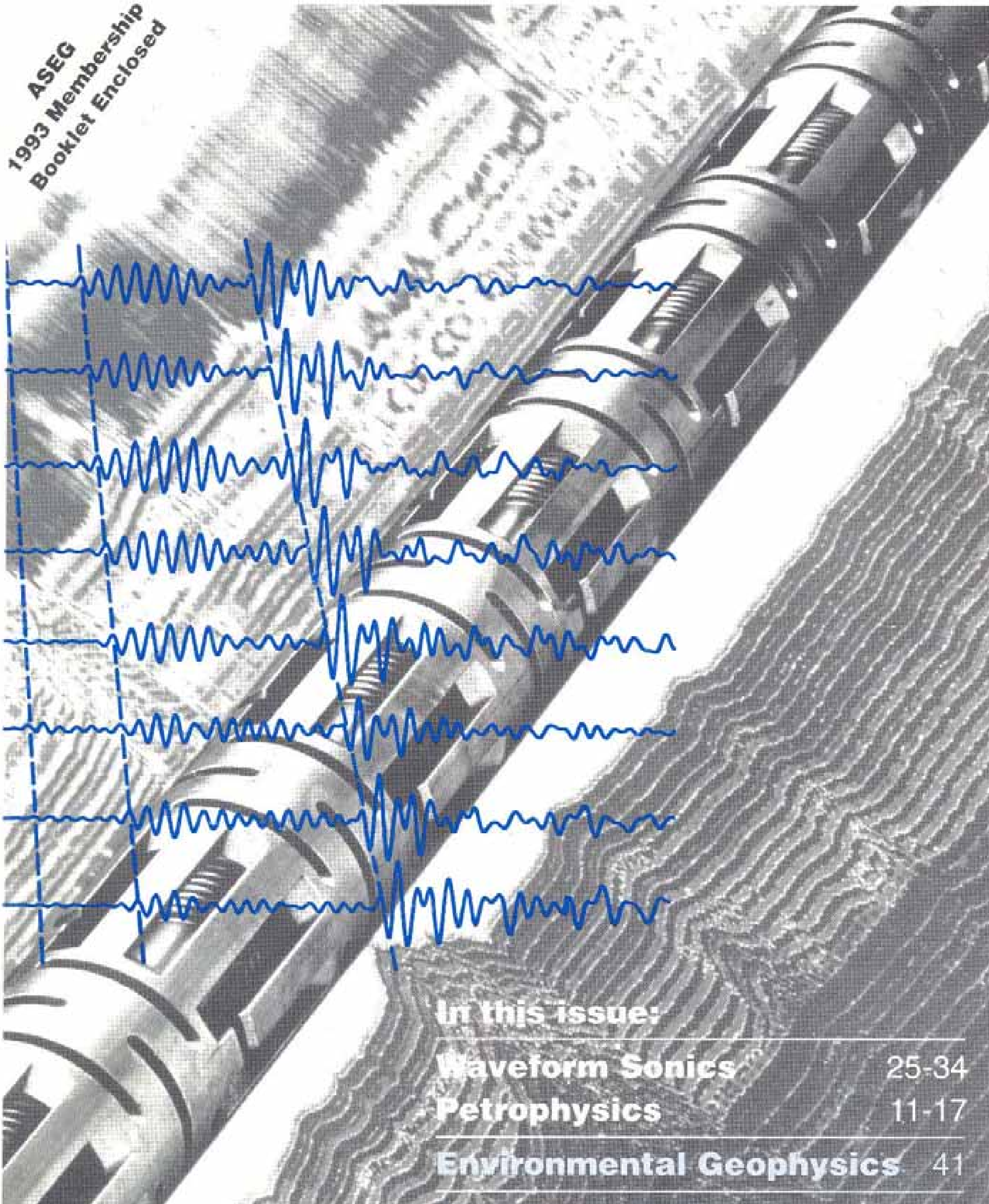
Australian
Society of
Exploration
Geophysicists
ACN 008 876 040

Preview

October 1993

Issue No.46



In this issue:

Contents

Preview Feature: Petrophysics

Also in this issue ....
Special Features

ASEG 1993 Membership booklet (Enclosed)

Regular Features

HEAD OFFICE: Suite 5, 672B Glenferrie Road Hawthorn Vic 3122
TEL:(03)818 1272 FAX:(03)818 1286

PRESIDENT: Mr Hugh Rutter, Tel:(03) 818 1272 Fax:(03) 818 1286

HON SECRETARY: Mr Brenton Oke, Tel: (03) 652 6625 Fax:(03) 652 6684

EDITOR: Mr Geoff Pettifer, Tel:(03) 412 7840 Fax:(03) 412 7803

email: grp@mines.vic.gov.au

NEWSLETTER PRODUCTION: Ms Janine Cross, Tel: (03) 818 1272 Fax: (03) 818 1286

ADVERTISING: Mr Greg Turner, Tel: (03) 881 1279 Fax: (03) 803 2052

PREVIEW ADVERTISING RATES (6 ISSUES): Business Card $100; ¼ Pg $200; ½ Pg $330; Full Pg $530; Back Pg (¾ Pg) $750; Colour Advertising Approx $1,000 per page per issue depending on demand. Special rates available for advertisements accompanied by colour review articles

Registered by Australia Post, Publication No. WBG 2390. PREVIEW is a publication of the Australian Society of Exploration Geophysicists, circulated to a membership of approximately 1,100.

Artwork by Mark Littler Design Pty Ltd & Geophysical Exploration Consultants Pty Ltd

Printed by Snap Printing

Editor's Desk

Geophysicists work with rocks and of necessity (because of resolution limitations) reduce them to aggregate rock masses of equivalent bulk petrophysical properties with simplified geometries. Somewhere in this process the detailed petrophysics gets lost. Is this situation redeemable? Maybe! If we can tie down the petrophysical properties and understand their potential variation our geophysical models can be refined and be more realistic. Also great strides have been made in geophysical logging to map in-situ petrophysics.

In this special petrophysics issue, in a colour feature article sponsored by Schlumberger (p25), Andrew Sutherland outlines the advances made in waveform sonics to define subsurface geotechnical and geophysical properties in detail that many have only previously dreamed of. Don Emerson, of Systems Exploration gives a useful summary of petrophysical properties to enhance our understanding of this important basis for geophysical interpretation (p11).

Environmental geophysics is coming of age in theUS and we can learn from the US experience (p41-43).

Prame Chopra, of AGSO has provided an excellent informative article (p47) on the capabilities of tapping into software archives through Internet e-mail services. If you are not on e-mail yet maybe this article will prompt you to join. ASEG members are reminded to register their e-mail addresses with the ASEG (p50).

Many ASEG members are concerned at the bizarre predicament of noted ASEG Grahame Sands Award winner Dr Terry Lee (p21). Terry's contributions to geophysics and his international reputation are exceptional and one can only wonder at the true maturity of the geophysical community in Australia when on one hand we have a frantic rush to establish a plethora of chairs in geophysics (p39) while elsewhere it seems "...the prophet is not welcome in his own land...".

On a brighter note the enclosed ASEG 1993 membership booklet and the parade of faces of ASEG officialdom (p53) will help make your ASEG and your colleagues more accessible.

Geoff Pettifer
Editor

Preview Deadlines

Issue	Deadline
December '93	November 27, 1993
February '94	January 21, 1994
April '94	April 1, 1994
June '94	May 27, 1994
August'94	July 29, 1994
October '94	September 30, 1994
December '94	November 25, 1994

President's Piece

ASEG and The SEG

Three weeks ago I attended the SEG conference in Washington D.C. and one of the objectives was to represent the ASEG at the Annual Council Meeting of the SEG; I was accompanied by Michael Asten. The ASEG, while being autonomous within Australia is also a Section of the American Society. Australians can be a member of the ASEG and, if they wish, can also apply for membership of the SEG. The number of members of the ASEG who are also members of the SEG determine the number of representatives we can have at the SEG Annual Council Meeting; at the moment our numbers provide for three. The Council Meeting is a formal occasion with representatives being "called" to check that they are present. Reports were presented by the President, Secretary and Treasurer, after which much of the business was concerned with ratifying decisions made prior to the meeting.

One item in particular stimulated considerable debate. There was a proposal to reduce the membership fee by $5.00. The council was evenly balanced and the casting vote from the President meant that the motion was lost. If our third ASEG representative had been there, maybe the fees would have been reduced; Norm Uren, where were you?

I attended a number of committee meetings during the week to see if I could learn anything that would help us in Australia. In general we appear to be in good shape; our membership is growing while that of the SEG is falling.

It was worthwhile attending the Council Meeting and strengthening the relationship between the two Societies. Michael Asten and I talked with the incoming President Michael Schoenberger about a joint ASEG/SEG conference sometime in the near future. He was very enthusiastic and we should be able to confirm arrangements when he visits Australia for the ASEG conference in Perth.

On the technical side, the SEG conference is a huge event with a large number of exhibitors and the presentation of many papers. The overwhelming emphasis is on petroleum exploration, with, I would estimate, only 10% of the papers directly addressing mineral exploration. This clearly represents the major activity on the North American continent; quite different to Australia.

My comments relating to ASEG involvment with professional positions stimulated some letters of response. Keep them coming; its good to have critical and constructive feed-back.

Hugh Rutter, President

Executive Brief

Your ASEG Executive at work ...

Two committee meetings have been held since the last report.

A proposal that the President should represent the ASEG at the SEG Conference Council Meeting in Washington (26 - 30 September, 1993) was discussed and approved. Representation gives our society the opportunity to raise items that effect the ASEG (eg joint conferences), to inform them of what we are doing and to contribute to discussions and debates. One of the outcomes of this visit is that selected case histories from "Exploration Geophysics" will be submitted to the SEG for publication in "Geophysics" - an opportunity for greater recognition of Australian geophysicists and geophysics. Council members were very impressed with the copies of Preview handed out by Hugh and we will be gaining some new members as a result. It was agreed by the Executive Committee that the President should attend future annual SEG Conferences.

Improvements to Preview, in particular the colour spreads and new layout, have generated considerable amount of positive feedback from members, advertisers and featured companies. Requests for reprints have already been received.

New student member applications continue to roll in as they take advantage ofthe free year of membership offer. The ASEG Executive welcomes you all and all new members and hopes that you will find the Society of benefit. Please, no more applications for a freebie from professional geophysicists; this offer applies to students only and does not apply retrospectively (I've already tried!).

A suggestion for the establishment of a 'Code of Ethics' or guidelines for geophysical exploration, in particular aerial surveys in Australia was raised by Mike Asten and discussed at length. This proposal is in progress.

Non-member subscribtion and advertising rates for "Exploration Geophysics" for 1994 were discussed and approved.

A request from the SEG to include the ASEG publications on the SEG digital cumulative index in their GEOROM was granted.

The possibility of formation of a technical section of the ASEG devoted to shallow exploration geophysics, analogous to a similar section set up recently in the SEG, was discussed.

Further discussion points have included:

- Reports from the Treasurer, Preview Editor, Business Manager, Publications Committee and Publicity and Promotions Committee
- Membership renewals
- a possible membership questionnaire
- updates on arrangements for the Perth Conference

A reminder that the new ASEG library, housed at the AMF in Adelaide, still requires copies of geophysical journals. If any member has copies of "Geophysics", "Geophysical Prospecting" etc they would like to donate to the library, please contact Koya Suto (Ph 03-895 3041 Fax: 03-890 0029). A 'warm feeling' inside and acknowledgement in Preview is guaranteed to all altruistic donators.

Brenton Oke, ASEG Secretary
Ph: (03) 652 6625, Fax: (03) 652 7315

ASEG People Profile

Andrew Sutherland; ASEG Executive Committee Member 1993

Andrew graduated from Melbourne University in 1981 with a BSc in Geophysics and Geology. He then went to Adelaide University to do his honours on a seismic stratigraphy project.

Upon graduating he joined Delhi Petroleum in late 1982. After one day he was sent to the Cooper Basin to see the operation. This was baptism by fire as several rigs and seismic crews were visited and copious quantities of beer were consumed after one week he returned to Adelaide in the middle of the December silly season, though by this time his liver was beginning to adapt to life in the oil industry. The next two years were spent in the field on seismic crews and well shoots followed by one year in regional studies.

In 1985 he joined Schlumberger. This was the biggest shock in his career since the first few days with Delhi. The pace is very quick with considerable pressure, though the work is fascinating.

Andrew is married with two sons. At the time of printing he just became a proud father for the second time. He enjoys sailing and snow skiing though doesn't indulge as much as he would like.

Preview: Next Issue

- *Geophysics in the new CSIRO Division of Exploration and Mining*
- *Gippsland Basin - Research Challenges identified by Esso - BHP*
- *Noise Prediction in Downhole TEM*
- *The Geosurveys Story*
- *New Regular Feature - "Seismic Window"*
- *Towards 2005 - Earth Science Research in Oz*

THE AUSTRALIAN SOCIETY OF EXPLORATION GEOPHYSICISTS

ACN 000 876 040

"INCREASING THE RESOLUTION: CLEARING THE HAZE"

10th GEOPHYSICAL CONFERENCE & EXHIBITION 1994

10th GEOPHYSICAL CONFERENCE & EXHIBITION

PERTH, WESTERN AUSTRALIA

20th - 25th February, 1994

at the Burswood Convention Centre

The Conference Venue

The Conference and Exhibition will be held at the Burswood Resort Casino, Perth's finest and most luxurious 5 star property.

The complex includes the Burswood Hotel with commanding panoramic views of the Swan River and Perth City and a 10 storey high glass enclosed lobby that provides a spectacular welcome amid cascading waterfalls, palm trees and lush gardens.

The Convention Centre is adjacent to the hotel and provides excellent facilities for the conference sessions and the exhibition as an integral part of the event.

The complex has 7 restaurants and cafes that provide a superb range of foods at all hours. For those who want to relax, golf, tennis and a Casino can be enjoyed.

The Conference Co-Chairman - N. Uren & K. Frankcombe

Norm Uren

Norm F. Uren received his BSc (1960) in Physics and Mathematics and a Dip.Ed. (1964) from the University of Western Australia. He completed a Postgraduate Diploma in Applied Physics (1969) and an MSc in Geophysics (1975) from the Western Australian Institute of Technology. Then in 1989 he was awarded a PhD in Geophysics from the University of Houston. From 1961 he taught in various Secondary Schools, Technical Colleges and W.A.I.T. (now Curtin University of Technology). Now Associate Professor in Geophysics and Head of the Department of Exploration Geophysics he has also held the position of Head of School of Physical Sciences and Head of the Department of Geology and Geophysics at Curtin.

He has spent periods of Industrial leave with Getty Oil (1979), Shell Development (1980) and was a full time consultant in Perth in 1981. In 1982 he returned to academic work and established the Postgraduate Geophysics program at W.A.I.T.

He is a member of the ASEG, SEG, EAEG, AIMM, ACE, GSH, GSA, AGU and is currently immediate Past President of ASEG, former ASEG President and WA State President ASEG.

Kim Frankcombe

Conference Co-chair Kim Frankcombe has been a member of the ASEG for 15 years and a member of State Branch Committees for the past eight years. He was also on the technical papers committee of the very successful Adelaide 88 Conference. He is a member of the SEG, EAEG, PESA and the Wild Turkey Club.

He graduated with dual geology-geophysics honours and started work as a geologist before seeing the light and re-writing his job description. He has spent approximately equal amounts of time as a company geoscientist and consultant. In this time he has acquired, processed and interpreted almost every geophysical method from reflection seismic through to airborne EM without necessarily mastering any of them.

He is currently a geophysicist with Normandy Poseidon Group, responsible for the geophysical component of exploration and Operations in WA, Turkey and Indonesia.

Applied Seismic Inversion for Estimating Velocity-Depth Models

Oz Yilmaz
Schlumberger

Processing and inversion of seismic data differ in one fundamental respect -- the output from *processing* often is displayed in *time*, and the output from *Inversion* is intended to be displayed in *depth*. The main goal in inversion is to estimate a geologically plausable subsurface velocity-depth model, which comprises two sets of parameters -- *layer velocities* and *reflector geometries*. To resolve the well-known velocity-depth ambiguity in inversion, these parameters need to be estimated, *independently*.

Estimation of velocity-depth models requires a set of integrated methods of inversion and utilities built around a workstation. Specifically, post- and prestack depth migration, prestack traveltime inversion and amplitude inversion can be used in some combination to estimate velocity-depth models for structural and stratigraphic targets.

For a structural problem, the subsurface model can be divided into two parts -- the *overburden* in which ray theory is applicable, and the *substratum* in which depth migration is imperative. Typical structural targets are associated with salt and overthrust tectonics. In case of salt tectonics, the top-salt constitutes the boundary between the overburden and the substratum. It also is the boundary where the most *severe ray* bending takes place.

Consider a 2-D seismic line along the dominant dip direction with minimal sideswipe energy present in the recorded data. The following package is then offered to estimate the velocity-depth model:

	Overburden	Substratum
Layer Velocities	*layer-by-layer prestack traveltime inversion*	*iterative prestack depth migration, and analysis of image gathers and image-gather stacks*
Reflector-Geometries	*layer-by-layer postack depth migration*	*image-gather stacks*

This scheme can be extended to estimate a 3-D velocity-depth model for structural targets as follows:

	Overburden	Substratum
Layer Velocities	*layer-by-layer 3-D prestack traveltime inversion*	*iterative 3-D poststack depth migration*
Reflector-Geometries	*layer-by-layer poststack depth migration*	*iterative 3-D poststack depth migration followed by 3-D prestack depth migration along selected traverses*

For a stratigraphic problem, the subsurface velocity-depth model can be divided into two parts -- the *macro-model* that represents the trend in velocity variations, and the *micro-model* that represents the details in velocity variations. Since stratigraphic targets are generally associated with low-relief structures and structure-independent velocity variations, the following package is equally applicable to both 2-D and 3-D cases.

	Macro-model	Micro-model
Layer Velocities	*prestack traveltime inversion*	*amplitude inversion*
Reflector Geometries	*poststack depth migration*	*not applicable*

Aside from inversion methods -- depth migration, traveltime and amplitude inversion, an inversion project also requires a set of utilities available on an *Inversion workstation*:

(1a) Interpretation of time horizons from 3-D stack volume of data.

(1b) Interpretation of depth horizons from 3-D depth-migrated volume of data.

(2) 3-D model representation of surfaces and solids.

(3) 3-D model visualisation.

(4) Editing of layer velocities and reflector geometries.

It is important to note that inversion is not intended to replace processing, rather to complement it. Conventional processing indeed is included in the data analyses described in this proposal. For instance, optimum DMO stack is used in conjunction with depth migration to facilitate accurate and efficient imaging of the overburden. Optimum DMO stack provides picked time horizon information for prestack traveltime inversion so as to avoid picking of reflection times on CMP gathers, and, following time migration, it is the principle input to poststack amplitude inversion.

Oz Yilmaz

Oz Yilmaz, author of the SEG best seller "Seismic Data Processing", holds a B.S., M.S. and PhD (Stanford) in geophysics with research in rock physics and exploration seismology. Oz is currently Director of Data Analysis Product Development Group of Geco-Prakla Division of Schlumberger. Oz's 20 years of experience includes research and geophysical software development, seismic data organisation, processing, teaching and interpretation and gravity and magnetic processing and interpretation. He has worked in senior research and management capacities with the Turkish Petroleum Company and Western Geophysical. He received the SEG Virgil Kauffman Gold Medal (1991) and is an EAEG Conrad Schlumberger Award winner and is currently Vice President of the SEG and an associate editor of EAEG Geophysical Prospecting and First Break.

The Role of New Technology in Seismic Exploration

Brian H. Russell

Hampson-Russell Software Services Ltd., Calgary, Canada

There have been two major technological revolutions in the geophysical business. The first one occurred from the late 1950's to early 1960's and involved moving from analog to digital recording and processing, from single-fold to multi-fold recording, and from field analysis to large dedicated processing centres. The second revolution is occurring right now, and is seeing us move from 2-D to 3-D data, from acoustic to elastic earth assumptions, and from mainfame to individual workstation technology. This last step has opened up the possibility of fully interactive processing and interpretation. This talk will focus on the new hardware and software that is changing our approach to seismic exploration so dramatically, and how we can use this software in a productive way.

First of all, we must consider the objectives of seismic exploration. In an broad sense, our main objective has always been to determine the geology of the earth's near surface from seismic measurements. However, this is too general a definition and can be further subdivided into the determination of:

1) earth structure,
2) earth stratigraphy,
3) large scale rock properties, and
4) detailed rock properties.

As we move down the above list, we track the evolution of the seismic business. That is, pre-1960 seismic exploration involved determining only earth structure. In the 1970's, seismic stratigraphy was developed, and techniques such as bright-spot analysis were introduced. In the 1980's, we developed methods such as post-stack inversion to determine large scale seismic lithologic properties. We are now attempting to determine detailed rock properties from seismic measurements, using techniques such as AVO, multi-component analysis, and so on.

In the light of these new technologies, the geophysicist's task has become even more complex. Harnessing the new technology will involve the following steps:

1) providing each explorationist with adequate access to the necessary hardware,
2) developing an effective database management system which integrates such diverse datasets as 3-D seismic data, well logs, topographic maps, etc.,
3) determining which software packages best suit our needs in a particular area, and making sure that these software packages communicate with each other, and
4) educating each explorationist on the key aspects of the hardware and software technology, and then allowing him to make predictions based on a synthesis of his data using these analysis techniques.

While all of these points seem straightforward, there are a number of pitfalls that can occur. For example, it is almost as damaging to buy too much hardware and software too quickly, as it is to not purchase enough. A more sensible approach is to build up gradually with a long-range goal in mind.

It is also easy to fall into the trap of thinking that buying the technology is enough. The most important resource in any company is still the personnel running the hardware and software. A progressive training schedule must be implemented which allows each individual to utilize the new technology in a productive way.

