



## Preview Feature

Innovations - FLAIRTEM..... 21-24

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*Front Cover: FLAIRTEM helicopter cable laying (blue) and EM receiver (full colour).*

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A new Executive is welcomed this issue. Kathy Hill is the new President (p5) and Greg Blackburn, taking over the reins from Brenton Oke in the regular Executive Brief Column (p8), reports on the new Executive. I would particularly like to thank Brenton and outgoing members Andrew Sutherland and Rob Singh for their support for Preview. Two new committee members Nigel Hungerford and Ciaran Lavin are going to be assisting with Preview production and this is most welcome. Lindsay Thomas, ASEG Treasurer presents his report on ASEG 1993 finances (p6).

Derecke Palmer (assisted by Noel Merrick) kicks off his "Clean and Green" column (p42), a hopefully regular feature for the engineering, groundwater or environmentally inclined geophysicist. Please support Derecke with your contributions.

Innovations is another new column this issue which I am also excited about because it will tell the stories about Australian geophysical innovations and the innovators, that don't make it to the refereed journals. We start the series with the new FLAIRTEM system of Elliott Geophysical (p21). If you have ideas or are willing to contribute to this series please contact me.

We also celebrate the efforts of CSIRO researchers, among them ASEG members Ken McCracken and Andy Green, who were recently awarded the Australia Prize for remote sensing science excellence (p29). Another highlight this issue is Steve Mudge's outstanding "how to conduct helicopter magnetic surveys" article (p14). Mineral geophysicists, please distill your particular experiences and send your contributions to support Steve and your column: Excitations.

Industry news is all new instrumentation this issue: a borehole televiewer, a higher resolution ground magnetics system and an EM subsurface imaging system. Again news of industry is encouraged. With all the exploration initiatives and governments vying for exploration dollars there are some exciting geophysical data releases these days. We feature the Broken Hill and Vanuatu releases this issue (p37-39).

Preview advertising space is coming up for renewal starting October Preview. Colour advertising spaces are available for the inside front, back and inside back pages. Special advertising rates apply to the August Conference Handbook Edition of Preview (see February Preview page 12). More details on advertising regularly in Preview will be given in the June Preview. In the meantime enjoy this issue.

*Geoff Pettifer, Editor*

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## Past-President's Piece



This edition, the column is entitled past-President's Piece as it is the last time I will be contributing to Preview as President of the Society. We now have Kathy Hill as President and for those who are unaware of Kathy's position and achievements a profile is given below. Kathy is currently General Manager of Petroleum Division with the

Department of Agriculture, Energy and Minerals in Victoria and her duties there require hours extra to those of the normal working day. So we are fortunate that her nomination for President was successful and that she can spare the additional time required by this position. Again we have a robust federal committee and I feel confident that the society will be in capable hands for another year.

Kathy Hill's election to President of the Society makes her the second woman to hold this position; the first being Eve Howell, a few years ago. Both are

excellent role models for female geophysicists. The February Preview emphasises the need for an increased female participation in geophysics and Kathy's presidency is extremely timely.

Nigel Hungerford and Ciaran Lavin are welcomed to the committee this year. They will help to fill the gaps left by Rob Singh and Andrew Sutherland, who, due to increased work commitments will not be able to provide the time they feel their committee positions require; Andrew and Rob have both offered to help on a short term basis when required. Their contribution over the previous years was high, and their continued involvement, even if it is only to offer advice now and again, will be greatly appreciated.

And so, I would like to thank the Federal Committee, and the ASEG membership in general for supporting me as President for the last three years; I now look forward to supporting the society in a more specific, though less prominent role during the following years. I leave you with the conviction that the society is going from strength to strength with growing status and recognition both in Australia and overseas.

*Hugh Rutter  
Past-President*

## ASEG People Profile

### Kathy Hill

#### ASEG President



Kathy Hill, ASEG President-elect is General Manager of the Petroleum Unit with Energy and Minerals Victoria.

One of the many Canadian refugees from the hostile climes to the north,

Kathy took a rather more circuitous route to Australia than most of her compatriots. After a first degree in geology in 1979 she discovered an interest in reflection seismic data in the Alberta Basin for Esso.

Graduate courses in processing (entertainingly presented by Hans Den Boer) in Calgary whilst at work were followed by full time studies in Oxford in seismology.

Exposure to the high standards of research in processing in the UK, a heated argument with the head of Basin Studies in BP over Vaillian stratigraphy and temporary duty posting in London from Calgary of Kathy's husband Kevin, all led to Kathy accepting a post in 1984 with BP in the European Appraisal and Basin Studies Groups in London. She spent about 6 months looking at places with very interesting geology (the Apennines, Jura, Sicily) but very little oil. However her trips to Rome and Milan developed a taste for risotto and northern Italian Wines.

Following her husband's acceptance to the University of Melbourne to study with Andy Gleadow, Kathy was posted to Melbourne with BP in 1985. There her brief was to coordinate basin assessment for all of Australia and no amount of overlaying of Texas and Alberta on various parts of this continent could convince the London management that this was indeed a big country.

The 1986 oil shock intervened and left her as the only working geophysicist in the Australia group.

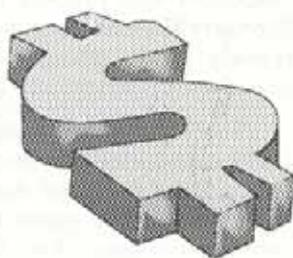
Kathy and Kevin decided to start a family and Kathy resigned from her contract in 1989. She was offered a research position at Monash University and stayed on as a lecturer there for five years, taking advantage of the flexibility that university life provides to have another child. With Kevin she taught Petroleum Geology and reflection seismic, sequence stratigraphy and geology courses, and collaborated with her husband on ARC funded projects, helping to set up two geophysical labs at Monash. In her teaching she attempted to de-mystify processing to geologists.

Kathy firmly believes that pigeonholing people as geophysicists or geologists is inappropriate in exploration and that there should be a concerted push for increasing the numeracy of geologists and geological theory and practice to geophysicists. Geophysics should be an integral part of any geologists training as should the foundation of mathematics to support it. Geophysicists however who do not consider themselves geoscientists narrow their perspectives.



## ASEG Financial Statements for 1993

The ASEG's accountants (T & J Daffey of North Essendon, Victoria) have produced the financial statements for the year ended 31 December 1993 as required by both the Society and the Australian Securities Commission. A copy of the report can be obtained from your State Branch Executive.

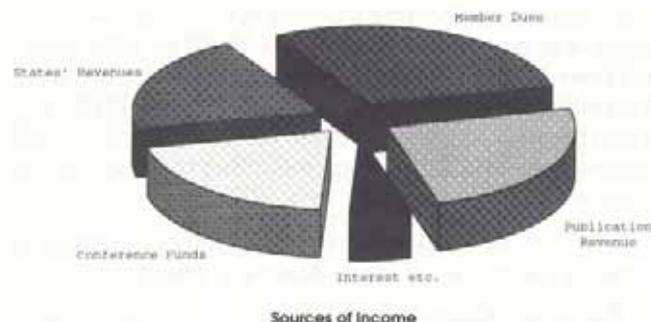


The overall income to the Society was just over \$203,000 and exceeded expenditure by \$7,000.

The distribution of income and expenditure by major divisions is illustrated here, with some comments.

Publications income and expenditure includes both Preview and Exploration Geophysics. These are separately isolated by the Accountants in the Financial Statement.

The membership income offsets roughly the losses incurred in publishing Exploration Geophysics and Preview.



The Conference funds are associated with the Perth, 1994 Conference.



The "Running Costs" item includes secretariat expenses and accounting fees.

A significant item in the Publication Expenses area was a significant downturn in subscription revenue received during 1993, which has been turned around during 1994.

The major factors in "grants" is the Executive contribution of \$15,000 to the ASEG Research Foundation.

The net assets of the Society at the end of 1993 totalled \$418,000, of which 20% was in States' accounts.

The Executive Policy has been to build up reserves against a catastrophic loss on a Conference or Publication, but we commenced a plan in 1993 to encourage the use of reserves for development initiatives.

*Lindsay Thomas*  
Honorary Treasurer

## Executive Brief



At the ASEG AGM in April 1995, the new Federal Executive Committee was elected.

The Executive welcomes new members Kathy Hill, Nigel Hungerford and Ciaran Lavin. The Society is fortunate to have Kathy as our new President. Kathy, formerly a lecturer at the Victorian Institute of Earth and Planetary Sciences and currently General Manager Petroleum in the Victorian Government Department of Agriculture, Energy and Minerals will provide an excellent balance between academia, government and industry. Her enthusiasm for her science is well known. The new Executive wishes to thank the services of outgoing members Robert Singh

and Andrew Sutherland and is grateful that John Denham will continue as Editor for Exploration Geophysics.

The new committee is comprised as follows:

<b>President:</b>	Kathy Hill
<b>Past President:</b>	Hugh Rutter
<b>1st Vice President:</b>	Mike Asten
<b>2nd V.P. &amp; Preview Editor:</b>	Geoff Pettifer
<b>Secretary:</b>	Greg Blackburn
<b>Treasurer:</b>	Lindsay Thomas
<b>Committee:</b>	David Gamble
	Nigel Hungerford
	Ciaran Lavin
	Brenton Oke
	Koya Suto

As incoming Secretary I would particularly like to pay tribute to Brenton Oke, my predecessor, for his fine efforts and the standard he has set as ASEG Secretary and I look forward to bringing members news of the ASEG Executive through the Executive Brief column started by Brenton.

Craig Gumley and David Tucker, Joint Co-Chairman for the ASEG 11th Geophysical Conference and Exhibition in Adelaide on 3-6 September 1995 have organised an excellent programme. Members should have received their Registration Brochure which details the six keynote speakers, 194 presentations, 21 poster sessions, four workshops and Trade Exhibition. Their are 142 people involved in formal presentations (the ASEG currently has 1250 members) which represents a tremendous effort on behalf of members. The generous support of principal sponsor Western Atlas and major sponsors SAME, ER Mapper, Digicon, Schlumberger and World Geoscience is gratefully acknowledged. The Executive hopes that all members will support Craig and David by attending the Conference.

While it is still months away to the Adelaide Conference, Tim Pippett and the Executive are busily preparing for the Sydney Conference to be held in association with the SEG during March 1997. Another major project is to finalise the 5 year ASEG business plan. While the Society's accounts are on a yearly basis, a large proportion of the income is derived from the ASEG conferences which are held approximately every 18 months, resulting in widely varying balance sheets from year to year. With costs rising all the time, particularly for producing and distributing Exploration Geophysics and Preview and the Secretarial running costs, it is timely to put a long term business plan in place. David Gamble has done much of the preparation, and the plan, upon finalisation, will be included in a future issue of Preview.

*Greg Blackburn, Secretary*

## Letters to the Editor

March 27 1995

The Editor, Preview

When I have a chance to catch up on my magazines, such as on a flight somewhere, of all the choices including New Scientist, Leading Edge, the one I eagerly choose first is **Preview**. What a great publication it is! And it just gets better every time. Who could not fail to find something of interest in the latest issue (No 52/53)? I will certainly be showing it to the geophysicists I meet in China next week. I know they will gasp at Plates 3 & 4 and I will sign up some new members as a result.



For those of us more familiar with the local scene, it's amusing to see in "Where Are They?" that the Society has lost track of people like Graham Bubner (how fitting some might say!). (You don't need the Bulletin when you run a Bar). Also how disturbing to note that we can have a page of Obituaries. Nevertheless, the Editor must take full credit for the interesting items and engaging layout. I know he needs some support to keep up this excellent standard and contributions, so how about it members?

**Roger Henderson**

Honorary Member

3 May, 1995

The Editor - Preview

I would like to find out whether geophysical contractors throughout Australasia (and the world?) are interested in setting up a page in Preview in which they can say in which regions their crews will be, over the forthcoming month or two.

Not infrequently geophysicists like myself are looking for a crew to do a small job of a few days for which we want to minimise mobilisation. If we know there's a suitable crew in the area (at a suitable price!) we can avoid a lot of unnecessary calling around.

Of course very often crews move around so fast it's impossible to predict where they will be especially over an extended period, but that's not always the case.

And for this to work Preview will have to be published on time, otherwise crews will have moved on. However there's presumably no reason why crew locations couldn't be faxed to Preview immediately before publication.

Could any interested contractors please call me on (03) 9822 1655 or fax me on (03) 9822 1711 and I'll discuss this with the Preview Editor.

Yours sincerely,

**Nigel Hungerford**



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## ASEG Branch News

### South Australia

The first technical presentation for the SA Branch for this year was held in March and featured **Mr Tom Blades** from Geco Prakla. Tom presented an overview of Geco's activities in the Australian region as well as recent innovations in seismic acquisition being developed and/or used by Geco (I am currently looking forward to seeing the seismic energy source which plays Mozart!). Tom's talk was well attended and very well received by those present. We extend our thanks to Tom for speaking to us at short notice and also to Geco for sponsoring the evening.

**Andy Oldham** from Santos has been rescheduled to present his case study of the Lake Hope 3-D seismic survey in April after voluntarily stepping aside to allow Tom's presentation at the last minute.

Preparations are underway for many further technical presentations and social events throughout the year.



*Andy Craddock  
Secretary*

### Western Australia

The new committee is:

**President:**

**David Howard** GSWA Ph: (09) 222 3331 Fax: (09) 222 3633

**Vice President:**

**Andy Padman** Woodside Ph: (09) 224 4308 Fax: (09) 325 8178

**Secretary:**

**Brian Evans** Curtin Uni Ph: (09) 351 7092 Fax: (09) 351 3377

**Treasurer:**

**Andrew Foley** Poseidon Ph: (09) 480 3232 Fax: (09) 480 3270

**Committee:**

**Anita Heath** Consultant Ph: (09) 367 3827 Fax: (09) 367 3827

**Keith Mayes** North Ltd Ph: (09) 277 8033 Fax: (09) 277 3844

**Shane Wright** Rust PPK Ph: (09) 389 9668 Fax: (09) 389 8447

**Dave Abbott** Tesla-10 Ph: (09) 364 8444 Fax: (09) 364 6575

**Paul Jelley** WAPET Ph: (09) 263 6566 Fax: (09) 263 6699

**Jim Frazer** WAPET Ph: (09) 263 6566 Fax: (09) 263 6699

**Bruce Craven** Southern Geo Ph: (09) 316 2804 Fax: (09) 316 1624

The Committee recently decided on a new approach to organising meetings. That is to become a bit more organised, for example:

All future Technical Meetings will be held on the third Wednesday of each month, so please take note of this for future reference.

