requiring any changes to the underlying data structure. A common mistake of many database systems is to allow users the flexibility to change the structure which then makes the dataset incompatible.

•	Ability to handle a whole company's exploration data including diverse coding systems.
•	A data structure that allows high speed subsetting and interrogation of geochemical samples based on collection, analytical methods and geographic criteria.
•	Look and feel of a professional Windows program, giving a familiar feel for novice users.
•	The ability to query data utilizing query by form and SQL access.
•	Ability to run across platforms and operating systems eg. Windows 3.1., Windows NT, Windows 95, Macintosh.
•	Multi-level security.
•	Synchronzing of data bases and time stamping of data (replication).
•	Ability to handle current exploration projects eg. Sample dispatch orders and assay tracking.
•	Ability to handle advanced projects, eg. Quantifiable geology, geotechnical data, other intensive drilling data.
•	Ability to handle duplicate, composite, preferred value samples and standards.
•	Interface with industry applicable commercial GIS and plotting software, eg. Micromine, MapInfo, Discover, Interdex, ArcInfo, Field Marshall, Surpac.
•	Global applicability – geographic coordinates and reporting systems.
•	Incorporate national coding systems developed by AGSO eg. Lithcodes, geol units, countries, qualifiers, geol provinces and regions etc.
•	Able to handle company specific coding systems and translate to standard codes.
•	Incorporate national coding systems utilized by AESIS eg. Company code, thesaurus, ASEX.
•	Incorporate standard company report module as a prototype for digital submission of statutory technical reports.
•	Able to handle tenement and company report numbering systems across states and countries.
•	Requirement of a fully relational structure allowing 2-way querying from data to libraries and vice versa.
•	Well documented, on-line help, entity relationships, user friendly manuals with tutorials.
•	Retain dynamism and flexibility for future developments.
•	Flexibility to use a multitude of database software so that the system does not become obsolete with new database technology.

Table 1: Key Requirements Exploration Data Base Management System

Visualisation of the data is achieved by direct integration with industry standard GIS and exploration packages (such as MapInfo, Arcview, Interdex, Discover, Micromine, Surpac and generic ASCII). Users therefore have the choice of working with data in their preferred GIS or plotting software application but still have their data housed and accessible in a comprehensive relational data base.

Figures 1 to 6 are examples of the types of data sets and attributes covered and relational cross links present within the Explorer 3 system.

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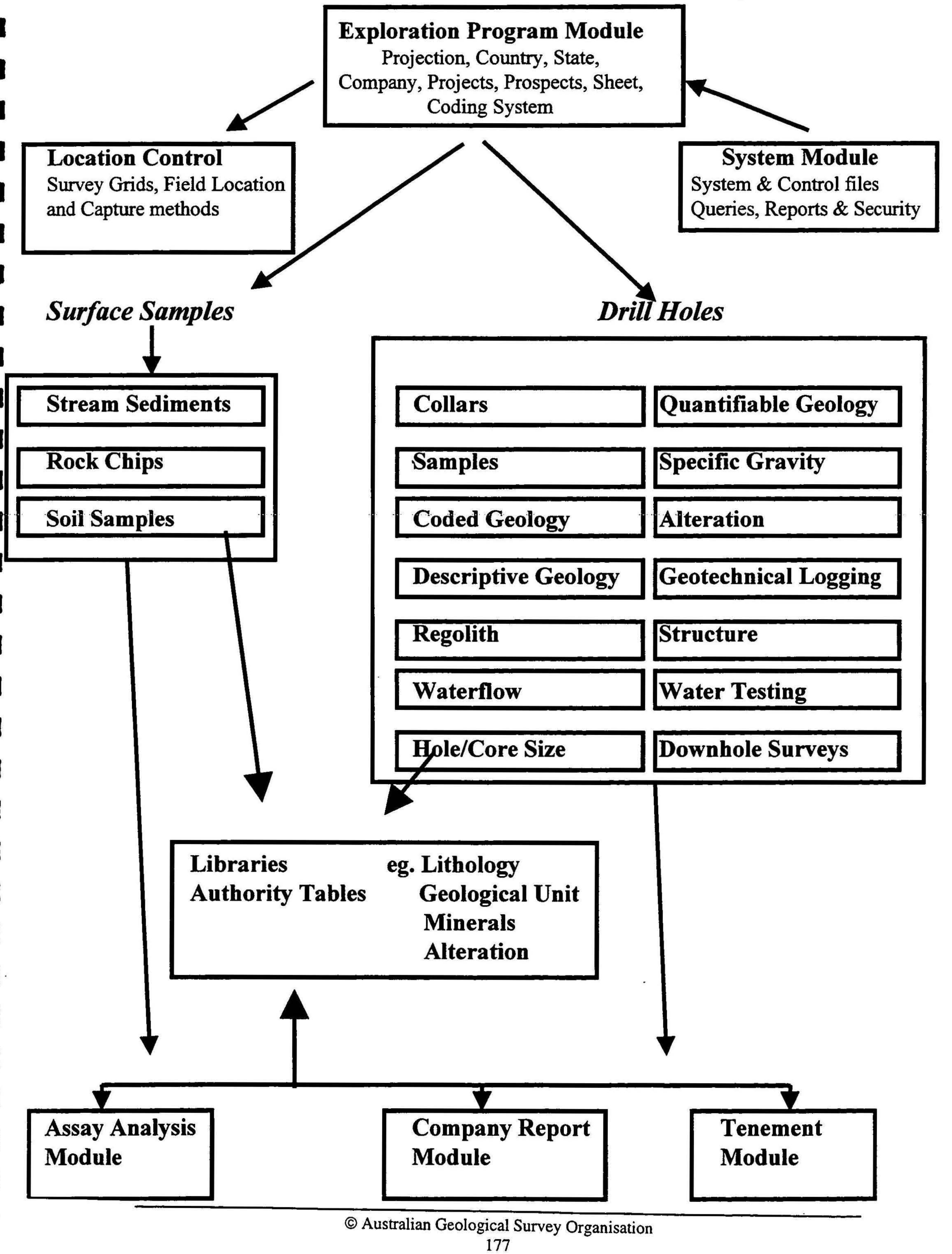
Figure 1. Major Data Categories of Explorer 3 RDBMS

