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and Mass Properties of
the Near Leinster,
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Lindsay Ingall 1927 - 1999

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COVER: The cover image shows airborne geophysical data collected over the Webb 1:250 000 map Sheet area, Western Australia. This survey filled the last 'hole' in the airborne magnetic coverage of Australia. Displayed is a colour composite of the gamma-ray spectrometric data, draped over the digital elevation model. The image is courtesy of the Australian Geological Survey Organisation.

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Editor's Desk

This issue of Preview represents the end of an era in two ways. It will be my last as editor and it will also be the last to be published by Jenkin Buxton Printers in Melbourne. The ASEG started using JB after the FE moved to Melbourne in 1992.



The Publications Committee decided it was appropriate to review our publishing contract and it was decided to call for tenders in the same way that we do for our conferences, our other major cost centre. Our publications cost between \$100k and \$250k every year. An invitation to tender was drafted during April and sent out to 6 potential publishers in early May. Tenderers were given a month to respond and the 3 proposals were received and reviewed in June. A recommendation was put to the FE and ratified by them on 5 July.

Accordingly RESolutions of Perth are announced as the new ASEG publishers for a period of 2½ years commencing with the next issue of Preview and the second volume of EG for 1999. Many of you will know of RESolutions through their involvement with PESA over the last 6 years.

I don't intend to overly discuss the details of the process but in summary the reasons for choosing RESolutions were:

- Cost competitive
- Ability to produce PDF files for easier proofing
- Track record in soliciting advertising
- Ability to work with volunteer professional group
- Ability to manage scientific/technical publishing requirements
- understood the requirements for CDROM publishing

This is not to say that other proposals did not fulfil these criteria but RESolutions was found to be superior overall. We look forward to working with Brian Wickins and his staff. We also take this opportunity to thank Jenkin Buxton for their efforts over the years and particularly to Debbie May who has been of great assistance to me since I have been involved.

The timing of the change is important since the PC was keen to make any changes well in advance of the Perth Conference which looks like it will be a huge one. In the short term it will help to have RESolutions in Perth for the conference but location is not the complicating issue that it once was.

Readers of the ASEG business plan (!) will see that we intend to make Preview cost neutral in the short term. The style of Preview in the last few years has meant that it has become more expensive to produce than in its' original format. I am strongly in favour of maintaining this standard and raising advertising income to cover this cost rather than downgrading standards to match income. This will be the big challenge for the new editor and publisher.

Many thanks to Andrew Mutton and other PC members for the support they have given me during the tender process and throughout my term as editor. I wish David Denham good luck and look forward to the next deadline coming... and then passing knowing that Preview is in good hands.

President's Piece

VALE LINDSAY INGALL

The geoscientific community lost a great friend and diligent supporter with the passing of Lindsay Ingall on May 21 1999. His cheerful disposition, his impish sense of humour, and his great knowledge of our industry will be missed by all ASEG members.



UNEMPLOYMENT SITUATION

A useful perspective is given in *Cyclical Waves in Exploration The Employment of Geoscientists* Proceedings of a Seminar held in November 1983 (AIG 1984) where many issues common to the present situation are reviewed by eminent geoscientists of the day. Ken Glasson commented wisely on "a looming government problem" regarding Aboriginal land issues: "The alienation of vast land tracts, or expensive access to them, will accentuate troughs in current and future exploration activity". He also noted "some mining companies appear to underestimate the value of continuity of both a planned program and the retention of qualified teams of geoscientists. I would suggest that companies that fluctuate widely in the intensity of their exploration programs have the least chance of success". Complementing this view, Ken Richards stated "The basic cause of fluctuating geoscience employment in the resource industry has been managements' inability to maintain reasonable stability in the level of their exploration programs". Graham Philip provides insights to the effects of the mining boom crash in 1971 "hundreds of geologists were fired, consultants moved into real estate and Sydney acquired a new breed of graduate taxi drivers". A politician of the day explains why governments should not be involved in eliminating some of the effects of the cyclicity of the resources industry. This is valuable material for those trying to understand the situation in 1999.

ASEG supports the efforts of AGSEAN (the Australian Geoscientist Skills and Employment Advancement Network) in providing self-development courses for under-employed geoscientists in Perth. ASEG encourages the running of similar courses in other states and will seek cooperation of sister professional and learned societies in assisting retrenched colleagues. Contact with AGSO prior to the release of the funding cuts indicated that ASEG could not influence decisions already made by the government. ASEG has responded to the staff reductions at AGSO and to the non-renewal of earth science CRCs by writing to the Federal Minister for Science, Development and Technology, the Hon. Senator Minchin, describing the importance of sustaining geosciences technologies in Australia (see copy in this issue if Preview). Members are encouraged to write individually to state and federal politicians in support of their industry. The example of Steve Mudge in contacting the various state Departments of Mineral Resources is commended (letters Preview no. 80).

AUSTRALIAN GEOSCIENCE COUNCIL

At the recent Annual General Meeting of the Australian Geoscience Council, Graeme Mackee was re-elected to the Executive Committee on behalf of ASEG. Doug Price continues as a voting representative for ASEG. The recent success of AGC President Bob Day in publicising the loss of opportunity in the decreased funding to AGSO and two minerals CRCs is very much appreciated. We have advised AGC that ASEG supports AGC as the umbrella organisation for all geoscience bodies in Australia, and that the ASEG is still reviewing its position with respect to the Federation of Australian Scientific and Technological Societies (FASTS). While FASTS may not have represented the geosciences in a manner consistent with our sector's substantial annual financial contributions, this is due in part to the lack of clear identification and documentation of specific geoscience issues by the AGC member organisations for FASTS to run with. The recent support by FASTS for AGSO is a positive development and ASEG is conducting discussions with other bodies to identify key common interest to take to FASTS.

DATABASE OF GEOSCIENTISTS

The ASEG is supporting the establishment of a Directory of Australian Geoscientists on the web site of the Australian Institute of Geoscientists, allowing members and non-members of AIG to contribute their chosen level of personal information (at the same time restricting general access as they prefer). The directory provides up to date information on contact details and allows current statistical information to be collated for submissions to government on education, training and employment in the industry. ASEG members are encouraged to inspect the site, observe the significant number of geophysicists already listed, and make their own decision on whether to submit data to the Directory.

EAGE MEETING

At the invitation of the President of EAGE, Vice President Brian Spies represented ASEG at the opening ceremony of the 1999 EAGE Helsinki Conference and Exhibition, speaking on industry activities in Australia and urging European geophysicists to visit Perth for our 2000 Conference.

ASEG COMMITTEES

Members are reminded of the considerable voluntary work achieved by the standing committees of the ASEG. This opportunity is taken to thank especially the Membership Committee, the Publications Committee, the Perth Conference Organising Committee and each of the State Branch Committees. The names are too numerous to list but this brief mention provides at least some recognition for the efforts of these ASEG members.

REFERENCE

AIG, 1984, "Cyclical waves in Exploration" Proceedings of a Symposium held at the University of Sydney in November 1983, AIG Bulletin No 2, Editor D. W. Emerson, Sydney 1984.

Mike Smith

President

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Executive Brief

With three Federal Executive meetings now completed I now have a much better appreciation of how our Society 'clicks'. As described in my last Preview article, the Committee is not just the Sydney based Executive. With various subcommittees whose chairpersons often reside in other States, the Society 'clicks' together around our continent.



The past few months has seen the Society forcibly comment on the lack of Federal Government research funding, implications of the severe cutbacks at AGSO, 'saving' the calibration pits in Adelaide, update of financial members, changing the publisher and addressing the reality that there will be less income than projected. The Executive very much appreciates the input from the 'wider' committee and its members.

The President has commented on the cutbacks of the Federal Government and in a separate article Elsewhere in preview are extracts of the exchange of letters over the 'saving' of the calibration pits in Adelaide. PIRSA now plan to refurbish the pit area.

The ASEG is now seriously considering a digital ASEG Photo Library Archive. This would service an educational, publicity and human interest role. SEG have begun their library with some extracts on the cover of the SEG Year Book. The Perth Conference Committee has suggested that they set up a scanning facility for such a library. The ASEG Committee is now seeking interest from any member who could champion this cause.

The ASEG together with the GSA and the AusIMM, are supporting the AIG Directory of Australian Geoscientists. Some of the features include an electronic register, members decide how much or how little information is included, Committee access to statistical data, and information will be current. The Directory is managed by a Councillor of the AIG, bound by the AIG's Constitution and Code of Ethics, and is a Registered Professional in the field of Information Geoscience.

Unfortunately many contributors of the Hobart Conference Volume have not yet paid for their colour pages. I agree that the invoices could have been more timely, but the ASEG is currently \$16,000 in debt over these colour pages. I appeal to those members to rectify this debt.

David Robson
Federal Secretary
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ASEG is a non-profit company formed to promote the science of exploration geophysics and the interests of exploration geophysicists in Australia. Although ASEG has taken all reasonable care in the preparation of this publication to ensure that the information it contains (whether of fact or of opinion) is accurate in all material respects and unlikely either by omission of further information or otherwise, to mislead, the reader should not act in reliance upon the information contained in this publication without first obtaining appropriate independent professional advice from his/her own advisers. This publication remains the legal property of the copyright owner, (ASEG).

