Australian Society of Exploration Geophysicists
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Preview

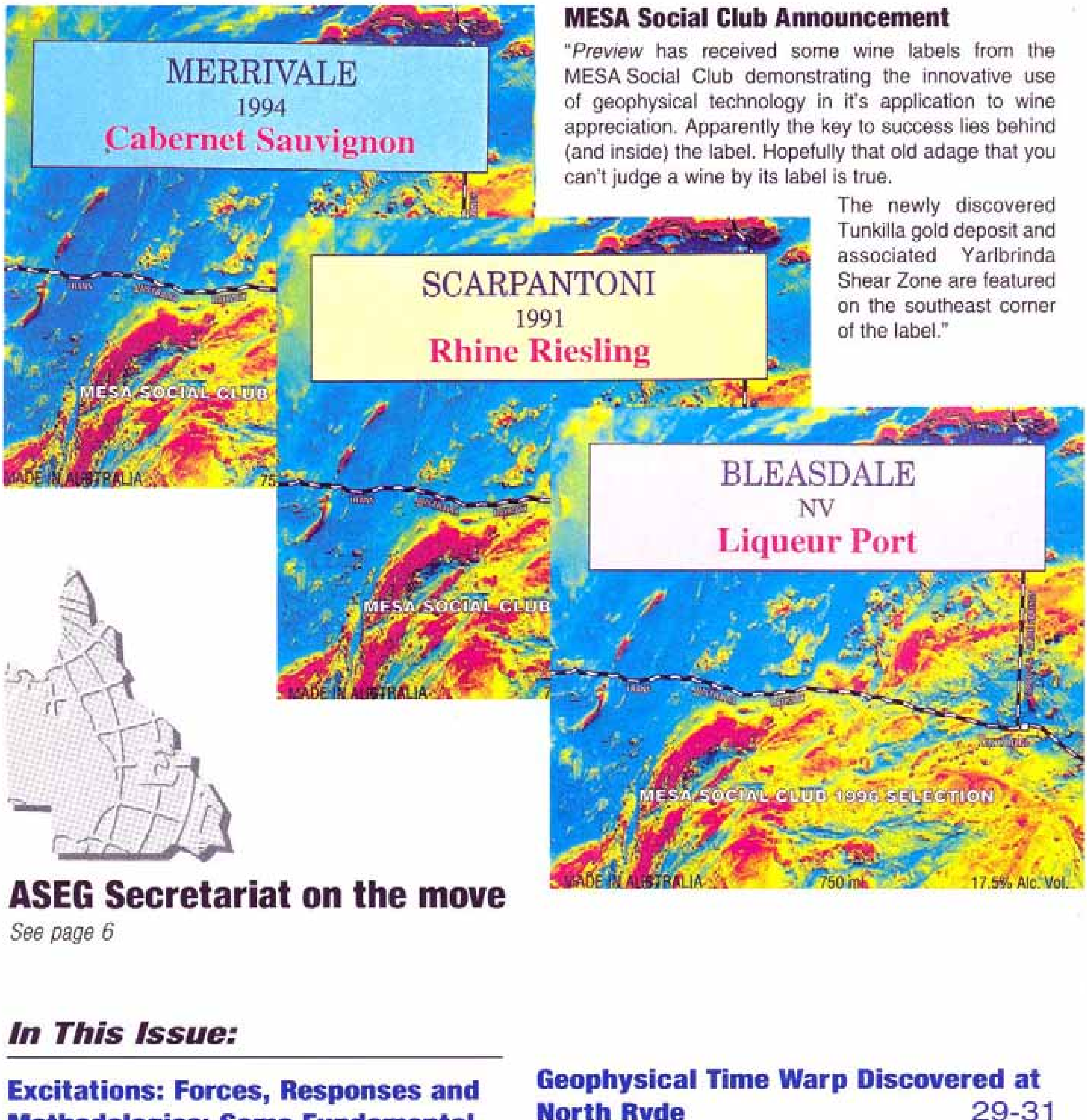
June 1997

Issue No. 68

MESA Social Club Announcement

"*Preview* has received some wine labels from the MESA Social Club demonstrating the innovative use of geophysical technology in it's application to wine appreciation. Apparently the key to success lies behind (and inside) the label. Hopefully that old adage that you can't judge a wine by its label is true.

The newly discovered Tunkilla gold deposit and associated Yarlbrinda Shear Zone are featured on the southeast corner of the label."



ASEG Secretariat on the move

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Editor's Desk

You will read elsewhere in this edition of the change of management within the ASEG. Suffice to say congratulations and good luck to Nick Sheard as the new president. Nick has plunged into the job with relish and will do a great job. Mike Shalley has retired gracefully to the bush but has promised to provide counsel to the new editor... me.

People have asked me whether I am just jumping from the frying pan into the fire. I hope not. The new publishing regime is now in place with Debbie May of Jenkin Buxton doing the greater part of the work and the editor doing the editing. So far it's worked OK. After coming to grips with my new role I want to pick up and the ideas of Mike and Geoff Pettifer and continue the enhancement of this great magazine.

For those of you that don't know I am now working as a consultant following the most recent takeover at Crusader. I must say that I am pleased with this outcome and so far have spent the time cleaning out my mind and generally having a rest. Email with ASEG colleagues has been marvellous. I feel like I'm part of an office full of friends.

A couple of things I would like to see are more letters to the editor on any topic but particularly on articles within *Preview* itself. As a petroleum geophysicist I will be looking to supplement Rob Kirk 's excellent Seismic Window.

In this issue Don Emerson gives his secret recipe for mud pies in his feature article on the effects of water salinity on the resistivity of clay. Unipulse is given over to the 50th anniversary of the University of Tasmania's Geological Department. There is also a review by Bill Fawcett of a geological mapping kit for schools available from the AGSO.

Speaking of Tasmania It was interesting to read a review of Prof Carey's latest book in the March edition of the EAGE 's First Break. The same edition carries a story about Earth Resource Mapping and Queensland aeromagnetic maps.

Please contact me with your thoughts and contributions for *Preview*.

Henk van Paridon, Editor

President's Piece

The ASEG is in a very sound state. The financial basis is strong and the transition of the Federal Executive from Victoria to Queensland is complete. Because of this work under Henk van Paridon we now have a good foundation to tackle some of the major issues that professional groups need to emplace to ensure quality support and technical/ scientific excellence to well into the next century.

Our society has a wide variety of issues to tackle in the next year in order to steer the ASEG into 2000 and beyond. For example:

- We must ensure we maintain our strong diversity across the wide spectrum of exploration geophysicists.
- We must resolve the professional registration issue. This will (or should) involve close co-operation with other professional bodies including AIG, AUSIM and PESA for example.
- The Society should participate in and show some leadership in the growing requirement to ensure safety in our business, for example : coordinate air safety guidelines combining both airborne contractor and exploration companies.
- We must maximise the use of the World Wide Web; debate and resolve the issues of publishing, advertising on the 'net'.
- Planning the future of exploration geophysics by maximising the quality of graduates. This by necessity involves "selling" our profession to attract top quality students and then ensuring quality education with entrance into a profession that is well regarded (see article this issue by D. Palmer).

Grappling with these and other issues the Federal Executive needs to maintain a professional business approach to running of the society. Foremost in our minds however, must be that the ASEG is a technical group dedicated to enhancing the science of geophysics as applied to exploration - we must keep this goal.

S.N. (Nick) Sheard
ASEG President

Executive Brief

AGM

The Society's AGM was held on 29th April at Oxleys Restaurant in Brisbane.

A new executive was elected as follows

President
Nick Sheard

1st Vice President
Steve Hearn

2nd Vice President Wayne Stasinowsky

Hon Secretary Robyn Scott

Hon Treasurer Peter Fullagar

Preview Editor Henk van Paridon

Committee Members Andrew Mutton
Noll Moriarty
Peter Hatherly
Koya Suto

Nick Sheard is currently the chief geophysicist at MIM Exploration and is well known to many of you. Henk van Paridon, the outgoing President gave an address summarising the major achievements of the Society over the last year.

- Relocation of the executive from Melbourne to Brisbane
- A successful conference in Sydney thanks to Roger Henderson and his COC
- Engaging the services of Jenkin Buxton as Preview publisher
- Relocation of the Secretariat to Brisbane (see below)

Challenges for the new executive:

- Further developing our publishing strategies
- Developing our relationship with the new secretariat
- Enhancing our WWW page
- Raising the profile of geophysics and our Society within the research institutions
- Raising the profile of Australian Geophysics in the global community

The AGM was followed by a technical presentation by Natasha Hendrick

New Secretariat

The Federal Executive has elected to move the secretariat to Brisbane where a local business ,Enterprising Events, will be used .The company is managed by Karen Foreman who was previously involved with the organising of the very successful 1992 Gold Coast conference . Karen's team can offer a broad service ranging from managing the membership database to providing full secretarial and accounting services. Karen also has some expertise in managing WWW sites.

As a result our new address will be: Suite 14, Portman Place, 220 Boundary Street, Springhill Qld 4000.
GPO Box 2179 Brisbane Q 4001.
Telephone 61 7 3832 8607 Facsimile 61 7 3832 8245.
Email aseg@enterprisingevents.com.au

The Federal Executive on behalf of the membership at large would like to pay tribute to Janine Verginadis our outgoing office manager. Janine has been of tremendous assistance to us all and has kept the Society in good repair. We wish her all the best.

Financial Status

The current financial status of the company is sound with a net worth near to $400,000 as at 20 May

Cheque account	$45,941
Cash management	$25,859
Term Deposit	$150,415
Sands-cash management	$9,522
Sands-Term Deposit	$40,000.

Further moneys are held by State branches and a final conference profit will be announced next *Preview.*

Audited Financial Statements for 1996 have been prepared and will be lodged on time.

Thanks are due to State Branch treasurers for their assistance.

PS: Robyn has forgotten to mention her new daughter Chloe born in January. Ed.

Robyn Scott
Honorary Secretary

Sneak Preview

A prelude of things to come in Preview.

- *Report on AGC's Fora on Registration*
- *PRINCE – Queensland's Information Centre*
- *Enhancement of Aeromagnetic Data using Grey Level Co-Occurrence Matrices*
- *Your input!*

Calendar Clips

July 7-10 1997
Istanbul '97International Conference and Exposition Istanbul, Turkey. Sponsored by SEG, Chmb. of Geoph. Engineers of Turkey and EAGE

September 4-5 1997
Funafuti to Mururoa
Stability or Chaos in Coral Reef Research - A Symposium Sydney NSW Australia

September 14-18 1997
Exploration '97 4th Decennial Conference on Mineral Exploration. Toronto Canada

September 17 1997
PESA Queensland Petroleum Exploration Symposium

September 28 - October 2 1997
The Fifth International Congress of the Brazilian Geophysical Society (Call for Papers). Sao Paulo Brazil

September 29 - October 1 1997
South African Geophysical Association Conference '97 Swakopmund, Namibia

November 2-7 1997
SEG 67th International Exposition and Annual Meeting. Dallas, Texas, USA.

November 8-12 1998
Australian Society of Exploration Geophysicists 13th International Conference and Exhibition. Hobart Tasmania Australia

Details and more events on Pages 38-39.

ERRATA

The award for best poster at this years conference was for "Geophysical Modelling of Structure and Technostratigraphic History of the Longford Basin, Northern Tasmania," by N. Direen and D. Leaman, and not as previously reported.

The Award for *Best Presentation (equal)* at this years conference was for "Automatic Interpretation of Magnetic Data Using the Source Parameter Imaging(tm) Method," by Richard Smith and not as previously reported.

Preview Deadlines – 1997

August	**July 15**
October	**September 15**
December	**November 15**

ASEG Branch News

Queensland

The Annual General Meeting for the Queensland Branch was held on the 3rd April. President Gary Fallon presented a summary of the years activities, which included eight technical meetings and a students night. Membership at the time was 145, which is 12 % of the total membership. Secretary and acting Treasurer Andrew Davids presented the Local Branch finances, noting that the Branch ran close to break-even or at a small loss to ensure the best value for our members. Office Bearers were elected, with President Gary Fallon, Vice-President Howard Bassingthwaite, and Secretary Andrew Davids being re-elected for another 12 months. Ex SA Branch Treasurer Grant Asser had recently moved to Brisbane, and was elected to the position of Treasurer.

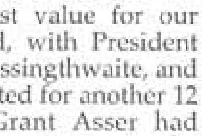
The AGM was combined with a technical presentation, with John Kingman of MIM Exploration presenting the application of high resolution Induced Polarisation Techniques for onshore hydrocarbon exploration.

On the 29th April, the Local Branch assisted with the running of the Federal Executive AGM, held at Oxley's on the River. Natasha Hendrick gave a presentation on seismic processing in areas of complex near-surface velocity fields.

Finally I'd like to apologise for the ommission of Seismic Supply Ltd from the list of Christmas Party sponsor companies listed in the last issue of Branch News.

Andrew Davids
Branch Secretary

New South Wales



After the very successful ASEG Conference and Exhibition (thank you, from the NSW Branch, for the tireless effort put in by many) the local branch has been getting back up to speed.

At the AGM held in April, a new executive was elected, comprising:

President: Timothy Pippett	**Secretary:** Dave Robson
Treasurer: Michael Moore	*plus a committee (to be confirmed)*

I would like to that the previous committee for their efforts and in particular Derecke Palmer, Mark Russell and Greg Skilbeck who held the executive positions.

At the AGM, Derecke Palmer gave us his comments entitled "Are These the End Days for the ASEG", I believe a shortened version of this will be forthcoming in *Preview*.

Regular monthly meetings will be held at the Rugby Club, down near Circular Quay, on the third Wednesday of each month. If you are in Sydney at this time, please give either Dave (ph. 9901 8342) or myself (ph. 9350 9288) and we would be only to happy to point you in the right direction.

The June meeting will be held on 18 June, the speaker will be Keeva Vozoff on 'Multi channel EM". The July meeting is planned to be a dinner (venue to be confirmed).

Timothy Pippett
NSW Branch President

ACT

On 14 May 1997 the ACT branch held a special meeting at AGSO.

