

50 Years of Potential Field Modelling

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Introduction

The history of potential field modelling in Australian mineral exploration goes back many years but the most dramatic changes have taken place in the last 10 years. The changes over the next 10 years promise to be more spectacular as computer and software performance continue to improve. The author started his career in geophysics with a slide rule, log tables and many pre-calculated interpretation charts. When first exposed to the power of computing in the mid 60's, the sensation was akin to stepping off a bicycle and sitting behind the wheel of a Porsche. Life has never been the same since.

This brief history of Australian potential field modelling has been prepared with a focus on the everyday tools available to the practising exploration geophysicist rather than advanced research and academic publications. Practical interpretation modelling is closely related to the computing resources available at the time, so it is appropriate to present a snapshot of the computing tools used by interpreters over the last 50 years.

Moore's Law

In 1970 Dr. Gordon Moore a co-founder of Intel Corporation predicted that the transistor capacity of an integrated circuit would double each year. In 1975 Moore revised his prediction to a doubling every 18 months. As can be seen in the graph below, his vision has proved close to reality.

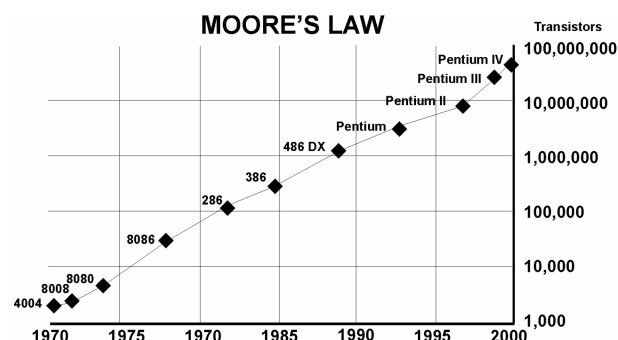


Figure 1. Transistor density on Intel cpu chips from 1970 to 2000. Graphic courtesy of Intel Corporation (www.intel.com).

Moore's Law provides a realistic way of predicting the rate of change in computing power that we can expect

from our desktop computers and this, in turn, allows us to plan strategies that will utilise this increased capacity.

Transistor density as shown in this graph does not provide the complete story, because the execution speed of these computer chips has increased from around 1 MHz in 1980 to 2 GHz in 2002. Geophysical modelling is computationally intensive and historical benchmarks provide a better guide to performance changes over time. A useful set of benchmarks can be found at <http://field.hypermart.net/CPU/cpu.htm>. This site reveals that the computational performance improvement from the Intel 386 (1985) to the Intel Pentium 4 (2002) is approximately 1000. Extrapolation of this benchmark back to the first IBM PC suggests that the desktop computer performance has increased by a factor of approximately 10,000 in the last 20 years.

A Brief History of Modelling

Doug Morrison (2002) uncovered an old publication that suggests the first magnetic modelling in Australia was performed by George Neumayer in 1861. Neumayer used quantitative methods to delineate the location, depth and size of a meteorite in outer Melbourne, Victoria and this is reported in his narrative on the Magnetic Survey of the Colony of Victoria.

1950 – 1980

In 1953, Lew Richardson worked with Bruce Kirkpatrick a senior lecturer in mathematics at the University of NSW to solve the maths for computation of the magnetic response of ellipsoidal targets including demagnetization (Richardson, R.L. 2002). They needed a method for accurate drill targeting of the deep narrow copper-gold bearing magnetite-hematite deposits of Tennant Creek. When the results of a BMR aeromagnetic survey of Tennant Creek were released in 1956, Richardson applied the modelling method to a number of targets identified by the survey (Farrar, 1979). Contour maps were produced by lengthy hand computation of the response of theoretical bodies and compared with the survey results. This led to an early geophysical modelling success where the Warrego deposit was intersected within 4 feet of a target depth of 970 feet (Farrar, 1979).

The method was computerised in 1965 using the CSA timesharing computer and by 1970, L.A. Richardson and

Associates had installed a Wang computer to perform the modelling in-house. Richardson (2002) reports that the programming was done in Basic and a model contour map could be prepared with approximately two days computation that replaced a tedious manual process of a similar duration.