Surface Samples			Drill Holes	
SOIL	STREAM SEDS	ROCK CHIP	HOLE TYPE	SAMPLE TYPE
Sieved Soil (SOIL)	Fine Sieved Fraction (SSS)	Rock Chip (RC)	Bedrock (BEDRK)	Drill Type eg. DD, REVC
Cyanide Leach (BCL)	Coarse Sieved Fraction (CFSS)	Continuous Channel (CONT)	Open Hole Percussion (PERC)	Duplicate (DUP)
Orientation (ORIENT)	Bulk Cyanide Leach (BCL)	Residual Lag (LAG)	Reverse Circulation (REVC)	Composite (COMP)
Shallow Auger (AUGER)	Panned Concentrate (PC)		Diamond Drill Core (DD)	Standard (STD)
	Unsieved (BULK)		Surface Trench (TRENCH)	Re-assay (RASSAY)
	Magnetic Lag (MAGLAG)			

Figure 2. Simplified Database relationships

Explorer 3



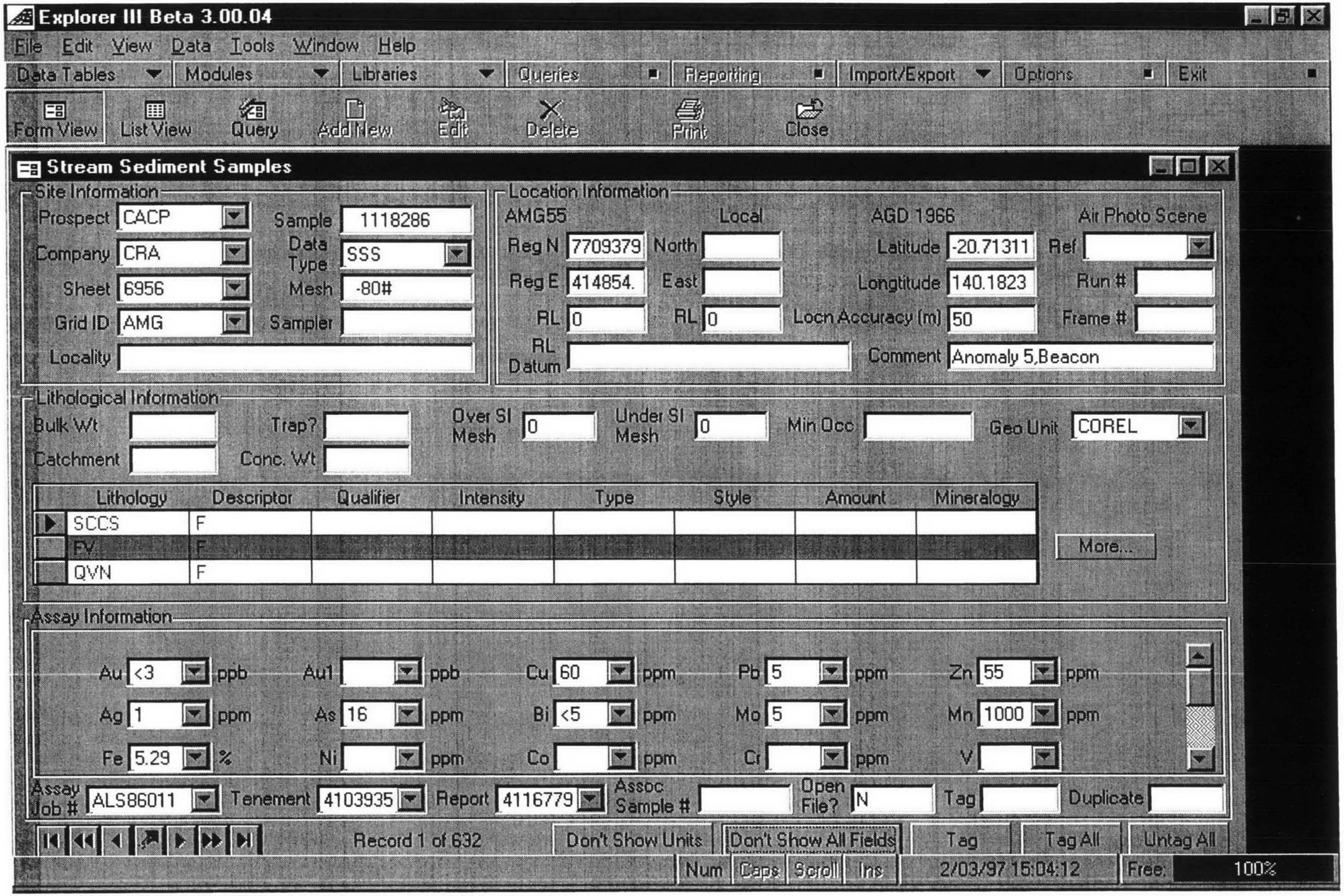
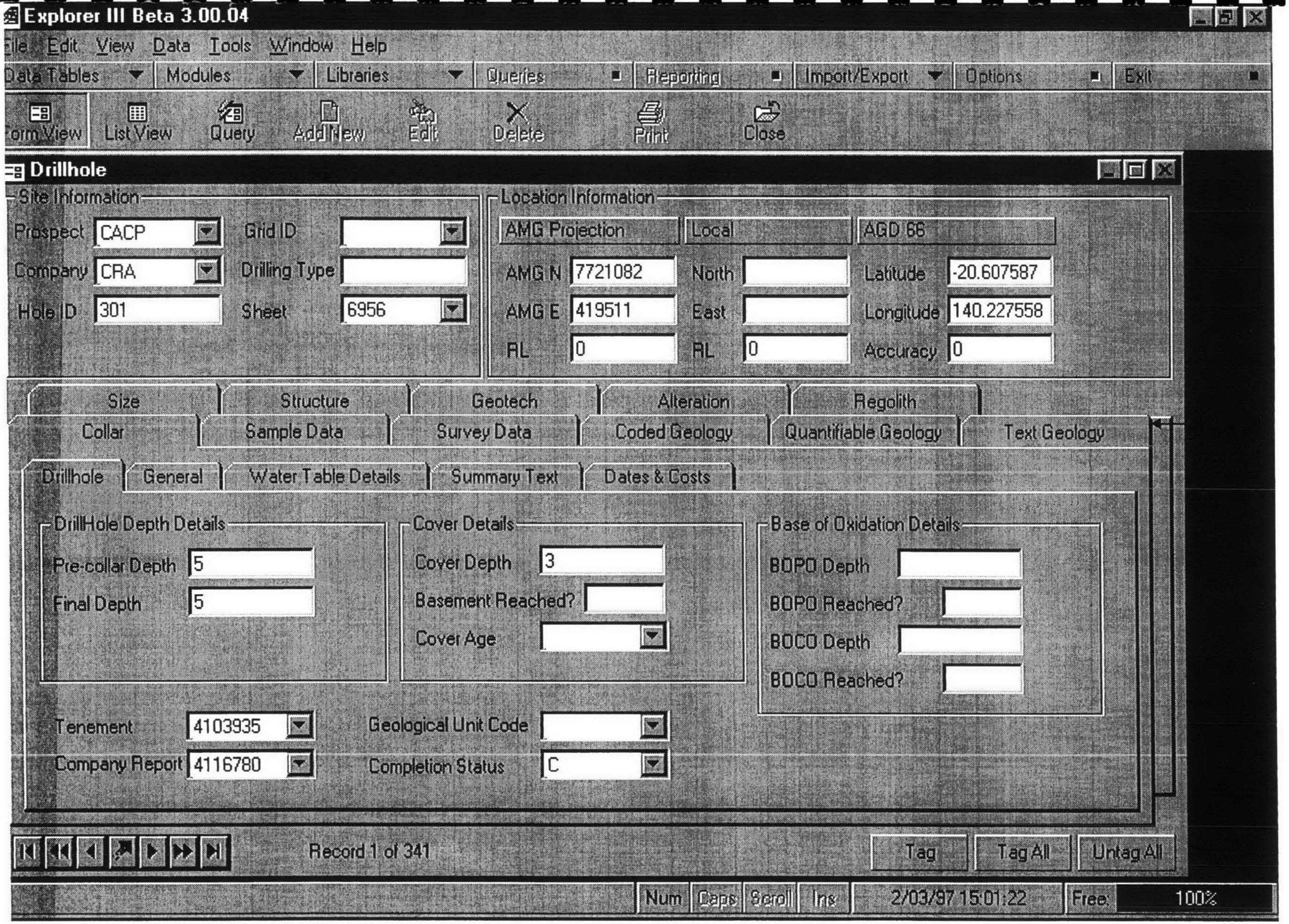