The special guest speaker for the evening was Dr W.H. Campbell from the World Data Centre for Solar Terrestrial Physics, Colorado, USA. His seminar was titled "Where oh Where is the Magnetic Pole? Where oh Where Can it Be?"

Dr Campbell's seminar was well attended and (as suggested by the title) a humorous and insightful look into the many Earth magnetic pole locations. This review topic included:

- Problems with cartographical representations
- Spherical harmonic analysis and the IGRF
- Geomagnetic coordinates and model dipole poles
- Poles from an eccentric dipole model location
- Dip poles from IGRF and eccentric dipole models
- The secular drift of the Earth's magnetic poles
- Paleomagnetic virtual magnetic poles
- Dip poles from local measurements.

Tim Mackey
Hon. Secretary
ACT Branch ASEG

Western Australia

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Secretary:	Bob Groves (08) 9370 1273
Treasurer:	Andrew Foley (08) 9480 3232

People

John McDonald, Branch President, is promoting closer ties with the Society of Exploration Geophysicists of Japan [SEGJ] and suggesting reciprocal promotion of SEGJ Symposia and ASEG Conferences.

Technical

For the one month only, our technical meeting was re-located from The Celtic Club to the Witch's Cauldron Restaurant in Subiaco on Wednesday, 21 May. It was a night for the Oil Industry. The two scheduled Speakers were Adam Craig [WMC Resources Petroleum] and Matthew Lamont [Woodside].

Adam spoke of the geophysics used for the *Appraisal of the East Spar Gas Field*, while Matthew spoke of *Seismic Multiple Attenuation* with a story of *surface-related multiples* and an example from the offshore Perth Basin. This procedure is based on wavefield transformations as a pre-conditioning step prior to multiple removal.

In June, the prospective Speakers, Andrew Duncan and Will Featherstone, both have recent technical publications.

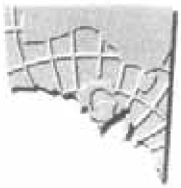
In *Preview* No. 67 [April 1997], Andrew Duncan [ElectroMagnetic Imaging Technology] et al, introduce SMARTem, a new, user-friendly, Transient Electro-Magnetic [TEM] receiver system which has been designed to recognise and remove TEM interference from cultural activities. Andrew Duncan will speak eloquently of this new instrumentation and the results it has produced.

In *Exploration Geophysics* Vol.28 No.s 1&2 [February 1997], Will Featherstone documented a case study of gravity and the use of the geoid in geophysics. We hope to hear more from Will… more of this Case Study over the North-West Shelf of Australia.

Interstate visitors are welcome to the WA Branch Technical Meetings. They are convened on the third Wednesday of each month at the Celtic Club, 48 Ord Street West Perth. Come and socialise at 6 pm, for a start at 6.30 pm.

P. Robert Groves
Branch Secretary

South Australia



It has been a fairly quiet time for the South Australian Branch of the ASEG in the last month or so; probably everyone is still recovering from the highly enjoyable national ASEG meeting in Sydney earlier in the year.

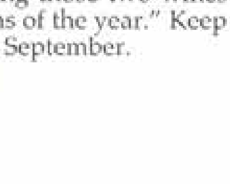
The last monthly meeting was held on 23 April 1997, which saw David Castillo, newly of University of Adelaide give a talk titled: "The San Andreas Fault Zone Drilling Project: Scientific Objectives and Technological Challenges." This talk was related to his recent work at the Lawrence Livermore National Laboratory, California, where he was involved in characterising the stress state, as well as the hydrological properties of that large fault system. David will be working with Richard Hillis at Adelaide Uni, where he will be examining crustal stress systems relevant to the oil and gas industry in Australia.

Our next meeting will be held in June when the topic will be Industry Highlights. Six (or so) local groups involved in geophysics will speak to the local ASEG on their latest and greatest.

SA's Wine Committee has swung into action, starting the long and arduous task of selecting those two wines that will become the "ASEG selections of the year." Keep your eye out for order forms around September.

Michael Hatch
Branch Preview Scribe

Victoria



The Victorian Branch held its Annual General meeting on 27 May, thanked the out-going committee and welcomed a new committee. The AGM guest speaker was Andrew Hugill of RTZ-CRA Research and Development who spoke on the development of the CG3 Autograv gravity meter, the instrument that has revolutionaised gravity acquisition. Andrew's talk on his invention (developed by Scintrex to a commercial meter) attracted much interest and discussion from old and new gravity people, including particularly Paul St John.

Sundar Sarma was presented with an SEG Silver Anniversary Certificate for 25 years membership. Congratulations Sundar!

The Branch has been relatively inactive of late but all that is to change with meetings planned for the rest of 1997. Joe Cucuzza is speaking in June on the effects of industry restructuring on cooperative geophysical research. July meeting is yet to be confirmed; August meeting will be Bob Sneider, Esso Distinguished Lecturer, on the impact of geophysics on improving recovery from marginal oil fields; September meeting sees the AG speaker on the issue of registration of geoscientists.

For October we are planning for a joint GSA/ASEG Slewing Symposium on integrated approaches to geological mapping, focusing on the impact of modern geophysics in mapping in South East Australia.

The new Committee are:

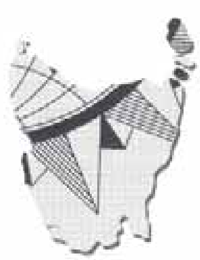
President:	Geoff Pettifer (03) 5133 9511
Vice-President:	David Boothroyd (03) 9412 5685
Secretary:	David Gamble (03) 9684 4925
Treasurer:	Mark Dransfield (03) 230 1261
Committee:	Shanti Rajagopalan (03) 9230 1240
	Geoff Dunn (03) 9478 3415
	Suzanne Haydon (03) 9412 7843
	Ciaran Lavan (03) 9412 5676
	Trevor Lobo (03) 9799 2192
	Paul McDonald (03) 9412 7866
	Ron Palmer (03) 9863 5208.

Any of the Committee would welcome ideas or feedback on Branch activities. The Tasmanian Conference Organising Committee is also hard at work and still needs volunteers to campaign and help with aspects of the Conference. Please contact Shanti, Geoff Pettifer, Dave Gamble or Suzanne Haydon if interested.

We look forward to an invigorated Branch under our new President.

Geoff Pettifer,
Vice-President

Tasmania



On 2nd June, after record terms in office, Bob Richardson and David Leaman retired as President and Secretary/Treasurer, respectively, and have been replaced by Michael Roach (University of Tasmania) and Jonathan Knight (J.M. Knight and Associates Pty Ltd). Bob and David cannot remember when they started, so we are confident that they have held office longer than any other Branch office bearers ever did!

The Tasmanian Branch will co-host the 13th Conference with the Victorian Branch in November 1998, at the Wrest Point Convention Centre in Hobart. It sounds a long way off, but time runs out fast, so preparations are well under way to ensure that this conference and associated social and technical events are a great success.

Jonathan Knight
Branch Secretary

Letters to the Editor

The following is an edited version (by Mike Shalley) of a letter from Ned Clark (Ark Associates pty ltd) in response to the article "Line Kilometres to Hectares – Towards a Magnetic Photograph" by Steve Mudge (Preview #63). Ned's company is involved in the production of unmanned air vehicles which may supply the technology that Steve is anticipating. We have to apologise for both the late and limited publication of parts of the original letter as dictated by space limitations. Every effort has been made to extract the essence of the original and we are aware that this is a fast moving technology which may be quickly dated.

Dear Sir,

Thanks greatly for the copy of *Preview* which I found stimulating and instructive. Of special interest was the article by Steve Mudge of RGC Exploration Pty Ltd (Excitations).

Over the last twelve months there has been a confluence of need and readily available off the shelf technology, Satellite Communications and differential GPS being perhaps the most dramatic entrants. Need, as accepted in this context, is the primary driving force in all fields of endeavour and here in Australia our primary industries have long understood that. Specific to the mineral sector, exploration, production and environmental impact have undergone huge advances and will continue to do so.

Ark Associates is presently developing a high duration drone (unmanned air vehicle) with a total lift capacity of 9 kg that will initially offer remote/programmed control within line of sight using real time telemetry. Within twelve months we expect development of the ability to fly out of sight at speeds of up to 100 km/hr and altitudes of 6000m or better for six to twelve hours duration. Applications of the aircraft include magnetometer surveys, high definition real time imagery, environmental monitoring and many others.

Ark is also involved in the development of softwing platforms (presently manned) with high lift capacity (approx. 300 kg in present configurations) and with up to 1lw power take off for survey systems. Straight and level flight to within 0.5m lateral displacement at tree top height whilst making 35 km/hr is achievable. The Softwing will, in the near future, will be reconfigurable to a canard fixed wing so that the flight parameters can be altered, if required, to 25/75 km/hr. It will also be simple to fly the Softwing unmanned with the release of 100 kg payload potential which will allow heavier payloads or extended duration. Electromagnetic surveys may be the first to benefit from this system. The application of systems like the Softwing will cut costs previously encountered with fixed and rotary wing aircraft by as much as 80%.

Comparison of costs of lightweight airframes between Australia and Europe suggest that Australia is well placed to take advantage of this developing technology. We must also be aware of the regulatory environment in which the systems will operate. In Australia regulatory authorities have recognised the need for prompt action and it is hoped that the very near future will show this country to have defined safe working standards that will engender the industry's growth.

Ned Clark
Ark Associates pty ltd. (Nov. 1996)

Response to 'Letter to the Editor' from Ned Clark, 27 November 1996

Dear Sir

Ned Clark's letter of 27 November 1996 describing various applications for unmanned airborne vehicles (drones) is of great interest. Ned is involved in the development of drones and his comments prompt a few more ideas on the matter of geophysical drones.

I have no experience with this technology so the only comment I would venture to make is that the aerodynamic conditions under which most aerial geophysical surveys are conducted, for prospecting applications, are quite different to those that the Boeing 747 jet airliner, one of the drone applications Ned referred to, operates in. The air is pretty turbulent at the 25 to 100 metre terrain clearances the exploration industry conducts its airborne operations so a low-flying drone would need to have special aerodynamic capabilities to avoid unscheduled ground contact.

Ned's comment about the legislation and control of drones being in a state of flux in Australia and overseas is an important point. It seems that aviation parameters of the various drone applications need to be defined so as to help guide legislators in formulating operating standards for these devices.

I look forward to seeing the results of current investigations into the application of this technology to exploration geophysics.

Yours,
Stephen Mudge

Are These the End Days For the ASEG

By Derecke Palmer, Senior Lecturer in Geophysics
The University of New South Wales
Telephone: 02 - 9385 4275 Facsimile: 02 - 9385 5935
E-mail: d.palmer@unsw.edu.au

A highlight of the 12th ASEG Conference and Exhibition held recently at Darling Harbour in Sydney, was the address by Professor Ian Plimer at the Conference Dinner. He described the multitude of predictions over hundreds of years for the end of the earth. It was an entertaining performance and most of the audience thoroughly enjoyed his ridiculing of committed but perhaps misguided zealots.

In spite of the poor record of these doomsday prophets, I will risk my remaining credibility, and make two predictions about the inexorable demise of the ASEG. The first is that the ASEG has reached its zenith and is now on the downhill run, while the second is that it will take about ten years for the full impact of this downturn to become apparent. I will attempt to provide sufficient evidence to support this rather pessimistic view, which hopefully does not qualify me for the Henny Penny Award (The sky is falling down!) at the next ASEG Conference in Hobart.

My position is based on three major assertions. The first is that there has been a decline in the number and calibre of new earth sciences graduates from the universities for more than a decade. The second is that the age profile of our membership is skewed towards the older generation, many of whom graduated around the boom times in the 1960s and 1970s, and large numbers will eventually leave the profession in the next decade. The third is that the level of technical innovation has shown a small but significant decline which is more likely to accelerate.

Continuing Decline In Exploration Geophysics In The Universities

Exploration geophysics in the universities is facing major problems. With the exception of a few institutions, student numbers and calibre are generally falling. In order to maintain the prescribed staff-to-student ratios, the numbers of lecturers are also falling. This process has been going on for some time, with the result that in many cases, there is now only one geophysicist on staff. Academic geophysicists are therefore being faced with the added difficulty of teaching outside of their fields of specialisation (e.g. a seismic expert being expected to be also erudite in quite different fields such as electromagnetic methods). Not only does the sheer volume of teaching in these situations leave little time for other activities such as research, but in many cases, there is also the lack of a critical mass for effective research to be undertaken.

The Australian Research Council (ARC), which provides most of the government funds for research within the universities, is very concerned about the situation. Despite the ARC designating exploration geophysics as a priority area for the last three years, there has not been a significant improvement in either the quantity or the quality of applications for research funds. A three day seminar was held near Perth in 1966 in order to develop strategies to address the situation, and a position paper was prepared and published in Preview for discussion at the recent ASEG Conference & Exhibition at Darling Harbour. Regrettably, widespread interest or comment has not occurred.

Some of those who are well connected with the ARC, are strongly advocating collaborative research with industry. On the surface, this looks to be an attractive option, with equal contributions from both parties. However, most universities have superseded computing and field equipment (for example, I still use one of the first Austral proton precession magnetometers!), as well as a limited range of students to carry out the research, and so the partnership tends to become a little one sided. Industry also expects to have results in a short time-frame (commonly a few weeks), while projects for student theses typically extend over periods of several years.

Furthermore, in many research groups, postgraduates are recruited from overseas, and it is not uncommon for them to outnumber the indigenous students. This is an indication that our local exploration geophysics industry is not self sustaining, because the research students usually return to their countries upon the completion of their degrees, and the full benefit of their newly acquired expertise is not realised by the Australian exploration industry. New graduates and post graduates provide new energy, new knowledge, and new approaches, and they make a significant contribution to the technical and managerial regeneration of our profession. A reduction in their numbers slows this renewal process.

