DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

REPT BK NO 90/11

DESIGN AND IMPLEMENTATION OF SA_GEOLOGY:

A COMPUTERIZED GEOLOGICAL MAP DATABASE SYSTEM

GEOLOGICAL SURVEY

by

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of

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SA_GEOLOGY is a computerised geological map database system for the capture, storage, manipulation, viewing and plotting of statewide geological map data. It has been developed by the Regional Geology and Drafting Branches of the South Australian Department of Mines and Energy for geologists and drafting personnel with minimal computer training and will provide the basis for geological map production into the 21st Century.

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INTRODUCTION

Geological maps form the basis for all geological investigations including mineral and hydrocarbon exploration, engineering site investigations, groundwater investigations, environmental management, geological research and many other forms of geological and natural resources planning and management.

Geological maps are the fundamental database upon which many management decisions are made involving millions of dollars annually. They describe the location, distribution and form of consolidated and unconsolidated rocks and rock formations, and they record that information for both surface exposures and concealed formations.

…..urgent need for digital geological data and data manipulation, integration and interpretation systems …..

A recent review (Woods, 1989) of the role and functions of the Bureau of Mineral Resources emphasised that "geoscientific maps and data sets .... should be regarded as the most important products" (p3), that "effective exploration required a sound knowledge base" (p 10) with "concentration on 'three dimensional maps' and databases" (p 17), and that there is an urgent need for digital geological data and data manipulation, integration and interpretation systems facilities (p 22).

Although geological maps have been available for many years as published, multi-coloured maps on various paper and film media, the enormous volume of data and unsuitability of various computerised geographic information systems (GIS) have restricted their being transformed to digital form. Some organisations such as the U.S. Geological Survey (USGS) and the Geological Survey of Lower Saxony (Hannover, F.R.G.) have made substantial commitments to develop their own geological map storage systems. Research by the Geological Survey of Lower Saxony identified that in tests of commercial systems for geoscientific applications there were unexpected limitations and a lack of many functions. Consequently they established a research program titled "Digital Geoscientific Maps" sponsored by the German Science Foundation, and by the end of 1988 had developed the first version of a software package for map construction using advanced raster techniques (Vinken, 1988; Preuss, 1988).

The USGS began its research many years before computerized geographic database or information systems became popular and in fact has been instrumental in establishing model data structures and processing techniques (Fegeas et al., 1983). One system which was developed for the gathering and handling of spatial information such as geology, topography and water resources, is GIRAS (Geographic Information Retrieval and Analysis System; Mitchell et al., 1977). It was designed to input, manipulate, analyze, and output digital spatial data and in particular to hold large volumes of map data of irregular-shaped polygon type. However, it is essentially a 2-D mapping system.

Today there are many other systems being used, including ARC-INFO (a GIS being used widely throughout the world including the S.A. Department of Environment and Planning, the Queensland Department of Mines, the Tasmanian Department of Mines and a large proportion of geological surveys in the USA), simple personal computer (PC) mapping systems such as GS-MAP (Selner & Taylor, 1988), and the 3-D mapping, geographic database and modelling system selected by this Department in 1987, Data General's TEO/3D and DG/GEO.

GEOLOGICAL MAP REQUIREMENTS 1990 - 2010

Following the Wood's Review of the BMR (Woods, 1989), the 1989 Chief Government Geologist's Conference resolved to establish a National Geoscience Mapping Accord (1990 - 2010) between the BMR and state geological surveys. A principal function of the Accord is to identify mapping priorities and establish a co-operative mapping program for the next 20 years.

In order to identify mapping priorities in S.A. both in terms of type and location, a questionnaire was distributed in April 1989 inviting a broad variety of map users to specify map requirements, preferred map scales and areas of priority. 78% of the respondents were from private enterprise, 15% from Tertiary institutions and 7% were from Government.

.... the first priority .... is for published geological maps at 1:250 000 and 1:100 000 scales closely followed by geological field compilation sheets and structure/tectonic maps .... other priorities must include .... metallogenic maps, geochemical maps and .... other geographically-located data .... the geoscience map of the 21st Century is going to be a complete computerized geological GIS.

For geological maps, the first priority of 59% of all respondents (whether from the mineral or petroleum industry or Government) is for published geological maps at 1:250 000 and 1:100 000 scales (Parker & Felstead, 1989). A substantial number of respondents identified geological field compilation sheets (18%) and structure/tectonic maps (11%) as their main priority and these maps also scored well with respect to second and third priorities.

Mineral Exploration Index Series (MEIS) maps, viz. mineral occurrence, geochemical and drillhole location maps, were not adequately covered in the questionnaire, but mineral occurrence and drillhole location maps did rate highly with, respectively, the mineral industry (3rd priority) and the petroleum industry (4th priority). Currently, MEIS mineral occurrence maps contain no more than a location cross-referenced to a table of mine/prospect names, references and commodities. However, there is a general consensus that these maps should be upgraded to true metallogenic maps where mineral occurrences are plotted/printed on a geological base map using a plot symbol which records details such as commodity and resource size.

Geochemical maps were not addressed by the questionnaire but are clearly a major requirement for future exploration and land management. At a recent BMR Symposium, a leading industry exploration geologist identified geochemical maps and databases as a major priority stating that, "regional geochemistry constitutes one of the more direct approaches towards ore discovery ... an essential part of regional mapping" (Herriman, 1989). Regional geochemistry is also essential for environmental research and monitoring, agriculture and land management.

While published geological maps must remain the priority of the BMR and state geological surveys, other priorities must include provision of metallogenic maps, geochemical maps and a range of other geographically-located geoscientific data. The geoscience map of the 21st Century is not going to be a single-sheet geological map but a complete, computerized geological GIS.

MANUAL MAP COMPILATION AND PUBLICATION PROCEDURES

Clearly, a major recommendation of the National Geoscience Mapping Accord is to publish more geological maps both at 1:250 000 and more detailed scales and to also produce geological field compilation maps, structure/tectonic maps, mineral occurrence maps, drillhole location maps and geochemical maps. Current manual procedures in the Department (including field mapping, map compilation and map publication; Fig. 1) could potentially publish 7 maps per year and produce about 30 compilation maps per year but in practice these figures are more like a maximum of four 1:250 000 scale geological maps, 1-2 1:50 000 scale geological maps, and 15-20 compilation maps per year. The average output of published geological maps over the last 5 years is about 5 maps per year using about 47% available staff time so that there is potential for publishing 8-9 maps per year if other duties are sidelined (e.g. compilation of geophysical maps!).

> **Current manual procedures....produce about 4 1:250 000 scale geological maps, 1-2 1:50 000 scale geological maps and 15-20 compilation maps per year.**

At this rate of map publication, it is impossible to publish more than the occasional 1:100 000 (or 1:50 000) scale map in addition to the 1:250 000 atlas series without additional resources. Furthermore, it will be also very difficult to produce new special purpose maps, such as structure/tectonic maps, mineral occurrence maps and geochemical maps, which are not currently being produced on a regular basis.

An additional problem with current map compilation and publication procedures is related to timeliness and accuracy of published maps. From the time a geologist completes field work and photo interpretation to the time that map is published, the elapsed time is often up to several years; rarely is a map published within two years of completion of field work. This can be due to a number of factors. For example, it normally takes at least 2-4 field seasons to complete mapping for an entire 1:250 000 map area. This implies that the geology of the area mapped in the first field season will not get published for at least two years (while the rest of the map area is being mapped) plus the actual drafting time. Therefore, not only is there a substantial delay before the data are readily available to the public, but also, some of that data can be out of date before they are even published (due to the development of new ideas etc)! The problem also extends to maps published several years ago and it is generally agreed that the "half-life" of a geological map is about 10 years. New data such as drillhole or mineral occurrence data may have become available during that period but it is impossible to change or edit a published map until the 2nd edition of that map is produced (often more than 20 years later!).

Existing map compilation procedures in the Department enable some field data to be released in the form of dyelined 1:100 000 compilation maps prior to publication at 1:250 000 scale. This is a partial solution to the above problem but the choice of scale is often inappropriate, the lack of colour often renders them difficult to read and interpret, and they don't contain sometimes vital information such as field notes or drillhole locations as supplied on field compilation maps produced by some other state surveys (e.g. Queensland Department of Mines). There is therefore a need for a more flexible system without at the same time losing the advantages of maintaining a standard format or scale.

.... to satisfy user requirements and hence to further encourage .... exploration and development in S.A. .... (the Department) must increase map publication, provide greater flexibility .... and improve the timeliness ....

If the Department is going to attempt to satisfy user requirements and hence to further encourage multiple land use and mineral, petroleum and groundwater exploration and development in S.A., it must increase its rate of map compilation and publication, provide greater flexibility in the types and scales of maps produced and improve the timeliness of map publication. This could be achieved by employing more geologists and drafting personnel or by introducing new techniques, procedures and map formats with no or only minimal increases in staff levels.

INITIAL DEVELOPMENT OF A DIGITAL GEOLOGICAL MAP GIS FOR S.A.

As early as 1986, SADME recognised a need for digital geological map and related data but, rather than develop its own system, opted to purchase an existing GIS. At the time there were two GIS packages being used in other State Government Departments, ARC-INFO (Department of Environment and Planning) and EASINET software (E & WS and Lands Departments). The latter was an engineering software system that combined the functionality of Computer Aided Drafting (CAD) with GIS enquiry facilities to form a 3-D GIS. EASINET software was developed entirely in Australia and was chosen by SADME to form the basis of a graphical digital database. Since purchase (in late 1987), EASINET has been taken over by Data General and it's software are now known as TEO/3D and DG/GEO though its basic structure and functionality have not changed greatly.

In early 1987, preliminary data modelling was undertaken by G. Pilkington (Geophysics Branch) and J. Parker, with the assistance of EASINET personnel, to define a relatively comprehensive data model for the Department. For several reasons (amongst them being the takeover of EASINET by Data General), the data model was never completed nor put into practice. A few computing personnel were reluctant to use the hierarchical database system (INFOS) which was essential for handling of attribute data in EASINET software, and DG-SQL, which was briefly tested, proved difficult to use and interface. Therefore, very little GIS development work was and has been carried out.

Geological Maps Pilot Project

In 1988, Regional Geology Branch initiated a pilot project to digitize the ADELAIDE and BARKER 1:250 000 geological maps for the Mount Lofty Ranges Review. The project was set up and co-ordinated by J. Parker with W. Preiss (Regional Geology Branch) and W. Mitchell (Drafting Branch) preparing updated 1:50 000 and 1:100 000 geological maps for digitizing, and G. Young and S. Rossi (Drafting Branch) undertaking the digitizing on Regional Geology Branch hardware.

The entire project was undertaken using TEO/3D as the sole graphics or spatial GIS and much of the work was done on the Data General MV 20 000 computer. Data for digitizing was compiled from existing published and unpublished mapping at a variety of scales onto 1:50 000 and 1:100 000 base maps. No new mapping was carried out during the pilot project but revision of the geological interpretation from future field mapping is to be expected and can be easily facilitated.

Digitizing was carried out using a GTCO A-1 digitizer and a NEC APC IV PC with graphics terminal emulation software (TGRAF-07) both connected to the Data General MV 20 000 computer. As such, the PC acted as a dumb terminal and all processing was done on the MV 20 000. The digitizer was connected directly to the MV, but the PC was connected via the EQUINOX switching system.

Considerable experimentation with digitizing techniques was carried out using this setup but it was soon apparent that it was not ideally suited to rapid digitizing, with frequent delays of more than 60 seconds between sample points. These delays were mainly due to competing activity on the MV 20 000 and communication processing. Nevertheless, 75% of the digitizing of ADELAIDE and BARKER was completed using this system.

To facilitate the digitizing and remove some of the workload from the MV 20 000, a Data General DS-7540 graphics workstation with a 108 Mb hard disk and TEO/3D, was leased in December 1988 for a six month trial period. The digitizer was connected directly to the workstation so that all digitizing and related processing could be carried out on this machine with only occasional file transfer to or from the MV 20 000 on which the main database was still kept. There were immediate improvements in digitizing by at least an order of magnitude and no major delays have since been experienced.

Data are stored in a "global" database structure (on the MV 20 000) which enables queries to be made on any randomly defined area and enables other datasets such as rock sample locations, drillhole locations, gravity data etc to be superimposed. The ADELAIDE and BARKER sheet areas were subdivided into a number of partitions (Fig. 2) each of which can be treated as either separate datasets or as part of much larger datasets combined with other partitions. On advice from Data General personnel, the partitions were designed to hold about 10,000 nodes (or line segments) and 1,000 polygons. Therefore the size and shape of the partitions was varied according to density of geological linework. Partition shape does not present any substantial problems but with the current limit of 32 000 nodes in a partition or "drawing" (working file), 10 000 nodes per partition presented several problems not only with speed and efficiency but also with certain graphics functions. Smaller partitions or a larger partition limit are required for future development.

