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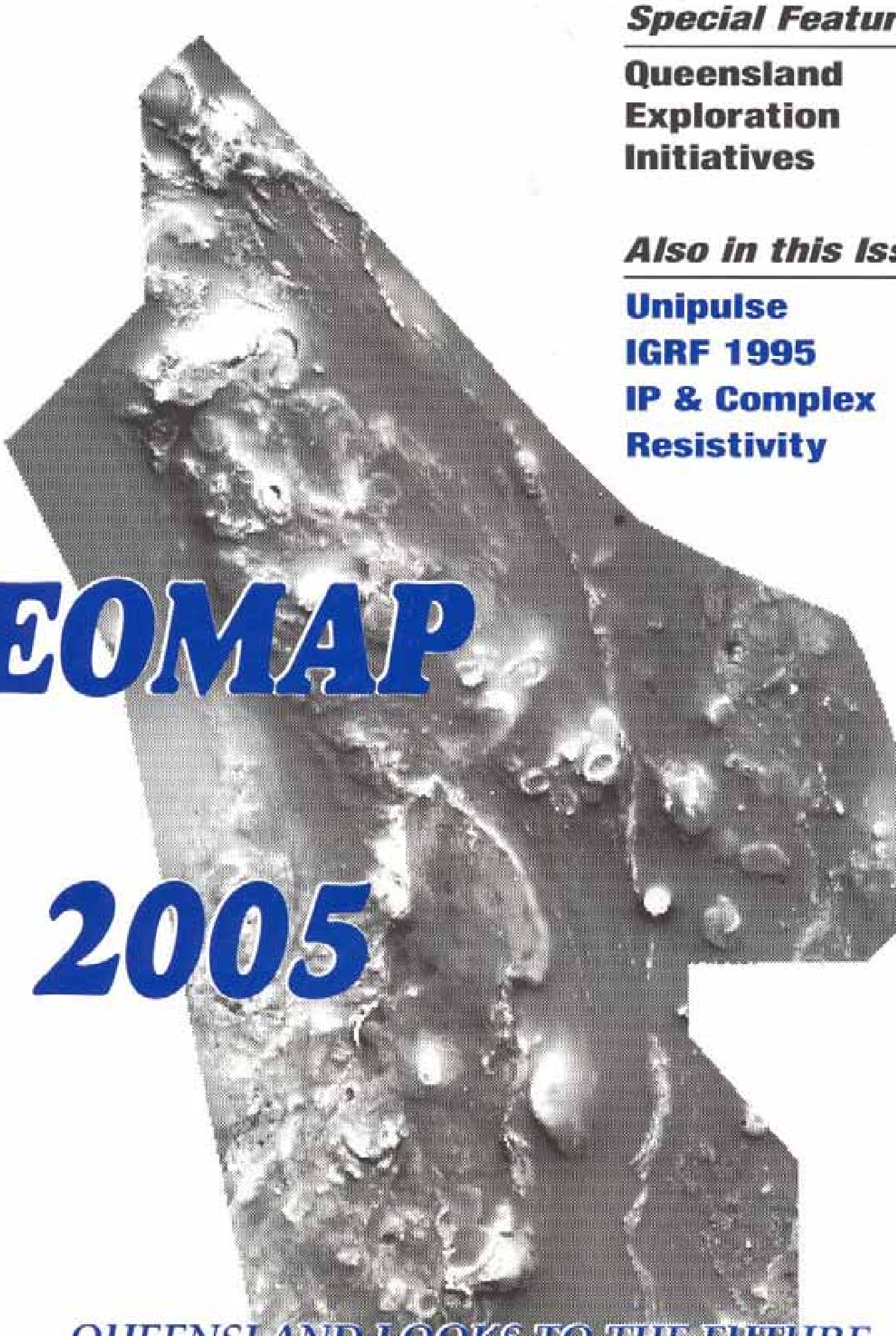
Special Feature:

Also in this Issue:



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Printed by Jenkin Buxton Printers

Editor's Desk

Another Conference has come and gone. For those participating in an ASEG Conference there is the usual cycle of preparation with all the energy that is required over and above a normal busy life. The conference itself is a "full on" experience. Then there is the anticlimax feeling after, plus the catching up on work that has been put on the "back burner" mentally while all this conference activity has been going on.

The necessary ingredients of a good conference are the commitment of ASEG members and sponsors, and the often uncredited support of our employers in facilitating our participation. Well done and thanks to all concerned.

ASEG publications and their future were one of the many items of ASEG business discussed at the conference. Decisions regarding improvements in the viability of ASEG publications will be made by the Publications committee in late December in time for 1996. Greg Blackburn's Executive Brief Column (p7) discusses options for these improvements. Member feedback via the questionnaire sent out with membership renewals in November, is welcomed. Please return you questionnaire by mid December to assist the Publications Committees deliberations.

The ASEG salutes two members for their recent international contributions and achievements for geophysics; notably Norm Uren, Vice President elect SEG and Derecke Palmer, SEG Reginald Fessenden Award recipient.

We introduce a new Preview regular feature this issue - UNIPULSE - regular news from geophysics in academia and welcome new Associate Editor Leonie Jones.

Thank you finally to the Queensland Department of Minerals and Energy for their colour article sponsorship (p21-24) and other contributions to this issue.

Geoff Pettifer
Editor

Norm Uren

Derecke Palmer

President's Piece

Kathy Hill
President ASEG

For those of you who were not fortunate enough to attend, we have just had another outstanding conference in September in Adelaide. At final count we had 590 attendees - a very healthy participation rate for a society of some 1450 members (active, associate and student). Once we have received all of the "wash up" reports concerning the conference I would like to devote the next "Piece" to the form and content of the Adelaide conference and future conference plans. In the interim I would like to thank all of the hardworking ASEG members who were responsible for its success. It must be emphasised that the exhibitors also comprise an essential part of our conference and make an unsung, but significant, contribution to our education.

I would like to turn to other geophysical conferences. I have just returned from the SEG Convention in Houston, representing our Society and continuing an initiative by Hugh Rutter to increase our contacts with the SEG. Norm Uren, Professor of Geophysics at Curtain University is now Vice President Elect (see p4) and will be taking on international responsibilities in that role, but I am sure will remember his Antipodean origins.

The SEG Convention had 10,500 attendees, making it the largest exploration geoscience conference in the world. There were 300 exhibitors occupying approximately seven (American) football fields worth of floor space (well, it was Texas and nothing is done there unless it can be done in a big way). The AAPG Convention, held at the same Houston venue in March, had 6800 attendees. Apparently SEG conventions over recent years achieve a greater attendance than the AAPG and on my casual observation the attendees appeared to be younger on average than those at the AAPG Convention, auguring well for the SEG's future.

The SEG has approximately 25 staff based in Tulsa whilst the ASEG has half of the very efficient and hard-working Janine Cross in Melbourne. They have two full-time professional editors for the Leading Edge, the monthly news magazine, and we have the voluntary time of Geoff Pettifer, Editor of Preview (supported by a team of volunteer Associate Editors), published bi-monthly. (Geoff is also in charge of layout, advertising, production and transport, as well as head office liaison.) The technical editors of Geophysics are supported by SEG staff in author liaison and in the layout of Geophysics.

The SEG has permanent conference organising staff while we rely on outside Conference organisers and rotate the anguish of planning and executing a conference. We depend on the hard core of ASEG membership within the conference city, advised by the Conference Organising Committee.

If it appears that I am in awe of the sheer scale of the SEG (with its 14,000 members) there is some truth to that assertion. A comparison between the two societies however emphasises how much the ASEG is able to deliver through its voluntary component and how much it is asking of those volunteers. In terms of size the ASEG is at a critical mass - an issue that has been raised before. Our Society is enriched by its level of volunteer involvement but demands perhaps too much of some of the individuals who have been providing their time for years. If you are aware of someone who is having difficulty juggling home, work and ASEG, consider helping him through a bottleneck by offering assistance. It may be that you may want to take the ASEG job off their hands in the future.

Ultimately at least one permanent full time staff member may be required and funding this position will require a significant portion of the ASEG budget.

Returning to the SEG Convention itself, one of ASEG's own - Derecke Palmer of the University of NSW (see photo p4) - received the Reginald Fessenden Award for technical excellence and joins the distinguished list of recipients including Robinson, Treitel, Claerbout, and Hubral to name a few Congratulations, Derecke!

Derecke demonstrates that there is no place for the cultural cringe in the ASEG. There is no doubt that Australian geophysicists have led the world in development of techniques, particularly in applications to mineral exploration. The SEG is taking on a more global perspective and has co-sponsored conferences in St Petersburg and Brazil in the last year. The SEG president - elect, Gordon Greve, is very interested in co-operative arrangements with the ASEG or other Australian organisations in mineral geophysics education at international venues. We hope to pursue this area further in the next few months. Please contact any member of the Federal Executive if you have some ideas in this area.

The SEG recognises this pre-eminence in minerals. They have asked us to co-sponsor the April 1996 SEG/HAGI International Conference in Jakarta (see details pp 10-11) with the European Association of Geoscientists and Engineers (replacing the EAEG). They are hoping that we can contribute conference papers to mineral exploration in the "Asian area". The 1997 ASEG Conference in Sydney will have a strong "Asian" focus (if an area as vast and diverse as Asia can be considered the subject of a single focus). It also reflects the growing interest by Australian exploration companies in the Asian region.

For the Jakarta conference, short articles or papers on topics relevant to exploration in Asia (by area or by analogous accumulation) are being canvassed by the Leading Edge magazine. *The press deadline is December 15* for the TLE conference issue - please see the advertisement in this issue of Preview). Please contact me (ph 03-412- 5639) or John Jackson (ph 07-214-9208) for further information. The articles submitted may be published previously.

Executive Brief

The ASEG Federal Executive has just completed their 5 Year Business Plan and concludes that there is a shortfall of some $50,000 per year at current expenditure levels, which would reduce existing capital within the 5 year period. Tighter financial control of the Society, and the various Sub-committees and State Branches will be necessary with the various operating committees required to submit budgets for approval by the Federal Executive. This is particularly important for the Publications Committee which overseas some 51% of the Society's income and accounts for over 69% of expenditure and the Conference Committee (17% of total income). the Society's present cash balance is due largely to sucessful conferences in the past, but these profits can be quite variable. Due to the likely shortfalls, the Society regretfully has raised the membership fees for 1996 to $60 per year for active and associate members and corporate membership to $360 per year. Student membership remains at $20 per annum. At present there are 197 student members, which represents a large capture rate of potential students. By fostering members during their early career, the Society has been able to increase membership by 30% over the last 3 years.

On another matter it is important that all members help to make the ASEG strong. For example the Society is likely to be fined by the ATO for late submission of income tax returns, which was due to late submission of relevant information from the State Branches.

The Publications Committee met at the ASEG Conference and discussed several issues and options for future viability and improvement of ASEG publications. Concerns discussed included:

- Cost of publications (particularly conference issues).
- Exploration Geophysics - Conference issues large - other issues very small.
- Sustaining Preview on voluntary efforts -alternatives

Some members value Preview over Exploration Geophysics and others regard Exploration Geophysics as more valuable. Naturally Exploration Geophysics is the measure of our value as a scientific society. Certainly quality in both these publications which meet different needs, is a desirable goal for ASEG.

The Publications Committee believe that ASEG publications are approximately $40,000 too expensive. Costs could be reduced by combining Preview and Exploration Geophysics or by reducing the number and size of the volumes. Alternatively increasing advertising revenues by this amount would allow the publications to continue as is. In order to contain costs the Publications Committee wish to canvass the general membership on the following options:

1) **Conference papers abstracts only at the conference.** This radical option reduces the Conference volume to the standard of the Conference Preview, a substantial reduction in cost. This would take us back to the situation of 1991. The change to full papers (extended abstracts) where possible was responsible for the major increase in the size of the Conference volume, but resulted in timely publication of many papers which could otherwise be published late or not at all. The disadvantage of loss of prepublished papers weighs heavy against this option.

2) **Reduce size of Conference Exploration Geophysics.** Status quo, with the Conference Exploration Geophysics volume (anticipated cost for the Adelaide Conference $120,000) slimmed down (say to 350 pages) in order to contain costs. The major cost of ASEG publications is tied up in Conference issues and little can be done to reduce costs without adopting this measure to some degree. The advantages are that slimming of the Conference volume by using selected/on-time papers only, will enable conference papers to be published in later volumes of Exploration Geophysics, sustaining inter-conference issues of Exploration Geophysics and offering later published conference papers less restrictions on format. The higher selection standards for papers both in presentation and publication would tighten up the Conference Volume as well. The disadvantages include the loss of expectation of the prestige of publishing in the Conference Volume and it being the complete conference prepublication record. There is a concern that authors that miss out on the Conference volume may not bother to follow through with publication and the flow over of papers from the Conference may not occur.

3) **Reduction of Conference and regular Previews.** This saves some money and effort in Preview production but a disadvantage of slimming Preview down is that it may undo the improvement in quality achieved in the last few years.

4) **Combine Exploration Geophysics and Preview for all issues.** are combined to a 6 volume/year Exploration Geophysics with a third party covering advertising and production. The format proposed is similar to the journal "Nature" with two distinct and identifiable sections - a magazine section with reviews, articles, news etc in one section and a refereed paper, research articles section. With option (2) and a steady supply of refereed papers 6 issues/year could be sustained with the current timeliness of news through Preview. Two editorial boards will supply material for both sections and fluctuations in supply of material could be counterbalanced. This format is similar to the old GEOPHYSICS publication (pre Leading Edge days). The advantages of this option are that it will reduce costs and all advertising will be in one journal with no competition for advertising revenue between two publications as at present. The disadvantages are that some may consider it diminishes the reputation of refereed papers and Exploration Geophysics as a journal by mixing papers and ephemeral unrefereed

Preview type material. Further it would need careful management. Advertising rates would need to rise to cover commercial production. This option is also heavily dependent on a steady stream of refereed papers and acceptance by membership of option (2).