An Ageing Membership

The second item of evidence to consider is the demographics of our society. It is my contention that the age profile of our membership is skewed towards the senior citizen end of the community. In the next ten years, large numbers of our members who graduated in the boom years in the 1960s and 1970s will contemplate retirement and adopt a less frenetic life style. Accordingly, a significant proportion of our technical and managerial expertise will cease to be involved in the day to day activities of the exploration industry and in many cases, they will not have been passed on their knowledge to the newer graduates.

Declining Technical Innovation

It is my contention that the best ASEG conferences were in 1992 (Surfers Paradise), and in 1994 (Perth), when there was a strong group of talented recent graduates. This is not an indictment of the efforts of our long-suffering technical chairmen at subsequent conferences. Rather, it is a reflection of the quality of material with which they had to work. People are generally most productive in the early years of their careers, and at those times, the science is advanced, or at least challenged, through their innovative ideas. However, with some of our aging profession, the bright ideas do not come quite so readily. At the most recent Sydney ASEG conference for example, the major contributors were the more senior members of the profession, particularly the researchers from government organisations. While these contributions are most welcome, I for one am concerned about the numbers of the younger members available to become future leaders of the geophysics profession.

Is this really a problem? Should we let the market forces, so revered by the economic rationalists, take their natural course? In past years, Australia had a multiplicity of banks, newspapers, motor vehicle manufacturers, etc, which have now virtually been reduced to oligopolies. Do we want the same situation with just two geophysics departments - one on either side of the continent - to produce all of our graduates? Furthermore, do we want a petroleum, mineral, or solid earth bias imparted to these graduates? As an alternative, should Australia simply import its geophysicists from Europe and North America? Given the unique geology and weathering characteristics of this continent, what would be the effects of the Americanisation of our petroleum exploration or the Canadianisation of our mineral exploration programs?

What Can Be Done To Reverse These Trends?

One obvious solution is to attract more undergraduate students. The advantages of this strategy are that increased students would at least reduce the pressures on academic staff (and may even justify increases), and that a larger student base would result in improvements in the calibre of graduates for industry and research. It is an obvious strategy, and any sportsman would draw the analogy of supporting the junior levels in order to generate an appropriate elite.

Unfortunately, most of our attempts at attracting students to undergraduate courses in the earth sciences, have been less than major successes. Our profession is still largely invisible to most of the community (as are the other branches of the geoscience profession), or it has negative associations with popular misconceptions of the earth resource industries. It is a rather sobering experience to attend a careers market, only to realise that irrespective of the merits of our profession, it is not treated as a valid career option by the vast majority of high school students.

However, the two student days at the 1995 Adelaide and 1997 Sydney Conferences were outstanding success. Although there is no substitute for the outstanding live performances of Mike Smith and Nick Sheard, nevertheless, it should be possible to adapt their contributions to a suitable web page format, so that all Australian students can gain some benefit from our efforts.

A Broader Perspective Of The Value Of A Geophysics Degree

I consider one of the most important aspect to be addressed is a broader perspective of the value of a geophysics degree, not only in terms of the earth resource industry requirements, but also in terms of the students' and community needs. The students' needs include sound employment opportunities, together with career and life style alternatives. While there are careers available in the urban, environmental and groundwater areas of geophysics, as well as in mineral and petroleum exploration, students are often all too unaware of these diverse career and associated life style options from which they may ultimately be able to choose.

In addition to its geoscience applications, there is a need to broaden the view on other careers which are possible with a geophysics degree. The geophysics undergraduate course at UNSW for example, includes a mix of mathematics, physics, computing, geology, as well as geophysics subjects. This course provides an excellent general physical science degree, suitable for careers in teaching, computing, and many other areas of the physical sciences and engineering, as well as for geophysics. As such, it offers the graduate, genuine career flexibility upon graduation, as well as a firm basis for any changes in career path at a later date.

It is important to recognise this versatility of geophysics courses, because some members of the profession are concerned that there are simply not enough job vacancies to accommodate a full quota of graduates from all of our universities, if such an expansion were to take place. Such concern for employment prospects however, is not shared by many other currently fashionable professions. For example, almost as many solicitors graduate each year as are in full time employment!

Although this discussion has focussed on the problems at the university level, the real problems begin within the high schools. The falling numbers of geophysics students are really a harbinger of a coming crisis with science in general. Recent surveys have shown an average drop in high school science enrolments of about 18% across Australia over the last six years. This situation has been attributed to a drop in the number of graduates capable of teaching the physical sciences. A strong case can be made for the promotion of the geophysics and the geochemistry degrees as also being suitable for teaching careers in the physical sciences at secondary level. Not only could this strategy contribute to the rejuvenation of science within the high schools, but it might also help redress widespread community misconceptions of the earth resource industries.

Conclusions

Peter Drucker, who claims to have invented the science of management, stated that the only unique resource of business is knowledge, whether it be managerial, financial, marketing or technical knowledge. All other resources, such as equipment, finance, labour, etc., can be purchased readily. It is clear that the current community trends away from science and technology, together with governments' conversions to the new panacea of economic rationalism, have accelerated an unchecked and disproportionate swing towards the managerial and financial aspects of economic growth. Australia must act quickly through appropriate policies, to maintain and advance the science and technology base which has facilitated our earth resource industries achieving world's best practice. It must start with the need to ensure sufficient numbers of high quality graduates to meet future requirements. To do otherwise will be a failure of leadership!

This letter was previously published in the AIG Newsletter as "Are these the End Day for Australian Geophysics?" It was reduced in length for publication in ***Preview****.*

No doubt many readers will have an opinion which I look forward to printing in the next issue.

Ed.

Australian Scientist Honoured

"Australian geophysicist **Professor Kurt Lambeck** has won one of the world's most prestigious awards for achievement in science – the European Union of Geosciences Alfred Wegener Medal.

The professor of geophysics at the Australian National University is the first Australian win the medal. His work is on 'glacial rebound' which studies how the sea responds to changing levels, its impact on civilisations and the future."

(Taken from the "Australian")

Excitations

Stephen Mudge
RGC Exploration Pty Ltd

Forces, Responses and Methodologies: Some Fundamental Concepts in Geophysics

Techniques of exploration geophysics are closely tied to developments in mathematics, physics, computing and electronics as these disciplines provide geophysicists with the tools to measure and analyse a wide variety of the Earth's physical properties. They allow us to see the Earth through different eyes - the geologist can get a different view of the Earth. Concurrent with these developments, our understanding of the Earth's geological mechanisms has improved and this has directed the types of geophysical measurements, and their resolution, needed for detecting and mapping the various geological structures.

I present here an overview of some of the fundamental concepts of geophysics such as, 'forcing function', 'response function' and 'measurement methodology' all of which are often overlooked when making geophysical measurements.

Introduction

Geophysics = (maths + physics + rocks)
x (electronics + computing).

This simple mathematical equation is a fairly exact description of the science of geophysics. The sum of physics, mathematics and geology (the rocks) are the fundamental ingredients of the science and, electronics and computers simply multiply the way in which these ingredients are used to understand the physical structure of the Earth. In exploration we apply this equation to geological mapping and target detection - to find mineral deposits, petroleum reservoirs, supplies of ground water and to investigate engineering problems.

In geophysics we make measurements of some physical property of the Earth, be it electrical resistivity, magnetic susceptibility, density or a variety of other physical parameters. These phenomena are generally observed through the effects they have on some physical force field. For example, we map changes in rock density by measuring acceleration due to the Earth's gravity field - by conducting a gravity survey. How we make these measurements and how much information we obtain from them, and the complexity of the measurement and data analysis process, is largely dependant on how the forcing function, ie the induced field, excites the Earth to produce a measurable response function.

Passive and Active Methods

The concept of a 'forcing function' sounds rather abstract, but this is of fundamental importance in understanding the techniques of exploration geophysics. The methods of measuring the physical properties of the Earth can be divided into two quite distinct groups depending how the 'forcing function' is applied to the Earth. Figure 1 shows the Earth and a forcing function 'F' applied to it, and a response function 'f' produced by some physical property of the Earth that causes an effect on the forcing function 'F'. For the case where 'F' is supplied by nature, I have classified the geophysical methods as PASSIVE, and for the case where the function is supplied by artificial means, ie. by the geophysicist, I have classified the methods as ACTIVE.

The PASSIVE group shows the various force fields that nature applies to the Earth. The list includes the gravity field, which is measured to map variations in rock density, the magnetic field, which is measured to map variations in magnetic susceptibility, radiometrics for mapping radioactivity, natural electro-chemical self potentials (natural voltages) which are measured to map oxidising sulphides and hydraulic streaming potentials, and electrical currents induced in the Earth's crust by ionospheric activity that can be measured to map the electrical resistivity of the rocks. We have no control over these fields, their presence is a fact of nature. We can also include the tidal force in this group, but we don't seem to measure this directly for exploration purposes (why not?).

The ACTIVE group comprises a greater number of methods than the PASSIVE group. It includes seismology, for measuring and mapping the acoustic impedance of rocks, and electrical resistivity, induced polarisation and electromagnetics for mapping electrical properties such as resistivity and conductivity. This group offers the geophysicist an opportunity to control the way in which the forcing function 'F' is applied to the Earth and also to control the properties of 'F'. For example, when conducting electrical surveys, the direction, amplitude and shape of the applied electric field can all be controlled by the geophysicist. The geophysicist also has greater choice in the way the response function 'f' is measured, ie the electrode array/loop size and orientation, and data sampling intervals are all under the control of the geophysicist. Consequently, survey design, response measurement and the analysis of the observed data are generally more complex for the ACTIVE methods. However this group promises, and generally offers, more information about the Earth.

On the other hand, the PASSIVE methods give the geophysicist no opportunity of controlling 'F', we are entirely in the hands of nature and consequently we obtain limited information about the Earth. However the measurement techniques and data analysis are generally simpler than those of the ACTIVE methods but, importantly, the forcing field is always present in the PASSIVE methods. So for the PASSIVE group we don't have to concern ourselves with the complex problems of generating and applying the forcing function 'F'.

Geophysical Methodology

Figure 2 shows the geophysical methodology or measurement process. In accordance with some rigorously defined mathematical description (the mathematics) of some physical phenomena (the physics) of the Earth (the rocks) an instrument (the electronics) is used to make a series of measurements of the response field 'f'. Often it is necessary to mathematically correct the observed data for various effects caused by the way in which the forcing function 'F' is applied to the Earth, and also to correct for the effects that the measurement system may have on the measured response. This is known as 'reducing the data' to a form that is free from these distortions, ie. the data is transformed into a form that more accurately reveals the true nature of the Earth's response.

Following the DATA REDUCTION stage, more mathematics can be applied to enhance the reduced data in order to resolve various characteristics of the measured field: so as to more accurately depict the Earth's physical parameter being investigated. The data enhancement stage allows for the application of a variety of mathematical filtering techniques, this is referred to as DATA FILTERING. Note in Figure 2 the optional repetition of the enhancement (filtering) process - a wide variety of filters are available for all types of geophysical data.

The geophysicist's ability to make large numbers of measurements with high precision, and to reduce, process and present the measurements in a multiplicity of forms, and to build complex 3-dimensional models of the Earth's physical structure can be attributed directly to the availability of powerful mathematical and computer resources at every step of the measurement process.

Geophysical Techniques

Research and development in the component disciplines of geophysics has provided geophysicists with increasing ability to measure, process and present data in many ways. Modern instrumentation combined with more than 50 years of survey experience has given the exploration industry a wide variety of large area, high resolution survey techniques for the measurement of most of the Earth's physical parameters. For example, GPS controlled high resolution aeromagnetics, three-component airborne EM, 3D seismology and airborne radiometrics to name just a few. Mathematical analysis, some of it very complex, has provided us with sophisticated mathematical tools for accurately reducing survey data. Some examples are, digital terrain models for correcting gravity data, micro-levelling of aeromagnetic data and radon gas correction of radiometrics. The mathematics has also provided tools for processing and enhancing data, for example, reduction-to-pole filters for aeromagnetics, depth imaging of EM data etc.

During the 1980's, developments in computer technology produced imaging techniques. This technology strongly influenced the acceptance of geophysical techniques by the exploration industry.

Most geophysical methods can be applied from an airborne platform in the form of an airborne survey to rapidly cover large areas of ground. I like to refer to this mode of operation as regional or 'broad acre' geophysics, it is the lowest unit-cost surveying mode. The ground survey mode, which is often confined to smaller prospect scale areas, provides higher resolution than the airborne methods simply because the measurement system is closer to the rocks. Surveys are slower to conduct and are of higher unit-cost.

Instruments and survey procedures have been modified over time so that they can be lowered into drill holes to 'probe' the ground. These 'downhole' methods provide the highest resolution of buried structures, but

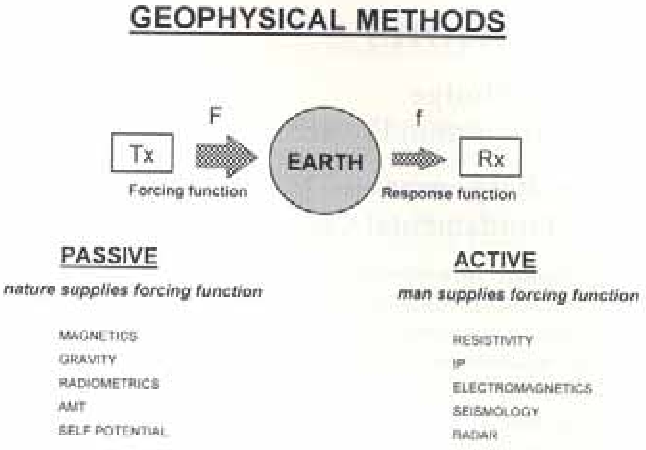


Figure 1. The 'forcing function' and the Earth's 'response function'. The 'forcing function' can be classified as either ACTIVE or PASSIVE depending on its origin.

are entirely dependant upon the presence of an open drillhole. They are also the highest unit-cost methods in geophysics but they are capable of producing a high resolution 3D view of the Earth.

There is another very important branch of geophysics that forms the fundamental basis of the science. This is the large and often complex science of petrophysics: the laboratory measurement of physical properties of rock specimens. It is petrophysics that provides the geological understanding of geophysical measurements. Some of these measurement techniques have been adopted to downhole mode for in-situ measurement of the physical properties. Downhole techniques provide a more accurate measurement of physical properties that are sometimes distorted in laboratory analysis due to the absence of important physical effects of the in-ground environment.