Linework was digitized first then visually checked both interactively and from check plots. Polygons were automatically defined from digitized nodes and line segments, then colour coded and given stratigraphic symbols according to normal practice, using either the workstation or a PC connected as a dumb graphics terminal to the MV 20 000. Each stratigraphic unit is stored in a separate layer (Fig. 3) to enable specific colours to be assigned and to enable selective display of particular rock units (e.g. stripping of the surficial data).

In January 1989, the first full-colour plots of geological map data were generated from the database; several line plots had been previously produced at various scales on the Departmental ZETA plotter for checking purposes but had to be coloured by hand. The colour plot files were generated on the workstation, transferred to tape and taken into either the Department of Lands or E and WS Department for plotting on their CALCOMP electrostatic plotters (Fig. 4). The cost to the Department for a full-colour 1:100 000 plot is currently (Nov. 1989) $38 per map.

Since January, line digitizing, colour filling (layer assignment of polygons) and labelling have been completed for ADELAIDE and BARKER, the State 1:2 million geological map has been digitized and check plots generated, and a detailed geological cross section has been digitized, edited and plotted both in full colour and as a line diagram with cross hatching etc (Fig. 5). Editing will continue on the map databases to correct errors and to add new information as it becomes available

.... creation of a digital geological map database is not only feasible but offers .... flexibility .... near publication quality colour maps .... timely provision of map data .... update facilities .... potential time savings ....

The results of the pilot project have clearly indicated that creation of a digital geological map database using TEO/3D and DG/GEO is not only feasible but also offers a number of advantages over traditional manual mapping procedures:

- provision of digital geological map data
- greater flexibility in choice of scale for map plots
- greater flexibility in choice of map style and attributes for output (e.g. can selectively plot only Precambrian geology and ignore Cainozoic subdivisions; or can add drillhole data or geochemistry etc)
- provision of relatively cheap full-colour geological maps of near publication quality (at any scale)
- timely provision of field compilation maps and map data (in colour if required)
- full edit and update facilities such that map data can be more easily updated whenever new data are available
- potential time savings in preparation of colour manuscripts prior to traditional map publication
- potential savings in actual map publication time
- potential for addition of mineral deposit data to produce a metallogenic map series.

Other important conclusions that can be drawn from the pilot project are:

- workstations are essential for efficient digitizing and processing
- while digitizing techniques can be taught relatively quickly by existing Drafting personnel, there are advantages for all Drafting personnel (who will be using TEO/3D) to undertake a tailored course in the full use and facilities of TEO/3D and DG/GEO (or equivalent GIS software). G. Young's value to the project was partly a result of the knowledge he had gained from an external course on TEO/3D.
- existing Branch responsibilities need only be slightly modified (viz Regional Geology will still generate maps and Map Compilation Section will compile the map into a computer database rather than onto paper).

It must be emphasised that there are no major time savings to be made during the initial map compilation stages; it takes just as long (or maybe longer) to digitize geological boundaries as it does to draw them by traditional means. The advantages of a digital system are in the range of map products and their timeliness. In 12 months the pilot system has effectively produced 12 1:100 000 scale geological maps, 48 1:50 000 scale geological maps and numerous other special purpose maps, all of which can be plotted in full colour and at near publication quality, with little more than one manyear of drafting input!

GIS Development Interstate

Several projects are underway interstate to develop geological mapping GIS systems. The N.S.W. Geological Survey is the most advanced using Synercom INFOMAP software - running on a micro VAX and four VAX 2000 workstations (each with an A1 or AØ digitizer). INFOMAP is a CAD-based 2-D mapping system organised into 128 layers of which about 10 are dedicated to geology (geological boundaries, structure, etc). Polygon attribute data are attached to a centroid within each polygon.

Map data are subdivided into three classes each with its own separate layer definition:

- 1:250 000 geological maps
- 1:100 000 geological maps
- 1:25 000 geological maps

Only the 1:250 000 geological map series is currently being digitized but state coverage was expected to be complete by mid-1989. Stream digitizing techniques are being used and, on average, a single 1:250 000 map can be digitized in about 7 days (generating about 30 000 line vectors per map). While colour-fill facilities were not available in March '89, these were expected to be available in a future upgrade. INFOMAP is a map sheet-based system but does ultimately form a "continuous" or "global" dataset. Emphasis at the N.S.W. Geological Survey is on the GIS aspect for on-line queries rather than use as a map compilation/publication aid.

The Queensland Department of Mines has ARC-INFO which has been used as a computer aided drafting (CAD) tool to partially compile the Bowen Basin province map from existing 1:250 000 maps. They also have access to GDS software which, in March 1989, was being used in a pilot project on the Broken River area to compile data from 1:25 000 maps to produce 1:100 000 scale maps. The Queensland Department did not have any formal plans for a geological GIS at that time but, rather, were concentrating on implementing their Titles and Tenements system on which half of the Drafting Branch was working.

The Victorian Geological Survey (Department of Industry, Technology and Resources) has recently selected GENAMAP GIS software which will be used initially for tenement administration but, ultimately, also for geological applications. In Western Australia, the Geological Survey and Mapping Divisions are about to commence a two-year pilot project in GIS using both ARC-INFO and GEOVISION software. Like the BMR they already use INTERGRAPH systems for drafting work. The BMR has no formal plans for a geological map GIS but has purchased SPANS (a PC-based GIS) for a pilot project in the Yilgarn region. BMR does have several ORACLE databases for rock samples, mineral deposits and geochemistry and these include locational data which can be plotted at selected scales using in-house-developed MAPDAT software.

The Tasmanian Geological survey has recently acquired ARC-INFO to run on SUN workstations. They intend to digitize their detailed geological maps in addition to using the software for other purposes. Tasmanian 1:250 000 geological maps have been digitized on ARC-INFO by the Tasmanian Forestry Department.

SA GEOLOGY

Aims

While it will no doubt be of different use to different people, the principal aim of SA_GEOLOGY is to supplement published 1:250 000 geological maps and provide more detailed surficial and subsurface geological information in a form which can be easily retrieved, interpreted and comprehended. SA_GEOLOGY must provide geological field compilation maps in a timely manner (a few months), and detailed geological maps (particularly at 1:50 000 and 1:100 000 scales) of publication or near-publication quality. It must also provide facilities for readily updating map data as new information becomes available. It is not the aim of SA_GEOLOGY to duplicate 1:250 000 geological maps in order to provide a state-wide GIS. This function can be provided by detailed data in the long term and regional (1:1 million or 1:2 million) data in the short term. Development of a geological map GIS for integration with other GIS data, is however, an important subsidary aim of SA_GEOLOGY.

> **The principal aim .... is to supplement (not duplicate) published 1:250 000 geological maps .... provide geological field compilation maps in a timely manner, and (readily updated) detailed geological maps .... of publication or near-publication quality ....**

To achieve these objectives, SA_GEOLOGY must be a 3-D digital geological map storage, analysis and retrieval system which will:

- describe the location and form of all relevant geological data including:
    - geological boundaries and unconformities
    - geological structures (faults, folds, fractures)
    - geological formations and rock types
    - stratigraphic names and type sections
    - mineral occurrences (size and commodity)

- drillhole locations (and all related data such as summary geological logs)
- rock samples (and all allied data such as geochemistry and biostratigraphy)
- point structural information (dip/strike etc)
- sedimentary and stratigraphic point information (facing direction, current directions etc)
- other field measurements (magnetic susceptibility etc)
- field notes and additional comments.

• describe the location and form of all relevant geological data in the subsurface as well as that which is outcropping.

• ensure that all geologic data is accurately pinpointed and stored in a standardised or compatible format.

• provide an efficient and fast capability for the input (digitizing) and maintenance (editing) of geologic map data. This includes the development of techniques for digitizing directly from aerial photographs and satellite or remotely-sensed images.

• interface input from both digitizers and raster scanners and provide raster/vector conversion of lines.

• interface all appropriate computing facilities/installations such as various graphic input and output devices, workstations and host computers.

• provide continuous, efficient storage for an unlimited number of polygons, points (nodes) and lines.

• provide a simple-to-use, interactive facility for the input of field data and notes etc.

• provide an interactive retrieval capability which will enable the best use to be made of the data particularly with respect to fast overlay and display of map and other geologic/geophysical data layers (i.e. to enhance analysis of related and unrelated sets of data).

- provide an easy-to-use retrieval capability which will enable rapid generation of hard copy of selected special-purpose maps at any predetermined scale (e.g. metallogenic maps, drillhole location maps, geochemical maps).

- improve the speed and efficiency of map compilation and publication procedures commensurate with the quality and quantity of data.

- provide an interface to a relational database management system and dynamic linkage of graphic and alphanumeric data (in a "windows" environment).

- provide a query language which utilises common English words, which is compatible with SQL database management systems, and which can be used by geologists, drafting personnel and others with minimal computer background/training.

During both the initial development of SA_GEOLOGY and all subsequent revisions, it is essential that a well-documented user manual be prepared and maintained. There should be at least two complete and identical manuals of all procedures etc, one for Drafting Branch and one for Regional Geology Branch. These would be regularly updated.

System Outline

A basic outline of the SA_GEOLOGY system is summarized in Fig. 6 indicating its relationships to Departmental users and procedures for producing geological maps and other products.

The principal components of SA_GEOLOGY will be:

- appropriate GIS mapping, CAD and image-processing software for a digital geological map database providing efficient continuous storage of large volumes (ultimately several hundred Mbytes) of map and attribute data.

- an appropriate computer hardware system with a central file server (to store the main database) and several satellite workstations, graphics terminals and input/output devices for data input, analysis and output in a variety of forms (including coloured near-publication-quality maps).

- efficient procedures for data capture, map compilation, storage, manipulation, editing and output.

- appropriate measures to maintain absolute data security.

- commitment from Government, Departmental management and all branches concerned to provide adequate resources for the system(s) to function efficiently, to maintain or improve quality control and to increase the mapping products of the Department.

- appropriate training.

- ongoing research and development.

Hardware and Software Requirements

Current hardware resources within the Department, relevant or available to SA_GEOLOGY as at November 1989, are:

- Data General MV 20 000 minicomputer

- Data General DS-7540 graphics workstation with 108 Mb and 160 Mb hard disk drives (leased by Regional Geology)
- GTCO A1 digitizer (jointly owned by Regional Geology and Mineral Resources branches)
- 2 NEC APC IV and 2 Microbyte PC-230 PC's in Regional Geology Branch (2 equipped with TGRAF-07 graphics terminal emulation software)
- 2 Data General D411 alphanumeric terminals in Regional Geology Branch
- 1 NEC APC IV PC in Drafting Branch
- Zeta and Calcomp plotters in Drafting Branch.

Two additional digitizers and graphics terminals/PC's are available for occasional use in Drafting Branch when not required for other work.

Relevant GIS software resources are limited to TEO/3D (Ver 1.5) and DG/GEO (Ver 1.0) on the MV 20 000, and TEO/3D (Ver 1.5) and DG/GEO (Ver 1.0) on the DS-7540.

Regional Geology Branch has recently installed GSMAP and GSDRAW (2-D PC-based mapping and drawing software from the USGS) on PC's but neither package has been fully evaluated. They do not, however, provide GIS functionality and will not be considered further in this report.

.... TEO/3D and DG/GEO could provide GIS and computer aided mapping capability .... but there is a definite need for links to ORACLE relational database .... and it is essential that either TEO/3D be upgraded substantially to include .... implementation on UNIX workstations, capable of image processing .... or a more suitable GIS be acquired ....

Although there are some shortcomings with TEO/3D and DG/GEO as a geological GIS, many of these shortcomings are common to many GIS packages including ARC-INFO which is recognised, by default, as a standard amongst GIS throughout the world. The pilot project has identified and overcome some of the shortcomings and has established beyond any reasonable doubt that, provided they are fully supported by either Data General or a third party, TEO/3D and DG/GEO could provide the GIS and computer aided mapping capability required by the Department for the near future. Limited attribute data can be incorporated into TEO/3D and DG/GEO databases, but there is a definite requirement for a SQL-type relational database (such as ORACLE) linked to TEO/3D to handle potentially large volumes of attribute data, particularly time-series data. If SA_GEOLOGY is to reach its full potential, it is essential that TEO/3D be upgraded substantially to include not only links to relational databases, but also implementation on UNIX workstations, capable of image processing, and on PC's.

If, as proposed, all geological map compilation, editing and manipulation are undertaken through TEO/3D or an equivalent system, the traditional drafting table will be replaced by digitizers and workstations. Ultimately, each drafting person will require at least a graphics terminal or workstation and access to an A1 or AØ digitiser for several hours each day. This situation will not be attained for several years; maps currently well advanced in the compilation process will be completed by traditional manual means so that there will be a gradual phasing in of new techniques and procedures.

The proposed hardware requirements for both Drafting and Regional Geology branches for the next 3-5 years are outlined in Fig. 7. The absolute minimum requirement in the Map Compilation Section of Drafting Branch for the next 1-2 years is one graphics workstation (configured as a file server), two graphics terminals (PC's with emulation software) and frequent (several hours per day) access to a second, maybe diskless, graphics workstation (both workstations complete with A1 or AØ digitizers). Usage of the second workstation will increase to full-time use probably well before the end of the second year at which time a third workstation (also maybe diskless) and graphics terminal should be phased in.