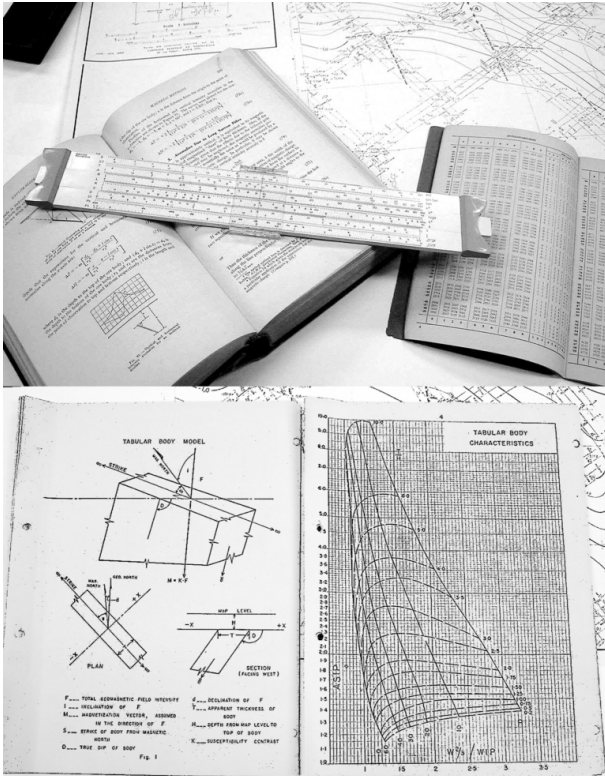


Figure 2. Examples of tools used by geophysicists up until the mid to late '70s. (a) slide rule and log tables, (b) nomograms of magnetic characteristic curves.

30 years ago, geophysicists wrote their own software. Computing environments were much simpler than they are today and programs typically contained several hundred to several thousand lines of code. Geophysicists used timeshare systems that were normally accessed from slow speed (10 characters per second) terminals. Towards the end of the '70s Digital Equipment Corporation released the PDP 11 minicomputer. This was a relatively affordable and powerful computer and its arrival sounded the death knell for the expensive timeshare services.

Interactive modelling was not available to most geophysicists during this time – most computer modelling involved the development of forward models with results being printed as tables or displayed as simple graphs on a pen plotter. For most geophysicists, modelling was still performed using charts and simple methods such as the direct approach developed by Peters (1949) or nomograms (Fig. 2).

1980 - 1990

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In the early 80s both Hewlett Packard and Texas Instruments released programmable calculators. These rapidly became popular as computational aids and both the SEG (Ballantyne et.al., 1981) and the ASEG (Emerson et.al., 1985 and Clark et.al., 1986) published a suite of geophysical programs for them.

By 1981 desktop computing had become a reality. The Digital Equipment PDP 11 and VAX computers were the most popular corporate computers. Affordable monochrome graphics terminals appeared on the scene and to a lesser degree, colour terminals began to provide interactive capabilities for some exploration companies.



Figure 3. SEG programs for the Texas Instruments 59 calculator and an image of the HP 67 hand held programmable calculator.

The early '80s heralded the start of the age of personal computers. Users had a choice of many different personal computers such as the Apple II, Osborne and Kaypro computers running CP/M and later the IBM PC running MS-DOS. Although most of these computers were limited in their capabilities, lower operating costs made them an attractive alternative to expensive timeshare facilities.



Figure 4. Examples of early desktop PCs, HP85 (a), Apple II (b), Osborne (c) and the first IBM PC (d).

Computer technology had evolved to a stage where users could write their own programs and solve many of the operational needs of their exploration companies. Most

software for magnetic and gravity modelling was developed internally within exploration companies but a new breed of service company was emerging – the specialist software developer.

By the mid 80's a number of low cost personal computer modelling programs were available on a number of desktop and mini-computers (Pratt & Doyle, 1984), MacLeod & Reeves (1984). CP/M based computers had all but disappeared and the MS DOS based IBM PC had taken over as the personal computer of choice for most geophysicists.

Early programs were relatively simple, but they did allow the interpreter to build arbitrary geological sections, compute a model response and compare it with field data without having to worry about expensive computer time or budgets. Most companies could afford to place a personal computer at the disposal of a geophysicist.

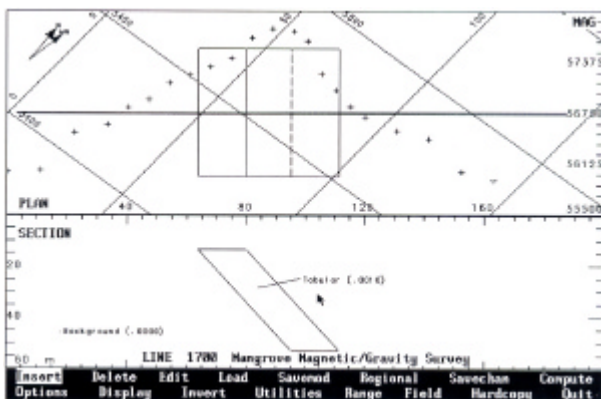


Figure 5. Example model display from the DOS based TOOLKIT modelling package.