The measurement of some petrophysical properties are based on the concept of measuring the response of a forcing function applied to the rock specimen, eg electrical conductivity and resistivity are measured with the application of an external electric field. Other physical properties are actually measured by observing the effect (the response function) the rock specimen has on an external measurement system, hence the rock becomes the forcing function. An example is the determination of the density of a rock specimen by measuring the volume of water displaced from a vessel when the rock is immersed. In this case the sensor is the device for measuring the volume of water displaced and from this measurement the density of the rock specimen can be calculated.

Conclusions

The future for exploration geophysics is exciting. Developments in electronics, computers, physics, mathematics and geology, and above all our desire to learn more about the Earth, ensure the ever-increasing use of geophysics in future exploration programs. Of course, whilst there are forcing functions acting on the Earth and associated response functions to measure, we'll have plenty of opportunities to adopt new developments in the component disciplines of geophysics to learn more about the Earth.

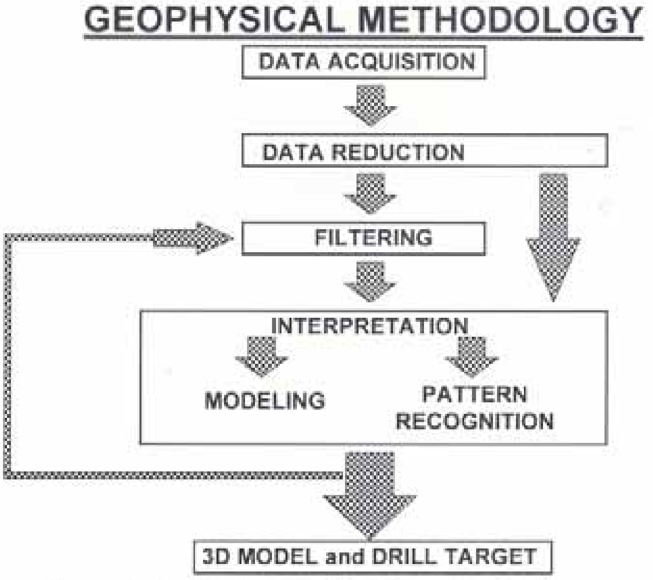


Figure 2. The geophysical methodology or measurement process. The filtering of data is an optional part of the measurement process.

Naturally, the training of geophysicists must ensure that they have a good knowledge (the response function!) of the various component disciplines of geophysics to ensure the effective application of mathematics, physics, geology, electronics and computing (ie geophysics) for the discovery (the driving-force function!) of new occurrences of natural resources.

Happy Excitations!

The Mt Todd Map Kit

The Australian Geological Survey Organisation (AGSO) has released a new Geoscience Education Kit for use in Australian High Schools. The kit has been sponsored by a number of public and private sector groups including the Australian Geoscience Council Incorporated (AGC), Australian Surveying and Land Information Group (AUSLIG) and Pegasus Gold Australia Pty Ltd. The aim of the kit is to support the new national science curriculum using the Mt Todd Geological and Topographic map sheets as the primary data source. The project has specifically chosen real map data for authenticity and Mt Todd offers relatively simple geology on which to base the student and teacher tasks outlined in the kit. The kit includes gold ore samples from the Batman Deposit of the Mt Todd Gold Mine, 15 copies of the geological and topographic maps, overhead projector sheets and plastic map cards scaled to the 1:75,000 sheet.

The educational philosophy behind the kit is "scenario-based activities" and it embraces a wide range of teacher and student tasks. The ages targeted by the kit range from Year 9 to 12 but some of the content would be applicable to the Year 8 syllabus. Basic map reading skills, in particular, are encouraged by a variety of student activities ranging from choosing a site for a new adventure sports location to planning a four-wheel drive expedition; Latitude and longitude of prospective sites must be measured and topographic relief determined as part of the exercises. These tasks present 'real life' applications for maps and, in doing so, educate students about map-reading in a stimulating fashion. Older students also may become involved in a simulated police forensic investigation following the discovery of a prospector's body: the investigators are required to determine both the prior movements of the victim and a likely motive in order to confirm foul play. This exercise relies heavily on geological information gleaned from the map and skills in deduction to answer the student activity sheets.

The geological section of the Mt Todd Map Kit contains considerable information. Diagrams relating to structure are concise and a glossary is included to allow the kit to stand alone in the absence of other resources. The focus on Year 11 and 12 is apparent by the complexity of concepts but knowledge of the abilities of younger classes would allow a teacher to filter this data to target the appropriate level of comprehension. Cross sections, unconformities and the concepts of superposition are presented as well as a brief history of the economic geology of the region. The more human side of the region is presented in the form of a discussion about the life of a field geologist and the Jarwoyn Association has contributed an Aboriginal perspective via their interpretation about the significant events which formed the land. The Mt Todd region contains several culturally significant sites as well as a quarry from which materials for spears and stone axes were obtained. Billabongs and rock pools were inevitably of concern to nomadic people and their existence was documented in legends for oral transmission to succeeding generations. The maps again may be used to determine why such features were formed and add to an understanding of the natural environment.

The Mt Todd Map Kit retails for $ 44.00 and represents excellent value in view of current map prices. Fifteen map sheets are provided with both a geological and topographic map per sheet. Samples of gold ore have been included and the samples viewed exhibited sulphides and boxworks indicative of weathered gossan. The grade of gold (1.05g/ tonne) is unlikely to promote theft and their survival in the kit should be assured for some time! The plastic map cards are clearly marked and easy to read - they become extremely important due the atypical scale of the maps (1:75,000). The Teacher's guide has an answer section for convenience and overhead transparencies for class demonstrations have been enclosed. The guide has been bound with spiral wire to facilitate photocopying, an essential feature of such teaching resources - reproduction of the student activities is authorised by the publisher and pages have been laid out with reproduction in mind.

In summary the Mt Todd Map Kit combines geology with a range of activities which focus on map reading skills and interpretation. Student tasks focus on 'real world' situations and span the High School educational spectrum from Year 9 to 12. The price is extremely attractive for a resource which will occupy an entire class and its use in secondary schools is recommended.

W R Fawcett

I asked Bill Fawcett to review this kit. Bill is both an explorationist and a former teacher. Ed.

Conferences

Honorary Memberships Awarded at ASEG 12th Conference

Honorary membership is awarded to those who have made a significant contribution to the profession of exploration geophysics. There were two recipients, namely Prof David Boyd and Robert ("Bob") Smith. The following citations were written by the editor from material supplied in the original nominations to the HAC

Robert ("Bob") J. Smith

Bob graduated from the University of Melbourne with an Honours degree in Physics. He began his career with the Bureau of Mineral Resources where he worked from 1961-1968. He joined McPhar early in the nickel boom where he spent a year living out of the famous Palace Hotel in Kalgoorlie during an exciting time in Australia's mineral exploration history. In 1974 after the boom he worked as a consultant in Adelaide where he began his teaching career. Since 1977 he has worked with CRA Exploration where he is the Chief Geophysicist.

Bob Smith receiving his award from Henk van Paridon.

Bob's extensive involvement with the Society has included his serving as the Federal President for two terms and also as SA Branch President and most importantly his establishment of the ASEG Research Foundation. The work of this foundation is highly successful and has quickly proved to be one of the Society's important achievements. Through his extensive international travel Bob has acted as a superb ambassador for both the Society and for Australian geophysics. He is held in high regard in many countries including the United States, Canada, china and Russia to name a few. Bob contributed substantially to the development of mechanisms for social contact between geophysicists scattered throughout our broad nation. He has also helped to maintain good relations with SEG .

Bob's involvement with the profession in general has included his role as a foundation lecturer with Prof David Boyd in the very successful AMF courses "Geophysics for Geologists". He has also been an occasional lecturer at the University of Adelaide. As Chief Geophysicist of the largest mineral exploration company in Australia he has supervised a great number of exploration geophysicists. By virtue of his travel he has brought back to Australia many new ideas and research developments to be applied in this country. His innovative use of image processing for visualisation of gravity and magnetic data typifies Bob's sustained efforts to communicate our science more effectively to geologists and to managers.

Professor David Boyd

David Boyd graduated with a degree in geology and physics from the University of Glasgow in 1946 and went on to become a geophysics lecturer there from 1946 to 1955. From 1955 to 1958 he worked as Principal Geologist and Geophysicist for John Taylor and Sons, Mining Engineers covering the United Kingdom, Eire, Cyprus and India. As Chief Geophysicist of Hunting Surveys from 1958 to 1968 David was responsible for the application of geophysics to mineral exploration in Africa, the Middle East, S.E. Asia and Australia. He arrived in Adelaide in 1969 and became professor of Geophysics, one of the few successful transitions from industry to academia. David retired in 1991 and was made Emeritus Professor by the University of Adelaide.

David Boyd receiving his award from Henk van Paridon.

In many respects David pioneered the teaching of true "exploration geophysics" as he integrated a good understanding of practical economic geology with the

L to R: NSW PESA President Dennis Morton, SEG President Fred Hilterman, ASEG President Henk van Paridon, Conference Co-Chairmen Wes Jamieson, Roger Henderson.

interpretation of airborne magnetics. Many eminent Australian geophysicists, and many from other countries also, owe their start in our profession to teaching and encouragement by David Boyd. David is widely known around the world and students have flocked to Adelaide to work with him. His support of their studies has built bridges between Australia and many other countries in our region.

David worked with Bob Smith presenting the well known AMF course "Geophysics for Geologists". This course was extremely well supported and has contributed to the high level of appreciation of geophysics among Australian exploration geologists and exploration managers. Australian mineral exploration makes very widespread use of geophysics and, in some respects, leads the world. Certainly our local contractors offer some of the best aeromagnetic data in the world and it's application and interpretation has it's roots in David's teaching.

David has always emphasised and indeed insisted that the geological component in any geophysical endeavour is the most crucial. The approach to being a geophysicist that he has practised and engendered in his students has been an important element in making Australian hard rock geoscience arguably the world's leader.

Don Emerson receiving his ASEG Gold Medal from Henk van Paridon at the 12th ASEG Conference and Exhibition.

Effects of Water Salinity and Saturation on the Electrical Resistivity of Clays

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Introduction

What can resistivity data tell us about clayey terrains? Clays are quite common in Australian weathered and alluviated areas. Clays are conductive solids and knowledge of their likely resistivities in the regolith is important for mineral exploration, groundwater, engineering and environmental investigations. However, little *detailed* information is available on their electrical characteristics or indeed other characteristics such as densities and velocities.

Clays are plastic, very porous and fine grained (<4μ) materials with active platy particle surfaces exhibiting cation and anion ion exchange capacities. Other materials when finely ground do not exhibit clays' special properties. Sodium montmorillonite, a common member of the smectite group, is the dominant component of bentonite, a swelling clay with a cation exchange capacity typically around 100meq/100g. Such a clay may form from the weathering of mafic volcanics. Because of broken bonds and unbalanced lattice charges this clay has a considerable cation population and it also has high adsorption capacity for electrolyte. A relatively large number of cations may dissociate at the charged clay particle-water interface, so a montmorillinote's resistivity is relatively low. In comparison, kaolinite is relatively inert with a moderate adsorption capacity and a dearth of cations, so its resistivity tends to be higher. It is often found as a weathering product of felsics. Anions may be involved in clay conduction too, but this has been less studied. For details on clay mineralogy, structure and properties see Grim (1968) and Deer, Howie & Zussman (1992).

Properly processed data from formations studied by borehole logging, resistivity probing or electromagnetic sounding provide resistivities that depend on water saturation, water salinity, temperature, porosity (and its structure) and the presence or absence of conductive solids. For the clays we are particularly interested in the effects of salinity on resistivity, so it is necessary to appreciate that the primary resistivity of a water passing into the pores may be diminished by secondary effects such as the solution of minerals in the pores or the contribution of exchangeable ions. Conversely, water extracted from a formation may show an observed resistivity greater than that inferred to occur in the pores.

In this article we look at some laboratory resistivity data for two common clays - kaolinite and montmorillonite (in bentonite) and make some observations on the effects of salinity and water saturation and explore the use of the EC 1:5 measurement in weathered zone studies.

Agricultural scientists have long employed electrical conductivity measurements to gauge soil condition for crop suitability. The very useful EC 1:5 test is one simple measure. It entails measuring the conductivity of the supernatant liquid resulting from shaking 20g of finely ground test material with 100cm^3 of deionised water for 30 minutes (see Loveday, 1974). This test is ideal for qualitatively or semi quantitatively estimating the mobile soluble salt content and hence the local salinity environment of the material studied. An arbitrary scale of EC 1:5 readings (μS/cm corrected to 25°C) is: low - up to 100, medium - 101 to 500, high 501 to 1000, very high - 1001 to 5000, extremely high - over 5000 [100μS/cm corresponds to a water resistivity (ρ_w) of 100 ohm m].

Mobile salt does not necessarily comprise only NaCl and an EC 1:5 reading is not the ion exchange capacity. Ion exchange is a mechanism whereby ions in solution replace ions residing on the surfaces of fine grained materials with the direction of exchange being towards an equilibrium of solution and surface ions. However, depending on chemistry and mineralogy, weakly held exchange ions can go into solution and contribute to an EC 1:5 reading. EC 1:5 is not a new electrical variable in rock resistivity, but it does offer insight into the effective resistivity of water in place in the pore structure.

Test Materials

For the laboratory study a range of common materials were chosen for testing:

(i) a Hawkesbury River freshwater clean sand that was poorly sorted with angular to subrounded quartz grains averaging about 0.5mm diameter, this type of sand has a fairly high formation factor (e.g. see Wyllie et al, 1953) i.e. when saturated with a particular ρ_w it is more resistive than a well sorted sand with spherical grains;

(ii) a clean kaolinite from Georgia;

(iii) kaolinitic clays containing appreciable sand and silt (up to 30%) and minor amounts of montmorillonite and illite, one was the Londonderry Clay from west of Sydney with a cation exchange capacity of around 15meq/100g (probably owing to its montmorillonite content), and the other a white pottery clay from Victoria;

(iv) two bentonites comprising mainly sodium montmorillonite with cation exchange capacities of the order of 100meq/100g, one bentonite was from NSW and the other was from Wyoming.

