ISSN 0727-0097

ADVANCES IN THE STUDY OF THE SYDNEY BASIN

SEVENTEENTH SYMPOSIUM PROGRAMME & ABSTRACTS

DEPARTMENT OF GEOLOGY
THE UNIVERSITY OF NEWCASTLE N.S.W. 2308

DEPARTMENT OF GEOLOGY

THE UNIVERSITY OF NEWCASTLE

N.S.W. 2308

SEVENTEENTH NEWCASTLE SYMPOSIUM

ON

"ADVANCES IN THE STUDY OF THE SYDNEY BASIN"

29TH, 30TH APRIL & 1ST MAY, 1983

NEWCASTLE, N.S.W.

K.H.R. MOELLE
Convener

PREFACE

The staff of the Department of Geology welcome you to the Seventeenth Newcastle Symposium. We wish to thank our many contributors and, in particular, our Keynote Speaker, Professor David Branagan from Sydney University who is attempting to "sum up" the Sydney Basin.

The programme follows the now traditional format, although the great diversity of papers offered this year made groupings very difficult. We had to schedule many more concurrent sessions than we wished; the extraordinarily large number of papers made this necessary.

Special Topic Sessions have not been requested for this year.

In response to suggestions made last year, we have changed to an extended format for the current symposium abstracts. Authors of papers have been requested to supply a camera-ready copy of their abstracts, extending up to four pages in length, on supplied format pages. As a result, contributors have retained all editorial control over their papers. We welcome your comments upon the suitability of this new style of publication.

We look forward to your traditionally enthusiastic participation in the proceeding of the 17th Symposium and bid you a cordial welcome.

K.H.R. MOELLE

B.A. ENGEL

PROGRAMME

FRIDAY, 29th APRIL, 1983

REGISTRATION in the foyer of the Geology Building, The University of Newcastle	09^{00}-18^{00}
EXCURSION	13^{30}-17^{30}

Inspection of outcrops along the coastline between Merewether and Swansea. The excursion will deal with sedimentological and related features in the lower and middle Newcastle Coal Measure sequence.

Participants should bring suitable clothing and footwear.

Leader: A/Prof. C.F.K. Diessel

INFORMAL GATHERING at the STAFF HOUSE (near Union Building	After 20^{00}

SATURDAY, 30th APRIL, 1983

REGISTRATION in the foyer of the GEOLOGY BUILDING	08^{00}-09^{00}
MORNING TECHNICAL SESSION (LECTURE THEATRE E01 adjacent to Geology Building)	
OPENING of the 17th NEWCASTLE SYMPOSIUM by the Vice-Chancellor of the University of Newcastle, Professor D.W. George, A.O., F.T.S.	09^{00}-09^{05}
GEOLOGY AND MINERAL CHEMISTRY OF FUSED SHALES WITHIN THE OVERBURDEN STRATA OF THE LIDDELL SEAM NEAR BOWMANS CREEK, N.S.W. D.R. Mason, University of Newcastle R.W. Davis, Coal & Allied Operations Pty. Ltd.	09^{05}-09^{35}
CLIMATE OF THE SYDNEY BASIN AND ENVIRONS IN THE CARBONIFEROUS, PERMIAN AND TRIASSIC J.M. Dickins, Bureau of Mineral Resources	09^{35}-10^{05}
CHARACTERIZATION OF SOME STRONG MOTION EARTHQUAKES IN THE SYDNEY BASIN REGION I.A. Mumme, C.S.I.R.O. Division of Mineral Physics R. McLaughlin, Australian Atomic Energy Commission	10^{05}-10^{35}
MORNING TEA in the DEPARTMENT OF GEOLOGY	10^{35}-11^{00}
STRESS VERSUS DEPTH IN THE SYDNEY BASIN R.L. Blackwood, University of New South Wales	11^{00}-11^{30}
*** KEYNOTE ADDRESS ***	
SUMMING UP THE SYDNEY BASIN D.F. Branagan, University of Sydney ***	11^{30}-12^{15}
LUNCH at STAFF HOUSE	12^{20}-13^{45}

CONCURRENT SESSIONS

Theatre E01		Theatre DG08
SUGGESTED MODIFICATIONS TO THE STRATIGRAPHIC NOMENCLATURE OF THE SINGLETON SUPER-GROUP J. Bailey, Earth Technics Pty. Ltd.	$13^{45}-14^{00}$	COAL QUALITY AND GEOLOGICAL SETTING, WESTERN COALFIELD, SYDNEY BASIN J. Hunt, A. Telfer C.S.I.R.O.
FACIES AND SEDIMENTARY ENVIRONMENTS OF THE WITTINGHAM COAL MEASURES NEAR MUSWELLBROOK, N.S.W. R. Uren, The University of Newcastle	$14^{10}-14^{35}$	STRUCTURAL CONTROL OF SEDIMENTATION OF THE COAL MEASURES IN THE RYLSTONE AREA G. Bradley & J. Moloney, Dept. of Mineral Resources
MAULES CREEK - AN INTERESTING COAL DEPOSIT D. Butel et al., Kembla Coal & Coke Pty. Ltd.	$14^{35}-15^{00}$	FOURIER TRANSFORM INFRA-RED SPECTROSCOPY OF COALS AND TORBANITES P. Fredericks, B.H.P. - C.R.L.
COAL QUALITY AND GEOLOGICAL SETTING IN THE EARLY PERMIAN SYDNEY AND GUNNEDAH BASINS J.W. Hunt, C.S.I.R.O. A.T. Brakel, H.J. Harrington Bureau of Mineral Resources	$15^{00}-15^{25}$	A NEW FOSSIL FISH DISCOVERY IN THE TRIASSIC OF THE SYDNEY BASIN: PRELIMINARY FINDINGS P.S. Watson, University of Sydney
AFTERNOON TEA	$15^{25}-15^{50}$	in the DEPARTMENT OF GEOLOGY
A COAL RESOURCE DATA SYSTEM O. Shiels, Joint Coal Board	$15^{50}-16^{15}$	DIVERSITY, STRUCTURE AND COMPOSITION OF SOME EARLY CARBONIFEROUS BENTHIC MARINE FAUNAS IN THE SOUTHERN TAMWORTH SHELF I.H. Lavering, Esso Australia
NATURAL OXIDATION OF COAL P.Warbrooke, B.H.P. Coal Geology	$16^{15}-16^{40}$	A PRELIMINARY INVESTIGATION FOR THE RECONSTRUCTION OF THE NEW ENGLAND HIGHWAY OVER THE LIVERPOOL RANGE D.C. Starr, J.P. Harvey Soilmechanics Ltd. J. Williams, Dept. of Main Roads
THE EFFECTS OF COAL MINING ON THE HYDROGEOLOGY/HYDROCHEMISTRY OF THE UPPER HUNTER VALLEY G.W.B. Gates, F.R. Kalf, Australian Groundwater Consultants Pty. Ltd.	$16^{40}-17^{05}$	SEDIMENTOLOGY OF THE EARLY FLAGSTAFF SANDSTONE I.H. Lavering, Esso Australia
SUMMARY AND VOTE OF THANKS	$17^{05}-17^{10}$	BY THE CHAIRMEN

SYMPOSIUM DINNER in the Great Cask Hall, The Rothbury Estate

Buses Depart from Newcastle East (near Travelodge Motel) at 18^{00} hours,

and from The University at 18^{15} hours.

SUNDAY, 1st MAY, 1983

COFFEE	$08^{30}-09^{00}$	in the DEPARTMENT OF GEOLOGY

CONCURRENT SESSIONS

Theatre E01		Theatre DG08
MACQUARIE COLLIERY, YOUNG WALLSEND SEAM, AN ANALYSIS OF STRESS RELIEF MINING R. Turner & R. Warner B.H.P. Coal Geology Dept.	$09^{05}-09^{35}$	A PRELIMINARY REPORT ON IGNEOUS ACTIVITY NORTH OF MT. YENGO, N.S.W. A.S. Ritchie & R. Evans Amateur Geological Society of the Hunter Valley
RELATIONSHIP BETWEEN SEAM GAS PARAMETERS AND GEOLOGY R.J. Williams, J. Giedl, Collinsville Coal Co. Pty. Ltd.	$09^{35}-10^{05}$	THE LONGITUDINAL GRAVITY HIGH OVER THE SYDNEY BASIN AND ITS GEOLOGICAL SIGNIFICANCE I.R. Qureshi, University of N.S.W.
GEOLOGICAL OBSERVATIONS AND MINING CONSIDERATIONS AT ULAN, N.S.W. M.A. Johnstone, J.S. Luxford Ulan Coal Mines Ltd. K.H.R. Moelle, The University of Newcastle	$10^{05}-10^{35}$	ORIGIN OF THE COASTAL VALLEYS IN THE SYDNEY REGION R. Coenraads, University of British Columbia
MORNING TEA	$10^{35}-11^{00}$	in the GEOLOGY DEPARTMENT
PETROLEUM SOURCE ROCK STUDIES IN THE GUNNEDAH BASIN L. Etheridge, Dept. of Mineral Resources	$11^{00}-11^{30}$	THE SIGNIFICANCE OF SULPHIDE PSEUDOMORPHING WOOD IN SANDSTONES R.A. Creelman, Macquarie University
HYDROCARBON SOURCE ROCKS IN THE SYDNEY AND GUNNEDAH BASINS M. Smyth, C.S.I.R.O.		PREPARATION OF A PHOTOGRAPHIC GUIDE TO THE CORED ROCKS OF M. OF THE SYDNEY BASIN G. Skilbeck, University of Sydney G. Bradley, Dept. of Mineral Resources
SUMMARY AND VOTE OF THANKS	$12^{00}-12^{05}$	BY THE CHAIRMEN
LUNCH	$12^{05}-13^{30}$	at the STAFF HOUSE

POSTER PAPER

DETAILED GEOLOGICAL MAPPING IN THE UPPER HUNTER VALLEY
G.R. McIlveen, Dept. of Mineral Resources

GEOLOGY AND MINERAL CHEMISTRY OF FUSED SHALE WITHIN THE OVERBURDEN STRATA OF LIDDELL SEAM IN THE BOWMANS CREEK AREA, HUNTER VALLEY, N.S.W.

D.R. Mason, The University of Newcastle
R. Davis, Coal & Allied Operations Pty. Ltd.

INTRODUCTION

In coal exploration and mining it is important to establish the presence and extent of post-depositional thermal perturbations. Two unrelated phenomena have caused thermal effects within the coal-bearing sequences of the Hunter Valley: igneous intrusions and burning coal seams. Whereas the presence of an igneous intrusion may imply extensive heating of the coal sequence to great depth, effects of burning coal seams are more localized and therefore less disruptive to projected coal recovery. However, the distinction between igneous intrusions (basaltic) and products of burning coal seams ('clinker', 'paralava', 'basaltic-slag') is often difficult due to the close physical similarity of these materials. This study discusses the distinction of fused sedimentary rock in the Bowmans Creek area, upper Hunter Valley, using geophysical and petrological techniques.

