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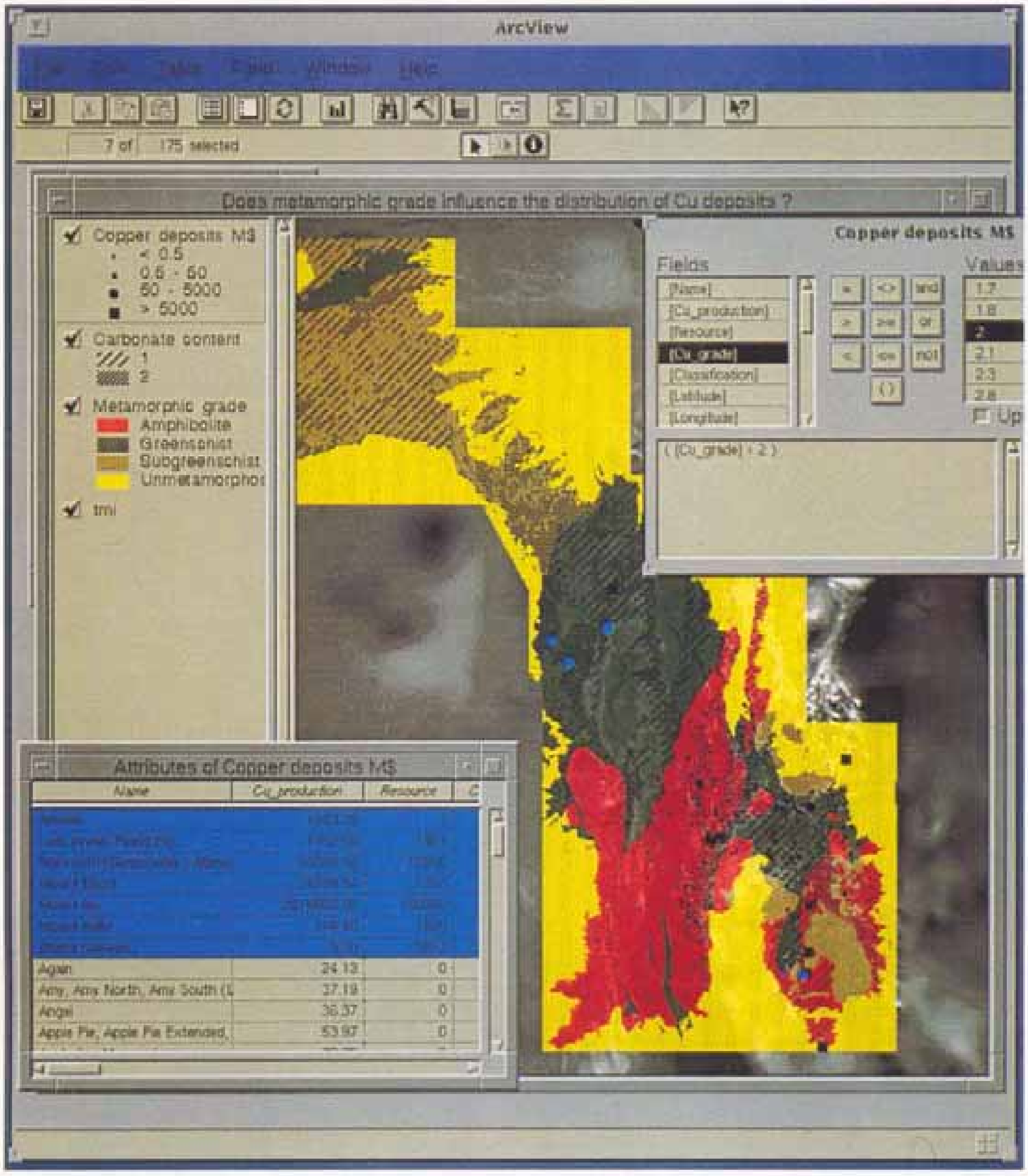

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HEAD OFFICE: 411 Tooronga Road Hawthorn East Vic 3123
TEL:(03)9822 1399 FAX:(03)9822 1711

PRESIDENT: Mrs Kathy Hill, Tel:(03) 9412 5639 Fax:(03) 9412 5655

HON SECRETARY: Mr Greg Blackburn, Tel: (03) 9819 9596 Fax:(03) 9819 9596

EDITOR: Mr Geoff Pettifer, Tel:(03) 9412 7840 Fax:(03) 9412 5655
email: grp@mines.vic.gov.au

ASSOCIATE EDITORS:

Petroleum: Rob Kirk, Tel: (03) 9652 6750; Fax: (03) 9652 6325;

Minerals: Steve Mudge, Tel: (09) 442 8100; Fax: (09) 442 8181;

Engineering, Environmental & Groundwater: Derecke Palmer, Tel: (02) 697 4275; Fax: (02) 313 8883

NEWSLETTER PRODUCTION: Ms Janine Cross, Tel: (03) 9822 1399 Fax: (03) 9822 1711

ADVERTISING: Mr Andrew Sutherland, Tel: (03) 9696 6266 Fax: (03) 9690 0309

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Editors Desk

I don't often editorialize, but a letter to the Editor (p38) on the dearth of seismic content in Preview plus Rob Kirk's Seismic Window article (p13) on the excellent cooperation of SEG and AAPG in Seismic Interpretation and Data Integration in the US has prompted me to pull out the soap box and step up.

I agree that Preview has a mineral geophysics bias as arguably also does Exploration Geophysics, even though half our membership are in the petroleum industry. Also most advertising support for the ASEG publications is from the minerals industry.

It is my fervent wish to bring balance to this situation with Preview content. The support is there, witness the ASEG Conference principal sponsorship is invariably from the petroleum industry, but more needs to come from the members (eg send articles, news to Rob Kirk or myself).

It seems that much of the petroleum industry publishing and advertising energy in Australia is going to PESA News and Journal. Like the SEG, the ASEG is finding many of the good seismic case histories/interpretation articles are going to the AAPG equivalent in Australia: PESA.

I think there is an issue here for the ASEG to address. Maybe the answer is more cooperation with PESA (eg similar to the SEG-AAPG nexus) and certainly an Australian petroleum geophysics and ASEG presence on the SEG-AAPG joint committee, which up until now appears to be mainly focussing on the Leading Edge and the Canadian SEG Explorer, not Australia's Preview.

No better example of our isolation, can be found than the fact that the ASEG Executive finally received the CSEG Explorer magazine (a publication of PESA standard News) on journal exchange earlier this year. None of the then Executive knew of the existence of the Explorer (now in its 20th year). I'm working at closer links with the Leading Edge and the Explorer. What can you the petroleum geophysicist readers do to help lift the petroleum content in Preview?

I feel my soapbox creaking so I'll step down. Enjoy this issue and I look forward to meeting some of you at the conference.

Geoff Pettifer, Editor

President's Piece

Geophysics in Australia - An immigrant's perspective

I find myself quite intimidated by the list of predecessors in the Federal presidency and was surprised but very honoured when asked to nominate. And so here I am. The Preview editor has reminded me that my inaugural "piece" for the magazine is due and that with it I have the opportunity to place my presidential stamp on my forthcoming year in the office.

I've been in Australia ten years this month and in that period have witnessed a tremendous transition in geophysics in Australia. Australia is uniquely placed in that it is the only continent with a single language, single continent-wide "geological" survey and cooperative (well - mostly) regional geological surveys. In addition the oil and minerals companies are situated in several cities rather than in one national centre. In Canada by contrast, oil was in Calgary and minerals in Toronto or Vancouver and never the twain would meet.

Coming from Canada and the UK in the oil business my perception of geophysics was skewed very heavily toward reflection seismic interpretation. Refraction was something that you did to sort out the weathered zone or that you muted from your shallow and far offset signal. Gravity and magnetics (beyond the cost effective university practicals) was something that was paid lip service to in plate scale regional studies, with one or two 2D models done by a specialist in isolation. Electrical methods were restricted to their related down-hole log applications. That's perhaps stating the case a bit strongly but not by much.

Then I came to Australia and was soon set to work on the onshore basins. The world famous Landsat images of the Amadeus Basin and the SAR imagery were supplemented by gravity and magnetic images. Suddenly (at least for me) integration of all geophysical data sets was a matter of routine. Also almost unheard of elsewhere were the Australian exploration geophysicists (and geologists) who could and did move between the minerals and petroleum sectors.

Australians were world leaders in the development of end-user based mapping and imaging software (very notably ERMapper) which received worldwide endorsement (where it counts - in licence purchases) from both the minerals and oil sectors. At last! Synergy! In 1990 Australian companies and the surveys were leading the way in combining seismic and potential field imagery and were even planning real iterative integration of the data sets.

Local papers were published and it seemed that Australia was going to lead the rest of the world in geophysical data integration as it had in the early stages in remote sensing, GIS, and other terrain analyses. It didn't happen, not really, for a lot of reasons. First, downsizing hit the large companies in the oil sector and sent them back into the tried and true and chargeable methods. Second, many of the international oil majors left and with them the link to much of the research support in their head offices. Third, the data they were trying to analyse the basin section with were too coarse to address imaging the intrabasinal structures. Finally, reflection seismic data has yet (unless this year's conference demonstrates otherwise) to demonstrate real utility in the minerals sector in Australia. It seemed that only the state and national surveys were left to bear the integration torch.

Many of those local papers were in Exploration Geophysics. One of the Federal executive's major undertakings will be to ensure that the local work published in Exploration Geophysics is exposed to the international geophysical community. In some small way the association may be able to help some of those great Australian ideas reach a wider a community and foster a greater degree of exchange with the international geophysical community.

The character of this geophysical society, I suspect is like no other because of its balance of expertise and the vast laboratory that is the continent of Australia. Lets endeavour to keep it broadly based, scientific and open in its approach to all geoscience disciplines.

Kathy Hill, President

Preview - Next Issue

- **ASEG Conference Handbook Edition**
- *Student Feature - Career in Geophysics*
- *Seismic Lithology and Reservoir Characterization*
- *3 Component Aeromagnetics*
- *Excitations: Models Anomalies*

Executive Brief

Arrangements for the Adelaide Conference and Exhibition, Adelaide, South Australia (3-6 September, 1995) are in full swing with registrations rolling in. At the Conference, while delegates are enjoying convivial chats with friends and colleagues and attending technical sessions, there will be much activity behind the scenes, much of which will go unnoticed. Twelve meetings are scheduled during the Conference:

1) APEA Seismic Operators Committee Meeting (Peter Vaughan)
2) ASEG Federal, State and Standing Committee Officials Meeting (Kathy Hill)
3) Government Representatives Meeting (Terry Crabb)
4) Consultants Meeting (to be announced)
5) Research Foundation Committee Meeting (Bob Smith)
6) IAGC Meeting (Steve Pickering)
7) Student Liaison Committee Meeting (Norm Uren)
8) Technical Standards Committee Meeting (Paul Wilkes)
9) Exhibitors Meeting (Doug Roberts)
10) Conference Advisory Committee Meeting (Craig Gumley and David Tucker)
11) Publications Committee Meeting (Mike Asten)
12) Paper Judging Meeting (Craig Gumley and David Tucker)

It is an opportune time for any ASEG member to contact any of the above Committee chairpersons should they have any comment or topic that they wish to be discussed.

The Federal Executive is currently drafting an options paper on the 5 Year Business Plan which will be distributed to the State Branches during August. The plan will be discussed and ratified at the ASEG Federal, State and Standing Committee Officials Meeting at the Adelaide Conference and later presented in Preview.

Capitation Fees, based on a rate of $10 per ASEG member in each State, have been sent to the state branches.

Greg Blackburn, Secretary

ASEG People Profiles: ASEG 11th Conference Co-Chairmen

Craig Gumley

Craig Gumley graduated with a BSc (Hon) in geophysics from the University of Adelaide in 1984. Upon graduating, he joined Pacific Oil and Gas (formerly CRA Exploration, Basin Studies) as a Petroleum Geophysicist. He supervised the acquisition, processing and interpretation of geophysical data within Pacific's operated blocks.

In 1991 Craig joined Santos as a Senior Geophysicist and has been involved in exploration and development within the Cooper/Eromanga Basins.

Craig has been a member of the ASEG since university. He served as the secretary of the Victorian Branch from 1986 to 1988 and was a member of the organising committee for the 1989 Melbourne conference. He joined the Adelaide committee upon his return in 1991 and served as the South Australian president in 1992 and 1993. He accepted the position of COC Chairman because "it seemed like a good idea at the time". He has also served on other local ASEG sub-committees such as the Wine Selection Committee which as a reputation for selecting only good red wine.

Craig is a member of the ASEG, SEG, AAPG, PESA and AIP.

David Tucker

David Tucker started on the path to becoming a geophysicist by joining the Seismic section of BMR in 1966. He had graduated with a BSc (Hon) from Adelaide University, completing his Honours project in solid state physics.

In 1969 David returned to Adelaide University to undertake a PhD, which he completed in 1972. His thesis was on aeromagnetics and gravity. He returned to BMR and worked on aeromagnetics, ground electrical methods, basin studies, large scale multi-disciplinary studies and on being a constant thorn in the side of managment.

In 1980 he joined CRA Exploration and for a few years worked in Broken Hill on the hunt for 'the mother lode', before returning to BMR (some people never learn) as Principal Research Scientist and head of the Airborne Geophysics Section. From 1986 David has worked as a consultant geophysicist in all parts of Australia, some parts of the world, "for all sorts of companies, on all sorts of projects, using all sorts of methods" (hiswords).

David is a member of ASEG, SEG, AusIMM, Geol. Soc. and some others and drinks only good red wine.

Branch News

Victoria

In our March monthly meeting Dr Tony Siggins of ISSP gave a well received and informative presentation on the principles of Ground Penetrating Radar. This was followed up in April by a presentation by Dr Peter Hannaford of CSIRO on the principles and applications of Laser Spectroscopy to Mineral Exploration. Dr Hannaford's work and proposed areas of investigation fascinated every member present with its high precision instrumentation which served to whet our appetites for revolutionary exploration tools in the future. Both meetings were very well attended which is encouraging to see.

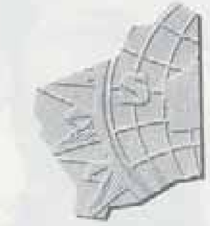
On April 11 a combined Victorian Branch and Federal AGM was held. The Victorian Committee was re-elected without change, and everything else was business as usual.

On the 22nd May the Minister for Energy and Minerals announced at a Data Release and Seminar that $16M will be spent over the next 3 years in Geological and Geophysical Surveys over Victoria (see p39). Also on this day the AusIMM Bursaries for studies in Geology and Geophysics were released.

In other news, the Victorian Branch President, Dr Jim Cull of Monash University, has been placed on the National Committee for Solid Earth Geophysics in the Australian Academy of Science.

Shaun Whitaker, Secretary

Western Australia



In May, the WA branch was pleased to invite Greg Street onto the committee. The second technical meeting was held on Wednesday, 17th May, during which papers were presented by Brian Evans (Curtin University) titled "A comparison of physical model with field data over Oliver Field, Vulcan Graben", and Hugh Jones (DME) titled "Mineral exploration -the Department's Environmental guide lines". The talks were poorly attended with about 20 turning up, but there was lively discussion on both topics.

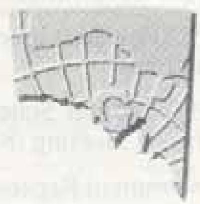
Richard Smith (Geoterrex) is due to present a talk on 21st June meeting, titled "Airborne EM in a conductive environment", followed by Peter Baillie (DME) titled "The structural evolution of the Carnarvon Terrace, W.A.", which is a re-run of the successful APEA paper co-authored with Ted Jacobson.

News on the social front is that we have organised a joint ASEG/PESA wine tasting evening for 4th August, which we pioneered last year and found extremely enjoyable. Last year, we had a four course meal with a local wine specialist asking members the names, varieties and years of individual wines they received with each course. The evening was very instructive but expensive for the local branch finances. This year, things will be slightly trimmed back (in terms of expensive meals), and for anyone interested, they can contact David De Pledge on (09) 224 4194. It should be a good evening for $15.

News on the technical front is that Oz Yilmaz will be in Perth for the last two weeks of June, so we expect to organise a seminar with him for the petroleum gurus in town. WAPET has been approached to support the venue costs, while Geco-Prakla hopefully will support the refreshments. ASB may support other areas of entertainment.

Brian Evans, Secretary

South Australia



There has been much activity within the SA branch of late with technical meetings being organised monthly, conference preparations intensifying and plans for social events later in the year getting underway.