A series of subsamples were prepared from the parent materials. Accordingly slight differences in texture (packing, porosity) were encountered from subsample to subsample. Porosities of the sand, kaolinites and bentonites were (relatively) moderate, high and very high, about 30, 45 to 50 and 60 to 65 percent respectively. Clay porosities are total porosities including clay bound water.

EC 1:5's were very low for the sand and Georgia kaolinite - around 30μS/cm, low to medium for the impure kaolinites - varying around 100μS/cm, and presumed moderate to high for the bentonites. The bentonites were very difficult to handle because of their huge water adsorption capacities and this also made it impossible to carry out conventional EC 1:5's as there was no supernatant fluid remaining after shaking. However, filtrates from the slurry/gel resulting from EC 1:20 tests gave readings of 640µS/cm and 1190µS/cm (25°C) for the NSW and Wyoming bentonites, respectively suggesting fairly salty material. For comparison, a NSW beach sand registered 745µS/cm in an EC 1:5 test.

Salinity

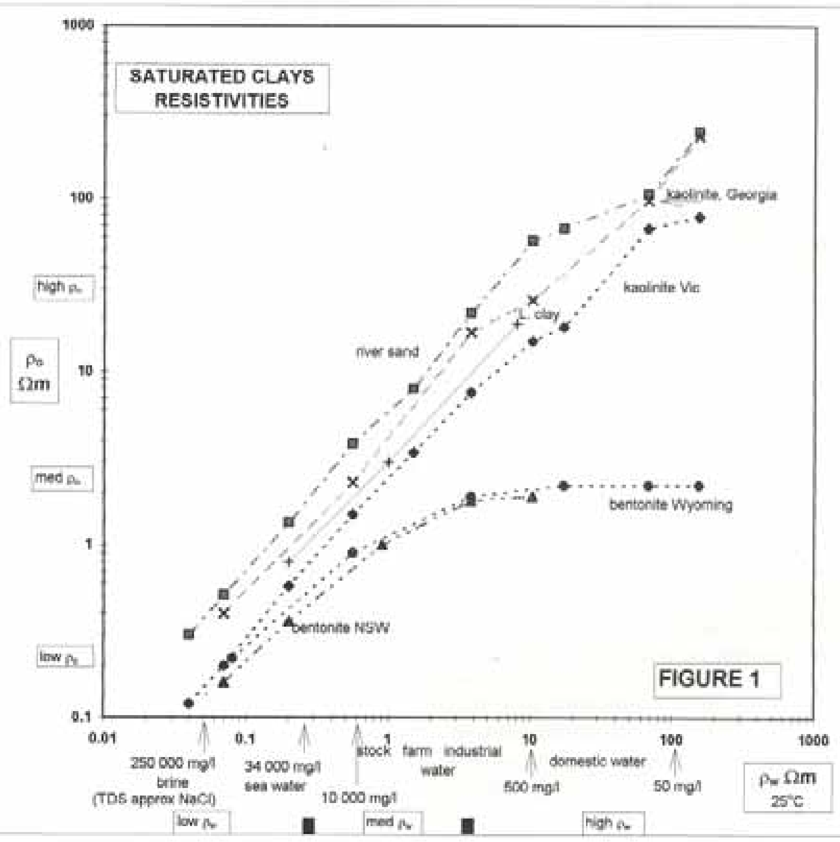
Clays have very low water yields, but their resistivities do depend on local salinity conditions. In an experimental study on the effects of salinity on clays the saturated resistivities (ρ_o) were determined with NaCl solution saturant resistivities (ρ_w) ranging from 0.04 to 150 ohm m (25°C). The results are given in the log-log plot of Figure 1 where arbitrary ρ_o and ρ_w categories (high-medium-low) are shown together with equivalent salinities.

The medium grained, clean, poorly sorted sand was included for comparison. It shows an expected ρ_o - ρ_w curve, with low ρ_w (highly saline), medium ρ_w (moderately saline) and high ρ_w (fresh)waters imparting a progression of low to high ρ_o's as would be expected from the Archie relationship $\rho_o = F\rho_w$ where F, the formation factor, is an inverse function of porosity. Archie (1942) determined resistivities of brine saturated sandstones with porosities ranging from 10 to 40 percent and saturant salinities ranging from 20 to 100g NaCl per litre. Here the formation factors are intrinsic. He did not use fresh waters and it is a popular misconception that Archie's extraordinarily simple equation applies in the fresh water domain - it does not. In fresh water, say in excess of 10 ohm m resistivity, the apparent formation factor diminishes (e.g. see the sand data of Beilla et al, 1983). This is caused by surface conduction acting through adsorbed water on pore walls. The effect can be seen in the river sand with the ρ_o trend breaking at ρ_w = 10 ohm m and then increasing more slowly with ρ_w. Nevertheless, the sand ρ_o's can be regarded as a reasonable indication of the saturant ρ_w if an accurate F can be established. The sand resistivity data are included as a relatively low porosity and resistive upper envelope for the clay data.

The kaolinites' ρ_o's also follow the sand trend but are less resistive. The Londonderry and pottery clays, despite their silt and sand contents, plot below the Georgia kaolinite. This is due to their mineralogy (montmorillonite content) and texture (porosity). Intriguingly, these three low cation exchange capacity kaolinites seem to follow the Archie type of ρ_o - ρ_w behaviour seen in the sand.

The bentonite displays a quite different behaviour. At high saturant salinities, or very low ρ_w, the bulk electrolyte dominates conduction in the pores and the merged trend is similar to the sand and kaolinites, but in a lower resistivity range as the bentonites were the most porous of the materials tested. However, with an increase in resistivity of the introduced saturant the significant exchangeable ion conduction mechanisms are no longer masked by electrolyte salinity and the bentonite ρ_o's change trend to level out at 2.2 ohm m. The bentonite/montmorillonite ρ_o - ρ_w behaviour documented here is similar to that reported by Patchett (1975) from theoretical considerations. He also cited some experimental data to support his equations.

In the case of the sand and kaolinites reasonable inferences may be made regarding a possible ρ_w and salinity range by considering ρ_o and taking into account



likely sandiness, porosity and clay purity. This cannot be done in montmorillonite terrain where the ρ_w cannot be reliably inferred from ρ_o, except at high salinities or with prior knowledge of the chemistry and mineralogy. Accordingly, estimates of salinity conditions from electrical or electromagnetic geophysical surveys require supplementary geological (especially mineralogy), and geophysical (e.g. magnetics to highlight likely mafic areas) and petrophysical information.

Furthermore, endeavours to use ρ_o to interpret the presence of zones of saturated sand, kaolinites or montmorillonites in the regolith really require prior information on ρ_w or salinity, and some petrophysical characterisation from control sites. From region to region or even locally, montmorillonites may vary in porosity and ion exchange capacity and so may be more resistive or less resistive than those measured here.

The information presented herein is not claimed to be definitive, but it is indicative and Figure 1 does broadly illustrate possible pitfalls in ρ_o interpretations. The recognition of clay types is important in efforts to assign the rock parentage of weathered assemblages (e.g. Stewart & Komprad, 1997). For kaolinitic, illitic and smectitic materials there seems to be a real need for more experimental data, corroborated interpretations and mathematical models along the lines developed in the petroleum industry to describe the electrical behaviour of shaley sands e.g. Worthington (1985).

Saturation

The data plots in Figure 1 are for saturated materials. In clay zones nearer the ground surface water saturation (S_w) may be less than 100 percent. In this case the material's resistivity is designated as ρ_t. The effects of desaturation in sands and sandstones can be estimated from the Archie resistivity index equation $\rho_t/\rho_o = S_w^{-n}$ where n has been generally accepted as having a value of around 2.0, for water saturations down to around 30 percent. When a sand dries out its resistivity increases as $1/S_w^2$, so for an S_w of 0.5, $\rho_t = 4\rho_o$. Keller's (1953) sandstone data showed an increase in the exponent at lower water saturations.

The Georgia kaolinite did not shrink much in slow evaporation and drying - about 13 percent from saturated to the oven dry (105°C) state, so resistivity measurements were made on specially prepared subsamples as they slowly dried in air to track the ρ_t - S_w behaviour.

The desaturation data in Figure 2 are for two Georgia kaolinite cores, one saturated with 3.8 and the other with 0.6 ohm m NaCl solution. The data show n values between 1.2 and 1.5 and averaging around n = 1.3, to an S_w of 30 percent. This implies a slower increase of resistivity for kaolinites than for sands as they dry out. For an S_w of 0.5 in the kaolinites, $\rho_t = 2.5\rho_o$. Experiments with fresher and saltier saturants were less well behaved but the data suggest that fresher saturants impart lower n values and saltier saturants result in higher n values than those for the kaolinite in Figure 2. Waxman & Thomas (1974) noted similar behaviour in shaly sandstone. The implication from the kaolinite's low n value is that the clay's porosity structure continues to hold continuous water paths more effectively than other rocks when S_w is decreased to quite low levels. Below an S_w of about 10 percent the water ceases to be linked and n increases substantially as water disappears. Diederix (1982) demonstrated a similar effect with measurements on beads with smooth and coarse textured surfaces.

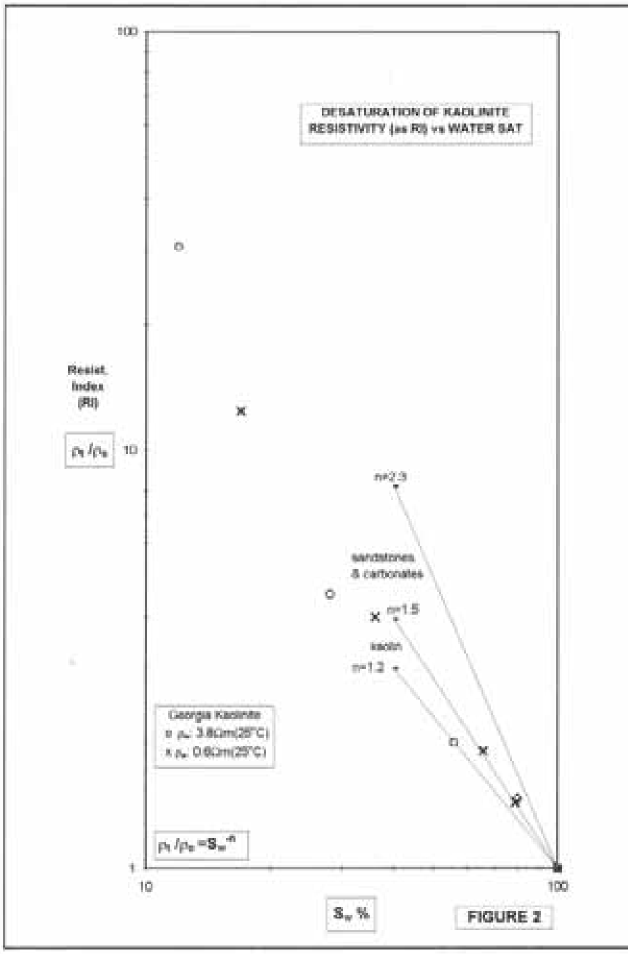
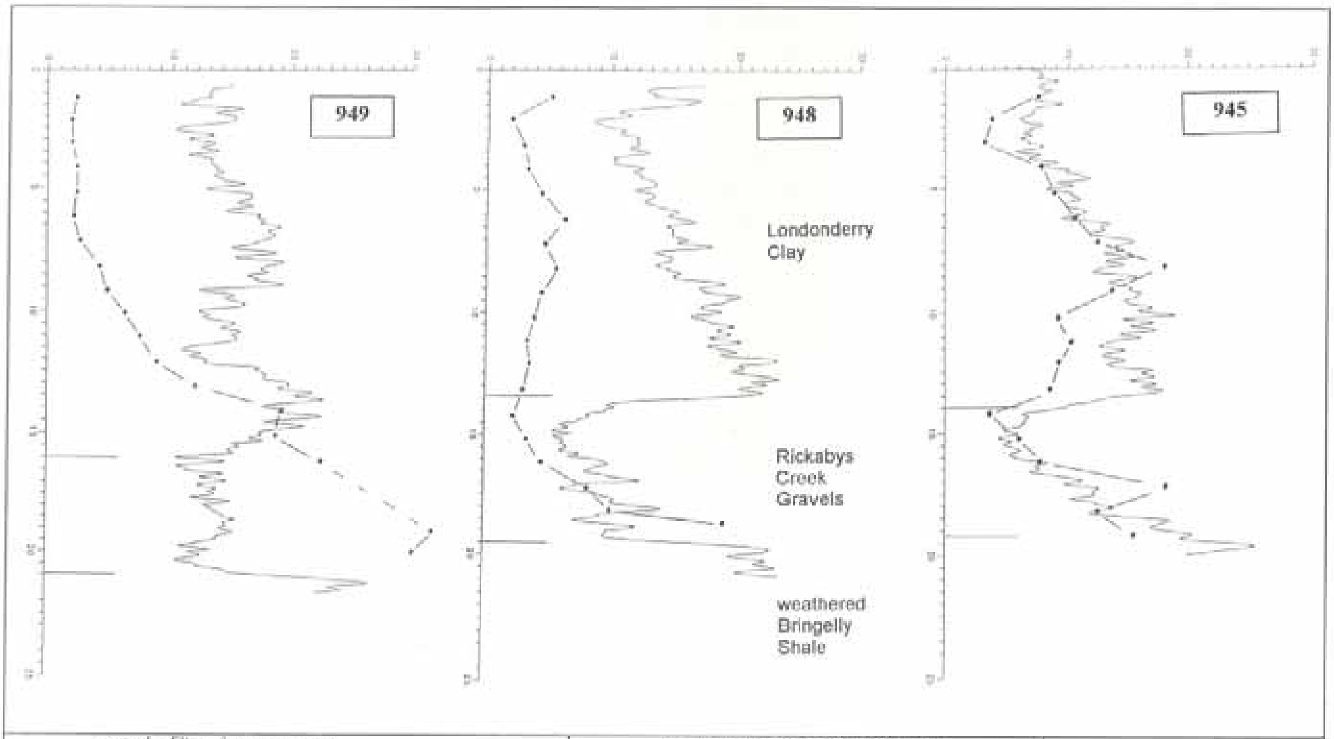


FIGURE 2

The Londonderry Clay, Salinity and EC 1:5

The NSW Waste Service's Castlereagh Disposal Depot has been the subject of detailed geotechnical and environmental investigations for many years. As part of these studies an airborne electromagnetic survey was carried out over and around the Depot to define regional and local geoelectric characteristics that might have a bearing on salinity patterns and fluid migration. The results of this work will be published in due course. The relevance of the Depot to the clay study was the availability of samples through the Londonderry Clay which is a major source of plastic, red firing clay for the Sydney district (Jones & Clark, 1991).