5) **Preview published professionally.** Preview published by a third party with all advertisements concentrated in Preview and with Preview operating at a profit to subsidise Exploration Geophysics. The advantage of this option is that Preview becomes more professional and sustainable in its production. The disadvantage is that advertising revenue will need to rise and further that advertisers may prefer to advertise in the refereed journal Exploration Geophysics with its perceived longer shelf life.

A questionnaire seeking the views of the ASEG membership on this and other matters will be sent shortly with the annual dues notice. Your prompt responses by early December will help influence the Executive in deciding this important issue in time for the 1996 publication schedule.

Greg Blackburn
Executive Secretary

Preview - Next Issue

- *Radio Imaging in Mine Tomography*
- *Conference Student Day Report*
- *Early Aeromagnetic Surveying - Canning Basin*
- *POSC - A Petroleum Database Standard*

ASEG 11th Conference And Exhibition - News

The 11th ASEG Conference and Exhibition was an outstanding success. This could not have been achieved without the support of the sponsors, exhibitors, authors and presenters, and, of course, the delegates. Thank you all for making the event such a memorable one.

590 delegates attended the Conference and this represented 553 full time delegates and 37 day delegates. 75 delegates (12.7%) were from 19 overseas countries, making the 11th Conference and Exhibition a truly international Conference.

This means that the 1995 Adelaide Conference attracted the largest number of delegates for an ASEG Conference in its own right, a further measure of the success of the Conference.

This success relied on the strength of the technical papers, and the papers sub-committee, headed by **Danny Burns**, is to be congratulated on bringing together such a diverse range of papers. In all, one hundred technical papers were presented at the Conference.

The Adelaide Conference Organising Committee had the difficult task in awarding Best Paper and Best Paper Presentation. The calibre of the papers was demonstrated not only by the winners, but also the number of papers worthy of a special mention in each category.

Best Paper

The best paper was based on the quality of the paper plus the significance of the work it represented and its relevance both to exploration geophysicists and the Conference theme of ***'Increasing the Resources, Reducing the Risk'***. The winning paper was:

'Esoteric and mundane geophysics for diamondiferous pipe exploration' - James MacNae

Papers worthy of a Special Mention for Best Paper were:

'AVO as an exploration tool in the Penola Trough' - Rod Lovibond

'Spectral acoustic techniques for joint and fracture characterisation' - George Jung

Thanks must be given to the Publications Committee, and notably the Special Conference Editor, **John Denham**, for ensuring the majority of papers appeared in the Conference Volume of Exploration Geophysics, despite the tardiness of some authors and referees, in relation to deadlines.

Best Paper Presentation

The actual presentation or delivery of a paper is vital to get the message across to the audience, and the high standard of most papers presented at the Conference is to be commended.

The Best Paper Presentation was awarded to:

Noll Moriarty for his paper **'3D Seismic Surveying in the Otway Basin'**.

Special Mention also goes to the following presenters for their papers:

Hege Smith - 'The Integrated use of 3D Seismic Data, Well Information and Seismic Forward Modelling - Lake Hope Field Area'

Peter Gunn - Evolution and Structuring of the Joseph Bonaparte Gulf as Delineated by Aeromagnetic Data'

John Jackson -'Deep DHEM exploration at the Isa Mine - the Anhydrite Prospect'

Fabio Boschetti - A Staged Genetic Algorithm for Tomographic Inversion of Seismic Refraction Data'

Not only were there a wide range of world class technical papers but there were six keynote addresses covering different aspects of the Conference Theme 'Increasing the Resource, Reducing the Risk'. The keynote speakers were:

Ross Adler (Santos Limited), **Rob Willink** (Boral Energy Limited), **Michael Zhdanov** (University of Utah), **Craig Beasly** (Western Geophysical), **John Main** (CRA Exploration Pty Ltd) and **Jamie Robertson, SEG President** (ARCO International Oil and Gas Co.).

Conference Innovations

The Adelaide Conference also introduced a number of innovations, and following their success it is hoped they may be incorporated in future Conferences. These were:

1. Students Session

The very successful students day, where some 120 secondary students and teachers attended a morning session of 5 papers followed by a tour of the Exhibition Hall and a geophysical software demonstration. This enabled the students to gain some insight on what geophysicists actually do and why they do it. It also emphasised the environmental awareness now within the industry, the importance of the resource industry to Australia's economy and highlighted the possibility of geophysics as a possible career option.

2. Legal Session

The legal session and forum on **'Native Title and Land Access'**. This provided the opportunity for minerals geophysicists to discuss the key issues of this topic in a forum similar to that afforded petroleum geophysicists through the APEA Conference. While this was a departure from the pure technical papers of past Conferences, its was well attended.

3. Poster Session

The poster paper sessions were an important part of the Conference. The committee tried to raise the profile of the poster papers, to include "hot-off-the-press" research that could not be captured in a refereed paper format in time. The 17 posters had an 8 minutes presentation in one of the meeting halls, followed by discussion at the posters over lunch.

It is important to note that the **Laric Hawkins Award**, for the most innovative use of a geophysical technique, was awarded to the poster paper by **Michael Hallett** and **Edward Tyne** of Geoterrex on **'An application of the GEOTEM airborne electromagnetic method to the study of a salinity affected area in eastern New South Wales'.**

The Conference also continued with proven winners from earlier Conferences. This included the Special Session and Case History, focussing on the **South Australian and Northern Territory Oil and Gas case histories.**

Workshops

The three workshops held prior to the Conference were well attended. The topics on offer were diverse and catered for both petroleum and minerals disciplines, ranging from **'Geological application of airborne TEM methods'**, through **'Integrated image interpretation for mineral exploration'** to **'Databases in petroleum exploration and development: A practical introduction'.**

Exhibition

The Adelaide Exhibition Hall was the venue for the exhibition and again demonstrated what a world class venue it is for the needs of our society. The exhibition attracted 70 exhibitors, utilising one hundred booths, and was an important focus of the event, with morning and afternoon teas and lunch being served there, as well as the poster paper display.

Landmark Graphics International Inc were again successful in winning the coveted **"Best Exhibition"** award. Congratulations go to them, and to all exhibitors for their continued support and the efforts expended in putting together such a stunning exhibition.

Honours and Awards

The Honours and Awards Committee presented the **Grahame Sands Award** for Innovation in Applied Geoscience to **Malcolm Cattach and John Stanley** for their efforts in ***'Sub Audio Magnetics'***. Thanks also go to **Barry Long**, in his capacity as representative for the Honours and Awards Committee, and also for agreeing to act as Master of Ceremonies at the Conference Dinner. His contribution was certainly appreciated.

In concluding, we hope that the Conference was not only enjoyed by all delegates but that everyone got what they wanted from the Conference. Also many thanks must go to the Conference Organising Committee.

Craig Gumley and Dave Tucker, Conference Co-Chairman

The Conference Organising Committee

Craig Gumley	Santos Ltd
Dave Tucker	Preview Resources
Mike Brumby	Petrosys Ltd
Danny Burns	Schlumberger - GeoQuest
John Hughes	Santos Ltd
Doug Roberts	Boral Energy Resources Ltd
Andy McGee	Santos Ltd
Terry Crabb	MESA
Murray Symonds	Western Geophysical
Koya Suto	Maru Beni

ASEG Research Foundation - 1995 Annual Report

ASEG Research Foundation now in its Sixth Year

Joe Cuccuzza -
Chairman
ASEG Research
Foundation

1995 represents the sixth year of operations for the ASEG Research Foundation. The ASEG RF formally commenced its function in September, 1989, with the first projects supported in 1990. It was established to address the decline in student enrolments in exploration geophysics which is no doubt part of the apparent worldwide declining interest in science. The overall aim of the ASEG RF is to attract high calibre students into our profession and thus ensure a future supply of talented, highly skilled, geophysicists for industry.

The ASEG RF achieves its aim by promoting research in geophysics specifically by providing research grants at the B.Sc.(Hons.) and M.Sc level or equivalent. The ASEG RF Committee has now decided to extend support to Ph.D. projects. The grants are paid directly to the relevant University departments to cover field or laboratory expenses associated with the project. Grants are not provided as student scholarships in order to preserve the tax deductibility status of donations.

ASEG members from mining and petroleum as well as from academia serve on an honorary basis on the ASEG RF Committee. The current committee members are listed below. All administrative costs are borne by the committee members and no ASEG RF funds are used for operating expenses. At the recent annual meeting of the ASEG RF Committee new office bearers were elected as a result of the retirement of its first Chairman, Bob Smith. I would like to take this opportunity to thank Bob for his great job in steering the ASEG RF through its period of gestation, birth and early growth. Bob has agreed to serve as a Committee member.

For my sins I have been elected as the new Chairman, while Nigel Hungerford was elected as vice-Chairman.

Bob Smith inaugural Chairman of the ASEG Research Foundation retired after 5+ years of fine service to geophysical research support.

ASEG Research Foundation Office Bearers

Chairman:
Mr. Joe Cucuzza
Australian Mineral Industries Research Association

Vice-Chairman:
Mr. Nigel Hungerford
Hungerford Geophysical Consultants

Secretary:
Mr. Doug Roberts
Boral Energy Resources Limited

Treasurer:
Mr. Peter Priest
Chartered Accountant

Immediate past-Chairman:
Mr. Bob Smith
CRA Exploration Pty Limited

Committee members

Prof. David Boyd	The University of Adelaide
Mr. John Denham	Consultant
Dr. Brian J. J. Embleton	CSIRO - COSSA
Prof. Don W. Emerson	Systems Exploration Pty Ltd
Mr Nigel J Fisher	Digital Exploration Ltd
Dr. Steve Hearn	The University of Qld
Mr. Dick Irvine	BHP Minerals
Mr. Wes Jamieson	Parker & Parsley Australasia
Dr. David King	Consultant
Mr. Steve Mudge	RGC Exploration
Mr. Mike J. Sayers	West Australian Petroleum Pty. Limited (WAPET)
Mr. Nick Sheard	M.I.M. Exploration Pty Ltd.
Dr. Norm Uren	Curtin Uni of Technology
Mr. Peter K Williams	Western Mining Corporation
Past president of ASEG (Hugh Rutter)	Ex-officio member

Sub-Committees

Mining	Petroleum
Mr. Nigel Hungerford	Mr. John Denham
Mr. Steve Mudge	Mr. Wes Jamieson
Mr. Peter K Williams	Dr. David King
Mr. Nick Sheard	Mr. Doug C. Roberts
Mr. Dick Irvine	Mr. Mike J. Sayers

ASEG RESEARCH FOUNDATION

Post to: Treasurer, ASEG Research Foundation
Peter Priest, Ste 3, 17 Hackney Rd,
Hackney SA 5069

NAME: ....

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COMPANY: ....

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ADDRESS: (for receipt purposes)

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AMOUNT OF DONATION: $ ....

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Receipt of donation

Received from ....

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The Sum of ....

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$ ....

In accordance with Income Tax Assessment Act S73A, this donation to the ASEG Research Foundation is tax deductible.

Signed: ....

(This form should be retained for tax purposes)

Doug Roberts from Boral Energy was elected to take over as Secretary. Peter Priest will continue to support the ASEG RF as Treasurer. Thank you to all these people as well as the rest of the Committee members for contributing their valuable time to the ASEG RF.

Applications for grants are invited from Institutions around September or October of each year. Typically the person responsible to supervise the student submits a two to three page summary of the project. The application must detail the aims of the project, degree level, and the nature of the expenditure. It is not necessary when submitting an application for a student to be identified. However, successful Institutions will need to submit the student's CV and approved by the ASEG RF before the grant is paid. Project selection is made by sub-committee of specialists on the basis of the project's quality, relevance to either mineral or petroleum exploration and potential to impact on exploration technology or know-how. In this way we support quality research projects in exploration geophysics of interest to a wide cross-section of the mineral and petroleum industry. The balance between mineral and petroleum projects supported is roughly in the proportion to the donations received from the two sectors.

For each project, we appoint a liaison officer, who is a member of ASEG (but not necessarily of the ASEG RF Committee), and who monitors the progress of the project and reports to the Committee. On the completion of the project, a copy of the thesis is forwarded to the ASEG RF. Theses are stored at the Australian Mineral Foundation library in Adelaide and are accessible through the library. Furthermore, we require that at the completion of the project an abstract is published in "Preview" and any publication as a paper is first submitted to "Exploration Geophysics". The supervisor is normally expected to co-author the publication and is responsible for submission.

The project supervisor is also responsible for drawing the grant funds as required and for managing the expenditure. He/She ensures that a research report and financial reconciliation is provided to the ASEG RF on completion (or cessation) of the project. Grant funds must be accounted for and, if not used, are returned to the ASEG RF.

Since 1989 the ASEG RF has supported 24 projects. The following summarises some statistics of the projects that have been supported to date.

ASEG Research Foundation Project Supported

Total supported (to date):	24
Mineral projects:	11
Petroleum projects	11
Coal projects:	2
B.Sc.Hons. (or equivalent) level:	16
M.Sc. Level:	8

As can be seen from the following Table a significant number of Australian Institutions have received grants from the ASEG Research Foundation

Institution	No of Grants	Focus Petr.	Min.	Coal
Univ of Adelaide (incl. NCPGG)	7	☑	☑	☐
Monash Univ	3	☐	☑	☐
Univ of Sydney	3	☑	☐	☐
Univ of QLD	3	☑	☐	☑
Univ of WA	3	☐	☑	☐
Curtin Univ of Technology	1	☑	☐	☐
Univ of Armidale	1	☐	☑	☐
Univ of Melbourne	1	☑	☐	☐
Univ of Tasmania	1	☐	☑	☐

Donations

The ASEG RF can only carry on its work through the generous donations from individuals and companies. The ASEG has provided a significant contribution in the past and we hope will continue to do so in the future. The SEG has also made a contribution and has been invited to do so again. Although it is our hope that the ASEG RF will eventually have a sustainable funding base through interest earned on its capital we still rely heavily on donations to ensure that we can support four to five worthy projects per year at the B.Sc. or M.Sc. level. We therefore like to encourage individual ASEG members, companies and other Institutions with an interest in exploration geophysics to make a donation to the ASEG RF. We encourage contributions of $5,000 per annum from major companies or lesser amounts from smaller companies, Institutions and individuals. All contributions are fully acknowledged in Preview. Furthermore, since the ASEG RF is an Approved Research Institute, all contributions are fully tax deductible.

