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Geological Survey of Victoria

ENGINEERING GEOLOGY OF MELTON - MAP PRESENTATION OF DATA

P G DAHLHAUS

UNPUBLISHED REPORT 1986/6

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DEPARTMENT OF INDUSTRY, TECHNOLOGY AND RESOURCES

ENGINEERING GEOLOGY OF MELTON - MAP PRESENTATION OF DATA

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ABSTRACT

An engineering geological mapping program has been conducted to provide essential geological information for use by planners and engineers working in the Melton Development Area, Victoria.

A review of past and current examples of thematic mapping for land use purposes was initially conducted. A data base of over 800 sampled locations was collated from previous work, and supplemented by additional drilling and testing in areas where little was known of the geological materials. This information was compiled using available computer facilities and combined with traditional field mapping methods. Seven unpublished reports including a map folio presenting individual aspects of the engineering geology was produced.

Computer draughting was used to produce the maps, providing the ability for rapid future revision.

This report reviews the possible methods for production of the engineering geological maps and describes the techniques used.

KEYWORDS: Engineering Geological Mapping, Medium Scale, Soils, Maps, Engineering Geology, Engineering Soils, Kriging, Urban Planning, Hydrogeological Maps

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LIST OF ABBREVIATIONS used in reporting the Melton Engineering Geology Mapping Project.

Abbreviation	Definition
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AHD	Australian Height Datum
AMG	Australian Metric Grid
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AS2870	Australian Standard AS2870 - Residential Slabs and Footings
CAD	Computer Aided Drafting/Design
CBD	Central Business District
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CRB	Country Roads Board
CSIRO	Commenwealth Scientific and Industrial Research Organisation
DITR	Department of Industry, Technology and Resources
DOE	Department of Environment
DVA	Dandenong Valley Authority
ECS	Engineering Computer Services Pty. Ltd.
EDP	Electronic Data Processing
EPA	Environment Protection Authority
F&L	Farley and Lewers Pty Ltd
FAO	Food and Agriculture Organisation
FS	Free Swell
GEOSIS	Geoscience Spatial Information System
GLQ	Genesis-Lithology-Qualifier
GSV	Geological Survey of Victoria
IAEG	International Association of Engineering Geology
IGS	Institute of Geological Sciences
LL	Liquid Limit
LPS	Land Protection Service
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SCS-USDA	Soil Conservation Service - United States Department of Agriculture
TDS	Total Dissolved Solids
UBR	Uniform Building Regulations
ULA	Urban Land Authority
USGS	United States Geological Survey
VBR	Victorian Building Regulations
WHO	World Health Organisation
XRD	X-Ray Diffraction

INTRODUCTION

The City of Melton is located on the Western Highway 39 km WNW of Melbourne and was chosen by the Victorian Government for satellite township development in 1973.

The Melton Engineering Geological Mapping Project commenced in March 1983, as part of an on-going mapping scheme conducted by the Geological Survey of Victoria (GSV), now a branch of the Department of Industry, Technology and Resources (DITR). The project aims at the production of a map (or maps) depicting relevant geological features and properties in a useful manner for engineers and planners working in the Melton Development Area.

An engineering geological map is a thematic map which provides a generalized representation of all those components of a geological environment of significance in land-use planning, and in design, construction and maintenance as applied to civil engineering.

A 'state-of-the-art' review of mapping methods for land-use planning was conducted to examine the past and present progress in a broad context. In particular, medium-scale engineering and environmental mapping methods, and their map presentation formats, were examined.

A review of readily accessible data highlighted shortcomings in both the quality and quantity of data outside of the established City of Melton. Consequently, a drilling, sampling and testing program was conducted. Research of previous work and additional geological mapping supplemented the data analysis. The presentation of the study has been largely cartographic, with each component of the geology being a separate theme on a basic map.

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Unpublished Report 1986/5
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MAP PRESENTATION OF DATA.

1 Maps

Maps provide a structure for storing geographically related knowledge and experience. Without them it would be difficult, if not impossible to conceptualize the larger environment. Moreover, maps provide the means not only for storing information, but for analyzing it, comparing it, generalising or abstracting from it.

The definition of a map can vary considerably; for example:

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* A map should be easy to use. The ideal map requires a minimum of special skills or learning time to use. Abstruse technical data and jargon should be avoided for simplicity of use.

* Maps should be accurate, presenting information without error, distortion, or misrepresentation. Often data is lifted from older maps without checking for accuracy. Exceptions to this principle are propaganda maps or decorative maps, where distortion is intentional.

* The fit between the map and the environment represented should be good. Base information should be sufficient to allow the map user to connect the map to the environment and the environment to the map.

* The language of the map should relate to the elements or qualities represented. Graphic symbols should be standard symbols (eg. crossed picks for a quarry) or otherwise reflect the element represented (eg. armoured tank for a military base).

* A map should be clear, legible and attractive. Legend, scale, title, colours, and text should promote clarity and ease of use.

* Many maps would ideally permit interaction with the user, allowing change, updating, or personalization. The traditional printed map is made interactive only with difficulty and imagination: informational overlays or allowance for the user to make notation are examples. Computer technology can allow changes and updating to be easily made.

2 Scale

The scale of a map indicates its size in relation to the environment portrayed. Obviously, a map must reduce the spatial dimensions of the earth. The map scale is the extent of that reduction in size from the environment to the earth. Specifically, map scale is the ratio of map distance to the ground distance.

The scale relationship between map and reality depends more on the map purpose than anything else. Different map scales have the effect of placing the user at different viewing distances from the environment in a direct relationship between viewing distance and scope of view. Since the space constraint on the greatly reduced map surface is always severe, a functional relationship exists between this poverty of space and the number and detail of phenomena that can be mapped (Fig. 1).