The kaolinitic Londonderry Clay occurs in the Tertiary Cumberland Basin 50km west of Sydney. It is a lateritised horizon and overlies the quite clayey Rickabys Creek "Gravels" which rest on weathered Triassic Bringelly Shale. The Tertiary section essentially comprises an upper aquiclude, up to 10m of sandy clays, and a lower aquitard, up to 10m of clayey sands, with permeabilities of about 0.1 and 1.0 millidarcys respectively. A series of boreholes revealed an overall change in groundwater salinity from west (saline) to east (fresh) across the Waste Service site. This showed up quite well on early time conductance contours from an airborne transient electromagnetic survey. Available evidence suggests that the salinity of the clay's pore water is only broadly similar to the underlying gravel. The whole of Tertiary section can be regarded as water saturated except very near the surface where the clay dries out.



x scale: filtered gamma cps
• EC 1:5 µS/cm (x 1/20)
[multiply γ scale by 20]
y scale: depth, metres

GAMMA LOGS & EC 1:5's
KAOLINITIC CLAYS
TERTIARY, CUMBERLAND BASIN NSW

FIGURE 3

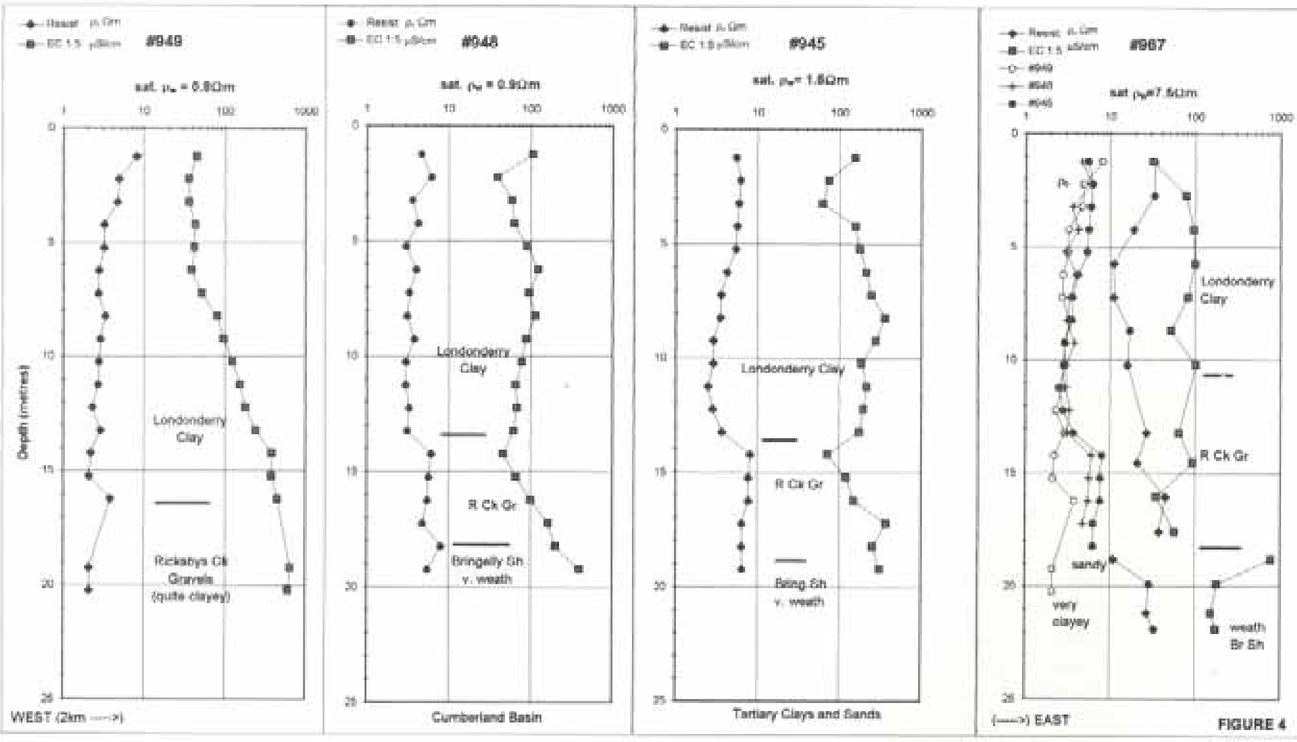


FIGURE 4

The availability of tube-cored sediment samples extracted ahead of the drill bit (to minimise contamination) in four drill holes across the salinity front permitted a petrophysical study of the Tertiary salinity environment as it freshened from west to east. The four drill holes were nos 949 (in the west), 948, 945 and 967 (in the east). Gamma logs and EC 1:5 values for 945, 948 and 949 are shown in Figure 3. The saturated resistivities (ρ_o's) of the test samples are plotted with their EC 1:5's in Figure 4.

The natural gamma count logs in Figure 3 indicate the relative clayiness (high gamma) and sandiness (low gamma), quite well in fact when the logs are compared in detail with binocular microscope examinations of subsurface samples. In the Londonderry Clay the sequence is seen to be upward coarsening with the gamma counts decreasing towards the surface. Borehole 949 is, overall, quite clayey from top to bottom (see gamma counts). Its EC 1:5 increases with depth and shows no correlation with the gamma log. Borehole 948 shows a similar Londonderry Clay pattern but here the gravels are sandier. The EC 1:5 is mostly low and then increases near the bottom of the hole. Borehole 945 does show some correlation between EC 1:5 and clayiness as indicated by the gamma log and, in the middle of the clay, the EC 1:5's are higher (than for 949 and 948). The clay salinity conditions in 945 differ from those in 948 and 949. Integrating EC 1:5 with depth shows up the relatively high salinity in 945.

In the profiles of Figure 4 the groundwaters freshen from west to east. Water similar to that produced from each borehole was used to saturate the test samples i.e. rw's of 0.8, 0.9, 1.5 and 8 ohm m 25°C were used. The measured sample resistivities should be regarded as minimum resistivities as the samples were not washed or flushed prior to saturation.

For 949-948-967, the EC 1:5 profiles clearly show the overall lateral change in salinity conditions from saline to fresh and the detail of the subsurface salinity distribution in each borehole where conditions become more saline with depth. The resistivity profiles show the expected inverse relation to the EC 1:5 profiles. The clay resistivities increase from around 2.5 ohm m in 949 to 3.0 ohm m in 948 to 17 ohm m in 967. For the deeper sands, porosity and texture cause the resistivities to increase, despite the rise in EC 1:5.

Borehole 945 represents anomalous ground in that geophysical survey observations suggest relatively low resistivity terrain, somewhat similar to that around 948, but the produced water is fresher. The answer lies in the saltiness of the section in 945 as shown by the EC 1:5 data. The saturated clay sample resistivities are indeed quite similar to those in 948 and 949. Although the EC 1:5 patterns are similar, the deeper sandier samples in 945 are a little more resistive than those in 948, because 945's saturant is fresher and the upper gravels are cleaner (see gamma log). The treated sample resistivities for 949, 948 and 945 can be compared in 967's panel in Figure 4.

The profiles in Figure 4 are not the complete answer to an investigation of the Tertiary's resistivities. The ρ_o data derive from a uniform saturant for samples from each hole with the saturant matching the produced water. However, the EC 1:5's show a somewhat varying but broadly increasing salinity with depth in the Tertiary of 949, 948 and 945 (in 967 there is a marked increase deeper in the weathered Triassic). This is corroborated at one nearby site where a series of differently perforated drillholes revealed that the water produced from the whole section had ρ_w = 2.5 ohm m and this was a composite of 8.0 ohm m from the lower clay's low yielding sandier lenses, 3.3 ohm m from the upper sands and 2.0 ohm m from the lower sands. The reasons for this are the subject of continuing hydrogeological debate to do with salt imprinting and leaching and will not be addressed here.

On this evidence, the produced water largely has the deeper sands' characteristics and the Londonderry Clay, where EC 1:5's are low (compared to deeper sands), may have a rw about three times that of the sands. A consideration of the EC 1:5 data and the clays apparent formation factors, about 3.0 but varying with salinity, permits the upward adjustment of the clay ρ_o values, where warranted. Alternatively, data may be (and have been) obtained by laboratory tests with appropriate saturants. Such adjustments tend to bring the clay resistivities into the higher range of the gravels and this results in fairly uniform resistivities over the Tertiary section at any one spot and gives a good match to the ρ_o's inferred from DC resistivity and TEM ground probing where, initially, the interpreted electrical uniformity of the Tertiary section was quite puzzling.

The data suggest that in a heterogeneous kaolinitic terrain only order of magnitude changes in clay salinity may be reliably inferred from ρ_o data. For this west to east section, the ρ_w, ρ_o, EC 1:5 and lithological data combine to provide a very clear picture of geoelectric conditions in the subsurface.

Conclusions

The direct use of a logged or interpreted ρ_o value is rendered difficult by it being a dependent variable, so it is very advantageous to have some ideas about the independent variables contributing to it. The resistivity behaviour of clays can be better understood in the light of information of their mineralogy, salinity, saturation and porosity. This information may be gleaned from some petrophysical studies at control sites. The resistivities of low cation exchange capacity kaolinites appear to reflect directly their saturant water resistivities, but this is not the case for montmorillonites. EC 1:5 is not another variable, rather it is a local salinity index and its electrical effects are subsumed in the effective ρ_w. The use of ρ_o clay data in regolith interpretations is optimised by considering auxiliary geological, geophysical (including conductivity logging) and petrophysical information.

Acknowledgements

Thanks are due to Mr David Williams and Mr Janusz Dobrolot of the Waste Service NSW for data, samples and discussions and also to Dr David Airey of the Geotechnical Laboratory, University of Sydney, Dr Peter Fullagar of CRA Exploration Pty Ltd, Dr Andy Green of CSIRO Division of Exploration & Mining, Mr Greg Street of World Geoscience Corp. (who carried out the QUESTEM airborne EM survey), and Professor Michael Knight of the National Centre for Groundwater Management, University of Technology, Sydney. Dr Edward Tyne carried out the gamma logging for the Waste Service NSW. Mrs Susan Franks and Mr Robert Astridge assisted with the experiments and data compilations. Don Emerson is an Honorary Research Associate in the Department of Geology and Geophysics, University of Sydney. Ying Yang worked on a Waste Service funded conductivity-depth imaging project at Macquarie University with Professor James Macnae of the CRCAMET.

Procedures

This experimental study is part of an in-house research program on the mass, electrical and velocity properties of clays by Systems Exploration (NSW) Pty Ltd. The materials in the Systems Exploration laboratory program were saturated with the appropriate fluids, consolidated into cores in special jigs and then subject to resistivity determinations using a two electrode technique (Emerson, 1969) at a frequency of 1kHz and one volt energisation. Phase angles were low (<2°) for saturated specimens, but when oven-dried the materials became dielectrics with very high resistivities (100 000's Ωm) and high phase angles (>70°). Some trial four electrode measurements showed that contact resistance effects in the two electrode technique were minor. The measured resistivities are regarded as having an accuracy of five percent. Data cited are for samples that were not pre-washed prior to introducing the saturant. Bentonite when washed with deionised water had a consolidated state resistivity of 7 ohm m - still clearly in the medium ρ_0 range. For these and other samples studies are continuing on mineralogy, densities, porosities, saturation, velocities and electrical properties including frequency effects.

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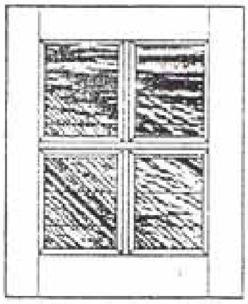
Seismic Window

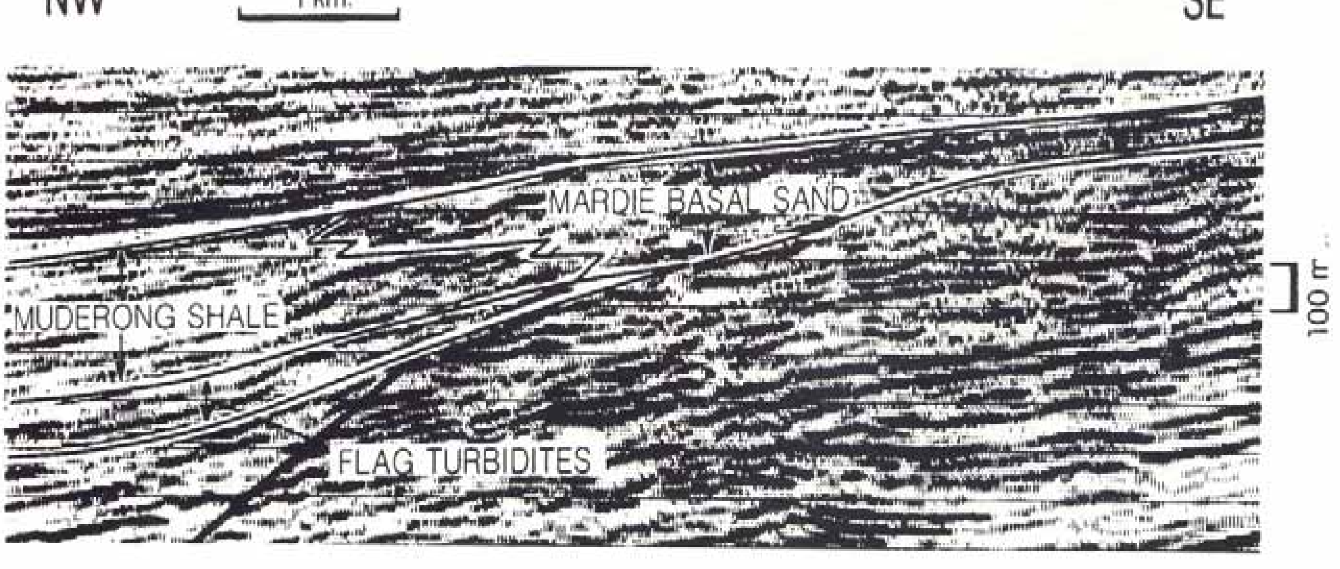
with

Rob Kirk
BHP Petroleum



The following Example is taken from the Carnarvon Basin, Western Australia

Carnarvon Basin, Western Australia – early Cretaceous. Second order basal transgressive sand (Binding plus Zeepaard sequences plus Mardie basal sand). This glauconitis sand facies is unusually thick, east of Barrow Island and its seismic character is similar to that of the Muderong Shale with which it interfingers.



