A Review of GIS Techniques for Handling Geoscience Data Within Australian Geological Surveys

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ABSTRACT

The geological surveys within Australia have undergone major changes in recent years in order to manage and process information. The scale of the problem has forced them to adopt improved work processes, data standards and models. Collaboration between the agencies should permit national standards to be agreed upon by 1999. Digital map data and spatially located data are now a standard alternative to hard-copy products. Normal programs of digital data capture have been augmented by major funding for exploration initiatives in five States. Large compilations of geoscience data are now being sold as GIS packages on CD-ROM. GIS applications are used for core activities such as mapping, resource information and land use queries. Spatial analysis of prospectivity is conducted by three agencies. More applied research, e.g., 3-D and 4-D modelling, is being carried by various research bodies with some participation from the surveys, particularly AGSO.

INTRODUCTION

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 geographic information system (GIS) technology. This paper attempts to summarise the status in 1997 of GIS usage and related activities for the Australian geological surveys. The following major topics are covered:

1. Data management issues and the integration with GIS functionality, national and international standards;
2. GIS use in core business areas, data capture, map generation to map making, resources, land use and title management;
3. Presentation of data; as single theme GIS coverages and the packaging of data as multi-theme GIS CD-ROM products; and,
4. Research activities and applications using GIS functionality.

In 1987 no Australian survey was producing maps with fully attributed topology. Only the Bureau of Mineral Resources (renamed as Australian Geological Survey Organisation, AGSO) had any form of data model in place to handle geoscience information. Most information was resident in islands of single flat files, or rarely as small sets of relational tables. Few, if any, rules were followed and geoscientists were generally ignorant of the need for data standards. GIS software was limited to vector-based UNIX-systems. In New South Wales, for example, a vector based set of programs of digital map production linked to flat files was in use (MRLIS). Other organisations were less advanced, using either traditional drawing techniques or a simple computer-aided drawing (CAD) package.

In 1997 the picture is very different, as summarised by the following points:

- All organisations produce geological maps with full topology, varying amounts of linked data (to points, lines and polygons), often with pre-set legends and colour schemes. Most are on sale as digital files;
- Data-modelled information systems are in place or well advanced in South Australia, Queensland, Tasmania and AGSO. Plans are in place for New South Wales and Western Australia to have corporate systems by 1998. Data-definition/dictionaries-models are being established for adoption as national standards for use by government and the exploration industry;
- Thematic GIS products are now common alternatives to traditional reports and maps;
- All organisations have the capacity to process geophysical data to industry standards. Image processing of satellite scenes (Thematic Mapper (TM), SPOT etc.) is often done in-house using standard commercial software; and
- New South Wales, AGSO and South Australia apply advanced GIS techniques for data processing of resource and geoscience information.

In the mid-1990s most Australian surveys received additional funding to stimulate exploration activity, to combat the shift of funds to overseas targets, and to retain their market share of domestic exploration. The total funding for these exploration initiatives exceeded A$120 million. This money was mainly spent for large airborne geophysical surveys, the remainder being used for data collection, information systems and GIS technology. The result has been an acceleration in the availability of spatially located data and the application of GIS technology.

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INFORMATION MANAGEMENT ISSUES

Table 1 shows the status of data models and information management in the State and Territory organisations. The various State and Federal surveys (Figure 1) hold a vast amount of information relevant to exploration. For example the State surveys hold company reports on areas explored under title (mostly 1960 to present); in the example of NSW this amounts to a million documents, equivalent to 3–4 terrabytes of data. All the survey bodies recognise the need for proper management and speedy access to these data, and especially for spatially located information. Most are well advanced or have planning in place for effective information systems. If funding levels are maintained for the coming two to three years Australia will have a network of data-modelled, relatively uniform database systems.