Finally, it is important to be able to walk the tightrope between too much belief and the new technology and total rejection of it. That is, we must develop a healthy skepticism about our results, but still be able to trust them within their limits.

There is no doubt that we are at the threshold of a new era of sophistication in seismic exploration. It is important that we take full advantage of this opportunity, and learn to control the new technology, rather than let it control us.

Brian Russell

Brian Russell holds a BSc. in Geophysics from the University of Saskatchewan, Canada, and an MSc. in Geophysics from the University of Durham, England. He started his career in 1976 at Chevron in Calgary as an exploration geophysicist. He then worked for Teknica as a senior explorationist, Veritas Seismic as a research and training geophysicist, and Veritas Software as vice president of marketing and training. In 1987, Brian co-founded Hampson-Russell Software Services Ltd. along with Dan Hampson, and is currently vice president of that company, co-ordinating their worldwide marketing efforts and participating in new software development and training. Brian also presents courses on new geophysical technology throughout the world for IHRDC and the SEG. He is active in the SEG, and is currently Chairman of the The Leading Edge editorial board. He is also a past-president of the Canadian SEG, and is registered as professional geophysicist in the province of Alberta.

Petrophysics In Exploration

Don Emerson,
Systems Exploration (NSW) Pty. Limited

Physical properties of rocks are studied in many fields of applied geoscience including minerals prospecting, mine planning, coal and petroleum search, and in groundwater, engineering-site, environmental, mining and geotechnical investigations. Routine and research studies are generally focused on core or hand specimens, but in-situ probing, with downhole, crosshole or surface geophysical equipment, is possible and desirable.

Petrophysical studies are carried out in Australia by individual scientists, companies, universities, co-operative research centres, CSIRO, and government departments either directly or by commission to consultants or commercial laboratories. Petrophysical knowledge of sedimentary basin lithologies has been highly developed by international oil companies, especially in subsurface well logging. Locally there is an increasing awareness and use of petrophysical measurements where gravity, magnetic, electrical, electromagnetic, thermal, seismic and radiometric techniques are employed.

To use magnetics as an example, the scope of petrophysical work ranges from the company field geophysicist using a hand held susceptibility meter to quickly assess large lengths of core, to the CSIRO's Rock Magnetism Group employing very sophisticated equipment to carry out extensive, funded, laboratory research on various magnetic characteristics of interest to company sponsors.

Applied geophysics is concerned with the location, definition, enhancement and evaluation of anomalies. Anomalies are perturbations in natural (e.g. magnetic) or induced (e.g. electromagnetic) fields that generally may be interpreted in geological terms as the deviations from background response. The anomalies arise from local and deep physical property contrasts embodied in geological features with particular depths, sizes (volumes) and geometrics.

An anomaly from a causative body constitutes a signal of the form (Ward and Rogers, 1967):

A = (IF) (SF) (PPF) (GF)

where A = Anomaly measured in a survey

IF = inducing field, i.e. the acting force

SF = size factor, i.e. the active volume which may be the whole volume in the case of gravity or magnetics, but in the case of electromagnetics only the area of the conductive parts of the body normal to an inducing field,

PPF = physical property factor, i.e. the contrast,

GF = geometric factor which includes shape and depth of burial which has an inverse effect on the anomaly magnitude.

There are many difficulties associated with geophysical interpretations. From the above equation it can be seen that the dependent variable is the anomaly and that there are a large number of independent variables in the absence of auxiliary geological, geophysical, petrophysical and drillhole control. Traditional interpretation problems include: survey technique (location, sensor orientation errors), anomaly detectability, fundamental ambiguity (an infinity of solutions in potential field analysis), residual isolation of local from regional effects, resolution (separation of anomalies) and terrain noise (comprising geological and topographic noise).

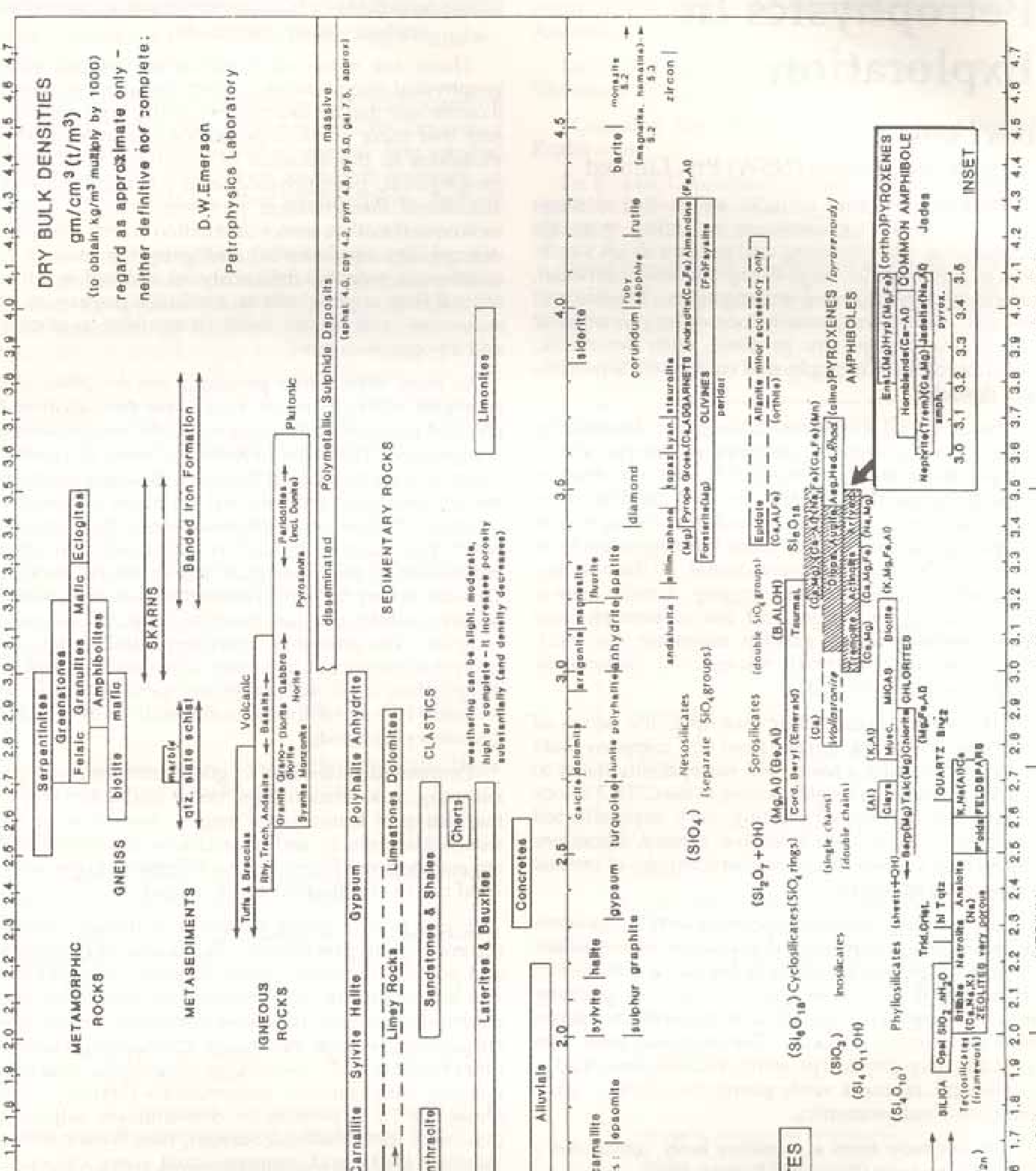
In most cases these problems can be overcome, especially when there are reasonable geological and physical property constraints available to experienced interpreters. However, even in the most favourable cases, in must be stressed that even the interpretations are not geological pictures, but are given in terms of causative bodies with **physical property** contrasts, which then need to be tied in realistically, but often indistinctly, to the lithological and structural settings. This can be very difficult because the relationships may be very subtle and not clear; or they can be quite complex. The process is sometimes called an art, but really it is a science as it requires understanding and by its systematic approach and by independent checks on its utility it does contribute to the body of formulated geoscience knowledge.

Petrophysics is the way to: good data interpretation; assessing rock relationships; better understanding of the setting of features and targets; awareness of the reasonable limits to and expectations of surveys; and appreciating rock fabric and the differences in the micro - and macro - properties of rock masses.

Eight petrophysics property summary charts accompany this general note. The charts cover: density and porosity (Emerson, 1990); magnetic susceptibility and susceptibility as a function of magnetite and pyrrhotite content (Clark & Emerson, 1991); low frequency electrical resistivity/conductivity ranges (after Palacky, 1987); resistivities of economic minerals, labelled with common abbreviations (Harvey, 1928; Shuey, 1975); resistivities of disseminated sulphides (Maxwell, 1881; Maillot & Sumner, 1966; Nelson & Van Voorhis, 1983); and compressional wave velocities (various sources).

Some geophysicists may find these charts useful in a general way. However, it should be very clearly understood that the information contained therein is approximate, incomplete and by no means definitive.

"Reading the rocks" by the petrophysical approach is important and interesting work. It is expected that applied petrophysics will continue to develop in Australia where minerals, water and land use matters are emerging as vital issues in the nation's educational, economic and social program.



DRY BULK DENSITIES
gm/cm³ (t/m³)
(to obtain kg/m³ multiply by 1000)
regard as approximate only – neither definitive nor complete;
D.W.Emerson
Petrophysics Laboratory
ROCKS
incl. porosity effects
Pumice
METAMORPHIC ROCKS
GNEISS
Serpentinites
Greenstones
Felsic
Granulites
Mafic
Eclogites
Amphibolites
biotite
mafic
METASEDIMENTS
marble
qtz. slate schist
SKARNS
Banded Iron Formation
IGNEOUS ROCKS
Tuffs & Breccias
Volcanic
Plutonic
Polymetallic Sulphide Deposits
disseminated
massive
SEDIMENTARY ROCKS
EVAPORITES
Carnallite
Sylvite
Halite
Gypsum
Polyhalite
Anhydrite
CARBONATES
Marls
Chalks
Limey Rocks
Limestones
Dolomites
CLASTICS
COALS
Peat
Lignite
(sub) Bit.
Anthracite
Sandstones & Shales
Cherts
WEATHERED ROCKS
Laterites & Bauxites
Limonites
weathering can be slight, moderate, high or complete – it increases porosity substantially (and density decreases)
UNCONSOLIDATED
Soils(agric.1.2–1.6)
Alluvials
Concretes
ROCK FORMING MINERALS
carbonates:
halides:
sulphates & phosphates:
others:
carnallite
epsomite
sylvite
halite
gypsum
sulphur
graphite
turquoise
calcite
dolomite
aragonite
magnesite
fluorite
anhydrite
apatite
andalusite
diamond
topaz
staurolite
siderite
corundum
ruby
sapphire
rutile
barite
zircon
SILICATES
Nesosilicates
Sorosilicates
Cyclosilicates
Inosilicates
Phyllosilicates
Tectosilicates
OLIVINES
Forsterite(Mg)
Fayalite(Fe)
PYROXENES
AMPHIBOLES
Epidote
Allanite
GARNETS
Pyrope
Grossular
Almandine
Andradite
Cord.
Beryl
(Emerald)
Tourmal.
Muscovite
Biotite
CHLORITES
QUARTZ
FELDSPARS
ZEOLITES very porous
Opal
Diatomite
WATERS
in pore spaces
Crude Oil
Ice
Gas
Brine
INSET
(ortho)PYROXENES
COMMON AMPHIBOLE
Jades
VERY LOW
LOW
MEDIUM
HIGH
VERY HIGH
arbitrary designation

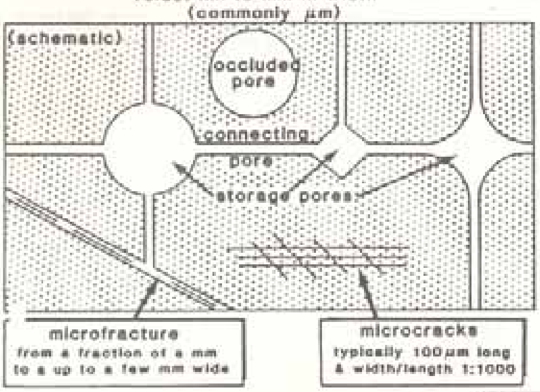
ROCK POROSITY

VOIDS VOLUME/ROCK VOLUME

as a fraction or as percent

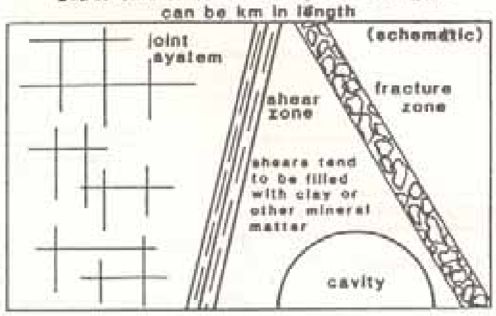
MICRO POROSITY

voids: nm to mm in width
(commonly μm)



MACRO POROSITY

gaps: cms to tens of metres (±) across
can be km in length



P_A APPARENT POROSITY : INTERCONNECTED, FLUID ACCESSIBLE

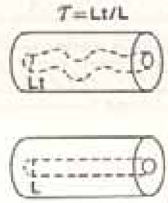
P_T TOTAL POROSITY : APPARENT POROSITY + ISOLATED, OCCLUDED POROSITY
occluded porosity is usually minor in sedimentary rocks but can be significant in crystalline rocks and limestones

Primary Porosity : intergranular, intercrystalline, vuggy, vesicular voids, in rock matrix

Secondary Porosity : solution, recrystallization, dolomitic, fracture effects

TORTUOSITY OF PORES

$T = Lt/L$



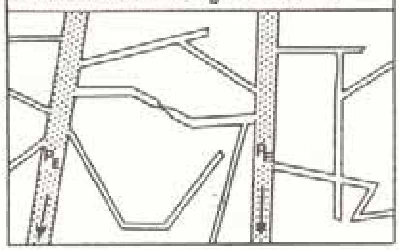
Theoretically $T \sim \sqrt{F P_A}$ where F is (electrical) Formation Factor usually between 10 (highly porous) and 1000 (tight rocks) and P_A is fractional apparent porosity

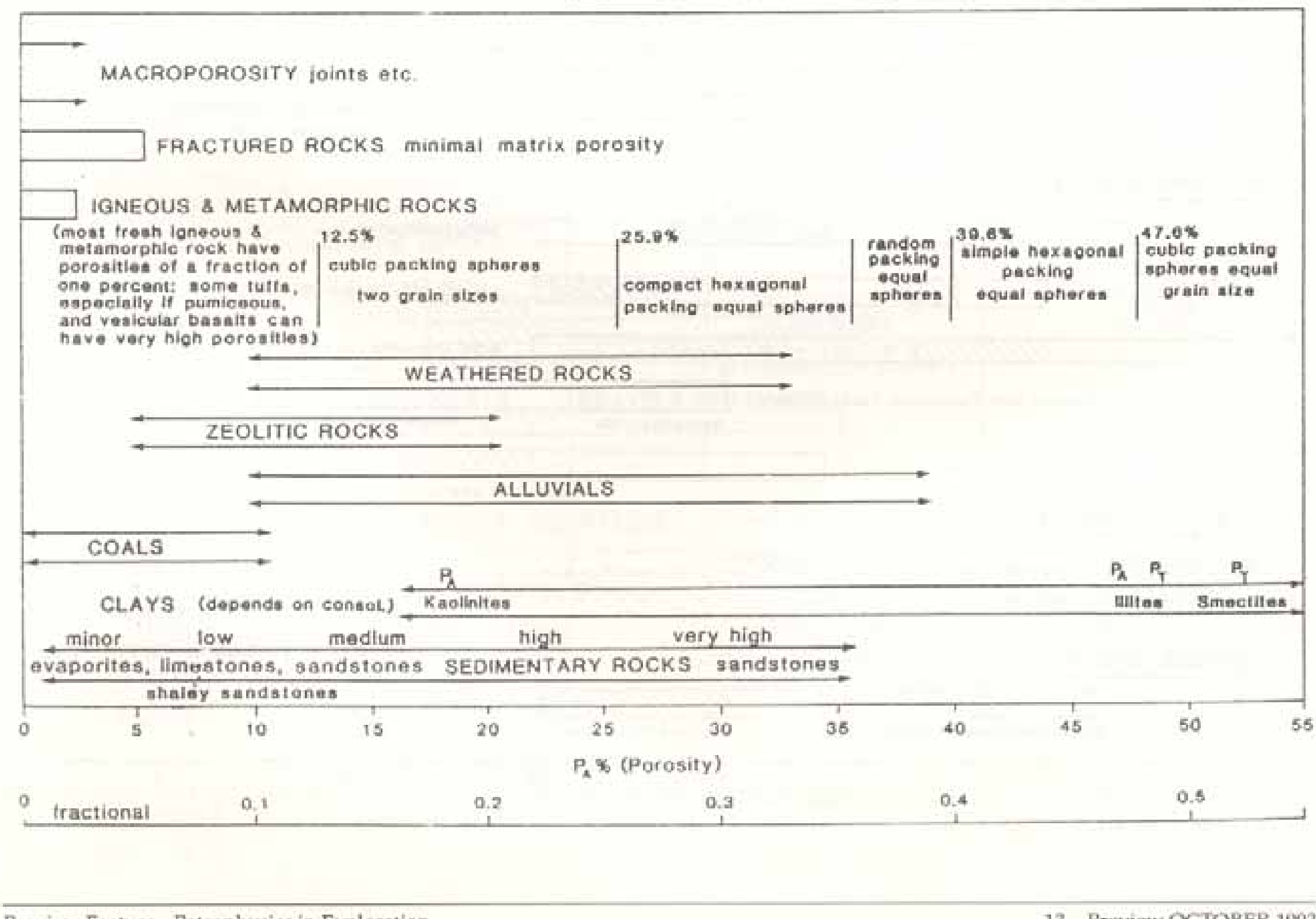
NOTE
regard as approximate only – neither definative nor complete
D.W.Emerson
Petrophysics Laboratory

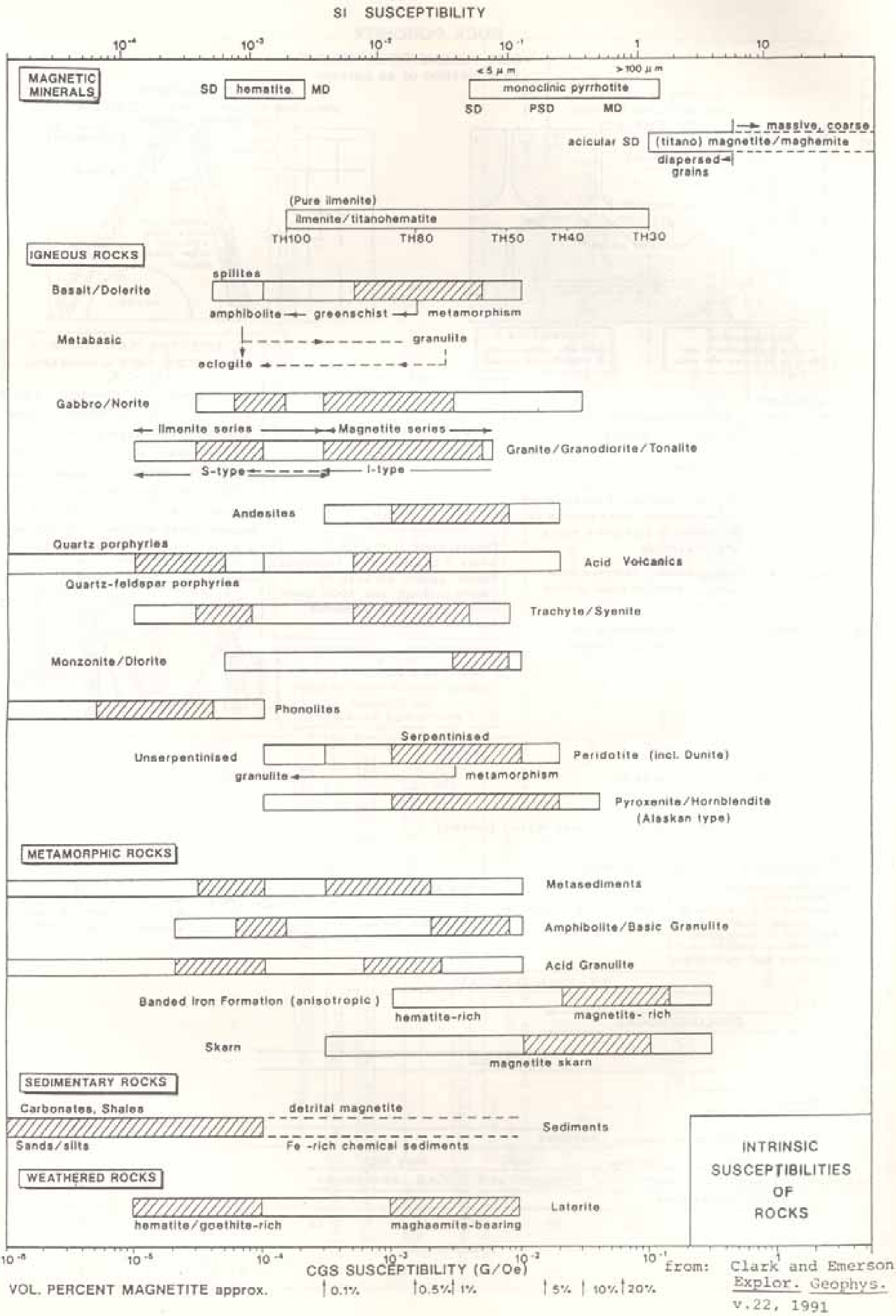
P_E: EFFECTIVE, FLOW POROSITY (or SPECIFIC YIELD in AQUIFERS)