Geophysical Practice at the University of Tasmania: 50 Years Past... and Future?

by N. G. Direen

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In the UNIPULSE column in this issue of Preview, I will be featuring a paper by Nick Direen which was written for the 50th anniversary of the Department of Geology at the University of Tasmania. This paper was of special interest to me, as I was a Senior Lecturer in Geophysics in Tasmania for a four year period in the late eighties. I feel that one of the particular strengths of the geophysical tradition at the University of Tasmania has been the marriage of "global" geophysics and exploration geophysics, which is illustrated in the following paper.

Leonie Jones

Introduction

It has been claimed recently (Uren, 1996) that the teaching of geophysics within the Tertiary Education system is presently in a state of crisis. Increasing costs, governmental neglect, declining Science enrolments, and movement of students away from "hard" sciences, such as maths and physics, to perceived "soft" sciences such as environmental studies have contributed to this crisis. This crisis has occurred despite the fact that Australia is still a resource based economy. As shallow mineral targets and straightforward petroleum plays are becoming rarer, it is thus likely that geophysics and its practitioners will be in greater demand than at present.

The Department of Geology at the University of Tasmania has been teaching geophysics from its inception, due to the vision of its foundation professor, S. Warren Carey. As the Department celebrates its 50th Jubilee, it is fitting to examine how this crisis in the teaching of geophysics is affecting Tasmania, and in a "reverse actualism" to see if the experiences of the past give us a key to the present, and to the future.

All crises are turning points, and times for decision. Let us hope that the decisions of the present will see us celebrating 100 years of geophysics at the University of Tasmania some 50 years hence.

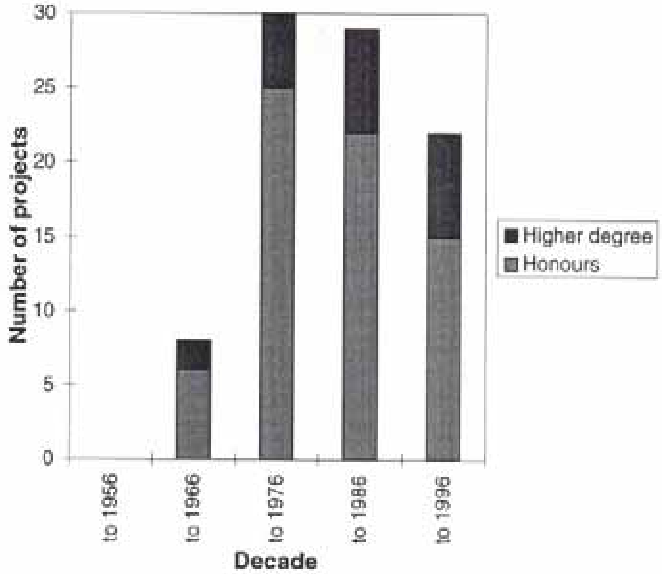

Figure 1.

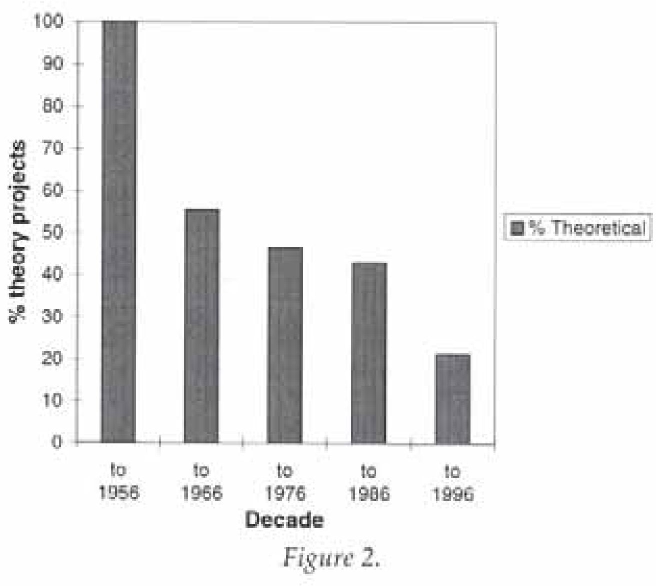

Figure 2.

Some Facts (or some statistics at any rate)

In order to give this research some historicity, the author adopted a palaeontological approach, and with the help of the Geology Department Curator, Kathi Stait, constructed an electronic database of the departmental thesis collection. The thesis collection represents perhaps the only continuous, concrete record of achievement by students within the Department, many of whom have gone on to illustrious careers in the discipline.

Figure 1 shows the number of senior students completing major geophysical practical projects, with the apex occurring in the decade 1966-1976. Figure 2 shows the decline in theses related to theoretical aspects of geophysics as opposed to practical/applied geophysics. Figure 3 shows the number of geophysical Doctoral and Masters theses as a percentage of all geophysical projects, which has generally been increasing with time. Figure 4 shows the number of staff involved in the teaching of geophysics in the department over time: this displays a similar pattern to that of Figure 1, but with a different temporal peak.

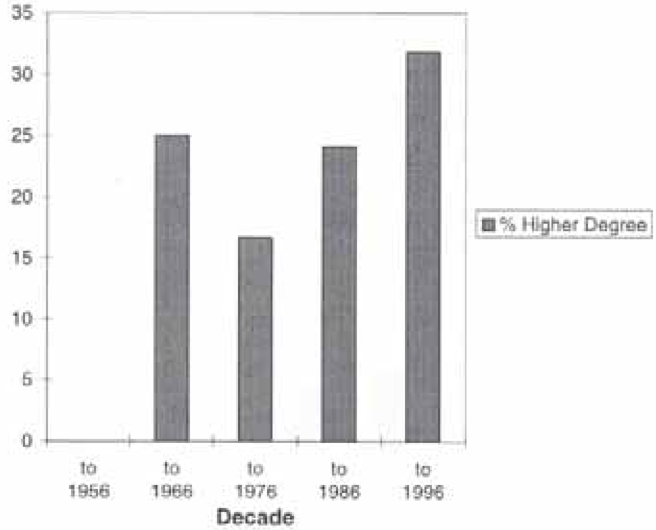

Figure 3.

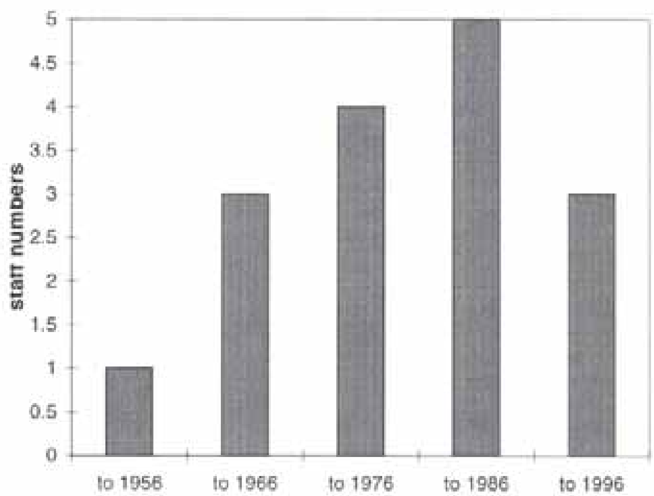

Figure 4.

The trends expressed in our "fossil record" of theses accord well with trends in University geophysics commented on by Uren (1996), namely: a recent fall in undergraduate enrolments; small but increasing numbers of postgraduates, due to increasing disciplinary complexity and specialisation; a decline in the willingness of undergraduates to undertake more rigorously physical/mathematical projects, perhaps due to falling standards; and recent rationalisation by Universities of small classes, resulting in non-replacement of retiring staff.

Some further trends not revealed by this simple analysis, but readily discovered upon discussion with past and present staff, are the increasing costs and declining real budgets needed to maintain geophysical equipment, which often becomes outdated; and an increasing reliance on computer hardware and software. This last phenomenon has evolved from a situation where computers were programmed "in house" to one where complex and specialised software has been imported. The benefit of the increased monetary outlay has been training in a more standardised computing environment akin to that in industry.

Thus geophysics at the University of Tasmania has not been unaffected by this crisis. In order to maintain the discipline, which is already a cornerstone of national development, we need to attract more students. What does geophysics at the University of Tasmania have to offer them?

Some Historical Highlights

1950s: Hydro Engineering

From the very beginning of the Department, Prof. Carey maintained a close relationship with the "Hydro", the Tasmanian Hydro Electric Commission, which was engaged in an aggressive campaign of dam building. In order to reduce structural risks associated with poor geological knowledge, geophysics was used by students in a variety of applications, from predicting rock quality by seismic refraction, to determining optimal routes for canals through the weathering profile and porosity characteristics by resistivity surveying.

Through the auspices of the Hydro, Prof. Carey was able to obtain funding for a more enduring asset: the Tasmanian seismic net, which was begun in 1958 with a single station at Fort Nelson, above the University site. The Sprengnether seismometer for this station was scavenged from the Academy of Science, after the University of Queensland failed to find a home for it.

Three further stations were added at Tarraleah, Savannah and Moorlands, to create the Net in 1960. At the same time, the Hobart station (TAU) was moved to the present vault at Bend 5, Nelson Rd. In 1962 the US Coast and Geodetic Service installed a further six seismometers at TAU as part of the World Wide Standardised Seismograph Network (Ripper, 1963). Over the years, the Tasmanian Net has expanded to a total of six stations around the state, with another one to be installed at Gladstone by the end of 1996. The Seismic Net is still largely funded by the Hydro, as well as by AGSO, and has just been upgraded to utilise digital microwave links, as opposed to radio telemetry.

The daily records of Tasmanian seisms and teleseisms have provided ample material for both student practicals and student projects in the past (eg Ripper,1963), and still represent a somewhat under-utilised but valuable legacy. This is attested to by the fact that all data generated by TAU is automatically transmitted to the University of California (San Diego), as part of the worldwide IDA network.

1960s: Papua and New Guinea Surveys

Prof. Carey's pre WWII involvement in Papua and New Guinea, and wartime escapades thereabouts, meant that the Department was able to use his knowledge and experience as a basis for some frontier geoscience, including geophysics. Helped along by the Bureau of Mineral Resources and sponsorship from several oil companies including The Australasian Petroleum Co, Marathon Petroleum and Papuan Apinaipi Petroleum, five of Carey's students undertook a multidisciplinary study of Papua and New Guinea, which became known as the Papuan Tectonics Project. The work lasted from 1961 to 1967, and involved two major gravity projects by John Shirley and Paul St.John.

John Shirley's Honours project involved acquisition of new gravity stations in the Eastern Highlands of New Guinea, as well as converting oil company proprietary data around the Gulf of Papua to a common datum.

Paul St.John built on Shirley's earlier work as part of his PhD. He teamed up with the Commonwealth Division of National Mapping, the Australian Army HQ Survey Regiment and the United States Army Map Service, who were all at that time establishing the Geodetic Datum for PNG. Using the combined resources of the geodetic surveyors, including Landrovers, boats and helicopters, in 13 months, he was able to establish a gravity database for the whole of Papua and New Guinea, an area of some 400 000km^2 - a phenomenal task, given the remoteness of some of the highland areas. Paul reports that all the field work cost him only "five quid a week" (!!). His work was incorporated into the University of Hawaii's global geoid mapping project, which became the basis for the 1967 gravity ellipsoid, and was used to do calculations for the first geostationary satellites.

1970s: Links with Asia

In 1976, Dr Dudley Parkinson, the senior lecturer in Geophysics, was approached by one Dr. Mugiono of Gajamada University in Indonesia about the possibility of establishing a geophysics course at that university. Due for study leave, Dr Parkinson took up an offer to go to Bandung for two months, taking with him some of the Departmental gear, including the "Tellohm" resistivity bridge, and a vertical fluxgate magnetometer. Despite the usual fuss in customs over flying with gadgets that look like primitive bombs (still a problem!), he was able to spend a profitable time helping to set up a geophysics course at Gajamada. The campus, in the city of Bandung, is situated near the active Mt Merapi volcano, an excellent geophysical laboratory for a variety of techniques, including gravity, seismic and electrical methods. This relationship continued upon Dr Parkinson's return, resulting in a stream of Indonesian postgraduate students coming to Tasmania to study geophysics. The first was Nazhar Buyung, who from 1978 to 1980, worked on an MSc project on geomagnetic induction and "Parkinson Arrows" in N E Tasmania. Since Buyung, a further four Indonesians have graced the Department, three returning to complete both Masters and PhD's, the last in 1993, and all on similar projects. This link is still quite recent: what possibilities may now exist for student exchanges to study geophysics in Indonesia, our closest Asian neighbour?