By the late '80s a large number of IBM PC compatible computers were available. The Apple Macintosh was very popular in educational institutions and with geologists, but its closed architecture and high price lessened its appeal to geophysicists.

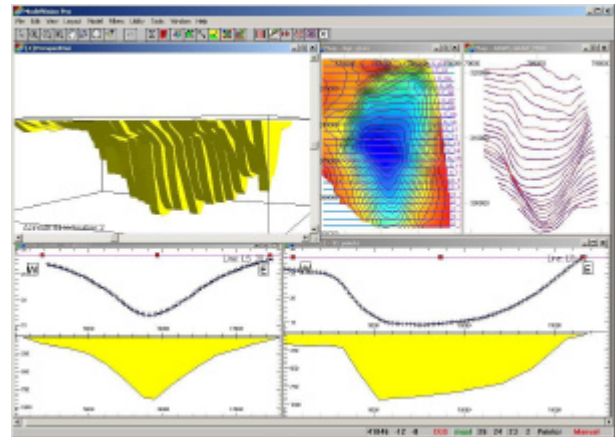
1990 - 2000

By the early '90s personal computers were capable of performing significant work but the high ground for geophysical processing was held by Sun and Silicon Graphics workstations. These were expensive but provided higher performance, better graphics and a more robust operating environment than the PCs of the day. By the mid '90s, PCs had evolved to the stage where they were starting to compete favourably with the workstations. PCs were becoming ever more powerful and the introduction of the Windows 3.0 operating system provided an effective graphics environment for technical applications.

While the Windows operating system offered PC users a friendlier working environment, it posed significant

challenges for software developers. The major effort in developing a program now involved the coding and testing of its user interface rather than the coding and testing of the underlying geophysical algorithms.

Figure 6. Microsoft Windows 3.1 & Windows 95/98 example



from ModelVision

ModelVision was first released in 1994 as an early example of 3D magnetic and gravity modelling on the Microsoft windows 3.1 operating system. Multiple graphics windows and direct operating system support for graphics printers represented the most significant benefits of this new operating system.

Today

In 20 years, the personal computer has come a long way. Processor performance has increased 10,000 fold, programs are more powerful and less cumbersome and personal computers sit on every desk. Software professionals require far greater skills to develop programs than they ever did in the past.

Object-oriented programming techniques are used to build applications as a set of co-operating objects each of which is designed to perform a specific task. These objects can be reused in different applications thereby decreasing the overall cost of software engineering. Figure 7 from QuickMag (Pratt, et.al. 2001), illustrates this style of program. The frames in this application are a set of co-operating objects. The magnetic model is also an object that knows how to render itself in each of the companion windows. In the map view, the object renders only the upper surface, while in the spreadsheet view it displays the physical properties of the model and in the 3D view it provides a dynamic view that can be manipulated using zoom and rotate tools. The scale bar is also an active object that can be used to control the scale of the main map.

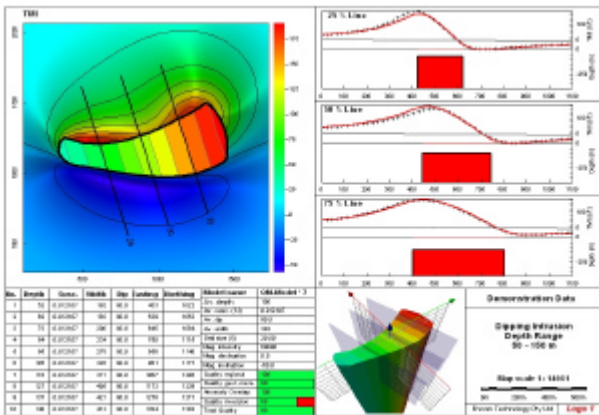


Figure 7. Example of an interactive object oriented application for magnetic modelling

Interactive modelling programs are more complex than procedural processing programs. With procedural programs data are read, processed and outputs generated with little if any input from the user. By comparison, during the running of an interactive application the user will interact with the data in many different ways. Interactive applications must cope with a wide range of user operations and cannot rely on a user performing these operations in a pre-ordered sequence. This means that interactive applications require a more robust and richer user interface that must be programmed to respond to a wide range of possible error conditions.