PREVIOUS WORK

Within the Hunter Valley region, Whitworth (1959) described six occurrences of "fused sedimentary rocks" near Ravensworth, and attributed them to the effects of burning coal seams. He pointed to mineralogical and textural features that distinguished them from superficially similar vesicular basaltic rocks. Detailed mapping of these occurrences has been performed during unpublished honours thesis work (Gray, 1971; Tobin, 1980). Some of the mineralogical details have been published (Hansen and Gray, 1978).

FUSED SHALES, BOWMANS CREEK AREA, N.S.W.

During 1980-81, magnetometer surveys were conducted by Coal & Allied Operations Pty. Ltd. over several areas of the Liddell Colliery Holding, Hunter Valley. Many magnetic anomalies were detected, and, in the light of past experience, most could have been interpreted as basaltic igneous intrusions. Certainly, earlier field mapping (Hansen, 1968) had identified two generations of basaltic dykes in the area. However, field mapping over some of the recently detected magnetic anomalies in the Bowmans Creek area revealed a number of small outcrops of dark basaltic slag-like material closely resembling the Ravensworth occurrences.

The outcrops form the tops of small knolls generally less than 10 metres in diameter, and although more resistant to weathering than adjacent rocks, their margins are masked by soil cover. The extent of the bodies in subcrop was delineated by use of a magnetometer over a closely spaced grid. In a typical exposure angular fragments of light coloured, hardened clayshale are seen embedded in a dark grey-black and generally heavily vesicular slaggy matrix. The matrix branches and invades the surrounding sediments, and in places resembles a volcanic agglomerate. Shale fragments are very irregular in shape and size, show no preferred orientation and far exceed by volume the amount of dark matrix material. Associated with the agglomeratic materials are heat affected sandstones, shales and claystones in all stages from slight baking through partial fusion to complete melting. A pink to brick red colouration is common in conjunction with the alteration of this surrounding rock mass.

In thin section the fused rocks are observed to consist of calcic plagioclase needles, pyroxene prisms, opaque oxide (magnetite) granules, subrounded quartz grains, brownish glass, cryptocrystalline patches, and vesicles. Plagioclase invariably forms randomly oriented needles that display polysynthetic twinning. Pyroxene may be represented by a single clinopyroxene (augite-endiopside) or coexisting augite and enstatite. Significant compositional variation in clinopyroxene occurs from place to place in a single thin section. Abundance of magnetite ranges up to about 5%. Subrounded quartz grains appear to be residual sedimentary clasts that have escaped melting, and are frequently rimmed by pyroxene granules. Interstitial brown to colourless glass is siliceous and corundum normative, and varies significantly in composition within a single thin section. Colourless to buff cryptocrystalline patches are dominated by cordierite. Spherical vesicles, which may constitute up to 35% of the rock, have not been modified in shape by magmatic flow.

While the fused shales superficially resemble basaltic rock, there are important features that indicate their origin by fusion of peraluminous inhomogeneous sedimentary material: 1) presence of cordierite, 2) compositional variation within clinopyroxene, 3) presence of relict quartz clasts, 4) textural inhomogeneity on the scale of thin section.

DISTINCTION BETWEEN BASALTIC INTRUSIONS AND FUSED SEDIMENTS

Results of this study indicate that geophysical and petrological methods, used jointly, can successfully distinguish between superficially similar 'lava-like' rocks of two different origins.

Magnetic anomalies detected over fused sediments are much more intense than those over basaltic intrusions. Reasons for this include mineralogical differences (magnetite is the sole opaque oxide in the fused sediments, whereas ilmenite may be present or may even dominate in the basaltic intrusions) and weathering differences (the older, holocrystalline basaltic rocks have suffered more intense weathering).

Petrological differences stem from the fundamentally different compositions of basaltic magmas and melts derived from fusion of sediments. Alkali basaltic rocks, commonly found as intrusions in the Hunter Valley, are characterized by a very consistent mineral assemblage dominated by titan-pyroxene, plagioclase and olivine, whereas the fused sediments are characterized by widely varying peraluminous assemblages that include pyroxene/s, calcic plagioclase, cordierite and relict quartz clasts in a brownish glassy groundmass.

ORIGIN OF THE FUSED SHALES

The fused sedimentary rocks occur within a sequence of shales, sandstones, conglomerates and coal seams (Burnamwood Formation underlain by Foybrook Formation, at the base of which lies the Liddel Seam). In the immediate area of outcrop, regional structure and mapping indicate that limited subcrop of the Bayswater Seam, lowest member of the Burnamwood Formation, would occur. Ignition of this seam, possibly by spontaneous combustion, would have occurred in a near-surface, oxygen-rich environment. Intense baking and partial melting of the sedimentary rocks would have ensued, especially adjacent to subvertical 'flues' defined by pre-existing fracture or joint systems. Available experimental work suggests that temperatures greater than 1000°C were achieved in order to partially fuse the sedimentary rocks.

References:

Gray, D.R. 1971: The geology of the Hebden region, N.S.W. Unpub. Hons. thesis, University of Newcastle.

Hansen, G.W. 1968: The geology of the Goorangoola-Bowmans Creek district, N.S.W. Unpubl. Hons. thesis, University of Newcastle.

Hansen, G.W. and Gray, D.R. 1978: Clinohypersthene and hypersthene from a coalfire buchite near Ravensworth, N.S.W. Prog. & Abs. 12th Symposium on Advances in the Study of the Sydney Basin and the New England Fold Belt. University of Newcastle, Geology Department, pp.16-17.

Tobin, C. 1980: The geology of the Balmoral area. Unpubl. Hons. thesis, University of Newcastle.

Whitworth, H.F. 1959: The occurrence of some fused sedimentary rocks at Ravensworth, N.S.W. J. Proc. Roy. Soc. N.S.W. 92, pp.204-208.

CLIMATE OF THE SYDNEY BASIN AND ENVIRONS IN THE CARBONIFEROUS, PERMIAN AND TRIASSIC

J.M. Dickins, Bureau of Mineral Resources

Published information on palaeoclimate presents a confused picture and this paper is aimed at provoking thought and discussion rather than enumerating fixed conclusions.

The available work is largely that of Loughnan (1975), Retallack (1980), and peripherally my own work (1977, 1978; in press). I want to consider mainly temperature and rainfall variations. The data are derived mainly from the marine fauna, the plants and from other information based on the study of stratigraphy and are not primarily biological data.

At the outset I would make a plea for consideration of climate independently of other factors such as drift, palaeolatitude and so on in order to get a clear understanding of climate and to apply it in various contexts.

I propose to consider temperature in terms of a fairly simple model of the present earth: tropical or subtropical (warm) presently found in Queensland and northern New South Wales, temperate (warm to cool temperate) as in New South Wales, Victoria and Tasmania, and cold (or glacial) not found in Australia at sea level today.

The cosmopolitan elements in fauna and flora during the Lower Carboniferous point to a warm and reasonably humid climate. The presence of red beds confirms these conclusions. This fits a world pattern of widespread equable climate at this time. During the Upper Carboniferous the Sydney Basin area became colder and this is reflected by the fauna and flora of the time. During the Asselian (Lochinvar and Allandale Fms) mountain glaciation was significant in the hinterland. Rather than a continental ice sheet, widespread mountain glaciers may have come down to sea level. The climate was humid during the Permian.

Seasonal ice seems to have been present during much of the Lower Permian and in the lower part of the Upper Permian. Red beds have been recorded by Loughnan (1975) in the Greta Coal Measures and this may represent a warmer phase. During Upper Coal Measure time probably no ice was present and the climate temperate. The distinctive occurrence of kaolinites, both in the Sydney Basin and in the Bowen Basin, supports this interpretation. The red beds referred to by Retallack

(1980) in the Illawarra Coal Measures may represent a recent weathering feature and do not seem to be of significance for climatic reconstruction.

It is suggested that the climate became warmer in the Narrabeen Group times, although there are conflicting opinions on this matter. Widespread fine-grained red beds of the type found in the Narrabeen Group indicate strong oxidizing conditions. They were probably formed in a flood plain environment, under a warm climate with at least intermittent rainfall. This conclusion is borne out by faunal and floral data. The change from the Upper Coal Measures to the Narrabeen represents a distinct change in the prevailing temperatures, without a necessary change in precipitation amounts. The Permian appears to have been generally humid and seasonal rainfall patterns may have been established subsequent to the coal measures deposition.

Although palaeolatitudes are not considered to have changed greatly from Upper Carboniferous to Triassic times, radical changes do occur in the temperatures. It is concluded that such changes reflect global temperature patterns.

DICKINS, J.M., 1977: Permian Gondwana Climate. Chayanica Geologica 3(1), 11-22.

DICKINS, J.M., 1978: Climate of the Permian in Australia: the invertebrate faunas. Palaeogeog., Palaeoclimat., Palaeoecol., 23, 33-46.

DICKINS, J.M., in press: Late Palaeozoic climate - with special reference to the invertebrate faunas. Comp. Rend., 9, Int. Cong. Carb. Strat. Geol.

LOUGHNAN, F.C., 1975: Laterites and flint clays in the Early Permian of the Sydney Basin, Australia, and their palaeoclimatic implications. J. Sed. Pet., 45(3), 591-598.

RETALLACK, G., 1980: Late Carboniferous to Middle Triassic megafossil floras from the Sydney Basin. In A Guide to the Sydney Basin (C. Herbert & R. Helby, Eds.). Geol. Surv. NSW Bull., 26, 384-430.

CHARACTERIZATION OF SOME STRONG MOTION EARTHQUAKES IN THE SYDNEY BASIN REGION

I.A. Mumme, C.S.I.R.O Division of Mineral Physics
R. McLaughlin, Australian Atomic Energy Commission Research Establishment

ABSTRACT

This paper deals with an investigation of important features of recorded earthquakes in the Sydney Basin region based on the fast Fourier transform technique.

1. INTRODUCTION

Earthquake data corresponding to horizontal components of the Robertson-Bowral earthquake of 21 May 1961 and the (E.W.) component of the Picton earthquake of 9 March 1973 (in the form of displacement time histories recorded on Mainka and Galitzin seismographs at the Riverview Observatory) have been analyzed and interpreted using the fast Fourier transform for identifying the frequency components making up the records of these earthquakes. Such information should be useful in forecasting ground motion characteristics of earthquakes in the Sydney Basin region.