1980s: New Methods in Mineral Exploration

The 1980s saw a burgeoning of seismic reflection and refraction projects being conducted by students in the Department. This was due to the purchase and acquisition by Dr. John Shirley of such equipment as the departmental seismic truck (purchased from the Hydro bargain basement), geophone arrays, and the Texas Instruments 9000 seismic recorder (from Geophysical Services International, for the cost of the freight).

While some students used seismic reflection to investigate more traditional targets such as Tertiary lignites and bridge foundation sites, one of the more novel uses of the method was its application to mineral exploration at Hellyer (Read, 1986) and Tennant Creek (Root, 1989). Although unusual, the method was particularly successful at Aberfoyle's Hellyer site, where Jeremy Read, under the supervision of Dr Roger Lewis and Dr Leonie Jones, cooperated with a cast of thousands including Aberfoyle, the Hydro and Mines Department. He was able to discriminate important features of the ore environment, such as the alteration and stringer zones, the position of the Jack Fault, as well as the massive sulphide ore bodies themselves. The value of this project was to demonstrate the viability of CDP seismic in exploring a complexly structured environment, and one that was blind to more mainstream geophysical methods including magnetics and IP. This was done in the pre-production stage, adding valuable knowledge to the exploration model.

Also in cooperation with Aberfoyle at Hellyer, a second Roger Lewis student, Julian Mather, trialed a relatively new method known as Time Domain Spectral Induced Polarisation, which was another of the Lewis "hobbies". The method proved successful in being able to discriminate massive sulphide mineralisation from conducting black shales, a previously insurmountable problem with conventional IP at Hellyer, and elsewhere.

1990s: New Frontiers, New Technologies

The 1990s have seen the Department expand its horizons in terms of place and methods. New technologies have played a part in this expansion. In 1994, under David Leaman's supervision, Andrew Wellington was sponsored by AGSO to participate in the cruise of the French oceanographic research vessel *L'Atalante*. This cruise was designed to conduct a multidisciplinary study over the South Tasman Rise in the Southern Ocean. Andrew was able to use seismic reflection, shipboard gravimetry and magnetics, as well as forward and side scanning high resolution sonar, plus deep dredging to interpret the provenance of the South Tasman Rise: a detached piece of continental crust with affinities to both Tasmania and Antarctica (Wellington, 1994).

Graham Crook, one of the 1996 students, conducted a pilot study using aeromagnetics, airborne radiometrics, with remotely sensed Landsat Thematic Mapper and Synthetic Aperture Radar data to determine the usefulness of combining these techniques for geological mapping in different Tasmanian conditions. This project was carried out under the guidance of Dr Michael Roach.

Lessons from the Past

If we are to learn anything from these short vignettes, it must be this: geophysics at the University of Tasmania has been capable of offering both the exotic and the cutting edge in terms of viable projects; further, such projects are often of practical value to organisations outside the university. In the past, geophysical staff have forged strong and mutually beneficial ties with such bodies, enabling students to overcome quite severe limitations on funding and equipment. With the demand for well-trained geophysicists almost certain to increase in future, because of the desire to probe the third dimension beneath us, we should also be sure that there will be government entities and companies who are prepared to "put in" to assist in training the geophysicists of the future.

The Future?

What then of the future? All useful practical geophysics depends on acquisition and processing. Both these parts of a project, in an environment that increasingly demands greater precision, are becoming more and more expensive, due to developments in hardware and software. Although the University of Tasmania no longer owns much of the equipment necessary for many projects, students can still be trained in the use of the latest equipment with some effort, imagination and opportunism on the part of their supervisors.

In addition, because of the recent exponential increase in data quality, and cost reduction, many organisations have routinely acquired vast geophysical databases. Close cooperation with the owners of such databases means the Department can now offer projects working with data acquired and processed by others to provide interpretation at larger scales than in the past. This is training for a world where most geophysical data is now acquired by large, sometimes multinational, contractors, and where the geophysicist is primarily a skilled interpreter.

Summary

Fifty years of geophysics at the University of Tasmania have produced many well-respected practitioners of the art, as well as many novel projects, and strong links with supporting organisations. Geophysics will remain a strong, and increasingly integral part of training for earth science graduates, as long as there are imaginative, resourceful staff to maintain both the geological and physical integrity of the discipline as they have in the past.

Acknowledgments

Thanks to those whose knowledge of the past 50 years has contributed to this paper, especially Prof. Carey, Drs. Dudley Parkinson, Roger Lewis, Dave Leaman, John Shirley, Paul St.John, Leonie Jones, and Michael Roach. Also to Vagn Jensen. Thanks also to Kathi Stait for her assistance with the database.

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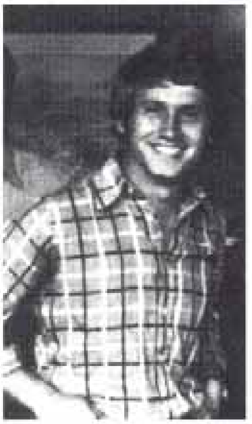
Geophysical Time Warp Discovered at North Ryde

(or Should AEM be used for Bump Picking or for Geological Mapping?)

by Ned Stolz
CRC AMET, Macquarie University

One view presented at a forum of prominent minerals industry geophysicists was that airborne EM in Australia is technically at a similar level of development to that which aeromagnetic surveys had attained in the late 1970's! While this concept helps explain many phenomena among Australian geophysicists, including one well known individual's taste for safari suits (!), the lag in AEM development is a major challenge facing the exploration industry in this country.

A workshop addressing this topic was organised by the CRC AMET at the CSIRO Division of Exploration and Mining, North Ryde on Friday 29th November, 1996. CRC AMET, or the Cooperative Research Centre for Australian Mineral Exploration Technologies, has it's major research objective to improve the use of AEM methods in regions of conductive regolith cover. As the participants made their way through the crowd of platform shoes, flared trousers and paisley body shirts they may have twigged that this was to be a geophysical meeting from the twilight zone!



Jovan Silic before the AEM workshop . . .

. . . and during! Where did the years go? Brian Spies and John Slade appear thoroughly bewildered!

Presentation and Resolution Issues

Talks in the morning session included contributions from two AEM contractors, CRC AMET program leaders, Victor Labson of the US Geological Surveyand a summary of the thirty years, go to woe history of AEM from Professor Alex Becker of University of California, Berkeley.

Andy Green of the CRC AMET presented preliminary results of principal component analysis of SALTMAP data. The aim of this research is to compress AEM data into an image that looks like geology and can be qualitatively interpreted directly by geologists. Geological interpretation was a recurring theme of the workshop. Andy's approach is to reduce the dimensionality of the AEM dataset by principal component analysis. This is much faster than inversion of the data to conventional parameters such as conductivity and depth to layer boundaries. The principal components are imaged using standard image processing technology to allow zones of distinct decay character to be recognized. The work is being combined with Tim Munday's research into regolith properties for a more complete understanding of the geological significance of the images.

After lunch it was the turn of the exploration industry to lead the discussion. Jovan Silic posed the questions; 'How deep should we look?' and 'How much should we pay?'. The general consensus of the group was as deep as possible for the first and as little as possible for the second.

Jovan then noted that geophysicists still relied heavily on decay time constant when rating anomalies and pointed out that when the target is deep the late time response is often lost. He illustrated this with an example from the Broken Hill region. After discussion, the group decided that the response was probably a current gathering effect and not a regolith feature. In such cases the problem becomes one of how best to sort early time conductors. Jim Macnae reminded us that the double derivative response to AEM waveforms emphasised shorter time constant decays.

Hugh Rutter provided an example of an AEM survey which didn't work. A frequency domain, helicopter EM survey flown in Africa failed to detect graphitic schists, which normally respond extremely well to AEM. Problems with excessive terrain clearance offered the most likely explanation. Jim Macnae noted that the response of steeply dipping bodies falls off very quickly with altitude and pointed out that the strongest AEM responses come from flat lying bodies - especially the regolith!

Guimin Liu provided a comparison of GEOTEM and QUESTEM data over the HYC zinc deposit in the Northern Territory. The results were similar except for minor amplitude differences and there was some discussion about the disparity and the need for careful calibration. Andy Green emphasised the effects of variation in geometry and uncertainties in bird and aircraft position, especially when flying over a conductive overburden.

Bump Hunting versus Geological Mapping

Marcus Flis's presentation about mapping magnetite in the Hammersley Basin using frequency domain helicopter EM precipitated a debate over the attraction of bump picking against the virtues of geological mapping. This issue was also raised by Jim Hanneson and the WMC geophysicists.

Industry representatives stated that the primary reason their companies fly AEM is for direct detection of massive sulphide ore bodies. Jovan Silic said that geology is the main signal in AEM and orebodies constitute the unusual, anomalous part. Explorationists were always looking for unusual things, whether dealing with geological, geochemical or geophysical data. Marcus reiterated that geology is the background while we had to look at anomalies to find ore.

Brian Spies countered that this obsession with bump hunting was taking us backwards and that the future lay with the production of geologist friendly products for mapping. Some people thought the issue had been settled ten years ago (see Macnae and Spies, further reading).

Jim Hanneson said that AEM did not have a proven record of finding ore in Australia and that this was a major obstacle to persuading exploration mangers to fly it. He also questioned the importance of AEM for mapping in the exploration process, commenting that often the geology was not understood anyway! During the course of discussion it was established that AEM had in fact discovered Que River in Tasmania (apparently using a quadrature frequency domain system now long gone) as well as the Panorama deposit in WA. It is also proving extremely useful in kimberlite exploration. Discussion emphasised that we must publicise these successes.

Derecke Palmer said there was a need for a presentation which fulfilled both anomaly picking and mapping roles. Andy Green commented that multiple presentations could be optimized to whatever role was required. Derecke went on to say that geologists now felt that they owned aeromag data while AEM still belonged exclusively to the geophysicist. Steve Mudge said that once geologists could understand AEM data they would use it more, more surveys would be flown and the price would come down.

Jim Hanneson also pointed out that large, high quality government datasets and multiclient surveys had done a lot to popularise aeromagnetics. He asked if there was a role for government in improving the perceptions of AEM methods, specifically by flying public domain surveys.

Cost versus Quality

Jim stated that WMC would rather have a significant cost reduction than incremental technical improvements. Brian Spies asked if they would accept a major technical improvement instead of lowering the price and Jim replied 'yes', so long as AEM was improved to be comparable with ground EM. Art Raiche quipped that Jim apparently wanted to pay less so he could fly more of a system that didn't find ore, that is, less money for the same lack of information.

The general consensus from industry was that their companies were always interested in looking deeper. Jovan Silic proposed that careful analysis of data could be more effective for this than increased transmitter power.

Marcus Flis suggested that the price and quality of AEM was unlikely to change quickly but that value could be enhanced by running as many sensors as possible from the aircraft, i.e. EM, magnetics, radiometrics and radar. Andy Green noted that Australian companies were notoriously unwilling to pay for extra datasets, stating the case of radiometrics in aeromag surveys. Keeva Vozoff commented on ground geophysical contracting in Australia, stating that hard-nosed clients had drastically squeezed contractors and profit margins, resulting in lack of reinvestment and poorer data quality.

Technical Issues

Jim Hanneson called for a step response or quadrature frequency- domain AEM system to get more response from the best conductors. He also proposed measuring the magnetic field directly from a transmitter current step or the use of a narrow band magnetic measurement to supplement the dB/dt reading. Phil Pik and Jock Buselli said that they had yet to find a small, cheap magnetic sensor that met the requirements of AEM. Jim Macnae said it was now possible to obtain a step response by deconvolution of data from any arbitrary waveform.

The possibility of measurements during the pulse was also raised. Jim Macnae commented that GEOTEM can do this but it is actually more useful for offscale resistive features than offscale conductors because these can be interpreted without having exact knowledge of the geometry for primary field removal.

Future Trends

Bob Smith pictured geophysicists pouring resources into making AEM geologist - friendly and in effect begging them for money so we could fly more. In his experience exploration managers are not just geologists and as long as geophysicists can demonstrate that AEM finds ore the money will come. Hence the need for well documented discoveries was raised again.

Keeva Vozoff drew the parallel with 3-D seismic surveys which had blossomed from a laughing stock a decade ago to a routine exploration exploration tool today. Joe Cuccuzza remarked dryly that petroleum wells can cost fifteen million dollars! Andy Green was confident that demand for AEM would grow as people saw the need for it, just as had happened for aeromagnetics. Brian Spies stressed the need to improve data quality in AEM before any of the above could happen.

As the workshop participants were whisked back to the 1990's by the waiting fleet of Leyland P76's, Brian was already making plans for the next AEM conference to be held two years hence. What decade will the time vortex find us in next time round? Will AEM be taken forward or backward or will it perhaps remain stranded in the endless strobe light discotheque of the seventies? Will it remain the last comfortable haven of the geophysicist or will it have been cast out to the ignorant hoards of geologists. The specialist tool of the expert or the routine procedure of the general prospector? Strangely enough, the answer is in our hands!

Further Reading

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Where are they?

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Calendar of Events

July 7-10 1997
Instanbul '97International Conference and Exposition Instanbul, Turkey. Sponsored by SEG, Chmb. of Geoph. Engineers of Turkey and EAGE
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Fax: 44-1753-818-948
Exposition Arrangements
Oguz Gundogdu,
School of Earth Sciences Istanbul University Istanbul, Turkey
Tel.: 90-212-591-1921
Fax: 90-212-257-3979

July 30 1997
AGIA Seminar and Technology Expo on Making Data Work for You II
CSIRO Floreat Park, WA
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September 4-5 1997
Funafuti to Mururoa
Stability or Chaos in Coral Reef Research - A Symposium
For further details:
The General Manager
The Earth Resources Foundation, Edgeworth David Building FO5 The University of Sydney NSW 2006

September 14-18 1997
Workshops Sept 7-14 Tours & Seminars Sept 19, Exploration '97 4th Decennial Conference on Mineral Exploration.
Toronto Canada
For further details:
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L3R 9S9
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15-18 September 1997
Moskba'97/Moscow'97
International Geoscience Conference & Exhibition
Cosponsored by EAGO, EAGE & SEG
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Sept 17 1997
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