Our April technical meeting featured Andy Oldham from Santos presenting a case study of the Lake Hope 3-D seismic survey. Our thanks to Andy for this interesting and informative presentation. This was followed in May by the ever popular Industry Information Evening. This meeting, despite the limitations of our chosen venue, proved to be very successful with a near record turnout of around 70 attendees. Five to ten minute overviews of current activities were presented by representatives of the following organisations:

Western Geophysical	Pasminco
SAGASCO	CRA
Zonge Engineering	Schlumberger
SANTOS	NCPGG
Mines and Energy SA	

Many thanks to those people who gave up their time to make presentations for this evening. Also available on the night were lists of post-graduate geophysics students and their projects provided by the NCPGG, Adelaide and Flinders Universities, extra copies of which are still available by contacting either me or the universities direct.

Coming up, we have Richard Smith from Geoterrex and Andrew Hugill confirmed for technical presentations in June and July and Mike Dentith from the University of WA for later in the year.

Finally, our recent drive to create a database of SA branch members e-mail addresses has been very successful with nearly one third of our members now included. For any new or existing members who now have access to e-mail, to be included on our electronic mailing list, just send your e-mail address to:

andy.craddock@waii.com

Andy Craddock, Secretary

Total Quality Management of Collaborative R&D or Tilting At Windmills

Joe Cucuzza
Research Coordinator
Australian Mineral Industries Research Association Limited

Introduction

The purpose of this paper is to examine the concept of Total Quality Management (TQM) and explore whether it can be applied to management of collaborative R&D.

For many of us who have had a modicum of exposure to literature, the Quixotic parable on self deception comes to mind when considering the idea of managing R&D. R&D is considered by many as a creative pursuit without any guarantee of success, so how can one manage creativity? Can a non-manufacturing intellectual process such as R&D really be managed? After all it is not as if it involves improving a manufacturing process to build better aluminium beer cans, is it?

> *.....Focus on customer needs is arguably the most important keystone of TQM ....*

Most of us have come across the management buzz words of the nineties; downsizing, business process re-engineering, outsourcing, innovation and TQM in its many guises. To the cynics the buzz words mask what at times has been a ruthless drive by management for the bottom line without much regard for the human capital of an organisation. This has been part of the cost cutting strategy in evidence recently, although I understand that having shaved to the bone some companies are now moving towards new growth strategies. It is no wonder, therefore, that a common response to these management concepts is one of profound scepticism and they are dismissed as fads. The optimists (or is it the pragmatists?) amongst us would point out that at the core of some of these management fads, once the jargon is stripped away, there is some common sense advice on how individuals and organisations can be more effective at what they do.

Principles of TQM

So what is all the fuss about? Many of the basic principles of TQM have been around for many years, after all the Japanese have apparently been at it for yonks. P. B. Crosby in his book 'Quality is Free' was one of the earliest books on the subject. Many of the early efforts to promote TQM tended to focus at the manufacturing end of things. However, momentum is building to use TQM as a tool for process improvement and in particular in R&D management. Although the literature indicates some differences in emphasis, the core concepts of TQM can be best summarised as follows:

Focus on customers needs. The customers (whether internal or external to the organisation) must define the objectives and the outcomes of the R&D. Achievement of customer satisfaction is a central plank of TQM

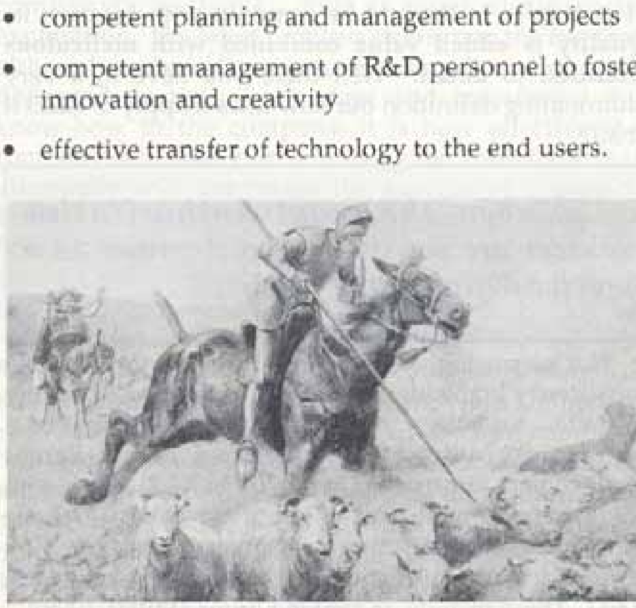
Zero tolerance against specifications. Quality requires conformance to requirements

Having a methodology in place for continuous improvement, and means to measure progress. Enhance Quality by learning from mistakes and successes. Empowering project teams to own quality of outcomes.

Linking continuous improvement to corporate goals. Top management must clearly articulate the corporate vision and drive the improvement process.

Focus on customer needs is arguably the most important keystone of TQM. The role of the customer in TQM will become self evident by the end of this paper. It suffices to point out two factors. Firstly the importance of recognising that there are both internal and external customers in any organisation. Secondly, the ultimate goal should be to achieve superior customer satisfaction. According to Szakonyi (1994), to achieve superior customer satisfaction the research supplier must improve the effectiveness of R&D by:

- identifying the market need
- generating new ideas
- competent planning and management of projects
- competent management of R&D personnel to foster innovation and creativity
- effective transfer of technology to the end users.



Don Quixote was not only into tilting at windmills; here seen attacking what he thought was a troop of enemy soldiers. Have our approaches to R & D been at times Quixotic?

Industry pays a considerable cost penalty for non-conformance to specifications (Crosby, 1979). This concept of zero tolerance against specification is another keystone of TQM. Zero tolerance against specifications is all about doing things right the first time. It is about having performance standards and systems in place to ensure conformance to requirements.

Having a methodology in place to facilitate continuous improvement in process and work place practices and of course ways of measuring progress is an essential platform of TQM. In practice, this can be achieved through a process loop consisting of planning, execution, checking, and improving. Planning means setting the targets for improvement and procedures to identify those aspects of the process that require improvement. Identification of those parts of the process that require improvement can be done by involving the customer. Once the improvements have been identified then it is necessary to implement them. After implementation it is necessary to check how effective the improvements have been. Again it is important to seek feedback from customers. The final link in the loop is incorporation of the changes in the TQM process.

Another keystone of TQM is linking the continuous improvement process to corporate goals. Studies have shown that TQM will not work unless there is commitment to the process at all levels in an organisation. A quality culture needs to be built in an organisation to ensure success with TQM. Management must articulate its goals and provide the leadership to all levels in the organisation and get commitment to the quality process.

Definition of Quality

But what is meant by quality? In a recent article on this very subject, (Gorecki, 1995) tried to answer this question. He noted that "even the most authoritative sources are evasive when it comes to a precise definition of quality". In the end he came up with his own ie. **Quality is added value combined with meticulous attention to detail**. Well there you have it, a very illuminating definition but how does it apply to R&D if at all?

> *......even the most authoritative sources are evasive when it comes to a precise definition of quality.......*

Not surprisingly, like Gorecki, I could not find any consistency in the literature on the definition of quality in R&D. Recently, in a survey of 45 multinational companies, Miller (1995) identified four different management approaches to quality in R&D. Each with their own conception of quality. Despite these differences however, there does appear to be a common set of practices which are necessary to ensure quality in R&D. These include, in ranking order, (Miller, 1995);

- undertaking strategic analysis to assess value, applicability and transferability of R&D,
- periodical assessment of competitiveness and technology,
- use of multi-disciplinary teams,
- using post-project audits to evaluate performance and accomplishments,
- participation of R&D personnel in a company's strategic planning process,
- undertaking of customer surveys to assess efficiency and effectiveness,
- initiate meetings between customers and researchers to define aims and to evaluate progress,
- carry out periodic reviews of systems and processes to ensure that such processes and systems are continuously improved as experience dictates,
- setting up cross-functional teams to explore possibilities from emerging technologies, and
- having common databases and design methodologies across the organisation.

> *.....research and development are simply components of the much more complex process of innovation.....*

Szakonyi (1994) proposed a similar set of criteria to measure R&D effectiveness. It is difficult to identify "good" R&D with an end result, however, a company that gets the innovation process right is more likely to be in the top categories of profit performance.

Application to Collaborative R&D

Having briefly described the principles that underpin TQM and the practices commonly used to implement it in companies (readers are referred to the references for more details), let us now examine whether these practices can be applied to collaborative R&D. To do this we must assume that the R&D process can be broken down into a series of well defined actions or sub- processes. For the sake of this discussion let us assume that these sub-processes are as follows.

- Identifying the research opportunity
- Identifying the scientific problem to be solved and linking it with the industry need
- Translating the idea into a proposal and marketing the proposal to industry
- Managing the project to deliver outcomes
- Technology transfer

It should be understood that the overall process cannot be described by the linear model implied by the above list. In fact, research and development are simply components of the much more complex process of innovation (Industry Commission draft report on Research & Development, Dec. 1994).

Identifying the research opportunity involves identifying who has a problem and the nature of the problem. This can only be achieved through a robust industry network. AMIRA assists in this process in its role as broker or facilitator between the mineral industry and research suppliers. Clearly the process revolves around knowing who the customer is and determining what are his needs. This requires identification of technical champions in the companies. As indicated above the focus on customer needs is one of the primary tenets of TQM. The industry-wise researchers are doing just this in many cases through the assistance of AMIRA. An important question in this process, however, is how effective are the research suppliers in identifying customer needs. What measures can be used to assess the effectiveness of this process? For the research supplier this can be measured by the level of support the organisation receives from industry over time. An equally valid measure, but less quantifiable, is the recognition the research supplier has in industry or the researcher himself has amongst his/her peers. If a research supplier has a reputation for having high quality people who deliver, it will simply attract business. Measures such as number of patents or number of papers published are at best incomplete and at worst misleading.

Having established the nature of the industry problem the next task for the research supplier is to determine the scientific problem that needs to be resolved and come up with ideas to solve the problem. Why the distinction between the industry problem and the scientific problem? An example will suffice to illustrate this distinction. One of the main problems Geophysicists have in applying airborne EM in Australia is the presence of a thick conductive regolith which in many areas effectively masks deep seated conductors. Industry's problem in this case is, therefore, the inability of airborne EM to detect deep conductors under a thick conductive overburden. This, however, says nothing about the physics that needs to be understood in order to come up with a solution. It is this physics that is referred to as the scientific problem, eg. understanding the propagation and attenuation of EM waves in heterogenous conductive media. AMIRA assists researchers in ensuring that the linkage between the industry need and the scientific problem is established.

.....(A Quality) organisation has developed a team culture supportive of creative problem-solving......

How are the ideas to solve the scientific problem going to be generated? This is where a good (Quality?) research organisation is going to excel. Such an organisation has developed a team culture supportive of creative problem-solving. The teams are generally interdisciplinary, they encourage cross-fertilisation and are empowered to own the quality of the outcome. They successfully use the brainstorming process as well as other techniques to generate ideas.

Having identified some potential solutions to the scientific problem, the next task is to prepare a proposal for marketing to the industry at large. If we are to follow the quality principles such a proposal should be prepared in partnership with the customer. The customer sets the objectives and together with the research supplier they agree on a work program and measures of progress. The proposal will focus on setting clear objectives for the research, on how the industry problem is going to be solved, on what resources will be required, on how the project is going to be managed, on what the outcomes will be, on how the technology is to be transferred to the customer, on how the intellectual property is going to be shared and how progress is going to be reviewed. The process of developing a marketable proposal is an iterative one that should involve the research team and the customer. AMIRA plays a pivotal role in this process.

The customer will consider that delivering on time and on budget is a necessary (but not sufficient) condition for a successful project. One way of ensuring this is if the project, once it is supported, is managed to deliver outcomes. This will be facilitated through timely and relevant reporting and continuous monitoring of progress. Clearly, project management systems must be in place to ensure the proper conduct of the R&D.

.....it is not difficult to find out when projects have failed, it is a little more difficult to determine whether they (the outcomes) have made any difference to a company's business.......

Satisfaction in the project outcomes will be based on the whether management in the company sponsoring the project perceives that the company got value from its investment. A measure of success will be whether the company will continue supporting projects from the research supplier. Clearly, it is not difficult to find out when projects have failed, it is a little more difficult to determine whether they have made any difference to a company's business. This is particularly so in exploration. The latter problem stems from the fact that although technically a research supplier may have delivered on time, on budget and transferred the know-how to the company, it is how effective the company is in taking up and using the know-how that ultimately will determine the success of a project. Post-project audits are clearly one way to determine how successful or not the project was technically. In fact post-project audits can be a very powerful way of identifying successful practices which can be incorporated in the quality process. They will not however, address the issue of whether a company has actually appropriated the results effectively. Ultimately success should be determined on whether the company has appropriated the outcomes in its business. To achieve this the company must invest the resources not only to monitor the R&D but also to implement the outcomes. To obtain a complete picture of a project's success there is a need to audit this process as well.

Most of what I have written is common sense, it is essentially about doing the right things and doing things right. TQM provides a set of tools that help to achieve this end. It does not matter whether we call the process TQM or better business practice, or what ever, at the end of the day the aim is to able to continuously improve what is done and how it is done.

As companies become more global in their outlook they are being forced to do things faster and smarter. Increasingly they are employing TQM principles in their business. They carry out benchmark studies and implement world best practices (both of which are quality tools) to ensure that they remain ahead of the pack. They will appropriate technology from anywhere in the world and they will support those research suppliers who are responsive to their needs. Such research suppliers will have management structures that encourage innovation, creativity and continuous improvement. They are staffed by highly motivated scientists trained in project management principles, skilled in communications and people management. As I see it, this is one of the main ingredients to ensure success with TQM and what defines a Quality organisation.

Before I conclude I would like to make some comments on fundamental research versus industry led research. TQM is a process which is not incompatible with fundamental research. The aim of TQM must be to ensure that both researchers and industry win. Fundamental research occurs within the context of industrial focussed R&D when industry provides the right environment. Good examples are the CSIRO medal winner Ray Smith for his work in regolith geochemistry and Australian Prize winners McCracken, Huntington and Green for their work in remote sensing. Both groups have worked with AMIRA for many years delivering valuable tools to industry and achieving fundamental breakthroughs acknowledged by the community.

> ***....Unless management as well as individual scientists in research organisations add value to their customers particularly to companies supporting their projects they will, sooner rather than later, be seen as irrelevant ......***

Let me now close by visiting Gorecki's definition of Quality ie. **added value combined with meticulous attention to detail**. Ensuring that the right things are done and that things are done right means paying meticulous attention to project development, project management and technology transfer. It means having a culture that encourages innovation and creativity. It means having highly motivated staff skilled it all aspects of project management. This is how the research supplier and the individual researcher is going to ensure customer satisfaction, both internal and external to the organisation. Unless management as well as individual scientists in research organisations add value to their customers particularly to companies supporting their projects they will, sooner rather than later, be seen as irrelevant and simply disappear from the scene. Maybe, therefore we are not tilting at windmills in suggesting that TQM can be applied to the management of collaborative R&D. Instead TQM should be considered a necessary component of any comprehensive program designed to deliver hard products from intellectual activity.

Further Reading

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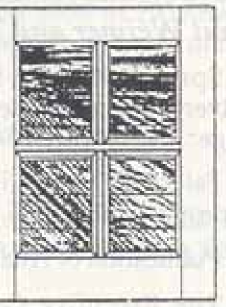
Seismic Window



With

Rob Kirk
BHP Petroleum

An insight into the vigorous activity of the SEG and AAPG sub-committees on Seismic Interpretation and Geophysical Integration can be gained from the excerpts of the minutes of a recent joint AAPG - SEG committee meeting at the AAPG Annual meeting in Houston, 1995. These excerpts are presented in this issue's Seismic Window, as a challenge to Australian geophysicists to liven up and participate in the debate on seismic interpretation in this country and in the SEG. The debate continues at the SEG 1996 Conference Meeting. Will the ASEG and Australian Geophysicists be there?