2. EARTHQUAKE SOURCE DATA

The Robertson-Bowral earthquake had a magnitude of 5.5 and occurred in an area some 100 km south-west of Sydney which had shown little previous activity. This earthquake was one of the most widely felt in New South Wales and caused considerable damage to old buildings in the epicentral region as well as a landslide. It was followed by an after shock sequence of over 100 earth tremors that were aligned in a north-west direction. Direction of motion studies, however, suggested that the fault of the main shock was a north-easterly striking reverse fault (Cleary and Doyle 1962). Thus the after shocks may delineate secondary faulting orthogonal to the main fault which, ilke that of the Robertson-Bowral earthquake, also occurred near the western margin of the Sydney Basin.

The effects of the Picton earthquake of 10 March 1973 (located at approximately 34°14'S and 150°29'E) also of magnitude M_L = 5.5, have been described by Denham (1976).

Although the focal mechanism of this fault has not been determined, analysis of this earthquake, like that of others in South-East Australia, indicates the crust in this region is under horizontal compression (Fitch 1973; Denham 1979). In the 1973 Picton earthquake, damage was confined to old buildings.

3. THE FOURIER SPECTRUM

The Fourier transform of the earthquake displacement is defined as:

$$F(\omega) = \int_{-\infty}^{\infty} d(t)\ e^{-i2\pi\nu t}\ dt \quad ,$$

where ν = frequency and $\omega = 2\pi\nu$.

If the duration of the vibratory ground motion is from T_o to T_o+T

$$F(\omega) = \int_{T_o}^{T_o+T} d(t)\ \cos 2\pi\nu t\ dt - i \int_{T_o}^{T_o+T} d(t)\ \sin 2\pi\nu t\ dt \quad .$$

The Fourier spectrum or Fourier transform essentially resolves the complicated ground displacement time record into an infinite series of simple harmonic functions in the frequency domain.

The fast Fourier transform technique originally developed by Vern Herbert, and widely publicized by Cooley and Tukey in 1965, is a computer algorithm for calculating the transform of the periodic extension of the function d(t) with period T by means of

$$F(j) = \frac{1}{N}\left[\sum_{K=0}^{N=1} d(K)\ e^{-\frac{i2\pi jK}{N}}\right]$$

where $N = T/\Delta t$.

If we were working out values of F(j) by a direct approach, we should have to make N multiplications of the form

$$d(K) \times e^{-\frac{i2\pi jK}{N}}$$

for each of N values of d_K and so the total work of calculating the full sequence F(j) would require N^2 multiplications. The fast Fourier transform reduces this work to a number of operations of the order $N \log_2 N$.

The fast Fourier transform, therefore, offers an enormous reduction in computer processing time. Moreover, there is the added bonus of an increase in accuracy because fewer operations have to be performed by the computer, round-off errors due to the truncation of products by the limited number of available digits of the computer are reduced. As a result, the accuracy is accordingly increased.

The procedure was thus to take each displacement time history and go through a mathematical exercise using a program to derive fast Fourier transforms (Claerbout 1976), and by making use of the equation,

$$|F(\omega)| = \left\{\left[\int_{T_o}^{T_o+T} d(t)\ \cos 2\pi\nu t\ dt\right]^2 + \left[\int_{T_o}^{T_o+T} d(t)\ \sin 2\pi\nu t\ dt\right]\right\}$$

where $|F(\omega)|$ is called the Fourier amplitude spectrum for displacement denoting the amplitude plots of the Fourier spectrum for each displacement time history as a function of frequency.

4. COMPUTATIONAL PROCEDURES

The compilation of the Fourier transform of the displacement records involved the following steps:

1. Digitization of the records.
2. Selection of the time interval.
3. Selection of the length of record to be analyzed.
4. Compilation of the Fourier transform.
5. Smoothing of the spectrum using linear filters.

1. Digitization of the Records

The records were digitized by photographing, enlarging, scaling and adjusting the base-line and subsequently interpolating equal time intervals using a computer program, to permit their use in the fast Fourier transform computer program. As mentioned earlier in this paper, the fast Fourier transform is simply an efficient method for computing the discrete Fourier transform. It can be used in place of the continuous Fourier transform only to the extent that the discrete Fourier transform could before, but with a substantial reduction in computer time.

2. The Time Interval

In order to adequately represent all the frequencies of interest in the earthquake records, the choice of a suitable small time interval is very important. However, the minimization of human time in digitizing, and machine time in computations, calls for the largest time interval possible.

One pitfall often encountered in using the discrete Fourier transform is aliasing. The term aliasing refers to the fact that high frequency components of a time function impersonate low frequencies due to too small a rate of sampling. This uncertainty can be avoided by demanding that the sampling rate be high enough for the highest frequencies present to be sampled at least twice during each cycle. If this is not accomplished, the frequencies higher than the folding (or Nyquist) frequency present in the records will appear folded into a lower frequency than the folding frequency, giving an erroneous spectral amplitude at those frequencies. The folding frequency is defined as $\pi/\Delta t$ in this regard.

In order to select the optimum time interval, the records were inspected and it was decided that the highest frequency present in them was around 60 rad/s. If 60 rad/s is the maximum frequency present in the records, the time interval for sampling the records is:

$$\Delta t = \frac{\pi}{2\omega} = 0.052 \text{ seconds,}$$

where $\omega_{max} = \frac{60 \text{ rad}}{s}$, $T_{min} = \frac{2\pi}{60}$ seconds.

As the records had to be interpolated to obtain displacement information at equal time intervals of 0.05 seconds, since only the time points are those actually sampled, no information should be added about what is between the sample points. However, as the records are smooth and with relatively long periods, it is assumed that the interpolated points obtained by curve following techniques, which were applied, will in fact be reasonably close to the real displacement records and thus add information to the records.

3. Record Length

A displacement earthquake record is a time function that can be expressed as:

$$d(t) \begin{cases} f(t) & T_o < t < T_o+T \\ 0 & \text{otherwise} \end{cases}$$

T can be large, but displacements are very small for a significant part of the time, as can be seen from the records. Because of this situation, the earthquake records were analyzed, computing the spectrum for different time durations.

4. Compilation of the Fourier Transform

See section 3 for details.

5. Smoothing of the Spectrum Using Linear Filters

As the patterns of the spectra obtained are jagged and difficult to evaluate the frequency content and amplitudes, a procedure was needed to simplify the plots for interpreting without losing their significance. In this study, a linear filter was employed for the purpose of presenting the results showing the main features of the Fourier transforms. The results are shown in Figures 1 to 10.

5. ACKNOWLEDGEMENT

We wish to acknowledge the assistance of Dr L. Drake of the Riverview Observatory who supplied the seismic records for this study.

6. REFERENCES

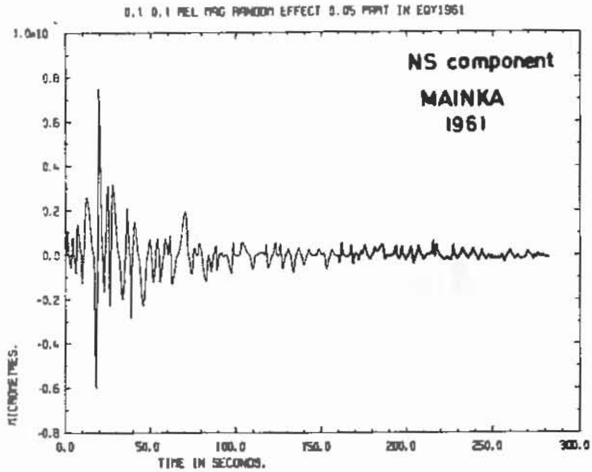
1. Claerbout, John F., Fundamentals of Geophysical Data Processing. McGraw-Hill International Series in the Earth and Planetary Sciences, p. 12, 1976.

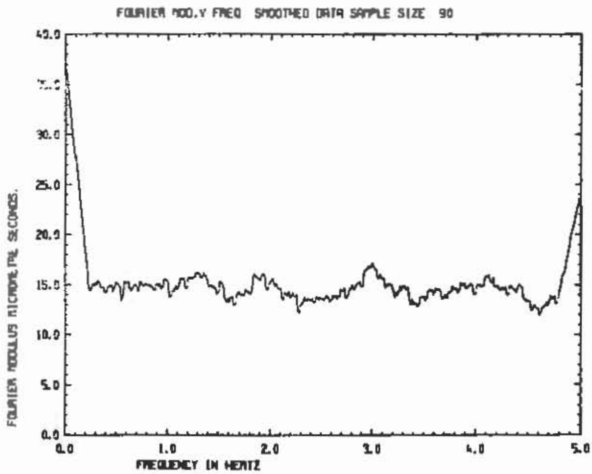
2. Cleary, J.R. and Doyle, H.A. (1962), Application of a seismograph network and electronic computing in new earthquake studies. Bull. Seism. Soc. Am., 52, pp 673-682.

3. Denham, D. (1976), Effect of the 1973 Picton and other earthquakes in Eastern Australia. Bureau of Mineral Resources, Bull. 164.

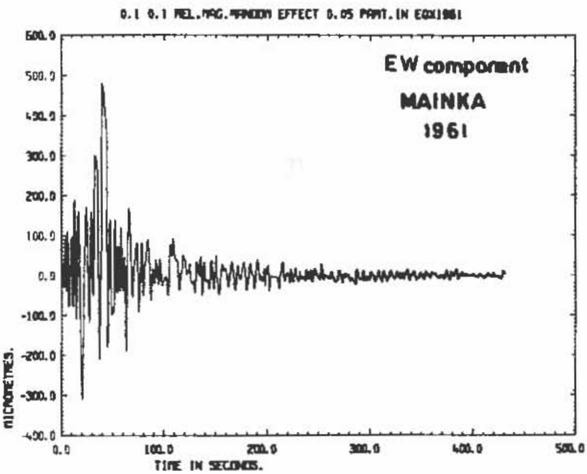
4. Fitch, T., Aftershocks and tectonics related to Picton earthquake. Papers presented at Symposium on Seismicity and Earthquakes by BMR, Canberra, ACT, 5 Dec. 1973.

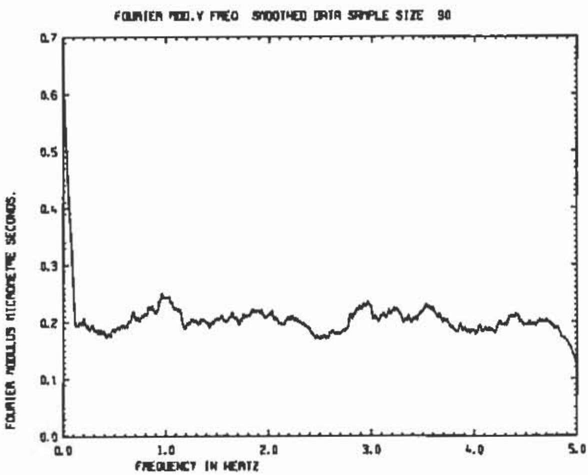
5. Denham, D., Alexander, L.G. and Worotnicki, G., Stresses in the Australian crust: evidence for earthquakes and *in situ* stress measurements. BMR J. of Australian Geology and Geophysics, 4 (1979) 289-295.