Please send your donations to

Mr. P. Priest
Treasurer
ASEG Research Foundation
Suite 3,
17 Hackney Road
HACKNEY
S.A. 5069

To assist you in making a donation use the form on page 14. Your support of the ASEG RF will help to attract high quality students to exploration geophysics and bias university research towards more applied research of interest to industry.

Joe Cucuzza

New Preview Feature - University & Research Geophysics

Unipulse

With

Leonie Jones
University of
Wollongong

This is the first appearance of what promises to be an exciting column with its finger on the pulse of activity in university geophysics - hence the name. Choosing the name involved several discussions and some frantic dictionary searching, with suggestions like "cross-talk", "pseudo-section" and "random noise" being summarily discarded, you will be glad to hear. In each issue, I will present news about the teaching and research activities in geophysics in Australia's tertiary institutions.

First of all, a personal introduction is appropriate. I am the sole geophysicist in the School of Geosciences at the University of Wollongong and have been a member of ASEG since 1991. My qualifications include a BSc in Physics from Queensland University, a PhD in Geophysics from ANU, professional experience in industry in petroleum exploration and in academia as a geophysics lecturer. My research interests include laboratory rock physics, seismic surveys, and gravity and magnetic methods. In addition, I am interested in the use of computers in geophysics teaching and in innovative ways of teaching geophysics for geologists.

As I see it, the aim of this column is to provide an informal forum for publicising geophysical activities in our universities, focussing in particular on

- geophysics research
- geophysics teaching
- ASEG student activities
- general geophysics initiatives

Possible topics include current research areas, preliminary results of specific projects (including CRC projects), student projects, theses submitted, grants awarded, and collaborations with industry and government. Reports on undergraduate teaching might focus on innovations in teaching geophysics, problems in teaching geophysics, and use of computer assisted learning. Other possibilities would be reporting on ASEG student forums, summer schools, short courses, distinguished visitors, development/evaluation of geophysical software, and geophysics on a shoe-string budget. Ideally, I would like to focus on a particular university at a time, but not necessarily covering all of the above topics.

In order to provide an overall view of geophysics in Australian universities, I will be sending out a questionnaire to all departments involved in geophysics to gather information on staff, students, courses offered, areas of specialisation, equipment, computer software, current student projects, publications, theses submitted etc. But please remember, don't wait for me to chase you - this is your opportunity to promote your current activities. This column has tremendous **potential** and I hope there will be no **resistance** at all to **input** (sic).

Please send contributions to UNIPULSE column to:

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or (042) 213841
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Email: l.jones@uow.edu.au

Seismic Window

With

Rob Kirk
BHP Petroleum

A methodology for establishing structural history using a reconnaissance 3D seismic survey in the Timor Sea

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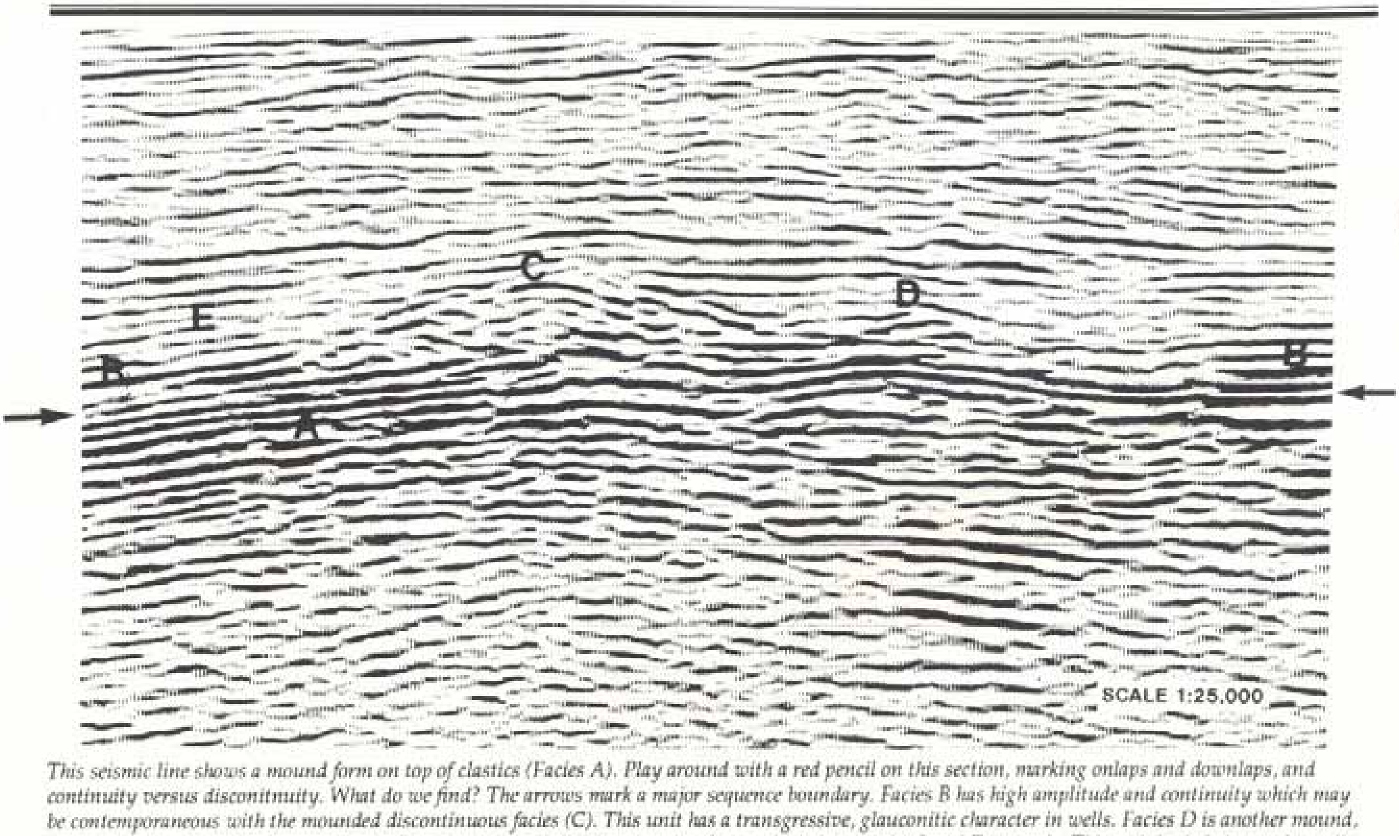
The flexibility and data density provided by a reconnaissance 3D seismic survey in the Timor Sea has enabled the generation of a detailed structural history for the area which can be used for reservoir prediction. The model has analogues throughout the Timor Sea and establishes relationships between early and late faulting episodes.

An iterative method was used to establish fault correlations within the dataset. Faults were interpreted on every tenth line (250 metres spacing) and assigned different colours in LANDMARK. Time slices were generated, displaying the fault intersections from the vertical sections. Faults were then interpreted on the time slices thereby smoothing out inconsistencies in the vertical section fault traces. The vertical sections were reinterpreted after displaying the fault intersections form the time slices. This process removes ambiguous fault correlations and generates smooth fault planes in areas of poor data quality. Animation displays from both the vertical sections and the time slices can then be generated to provided a graphic demonstration of the way the faults develop and their relationships with each other.

After establishing fault correlations, a series of structural reconstructions backstripping to prominent seismic markers was undertaken using representative seismic sections from the dataset. From this analysis, three phases of fault movement were identified:

- Jurassic, setting up a large horst in the pre-Cretaceous section
- Early Cretaceous, reactivating the southeast bounding fault of the horst
- Late Miocene to Recent, on a slightly different trend to the previous faulting and developed in an en-echelon pattern with the faults linking through to the earlier faults near their maximum displacement

A switch in polarity between the Jurassic and Late Miocene faults is recognised with the section downthrown in the Jurassic forming the upthrown side of the Miocene structuring. The presence of reservoir section under the base Cretaceous Unconformity is controlled by Jurassic age faulting with the final structural geometry being determined by the later episodes of faulting.



This seismic line shows a mound form on top of clastics (Facies A). Play around with a red pencil on this section, marking onlaps and downlaps, and continuity versus disconitnuity. What do we find? The arrows mark a major sequence boundary. Facies B has high amplitude and continuity which may be contemporaneous with the mounded discontinuous facies (C). This unit has a transgressive, glauconitic character in wells. Facies D is another mound, younger than the main C mound. Facies E is a variable amplitude onlapping facies which drowns the C and D mounds. This unit is shale in nearby wells. Note that the C mound exhibits different internal mound forms. The areal mapping of these mounds suggests that they are circular features. An interpretation is that the mounds are sea floor volcanoes erupting contemporaneously with the marine facies B which has transgressed over the fluvial-deltaic facies A. The volcanic islands are eventually drowned by the facies E shales.

Geomap 2005 - unlocking Queensland's mineral wealth

Queensland has a rich and diverse geological endowment. Historically, the discovery of gold and base metal deposits in rocks of the Tasman Fold Belt and the Mount Isa and Georgetown Provinces in the 1860s–1880s was extremely important for the economic development of the State. Today Queensland's economy remains heavily dependent upon the exploitation of mineral and energy resources for new investment, export earnings, employment and regional development.

The potential to discover new mineral and energy resources to replace those currently in production is high. In the last seven years, eight new major mineral discoveries have been made in the Mount Isa Province. Collectively, these will replace all of the copper, lead and zinc mined in the State's history.

These discoveries owe much to the geological information provided by the investment programs of the Queensland and Commonwealth Governments.

GEOMAP 2005, a program of geoscientific investigations, has been prepared to generate information needed to underpin new exploration programs for mineral and energy resources and so ensure that the recent discoveries in the Mount Isa region are repeated.

History lesson

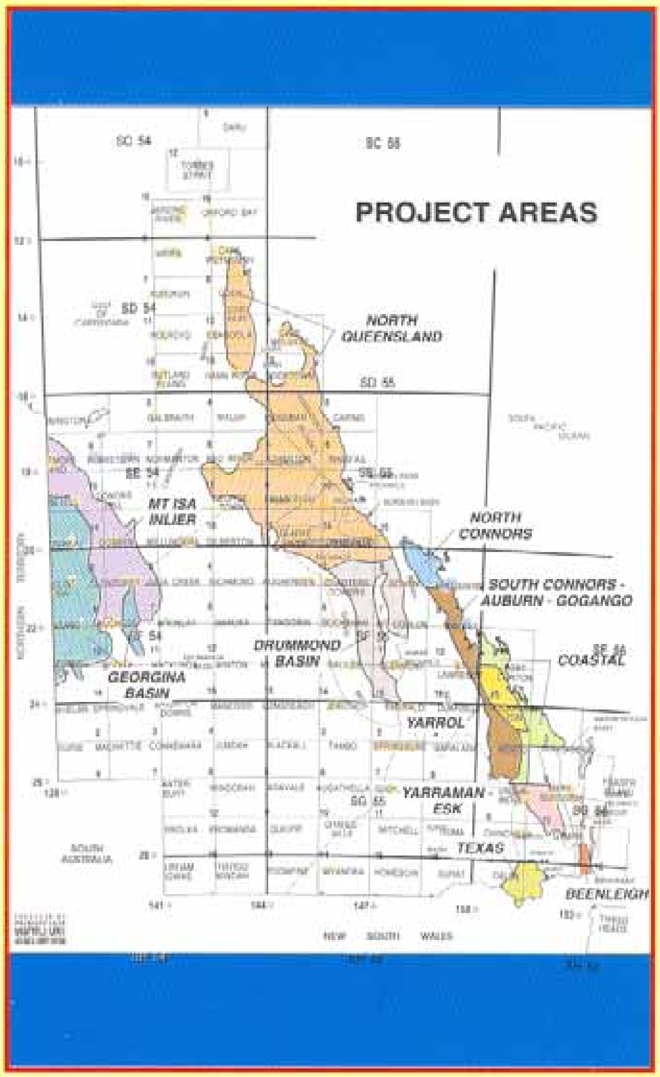
There is a general consensus that while organisations such as universities and private exploration companies carry out geological mapping over relatively small areas, systematic mapping of the entire State is a government responsibility.

This responsibility has been shared by the State and Commonwealth governments since 1950, when the Geological Survey of Queensland (GSQ) and the Bureau of Mineral Resources, Geology and Geophysics (BMR, now the Australian Geological Survey Organisation, AGSO) jointly commenced the first systematic program to map the whole of Queensland.

A summary of the mapping programs in Queensland is presented in the following table.

Program	Participant	Strategy	Field Period	End	Outputs	Impacting technology
1st pass mapping	BMR-GSQ	systematic geological and geophysical mapping to improve understanding of Queensland's prospectivity and resource potential	1950-73	1978	110 maps @1:250 000	RC9 aerial photography & 4WD vehicles
2nd pass mapping	BMR-GSQ	mapping of geologically complex areas with high perceived potential for future mineral discoveries, and where existing maps provided an inadequate basis for mineral exploration	1968-83	1987	13 maps @1:250 000 in Mt Isa/ Georgetown area	1:25 000 colour aerial photography
Urban area mapping	GSQ	needs of the construction materials industry and of local authorities for land use planning	1974-83	1991	7 maps @1:100 000	
RGMP	GSQ	extension of 2nd pass mapping program	1984-92	1996	10 maps @1:250 000	satellite imagery and imaging systems
NGMA -North Qld, SBEA	AGSO-GSQ	new generation geoscientific maps, datasets and other information should be produced during the next 20 years in areas of high priority for mineral and petroleum exploration and/or where significant issues on land use exist	1990-95	1996	4 maps @1:250 000	aerial geophysical data
GEOMAP 2005	GSQ	that no geological map data for potentially mineralised areas are more than 20 years old and the current investigation of Qld sedimentary basins petroleum prospectivity is completed by 2000	1993-	2005	targeted 60 map areas @1:250 000	GIS & GPS technology

GEOMAP 2005 PROJECT AREAS



There are three basic points demonstrated by the data in this table:

1. The strategic goal for the State's mapping program has not changed since its inception in 1950. This observation reinforces the importance of quality geoscience information to the successful development of the State's geoscience resources and the responsibility governments have to ensure the integrity of this information resource.