Personality Profiles

BILL PETERS

CHAIRMAN ASEG HONOURS & AWARDS COMMITTEE



Bill spent his childhood on the family farm near Mt Barker in WA and finished an Honours Degree in Geology and Physics at UWA in 1972. After a hot Pilbara summer doing IP and gravity surveys with McPhar Geophysics, the travel bug lured him off to a year or so on the hippie trail exploring Central and South America.

In 1974 Anglo American Corporation in South Africa hired him as a geophysicist sight unseen (very brave of them) from Seattle. This was the start of a rapid and exciting learning experience as AAC had its own equipment including an airborne EM plane and carried out all types of surveys for both AAC and De Beers. An initial three years were spent based out of Johannesburg working in various African countries. This ranged from running airborne survey crews during the guerrilla wars in Rhodesia (Zimbabwe) and South West Africa (Namibia) through to seismic surveying of 100 kilometres of beach in Namibia delineating diamond bearing trap sites. The following three years were spent based in Cape Town with responsibility for base metal, uranium and diamond geophysics in the Western and Southern Cape Province. During this period, he met his wife Julia, and the first of their two children, Lucinda was born.

In 1980, the diamond boom in WA resulted in several job offers and Bill moved back to Perth with BHP as their diamond exploration geophysicist. This was an exciting time with numerous airborne surveys, much speculation about discoveries and the occasional bit of helicopter-borne espionage. A slow down in diamond exploration resulted in Bill also working on the Lennard Shelf lead-zinc projects, iron ore prospects and various gold projects.

Bill left BHP in 1982 and moved to Sydney as a geophysical consultant to DIGHEM and Teck Corporation. This involved working in Canada and Australia marketing and interpreting DIGHEM surveys and also carrying out general geophysical exploration for VMS deposits.

A collapse in exploration meant moving back to Perth and in 1985, Bill, Greg Steemson, and John Ashley formed Southern Geoscience Consultants (SGC). With the start of the 1987 boom and new mining floats every week, the only problem was keeping up! SGC has flourished and grown considerably in size since then. The past 14 years with SGC have seen Bill work for over 200 companies and government organizations in many different counties on almost every conceivable type of geophysical project. This also included training and supervision of geophysicists in Algeria for the United Nations and Fiji for AusAID. Notable highlights have been the discovery of a diamondiferous kimberlite in Russia with magnetic surveys, the Radio Hill, Maggie Hays North & Emily Ann nickel deposits with electromagnetic surveys and gold deposits with gravity and magnetic surveys.

Bill joined the ASEG in 1973 and has served as the WA Branch Treasurer, the Federal Treasurer and twice as the Treasurer of ASEG Conferences (someone foolishly thinks he knows something about finance!). He has been on the

Honours & Awards Committee for many years and has recently become Chairman. He is an active member and former committee member of the AIG, active member of the SEG, active member of SAGA and a Fellow of the AusIMM.

Bill lives in Perth with Julia and their teenage children, Jonathan and Lucinda. He is a keen but bad skier when he can get to the snow and spends as much time as he can fishing and diving in the summer months.

DAVID ROBSON

FEDERAL ASEG SECRETARY

David Robson is Chief Geophysicist of the New South Wales Department of Mineral Resources. He graduated from the University of New South Wales with a B.Sc. in 1975, and a Grad. Dip. App. Geophys. in 1976. He then worked with Scintrex for two years before joining the Metalliferous sub-section of the Bureau of Mineral Resources (BMR - now the Australian Geological Survey Organisation). David spent nearly four years with the BMR where he worked in the Georgetown and Alligator Rivers areas before joining Western Mining Corporation (WMC). With WMC, David was part of the mineral exploration team and worked throughout Australia (in particular the Western Australian goldfields) and the Philippines. In 1994 he joined the Department and has been involved with the Discovery 2000 Exploration Initiative for minerals and petroleum. Besides the Discovery 2000 program, David has been intimately involved with the regional geological/geophysical mapping program and provides geophysical advice for the coal assessment program. Prior to being elected as Federal Secretary, David was ASEG NSW Branch Secretary and has previously served on the ASEG Victorian Committee. David's hobbies(?) include house and garden refurbishment and keeping track of 3 teenage girls.

ASEG Branch News

Queensland

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The Queensland Branch has enjoyed increased activity over the last few years. This can partly be attributed to the enthusiasm of its past president Andrew Davids. Andrew has recently been relocated at Boral Energy in Adelaide, whilst disappointed to see him leave, the branch wish him all the best for the future.

On Tuesday the 11th of May the branch held its second annual Geophysics Career Night and BBQ. This allowed Industry members and students to meet and interact, and the night was well attended by both groups. There were two presentations as a pre-cursor to the social side of the evening. Randall Taylor (OCA) gave students an insight into life as a Petroleum Geophysicist through a series of snapshots depicting seismic acquisition in remote locations. Randall was followed by Nick Sheard (MIM), who used a highly animated power point presentation to sell the laid back lifestyle of a Mineral Geophysicist.

The branch is still interested in locating presenters for at least one meeting in the second half of the year. So if anyone in the branch has an interesting topic worthy of discussion please contact myself or any of the committee.

Calendar Clips

1999

Sept 28 - Oct 1 SAGA/SEG Conference Cape Town

Oct 27-29 3D EMT Conference Salt Lake City

Oct 31 - Nov 5 SEG Convention Houston

2000

March 12-16 ASEG 14th Conference Perth

May 7-10 APPEA 2000 Brisbane - Call for Papers

May 23-26 GPR 2000 Gold Coast

Preview Deadlines - 1999/2000

October	September 15
December	November 15
February	January 15
April	March 15

New South Wales

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The July meeting was to have been our annual dinner. However, to take advantage of the opportunity offered by the visit of Dr Carol Finn from the United States Geological Survey in Denver, a technical meeting was held on 14 July 1999. Although it was in the middle of a rather wet week, and good attendance (about 25 to 30) met (in the Rugby Club) to hear Carol talk about "The aeromagnetic connection: a new look at the Gondwana geology of Antarctica and Australia".

Carol showed maps of the aeromagnetic coverage - with gaps - of eastern Antarctica and compared that with the aeromagnetic data for the western Lachlan Orogen and the south-eastern Australian shield. That comparison

allows the greater control offered by closer-spaced aeromagnetic data and much better geological control (even for south-eastern Australia compared with Antarctica!) to help correlate between the two landmasses. Thus the geology and tectonics of ice-covered Antarctica can start to be deciphered. Carol drew further comparisons with both California and Japan - younger areas that can offer clues to the evolution of the older Australia-Antarctica "connection". Carol's talk drew warm discussion and appreciation.

The annual dinner is now planned for the August meeting date (18 August).

During July the NSW Branch joined with AIG and PESA, four Sydney universities and Optum in supporting NNESEL (the National Network for Earth Science and Engineering Learning). That support reflects a decision taken by the branch last year, and has been recognised by the inclusion of ASEG's logo in publicity material of NNESEL. Additional information will be provided elsewhere in *Preview*. NNESEL is designed to help high school teachers and students, and others interested, to learn more about the importance of earth science studies and engineering in developing the nation's wealth and health.

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On 30 March, the ACT branch held its 1999 AGM in the main meeting room of the AGSO building. The 1999 committee was elected as follows:

President:	Tim Mackey
Vice President:	Kevin Wake-Dyster
Secretary:	Nick Direen
Treasurer:	Peter Milligan
Committee Members:	Adrian Hitchman, Jane Mitchell, Alice Murray, Prame Chopra, Tony Meixner

The guest speaker for the meeting was Tony Meixner, AGSO. His seminar was titled: "The nature of the Basement to the Cooper Basin, South Australia".

Western Australia

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Abstracts for all past technical presentations are available on the WA Web page under Technical Meetings.

The 12th Annual PESA/ASEG (WA) Golf Classic will be held at Meadow Springs on 3 December 1999. Players and potential sponsors should contact David Howard (mail to d.howard@dme.wa.gov.au for details or visit the web site at www.aseg.org.au/wa/golf.

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Technical and general meetings held every third Wednesday of each month at the Celtic Club, 48 Ord Street, West Perth, from 5:30pm.

June 1999:

Meeting sponsored by Baker Hughes Western Atlas:

Fred Herkenhoff, WAPET	<i>"The Wide Angle Reflectivity Dimension"</i>
Pru Leeming, WGC	<i>"EM as a regolith tool"</i>

July 1999:

Meeting sponsored by: Schlumberger:

Kevin Dodds, CSIRO Petroleum	<i>"Sonic Imaging: A tool for high resolution reservoir description"</i>
Adam O'Neill	<i>"Rapid geological investigations with a NEW 24 channel Rayleigh wave receiver"</i>

If your company would like to advertise at future meetings please contact one of the persons above about sponsorship opportunities.

Distinguished Instructor Short Course (DISC) Perth, September 13, 1999: "The Seismic Velocity Model as an interpretation asset". Phil Schultz, Spirit Energy, a division of Unocal Corporation. You may still have an opportunity to register by the time this is received, so don't delay. Summary to be reported in the next issue.

Other News:

July saw the resignation of our Treasurer, Mr Bob Groves, whom we wish all the best in his future endeavours and many thanks from all of us for your hard work to date.

Mr Tony Endres of WA University also resigned from the WA committee and ASEG 2000 Conference due to an overseas appointment shortly. We also wish Tony all the best.

Due to continued financial constraints, exacerbated by the Federal Executive's cut in capitation, the WA Branch has implemented further cost cutting measures. Upon arrival at monthly technical meetings, all attendees now sign in, whereupon they receive a voucher which provides them with the opportunity to win a bottle of wine when drawn at the end of the session.