Figures 1 and 2 Ground displacement and fast Fourier transform of N.S. component of the Robertson-Bowral earthquake, 1961, based on Mainka seismograph recording.





Figures 3 and 4 Ground displacement and fast Fourier transform of E.W. component of the Robertson-Bowral earthquake, 1961, based on Mainka seismograph recording.

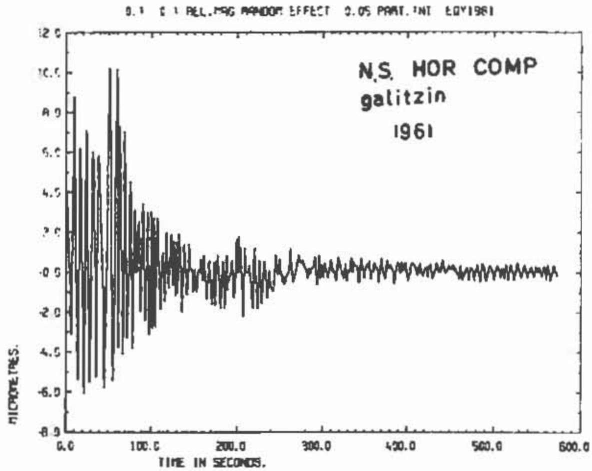


Figure 5 N.S. horizontal recording of the Robertson-Bowral earthquake, 1961. (Galitzin Inst.)

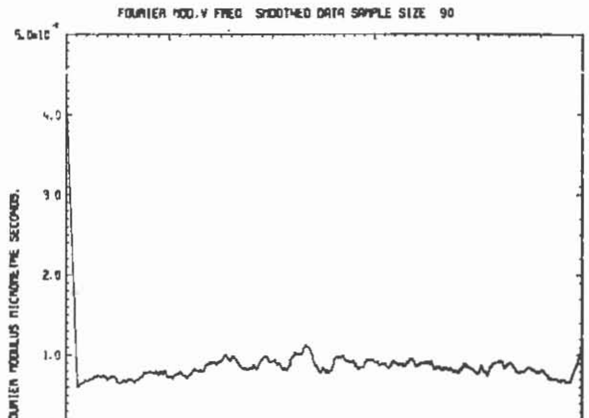


Figure 6 Fast Fourier transform of the ground movements based on average amplification effect.

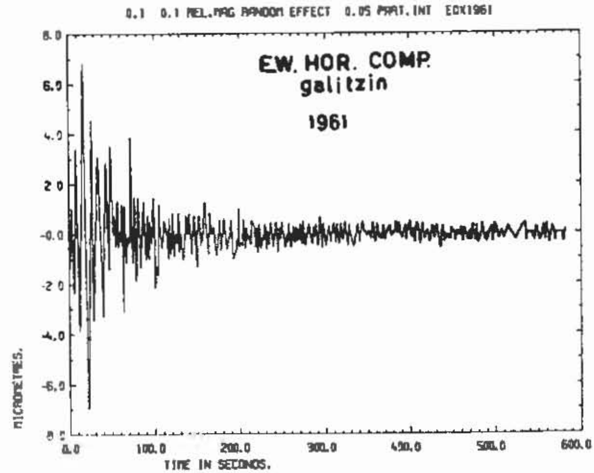


Figure 7 E.W. horizontal recording of the Robertson-Bowral earthquake, 1961. (Galitzin Inst.)

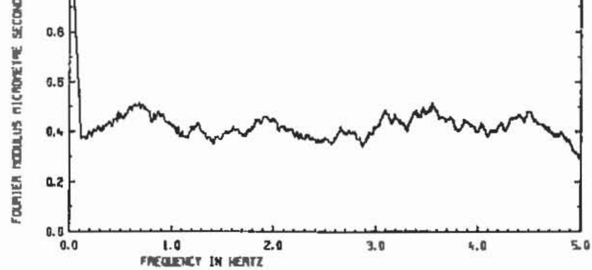
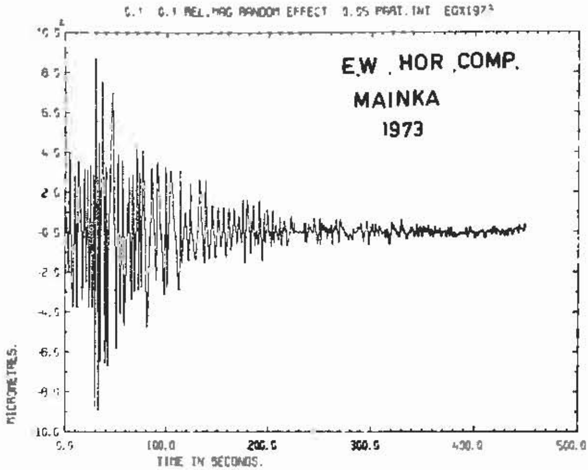
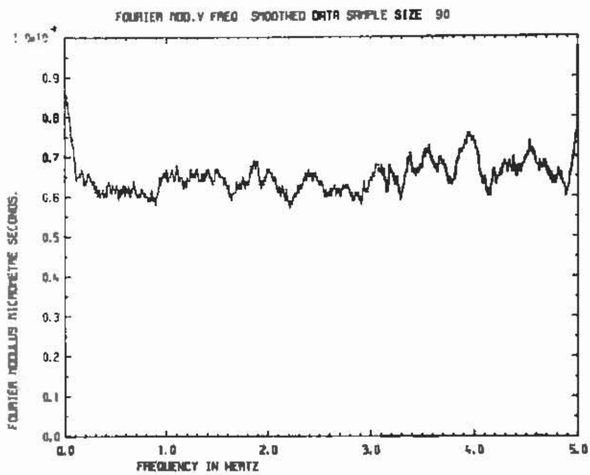


Figure 8 Fast Fourier transform of the ground movements based on average amplification effect.





Figures 9 and 10 Ground displacement and fast Fourier transform of E.W. horizontal component of the Picton earthquake, 1973.

STRESS vs DEPTH IN THE SYDNEY BASIN OF NEW SOUTH WALES: A PRACTICAL INTERPRETATION

R.L. Blackwood, The University of New South Wales

THE NATURE OF CONTINENTAL STRESSES

To help understand the stress environment at mining depths, in-situ stress measurements have been carried out in many parts of the world over the past 20 years or more. These give some inkling as to the way in which the stresses vary with depth, in turn enabling the maximum regional stress at mining depths to be predicted.

One of the most interesting observations is that each of the Australian, North American, African and European continents possesses a unique stress signature (Ref. 1, 2, 3).

Vertical Stresses

In all continents the vertical component of stress is due mainly to overburden weight, modified by the fact that a residual vertical stress apparently exists in the near-surface rocks, which must be added to the weight of overlying rock. Thus the vertical stress component can be readily calculated from rock density and depth. For the whole Australian continent observed data yield the expression

$$\sigma_V = 0.020H + 5.09 \qquad \dots (1)$$

where σ_V is vertical stress (MPa), H is depth (m).

Horizontal Stresses

Observed horizontal stress magnitudes, however, do not increase linearly with depth. Furthermore the manner of increase varies significantly between the continents, a point which has either eluded or been ignored by other investigators who give only a global interpretation (Ref 4, 5). The non-linearity of stress increase indicates that the horizontal stresses are only partially dependent on vertical stress or perhaps independent of it, which eliminates elastic theory concepts used in engineering practice to explain the presence of the horizontal stress as being due to the Poisson effect of vertical compression.

The stresses in the horizontal (or sub-horizontal) plane are also often highly anisotropic. The stresses are possibly linked to the tectonic history of the continents and are structurally controlled on a regional scale.

Upon plotting the observed horizontal-to-vertical stress ratios against depth of measurement for the whole Australian continent it is clear that some limiting curve can enclose all plotted values, which are seen to diminish with depth (Fig 1). (Likewise a unique envelope curve can be drawn for each of the other continents). Two types of curves suggest themselves; either negative exponential or hyperbolic. Taking the latter first, it has been shown that the hyperbolic relationship may be obtained from a global analogy consisting of an elastic solution of the stress increase through a self-gravitating thin shell covering an unyielding spherical body (Ref 6). It is known from observation that crustal stress behaviour cannot be explained by elastic considerations alone. Such an approach furthermore predicts the horizontal stress at the earth's surface to be either infinite or zero, followed by linear increase with depth. None of these agrees with observation; nevertheless this interpretation is spread widely through the literature (Ref 4, 5).

The alternative originally put forward by the author in 1976 (Ref 1) is that the ratio of horizontal to lateral stress vs depth below the surface tends towards a maximum value at any depth given by a negative exponential expression. It is, therefore, analogous to a decay rate and therefore compatible with observations about crustal rheology at shallow depths (Ref 2). For the Australian continent as a whole it is suggested to be

$$\frac{\sigma_{Hmax}}{\sigma_V} = 7.40 \exp(-0.0010H) \qquad \ldots (2)$$

where σ_{Hmax} is the maximum horizontal stress (MPa) encountered at depth H. This is shown superimposed on Fig 1. Since the vertical stress component increases in a predictable manner with depth as in Eq (1), σ_{Hmax} at any depth is simply the product of Eq (1) and (2):

$$\begin{aligned}\sigma_{Hmax} &= \frac{\sigma_{Hmax}}{\sigma_V}.\sigma_V \\ &= 7.40 \exp(-0.0010H).(0.020H+5.09) \\ &= 0.148 \exp(-0.0010H)(H+254.4) \qquad \ldots (3)\end{aligned}$$

Fig 2 shows Eq (3) superimposed on a plot of measured horizontal stresses. This curve represents the largest horizontal stress likely to be experienced at any given depth. This is therefore the maximum stress able to be transmitted by the rock at that depth; a function of the rock strength at that depth. This is seen to reach a peak value at a depth of about 750m then slowly reduce as rheidic flow becomes significant at higher confining pressures.