2. The decline in the rate of coverage associated with second pass mapping. This decline in the rate of geological map production has been attributed to a decrease in levels of resources (funding and staffing), to the withdrawal of the BMR from systematic regional geological mapping in 1982 and that geological mapping is a much more complex and time consuming process than it was 30 or 40 years ago.

3. The impact of technology on the mapping process. B&W photography, colour photography, satellite imagery, geophysical map and Geographic Information System (GIS) and Global Positioning Satellite (GPS) technology exemplify an evolution from paper base medium to a totally digital environment.

Geomap 2005 today

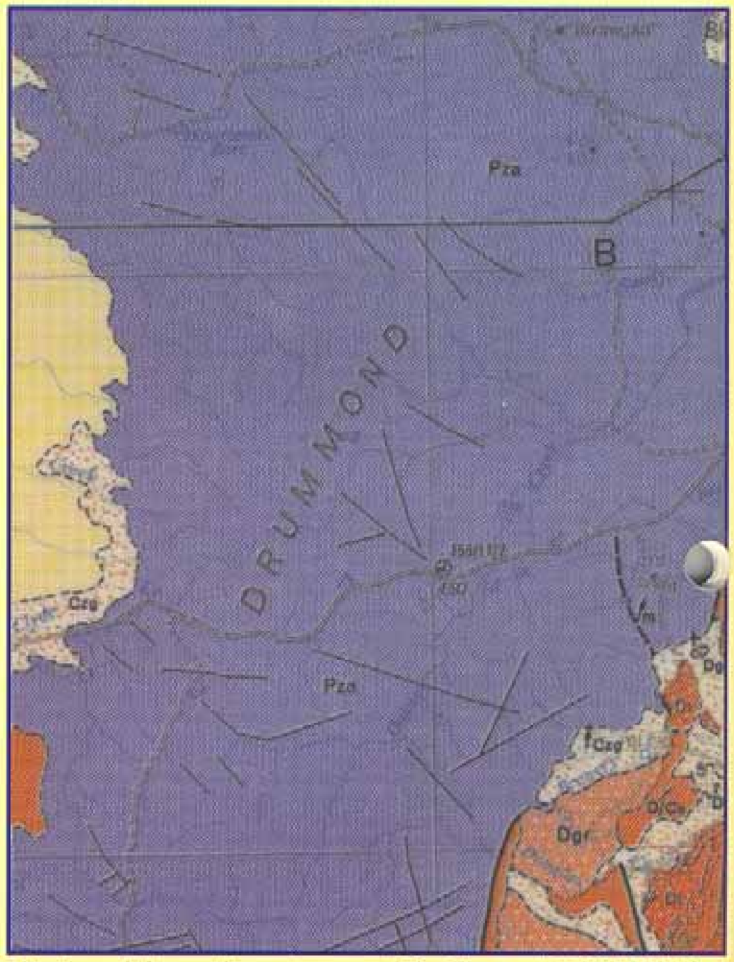
A 12-year program, GEOMAP 2005, entails updating the geology of 60 standard 1:250 000 sheet areas that are considered to have mineral potential. The GEOMAP 2005 program project areas are shown on the left.

Clearly the second pass mapping rate documented in the table (one 1:250 000 sheet per year) will not solve the problem of the ageing of the first pass mapping.

The primary geological knowledge base for known or potentially mineralised areas in Queensland remains more than 20 years old, and some maps are more than 30 years old.

It is in these areas that the need for accurate and up-to-date geological data is greatest to assist both exploration and land use management.

The second pass mapping process must be accelerated. The GEOMAP 2005 program has implemented a project-based management process and revamped DME mapping systems to optimise the impact of new technology.



Portion of the south-west corner of the Clermont 1:250 000 Sheet area. During the first pass geological mapping of the area in the 1960s, no attempt was made to subdivide the Anakie Metamorphics which make up most of the area depicted. This was partly because of the quality of the available B&W aerial photographs, and the emphasis of the mapping team on rocks prospective for coal and petroleum. Only the limits of the metamorphics were delimited, such as the boundaries shown with the Cainozoic cover in the west and the Retreat Batholith in the south-east.

Key elements of the new mapping system are:

- clear geological focus established before the project starts
- adopting a digital environment (MERLIN) for the projects from conception to finalisation,
- extensive pre-field mapping data capture process including geophysical and satellite imagery data,
- fixed time frames for the project, and
- digital map production processes.

Many of the new processes involving the integration of modern data sets have been piloted during the Anakie mapping program. The figures below demonstrate the role of geophysical and satellite imagery data and the increased geologic complexity associated with modern exploration programs. The figure on the left represents the geology from the SW corner of the Clermont 1:250 000 sheet area prior to the Anakie Project. In the centre, the ternery radiometric image of the same area can be seen. On the right is the geology of this area at the completion of the new mapping program.

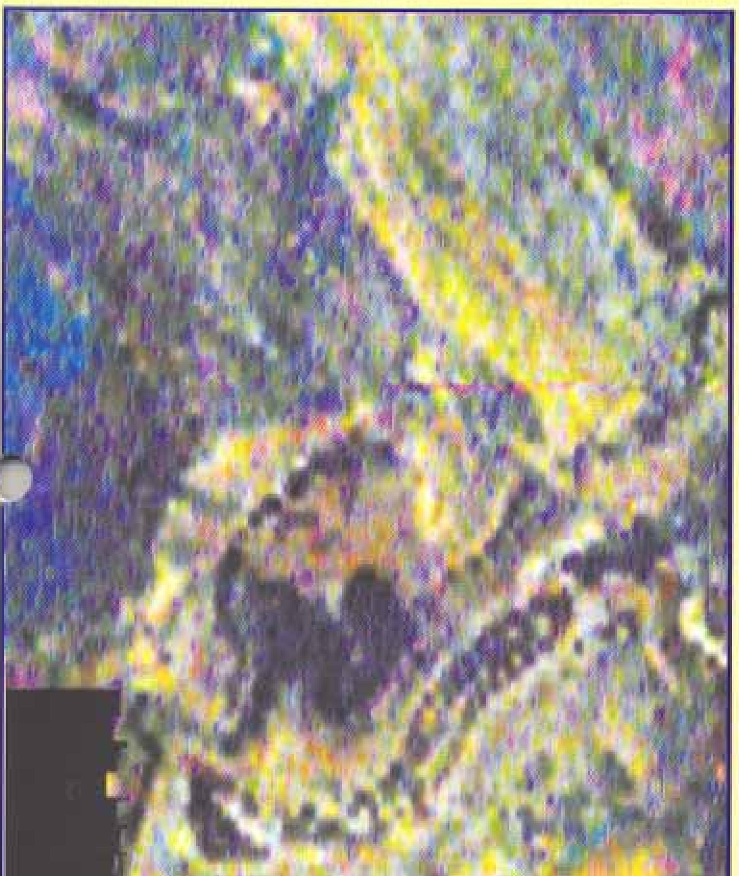
The mapping team compiled this interpretation from:

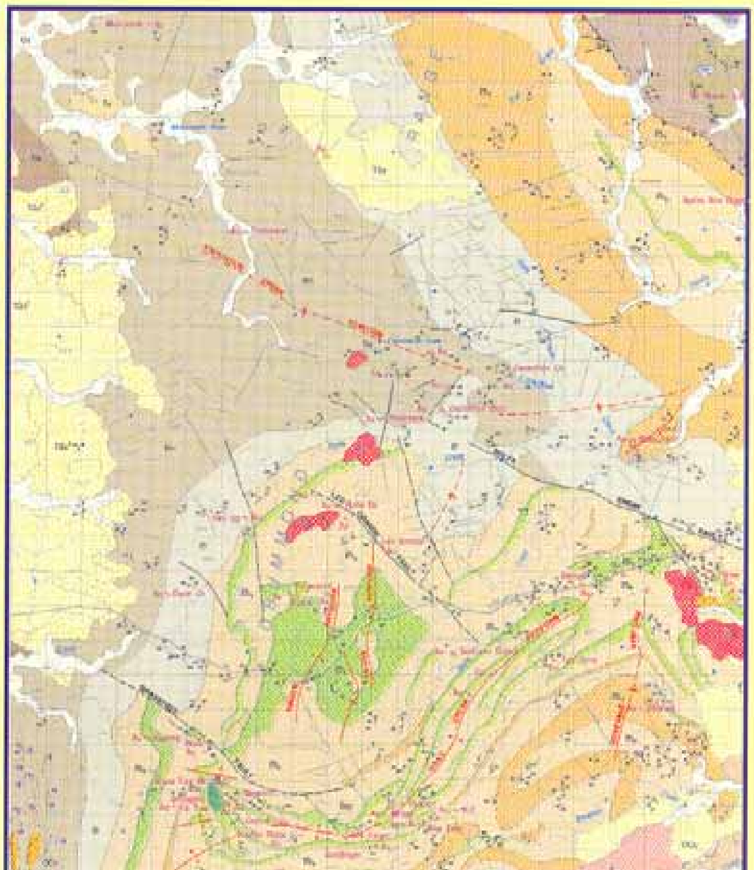
- previous exploration work that occurred in the area subsequent to the first pass mapping,
- TM imagery,
- aerial geophysical data, and
- ground truth surveys.

The future - MERLIN

The impact of technology on the mapping process (B&W photography, colour photography, satellite imagery, geophysical data and GIS & GPS) is driving an evolution toward a totally digital environment.

The Department of Minerals and Energy, Queensland is **leading the way** with MERLIN, the Department's state-wide digital information system providing access by explorers to comprehensive datasets including tenure, geoscientific data, and resource data. On the following page are examples of new digital geoscientific data sets available from the DMEQ.

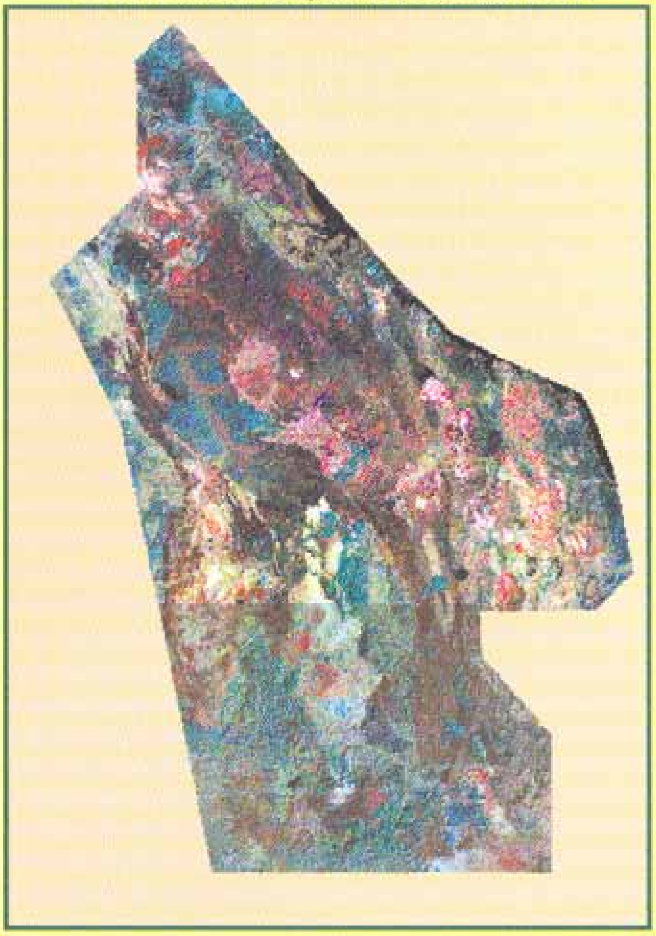




As a result of second pass mapping using satellite and geophysical imagery in conjunction with ground traversing, the Anakie Metamorphics have been subdivided into six named formations and several members. The units are defined by different proportions of pelitic to psammitic metasediments and mafic igneous units (greenstone). Ground traversing revealed that the outcrop patterns, which are clearly shown on the images (see left), are produced by open antiforms and synforms that fold an originally flat-lying metamorphic fabric.

AIRDATA 94/95 TMI

AIRDATA 94/95 RGB IMAGE



RAWBELLE BATHOLITH FIRST VERTICAL DERIVATIVE

RAWBELLE BATHOLITH RGB IMAGE

International Geomagnetic Reference Field, 1995 Revision

IAGA Division V, Working Group 8 [1]

The International Geomagnetic Reference Field (IGRF) is a series of mathematical models of the main geomagnetic field and its secular variation. Each model comprises a set of spherical harmonic (or Gauss) coefficients, g_n^m and h_n^m, in a series expansion of the geomagnetic potential,

$$V = a \sum_{n=1}^{N} \sum_{m=0}^{n} \left(\frac{a}{r}\right)^{n+1} \left(g_n^m \cos m\phi + h_n^m \sin m\phi\right) P_n^m(\cos\theta),$$

where a is the mean radius of the Earth (6371.2 km), r is the radial distance from the centre of the Earth, ϕ is longitude eastward from Greenwich, θ is geocentric colatitude, and $P_n^m(\cos\theta)$ is the associated Legendre function of degree n and order m, normalized according to the convention of Schmidt (e.g., Chapman and Bartels, 1940; Langel, 1987). N is the maximum spherical harmonic degree of the expansion. The main field models are defined for successive 5-year epochs. At the final epoch, presently 1995.0, a secular variation model is included for forward continuation of the field for the following 5 years.

A 7th generation (1995) revision of the IGRF was adopted by the International Association of Geomagnetism and Aeronomy (IAGA) during the XXI General Assembly of the International Union of Geodesy and Geophysics held in Boulder, USA in July 1995. Spherical harmonic coefficients for the complete IGRF are listed in Table 1. The IGRF now consists of a new set of IGRF models at 5-year epochs from 1900.0 to 1940.0, the existing DGRF models at 5-year epochs from 1945.0 to 1985.0 (IAGA, 1991; Langel, 1992), a new DGRF 1990 model that replaces IGRF 1990, and a new IGRF 1995 model that includes secular variation (SV) terms for forward continuation of the 1995 field to the year 2000.0. Coefficients for dates between the 5-year epochs are obtained by linear interpolation between the corresponding coefficients for neighbouring 5-year epochs.