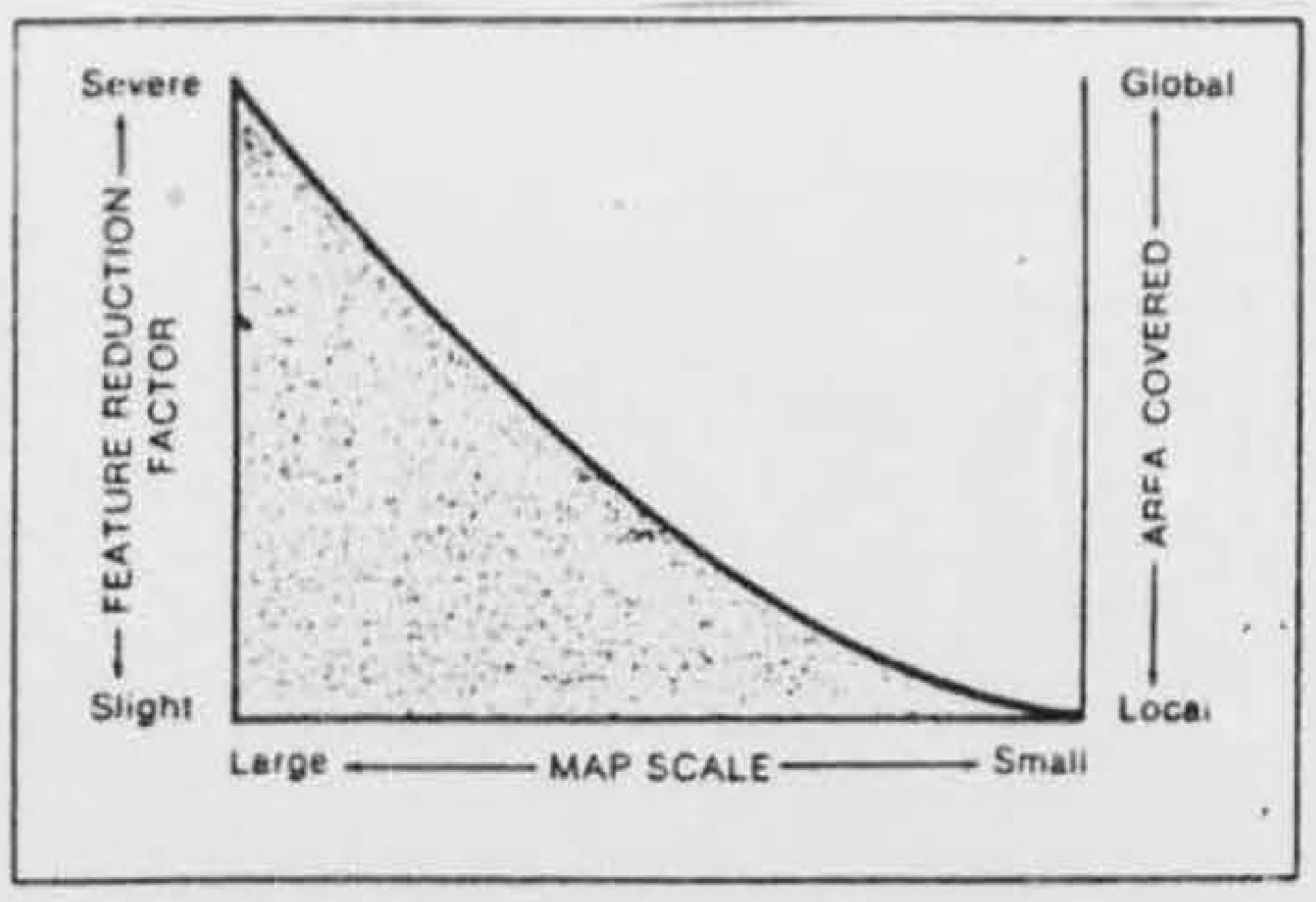


Figure 1. Functional relationship and
poverty of space (Muehrcke, 1978).
The more area a map covers, the less detail that can be shown. maps which cover large areas provide little detail.

Map scale is not independant of the dimensional character of mapped phenomena. In other words, there is a close relationship between the scale of the map and the way it represents environmental features of different sizes. What at large scale seems to be a boundary concern, at small scale becomes a simple matter of location. For example, a city which can be shown clearly on large scale map, becomes a mere point on a smaller scale map of the surrounding region. Thus, the choice of scale and variable to be mapped are totally interrelated. Choosing the scale can be greatly influenced by the number of variables to be depicted, the accuracy to which they are to be presented, and the confidence that the map is to portray.

3 Perception

Only in relatively recent years has map use been seriously studied, and much has been written on that subject (eg. Muehrcke, 1980; Taylor, ed. 1983). The concept of mental maps or cognitive mapping (Gould and White, 1974) has made map makers aware of the importance of an individual's perception of the environment. Many experiments with mental maps have been conducted to show that a map drawn from memory, of a familiar place (for example, one's own neighourhood), rarely corresponds precisely with cartographic maps. Instead it is likely to portary the biases in the individual's environmental images - important things are often closer or larger than they really are.

Simplification of the environment through mapping is nothing but an illusion which appeals to our limited information-processing ability. While the environment remains unchanged, a map can model of a portion of it, on a flat small surface, to assist in simplifying the confusion of information. Yet it is the environment that the map user is trying to understand.

The credibility of maps is also an important consideration. Some map features are distortions; others are errors; and some may have been omitted by oversight or design. So many perversions of reality are inherent in the the mapping process that the result may be best viewed as an intricate, controlled fiction. Maps are like statistics in the sense that they can be made to show nearly anything that is desired (Fig. 2).