All drinks are now at each individual's expense. Finger food is still provided.

South Australia

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Much to report for the SA group this time around.

Our June technical meeting was titled: Marine Electromagnetic Studies of the Crust and Mantle, and was presented by Graham Heinson of the School of Earth Sciences at Flinders University. It was an excellent presentation on a "less traditional" geophysical technique that got us all thinking.

We are looking forward to our July and August talks. We are presently arranging the July (early August?) talk, which will be a presentation on native land rights and implications for exploration over the next few years.

Our August talk will be by Graham Bubner, who will enlighten us on exploration in the Middleback Ranges.

In early July members of the SA branch helped with a booth at the CONASTA conference held in Adelaide this year. This booth was set up by a "consortium" of professional societies and groups involved in the earth sciences (ie ASEG, PESA, SPE, NCPGG, University of Adelaide Geophysics, PIRSA, and the SA Chamber of Mines and Energy). The CONASTA conference is the annual national conference for science teachers, which seemed like a good forum for our professional groups to find out where the level of knowledge and understanding of geosciences is at in the secondary schools.

We will be putting together a review of the conference and a summary of our questionnaires over the next few weeks, which we will pass on to the Federal Executive and any other interested group.

We are also looking forward to the SEG Distinguished Instructor Short Course (DISC) which will be coming to town in mid September. The title of the course is "The Seismic Velocity Model as an Interpretation Tool" and will be presented by Dr. Phil Schultz of Spirit Energy 76 (UNOCAL). This should prove to be a low to no cost (for ASEG/SEG members) day of interesting science that shouldn't be missed. We will be putting out mailers with specifics soon.

Victoria

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Monthly meetings held at the Kelvin Club, Melbourne on the 3rd Tuesday of every month have included the following:

- | | |
|----------|--|
| April 20 | Dr. Xiong Li, BHP research and technology department "Borehole Gravimetry: An old tool has new life" |
| May 11 | Dr. Peter Elliott, Elliott Geophysics "FLAIRTEM-Development and Case Studies" |
| June 15 | David Gamble (Acacia Resources) Workshop discussion on "Safety in Airborne Geophysics" |

Committee meetings were held in May and early July to enable planning for future activities. This included organisation for a course to be held in late 1999 and publication preparation for Dr Mark Jessel's Structural Geophysics Atlas.

The search for penguins continues...



1999 Corporate Plus Members

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1999 Corporate Members

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Ashton Mining Limited
Australian Geophysical Surveys Pty Ltd
BHP World Minerals
Boral Energy Resources Limited
Earth Resource Mapping
ECS International Pty Ltd
Encom Pty Ltd
Geo Instruments Pty Ltd
Geosoft Australia Pty Ltd
Haines Surveys Pty Ltd
Kevron Geophysics Pty Ltd
Maytex Pty Ltd
Normandy Exploration
Pasminco Exploration
Petrosys Pty Ltd
PGS Australia
Primary Industry & Resources South Australia
Quantec Consulting
Rio Tinto Exploration
Schlumberger Australia Pty Ltd
Scintrex Pty Ltd
Terracorp Pty Ltd
Tesla-10 Pty Ltd
West Australian Petroleum Pty Ltd
Western Geophysical / Baker Hughes
Woodside Offshore Petroleum Pty Ltd
Zonge Engineering & Research Organisation*

Vale Lindsay Ingall 3-Mar-1927 / 21-May-1999

The February-March 1999 issue of Preview presented the citation for the award to Lindsay Ingall of the ASEG Service Medal for extraordinary service to the ASEG over many years. It is with very great regret that so soon afterwards, Preview carries this obituary to Lindsay who passed away at his home in the NSW Blue Mountains on 21 May, 1999.



Details of Lindsay's academic training and extensive career are given in the Service Medal citation in Preview No. 78. The citation explains Lindsay's important role in the foundation of the ASEG and later in the foundation of the Australian Institute of Geoscientists (AIG). He was twice elected President of the ASEG, and also elected President of the AIG. He served lengthy terms on the Executive Committees of both bodies, most recently as Chairman of the ASEG Honours and Awards Committee and as Treasurer and Membership Committee Chairman for the AIG. It is apparent that Lindsay was always willing to contribute his energy and time to assist fellow professionals, both those he knew well and those he had never previously met.

Roger Henderson, standing in for Mike Smith, President of the ASEG, spoke on behalf of the ASEG at Lindsay's Funeral Ceremony. This ceremony was noted for the large number of geoscientists attending and also for the tributes to Lindsay given by his three sons, and by AIG Past President and current Vice President Ian Levy.

As well as Lindsay's many formal achievements he will be remembered by many who have had the privilege of working with him for his energy, enthusiasm and fun loving nature. Andrew Mutton, for example, can recall the way in which Lindsay aroused the sleeping gravity survey crews in the centre of Australia in the early winter mornings by throwing some aviation fuel on the dying embers of the previous nights campfire.

One of his many characteristic expressions was "always keep a sense of humour". Lindsay was also renowned for his interest in people as human beings. He would always want to know the name of the person he was dealing with in hotels and restaurants and would show an immediate and enthusiastic interest in each person he encountered. This also extended to his dealings with company receptionists for whom he always had some cheerful remark and was thus known by them as a most pleasant and welcome caller. Lindsay was aware of the value of kindness in smoothing relationships and a small gift for an appropriate recipient was often his practice. Lindsay had a natural flair for knowing a good deal when he saw one and was Robin Hood-like in his wish to support the poor at the expense of the well-to-do. He practised this in one of his many commercial ventures when he owned a delicatessen for a time.

Those of us who knew Lindsay will miss him greatly. However we will always be thankful that we had the privilege to learn much from his fine example of a very personable, fully professional geoscientist.

A Personal Perspective on Lindsay Ingall

It was about 5 am on a frosty, pitchblack morning somewhere in western NSW in the middle of May 1974. I was suddenly awakened by the sound of an explosion (fuel being poured on the dying embers of the previous night's campfire), and the accompanying flash of light as fire breaks out within metres of where one was sleeping. An incredibly awake voice yelled "Ok you bunch of layabouts, its time to get going. What do you think this is - a holiday camp? Choppers need to be running, ready to lift off at first light"

This was my introduction to Lindsay Ingall. I had only met Lindsay about 24 hours earlier at an ASEG meeting in Sydney. I introduced myself to this cheerful person at the meeting. Our conversation soon came around to my status as a recently graduated unemployed geophysicist. "Want a job? Be ready to leave at 7 in the morning." So started a long association with the man who taught me much about geophysics and life.

Lindsay was a great motivator and organiser. The helicopter gravity survey of Australia needed to be run as a military style operation due to the logistics involved. Three or four helicopters, geophysical equipment, supplies, support vehicles, a new camp virtually every night, often hundreds of kilometres from the last. Largely due to Lindsay's great organisational skills, his company, Wongela Geophysical, was awarded most of the BMR contracts over a period of ten years to carry out the regional gravity survey of Australia. The resulting continent-wide gravity map of Australia is to some degree a testimony to Lindsay's dedication to his work and his organisational proficiency.

Most of all, Lindsay demonstrated through his lifetime how important it was to give something back to the profession which feeds you. His involvement with the ASEG since its inception is now legend. His unselfish contributions to the development of the ASEG and the AIG for over 25 years has set a precedent that will be difficult to emulate. He will be missed by all his associates. Farewell mentor, rest in peace - you have earned it.

Andrew Mutton



Society Briefs

Letter to Senator Minchin

The Minister for Science, Development and Technology
The Hon. Senator Minchin,
Parliament House,
Canberra ACT

8 July 1999

Dear Minister,

Re: Importance of Sustaining Geoscience Technologies in Australia

As President of the Australian Society of Exploration Geophysicists, I have been asked by my Federal Executive to write to you and record the Society's grave concerns about the impact of Federal Government's Budget cutbacks to funding earth science related activities, including the Australian Geological Survey Organisation (AGSO) and Co-operative Research Centres (CRC's). In doing so, I voice the concerns of not only my Federal Executive but also our 1300 strong membership of geoscience professionals, the majority of whom are working in the Australian mineral and petroleum exploration industries.

We believe that the cut-backs, including the loss of approximately 100 staff from AGSO, is not in the national interest and that the decision to cut funding was been taken without due consultation with major stake-holders including the relevant State Government departments and industry. As a consequence we are concerned that there may be inadvertent and deleterious consequences to the petroleum and mining industries in Australia, and to Australia's international competitiveness as a world leader in the extractive industries. The reduction in AGSO staffing levels and closure of two CRC's at a time when we already have record low commodity prices, lack of venture capital, subdued Asian economy and major Native Title impediments may tip the balance and result in jeopardising the maintenance of our current levels of activity within the petroleum and mining industries.

At the Senate Economics Legislative Committee hearings, as reported in Hansard on June 7th 1999, you indicated that State Governments need to be encouraged to take a more active role in onshore geoscience activities. Yet, evidence presented to that Committee indicated that the States' contributions to these activities has almost doubled since the inception of the National Geoscience Mapping Accord (NGMA) Program. This program has delivered regional geoscience, mineral and petroleum resources data sets of lasting value to the nation. The NGMA is widely recognized as an excellent model for Commonwealth-State/Territory collaboration. We believe AGSO should continue to lead this nationally significant, strategic geoscience program and be funded to do so.