Furthermore, the incoming Committee has decided to:

1. Provide free drinks and snacks, from 6pm to 6.30pm prior to the start of each technical meeting.
2. Start the technical sessions promptly at 6.30pm.
3. Use fax as the main medium for mail-out of notices in the future.
4. Those not on fax will receive the notices by normal mail.

The first technical meeting under the new Committee was held on Thursday 13th April 1995 at the Celtic Club, 48 Ord St, West Perth.

The half-hour papers presented were:

1. **Paul Jelley** (WAPET) "Land 3-D seismic - Case histories of WAPETs 1994 North Dongara and North Barrow 3-D surveys".
2. **Steve Mudge** (RGC) "Helicopter magnetics in rugged terrains - specifications, processing and logistics" (See Excitations, p14).

This meeting was attended by double the normal number that customarily attend technical meetings. One obvious reason was the advertising of free booze and nibbles for the first half-hour. The other reason given was that maybe faxing notices of technical meetings applied a more business-like emphasis to the meetings. Anyhow, the meeting was very enjoyable and we recommend other branches try faxing.

Of course, it does demand keying in fax numbers (which took us about five hours of total boredom), and many machines won't take more than 150 numbers in memory. Consequently, we have grouped people by company fax number, which also reduces the number of phone calls. The upshot is that a fax costs 20c per call rather than a mail out costing at least 45c per letter, and hence faxing is cheaper (we still do mail outs to 70 people who claim not to have a fax number). However, the fax is very quick and faxing notices out can be done overnight.

We did consider email, but we think it is too early for such technology. When we fax out notices now, we include a notice for their company notice board.

The second technical meeting is to be held on Wednesday, 17th May, at the Celtic Club.

The Papers to be presented are:

1. **Brian Evans** (Curtin) "A comparison of physical model with field data over Oliver Field, Vulcan Graben". This is a re-run of the APEA paper which received a 'highest commendation' (otherwise known as second prize).
2. **Hugh Jones** (DME) "Mineral exploration - the Department's guide lines".

We have also lined up Richard Smith for the 21st June meeting, who will talk on "airborne EM in a conductive environment". We are looking for a petroleum paper for that evening.

*Brian Evans  
Secretary*



## New South Wales

At the Branch AGM in February, the executive from last year was re-elected, (despite running on their past records!). The office bearers are: **Derecke Palmer**, president, **Greg Skilbeck**, treasurer, and **Mark Russell**, secretary. A pleasing development was the acceptance of positions on the committee by **Ned Stolz** of Macquarie University, and **Scott Reid** of Geoterrex.



The AGM was followed by a very entertaining talk by **Andy Green**, Director of the CRC for Australian Mineral Exploration Technologies. The talk entitled "Minerals, Mabo, mapping and modelling - where does geophysics fit in?" covered a wide range of issues including image processing and remote sensing.

It was a rather timely presentation, as Andy along with **Ken McCracken** and **Jon Huntington** of CSIRO and Emeritus Professor **Richard Moore** of Kansas University, had just been awarded the 1995 Australia Prize for their pioneering work on remote sensing, in a ceremony at the Powerhouse Museum, by Senator Peter Cook, Federal Minister for Science. The Australia Prize, which is the nation's equivalent of the Nobel Prize, is worth \$300,000 to the recipients. Congratulations from the ASEG (See page 29).

February boasted a second talk by **Niels Christensen** from Aarhus University in Denmark on "Integrated use of electromagnetic methods for hydrogeological investigations" Niels was in Australia on study leave at Macquarie University. The electrical methods received further coverage with **Ron Barker** from the University of Birmingham (also in Australia on study leave, this time with Ian Acworth of UNSW) with the talk "Electrical imaging and its application in groundwater resources and contamination studies" Ron's talk featured an impressive inversion software package which is described further in "Clean and Green" (p42).

It was clear that the petroleum geophysicists were probably feeling a little neglected with the minerals bias in the talks up to that date. Accordingly, we were fortunate to be able to include the talk "Techniques for improved seismic imaging" by **Peter Whiting** of Digital Exploration Limited, Brisbane for our March meeting.

*Derecke Palmer  
President*

## Preview Deadlines

Issue	Deadline
June 1995	May 31, 1995
August 1995	June 23, 1995
October 1995	September 29, 1995
December 1995	November 24, 1995

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## ASEG 11th Geophysical Conference & Exhibition News



### Final Announcement!

A stimulating and informative technical program has been developed around the theme,

*Increasing the Resource, Reducing the Risk.*

Topics will include:

- Petroleum exploration and development
- Mineral exploration and development
- Gold geophysics
- Environmental geophysics
- Mine applications/tomography
- Geophysical Case histories
- Special South Australia/Northern Territory session on hydrocarbon exploration
- Cross-disciplinary geophysical applications
- Regional geophysics

Confirmed Keynote speakers include:

- **Ross Adler** is the Managing of Santos Ltd, Australia's leading independent oil and gas company, with extensive exploration and production interests in Australia, Asia, the USA and the UK. Ross is also a Director of the Commonwealth Bank of Australia and of QCT Resources Ltd. He is Chairman of the Art Gallery of South Australia, Deputy Chairman of the Australian Formula One Grand Prix Board and a member of the board of the MFP Development Corporation and the MFP International Advisory Board.
- **Craig Beasley** joined Western Geophysical in Houston in 1981 after receiving his doctorate in mathematics. He served in several capacities in both the computer sciences and geophysical research and development departments. He is currently General Manager of research and development.
- **John Main** is the Group Geologist for CRA Exploration. John commenced his career in New Zealand as a geologist in a small silver mine. Following this he worked in South Africa for four years as an exploration geologist. John moved to Australia in 1979 and worked for the Peko Group in Tennant Creek prior to joining CRA Exploration at Broken Hill in 1980.
- **James Robertson** received a BSE in civil and geological engineering from Princeton University in 1970 and a PhD in geophysics from the University of Wisconsin in 1975. He joined ARCO in 1975 and has

held technical and management positions in both ARCO's US and international E&P divisions. He is currently Exploration Vice President for Asia and Latin America. James has been active in the Society of Exploration Geophysicists for more than 20 years. He received SEG's Best Paper in Geophysics Award in 1985, served as SEG Distinguished Lecturer in 1988 and was technical program chairman of the 1989 SEG Annual Meeting in Dallas. He is the 1994-95 President of the Society of Exploration Geophysicists.

- **Robbert Willink** is responsible for directing the exploration efforts of Sagasco Resources, a wholly owned subsidiary of Boral Limited. Robbert is a petroleum geologist with 16 years experience in exploration, mainly with the Shell Group in Australia, the Middle East and Turkey. Prior to joining Sagasco he was senior lecturer in petroleum geology at the National Centre of Petroleum Geology and Geophysics in Adelaide.
- **Michael Zhdanov** is presently Professor of Geophysics in the Department of Geology and Geophysics at the University of Utah. From 1978 until 1990 he was head of the Department of Deep Electromagnetic Study, Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation, USSR Academy of Sciences. He was then appointed head of the Troitsk Branch, Institute of the Physics of the Earth, Russian Academy of Sciences, where he stayed until 1992. For the following year, Professor Zhdanov was visiting professor at the Colorado School of Mines. He is a full member of the Russian Academy of Natural Sciences; Honorary Gauss Professor, Göttingen Academy of Sciences, Germany; and a member of the Society of Exploration Geophysicists, USA and of the American Geophysical Union.

### Workshops

A number of workshops will be held prior to the conference.

#### A. Integrated image interpretation for mineral exploration

Presenters: **Colin Nash & Helen Anderson**, World Geoscience Corporation Limited, Perth

Saturday 2 - Sunday 3 September 1995

0900-1700 hours daily

Fee: AUD\$750

Minimum number of participants: 15

This workshop is based on the integrated interpretation of satellite, airphoto, aeromagnetic and radiometric data and is intended for mineral explorers in Australia and South East Asia. Existing geological maps in Australia do not adequately depict structural

information and in many South East Asian countries geological maps are of poor quality or are non-existent. This practical course will be based on lectures, case studies and practical exercises to allow participants to interpret and integrate remotely sensed and airborne geophysical data as an aid to geological mapping and structural interpretation.

## **B. Databases in petroleum exploration and development. A practical introduction.**

Presenter: **Wence Sulda**, Petrosys Pty Ltd, Adelaide

Saturday 2 September - Sunday 3 September 1995

0900-1700 hours each day

Fee: AUD\$735

Minimum number of participants: 10

This workshop presents a practical introduction for those using or wishing to implement database solutions to corporate data management for E&P systems. Database topics include client/server, distributed databases, the role of SQL, data modelling concepts, relational vs object models and projections, the role of GIS, common horror stories. The philosophy and structure of publicly available data models including the Petroleum Public Data Model, Petrotechnical Open Systems Corporation, and those implemented by individual software vendors are presented in detail. A comparative summary between individual data models is presented and discussed. The workshop is especially suited to data managers and seniors E&P technical staff.

## **C. The use of geostatistical methods in reservoir characterisation/production planning.**

Presenters: **Philippe Doyen**, Western Geophysical, United Kingdom; **Steve Tyson**, Santos, Adelaide; **Greg Smith**, BHP Petroleum, Melbourne.

Saturday 2 September - Sunday 3 September 1995

0900-1700 hours each day

Fee: AUD\$780

Minimum number of participants: 25

The workshop will highlight current geostatistical methods used in the oil industry in reservoir characterisation and production planning. Of particular focus will be the use of geostatistical methods constrained by geophysical information. Real life North Sea and Australian examples will be studied. Current commercially available geostatistical software employs techniques which populate a fairly regular grid with data. Some alternative Boolean methods for generation of reservoir heterogeneities will be examined discussing the advantages and disadvantages of these techniques.

## **D. Geological applications of airborne TEM methods.**

Presenters: **Sue Jaggar**, **Peter Wolfram**, **Stephen Kilty**, Geotrex Pty Ltd, Sydney.

Saturday 2 September - Sunday 3 September, 1995

0900-1700 hours each day

Fee: AUD\$620

Minimum number of participants: 15

While aeromagnetic maps are well-known as valuable tools in a variety of exploration scenarios, the airborne transient electromagnetic (TEM) techniques have proven their value mainly in the direct detection of mineral deposits. This two-day course is designed to give geologists and geophysicists an overview of the possibilities and limitations of airborne electromagnetics (primarily fixed wing, but with a section of helicopter techniques). The meaning of "good-conductors" is illustrated as well as the technology involved in airborne survey. Guidelines on survey planning, interpretation procedures and ways of presenting results are illustrated with examples from surveys flown over known mineral deposits. Attendees are provided with multichannel GEOTEM data along several flight lines over a base metal deposit. For one exercise the object is to test the response of GEOTEM to the style of mineralisation and to detect any along-strike continuation of the known mineralisation. It was only during the last few years that improvements in technology have opened up such applications as geological mapping, kimberlite exploration and soil salinity mapping. Examples of these applications are included in the course, together with case histories from mineral exploration.

## **Student Day**

A special day for 120 secondary students and teachers will be held in conjunction with the conference on Tuesday 5 September 1995. The session will include presentations on the importance of the resource industry to Australia's economy, an overview of geophysical techniques, and possible career paths in geophysics. The students will be taken on tours of the exhibition hall while the conference delegates are in technical sessions.

## **Trade Exhibition**

The conference trade exhibition undoubtedly will be as successful as in the past, resulting in valuable sales leads, business development opportunities and interaction. Displays will span all sectors of the geophysical industry, from petroleum and minerals through to engineering and the environment. As well, a wide range of textbooks and latest publications will be displayed. Academic institutions and kindred scientific and professional bodies are also encouraged to exhibit.

*For further information about attending or exhibiting at the conference and exhibition, please contact the Conference Secretariat:*

**ASEG 11th Geophysical Conference & Exhibition,**  
PO Box 1280,  
Milton, QLD 4064,  
Australia.

Tel: 07 369 0477;

Fax: 07 369 1512.



## ASEG Research Foundation News

### ASEG Research Foundation Grants - 1995

The following projects have been successful at attracting an ASEG Research Foundation Grant for 1995.

**Fracture Analysis in the Australian Coal Environment using Shear Wave Splitting.**  
B. Sc.App. (Geophysics) Honours  
Supervised by Dr. S Hearn, Department of Earth Sciences, University of Queensland.

The project will; determine whether shear polarisations can be detected using 3-component coal VSP's; compare the performance of single-source and double-source anisotropy estimation algorithms; and examine microseismic events for polarised shear waves.

**Review of alternative AVO Approaches.**  
B. Sc.(Hons.)  
Supervised by Professor J. K. Applegate, National Centre for Petroleum Geology and Geophysics.

The project will; collect and review the AVO literature; use relevant software to run a number of AVO models; and attempt to use simple methods for removing AVO effects on the travel path of each of the seismic waves.

**Geophysical Exploration Using Power Lines.**  
B.Sc.(Hons.)  
Supervised by Associate Professor J. Cull, Department of Earth Sciences, Monash University.

The project will; record data using MT equipment close to power line including galvanic soundings; assess the spectral content to determine noise levels; and if possible isolate galvanic current streaming signals from direct EM induction signals by using analytical models and phase determinations.

**Structure of the Longford Basin, Northern Tasmania.**  
B.Sc.(Hons.)  
Supervised by Dr. M. J. Roach & D. E. Leaman, Geology Department, The University Of Tasmania.

The project will refine the structure of the northern portion of the Longford Basin. It will involve acquisition of new geophysical data and interpretation of this information in conjunction with existing geophysical and geological data.

ASEG Research Foundation will be seeking applications for 1996 grants later this year.