Figure 3. Stream Sediment Screen - This is an example of a typical form for a surface sample. All samples have locational, geological and analytical data stored along with information on the relevant tenements and reports. Spreadsheet style views are also available.



Three methods of storing geology gives the flexibility needed for plotting and reporting.

Figure 4. Drillhole Screen - A sophisticated set of drillhole tables allows storage of all information on a drillhole whether it is a regional RAB hole or part of a resource drilling program.

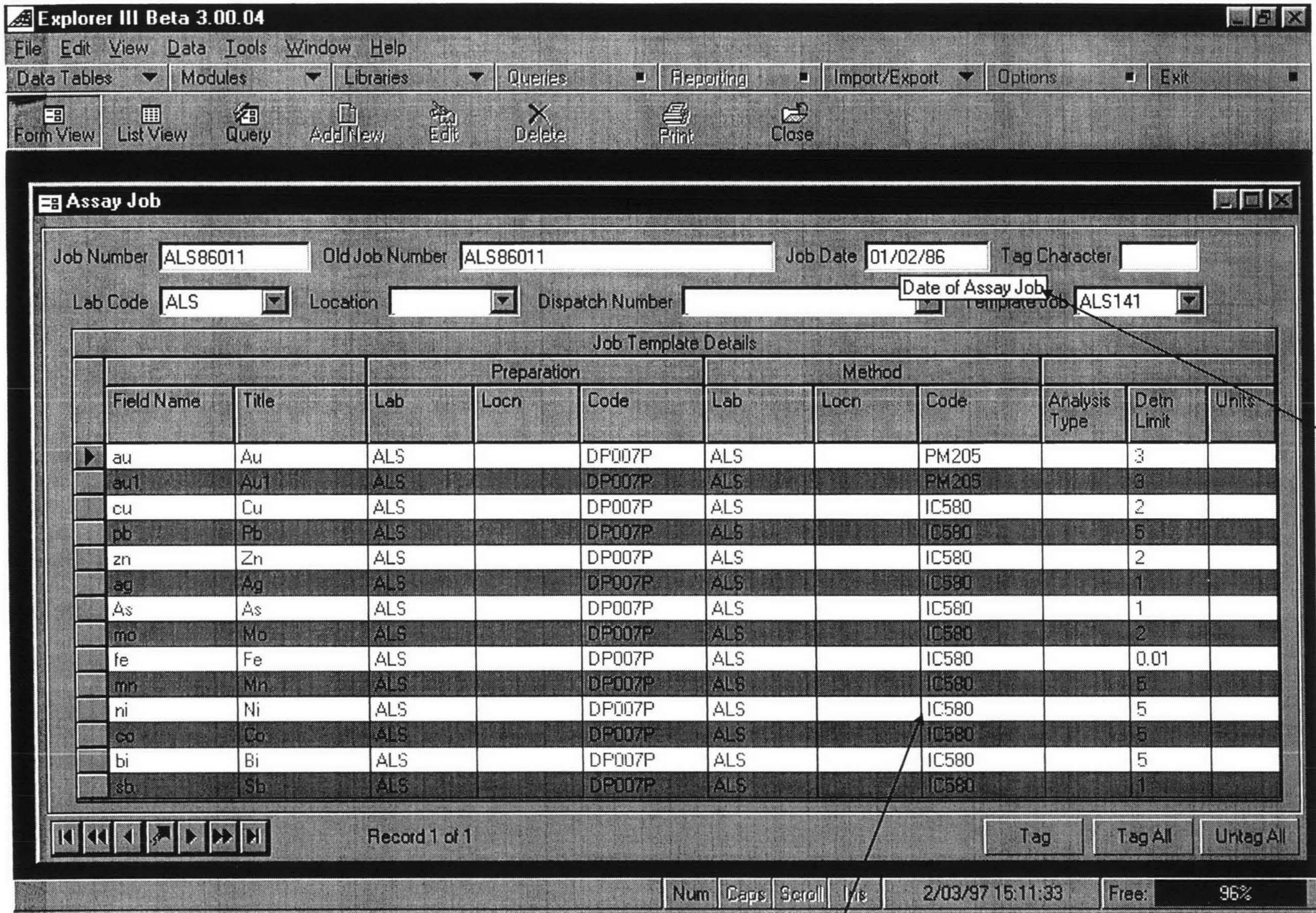


Figure 5. Assay Job Library-