Most information collected by the surveys is stored in data sets as single or relational tables. This is not always the situation for data supplied by industry. There are two methods of storing company data; either as metadata tables (indexes) referring to hard copy, or as scanned image files (raster) referenced by indexes (e.g., DIGS system in NSW (Brookes, 1995). In its original form few of the data are spatially located, except to local grids or a map sheet. When GIS information packages are compiled, see below, data are extracted from the original reports and georeferenced making them suitable for GIS processing and analysis.

Two initiatives are in place to create national standards, the first for data submission by industry by the Government Geologists Data Processing Advisory Committee (GGDPAC), and the second covering data-definition, dictionaries and models GEODATA (an Australian Minerals Industry Research Association (AMIRA) project). There is good collaboration between the States on these issues and it is expected that national standards will be established in the near future.

A geoscientist in 1987 may have been able to keep his material in notepads and on the backs of envelopes. In 1997 most survey staff place the valuable project (corporate) data onto databases with UTM coordinates from a map or via a geographic positioning system (GPS).

GIS AND CORE BUSINESS AREAS

Geological mapping

The process of map production is a prime candidate for the use of GIS techniques and technology. Problems arise in field data capture, data compilation and cartographic production. Industry places an emphasis on being able to view and print maps on demand. The challenge for Australian survey bodies is to adopt work procedures to meet this requirement. It has been estimated that in a 30-day period a geologist collects at least 250–300 data points. To key in the attributes for each point takes many days. AGSO is currently using a FieldPad (a customised Apple Newton palmtop computer), essentially a structured field notebook with links to a GPS. The data are downloaded to project or corporate databases. Other surveys are likely to copy the AGSO model. The advantages are obvious; no transcription errors, good location accuracy and time savings.

Most geologists now recognise the benefits of merging data sets and imagery to aid mapping. A common practice is to drape radiometric imagery over a DTM, or even the principal component of a TM scene, to enhance structures. Other views can be derived by mixing magnetics with radiometrics. Since it is normal practice in most surveys for areas to be flown by airborne geophysics prior to mapping, these data are readily available.

There are still problems for the majority of organisations in getting maps into digital form with full attributes, linked to geoscience data sets. The next few years will see many changes in the roles of geoscientists and cartographers. GIS software allows geologists to edit their own maps, and cartographers are having to adjust to a changing working environment, that of producing a hard-copy map and GIS products.

Table 1: ***A comparison of data models and GIS use within Australian geological surveys.***

Geological Survey / Organisation	Database status [1]	Estimated % of maps available as digital products	Number of multitheme geoscience data packages available	Exloration initiative incentive funding (millions $Aus)	Spatial Analysis of prospectivity / land use	Application of GIS to field mapping and map production	Estimated % of geoscientist staff using GIS routinely
Australian Geological Survey Organization	a	80	2	*	yes	advanced	30–40
Queensland	a	60+	nil	30–60	no	being reviewed	10–20
New South Wales	b, c	60+	5	35	yes	being reviewed	20–30
Northern Territory	b, c	95	nil	nil	no	not applicable	10–20
South Australia	a	80	5	20+	planned	being reviewed	30
Tasmania	a	70	nil	3+	no	not applicable	20–30
Victoria	b, c	80	4	17	no	not applicable	20–30
Western Australia	b	60+	1	nil	no	not applicable	30–40

1. Key: a = well-developed information system b = partial relational database system c = predominantly non-relational * = included in overall funding