SEG Interpretation Committee & AAPG Geophysical Integration Committee Joint Meeting held at the AAPG Annual Meeting

Houston, Texas
March 5, 1995
Edited Extract of Minutes

Present:

1. Kevin Allison	*12. David Greenlee*	*3. John B. Sangree*
2. Roger N. Anderson	*13. Mark Gresko*	*24. R.E. Sheriff*
3 David Agarwal	*14. Patrick Hooyman*	*25. Yoram Shoram*
4. George A. Ball	*15. Paul Hunt*	*26. Gene Sparkman*
5. E.R. "Buck" Ballard	*16. Elizabeth Johnson*	*27. Tracy J. Stark*
6. Alistair Brown	*17. Rick Johnson*	*28. Richard Steinmetz*
7. Larry Geist	*18. J.P. Land*	*29. M.Ray Thomasson*
8. Mark Gettings	*19. David C. Metzner*	*30. Lynn Trembly*
9. Ashok Ghish	*20. Norman S. Neidel*	*31. Joel Watkins*
10. Scott B. Gorham	*21. Jory Pacht*	*32. Eric A. Williams*
11. Arthur R. Green	*22. Elwin Peacock*	*33. Jim Wolleben*
34. Michael Zietzlin		

Reports of the AAPG Committee Chairmen

Gravity - Magnetics Exploration Case Histories Committee - *Dick Gibson and Pat Milligan*

Current Status: over 40 papers from 15 countries have been accepted (with a final draft deadline in September 1995) in the categories of Regional, Local/Prospect Studies and Micromagnetic Studies

The papers have been organised into the following categories:

- philosophy papers;
- sketches on history of gravity/magnetics and;
- significance and lessons highlighted

Betty Johnson also stated that the SEG expected to press a CD-ROM of this work - **Rick Johnson** said that the SEG Interpretation Committee will assist in any way possible with this effort.

Stratigraphic - Structural Seismic Study Set for College Teaching Committee - *Joel Watkins.*

The rationale for this committee is that most colleges lack geophysical interpretation expertise and that many colleges want to include geophysics in their program.

Objectives are to provide course materials for college level; provide material that can be taught by a non-expert; and that can be used for AAPG sponsored short courses outside United States.

Current Status

- Completed course notes for seismic stratigraphy section
- Seis-Strat consists of 5 exercises
- Field tested at Bandung (China) Institute Of Technology

Activity in progress includes

- One additional seis-strat exercise
- 5 To 6 structural interpretation exercises
- With N.G.D.C and U.S.G.S. loading data on CD-ROM with structure to use "off the shelf" PC based interpretation methods

Discussion was held about AAPG possibly publishing this series.

A general discussion was held on CD-ROM publishing, and **Richard Steinmetz** pointed out that:

- All AAPG Bulletin articles are now available on CD-ROM
- All Special Publications will be in CD-ROM by end of 1995.
- current books are going on CD-ROM as they come out.
- The gravity-magnetics case histories is expected to be published as a CD-ROM*

**Note an overlap here. Betty Johnson stated that the SEG intended to publish the Gravity-Magnetics Case Histories on CD-ROM, while Richard Steinmetz stated that the AAPG intended to do the same thing. As a Committee it has been our desire to do this jointly - thus if AAPG publishes the printed copy, then the SEG could publish the CD-ROM.*

AAPG/SEG Exchange Committee: - *Rick Johnson and Margaret Welsh*

Current efforts:

- Evaluate papers and posters at National 1995 Meeting-Houston
- Prepare selections for SEG Annual Meeting, October 8-13, 1995 (Houston)
- Meet SEG meeting program specifications.

A possible name change from "Best Of AAPG/SEG" to "Technical Paper Exchange Committee" was suggested by **Rick Johnson**. The exchange of paper, poster, seminars, etc. could be stimulated by this committee.

Rick Johnson asked everyone at the meeting to report back to him by the end of the week with comments on papers using the following ranking:

- Should be used by SEG
- A possible candidate for use by SEG
- Should not be used by SEG

Visualization Workshop Committee: - *Roger Anderson and Roice Nelson*

The Workshop will be held may 18, the fourth day of the Archie Conference to be held May 15 - 18, 1995. **Roger Anderson** described the organization which includes three simultaneous sessions:

Simultaneous Session 1 - Presentations By Visualization Experts From:

Entertainment Industry
Medical Industry
Space Industry

Simultaneous Sessions 2 - Interactive Poster Presentations

Technologies
Visualization projects in oil and gas industry
Visualization projects in academia

Simultaneous Sessions 3 - Interactive Demonstrations Of Upcoming Visualization Technologies

Live Internet Demonstration
Remote medical diagnosis
Real-Time QC of offshore seismic acquisition
Remote electronic geotechnical consulting
The Cave: a room with simulation projected on three walls

Norman Neidel suggested contacting the SPOE (Society of Photo Optical Engineers)

Roger Anderson solicited five people to help select a group of industry electronic posters for the poster portion of the program.

3-D Seismic Atlas Committee - *Paul Weimer and Tom Davis*

Spring 1994: 650 Solicitation Letters Mailed And Advertisements Posted In Explorer And The Leading Edge.

Fall 1994: 50 tentative titles compiled, AAPG seeking approval of SEG, SPE and SPWLA.

Publication of Atlas scheduled for Spring/Summer.

The Executive Committees of the AAPG, SEG, SPWLA and SPE have all now agreed to participate subject to a final review of the papers.

Geophysical Notes For Geologists - AAPG Explorer - *M. Ray Thomasson*

The requirements for such notes are that they must be brief with a clean message using simple illustration and written for a lay person

Editors
Dick Gibson, Randy Ray, Bob Kettle, Ray Thomasson
and selected Special Authors
Survey:
24 Subjects
Ranking To Select First Topics

Reports of the SEG Committee Chairmen

Interpretation Committee - *Rick Johnson*

Rick Johnson discussed plans to change the mission statement of the SEG Interpretation Committee, possibly similar to the new **AAPG Geophysical Integration Committee** mission statement.

Ray Thomasson described that Rick Johnson had suggested the concept of a joint meeting between the two committees and that this was the first effort at a joint meeting between individual committees of the two societies.

"The purpose of the committee on geophysical integration shall be to promote better and more complete integration of geological, petrophysical, and reservoir engineering data"

The philosophy of and the thrust of the new **Interpretation Committee** was to grow a larger committee, and to have active participation by members. The primary goal is to significantly impact the individual interpreter.

Case Studies of 3-D Seismic Committee *Rick Johnson*

This project has been temporarily "shelved"

Shallow Interpretation Committee - *John Clark*

This Committee is focused on improving the resolution of shallow data. One of the goals is to create a paper for the Leading Edge.

Ray Thomasson mentioned that **John Andrew** is working with shallow data in the 1000 to 2000 hertz category and suggested he be added as a member of this committee.

Sequence Stratigraphy Committee - *Mark Gresko*

The main goal of the committee is to increase the number of papers on this subject in the Leading Edge and Geophysics.

Mark Gresko described the "explosion" of papers on this subject in the AAPG and the dearth of papers in SEG publications.

Mark Gresko also suggested a work shop on this subject possibly sponsored by both committees.

Alistair Brown asked if it was going to be the same format as the recent "Interpretation 2000" workshop and was assured by **Gene Sparkman** that it would be.

Workshop Committee: - *Gene Sparkman.*

Jointly sponsored AAPG/SEG Workshop at '95 SEG Annual Convention entitled **"Beyond The Workstation: Risk Reduction".**

The Workshop will utilize an open forum with 'Sparks' sprinkled among the audience.

Other business

The remainder of the meeting were devoted to a free flowing discussion generally centered about the question **'What were the most important things we could do to help the interpreter and the geoscience integrator in their professional pursuits?"**

Betty Johnson: suggested the concept of video taping the workshops.

Lynn Trembly: explained that this was prohibitedly expensive.

Yoram Shoreham, (the Oprah Winfrey of workshops), and Bob Sheriff: both discussed the audio tape which was used to write the two articles in the Leading Edge on **"Interpretation 2000"**. A joint workshop between the AAPG and the SEG after the SEG meeting was discussed. a workshop devoted to carbonates was one of the suggestions.

Jack Land: Discussed A new group called The **Association Of Petroleum Geochemical Explorationists** and described that they are concerned with shallow exploration. should be of wider and more general interest. The APGE is associated with the AAPG.

Elwin Peacock: Described the problems of converting time to depth. " no one has ever drilled a well to two seconds".

Gene Sparkman: The sub salt was a classic area in which to examine problems of velocity and depth.

Yoram Shoram: There are different kinds of velocities. We need a workshop focusing on pre-stack imaging. He posed the question "What new aspects of velocity can be brought to bear on this problem?"

Dave Agarwal: Described an SEG Workshop on depth conversion from velocity which was held in Houston.

Eric Williams: Posed the problem of how to migrate time data after he has made a map and adjusted to depth. He pointed out how he was off several hundred feet when he attempted to do this because of lateral velocity changes. Even with vertical seismic profiles he still has problems. He summed it up that we are "not posting wells in the time domain". This subject was considered by many in the room and Eric and they will communicate on this subject.

John Sangree: Reemphasized the problem with tying time to depth using velocities and stated that in his work this is almost a universal mistake that people make.

Patrick Hooyman: Asked the question 'What is a seismic datum? He said he had encountered many people who simply didn't understand the concept and that a lot of interpreters were making integration mistakes because of their lack of understanding.

Alistair Brown: The SEG Summer Workshop this year will be August 13-18 and it's in Vail, Colorado. The title is **"Integrating Seismic Data And Well Data"**.

Elwin Peacock: "The problem is you won't find the geologists who are doing a lot of the interpretation and making a lot of the mistakes at this meeting".

General Discussion: A lot of people felt that they would rather publish in the AAPG because they would get a better audience for their interpretation papers, whereas Geophysics won't publish the same material and the Leading Edge doesn't have as wide an audience. The Explorer also has wide exposure. It was suggested that the minutes of this meeting might be published in the Explorer.

General Discussion: Would it be possible to create a project by which there would be cross publication in both the Explorer and the Leading Edge of the same information.

Jory Pacht: Why not have reprints from the Explorer published in the Leading Edge and vice versa.

Mark Zietlin: there is a new group on the internet in which this kind of information can be instantly accessed. There was a show of hands of the number of people who have Internet available and out of the thirty-five people present only five are on line. It was agreed that three years from now that would be totally different.

Kevin Allison: Kevin is the Education Committee representative on the GIC. We will need some new courses in the Education Committee since in todays work practices geologists and geophysicists sit side by side in front of a 3-D screen. **Rutt Bridges** paper states the situation that we will face in the future very well. What the geologists see is a cross section. The SEG Summer Workshop at Vail will only effect a very select few. Since the term 3-D gets managements attention this year we need to teach an integration course which features 3-D. We also need a course on High Resolution Sequence Stratigraphy.

General Discussion: As a result of Kevin's request **Bob Sheriff & Joel Watkins** agreed to work on a course that focuses on Integration for the broader audience.

Gene Sparkman: Suggested that a more basic course is needed and the emphasis should be on interpreters. He also mentioned that the Explorer is the best vehicle to get information about this sort of thing disseminated.

Lynn Trembly: Beyond the question of conversion of time to depth, and after we get it into depth, that is just the start. fluid content must be an objective. What other kind of information do we have such as shear waves, etc. that can be integrated into the total solution.

Rick Johnson: The definition of an interpreter means you must be an integrator.

Yoram Shoram: Some people believe we are in a mature science and with that concept it allows people to take liberties with how we do our work. on the contrary, integration is a very immature science.

Alistair Brown: The Problems of cooperation have had a rocky road historically. there are many points at which cooperation takes place. Joint meetings have been contemplated previously.

Rick Johnson: Possibly a joint mission statement should be to create for the two groups.

General Discussion: Should the committees be merged? It was decided that at the Interpretation Committee meeting (October 8) to be held at the SEG Annual Meeting all AAPG members of the Geophysical Integration Committee will be invited.

Rick Johnson: Possibly this could be done the same day as a workshop. Rick will follow up on this.

Mike Zietlin: Is it possible for SPE to be a part of these integrated meetings?

Norman Neidel: Norman gives a course for geophysics to engineers and they are extremely interested.

Ray Thomasson: Ray knows Roy Kerner and will follow up with Mike Zietlin in a discussion with Roy to further augment this concept.

Dave Agarwal: How do we get the groups together?

Patrick Hooyman: There was a SEG Workshop In L.A. Put on by the **Development and Production Committee** where there were geologist, engineers, and geophysicists. And it was an excellent workshop on integration.

Jory Pacht: Jory gave a summary of the 1996 **GCSEPM Research Conference on Application of Advanced Geophysical and Wireline Technology for Stratigraphic Analysis.**

Normal Neidel: Mathematics and mathematical equations frighten people. "Doing mathematics in todays polite society is a private act".

Jory Pacht: The "Waveheads" of SEG are contrasted with the "Rockhounds" of AAPG. Both groups need a method of communication that is not mathematical.

Patrick Hooyman: "We shouldn't underestimate the membership and its capacity for handling equations.

Betty Johnson: With all the down sizing the individual interpreters are swamped and really can't take advantage of the information that's available - it's exploding. The question is how can the interpreter get what he or she needs from publications, conventions, Internet, local societies, special workshops, etc.?

Laray Geist: There are only three things we deal with (1) data, (2) ideas, and (3) time -70% of our time is spent putting the data together. Many people are swamped with data (and putting it together) and have no time for ideas.

Mike Zietlin: One of the ways to help is to bring data together quickly using the computer and access ideas quickly on the computer. The Internet is ideal for this.

Norman Neidel: If the abstracts at a convention were graded we'd know which ones to see and which ones to ignore.

Mike Zietlin: An image is worth 10,000 words and you can deal with images best on the computer.

Laray Geist: You get graded on the Internet very quickly by how many "Hits" **A Particular Item Gets.**

Bob Sheriff: If the information is indexed it would help tremendously.

John Sangree: consultants seem to spend a great deal of their time folding sections and finding data and messing around before they can really do an interpretation. Some companies have solved this but others haven't and it has nothing to do with size. Both large and small companies do a good and bad job of this. We used to have technicians for this but not any more.

General Discussion: There are variations wlthin companies. For instance some companies can collect data effectively in some portions of the states and can't do it at all internationally and visa versa.

Mike Zietlin: The mentoring and apprenticeship concept seems to be a thing of the past. Management tends not to recognize or appreciate the need for mentoring. Its good to have some of the more experienced people just "walking the halls" and making themselves available.

Art Green: Everybody agrees that its important to have workstations but so many of the younger staff want to get a "fast fix". In his experience the most productive staff are older staff who have greater intensity and can stay with a subject long enough to solve the problem.

Rick Johnson: The journals need to become more of a vehicle for interaction and communication. Possibly we need a workshop for managers to broaden their understanding of the problems.

Time And Place Of Next Meeting:

Sunday October 8, 1995 at the SEG National Convention, Houston.

Details to be Notified by Rick Johnson.

Geographic Information Systems - An Essential Toolbox for Exploration

Robyn Gallagher
GI Solutions

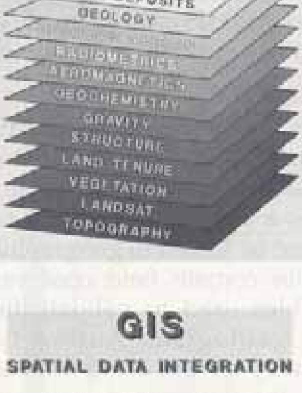
Geographic Information Systems (GIS) are packages designed to store, maintain, display and analyse geographically referenced information. Because geological and geophysical data are (or should be) georeferenced, GIS is an excellent tool for integrating the diverse data sets commonly used by the minerals and petroleum industries for exploration and project generation.

Although people tend to think of GIS in terms of commercial software, it is really an organised collection of computer hardware, software, geographic data and personnel. Generally, the most expensive component of the system within the exploration industry is data; but it is particularly easy to overlook the value of experienced and enthusiastic users who contribute both technical expertise and imaginative ideas.

Amongst the software systems available it is not always clear what delineates Computer Aided Drafting (CAD), desktop mapping, and Geographic Information Systems. GIS is not simply a vehicle for storing digital maps, or even for interactively displaying a collection of related themes: because it contains spatial and thematic databases it also allows query and analysis of individual themes and of the relationship amongst themes. Image processing systems provide complementary functionality. They are used to prepare many of the raster data sets so important for GIS analysis, and nowadays have the capability to make use of vector data produced by GIS.

For many groups involved in the collection and maintenance of geophysical or geological data, the critical component of the system is data structures and functionality which encourage clean, useable data. Most GIS are able to store and use both vector (points, lines, regions) and raster data types. Vectors have traditionally been used to represent geological layers, sample site data, topography and cultural information; satellite and geophysical images, and scanned photographs are examples of raster data. However, GIS also provides other, more complex data structures which are sometimes overlooked in the rush to create digital maps: for example dynamic segmentation for storing survey lines, triangulated irregular networks (TINs) which describe surfaces and 'intelligent' (attributed) rasters which are invaluable for any type of metallogenic or hydrological modelling.

There are a number of GIS software packages available to the exploration community, each with its strengths and weaknesses. The most commonly used are ARC/INFO ,ArcView and MapInfo, but Genamap, SPANS and TNTMips are also in use. Although each of these packages has GIS functionality, the range in data management and analysis functionality varies greatly. For instance, ARC/INFO provides a complete geoprocessing toolbox, whereas ArcView provides simpler analysis and focuses on ease of use.