The decision to cut funding in the Budget was made unilaterally, without proper consultation with those State Government Departments and industry. Moreover, this policy, based as it is largely on Federal Government not enjoying the benefit of onshore royalty streams, cannot be

sustained. We submit that royalties are but one aspect. Very substantial benefits flow to the Commonwealth through other mechanisms, including excise, corporate and salary/wage-earner taxation, infra-structure development, decentralization and regional development, employment opportunities, training, export earnings and reduction in import replacement.

The mining and petroleum industries make unique contributions by providing major sources of expenditure, employment opportunities and infra-structure in locations which are notably remote from the major sea-board population centres. However, there appears to be little readily available information on the economic impacts of this contribution. In addition, there is a paucity of information concerning the numbers of geoscientists in Australia, their educational and skill levels, employment details, age profile, geographic spread and, most importantly, the necessary levels of earth-science employment needed to sustain current and future levels of national exploration activity.

We are particularly concerned that the cuts to AGSO and the CRC's are part of a longer term marginalisation of the geosciences in Australia. For example industry R & D is falling, AGSO currently employs 3 or 4 new graduates, (that is, less than 1% of its professional staff) and geology is no longer offered in some science syllabuses in State High Schools. Many of the new challenges facing the nation, including water quality and salinity of the Great Artesian Basin and Murray Basin, soil quality and land use, "land-abuse", forestry and natural hazard identification and monitoring will require the involvement of a future generation of geoscientists. Ironically many of these emerging areas will also require a high level of Federal participation, involving both strong technical knowledge base and national resolve in order to override potential State self-interest, particularly as our principal sedimentary basins encompass several state jurisdictions.

We would like to see a broader consultative process and in this regard respectfully request that consideration be given to putting a number of matters before an appropriate meeting of ANZMEC. In particular:

- the impact of the current circumstances, including the level of Federal funding, on the viability of the petroleum and mining sectors;
- determination of the numbers of professional geoscientists required to maintain adequate levels of activity in Australia;
- development of strategies to ensure that adequate levels of professional employment are accommodated, including opportunities for new graduates in both private and public sectors;
- development of projects and funding schemes, involving State and Federal participation, aimed at promoting petroleum and mining activities both onshore and offshore. Certainly guaranteed levels of funding, for three to five years, for AGSO and the appropriate CRC's would greatly assist in stable long term product planning in areas currently beyond the resources of States or industry.

We thank you for your consideration of, and attention to this submission. We would be pleased to contribute to further explanation of these matters if this would be of assistance.

Yours sincerely

Michael J. Smith
Federal President
Australian Society of Exploration Geophysicists

Copy

Professor Peter Cullen, President, Federation of
Australian Scientific and Technological Societies
Dr Bob Day, President, Australian Geoscience Council



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The following abstracts were unfortunately omitted from our special student edition in February. My apologies to these students. Mike Dentith has brought to my attention the fact that an Australian Ph.D student, Tom Ridsdill-Smith, from the University of Western Australia has recently been awarded the Best Student Paper prize at last years SEG conference. Congratulations to Tom. Preview will publish his paper at a later date.

Ed

Multiple Attenuation Via Wavefield Transformations

Matthew Lamont B.Sc (Geophysics)
Department of Exploration Geophysics, Curtin University
Supervisor: Prof. Norm Uren (Curtin University)

PH. D ABSTRACT

Seismic multiples are a serious hindrance to hydrocarbon exploration in Australia. In particular, water bottom multiples can be very difficult to attenuate. This is because there often exists a strongly reflective sea floor which gives multiples large amplitudes when compared with the primary events they overlay, and secondly, because of a widely occurring velocity inversion, which seriously reduces the effectiveness of a very important class of multiple attenuation techniques.

Multiple attenuation techniques can be classified according to the characteristic of the data which is used to discriminate against the multiples in conjunction with the operation behind the demultiple process. Common multiple attenuation processes include FK demultiple, Radon Demultiple, predictive deconvolution, wave equation based demultiple procedures and the family of techniques which come under the umbrella of Surface Multiple Attenuation (SMA). All of these techniques, given the right conditions, can be very effective. They also vary in price from very cheap (FK demultiple) through to expensive (wave equation based demultiple procedures).

However, despite these procedures, and fifty odd years of research, there is no effective general solution to multiple problems off the coast of Western Australia and indeed in many regions around the world.

Two new wavefield transformations, Multiple MoveOut (MMO) and IsoStretch Radial Trace (ISR), have been developed in this research to precondition data prior to the removal of surface related multiples by existing techniques. These form the basis of a new multiple attenuating procedure.

MMO shifts the data so that the water bottom primary event is flattened and the simple water bottom multiples are also flat and periodic. Water bottom peg leg multiples are made approximately periodic.

To solve the stretch problem introduced by the MMO transform, ISR interpolates oblique traces of constant stretch, which also map constant shot emergence angles. The water bottom primary and multiple events form a

stationary time series after MMO and ISR. They are then amenable to removal by autoconvolution and predictive deconvolution.

The results of the new procedure are demonstrated on two case studies from offshore Western Australia. It is shown to be more effective at removing both simple and peg leg water bottom multiples than traditional techniques. Finally, it is an inexpensive procedure, which does not require velocity analysis prior to its application.

The Effects of High-Velocity Layering on Seismic Wave Propagation

Damian Leslie B.Sc. (Geophysics)
Department of Exploration Geophysics, Curtin University
of Technology
Supervisor: Assoc. Prof. Brian Evans

HONOURS ABSTRACT

Seismic methods are commonly used by the petroleum industry to obtain reflections from geological boundaries that are prospective for oil and gas production. In the case of near-surface high-velocity layers (ie. sea-floor carbonates or basalts), a significant portion of the downgoing seismic energy is scattered. This results in very poor seismic data as little energy remains to be transmitted down further and subsequently reflected back to the surface. This dispersal of energy is characterised by the generation of guided-wave energy in low-velocity layers underlying the high-velocity overburden, resulting in the dominant horizontal propagation of seismic energy. This poses a significant problem for data acquisition in many petroleum-prospective regions of the world including where sea-floor carbonates are present in the Carnarvon Basin, Timor Sea, and offshore Perth Basin, and also where there are thick salt diapirs, such as the Gulf of Mexico.

The objective of this research is to investigate the effects of high-velocity layering on seismic wave propagation. Physical modelling can be used to simulate field situations, in a controlled environment, in order to improve the understanding of guided wave propagation. Single shot records were acquired over physical models to examine the effects of various parameters on seismic wave propagation. Such parameters included the thickness of the high-velocity overburden, the thickness of the low-velocity layer, the depth of the water column and the depth of the source and receiver with respect to the high-velocity overburden.

Numerical modelling results were also acquired using elastic wave equation modelling software, and critically compared to the physically modelled datasets. Analysis shows that the numerical modelling algorithm used was unable to accurately model the generation and propagation of guided wave energy. The unreliability of the numerical modelling results is associated with the truncation of computational algorithms, often sacrificing accuracy for improved computer run-time and efficiency. The inability to accurately model guided waves with numerical models may also be indicative of a complex propagation mechanism associated with guided waves.

The guided wave data produced in this thesis has been analysed to illustrate the direct relationship between the group velocity, dominant frequency and dominant wavelength of the guided waves to the thickness of the low-velocity layer. An empirical formula is presented to estimate the interval velocity of the low-velocity layer, for the case of horizontally layered media. The results of three-component recording indicate that guided wave propagation is of pseudo-Rayleigh wave particle motion. This implies that the generation of guided waves is not solely due to total internal reflections within the waveguide, but also involves surface wave propagation along the surface of the lower-bounding high-velocity layer. It is proposed that this surface wave refracts energy into the low-velocity layer at post-critical angles, thus providing additional energy for total internal reflections within the waveguide.

A Comparison of Observed and Theoretical Seismic Reflection Travel Times of Simple Three-Dimensional Models

Oystein Lie

Department of Exploration Geophysics, Curtin University
Supervisor: Dr Bruce Hartley (Curtin University)

MASTERS ABSTRACT

Finding analytical solutions to time-distance relationships from two-layer models are a previous unsolved problem. Standard methods to find these relationships are the finite-difference method and ray tracing methods and are expressed by means of Taylor series. General analytical results cannot be derived from these methods, and they only give approximate numerical results except for in the case of unrealistic assumptions. If the exact offset-traveltime relationship is found, optimum interval velocities can be derived. Therefore, modern techniques of computer algebra should be preferred to find complete analytical solutions to the time-distance relationship.

The objectives of this project are to verify the performance of an analytical ray tracing program and to find exact seismic reflection traveltimes for simple three-dimensional models in the case of the first and the second P-wave reflection. The process involves comparison of observed seismic reflection traveltimes acquired from physical modelling with the theoretical traveltimes calculated from analytical ray tracing. The computer algebra program Maple was used to trace rays analytically through two-layer models, and by comparison to the observed data the performance of the analytical ray tracing program could be examined. Homogenous, isotropic two-layer plexiglas models in simple geometrical settings were applied in the physical modelling and the model parameters were used in the analytical ray tracing program.

In general the fit between the observed and the theoretical results was good, and gross deviations between the two data sets are addressed to errors in the experiments and not to the performance of the analytical ray tracing program. Limitations of the program were, however, detected and included long computing time and a few non-evaluated results for some pre-assigned receiver positions in the case of the second reflection.

This project illustrates that analytical ray tracing by use of computer algebra finds exact solutions to time-offset relations for two-layer models in the general case. The performance of the program is independent of the orientation of the model surfaces, and by use of computing algebra the understanding of seismic reflections can be improved.