In Regional Geology Branch, 2 graphics terminals (ie PC's with emulation software) preferably with large monitors, a graphics workstation (with image processing capability), an A1 digitizer and a colour printer are required initially. Image processing software such as CSIRO's DISIMP will be required and, to get the most value from image processing, a hard copy unit (to "write" images to photographic film) is also necessary. A second graphics workstation will be required as the database grows (in ca. 2 years).

Currently, TEO/3D is only implemented on Data General mini-computers, such as the MV 20 000, and DS 7500-series workstations. Data General originally assured us that TEO/3D would be available on UNIX-based AViiON workstations early in 1990. However, in a letter to the Department (dated 3rd January 1990), Data General have advised that while they will continue to support the existing TEO/3D and DG/GEO products (at least in the short term) they will no longer continue to develop those products. That is, all research and development work on a 32-bit system, implementation on AViiON workstations, and linkage to ORACLE will cease. While a 32-bit system is not essential, linkage to SADME ORACLE databases is mandatory; for example, most rock sample, drillhole, geochemical and mineral resource attribute data will be stored in ORACLE tables and links to these data are essential for SA_GEOLOGY. Implementation on UNIX-based workstations is also essential because much of the interpretation and manipulation of SA_GEOLOGY data will require image-processing facilities which are not available on DS-7500 series workstations but which are widely available on UNIX-based hardware.

Therefore, it is recommended that SADME abandon TEO/3D and select another GIS, such as ARC/INFO, which is not hardware-specific and which could be implemented on a range of UNIX-based workstations (eg AViiON, APOLLO or SUN workstations) or even PC's. It would certainly provide greater flexibility in the future and, potentially, greater compatibility with interstate surveys, NRIC (National Resources Information Centre), the SA Department of Environment and Planning, the University of Adelaide (Geography Department), and many other Government and non-Government organisations.

Irrespective of what hardware/software is used, an AØ flat-bed colour ink-jet plotter or similar is essential. Colour plots can currently be generated at the Lands or E & WS Departments on Calcomp electrostatic plotters, but cannot be plotted on topographic base maps. Access to a colour ink-jet plotter is available through the SA Centre for Remote Sensing and this will potentially allow plotting on existing maps (such as magnetic contours or topography). If the full value of SA_GEOLOGY is to be realized (viz. to produce near-publication-quality 1:100 000 scale etc geological maps), then in-house colour plotting facilities are essential. Existing in-house plotters are adequate for producing check plots and maps or diagrams not requiring colour fill.

To date, SA_GEOLOGY has been implemented by Drafting Branch on the MV-20 000 using equipment belonging to or being leased by other branches. For the efficient and maximum implementation of SA_GEOLOGY it is necessary for the Map Compilation Section of Drafting Branch to acquire and maintain their own hardware. They should also be responsible for plotters.

Personnel Requirements

For the life of the pilot project, one drafting officer has been working effectively full time on digitizing, editing, developing macros and procedures, generating plots, assisting/training other TEO/3D users, and evaluating various options. Two other drafting officers have been involved in the digitizing process doing jobs that would normally have been done by traditional manual means (pen and ink). One geologist (with a computing degree) has been involved on a part-time basis (< 1 day per week) in programming and development.

At least for the next 1-2 years, one experienced drafting officer (with a strong computing background) will be required to continue developing macros and procedures, providing assistance/advice to other drafting personnel, running occasional training programmes, and performing system maintenance duties such as weekly backups etc. This is not expected to be a full-time job (probably at most 2 effective days per week). That person may, however, be required to digitize existing maps or produce colour plots or digital map files on disc or tape for external clients, so it is likely that person will have to be effectively assigned full-time to the system (NB this does not necessarily mean only one person, the job could be shared by two or more persons doing other jobs as well). This requirement should steadily decrease after the first 2 years.

In the first 6 months of 1990, a major programming effort will be necessary to fully implement the system proposed in this report. While this should not require the full 6 months to develop, other tasks such as hardware purchases etc will take some time. Therefore, there is a requirement for a full-time geologist with extensive computing and mapping experience for a period of 6 months in early 1990. That same person would continue to be involved, on a part-time basis (1-2 effective months per year), in ongoing research and development.

Other personnel requirements are not deemed to be significant in the long term. Digitizing will take slightly longer to produce preliminary 1:100 000 maps for example, but is likely to be counter balanced by time savings in other areas such as preparation of 1:250 000 colour manuscripts. Therefore they will not be taken into consideration.

Data Model and Related Datasets

There is a long term goal within the Department to establish a "global" computerized database in which all mineral, petroleum, water resource and environmental data for S.A. are closely inter-related, readily accessed by simple easy-to-use commands and readily updated without duplication of either effort or data.

It is currently untenable (if not impossible) to incorporate all data into a model which satisfies all users equally, but it is possible to break the model into modules in which individual datasets are closely related not only in type but also in origin. For example, geological maps, stratigraphic names, field notes and rock samples are all different but closely related datasets generated mainly by one group of geologists. They are quite different from tenements or company names which are generated by a different group of people.

The SA_GEOLOGY module is based on the activities of and data generated mainly by Regional Geology Branch and incorporates all datasets closely related to geological mapping and map production. It therefore includes datasets such as field notes, structural data, mineral occurrences, summary geological drillhole logs and stratigraphic units as well as the actual graphical geological map database (Fig. 8). There are links to various other databases such as the stratigraphic nomenclature, rock sample, geochemistry, MINDEP, biostratigraphic, and drillholes databases. These links are by unique numbers such as the rock sample number, stratigraphic unit name or drillhole unique number and will ultimately allow related data from these databases to be accessed from SA_GEOLOGY. The immediate and most critical concern with these related datasets is that they incorporate a geographic location stored within the GIS and linked to the

ORACLE tables. Rock sample, drillhole or mineral occurrence locations can then be easily overlayed and plotted on top of geology through SA_GEOLOGY. Furthermore, particularly when links have been established with the relational (ORACLE) database, attribute data such as geochemistry or summary geological drillhole logs can be plotted on maps, contoured and image processed etc.

It is impossible at this point in time to define the various attribute databases, their record structure, data fields, unique keys and indexes without detailed knowledge of databases outside of SA_GEOLOGY. A data model is well established for the ROCK SAMPLE, GEOCHEMISTRY and MINDEP databases but others are still being defined. Nevertheless, record structures for all related attribute datasets/tables/arrays have been defined (Appendix A) and some have already been set up (e.g. summary geological drillhole logs). Changes may have to be made to this data model and its record structure during the next year or two.

Data Volumes and Disc Storage Requirements

The current digitizing procedures that have been used for the ADELAIDE and BARKER pilot project and State map give a basic estimate of data volumes that might be expected over the next few years.

- ADELAIDE (geological boundaries, polygons and labels) 7 Mb
- BARKER (geological boundaries, polygons and labels) 8 Mb
- State 1:2 million geological map (geological boundaries only) 4 Mb

These figures represent absolute minimum data volumes since attribute data (i.e. field notes etc) have not yet been included, and digitizing was carried out using point digitizing techniques rather than stream digitizing. Furthermore, TEO/3D and DG/GEO are 16-bit systems so any change to a 32-bit system would lead to a doubling (at least) of disc storage requirements.

Therefore, for each 1:250 000 map area (e.g. ADELAIDE) at least 20 Mb of disc storage space is required in the short term. There are about 70 1:250 000 map sheets in S.A., so total data volumes for the detailed geological map database will be in excess of 1500 Mb (1.5 Gb). This of course will not be required for some years since, at the current rate of digitizing, no more than ten 1:250 000 maps can be manually digitized from detailed data in any one year. The State map is unlikely to require more than 20-25 Mb of disc space in the near future and mineral occurrences and drillhole locations should not require much more than approximately 25 Mb depending on how much attribute data are attached to them.

Based on this scenario, disc storage requirements are likely to be:

• 1989 - 90	100 - 150 Mb
• 1991 - 95	250 Mb - 1 Gb
• 1996 - 2000	1.5 - 2.5 Gb

However, if digitizing techniques are changed and, for example, scanning technology is utilized, then greater disc storage requirements may need to be brought forward. The recommended approach is to utilize existing disc capacity in the next 12 months, purchase a ca. 500-600 Mb disc drive by 1990-91 when data volumes exceed 100 Mb, and then purchase additional disc drives when data volumes exceed the operating capacities of existing discs. As data volumes increase, usage of the system will also greatly increase, so it is highly desirable that the geological map database be kept online at all times, hence the requirement for dedicated disc drives. Geological maps are, after all, the fundamental database upon which all geological investigations are based.

DIGITAL MAP COMPILATION PROCEDURE

Although the overall geological map compilation process will remain essentially unchanged, SA_GEOLOGY will introduce several new procedures or techniques in that process. Furthermore, rather than the 1:100 000 geological compilation sheet being an integral part or central core of the process, it will now become a by-product; the digital geological map database now becomes the central core or "master copy".

... the overall geological map compilation process will remain essentially unchanged ...

The various stages or sub-processes in geological map compilation are outlined in Fig. 9. Initially, the first stage in the process will be by traditional manual drafting: the geologist will annotate aerial photos from field observations and photo interpretation, and drafting personnel will manually transcribe that data onto a photo-scale clear-film compilation map or overlay using an underlying topographic base map for photo control. The actual compilation map (sheet of film) must be devoid of topographic etc linework to enable potential digitizing by scanning and raster-vector conversion techniques.

After checking and correction, the compilation map will be digitized and the data stored in the appropriate SA_GEOLOGY database (on the MV 20 000 or GIS file server). Digitizing will be a bottleneck and, for greatest efficiency, must be undertaken on either a graphics workstation or PC-based digitizing station. Due to various facilities offered by the digitizing process of TEO/3D and other GIS/CAD software (e.g. "latching" onto existing nodes/lines) the graphics workstation is the preferred option. A PC option should only be considered if the GIS/CAD software on the PC is 100% compatible with the UNIX or mainframe software. After digitizing, check plots can be generated for the geologist at any preferred scale.

A future alternative to the above two stages, is to develop a procedure for direct digitizing of annotated aerial photos. Stereoscope hardware and software exist now to do this, but they are expensive and untested by the pilot project. However they should be seriously considered as an alternative to purchasing a third or fourth digitizer.

Following map digitizing and "posting" into the main database, field notes and point structural data could be added interactively using a graphics terminal and either DG/GEO or equivalent GIS facilities. This procedure could be undertaken by either the geologist or drafting personnel. At the same time, the map database could be edited/corrected and stratigraphic units defined.

Once all amendments have been made to the satisfaction of both the geologist and drafting personnel, the region or partitions in which the data reside can be "unlocked" and released for internal and external enquiries or plots. Map products at this stage could include single-colour compilation sheets with or without field notes and/or full-colour, near-publication-quality 1:100 000 (or 1:50 000) scale geological maps.

The above sub-processes would continue until all data have been collated and corrected for an entire 1:250 000 map sheet. At this time a query would be made of the database for the entire map area and that data transferred to a working file or "drawing" for editing to make it suitable for publication in the 1:250 000 atlas series. Editing might require smoothing of some geological boundaries, amalgamating or enlarging small outcrops etc. Legends, rock relationship diagrams, cross sections etc would be digitized at this stage and ultimately appended to the main working file or "drawing". A full-colour 1:250 000 scale plot or colour manuscript would ultimately be produced from this "drawing" and forwarded to Map Publication Section for publication. While this "drawing" would be kept and archived, it would not, at this point in time, be stored in the "global" database.

Though not critically discussed or evaluated in this report, procedures for utilizing the digital data during the map publication stage should be considered for introduction. In theory, it should be relatively straight forward to perform the scribing and colour separation processes automatically thus saving considerable drafting time. The Queensland Department of Mines have demonstrated that this is feasible (e.g. the Bowen Basin map) but that lettering etc is still performed better manually. It is recommended that Drafting Branch evaluate map publication techniques from digital data.

DATA SECURITY

A critical component of SA_GEOLOGY is that of data security: who can input, edit or view data, who "owns" or is the custodian of the data, when should data be archived or backed up, and when can data be made available to the public for either internal of external use.

.... the existing Departmental structure and responsibilities are not only adequate but essential...

With respect to the capture of data (both in the field and in the office) and compilation and publication of geological maps, the existing Departmental structure and responsibilities are not only adequate but essential. Provision of raw data in the form of annotated aerial photos, field and office compilations is the sole responsibility of Regional Geology Branch; map compilation, digitizing, editing and storing (in the "global" database) should be the sole responsibility of Map Compilation Section, Drafting Branch. Drafting Branch would be responsible for defining database partitions according to data density.

During the digitizing process, the database partition which is being worked on must be "locked" such that only the drafting person and geologist(s) responsible for that area can work on it. This "lock" should remain in place until digitizing has been completed, check plots generated, and editing of linework completed. If all this has been completed to the satisfaction of the supervising drafting officer and the geologist(s) then the data partition may be unlocked and released for public viewing.