ER Mapper has become the most popular image processing system within the Australian geoscience community in spite of recent improvements to ERDAS. Most GIS packages are able to communicate with the commonly used relational databases: Oracle, Ingres, Sybase and ACCESS.

Creating Data Sets

A great deal of effort has been devoted by state and federal agencies and some bureaus to preparing geoscientific GIS data sets, ranging from relatively simple digital maps to sophisticated value-added products. Digital geology was first assembled by the Australian Geological Survey Organisation (AGSO) and some mines departments such as South Australia for the purpose of storing, editing and printing geological maps. The data were obtained both by digitising existing maps and by entering the results of ongoing field mapping programs such as National Geoscience Mapping Accord (NGMA). The spatial data were often only attributed to the extent necessary for creating hardcopy maps, and contained layers appropriate to that purpose: geological units; linear features such as faults, folds, veins and dykes; field sites showing structural measurements; and some topographic information and streams.

Data destined for storage and use within GIS is not always digitised using GIS. Many CAD packages provide a comfortable vehicle for creating digital data layers, provided there is careful attention paid to the demands which will later be placed on them. Most organisations now have rules in place for the creation of such data sets: for example clean, stable originals must be sourced for digitising; all polygons must be closed; patterns are not digitised; themes must be separated into meaningful layers. Other considerations, such as the scale, accuracy and precision of the digitising are vitally important regardless of the software used, so an understanding of how to use the software to produce good GIS data is critical.

There are other ways of getting geoscientific data into GIS, including using one of the older exchange formats like DXF or loading ASCII files. Scanning and vectorising of maps is increasingly becoming an alternative to tablet digitising for some types of maps. The hardware and software required for this are quite complex, but affordable systems are now becoming available. It should result in more accurate data, and is much less stressful than hand digitising. Many field measurements are now collected in a digital form, and can be loaded into GIS either directly or via a relational database, with locational coordinates obtained from GPS.

As well as the spatial or positional component, GIS data also have descriptive (thematic) attributes. Relational databases such as Oracle or ACCESS are often used as a vehicle for creating tables of thematic data which can be linked to geographic locations. Some of these tables contain field observations; others are authority tables used to validate field data as it is entered by geologists. Authority tables are an invaluable way of ensuring that all data entered conforms to the database design, removing spelling variations and reducing the need for long unstructured text strings. Early work in this field by AGSO was built on by state agencies and mining companies, with a growing number of experienced GIS users pushing continued cooperation. Many of these databases are documented in internal reports issued by the responsible agency.

The other, indispensable component of each GIS theme is metadata - information about the data (Figure 1). This includes not only information about the creation

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Theme:  geolpg
Description:
geological boundaries for the Minerie 1:100000 mapsheet

Document Revision:      2.0.0a-T
Creation Date:        950515.160427

Update Person:      RGallagher
Update Date:     950515.160427
Contact Person ID:         Head of Program DRCM
Distribution Profiles:            1:                        2:
                                  3:                        4:
Organization:      Aust Geological Survey Org
Cover Revision:       1

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Dangle Tolerance:          0
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Number of Segments:         63835
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Number of Points:        885
Number of Tics:      4
Number of Annotations:          0

Storage location, if archived:


Publication or review status:
complete

Exact citation of this data set:

P R Williams
AUSTRALIA 1: 100 000 GEOLOGICAL SERIES
MINERIE - WESTERN AUSTRALIA                          map
```

Figure 1. Metadata for a geological data set.

of the data set (scale of capture, accuracy, pixel size, survey methods, projection, who captured it and when, ...) but also its database structure (the data dictionary), information on its uses and availability, and a history of the processing done on it. While the importance of metadata has long been recognised, only some groups supply it on a routine basis. A metadata component is part of the Spatial Data Transfer Standard (SDTS) and the US Federal Geographic Data Committee (FGDC) has formulated a metadata standard which will be mandatory for agencies like USGS. Ultimately, the responsibility rests with the geologists or geophysicists who are custodians of a data set to provide information on how to use it.

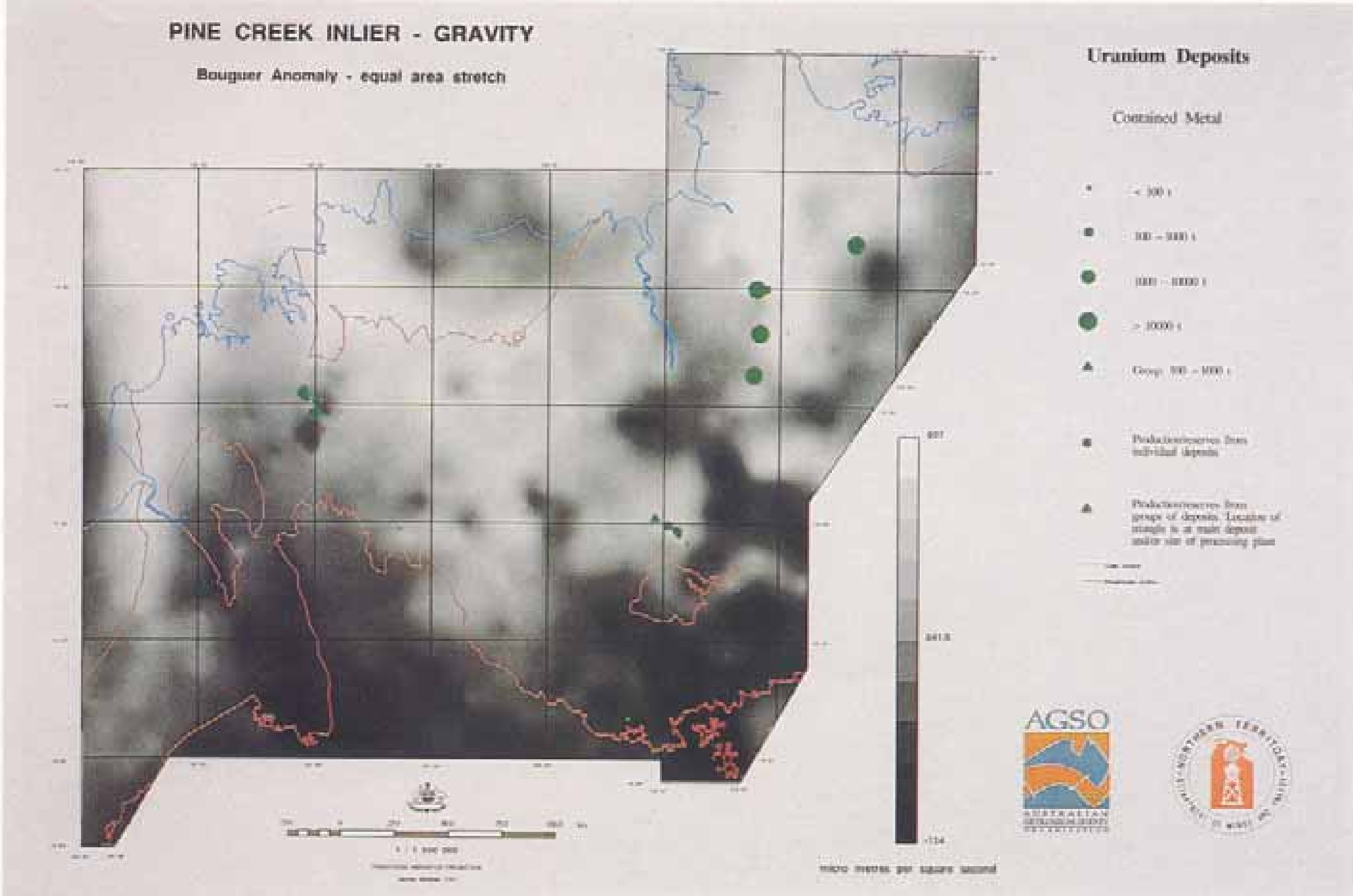
To a certain extent, the design of the GIS layers and their accompanying tables has influenced the data collection methods used in field mapping. The REGMAP system developed by the Geological Survey of Queensland (GSQ) and adopted in a modified form by AGSO attempts to structure the data collection process so that the resulting information may be better incorporated into a digital environment. These schemes use standardised field notebooks, with information collected at each outcrop for site, structure and lithology. The site information contains a set of fixed fields, some of which are mandatory, and many of which (province, rock unit, age...) allow simple coded abbreviations.

Map Production

As mentioned earlier, GIS has been recognised as a tool for storing and editing geological data for hardcopy map production. It has not always made map production 'easier', since the rules and restrictions placed on digital data by GIS are more rigorous than those imposed by hand cartography or some desktop drawing packages. The advantages of GIS are the ability to produce customised maps on request and the availability of the data for other purposes such as modelling and analysis, when it has been assembled in a satisfactory form.

AGSO and some state geological surveys, particularly South Australia and Queensland, have automated their map production using GIS. These maps are increasing in complexity, incorporating many different types of data, including geophysics. The ability to produce a variety of customised maps is also important to mining companies which typically operate in many areas and need maps at a variety of scales and projections, but conforming to company standards of content and layout.

GIS also provides many tools for ensuring the completeness and integrity of map products, which are often ignored. For example, the software can be used to check that the map legend accurately reflects the contents of the geology layers, or better still can create the legend from the layers used in the map. A quite different example of letting GIS do the work is AGSO's use of magnetic declination values obtained directly from AGRF90 model contours to add declination to a 1:250,000 map index, or creating the north arrow for a 1:100,000 map using declination from the same source (Figure 2).



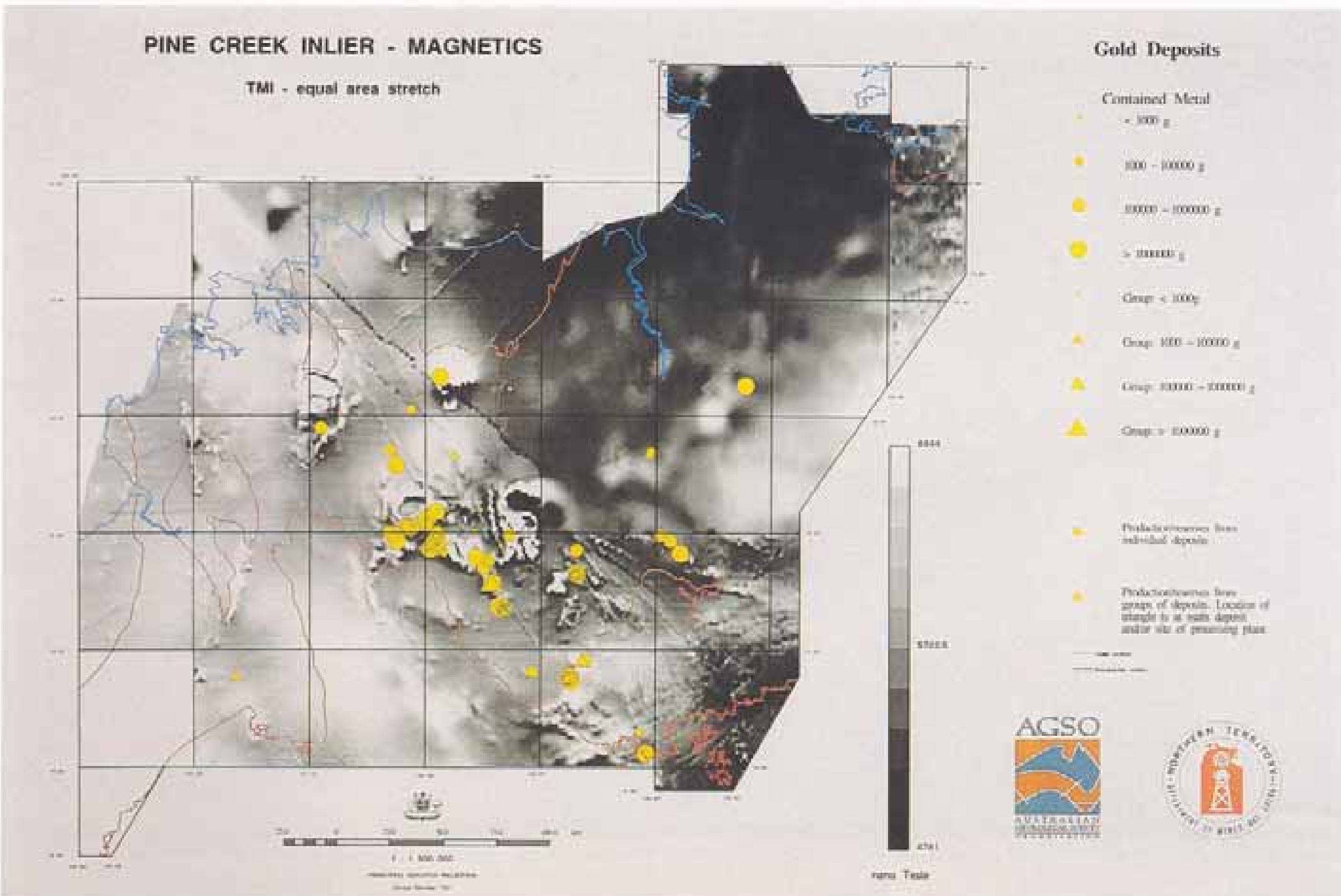


Plate 1. Simple examples of data integration.

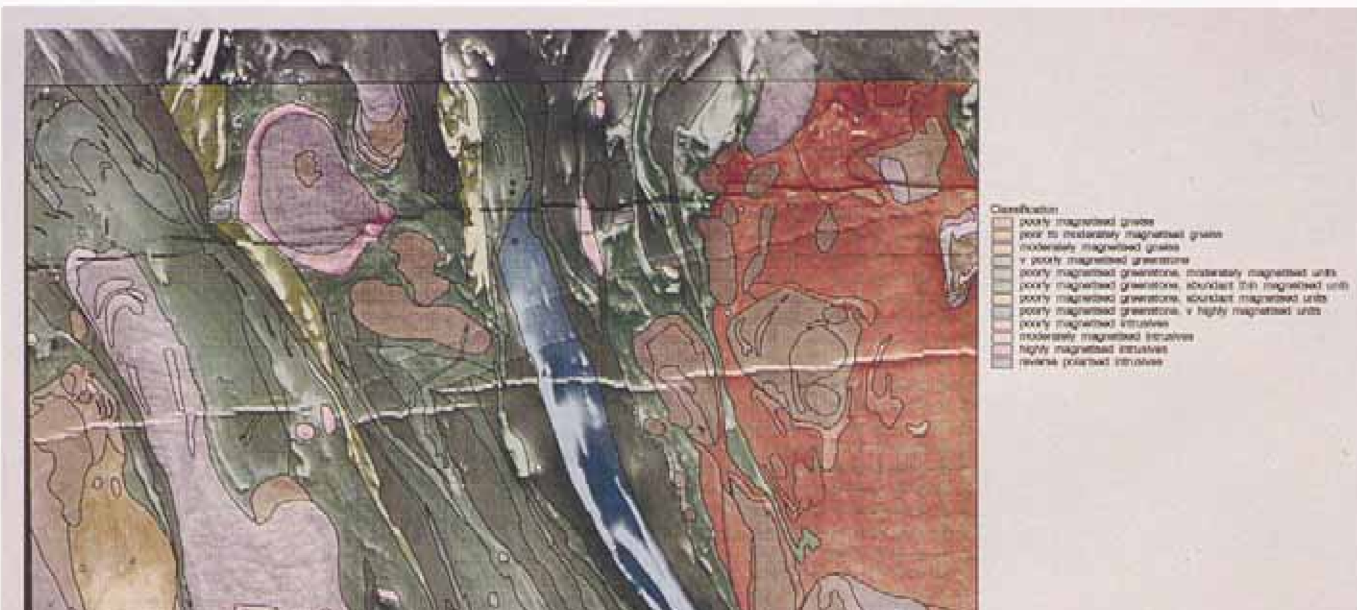


Plate 2. Interpretations created from a geophysical image.

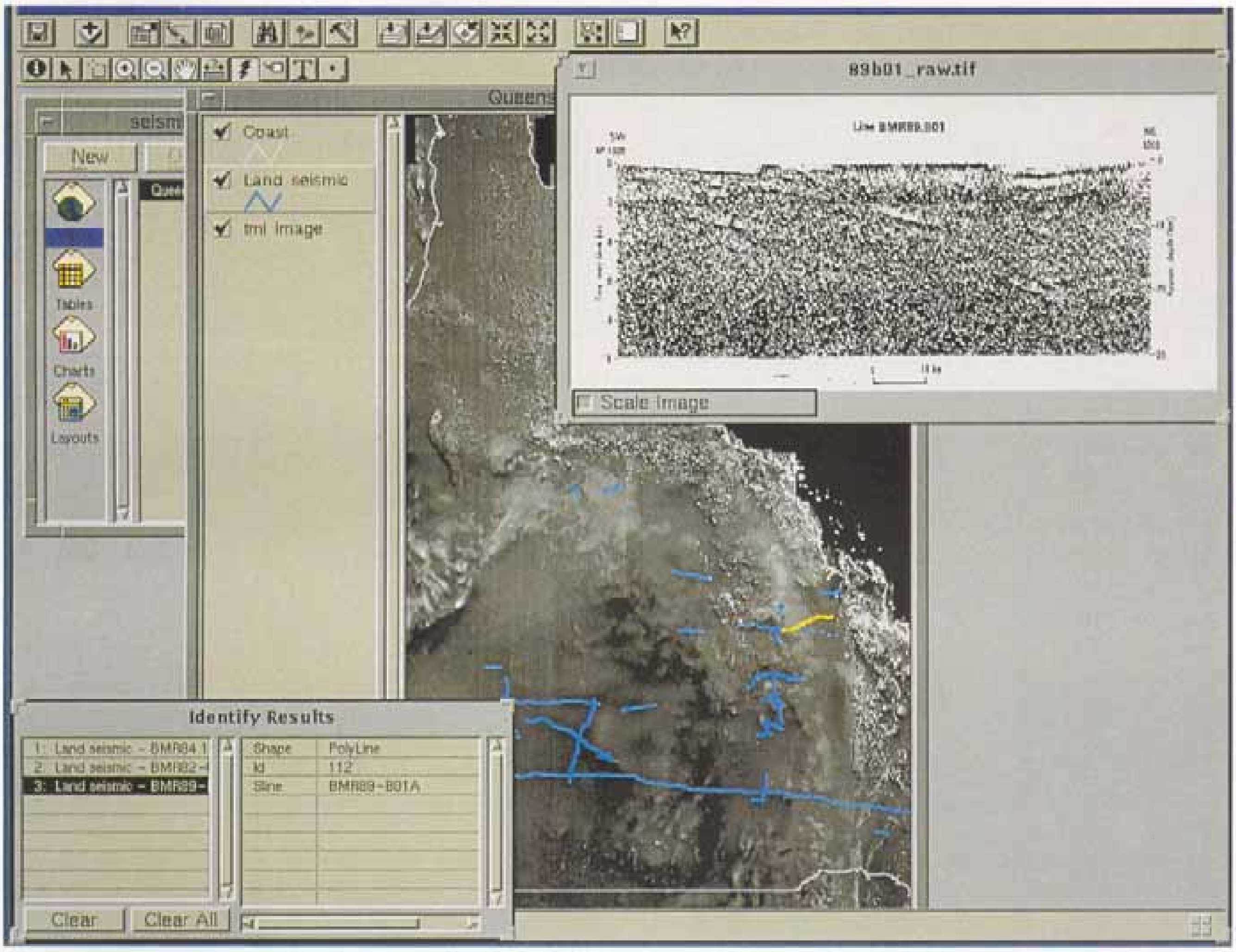


Plate 3. Incorporating seismic data into a GIS package.

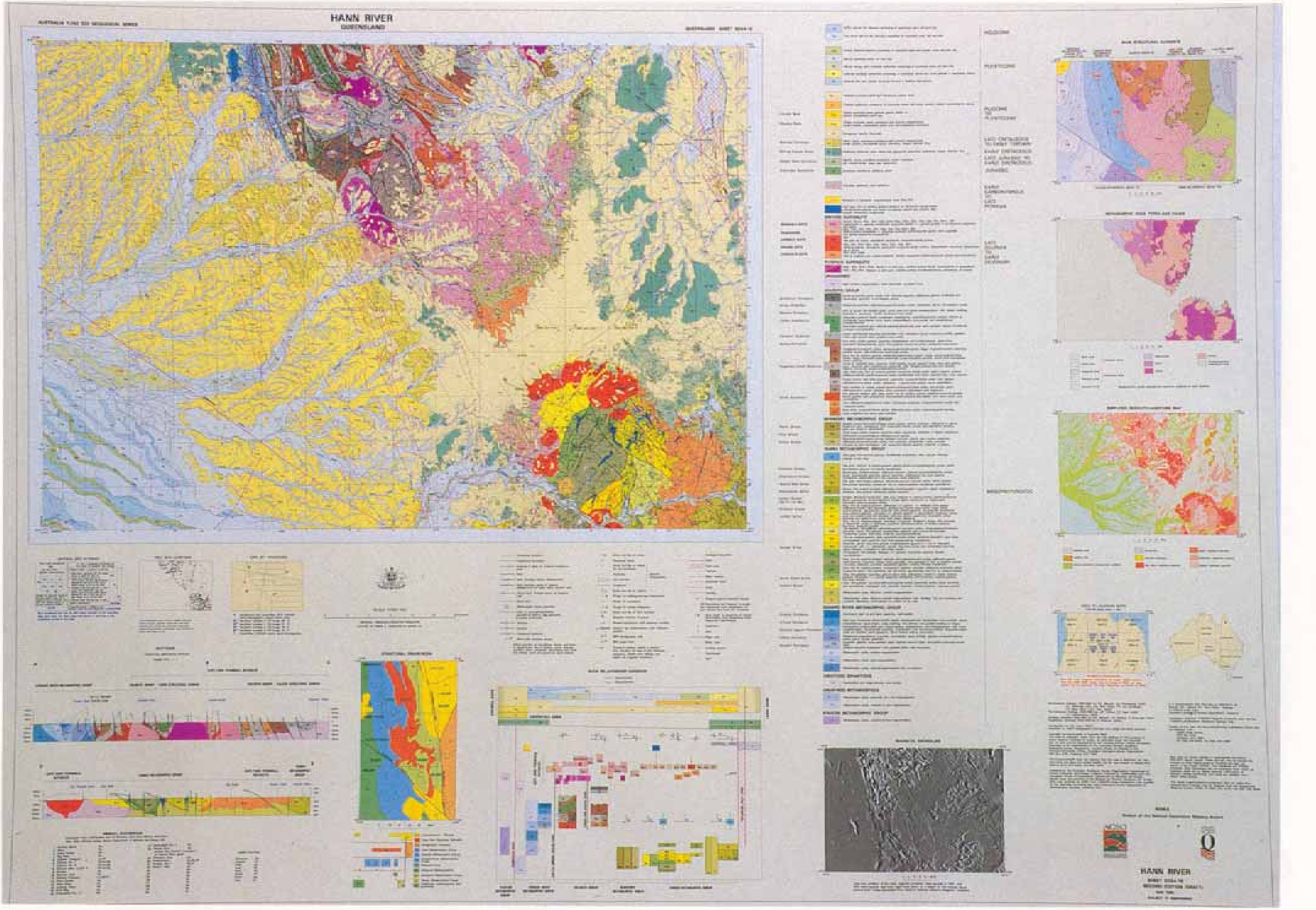


Plate ... A soon-to-be-released example of a sophisticated map created using GIS.

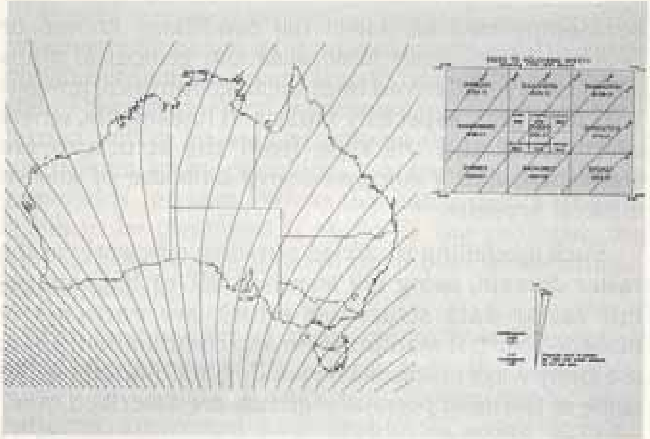


Figure 2. Declinations from AFRF90 can be used to draw a map index and north arrow.

Data Integration

It is clear that GIS has many more uses than just re-creating geological maps: most geoscientists want to use it for interactive display, query and analysis. This places demands on the data in terms of both its GIS 'correctness' and its suitability for such operations. Most GIS software is geared to interactive display and query, but the most commonly used packages within the Australian geoscience community are ARC/INFO, ArcView and MapInfo.

At its simplest level, integration involves the interactive display or printed output of a collection of data layers from the same geographic area. If thematic (attribute) information has been added to those data sets, it may be queried and selections made on the basis of meaningful criteria, eg. all gold analyses > 50 ppb. If the data sets are accurately located with respect to each other, query and selection may be made on one data set based on another, e.g. all gold analyses > 50 ppb within a given distance of NE trending faults.

Some agencies have worked to assemble multi-layer data packages for particular areas of interest to the Australian mining community such as Mt Isa, or whole states like South Australia. These data sets are typically supplemented by proprietary data when purchased and used by mining companies. The packages contain both vector and raster data imported into the GIS from a wide variety of sources such as PC databases and spreadsheets, desktop mapping packages, and image processing systems.

The individual layers which can be integrated vary according to the data available for the area being studied and the purpose of the study: regional exploration, project generation, environmental assessment, planning fieldwork. Some fundamental data sets which are usually included are: geophysical and remotely sensed images (magnetics/ gravity/ radiometrics/ TM/ MSS/ SPOT); a base geological map with at least sufficient thematic information to describe the rock units; structural layers such as faults and folds; some derivative geology such as tectonic or metamorphic units; mineral deposits; geochemical sample results. A large number of additional geoscientific data sets may be available, such as mineralogy, stratigraphy, age measurements, regolith classification, drillholes, seismic lines and current tenement outlines. Finally, it is always necessary to provide supplementary data from other sources to make the package more meaningful: coastlines and political boundaries; rivers and streams; population centres; reserves and national parks.

For some organisations this digital data integration step has provided, for the first time, an index to all data available for an area of interest. Explorationists were often unaware that useful data had already been collected by another group within the organisation, and even if that data were unearthed, manual integration was a difficult task. Because GIS is able to operate in a distributed environment, local custodians can retain control over their data while it is accessed by other customers, or the data can be brought into a central administrative framework. In many cases this step of integrating an organisation's data within a real-time display and interrogation environment has led to increased commitment to data collection and cooperation between specialist groups.

Creation of integrated GIS data packages for sale to the exploration community emphasised the time and care which are required during the data preparation stage to ensure that the data layers can be validly integrated:

- an appropriate projection (coordinate system) must be chosen

- the data sets must all be of approximately the same spatial accuracy so that the features are correctly located within their own layer and relative to features in other layers

- geophysical and remotely sensed images and/or topographic layers and/or standard mapsheet outlines are invariably required for locational purposes, or to put the geological and geophysical data into a more meaningful context

- GIS data must have sufficient thematic information attached to the features to allow geoscientists to carry out useful queries: this often requires additional effort beyond simply digitising the contents of a paper map

- thematic information must be encoded in such a way as to make queries easy to construct and the results they produce meaningful: long, unstructured text strings are of little use

- data sets must be as complete as possible: interactive display and query quickly reveals 'missing' features or layers whose attributes are inadequate

- there must be documentation of the data, both at the level of metadata for each individual data set and general information about the package as a whole

During the data integration phase some problems are ignored, at least initially, in the interest of providing a useable package as quickly as limited resources allow. The most obvious of these is the multiple definition of some features at different locations in different layers: for example, different coastlines inevitably occur in topographic layers, surface geology, regolith and vegetation maps, and eventually a 'standard' coastline must be determined for all maps in a range of scales. It is also very tempting to store field samples in many different databases so that the 'same' point acquires slightly different coordinates each time. Strong discipline is required to enforce that the coordinates of each field site are stored only once .

One of the great advantages of GIS is that it facilitates incremental improvement to the data sets once they have been assembled. New thematic data may be added to existing tables; new tables may be created and linked to spatial features; data layers such as solid geology, metamorphic geology and mineralogy may be derived by combining or modifying existing layers. Similarly, existing maps may be improved by comparison with other layers or reference to images, allowing inaccurately drawn boundaries or unmapped features to be located. Geophysical images have been particularly useful in adding to our knowledge of regional geology, and can be effectively used to update digital data or create new interpretative themes.

In some cases, interactive display and query of GIS datasets has been the endpoint of data integration. However, once the digital data have been assembled and verified, it is often easy to create derivative data layers which embody imaginative ways of looking at 'old' data, for example presenting analyses of whole rock geochemistry for the geological unit in which they fall. Because customised output is possible, whole atlases of such data, like the AGSO Metallogenic Atlas Series, may be created with only a small amount of extra imagination and effort.

Modelling and Analysis

The ultimate goal of some groups in the geoscience community is to use their GIS data for mineral potential mapping, i.e. by understanding the relationships between various data layers, to produce prospectivity maps delineating areas favourable to particular types of mineralisation.

This activity imposes even more stringent standards of data quality and completeness. Conditions which were 'desirable' for the purposes of data integration become 'imperative' if modelling is to be carried out successfully. For example:

- the scale at which the data are collected must be appropriate to the analysis

- the spatial accuracy of the data must be checked, both in the absolute sense that digitising has been carried out with sufficient care and in the relative sense that data from one layer is positioned correctly with respect to data in another layer

- boundaries common to more than one data layer must be taken from a common template so that they always lie in exactly the same location

- if fields, especially in mineral deposit or geochemical data, are to be used for analysis they must be numeric and all measured in the same units

While GIS can be used to test individual, region- or deposit-specific models, most groups involved in this work are developing general methodologies which range from a purely conceptual approach to a statistical one. In all cases the data sets used are those which can be manipulated to reflect the conditions known or believed to influence mineralisation: geological maps and data layers derived from them; geophysical images; structural data, especially faults and lineaments, where orientation and distance from the structure are significant; and a comprehensive database of known mineral deposits.

Such modelling is carried out most efficiently in the raster domain, using not standard BIL or BSQ images but raster data structures which are particularly designed for fast manipulation and combination. There are many ways to approach metallogenic modelling, but some of the most popular methods are described here.

AGSO has adopted a purely conceptual approach to modelling, which relies heavily on an understanding of both the factors required to formulate a specific deposit type and on the geology of the area being analysed. This approach was considered more applicable for areas with few known mineral prospects. It requires two main steps. The first is to determine the essential ingredients of particular styles of deposits in terms of specific combinations of mappable elements that can be searched for in a GIS. The second step is the development of digital maps of regional geoscientific data which show the distribution of significant factors for mineral systems in general. Based on detailed studies of ore deposits it is possible to determine which specific mappable geological factors are essential to form a particular deposit type, and it is relatively simple to locate those areas that contain the relevant factors.

In an 'interactive interrogative' procedure, a geologist is able to impose conditions on data layers, e.g. distance from a granite boundary or fault, host rocks that contain magnetite but not feldspar, a range of pixel values in a magnetics image. The relevant data layers are combined, with the study area coded as a raster map containing pixel values which reflect how many of the geologist's conditions are satisfied. An alternative 'generic' procedure determines which conditions occur in selected data layers within a radius of a deposit or group of deposits. These unique conditions are reported, then the utility locates all other regions in the study area where identical conditions occur. New deposits can be selected or further points added to the analysis and the process repeated. This allows pictures to be built up of conditions at selected locations with very little user intervention.

A conceptual approach combined with statistical methods has been employed by University of Western Australia. Aimed at regional-scale gold prospectivity mapping in Western Australia, it tests and refines the conceptual theories regarding the siting of ore deposits before incorporating them in the final prospectivity map. Three types of spatial relationship are tested: association dependence in which deposits are directly associated with a particular feature (for example, host rock dependence); proximity dependence in which deposits are hosted close to a feature (for example, deposit size versus distance to faults); and density dependence in which deposits are related to an abundance of a particular feature (for example, more deposits occurring where there is a greater density of crustal fractures).

Purely statistical modelling methods present their prospectivity maps as a measure of probability or possibility that the given deposit type will occur in an area. They assume that sufficient exploration has been carried out in an area of interest to allow statistical coefficients to be calculated, so are less popular in greenfields terranes. While the initial choice of data layers to be combined is made by the geologist, the contribution of each layer to the model is determined mathematically.