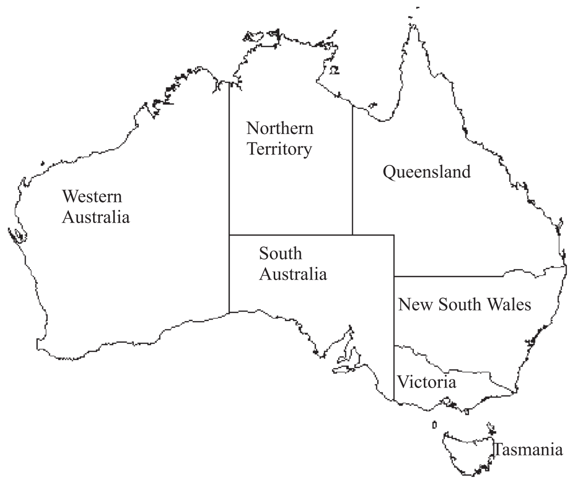

Figure 1: *Australian states.*

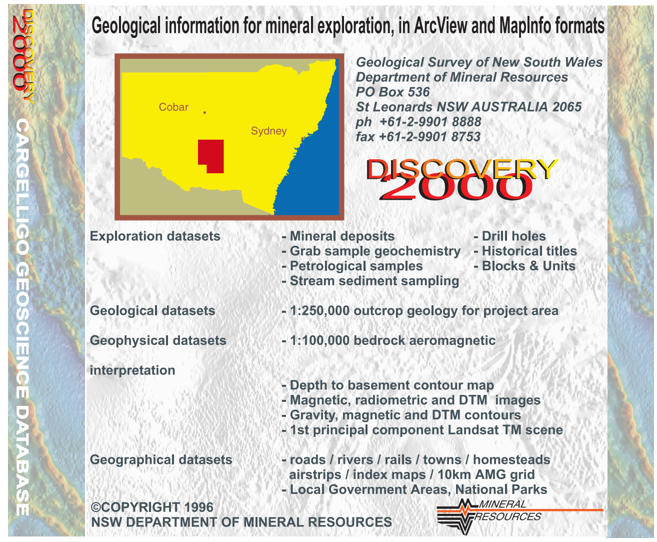

Figure 2: *The Bourke geoscience data package, CD-ROM back cover showing package contents.*

GIS DATA PACKAGES

GIS single-theme data sets (maps)

Australia is in step with other developed countries in making as much material available in digital form as possible. The majority of geological maps are for sale as GIS products, such as the Northern Territory GIS (NTGIS) 1:100 000 map series. An example of thematic maps as GIS is the series produced by the Western Australia Geological Survey (Bandy and Smith, 1995) combining geology and whole-rock sampling.

GIS packaging of large multitheme data sets

The advent of writeable CD-ROM technology led to a marked increase in the uptake of GIS software by industry. Almost overnight the project geologist could carry around all his digital files on a single CD and view them on any PC with enough memory and a CD-ROM player. Within Australia several survey organisations saw the potential of marketing their information this way and since 1994 a range of products have been released, including:

- Information packages over exploration initiative areas;
- Regional reviews of fold belts, mineral provinces, etc; and,
- Educational products.

Exploration initiatives

Funding for the exploration initiatives since 1994 led to comprehensive data collection of exploration-related geoscience material plus the assembly of maps and images in digital format. The credit for producing the first package of geoscience data designed for explorers goes to South Australia who released the Kingoonya CD-ROM in 1992 (Parker, 1992). Data were assembled in digital format to encourage gold exploration in NE Tasmania in 1993 (Roach, 1995) but were not bundled into one package. Currently three States (South Australia, New South Wales and Victoria) routinely produce CDs with packages of information over areas, to make them more prospective to industry. South Australia and New South Wales customise their products to enhance their functionality. Both attempt to make researching the data sets as efficient as possible, and also feature hot links from images to appropriate text and diagrams. (The CDs contain a range of file formats but customisation is done in ArcView and MapInfo.) The States market these products at a nominal value (A$500–1000).

In general, the amount of information (metadata) in the CD is sufficient for semi-quantitative research. The average CD contains 80–150 Mb of data. If more detail is necessary the metadata are provided to guide the searcher back to the source material. The typical package contents are displayed in Figure 2 which displays the back cover of the Cargelligo CD released by NSW in 1997.