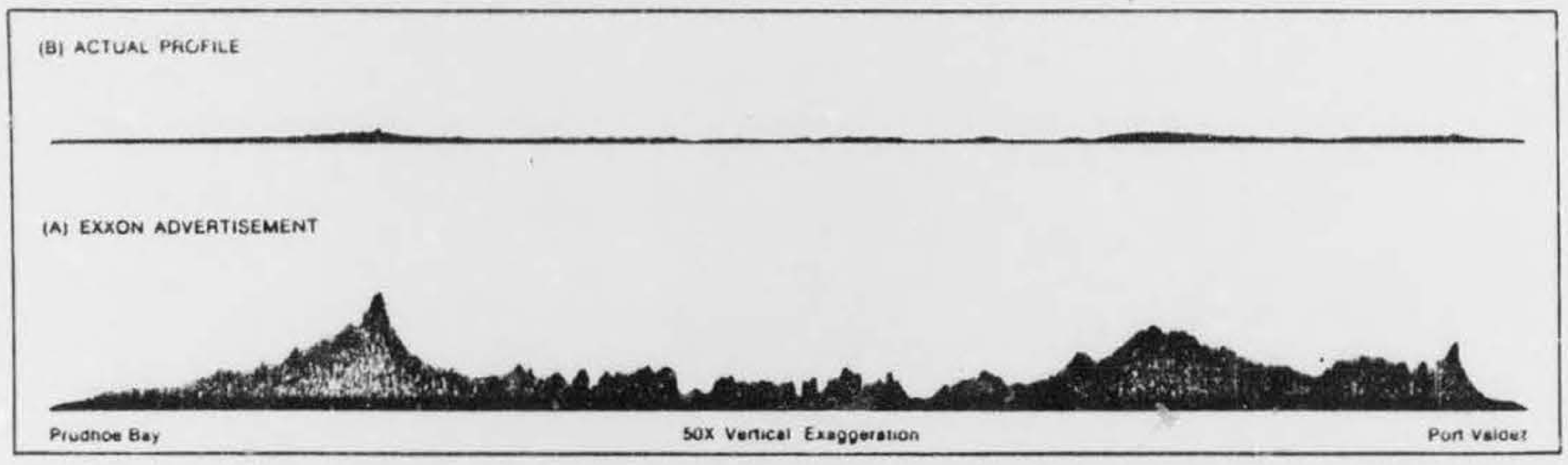


Figure 2. Use of vertical scale to exaggerate severity of topography.
By exaggerating the vertical dimension 50 times in this advertisement showing the Alaska pipeline, Exxon can demonstrate the engineering difficulties in construction by which they justify the higher fuel prices.

Similarly, in the strive for visual impact, there is a danger that a map's pictorial suggestiveness will be confused with proof or explanation. Map patterns and relations are deceptively simple, although no cause-effect interpretations are intended by the map maker. Just because things are close together on the map doesn't mean that they have any relation to one another, and simply because there is a pattern on a map doesn't mean that it has any spatial meaning.

Many map features are pure cartographic fiction - the result of the mapping process. In the process of organizing and reducing the detail of the environment onto a map, the transformation may add map features which bear little or no relation to attributes of reality. The danger is that the effects of generalization will so dominate the look of maps that the user mistakes them for aspects of the environment.

Photomaps provide a particularly good illustration of the hazards of map abuse because so many people don't think of photographs as maps at all. Photographs, as the reasoning goes, can never contain misleading artifacts, since they show the environment exactly as it is. This can be one of the biggest pitfalls of map perception. The New Zealand Geological Survey has used photomaps as bases onto which engineering geological data was plotted in an 1:25000 'industrial map' series (eg. Kear, Schofield & Kermode, 1964; Kermode, 1966; Kermode & Searle, 1966;). However, production of these maps were soon discontinued when it was found that map users imposed an unjustified reality on the maps. People could clearly identify exactly where the geological boundaries were - and show exactly where the maps were in error.

To guard against litigation arising from map abuse, disclaimers or cautionary notes have been used on some maps. The environmental geology sheets prepared for the Glenrothes district, Fife region, Scotland (Nickless, 1982) carry the following cautionary note:

> "This map is to be used only for preliminary studies and is not intended as a substitute for on-site investigation."

The use of disclaimers in regard to geotechnical information has been commonplace in tender documents and contracts for some time (Aust. Geomech. Soc., 1983), even though lawyers frequently warn that disclaimers of liability are notoriously difficult to enforce as effective protection against actions (Tyrril, 1983). Maps such as soil depth maps are extremely liable to abuse in the drafting of contract specifications, and cautionary notes should always be included to warn against misuse.

4 Map Production Methods

Two distinctions are made in the preparation of materials to be reproduced. First, is the difference between camera-ready work and the use of separations; and second, the use of positive art work versus negative art work. A complete discussion of the techniques embraced by these terms is not appropriate here; but a brief definitions (Cuff and Mattson, 1982) are provided as follows:

Camera-ready art work leaves the drafting table as a map, graph or other illustration that is essentially complete. Its features are simply reproduced, in the literal sense, without alteration.

The use of separations requires the draftsman to produce separate pieces of art that constitute different elements of the final product. These pieces are photographed to make a series of negatives whose features are combined when the printing plate is produced.

The terms positive and negative art work are used in the same sense as in photography.

Figure 3 summarizes the four possible modes of cartographic production.

	CAMERA-READY	USE OF SEPARATIONS
POSITIVE ARTWORK	Usual for low-cost illustrations for theses , journal articals, or books printed in one ink	For superior maps in journals, books, or atlases printed in one or more inks
NEGATIVE ARTWORK	(This combination not practical)	Usual in high-volume government mapping operations using black and colored inks

Figure 3. Modes of cartographic production.

4.1 Computer-aided map production

The use of computers in map production has, in recent years, evolved from a novelty to a technology that is relied on for day to day map production. Automation has brought to cartography unprecedented speed of production, reliability, flexibility in design, and ease of revision. Some of the technical advances have eased and speeded up the production of conventional looking map products. But in addition, computer use has made widely accessible some interesting graphics that are difficult to produce without the aid of machines.

The ability to produce maps quickly from information stored on magnetic tapes or discs has substantially changed the concept of a map. No longer are maps limited to precious paper copies - products of labour intensive compiling, drafting, photography, plate making, and printing. The permanent map can be replaced by the ephemeral map - a short lived version on a computer terminal screen, or 'today's version' drawn on an automatic plotter. Scale, content, symbolization, colour, and geographic scope can be immediately revised.