The main field models are truncated at N=10 (120 coefficients), which is the practical compromise adopted for producing well-determined main field models while avoiding most of the contamination from crustal fields. Main field coefficients are rounded to the nearest nanotesla to reflect the limit of resolution of the observational data. The prospective secular variation model is truncated at N=8 (80 coefficients) with coefficients rounded to the nearest 0.1 nT/yr, again reflecting the resolution of the available data. When

[1] *Participating members: C.E. Barton (Chairman), R.T. Baldwin, D.R. Barraclough, S. Bushati, R. Coleman, P. Kotz, V.P. Golovkov, A. Jackson, R.A. Langel, F.J. Lowes, D.J. McKnight, S. Macmillan, L.R. Newitt, N.W. Peddie, J.M. Quinn, and T.J. Sabaka.*

Table 2. IGRF 1995 - World Data Centres

World Data Center–A: Solid Earth Geophysics National Geophysical Data Center NOAA, Code E/GCI 325 Broadway Boulder, CO 80303-3328, USA	Tel: +1-303-497 6521 Fax: +1-303-497 6513 Email: info@ngdc.noaa.gov
World Data Center–B2 Russian Geophysical Committee Academy of Sciences of Russia Molodezhnaya 3 Moscow 117 296 RUSSIA	Tel: +7-930 0546 Fax: +7-930 5509 Email: sgc@adonis.iasnet.com
World Data Centre–C1: Geomagnetism British Geological Survey Murchison House, West Mains Road Edinburgh, EH9 3LA, UK	Tel: +44-131-667 1000 Fax: +44-131-668 4368 Email: drbar@wpo.nerc.ac.uk
World Data Center–A: Rockets and Satellites NASA/Goddard Space Flight Center Code 633 Greenbelt, MD 20771, USA	Tel: +1-301-286 6695 Fax: +1-301-286 1771 Email: request@nssdca.gsfc.nasa.gov

TABLE 1. Spherical harmonic (Gauss) coefficients of the 1995 revision of the International Geomagnetic Reference Field.

			IGRF	IGRF	IGRF	IGRF	IGRF	IGRF	IGRF	IGRF	IGRF	DGRF	DGRF	DGRF	DGRF	DGRF	DGRF	DGRF	DGRF	DGRF	DGRF	IGRF	
g/h	n	m	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	SV(nT/yr)*
g	1	0	-31543	-31464	-31354	-31212	-31060	-30926	-30805	-30715	-30654	-30594	-30554	-30500	-30421	-30334	-30220	-30100	-29992	-29873	-29775	-29682	17.6
g	1	1	-2298	-2298	-2297	-2306	-2317	-2318	-2316	-2306	-2292	-2285	-2250	-2215	-2169	-2119	-2068	-2013	-1956	-1905	-1848	-1789	13.0
h	1	1	5922	5909	5898	5875	5845	5817	5808	5812	5821	5810	5815	5820	5791	5776	5737	5675	5604	5500	5406	5318	-18.3
g	2	0	-677	-728	-769	-802	-839	-893	-951	-1018	-1106	-1244	-1341	-1440	-1555	-1662	-1781	-1902	-1997	-2072	-2131	-2197	-13.2
g	2	1	2905	2928	2948	2956	2959	2969	2980	2984	2981	2990	2998	3003	3002	2997	3000	3010	3027	3044	3059	3074	3.7
h	2	1	-1061	-1086	-1128	-1191	-1259	-1334	-1424	-1520	-1614	-1702	-1810	-1898	-1967	-2016	-2047	-2067	-2129	-2197	-2279	-2356	-15.0
g	2	2	924	1041	1176	1309	1407	1471	1517	1550	1566	1578	1576	1581	1590	1594	1611	1632	1663	1687	1686	1685	-0.8
h	2	2	1121	1065	1000	917	823	728	644	586	528	477	381	291	206	114	25	-68	-200	-306	-373	-425	-8.8
g	3	0	1022	1037	1058	1084	1111	1140	1172	1206	1240	1282	1297	1302	1302	1297	1287	1276	1281	1296	1314	1329	1.5
g	3	1	-1469	-1494	-1524	-1559	-1600	-1645	-1692	-1740	-1790	-1834	-1889	-1944	-1992	-2038	-2091	-2144	-2180	-2208	-2239	-2268	-6.4
h	3	1	-330	-357	-389	-421	-445	-462	-480	-494	-499	-499	-476	-462	-414	-404	-366	-333	-336	-310	-284	-263	4.1
g	3	2	1256	1239	1223	1212	1205	1202	1205	1215	1232	1255	1274	1288	1289	1292	1278	1260	1251	1247	1248	1249	-0.2
h	3	2	3	34	62	84	103	119	133	146	163	186	206	216	224	240	251	262	271	284	293	302	2.2
g	3	3	572	635	705	778	839	881	907	918	916	913	896	882	878	856	838	830	833	829	802	769	-8.1
h	3	3	523	480	425	360	293	229	166	101	43	-11	-46	-83	-130	-165	-196	-223	-252	-297	-352	-406	-12.1
g	4	0	876	880	884	887	889	891	896	903	914	944	954	958	957	957	952	946	938	936	939	941	0.8
g	4	1	628	643	660	678	695	711	727	744	762	776	792	796	800	804	800	791	782	780	780	782	0.9
h	4	1	195	203	211	218	220	216	205	188	169	144	136	133	135	148	167	191	212	232	247	262	1.8
g	4	2	660	653	644	631	616	601	584	565	550	544	528	510	504	479	461	438	398	361	325	291	-6.9
h	4	2	-69	-77	-90	-109	-134	-163	-195	-226	-252	-276	-278	-274	-278	-269	-266	-265	-257	-249	-240	-232	1.2
g	4	3	-361	-380	-400	-416	-424	-426	-422	-415	-405	-421	-408	-397	-394	-390	-395	-405	-419	-424	-423	-421	0.5
h	4	3	-210	-201	-189	-173	-153	-130	-109	-90	-72	-55	-37	-23	3	13	26	39	53	69	84	98	2.7
g	4	4	134	146	160	178	199	217	234	249	265	304	303	290	269	252	234	216	199	170	141	116	-4.6
h	4	4	-75	-65	-55	-51	-57	-70	-90	-114	-141	-178	-210	-230	-255	-269	-279	-288	-297	-297	-299	-301	-1.0
g	5	0	-184	-192	-201	-211	-221	-230	-237	-241	-241	-253	-240	-229	-222	-219	-216	-218	-218	-214	-214	-210	0.8
g	5	1	328	328	327	327	326	326	327	329	334	346	349	360	362	358	359	356	357	355	353	352	0.1
h	5	1	-210	-193	-172	-148	-122	-96	-72	-51	-33	-12	3	15	16	19	26	31	46	47	46	44	0.2
g	5	2	264	259	253	245	236	226	218	211	208	194	211	230	242	254	262	264	261	253	245	237	-1.5
h	5	2	53	56	57	58	58	58	60	64	71	95	103	110	125	128	139	148	150	150	154	157	1.2
g	5	3	5	-1	-9	-16	-23	-28	-32	-33	-33	-20	-20	-23	-26	-31	-42	-59	-74	-93	-109	-122	-2.0
h	5	3	-33	-32	-33	-34	-38	-44	-53	-64	-75	-67	-87	-98	-117	-126	-139	-152	-151	-154	-153	-152	0.3
g	5	4	-86	-93	-102	-111	-119	-125	-131	-136	-141	-142	-147	-152	-156	-157	-160	-159	-162	-164	-165	-167	-0.1
h	5	4	-124	-125	-126	-126	-125	-122	-118	-115	-113	-119	-122	-121	-114	-97	-91	-83	-78	-75	-69	-64	1.8
g	5	5	-16	-26	-38	-51	-62	-69	-74	-76	-76	-82	-76	-69	-63	-62	-56	-49	-48	-46	-36	-26	2.3
h	5	5	3	11	21	32	43	51	58	64	69	82	80	78	81	81	83	88	92	95	97	99	0.9
g	6	0	63	62	62	61	61	61	60	59	57	59	54	47	46	45	43	45	48	53	61	66	0.5
g	6	1	61	60	58	57	55	54	53	53	54	57	57	57	58	61	64	66	66	65	65	64	-0.4
h	6	1	-9	-7	-5	-2	0	3	4	4	4	6	-1	-9	-10	-11	-12	-13	-15	-16	-16	-16	0.3
g	6	2	-11	-11	-11	-10	-10	-9	-9	-8	-7	6	4	3	1	8	15	28	42	51	59	68	0.6
h	6	2	83	86	89	93	96	99	102	104	105	100	99	96	99	100	100	99	93	88	82	77	-1.6
g	6	3	-217	-221	-224	-228	-233	-238	-242	-246	-249	-246	-247	-247	-237	-228	-212	-198	-192	-185	-178	-172	1.9
h	6	3	2	4	5	8	11	14	19	25	33	16	33	48	60	68	72	75	71	69	69	67	-0.2
g	6	4	-58	-57	-54	-51	-46	-40	-32	-25	-18	-25	-16	-8	-1	4	2	1	4	4	3	2	-0.2
h	6	4	-35	-32	-29	-26	-22	-18	-16	-15	-15	-9	-12	-16	-20	-32	-37	-41	-43	-48	-52	-57	-0.9
g	6	5	59	57	54	49	44	39	32	25	18	21	12	7	-2	1	3	6	14	16	18	17	-0.2
h	6	5	36	32	28	23	18	13	8	4	0	-16	-12	-12	-11	-8	-6	-4	-2	-1	1	4	1.0
g	6	6	-90	-92	-95	-98	-101	-103	-104	-106	-107	-104	-108	-107	-113	-111	-112	-111	-108	-102	-96	-94	0.0
h	6	6	-69	-67	-65	-62	-57	-52	-46	-40	-33	-39	-30	-24	-17	-7	1	11	17	21	24	28	2.2
g	7	0	70	70	71	72	73	73	74	74	74	70	65	65	67	75	72	71	72	74	77	78	-0.2
g	7	1	-55	-54	-54	-54	-54	-54	-54	-53	-53	-40	-55	-56	-56	-57	-57	-56	-59	-62	-64	-67	-0.8
h	7	1	-45	-46	-47	-48	-49	-50	-51	-52	-52	-45	-35	-50	-55	-61	-70	-77	-82	-83	-80	-77	0.8
g	7	2	0	0	1	2	2	3	4	4	4	0	2	2	5	4	1	1	2	3	2	1	-0.6
h	7	2	-13	-14	-14	-14	-14	-14	-15	-17	-18	-18	-17	-24	-28	-27	-27	-26	-27	-27	-26	-25	0.2
g	7	3	34	33	32	31	29	27	25	23	20	0	1	10	15	13	14	16	21	24	26	29	0.6
h	7	3	-10	-11	-12	-12	-13	-14	-14	-14	-14	2	0	-4	-6	-2	-4	-5	-5	-2	0	3	0.6
g	7	4	-41	-41	-40	-38	-37	-35	-34	-33	-31	-29	-40	-32	-32	-26	-22	-14	-12	-6	-1	4	1.2
h	7	4	-1	0	1	2	4	5	6	7	7	6	10	8	7	6	8	10	16	20	21	22	-0.4
g	7	5	-21	-20	-19	-18	-16	-14	-12	-11	-9	-10	-7	-11	-7	-6	-2	0	1	4	5	8	0.1
h	7	5	28	28	28	28	28	29	29	29	29	28	36	28	23	26	23	22	18	17	17	16	0.0