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Electrical, Magnetic and Mass Properties of the Nickeliferous Komatiite Sequence Near Leinster, Western Australia



"The Rock Doctor"

D W Emerson, K Martin, & P K Williams

Introduction

In Western Australia the Norseman-Wiluna Archaean greenstone belt hosts nickel deposits of the pyrrhotite-pentlandite-pyrite-magnetite family. This association of Fe minerals is of great economic importance and geophysical methods are applied frequently in the search for and delineation of their accumulations (Trench & Williams, 1994). A summary of nominal physical properties of these key minerals is given in Table 1 (based on various sources). It can be seen that contrasts in density, magnetic susceptibility and electrical conductivity may be reasonably expected for such ores set in silicate hosts.

The ores in the WMC Resources' Rocky's Reward mine near Leinster, 380 km north of Kalgoorlie, fit the Hill & Gole (1990) classification of high-tenor massive and semi-massive sulphides hosted in relatively thin komatiites (Mg-rich ultramafic flows). They are similar to those of the better known Kambalda deposits (Stone & Masterman, 1998) 60 km south of Kalgoorlie. Such ores contrast with the large, layered, olivine-serpentine cumulate bodies hosting disseminated sulphides such as at Mt Keith, to the north of Leinster. The Rocky's Reward nickel deposit geology has been described by De-Vitry et al (1998), and its geophysics by Mutton & Williams (1994) who noted the lack of systematic electrical property measurements. These komatiite ores have a genesis and style that differs markedly from the Canadian Sudbury norite nickel/copper contact ores for which quite conductive examples were discussed by King (1996).

This article reports the results of a systematic WMC sponsored mesoscale laboratory petrophysical study on mine samples and diamond drill core. The objective of such studies was to increase the efficiency and effectiveness of minescale and camps scale exploration as well as provide a basis for improving beneficiation in mineral processing. Mass, magnetic, galvanic electrical and inductive (electromagnetic) measurements followed the procedures outlined by Emerson (1990), Clark & Emerson (1991), Emerson (1969), and Yang & Emerson (1997), respectively. A previous article (Emerson et al, 1998) presented P wave velocity information on ores and associated lithologies similar to those discussed herein.

Geology

Rocky's Reward is a significant example of massive nickel mineralisation in the WA Yilgarn Craton. The deposit has approximate reserves of 6 Mt @ 2.2% Ni and lies in a discrete shear zone in a high strain corridor. A mineralised

system comprising massive and disseminated sulphides has been developed within the corridor, over a strike length exceeding 3.5 km. It includes the WMC underground mines Rocky's Reward and Perseverance. Perseverance is 2 km to the south of Rocky's Reward and has reserves of 33 Mt @ 1.7% Ni approximately (Libby et al, 1998).

Rocky's Reward mineralisation is hosted by three ultramafic cumulate layers of which two are sub-vertical, and separated by a sub-horizontal ramp (De-Vitry et al, 1998). The country rocks comprise felsic metasediments and volcanoclastics with some dolerites. The massive ore is medium to coarse grained (0.2 to 2 mm) and typically contains around 5% Ni; the disseminated ores grade down to 0.7% Ni.

Primary sulphides comprise pyrrhotite and pentlandite (nickel content of around one third of its weight) with trace chalcopryrite. Table 1 shows the approximate or nominal magnetic, conductivity and density values of the key minerals. The sulphide minerals have been remobilised and recrystallised into interlocking granoblastic textures in the massive ore which often shows ductile tectonite fabrics manifest as alternating coarse grained pyrrhotite and pentlandite rich layers. The disseminated sulphides are interstitial to and included within serpentine pseudo-morphs after coarse grained olivine.

Table 1. Nominal Physical Property Values Key Nickel Association Minerals.

mineral	formula approx.	density g/cm ³	mag k SIx10 ⁻³ (grainsize dependent)	crystalline conductivity S/m
pyrrhotite - mon.	Fe ₇ S ₈	4.60	~70 000 ±	≥ 100 000
pyrrhotite - hex	Fe ₉ S ₁₀	4.65	145	≤ 100 000 ?
pentlandite	(Fe,Ni) ₉ S ₈	4.96	1	≥ 100 000 ?
pyrite	FeS ₂	5.02	4	1 000 ±
magnetite	Fe ₃ O ₄	5.18	~1.3x10 ³ ±	10 000 ±

Sampling

Sampling at Rocky's Reward was carried out mainly near the top of the West Fault primary ore zone at 150 m depth. The overlying supergene (violarite-pyrite-magnetite) and oxide zones were not sampled except for two specimens of highly oxidised ore. A total of 104 mine and drillcore rock samples and five mine groundwater samples were taken for testing.

Results

The grouped results are given in Table 2 as mean values. Individual values for sulphides and cumulates have been crossplotted: magnetic susceptibility against bulk density in Figure 1, and the EM conductivities against density and susceptibility in Figures 2 and 3, respectively. Reference minerals are plotted *approximately* on these Figures.

For the massive, sub massive and semi massive pyrrhotitic ores, conductivities range from good to excellent (i.e. from around 1000 to over 100 000 S/m), magnetic susceptibilities are high, often in excess of $10\,000 \times 10^{-5}$ SI, and densities range from 4.0 to 4.6 depending on the amount of brecciation, dilution and oxidation. The Rocky's Reward massive sulphides are commonly brecciated and incorporate up to 30% (volume) of country rock clasts (Mutton & Williams, 1994). The sampled pure primary ores (first row Table 2) have the highest densities, high susceptibilities and spectacular conductivities (ranging up to 170 000 S/m), but they are not quite representative of the bulk of the massive ores (see the other massive ore categories in Table 2). Transitional ores, just below the oxide zone, are further diminished in density, conductivity and susceptibility.

Intermediate density mesocumulate disseminated ores (up to 20% sulphide) occur mainly in a lizardite (serpentine, altered ultramafic) matrix with veined and interstitial magnetite. The sulphides can occur as grains, blebs, blades and veinlets with varying degrees of networking. The ore susceptibilities are very high, but conductivities fall well below those of the massive ores except when the pyrrhotite occurs in a networked texture exhibiting good electrical continuity and resulting in conductivities approaching those of the less conductive massive ores. Adcumulates (under 5% sulphide) are resistive and, having less magnetite, are less magnetic, but susceptibilities are still high.

The barren ultramafic host has a relatively low density, high susceptibility and is highly resistive. The country rock metasediments and metavolcanics are low in density and susceptibility but high in resistivity. Sulphidic metasediment bands having some foliation plane conductivity do occur in the country rock stratigraphy. Water filled fracture zones, if they occur, will lower the bulk resistivity of these rocks (Emerson & Yang, 1998). Groundwaters, in the mine, are fairly fresh: $\rho_w = 8$ ohm m, 25°C [$\sigma_w = 1250$ $\mu\text{S}/\text{cm}$]. The ρ_o values in Table 2 are for samples vacuum saturated with water of this type.

The highly weathered zone in the first 50 m has high porosity, low density and susceptibility, and is slightly conductive. Altered ores in this zone can attain significant magnetic susceptibilities owing to the generation of magnetite. It can be seen in Table 2 that the weathered and oxide mineralised zones are quite porous and that the rest of the lithologies range from tight to slightly porous, except for one fractured mesocumulate ore.

The crossplots show the spread of data and certain features controlled by mineralogy and texture. In Figure 1 the massive sulphides lie near the pyrrhotite points while the influence of magnetite and pyrrhotite causes the lower density cumulates to plot as a separate group. In Figure 2 sulphide conductivities increase with density to the nominal 100% pyrrhotite point, but well networked pyrrhotite in lower density ores is anomalous in the

overall trend. Some of the massive ores have low susceptibility and may contain substantial amounts of hexagonal pyrrhotite. In Figure 3 the massive sulphides trend towards the nominal 100% pyrrhotite point but do not attain pure coarse grained monoclinic pyrrhotite's susceptibility value of around $70\,000$ to $100\,000 \times 10^{-5}$ SI (Clark & Emerson, 1991). The disseminated lizardite ores trend towards the nominal 100% magnetite point.

The massive pyrrhotite ores are quite anisotropic in magnetic susceptibility ($k_{\text{max}}/k_{\text{min}} = 2:1$) and they carry considerable remanence ($Q_n \sim 4$). Electrical anisotropy in the sulphides can be seen in the differences between the inductive and galvanic (DC, four-electrode) conductivities. This is a textural and compositional effect manifest in measurements on the 25 mm and larger diameter drilled test cores. Banding, foliation and heterogeneity are responsible. The galvanic method drops its potential across silicates, carbonates and sulphides along the core axes; the inductive method sees only the sulphides which, if banded, have optimum laboratory response when banding is normal to the core axes. However, in the case of the extremely conductive pure primary ores anisotropy is not high. The cored samples were still showing skin effect at 10 kHz in the induction coil, so the galvanic conductivities are the preferred values.

Mineragraphy

Two pure massive and one sub-massive primary sulphides were selected for mineragraphic and XRD crystallography. These observations are summarised in Table 3. The two extremely conductive massive sulphides (to $\sim 170\,000$ S/m) are shown to be virtually pyrrhotite-pentlandite rocks. There were trace amounts of gersdorffite (NiAsS), but no pyrite, and insignificant amounts of magnetite. The medium to coarse grained, pervasive pyrrhotite is favourably textured from an electrical viewpoint i.e. anhedral grains with well sutured grain boundaries and an enveloping habit. Ohmic microprobe tests on the pyrrhotite matrix, on the pentlandite bands and blebs, and between the pyrrhotite and pentlandite gave identical (0.1 ohm) readings suggesting that the pyrrhotite and pentlandite form an effective electrical continuum.