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# Excitations

with

**Stephen Mudge**  
RGC Exploration Pty Ltd.

## Helicopter Magnetic Surveys in Rugged Terrains - Planning, Costing, Logistics and Data Processing.

I have been responsible for a dozen helicopter surveys, many in the rugged terrains of Asia, the Pacific and Tasmania. This issue I thought others may like to learn something about these types of surveys and the sorts of considerations needed to plan a successful survey. The data processing issues involved are a topic in themselves for further research and perhaps another Excitations column.

### Introduction

Helicopter magnetic surveys are becoming more popular as explorers seek to explore terrains that are too rugged for operation of fixed-wing aircraft and as a faster alternative to ground magnetic surveys. The planning, costing, logistics and data processing from these surveys presents different challenges to the geophysicist who is usually familiar with the well established procedures of fixed-wing surveys.

I will only consider here the requirements for surveying in rugged terrains as it is in these situations that all aspects of the survey and data processing vary considerably from fixed-wing operations. But firstly, we must consider why a helicopter should be more appropriate for the survey than a fixed-wing aircraft and what the implications are of operating in rugged terrains.

Two options are available to the explorer in rugged terrains, a survey conducted close to the terrain that attempts to maximise the resolution of magnetic responses of buried sources, or a fixed-wing survey flown at a higher elevation above the terrain. It will produce lower resolution because it is further from the buried magnetic sources. This option is well catered for with the usual procedures for planning and operating fixed-wing surveys. The former higher resolution alternative however involves very different operational logistics, attracts higher costs and presents new data processing challenges that all contribute to change the explorers expectations of the resultant magnetic map. The higher resolution, low-level helicopter option is often taken by mineral explorers in order to meet their need for detailed magnetic lithostratigraphic mapping and ore detection.

It is a quirk of nature that rugged mountainous terrains are usually associated with weather conditions that are not conducive to long periods of safe aircraft



operations. These terrains are often covered by low-level cloud and are subject to variable wind and rain patterns. Surveys under these conditions are usually broken into 'postage stamp' pieces as dictated by the time-varying windows in the weather, favourable for survey flying. It is not uncommon for survey lines to be broken during flight because of deteriorating weather. The periods of acceptable flying conditions can often be less than one hour, so it is not uncommon for these type of surveys to continue for several weeks, even months in very difficult environments in order to complete the job. This piece-meal procedure operating over extended periods calls for different survey specifications and logistical considerations, and produces new data processing issues.

Money in the form of the exploration budget, and time allocated as the operating schedules are the basic components of every exploration program. It is very clear from my experience that there is one underlying, fundamental aim in managing these types of high resolution helicopter magnetic surveys: "to maximise survey resolution within the limits of sensible and practical aircraft operations in an acceptable time frame and to produce a magnetic map having limitations imposed by operational, processing and cost restrictions". With this clearly in mind, I will proceed with an explanation of each aspect of managing these surveys.

### Specifications and Planning

The cost of these helicopter surveys is generally several times higher than equivalent fixed-wing surveys. As I will explain later, costs can easily get out of hand or the survey can go horribly wrong for the both the survey contractor and the client if the client has unrealistic expectations of survey procedures and the nature of the resultant magnetic map. But with an awareness of the problems associated with low-level helicopter surveys in these environments both parties can embark upon an effective survey that will meet the explorers requirements.

It is absolutely essential that the geophysicist designing the survey visit the survey area at the planning stage to examine the terrain, in particular the location and height of mountain peaks, and become familiar with the daily, weekly and monthly weather patterns for the proposed survey date. In addition the location of major land marks and cultural features such as radio towers, power lines and community centres is also essential, remember we are intending to fly low-level.

The location and facilities offered by a suitable operations base is obviously important: long ferry times to the survey area from a distant operations base can significantly increase survey costs, particularly during inclement weather. I've experienced situations where the aircraft has been "locked in" to the operation base by low cloud whilst the not so distant survey area was basking in calm, clear sun-light conditions. All along costly standby charges for crew and aircraft were quickly mounting up. The operational advantages and cost savings of multiple operational bases can be so significant that the selection of alternative bases is an essential item in planning these surveys.

In the event that your survey requires the deployment of ground based navigation beacons and radio repeaters, for real-time communication of navigation information to the aircraft, then some words of warning are necessary. These devices usually need to be located on high mountain peaks to ensure radio coverage across all, or at least a large part, of the survey area. It is often the case that they will need to be relocated during the course of the survey to gain coverage in other parts of the area which may be over the radio horizon for the initial primary beacon site or shadowed by intervening high terrain. A major problem will arise if these helicopter accessible beacon sites become clouded-in thus preventing their retrieval. This can cause a major disruption to the progress of the survey. Try to locate beacons on lower hills that are more accessible by aircraft, road vehicle or even walking.

There are currently two methods of equipping a helicopter for an aeromagnetic survey. They are the older and well established towed bird configuration and the recently developed stinger mounted systems.

The towed bird system (Figure 1) has the magnetometer sensor mounted in a aerodynamically smooth bomb shaped "bird" and towed about 30 metres below the aircraft. This configuration followed directly from the now redundant towed bird fixed-wing systems that places the magnetic sensor well away from the aircraft's own magnetic anomaly and sources of magnetic noise in the aircraft. The smooth and stable flight of the bird depends upon the constant forward velocity of the aircraft. The speed of a helicopter in low-level survey flight over rugged terrain is often variable. The bird experiences extreme changes in flight characteristics: it often undergoes swinging motion and this produces significant noise in the data, particularly in strong magnetic gradients. The actual position and height of the bird is unknown, but I hasten to add that in recent times contractors have installed GPS navigation systems in the birds to continually record bird position. Also, pilots flying with the under-slung towed-bird tend to fly the survey at slightly higher elevations, a consequence of not being able to visually monitor the bird's flight to avoid losing it in trees on the rising terrain.

Helicopter stinger systems (Figure 2), like their fixed-wing counter parts, have the sensor mounted in a rigid plastic boom protruding from the front of the aircraft where the pilot has continual visual contact with it. Pilots favour this configuration as they can fly the



Figure 1. A towed-bird helicopter magnetic system.

survey closer to the terrain and can more confidently determine when to take evasive action to avoid cultural features and rising terrain. A more uniform survey height and line position is obtained with the stinger mounted systems. Correction for the aircraft's own magnetic anomaly is automatically made in-real time with the inclusion of a magnetic compensation unit mounted next to the magnetometer sensor. Magnetic noise is known to be a problem with some types of helicopter. The location and elevation of the magnetic measurements is recorded by a GPS unit mounted close to the sensor.

The stinger mounted systems also have the advantage of being able to execute faster turns at the ends of lines and more immediate correction to navigation errors. The resultant flight path appears to be more uniform than for towed bird systems.

The selection and availability of an aircraft capable of climbing over the terrain at the often high altitude (lower barometric pressure) of the survey area is obviously an essential consideration that is best left to the survey contractor who is familiar with these matters. Aircraft power and survey altitudes are important and dependent parameters. The need to have sufficient reserves of power to avoid and get out of dangerous situations at high altitudes in the small time frames imposed by survey specifications is obvious.

The quality of the data acquisition phase is governed chiefly by the ability of the pilot(s) to fly the survey to the geophysical specifications. Pilot training will be an essential component to presurvey preparation if an experienced geophysical pilot is unavailable. Continuous low-level geophysical line flying is probably the most demanding call on a pilot's flying skills.

Survey lines need to be spaced to suit the size and strike extent of the geological target being sought with due consideration for the survey height. Increasing survey height will attenuate the higher frequency components of the observed signal thus placing less

stringent demands for closer line spacing. However I strongly recommend that specifications lean towards a closer line spacing than you consider necessary for target definition. Rarely does an explorer get the opportunity to resurvey these rugged terrains at a later time with the hindsight of results of an early and possibly less optimum survey: the high cost of these surveys precludes this luxury. Plan your survey as a "one off" job and aim to acquire as much data as you can to maximise the value of your survey dollar.

The usual fundamental rules for magnetic survey line direction apply. In areas of high magnetic inclination, greater than about 30 degrees, lines should be oriented perpendicular to the overall geological strike. In low latitude areas where the magnetic field is inclined by less than about 30 degrees, and extending to the magnetic equator where the inclination is zero, survey lines should always be oriented north-south, irrespective of geological strike. This seemingly bizarre situation at low latitudes can be appreciated by examining any low latitude magnetic map or magnetic model anomaly which will clearly show the high and low of the dipole anomaly displaced to the north and south of the magnetic source. There is generally no obvious relationship between the shape of the magnetic source and the magnetic anomaly in low latitudes; detailed mathematical analysis (modelling) of the anomaly is needed to accurately resolve the source geometry. Only north-south (meridian) survey lines can be expected to pass through both the high and low of the anomaly to provide the critical dipole information needed for interpreting the line profiles. The meridian profile information is also critical for gridding, contouring and imaging the survey data to accurately reveal important detail of the anomaly. This is fundamental magnetic anomaly mapping criteria applicable to all magnetic surveys conducted above the ground.

Procedures have been adopted from time to time that position survey lines at constant elevation around the terrain (contour flying) to minimise magnetic levelling errors. These errors show up when the data is gridded to make contour maps and images of the data. They always occur with parallel survey lines crossing over the terrain at different terrain clearances. I recommend that contour flying not be adopted. The fundamental aim of the survey is to acquire data that can be interpreted to resolve the sub-surface geology as accurately as possible. I can think of nothing worse than trying to model contour flight lines that probably don't cross the ground in a direction optimum for target definition. Furthermore, how can you easily display and interpret stacked profiles from contour flights at different elevations above the target?

The height of the survey above the ground ought to be as low as an experienced pilot, in a sufficiently powerful aircraft, is capable of maintaining safe operations. The survey contractor will strongly influence the specified mean terrain clearance, but the usual and mandatory contractual requirement "the pilot's decision regarding the actual survey height, commensurate with aircraft safety, will be conclusive and binding.....etc, etc" sets the lower limit on this survey parameter.



Figure 2. A stinger mounted helicopter magnetic system, note the GPS antennae

In the interest of maximising the opportunities for data acquisition it is sensible (and cheap insurance) to specify two base-station magnetometers in the event that one should fail. I don't have to elaborate on the thought of an eager crew and an operational aircraft grounded during perfect flying conditions because of a malfunctioning base station magnetometer, then to have the weather turn foul the following day when the base-station fault has been rectified.

### Costs

Having examined the survey area, specified line spacing, line direction, and determined the type of aircraft for the job, the extent of the survey can be determined and the total survey cost estimated. It is foolish to compromise the resolution of the survey by increasing line spacing and survey heights in order to survey a larger area with a small budget. The resultant lower resolution obtained could hardly justify the high cost of using a helicopter, with all its attendant operational and logistical complexities. Anyway, if maximum survey resolution is not paramount to your helicopter survey, and remember getting in low amongst the hills to get the high resolution is the reason we choose to use a helicopter, then a higher level, lower resolution fixed-wing survey would probably better service your needs for much lower cost.

The costing of helicopter surveys in rugged terrains will consider the needs of both parties to the survey contract. A considerable amount of the on-site survey time will be spent waiting for favourable weather conditions. Clearly this will attract a charge related to time the crew and the aircraft are available on site even though no data was acquired during these non-production periods. Standby charges will reflect the contractor's complete cost recovery and an amount which reflects the on-site availability of survey equipment that is being deprived of earning its keep elsewhere in more profitable environments.

Production days are days when data is acquired on survey. Unlike fixed-wing surveys where acquisition is costed on a line kilometre basis, helicopter surveys will attract a line kilometre charge and a time component charge for the time the contractor has spent in acquiring the data. It is quite common for survey crews to spend several hours in a day hunting around the survey area

for a cloud free area to acquire a small quantity of data. In addition to aircraft charges, the survey contractor will charge for the time that their (good) efforts took to get your data. It's all part of the cost of chiselling away at the job in the adverse conditions that nature throws at the explorer.

The relatively low daily data acquisition rates which typify helicopter surveys (several hundreds of line kilometres per day) contrasts strongly with the much higher acquisition rates of fixed-wing operations (up to two thousand line kilometres per day). Survey costing procedures generally make provision for uncertain but variable data acquisition rates and survey times. This is often accommodated by specifying a minimum daily number of line kilometres for acquisition rates to apply and below this amount a time charge is applicable. A simple costing formula has been adopted by the survey industry to calculate the actual cost, based on the duration and total number of kilometres of data acquired for the survey. Standby and data processing charges are additional to this. Allow a realistic number of standby days for your survey. I calculate this by estimating the number of acquisition days for the job in fine weather conditions and then add 50% for standby. The average daily data acquisition rate, needed for estimating the duration of the survey, can be supplied by the contractor. This maybe as low as 100 line kilometres per hour of useable data for two hours of flying. It is a figure that comes from the contractors experience from operating in your survey environment and will change from area to area and depend upon the weather conditions for that time of the year.

But remember, the survey contractor will charge an amount that ensures he can make some profit from the job under the worst conditions, even if the survey is curtailed due to continuing inclement weather or that costs have accumulated to consume the clients budget for the job.

The main consideration in formulating a budget for these surveys is to be fully aware of the cost of each component of the survey and how they accumulate throughout the course of the job. Moreover realise that the cost analysis must account for the worst-case event of bad weather etc. This will give a good indication of the amount of funds that need to be available to do the job and represents an upper limit, hopefully the job won't consume the full amount. In the event that the budget is fully spent before the job is completed, you will then have to face a decision: pull-out now or budget further funds to complete the job as originally intended. Just don't neglect the progress of the survey and the accumulating charges, or things could go horribly wrong for you, the contractor and your accountant.

## Aircraft Operations

It is often the case that a separate contract will be established for the hire of the helicopter as most geophysical contractors do not own helicopters dedicated to geophysical operations. This will attract a daily charge for availability of the aircraft and pilot, and an hourly operation charge. Be aware that aircraft charges apply even for days when flying is carried out but no data can be acquired. It lies with the survey crew

to use the aircraft sensibly, to control costs and to make every effort to get the job done in a timely manner.