THE STRESS FIELD IN THE SYDNEY BASIN

In the past few years a considerable amount of stress measurement has been carried out in the Sydney Basin, almost all being connected with underground coal mining needs. There is now sufficient information to allow an analysis of rock stress behaviour in the Sydney Basin to be carried out as described above. The best-fit envelope curve for the stress ratios is given by

$$\frac{\sigma_{Hmax}}{\sigma_V} = 9.00 \exp(-0.0015H) \qquad \ldots (4)$$

shown on Fig 1. The maximum likely horizontal stresses at mining depths may then be calculated by the process described above. Two possibilities emerge, depending on the most likely value of the vertical stress component within the basin rocks. A linear regression analysis of the available data yields

$$\sigma_V = 0.022H + 1.12 \qquad \ldots (5)$$

for n = 19, r = 0.83. That is, a residual vertical stress of 1.12 MPa is indicated at the surface (H = 0). Combining (4) and (5) as before,

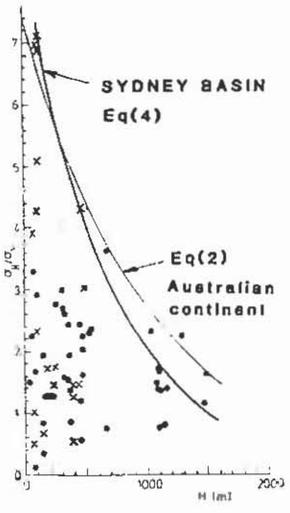
$$\sigma_{Hmax} = 0.198 \exp(-0.0015H)(H + 50.96) \qquad \ldots (6)$$

Alternatively, since the number of observations leading to Eq (5) is small it may be more acceptable to assume $\sigma_v = 0$ at the surface, in which case $\sigma_v = 0.022H$. Combining this with Eq (4) we obtain

$$\sigma_{Hmax} = 0.198 \exp(-0.0015H)H \qquad \ldots (7)$$

Both Eq (6) and (7) are shown on Fig 2. They are not greatly different and both enclose all the observed data points. It was to be expected that the sedimentary rocks of the basin would be weaker - that is, would transmit lower horizontal stresses - than the basement and shield rocks for which Eq (3) were obtained. The peak horizontal stress for the Sydney Basin is about 52 MPa at a depth of 625m.

Fig 1. Stress ratio plot.
(x = Sydney Basin values)



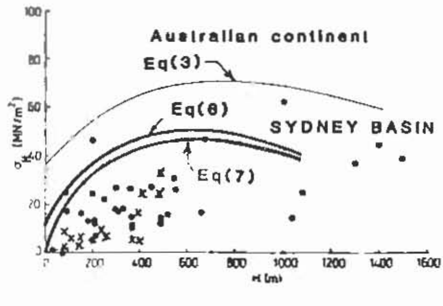


Fig 2. Plot of σ_H vs. depth
(x = Sydney Basin values)

CONCLUSION AND PRACTICAL IMPLICATIONS

The problem of understanding the way in which rock stress increases with depth has important implications for underground coal mining in the Sydney Basin. The magnitude and direction of the dominant horizontal stress can determine the method of working, development direction, roof support method and, to an increasing extent, the shape of roadway cross sections. Stress magnitude and direction must be known for rational design to be possible.

An interpretation of compiled stress meaurement data has produced a "design curve" which allows a first estimate to be made of the magnitude of the maximum horizontal stress likely to be encountered in the Sydney Basin at coal mining depths. The stress may turn out to be less than that predicted by the curve but is unlikely to exceed it. When combined with stratigraphic and structural geological information to indicate likely stress directions, initial mine layout and support estimates may be rendered more effective.

This does not replace field measurement in any way, but gives an indication of the sorts of conditions that might be expected.

ACKNOWLEDGEMENT

The author is grateful to Dr. Winton Gale, CSIRO Division of Applied Geomechanics, Wollongong, for helpful discussion and access to some as yet unpublished stress data for the Sydney Basin.

REFERENCES

1. Blackwood, R.L. The tectonophysical significance of large lateral in situ stresses in the Australian continent. In Geodynamics in South-West Pacific: Symposium, Nouméa, 1976 (Éditions Technip, Paris, 1977), pp.395-404.

2. Blackwood, R.L. An inference of crustal rheology from stress observations. Proc. Fourth Congress Int. Soc. Rock Mech., Montreux, 1979, Vol 1, pp.37-44.

3. Blackwood, R.L. Towards the prediction of pre-mining stresses in the European continent. In Application of Rock Mechanics to Cut and Fill Mining, Stephansson, O. and Jones, M.J. (eds), Inst. Min. Metall., London, 1981, pp.162-168.

4. Jaeger, J.C. and Cook, N.G.W. Fundamentals of Rock Mechanics, 3rd edit., Chapman & Hall, London, 1979.

5. Brown, E.T. and Hoek, E. Trends in relationships between measured in-situ stresses and depth: technical note. Int. J. Rock Mech. Min. Sci. & Geomech. Abstr., Vol 15, 1978, pp.211-215.

6. McCutchen, W.R. Some elements of a theory for in-situ stress: technical note. Int. J. Rock Mech. Min. Sci. & Geomech. Abstr., Vol 19, 1982, pp.201-203.

*** KEYNOTE ADDRESS ***

SUMMING UP THE SYDNEY BASIN

D. Branagan, University of Sydney

Although geology is traditionally regarded as a science which is of its nature qualitative, measurement plays an important part in what we regard as progress in knowledge of this science.

From the earliest days of the study of the Sydney Basin workers have been fascinated with questions such as how big, how much, what direction, how hot, how cold, how old, as they attempted to study the present and past characters of the basin and to predict future trends.

Some early measurements, such as the likely depth to coal near Sydney, were essentially of a practical nature, but others, such as Thomas Mitchell's 1838 estimate of the volume of material eroded from the Blue Mountains valleys could only have been of theoretical value, and perhaps of aesthetic interest.

Records of seismic events made from the earliest days of European settlement have been converted to numerical values by Burke-Gaffney (1952), and Everingham et al. (1982), and others, and thermal gradient measurements by Rae et al. (1899) were the link between the earlier interests of the Rev. C.P.N. Wilton in the Burning Mountain at Wingen and the later discussions on heat sources and heatflow of Dulhunty et al. (1951), Facer et al. (1980) and others. An incalculable number of rock (particularly coal), mineral, water and air analyses made over the past two centuries also attest to the attraction of numbers in documenting the nature of the basin, albeit in a fragmented sense.

In the broader geological framework attempts to apply numbers to various events which have occurred during evolution of the Sydney Basin involve the concept of time. We have to rely on measurements of time to evaluate both the physical position of the basin relative to other parts of the Earth, and the difficult-to-measure space events. How accurate have we been in these matters since Curran's bold use of "impossible" numbers in 1898? Only by attempting to grapple with the intangible subject of time can we hope to understand the true nature of the basin.

It is interesting that many of the earliest students of the geological character of the Sydney Basin were not afraid to view it aesthetically and left records of many of its features by way of painting and sketches while poetry, purple prose and music were also not forgotten. Mitchell, Rev. W.B. Clarke, P.P. King, and particularly the topographical artists Conrad Martens, Augustus Earle and Eugene von Guerrard, perhaps tell us more of the essence of the basin in their illustrations while encapsulating much of the detail which many geologists have become lost in.

In more recent times we have reached the great divide: the geologists have gone in one direction towards the minutae, while the artists, no longer with a scientific background, are looking at the basin with very different eyes. Do they have anything of value to tell us?

The coming of the satellite photography has presented us with some answers and many new questions about the basin. Can we integrate the geologist's detailed analysis of this huge corpus of information with the imaginative viewpoint of the artist?

I believe there is much to gain from such attempts.

References:

BURKE-GAFFNEY, T.N., 1952: Seismicity of Australia. J. Proc. R. Soc. N.S.W., 85, pp.47-52.

CURRAN, J.M., 1898: Geology of Sydney and the Blue Mountains. Sydney, Angus and Robertson.

DULHUNTY, J.A., HINDER, N., and PENROSE, I., 1951: Rank Variation in the Central Eastern Coalfields of New South Wales. J. Proc. R. Soc. N.S.W., 84, pp.99-106.

FACER, R.A., HUTTON, A.C. and FROST, D.J., 1980: Heat Generation of Siliceous Igneous Rocks of the Basement and its Possible Influence on Coal Rank in the Sydney Basin, New South Wales. Proc. Linn. Soc. N.S.W., 104: 95-109.

MITCHELL, T.L., 1838: Three Expeditions into the Interior of Eastern Australia. London: T. and W. Boone.

RAE, J.L.C., PITTMAN, E.F. and DAVID, T.W.E., 1899: Records of Rock Temperatures at Sydney Harbour Colliery, Birthday Shaft, Balmain, Sydney, N.S.W. J. Roy. Soc. N.S.W., 33, 211-219.

SUGGESTED MODIFICATIONS TO THE STRATIGRAPHIC NOMENCLATURE OF THE SINGLETON SUPER-GROUP

Judith Bailey, Earth Technics Pty. Limited

The Singleton Super-Group as defined by Britten (1972), is divided into the Wittingham Coal Measures and the overlying Wollombi Coal Measures, both having group status.

Making extensive use of the abundant and sophisticated borehole data currently available in the Broke, Mt Thorley, Warkworth and Mt Arthur areas, and with reference to the Code of Stratigraphic Nomenclature, the following modifications to the current stratigraphic nomenclature of the Singleton Super-Group are proposed.

Within the Wittingham Coal Measures it is suggested that the Vane and Jerry's Plains Sub-Groups are redundant except to define an incomplete cyclicity and that the group may be usefully subdivided into only six formations. In ascending order, these six formations are the transitional Saltwater Creek Formation (Robinson, 1963; Britten, 1972); the coal-bearing Foybrook Formation (Britten, 1972); the Broke Formation which combines the transitional units of the present Bulga Formation and Archerfield Sandstone; two coal-bearing formations named the Ravensworth and Mt Thorley Formations, and finally the transitional and bioturbated Denman Formation.

The Saltwater Creek Formation represents the transition between the underlying marine Maitland Group and the coal-bearing Foybrook Formation. The Foybrook Formation comprises a sequence of thin, interlocking coal seams and intervening sediments of the lower delta plain depositional facies.

Overlying the Foybrook Formation is the proposed Broke Formation, a gradational, coarsening-upward unit chiefly consisting of sandstone, and representing the migration of a coarse beach sand with some conglomeratic storm deposits over finer, bioturbated offshore deposits. The formation is so named since it was clearly exposed in its sub-crop zone in the B.H.P. Saxonvale Exploration Trench in the Broke area. The Bulga Formation of Britten (1972) is defined to contain laminite with worm burrows, while the Archerfield Sandstone is defined to be a bronze-coloured, medium to coarse grained and even-textured sandstone. Whilst a bioturbated laminite does occur at the base of the Broke Formation in the vicinity of Bulga, in general the sequence merely coarsens upward from very fine but even-textured sandstone to coarse sandstone. Large, lined burrows persist into the upper, coarse phases of the unit. Petrologic evidence and x-ray diffraction studies of clay composition confirm the gradational and homogeneous nature of the entire Broke Formation. It is considered sufficient to retain the Bulga Siltstone and Archerfield Sandstone as members of the Broke

Formation, to accommodate those areas where their characteristics are well developed.