g	7	6		18	18	18	19	19	19	18	18	17	15	5	9	17	13	13	12	11	10	9	10	0.2
h	7	6		-12	-12	-13	-15	-16	-17	-18	-19	-20	-17	-18	-20	-18	-23	-23	-23	-23	-23	-23	-23	-0.3
g	7	7		6	6	6	6	6	6	6	6	5	29	19	18	8	1	-2	-5	-2	0	0	-2	-0.6
h	7	7		-22	-22	-22	-22	-22	-21	-20	-19	-19	-22	-16	-18	-17	-12	-11	-12	-10	-7	-4	-3	0.0
g	8	0		11	11	11	11	11	11	11	11	11	13	22	11	15	13	14	14	18	21	23	24	0.3
g	8	1		8	8	8	8	7	7	7	7	7	7	15	9	6	5	6	6	6	6	5	4	-0.2
h	8	1		8	8	8	8	8	8	8	8	8	12	5	10	11	7	7	6	7	8	10	12	0.4
g	8	2		-4	-4	-4	-4	-3	-3	-3	-3	-3	-8	-4	-6	-4	-4	-2	-1	0	0	-1	-1	0.1
h	8	2		-14	-15	-15	-15	-15	-15	-15	-15	-14	-21	-22	-15	-14	-12	-15	-16	-18	-19	-19	-20	-0.2
g	8	3		-9	-9	-9	-9	-9	-9	-9	-9	-10	-6	-1	-14	-11	-14	-13	-12	-11	-11	-10	-9	0.4
h	8	3		7	7	6	6	6	6	6	6	5	-12	0	5	7	9	6	4	4	5	6	7	0.2
g	8	4		1	1	1	2	2	2	2	1	1	9	11	6	2	0	-3	-8	-7	-9	-12	-14	-1.1
h	8	4		-13	-13	-13	-13	-14	-14	-14	-15	-15	-7	-21	-23	-18	-16	-17	-19	-22	-23	-22	-21	0.7
g	8	5		2	2	2	3	4	4	5	6	6	7	15	10	10	8	5	4	4	4	3	4	0.3
h	8	5		5	5	5	5	5	5	5	5	5	2	-8	3	4	4	6	6	9	11	12	12	0.0
g	8	6		-9	-8	-8	-8	-7	-7	-6	-6	-5	-10	-13	-7	-5	-1	0	0	3	4	4	5	0.2
h	8	6		16	16	16	16	17	17	18	18	19	18	17	23	23	24	21	18	16	14	12	10	-1.2
g	8	7		5	5	5	6	6	7	8	8	9	7	5	6	10	11	11	10	6	4	2	0	-0.9
h	8	7		-5	-5	-5	-5	-5	-5	-5	-5	-5	3	-4	-4	1	-3	-6	-10	-13	-15	-16	-17	-0.7
g	8	8		8	8	8	8	8	8	8	7	7	2	-1	9	8	4	3	1	-1	-4	-6	-7	-0.3
h	8	8		-18	-18	-18	-18	-19	-19	-19	-19	-19	-11	-17	-13	-20	-17	-16	-17	-15	-11	-10	-10	-0.6
g	9	0		8	8	8	8	8	8	8	8	8	5	3	4	4	8	8	7	5	5	4	4	0.0
g	9	1		10	10	10	10	10	10	10	10	10	-21	-7	9	6	10	10	10	10	10	9	9	0.0
h	9	1		-20	-20	-20	-20	-20	-20	-20	-20	-21	-27	-24	-11	-18	-22	-21	-21	-21	-21	-20	-19	0.0
g	9	2		1	1	1	1	1	1	1	1	1	1	-1	-4	0	2	2	2	1	1	1	1	0.0
h	9	2		14	14	14	14	14	14	14	15	15	17	19	12	12	16	16	16	16	15	15	15	0.0
g	9	3		-11	-11	-11	-11	-11	-11	-12	-12	-12	-11	-25	-5	-9	-13	-12	-12	-12	-12	-12	-12	0.0
h	9	3		5	5	5	5	5	5	5	5	5	29	12	7	2	7	6	7	9	9	11	11	0.0
g	9	4		12	12	12	12	12	12	12	11	11	3	10	2	1	10	10	10	9	9	9	9	0.0
h	9	4		-3	-3	-3	-3	-3	-3	-3	-3	-3	-9	2	6	0	-4	-4	-4	-5	-6	-7	-7	0.0
g	9	5		1	1	1	1	1	1	1	1	1	16	5	4	4	-1	-1	-1	-3	-3	-4	-4	0.0
h	9	5		-2	-2	-2	-2	-2	-2	-2	-3	-3	4	2	-2	-3	-5	-5	-5	-6	-6	-7	-7	0.0
g	9	6		-2	-2	-2	-2	-2	-2	-2	-2	-2	-3	-5	1	-1	-1	0	-1	-1	-1	-2	-2	0.0
h	9	6		8	8	8	8	9	9	9	9	9	9	8	10	9	10	10	10	9	9	9	9	0.0
g	9	7		2	2	2	2	2	2	3	3	3	-4	-2	2	-2	5	3	4	7	7	7	7	0.0
h	9	7		10	10	10	10	10	10	10	11	11	6	8	7	8	10	11	11	10	9	8	7	0.0
g	9	8		-1	0	0	0	0	0	0	0	1	-3	3	2	3	1	1	1	2	1	1	0	0.0
h	9	8		-2	-2	-2	-2	-2	-2	-2	-2	-2	1	-11	-6	0	-4	-2	-3	-6	-7	-7	-8	0.0
g	9	9		-1	-1	-1	-1	-1	-1	-2	-2	-2	-4	8	5	-1	-2	-1	-2	-5	-5	-6	-6	0.0
h	9	9		2	2	2	2	2	2	2	2	2	8	-7	5	5	1	1	1	2	2	2	1	0.0
g	10	0		-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-8	-3	1	-2	-3	-3	-4	-4	-3	-3	0.0
g	10	1		-4	-4	-4	-4	-4	-4	-4	-4	-4	11	4	-5	-3	-3	-3	-3	-4	-4	-4	-4	0.0
h	10	1		2	2	2	2	2	2	2	2	2	5	13	-4	4	2	1	1	1	1	2	2	0.0
g	10	2		2	2	2	2	2	2	2	2	2	1	-1	-1	4	2	2	2	2	3	2	2	0.0
h	10	2		1	1	1	1	1	1	1	1	1	1	-2	0	1	1	1	1	0	0	1	1	0.0
g	10	3		-5	-5	-5	-5	-5	-5	-5	-5	-5	2	13	2	0	-5	-5	-5	-5	-5	-5	-5	0.0
h	10	3		2	2	2	2	2	2	2	2	2	-20	-10	-8	0	2	3	3	3	3	3	3	0.0
g	10	4		-2	-2	-2	-2	-2	-2	-2	-2	-2	-5	-4	-3	-1	-2	-1	-2	-2	-2	-2	-2	0.0
h	10	4		6	6	6	6	6	6	6	6	6	-1	2	-2	2	6	4	4	6	6	6	6	0.0
g	10	5		6	6	6	6	6	6	6	6	6	-1	4	7	4	4	6	5	5	5	4	4	0.0
h	10	5		-4	-4	-4	-4	-4	-4	-4	-4	-4	-6	-3	-4	-5	-4	-4	-4	-4	-4	-4	-4	0.0
g	10	6		4	4	4	4	4	4	4	4	4	6	12	4	6	4	4	4	3	3	3	3	0.0
h	10	6		0	0	0	0	0	0	0	0	0	6	6	1	1	0	0	-1	0	0	0	0	0.0
g	10	7		0	0	0	0	0	0	0	0	0	-1	3	-2	1	0	1	1	1	1	1	1	0.0
h	10	7		-2	-2	-2	-2	-2	-2	-2	-1	-1	-4	-3	-3	-1	-2	-1	-1	-1	-1	-2	-2	0.0
g	10	8		2	2	2	1	1	1	1	2	2	-3	2	6	-1	2	0	0	2	2	3	3	0.0
h	10	8		4	4	4	4	4	4	4	4	4	-2	6	7	6	3	3	3	4	4	3	3	0.0
g	10	9		2	2	2	2	3	3	3	3	3	5	10	-2	2	2	3	3	2	3	3	3	0.0
h	10	9		0	0	0	0	0	0	0	0	0	0	11	-1	0	0	1	1	0	0	-1	-1	0.0
g	10	10		0	0	0	0	0	0	0	0	0	-2	3	0	0	0	-1	-1	0	0	0	0	0.0
h	10	10		-6	-6	-6	-6	-6	-6	-6	-6	-6	-2	8	-3	-7	-6	-4	-5	-6	-6	-6	-6	0.0

** for extending the 1995.0 field to the year 2000.*

converting between geodetic and geocentric coordinates, use of the IAU ellipsoid (International Astronomical Union, 1966) is recommended; it has an equatorial radius of 6378.160 km and flattening 1/298.25.

The IGRF 1995 model will be superseded when a definitive model of the main field at 1995.0 is adopted at some later date. Similarly, the IGRF models for 1900 to 1940 may be revised later. Details about the derivation of the 1995 revision of the IGRF will appear in a special issue of the Journal of Geomagnetism and Geoelectricity in 1996. The name IGRF refers collectively to the entire series of spherical harmonic models; if a particular epoch model is intended, the reference must be specific, e.g., IGRF 1995 or DGRF 1980.

ASCII files of the IGRF coefficients and computer programs for synthesising field components are available from the World Data Centres listed in Table 2 and also from cooperating national geomagnetic observatory agencies and geological surveys throughout the world.

IGRF is produced by **IAGA Working Group V-8: Analysis of the Global and Regional Geomagnetic Field and its Secular Variation.** The new models adopted for the 1995 revision of IGRF are based on candidate models provided by NASAs Goddard Space Flight Center (Terry Sabaka, Rich Baldwin, and Bob Langel), The Institute of Terrestrial Magnetism, Ionospheric and Radio Wave PropagationIZMIRAN (Vadim Golovkov), and jointly by the US Navy (John Quinn and Rachel Coleman) and the British Geological Survey (Susan Macmillan and David Barraclough). We thank the staff of magnetic observatories and survey organisations world-wide for providing the data on which IGRF depends. For further information about IGRF, contact IAGA Working Group V-8 (Chairman: C.E. Barton, Australian Geological Survey Organisation, GPO Box 378, Canberra ACT 2601, Australia. Fax: +61-6-249 9986, email: cbarton@agso.gov.au).

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Time Domain IP and Complex Resistivity Data

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Abstract

The Complex Resistivity technique can be used to describe the total circuit response of a conductive ore body. The combination of an EM and IP response can be used to construct a unique signature diagnostic of each deposit. However more complex and costly survey methods are normally required for a comprehensive survey covering a wide range of frequencies. Comparable data may now be generated using FFT techniques with time domain data to isolate several harmonics in each chargeability decay curve. Data obtained in central Victoria confirm the viability of the technique and the equivalence of the time domain and frequency domain parameters.

Introduction

Zonge and Wynn (1975) have described how the Complex Resistivity (CR) method can be considered as a combination of electrical measurements. They indicate that CR measurements are a combination of typical IP parameters such as apparent resistivity, percent frequency effect and phase angle (or the equivalent chargeability). Also measured are the host rock response, type and approximate quantity of mineralization, and additional information concerning vertical or horizontal rock discontinuities (derived from electromagnetic reflection data, and used to interpret resistivity pseudosections). The combination of this information gives an apparent geological cross-section of considerable detail based solely on electrical measurements. Electrical responses can be separated into major categories (Zonge and Wynn, 1975) - anomalies caused by economic mineralization can be distinguished from those caused by EM coupling, non-economic polarization sources, cultural coupling (pipes, wires, fences), and odd geologic environments.

Frequency Domain and Time Domain IP measurements are equivalent in a linear system, and are interrelated through the Fourier transform (Soininen, 1984). The appealing quality of the Time Domain method is that the whole transient can be recorded in a single measurement. A pulse train transmitted waveform is often used, and spectra are often recorded in the Time Domain by measuring the voltage transient at a number of instances after the current pulse has been turned off (Soininen, 1984). The advantage that the pulse-train transmitted waveform has over a single pulse is that it improves the signal-to-noise ratio. Consequently CR surveys based on modifications of conventional Time Domain IP techniques are an attractive proposition (Boothroyd, 1994).

Time Domain Conversions

The conventional Frequency Domain IP method often requires considerable effort to obtain sufficient volumes of data to make an accurate presentation of complex impedance. In contrast time domain methods can be used to obtain similar information but at a much quicker rate. The equivalence that exists between Time Domain and Frequency Domain IP data can be used to convert Chargeability values to their PFE counterparts.

This then enables time domain data to be plotted as a function of frequency. Each point gives a Complex Resistivity data point (relating to phase and amplitude). A set of Complex Resistivity points gives a Spectral IP plot. In the frequency domain this plot would normally be extrapolated back to zero frequency (DC level) to give an indication of the pure capacitive response, unaffected by higher frequency inductive effects.

Time domain measurements are usually a normalisation of a secondary measured decay voltage against a primary voltage. Most Time Domain receivers integrate the decay curve over some fixed interval, at a time after current termination. The ratio of secondary to primary voltage is defined as the Chargeability, (m). Interpretation of variations in decay curves led to the development of the Newmont Standard IP decay -this then formed the basis of comparison for future Time Domain receivers (Johnson, 1984). The L/M parameter was developed (Swift 1973) to define a ratio between the area over the decay curve spanning 0.45 to 1.75 seconds, and the calculation of the subsequent Chargeability for the decay.

Time Domain and Frequency Domain IP data can be linked by manipulating the basic definitions for each response function. For Time Domain data the IP effect is described using the concept of chargeability variously given as :

$$m = \frac{\text{secondary voltage}}{\text{primary voltage}}$$

$$= \frac{V_s}{V_p} = \frac{V_c \cdot V_1}{V_c} = \frac{1}{V_c} \int_{t_1}^{t_2} [V(t) \cdot dt]$$

For Frequency Domain data the IP effect is given as a Percentage Frequency Effect defined as :

$$PFE = \frac{\text{low frequency response - high frequency response}}{\text{high frequency response}}$$

$$= \frac{\rho_{DC} - \rho_{AC}}{\rho_{AC}} \cdot 100$$

where: ρ_{DC} = apparent resistivity at low frequency.

ρ_{AC} = apparent resistivity at higher frequencies.

$\rho_{DC} < \rho_{AC}$

Seigel (1959) defined the chargeability in the time domain as:

$$m = \frac{\lim_{\tau \to \infty} V(t) - \lim_{\tau \to 0} V(t)}{\lim_{\tau \to \infty} V(t)}$$

By use of the LaPlace transformations, chargeability can be expressed as a Frequency domain phenomenon:

From circuit theory

$$\lim_{\tau \to \infty} V(t) = J\rho_{DC}$$

$$\lim_{\tau \to 0} V(t) = J\rho_{\infty}$$

Hence approximating $\rho_{\infty} = \rho_{AC}$ the IP parameters can be re-defined giving

Time Domain: $\text{Chargeability} = m = 1 - \frac{\rho_{AC}}{\rho_{DC}}$

Frequency Domain: $\text{Frequency Effect} = FE = \frac{\rho_{DC}}{\rho_{AC}} - 1$

Substituting for ρ_{AC}, ρ_{DC}: $m = \frac{FE}{1 + FE}$

$m \approx FE$ (as $FE \ll 1$)

This relation may not be valid in practical situations, as the measurements are not made at DC and VHF, for either the Time or Frequency systems. The equivalence of the methods is not accurate, as there is no relation between a point in the Frequency Domain, and a point in the Time Domain (Marshall and Madden, 1959). However when the phenomena are linear (a homogeneous half space), frequency information can be derived from the transient measurements (or vice versa), using Fourier Transforms. Unfortunately, transformations from Time to Frequency Domain data are inexact. Time Domain data does not correspond with a single point in the Frequency Domain. Chargeability values are a total polarization effect parameter, and Frequency Domain PFE values are a differential polarization parameter (Zonge et al, 1972).

Van Voorhis et al (1973) related both the m and PFE values to an exponent "b". This, they suggested was a complete measure of the IP phenomenon. They found that the PFE value is independent of the specific measurement frequency, rather the relationship is dependent upon the spread of frequencies and an exponent b:

$PFE = (1 - A^{-b}) * 100.$

where A specifies the spread between measurement frequencies.