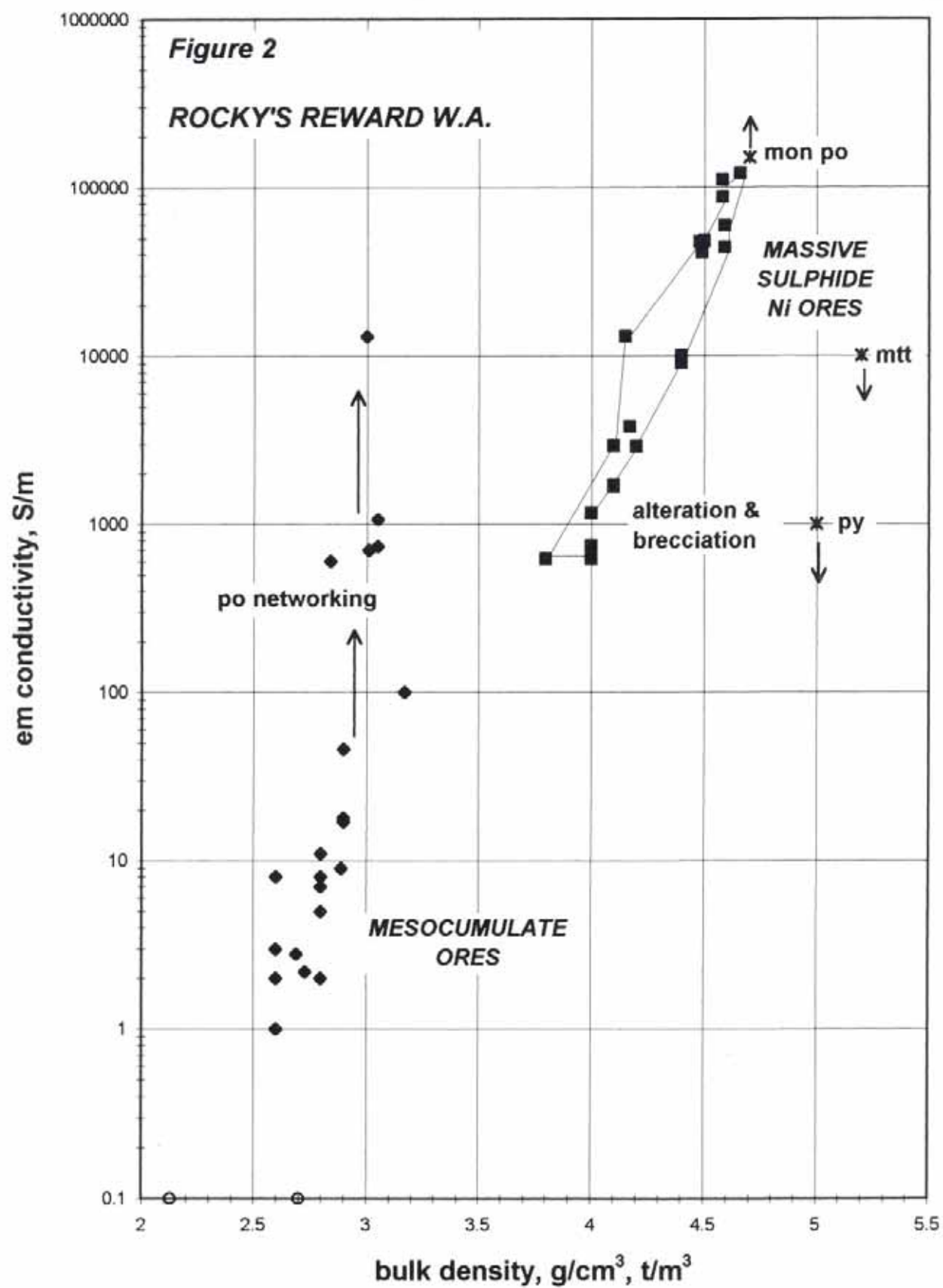
Millerite

Millerite (NiS) or capillary pyrites is a low temperature supergene alteration mineral in nickel deposits, but does not occur in large quantities at Leinster. Measurements were carried out on a specimen from the Perseverance open cut to the south of Rocky's Reward. The sample's density was 5.13 g/cm³ which is less than that of pure millerite (5.5 g/cm³) owing to minor encrustations of other (unknown) alteration minerals. This sample displayed an extraordinary DC galvanic conductivity of $1,212,524$ S/m and in EM tests was still showing skin effect (Yang & Emerson, 1997) at 1 kHz where the apparent inductive conductivity was $1,120,000$ S/m. Magnetic susceptibility appears to be very low, but could not be measured satisfactorily owing to skin effect persisting to low frequencies.

KEY METALLIC LUSTRE MINERALOGY		
mon po	Fe ₇ S ₈	pyrrhotite (po-m)
hex po	Fe ₉ S ₁₀	pyrrhotite (po-h)
pn	(Fe,Ni) ₉ S ₈	pentlandite
v	FeNi ₃ S ₄	violante
py	FeS ₂	pyrite
mtt	Fe ₃ O ₄	magnetite (mtt)

TABLE 2
SUMMARY LABORATORY PETROPHYSICS
ROCKY'S REWARD LITHOLOGIES
mean values, mesoscale sampling mainly of Mine West Fault Area

lithology	DBD g/cm ³	P _A %	mag k SIx10 ⁻⁵	em σ S/m	galv DC σ S/m	1kHz galv resistivity ρ _o ohm m	n
OLIVINE/SERPENTINE-SULPHIDE CUMULATES							
MASSIVE ORES >80% sulphide							
massive sulphide (po, pn)	4.56	0.8	20985	69488	115905		8
slightly bx/ox mass. sulph. (po, pn)	4.33	n.a.	10559	7297	4609		3
brecc/part ox mass. sulph (po, pn)	4.01	n.a.	339	1346	591		7
incip. weath mass sulph (po, pn) <i>stockpile</i>	4.17	2.1	7165	3800			1
semi massive sulph (po, pn)	4.15	0.9	8171	13000	9209		1
MESOCUMULATES 5-20% sulphide							
high cont. net texture sulphide (po, pn)	3.00	2.6	17648	13000	16400		1
net textured sulphides (po, pn)	2.99	1.5	13020	778	2183		7
fract. net textured sulphides (po, pn)	2.83	8.8	19232		11		1
dissem-blade sulphides (po, pn)	2.75	1.6	24103	24 (22 samples)		2754	28
ADCUMULATES <5% sulphide							
olivine matrix	3.17	1.0	2184			1136	4
serpentine matrix	2.58	2.1	5194			174	7
HIGHLY OXIDISED MIN.							
very alt, former mass sulphide: v, mtt	2.68	7.9	18855	-0.1		7	2
HOST & COUNTRY ROCKS							
regolith, felsic (highly weathered)	1.82	30.9	5	-0.1		6	2
metasediment, sulphidic (py, po)	3.02	<1	2388	35 (bands only)		39 (bulk)	1
metasediment, felsic	2.72	0.3	108			40714	13
metasediment, tuffaceous	2.67	0.7	24			34240	6
meta-dolerite	2.84	1.9	61			19146	4
pegmatite	2.60	2.0	8			1439	2
ultramafics, undiff. (HOST) (olivine/talc/carbonate/serp/amphibole)	2.66	1.2	5212			35835	6
groundwater ρ _w 25°C						8	5



Discussion

The Rocky's Reward pure sulphides' results offer the opportunity of studying the conductivities of favourably textured pyrrhotite-pentlandite rocks devoid of pyrite and magnetite - cubic minerals with high single crystal conductivities (1000 to 10 000 S/m). However, such conductivities seem rarely to translate to mineral aggregates of pyrite and magnetite - from an achievable conductivity viewpoint they are spoiler minerals, usually (Emerson & Yang, 1994a & b). Pyrrhotite, which can be considered a low mobility metal, is consistently a good conductor and the high density sulphides, uncontaminated by country rock fragments and clasts, show this clearly. The Rocky's Reward ores are unusual in the magnitude of their conductivities which appear to be among the highest recorded for *mineable ores*. Ward (1970) and Shuey (1975) cite very high conductivities for natural pyrrhotites, around 100 000 S/m, and up to 500 000 S/m for a galvanic microarray on a small polished surface, but such conductivities in ores are not common and may go unrecognised in inductive core-tests because of skin effect.

Most accumulations of pyrrhotite are mixtures of magnetic monoclinic and non magnetic hexagonal pyrrhotite (Arnold, 1967) and the susceptibility data suggest that this is the case at Rocky's Reward. Hexagonal pyrrhotite, which is unstable in the presence of pyrite, is common in the Perseverance-Rocky's Reward system (Martin & Allchurch, 1975). It seems to occur approximately in a 1:1 ratio with the monoclinic variety in the Rocky's Reward massive ores. Ward (1970) notes that despite pyrrhotite's large magnetic anisotropy there is little evidence for electrical anisotropy, and measurements on the pure massive Rocky's Reward ores corroborate this. Ward (1970) quotes synthetic hexagonal pyrrhotite conductivity measurements (10 000 to 100 000 S/m) as evidence of it being a poorer conductor than the monoclinic variety. To test this at Rocky's Reward would require several petrographically controlled specimens, with similar

densities and known pentlandite contents (of known conductivity) to be measured for susceptibility and conductivity. Pentlandite's conductivity is a moot point, although it appears to be high in crystals (Harvey, 1928) its aggregate behaviour is not known. Amann & Pietilla (1998) reported conductivities of 90 000 S/m and 40 000 S/m parallel and normal to foliation, respectively, for coarse, banded, very dense (4.8 g/cm³), pentlandite-rich pyrrhotitic nickel ore from Silver Swan about 300 km south of Rocky's Reward.