Province-wide studies

The Mount Isa province package (AGSO), Lachlan Fold Belt (NSW) and Curnamona Province Package (SA-NSW-AGSO), as compiled by Belperio (1996), are examples of regional GIS-packaged data sets. These packages are often designed to display specific themes involving complex data sets, and to allow investigation of strato-tectonic-mineralisation relationships or regional geochemical/lithological/mineralisation affinities.

The Lachlan Fold Belt Package (Scheibner *et al.*, 1996) for example, is an attempt to allow interrogation of data on mineral deposits, depositional environments, deformation and thermal events using a time-space plot linked to thematic maps. The data are classified by structural zone, age, facies, deposit class, granite style, etc. to permit the reader to explore the mineral associations present. The time-space plot is linked

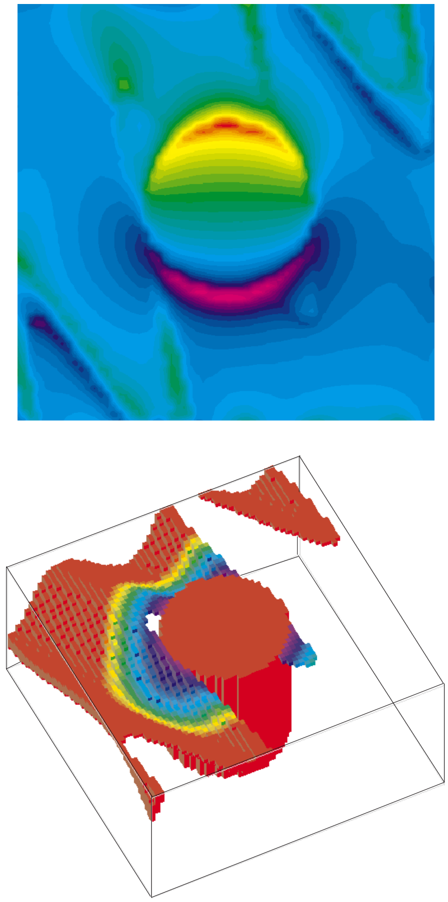

Figure 3: *The Noddy modelling system. (Block diagram depicts a folded basalt intruded by cylindrical body, with local demagnetisation. The magnetic image is calculated for an airborne survey flown at 80 m.)*

to the geological and structural layers, and after choosing data, e.g. a mineral association on the time-space plot. The user can switch layers to see where it is located. Of interest is the ability to overlay deformational and thermal histories for possible genetic links to mineral classes.

Province-wide CD packages are valuable tools for data interrogation and review, but the large area covered places constraints on the ability to see the whole picture. In most instances, unless an enormous screen is available, it is the author's opinion that hard-copy maps and legends and possibly a report are still needed to guide the user around while testing the database.

VAR products

In some instances, a third party has been contracted to compile data sets, which are priced at commercial rates. This is usually done in joint venture situations between the State and a consortium of companies. The Mount Isa GIS data set compiled by Terra Search is the largest of these (Beams, 1995) and is an assembly of geochemical results from soil, stream and rock chip sampling, plus drill results, ground geophysical results and geology.

RESEARCH AND ANALYSIS TECHNIQUES

Spatial analysis and research using GIS applications is not normally carried out by Australian geological surveys. In many surveys the use of GIS is confined to cell-based or raster processing of geophysical data and/or traditional image processing of aerial and satellite imagery. The exception is the spatial analysis for mineral potential undertaken by NSW. Pure and applied research projects are at present being carried out by the major research bodies (Commonwealth Science and Industrial Research Organisation (CSIRO), universities etc.). Survey bodies are often joint venture partners of this work, either contributing direct cash payments or in-kind. Two significant examples of this activity are:

- 'Noddy' package for integrative modelling of Structural and Geophysical data sets (AMIRA Project at Monash University), see Figure 3 and the paper by Jessell in this volume.
- 4-D GeoDynamic Model of Australia, and various projects of the AGCRC (Cox, 1995).