$P_E < P_A$

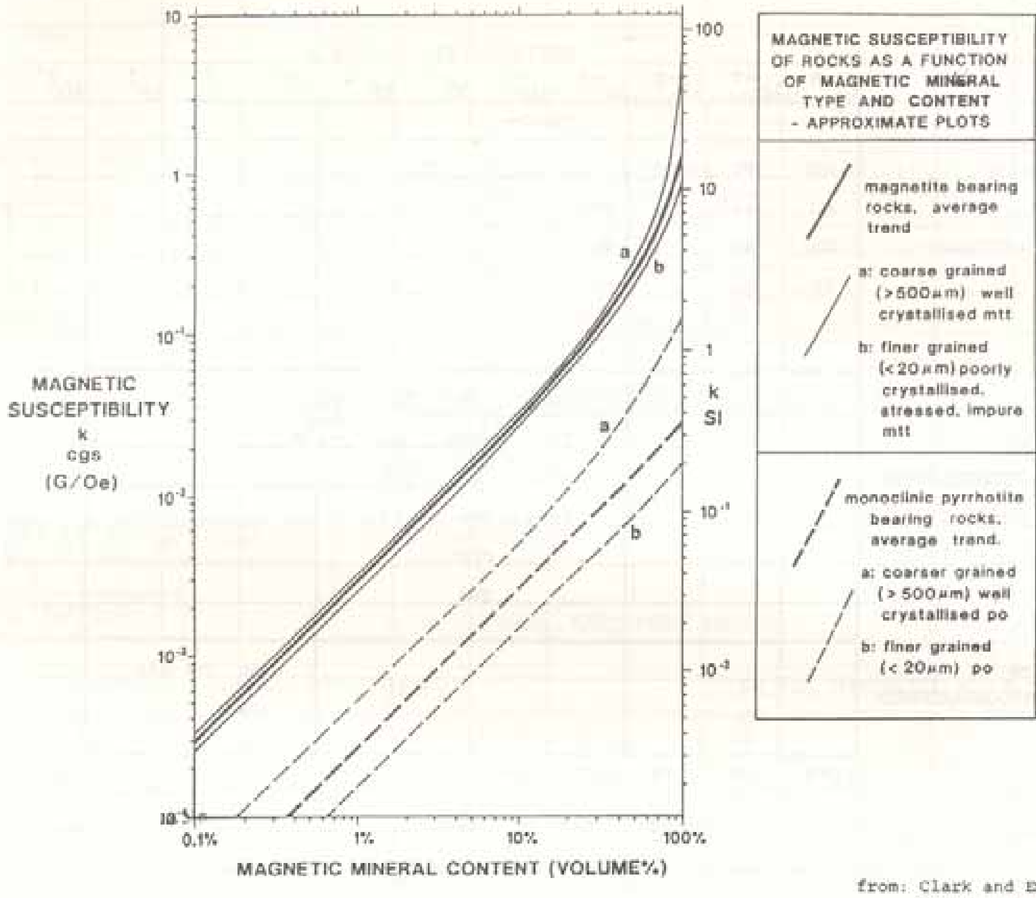
Flow pores can effectively drain fluid from a porous medium; these constitute the permeability framework. Lateral, dead end and very fine pores extending from flow pores do not contribute to significant fluid flow; the dominant transport mechanism is by aqueous phase diffusion – this porosity is diffusion porosity P_D (unstippled)





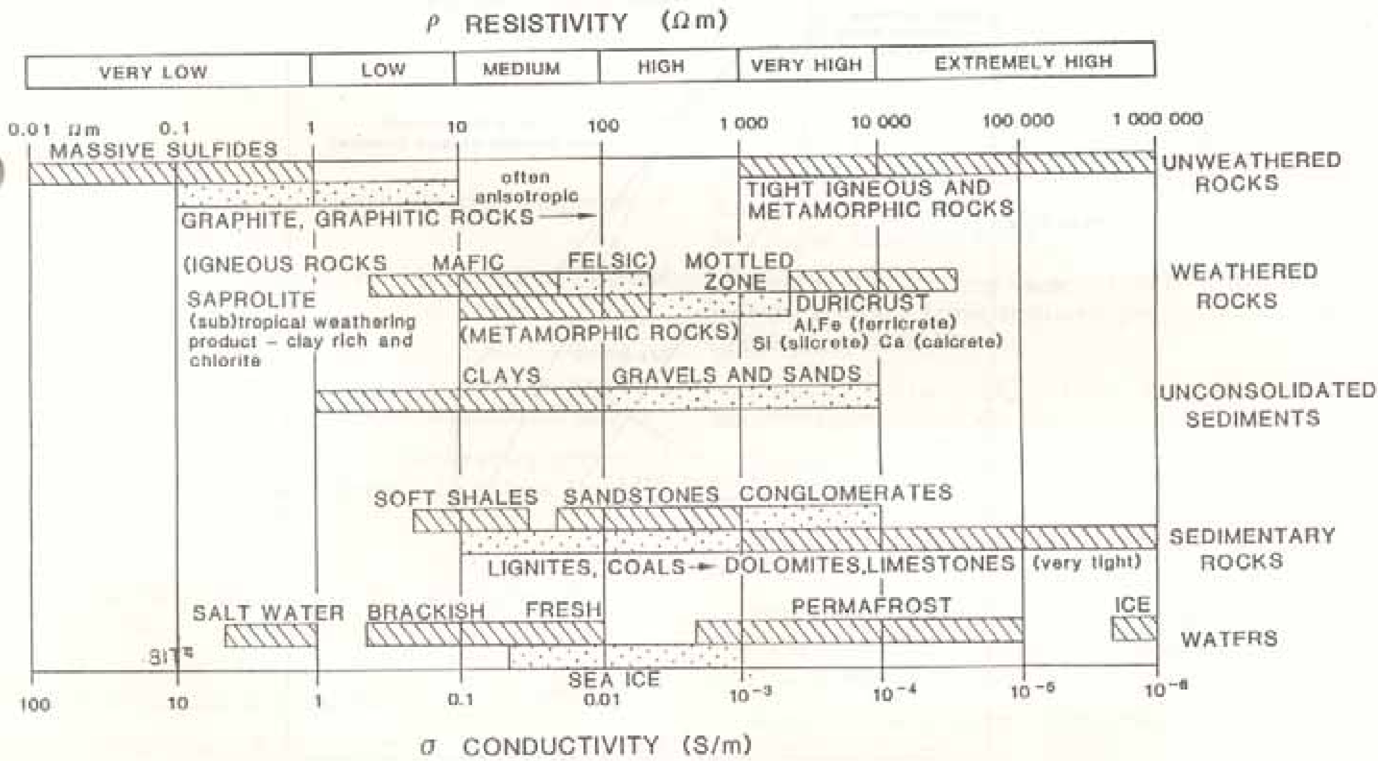


SI SUSCEPTIBILITY
MAGNETIC MINERALS
SD hematite MD
<5 μm
>100 μm
monoclinic pyrrhotite
SD PSD MD
massive, coarse
acicular SD (titano) magnetite/maghemite
dispersed grains
(Pure ilmenite)
ilmenite/titanohematite
TH100 TH80 TH50 TH40 TH30
IGNEOUS ROCKS
spilites
Basalt/Dolerite
amphibolite greenschist metamorphism
Metabasic
granulite
eclogite
Gabbro/Norite
Ilmenite series
Magnetite series
Granite/Granodiorite/Tonalite
S-type
I-type
Andesites
Quartz porphyries
Acid Volcanics
Quartz-feldspar porphyries
Trachyte/Syenite
Monzonite/Diorite
Phonolites
Serpentinised
Unserpentinised
Peridotite (incl. Dunite)
granulite
metamorphism
Pyroxenite/Hornblendite (Alaskan type)
METAMORPHIC ROCKS
Metasediments
Amphibolite/Basic Granulite
Acid Granulite
Banded Iron Formation (anisotropic)
hematite-rich
magnetite-rich
Skarn
magnetite skarn
SEDIMENTARY ROCKS
Carbonates, Shales
detrital magnetite
Sediments
Sands/silts
Fe-rich chemical sediments
WEATHERED ROCKS
Laterite
hematite/goethite-rich
maghaemite-bearing
INTRINSIC SUSCEPTIBILITIES OF ROCKS
CGS SUSCEPTIBILITY (G/Oe)
VOL. PERCENT MAGNETITE approx.
0.1%
0.5%
1%
5%
10%
20%
from: Clark and Emerson
Explor. Geophys.
v.22, 1991



from: Clark and Emerson
Explor. Geophys.
v.22, 1991

RESISTIVITY RANGES (APPROX.) FOR VARIOUS ROCK TYPES

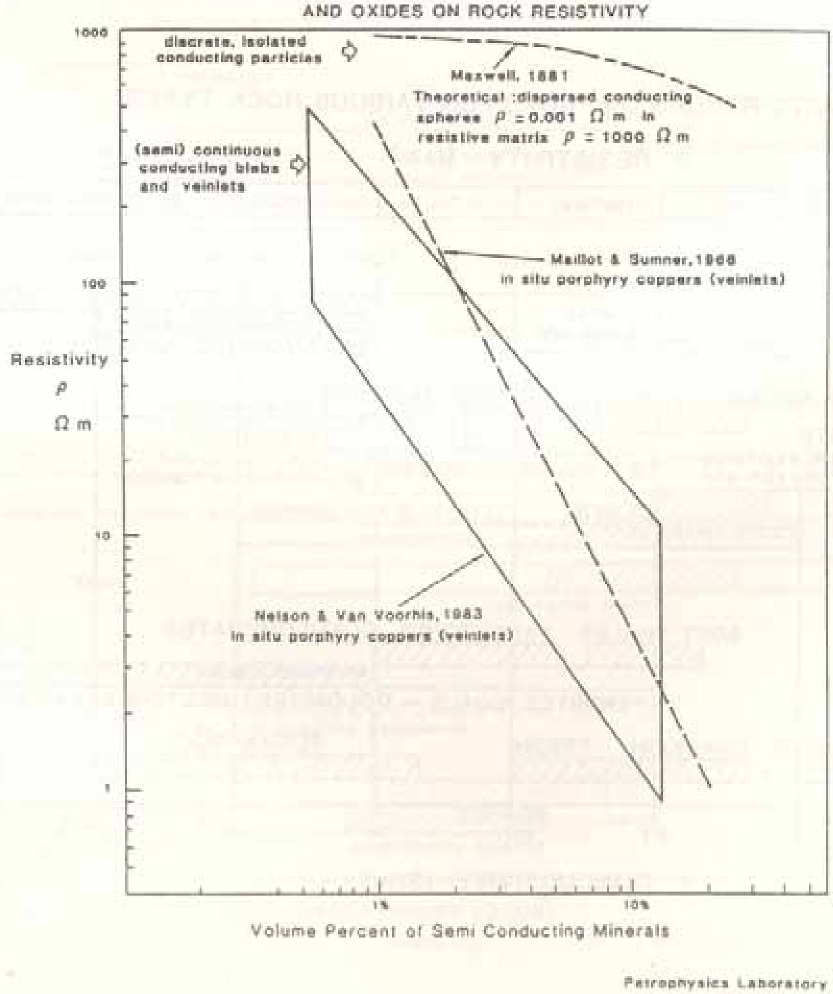


Petrophysics Laboratory
D.W.Emerson
(after Palacky, 1987)

APPROXIMATE RESISTIVITIES OF SOME ECONOMIC MINERALS

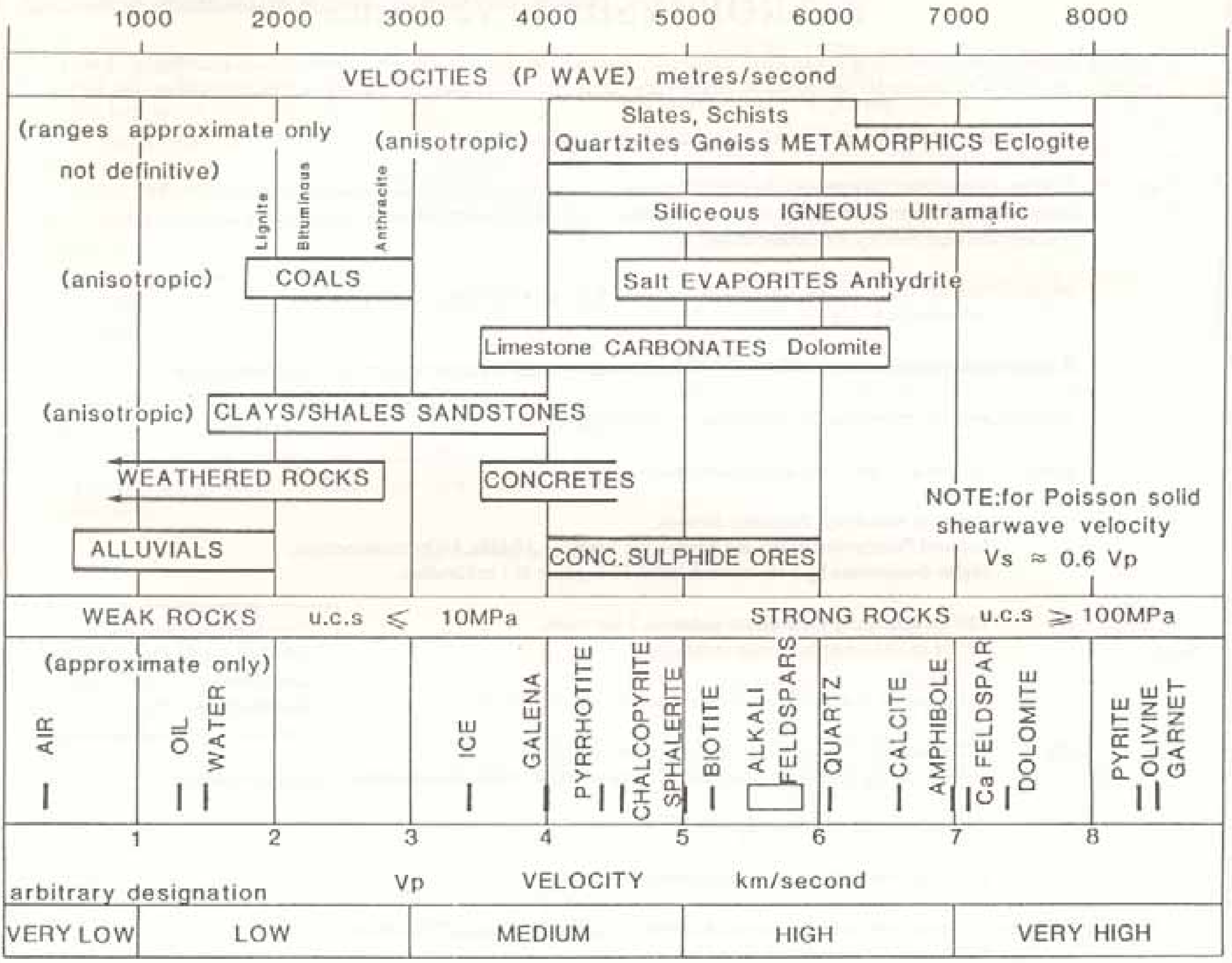
	RESISTIVITY, ρ, ohm m										
	10^{-8}	10^{-7}	10^{-6}	10^{-5}	10^{-4}	10^{-3}	10^{-2}	10^{-1}	10^{0}	10^{1}	10^{2}
METALS and SEMIMETALS	Ag	Pt	pn								
	Au	mil		mtt							
	Cu	cv		po							
	Fe	Bi		gr							
			nic								
GOOD SEMICONDUCTORS (p and n type)				agt	py	dig	plu				
				lol	aspy	en	hem -ilm				
				sku	bn	cob					
				tell.	cc	tt					
					cpy						
					gal						
POOR SEMICONDUCTORS								mb	cu bis		
								cas			
	10^{+8}	10^{+7}	10^{+6}	10^{+5}	10^{+4}	10^{+3}	10^{+2}	10^{+1}	10^{0}	10^{-1}	10^{-2}
	CONDUCTIVITY, σ, S/m										

INFLUENCE OF SEMI CONDUCTING METALLIC LUSTRE SULPHIDES AND OXIDES ON ROCK RESISTIVITY



Volume Percent of Semi Conducting Minerals

Petrophysics Laboratory
D.W. Emerson



D.W.EMERSON, Petrophysics Laboratory

Bibliography

Angenheister, C. ed. (1982). Physical Properties of Rocks. Springer-Verlag

Carmichael, R.S., (1962,4). Handbook of Physical Properties of Rocks Vols 1, 2, 3. CRC Press.

Clark, D.A. and Emerson, D.W., (1991). Notes on rock magnetisation characteristics in applied geophysical studies. Explor. Geophys., 22, 547-555.

Emerson, D.W., (1969). Laboratory electrical resistivity measurements of rocks. Proc. Aust. Inst Min. & Metal., no. 230, 51-62.

Emerson, D.W., (1990). Notes on mass properties of rocks - density, porosity, permeability. Explor. Geophys., 21, 209-216.

Harvey, R.D. (1928). Electrical conductivity and polished mineral surfaces. Econ. Geol., 23, 778-803.

Kobranova, V.N., (1986). Petrophysics. Mir/Springer-Verlag

Maxwell, J.C., (1881). A Treatise on Electricity and Magnetism. Clarendon Press.

Maillot, E.E., and Sumner, J. S. (1966). Electrical properties of porphyry deposits at Ajo, Morenci, and Bisbee, Arizona. Mining Geophysics, Vol. 1, 273-287. Soc. Explor. Geophys. Tulsa.

Nelson, P.H., and Van Voorhis. (1983). Estimation of sulfide content from induced polarization data. Geophysics, 48, 62-75.

Palacky, G.J., (1987). Clay mapping using electromagnetic methods. First Break, 5, 295-306.

Parkhomenko, E.I., (1967). Electrical Properties of Rocks, Plenum Press.

Shuey, R.T., (1975). Semiconducting Ore Minerals. Elsevier.

Touloukian, Y.S., Judd, W.R. and Roy, R.F. (1981)., Physical Properties of Rocks and Minerals. McGraw Hill/CINDAS Data Series, Vol 11-2.

Ward, H.S. and Rogers, G.R., (1967). Introduction (to:) Mining Geophysics, Volume 2, 3-8. Soc. Expl. Geophys. Tulsa.

ASEG Branch News

Victoria

On Friday September 17th The Victorian ASEG branch held a beer tasting evening which was quite a hit with attending members. The branch also sponsored the Mad Hatters Ball (ASEG - GSA - PESA - SPE) combined ball on October 9th. We had over 160 participants in what turned out to be a most enjoyable evening.

Ken Witherly, Chief Geophysicist of BHP Minerals gave a presentation on the "Issues facing Mineral Exploration in North America" on October 20th at the Kelvin Club. The evening was well attended and our thanks are extended to Ken for the interesting presentation.

Zis Katelis, Secretary

Western Australia

On September 5th, the WA branch met at the Celtic Club in West Perth for the presentation of two excellent talks. Thanks to both Scott Thomson who presented "Radio Imaging Method and Application to Hard Rock Mining" and Rolf Klotz who presented "Deconvolution in the Polar Domain". Each was presented with an appropriate momento to mark the occasion.

Looking forward, there seem to be quite a few functions and occasions on th horizon. Octoberfest will be celebrated with a beer tasting evening on October 29th.

Students night will be held on November 3rd and 10th at the Celtic Club at 6pm. Students will be presenting the results of their projects and studies over the past year, and should make for two very interesting evenings.

The lead up to the Christmas silly season will start with the annual PESA/ASEG golf day on December 3rd ..... more details on that later.

Andy Padman, Secretary

New South Wales

The NSW ASEG held an impromptu General Meeting at the Bowlers Club, Sydney, on the 6 September to coincide with a visit to Sydney by Nick Sheard. Amidst some frantic phoning and faxing a substantial number of members were informed of the event producing another very good roll-up. There were some minor hitches with slide projectors during the night establishing Murphy's Law, though these were overcome.

A cavalier presentation by Nick took in a large portion of the recent aeromagnetic, electrical and gravity surveys performed in the Diamantina River region of northwest Queensland. It was an enlightening as well as thoroughly entertaining talk as repartee was exchanged between the speaker and Austirex. Many thanks to Austirex who partly sponsored the evening's presentation.

The environmental geophysics address undertaken by the AIG in association with the ASEG is proceeding extremely well, with good industry support. The environmental topics will continue at the next General Meeting with Noel Merrick from the National Centre for Groundwater Management delivering a tak on the Groundwater Modelling of the Third Runway at Sydney Airport.

Shane Wright, Secretary

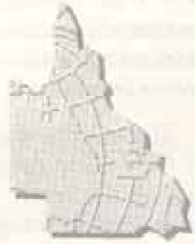
ACT

Many members of the ACT Branch of ASEG attended a seminar held by the Institute of Engineers, Australia (IEA) and the Institute of Radio and Electronic Engineers (IREE) on the 21st September. The seminar was presented by Dr. Mike McDonnell of BHP Research on the topic of "Subterranean Imaging within BHP". Mike highlighted the wide ranging services that BHP Research provides to its main costumers within quality control in steel manufacture, developing ground probing radar systems and formulating imaging software to analyse geophysical datasets. The seminar was very useful in describing the internal structure of a large company such as BHP, and the resources and manpower requirements needed to maintain BHP as one of Australia's most successful companies.

The geophysical exploration industry should also be aware of the current federal budget's impact on the long term directions for support into regional geoscientific mapping. Following on from the Richards Review into the Australian Geological Survey Organisation (AGSO), the federal government has taken the decision to implement many of the recommendations of the Richards Review. New accommodation for AGSO will be built over the next 5 years, still located in Canberra. The allocation of a new purpose-built building highlights the strong long term commitment by the federal government to maintain a national geoscientific facility. In addition the federal government is providing additional funds to accelerate the National Geoscience Mapping Accord (NMGA) and allow better utilisation of the vessel 'Rig Seismic'. AGSO will also be required to meet an external funding target of 30% of budget appropriation. The new Mission Statement for AGSO is as follows: "AGSO is to build a vigorous, client-driven national geoscientific mapping effort to encourage economically and evnironmentally sustainable management of Australia's minerals, energy, soil and water resources."