Some of the traits of computer-aided map production are analogous to the use of separation techniques defined in section 3. A base map, for instance, exists as a record of digitally coded roads, rivers, and railway lines. All or part of the map may be summoned and associated with some selected data which, too, are stored and await use or revision. If there is data revision to be made, only the data file need be altered. If some feature on a base map needs improvement, only the base file need be dealt with. The difference between the traditional map separates and the computerized version is that revisions are made only to the electromagnetic record - not to a paper copy, negative, or a scribed sheet. The physical maps are seen as just temporary and perhaps obsolete expressions of the mappable data. The latest and most suitable map resides in some combination of base features and data that exist in digital form, and can be produced virtually on demand.

It is through the use of one base that computerised map production really justifies the effort of converting base maps into digital form. In a well equiped and well conceived mapping facility, a map maker can quickly combine a number of different variables with one base to make a series of maps. Or, experiments can be carried out with different presentations of the same data set - changing the map scale, projection, symbolization, pen colours or legend.

The capability to manipulate digital map bases and combine them at will with old and new data sets converted to symbolic form is, unfortunately, not commonplace. It exists only at facilities that have the necessary computer hardware combined with appropriate computer software.

The equipment needed for computer-aided map production can be grouped into three categories: devices for input, for processing, and for output. Input devices generally include tape readers and/or disc drives for loading digital information into a processor or storage. In mapping applications, however, input devices are needed to convert images into digital form so they can be stored, manipulated, and mapped. These vary from sophisticated scanners to relatively simple digitisers.

In general, the processor is a computer in which the data can be sorted and subjected to mathematical operations before being mapped. The operations carried out by the computer are directed by the program (software), which would be especially written for cartographic needs in mind. In the last few years much of the hardware and software aspects of the processing have become inter-dependant, and are marketed as Computer Aided Drafting (CAD) packages. An example of this is the INTERGRAPH system which is marketed as a workstation comprising input, processing and output devices especially tailored to the software.

The output device dictates the overall appearance and character of the map or graphic that is produced. Some devices produce images that can be immediately recognised as computer products, while others imitate conventional maps. The most successful at producing hard-copy products are pen plotters, ink-jet plotters, electrostatic plotters, and laser printers. Pen plotters are simply robot draftsmen, moving pen across paper with startling speed and accuracy, as commanded by the computer program. The other devices, however, make use of scanning techniques, building an image up line by line, to produce quite complex maps at remarkable speed. Producing maps using these scanning devices is far more efficient than directing a mechanical plotter to chase here and there across the map as it traces the various lines and lettering elements that make up the map.

Besides the CAD packages now available, recent changes in microcomputer technology have facilitated the creation of map information systems also called Geographic Information Systems or Spatial Information Systems. These systems are designed to include data base information as well as the map files.

A Geoscience Spatial Information System (GEOSIS) is being designed by the Ontario Ministry of Northern Development and Mines (Canada) to provide users from industry, governments and universities the access to geoscience data at their place of work. Documents such as geological reports, mining licence and lease details, and property descriptions are entered into the database by the use of scanners. The Ontario Geological Survey (OGS) has developed a computer field note system which will permit field notes to be recorded directly into a portable computer at base camp. The notes may be transferred onto an in-house computer to reorganise and process the data as requested by the geologist. Map data is input through raster scanning techniques (Fig. 4).

The real strength of systems like GEOSIS is that they allow the user to perform searches of the map database. Examples are shown in Figure 5. A typical search of the map database by the geologist would include:

Search 1: Find all locations where two map units (eg. Silurian mudstone and Tertiary gravels) share a common boundary.

Search 2: Search 1 + where a fault intersects that boundary

Search 3: Search 2 + where boreholes are located within 2 kilometres of the fault and common boundary.

A pilot study by the OGS is due for completion in 1987, and aims to allow the user to:

- Use a microcomputer with the OGS map graphics file of area under study.
- Select or deselect data from the OGS map graphics file.
- Query host system database using locally displayed OGS map graphics file.
- Display user's map graphics data superimposed on OGS map graphics file.
- Print out in colour the map graphics on a colour plotter.

Each map would be a unique combination of map graphics and data base information, as current as the information system, tailored to suit the user's needs.