Aircraft unavailability will also attract a charge from the survey contractor. A second pilot can continue during rest periods of the first pilot and is worth considering for jobs that are expected to extend for more than several weeks. It is essential that an aircraft engineer be available at the survey base, or available nearby in order to keep the aircraft airworthy. This should be clearly stated in the aircraft contract and all routine aircraft servicing should be carried out at night or during standby days in order to maximise the opportunities afforded by favourable weather conditions. This is the fundamental operational criteria in operating helicopter surveys in rugged terrains

## Survey Logistics

Efforts to maximise the opportunities afforded by the weather to acquire data controls the logistics, quality and final cost of the survey. It is essential to give priority to acquiring new data at every opportunity the weather offers for survey operations to continue.

Reflights should be given less consideration until all opportunities for acquiring new data have been exhausted. To this extent every effort should be made to make use of all data collected and only conduct reflights if absolutely needed. The on-site evaluation of the data by the client is essential here. Remember that unlike fixed-wing surveys the client pays for all reflights, including aircraft charges, so think twice and decide whether the reflights are essential and worth the extra cost of getting them. Also consider the availability of favourable weather to actually get the reflight data. You might encounter standby charges whilst waiting to get a few kilometres of data - they could turn out to be a very expensive few kilometres of data for little improvement in the final product. It could be cheaper and perfectly acceptable to process noisy data to a clean state than conduct costly reflights.

There is one other vitally essential logistical consideration when conducting these types of helicopter surveys. It is prudent to acquire the tie line data first, this will give the survey crew an opportunity to look the area over, but more importantly, to get the tie line data in hand. This is essential in the event that the survey is curtailed before completion so the acquired data can be processed. Leaving the survey area without the tie line data can severely restrict the efforts of the data processing department to process the data and make a magnetic map

The piece-meal approach of acquiring the data is forced upon the crew in their efforts get the most out of breaks in the weather. This necessitates the insertion of extra tie lines in addition to those originally specified. These ties are essential for levelling the separate blocks of survey lines. More ties are probably better than too few and their length should be carefully planned to cross an appropriate number of survey lines so that they are effective in levelling the survey blocks.

It is essential that the explorer (the client to the job) has his representative on site for the duration of the survey. Survey progress and costs need to be

continually monitored and decisions regarding daily logistics and survey flying can be made in consultation with the contractor. Furthermore reflight requirements can be evaluated and areas difficult or impossible to survey can be identified and survey specifications changed accordingly.

## Data Processing and Interpretation

The data processing department inherits all the problems encountered during the survey and all the effects of the actual survey procedure. A characteristic feature of helicopter data acquired in rugged terrains is the constant variability of the terrain clearance, which is generally extreme compared to fixed-wing operations. A helicopter will generally have different terrain clearances when climbing a steep slope and when descending the same slope on the adjacent flight line. It is impossible to attain constant terrain clearance on reciprocal headings over steep terrain, it has to do with the way a helicopter flies.

The errors in elevations of tie line cross-overs will often be large, thus introducing errors into the data levelling process. It is often difficult to accurately adjust the magnetic levels of the flight line data using conventional levelling procedures because the cross-over errors are much greater and more variable than fixed-wing data. Grid based micro-levelling procedures can produce levelled grids from which contour maps and images can be prepared. However the corrections applied with these techniques often removes geological detail from the grid. Furthermore some data processing groups apply the grid corrections back to the line data. Both procedures significantly reduce the detail that was fervently obtained in the expensive acquisition phase. If you are prepared to destroy the detail measured in the acquisition phase then I suggest you reconsider what you are trying to achieve from your expensive high resolution helicopter survey.

The interpreter of helicopter magnetic data needs to fully understand that the line data will not be perfectly levelled but, along with the radio altimeter and GPS data recorded during the survey to monitor terrain clearance, it can be used to accurately model and interpret the data whilst preserving the high resolution detail. On the other hand, levelled (smoothed) gridded data can be used to provide a lower resolution 2 dimensional display of the data and provide a basis for overall 3 dimensional modelling and interpretation. It is not uncommon for gridded data to show levelling errors despite all attempts to level the line data and preserve detail. One just learns to live with this situation until improved levelling techniques have been developed to accurately adjust the level of line data and preserve detail without first resorting to gridding (with its own inherent inaccuracies).

It is important for the interpreter to realise that the resultant maps and images of the survey data falsely depict the data on a flat surface. In reality the maps and images display the data from a undulating survey surface and in essence the maps and images ought to be warped over the terrain to correctly represent the

observed magnetic field. This raises important considerations in the analysis and modelling of the data.

Methods for resolving detail from line data without the levelling errors distorting the detail have been presented by the author, see Mudge (1991). As mentioned earlier, interpretation and modelling of the data must also correct for the attitude of the survey surface: the data is actually acquired on sloping survey planes and not a flat horizontal surface. This has ramifications in determining an appropriate value of magnetic inclination for analysis of the data. A magnetic profile at the equator measured on a sloping side of a mountain will produce a non-equatorial anomaly from the buried magnetic body, see Mudge (1988) for procedures to correct for this situation.

The levelling of helicopter aeromagnetic data from rugged terrains is a subject that requires further investigation. In this regard the work of Grauch and Campbell (1984), and the references cited in that paper, ought to be seriously considered.

The interpreter needs to be accustomed to analysing line data having variable height above the magnetic sources. Furthermore the interpreter also needs to be aware that often magnetic sources are present adjacent to and above the magnetometer in rugged terrains. The benefits of a 3 component magnetometer, like those used for drillhole magnetics, are probably worth considering to help resolve the 3D interpretation problems presented by these types of surveys.

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(Note: The author presented this paper to a meeting of the Western Australian Branch of the ASEG in Perth WA on Thursday, 13th April 1995).

Happy Excitations.

## Contributions:

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# FLAIRTEM - A Deep Exploration Airborne Electromagnetic Method

Peter Elliott  
Elliott Geophysics Pty. Ltd.,

## Introduction

Airborne electromagnetic methods have been applied extensively over the last four decades to exploration for base metals, precious metals, salinity studies, and general geological mapping. They are becoming more favoured as a rapid reconnaissance search method which can be used to cover large tracts of land, particularly in areas of soil cover. Moving source AEM systems have improved much over the last decade such that lower frequencies, and more precise measurements can be made thereby increasing their effective depth of investigation. However, further improvements are likely to be gradual, depending greatly on new innovations in data collection and processing. The existing systems still have a limited search depth, particularly in arid and mountainous terrains. In the arid outback areas of Australia where the surface cover is generally conductive (e.g. overburden conductance of greater than 4Siemens) the maximum search depth will often be less than 50m. Similarly, in mountainous terrain where ground clearance is often greater due to vegetation or narrow valleys the effective search depth of moving source AEM systems is restricted.

FLAIRTEM (Fixed Loop Airborne Transient ElectroMagnetics) (Figures 1&2), is a new patented

**innovate** (in'-o-vāt) *v.t.* [L. (part.) *innovātus*, fr. *in*, and *novus*, new] to change by introducing something new. **Innovator**, *n.* **Innovation** (in-o-vā'shun) *n.*

*In this occasional series - Innovations we celebrate ingenuity and enterprise in the Australian geophysical industry and the efforts of those who are pushing the frontiers. The first article profiles the FLAIRTEM system, devised by Peter Elliott.*



Peter Elliott graduated with a B.Sc (Hons) in Geology and Geophysics from the University of Melbourne (1976). The last two years of study were completed under a cadetship with the Dept. Of Mines (Victoria). He worked as a geologist and geophysicist with the Dept. of Mines (1977-1980). He then joined the Shell Company (Australia) Ltd. where he worked as a Regional Geophysicist with the Metals

Division (1981-1987). Peter was awarded an M.Sc. from the University of Melbourne in 1983. He left Shell in 1987 to join Search Exploration Services Ltd., as Managing Director. In 1991, he started his own company, Elliott Geophysics Pty Ltd, which currently services the minerals industry in Australia, Papua New Guinea, and South East Asia. He is also completing a Ph.D. through Macquarie University, in conjunction with the CRCAMET. Peter Elliott was President of the W.A. Branch of the ASEG (1982-1983); Secretary and Business Manager of the ASEG Federal Executive (1984-1986); and First Vice-President ASEG Executive (1986-1988). He also chaired a number of subcommittees for the ASEG in the period (1981-1988).

geophysical technique which was designed in Australia for Australian conditions. It was developed over a period of three years with the support of major mining companies, through AMIRA (Australian Minerals

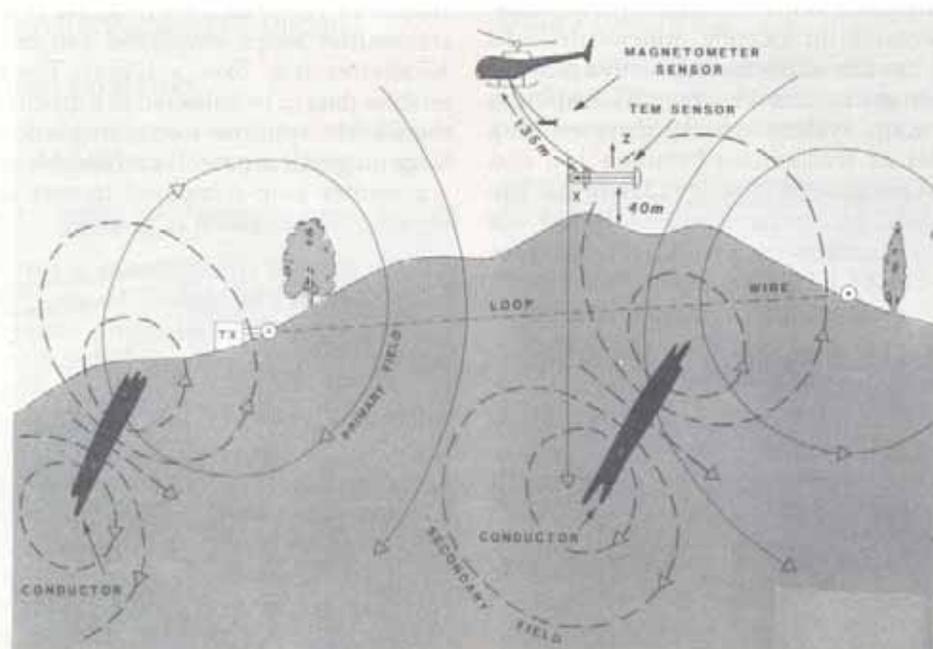


Figure 1. Schematic of the FLAIRTEM system in mountainous terrain.

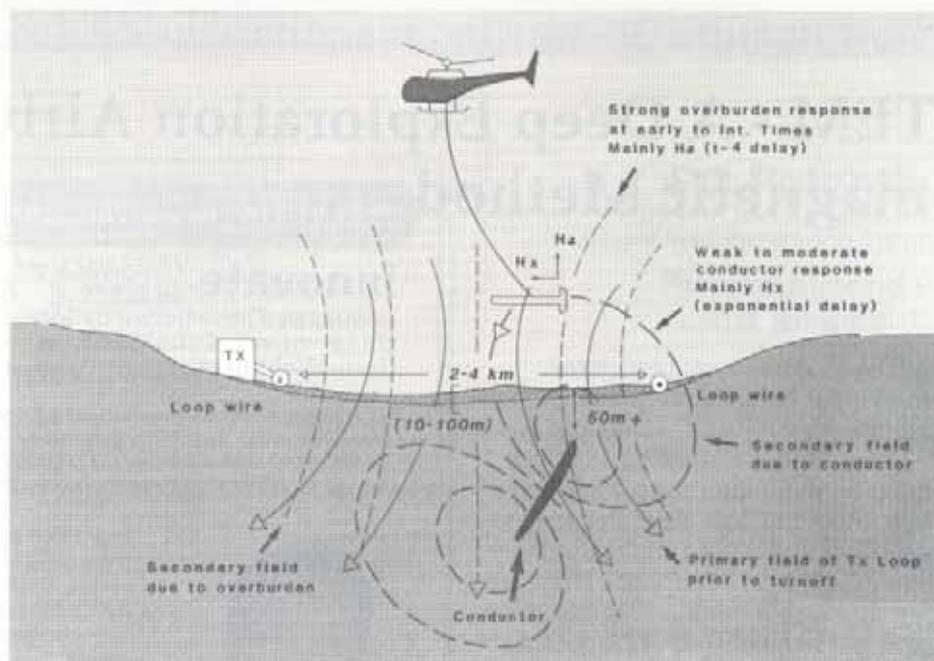


Figure 2. Schematic of the FLAIRTEM system in arid terrain.

Industry Research Association). The method was initially conceived as a way of "seeing" through conductive overburden in the arid parts of Australia, and as a means of investigating to much greater depths than currently achievable by moving source AEM (Airborne ElectroMagnetic) systems. Since its inception it has also found use in the rugged parts of South-East Asia and the South Pacific where it suffers much less than other AEM methods from problems associated with excessive ground clearance.

## Comparison with TURAIR

FLAIRTEM is a significant advance on the TURAIR method, used by Scintrex Pty. Ltd. in the 1970's (Bosschart and Seigel, 1972). Both systems employ a ground based transmitter loop and an airborne receiver. TURAIR was successful in locating mineral deposits which would not have been discovered with a moving source AEM system at that time. However, TURAIR was a frequency domain system which operated at a restricted number of frequencies between 100 and 800Hz. It also measured the gradient of the electromagnetic field. In comparison, FLAIRTEM is a broad band time domain system which operates between frequencies of 1 Hz and 32 Hz. It currently measures the absolute transient electromagnetic field.

FLAIRTEM therefore has potentially a much greater depth of penetration than TURAIR. It has a much greater band width than TURAIR, and it will potentially return much more information about the various conductive zones detected. Another improvement FLAIRTEM has over the earlier frequency domain system is that it is more environmentally sensitive. Transmitter cables not only can be dispensed from an airborne platform but can also be collected in a similar manner.

In addition many of the positive attributes expounded by Bosschart and Seigel (1972) for TURAIR,

are also true for FLAIRTEM. The main attribute is the ability to investigate to much greater depths than moving source AEM systems. This has become increasingly important in recent years, especially in Australia, because near surface zones of mineralisation are becoming increasingly scarce. There is pressure on all exploration techniques to investigate to greater depths. FLAIRTEM provides a way of doing this on a rapid reconnaissance basis.