Overlying the Broke Formation, the Burnamwood, Mt Ogilvie and Malabar Formations of the current nomenclature do not appear to be bounded by reliable boundary markers and are lithologically and petrologically very similar. The upper boundary of the Burnamwood Formation is the Mt Arthur Coal Member, defined to contain the Fairford Claystone Tongue. However, correlations based on the drillhole data now available show that the Fairford Claystone originally named in the Muswellbrook area is not equivalent to that named in the Type Bore for the Singleton Coal Measures, D.M. Doyles Creek DDH 11. This formation boundary is therefore placed in doubt.

The upper boundary of the Mt Ogilvie Formation is defined to fall between the Blakefield and Whynot Coal Members. However the Whynot is a trivial and often unidentifiable seam which frequently coalesces with the Blakefield Coal Member. It is suggested that the Whynot seam revert to informal nomenclature and that it be considered to be a subsection of the Blakefield Coal Member.

Further, the Mt Ogilvie and Malabar Formations, and that section of the Burnamwood Formation above the Vaux Coal Member, are very similar in character. They contain coal seams with a great propensity to splitting, large conglomerate and sandstone wedges, a higher percentage content of sandstone than of all finer clastic sediments combined, and several resistant, white tuffite units. The sediments of these formations are petrologically similar and represent an overall upward progression to increasingly terrestrial and high energy depositional environments. At the onset of deposition of this interval, one coeval model of deposition may be assumed throughout the area studied - namely the Warkworth, Mt Thorley and Broke areas. While proximal braided stream and alluvial fan deposition occurred in the north, on the same horizon, more distal facies of sedimentation such as the meandering streams of the upper delta plain were in evidence in the south-east. Toward the close of deposition of the interval, the development of braidplain deposits in the south-east as well as in the north, indicates the migration of the proximal facies of sedimentation to the south to encompass by this time the entire area.

It is therefore proposed that the coal-bearing strata between the Broke Formation and the Denman Formation be divided into only two formations: the lower Ravensworth Formation and the overlying Mt Thorley Formation. The Ravensworth Formation is bounded below by the base of the distinctive, dull Bayswater Coal Member, and above by the base of the Vaux Coal Member. It contains comparatively finer sediments of the lower delta plain depositional facies as well as the thin sub-parallel coal plies of the Broonie Coal Member, and the dull Bayswater Coal Member. According to microlithotype facies analyses after Hacquebard and Donaldson (1969), these coals represent the Limno-Telmatic Forest Moor Facies.

The Mt Thorley Formation extends from the base of the Vaux Coal Member to the top of the Whybrow Coal Member and is characterised by coal seams of the Telmatic Forest Moor Facies, which are frequently split about thick lenticular lithosomes of coarse-grained sediment.

It is proposed that the coal seams within both formations be retained as stratigraphic members, with the exception of the Whynot seam. The Fairford Claystone could be redefined to occur within the Piercefield Coal Member to conform with widespread local usage. Alternatively, since a new Type Section cannot be designated, the current Type Section should be recorrelated, with the coal seam containing the Fairford Claystone defined to be the Mt Arthur Coal Member. This would necessitate a formal renaming of those coal plies currently named the Mt Arthur Coal Member, and would thus require renaming of several economic seams currently being mined in the Broke-Mt Thorley area.

It is proposed that the Denman Formation, a generally thin bioturbated laminite, be retained at the top of the Wittingham Coal Measures.

Within the Wollombi Coal Measures it is suggested that since the coal seams are currently considered to be sub-economic and have not been drilled or correlated in detail, they should have rank no higher than that given to the coal seams of the Wittingham Coal Measures.

Although the Lucernia Coal with its intervening sediments may comprise in places a considerable thickness of strata, up to 61m, the Piercefield Coal Member of the Wittingham Coal Measures reaches a greater thickness of 74m as it splits westward in the Mt Thorley area. Therefore, it is proposed that the Abbey Green, Alcheringa, Lucernia, Dights Creek and Greig's Creek Coal Formations should revert to the status of member.

Certain coal subsections within these seams have been described as distinctive phases and defined as coal members. According to the Code of Stratigraphic Nomenclature, "A member is established when it is advantageous to recognise a specially developed part of a varied formation". It is considered that these named coal horizons are not, at this stage, sufficiently correlatable or distinctive to warrant retention as members. The "General comment on seam nomenclature" by the Standing Committee on Coalfield Geology (1974) states that "The term seam has been and may be applied informally to denote in discussion any local subsection of the defined coal member. This will be especially useful for discussion of economic subsections.....". Subsections of the coal members of the Wollombi Coal Measures which future drilling may reveal to be distinctive and correlatable, may adequately be referred to as seams.

It is suggested that the strata separating each pair of coal seams within the Wollombi Coal Measures are insufficiently drilled, correlated and characterised to be each defined as formations. Rather, it is proposed that the currently defined sub-groups of the Wollombi Coal Measures revert to the rank of formation, and that the two lowermost and similar sub-groups may be combined. Thus, the Wollombi Coal Measures would comprise, in ascending order, the Watts Sandstone Formation, the Horseshoe Creek Formation containing the Abbey Green, Alcheringa and Lucernia Coal Members; the barren Doyles Creek Formation; and the Glen Gallic Formation containing the distinctive cobble conglomerate of the Redmanvale Creek Member and bounded by the Dights Creek and Greig's Creek Coal Members.

SUGGESTED MODIFICATIONS TO STRATIGRAPHIC NOMENCLATURE OF SINGLETON SUPER-GROUP.

BRITTEN (1972)				THE AUTHOR		
SUPER-GROUP	GROUP	SUB-GROUP	FORMATION	SUPER-GROUP	GROUP	FORMATION
Singleton Coal Measures	Wollombi Coal Measures	Glen Gallic	Greig's Crk Coal Redmanvale Crk. Dight's Crk Coal	Singleton Coal Measures	Wollombi Coal Measures	Glen Gallic
		Doyles Creek	Waterfall Gully Pinegrove			Doyles Creek
		Horseshoe Creek	Lucernia Coal Strathmore Alcheringa Coal Clifford			Horseshoe Crk.
		Apple Tree Flat	Charlton Abbey Green Coal			
			Watts Sandstone			Watts Sandstone
	Wittingham Coal Measures	Jerrys Plains	Denman Malabar Mt Ogilvie Burnamwood Archerfield Ss		Wittingham Coal Measures	Denman Mt Thorley Ravensworth
		Vane	Bulga Foybrook			Broke Foybrook
			Saltwater Creek			Saltwater Crk.

FACIES AND SEDIMENTARY ENVIRONMENTS OF THE WITTINGHAM COAL MEASURES, NEAR MUSWELLBROOK

R.E. Uren, The University of Newcastle

The area studied lies on the western side of the Hunter River between Muswellbrook and Aberdeen, centred on "Kayuga" property. The Late Permian Wittingham Coal Measures underlie the area, producing poor outcrop. Many fully-cored boreholes have been drilled in the area for coal exploration, and these have provided data for an interpretation of the depositional environments.

The stratigraphic nomenclature for the Wittingham Coal Measures on the western flank of the Muswellbrook Anticline (Britten 1972) has been modified for the purposes of this study to incorporate the stratigraphy observed in the Kayuga area (Table). The lower Jerrys Plains Sub-Group, extending from the base of the Bayswater Coal Member to the top of the Upper Piercefield Seam, is characterized by abundant, thick sandstone units and many thick coal seams. Most of the coal reserves of the sub-group occur in this section. In contrast, the upper Jerrys Plains Sub-Group, extending from the top of the Upper Piercefield Seam to the top of the Whybrow Coal Member, contains sparser, thinner sandstones and coal seams, but a much larger proportion of burrowed fine sandstone, siltstone and claystone, and more tuffaceous beds. Only seams near the top have economic potential.

To facilitate description and correlation of the clastic sediments and aid interpretation of the coal measures, a number of facies have been defined, on the basis of lithology and sedimentary structures. Detailed graphic logs of nine bores were constructed to establish the facies. These logs included over 2000m of core, covering the interval from the top of the Bayswater Coal Member to the top of each bore, which varied between the Kayuga Seam and the unnamed seam above the Upper Piercefield Seam. Nine facies were defined, and they are described briefly below.

Sandstone Facies is composed of fine-medium to very coarse sandstone, and it may contain up to 5% thin claystone and siltstone interbeds. The facies is characterized by large-scale medium to high angle cross-bedding, coaly fragments, and a sharp or erosive base. The maximum thickness encountered is 37m, but most intersections are less than 6m thick. In terms of total thickness, the sandstone facies constitutes 24% of the sections examined.

Interbedded Facies. Three interbedded facies were defined. All comprise fine to medium sandstone interbedded with siltstone and/or claystone, and contain more than 15% and less than 95% sandstone. Fine sandstone tends to be the major lithology, whereas siltstone tends to be the minor lithology. These facies are generally laminated and/or finely bedded, and commonly display small-scale and/or large-scale cross-bedding. Carbonaceous laminae are abundant. The base can be either sharp or gradational. The three interbedded facies were also defined on the presence or absence of root traces, invertebrate burrows, and bioturbation (churned bedding caused by burrowing invertebrates).

Rooted Interbedded Facies contains root traces but no burrows or bioturbation. The thickest intersection encountered is 38m, but the facies is generally less than 4m thick. It comprises 22% of the section.

Undisturbed Interbedded Facies has no root traces, burrows or bioturbation. It has a maximum thickness of 24m, but is generally less than 4m thick. It comprises 12% of the section.

Burrowed Interbedded Facies contains burrows and/or bioturbation. Nearly all examples display burrows rather than bioturbation. Root traces are common. Shrinkage cracks, although sparse, occur more often in this facies than in the other interbedded facies. It has a maximum thickness of 25m, but is generally less than 6m. The facies comprises 9% of the section.

Claystone Facies. Three claystone facies were defined, all consisting of siltstone and/or claystone, with up to 15% fine sandstone. About one half of all intersections are carbonaceous in places. The various claystone facies were defined on the presence or absence of root traces, invertebrate burrows and bioturbation.

Rooted Claystone Facies contains root traces but no burrows or bioturbation. The facies reaches a maximum thickness of 11m, but it is generally 3m or less thick. It comprises 11% of the section.

Undisturbed Claystone Facies is devoid of root traces, burrows and bioturbation. The thickest intersection is only 5m thick, and most are 1m or less thick. The facies comprises only 3% of the section.

Burrowed Claystone Facies contains burrows and/or bioturbation. Root traces are sporadic. The maximum thickness is 12m, most examples are between 1.5 and 3m thick. The facies constitutes only 3% of the section.