Kevin Wake-Dyster, Secretary

Queensland



Branch meetings were held on September 21 and October 19.

In September we had the pleasure of a talk from Dr John Stanley of the Geophysical Research Institute in Armidale. John's primary theme was about his search for the Mahogany Ships, lost in beach sands. However, he digressed to other archaeological matters and also to his search for bomb and other military ordinances. His talk was fascinating and showed a different side of geophysics to what most of us are accustomed to.

Noll Moriarty from Oil Company of Australia and our current branch Vice-President, gave an interesting talk titled "Otway Basin Onshore 3D Seismic Acquisition - Trials and Tribulations". The talk was very interesting and informative. Most of us were very interested in how Noll managed to conduct a survey through the Coonawarra Vineyards. We all saw the need for further follow-up surveys and a branch overview committee is being formed to gain first hand knowledge of this interesting area.

Our Rhodes Scholar, Natasha Hendrick, has left for England and is settling into life at Oxford. The Qld Branch Committee has decided to award Natasha a complimentary Associate Membership at the overseas rate. We felt that she deserved more than a student membership in recognition of her achievement. We hope to stay in contact with Natasha and follow her progress.

Some members went to the inaugural "Oilman's Ball". It was organised independently of ASEG and PESA but was promoted through both. From all reports of those who remember, it was a huge success. Money raised was presented to the Royal Flying Doctor Service. The ASEG Qld Branch took this opportunity to also donate $500 to the RFDS in recognition of the services they provide to exploration personnel.

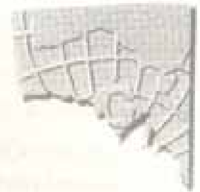
Funds from the successful conference are now available to the branch and we are currently looking to invest some of this in subsidising short courses for our members. We hope to have a course on Airborne EM if we can convince enough people with the relevant expertise to share it with the wider geophysical community. Anyone who would like to be part of this can contact one of the Qld Executive. We also hope to have a course on DMO or some similar oil oriented subject.

We are currently organising our Annual Dinner to be held on November 27 in conjunction with the Australian Institute of Geoscientists. We hope to have a Thai theme this year.

Our next meeting will probably be the Student Presentation evening. We are looking forward to hearing the latest developments in geophysics from our Honours and Post Graduate Students.

Wayne Stasinowsky, President

South Australia



The SA Branch has had two very successful meetings of late. On September 1, David Tucker and Professor David Boyd presented an update on the SA Exploration Initiative Airborne Surveys to a near record audience of about 80 geophysicists. The true value of this meeting was its relevance to both the mineral and petroleum fields. This meeting was sponsored by SADME and the SA Branch.

On 28 September we had our Schlumberger Geoquest sponsored beer tasting evening. This was a great evening, enjoyed to the utmost by the 40 or so present. Congratulation's to Murray Symonds of Halliburton who managed to correctly identify 8 out of the 12 beers presented before him.

The next meeting will be on 20 October, when Malcolm Lansley of Halliburton will be in Adelaide presenting a course on 3D Seismic Acquisition and Processing. Other coming events include the Students night in late November and the Christmas BBQ on 7 December - loot out for the flyers for these events.

I would like to thank Craig, Mike and the rest of the committee for all their help over the past 18 months and wish you all a successful 1995 Conference.

Ashley Duckett, Outgoing SA Branch Secretary

Ashley is Leaving ....

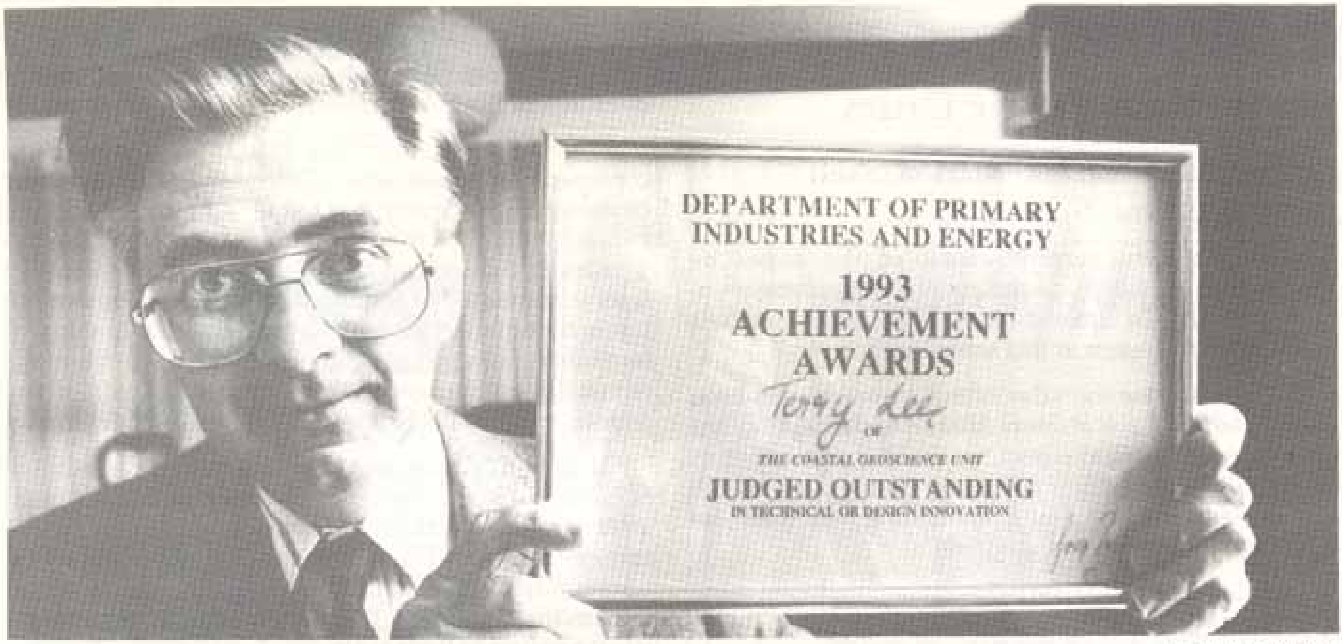
The SA Branch Secretary, Ashley K. Duckett, has resigned from his post, as he has taken a position with Ampolex in Perth, and consequently will be leaving the State.

I would like to take this opportunity to wish Ashley all the best for his future career in the West, and to thank him, on behalf of all the State Membership, for his tireless efforts, and complete patience as local Branch Secretary. It has been a pleasure to work with him on the executive committee.

I also wish Ashley and Noeline the best for their impending nuptials in early 1994.

Thanks again Ashley.

Craig Gumley
President SA Branch ASEG



Picture: RICHARD BRIGGS

Research scientist and top theoretical mathematician, Terry Lee, with the achievement award he received the day he was made redundant after ten years with the AGSO.

Job loss reason 'a mystery'

By GRAHAM DOWNIE

On the day he shared his departmental secretary's achievement award for outstanding innovation in science, Dr Terry Lee lost his job.

He had worked for 10 years as a research scientist for the Australian Geological Survey Organisation, formerly the Bureau of Mineral Resources.

Having previously declined an offer of voluntary redundancy, Dr Lee was given a letter on September 19 confirming his involuntary redundancy had been approved. The letter took the gloss off the secretary's award to a three-member team of which Dr Lee had been a member.

Felicity Raferty, national industrial officer of the professional division of the Public Sector Union, said Dr Lee was a world renowned theoretical mathematician. He had been told he was no longer required because he was too specialised. She said Dr Lee believed he had been subjected to systematic attempts to discredit him.

Dr Lee said he did not know the real reason for his dismissal. The official reason had been shown to be false by the secretary's award. His contribution had not been in his specialty area — transient electro magnetics, being developed for mapping salinity.

When he had suggested a particular mapping technique, he had been told the AGSO was not interested. But a company had been commissioned for a map using that principle. "If I am involved they don't want it," he said.

Comments were sought from the secretary of the Department of Primary Industry and Energy, Greg Taylor, but our inquiry was directed to the head of the business management branch of AGSO, John Cahill. He said Dr Lee had been recruited on the basis of his specialist skills, relevant to what the then BMR had then been doing. Voluntary redundancy had been offered to some staff three or four years ago but a number had remained whose skills could not be matched with scientific requirements. "Terry was one of them," Mr Cahill said.

A three-year process had followed to ensure all options of redeployment had been pursued. No position had been found for Dr Lee so a month ago the PSC had certified it was not in the interests of the public service for him to be re-deployed. It had then been up to the department to retire him. The timing with the award had been unfortunate, he said.

Dr Lee's retirement had come at the end of a very exhaustive process but he had the right to appeal. He had been given poor advice from his union. Had he accepted voluntary retirement he would have received more money.

(Reproduced with permission of the Editor, Canberra Times. Story: G. Downie)

Dr Terry Lee

Dr Terry Lee completed a Bachelor of Science degree in Geophysics at the University of Melbourne, Victoria, in 1968 and a Bachelor of Science degree with Honours in Geophysics at the University of Tasmania in 1969. In 1972 he was awarded a Master of Science degree in Theoretical Geophysics from the University of New England, Armidale, NSW, and in 1975 he was awarded a Doctor of Philosophy degree in Theoretical Geophysics from Macquarie University in Sydney, NSW. In 1976 he was awarded the Van Weeldon Award of the European Association of Exploration Geophysicists for his PhD research.

From 1975 to 1983 he was employed as research geophysicist with geophysical consultants L.A. Richardson and Associates in Sydney, which was later incorporated into Geopeko Ltd, the exploration division of the mining company Peko Wallsend Ltd. During this period he was responsible for all theoretical research into exploration geophysics which included gravity, magnetic, radiometric, electrical and electromagnetic methods and in particular transient electromagnetic methods.

During 1980 he was on study leave from L.A. Richardson And Associates as a visiting Fellow at the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado. In 1983 he took up a position with the Australian Bureau of Mineral Resources in Canberra as a Senior Research Scientist in theoretical geophysics. His responsibilities included research into potential fields, heat flow, remote sensing and in particular transient electromagnetics.

In 1986 he was awarded a Doctor of Science degree in theoretical geophysics from the University of Tasmania and in 1991 he was awarded the Grahame Sands Award for innovation in Applied Geoscience from the Australian Society of Exploration Geophysicists. Both awards were granted for original research in transient electromagnetics.

Dr Lee has also consulted in theoretical geophysics to several resource exploration companies in Australia and in addition is a member of the Editorial Board of the Journal of Applied Geophysics (formerly Geoexploration).

Terry's other interests include gemmology, numismatics, Australiana, book collecting, Australian art and Asian art. He was awarded a Diploma in Gemmology from the Gemmology Association of Australia in 1976 and a Bachelor of Arts (Honours) degree in art history from the University of Sydney in 1984.

SIROTEM Detects Conductive Fluid Filled Plastic Drum

Roger Henderson and Mark Russell
Geo Instruments Sydney

Following the recent release of the paper by Emerson, et al., (1992), on the geophysical responses of buried drums, Dr Emerson invited the authors to use the SIROTEM system at this same location.

So far, only one short day of measurements has been conducted, but it was immediately apparent that not only could SIROTEM detect the 50 litre capacity steel drum still buried at Site B but also quite clearly the 20 litre plastic drum at Site E containing salt water, as described in Emerson, et al. (1992).

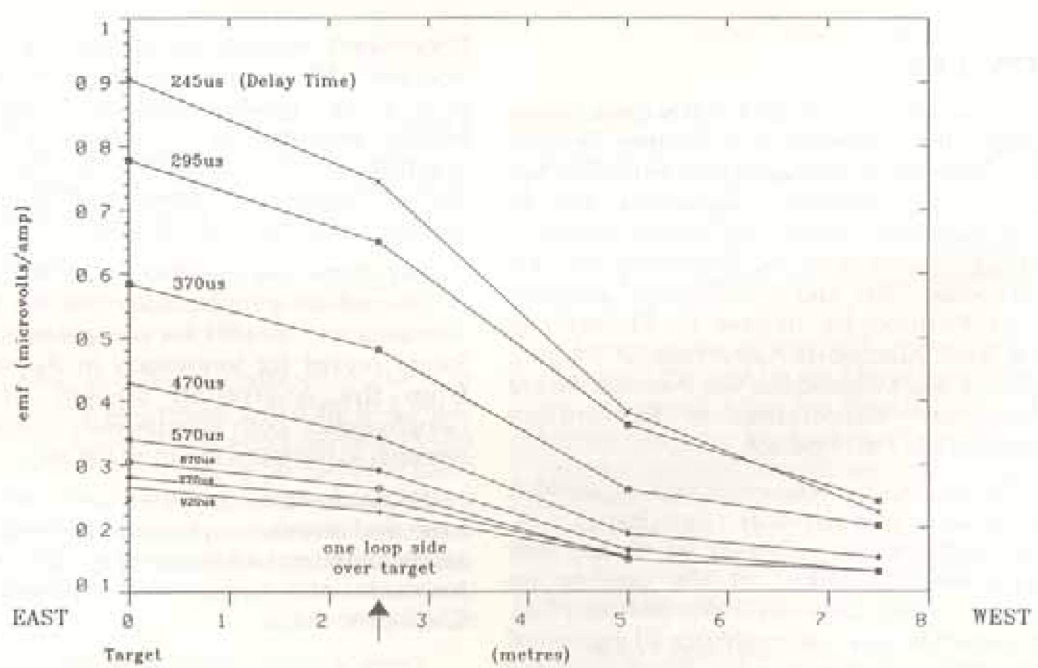
At Site E, the SIROTEM method was employed using a single loop configuration with a side length of 5m in order to match that of the Protem system previously conducted using a 5m transmitter loop. However, whereas the Protem system used the offset sounding configuration with a receiver coil 12.5m from the centre of the transmitter loop, the SIROTEM used the same transmitter loop as the receiving loop. As there was only less than one hour of daylight left by the time Site E was surveyed, the number of measurements had to be restricted and the first reading was taken by moving the loop to the west at 2.5m intervals. The results of this profile of 4 readings is given as Figure 1. The normalised voltages are of relatively low levels (less than 1 microvolt per amp throughout) but nevertheless, repeatable and smoothly varying at each station and from station to station. The results would suggest a clear detection of the buried drum.

It is believed that this SIROTEM single loop configuration is more able to detect targets of such small dimension, principally due to the fact that the receiver measurement is made in the same place as the maximum transmitted field. It is intended to conduct tests to simulate the configuration used by Protem but it is to be expected that the strength of the anomaly will be much reduced at a distance of 12.5m from the transmitter loop centre due to the fall off of the transmitter field being one over the cube of the distance.

This would suggest that the unique ability of SIROTEM to use the single loop configuration is a great advantage in such environmental situations where targets are small and the loop sizes need to be correspondingly small. In such cases of small transmitter loop sizes, it is not possible to use a single point receiver at their centre.

Finally, it is believed that the conclusion reached by Emerson, et al. (1992) that "it would appear that the TEM method cannot detect them (plastic drums) either empty or filled with salt water" is not necessarily true of all TEM systems and the SIROTEM single loop configuration has the potential to detect these types of targets.

D.W. Emerson, J.E. Reid, D.A. Clark, M.S.C. Hallett, and P.B. Manning. (1992). The magnetic and transient electromagnetic responses of drums - field tests in weathered Hawkesbury Sandstone, Sydney Basin, NSW. Explor. Geophys. 23. 589-617.



NB: Maximum Ambient Noise Level less than 0.08uV/A

SIROTEM-3 E-W Profile, 5m x 5m Square Loop (2 turns)
Saline Solution in Plastic drum (Area 'E') Aug 12,1993
Geo Instruments Pty. Ltd., Sydney, Australia.

The Principles and Applications of Waveform Sonics

Compiled by: A.Sutherland
Schlumberger Wireline and Testing

Introduction

Sonic logging has played a major part in logging for over 30 years. Historically the main applications have been synthetic seismograms, porosity determination, correlation and lithology identification. In its simplest form a fire pulse is transmitted to the edge of the well-bore, refracted up the side of the wellbore and then refracted back to the tool where the travel time is detected. Therefore the total travel time includes the travel time through the formation and two passes from the side of the borehole to the tool through the mud. This type of sonic survey is essentially a downhole refraction survey.

Early sonic tools utilised two detectors . The difference in travel-time between two detectors represents the formation transit time(for the detection separation). Subsequent tools were developed with multiple sources and receivers to allow the removal of the effect's of irregularities in the borehole (Borehole Compensation). Tools were developed with increased source to receiver distances. This increases the depth of penetration of signal, therefore the tool will be more likely to read virgin formation velocities. Transit-time units are generally used to describe sonic measurements. Transit time is the reciprocal of velocity.

These earlier tool designs utilised first motion detection ie. when the received signal is above a threshold value the receiver is triggered. The main disadvantages of first motion detection are:

1. Noise can cause an incorrect detection of time.
2. Weak signal will also cause errors in transit time (ie. cycle skipping).
3. Only the 1st arrivals are detected T shear, T stoneley can't be recovered. Sonic data cannot be recorded behind casing.

To overcome these problems full waveform sonics were developed. The Array Sonic * was released in the mid eighties. This tool records the entire wave form on 8 receivers spaced 6"apart (refer fig. 1).

The DSI* (Dipole Shear Sonic Imager) released in the early nineties incorporated a dipole source (refer fig. 2).

The three primary wave types of interest in the borehole environment are:

Compression waves- where the particle motion is in the direction the wave propagates (refer fig. 3). The waves travels through solids, liquids and gas. A compressional wave is the first waveform to arrive at the receivers (refer fig. 4).

Shear waves- where the particle motion is perpendicular to the direction the wave propagates (refer fig. 3). These waves only travel through solids. The shear velocity of slower rocks is often less than the fluid velocity of the mud. In this situation critical refraction's can not occur(according to Snell's Law), therefore the shear wave train cannot be recorded in the

* *Trademark of Schlumberger*

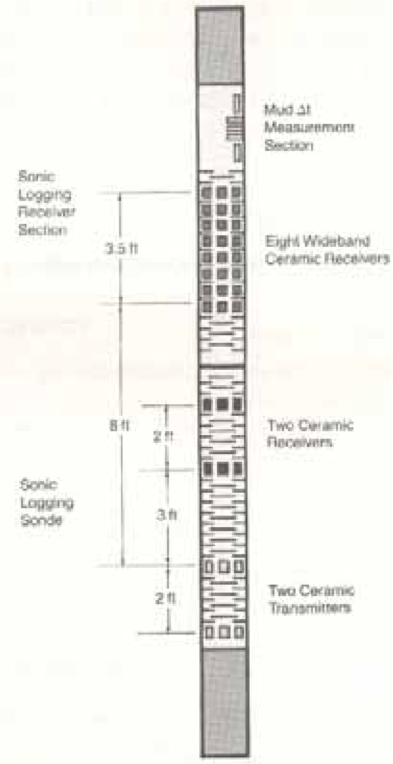


Figure 1. The Array Sonic Tool

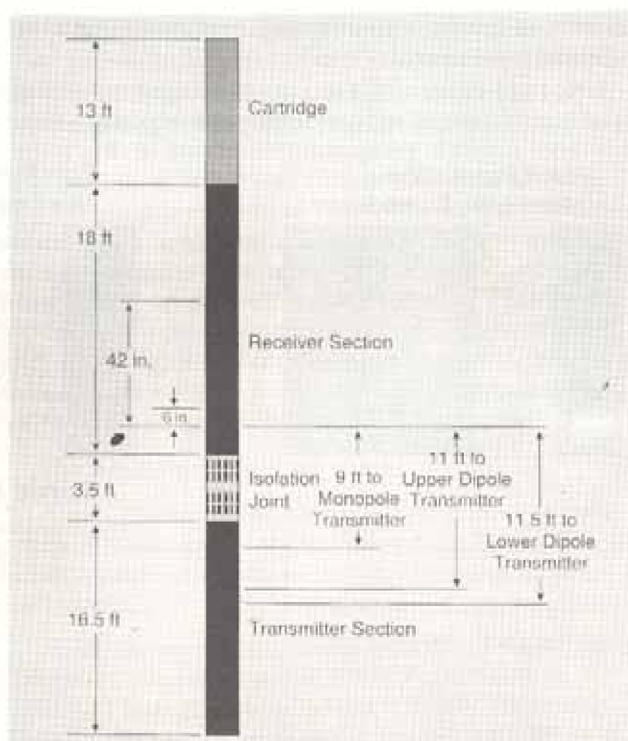


Figure 2. The DSI Tool

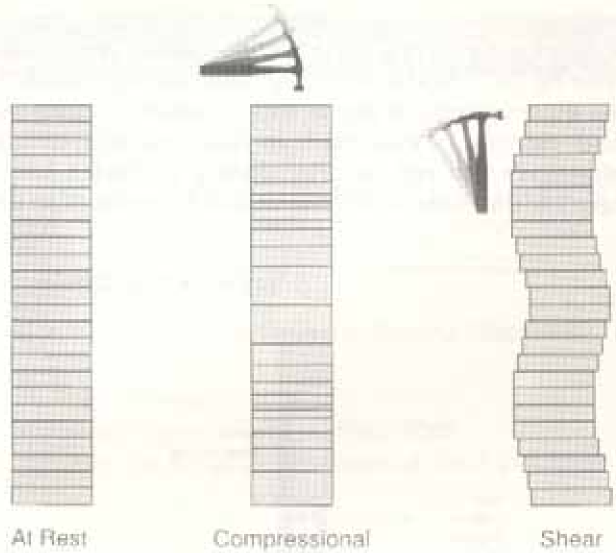


Figure 4. Sonic waveforms (monopole)

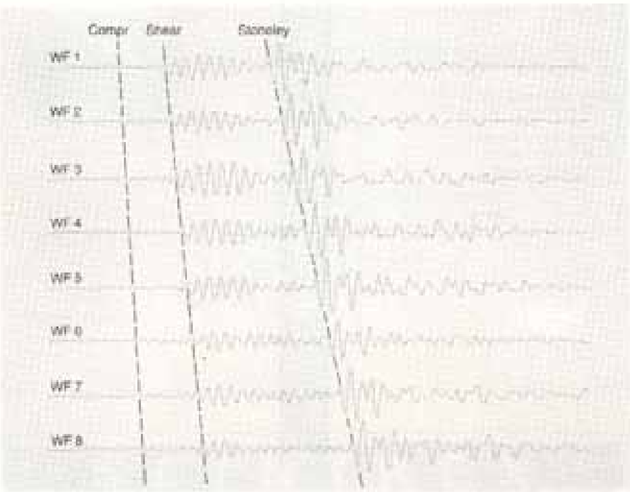


Figure 3. Compressional and shear wave propogation

borehole using conventional monopole sources as shown in the centre of fig. 5.