These are interesting observations on pure high density massive sulphides with only two significant components: pyrrhotite and pentlandite. However, the majority tonnage of mined massive ore is from brecciated, clast-laden sulphides and sulphides that have undergone or are undergoing alteration. Mutton & Williams (1994) quote the results of 1605 massive ore density determinations with a mean of 4.3 g/cm³ (sd 0.5) for deeper massive ores (5.5% Ni) and a mean of 4.2 g/cm³ (sd 0.4) for shallower supergene massive ore (4.9% Ni). An inspection of Table 2 and Figure 2 suggests that the bulk of the massive mineralisations would have conductivities an order of magnitude less than the pure massive sulphides.

A schematic cross-section is presented in Figure 4. It depicts idealized lithological and ore units with their corresponding physical properties, in rounded figures. In this simplified picture the salient features lie at depth and are the high conductivity of the thin massive ore zone and the moderate to fair conductivity of the better class of disseminated ore in an equally thin zone (few metres maximum total, for both). The disseminated sulphide zone may display significant electrical anisotropy with maximum conductivity in the plane of sulphide banding, where it occurs. These conductive features are flanked by resistive country and host rocks below the base of oxidation and overlain by low density, slightly conductive weathered zone materials. The ores' magnetic susceptibilities are not a salient feature; the massive sulphides' susceptibilities are due to monoclinic

Table 3
Rocky's Reward West Fault Massive Sulphides Detailed Data

sample	comments (optical study)	DBD g/cm ³ t/m ³	P _A % (poros.)	mag k SIx10 ⁻⁵	conductivity σ		XRD mineralogy - weight percent					
					em Inductive	DC galvanic	po	pn	v	sili- cate	carb- onate	Fe/Cr oxide
2	medium to coarse grained massive sulphide with inclusions of serpentine and carbonate, massive fresh po hosts pn and minor cpy, deformation texture in po - shows lamellar structure	4.66	0.5	11874	>120000	169552	84	14	1	tr	tr	tr
9	medium to coarse grained massive sulphide, dominant equigranular po hosts sporadic pn which also occurs as mm bands, pn has v spotting, minor cpy; minor chlorite tremolite & talc	4.58	0.9	18847	>110000	138410	82	11	3	4	tr	
94	medium to coarse grained sub-massive sulphide with dominant po, pn & v alt, minor cpy; carbonate inclusions and abundant chlorite with mica	4.15	0.9	5778	13000	9209	61	11		18	4	tr

(note, there is an additional 5% undetermined sulphide to be included in the mineralogy)

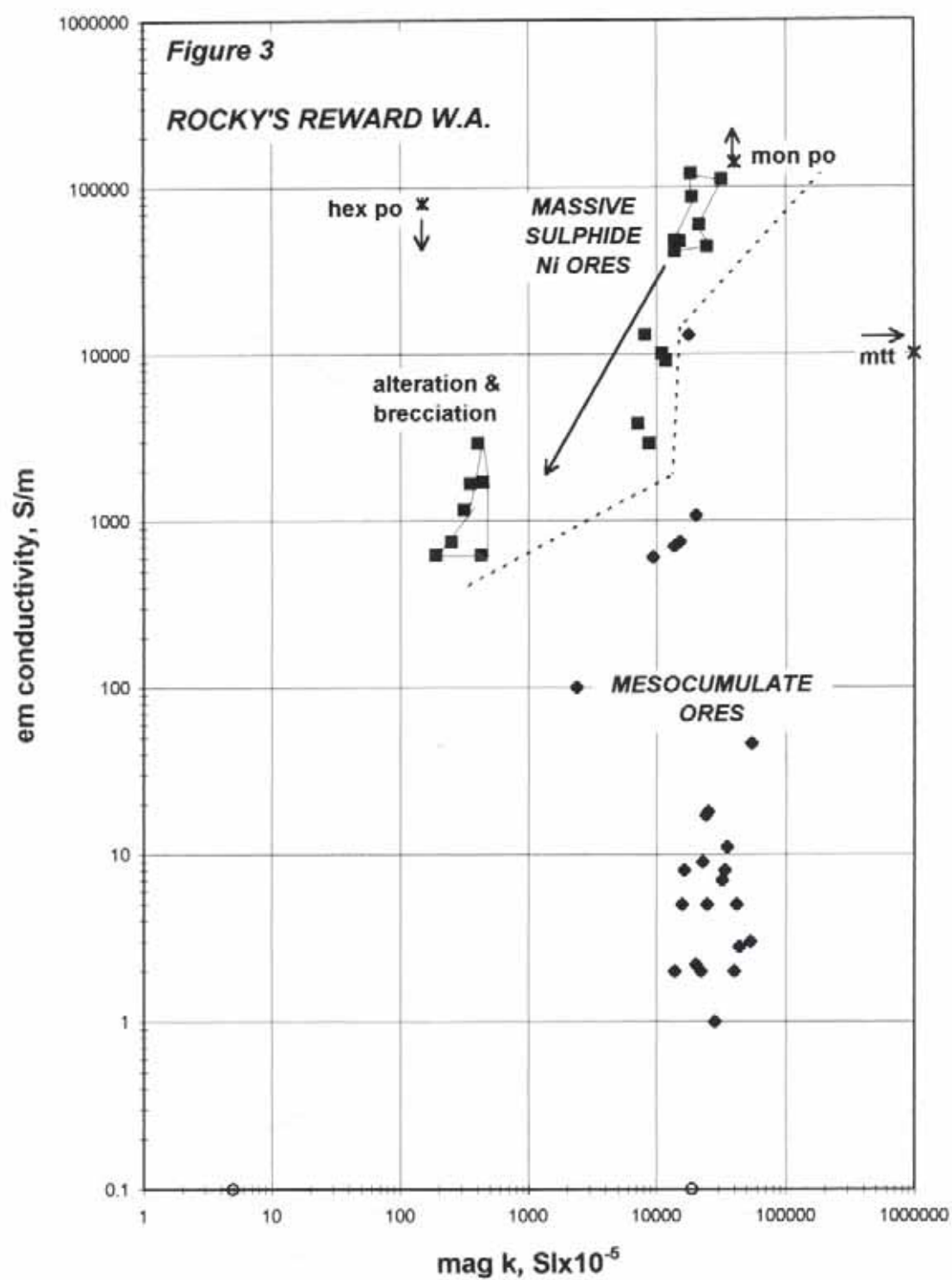
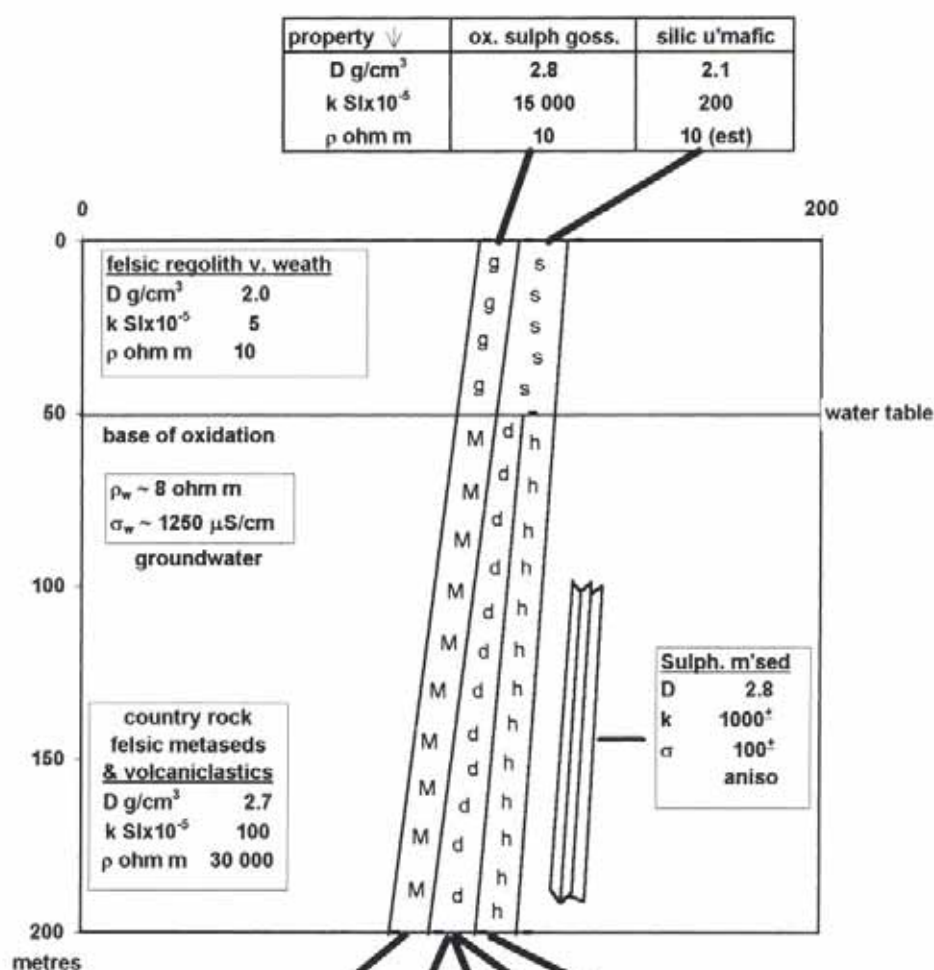