Clearly the Department through the Regional Geology Branch is the owner of all data, but the officer who is responsible for map data integrity, deciding what data can be appended, edited or deleted in any particular area, for checking, and for overseeing the entire compilation process, is the geologist (or geologists) assigned to that map area by the Chief Geologist, Regional Geology Branch. No other person shall authorize any additions, changes or deletions to the database. Should changes etc be required in an area on which no geologist in Regional Geology Branch is actively working, those proposed changes must be authorized by the Chief Geologist, Regional Geology Branch before they are made. Irrespective, all changes etc will be made by the Map Compilation Section.

.... only suitably experienced drafting personnel in the Map Compilation Section (Drafting Branch) shall have "write" access to the spatial database .... all other Departmental personnel .... may have "read" access ....

Only suitably experienced drafting personnel in the Map Compilation Section shall have "write" access to the geological spatial part (lines, nodes, polygons etc) of the maps database. All other Departmental personnel (including other drafting personnel, computing staff, geologists etc) may have "read" access but only after undertaking basic training in the use of GIS facilities to the satisfaction of the geological maps database manager (i.e. Chief Geologist, Regional Geology Branch). All SA_GEOLOGY user profiles must be authorized by the latter.

Archiving and backing up of all data on the MV 20 000 or GIS file server are currently the responsibility of O. Polatayko and D. Cook in the Computing Branch. This is carried out regularly (weekly) and is deemed adequate for SA_GEOLOGY data stored on that computer. However, data on the existing DS-7540 workstation (including all files etc on the hard disk drives) are only backed up monthly (to tape). All active data (i.e. data being worked on) on workstations should be backed up or "posted" to the GIS file server daily and then regularly backed up independently on either a weekly or monthly basis. Daily backup of working files is the responsibility of the relevant drafting officers whereas a complete backup should be carried out by the senior drafting officer responsible for the workstation(s) and/or file server.

The above security procedures and user profiles apply specifically to geological map data viz. geological boundaries, faults etc. However, attribute data, viz. field notes etc, can be treated slightly differently. In the case of field notes, these can be input by either the geologist who made the notes (and who is therefore the "owner") or by someone he/she designates (eg drafting or clerical personnel). Once attribute data has been input and saved, only the originator or "owner" may change that data in any way. Other data can be appended indirectly as separate notes at the same locality by another person but the original notes may not be altered by another person. In this situation there would be two (or more) sets of notes, each with separate "owners", at one locality. Dip/strike data etc can be treated in the same manner.

Mineral occurrence (metallogenic map) attribute data (including mine plans) are the sole responsibility of the Mineral Resources Branch and only the Chief Geologist, Mineral Resources Branch (or authorized geologists/technical officers) shall make any additions, changes or deletions to/from this dataset. Geographic locations, metallogenic map symbols and mine plans (ie spatial data) should only be input or entered by Map Compilation Section (as per geological map data).

Drillhole location data and summary geological logs (as commonly portrayed on geological maps) should be the responsibility of, respectively, Drafting Branch (currently R. Herraman) and geologists in Regional Geology Branch. All drillholes must contain a unique borehole number/ID (as per the Bore General File; Selby, 1985) and locations should be digitized directly into the appropriate and existing GIS database (viz. DRILLHOLES overlay) by Drafting Branch. Only the Drafting Branch officer(s) responsible for the DRILLHOLES data shall make additions, changes or deletions to/from the locational dataset. Backup procedures should be similar to those outlined above (viz. daily to the MV 20 000 or file server).

Security and backup procedures of rock sample and geochemical data are discussed in a separate report (Clough, 1989).

DATABASE MANAGEMENT AND BRANCH RESPONSIBILITIES

SA_GEOLOGY is not a brand new system doing something that has never been done before; it is a modification of an existing manual system that has been in place for more than 40 years. It does not create a brand new database, but rather, converts an existing paper database into digital form. Therefore, there is no need to change a proven and successful management and divisional structure. As has always been the case, the Chief Geologist, Regional Geology Branch, has the ultimate responsibility for maintaining the State's geological map database and therefore shall be the sole manager of the SA_GEOLOGY database.

> **.... the Chief Geologist, Regional Geology Branch .... shall be manager of the SA_GEOLOGY database .... responsible for its timely and efficient development .... quality and security .... The Chief Drafting Officer should be responsible for .... GIS software .... hardware .... compilation procedures .... quality of linework .... plotting ....**

As manager, the Chief Geologist, Regional Geology Branch, shall be responsible for the timely and efficient development of the database commensurate with given resources and Departmental priorities particularly in regard to the National Geoscience Mapping Accord. He/she shall also be responsible for ensuring that the quality and security of data in the database is maintained at a high level commensurate with the Department's role to assist and promote mineral, petroleum and water resource exploration and development in S.A. in accord with sound environmental and land management practices. A further responsibility is to ensure that the database is developed and maintained in accordance with Departmental standards including those in other computing areas.

The Chief Drafting Officer, Drafting Branch, should be ultimately responsible for ensuring that GIS software are maintained (by a suitably qualified drafting/computing person), purchasing and maintaining appropriate hardware for Map Compilation Section in accordance with these recommendations, implementing and supervising database/map compilation procedures, and for ensuring continuing quality of linework etc whether on traditional paper/film products or in digital form. All map digitizing and compilation will be undertaken by the Map Compilation Section which should have exclusive use and management of digitizers, work stations and graphics terminals (in lieu of traditional drafting tables).

Because plotting facilities will not be required continually by SA_GEOLOGY (at least in the short term), they should be a shared resource under the management of the Chief Drafting Officer. It is recommended that a drafting person(s) be trained as a full-time operator to ensure plotting hardware is maintained adequately and that plots are of a quality commensurate with existing drafting practices.

Management of the MV 20 000 computer should remain with the Computing Steering Committee since it is a shared resource. However, it must continue to be regarded as a tool for database storage and analysis <u>not</u> elevated to any greater position! Backing-up responsibilities (including backing up and maintenance of SA_GEOLOGY data and disc drives on the MV 20 000 and file servers) should remain with existing personnel in Computing Branch.

TRAINING AND USER'S MANUAL

There will be four broad categories of SA_GEOLOGY users and each will require different levels of training. They are:

- programmers and officers responsible for development of SA_GEOLOGY including data structures, macros, menus and procedures
- drafting personnel responsible for digitizing
- geological mapping personnel responsible for map compilation, attribute data, legends, cross sections and etc
- casual or occasional users.

The first group will need to have a full appreciation of geological maps and GIS, and be proficient in programming in the GIS environment (viz. TEO/3D or ARC/INFO etc) and/or in the attribute DBMS (viz. ORACLE). Programmers in this category will therefore require extensive external training in advanced facilities of the various software packages. Ideally they should be geologists or geological drafting personnel with an extensive knowledge of geological mapping techniques and requirements. If not, they will need to undertake Tertiary geological courses.

Drafting personnel responsible only for digitizing will need to be familiar with the GIS software, its uses and functionality, but need not have any programming expertise. Given an introductory, tailored, 3-5 day in-house course on SA_GEOLOGY and the GIS software (particularly Easidraw in the current situation), they would learn mainly by experience in an hands-on environment working alongside of experienced drafting personnel (eg. G. Young).

Geological mapping personnel (mainly geologists in Regional Geology Branch) could likewise be trained in-house during a 3-5 day course specially tailored for their needs. Their needs would be quite different from drafting personnel since the emphasis would be on querying the map GIS and entry of attribute data.

Casual users would require a 2-3 day in-house course tailored for querying both the geographic and attribute databases.

It is assumed that all potential SA_GEOLOGY users will be proficient in computer usage prior to undertaking any of the above training programmes. If not, they would be required to attain such either internally or externally. In-house courses could currently by given by A.J. Parker and P.G. Young or N. Sandercock.

.... success of SA_GEOLOGY will depend on .... adequate training and .... a comprehensive User's Manual ....

The ultimate success of SA_GEOLOGY will depend not only adequate training and familiarity but also on comprehensive documentation of all procedures in the form of a User's Manual. This will be particularly important for casual or occasional users or regular users attempting different procedures with which they may not be familiar. A User's Manual has already been compiled in draft form covering procedures currently being used. While SA_GEOLOGY is being developed, the Manual will require extensive changes and additions. For this reason it is recommended that only two complete copies be maintained, one in Map Compilation Section and one in Regional Geology. They should be loose bound to facilitate updates. Maintenance of the Manual should be the responsibility of the Chief Geologist, Regional Geology Branch, and the Senior Draftsman in Map Compilation Section (or assignees). Other copies may be made but will not necessarily be maintained regularly.

RESEARCH AND DEVELOPMENT

Geographic information systems, image processing, geological GIS applications and methods of capturing, storing and presenting data have all changed radically over the last ten years. They will continue to change and user requirements (including those of geological map users) will also shift. Therefore, there is a continuing need to maintain an active research and development program to ensure that the Department not only keeps up with but remains in the forefront of geological mapping and mapping compilation and presentation techniques. Liaison with interstate geological surveys, the BMR, universities and the CSIRO is essential and overseas developments should also be closely monitored particularly with respect to geological map GIS.

It was frequently stated at the 1989 BMR Symposium (Geoscience Mapping Towards the 21st Century) that the geoscience map of the 21st Century would not be a traditional paper map, but would be a computerized geological and geophysical GIS.

It is not possible to list all areas of research and development here, but some areas for immediate attention are:

- map compilation procedures viz. the capture or digitizing of data directly from annotated aerial photos using stereoplotting facilities and/or image analysis (Taylor, 1988)
- 3-D modelling and automated or semi-automated construction of balanced cross-sections (De Paor, 1988)
- incorporation of cross-sections, drillhole data and fence diagrams into tectonic maps to produce "3-D maps" (Voss, 1988; van Driel, 1988)
- image processing of geological and geochemical data in conjunction with more traditional satellite and/or aeromagnetic images (Lindquist et al., 1987)
- automated or semi-automated capture of field data (field notes (Lang et al., 1988; Grimes et al., 1988), on-site geochemical analysis, etc) and, in particular, incorporation of GPS (Global Positioning Satellite) navigational system locations
- stereonet analysis of structural data
- plotting techniques and transfer of digital data to external users (including the use of CD-ROM; Cooke, 1987)

- development of portable field-based GIS systems for use on lap-top or equivalent PC's. This is potentially a very exciting area of research which might lead to geologists being able to take all their maps and a "filing cabinet" full of information out into the field on a floppy disc!

- incorporation of metallogenic map data (viz. metallogenic map symbols indicating deposit type and size)

- production of geochemical maps (Bjorklund & Gustavsson, 1987)

- development of digital geological/cartographic data standards (Morrison, 1988).

SA_GEOLOGY as described here deals only with geological map compilation procedures and compilation of a geological GIS. Obviously with map data in digital form, there is enormous scope, and potential economic benefits, for using them in map publication procedures. With the State 1:2 million geological map in digital form and currently being revised, opportunity exists for a pilot project to be established by the Map Publication Section of Drafting Branch. Scribing of linework and preparation of colour separations, for example, could be automated using the digital data thus potentially saving considerable time and effort. Map Publication Section has already explored some avenues for automatically producing colour separations using the SCITEX scanning system of the Advertiser group of companies. This proved successful but did cost approximately $2500 - 3000 for a standard 1:50 000 map sheet.

ESTIMATED COSTS AND SALES REVENUE

By early 1990, SA_GEOLOGY should be fully functional on the MV 20 000 and DS-7540 workstation using TEO/3D. Procedures are already well established for digitizing, storage in partitions, layer or colour assignment, labelling of polygons, and plotting. Attribute datasets will be established shortly. Therefore, as of January 1990, the main priority will shift from development and testing to routine data capture (map digitizing and input of attribute data). This will require improved digitizing facilities.

In view of Data General's decision concerning TEO/3D and DG/GEO, it is recommended that the Department acquire alternative GIS software and there is no question that ARC/INFO would be highly favoured in view of its usage elsewhere in South Australia, interstate, and in overseas geological surveys. There are other GIS options but for the purpose of this report the costs of acquiring an UNIX-based ARC/INFO solution are incorporated.