Part of a comprehensive module that stores all analytical information on a sample.

On Line Help includes Tooltips for every field.

Status Bar shows system resource use to avoid overloading Windows System.

Each Code in the system decodes using dropdown menus or full library decodes.

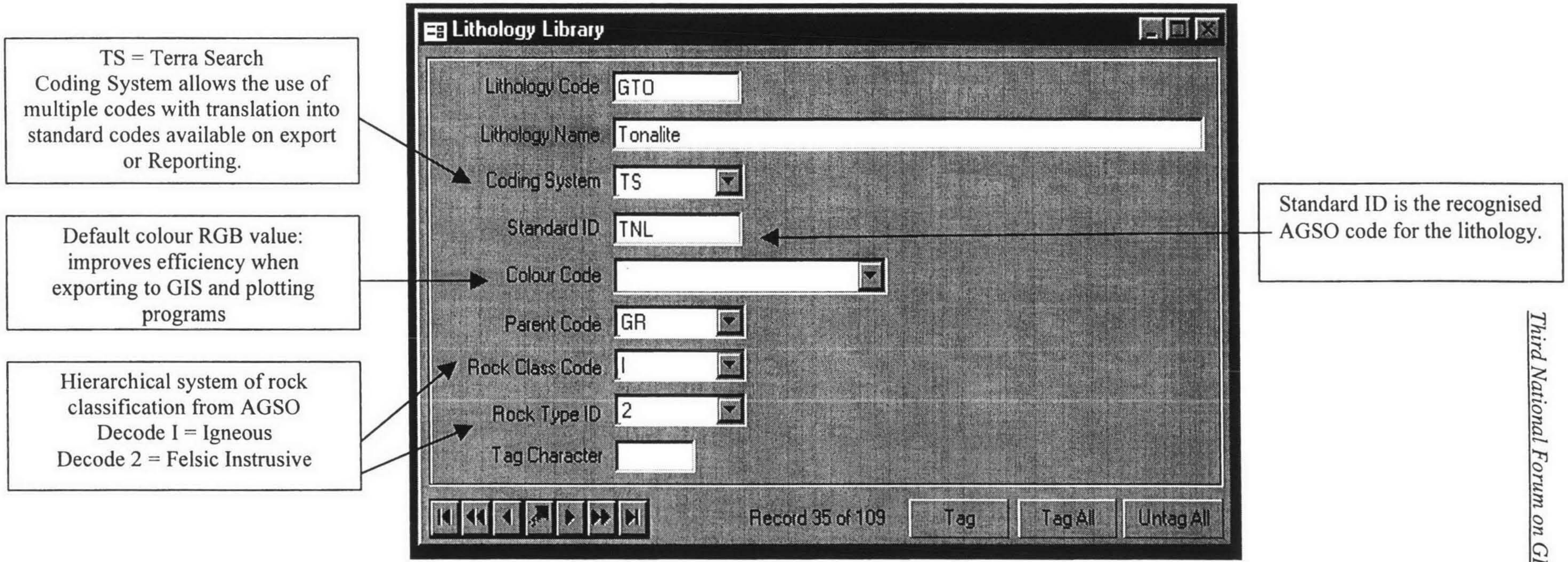


Figure 6. The Lithology Library is an example of a standard look-up Library where information on the code is collected along with a standard code which will allow translation of data from one coding system to another.

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