Tuffaceous Facies comprises the Fairford Claystone (1 to 6m thick) as well as several thinner tuffaceous beds up to 1m thick. This is the least abundant facies, 2%.

Coal Facies refers to all coaly beds thicker than 0.3m, composed dominantly of coal and black carbonaceous claystone. Coal seams comprise 14% of the section.

The nature and geometry of the facies, their relationships as determined from vertical profile analyses, and stratigraphic cross sections, together with their relative abundance, suggest that the clastic sediments in the lower Jerrys Plains Sub-Group were deposited in a fluvial environment. A high fine to coarse sediment ratio, as well as sandstone percentage maps drawn for several interseam sections, indicate that meandering rivers predominated. The high percentage of coal in the sequence, however, demonstrates that peat swamps covered the area most of the time. The presence of rooted strata beneath almost every cored coal seam illustrates that the coal seams developed from peat growing in situ. Periodically, fluvial activity interrupted peat growth.

The lower Jerrys Plains Sub-Group was deposited after a rapid marine transgression which preceded the deposition of the Archerfield-Bulga Formation. This formation, which has been correlated with the Kulnura Marine Tongue in the central part of the Sydney Basin (Mayne et al. 1974), lenses out in the northern part of the Kayuga area, between the underlying upper split of the Wynn Coal Member and the overlying Bayswater Coal Member. Beyond the northern limit of the Archerfield-Bulga Formation, these coal seams coalesce to form one thick seam. The Archerfield-Bulga Formation, a coarsening-upward silty sandstone containing large burrows, is interpreted as a prograding shoreline deposit, laid down during the subsequent marine regression.

The upper Jerrys Plains Sub-Group is thought to comprise delta plain deposits, except for the "False Denman" which may represent a small marine incursion.

Acknowledgement:

The author wishes to thank the N.S.W. Department of Mineral Resources for free access to borelogs and drill core.

References:

Britten, R.A., 1972. A review of the stratigraphy of the Singleton Coal Measures and its significance to coal geology and mining in the Hunter Valley region of New South Wales. Australasian Institute of Mining and Metallurgy Conference, Newcastle, 1972, 11-22.

Mayne, S.J., Nicholas, E., Bigg-Wither, A.L., Rasidi, J.S., and Raine, M.J., 1974. Geology of the Sydney Basin - A Review. Australia Bureau of Mineral Resources - Bulletin 149.

TABLE
STRATIGRAPHIC NOMENCLATURE
WITTINGHAM COAL MEASURES
WESTERN FLANK OF MUSWELLBROOK ANTICLINE

Britten 1972			This paper (Kayuga Area)		
SUB-GROUP	FORMATION	MEMBER	SUB-GROUP	FORMATION	MEMBER AND SEAM
	Denman			Denman	lenses out to N
JERRYS PLAINS	Malabar	Whybrow Coal Althorpe Claystone Redbank Creek Coal Wambo Coal Whynot Coal	JERRYS PLAINS	upper	Whybrow Coal Althorpe Claystone Redbank Creek Coal Wambo Coal "False Denman" Whynot Coal
	Mt. Oglivie	Blakefield Coal Glen Munro Coal Woodlands Hill Coal			Blakefield Coal Saxonvale Claystone Glen Munro Coal Several uncorrelated seams
	Burnamwood	Mt. Arthur Coal (incl. Fairford Claystone Tongue) Piercefield Coal Vaux Coal Broonie Coal Bayswater Coal		lower	Upper Piercefield Seam Middle Piercefield Seam (incl. Fairford Claystone) (Kayuga Seam (Lower Piercefield (field Seam Vaux Coal Broonie Coal Bayswater Coal
	Archerfield Sandstn.			Archerfield-Bulga	lenses out to N
	Bulga				
VANE	Foybrook	Wynn Coal Edderton Coal Clanricard Coal Bengalla Coal Edinglassie Coal Ramrod Creek Coal	VANE	Foybrook	Wynn Coal Edderton Coal Clanricard Coal Bengalla Coal (several thin splits) Edinglassie Coal Ramrod Creek Coal
	Saltwater Ck			Saltwater Ck.	
MAITLAND GROUP					

MAULES CREEK - AN INTERESTING DEPOSIT

D. Butel, A. McLean, A. Millar, Kembla Coal & Coke Pty. Limited

Abstract

The Maules Creek Exploration Permit is located on the north-eastern margin of the Gunnedah Basin (Bembrik et al 1973). It originally covered some 250 sq. km. and lies northeast of Boggabri and southeast of Narrabri.

The 250 sq. km. had previously been totally assessed in a vertical sense by only one Department of Mines' borehole.

The Early Permian Coal Measures of the Gunnedah Basin are contained within the Nandewar Group. This group can be subdivided into two distinct sedimentary units. The lower unit, the Leard Formation (Brownlow 1981) is dominantly a flint clay unit, and the upper unit, the Maules Creek Formation (Brownlow 1981) is dominantly lithic consisting of conglomerates, sandstones, siltstones and claystones interbedded with coal. The maximum intersected thickness is in excess of 1,000 metres.

In the presently accepted Standard Stratigraphic section for the area, (Amax/BHP ABB001), there exist twelve named coal members within the Nandewar Group.

The coal seam geology is complicated by seam splitting and the resultant high number of seams. A maximum of 71 coal seams have been intersected in any one borehole. The seam splitting in the Maules Creek Formation could be classified as Tectonic seam splitting (Warbrooke 1981 and Crosdale 1982).

Relatively small vertical variations in lithotypes occur within the coals of the Maules Creek Formation. The stratigraphic sequence shows a slight change from bright coals in the lower section to less bright coals in the upper section. Similarly vertical variations in maceral composition reflect this trend.

Geophysical traces of coal seams therefore reflect the internal variations within the seam, especially the incidence of a few minor stone bands, and are invaluable for correlation purposes.

The basal Permian Leard Formation is usually in fresh bore core section a buff to black, fine grained claystone containing angular to sub rounded kaolinite clasts within a silty matrix.

Coal seams are common within the Leard Formation, sometimes being in excess of 2 m in thickness. These coal seams are not necessarily obviously stratigraphic time equivalent units, e.g. a coal member at different locations may be either within the Maules Creek Formation or within the Leard Formation. The Leard Formation is considered to be a partly redistributed palaeosol and thus the lower boundary is often transitional into the Boggabri Volcanics.

The Boggabri Volcanic sequence is nonconformably overlain by the Nandewar Group. The Boggabri Volcanics are Late Carboniferous/Early Permian in age and comprise acid flows, tuffs and ignimbrites. The volcanics exhibit a relief of over two hundred metres over comparatively short distances, as evident both by local surface relief on the Boggabri Ridge and from borehole evidence, e.g. between MAC 14 and MAC 16.

The basement highs have results in the localised non-deposition of several of the lower coal members, the abrupt convergence of lower seam units into complex composite horizons and differential compaction.

The dominant structure feature adjacent to the exploration permit is the Hunter-Mooki Thrust. The thrust trends NW/SE and separates the New England Block on the east from the Gunnedah Basin on the west.

Recent Palynology results from MAC 36 (Relinquished Portion of E.P. No. 4 - Maules Creek) indicate the presence of a possible marine section within a previously interpreted Maules Creek Formation.

This 150 m unit has been assigned to Permian Upper Stage 4, age (McMinn 1983).

This unit may be a time equivalent to the marine Porcupine Formation to the west of Boggabri Ridge. (Russell, 1981)

COAL QUALITY AND GEOLOGICAL SETTING IN THE EARLY PERMIAN SYDNEY AND GUNNEDAH BASINS

J.W. Hunt, C.S.I.R.O. Division of Fossil Fuels,
A.T. Brakel, H.J. Harrington, Bureau of Mineral Resources

Coal quality data for Early Permian sequences in the Sydney-Gunnedah Basin are being reviewed in relation to the tectonic and depositional settings of the basins as part of the NERDDC project 78/2617 on the "Permian Coals of Eastern Australia".

Geological Setting

In the north east, the Lower Permian coal measures were deposited in north west trending troughs and highs that were precursors of anticlines and synclines, parallel to the Hunter-Mooki Thrust Fault System in the Sydney and Gunnedah Basins and on the Campbell High near Ashford (Harrington, 1982). In the Gunnedah Basin, thick sequences in the Maules Creek Formation represent alluvial fans derived from New England to the east. Distal fan facies interfinger with paralic facies in the south-east of the basin. At Muswellbrook and Cessnock in the Sydney Basin the depositional environments have been described as fluvio-deltaic by Moffit (1982) and Britten (1975). Herbert (1980) considered that in the south west the coal measures were deposited in topographic lows that were probably river valleys.

Petrographic Analyses

The Lower Permian coal measures in the Sydney and Gunnedah Basins form a petrographically distinctive assemblage composed of finely banded vitrinite-rich coals, with low to medium semifusinite ratios (Fig. 6) and generally higher and more diverse exinite content (Fig. 7) than the Upper Permian coals. Fineness of banding, measured by the condensed microlithotype analysis shown in Fig. 5, varies inversely with the thickness of the Lower Permian sequences (Fig. 8). This may be due to the effect of different subsidence rates and nutrient availability on plant productivity, although because of the north south orientation of the basins in the Lower Permian, significant climatic and vegetational gradients may have existed. Early Permian coals are vitrinite rich, with the exception of a seam recently encountered at the base of the Greta Coal Measures at Muswellbrook and seams in the Leard Formation in the Gunnedah Basin. The low-vitrinite seams may represent deposition in a back-beach and lagoonal setting at the beginning of regressive sedimentation. In the Gunnedah basin west of the Boggabri Ridge a single low-vitrinite seam is present in DMR Howes Hill DDH1, in a thin sequence assigned to the Leard and Maules Creek Formations. Much of the vitrinite is impregnated with resinite which shows a low intensity dull yellow-brown fluorescence under blue-light excitation. The coal has high inherent mineral matter, a low semifusinite ratio, and the presence of abundant pyrite petrifactions suggests deposition in a paralic (possibly lagoonal) facies. The Lower Permian coals of the Sydney Basin show low semifusinite ratios, while those in the thick braided fluvial sequences of the Gunnedah Basin show generally low to medium semifusinite ratios. Diessel (1982) has demonstrated a predominantly woody facies in the Braymont seam from the Maules Creek Formation. The difference in semifusinite ratios could be a result of climatically controlled vegetational differences discussed earlier in this astract, or a result of the depositional environments which were fan deltas in the Sydney Basin and braided fluvial systems in the Gunnedah Basin. It should be noted that coals in the Lower Permian braided fluvial sequences of the Gunnedah Basin have high vitrinite contents, whereas the Upper Permian coals in similar depositional environments in the Sydney Basin are low in vitrinite. The difference is probably due to much lower water tables in the top of the regressive Sydney basin sequence.