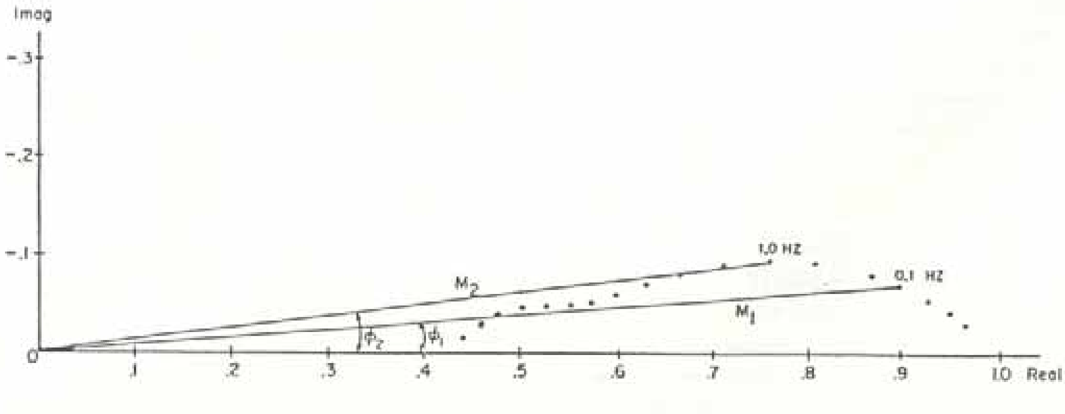
Data from 23 spectra were compared with the expected value from the equation above. Results were within an "error of measurement".

Complex Response

The Complex Resistivity technique measures the in-phase and out-of-phase components using additional frequencies to the conventional IP method. This creates the spectrum of frequency values -complex (real and imaginary) resistivity values. This involves a comparison of the magnitude and phase of the input and output waveforms, in Time and Frequency Domains via an intervening transform (Sumner, 1976). This is a ratio of input current to output voltage by Ohm's Law, and is defined as the transfer impedance of a system, which may involve complex waveforms. This enables the Complex Resistivity method to analyse the total electrical response of the Earth, in terms of the Induced Polarization, resistivity, and related electrical and electromagnetic properties, then separate their individual contributions (Sumner, 1976).

An example of CR data is given in Figure1 based on Frequency Domain measurements of PFE and phase angle. The complex plot displays an actual spectrum derived from a quartz porphyry breccia laboratory sample containing approximately 5% sulphides by volume (Zonge and Wynn, 1975). The plot was constructed using chargeability magnitudes m^1 and m^2, with 0.1 Hz phase angle. The standard IP measurements for the sample were then obtained (19% PFE, 80 milliradian phase shift, and 96 msec chargeability (empirically determined to be 1.2 times the 0.1 Hz phase angle, Zonge and Wynn, 1975). This diagram illustrates that the PFE values are proportional to the in-phase components, and that the phase angle corresponds to the out-of-phase components (Zonge and Wynn, 1975).

A Complex Resistivity survey measures the effects of discrete frequencies from 0.01Hz to 10.0Hz, using odd harmonics (1, 3, 5, 7, 9, 11) of full square waves with frequencies at decade intervals (0.01, 0.1, 1.0, and 10.0Hz) (Sumner, 1976). Pelton et al (1978), made Complex Resistivity measurements over the frequency range 10^{-2} to 10^{+5} Hz, over 26 massive sulphide,



$$PFE = \frac{M_1 - M_2}{M_2} \times 100\% \quad \text{(0.1 to 1.0 Hz decade)}$$

Figure 1. Graphic relationship between frequency domain IP and Complex Resistivity. (Zonge and Wynn 1975, p853).

graphite, magnetite, pyrrhotite, and porphyry copper deposits. The large frequency range (7 decades), was used to test the applicability of the Cole-Cole equivalent circuit model to the true IP response, the differences in observed spectra due to the mineralization detected, and if inductive coupling was inherently different from "natural IP behaviour" (Pelton et al, 1978). Sumner (1976) also suggested that data is checked for linearity by using the eleventh harmonic and comparing it with the next decade.

Conventional IP measurements are often disturbed by EM coupling at high frequencies, and data at lower frequencies are often masked by natural Earth currents which make noise an important practical factor (Marshall and Madden, 1959). Unless care is taken in designing a filtering program to be applied to the data, processing can detract from the target response rendering the data meaningless. However when a small electrode spacing is used, the resulting inductive coupling factor can be compensated. The inductive coupling depends upon the "frequency" x "the electrode spacing" (f x a), so a small spacing can accommodate a larger frequency (Pelton et al., 1978). This obviously restricts the depth of penetration for the Dipole-Dipole survey (depth = 1/2 electrode spacing). Pelton et al., (1978), therefore made all measurements on exposed mineralization, in open pits or fresh outcrop. An alternative method is required for practical field surveys over targets of large volume.

Johnson (1984) has suggested that Time Domain data can also be used to extract the Cole-Cole spectral parameters. Johnson (1984), illustrated a method whereby, decays were compared to a set of master curves (the Newmont Standard IP Decay). Decay parameters are fitted to the master curves, and the chargeability is then calculated. This then leads on to calculation of the Cole-Cole parameters. The Scintrex IGS-2/IP-4 Time Domain IP receiver available for this project calculates the Cole-Cole parameters "on line". Chargeability and the time constant values are computed. The time constant value can range between 21 binary values (2^{-10} to 2^{10} for a two second timing sequence).

An alternative method is used in this study to generate Complex Resistivity plots involving a manipulation of Time Domain Chargeability data. As illustrated previously, the Chargeability values can be roughly transformed to PFE values. This comparison is not exact, but does provide an efficient method for the accumulation of Spectral IP data. Johnson (1984) also concludes that the most practical method of Spectral IP plot generation came from studies of Time Domain decay curves. Time Domain decays can be modelled as a series of decay exponentials from which the Frequency Domain phase spectrum can be calculated (Johnson, 1984). However in the current project FFT's (Fast Fourier Transforms) were used to investigate the nature of individual harmonics in each decay obtained over potential IP targets.

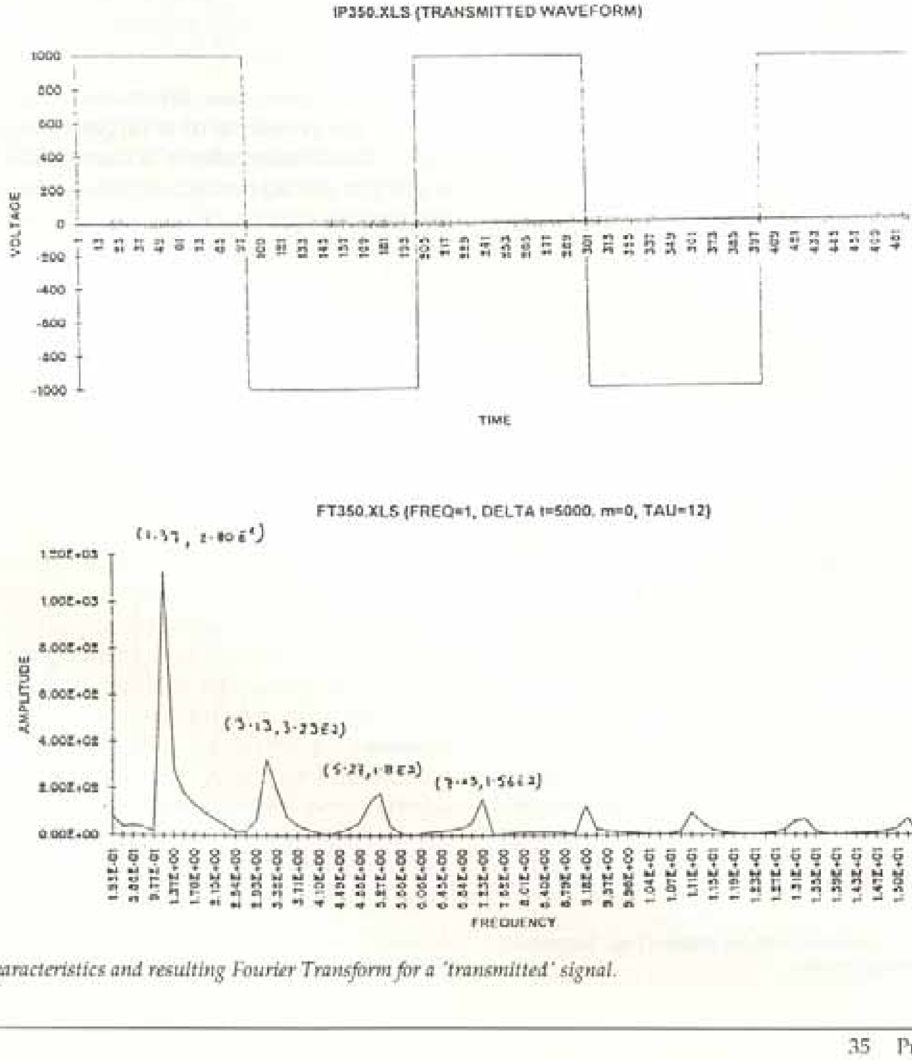


Figure 2. Waveform characteristics and resulting Fourier Transform for a 'transmitted' signal.

Data Reduction

Synthetic data were first prepared to demonstrate the techniques available for converting Time Domain IP data to the Frequency Domain equivalents. Typical capacitor like decay curves were constructed and transformed using an FFT technique. By observing graphs of amplitude verses frequency produced by the Fourier Transform, the effect by an arbitrary PFE value can be determined. Normally the odd incremental harmonics should be fractions of the 1st harmonic. The 3rd harmonic should be 1/3 of the 1st, the 5th harmonic should be 1/5 of the first, (etc). If the observed harmonics do not follow this theoretical decay, then the data is interpreted as being effected by a PFE associated with a target. The waveform and harmonic graph anticipated for a pure (zero PFE) 'transmitted' waveform is shown in Fig 2 any departures from this distribution can be attributed to an IP anomaly.

PFE values must be calculated as a function of the amplitude and frequency of the resulting harmonics in the Fourier Transformed graphs. Each fundamental frequency must be multiplied by the particular harmonic number for which a PFE value is being calculated. The PFE values were defined as the observed frequency from the Fourier Transformed data, multiplied by a fraction consisting of the amplitude of the transmitted waveform for that harmonic minus the amplitude of the received waveform for that harmonic, all divided by, the amplitude of the transmitted waveform for that harmonic.

Similar techniques were used to process field data obtained in central Victoria. Data were obtained using a Wenner array with spacings of 10 and 20m to observe the variation of response with depth. Measurements were repeated using periods of 1,2 and 4 seconds (= frequencies of 1, 0.5 and 0.25 Hz). Typical decay curves are indicated in Fig 3 showing values of chargeability on a log/log scale (recorded as a function of the data windows: the first window (M1) is recorded at 7.15msec, M2 at 12.5msec,.....,M14 at 795msec). A straight line is then fitted to the resulting plot, and extraneous points are filtered out.

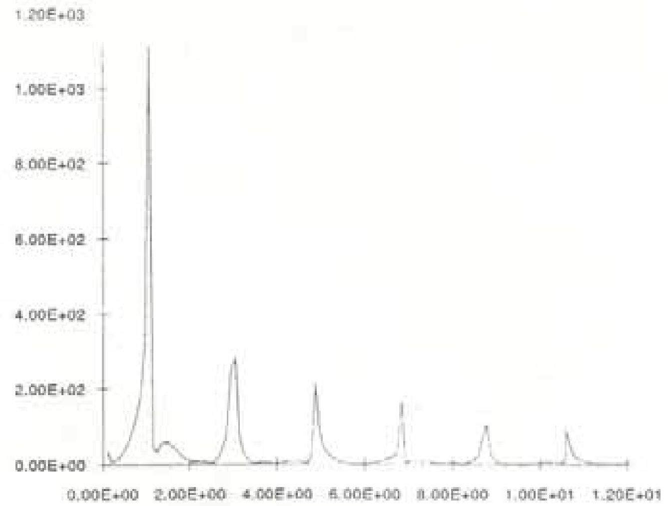


Figure 4. Raw harmonic data from Sharkeys Prospect (Central Victoria).

The results of Fourier Analysis are indicated in Figure 4 showing the raw harmonic data, and Figure 5 illustrates the graph of amplitude verses frequency for the compensated harmonics. The reason that the successive harmonics are not equivalent in amplitude to the 1st, is that the data has been influenced by a small PFE. The magnitude of this anomaly is very small (as observed by a parallel study of the chargeability values), but significant enough to effect the data. Unfortunately, for the purposes of the example, there does not appear to be a significant IP anomaly present at this site.

This method has illustrated that it is possible to model the response of a target from Time Domain IP data. Better examples of a chargeable anomaly should highlight the advantage of this technique. Converting the data to a plot of Real verses Imaginary (or in phase verses out-of phase) would indicate the presence of coupling effects. This technique has no phase reference

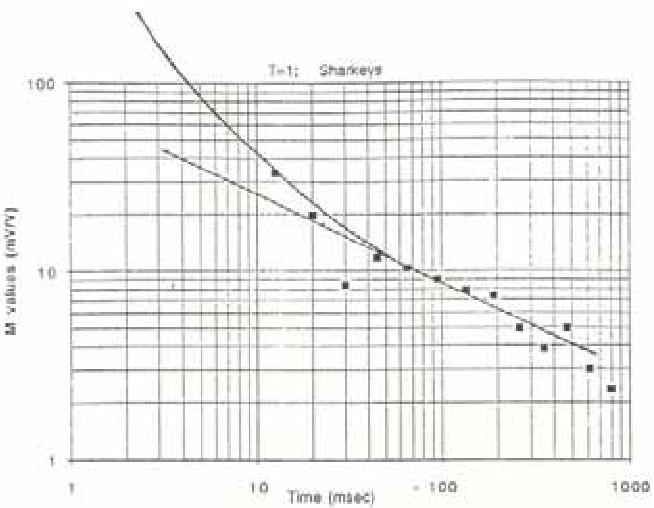


Figure 3. Varying gradients resulting from the graph of Log chargeability verses Log time-slice, SharkeysProspect

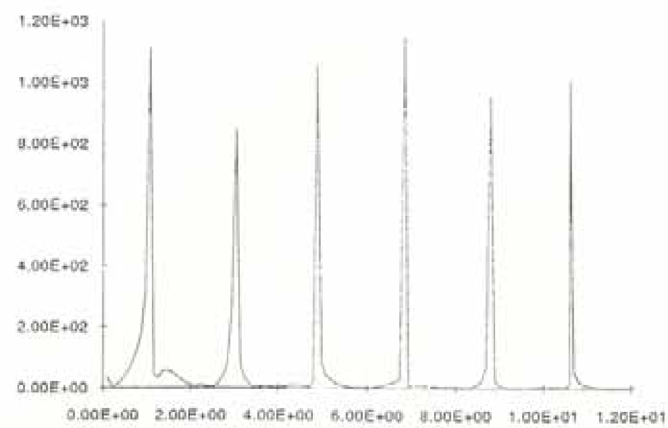


Figure 5. Compensated harmonics from Sharkeys Prospect (Central Victoria).

to do this, so in fact is considered to be a spectral analysis of the Earth's electrical response.