Figure 4
Rocky's Reward Physical Properties

this is a greatly simplified sequence for the Rocky's Reward subsurface which is highly complex with steep dips, flattening, folding, thickening, faulting and repetitions; the metasedimentary and volcanoclastic country rock occurs on both the hanging and footwall sides of the ore; felsic and dolerite dykes omitted; thicknesses of ultramafic and mineralised zone exaggerated; supergene and transition zones under base of oxidation, omitted; physical properties interpreted and rounded values; resistivities are for fresh water saturated state - nearer the surface, as materials dry, ρ 's will increase approx. as S_w^{-2} where S_w is the water saturation, in the usually very dry top few metres ρ 's may be very high as will be heavily siliceous pods anywhere in weathered ultramafic.



pyrrhotite, the disseminated sulphides contain magnetite as well, the host ultramafic has only magnetite. All these units are quite magnetic and not readily differentiated by magnetics. A sulphidic metasediment electrical noise source in the country rock is also depicted. These pyrrhotite/pyrite bearing beds are commonly highly anisotropic electrically and, elsewhere in the Leinster region, attain conductivities far in excess of the single example in Table 2.

Conclusions

The Rocky's Reward nickel deposit mesoscale sampling and petrophysical measurements have shown a spread of sulphide conductivities ranging from moderate to extremely high and due to medium to coarse grained monoclinic/hexagonal pyrrhotite. Pyrrhotite is also the host for nickel bearing pentlandite which, present in minor proportions, appears to contribute to the conductivity. Density aside, the outstanding feature of the Rocky's Reward mineralisation (below the weathered zone) is its conductivity; the pure massive sulphide ore values are possibly the highest recorded in the public literature. Magnetic susceptibilities are very high in the ore sequence and are due to monoclinic pyrrhotite in the massive ore and to monoclinic pyrrhotite and magnetite in the serpentine rich disseminated sulphide zones. High susceptibilities are also encountered in the barren host ultramafics which contain accessory magnetite. An exploration technology tuned to finding highly conductive units in a magnetic host is supported by this study.

Conductivity is the dominant and diagnostic physical property for the massive pyrrhotite-pentlandite ores and there is little reason to doubt that the mesoscale core conductivities reflect the distribution of effectively linked conductivities throughout the massively mineralised part of Rocky's Reward. The same cannot be said for the disseminated mineralisation conductivities which, although ranging to high value, may not have effective linkage throughout the bulk of the disseminated zones owing to heterogeneity and changes in pyrrhotite's habit which can vary from isolated to networked.

In ore treatment a beneficiation process which involved density and conductivity would appear to be effective.

Acknowledgements

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AGSO Rebuilds After Downsizing

As most members would be aware AGSO's funding was cut by 15% or \$7.6million in the recent May budget. This necessitated significant staff reductions and the sale of its aircraft. Staff losses are equivalent to 72 permanent and 17 temporary positions - a major blow to the organisation and the nation's geoscience capacity.

Neil Williams, AGSO's Executive Director has moved quickly to adjust and rebuild.

The restructuring has been completed and the Divisional Chief's, Research Group Leaders (RGL) and Senior Scientific Specialists (SSS) have now all been appointed and are shown below: -

PETROLEUM and MARINE (Trevor Powell)

- Ocean Drilling Program, RGL - Neville Exon
- Petroleum Promotion, RGL - Clinton Foster
- Marine Zone Management Information, RGL - Geoff O'Brien
- Petroleum technical Advice, RGL - Paul Williamson
- Petroleum and Marine SSS - Roger Summons

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- Minerals Promotion, Resources and Advice, RGL - Ian Lambert
- Regional Studies and Mineral Systems, RGL - Russell Korsch
- Australian National Seismic Imaging Resource Director, - Barry Drummond
- Minerals SSS - Lynton Jaques

GEOHAZARDS and GEOMAGNETISM DIVISION (Wally Johnson)

- Geomagnetism, RGL - Charlie Barton
- Seismology SSS - Ken Muirhead

Trevor Powell remains the Deputy Executive Director and Phil McFadden has been appointed to a new position of Chief Scientist.

AGSO is still primarily a resource focussed geoscience organisation. The severance of the Land and Water functions from AGSO after the October 1998 election still restricts the scope of the organisation in terms of its role as a national geoscience institution. Hopefully the Government will eventually see the sense and amalgamate all national geoscience research and mapping activities under the one roof.

MCA Annual Meeting

The Mineral Council of Australia's annual meeting held in Canberra was a somewhat subdued affair, given the current state of the minerals industry in Australia. In fact, Leon Davis the CEO of Rio Tinto stated publicly that, in today's economic climate of low commodity prices, one of the things he dreaded most would be his exploration manager announcing the discovery of a new ore body. Not a good view from the top of a major.

In spite of this gloomy picture, Andrew Stoeckel's paper 'Minerals - our wealth down under' articulated well the

importance of minerals to the wealth of the nation. It turns out that in 1994 the World Bank estimated that Australia was the sixth wealthiest nation on Earth (~US\$300k per person) and that our 'wealth derived from minerals and fossil fuels is 2.5 times the corresponding proportion for the wealthiest countries'. Furthermore, the wealth created by the minerals industry far exceeds its wealth reduction. Hence the need to maintain a vibrant competitive minerals industry, in which there is a strong investment in R&D, as well as a successful exploration program that ensures the supply of suitable ore bodies to replace those being mined at the present time.

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14th ASEG Conference & Exhibition Perth 2000

Conference News



Perth Conference Set For New Record

The Perth Conference is set to break new records with over 230 papers and posters submitted - almost double that of previous conferences. Multiplying that interest across the board we should see attendances go through the roof. Get your registration in early otherwise run the risk of missing out on your booking preferences.

The Technical Papers Committee, under Kevin Dodds (Tony Endres has recently moved overseas) have been swamped with papers and have molded together an impressive technical programme. We will have four concurrent sessions, including for the first time ever two Petroleum streams. Kevin tells us there are some excellent case histories in both the oil and minerals areas, and there has been significant interest from overseas.

The Exhibition promises to maintain the high standard expected at ASEG conferences with strong interest from both the Petroleum and Minerals sectors. Exhibition space is still available but is filling fast. Contact Mark Russell, Exhibition Co-ordinator, before it is too late !!

Sponsorship Co-ordinators, Alan Sherrard and Val Baird, have been astounded with the support from industry given the current economic climate. All major sponsorship packages have gone, although some opportunities still remain. We welcome WESTERN GEOPHYSICAL as the principal sponsor of the conference and thank Steve Pickering for his generous support.

The conference dinner will be held at the Perth Zoo, in the African savanna. This promises to be the highlight of the social calendar, so catch up with your friends and come along to this night of nights.

The Workshop programme under John Jackson is taking shape and includes a wide cross section of disciplines. Current topics include Fractures, Overpressures, Geostatistics, Aeromagnetism - recent developments, Geotrex's AEM and CRC AMET (Co-operative Research Centre for Australian Mineral Exploration Technologies).

Helen Anderson and Dom Howman are organising the students day. The required level of sponsorship was easily obtained, thanks to great support from a range of mineral, petroleum and contracting companies. Dom is now scouring the corridors of Curtin University and various government organisations for suitable resource material. The teachers will be provided with a significant amount of information so they can keep spreading the word of geophysics to their students. Any contributions or suggestions for resource material would be welcomed.

Due to prior bookings at the Burswood, another auditorium nearby will be used. This has a very large seating capacity that far exceeds our expectations of attendees. However, be warned that if we are overwhelmed with students wishing to attend, we now

have the necessary seating, so Helen will be back on the sponsorship warpath.

The publicity hungry Larry Tilbury will ensure all geoscientists know where they should be in March 2000. Keep a lookout on the ASEG conference web page for the latest in Conference News (link from the ASEG homepage or www.promaco.com.au/conference/2000/aseg/). You may be wondering what happened to Mawson the penguin in Hobart. The last we heard he had taken a job as a seismic observer and was working his way west onboard the Western Legend.

Kim Frankcombe and Mike Sayers

Co-Chairmen of the 14th Australian Society of Exploration Geophysicists Conference and Exhibition

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Honours and Awards

During the 14th ASEG Conference to be held in Perth in March 2000, several categories of honours and awards will be presented to members who merit recognition for distinguished service to the Society and to Exploration Geophysics. ASEG Members are invited to submit nominations for the following awards:

- **ASEG Gold Medal** - for distinguished service to geophysics.
- **Honorary Membership** - for distinguished contributions to the profession of Exploration Geophysics.
- **Grahame Sands Award** - for innovation in Applied Geophysics. It is made to a person or persons who has or have been responsible for a significant practical development of benefit to Australian applied geoscience. This could be in the field of instrumentation, data acquisition, interpretation or theory.

Nominations are now called for the above awards. Any member of the Society is eligible to nominate applicants. Nominations are to be supported by a seconder and include four copies of all relevant supporting documentation. They are to be sent to:

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