The best-known of these methods is Weights of Evidence, pioneered by a team from the Geological Survey of Canada. It utilises a combination of map patterns, converted to probabilities using Baysian statistics. In the simple case, those maps contain a binary pattern derived from the original data set (geology, geophysical signature, proximity to faults), with positive and negative weights dependent on the presence or absence of mineral deposits within a pattern. This is why the method is heavily dependent on known mineralisation. Combining the individual maps, which should represent conditionally independent patterns, results in a series of probability classes that the given mineralisation will occur.

Fuzzy Logic, another statistical modelling method, estimates possibility. Values from 0.1 to 0.9 are assigned to an attribute as a measure of the increasing possibility that a given style of mineralisation may be present when that attribute is present. Then a range of operators (and, or, algebraic sum or product, gamma) may be applied following conditional rules which approximate real world conditions pertaining to the type of mineralisation under study. Clearly the setting of fuzzy membership numbers and the selection of operators relies on expert opinion.

The GIS Perspective

In general, GIS data sets have been essentially 2-dimensional representations of a 3-dimensional space (or 4-dimensional if time is a variable). This is not only because the major commercial GIS packages have imposed such a limitation, but because the effort involved in collecting and verifying and integrating 2-dimensional data sets has proved demanding enough for many groups. Some data, such as drillholes or seismic profiles lend themselves to a simplified form of 3-dimensional display by linking subsurface snapshots to point or line locations on the earth's surface. Limited manipulation of data in the third dimension is also possible through the use of surface modelling techniques such as triangular irregular networks (TINs) which allow, for example, geological maps to be draped over digital elevation models.

Geoscience data is characterised by enormous variability in subsurface structure and dramatic changes in material properties over short distances. Uncertainty is further increased because of the cost and difficulty of obtaining subsurface data. The difficulties of managing and visualising uncertainties are probably one reason that 3D systems have been less successfully used in geoscience, compared with say medicine, where the structure of the human body is well-known.

The fourth dimension, time, has been traditionally handled as snapshots or time slices, whereas it should ideally be treated as a fourth, continuous variable. To accurately model geological processes such as faulting, folding or magmatic activity, time must be treated as a smoothly varying quantity in the data model.

The tools which GIS provides for the geoscientist are general-purpose ones, designed to be applied to a range of problems. This means that GIS is often used in combination with specialised software packages for image processing, mine-planning, seismic processing, geophysical modelling, or statistical analysis. Sometimes this requires tedious data exchange, but increasingly packages are able to share data formats and communicate with each other directly via programming constructs like APIs and DDEs. Some GIS packages have chosen this method for temporarily dealing with the problem of multidimensional data, preferring to link to the developments available in packages such as EarthVision.

Conclusion

Considerable effort is still being made by government agencies and private companies to add to the store of data suitable for GIS use. The emphasis has moved towards providing more than 'digital maps', so that the data can be queried, combined and analysed. Because the data sets are being used by groups across Australia and because of the expertise and experience of some of those users, there is a growing push for standardisation of data structures, authority tables and interchange formats. And an equally urgent need for adequate metadata to accompany those data sets. The geoscientific community has become an enthusiastic, and increasingly demanding, user of GIS.

This article was produced with the support of ESRI Australia. All figures and illustrations were created using ARC/INFO or ArcView.

Biography

Robyn Gallagher was captivated by GIS while working with the image processing group at CRA Exploration. After earlier being introduced to geophysics and image processing at CSIRO, she experimented with GIS as a tool for integrating CRAE's images with other map data. In 1991 she formed GISolutions, a consultancy designed to help the exploration industry (and other ARC/INFO users) get the most out of GIS. She works with AGSO, state mines departments, mining companies and other government agencies - principally in the natural resources area. While much of the early work involved helping clients get their data into GIS, this progressed to preparing data packages and maps for sale, then to metallogenic modelling. A computer science graduate originally, she is often employed to write utilities for ARC/INFO and ArcView.

Petrophysics of PHKB 1 (Bunnerong No. 1) Drill Core (Sydney Basin)—an Example of Integration, Co-operation and a Class Exercise

R.A. Facer, K. Viravong, N.M. Kelly, M.C. Lahiff, B.A. Miliauskas, N.C. Overkov, A. Rodeghiero, T.M. Simko[1], G. Tsoukalas, A. Winch.
Department of Geology & Geophysics (and [1] Department of Applied Physics), University of Sydney.

Introduction

Extending the important example set by Don Emerson, a third year course on Petrophysics was introduced (by Richard Facer) into the Geophysics program at the University of Sydney in 1994. The course included lecture and practical components, and was intended to show the importance of petrophysical studies in exploration geophysics. As such, a fundamental tenet was the place of petrophysics as a nexus between geological properties and geophysics - application and interpretation, and the need for integration of studies.

A significant component of the practical work of the class was a diverse study of drill core from PHKB1, Bunnerong No. 1, drilled in late 1993. The class was fortunate in having Pacific Power provide access to core from that fully-cored diamond drill hole, through the co-operation of Carl Weber, Malcolm Bocking and Peter Odins. Core size is HQ (diameter about 63.5 mm). R.A.F. and K.V. (post-graduate student) sampled the core, although at initial sampling only the rocks above the coal measures (the top of the coal measures is near 780 m down-hole) because the coal-bearing horizons were the subject of detailed study re coalbed methane. (Deeper sampling has subsequently been carried out for extended studies by Richard Facer and by others.)

As an example of integration of varied study perspectives, a range of investigations has been carried out within the Department of Geology and Geophysics, in part having been specifically designed to complement the program of Pacific Power. Jock Keene had already included study of the core in a Sedimentology course, so the students had been introduced to the rocks. K.V. had carried out preliminary work as part of another study (Viravong and Facer, 1994), and that work is continuing, along with a trace element project by Jock Keene and Richard Facer. In addition, Shields (1994) has conducted a major study of the secondary minerals in the coal measures; Smith (1994) has carried out a study of fluid inclusions and shale compaction; and Holzschuh (1994) used core from PHKB 1 to provide control on bedrock properties in his groundwater study on the shores of nearby Botany Bay.

Geological Setting

The Sydney Basin contains an approximately conformable sequence of late Palaeozoic to early Mesozoic rocks which are predominantly clastic, but which include significant volcanic units and coals. Some of the sedimentary rocks are volcaniclastic, even tuffaceous, in character. There is a diversity of minor, and some major, Mesozoic and Tertiary intrusive rocks, with relatively minor Tertiary basaltic flows as remnant caps. Some Jurassic sedimentary rocks appear to have formerly been present, and there is of course a diversity of Quaternary to Recent cover. Weathering depths and consequent effects on physical (and other) properties are rather variable across the Basin, and may exceed a hundred metres in places.

Bunnerong No. 1 was drilled near the northern shore of Botany Bay, and was hence sited near the centre of the Sydney Basin. The main purpose of drilling the hole was to continue evaluation of the coalbed methane potential of the Sydney Basin. That coalbed methane is generally assumed, with good reasons, to have its origin in the Late Permian Illawarra Coal Measures (or equivalents elsewhere in the Basin). Bunnerong No. 1 was drilled through the Triassic Hawkesbury Sandstone (under about seven metres of cover) and Narrabeen Group section. A dyke of unknown age was encountered in the Triassic interval, and sills (or a multiple sill) were encountered near the top of the Permian coal measures.

Core recovery in Bunnerong No. 1 was generally excellent, although some of the finegrained, clayey rocks were badly broken because of their nature. In many cases (generally all, below the weathered zone) it is possible to clearly see intact contacts, even of the dyke. The rock types included conglomerate, sandstone, siltstone, claystone, shale and coals (of varying thickness and quality), as well as the igneous rocks. Apart from the intrusions, there are significant tuffaceous/volcaniclastic rocks. There is a varying degree of lithification, cementation and secondary mineral development. Weathering effects, including "iron staining", are apparent, but seem to be restricted to relatively shallow depths of about 25 m to 30 m, presumably reflecting the water table level. Those weathering effects include the iron (hydr)oxide staining commonly shown by the Hawkesbury Sandstone near the surface at many places across the Basin, and which render the sandstone an attractive building stone.

Petrophysical Study

A range of non-destructive petrophysical tests were carried out on the core. The techniques were restricted to non-destructive procedures because, at the time of the course practical classes, integrity of samples was preserved until the testing program of Pacific Power had reached an appropriate stage. For example, that meant that P-wave velocities were not determined at that time by the class because the sampled core lengths were not all sawn (and instrumental difficulties were encountered). (Since then, Pacific Power have encouraged a diversity of physical, physico-chemical and chemical studies—some of which have been completed and some are continuing.)

Within the constraints of time and instrumentation, several aspects of the rocks were studied. Hand specimen study was considered important: there was a need to make observations which could influence the understanding of the other physical properties (porosity, permeability, composition, specific gravity, magnetic susceptibility, electrical and sonic properties). Magnetic susceptibility measurements were carried out with a Geo Instruments GMS-2 magnetic susceptibility meter. Generally, several readings were taken, and then averaged. Specific gravity was determined, although the variable degree of porosity and permeability—and in some cases stability of rock in water!—imposed some restrictions. Radiometric characteristics were measured with a Geometrics GR-3 10 gamma ray spectrometer, recording total count (TC) using readings at the 10 second setting and counts for each of potassium (K), thorium (Th) and uranium (U) using readings at the 100 second setting. Ratios of the discrete element counts were also calculated (and subsequently some neutron activation analysis data were acquired).

For all properties determined it was only possible in the class project to work on scattered samples rather than on continuous drill core. However, as an important part of the class work was to gain experience in the principles of the data acquisition, and to prepare some degree of interpretation, it was considered that the semi-continuous nature of the samples was appropriate. Some care had been taken to sample a range of rock types.

Results

Within the class arrangements there were limitations on the volume of data acquired, although those limitations were incorporated into class discussions. (It is important that parameters likely to influence any program of data acquisition be considered and included in teaching - to extend the learning experience / preparation for future professional work.)

The visual logging yielded a near-complete log of the core (from 7 m depth to 815 m depth). The main petrophysical properties data set included:

- 70 magnetic susceptibility measurements (7 m to 815 m);
- 26 radiometric (TC and K, Th and U) measurement sets (7 m to 151 m, 405 m to 708 m); and

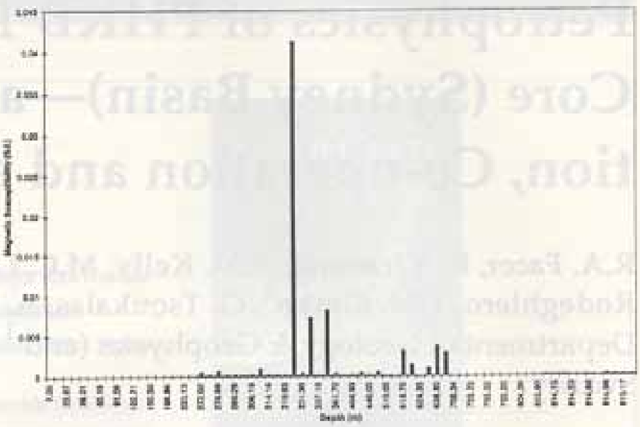


Figure 1. - Values of magnetic susceptibility measured on core from Pacific Power PHKB 1 Bunnerong No. 1. 36 samples yielded (averaged) measured values, from a total sample set of 70. The calibration factor used for these values was 1.41 (based on a separate study by R. Facer and K. Viravong).

- 15 specific gravity determinations (7 m to 747 m).

From 7 m to 198 m the core is predominantly sandstone, with minor mudstone and occasional coal "scares" (to a few millimetres thick). Interbedded sandstones, siltstones occur over the next 80 m. At about 278 m there is a strongly altered dolerite(?) dyke, with sharp contacts to dark, laminated siltstone. (The dolerite is predominantly altered plagioclase, with minor chloritised pyroxene and accessory iron-titanium oxides. The secondary minerals are calcitic carbonate and chlorite, with amygdales filled with calcite and/or chalcedony.) Below 300 m there are interbedded grey, black, green and red (mottled) claystones and mudstones, with siltstones and minor sandstones. Native copper is sometimes present in this fine-grained unit, which is the Narrabeen Group. Occasional coarse horizons (conglomerate and/or breccia) are present. The organic matter content is often moderate to high, although coal is not present in significant amounts until below 815 m, the lowest sample studied here. Possible intrusions (altered sills) are present, but are distinct from tuffaceous rocks and volcanic litharenites near 800 m.

Of the 70 magnetic susceptibility measurements, 36 yielded measurable values, with the very low values being obtained for the sandstones. Such an observation is to be expected because the Hawkesbury Sandstone, in particular, is generally very quartz-rich (albeit with varying amounts of clays). "Accessory" or trace minerals tend to be more variable in the Narrabeen Group sandstones. Figure 1 is a plot of the magnetic susceptibility values, after adjustment for the effect of core size (although the values were not initially adjusted in the class by a calibration factor, which is the object of separate studies by K.Viravong and R. Facer). The relatively high values of magnetic susceptibility (Figure 1) are for sedimentary rocks: at 330.35 m being a pebbly siltstone/sandstone with claystone clasts; at 340.05 m being a green coarse lithic sandstone; and at 613.7 m baing a green very coarse lithic sandstone. All those samples are from the Narrabeen Group, are from well below the weathering zone, and do not appear to have undergone any effects from the igneous rocks which

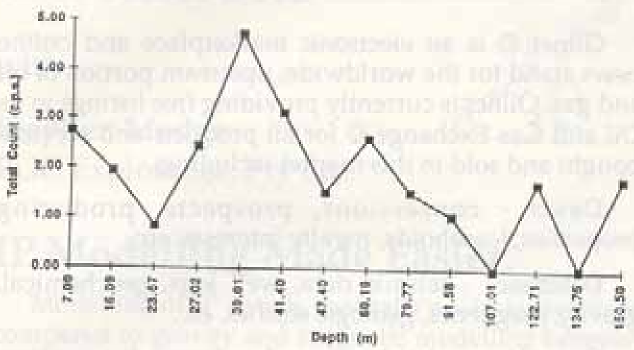


Figure 2(a). - Values of total count radiometric readings for core samples over the depth range 7 m to 150.5 m in Pacific Power PHKB 1, Bunnerong No. 1. (It is possible that the adjustment, for background reading, was a little severe. Nevertheless the trend should be unaffected.) The variation at shallow depth may be due to weathering effects the uranyl ion can be very mobile.

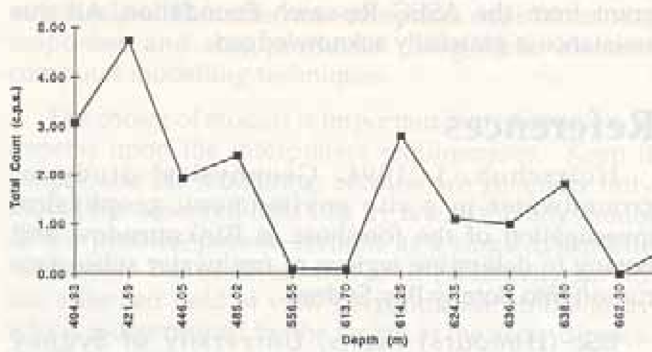