Based on this scenario and assuming that most map compilation will be undertaken using SA_GEOLOGY by mid-1991, the estimated costs (based on figures supplied by Data General for AViiON workstations and by ESRI Aust. for ARC-INFO) are:

	Estimated Cost	
	Reg.Geol.	Drafting
1989 - 90		
• complete development and testing on the leased DS-7450 workstation (upgraded to 280 Mb disc) 1 month @ $1 100, 3 months @ $1 485, 8 months @ $1 750 (including maintenance)	26 200	
• purchase two (or equivalent) graphics workstatons and an Aϕ digitizer for routine map compilation		70 000
• purchase two colour inkjet or thermal printers	5 000	5 000
• purchase an Aviion or equivalent graphics workstation with image processing capability (including appropriate software)	50 000	

• GIS (eg ARC/INFO) software	26 000	66 000
• system development personnel (computing geologist - 6 months)	20 000	
• dedicated drafting personnel (full time) 1990 - 91		33 000
• purchase a third graphics workstation and digitizer for routine map compilation and an additional software license		51 000
• purchase an AØ colour ink jet plotter		50 000
• purchase a 600 Mb disc drive for the file server	25 000	
• research and development (hardware for development of aerial photo digitizing techniques; international geoscience GIS meeting)	20 000	
• software and hardware maintenance	6 000	11 000
• personnel (drafting, research & development)	7 000	33 000

1991 - 94 (3 years)

• purchase a fourth graphics workstation, software and digitizer for routine map compilation (if required)		50 000
• purchase a second graphics workstation for image processing and GIS analysis	50 000	
• purchase additional disc drives for the MV 20 000 or file server (as necessary)	40 000	
• research and development (including hardware for possible CD-ROM development; national and	40 000	

	international geoscience GIS meetings)		
•	software and hardware maintenance	35 000	84 000
•	personnel (drafting, research and development)	20 000	60 000

The total implementation and development costs for SA_GEOLOGY over the next five years (1989-94) are:

	Hardware etc	**Staff**	**Maintenance**
1989-90	**222 000**	**53 000**	**26 200**
1990-91	**146 000**	**40 000**	**17 000**
1991-94	**180 000**	**86 000**	**119 000**
Total	**$548 000**	**$179 000**	**$162 200**

There is no perceived requirement for additional drafting or geological personnel to implement or maintain SA_GEOLOGY.

The real benefits of implementing SA_GEOLOGY are the provision of near-publication-quality colour 1:100 000 scale geological maps, metallogenic maps, and geochemical maps. To publish 1:100 000 scale geological maps by traditional means would mean publishing about 15-20 1:100 000 maps per year in addition to the 3-4 1:250 000 geological maps. If the National Geoscience Mapping Accord is accepted in its entirety, then geological mapping staff in Regional Geology Branch will be increased by 7 geologists. These geologists will produce an extra 2-3 1:250 000 and 10-15 1:100 000 maps per year taking the publication totals to 5-7 1:250 000 and 25-35 1:100 000 geological maps per year.

Although the Department has not published any standard 1:100 000 geological maps, it is estimated that publication of a 1:100 000 geological map would be equivalent to publication of a standard 1:50 000 geological map (for which publication costs and manpower requirements are available). Based on these figures and the cost of an average drafting officer (salary + 20% = $33 134 per annum), the estimated cost for publishing an existing 1:100 000 geological compilation map is:

Preparation of colour manuscript (2 months)	5 500
Publication drafting (4 months)	11 000
Computer colour separation (eg at SCITEX)	3 000
Drafting materials (film etc)	700
Printing costs (1000 copies)	1 300
Total	$21 500

....publication of 1:100 000 geological maps by traditional means would cost $1.6 - 3.8 million over a five year period...

If a minimum of 15 1:100 000 geological maps are published by traditional means each year, the total publication cost over a five year period (ie 75 maps at $21 500) is $1.6 million. If 35 1:100 000 maps were to be published each year (ie 175 maps at $21 500), this figure would increase to $3.8 million. To this figure must be added map storage costs and extra floor space required for the extra drafting personnel (approximately 40 square metres). Other costs such as geological checking etc would be approximately the same whether the 1:100 000 geological map was produced from SA_GEOLOGY or published by traditional means. Therefore they have not been considered here.

Currently, 1:100 000 scale colour plots of geological data from SA_GEOLOGY are being offered for sale at $50 per plot. This figure was based on the cost (currently $38 per plot at E & WS) to Regional Geology for plotting at either the Lands or E & WS Departments. It might be necessary to undertake a market survey to determine how many maps would be sold at this price, but discussions with geoscientists at the 1989 BMR Symposium clearly indicated that the Department should be aiming to sell colour plots at about $20-25 in line with current prices for published 1:100 000 geological maps (less than or equal to $18). At $50 per plot, sales of map plots alone are unlikely to generate much revenue. For example, the sale of 1000 colour plots over the next five years would generate about $12 000 profit. This figure could be at least doubled, however, from sales of metallogenic geological maps.

The sale of digital geological map data (as opposed to hard copy) is contingent on companies and Government organisations having appropriate GIS hardware and software. The ADELAIDE and BARKER data have been given to the SA Department of Environment and Planning as part of the Department of Mines and Energy contribution to the Mount Lofty Ranges Review. However, in the future, charges will have to be made for these data. Such charges will have to be competitive with costs for external digitizing to encourage organisations to buy the data rather than to digitize maps themselves. Manual digitizing of an average 1:100 000 per map by a contractor would cost about $300-500 per map. Therefore, it is recommended that realistic prices for digital geological data might be:

Simple 1:100 000 geological map (eg Mobilong which is comprised of only 1 partition)	$120

Complex 1:100 000 geological map (eg Milang which is comprised of 7 partitions)	$500

Prices should be put on a sliding scale between these end members but discounts could be offered for large volumes (several 1:100 000 maps).

The above figures would apply to the supply of digital geological boundaries, polygons, map symbols (labels) and selected structural data on tape or disc. Additional data such as field notes, summary geological drillhole logs, and mineral occurrence data could be sold for an amount related to a base rate (maybe $25) plus a fixed amount per sample point (maybe 50c per location for field notes; $5 per location for MINDEP mineral occurrence data).

It is difficult to estimate likely income from sales of digital data over the next five years particularly since the potential market at this stage is very small. However, if the consensus of the 1989 BMR Symposium is any indication, the market and demand for digital data are likely to grow rapidly. A conservative estimate of potential income from sales of digital data is:

Digital map data (200 maps of variable complexity	80 000
Digital field notes and summary drillhole logs	5 000
Digital mineral occurrence (MINDEP) data	20 000

In summary, direct tangible benefits of SA_GEOLOGY over the next 5 years (1989-94) are likely to be at least:

Geological maps (colour plots)	**12 000**
Metallogenic maps	**12 000**
Digital map and attribute data	**105 000**
Total	**$129 000**

Geochemical maps, drillhole location maps and maps reproduced from the digital data but in some other format (eg project reports) are not included in the above figures but would add to the tangible benefits.

IMPLEMENTATION SCHEDULE AND DIGITIZING PROGRAMME

Implementation, research and development will be ongoing concurrent with routine digitizing of existing and new geological map data. Therefore they are described together along with proposed hardware and software acquisitions.

1990 (January - June)

- purchase graphics workstations (3) and appropriate software (including image processing software) for Drafting (Map Compilation Section) and Regional Geology Branches

- purchase colour inkjet or thermal printers (2)

- complete development and testing of initial data structures (as defined in Appendix A), macros, customised menus, and procedures

- complete digitizing and layer assignment of the State 1:2 million scale geological map (by March 1990)

- complete digitizing and editing of the Mafic Dyke Swarms of Australia map (by March 1990)

- complete entry of summary geological logs for the Eyre Peninsula and Murray Basin basement Pb-Zn drilling projects

- commence digitizing of geological compilation sheets (as they become available) and entry of attribute data for BURRA, KINGSCOTE and other active mapping projects

- commence a programme of digitizing preliminary 1:100 000 and other detailed geological compilation sheets for the Gawler Craton (this could be a background programme of lower priority)

- commence a training programme for drafting personnel and geologists in Regional Geology (after installation of workstations).

1990 (July - December)

- continue digitizing of Gawler Craton preliminary 1:100 000 and other compilation maps
- continue digitizing of new geological compilation sheets (as they become available) and entry of attribute data (including summary geological logs) for active mapping projects

- commence a training programme for geologists in Mineral Resources Branch and other potential SA_GEOLOGY users

- commence entry of mineral occurrence locations and attribute data

- commence research into use of stereoplotting techniques during digitizing

- purchase a 600 Mb disc drive for the MV 20 000 or file server.

1991 (January - June)

- continue digitizing and data entry as listed above

- purchase an additional graphics workstation for Drafting Branch (Map Compilation Section)

- commence digitizing of preliminary 1:100 000 geological maps, existing 1:63 360 geological maps and any other detailed maps for the remainder of the Adelaide Geosyncline

- purchase an Aϕ colour inkjet plotter and train drafting personnel in its use

- purchase stereoplotting hardware for development of aerial photo digitizing techniques

- commence development of techniques for compilation of 1:250 000 scale colour manuscripts in readiness for publication drafting.

1991 (July - December)

- continue digitizing and data entry for active mapping projects

- commence research into use of CD-ROM for data transfer and 3-D map presentation techniques

- complete first-pass digitizing of all existing 1:100 000 preliminary geological maps, 1:63 360 and other geological maps. At this time (December 1991) there should be detailed geological GIS coverage for 75% of SA.

1992-94

- continue digitizing, updating and data entry for active mapping projects

- purchase additional graphics workstations, disc drives and other hardware/software as required
- continue research and development into new GIS, data transfer and map presentation techniques including development of a portable field-based GIS system.

SUMMARY

THE GEOSCIENCE COMMUNITY (both private and public), ENVIRONMENTAL GROUPS, and LAND PLANNERS WANT GEOLOGICAL MAPS. This message is loud and clear from right across Australia.

To satisfy this requirement, the Department must increase the range and timeliness of published, near-publication-quality and field compilation geological and related maps. This cannot be achieved by existing procedures and manpower resources. Furthermore, to meet growing needs, the Department must improve existing systems to fulfil the need for digital geological data, integration and interpretation systems.

SA_GEOLOGY can meet future needs. It is a viable system that offers the potential to increase, by an order of magnitude over existing methods, the range of geological and related maps of near publication quality without any increase in staff levels. It will require the acquisition of some hardware and software but the cost of these acquisitions is far outweighed by the potential benefits to the community in mineral and petroleum exploration, environmental management, land use planning, teaching, groundwater investigations, engineering site investigations and tourism etc.

A 12-month pilot project has successfully demonstrated the viability of SA_GEOLOGY in a preliminary form, has identified it's strengths and weaknesses, and has not only enabled quality, full-colour geological compilation maps to be produced in a range of scales, but has also provided digital data for integration with other land resource data in the assessment of resources, land use and the environment of, for example, the Mount Lofty Ranges.

The principal aim of SA_GEOLOGY is to supplement (not duplicate) existing and future 1:250 000 scale published geological maps by providing detailed geological compilation maps and map data in a timely and readily updated manner and in full colour at publication or near publication quality. It will also provide a central geological database with which all other Departmental data (such as drillholes, mineral occurrences, rock samples, geochemistry, geophysics, tenements etc) can be easily integrated for interpretation. The data model presented in this report integrates many of these datasets and provides the framework for the production of metallogenic maps, drillhole location maps (with summary geological logs) and geochemical maps.

Procedures and responsibilities for capturing geological map data are based on existing manual procedures: field mapping, compilation onto aerial photos and checking etc will be undertaken by Regional Geology Branch; map compilation, digitizing, geological map database maintenance (posting, editing etc) and plotting will be undertaken by the Map Compilation Section of Drafting Branch. There is no need for any changes in the Departmental structure nor for any additional personnel such as a data manager; the Chief Geologist, Regional Geology Branch, will be solely responsible. Access to data will initially be restricted to geologists and drafting personnel working on that particular map sheet. However, once the digital data have been checked and cleared for release, all Departmental officers familiar with the GIS software shall have read access. All input and editing of geological map linework will be

carried out by Drafting Branch under direction of Regional Geology Branch; attribute data (eg structural data, field notes etc) will be entered by geologists or technical staff under their direction.

In addition to image - processing software, there is a major requirement, in the short and long term for GIS software linked to ORACLE. Recent uncertainties with respect to TEO/3D and DG/GEO (particularly their implementation on UNIX-based workstations and linkage to ORACLE) imply that the Department must acquire alternative GIS software. In view of its world-wide usage by geological surveys, ARC/INFO is strongly supported.

There are major hardware requirements for graphics workstations, digitizers, disc drives and a flat-bed colour inkjet plotter. Some are required immediately, others should be phased in during the next five years unless new data capture techniques (e.g. laser scanners) are introduced sooner. Data volumes are projected to ultimately exceed 1.5 Gb but this will not likely occur until about 5 years time.

The total cost of hardware and software acquisition and maintenance over the next five years is projected to be:

	Hardware/Software	Maintenance
1989-90	222 000	26 200
1990-91	146 000	17 000
1991-94	180 000	119 000
Total	$548 000	$162 200

Potential map sales and sales of digital data may not necessarily recover all these costs and are projected to be about $129 000 over the same 5-year period. It will not be possible to fully recover costs since map prices must, for example, be kept in line with prices of similar-scale published maps in other states.

By comparison with manual map publication techniques there are very substantial cost benefits. Extra resources required to publish an equivalent number of 1:100 000 geological maps by traditional means would cost about $1.6 - 3.8 million. This would provide high-quality colour maps but they would quickly go out of date, would be difficult and costly to update, their scale could not be altered readily, and only limited attribute data could be presented!

An ongoing training programme is essential for the efficient implementation of SA_GEOLOGY. Except for advance facility programmers, most of the training could be conducted in-house by existing personnel. A comprehensive User's Manual is essential.