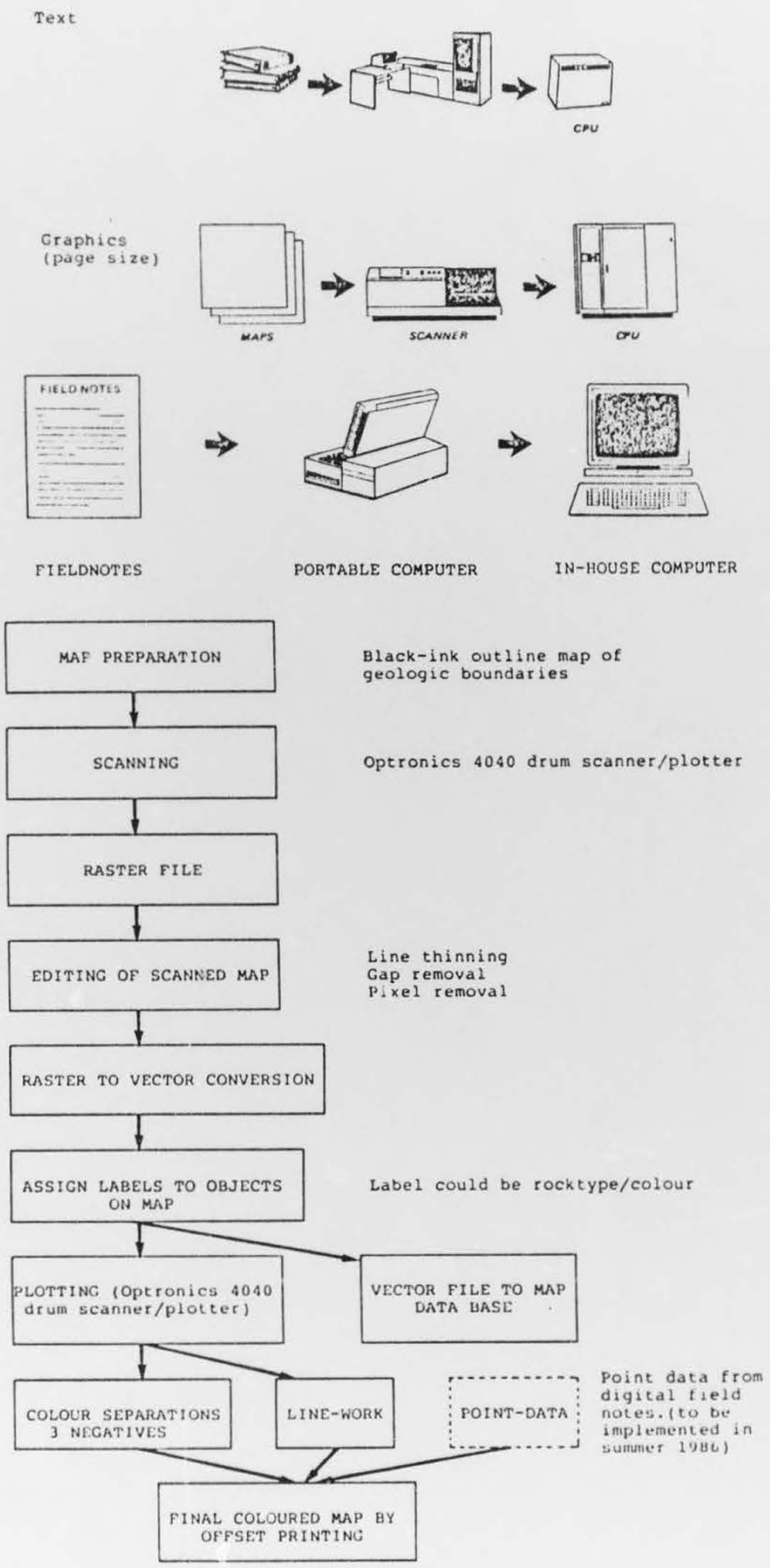
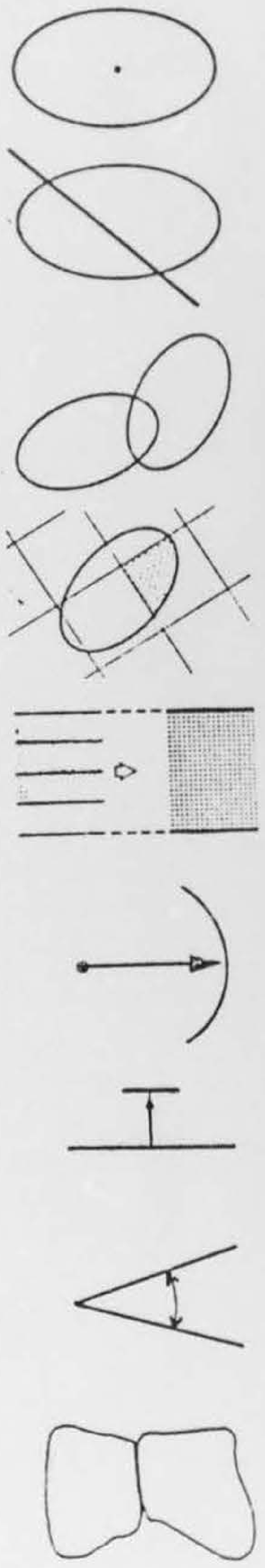


Figure 4. GEOSIS database elements. (GEOSIS newsletter, 1986)



Point in polygon	- Gold occurrences in metasediments
Polygon-line intersect	- Fault cutting granite
Polygon-polygon intersect	- Intersection of geochem anomaly with geological unit
Polygon overlay	- Portion of rock unit covered by claim
Polygon generalization	- Conglomerate + arkose + argillite = sediments
Distance from point	- Gold occurrence within 10 km radius
Distance from line	- All occurrences within 1 km of contact
Arc of search	-
Adjacent polygons	- Highlight all granite-metasediment contacts

Figure 5. Possible methods for GEOSIS database search. (GEOSIS newsletter, 1986)

5 Melton Engineering Geological Map Production

Essentially, the choice of viable map production methods for the Melton engineering geological mapping project was between the conventional drafting methods and the available computer methods. Computer production of maps has not been available to the Geological Survey in the past, as the hardware has been only recently purchased. The following devices were available:

Data input:
'Tektronix' and 'Digital' Graphic Screens
'GRCO' Digitising table

Processing:
'VAX 11/780' mini computer

Output:
'Benson' 3 pen plotter
'Calcomp' 8 pen plotter
'Tektronix' ink-jet colour plotter (A4 size only)

Available software was limited to a general purpose interactive gridding and contouring package (GPCINT) supplied by ECS.

Although the hardware and software was not particularly suited to the task, computer production was chosen for the following reasons:

- To avoid the drafting backlog, which meant that map production was not held in a queue for three years or more.

- There is flexibility of map scales so that several maps could be produced at appropriate scales, using the same base.

- Revision could be easily carried out as more data was made available. New versions could be drafted as required, which would make the map a more desirable working tool.

- A relatively small market did not justify the expense of full colour production to cartographic standards.

The concept of map folio production, similar to the Glenrothes environmental maps (Nickless, 1982), compliments the computer production method. A map folio allows:

- Flexibility of scale, so that individual maps can be produced at scales appropriate to their intended use;

- Easier revision of a singular component, such as soil depth, standing water level, or geology;

- Clarity in representing each aspect of the engineering geology, by avoiding a single cluttered map, especially using the available resources which do not allow much variety in symbols.

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- A map should be suited to the needs of its users. The purpose of the map must be narrowly and precisely defined so that non-essential data can be excluded.

- A map should be easy to use. The ideal map requires a minimum of special skills or learning time to use. Abstruse technical data and jargon should be avoided for simplicity of use.

- Maps should be accurate, presenting information without error, distortion, or misrepresentation. Often data is lifted from older maps without checking for accuracy. Exceptions to this principle are propaganda maps or decorative maps, where distortion is intentional.

- The fit between the map and the environment represented should be good. Base information should be sufficient to allow the map user to connect the map to the environment and the environment to the map.

- The language of the map should relate to the elements or qualities represented. Graphic symbols should be standard symbols (eg. crossed picks for a quarry) or otherwise reflect the element represented (eg. armoured tank for a military base).