Stonely Wave - this is a surface wave travelling up the solid fluid interface, it is dispersive and the velocity is slower than the velocity of fluid.

A conventional monopole source generates a compressional wave pulse in the fluid. At the formation this will be refracted as a compressional wave. Some energy will be mode converted to both shear and Stonely waves. Leakey mode and pseudo-Rayleigh waves may also be created .

The dipole sonic tool was developed to allow shear velocities to be recorded from slow formations. A dipole tool utilised a directional source and receivers. the dipole source behaves much like a piston, creating a pressure increase on one side of the borehole and a decrease on the other. This causes a small flexing of the borehole wall, as illustrated in Fig. 5 which directly excites compressional and shear waves in the formation. The sources operates at low frequencies, where excitation of these waves is optimum. The compressional and shear waves radiate most strongly straight out into the formation. There is, however an additional shear/flexural wave propagating up the borehole. It creates a "dipole-type" pressure disturbance in the borehole fluid. It is this pressure disturbance that the directional receivers detect. The shear/flexural wave initiated by the flexing action of the borehole is dispersive. At low frequencies it travels at a slower speed. Unlike monopole-only tools the dipole tool always records a shear/flexural wave regardless of shear wave speed. In slow formations the shear/flexural wave is short in time duration and concentrated at lower frequencies. In additional to the shear/flexural wave there is a higher frequency compressional arrival in the beginning of the wave form. In this typical slow formation example there is a clear flexural wave from which the shear slowness is computed.

Processing

STC (slow time coherence) is a full waveform analysis technique aimed at finding all propagating waves in the composite waveform. STC adapts a semblance technique.

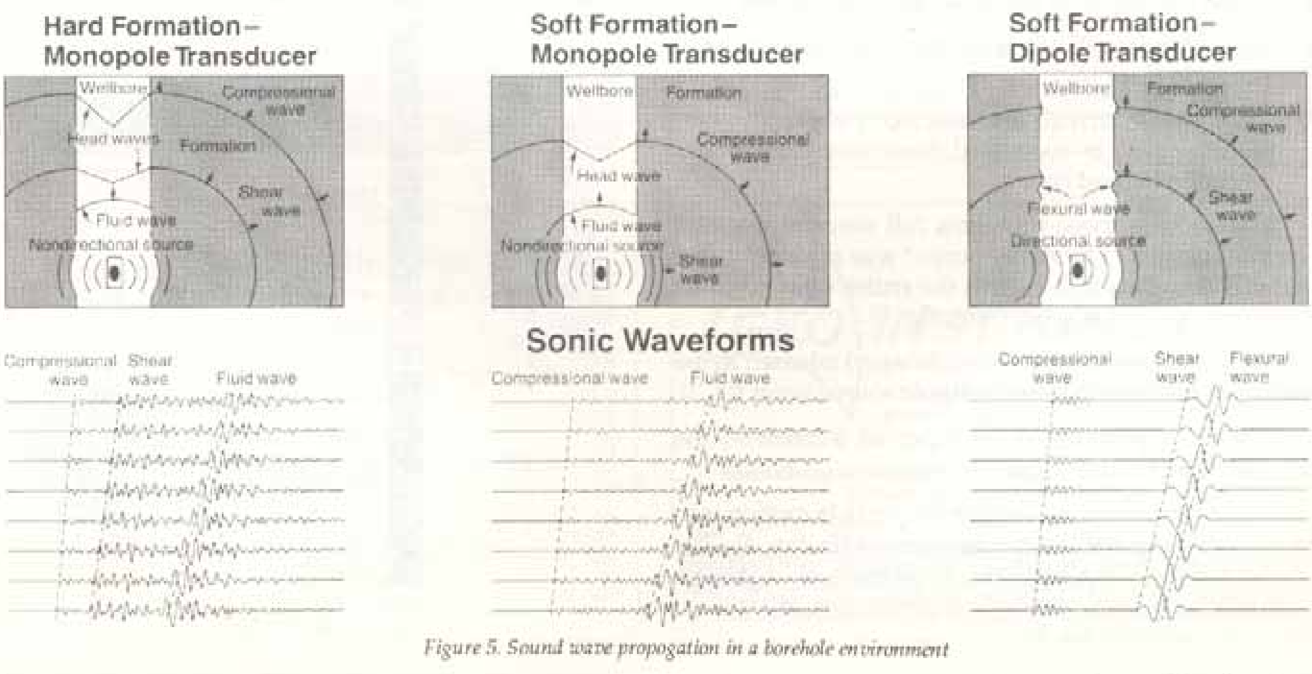


Figure 5. Sound wave propogation in a borehole environment

The STC algorithm used a fixed length time window which is advanced across the waveform in small overlapping steps through a range of potential arrival times. For each time position, the window position is moved out linearly in time, across the array of receiver waveforms(refer fig. 6). It begins with a move out corresponding to the fastest expected waves to the slowest expected waves.

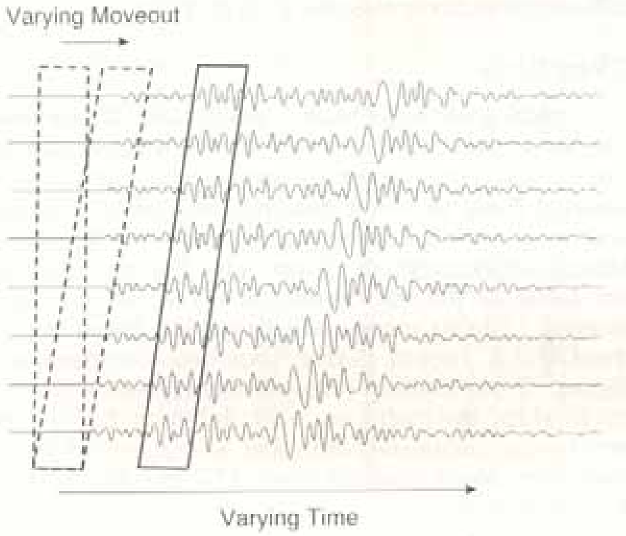


Figure 6. STC Computation

STC processing produces coherence contour plots as shown on the left in fig. 7. Regions of large coherence correspond to particular arrivals in the waveforms. The slowness and arrival time at each coherence peak are compared with the propagation characteristics expected of the arrivals being sought. The ones that agree best with these characteristics are retained. Classifying the arrivals in this manner produces a continuous log of wave-component slowness versus depth, as shown on the right of fig. 7.

When processing dipole waveforms, one of the coherence peaks will correspond to the dispersive flexural mode. The slowness of this peak is always greater (slower) than the true shear slowness. In fast formations a low frequency band pass filter usually

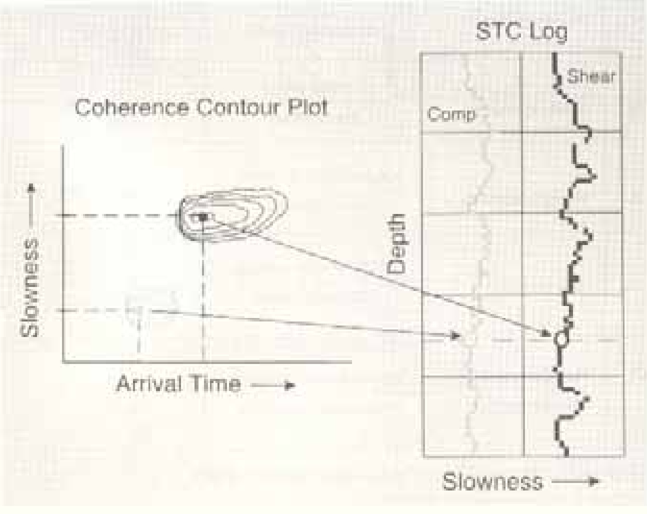


Figure 7. STC Contour Plot

produces a coherence peak very close to the true shear slowness. In slow formations the formation shear must be derived from the flexural data. The resulting slowness tends to correspond to that of the largest amplitude component. A precomputed correction, derived using data generated from numerical modelling, is included in the processing to correct for the bias caused by flexural wave dispersion. The amount of correction depends upon the acoustic response signature of the source, the STC filter characteristics, the borehole size and shear slowness. This correction is practically nil for fast formations but may reach almost 10 percent in medium slow formations with very large boreholes.

As the seismic waves travel up the side of the borehole they create head waves in the borehole fluid. These head waves propagate along the borehole at the velocity of the wave propagates in the formation The tool detects the head waves (refer fig. 4).

Applications

Besides the traditional uses for compressional data wave-form sonics are used for the following applications:

- Mechanical Properties
- Thin bed formation evaluation
- Obtaining a sonic behind casing
- Formation evaluation
- Fracture detection
- Seismic Applications

Mechanical Properties

This is becoming a major application for waveform sonic. Programs such as IMPACT* utilise the wireline log data to predict the mechanical properties of rocks. This provides valuable information for subsequent drilling in the vicinity of the well analysed as well as subsequent development work. Three concepts are important in mechanical property applications: rock strength, earth stress and rock failure mechanisms. All three concepts contribute to explain or predict when, where, why and how a formation fails. Waveform measurements are used to obtain quantitative information on dynamic elastic moduli. These moduli are critical in determining both the strength of the rock and the magnitude of the stresses within the earth. Several different rock failure models are considered when evaluating the mechanics of rock failure.

The basic processing steps are:

1. Calculate Dynamic Elastic Constants using r , T comp, T shear and V shale. There is an option to use either a single component or two component model (refer table 1)

2. Rock Strength Calculation uses the dynamic elastic constants. This is based on a correlation such as Plumbs, Coats/Denoo or a user defined correlation. Core results are useful to check the accuracy of different correlations.

3. Earth Stress calculates Pore pressure, vertical stress and horizontal stress. Several formula are available for calculating the horizontal stress. Generally the Poro Elastic or Mohr Coulomb formula are used.

4. Wellbore stability can be predicted once the mechanical properties have been calculated. Several models are available generally the Mohr-Coulomb or Griffith's failure criteria are found to be the most appropriate for shear failure.

Core data is not essential, though is highly recommended to calibrate the results. Data from any uniaxial, triaxial and leak -off test improves confidence in the analysis. Once the mechanical properties have been completed there are three main applications.

- Wellbore stability-determines the effect of azimuth and/or deviation on the wellbore stability and predicts the appropriate mud weight for stability. When the mud weight is too low shear failure and slouching are induced. Too high a mud weight induces a hydraulic fracture and lost circulation. The window for safe mud pressures will vary with deviation and azimuth of the well.
- Sanding-predicts the maximum draw down that can be applied to a formation. Different failure models such as Mohr Coulomb and Murrell's extension to Griffith's (refer fig. 8) are used.

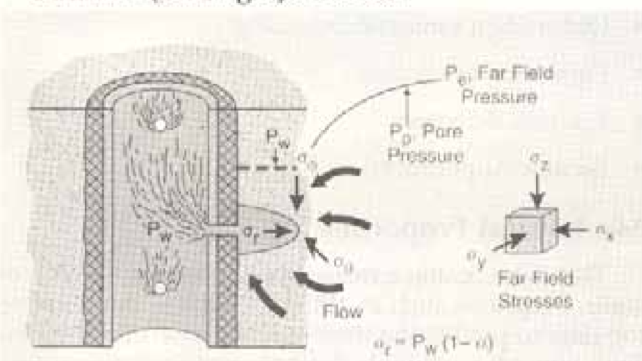


Figure 8. Sanding Model

Plate 1 is an example of the application of this model in a gas-bearing sandstone. The zones predicted to fail under producing conditions are those where the critical wellbore pressure is higher than the anticipated flowing well pressure Pwf.

The interval 2,873 to 2,977 m is perforated over one of the zones predicted to fail. Sand production from this interval is confirmed by the cavity log recorded with a 2 3/4-in. density tool. The perforated interval 2,887 to 2,889 m has also caved. The other weak zones were avoided in the perforation program.

- Fracture height determination predicting the height at which a fracture will extend to under different pressures assisting the design of a fracture programme. The most important factor limiting vertical growth of hydraulic fractures is in-situ stress differences. These data, plus the treatment fluid density, are also used to predict the fracture migration behaviour in relation to bottomhole treatment pressure.

Growth of vertical hydraulic fractures can be limited by controlling the injection pressure above formation closure pressure. A fracture vertical growth model predicting penetration into bounding layers from a fracture initiated in a lower stress layer is used to calculate total fracture height at the wellbore for a given injection pressure. An example of the FracHite* log is presented in Plate 2 where the vertical extension at different injection pressures is displayed.

Thin Beds

Typical sonic tools have 2' resolution. By utilising the detection in the array 6" resolution can be obtained.To obtain the measurement for any given 6" interval three slowness readings are taken with the receivers across a 6" interval to give an uncompensated slowness measurement. Three more slowness readings are taken as the transmitter moves across the same interval. The six measurements are combined to give the DDBHC (depth derived borehole compensated) signal. If one reading (measurement) has an obvious cycle skip, the software will delete it before the remaining measurements are averaged. Plate 4 compares short spacing sonic (TT curves) with 6" resolution sonic.

Formation evaluation

In sedimentary formations the speed of sound depends on many parameters; principally it depends on the rock matrix material and on the distributed porosity. Application of accurate shear wave data in formation evaluation is useful in identifying matrix materials and pore fluids. Plates 7 and 8 compare compressional slowness to shear slowness for both core and the log data.

Gas Detection

The ratio of compressional to shear velocity or poissons ratio (refer table 1) can be a powerful tool for gas detection in either open or cased hole.Wave theory predicts that a small percentage (5%) of gas in the pore space significantly decreases the compressional

ν	Poisson's Ratio	Lateral strain / Longitudinal strain	$\frac{1/2\,(DTS/DTC)^2 - 1}{(DTS/DTC)^2 - 1}$
G	Shear Modulus	Applied stress / Shear strain	$\frac{\rho_b}{DTS^2} \times a$
E	Young's Modulus	Applied uniaxial stress / Normal strain	$2G\,(1 + \nu)$
K_b	Bulk Modulus	Hydrostatic pressure / Volumetric strain	$\rho_b \left[\frac{1}{DTC^2} - \frac{4}{3DTS^2}\right] \times a$
C_b	Bulk Compressibility (with porosity)	Volumetric deformation / Hydrostatic pressure	$\frac{1}{K_b}$

Note: coefficient $a = 1.34 \times 10^{10}$ if ρ_b in g/cm³ and DT in μs/ft.