Conclusion

Conventional EM and galvanic techniques normally concentrate on a single component of a complex circuit. In particular separate geophysical methods have been developed to measure the EM and IP response for any particular target (Keller & Frischnecht, 1970). However EM and IP targets are often present in the same horizon (eg Mt Isa where mineralization is confined within a graphitic horizon, Pelton et al. 1978) and a pure electrical response may be impossible to identify. Complications related to IP effects have been observed with conventional TEM surveys (Smith & West 1988) and IP surveys are commonly subject to EM coupling effects. In contrast the CR technique has been developed to fully exploit the combined response over a range of different frequencies. The results of the current study now indicate that CR data can be obtained efficiently using modifications of well established time domain techniques.

The advantage that the Complex Resistivity technique has over conventional galvanic methods, is that there is the possibility to differentiate between various target responses. More familiar techniques such as IP and EM are used to detect the presence of a conductor in terms of specific electrical responses of the Earth. The Spectral analysis obtained using Complex Resistivity data, enables the conductive responses to be further defined in terms of their economic ore mineralogy (ie: the causative body of the detected response). Pelton et al (1978), discovered that differences occurred between the spectral responses of Massive Sulphides and Graphite. This is a major break-through in Geophysical methods in Precambrian areas such as Canada, Australia, Scandinavia, and more recently the Brazilian shield, where previous electrical prospecting methods have had an inability in distinguishing between volcanogenic massive sulphide mineralization and graphitic schists (Pelton et al 1978). This is a major step forward as some of the largest known Massive Sulphide deposits in the world occur in graphitic areas and even along graphite horizons (eg: Mt Isa, Australia) (Pelton et al, 1978).

Plotting the data on Real and Imaginary axes (rather than Amplitude verses Frequency) would give an indication of the coupling effects observed in a survey. Removal is essentially easy - a curve is plotted to the points on the graph, and this curve is then extrapolated towards the low frequency end (DC level). This removes the coupling effects, and gives an indication of the pure IP response at the low frequency end. Host rock responses can be determined, and Mineral Discriminations are possible in terms of Massive Sulphides and Graphitic Shears. With more data being gathered, the discriminations could possibly be extended to differentiate between the types of economic 'ore' minerals, identifying the mineral detected (ie: Galena [PbS] which is a chief ore of lead, verses Chalcopyrite [CuFeS2] the chief ore of copper). Currently this has been possible in a limited number of survey results - Pelton et al. 1978, have indicated that they were able to observe differences between the spectra of Pyrrhotite and Magnetite, and those of wet and dry mineralization. As a greater data base of results is obtained, an 'atlas' of type signatures could be devised to define certain classes of ores, so that identification is then made even easier.

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Excitations

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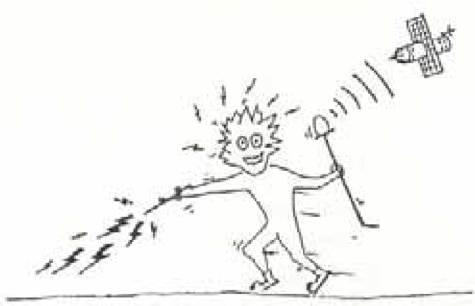


Different Anomalies from Different Sources or Different 'Kicks' from the Same Body.

The wide variety of geophysical parameters that the explorer can measure in the field means that we need to think carefully about the source of the responses we observe and the meaning of our interpretations of those observations. It is generally worth the effort and cost to make a variety of field measurements to observe as many geophysical 'kicks' as the buried target can produce. The combined analysis of these responses can provide a fairly comprehensive picture of the target. Self Potential (SP) and a Transient Electromagnetic (TEM) surveys I conducted a few years ago at a basemetal prospect provide an excellent example of multiple and varied geophysical responses from a single mineralised structure. It also shows a useful application of the lesser used SP method for target delineation.

SP

The SP method is very simple to apply and is probably the lowest cost geophysical method available. A survey was conducted at the Mossgrove Prospect, near Burraga in NSW, to map anomalous Cu/Pb/Zn geochemistry in an outcropping gossanous siltstone. Measurements were made at intervals of 10 metres along a series of survey lines space 50 meters apart. The survey mapped a self potential anomaly about 1 km in strike length with amplitude peaking up to 250 millivolts. The SP anomaly was coincident with the geochemical anomalies and mapped the buried strike extension of the target horizon. The SP results indicated the presence of a significant sulphide oxidation system and hence supported the supposition that a massive sulphide could be the source of the anomalies.

Interpretation of the SP data involved computing responses of sphere and dipping line-dipole models to determine the depth to centre and dip direction of a suitable source geometry. We actually found that a combination of several sphere and line-dipole models were required to account for the local anomalous 'highs' observed on the broader background response. Depths for the bodies ranged from 25 to 85 metres, most being about 50 metres. The strongest geochemical anomalies were coincident with the shallowest SP sources. Dips of individual bodies varied from vertical to 80 degrees west, the target horizon in outcrop showed an easterly dip.

TEM

Following the SP survey a large fixed-loop MK2 SIROTEM survey was conducted to test for an electrically conductive massive sulphide source for the geochemical and SP anomalies. The survey was conducted with the roving vector receiver along lines spaced 100 metres with measurements made at intervals of 25 metres. The survey was repeated with the transmitter loop relocated on the opposite side of the area to account for possible changes in dip of the target horizon.

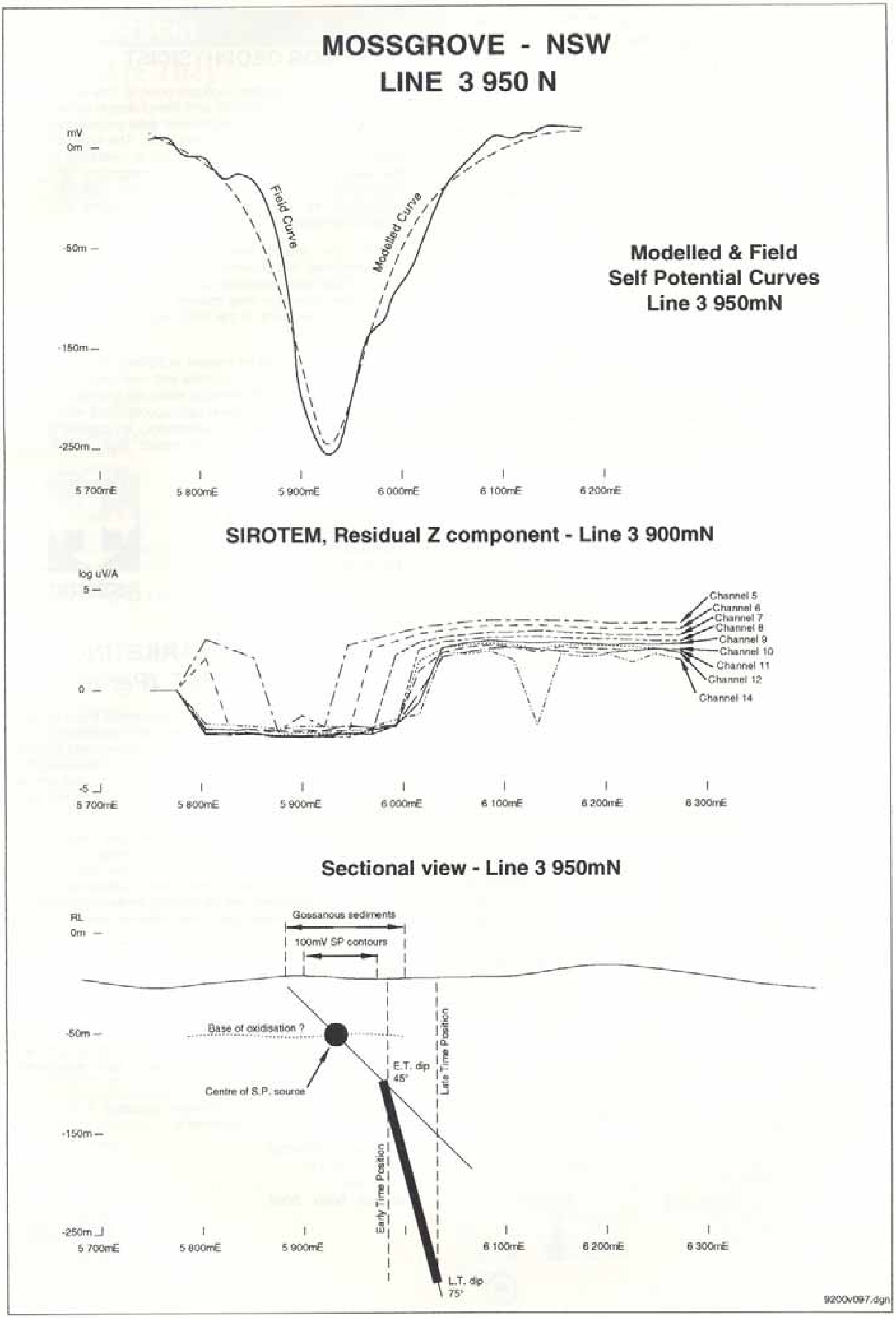
A strong half-space response was measured on all lines and the response from one line, showing only a half-space response but no target response, was used for removal of the half-space response from the rest of the data. This process revealed X component data having well defined peaks and Z component data showing cross-over points migrating toward the east, indicative of an easterly dipping conductor. These responses were displaced about 50 to 75 metres east of the SP and geochemical anomalies.

Analysis of the early time data revealed a conductor having an average dip of about 45 degrees east and late times indicated a dip of about 75 degrees east. Depth-to-top estimates ranged from 120 to 175 metres. This analysis was done using characteristic points (inflection and turning points) on the observed profiles, we did not have numerical modelling facilities at the time (quite a few years ago now).

Combined Interpretation

Figure 1 shows the strongest SP response (through the centre of the anomaly) from Line 3950N with the interpretation of the SIROTEM and SP data. The SIROTEM responses were strongest on lines 3900N and 4000N (there was no data acquired from Line 3950N). The interpreted conductor is shown with a dip of 75 degrees east. Its location, east of the SP and geochemical anomalies, is a best fit as the conductor strikes about 15 degrees grid west. The survey lines are oblique to the geological strike.

It was noted that the SIROTEM early time dip estimate of 45 degrees at a depth of 125 metres points up dip to the centre of the interpreted SP source. The SP source is probably located at the base of oxidation and associated with the gossan. We concluded that the gossan is the upper level of a deeper conductor dipping to the east, its dip increasing to about 75 degrees with depth. The vertical to steep westly dips determined for the SP sources are probably related to the shape of the


MOSSGROVE - NSW
LINE 3 950 N
mV
0m
-50m
-150m
-250m
Field Curve
Modelled Curve
Modelled & Field
Self Potential Curves
Line 3 950mN
5 700mE
5 800mE
5 900mE
6 000mE
6 100mE
6 200mE
SIROTEM, Residual Z component - Line 3 900mN
log uV/A
5
0
-5
Channel 5
Channel 6
Channel 7
Channel 8
Channel 9
Channel 10
Channel 11
Channel 12
Channel 14
6 300mE
Sectional view - Line 3 950mN
RL
Gossanous sediments
100mV SP contours
Base of oxidisation ?
Centre of S.P. source
E.T. dip
45°
Late Time Position
Early Time Position
L.T. dip
75°
9200v097.dgn

base of oxidation and not the dip of the mineralised structure. So don't be perturbed that dip directions determined from SP surveys may be different to those of the surrounding rocks (a potential trap for young players).

The interpreted conductor was tested by a drillhole collared to the east of the conductor and drilled to the west. A significant interval of Cu/Pb/Zn vein mineralisation was intersected at the interpreted target depth and subsequent downhole SIROTEM surveys confirmed that the hole had tested the only conductor present.

Conclusion

The Mossgrove example demonstrates that a variety of geophysical anomalies can be observed from different parts of the same mineralised structure, in this case the shallow gossan and the deeper unweathered conductive mineralisation. The relationship between the various responses can provide the geophysicist with more information about the nature of the target.

The SP results increased the follow-up priority to these particular geochemical anomalies, other geochemical anomalies at the prospect were not associated with SP anomalies and consequently were ranked lower for follow-up. Also, the SP survey cost-effectively delineated the strike form of the buried gossan. In itself the SP anomaly did little to delineate the deeper and more important part of the mineralised structure however, its spatial relationship with the TEM anomalies was important in confirming the dip and depth estimates obtained from the SIROTEM interpretation. This gave us greater confidence in locating the expensive diamond drillhole which, as it turned out, successfully tested the anomalies.

If you think your target might 'kick' to more than one geophysical method then you ought to make it 'kick' again and again so that you can get a more accurate drill target. The cost of the extra 'kicks' will probably be much less than the cost of drilling a less accurate target a second time in an attempt to make an ore discovery. Don't neglect to use the simplest and least sophisticated geophysical methods such as SP, they all have their part to play, they all tell their own story about what's going on down there. If it 'kicks' more than once you'll probably want to drill it!

Happy Excitations.

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