- A map should be clear, legible and attractive. Legend, scale, title, colours, and text should promote clarity and ease of use.

- Many maps would ideally permit interaction with the user, allowing change, updating, or personalization. The traditional printed map is made interactive only with difficulty and imagination: informational overlays or allowance for the user to make notation are examples. Computer technology can allow changes and updating to be easily made.

2 Scale

The scale of a map indicates its size in relation to the environment portrayed. Obviously, a map must reduce the spatial dimensions of the earth. The map scale is the extent of that reduction in size from the environment to the earth. Specifically, map scale is the ratio of map distance to the ground distance.

The scale relationship between map and reality depends more on the map purpose than anything else. Different map scales have the effect of placing the user at different viewing distances from the environment in a direct relationship between viewing distance and scope of view. Since the space constraint on the greatly reduced map surface is always severe, a functional relationship exists between this poverty of space and the number and detail of phenomena that can be mapped (Fig. 1).

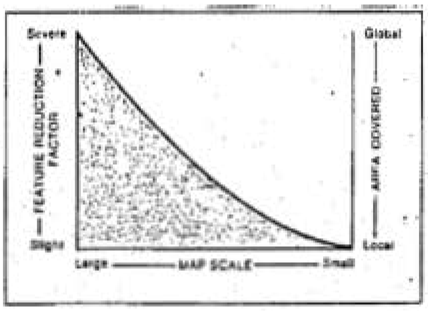


Figure 1. Functional relationship and
poverty of space (Muehrcke, 1978).
The more area a map covers, the less detail that can be
shown. maps which cover large areas provide little detail.

Map scale is not independant of the dimensional character of mapped phenomena. In other words, there is a close relationship between the scale of the map and the way it represents environmental features of different sizes. What at large scale seems to be a boundary concern, at small scale becomes a simple matter of location. For example, a city which can be shown clearly on large scale map, becomes a mere point on a smaller scale map of the surrounding region. Thus, the choice of scale and variable to be mapped are totally interrelated. Choosing the scale can be greatly influenced by the number of variables to be depicted, the accuracy to which they are to be presented, and the confidence that the map is to portray.

3 Perception

Only in relatively recent years has map use been seriously studied, and much has been written on that subject (eg. Muehrcke, 1980; Taylor, ed. 1983). The concept of mental maps or cognitive mapping (Gould and White, 1974) has made map makers aware of the importance of an individual's perception of the environment. Many experiments with mental maps have been conducted to show that a map drawn from memory, of a familiar place (for example, one's own neighourhood), rarely corresponds precisely with cartographic maps. Instead it is likely to portary the biases in the individual's environmental images - important things are often closer or larger than they really are.

Simplification of the environment through mapping is nothing but an illusion which appeals to our limited information-processing ability. While the environment remains unchanged, a map can model of a portion of it, on a flat small surface, to assist in simplifying the confusion of information. Yet it is the environment that the map user is trying to understand.

The credibility of maps is also an important consideration. Some map features are distortions; others are errors; and some may have been omitted by oversight or design. So many perversions of reality are inherent in the the mapping process that the result may be best viewed as an intricate, controlled fiction. Maps are like statistics in the sense that they can be made to show nearly anything that is desired (Fig. 2).

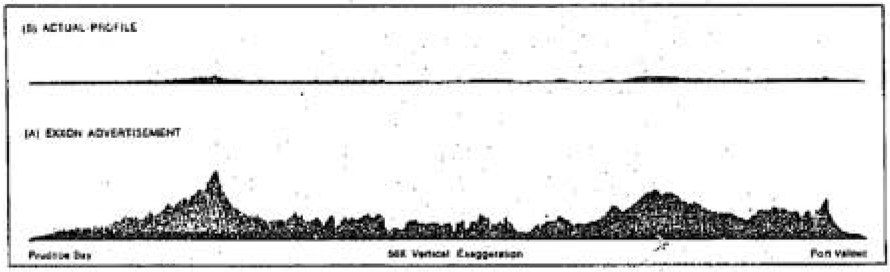


Figure 2. Use of vertical scale to exaggerate severity of topography.
By exaggerating the vertical dimension 50 times in this advertisement showing the Alaska pipeline, Exxon can demonstrate the engineering difficulties in construction by which they justify the higher fuel prices.

Similarly, in the strive for visual impact, there is a danger that a map's pictorial suggestiveness will be confused with proof or explanation. Map patterns and relations are deceptively simple, although no cause-effect interpretations are intended by the map maker. Just because things are close together on the map doesn't mean that they have any relation to one another, and simply because there is a pattern on a map doesn't mean that it has any spatial meaning.

Many map features are pure cartographic fiction - the result of the mapping process. In the process of organizing and reducing the detail of the environment onto a map, the transformation may add map features which bear little or no relation to attributes of reality. The danger is that the effects of generalization will so dominate the look of maps that the user mistakes them for aspects of the environment.

Photomaps provide a particularly good illustration of the hazards of map abuse because so many people don't think of photographs as maps at all. Photographs, as the reasoning goes, can never contain misleading artifacts, since they show the environment exactly as it is. This can be one of the biggest pitfalls of map perception. The New Zealand Geological Survey has used photomaps as bases onto which engineering geological data was plotted in an 1:25000 'industrial map' series (eg. Kear, Schofield & Kermode, 1964; Kermode, 1966; Kermode & Searle, 1966;). However, production of these maps were soon discontinued when it was found that map users imposed an unjustified reality on the maps. People could clearly identify exactly where the geological boundaries were - and show exactly where the maps were in error.

To guard against litigation arising from map abuse, disclaimers or cautionary notes have been used on some maps. The environmental geology sheets prepared for the Glenrothes district, Fife region, Scotland (Nickless, 1982) carry the following cautionary note:

> "This map is to be used only for preliminary studies and is not intended as a substitute for on-site investigation."

The use of disclaimers in regard to geotechnical information has been commonplace in tender documents and contracts for some time (Aust. Geomech. Soc., 1983), even though lawyers frequently warn that disclaimers of liability are notoriously difficult to enforce as effective protection against actions (Tyrril, 1983). Maps such as soil depth maps are extremely liable to abuse in the drafting of contract specifications, and cautionary notes should always be included to warn against misuse.