Table 1. Dynamic Elastic Properties

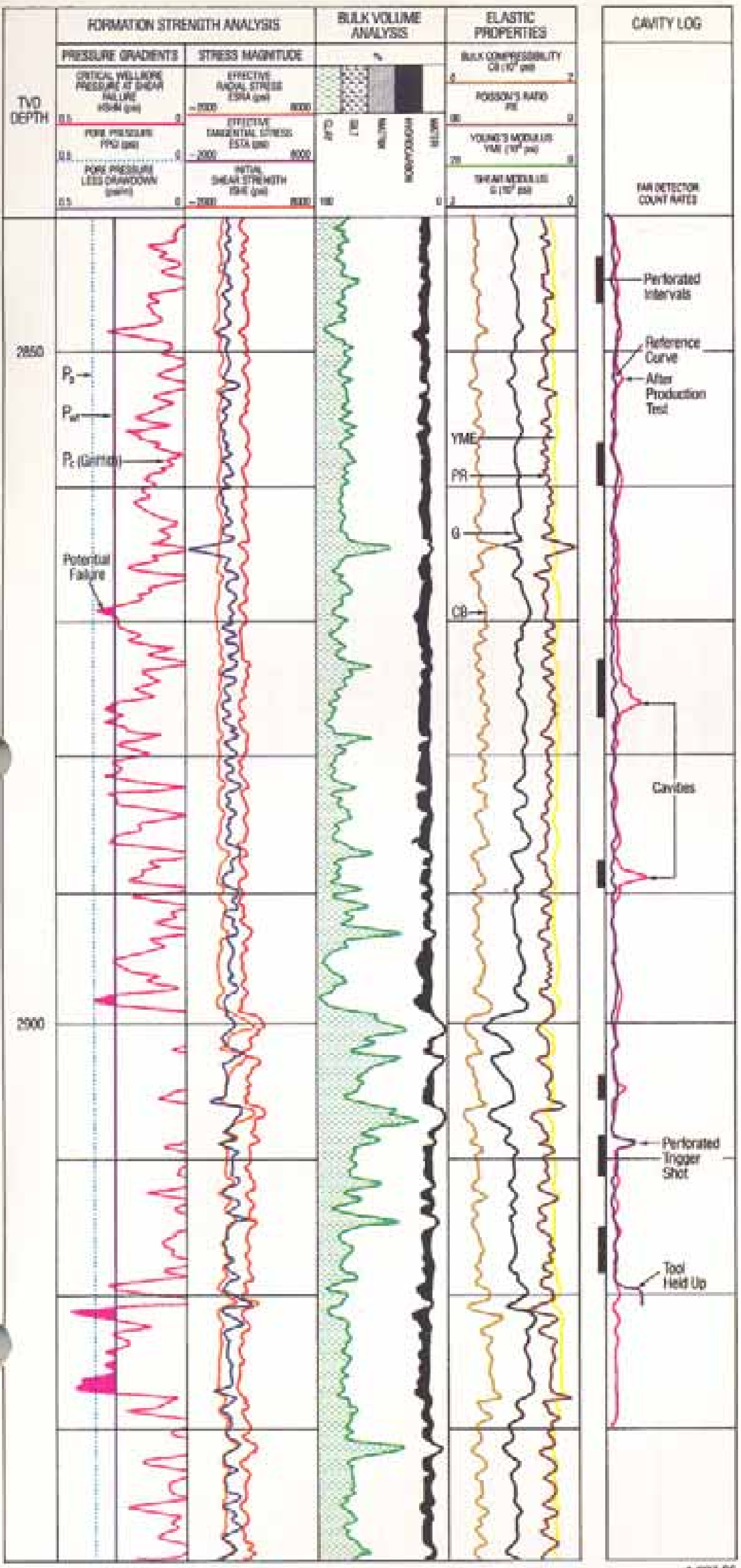


Plate 1. Formation Strength Analysis

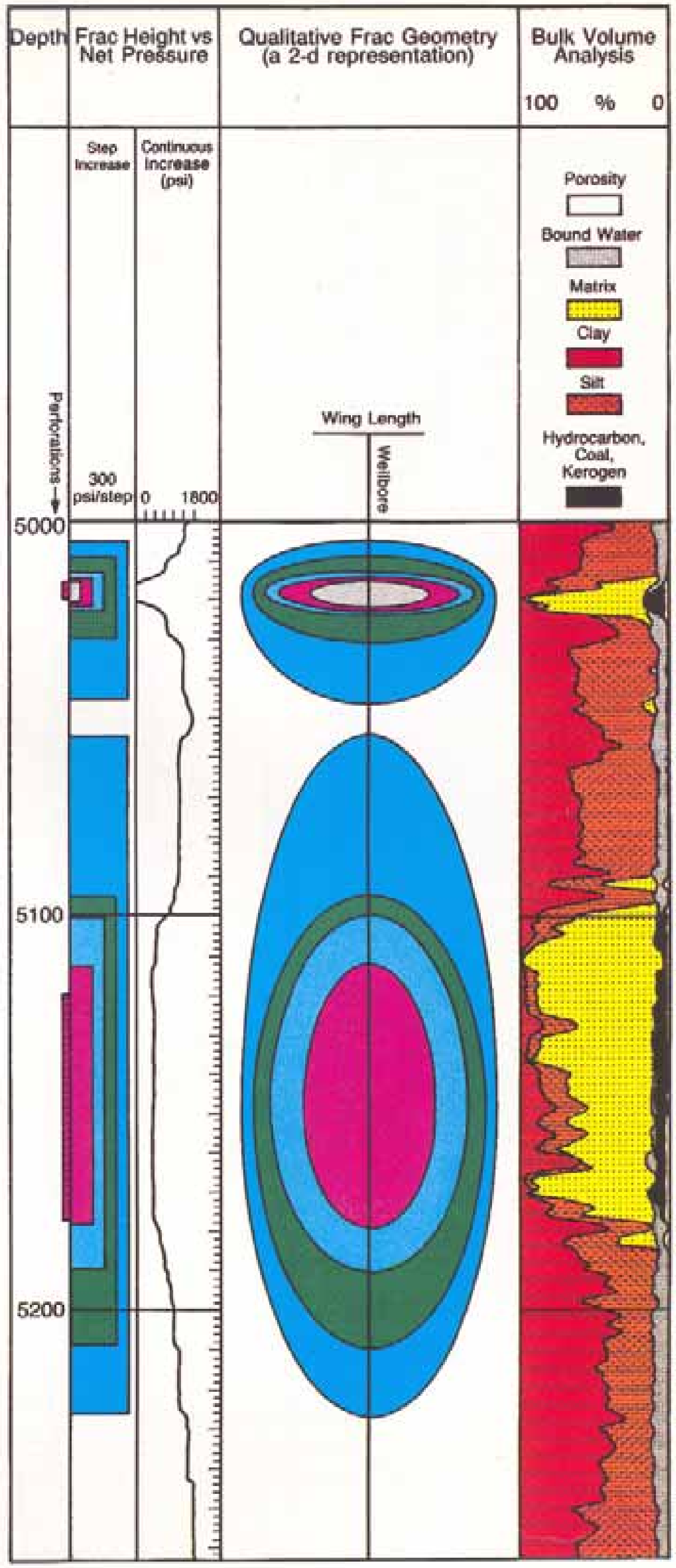


Plate 2. Frachite log

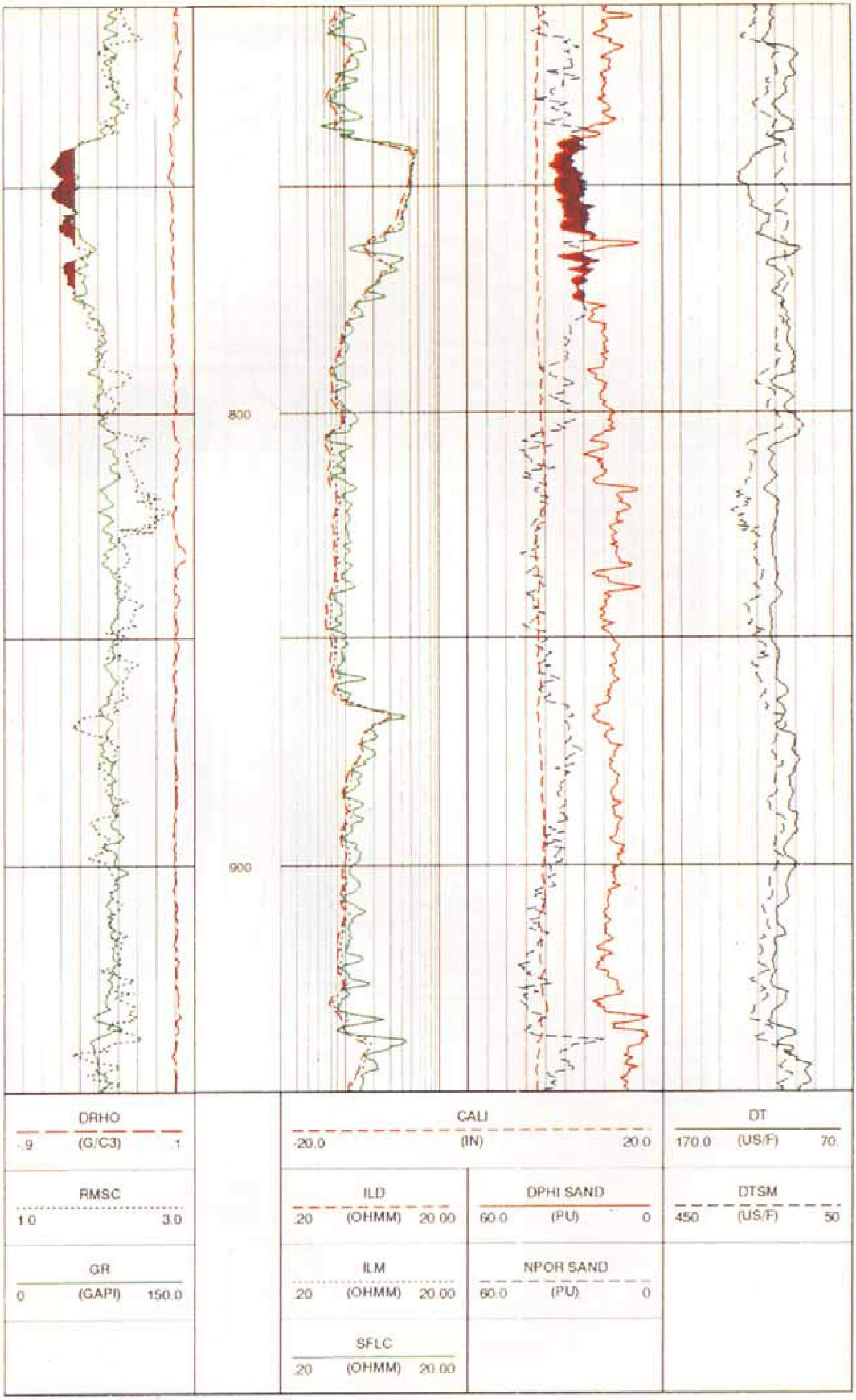


Plate 3. Effect of gas on DSI data

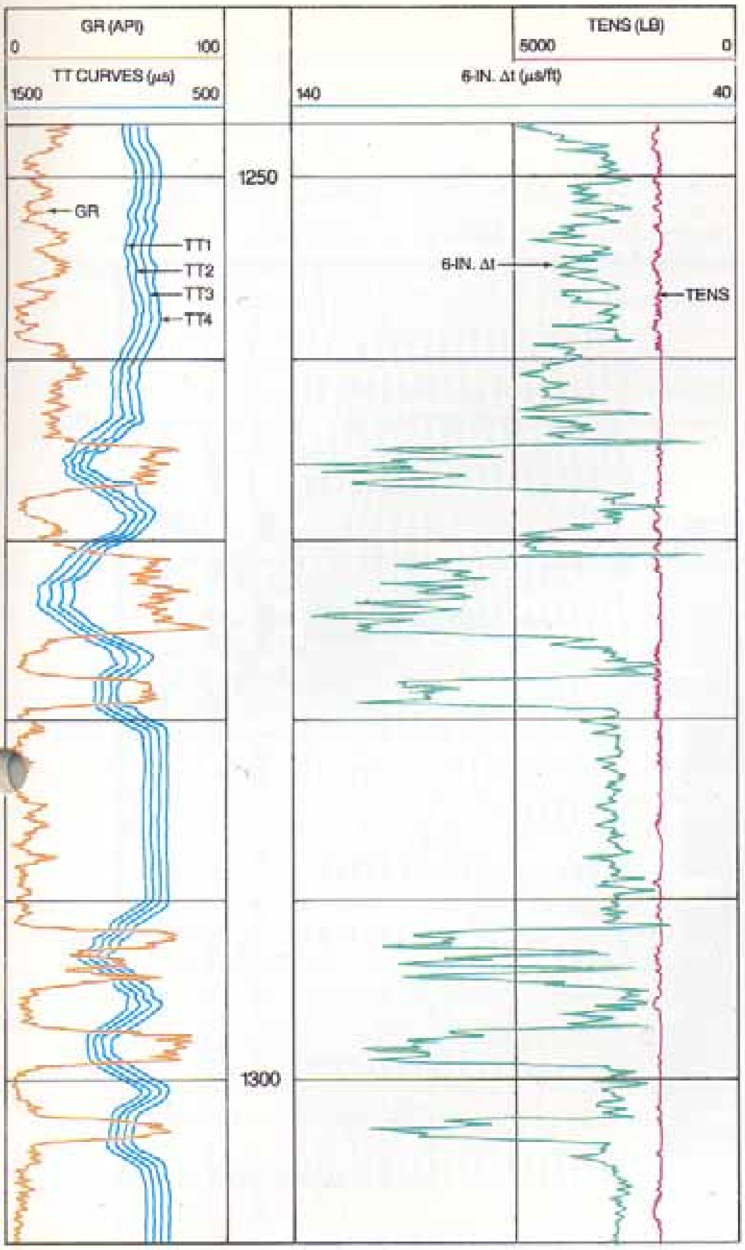


Plate 4. Thin Bed Analysis

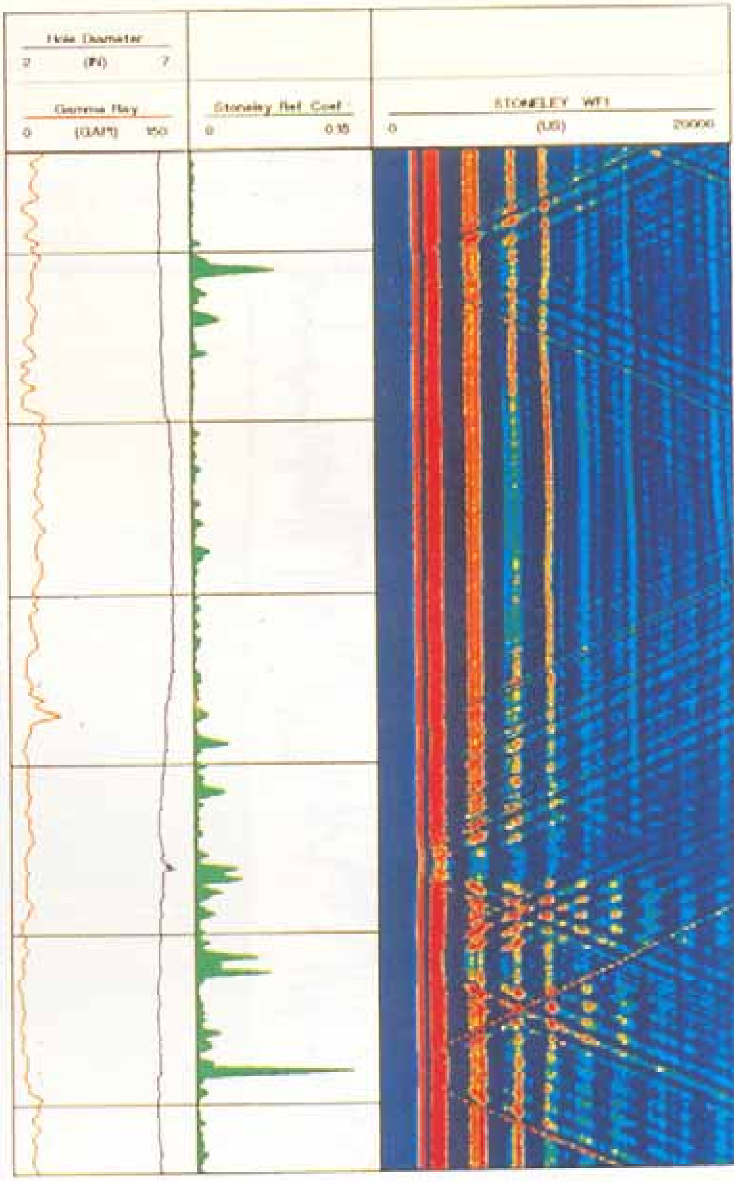


Plate 5. Fracture evaluation using Stonely

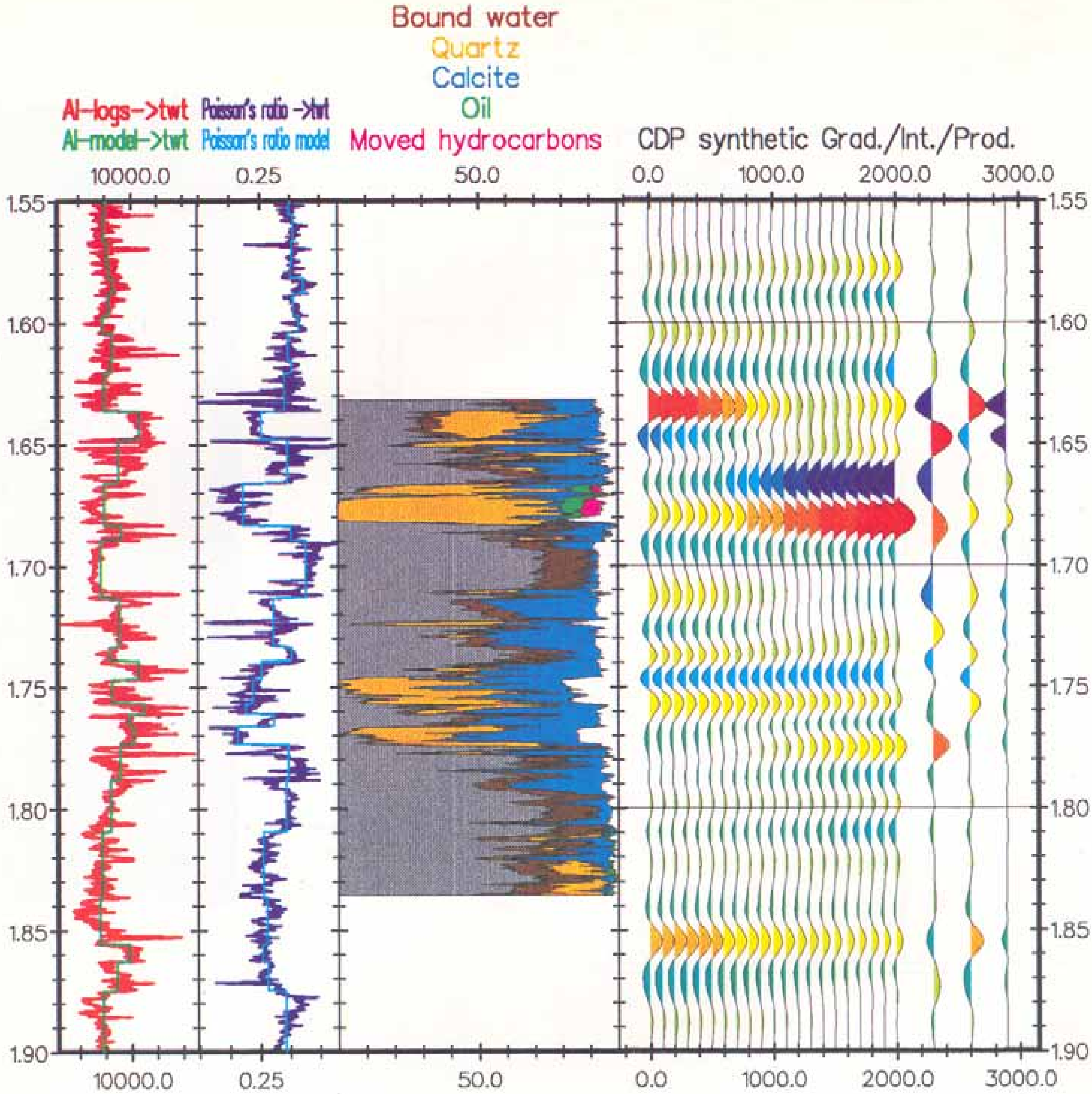


Plate 6. Synthetic AVO analysis

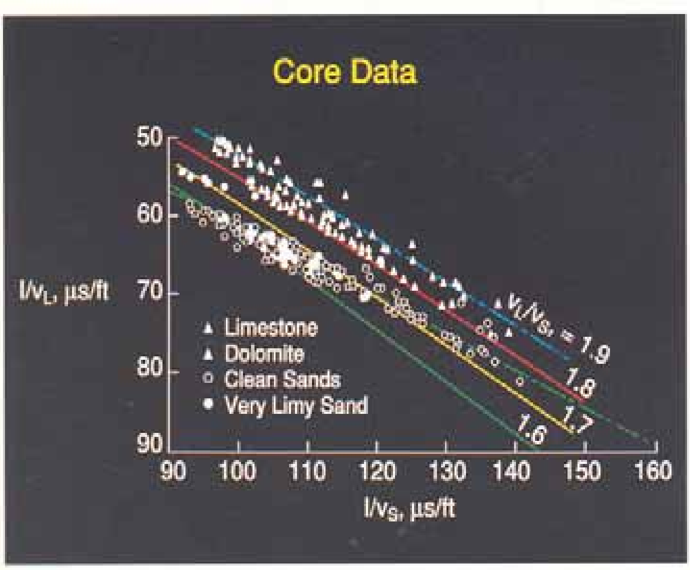


Plate 7. Plot of shear slowness versus compressional slowness from core data (Pichett 1963)

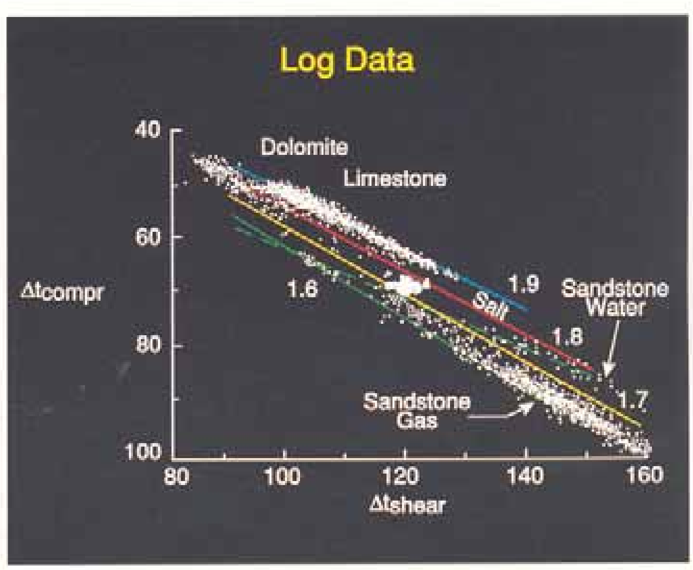


Plate 8. Plot of shear slowness versus compressional slowness from log data

velocity. The effect of gas on the shear velocity will be much less (refer fig. 9).

Plate 3 shows DSI data and other logs from the Yegua formation in Texas. The density-neutron logs show characteristic gas crossover at X740-85ft, and this zone produced gas after completion. The sand trend shown by Pickett suggests that ratios below 1.8 to 1.9 would be indicative of gas at this shear slowness. The shear-compressional slowness ratio (RMSC) is presented in track 1. Ratios lower than 1.8 are shaded and agree well with the density-neutron response and with production data.

Fractures

The monopole Stoneley can be used to assess fractures. The Stoneley wave reflectivity is used to locate permeable fractures. High quality Stoneley waves are required. When a bore hole Stoneley wave encounters an open fracture intersecting the wellbore some of its energy is reflected due to the large acoustic impedance contrast created by the fracture. Basically, this technique processes the acquired Stoneley waveforms to measure the reflection coefficient (from the ratio of reflected to incident energy) and uses it to determine the openness of the fracture.

Plate 5 shows the result of this processing in a well drilled through hard rocks. The log show significant reflections at 605, 781, 784, 807, 811 and 840ft. The Stoneley reflection coefficient indicates these fractures are open, with larger values meaning more permeable fractures. A Formation MicroScanner* log confirmed the presence of fractures at the first and last three depths (the reflections at 781 and 784ft were less certain).

Permeability indications

The Stoneley wave responds to several factors including matrix permeability and open fractures. It can be viewed as a pressure pulse, guided by the wellbore, creating fluid movement into zones with effective permeability. This causes a reduction in the Stoneley energy level and a decrease in the velocity of the Stoneley wave. The Stoneley wave is also affected by hole size, and formation and tool characteristics. With high quality data the Stoneley energy can be computed and used to indicate permeable zones.

Geophysical Applications

In addition to the traditional uses of sonic logs in geophysics, the waveform sonics are useful for many other seismic applications. These data are useful for shear seismic correlations, for shear synthetic seismograms for VSP interpretation and for models used in analysing offset VSP data. The measurement also provide data to distinguish gas-related amplitude anomalies and are used as input to modelling for AVO analysis.

AVO

Poisson's ratio, describes the amount by which a material increases in width along one axis when

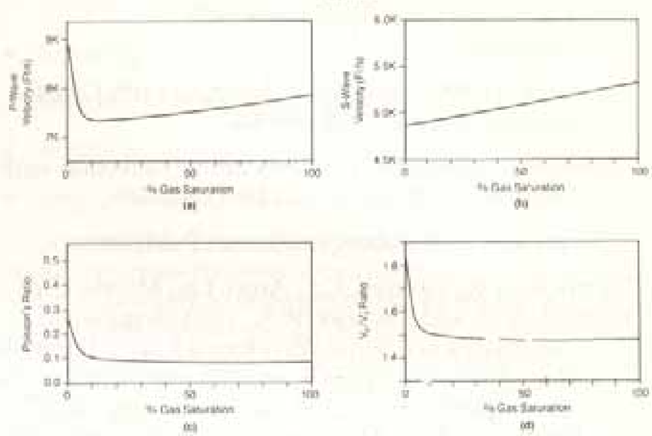


Figure 9. The effect of gas on the compressional and shear slownesses

compressed a certain amount along the other. It directly relates rock compressibility with stiffness. Accurate borehole measurements of compressional and shear velocities(refer table 1), with the computed Poisson's ratio, are helpful in the interpretation of seismic sections.

Gas-filled reservoirs often yield a markedly different Poisson's ratio than either the fluid-filled reservoirs or the shales around them. This difference can create an anomalous amplitude variation with offset (AVO) response in seismic data when compared to liquid-filled reservoirs. AVO can be described as amplitude changes in a reflected wave at a common sub surface point resulting from a change in the incident angle. Reflections from an acoustic impedance boundary are the function of four variables: compressional velocity, shear velocity, formation density and the angle of incidence of the plane wave striking the boundary. Reflection amplitudes from surface seismic data can be processed in true amplitude to enhance AVO effects for use as a potential hydrocarbon indicator.

Log data can be used to calculate a synthetic AVO response to determine if an AVO response can be anticipated and what it is likely to look like. Plate 6 shows the negative polarity event at the top of the sand (1.67 sec TWT)and a peak at the bottom of the sand getting stronger with offset. This is clearest in the CDP synthetic display to the right of the ELAN volumetrics display. The traces on the right of the plot show the gradient, intercept and product. On the left of the display is the Tcomp and poissons ratio with blocking applied. The analysis uses DSI* data and an ELAN* evaluation.

Conclusions

The applications discussed in this paper are not a complete list. There are many other applications such as anisotropy where considerable effort is being put into further developing the applications. The waveform sonic data we are acquiring today provides much better data quality and many more potential applications than sonic data acquired using first motion detectors.