## The FLAIRTEM Method

### System Configuration

FLAIRTEM uses a high powered ground based transmitter (up to 25kw) with a basic time domain pulse frequency range of 1 Hz to 32 Hz (Figures 3 & 4). The transmitter loops employed can be in the order of kilometres (e.g. 6km x 12km). The frequency range enables data to be collected at a much larger bandwidth than other airborne electromagnetic systems. A very large magnetic moment is achievable using a large fixed transmitter loop compared to that achieved using a moving loop airborne system.

The receiver configuration is currently a 3 channel arrangement. The  $H_z$  and  $H_x$  components (Figures 1 and 2) are measured using independent sensors attached to channels 1 and 2. The third channel is used to record radar altimeter data. Up to 16 channels can be fitted to the receiver. It is therefore easy to fit a third sensor for measuring the  $H_y$  component, plus attach other instruments that have a voltage output. The effective sensor areas are 10000 sq.m. or the equivalent of a 100m x 100m loop. Data is collected using a specially designed digital receiver (Figure 5), and data is stored on computer hard disk. Each independent transmitter cycle response can be stored, giving a minimum achievable sample interval in the order of 1 to 2 metres on the ground depending on flight speed and base



Figure 3. GGT-10 (10kw) Transmitter, Indonesia.

transmitter frequency. This allows for a large redundancy of data for various filtering techniques.

The currently favoured airborne platform is a helicopter with a towed bird (torpedo shaped container for the electronic sensors) (Figures 6, 7 & 8). However, other platforms, such as light aircraft, can be easily adapted. The preferred method of navigation is by RTDGPS (Real Time Differential Global Positioning System). A pair of interchangeable GPS units with radio link are currently being used. The acquired TEM and radar altimeter data are married to the RTDGPS data to provide a located data set.

The use of large (e.g. 10km x 5km) ground based transmitter loops, which can be laid and collected from the air (Figure 9), enables the effective penetration of the source field to be in the order of kilometres. As compared to less than 100 metres. The source field is relatively uniform over a large area thus allowing many kilometres to be surveyed off each loop. Large conductive mineral deposits can be detected at depths of 100's of metres due to their responses being enhanced relative to small conductors. To complement the extra large transmitter loops, very low transmitter frequencies are used for excitation, in the range 1 Hz to 32 Hz. This also favours the better conductors.

### Data Acquisition Logistics

Loop laying and collection is currently run at 10km/hr, for both rugged and flat terrain. In the case of



Figure 5. GDP-32 Airborne receiver and signal cables. Pre-survey checks, PNG.



Figure 4. High powered (25kw) transmitter/generator, Woodchester, SA.

rugged terrain it is done by helicopter, and in the case of flat terrain it can be done by helicopter or vehicle. In either case it is done at the same speed for safety reasons. Cable has been laid out from a helicopter at up to 80km/hr but the increased vibrations transmitted up the tow line suggest that this is not a good practice. Likewise by vehicle cable has been laid out at over 20km/hr but because it is supervised by an operator it is not advisable, in case of cables breaking and whipping back. The current motorised winchs are designed to wind in at an average speed of 10km/hr. They are also designed to handle about 5km of cable per run.

In heavily vegetated areas, in rugged terrains, there is some preparation required before laying cable which consists of making helicopter landing pads every 4.5 to 5km, where loop sections are joined. Example: to lay 5km x 2km loop will take approximately 1.5 hours. To collect may take 2 to 2.5 hrs, allowing for snags. To lay a 10km x 5km loop will take about 3 hrs. To collect will take about 4 to 5 hrs, allowing for snags, breaks etc. To fly 400 line-km over a loop will take about 5 to 6 hrs allowing for turning around at the end of each line. Normal flying speed is currently about 80km/hr.

### Data Processing

The located data set is filtered using tailored filtering methods. The processed data is then presented as profiles, contours, perspective plots, parametric plots,



Figure 6. Receiver bird and helicopter system, Woodchester, SA.



Figure 7. FLAIRTEM survey in progress in rugged terrain, PNG Highlands. The bird is some 60m below the helicopter and has a true top clearance of about 30m.

or any other form of presentation requested. Because the data is in digital form many different parameters can be calculated automatically from the located data set. These include decay constants, gradients, cross correlation parameters, and band ratios.

### Interpretation

An attribute of FLAIRTEM is that the same interpretation techniques that are used for fixed loop TEM data can also be applied to FLAIRTEM data. This enables a large range of modelling software to be used for pre modelling of surveys as well as the modelling of anomalies derived from surveys.

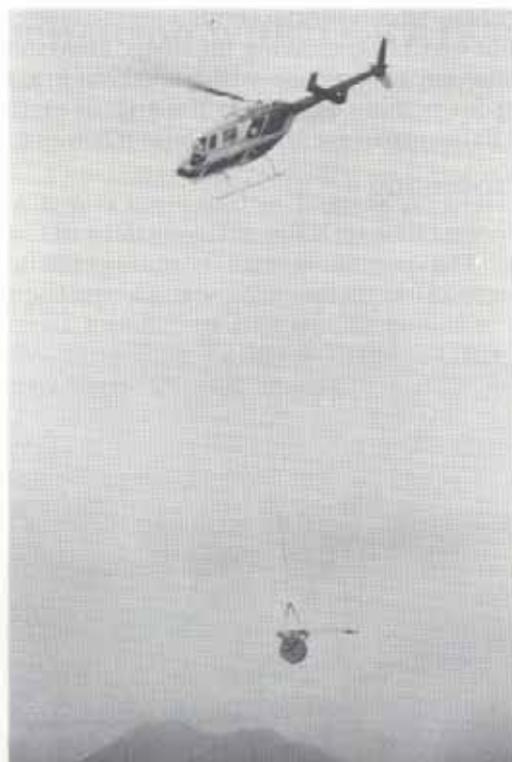


Figure 9. Prototype cable laying drum being used to layout transmitter loop cable, PNG. Laying rate is 15 to 20 km/hr.



Figure 8. Close up helicopter and bird in flight, PNG. The bird heads into the helicopter flight direction.

## Conclusions

FLAIRTEM so far has delivered everything that it has promised. Logistically it is a versatile method which allows immediate ground follow-up of anomalies detected from the air, using the same equipment. This allows for drilling programs to be run concurrently with survey programs. Data turn around is fast and the most modern processing and interpretation methods for TEM are directly applicable. It has proved itself a viable alternative to moving loop AEM methods and promises to be a much more successful approach for deep exploration targets. It has already located conductors which were not picked up by other AEM surveys.

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## Acknowledgements

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# 1995 Australia Prize For Scientists Who Showed Earth In New Light



Three scientists who used satellite images to revolutionise the search for minerals in Australia's deeply weathered landscapes, and an engineer whose inventions have provided unprecedented views of the Earth's surface and brought new precision to weather forecasting, are the joint winners of the 1995 Australia Prize.

The Minister for Science, Senator Cook, announced recently that Dr Ken McCracken, founding chief of the CSIRO's Division of Mineral Physics, and his colleagues, Dr Andrew Green and Dr Jonathan Huntington, of the Division of Exploration and Mining, will share the \$300,000 award with Dr Richard Moore, Emeritus Professor of Electrical and Computer Engineering at the University of Kansas.

The \$300,000 Australia Prize is an international award for researchers who have made outstanding contributions to science and technology promoting human welfare. The research category changes each year - this year's prize honors achievement in the field of remote sensing. Senator Cook said Dr McCracken, Dr Green and Dr Huntington had come from very different research backgrounds to form an outstandingly successful research team that had pioneered satellite-based remote sensing in Australia. Dr McCracken, an astronomer, Dr Green, a physical chemist, and Dr Huntington a geologist specialising in air-photo interpretation, had brought complementary skills to a new field of research and, in the face of initial scepticism, had persuaded Australian mineral companies that remote sensing could be a powerful new tool for mineral exploration.

Dr Green's skills in physics and computer image processing, and Dr Huntington's complementary expertise in interpreting geological information, allowed the group to develop innovative techniques for processing LANDSAT images.

From infrared and visible light images, they were able to extract the faint signatures of ore bodies obscured by vegetation and all but erased by millions of years of deep crustal weathering. These concepts were now routinely used by mineral exploration companies to enhance many other forms of spatial information.

Senator Cook said that while the CSIRO group had focused on mineral exploration, its work had provided the springboard for Australia to extend its use of satellite imagery into tasks as diverse as monitoring the development and health of crops, mapping ecosystems and monitoring overgrazing, erosion, flooding and fire damage.

In the 1980s the CSIRO team had ushered in a new era of high-resolution remote sensing by demonstrating the exploration value of images from sensors flown in conventional aircraft, satellite and aircraft remote sensing being mutually complementary.

Today, development of new sensing instruments for mapping surface mineral composition from the air, at a level of detail impossible with existing satellites, was still an important aspect of their work.

Dr McCracken's leadership had created a research unit that, in its highly focused approach to research and close ties to the minerals exploration industry, anticipated the form and style of the collaborative research groups that would be set up 15 years later under the Australian Government's Co-operative Research Centres scheme.

Senator Cook said that in 1984 Dr McCracken had described earth-orbiting satellites as "God's gift to Australia", saying few other countries of the world stood to gain so much from their use. His initiative and energetic leadership had been instrumental in Australia realising these gains.

The strong support that Australian industry had given to remote sensing as a consequence of the team's work had been a big factor in the Australian Government deciding to enter a joint venture with the United Kingdom to construct the infrared remote-sensing instrument on the European satellites ERS-1 and ERS-2. The joint venture had allowed the Australian aerospace industry to obtain first-hand experience in satellite manufacture.

The group's research, supported in part by funding through the Australian Minerals Industry Research Association, provided an outstanding example of how industry and government could collaborate to produce research with major pre-competitive benefits for a vital Australian industry sector, as well as enormous spillover effects in other areas of public national importance.

Senator Cook said Dr Richard Moore, had a remarkable record of innovation in another branch of space-based remote sensing, which exploited



Jon Huntington, Ken McCracken and Andy Green (left to right).

microwave radar systems to observe and explore the Earth's land surfaces and oceans.

Dr. Moore conceived the radar scatterometer/radiometer flown on the US Skylab space station in 1973. This was the first radar to fly in space and observe the earth. He has been involved with all earth-looking radars flown in space since then, except radar altimeters.

Dr. Moore and a colleague, Professor Willard Pierson of New York University, conceived the use of a radar in space to measure the winds over the ocean surface and proved the concept with aircraft radars and the Skylab radar. Dr Moore had coined the name "scatterometer" for this type of radar.

Senator Cook said scatterometers already flying, and others due for launch soon, should lead to big improvements in weather and wave forecasting over the oceans.

As early as 1965 Dr Moore had conceived the idea of a Synthetic Aperture Radar (SAR) with 3 wavelengths and multiple polarizations almost like that flown on the Space Shuttle in 1994. SARs like this produced "pictures" similar to those of LANDSAT, but containing very different information because they viewed the Earth's surface at much longer wavelengths.

Senator Cook said the synthetic aperture radars (SARs) flown on Seasat in 1978 and the Space Shuttle in the 1980s discovered ancient rivers still flowing beneath the dune fields of Africa's Sahara Desert and north-western Australia because their signals penetrate into the soil. Moreover, SARs can monitor soil moisture, crop conditions, forest health, and ocean wave patterns, all through clouds and at night.

Dr Moore's invention, the scanning SAR, would allow Canada's new RADARSAT, due for launch this year, to return to the same area more often than other SARs and LANDSAT, thus permitting new views of rapid environmental change.

Senator Cook said that between them, the four winners of this year's Australia Prize, had made enormous contributions to human welfare, literally by showing the Earth in a new light.

## 1995 Australia Prize - Winner's Profiles:

### Dr Ken McCracken



Dr Ken McCracken, 61, was founding chief of the CSIRO Division of Mineral Physics in Sydney, and Director of the CSIRO Office of Space Science and applications until his retirement in 1989. He is now combines life as a beef grazer with work as a private consultant to

the minerals exploration industry, working from his home at "Jellore", near Bowral in NSW.

Dr McCracken is a fellow of both the Australian Academy of Science and of the Australian Academy of Technological Sciences and Engineering.

As a post-doctoral fellow he became involved in space science in 1959 at the Massachusetts Institute of Technology, and later at the University of Texas, designing instruments that flew on nine US space probes.

His research for NASA was instrumental in protecting US astronauts from exposure to possibly fatal doses of cosmic radiation from enormous explosions - called flares - on the Sun.

As Professor of Physics at Adelaide University between 1966 and 1969, Dr McCracken led a team that pioneered X-ray astronomy of the southern sky with instruments launched on Skylark rockets from the Woomera Rocket Range.

In 1970 Dr McCracken was appointed chief of the CSIRO's new Division of Mineral Physics in Sydney. His first official task was to attend a research meeting in Canberra which was preparing Australia's response to a NASA invitation to make use of satellite images of Australia obtained by its recently launched Earth Resources Technology Satellite (later renamed LANDSAT).

Dr McCracken made two key appointments during the next four years: Australian spectroscopist Dr Andrew Green in 1972, and British-born geologist and air-photo expert Dr John Huntington in 1974.

The division's first satellite data came in the form of third- or fourth-generation photographic negatives, which had lost much of their original detail. Dr McCracken and Dr Green asked NASA for computer tapes of the original digital data from which the images had been generated.

After three years of development, the CSIRO group was ready to apply its findings to mineral exploration, but its initial submission for funding from the Australian Minerals Industry Research Association (AMIRA) was rejected - the industry saw little virtue in the new technology.

A year later, in 1977, a revised submission met with enthusiastic support, and an AMIRA research contract marked the beginning of one of Australia's most durable and successful industrial research collaborations.

By 1982 NASA had greatly improved the technology of its LANDSAT satellite, but the Australian Government decided against modifying the Australian satellite reception station to take advantage of the improvements.

Dr McCracken proposed that the necessary modifications should be provided by Australian researchers, and succeeded in gaining financial support from Australian industry and research laboratories to allow the project to proceed.

His colleague Dr Andy Green led the team that designed and manufactured the reception equipment. It provided Australian industry and research laboratories with the highest-quality remote sensing data available - and an important competitive advantage in the field.