4 Map Production Methods

Two distinctions are made in the preparation of materials to be reproduced. First, is the difference between camera-ready work and the use of separations; and second, the use of positive art work versus negative art work. A complete discussion of the techniques embraced by these terms is not appropriate here; but a brief definitions (Cuff and Mattson, 1982) are provided as follows:

Camera-ready art work leaves the drafting table as a map, graph or other illustration that is essentially complete. Its features are simply reproduced, in the literal sense, without alteration.

The use of separations requires the draftsman to produce separate pieces of art that constitute different elements of the final product. These pieces are photographed to make a series of negatives whose features are combined when the printing plate is produced.

The terms positive and negative art work are used in the same sense as in photography.

Figure 3 summarizes the four possible modes of cartographic production.

	CAMERA-READY	USE OF SEPARATIONS
POSITIVE ARTWORK	Usual for low-cost illustrations for theses , journal articals, or books printed in one ink	For superior maps in journals, books, or atlases printed in one or more ink.
NEGATIVE ARTWORK	(This combination not practical)	Usual in high-volume government mapping operations using black and colored inks

Figure 3. Modes of cartographic production.

4.1 Computer-aided map production

The use of computers in map production has, in recent years, evolved from a novelty to a technology that is relied on for day to day map production. Automation has brought to cartography unprecedented speed of production, reliability, flexibility in design, and ease of revision. Some of the technical advances have eased and speeded up the production of conventional looking map products. But in addition, computer use has made widely accessible some interesting graphics that are difficult to produce without the aid of machines.

The ability to produce maps quickly from information stored on magnetic tapes or discs has substantially changed the concept of a map. No longer are maps limited to precious paper copies - products of labour intensive compiling, drafting, photography, plate making, and printing. The permanent map can be replaced by the ephemeral map - a short lived version on a computer terminal screen, or 'today's version' drawn on an automatic plotter. Scale, content, symbolization, colour, and geographic scope can be immediately revised.

Some of the traits of computer-aided map production are analogous to the use of separation techniques defined in section 3. A base map, for instance, exists as a record of digitally coded roads, rivers, and railway lines. All or part of the map may be summoned and associated with some selected data which, too, are stored and await use or revision. If there is data revision to be made, only the data file need be altered. If some feature on a base map needs improvement, only the base file need be dealt with. The difference between the traditional map separates and the computerized version is that revisions are made only to the electromagnetic record - not to a paper copy, negative, or a scribed sheet. The physical maps are seen as just temporary and perhaps obsolete expressions of the mappable data. The latest and most suitable map resides in some combination of base features and data that exist in digital form, and can be produced virtually on demand.

It is through the use of one base that computerised map production really justifies the effort of converting base maps into digital form. In a well equiped and well conceived mapping facility, a map maker can quickly combine a number of different variables with one base to make a series of maps. Or, experiments can be carried out with different presentations of the same data set - changing the map scale, projection, symbolization, pen colours or legend.

The capability to manipulate digital map bases and combine them at will with old and new data sets converted to symbolic form is, unfortunately, not commonplace. It exists only at facilities that have the necessary computer hardware combined with appropriate computer software.

The equipment needed for computer-aided map production can be grouped into three categories: devices for input, for processing, and for output. Input devices generally include tape readers and/or disc drives for loading digital information into a processor or storage. In mapping applications, however, input devices are needed to convert images into digital form so they can be stored, manipulated, and mapped. These vary from sophisticated scanners to relatively simple digitisers.

In general, the processor is a computer in which the data can be sorted and subjected to mathematical operations before being mapped. The operations carried out by the computer are directed by the program (software), which would be especially written for cartographic needs in mind. In the last few years much of the hardware and software aspects of the processing have become inter-dependant, and are marketed as Computer Aided Drafting (CAD) packages. An example of this is the INTERGRAPH system which is marketed as a workstation comprising input, processing and output devices especially tailored to the software.

The output device dictates the overall appearance and character of the map or graphic that is produced. Some devices produce images that can be immediately recognised as computer products, while others imitate conventional maps. The most successful at producing hard-copy products are pen plotters, ink-jet plotters, electrostatic plotters, and laser printers. Pen plotters are simply robot draftsmen, moving pen across paper with startling speed and accuracy, as commanded by the computer program. The other devices, however, make use of scanning techniques, building an image up line by line, to produce quite complex maps at remarkable speed. Producing maps using these scanning devices is far more efficient than directing a mechanical plotter to chase here and there across the map as it traces the various lines and lettering elements that make up the map.

Besides the CAD packages now available, recent changes in microcomputer technology have facilitated the creation of map information systems also called Geographic Information Systems or Spatial Information Systems. These systems are designed to include data base information as well as the map files.

A Geoscience Spatial Information System (GEOSIS) is being designed by the Ontario Ministry of Northern Development and Mines (Canada) to provide users from industry, governments and universities the access to geoscience data at their place of work. Documents such as geological reports, mining licence and lease details, and property descriptions are entered into the database by the use of scanners. The Ontario Geological Survey (OGS) has developed a computer field note system which will permit field notes to be recorded directly into a portable computer at base camp. The notes may be transferred onto an in-house computer to reorganise and process the data as requested by the geologist. Map data is input through raster scanning techniques (Fig. 4).

The real strength of systems like GEOSIS is that they allow the user to perform searches of the map database. Examples are shown in Figure 5. A typical search of the map database by the geologist would include:

Search 1: Find all locations where two map units (eg. Silurian mudstone and Tertiary gravels) share a common boundary.

Search 2: Search 1 + where a fault intersects that boundary

Search 3: Search 2 + where boreholes are located within 2 kilometres of the fault and common boundary.

A pilot study by the OGS is due for completion in 1987, and aims to allow the user to:

- Use a microcomputer with the OGS map graphics file of area under study.
- Select or deselect data from the OGS map graphics file.
- Query host system database using locally displayed OGS map graphics file.
- Display user's map graphics data superimposed on OGS map graphics file.
- Print out in colour the map graphics on a colour plotter.