* *Trademark of Schlumberger*

References

Array Sonic Services, Schlumberger Internal Publication

Chen, S.T., (1988). Shear Wave Logging With Dipole Sources, *Geophysics* **53**, 659-667

Chilburis, E. etal, (1993). Hydrocarbon Detection with AVO Oilfield Review, (Jan 1993) p42-50

DSI Services, Schlumberger Internal Publication

Harrison, A.R., Randall, C.J., Aron, J.B., Morris, C.F., Wignall, A.H. and Dworak, R.A., 1990. Acquisition and Analysis of Sonic Waveforms from a Borehole Monopole and Dipole Source for the Determination of Compressional and Shear Speeds and Their Relation to Rock Mechanical Properties and Surface Seismic Data. Paper SPE 20557, presented at the SPE Annual Technical Conference and Exhibition, New Orleans, September 23-26, 1990.

Hornby, B.E., Johnson, D.L., Winkler, K.W. and Plumb, R.A., 1989. Fracture Evaluation Using Reflected Stoneley Wave Arrivals. *Geophysics*, 1274-1288.

Kimball, C.V. and Marzetta, T.M., 1984. Semblance Processing of Borehole Acoustic Array Data. *Geophysics* **49**, 264-281.

Koefoed, O. 1955. On the Effect of Poisson's Ratios of Rock Strata on the Reflection Coefficients of Plane Wave. *Geophys. Prosp.* **3**, 381-387.

Kurkjian, A.L. and Chang, S.K., 1986. Acoustic Multipole Sources in Fluid-Filled Boreholes. *Geophysics*, **51**, 148-163.

Leslie, H.D. and Mons, F., 1982. Sonic Waveform Analysis: Applications. *Trans.*, 1982 SPWLA Annual Logging Symposium.

Leslie, H.D. and Randall, C.J., 1990. Eccentric Dipole Sources in Fluid-Filled Boreholes: Experimental and Numerical Results. *J. Acoust.Soc.Am.* **87**, 2405-2421.

Morris, C.F., Little, T.M. and Letton, WIII, 1984. A New Sonic Array Tool for Full Waveform Logging. Paper SSPE 13285, presented at the SPE Annual Technical Conference and Exhibition, Houston, September 16-19.

Murrell, S.A.E., 1963. A Criterion for Brittle Fractures of Rocks and the Effect of Pore Pressure on the Criterion. *Proc*. Fifth Rock Mechanics Symposium in Rock Mechanics. University of Minnesota. C. Fairhurst (Ed.), Pergamon, Oxford, 563-567.

Newbury, B., Nelson, R., Cannon, D. and Ahmed, U., 1985. Prediction of Vertical Hydraulic Fracture Migration Using Compressional and Shear Wave Slowness. Paper SPE 13895, presented at the SPE/DOE Symposium on Low-Permeability Reservoirs, 1985.

Ostrander, W.J., 1984. Plane-Wave Reflection Coefficents for Gas Sands at Nonnormal Angles of Incidence. *Geophysics* **49**, 10.

Pickett, G.G., 1963. Acoustic Character Logs and Their Applications in Formation Evaluation. *JPT* **15**, 6 .

Rayleigh, Lord, 1985. Proc., London Math. Soc. **17, 1, 4.**

Schmitt, D.P., 1988. Shear Wave Logging in Elastic Formations. *J. Acoust. Soc. Am.* **84**, 2215-2229.

Scholte, J.G., 1948. On the Large Displacements Commonly Regarded as Caused by LOVE-Waves and Similar Dispersive Surface-Waves. *Proc.*, Kon. Ned. Akad. Wetenschap. **51**, 533-543.

Stoneley, R., 1924. *Proc.*, Roy Soc., Series A **106**, p416.

Formation Evaluation - Research

Enhanced Formation Evaluation Techniques for Australian Geological Conditions: Phase 1 - Prioritising the Problems

Declining oil production, marginal fields, thin oil columns and enhanced oil recovery projects demand ever more accurate saturation and porosity calculations to reduce economic risk and to achieve tighter cost margins. In many Australian basins estimates of these parameters can be severely affected by a number of different geological factors. In order to assess these factors, APIRA the Petroleum Division of the Australian Mineral Industries Research Association, recently carried out a study to identify the major formation evaluation problems by their economic impact and technical difficulty. APIRA's aim is to develop a research strategy to solve the industry wide problems through a series of well focussed collaborative research projects. The study represents the first phase in the development of the strategy. The study was supported financially by Esso Australia Limited, Sagasco Resources Limited, SADME and the Victorian Department of Energy and Minerals.

Dr Paul Baker from Monash University, now with McKenzie and Partners, carried out the study.

The methodology followed in the study encompassed the following four steps:

1. Circulation of a questionnaire to about 30 companies asking them to indicate the most critical and significant topics. The response rate was about 60%.

2. Follow-up interviews with almost all those companies who responded to detail the most significant projects in which each company is interested.

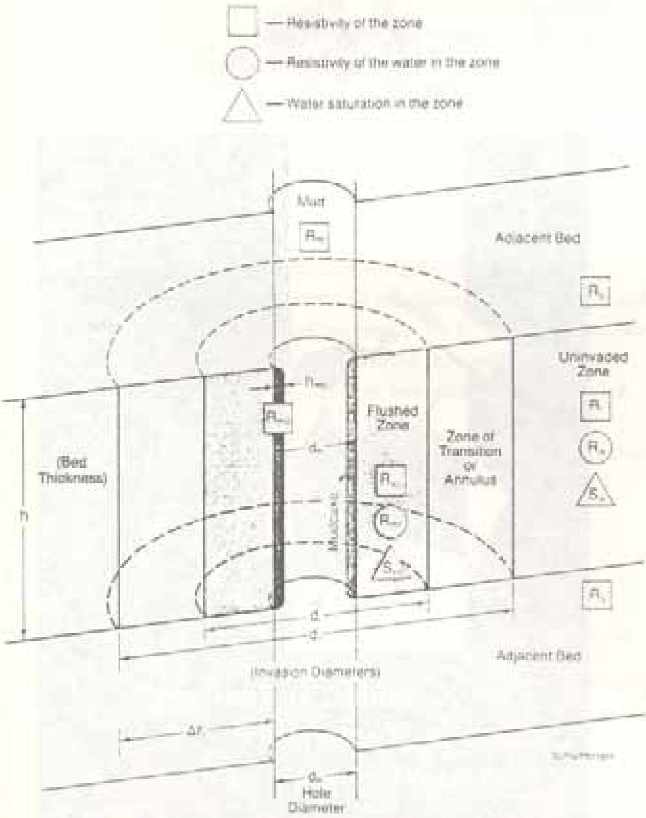
3. Analysis of the individual company responses to clearly identify the most significant collaborative research projects the industry is likely to support.

4. From contacts with service companies, oil industry research personnel, and literature searches, the

technical difficulty of solving the problems and the resources required was judged.

The major topics that were identified in the study are:

- Improved Shaly Sand Models
- Variable Cementation Exponents
- Sealing Capacity
- MWD Logging
- Log Analysis Systems
- Horizontal Holes
- Variable Water Resistivity
- Thin Beds
- Variable Saturation Exponents
- Long Transition Zone
- Glauconite
- Clay Typing
- Microporosity
- Core-Log Permeability Estimate
- High Resolution Logging
- Rw/low Contrast Sands
- Pyrite/Siderite
- Secondary Porosity
- Variable Conductivity Silts



- Formation Anisotropy
- Cased Hole Nuclear Logging
- Core-log Calibration
- Monitor/Production Logging
- Borehole Stability
- Log Quality Control

An analysis was undertaken to identify which of the above topics are the most worthwhile to develop, on the basis of economic impact versus technical risk, into APIRA collaborative research projects. In determining which are the most economically significant, but common problems, the following factors were taken into account:

- the likely benefit to wide cross-section of the industry,
- the likelihood of achieving a long term benefit versus an incremental improvement,
- the risk of failure, and
- whether the collaborative approach is the best mechanism for addressing the problem.

The report included preliminary proposal outlines for those key projects that are considered to have the most impact, reasonable risk and suitable duration. It is expected that these research ideas will be developed into complete research proposals for circulation to the industry at large.

At this stage the results of the study are confidential to sponsors. APIRA will be consulting the sponsors to determine which of the key problems should be addressed first and to identify the relevant researcher(s) with the necessary skills and resources to undertake the research. APIRA will be working with these researchers to prepare the research proposals.

I would be interested to hear from those researchers who are currently working in this field.

ACKNOWLEDGEMENTS

In preparing this short note I have drawn heavily from Dr. Paul Barker's report. I would like to thank Esso, Sagasco, SADME, and the Victorian Department of Energy and Minerals for their support of the project.

Joe Cucuzza
APIRA
9th Floor, 128 Exhibition Street
Melbourne Vic 3000
Tel: (03) 654 8844
Fax: (03) 654 8661
Email: Joe@amira.com.au

APIRA

Letters - The ASEG and Professorial Positions

Mr Hugh Rutter
President, ASEG

29 September 1993

Dear Hugh,

I have just read with interest your column in the August 1993 issue of Preview. In it you raise questions about funding of Australian geophysics research, and particularly exploration geophysics.

ASEG should not support a University department. This could result in a great misuse of funds and may generate ill-feeling. While perhaps requiring more effort, I would suggest that ASEG looks at the following possibilities:

(1) Mounting a competitive, targeted research round in which applications are sought and assessed by a panel of people from industry, economics and trade. ASEG would set the targets. ASEG could seek some equity in any product or process which resulted from the research.

(2) Compiling a complete document on geophysics research in Australia (not only in University geophysics and earth science departments) and deciding on priority areas and areas of existing strength. I know of a number of groups (including my own located within the School of Microelectronic Engineering) that have research interests in geophysics but do not fit into these traditional categories. There are some advantages for researchers in different environments. (Prof. James R Wait has always worked in Electrical Engineering Departments when holding University appointments.)

(3) Giving assistance to attendees at the ASEG Congresses to present papers at targeted sessions, forums and workshops. I think this is where ASEG can have a significant influence on the future of Australian geophysics by reducing fragmentation.

(4) Lobbying other research funding organisations to increase funding to geophysics; eg. A.C.A., A.R.C.

Good luck with with work. I would be more than happy to support you where I can.

Yours Sincerely

David V. Thiel, Director
Radio Science Laboratory, Griffith University

Mr Brenton Oke
Honorary Secretary, ASEG

4 October 1993

Dear Mr Oke,

It was nice to see Hugh Rutter's smiling face in the pages of the August Preview. However I should warn the membership of a serious problem intrinsic to the idea of setting up and supporting Chairs in Geophysics around the country. That is, the universities which house them depend for their income on having large student numbers. This puts serious pressure on the Professors to attract such numbers.

Who in the hell is going to employ all the graduates? If ASEG is behind the idea then it has an implicit committment to find jobs. So far we haven't been awfully successful in doing so, nor do we have any real prospects for doing so in the forseeable future.

This is an old problem in Earth Science departments. The fallback positions is to mount "general education" courses for students in accountancy, archaeology, etc, and many departments have tried this with limited success. I personally found that the archaeology departments are afraid of losing their students, even for a general education course which could be quite useful to practicing archaeologists. This approach also takes the geophysicists' energy away from the pressure to do research and publish.

I can see no easy solution to the problems, but I think the ASEG should consider very carefully how it will deal with them before we get deeply involved.

Sincerely

Keeva Vozoff
Professor of Geophysics, Univeristy of Cologne

Mr Hugh Rutter
President, ASEG

19 October 1993

Dear Hugh,

I read with interest your August "Piece".

The issue of professorial positions is an important one to which thought should be given. I feel that more information is needed by the "masses" (us) to better understand what is required.

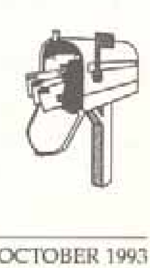
The ASEG should be involved in supporting our future but I am not sure that "pre-deciding" which university department will be the "best" for the ASEG is appropriate. We need a vehicle(s) for helping several departments (bursaries are a useful tool).

What about local industry "sponsorship" of the new professorial position (they are reasonably spaced geographically). Data sets and research problems are vital ingredients for departments which industry can help with. ASEG involvment on an appropriate committee would be pertinent.

I am sure that, if desired, ASEG members could directly help out in a lecture/tutorial capacity. (I really appreciated Chris Porter doing this at Adelaide University in the 70's). We have many members who are capable of giving a lecture (or a group of lectures) on a variety of subjects. We could even sponsor a "distinguished University lecturer" who "did the rounds" of specific departments.

Regards,

Rob Kirk
BHP Petroleum Pty Ltd



Environmental Geophysics

Its Particular Aspects and General Lessons to be Learned from its Practise

Roger Henderson
ASEG representative to EEGS

Environmental geophysics has generally been looked upon as the great new application of the future. Certainly we see plenty of evidence of environmental pollution in various parts of the world and we are aware that geophysical methods can be applied to their detection and delineation.

However, is it really all that easy? Actually, it doesn't take long after working in this field to realise that it is quite a bit different from the traditional geophysical fields of application such as mining and petroleum exploration. Firstly, the site conditions are generally extremely challenging often being in urban environments with all their attendant cultural interference, confined space and complex sub-surface conditions. (We have been spoilt by the fact that minerals are generally located in very remote, open spaces.)

Added to this is the fact that the budgets for these applications are often much smaller than those for mineral exploration. Thus, much of the expensive equipment that we use is hard to justify and specially modified and simplified equipment may need to be developed.

Finally, the clientele that one deals with are even less knowledgeable of geophysical techniques and their capabilities and limitations than even geologists (!), and the project managers have little idea of the value of the geophysics or even what is a reasonable fee to pay.

Geophysicists in the USA have had much more experience in this area than we have in Australia to-date, as they have been dealing with these matters for some years now, largely because of the establishment by the US Environmental Protection Agency of a fund of hundreds of millions of dollars to clean up hazardous waste sites in the US. It's interesting, therefore, to read the comments by the President of the newly formed Environmental and Engineering Geophysical Society, Jeff Daniels, in their latest newsletter (June 1993). Despite their headstart, Jeff makes the comment that "the environmental and engineering geophysical industry is still in the process of defining itself ...".

Another article in this same newsletter, entitled; "Geophysics in the Environmental Marketplace", by Mary-Linda Adams, V.P. of Resolution Resources, Inc., who has worked in environmental geophysics since 1982, is, I think, so instructive and illuminating about this field that it is worth reproducing the following page from the article. I would emphasise her remarks about there being "no highly marketable commodity at the end of the survey".

On this point, surveys to locate buried objects can sometimes result in the client marking the spot in some way and I've had it said to me that this is not geophysics when no interpretation or report is required but instead all that is to show for the expert work carried out by professionals is a "line painted on the pavement".

Also, that "the environmental business is plagued by politics and legal battles", etc. Mary-Linda also verifies that budgets are small and hence the least expensive equipment and very valid concern that our data presentation is often in the form of squiggles which are quite unintelligible to these types of clientele. It is my belief and that of many others that we have to drastically improve the way in which we present our data to make it more readily understandable to the non-conversant customer.

Mary-Linda then has some very interesting solutions to what she considers to be five problems related to the under use of geophysics in these situations. They include the need for better marketing of our discipline and one point that I feel is very valid that we as geophysicists tend to criticise each others work too readily. Sometimes this is, as she says, sour grapes at losing the contract and other times it's promotion of ones self at the expense of colleagues. Often it only serves to indicate to the customer that if geophysicists can't agree among themselves then why should their conclusions be trusted.

I commend you to read Mary-Linda's words of wisdom and experience in their entirety.

Geophysics in the Environmental Marketplace

Mary-Linda Adams,
Resolution Resources Inc.

Geophysical techniques have traditionally been used for oil and mineral exploration. They have also been instrumental in exploring the ocean basins and in proving plate tectonics. It was in the early 1960s that Vine and Matthews flew over the mid-ocean ridge, in an airplane equipped with a magnetometer, and discovered basalts exhibiting alternating bands of magnetic polarity on either side of the mid-ocean ridge. In the late 1960's, Lynn Sykes at Columbia University began his seismic survey of relative plate motions, thereby defining which way the continental and oceanic plates were moving. Geophysical methods were also widely used in lunar experiments and the characterise other planetary bodies.

Faster, Cheaper and Better

With the downsizing of mineral and oil exploration in the United States, geophysicists need to look to other areas to make a contribution and market their skills. The environmental engineering industry, in particular, could make good use of these talents and the associated technological developments that have taken place in exploration geophysics.

The environmental field developed primarily during the 1980's, expanding rapidly by the end of the decade and into the early 1990's. Presently much of the marketplace is in temporary stagnation as a result of the economy, but forecasters are hoping a change in the Oval Office to more environmentally-oriented leadership will move the industry forward in the next year or so. In addition, government agencies are eager to find innovative technologies that will do things faster, cheaper and better. This is especially true in light of plans to close various Department of Defense (DOD) facilities which require a cleanup before they are decommissioned. Also, certain government agencies have been critized by the press for wasteful spending and making little progress in actual remediation. Geophysics can provide a great deal of innovation and know-how to the environmental industry (and governmental agencies) that will result in a savings of both time and money.

.... Geophysics can provide a great deal of know-how and innovation to the environmental industry ....

Unlike the oil industry, however, the environmental field offers no highly marketable commodity that can be discovered at the end of a survey. A few responsible parties have environmental concerns, but, for the most part, these parties clean up only as much as regulators force them to. The environmental business is plagued by politics, legal battles, reams of next-to-useless work plans, and very little actual remediation work. However, the wastefulness of the past is giving way to demands for solutions.

......Geophysicists often collect data, add an ounce of interpretation and wash their hands of the project.......

Black Box Technology?

Presently, geophysics is a small portion of the budget in hazardous waste site cleanups. It is generally thought to be useful in locating drums or tanks to 20ft, in locating utilities, in downhole logging boreholes, and sometimes, to locate contaminant plumes. It has a reputation for sometimes working. Because many of the budgets are small, geophysical surveys are frequently done with the least expensive equipment, and the least experienced personnel are used to collect the field data. Geophysics is an art, to some extent, and because those little squiggles are unintelligible to all but the cognoscenti, geophysicists appear to fight over the interpretation of the data. This leads the project manager to throw his hands up in despair and yell "black-box technology!" He begins to see geophysics as an added expense that may, or may not, have any real application. Why spend the money for a geophysical survey? Why not just use the money to put in more wells and get "real data?"

Needed: A New Image

Much work is needed to change this image and forge ahead into new areas. Geophysics is underused at most contanimated waste sites. Why is this? What are the solutions to increasing the use of geophysics? What are the problems? Answers to these questions involves:

- educating environmental professionals in the usefulness of geophysical methods;
- cooperation between geophysicists;
- integrating geophysical data and solutions with the rest of the site characterisation and remedial design;
- informing various agencies, the public, and the responsible parties of successes in geophysics in solving problems and saving time and money; and , finally
- continuing to develop techniques to meet new challenges.

Marketing Geophysics

Let us examine each of these points in more detail.

The first step is to actively market geophysics in the environmental arena. This means becoming familiar with the needs and goals connected with the site assessment, including the jargon that is particular to this field. Many large engineering firms subcontract geophysical services, so it is important to meet with potential clients and describe how geophysics can expedite the site assessment. Many project managers are aware that geophysics can help them find drums or underground utilities, but few of them realize how important a role other types of geophysics, such as seismic methods, can play in better understanding the heterogeneity of the subsurface geology.

Marketing geophysics is important, because the environmental engineer is not going to come to the geophysicist. It is the responsibility of the geophysical firm to go out into the marketplace and in concise, clear terminology, discuss the benefits of the technology. This means interacting with chemists, hydrologists, means interacting with chemists, hydrologists, geologists, lawyers, regulators, responsible parties, bankers and the public. Education can occur at conferences, seminars, during presentations,and in publications.

Biting Reviews

One of the biggest hindrances to expanding the market is the geophysicist. Many professionals are negative and spend more time giving reasons why the existing techniques won't work than in figuring out how geophysics can solve the problem. Biting reviews that geophysicists heap upon on another is a glaring problem. The market is presently small and firms bitterly fight for the few contracts that are available; to lose a contract can make a difference as to whether a small business survives. As a result, a reviewer may become totally negative about work that has been performed by a rival firm, hoping that he or she will be called upon to bail the project out. More often than not, however, such reviews result in the elimination of geophysics from the entire program. Reviews need to be constructive and should promote discussion that will ultimately improve the final report.

What does this Data really Mean?

No matter how good the data is, it is useless to the outcome of the project if it is not integrated with the drilling results, site history, hydrology, geology, contaminant transport data, and groundwater flow models - in other words - the rest of the project. Geophysicists often collect data, add an ounce of interpretation, and wash their hands of the project. The project managers, engineers, geologists, and hydrologists, who may not understand the fine points of geophysics, need to be shown how the data can be used to get the answers they want quicker, better, or cheaper. What does the geophysical data really mean? In short, the data need to be used to solve the problem at hand, and not simply filed away in a report.

Proclaim Our Successes

We have all heard about the failures of geophysics in the environmental business. So it is vitally important to document the successes. The documentation should include cost comparisons with the alternatives. What would happen if geophysics had not been used? How many wells were eliminated because geophysical data provided an image of the subsurface which could be used to properly locate wells?

And finally, it is important to adapt technology from the petroleum and mining industries and to move forward with new innovations that will open up even more new markets.

(Reprinted with permission of the Editor of the EEGS Newsletter - June 1993)

The Internet - archie and anonymous ftp

How to find software, documents and datasets and how to download them

Prame Chopra
Australian Geological Survey Organisation
(email: pchopra@bmr.gov.au)

In the February 1993 issue of *Preview* David Hayward described the Internet, its Australian component, AARNet, and how new users can gain access to this excellent productivity tool. He also discussed Electronic Mail and Electronic News, two of the major facilities provided by the Internet.