The value of satellite images often depends on their immediacy; the tapes from NASA were often several months old before the CSIRO group could process them.

In the early 1980s Dr McCracken became concerned that Australia's space industry was fragmented and lacking direction, and had already missed out on commercial opportunities that had been seized by other Western nations.

He convinced the CSIRO Executive to establish the CSIRO Office of Space Science and Applications (COSSA) to provide a focus for space-related research in the organisation - COSSA's main focus was still remote sensing.

Soon after, the Australian Government established the Australian Space Board to coordinate Australia's space program. Dr McCracken was appointed as a board member, and later became Chairman of its remote sensing committee.

Remote sensing has since become a major component of the Australian space program, and Australia has invested \$17 million in a joint venture with the UK to build remote-sensing instruments for the European satellites ERS-1, 2 and 3.

Apart from its application to mineral application, remote sensing has become an indispensable tool for Australian agencies involved in oceanographic and climate-change research, or in monitoring agriculture, forestry, water pollution and desertification.

In addition to his interest in remote sensing, Dr McCracken has played a key role in the development of a number of forms of geophysics which allow Australian minerals explorers to detect deeply buried mineral deposits (see Preview 48, Mentor Article).

Dr McCracken says the CSIRO administration of the 1970s must take some of the credit for the award of the Australia Prize to his team. "They set the broad research goals and stipulated that I and my colleagues should develop the techniques and instruments the industry would need 10 years into the future."

### Dr Andrew Green



Since 1992 Dr Andrew Green, 48, has been director of the Co-operative Research Centre for Australian Mineral Exploration Technologies.

He began his remote sensing career as a CSIRO post-doctoral researcher at Stanford University's Department of Earth Sciences. His PhD training as a spectroscopist at the University of WA proved an ideal

grounding for his subsequent involvement in a new, space-based form of spectroscopy: potential mineral deposits can be identified in LANDSAT images through their distinctive spectral signatures at infra-red and visible wavelengths.

When he joined the CSIRO Division of Mineral Physics in 1972, Dr Green began developing computer software to analyse digital images from NASA's first remote-sensing satellite, ERTS-1 (later to be renamed LANDSAT-1).

Because LANDSAT's visible light and infra-red sensors were designed to optimise images of the green, forested landscapes of the northern hemisphere, they produced poor quality images of Australia's brown, sparsely vegetated landscapes. Dr Green devised one of the world's first image processing facilities to recover information hidden by background "noise", revealing previously hidden detail.

In the late 1970's on the basis of these research results Dr Green then defined the specifications for, and helped establish, Australia's reception facility for the LANDSAT multi-spectral scanner (MSS).

"By the mid 1980s, to ensure Australia could acquire data from the new LANDSAT thematic mapper we had to develop our own modifications for the Australian MSS reception facilities because the thematic mapper operated at higher resolution, and in more spectral bands - especially longer wavelengths that could tell us more about the nature of minerals on the Earth's surface.

"The work is still fascinating because of the constant challenge to detect the very weakly expressed characteristics of mineralisation tend to be swamped by other, more dominant features in a satellite image.

"I think of it as a signal-to-noise problem: the geological targets of interest are very hard to recognise against a background of paddock boundaries, fire scars, topographic features and other natural and man-made variability.

"Our success has been based on our ability to find new ways to express and enhance subtle geological features present in satellite data."

More recently, Dr Green and Dr Huntington have been involved in the development of the world's first pulsed-laser profiling spectrometer. The instrument, carried by a low-flying aircraft, can identify silicate and carbonate minerals that make up most rocks, and help detect patterns that may indicate mineral deposits.

### Dr Jonathan Huntington



Dr Jonathan Huntington, 50, is a geologist and senior principal research scientist with the CSIRO Division of Exploration and Mining. Born and educated in England, he joined the CSIRO Division of Mineral Physics in 1974 after

working as remote sensing expert with International Nickel Australia Ltd.

In 1972 Dr Huntington became involved in the early work to exploit images from NASA's LANDSAT satellites for mineral exploration, and coal extraction. The latter application included pioneering work interpreting LANDSAT data to reveal the surface expression of major fault systems intersecting coal seams in several NSW collieries and causing hazardous working conditions and loss of production.

In the early 1980s he spent three years trying to persuade the Commonwealth Government of the benefits of Australia building its own ground station to receive LANDSAT data. When support was not forthcoming, he played a key role in securing industry support to develop the facility.

"Our remote-sensing group in CSIRO consciously avoided direct involvement in the space industry. While others were trying to establish a space industry without really thinking about how to use the technology, we were more interested in the end uses, rather than the means - we focused on solving the minerals exploration industry's problems using remote sensing.

"Our philosophy has been very much one of studying the industry problem and being proactive in its solution by developing the most appropriate technology, rather than waiting for someone else to develop something that may, or may not, be applicable to exploration.

"Despite enormous use of LANDSAT and SPOT data by the mining and exploration industry, no space-based sensing system has ever been specifically developed for the needs of this industry. So the benefit has been basically fortuitous.

"The reality is that Australia couldn't afford a space program costing hundreds of millions of dollars. But that doesn't mean we can't obtain a huge competitive advantage by being more subtle and focusing on specific technologies capable of delivering benefit to Australian users. We should aim for excellence in niche areas rather than spreading our efforts too thinly.

"Clearly, one of the things that has worked in our favour is that the minerals exploration industry has been on our side almost from the beginning. We're very grateful for this.

"But the benefit has been two-way. The close relationship we have developed through collaborative, consortium research with this industry (through the Australian Minerals Industry Research Association) has led to our research results being rapidly implemented.

"I really believe this is a model for research support and interaction that could be very profitably followed

for better application of remote sensing to renewable resources issues in this country."

Dr Huntington said the fact that Australia previously could not afford to develop its own space-based sensing industry had led him and his colleagues to develop remote-sensing technologies that could be fitted into low-flying aircraft.

"These can be more versatile, allow you to test out new concepts, develop credibility and can directly involve your customers in the process, at a fraction of the cost of space borne systems," he said. "If you do this successfully then you may later develop the credibility and experience to develop space borne systems."

In 1980, he and his colleagues had concluded that airborne spectroscopy was the future direction of remote sensing, and had embarked on a 10-year project to develop airborne spectrometers that could simultaneously map at least 20 minerals. The relative abundance of these clay, silicate and carbonate minerals could signal the presence of buried mineral deposits.

This had been achieved using the world's first profiling reflectance spectrometer in the early 1980s and had, in turn, led to a new-generation of Australian airborne spectrometers, already in advanced stage of development, that could identify some 50 different minerals simultaneously.

These developments were part of the team's continuing commercialisation strategy, which was aimed at allowing Australian companies to gain operational benefits from their research.

### Professor Richard K. Moore

Dr Richard Moore, Professor Emeritus of Computer and Electrical Engineering at the University of Kansas, was a pioneer in the field of microwave-based satellite remote sensing, a prolific inventor of new remote-sensing devices that have helped revolutionise mapping and monitoring of the Earth's surface, and a major contributor to understanding how microwave signals vary with surface characteristics.

In 1957, before the US had even launched its first satellite, Prof Moore co-authored a research paper that described how a pulsed radar could be used as an altimeter to map the Earth's topography from orbit.

By 1963 the US was preparing to launch the first generation of communications and weather satellites; Prof Moore joined a NASA team which investigated how short wavelength (microwave) radar systems could be used for satellite-based remote sensing. Microwave systems offered at least one significant advantage over visible light and infra-red sensing systems: they could see the Earth's surface by day or night, and through dense cloud.

Prof Moore recognized the potential of synthetic aperture radar (SAR) for earth observation from space. Synthetic aperture radar employs a microwave beam that is scanned across the Earth's surface from orbit - or from a low-flying aircraft. The motion of the vehicle carrying the SAR produces images of the terrain below in a long, wide swathe. SARs flown on aircraft, unmanned spacecraft and the Space Shuttle have





provided high-resolution, stereoscopic images of the Earth's land surfaces.

As early as 1965 Prof Moore and several colleagues put to NASA a proposal for a multi band orbiting SAR to study and map the Earth's surface at many different wavelengths. But their visionary project was rejected.

"In the 1960s the Moon was the name of the game," he said. "NASA had the idea of putting sophisticated satellites into orbit around the Moon to study its surface, but we were more interested in doing the same thing for the Earth. We had couched our proposal in terms of testing all these new instruments in Earth orbit, before sending similar instruments to the Moon.

The concept was finally realised 29 years later with the launch of the Space Shuttle carrying the SIR-C synthetic aperture radar system. SARs had flown previously on unmanned spacecraft, and Professor Moore was involved in some way with all but those from Russia. These included Seasat (US), ERS-1 (European Space Agency), and JERS-1 (Japan), as well as single-band instruments (SIR-A and SIR-B) on earlier Space Shuttle flights.

In 1965 Prof Moore coined the name "scatterometer" for a radar sensor that could measure how the Earth's surface scattered a microwave beam looking down on the Earth from space; the scattering characteristics reveal detail of the structure and composition of the surface, including phenomena such as waves on the surface of the ocean.

Prof Moore found that ripples on the ocean's surface scattered microwave beams in patterns which could be interpreted to reveal both the strength and direction of the prevailing winds. Radiometers, scatterometers, and SARs also monitor sea ice cover in polar regions; ice is a natural insulator, and in ocean areas free of ice, or with only a thin cover, heat transfer to the atmosphere can be a hundred times more rapid than in ice-covered areas, resulting in significant changes in the earth's weather.

NASA began launching weather satellites equipped with radiometers in the early 1970s. NASA also had a scatterometer on the Seasat spacecraft, and European Space Agency has one on its ERS-1. They have helped revolutionise weather forecasting by mapping wind fields over remote oceanic regions where weather data is sparse - the technique has proved particularly valuable over tropical oceans, which are often obscured by dense cumulus cloud. SARs can also detect natural or man-made slicks on the ocean surface.

In the early 1970s Prof Moore helped develop a combined radiometer/scatterometer, called RADSCAT, for NASA. It was designed to explore the best ways to monitor the ocean's surface. The instrument was test-flown over the ocean on a C-130 Starlifter aircraft, and also on NASA's Skylab.

Because microwave radars operate at wavelengths beyond the visible and infra-red spectrum, they "see"

aspects of the Earth's surface that are invisible at these wavelengths. This was dramatically demonstrated when RADSCAT aboard SEASAT scanned the Sahara Desert.

Because the sand was extremely low in moisture, the dunes became transparent to the radar, and instead of producing images of the desert's sandy surface, Seasat revealed ancient river beds below the desert. Subsequently, SARs aboard the Space Shuttle produced large-scale images of ancient rivers beneath the Sahara, and beneath the deserts of north-western Australia.

Prof Moore's invention of the microwave scatterometer and promotion of spaceborne SAR has allowed researchers to monitor soil moisture levels from space, as an aid to weather forecasting. Crops also scatter microwave radar beams in distinctive ways that vary with the moisture content and architecture of their foliage. To study crops, SAR is needed to distinguish between the different fields.

These applications depend on an understanding of how microwave sensors "see" the Earth's surface. Since the early 1970s, Prof Moore and his faculty colleagues and students have conducted extensive experiments to determine how land and ocean surfaces, and agricultural landscapes, scatter and re-radiate microwave radiation. This information has been invaluable to agriculture, environment and resource managers, and weather forecasters.

This year NASA will launch a Canadian satellite carrying a sophisticated new synthetic-aperture radar, capable of more frequent imaging because of another of Prof. Moore's inventions, the SCANSAR. With its capacity to monitor any rapid change in features on the Earth's surface, it is expected to become one of the world's most powerful tools for monitoring global resources.

Still active in research, Prof Moore is now working on another microwave sensor to improve weather forecasting - it will monitor the dynamics of weather systems by observing rain and other cloud particles in motion.

Today, remote-sensing instruments designed, developed, and promoted by Prof Moore are used worldwide for:

- \* Monitoring and mapping forests in remote or inaccessible regions.
- \* Monitoring oceanic phenomena that influence weather.
- \* Identifying hurricanes, typhoons and cyclones in the early stages of formation.
- \* Collecting data on global weather and climate trends.
- \* Mapping and imaging cloud-covered landscapes.
- \* Synoptic-scale monitoring of soil-moisture levels that influence crop yields.
- \* Managing and monitoring land and water resources.
- \* Monitoring sea and lake ice.



### Slimhole Borehole Acoustic Imaging - ALT FAC 40

Borehole acoustic televiwers generate an image of the borehole wall by transmitting ultrasound pulses from a rotating sensor and recording the amplitude and travel time of the signals reflected at the interface between mud and borehole wall. The amplitude of these reflections is processed to provide high quality, oriented image data that is used to characterise and quantify the rock of the borehole wall. Such characteristics include tectonic structures, fractures and joints, bedding plane dips and directions, rock texture and other detailed lithological features. The travel time represents the borehole shape and diameter and is used to provide exceptionally accurate borehole open or cased) diameter measurements. For a number of years the televiwer has been used successfully as a primary tool for high accuracy casing and tube inspection.

Borehole acoustic imaging tools have been successfully used in the petroleum industry for a number of years. Due to the relatively high cost involved in running oil field specific logging tools there has been little migration of the technology out of the petroleum sector to the rest of the geoscience industry. Oil field tools are also generally extremely cumbersome to manage and often too great in diameter to allow their use for instance in shallow, slimhole geotechnical or mineral exploration boreholes.

New to the market is the ALT FAC 40 borehole acoustic televiwer which has been designed from the beginning for slimhole applications. The FAC 40 represents the culmination of over 10 years experience gained in televiwer design and operations. The FAC 40 one of the most versatile tools in its class, due to the revolutionary sensor technology which enables the tool to achieve superior image resolution over a large effective borehole diameter, ranging from 46mm to plus 400mm, depending upon mud conditions. This factor also means that the tool still delivers good image quality even when ex-centralised, a feature that is of immense practical value in boreholes where precise centralisation of the tool is difficult to obtain.