Resource analysis

Two agencies, New South Wales (Suppel *et al.*, 1995) and AGSO (Wyborn *et al.*, 1994), carry out semi-quantitative analysis of mineral potential, and South Australia is considering the methods discussed next. NSW has had a project in progress to conduct regional resource audits since 1992. Three areas have been spatially modelled and analysed for major mineralisation styles (Lewis, 1994) using probability and possibility testing (weights of evidence and fuzzy logic). The analysis techniques applied are based on the work of Bonham-Carter and others (Bonham-Carter, 1994). This cell-based modelling is customised to run in ArcInfo GRID via simple input screens. It is a two-stage process. The values (weights) are classified into seven indicative levels of prospectivity for presentation to explorers and land-use decision-makers.

By conducting two contrasting methods, data-driven versus operator-driven, the resulting models can be checked against each other. Experience to date indicates that if five or more suitable data layers are used then probability modelling is a good test of mineral potential. In the modelling of base metal/granite-related deposits in the South Coast Region of NSW seven layers were classified: magnetics; lineaments; fracture direction; intrusive type; level of fractionation; oxidation state; and, SiO_2 level. The fuzzy logic modelling has also provided good results.

The example displayed in Figure 4 depicts the results of modelling for porphyry-related deposits on a portion of the Bathurst New South Wales, Australia 1:250 000 map sheet. In general, these studies are limited to areas covering the equivalent of two 1:250 000 sheets, or 100 000 km^2, to ensure data consistency.

Note that this form of spatial analysis is also available on a commercial basis in Australia.

COMMERCIAL PROGRAMS AND INDUSTRY TRENDS

Several commercially available UNIX- and PC-based packages offer low cost analytical tools as standard inclusions (e.g., Idrisi) or as extensions (e.g., Spatial Analyser, grid module for ArcView). These packages have the functionality to process data for probability (Bayesian theory) and fuzzy sets. Other software is designed specifically to process exploration