In this article, I discuss the archives of free software, documents and datasets which abound on the Internet, and some of the ways to find what is available in them, and get copies of material of interest.

Searching the Archives

The archives on the Internet which are available to all users can be explored manually by using anonymous ftp (see below) if their Internet address or number is already known. Thus, the AARNet archive server *plaza.aarnet.edu.au* (which is also known as 139.130.4.6) can be searched by using the **ftp** commands **cd** and **ls** (or **dir**) to change to different directories and list their contents. PC users can use **cd** and **dir** (without the MS-DOS switches, e.g. /w and /p) just as they would on their PCs.

There are however much more efficient ways to search amongst the archives for material and one of these ways is to use *archie*.

Archie

The School of Computer Science at McGill University in Canada has developed *archie*, its Archive Server Listing Service. *Archie* maintains a list of around 600 Internet archive sites and updates this list about once a month. A software description database is also maintained which consists of the names and descriptions of the software packages, documents and datasets held on the archive sites across the Internet. The archie server is duplicated at a number of sites across the Internet. The most important of these for Australian Internet users, is archie.au which is maintained on AARNet.

Once an AARNet connection has been established for a user's computer, the TCP/IP **telnet** command can be used to access archie.au. A typical login (with user responses shown in bold faced font) would be:

```
telnet archie.au
Trying 139.130.4.6 ...
Connected to archie.au.
Escape character is '^]'.

SunOS UNIX (plaza.aarnet.EDU.AU)
login: archie

NOTE: THIS IS VERSION 2.1 OF ARCHIE
YOU ARE RUNNING ON ARCHIE.AU
(sometimes known as plaza.aarnet.EDU.AU)
If you have any problems with archie, send mail
to ccw@archie.au

archie
```

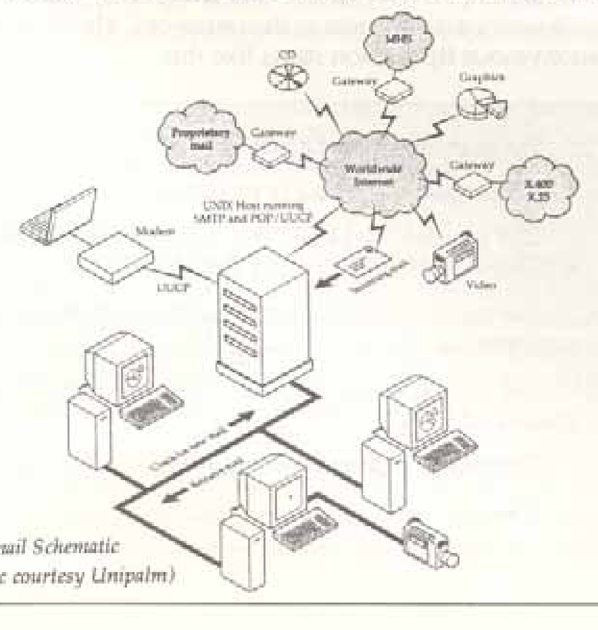
Once at the archie prompt, Internet users can search the *archie* listings and the software description database. On-line help with the commands used to search *archie* can be obtained by typing **help**. A list of all the Australian archive sites known to archie.au can be obtained with the *archie* command: **list \.au$**. There are 48 of these sites at present.

If the name of the software/document/dataset that is being searched for is known, *archie's* listings can be inspected directly. Alternatively, if the subject is known, but the actual name of the material is not, *archie's* software description database can be queried first using the **whatis** command. For example, if a ray tracing program was needed, the following command could be used:

```
archie whatis raytrace

mtvraytrace    A ray-tracing package
prt            A parallel raytracer

archie
```



E-mail Schematic
(Graphic courtesy Unipalm)

Thus the program **mtvraytrace** is a possible target to search for in the *archie* listing. *Archie's* **prog** command can then be used to locate Internet sites which store this program. For example:

archie **set maxhits 10**

archie **set sortby time**

archie **prog mtvraytrace**

matches / % database searched: 10 / 4%

Sorting by last modification time

Host archie.au (139.130.4.6)

Last updated 18:20 3 Mar 1993

Location: /usenet/comp.sources.unix/volume18

DIRECTORY rwxr-xr-x 512 Jan 16 10:15 mtvraytrace

Host unix.hensa.ac.uk (129.12.21.7)

Last updated 09:45 3 Mar 1993

Location: /pub/uunet/usenet/comp.sources.unix/volume 18

DIRECTORY rwxr-xr-x 512 Nov 2 05:00 mtvraytrace

This command sequence specified that only the first ten sites found by *archie* should be returned and that the listing of these sites should be ordered with the most recently updated entry listed first. Only the first two entries in the list are shown here but they illustrate the kinds of entries that *archie* reports. The most recently updated site for **mtvraytrace** from amongst ten sites found in the first 4% of the database held by archie.au is in fact itself. The **mtvraytrace** directory on archie.au was updated on 16 January 1993. The second host reported by archie.au is a computer in Britain. This archie entry is typical in that you can't tell exactly where the computer is, or what kind of computer it is, without logging on to it. In this case, the computer is at the University of Kent.

The results of an interactive *archie* query can be mailed to the user by using the *archie* command: **mail** ail address. Thus **mail pchopra@bmr.gov.au** would direct *archie* to send the query results to me (which is probably not a good idea for anybody but me).

Email can also be used to query *archie* remotely. Thus, an email message consisting of *archie* commands can be sent to archie@archie.au and a reply containing the results of the query will usually be received in an hour or two. An example would be:

mail archie@archie.au

Subject:

set maxhits 100

set sortby size

prog pvwave

.

EOT

It is not possible, at present, to restrict archie's searches to Australian sites. This, and many other new facilities, will be included in the next release of archie (version 3.0) which will be installed on archie.au soon.

Downloading the Files

More often than not, the files you want to download can be obtained from a number of archive sites. When this happens, you should put some thought into deciding which archive site to use. There are two competing factors to consider here. On the one hand, it is a good idea to copy files from Australian sites, when these have equivalent holdings to those overseas, because this helps to reduce Internet traffic out of the country over what are already heavily used links. On the other hand though, the download connection also places a load on the archive host computer. For this reason archive users are generally asked to do their downloads outside the normal working hours at each archive site. For this reason and given the time differences between Australia and North America/Europe, it is obvious that Australian archive users will often be more welcome on computers in those countries than on computers here.

By anonymous ftp

Once the location of the files to download has been established, the next step is to get your copies. The most common way of doing this is to use what is called "anonymous ftp". The file transfer protocol (**ftp**) of TCP/IP can be used to copy both ASCII and binary files from a remote computer to your local one if you have read access to the files on the remote computer.

The Internet archives address the read access issue by recognising a universal user called "anonymous". By convention, when you use this username you should give your email address as the password. Thus a typical anonymous ftp session starts like this:

ftp plaza.aarnet.edu.au

Connected to plaza.aarnet.edu.au.

220 plaza.aarnet.EDU.AU FTP server (Version 6.12 Sat Apr 10 21:13:31 EST 1993) ready.

Name (plaza.aarnet.edu.au:pchopra): **anonymous**

331 Guest login ok, send e-mail address as password.

Password: **pchopra@bmr.gov.au**

230-

```
230-     This is the AARNet Archive Server, Melbourne, Australia.
230-
230-This server is primarily for users within Australia. It consists largely
230-of shadows of international sites to reduce the load on the Australia-US
230-link.
230-
230-Local time is Thu Apr 22 10:36:33 1993
230-
230-Please read the file /info/welcome-ftpuser
230-it was last modified on Thu Mar 5 12:00:21 1992 - 412 days ago
230 Guest login ok, access restrictions apply.
ftp
```

Once you have logged on to the archive's host computer all you need do is to move to the directory of interest as reported by *archie* and download the files to your own computer. If your computer is running under UNIX, OS/2 HPFS or is a Macintosh, the files can be copied as they are presented in the archive. For example:

```
cd /usenet/comp.sources.unix/volume18/mtvraytrace
type binary
prompt
mget *
bye
```

If you are running under MS-DOS however, you need to be aware of the restrictions imposed by DOS's file naming conventions (i.e. a maximum of eight characters in a filename and a filename extension of, at most, three characters). It is quite common for files in the archives to have names which are illegal under MS-DOS and in these cases, the files must be downloaded one at a time and legal MS-DOS filenames provided.

The syntax for **ftp** varies a little amongst the various vendor implementations, both at the client end (i.e. your computer) and the server end (the Internet host). For example, the implementation of the **cd** command on VAX computers (e.g. NASA's Goddard Space Flight Centre's computer nssdca.gsfc.nasa.gov) does not recognise **cd ..** as a valid command to move up to the current directory's parent. Similarly, the **ls** command does not support the **-l** switch which means that long format listings of the contents of a directory can only be obtained using the **dir** command.

By email

There are a number of ways in which files of interest can be obtained from Internet archive sites by using email. This is particularly useful for users who do not have **ftp** capabilities. It can also be a very quick way for others users to obtain small files.

BITFTP — the Princeton BITNET ftp server

Princeton University in the USA has implemented a publicly available ftp-mail server which can be used to download files from any computer connected to the Internet for which a user has read access privileges. To use it, a mail message containing a sequence of commands understood by the mail server is sent to BITFTP@pucc.Princeton.edu. This sequence of commands is essentially the same as would be used in an **ftp** session and the mail server subsequently mails the results back to the user.

The following is an example of how to use BITFTP for ftp requests:

```
mail bitftp@pucc.Princeton.edu
Subject:
FTP nis.nsf.net
USER anonymous
cd introducing.the.internet
ASCII
get zen.txt
BINARY
get zen.zip
QUIT
.
EOT
```

In addition to any files you request, BITFTP also sends an email message containing a log of your **ftp** session. If BITFTP is unable to connect to your specified host, it will send an appropriate email message after the first attempt, and will keep trying at intervals over two days. It will send another email message either when it successfully completes the **ftp** to the host, or when the two days have elapsed.

There are several provisos in using BITFTP. Firstly, BITFTP will not return a file that contains more than 17,825,792 bytes of data. Secondly, directory listings from Internet archive sites cannot be longer than 15,000 lines. Lastly, binary files will be returned in a **netdata**, **uuencoded** or **xxencoded** format. These must be subsequently decoded. The **netdata** format is used to transfer data to IBM CMS and MVS systems. The **uuencode** program is found on most UNIX systems and **xxencode** information can be found with *archie*. The **uuencode** and **xxencode** files generated by BITFTP are broken up into a series of separate mail files each containing no more than 750 records of 62 bytes each.

BITFTP is also capable of connecting to host computers on the Internet other than archive sites for which a user has access privileges. Note that in this case however, a password must be supplied in the body of the email message to bitftp@pucc.Princeton.edu and that this password must necessarily be entered in plain ASCII text. This is an obvious security risk because email is not a secure form of communication.

For detailed instructions on how to use BITFTP, send an email message to bitftp@pucc.princeton.edu with the word "help" as the body of the message.

FTPMAIL@cs.uow.edu.au

The Computer Science Department at the University of Wollongong maintains an email to ftp gateway. This gateway provides a service to Internet users who have electronic mail facilities but no access to the Internet for **ftp**. It also implements an interface to *archie*.

To access the gateway, a user sends email to ftpmail@cs.uow.edu.au. The body of the email message contains **ftp**-like commands which instruct FTPMAIL to **ftp** an Internet site and return the results back as email. The syntax for FTPMAIL is less powerful than that of BITFTP. Only one kind of operation can be carried out with each email message to FTPMAIL (i.e. users can request either directory listings or file downloads but not both).

A typical email request to FTPMAIL might be like this:

```
mail FTPMAIL@cs.uow.edu.au
Subject:
HOST nis.nsf.net
USER anonymous
get    /introducing.the.internet/zen.txt
/introducing.the.internet/zen.zip
.
EOT
```

FTPMAIL does all file transfers from the specified host computer in binary format and then **uuencodes** the results as a series of separate mail files with a default size of 60 kbyte. This "chunksize" as it is called by FTPMAIL is user configurable between 20 and 200 kbytes.

For detailed instructions on how to use FTPMAIL, send an email message to ftpmail@cs.uow.edu.au with the word "help" as the body of the message.

Have you notified the ASEG of your e-mail address so that we can update our database.

If not fax details to :

Janine Cross
ASEG Secretariat
Fax No: (03) 818 1286

Ground Penetrating Radar Users Group

There has been much interest over the last few years regarding Ground Penetrating Radar (GPR) and its suitability as a geophysical technique for engineering and exploration applications. It is proposed to form a Users Group, providing there is enough interest, which would enable geoscientists to have a forum for discussion on GPR techniques.

The proposal would be for this Users Group to be people from industry, government and academia who are interested in contributing to the overall knowledge of GPR in Australian conditions. It would be envisaged that a Newsletter would be put out 3-4 times a year with contributions from users with specific emphasis on Case Studies. It would also be an aim to have a Workshop on GPR approximately every year, possibly in association with another conference such as the ASEG Conference.

If you are interested in the above proposal, then please contact Tim Pippett at Geo Instruments Pty Ltd, 348 Rocky Point Road, Ramsgate NSW 2219, Phone (02) 529 2355 or Fax (02) 529 9726. Looking forward to hearing from all those interested in GPR.

Tim Pippett.

EMU Grid Tasting

ER Mapper Users group (EMU) is to conduct a "grid tasting" - a trial of gridding techniques for geophysical data from the point of view of image aesthetics, sunangle display, filtering, fourier operations and compatibility with the ER Mapper image processing system.

Over 27 datasets incorporating a wide range of data biases will be submitted to participating gridding companies for gridding; and then testing and anonymous assessment (by voting) by users. Data bias types include random point, random line, regional and detailed aeromagnetics with several geological hands present in the data, badly levelled magnetic data, noisy radiometrics, rotated line directional data, contour data, faulted data, trend data and combinations of some of these various data biases.

The datasets used will form a useful reference standard for comparative assessment of gridding packages in the future.

Specialist testing of fourier techniques on the grids is planned also, subject to appropriate voluntary expertise.

EMU's and geophysicists who are not EMU members, are invited to participate or contribute expertise. Subject to interest and results, publication of the survey results in Preview or Exploration Geophysics is planned.

To register interest or for full details contact:

Geoff Pettifer
Tel: (03) 412 7840 Fax: (03) 412 7803;
email:grp@mines.vic.gov.au

ASEG Corporate Sponsor Profile

Halliburton Energy Services

Geophysical Products and Services

Halliburton Energy Services is one of the largest geophysical contractors in the industry today and a large manufacturer of geophysical equipment. Additionally, the company, with headquarters in Houston, USA, provides a wide range of services and expertise to the oil and gas industry including cementing, drilling, reservoir stimulation, testing, logging and perforating, and advanced information technology.

Halliburton's Geophysical line operates in over 30 countries around the world with major seismic operations for the acquisition and processing of both land and marine data. Regional offices in Houston, Bedford (UK) and Singapore complement local offices to provide full logistical support to Halliburton's clients and crews.

The Australian area is headquartered in Perth and provides a complete range of seismic exploration services. The land acquisition crew is equipped with MDS-18 instruments, capable of recording approximately 1000 channels, with full 3-D capabilities. During 1994, the company will be introducing the new 24-bit Vision Recording System incorporating fully automated spread management and the quality assurance system (QAS). The QAS forms a central database integrating all acquisition and positional data for subsequent 3-D data processing initialization. Vibroseis and dynamite land operations are currently available.

In recent years, Halliburton has developed advanced survey techniques using GPS which can replace conventional surveying and significantly improve accuracy and productivity. Gravity and magnetic software and acquisition techniques have also been developed for standalone as well as parallel surveys.

HES Australian flagship-Pacific Titan

Offshore, Halliburton has upgraded the M/V Pacific Titan with quadruple Titan Steamers and triple Sleeve Airgun arrays for the simultaneous acquisition of 12 subsurface lines to greatly improve the efficiency and economy of 3-D surveying. This vessel has been fitted with an on-board navigation processing capability via HALNAV to further improve the 3-D cycle time. A recent open house was held in Fremantle aboard this vessel.

The on-board Marine Control System (MCS) integrates and controls the streamer and source positions through acoustic networks, laser tracking systems, navigation buoys, and compasses.

The dual sensor Ocean Bottom Cable (OBC) techniques, successfully operated in the Gulf of Mexico, has now been introduced into West Africa and South east Asia. The cable, which comprises dual sensors (one hydrophone, one geophone), can currently operate in water depths up to 100 metres. The combination of pressure and velocity sensors yields excellent data quality in congested deep water areas by attenuation of water bottom multiples through wavefield separation.

Processing of 2-D and 3-D land and marine data is performed in Perth and Adelaide. These local centres are linked to mainframe systems in Melbourne which is further linked to Halliburton's seismic processing worldwide network. Networking of these computers ensures that massive processing capacity is available at any centre. Halliburton is currently developing a new generation seismic processing system which will be available at the end of 1994.

Halliburton offers a comprehensive range of processing technologies. These include advanced imaging capabilities such as full 3-D Kirchhoff DMO, full saddle operator 3-D DMO, pre-stack time and depth migrations and one-pass 3-D time and depth migrations; flexible wavelet processing, multiple attenuation and AVO capabilities meeting most requirements. Interactive PC-based technology plays a critical role in both Quality Assurance and reduced cycle time of 3D processing. Other workstation based interactive packages such as IVP (Interactive Velocity Package) and STATIX (interactive 3-D reflection and refraction statics) have successfully been introduced to provide leading-edge processing capabilities.

To meet the increasing demand for reservoir geophysics solutions, Halliburton provides a range of tools to perform AVO analysis, seismic lithologic inversion, and reservoir monitoring (in joint venture with SSI).

Halliburton was the first company to shoot speculative surveys offshore Australia and continues this effort today with both 2-D and 3-D surveys. Recent non-exclusive 3-D surveys include a Dampler Sub basin of the Carnarvon Basin survey performed in 1992. This survey is just south of the North Rankin, Goodwyn and Angel production fields. The West Barrow 3D Survey was completed in 1991. Recent 2-D surveys have been performed in the Perth Basin, North Rankin Platform and Otway Basin areas. Non-exclusive reprocessing projects of earlier data have been beneficial and an extensive seismic data library is maintained in the Sydney office.

Designing, developing and manufacturing state-of-the-art equipment for the geophysical industry, Halliburton is a single-source supplier for a vast array of equipment. Sales, service and manufacturing centres are located at strategic points throughout the world, in Houston, Calgary, Norwich (UK), Voorschoten (NL), Delhi and Beijing. The line of geophysical products includes the innovative VISION 24-bit Land Data Acquisition System, marine control systems, marine data acquistion and positioning systems, sleeve guns, various telemetry cables, streamers, sensor geophones, hydrophones, connectors, data processing, and plotting systems.

Halliburton's geophysical operations are part of the company's broad range of energy products and services. Founded in 1919, Halliburton is an integrated, full-service organisation providing unique opportunities for alliances and partnering on one-well ventures or entire field programs.

HGS

Halliburton Geophysical Services, Inc.

A Halliburton Company

Company News

Halliburton Plans Sale of Geophysical Business

Dallas, Texas - - Halliburton Company announced today that it has entered into a letter of agrement with LItton Industries, Inc, and its majority owned subsidiary Western Atlas International, Inc, pursuant to which the parties will continue negotiations of the terms including the cash purchase price for the acquisition by Western Atlas of Halliburton's geophysical services and produ cts business. The business includes land and marine seismic data acquisition, seismic data processing and seismic equipment manufacturing and sales. In 1992 the Halliburton geophysical business had revenues of approximately USD$470 million.

The completion of the sale of the geophysical business to Western Atlas is subject to negotiation and execution of a definitive agreement, receipt of certain regulatory and otherapprovals and consents and approval by the boards of directors of the parties. It is expected that a definitive agreement will be signed by the end of 1993.

In connection with the planned sale of the geophysical business and withdrawl from other related activities, Halliburton will be reporting a charge of about $200 million after tax to earnings for its third quarter ending September 30, 1993, to reflect the expected results of the proposed sale and withdrawl from other related activities.

Thomas H. Cruikshank, chairman of the board and chief executive officer of Halliburton Company, said, "The proposed sale of the geophysical business represents an additional action we are taking to focus on the services and products we believe will be the core of our business in the future. Although we will continue to participate in many aspects of information technology for the energy services business, we have concluded that it is not necessary for us to own a geophysical services and products business to achieve our objectives. The performance of our geophysical business in the past has been disappointing and it would takesignificant continuing investment for us to remain a major player in the geophysical market. The decision to sell the business enables us to devote our recources to our continuing energy services, business and to improving future financial results".

Halliburton Company is one of the world's largest diversified energy services, engineering maintenance, and construction companies. Founded in 1919, Halliburton provides a broad range of energy services and products, industrial and marine engineering and construction services, and property and casualty insurance services.

Nitro Consult acquires ABEM Instrument AB

ABEM Instrument AB has been bought by Nitro Consult AB, Stockholm, from the Swedish Geological Company.

The take-over, in line with the Swedish Government's privatization program, brings together two companies with complementary specialities.

Customers of Nitro Consult are involved in blasting technique and vibration control. They turn to Nitro Consult for vibration monitoring, blasting consultancy, pre- and post-blast inspections, risk analysis and seismographs for vibration monitoring.

ABEM's customers use seismographs for engineering geology and other shallow applications. Resistivity meters and VLF receivers are other ABM products as well as other geophysical instruments. 95 percent of these customers are active outside of Sweden.

Björn A Jonsson, president of both companies, says:

There is a tremendous potential in putting these two companies together. The combined technical know-how gives excellent opportunities for future development of new products and services. All customers, agents and distributors can rest assured of our continued support for training, consultancy services and instrument deliveries.

Nitro Consult is a member of the Norwegian chemicals group - Dyno Industrier A/S, and its Explosives Divison, founded in 1865 by Alfred Nobel. The group turnover in 1992 was about US$1.1 billion.