Research and development is also an essential part of SA_GEOLOGY to investigate and develop new techniques and technology, for example, capturing data direct from aerial photos, producing 3-D maps/models, and producing maps on CD-ROM. Liaison with surveys both interstate and overseas will enhance research and development substantially.

If SA_GEOLOGY is given the resources and support recommended in this report, it will maintain the South Australian Department of Mines and Energy in the forefront of high quality geological mapping in the country. It will provide greater service to the public, encourage exploration, and provide a framework for more equitable land use and environmental planning.

REFERENCES

Bjorklund, A. and Gustavsson, N., 1987. Visualization of geochemical data on maps: New options. In: R.G. Garrett (ed.), Geochemical Exploration 1987. Journal of Geochemical Exploration, 29(1/3): 89-103.

Clough, B.J., 1989. Feasibility study and implementation plan for revising the Rock Sample and Geochemistry databases. South Australia. Department of Mines and Energy. Unpublished Report 89/ .

Cooke, D.F., 1987. Map storage on CD-ROM. Byte, July: 129-138.

De Paor, D.G., 1988. Balanced sections in thrust belts, Part 1: Construction. American Association of Petroleum Geologists. Bulletin 72(1): 73-90.

Fegeas, R.G., Claire, R.W., Guptill, S.C., Anderson, K.E. and Hallam, C.A., 1983. Land use and land cover digital data. United States. Geological Survey. Circular 895-E.

Grimes, K.G., Withnall, I.W., Lang, S.C., Murphy, P.R. and Thornton, M.P., 1988. Regional mapping field data management system (REGMAP) - user's guide. Queensland Department of Mines. Geological Mapping Manual 2.

Herriman, N., 1989. Successful ore discovery: The need for goals, good science and geological maps. In "Geoscience Mapping Towards the 21st Century". Bureau of Mineral Resources, Geology and Geophysics, Australia. Research Symposium 1989.

Lang, S.C., Withnall, I.W. and Grimes, K.G., 1988. Regional mapping field data management system (REGMAP) - guide to data collection and entry. Queensland Department of Mines. Geological Mapping Manual 1.

Lindqvist, L., Lundholm, I., Nisca, D., Esbensen, K. and Wold, S., 1987. Multivariate geochemical modelling and integration with petrophysical data. In: R.G. Garrett (ed.), Geochemical Exploration 1987. Journal of Geochemical Exploration, 29(1/3): 279-294.

Mitchell, W.B., Guptill, S.C., Anderson, K.E., Fegeas, R.G. and Hallam, C.A., 1977. GIRAS: A geographic information retrieval and analysis system for handling land use and land cover data. United States. Geological Survey. Professsional Paper 1059.

Morrison, J.L., 1988. Digital cartographic data standards: The U.S. experience. Cartography, 17(2): 1-7.

Parker, A.J., 1989. SA_GEOLOGY: A digital geological mapping system. In "Geoscience Mapping Towards the 21st Century". Bureau of Mineral Resources, Geology and Geophysics, Australia. Research

Symposium 1989.

Parker, A.J. and Felstead, M.D., 1989. National Geoscience Mapping Accord: Results of 1989 questionnaire. South Australia. Department of Mines and Energy. Unpublished Report.

Preuss, H., 1988. Map construction using advanced raster techniques. Geologisches Jarbuch, A 104: 187-195.

Selby, J., 1985. Storage and retrieval of drillhole information: A review. South Australia. Department of Mines and Energy. Unpublished Report 85/64.

Selner, G.I. and Taylor, R.B., 1988. GSMAP and other USGS microcomputer programs for earth science applications. Geobyte, November: 36-43.

Taylor, G.R., 1988. Image analysis techniques for the interpretation of airphoto lineaments - petroleum exploration, Eromanga Basin, Australia. Geocarto International, 3: 53-60.

van Driel, J.N., 1988. Three-dimensional display of geologic data. Geologisches Jarbuch, A 104: 197-212.

Vinken, R., 1988. Digital geoscientific maps - a research project of the Deutsche Forschungsgemeinschaft (German Research Foundation). Geologisches Jarbuch, A 104: 7-20.

Voss, H., 1988. Digital geoscientific maps between information systems and expert systems. Geologisches Jarbuch, A 104: 41-54.

Woods, A.J., 1989. Review of the Bureau of Mineral Resources, Geology and Geophysics. Australian Government Publishing Service, Canberra.

APPENDIX A

Proposed record structure

of SA_GEOLOGY

attribute data

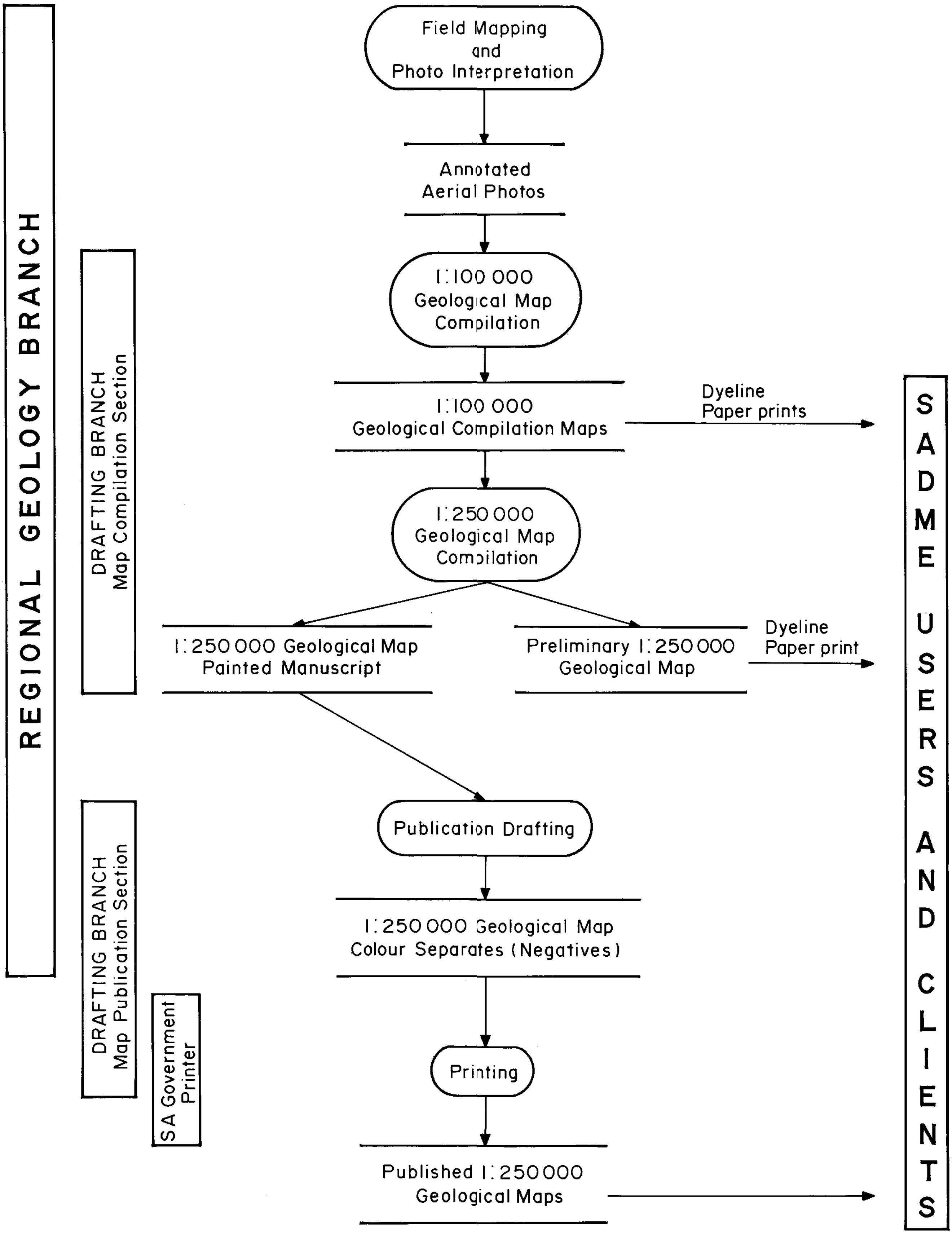


Fig. 1

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

SA GEOLOGY - DESIGN AND IMPLEMENTATION

CURRENT GEOLOGICAL MAPPING, COMPILATION AND PUBLICATION PROCEDURES

COMPILED A.J. Parker	C.D.O. DATE 22.3.90
DRAWN J. Gray	SCALE
DATE Jan. 1990	PLAN NUMBER S21225
CHECKED	

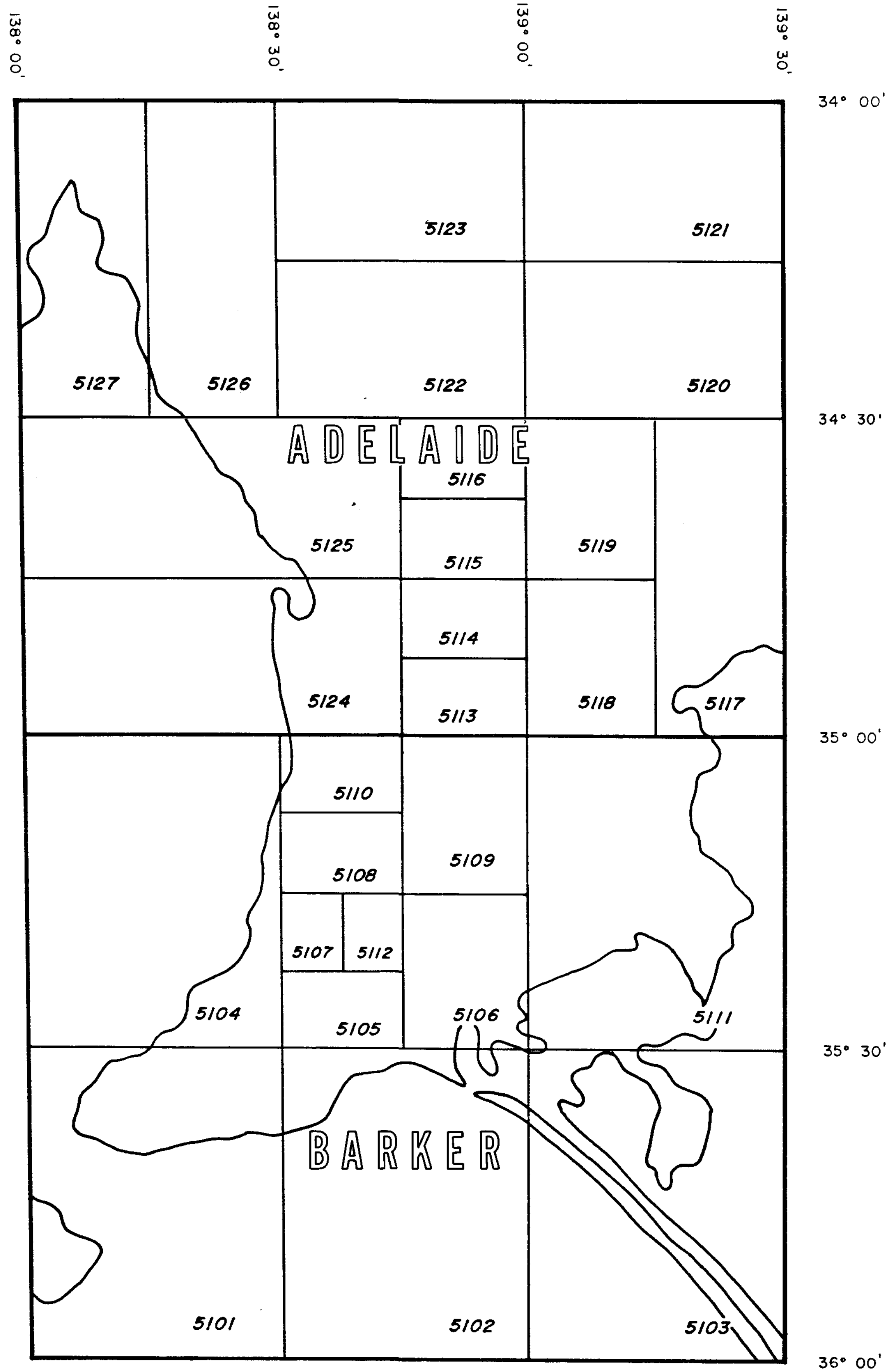


Fig. 2

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED A.J. Parker	C.D.O. DATE 22·3·90
SA_GEOLOGY - DESIGN AND IMPLEMENTATION	DRAWN J. Gray	SCALE
ADELAIDE AND BARKER PARTITIONS	DATE Jan. 1990 / CHECKED	PLAN NUMBER S21226