Figure 2(b). - As for Figure 2(a), but across the interval 404.9 m to 708.3 m there is a noticeable trend across the interval (within the Narrabeen Group), the origin of which can presumably be attributed to compositional change in the rocks. Apparently the increase in organic matter has not directly influenced uranium levels.

were encountered in the drill hole. That latter observation is supported by the relatively isolated nature of the high values.

Figure 2 presents the values of total count radiometric values for the two restricted intervals for PHKB 1 core samples. Apart from a few "high" values across the 27 m to 41 m interval, the total count readings across the Hawkesbury Sandstone (Figure 2a) show little change. The high value at 39 m (Figure 2a) is probably caused by a secondary concentration of radioactive elements in the sandstone as a result of weathering, although that depth is below the water table in the area (Holzschuh, *pers. comm.*, 1994). It is interesting to note that there is a noticeable decline in total count readings across the majority of the Narrabeen Group interval (Figure 2b), although the absolute values would need more precise "background" control. The values of K/U, K/Th or Th/U are not very distinctive, except at 41 m, 151 m, and 446 m where the K/U values are 4 or greater. This can be attributed to the presence of detrital feldspar, which is commonly found dispersed through much of the Sydney Basin.

Figure 3. - Specific gravity values in Pacific Power PHKB1, Bunnerong No.1 cores samples. There is a noticeable difference across the Hawkesbury Sandstone/Narrabeen Group boundary. (Sample 278.9 m depth is of a strongly altered dolerite(?) dyke.)

Values of specific gravity are plotted in Figure 3. There is a clear step in values at about 200 m—reflecting a change from sandstone at 198 m to a mudstone at 204 m. The relatively gentle decline in specific gravity over the next 500 m (excluding the dolerite at 278 m) is perhaps a little unexpected, with loading expected to increase specific gravity values. It is likely that an increase in organic matter could have influenced specific gravities, or some other subtle variation in mineral content. Although some care was taken with SG measurements there may be a need to encapsulate the samples in paraffin wax before immersion.

Discussion

Although this is a brief study, it has shown the value of carrying out integrated studies. The petrophysical (class) study described here has provided valuable "research training" or "industry training". Extension of the study would benefit from comparison with down-hole logs (which were not available at the time) and to correlation with similar petrophysical study of nearby drill core. Such direct petrophysical studies correlated with down hole logs should enhance across-basin correlation when drill holes are not (fully) cored.

There are, as might be expected, in such a class study, time constraints and hence some gaps. However, the variation(s) in petrophysical properties are real. The project was carried out with no prior knowledge of the petrophysical properties reported here, and thus provided students with a real "problem" that needed design, solution, and explanation. There is, of course, the added benefit that potential control on other studies for Bunnerong No. 1 has been achieved.

Acknowledgements

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Excitations

with

Stephen Mudge
RGC Exploration Pty Ltd.

IP Modelling Made Easier.

Modelling of IP data is generally an awkward task compared to gravity and magnetic modelling because the electrical response of the ground is often more complex than its gravity and magnetic responses. It can also be very time consuming because more time is required to compute the electrical response of complex ground structures for say, the dipole-dipole array, and the effects of changing various source parameters on the computed response are often difficult to predict.

Introduction

Unlike gravity and polar magnetic anomalies, IP and resistvity anomalies show little or no resemblance to the true shape and attitude of their buried sources. The situation is further complicated when the response of neighbouring rocks, the dampening effects of conductive overburden and topographic anomalies are all taken into consideration. Furthermore a wide variety of ground structures can produce similar IP/resistivity responses, further complicating the interpreters job of resolving the *true* electrical structure of the ground. Often many non-target electrical structures, such as weathering, water table, conductive water-filled structures, chargeable clays, electrical anisotropy of individual elements, to name just a few of these demons, contribute significantly to the measured ground response.

It is often impossible to predict the effects of changing various body parameters, such as dip and width, overburden thickness, proximity to adjacent structures etc., in guiding the modelling process. This is in addition to the problem of determining true values of chargeability and resistivity for each element of the model. Inversion techniques also generally need a reasonable starting model otherwise unrealistic results can be obtained. Be aware also that the observed data shows *apparent* values of these parameters, not their *true* values.

Atlas of Model Responses

I believe the only way around the problem of predicting dipole-dipole IP/resistivity model responses is to have an atlas of model responses available to assist with survey design and analysis of data.

Several atlases have been assembled by various research groups over the last 30 years or so. Originally these were derived from analogue scale model studies, later products were computed using numerical methods. I produced my own atlas of model responses for the dipole-dipole array which spans a wide range of electrical structures from elementary layered ground, 2D dipping dyke and 2D dipping contact models to complex multiple-body models with conductive overburden. The atlas now comprises over 200 model responses and was produced using finite element computer modelling techniques.

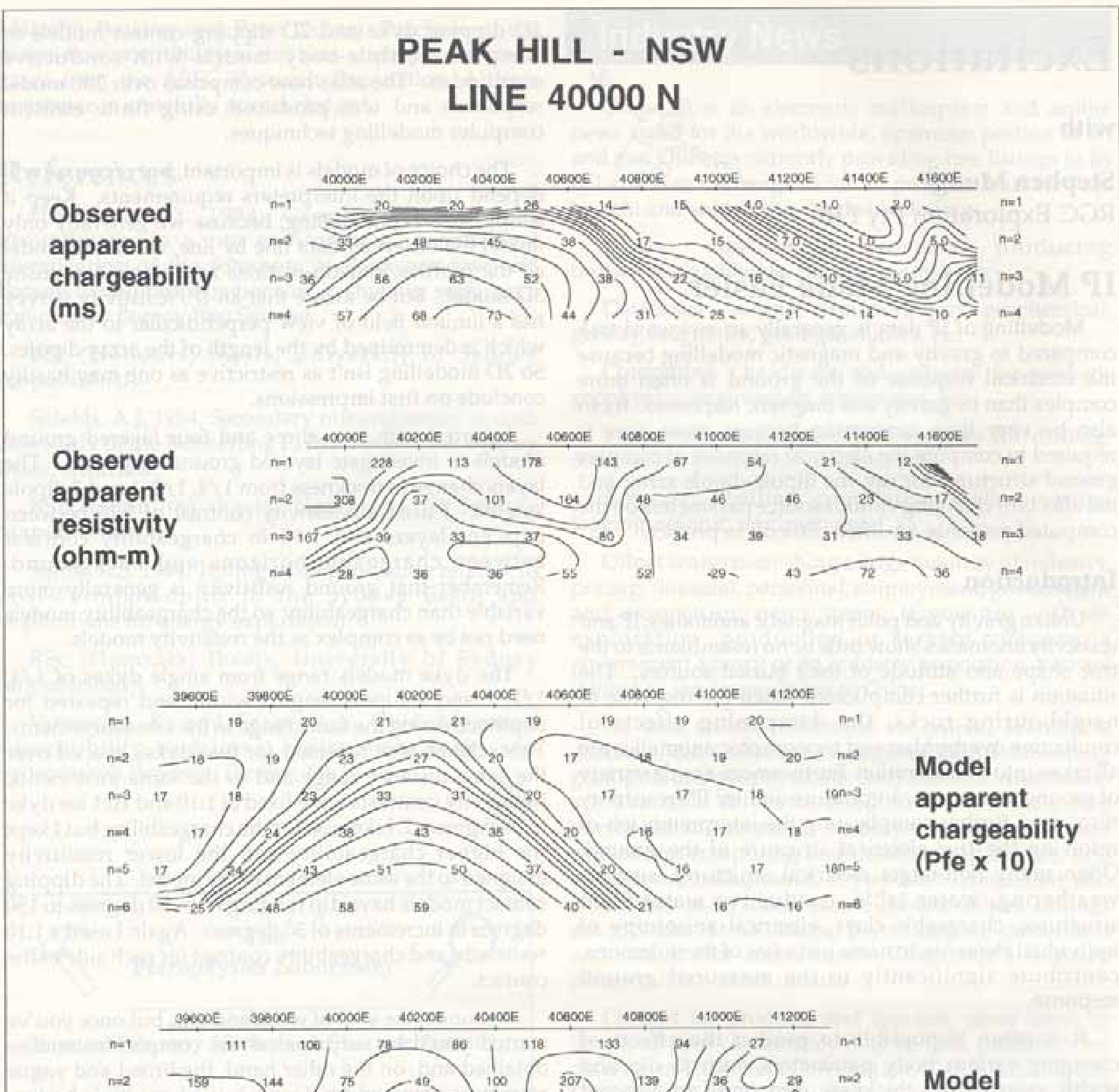
The choice of models is important, but of course will depend upon the interpreters requirements. Keep it simple, use 2D modelling; because we generally only model the observed data line by line, we rarely model all the profiles/psuedo-sections as a single composite 3D model. But be aware that an IP/resistivity survey has a limited field of view perpendicular to the array which is determined by the length of the array dipoles. So 2D modelling isn't as restrictive as one may hastily conclude on first impressions.

I started with two, three and four layered ground models to investigate layered ground responses. The layers change in thickness from 1/4, 1/2, 1 and 2 dipole lengths. I used a resistivity contrast of 1:10 between adjacent layers and 1:10 in chargeability contrast between chargeable horizons and background. Remember that ground resistivity is generally more variable than chargeability, so the chargeability models need not be as complex as the resistivity models.

The dyke models range from single dykes of 1/4, 1/2, 1 and 2 dipole lengths width, and repeated for depths covering the same range in the same increments. This scheme was repeated for two dykes spaced over the same distance range and in the same increments. Resistivity contrasts were fixed at 1:10 and 10:1 for dyke to background. Likewise for the chargeability, but I kept the higher chargeability and the lower resisitivity assigned to the same element of the model. The dipping contact models have dip ranging from 30 degrees to 150 degrees in increments of 30 degrees. Again I used a 1:10 resistivity and chargeability contrast for each side of the contact.

It sounds like a lot of work and it is, but once you've started you'll be surprised at the complex anomalies obtained and, on the other hand, the broad and vague responses obtained for deeply buried, multiple bodies. This can be a bit frightening when it is realised that survey data can be easily misinterpreted and erroneous drill targets specified. Also the addition of conductive overburden really smears out what are otherwise strong responses. The commonly used 50 metre dipole length dipole-dipole array isn't always the most appropriate array size for a range of target depths and sizes. I'll let you discover that for yourself from your own atlas of models. I also included some topographic models (valleys and hills) as topography strongly effects the resistivity response.

To get realistic and meaningful interpretations of your data you need to get as much geological information about the likely geometry and attitude of the target, and the structure and electrical properties of the background. Downhole measurements and vertical electrical sounding data are particularly important at this stage, actually having them is a luxury. Next find a suitable model in the atlas that approximates your geological situation. Use this as a starting point for forward modelling and for inversion modelling. Don't aim for high resolution as the complex interactions


PEAK HILL - NSW
LINE 40000 N
Observed apparent chargeability (ms)
Observed apparent resistivity (ohm-m)
Model apparent chargeability (Pfe x 10)
Model apparent resistivity (ohm-m)
39600E
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41400E
41600E
41800E
n=1
n=2
n=3
n=4
n=5
n=6
OXIDISED OVERBURDEN
ALLUVIUM
HOST ROCK
Drillhole
SULPHIDES
ρ = 100 Ω.m
Pfe = 2 %
ρ = 5 Ω.m
Pfe = 2 %
ρ = 500 Ω.m
Pfe = 1 %
ρ = 0.3 Ω.m
Pfe = 30 %
∞
9200v078.dgn

between elements of the model often have a significant effect on the final result. For forward modelling the atlas of model responses will guide you in judiciously changing the model parameters to optimise your analysis of the field data.

Model Resolution

Now a few words of caution are warranted to dampen the interpreter's enthusiasm about finding the perfect model to fit the field data. You will quickly realise from examining the atlas of model responses that often only subtle changes in response are measured for a range of values of a particular body parameter. For compact sources I have learnt that it is only possible to resolve depth to top, width and position along the survey line to not much better than about 1/4 of a dipole length. Sometimes it is difficult to get this relatively high degree of resolution, particularly in the presence of conductive overburden. Also it is often difficult to predict the amount of dip, beyond resolving its direction. So don't expect the higher resolution we are accustomed too from gravity and magnetics.

The atlas will also provide insight into the effective depth of investigation for the electrode array. There are some surprises for young players, especially when conductive overburden is involved. Don't forget to consider the effects of topography on the resolution of the resistivity data.

Field Example

The example shown in Figure 1 is from Peak Hill, NSW, the data was acquired in 1976 so grid measurements are in feet. It shows a dipole-dipole array pseudo-section measured with a dipole length of 200 feet (61 metres) for dipole spacing ranging from 1 to 4 dipole lengths. The geological information was good enough to predict the variable depth of the overburden and its dip to the east, and that disseminated sulphides could be expected (the target). There were no down-hole measurements or vertical electrical sounding data available for the interpretation.

Nevertheless it was possible with the aid of an atlas of model responses, to produce the forward model shown in Figure 1 as an explanation of the measured response. Changes in the thickness of the overburden and the position of its change in dip, with respect to the target body, had a significant effect on the response. It was difficult to resolve the dip of the target, changing this parameter had little effect on the overall response. Therefore dip was set vertical and modelling predicted the location and a depth of 1 to 1.5 dipole lengths (200 to 300 feet or 61 to 90 metres) for the target. Note that the observed chargeabilities were measured in milliseconds and the model chargeabilities were computed in percentage frequency effect. Obviously it is not possible to actually match these values so the modelling attempted to match relative changes of this parameter along the observed pseudo-section.

As is generally the case, it was impossible to accurately match the computed values of resistivity and chargeability with the observed values. You can't spend an inordinate amount of time modelling complex data, particularly when you have no accurate information about all the electrical structures contributing to the observed response. The important thing is to match the overall shape of the computed response with the observed response. Remember there are likely to be several other elements in the ground effecting the observed response that are not accounted for in the model. Anyway, highly chargeable and very low resistivity bodies generally dominate the overall response. So think carefully about what it is you are trying to determine from the modelling of your field data as this will provide a focus for your efforts. In the Peak Hill example we wanted to located sulphide mineralisation and then drill test the anomaly. The *true* electrical structure of the ground was of minor importance: to the extent that some effort was expended to try an account for its contribution to the measured response so that the target response could be resolved.

A vertical drill hole was sighted at 40250E and weak sulphide mineralisation was intersected at 57 metres, close enough to one dipole length for me. The hole terminated in the sulphides, at about 80 metres depth.

Happy Excitations.

Letters to the Editor

June 22, 1995

The Editor - Preview

Re: Excitations Column, April 1995 Issue

We would like to congratulate Steve Mudge on what would appear to us to be a very well researched paper from his not inconsiderable experience in the contracting out of helicopter geophysical surveys. It is particularly interesting for us as contractors of helicopter surveys to see that very little in the article would change, should it be written from the contractor's point of view.

We especially agree with Steve's discussions on the fact that bad weather goes with rugged terrain and plays a large part in the operations of helicopter surveys andthe processing of the resultant data. We also totally agree with the fact that the quality of data is very strongly dependant on the experience of the pilot. Helicopter surveys are also not only a faster alternative to ground surveys but are indeed often much cheaper, certainly in rugged and remote areas.

As to the discussion on towed bird systems and fixed boom systems, Steve didnot make mention of the fact that the boom system requires considerable calibration and generally results in a dedicated helicopter having to be employed, as opposed to the bird system being able to use any available helicopter of opportunity with a very much quicker installation. The cost of boom mounted helicopter surveys must therefore be greater than towed bird systems due to their need for, as it happens, an expensive helicopter (some of the smaller helicopters have metal blades which create magnetic fields) and the additional equipment required for the compensation of the helicopter. Also, it should be pointed out that while the automatic aircraft compensators that are used can compensate for all changes that occur during the calibration flights, they still cannot take account of slight and subtle changes inside the helicopter during flight, such as even the movement of the pilot's headphones, which can sometimes be detected on the very sensitive magnetometers in use.