Enhanced image resolution is a key feature of the tool, made possible by the unique focusing system employed. Features as small as 2mm can be resolved and fractures as small as 0.1mm in width can be detected. Resolution and flexibility is also further enhanced by the ability to change the speed of the transducer smoothly from three, through to twelve revolutions per second and to change the number of samples taken per revolution from as little as 72 up to a maximum of 288. In a varying borehole environment data integrity can also be enhanced by varying the sample time window offset and length, and receiver gain. These factors ensure that a high quality 360 degree image is achievable under difficult or varying borehole conditions. The FAC 40 also incorporates a deviation

device to allow for precise tool orientation and and borehole deviation measurements.

These days new hardware development must be complemented by appropriate software systems, ideally open software that that can be operated on a variety of platforms. The power and flexibility of ALT's WellCAD application allows the user to work with televiwer images (and other borehole data types) in a Windows environment. User defined display parameters include vertical scales, width of images and colour palette. Interactive interpretation allows the user to pick any number of sine wave shaped features and generate a summary log which can be presented as coloured sine wave or tadpole style display logs. The calculated sinus may be overlaid on the televiwer image. Image processing includes full image orientation (reference to north or the borehole high side), dynamic amplitude normalisation and eccentricity correction, calculation of the sinus from any number of picks on the screen and calculation of true and apparent dip and dip direction.

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## Industry News: New Instrumentation

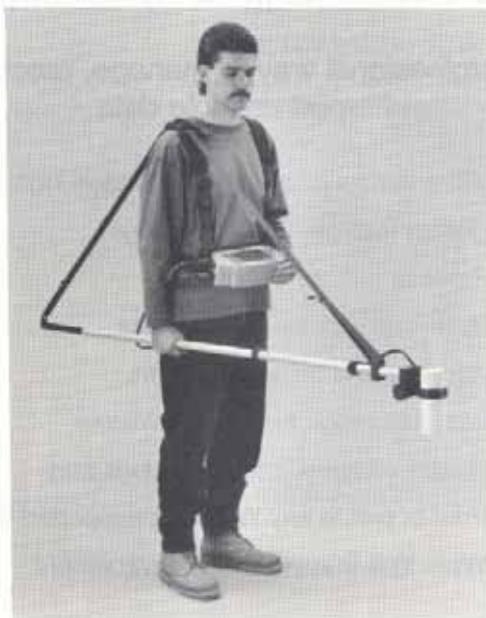
### New High-Speed Magnetometer

A new generation portable magnetometer, the MagMapper™ G-858, is now available from Geometrics, Inc. This magnetometer is 10 times faster and five times more sensitive than prior instruments, and is exceptionally easy to use. The MagMapper™ uses caesium vapour sensor technology combined with a ruggedized belt-mounted computer and proprietary data-mapping software. The user can go at a fast walk, taking five data points per metre. A high-resolution graphical interface shows a map of the area covered, with five lines of data displayed for comparison and edit.

The new Geometrics' magnetometer can measure magnetic-field perturbations as small as 0.05 nT, allowing it to sense a 1kg object buried 3 metres deep. The instrument stores 240,000 data points, with RS-232 readout for further analysis. The MagMapper™ can also be used as a base station, or as a gradiometer with an optional second detector. Applications include the detection of underground pipelines, buried drums, and unexploded ordnance, as well as the characterisation of archeological sites, mineral deposits and geological structures.

Geometrics, Inc. has designed and manufactured geophysical instruments since 1969. Offices are in California, England and China.

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Tel: (02) 529 2355; Fax: (02) 529 9726  
Email: [geoins1@ibm.net](mailto:geoins1@ibm.net)



### Stratagem™ EH4 Subsurface Conductivity Imaging System



A new subsurface conductivity/resistivity imaging system, Stratagem EH4 has been announced by Geometrics, Inc. and EMI, Inc., in a cooperative venture. Geometrics says the equipment will provide high-resolution conductivity/resistivity imaging for minerals exploration, ground water mapping, and engineering surveys, such as detection of voids and potential sink holes. The equipment will also be used for environmental site characterisation such as monitoring and mapping escapement plumes from pollution containment sites and determination of the level of salt-water invasion in fresh-water aquifers.

Stratagem™ offers the ability to image subsurface conductivity up to 1km of depth while maintaining excellent resolution of lateral changes in subsurface conductivity. The equipment features a portable transmitter and antenna to complement natural magnetic and electric fields that are measured using high-sensitivity electrodes and coil sensors. After a series of soundings are made along a profile line, Stratagem™ will produce a cross section of subsurface conductivity right in the field. The conductivity section can be displayed on Stratagem's own LCD display or on a separate VGA colour monitor, and printed out with either Stratagem's own internal printer or a separate colour printer.

A unique feature of the equipment is that both the Stratagem™ conductivity imaging system and Geometrics' well-known seismograph, StrataView™, can be combined in a single seismic/geoelectrical instrument at a price significantly less than if each piece of equipment were purchased separately.

Contact:  
Geo Instruments Pty Ltd  
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Tel: (02) 529 2355; Fax: (02) 529 9726  
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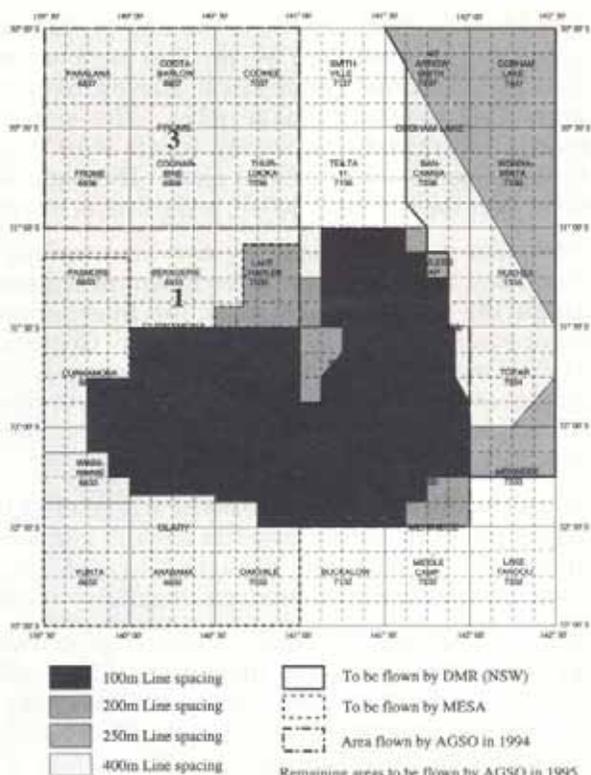
## Industry News?

Send all contributions to the Editor,  
Preview. (Contact details page 4).

## The Broken Hill Exploration Initiative Airborne Geophysics Program 1994 and 1995/96

The Broken Hill Exploration Initiative is a National Geoscience Mapping Accord collaborative project involving AGSO and the Departments of Mines and Energy South Australia (MESA) and Mineral Resources New South Wales (DMR). The object of the project is to provide a new generation of multidisciplinary geoscientific information as a basis for more efficient and effective mineral exploration in the Broken Hill area. This will hopefully result in new economic discoveries and thereby ensure the continued viability of the Broken Hill township and Port Pirie in South Australia where associated smelters are located.

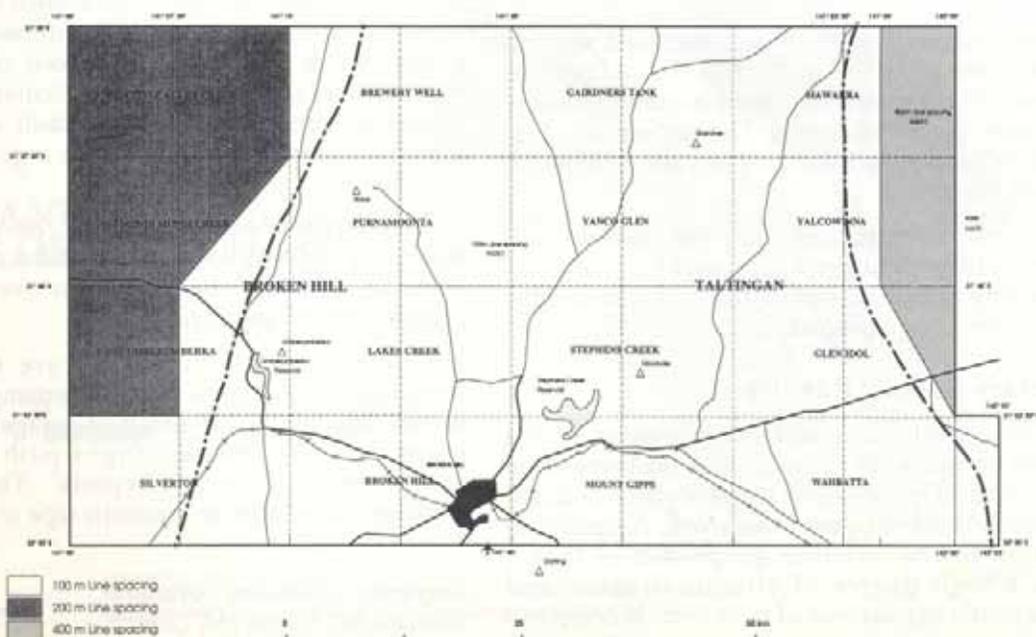
The acquisition and distribution of high quality aeromagnetic, radiometric and DEM data to assist with geological mapping and the targeting of areas for exploration is a vital component of the project. AGSO flew the Broken Hill and Taltingan 1:100 000 sheets with its own Aerocommander mounted acquisition system during 1994. The flying height for these sheets was 60 metres and the majority of the flightlines were spaced at 100 metres in an east west direction. These data were released to the public on 27 April 1995. AGSO is currently extending this detailed coverage to adjacent areas as shown on the index map. Flying with the above parameters over areas of outcrop and shallow surficial cover has allowed the production of detailed maps and images at scales as large as 1:25 000. These results are currently being used to upgrade previous 1:25 000 geological mapping. The 1994 survey parameters are being maintained for much of the continuing work although the line spacing has been increased in areas



BHEI Airborne Geophysics data acquisition program 1995/96

where the depths to prospective rocks is of the order of several hundred metres and where closer flightlines are do not provide greater detail.

The AGSO results will be merged with adjacent surveys currently being acquired under contract by MESA and DMR. These data will be progressively released between September 1995 and February 1996.



BROKEN HILL 1994/95 P617

## Vanuatu Mineral Exploration Initiative

On 15 May 1995 the Government of Vanuatu released the data acquired by the first regional and systematic airborne geophysical survey over the country (see magnetic image p39). The airborne magnetic and radiometric survey covers most of the islands and some offshore basin areas. The flight line spacing over the islands is 400 m, and offshore 800 m.

The project was initiated by the Government of Vanuatu and funded by the Government of Australia through the Australian Agency for International Development (AusAID). The Australian Geological Survey Organisation (AGSO) carried out the management and supervision. The survey was flown from August to December 1994 by World Geoscience Corporation Limited.

AGSO has also been asked to assist in marketing the products from this survey, and has entered into a five year agreement with the Vanuatu Government to process the sales of digital products, maps and images.

The regional and systematic airborne geophysical survey over Vanuatu is the first of this kind in the Southwest Pacific. The immediate aim of the survey is to provide the strategic framework for and to encourage mineral exploration in Vanuatu.

### Survey Specifications

The joint magnetic and radiometric survey was flown using a fixed-wing twin-engine aircraft (about 40 000 km) and a helicopter to cover the most rugged country (about 20 000 km). Flight lines were oriented east-west, and spaced at intervals of 400 m onshore and 800 m offshore; north-south tie-lines were 4000 m apart. The nominal ground clearance was 100 m. The position specifications are those appropriate for surveys with line spacings of 200 m. The figure outlines the extent of the survey.

The total magnetic intensity was recorded with an acceptable noise envelope of 0.2 nT. The radiometric (gamma-ray spectrometer) data were acquired over the full spectrum of 256 channels. The survey also has facilitated the production of digital elevation models of all the main islands.

AGSO and the contractor applied in-field and processing stage quality-control, which included micro-levelling of data, to ensure the data was suitable for high-quality image processing.

### Preliminary Survey Results

The initial evaluation and interpretation of the survey data have already demonstrated the presence of various geological features which had not been detected or were poorly defined by previous work. A significant contribution of the airborne geophysics is that it provides a high degree of structural detail and geological continuity in areas of poor or no outcrop as a result of dense vegetation, deep weathering, and the presence of young unprospective cover rocks, like the extensive sheets of reefal limestone in Espiritu Santo,

Malekula, Efate, and some other islands. The integration of the geophysical data with the existing geological data has produced solid-geology maps which greatly expand the scope of mineral exploration, and, in addition to identifying areas of potential mineralisation, the combined data have provided increased control and resolution of existing target areas.

In Espiritu Santo and Malekula, zones of high magnetic intensity, associated with shallow (<500m) and deeper (>500 m) features, correlate with mafic to intermediate intrusive complexes where these rocks are exposed. The distribution of the magnetic highs indicates that the intrusive complexes are more common than shown on the existing maps, partly because they are concealed. Many of these magmatic complexes are closely related to fracture and fault zones, of which the most prominent one is accompanied by graben and horst structures and changes trend from northwest on Malekula to north-northwest on Espiritu Santo.

The interpretation of the magnetic data supports the earlier findings that the northwest to north-northwest-trending major faults are mostly extensional and have a minor component of strike-slip movement.

The magnetic data also provide a more detailed insight of the young volcanic centres on the smaller islands, including Efate, in the central part of the archipelago. Magnetic highs are commonly associated with basalt flows, mafic dykes, and small (probably mafic) intrusive bodies. The mapping of these geological features provides clues to the occurrence of epithermal mineral resources. The grey scale image indicates some of these features.

The best results of the radiometric interpretation are obtained by applying a linear stretch to the K (Potassium)-channel data which isolates the highest 5 to 10% of K values in an attempt to identify the high K sources. There are a great number of K anomalies, of which many are associated with known and interpreted intrusives and/or with single or intersecting faults. In places, the K anomalies have been correlated with mapped alteration zones, and particularly where these anomalies are associated with fault structures and intrusive complexes they may be a guide to mineral occurrences.

The Department of Geology, Mines and Water Resources (DGMWR) on behalf of the Government of Vanuatu owns and has copyright over the Vanuatu digital airborne geophysical data.