Each map would be a unique combination of map graphics and data base information, as current as the information system, tailored to suit the user's needs.

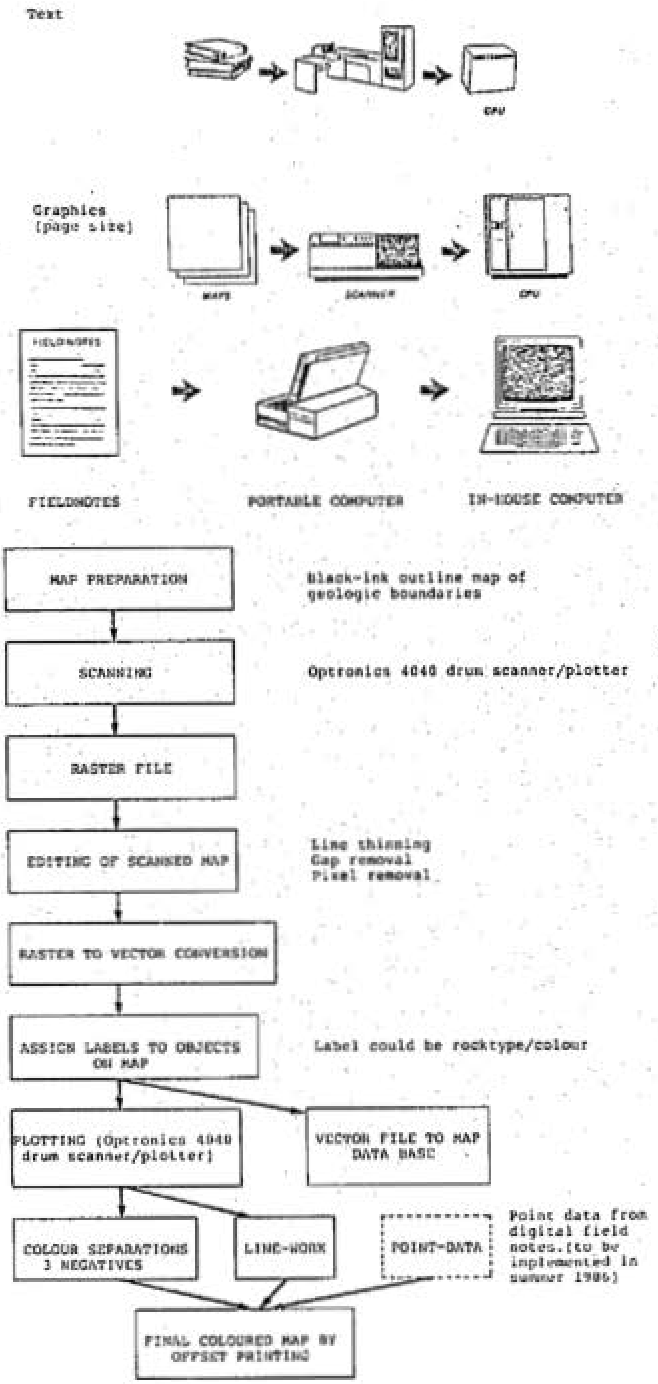
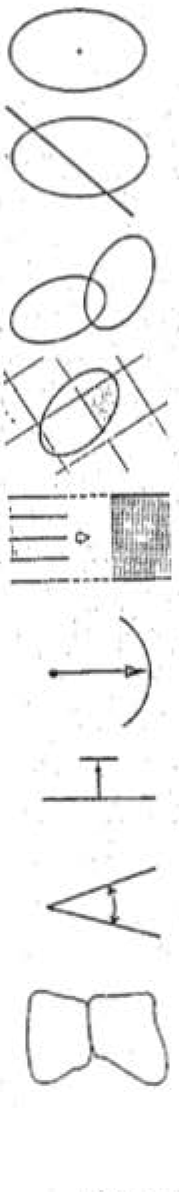


Figure 4. GEOSIS database elements. (GEOSIS newsletter, 1986)



Point in polygon - Gold occurrences in metasediments

Polygon-line intersect - Fault cutting granite

Polygon-polygon intersect - Intersection of geochem anomaly with geological unit

Polygon overlay - Portion of rock unit covered by claim

Polygon generalization - Conglomerate + arkose + argillite = sediments

Distance from point - Gold occurrence within 10 km radius

Distance from line - All occurrences within 1 km of contact

Arc of search -

Adjacent polygons - Highlight all granite-metasediment contacts

Figure 5. Possible methods for GEOSIS database search.
(GEOSIS newsletter, 1986)

5 Melton Engineering Geological Map Production

Essentially, the choice of viable map production methods for the Melton engineering geological mapping project was between the conventional drafting methods and the available computer methods. Computer production of maps has not been available to the Geological Survey in the past, as the hardware has been only recently purchased. The following devices were available:

Data input:
'Tektronix' and 'Digital' Graphic Screens
'GRCO' Digitising table

Processing:
'VAX 11/780' mini computer

Output:
'Benson' 3 pen plotter
'Calcomp' 8 pen plotter
'Tektronix' ink-jet colour plotter (A4 size only)

Available software was limited to a general purpose interactive gridding and contouring package (GPCINT) supplied by ECS.

Although the hardware and software was not particularly suited to the task, computer production was chosen for the following reasons:

- To avoid the drafting backlog, which meant that map production was not held in a queue for three years or more.
- There is flexibility of map scales so that several maps could be produced at appropriate scales, using the same base.
- Revision could be easily carried out as more data was made available. New versions could be drafted as required, which would make the map a more desirable working tool.
- A relatively small market did not justify the expense of full colour production to cartographic standards.

The concept of map folio production, similar to the Glenrothes environmental maps (Nickless, 1982), compliments the computer production method. A map folio allows:

- Flexibility of scale, so that individual maps can be produced at scales appropriate to their intended use;
- Easier revision of a singular component, such as soil depth, standing water level, or geology;
- Clarity in representing each aspect of the engineering geology, by avoiding a single cluttered map, especially using the available resources which do not allow much variety in symbols.