4961

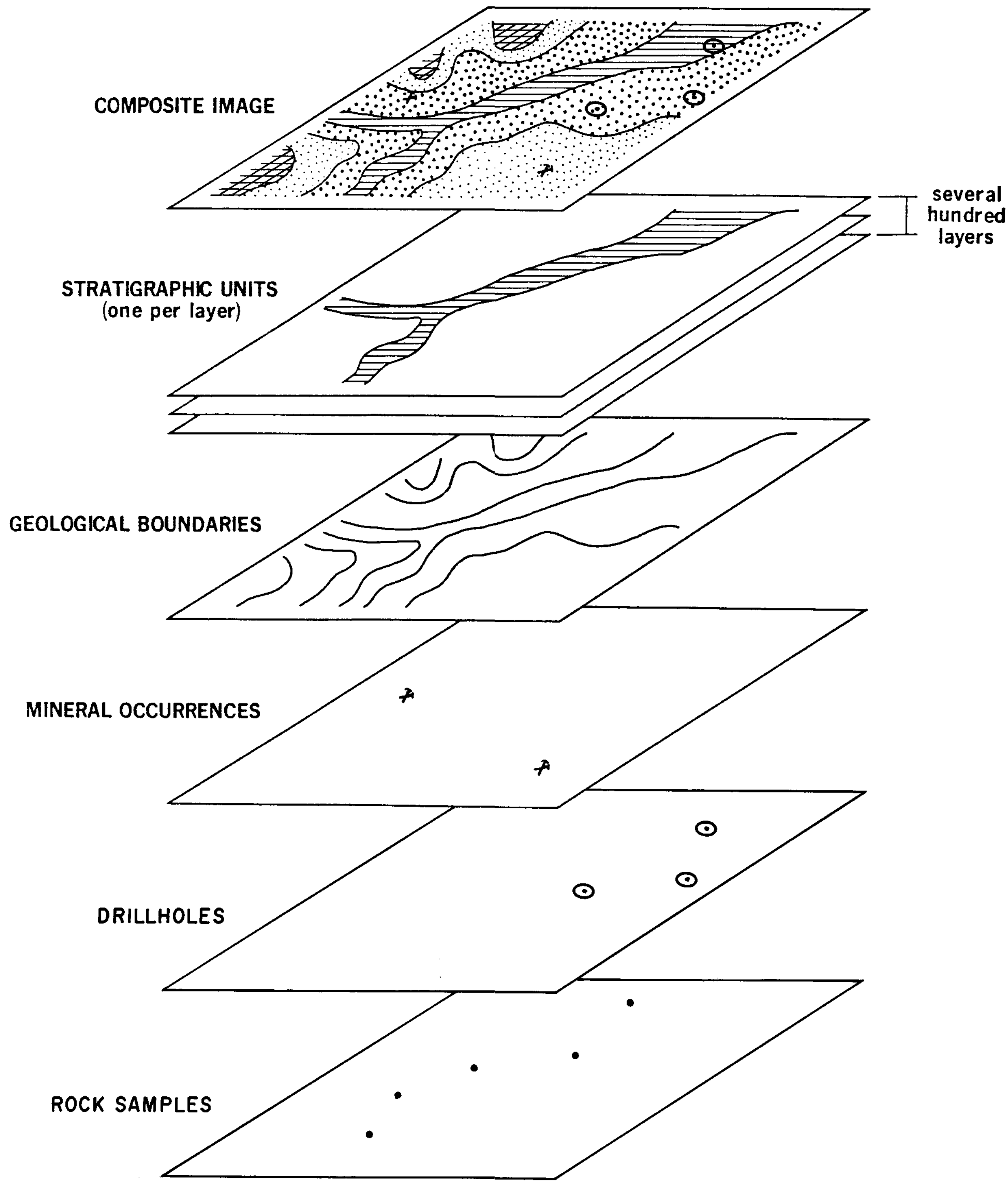


Fig. 3

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA

SA_GEOLOGY – DESIGN AND IMPLEMENTATION

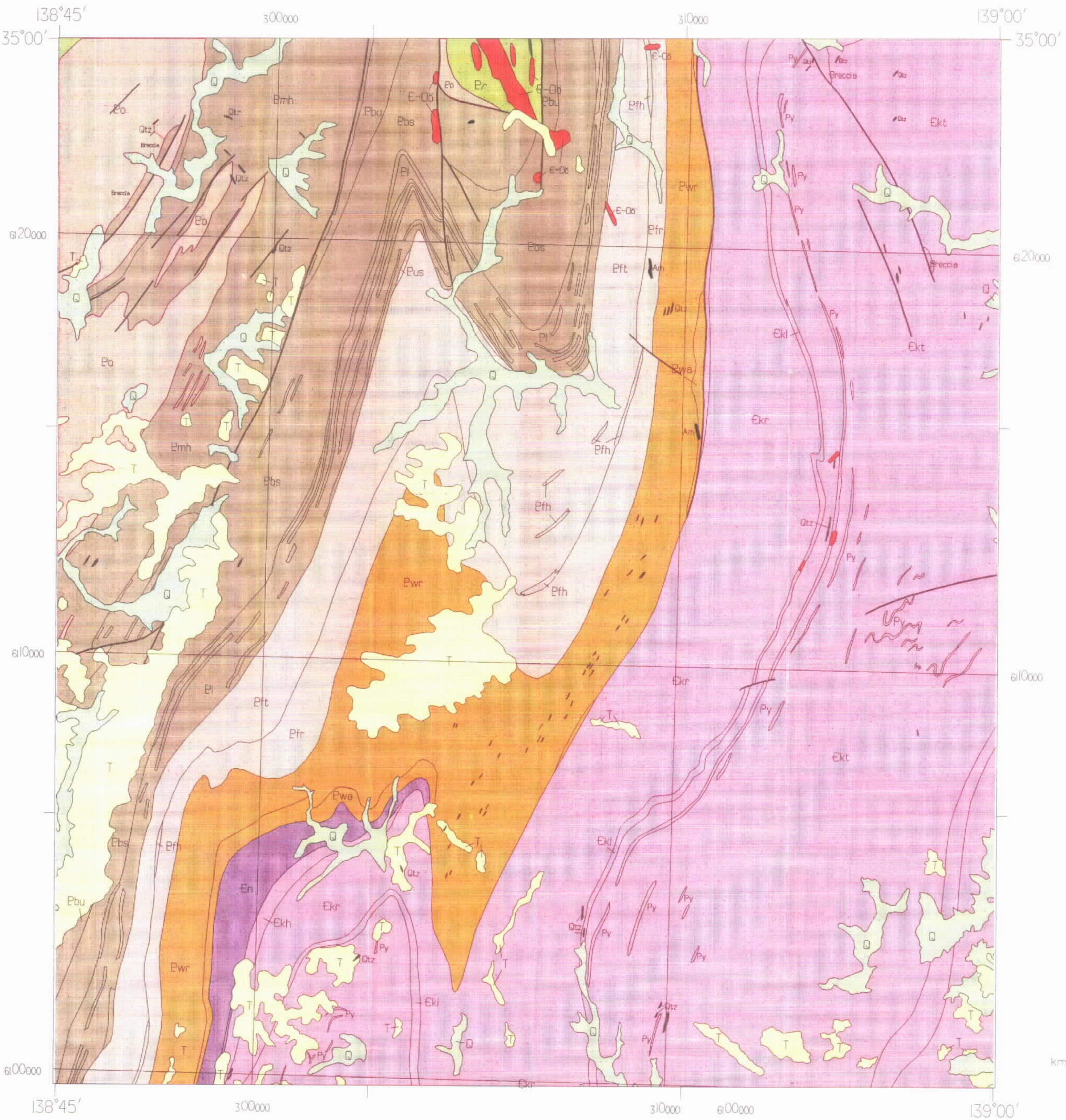
LAYER STRUCTURE

COMPILED A.J. Parker	C.D.O. [illegible]	DATE 22·3·90
DRAWN J. Gray	SCALE	
DATE Jan. 1990	PLAN NUMBER S21227	
CHECKED		

4961

Ptn ECHUNGA 6627 I

RB 90/11



DEPARTMENT OF MINES AND ENERGY

REFERENCE

CAINOZOIC	Quaternary	Q	Undifferentiated Quaternary deposits
	Tertiary	T	Undifferentiated Tertiary sediments
PALAEOZOIC	Cambro-Ordovician	Є-Ob	Undifferentiated Delamerian acid intrusives (syn and post-tectonic)
	Early - Middle Cambrian	Єkt	Tapanappa Formation
		Єkl	Talisker Calc-siltstone, Karinya Shale
		Єkr	Backstairs Passage Formation
		Єkh	Carrickalinga Head Formation
	Early Cambrian	Єn	Undifferentiated Normanville Group
PROTEROZOIC	Marinoan	Ꝑwb	Bunyeroo Formation
		Ꝑwa	A B C Range Quartzite
		Ꝑfr	Tarcowie Siltstone
	Sturtian	Ꝑfh	Brighton Limestone
		Ꝑft	Tapley Hill Formation
		Ꝑus	Sturt Tillite
		Ꝑl	Undifferentiated Belair Subgroup
	Torrensian	Ꝑbs	Mitcham Quartzite, Gilbert Range Quartzite
		Ꝑbu	Stonyfell Quartzite, Undalya Quartzite
		Ꝑmh	Woolshed Flat Shale
		Ꝑo	Undiff. Emeroo Subgroup, Aldgate Sandstone
	?Early-Middle Proterozoic	Ꝑr	Barossa Complex

SCALE 1:100000

km 0 2 4 6 8 10 km

4961

SADME

Fig. 4

90-54

19.12.89

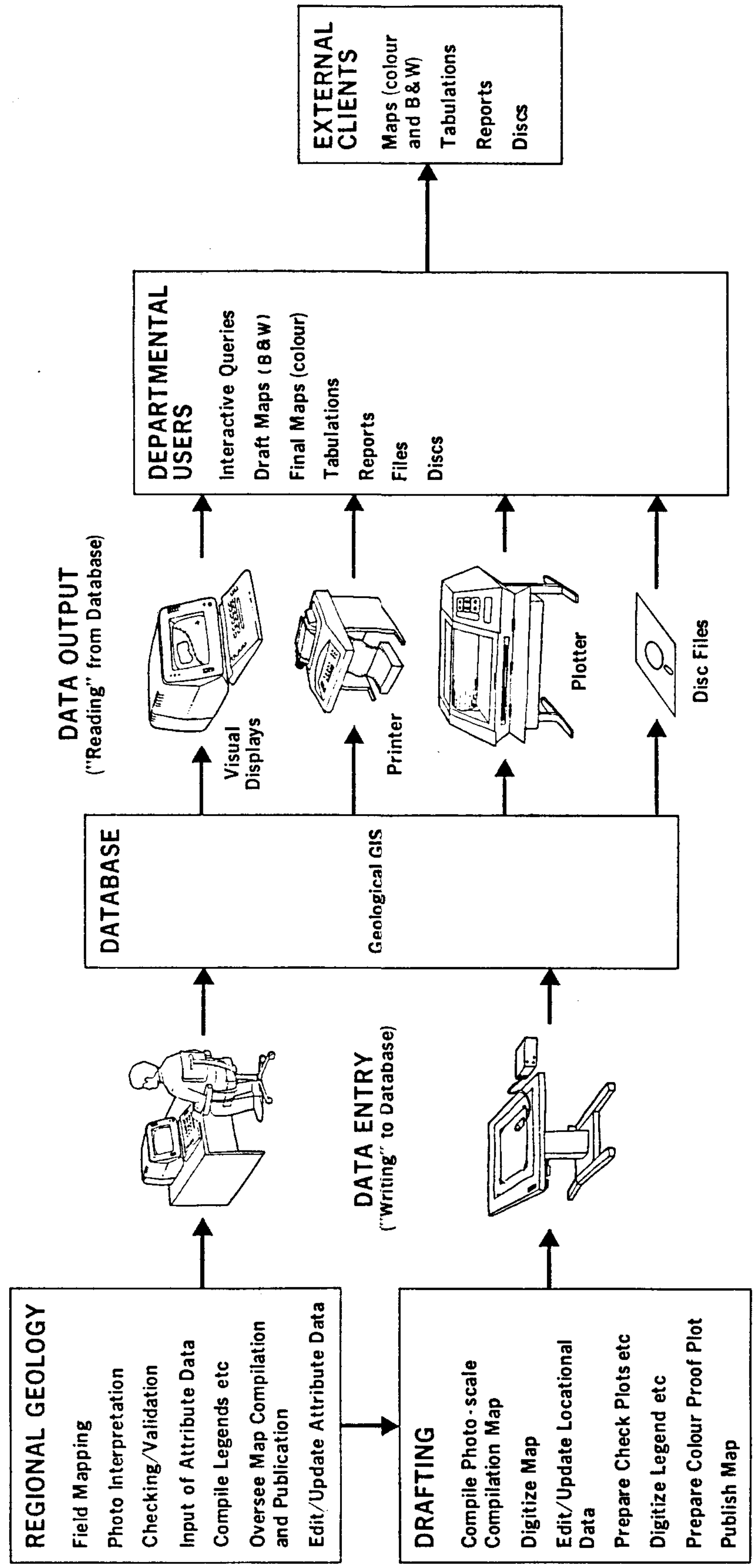


Fig. 6

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

SA_GEOLOGY- DESIGN AND IMPLEMENTATION

COMPONENTS AND PROCEDURES

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DRAWN J. Gray	SCALE		
DATE Jan. 1990	PLAN NUMBER S21229		
CHECKED			