The results of the survey are released as a comprehensive data package comprising point-located digital data, gridded digital data, image maps, contour maps, profile maps, flight-path maps, and interpretation maps and reports. The digital data package is available on magnetic tape in ASCII format

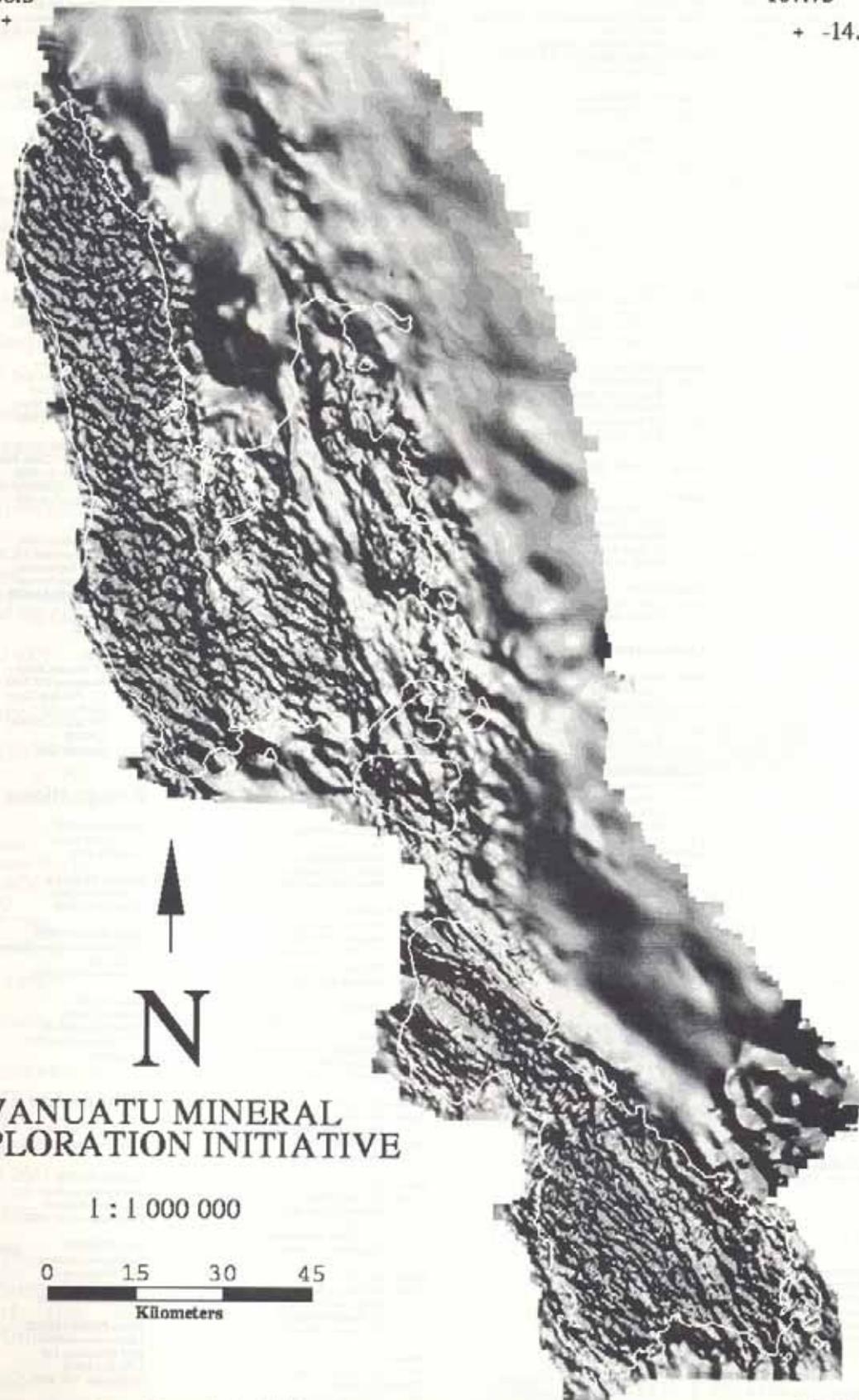
*For further information on the Vanuatu and Broken Hill Data Contact: AGSO Sales Centre Tel: (06) 249 9519; Fax: (06) 249 9982*



# ESPIRITU SANTO & MALAKULA, VANUATU

Total Magnetic Intensity (RTP), greyscale, with North East gradient enhancement

166.5 167.75  
-14.5 + -14.5



**VANUATU MINERAL  
EXPLORATION INITIATIVE**

1 : 1 000 000



-16.667  
+  
166.5

Image Processing by AGSO  
Miligan, P.R., Morse, M.P. & Rajagopalan, S., 1992 Pixel map preparation  
using the HSV colour model. *Exploration Geophysics*, 23, 219-224.

-16.667  
+  
167.75

# 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

**Ciaran LAVIN**  
27 Foster Avenue  
Malvern East Vic 3145

**Lisa MILLER**  
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**Sundar SARMA**  
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### New South Wales

**Brian O'NEILL**  
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## Change of Address

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

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Post Office Kambalda  
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Mt Magnet WA 6638

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## Where Are They?

Does anyone know the new address for the following members?

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**John HOLMES**  
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**Kevin Phillip JARVIE**  
Last known address:  
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GPO Box 1911R  
Melbourne VIC 3001

**Gregory SPILLANE**  
Last known address:  
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Melbourne VIC 3001

## New Engineering, Groundwater & Environmental Geophysics Column - Clean and Green

### Clean and Green

With

**Derecke Palmer**

University of New South Wales

#### New Resistivity Inversion Software

Recently I have had the opportunity to check out two new resistivity inversion software packages, which have been released commercially in the last few months. One is for a 1-D model, the usual multiple horizontal layer model; the other is for a 2-D model consisting of a mesh of rectangular blocks. Both packages perform rigorous least-squares inversion using the Marquardt algorithm.

The 1-D package, called RINVERT for Windows™, is a home-grown product. It was developed by Noel Merrick from the National Centre for Groundwater Management at UTS (Sydney). Noel's original Fortran code was converted to C++ code by programmers at C Vision Pty Ltd, using object oriented techniques for the Microsoft Windows™ environment. I was one of the beta testers for this product, and I found it extremely easy to use. You can produce some brilliant colour graphics from it (see p43), or high resolution black-and-whites if you use a laser. Because of the Windows interface, you can output to any printer supported by Windows.

RINVERT does forward modelling, inverse modelling and a Monte Carlo equivalence analysis on resistivity sounding data gathered with the Schlumberger, Wenner or Dipole-Dipole arrays. Convergence is achieved and displayed on-screen in a matter of seconds. One of the next features is an automatic report generator; you can get figures and tables captioned automatically, ready for slotting into your report (Good for consultants). Another nice feature is the extensive Help facility; you can get a rundown on-screen of resistivity basics, examine the glossary, and click on unfamiliar terms to see a definition. (Good for students).

The 2-D package, called RES2DINV was developed by M.H. Loke in a PhD thesis supervised by Ron Barker of the University of Birmingham. Ron, who has been on sabbatical in Sydney with Ian Acworth at the UNSW Groundwater Centre, demonstrated the software in a talk to the ASEG in April.

RES2DINV runs in a DOS environment and needs plenty of expanded memory (about 6MB for 800 data). It does inverse modelling on resistivity imaging data gathered with the Wenner, Pole-Pole or Dipole-Dipole arrays. Convergence is surprisingly fast and is achieved in a few minutes. Each iteration is displayed on-screen as colour-filled contours of the observed data, simulated data and true resistivity space. Because the section is discretised automatically into a finite difference grid,

the only unknowns in the problem are the true resistivities of the blocks. The inversion starts from an automatic initial model derived from the signal contribution section. Plenty of control is provided, if required, over the default values used for inversion parameters and block geometry. (No - it doesn't do IP yet!).

RINVERT for Windows sells for \$695 (US\$500) and is available from C Vision Pty Ltd, 185 Elizabeth Stret, Suite 307, Sydney, NSW 2000 (Tel: 02-283 4000; Fax: 02-261 4854). A square root pricing policy applies to multiple copies purchased for academic use. RES2DINV sells for US\$2700 and is also available from C Vision.

*Derecke Palmer*

#### Contributions:

Please send contributions to  
Clean & Green Column to:

*Derecke Palmer  
University of NSW  
Dept of Applied Geology  
PO Box 1  
Kensington NSW 2033*



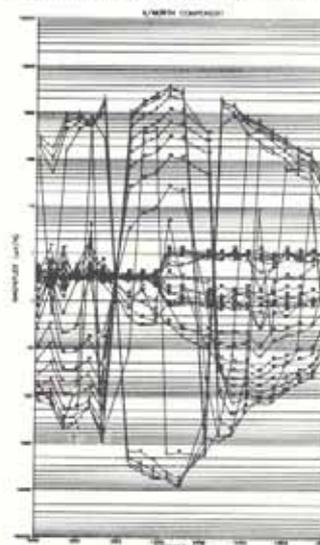
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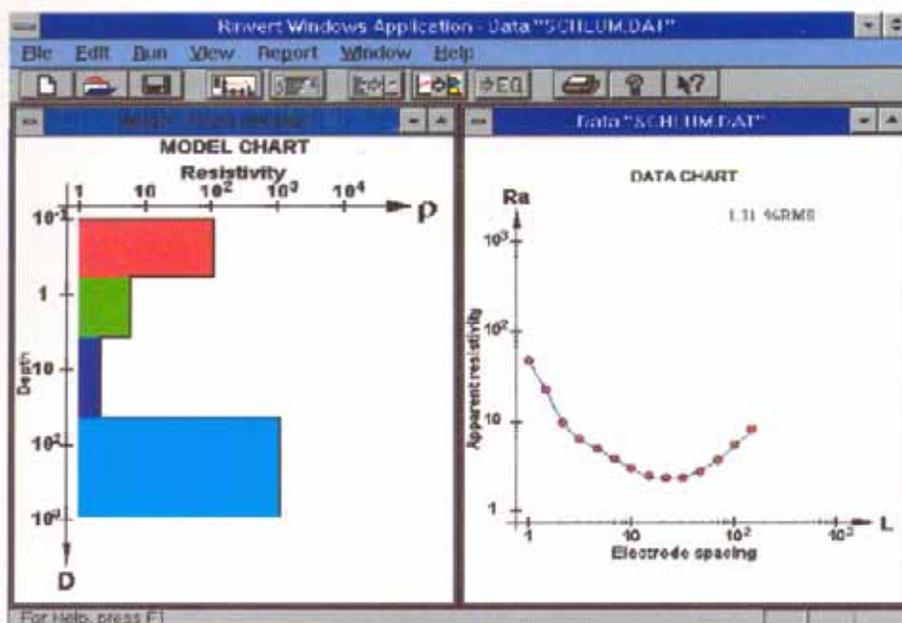


Fig 1. RINVERT's main screen

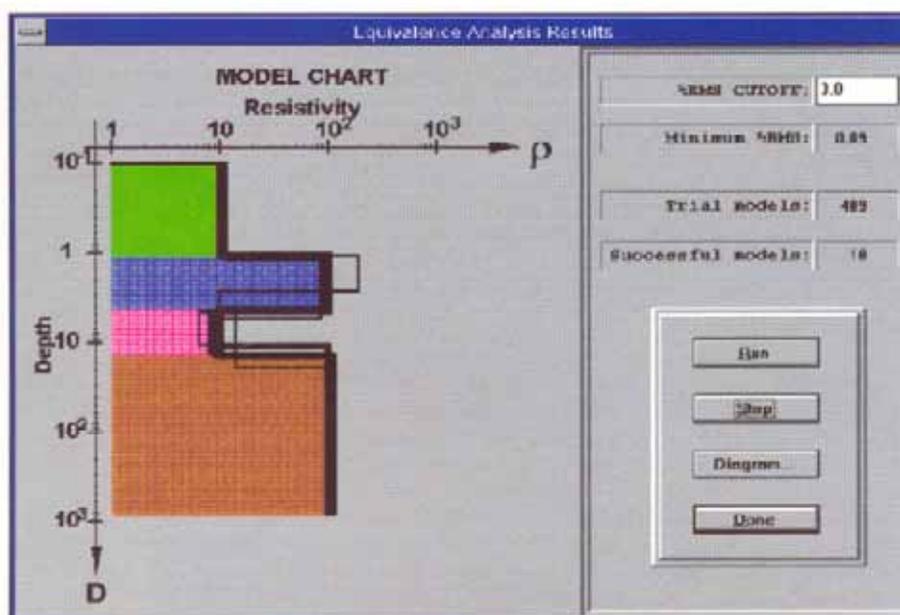


Fig 2. RINVERT's equivalent screen

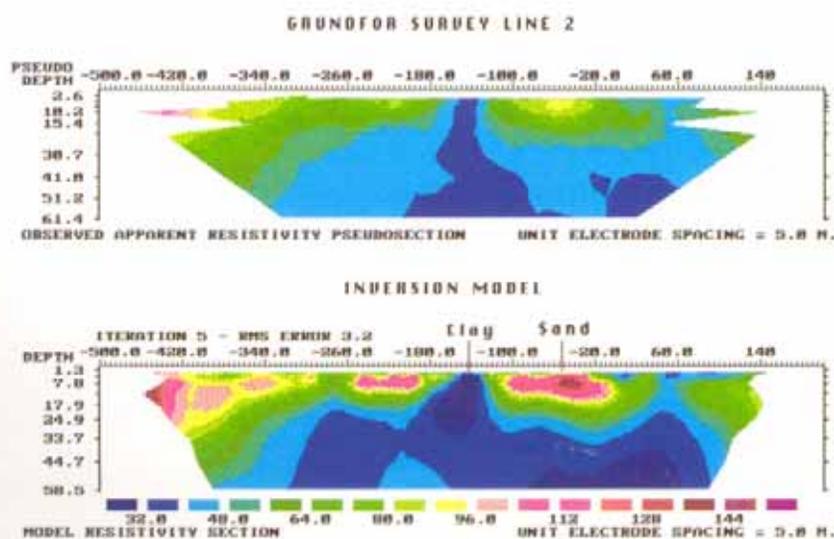


Fig 3. RES2DINV's screen display