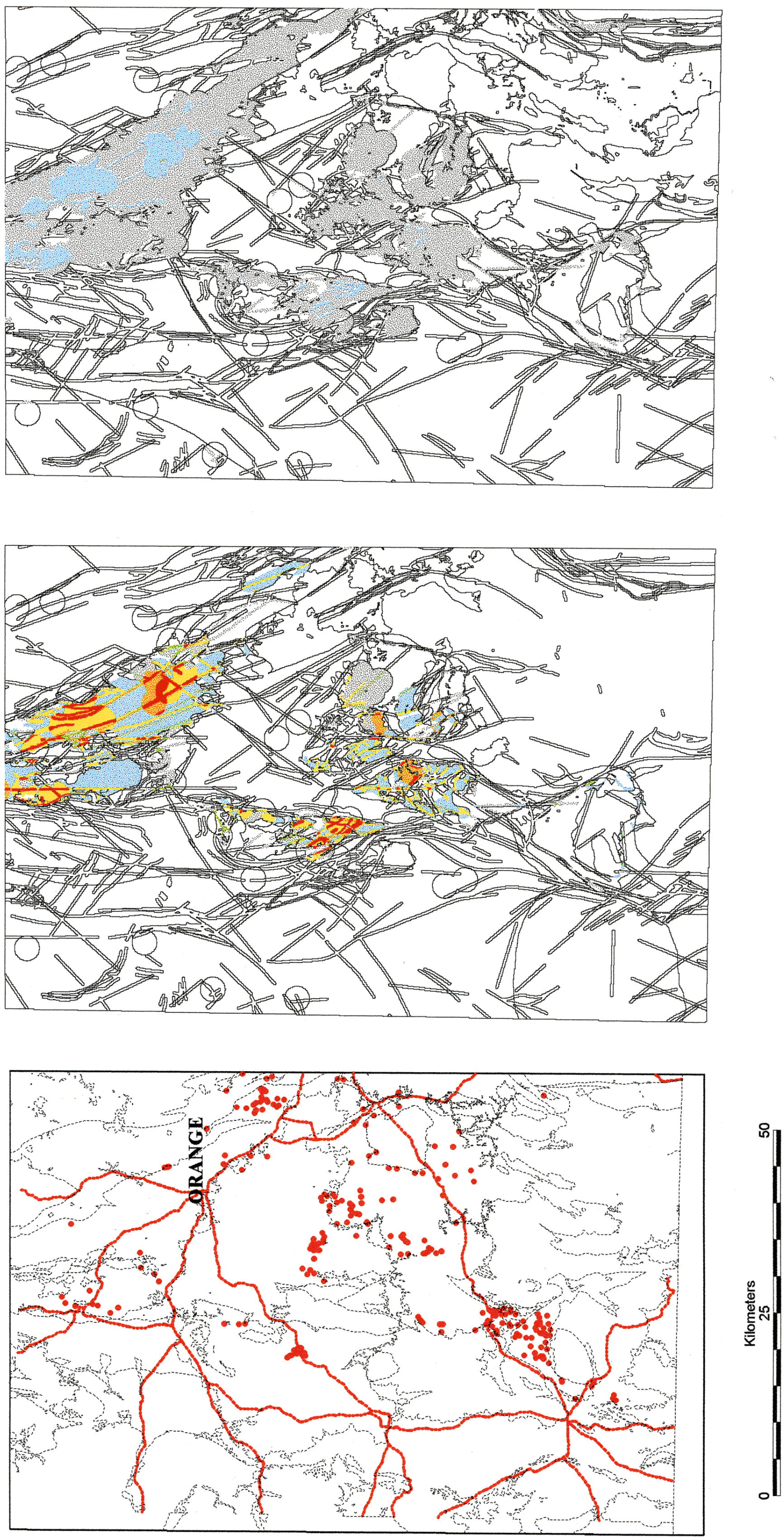

Figure 4: *The Bathurst Area, NSW Australia: results of prospectivity modelling (depicting location details and deposits on left panel, result of probability modelling on centre panel, and fuzzy logic result on right panel; colours refer to classes of mineral potential).*

data sets (Interdex). Such products are aimed at the average user to encourage them to test project-scale data. To gain a possible competitive edge the New South Wales and South Australia teams packaging geoscience data sets now provide data formats (fully attributed polygonised data sets) for use in these modules (e.g., Spatial Analyser and Interdex).

It is noticeable that the exploration industry is quickly adopting neural network analysis, particularly for its ability to determine trends and anomalous situations. One apparent strength of the method is its ability to analyse different types of unclassified material. To date, it is not a feature of exploration software packages and requires a high level of user expertise. It is offered by one agency in Australia, at a premium price. This trend of spatial analysis has not yet been adopted by any of the survey organisations, but it is under consideration and may become a popular analytical GIS tool in the near future.

CONCLUSIONS

Since the early 1990s there has been a move to incorporate GIS technology into the Australian geological surveys. The mandate of these organisations dictates that GIS is mostly used to manage and process data, plus aid map production. In a few projects GIS applications have been customised for research purposes. The trend for software developers to integrate modelling tools into packages will make spatial analysis a more routine practice. Recent developments include a move to national standards and hopefully international standards for geoscience data.

APPENDIX

Australia is a Federation of six states plus two federally run territories (Figure 4). Each state, plus the Northern Territory has a separate geological survey and Mining Act. Abbreviations used in this paper include:

AGCRC	Australian Geodynamic Cooperative Research Centre
DIGS	Digital Imaging of Geological Survey Report System
AGSO	Australian Geological Survey Organisation
SA	South Australia
AMIRA	Australian Mineral Industry Research Association
CSIRO	Commonwealth Science and Industrial Research Organisation
GEODATA	An AMIRA project for data modelling
GGDPAC	Government Geologists Database Policy Advisory Committee
NSW	New South Wales
NTGS	Northern Territory Geological Survey
Qld	Queensland
TAS	Tasmania

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