1967

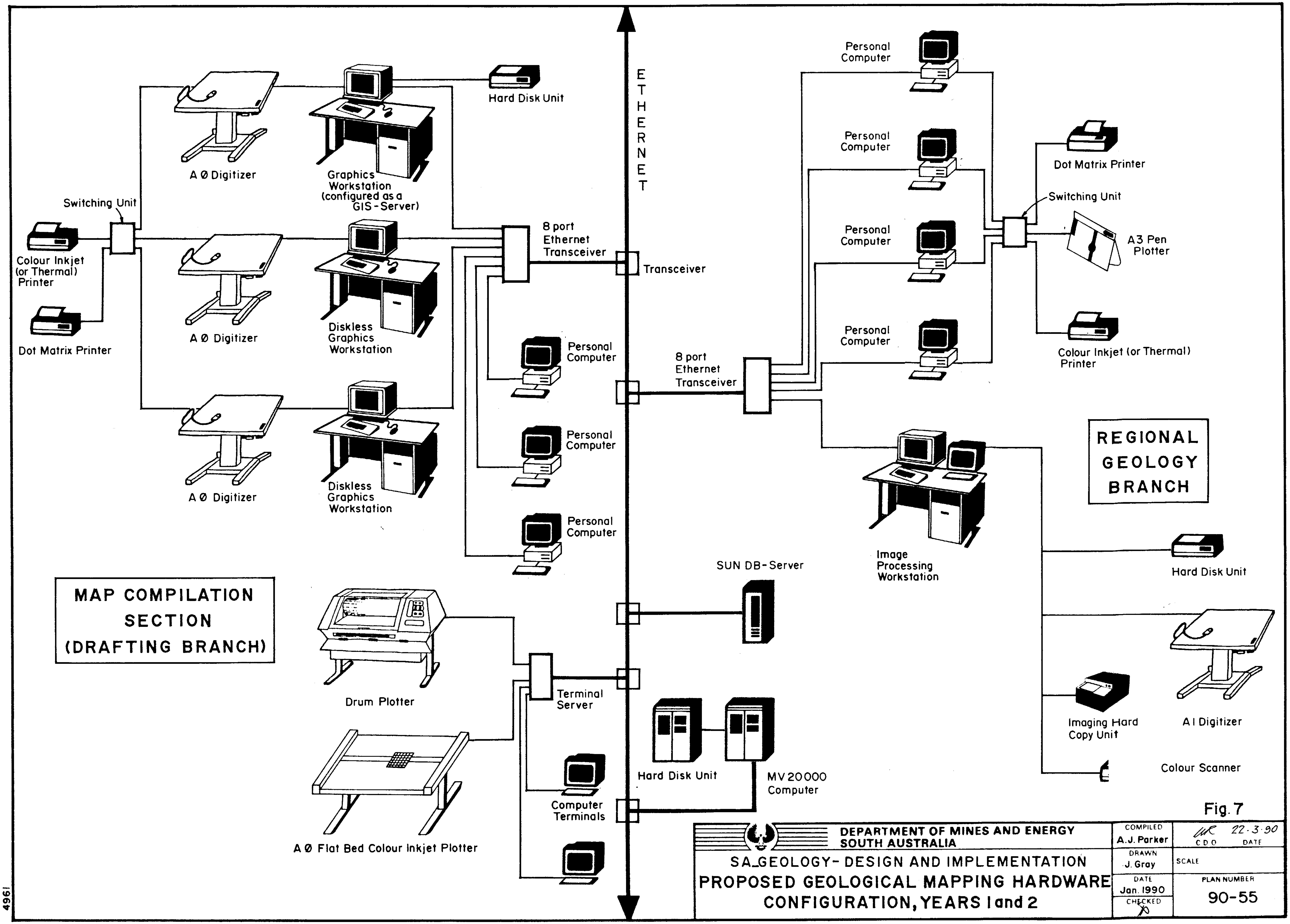


Fig. 7

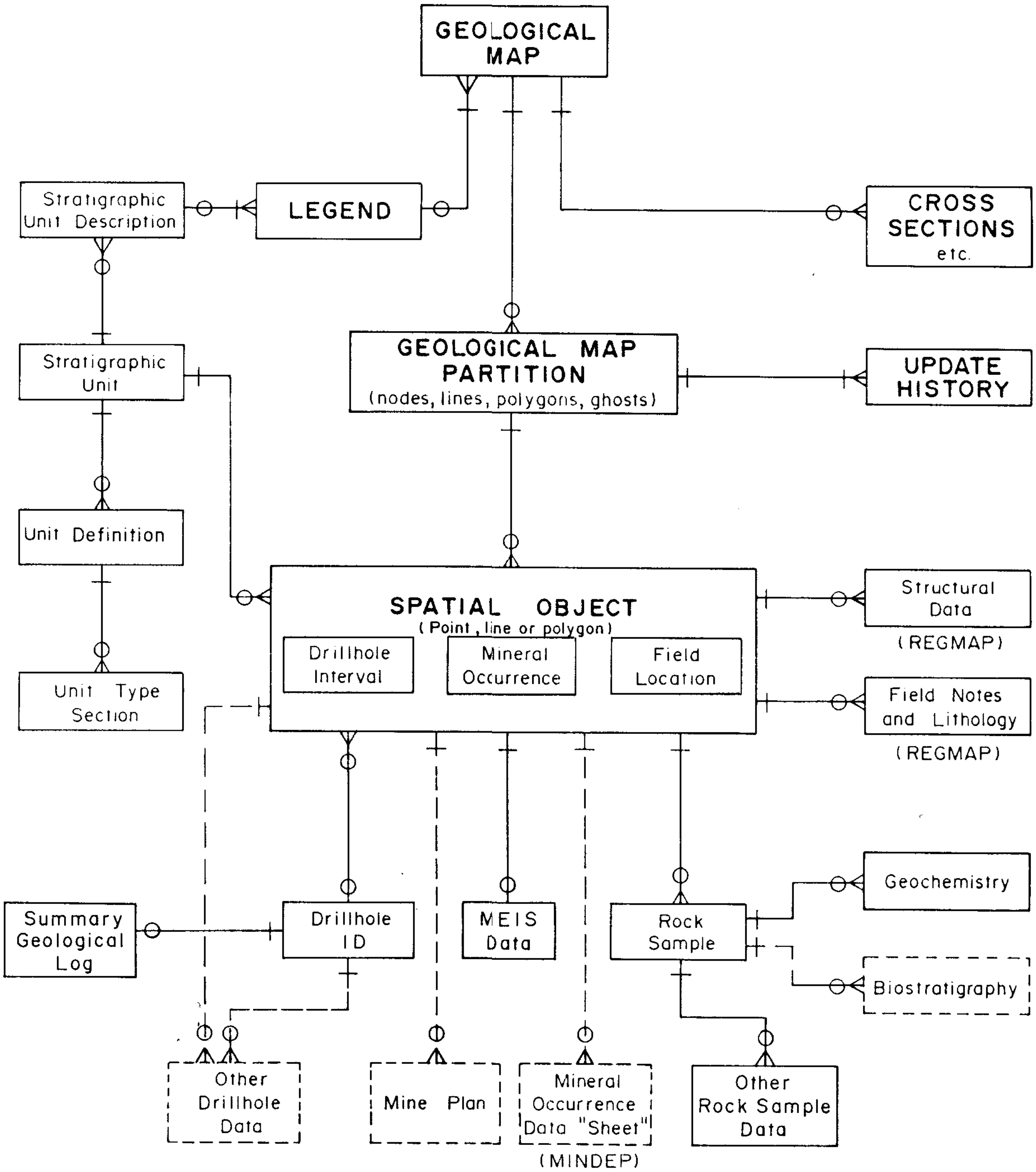
DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA

SA_GEOLOGY- DESIGN AND IMPLEMENTATION

PROPOSED GEOLOGICAL MAPPING HARDWARE CONFIGURATION, YEARS I and 2

COMPILED A.J. Parker | C D O | DATE 22·3·90
DRAWN J. Gray | SCALE
DATE Jan. 1990 | PLAN NUMBER 90-55
CHECKED

4961



KEY

(solid box)	Individual data set.
(dashed box)	Data "outside" SA_GEOLOGY Module
(crow's foot line)	Many-to-One relationship.
(line with circle)	Optional related record.
(line with bar)	Mandatory related record.
REGMAP	Qld. Geol. Survey field data system.
MINDEP	BMR mineral deposits database.
MEIS	Mineral Exploration Index Series

Fig.8

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

SA_GEOLOGY-DESIGN AND IMPLEMENTATION
PROPOSED GEOLOGICAL MAP
DATABASE MODEL

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DRAWN J. Gray	SCALE	
DATE Jan. 1990	PLAN NUMBER S 21231	
CHECKED		

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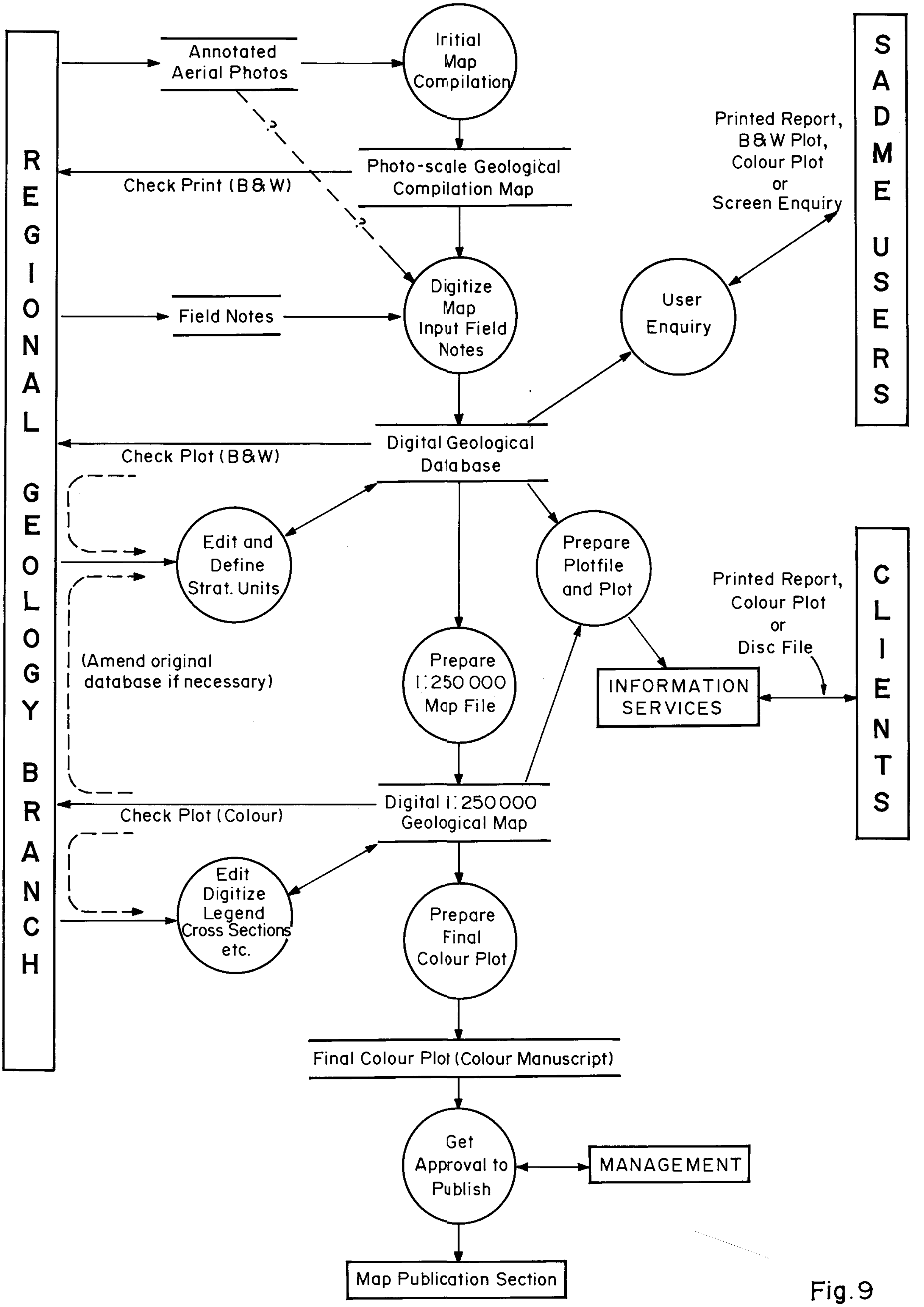

Fig.9

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

SA_GEOLOGY-DESIGN AND IMPLEMENTATION

PROPOSED DIGITAL GEOLOGICAL MAP COMPILATION PROCEDURES

COMPILED	A.J. Parker	C.D.O.	DATE 22-3-90
DRAWN	J. Gray	SCALE	
DATE	Jan. 1990	PLAN NUMBER	S 21230
CHECKED			