With regard to the processing, we also agree that there are many additional problems in the processing of helicopter data, as opposed to fixed-wing surveys, and we especially concur with the fact that the results should be warped over the terrain. Steve hinted, but did not make it entirely clear, that a terrain map can be produced from the results of the radar altimeter (not radio altimeter, as he states) and the height obtained from teh GPS.

Finally, it would have been interesting to have had Steve's more extensive thoughts on what he considers would be desirable features or improvements to the technology in the future, other than his suggestion of the possible use of three component magnetometers. In our opinion, the employment of gradiometers, both vertical and horizontal, would be one other such suggestion.

Roger Henderson & Zoltan Beldi

Geo Instruments Pty Ltd

June 22, 1995

The Editor - Preview

I am a regular reader of Preview and Exploration Geophysics published by ASEG. I have recently observed that most of the articles are from mineral geophysics and there is hardly any from petroleum geophysics and slowly I am loosing my interest from going through the magazines. It will be nice if we get some sort of short notes if not article like Leading edge.

Kalyan K. Chakraborty

Petroleum Initiative Project

Department of Minerals & Energy, Wa

Preview Deadlines

Issue	Deadline
August 1995	June 23, 1995
October 1995	September 29, 1995
December 1995	November 24, 1995

Book Review

Seismic Coal Exploration Part B: In-Seam Seismics.

L. Dresen & H. Rüter.

ISBN: 0080372260. Price £80.00 ($130.00)
Date of Publication, February 1994.

This text is one of a series of Handbooks of Geophysical Exploration published by Pergamon. (There are 24 in the Section on Seismic Exploration with some still in preparation).

It is a specific text restricted, as its title suggests to one particular aspect of the seismic method. But the approach is thorough and it will form a useful addition not only to the library of the geophysical researcher working in this field but also the mine manager who needs to understand the potential that can be gained from the application of the method.

The book begins with a description of coal mining methods, the geology of coal and the geological environment of coal seams. The scene is set for the proceeding chapters.

Chapter two discusses the physics of coal seams working methodically through seam waves, simple principles of reflection and refraction, Love waves and Rayleigh waves. The exhaustive mathematics is liberally interspersed with readable desciptions as to the meaning and purpose. The physics of the waves at part or full seam faulting, washouts seam splitting and seam thinnings are well treated both mathematically and verbally.

This is followed by a chapter on data processing which is extremely relevant because the raw data is not directly viewable and needs careful treatment and enhancement. Imaging, stacking, ray gathering, log-sum-methods and tomographic reconstruction are among the topics considered. In general the chapter discusses how to record and display the data with an awareness of the pros and cons of the different methods.

The fourth chapter describes analogue and numerical methods, again with very adequate mathematics accompanied by a clear written description. There is a very interesting section which compares the results and their relevance. Love waves and Rayleigh waves are modelled in the context of symmetrical and asymmetrical coal seam situations, with the transmission and reflection response associated with faults, washout and mylonization. This is clearly presented with conclusions drawn from each sub-section.

A section on instrumentation follows, describing equipment designs from Germany and Australia. This is followed by a description of geophone layouts and gathering-arrays for specific problems and geologica conditions.

Finally there are some excellent case histories drawn from Australian and German collieries which draw the preceeding chapters together.

In summary this is an excellent text on a specific but very appropriate subject and is recommended to all those involved in the mining of coal.

Hugh Rutter

Geophysical Data Releases

New VIMP Data Release for Victoria

A release of airborne geophysical data and imagery, and new maps, reports, data sheets, etc., was made on Monday 22nd May 1995 by the Minister for Energy and Minerals, the Hon. Jim Plowman, as part of the Victorian Initiatives for Minerals and Petroleum (VIMP).

A colour TMI image at 1:100 000 scale of North Western part of Victoria (NW VIMP Area) and enhanced TMI images and RGB radiometric-results of the Mallacoota Sheet (plus Orbost Area) at 1:50 000 scale were featured in a display. Nine VIMP reports, and the new Bendigo, Murrindal, and Eastern Otway Basin geological maps and reports were released at the same time.

Geophysical reports included amongst these were:

VIMP Report 1, which provides a summary of the geology and history of company exploration over the area of the detailed helicopter geophysical survey flown in 1994 in the Orbost region in eastern Victoria.

VIMP Report 2 and accompanying maps provide a new structural interpretation for the Mount Wellington area which significantly increases the area of prospectivity for epithermal gold systems.

VIMP Report 4 outlines regions along the southern margin of the Murray Basin which have the highest potential for mineralisation. These were identified from known geology, mineralisation and depth to basement, together with an interpretation of new and existing airborne geophysical data. There is potential for repetitions of the styles of mineralisation observed in the flanking Palaeozoic which have produced in excess of 8 million ounces of gold. The report provides useful information to explorers making application for tender areas in the south eastern part of the North West Initiative Area.

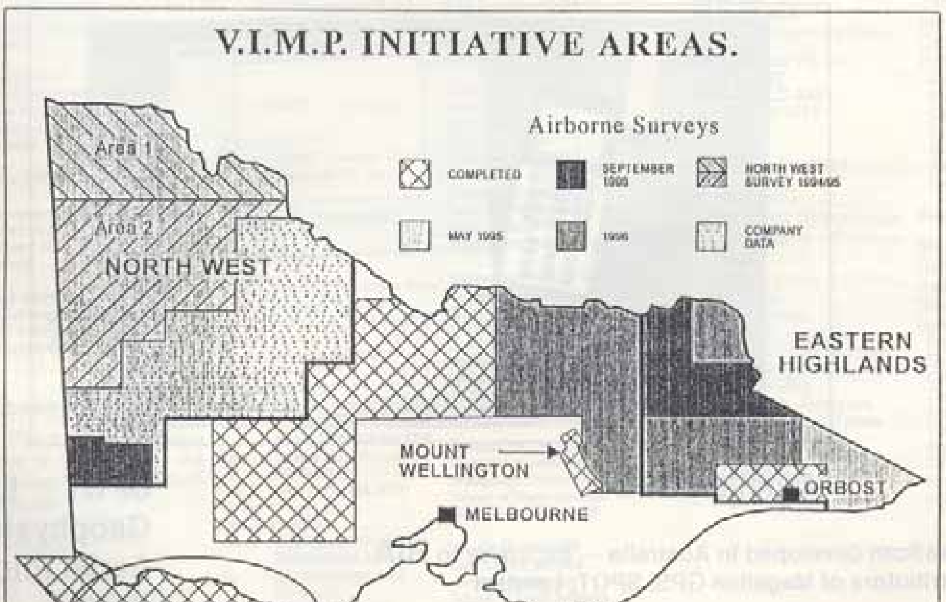
VIMP Report 6 is an appraisal of the airborne magnetic and radiometric surveys undertaken in the North West Initiative area which comprise about 120 000 line kilometres of data collected along lines spaced 400 metres apart. Reprocessing work has been undertaken on existing company data to form a composite data set.

VIMP Report 7. Geological mapping and a geophysical interpretation have been undertaken on the Dunolly 1:100 000 map sheet as part of the National Geoscience Mapping Accord. This interpretation is based on the AGSO/GSV airborne survey flown over this area in 1990.

VIMP Report 8 provides a summary of the geology, geophysics, mineralisation and exploration history of the Mallacoota 1:250 000 sheet, and has been prepared to provide basic information for the release of new geophysical data and the Call for Tenders for exploration in the area.

VIMP Report 9 is a geophysical interpretation of the detailed airborne survey of over 21 000 line kilometres flown in Eastern Victoria in 1994 over Palaeozoic rocks in the Orbost area.

For further information on VIMP
Contact: Bob Dalgano
VIMP Coordinator
Energy & Minerals, Victoria
Tel: (03) 9412 Fax: (03) 9412 7803



Location of VIMP airborne Survey.

Membership

New Members

We welcome the following new members to the Society. Their details need to be added to the relevant State Branch database:

Victoria

David TRIGGS
23 Marbray Drive
Glen Waverley VIC 3150

Justin WARD
Flat 4, 271 Balaclava Road
North Caulfield VIC 3161

Andrea BROADDUS
C/- International Office
Melbourne University
Parkville VIC 3052

Lachlan WELSH
36 Slattery Street
Werribee VIC 3030

Roy CLARK Jr
C/- Esso Australia Ltd
360 Elizabeth Street, Rm 39.41
Melbourne VIC 3000

New South Wales

Balakrishnan KUNJAN
C/- Command Petroleum
L1, 191 New South Head Road
Edgecliff NSW 2027

Rebecca DENNE
4/8 Munro Street
McMahons Point NSW 2060

Ian CAMPBELL
Austirex Pty Ltd
27 Merriwa Street
Gordon NSW 2072

Gregory POOLE
PO Box 91
Klama NSW 2533

Kathlene OLIVER
271 Welling Drive
Mt Annan, Narellan NSW 2567

Xiaou XIE
CRC for AMET
Earth Science School
Macquarie University NSW 2109

ACT

Robert PARUMS
C/- AGSO
GPO Box 378
Canberra ACT 2601

Travis KERSLAKE
Unit 15, 85 Northbourne Ave
Civic ACT 2604

Queensland

Randall TAYLOR
GPO Box 148
Brisbane QLD 4001

Xun LUO
CSIRO, Exploration & Mining
PO Box 883
Kenmore QLD 4069

South Australia

Brendan HARRIS
23 Baltic Avenue
West Beach SA 5024

Samantha Warren
RSD Kalbeeba SA 5118

Thomas GRUBER
Flat C1, Flinders Drive
Bedford Park SA 5042

Sian JOHNS
9 Walker Street
Craters SA 5152

Timothy BIRT
15 Piza Court
Hackham SA 5163

Martin FAIRCLOUGH
PO Box 565
Eastwood SA 5063

Brent JENSEN-SCHMIDT
29 Cowrie Avenue
Glenconne SA 5044

Western Australia

Simon KAWAGLE
Dept of Expl Geophysics
School of Physical Sciences
Curtin University
GPO Box U1987
Perth WA 6001

Annette McILROY
3A Glenelg Street
Mt Hawthorn WA 6016

Ian McATEER
5 Shore Place
Mullaloo WA 6027

Gregory NYEIN
34 Sexton Road
Inglewood WA 6052

Stephen CARTER
148 Canning Road
Kalamunda WA 6076

Wing CHEN
3/8 Hampton Street
Burswood WA 6100

Timothy OSBORNE
70A Wendouree Road
Wilson, Perth WA 6107

Lung DANG
213 Leach High Way
Melville WA 6156

Michael AYRIS
140 Bourke Street
Kalgoorlie WA 6430

Andrew WELLINGTON
C/- SPQ Durkin Road
Kambalda WA 6442

Tim ALLEN
PO Box 1231
West Perth WA 6872

Charles BROWN
182 Vardon Street
Kalgoorlie WA 6430

Matthew MAYNE
48 Graeme Street
Kalgoorlie WA 6430

Tasmania

Marcus HOLLOWAY
PO Box 406
Burnie TAS 7320

Overseas

Gaskun SARL
Dokuz Eylul University
Fac of Engineering, Dept of Geop
Bornova-izmir 35100
Turkey

Ruth PEACH
Hampson-Russell Software
Suite 510, 715-5 Ave SW
Calgary AB T2P 2X6
Canada

Brian RUSSELL
Hampson-Russell Software
Suite 510, 715-5 Ave SW
Calgary AB T2P 2X6
Canada

Gary OPPLIGER
Electromagnetic Instruments Inc
2485 Killington Drive
Reno NV 89511 USA

Change of Address

The following changes need to be made to the relevant State Branch database:

Victoria

Garry SPENCER
From: 1/480 Balcombe Road
Beaumaris VIC 3193
To: 21 Auckland Street
Bendeigh VIC 3204

Peter Craig SMITH
From: Posedon Exploration
4/66 Coonawarra Road
Winnellie Nt 0821
To: Pasminco Exploration
Level 7, 380 St Kilda Road
Melbourne VIC 3004

Robert HARMS
From: 3 Barcoo Place
Kaleen ACT 2617
To: 19 Otter Street
Collingwood VIC 3066

Phil McINERNEY
From: North Exploration
PO Box 231
Cloverdale Wa 6105
To: North Ltd
GPO Box 1903R
Melbourne VIC 3001

New South Wales

Hakseo HWANG
From: Macquarie University
School of Earth Sciences
North Ryde NSW 2109
To: 3/26 Thomas Street
Parramatta NSW 2150

John TESSELAAR
From: Box 899
Gawler Sa 5118
To: CRA Exploration
44 Leewood Drive
Orange NSW 2800

South Australia

Luke MORTIMER
From: 160 Swansea Street
East Victoria Park WA 6101
To: 36c Bopeechee Street
Roxby Downs SA 5725

Suzanne ROBERTS
From: 12 Turnbull Road
Enfield SA 5085
To: 49 packers Drive
Highbury SA 5089

Queensland

Andrew WOLSKI
From: 7 Lewin Street
Inverell NSW 2360
To: 8 Yvonne Street
Yeronga QLD 4104

Joe WILIAMS
From: QLD Uni of Technology
GPO Box 2434
Brisbane QLD 4001
To: 10 Omar Street
Ipswich QLD 4305

Stephen WAUCHOPE
From: CRA Exploration
PO Box 1201
Fortitude Valley QLD 4006
To: CRA Exploration Pt Ltd
PO Box 1641
Milton QLD 4064

Voya KISSITCH
From: CRA Exploration
PO Box 1201
Fortitude Valley QLD 4006
To: CRA Exploration Pt Ltd
PO Box 1641
Milton QLD 4064

Northern Teritory

Roger CLIFTON
To: 9/250 Casuarina Drive
Nightcliff NT 0810

Western Australia

Philip MUIR
From: WMC
Suite 4, 5 Stoneham Street
Belmont Wa 6104
To: WMC
PO Box 91
Belmont WA 6104

Julie WITHERS
From: Olympic Dam Operations
PO Box 150
Roxby DOWNS SA 5725
To: Wiluna MINES Ltd
PO Box 845
West Perth WA 6872

Philip HAWKE
From: 2/20 Charles Street
Plympton SA 5038
To: C/- Hamersley Iron
PO Box 21
Dampier WA 6713

Simon BODORKOS
From: 87 Cascade Street
Katoomba NSW 2780
To: 2/39 Lawler Street
South Perth WA 6151

Darryl HARRIS
From: Faulkner House Hale Schl
Hale Road
Wembley Downs WA 6019
To: Woodside Petroleum
1 Adelaide Terrace
Perth WA 6000

Overseas

William FRENCH
From: PGS Tensor Inc
PO Box 42805
Houston TX 77242-2805
USA
To: President
PGS Asia Pacific
271 Bukit Timah Rd #03-13
Balmoral Plaza
Singapore 1025

Grant ROBERTS
From: 130 Otitori Bay Road
Titirangi Auckland 7
New Zealand
To: PO Box 15-038
New Lynn Auckland
New Zealand

Resignations

The following members need to be deleted from the relevant State Branch database:

Michael ROONEY
4 Shadforth Street
Mosman NSW 2088

Alan TRIPP
Uni of UTAH
Dept of Geology & Geophysics
717 Browning Bldg
Salt Lake City Utah 84112
USA

John TODD
1901 Boradway, Suite 1550
Denver Colorado 80290
USA

Where Are They?

Does anyone know the new address for the following members?

John HOLMES
Last known address:
BHP Petroleum Ltd
GPO Box 1911R
Melbourne VIC 3001

Gregory SPILLANE
Last known address:
BHP Petroleum Ltd
GPO Box 1911R
Melbourne VIC 3001

Kevin JARVIE
Last known address:
BHP Petroleum Ltd
GPO Box 1911R
Melbourne VIC 3001

Vanessa HUMPHREYS
Last known address:
20 Hillcrest Avenue
Moorebank NSW 2170

Khmaphira VIRAVONG
Last known address:
Geology & Geophysics Dept
University of Sydney NSW 2006

Samantha SCHELLAARO
Last known address:
23 Danby Street
Torrensville SA 5031

Edward ESCANERO
Last known address:
Macquarie University
School of Earth Sciences
North Ryde NSW 2109

Desell SUANBURI
Last known address:
Flinders University
School of Earth Sciences
GPO Box 2100
Adelaide SA 5001

Bruce FINLAYSON
Last known address:
16 Franklin Street
Adelaide SA 5000

Michael HOUSE
Last known address:
Unit 17, 189 Fairway
Crawley WA 6009

Graham BUBNER
Last knwon address:
CRA Exploration Pty Ltd
PO Box 175
Belmont WA 6104

Ajay NALONNIL
Last known address:
64A The Promenade
Mt Pleasant WA 6153

Bill WALLWORK
Last known address:
198 Gildcliffe Street
Scarborough WA 6019

Neil YOUNG
Last known address:
19 Playfield Street
East Vic Park WA 6101

Charles SHEEN
Last known address:
Santos Ltd
PO Box 2319
Adelaide SA 5000

Boris ADAMEK
Last known address:
Unit 15, 118 Lipsett Drive
Brooklyn Park SA 5032

Maki PETKOVSKI
Last known address:
Ampulex Ltd
PO Box A323
Sydney South NSW 2000

Calender of Events

August 20-24 1995

The First Latin American Geophysical Conference & Exposition
Rio de Janeiro
For further details:
A.H. Rosa Jr.,
Technical Program Co-Chairman
RIO '95
SEG Business Office
PO Box 702740
Tulsa, OK USA 74170-2740
Ph: 918-493 3516
Fax: 918-493 2074

September 3-6 1995

ASEG 11th Geophysical Conference & Exhibition
Adelaide

October 1-3 1995

Bowen Basin Symposium
Mackay Entertainment Centre, Mackay
For details:
Mr Ken Preston
Secretary - Organising Committee
C/-Pacific Coal Pty Ltd
GPO Box 391
Brisbane QLD 4001
Fax: (07) 220 0217

8-10 November 1995

3rd SEGJ/SEG
International Symposium
Geotomography - Fracture Imaging
Nihondaigaku-kaikan, Tokyo, Japan
For further details:
Dr Toshifumi Matsuoka
Chairman of Organising Com.
Japan Petroleum Exploration
NYK Tennoz Bldg
2-2-20, Higashi-Shinagawa
Shinagawa, Tokyo 140 Japan
Tel: +81-3-5461 7324
Fax: +81-3-5461 7397
Email: toshi@japex.co.jp

19-23 February 1996

13th Australian Geological Convention, & AGSO Jubilee Symposium
Canberra
For further details:
See advertisement this issue
Or from 13th AGC
GPO Box 2200
Canberra ACT 2601
Fax: (06) 257 3256

March 25-29 1996

8th Australiasian Remote Sensing Conference
National Convention Centre, Canberra
For further details:
ACTS
GPO Box 2200
Canberra ACT 2601
Ph: (06) 257 3299
Fax: (06) 257 3256

23-27 July 1996

Western Pacific Geophysics Meeting of the American Geophysical Union
Brisbane
For further details:
Mike McElhinny
Gondwana Consultants
Po Box 5
Hat Head NSW 2440
Tel: (065) 65 7604
Fax: (065) 65 7604

Sept 30-Oct 3 1996

6th Int'l Conference on Ground Penetrating Radar
Aoba Memorial Hall, Tohoku University, Sendai, Japan
For further details:
Dr Motoyuki Sato
GPR '96 Technical Chairman
Dept of Resources Engineering
Faculty of Engineering
Tohoku University
Sendai 980-77, Japan
Tel: +81-22-222 1800 ext 4548
Fax: +81-22-222 2144
eml:GPR96@earth.tohoku.ac.jp