To further enrich the geophysical computing environment, Encom has been researching the use of expert systems to assist in the interpretation of magnetic anomalies. QuickMag utilises such a system to build complex three-dimensional geological models to help reduce the labour component of interactive modelling from hours to seconds. QuickMag replaces a time consuming set of manual steps that estimate the regional magnetic field, analyse anomaly interference, evaluate geological noise and invert the data based on a geological style selection.

This expert system method fits between full three dimensional modelling applications like ModelVision (Pratt et.al. 1994) and fast automated methods like Werner deconvolution and Naudy. With sophisticated software like QuickMag, useful geological information that was often left uninterpreted can now be extracted quickly and cost effectively.

Where to from here?

Potential field modelling is part of an exploration decision support system that helps decide on drill hole locations. Most exploration companies now use GIS packages to hold the important geological information and thus it has become the primary tool for managing the decision to drill. It is important for geophysical interpreters to capture the geological outcomes of their

interpretations so that they are compatible with the corporate GIS system.

Modern GIS systems such as MapInfo and ArcGIS provide development interfaces for communicating with companion applications. Specialist software modules can be developed and integrated into these products to enhance their usefulness to geoscience professionals..

In the near future you will be able to integrate geological sections, geological models, drill hole trajectories, assays, surfaces and other geophysical models in one seamless computing environment. Figure 8 illustrates the integration a 3D magnetic model with drill hole assay data, and geological sections generated in the Discover for MapInfo GIS application.

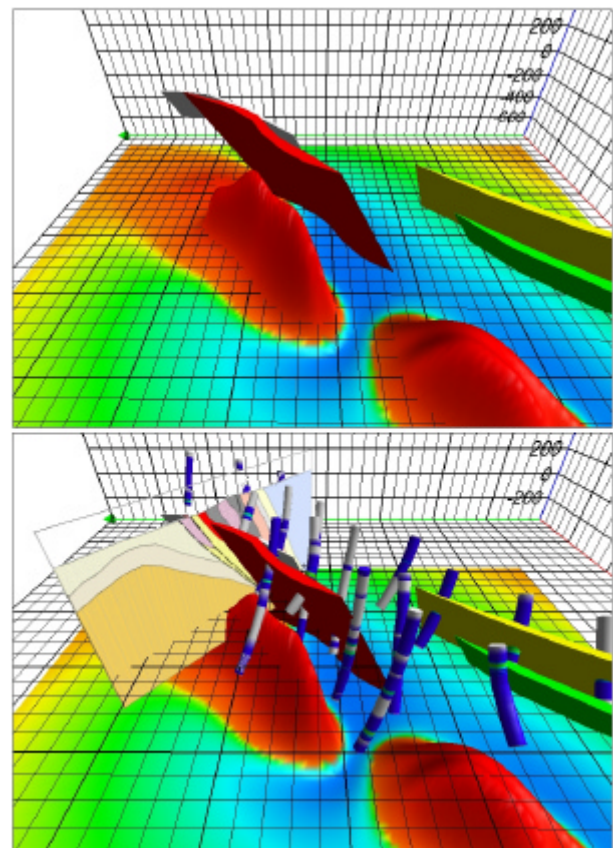


Figure 8. (a) magnetic model and simulated magnetic field, (b) magnetic model, drill holes and geological sections from the Discover for MapInfo GIS application.

Within two years, you will be able to perform near real-time, solid geology interpretations of map regions using expert systems. Encom is undertaking research with support from an Australian Government grant on gravity studies of basins and continuous magnetic mapping of the basement.

In 5 years, our personal computers will be at least 10 times faster than they are today. More memory and larger and faster storage devices will further improve computer

performance. This extra computing power will allow us perform real-time computing on more complex models.

The Internet has had a dramatic influence on the way we work, gather information, provide product support and distribute data. Little progress has been made, however, in utilising the Internet's potential for co-operative and complex computing. Our experience with most online interactive Internet environments is frustrated by unpredictable delays and limitations of the user interface. Reliable, low cost, high bandwidth Internet access from anywhere including field bases will help, but it is difficult to say when this will become a reality. Remote application servers for advanced modelling is a possibility, but the high cost of developing an effective Java based interface may relegate these tools to the top end of the market.

30 years ago, the modelling of even simple anomalies was an arduous task. 20 years ago the personal computer changed the way we work forever. Powerful computers, interactive software systems and integration of geological and geophysical data now provide an environment that allows us to apply realistic geological models to the interpretation of potential field data.

Acknowledgements

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