Chemical Analyses

Total sulphur content (Fig. 1) for the Greta Coal Measures and equivalents is generally medium (> 0.55% daf) to high (> 1.10 % daf) for clean coal composites or 1.60 float fractions. The proportion of pyritic sulphur (Fig. 2) usually increases as total sulphur content increases, and concentration of pyritic sulphur in the upper part of the Greta seam due to marine sulphate influence has been documented by sulphur isotope work (Smith and Batts, 1974). Seams in the Greta Coal Measures and a seam in the Leard Formation were deposited in paralic (mainly deltaic) environments. A seam from the Clyde Coal Measures (Cook and Read 1968) may also have been deposited in a paralic environment on the basis of its high sulphur content (Fig. 1). Seams in the Maules Creek Formation east of the Boggabri Ridge, have low sulphur contents consistent with their origin in continental alluvial piedmonts.

Phosphorus content has been characterised as low (< 0.010 % db) medium (0.010 - 0.030 % db) and high (0.030 % db) in Fig. 3. The areas of higher sulphur content coincide with those of medium to high phosphorus, and coals in the Maules Creek Formation east of the Boggabri Ridge show low sulphur and phosphorus contents.

Shibaoka (1972) found that in the Upper Permian of the Sydney Basin, the coals that formed in deltaic facies generally contained high silica ashes (SiO_2/Al_2O_3 mole ratio > 3.0), whereas those formed in fluvial facies containes less silica in the ash. The SiO_2/Al_2O_3 mole ratio of coal ash (Fig. 4) is low (< 3.0) and decreases up sequence for the Greta Coal Measures at Cessnock but is consistently high (> 3.0) at Muswellbrook. In the Gunnedah Basin the SiO_2/Al_2O_3 mole ratio is variable throughout the Maules Creek Formation, although the lower seam, and three upper seams in DM Maules Creek DDH5, are enriched in Al_2O_3. The very high ratio (> 6.0) shown by some samples suggests the presence of epigenetic silica. The relationship between the composition of coal ash and geological setting is not clear because of the sporadic presence of epigenetic silica.

Conclusions

Lower Permian coals in the Sydney Basin are usually vitrinite-rich, with low semifusinite ratios and medium to high sulphur contents, reflecting deposition in mainly deltaic environments. Low-vitrinite, medium-to-high-sulphur coals in the Leard Formation of the Gunnedah Basin and rarely in the Sydney Basin may be due to deposition in lagoonal settings. High vitrinite coals with medium semifusinite ratios and low sulphur contents are present in the Maules Creek Formation of the Gunnedah Basin east of the Boggabri Ridge reflecting deposition in entirely terrestrial piedmonts. Fineness of banding in the Lower Permian coals varies inversely with the thickness of the sequences; this may reflect productivity differences in the peat swamps due to differing subsidence rates and nutrient availability. North-south climatically controlled vegetational gradients may also have contributed, or may account for, the observed microlithotype banding.

Acknowledgements

Amax-BHP and L. Etheridge of the NSW Dept. of Mineral Resources provided samples for analysis from the Gunnedah Basin. The figures showing analytical data include material published by the Joint Coal Board, and information on the bore Wancol Blandford DDH1 was provided by both F. Morris of Coalex and the Cessnock office of the Joint Coal Board. We have been helped by a chapter on the Gunnedah Basin which has been written for the NERDDC Report by D.S. Hamilton, J. Beckett and C.R. Weber of the NSW Dept. of Mineral Resources.

References

Britten, R.A., 1975. Maitland Cessnock Greta District: In Economic Geology of Australia and Papua New Guinea, 2. Coal (Traves, D.M. and King., D eds). Australasian Inst. of Mining and Metallurgy. Melb. 191-205.

Cook, A.C. and Read, H.W., 1968. The petrography of a coal seam from the Clyde River Coal Measures, Clyde River Gorge NSW R. Soc. NSW J. Proc. 101, 109-118.

Diessel, C.F.K., 1982. An Appraisal of Coal Facies based on Maceral Characteristics. In Symposium; Coal Resources-Origin Exploration and Utilization in Australia. Proceedings. Ed. C.W. Mallett. Melb. 15-19 Nov. 1982.

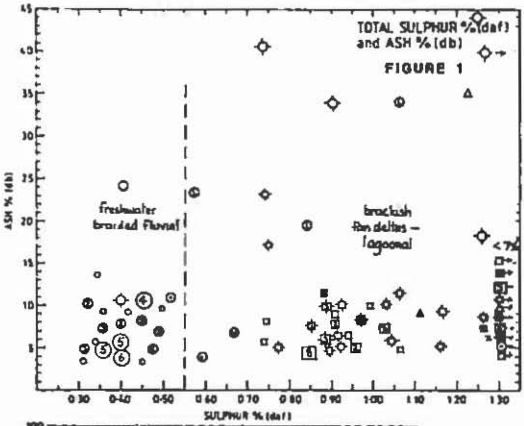
Harrington, H.J., 1982. Tectonics and the Sydney Basin. In Abstracts for the Sixteenth Symposium on Advances in the Study of the Sydney Basin, Newcastle, 1982 pp. 15-19.

Herbert, C., 1980. Southwestern Sydney Basin. In A Guide to the Sydney Basin. Geological Survey of New South Wales Bulletin 26. Department of Mineral Resources 1980 pp. 83-99.

Moffit, R.S., 1982. The 1980 East Muswellbrook Coal Drilling Programme. Quarterly Notes. Geological Survey of New South Wales Department of Mineral Resources 1st April 1982 pp. 17-26.

Smith, J.W. and Batts, B.D. 1974. The Distribution and Isotopic composition of sulphur content in coal. Geochemica et Cosmochimica Acta 38(1) pp. 121-133.

Shibaoka, M., 1972. Silica/alumina ratios of the Ashes from some Australian coals. Fuel 51 pp. 278-283.



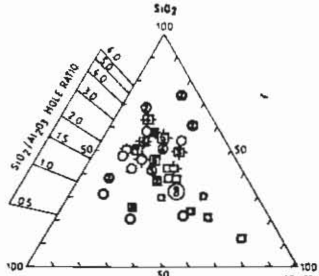
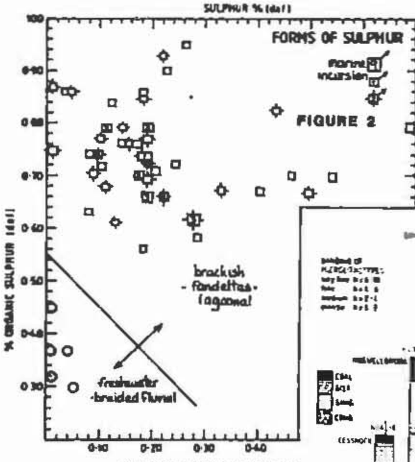


FIGURE 4

ASH ANALYSIS



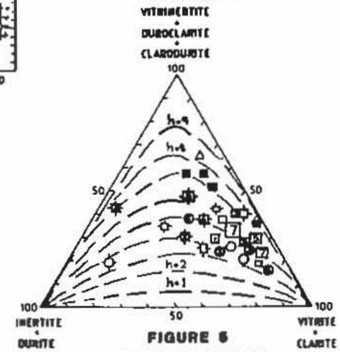


FIGURE 5

MICROLITHOTYPE ANALYSIS

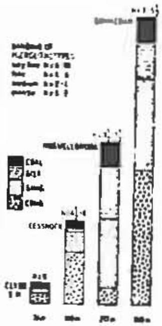
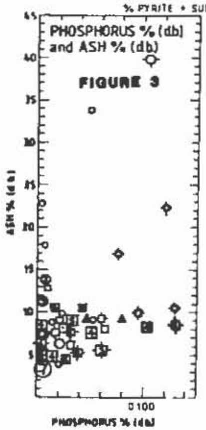


FIGURE 8

Microlithotype Banding and Tectonic Setting



KEY TO ANALYTICAL DATA

GUNNEDAH BASIN

MAULES CK. AND LEARD FORMATIONS

- ○ East of Boggabri Ridge 1.45/1.60F
- U=Upper L=Lower
- West of Boggabri Ridge
- Wingen Area 1.45F

SYDNEY BASIN

GRETA COAL MEASURES

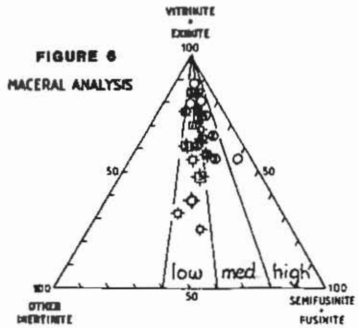
- □ Cessnock Area
- Muswellbrook Area
- Glendonbrook Area
- ■ Ladies Dome Bore 1 60F
- East Maitland Hill Bore 1 60F

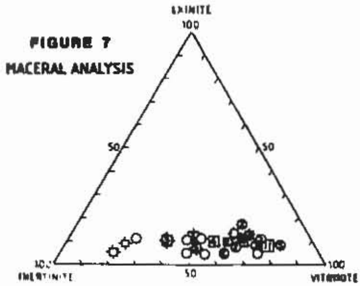
CLYDE COAL MEASURES

- △

GLOUCESTER BASIN

- ▲ DEWRANG FORMATION





COAL QUALITY AND GEOLOGICAL SETTING, WESTERN COALFIELD, SYDNEY BASIN

J.W. Hunt, A. Telfer, C.S.I.R.O. Division of Fossil Fuels

Analysis of coal samples from the bores DMR Kelgoola DDH3, Coalex Baal Bone DDH6 and Wancol Mt Tomah DDH1 was undertaken as part of the NERDDC project on the "Permian Coals of Eastern Australia". The the bores are located in the western coalfield of the Sydney Basin. Coalex Baal Bone DDH6 penetrated a sequence in the Late Permian Illawarra Coal Measures from the Katoomba to the Lithgow seams. DMR Kelgoola DDH3 terminated between the Lidsdale and Lithgow seams and Wancol Mt Tomah DDH1 terminated probably above the Lidsdale seam. The stratigraphic nomenclature established by Bembrick (1981) is used in this abstract.

Petrographic and chemical analyses were made on raw coal seam composites from the bores. The petrographic analyses included both microlithotype and maceral analysis. Chemical analyses were made on parameters likely to be related to the depositional environment of the coal seams, including chemical composition of coal ash, amount and forms of sulphur, and phosphorus content. Results of the petrographic and chemical analyses are shown in Figs 1 to 7.

Geological Setting

The Western Coalfield is located mainly on a thin "shelf" sequence where the coal measures lap onto the bounding western craton of the basin. Coalex Baal Bone DDH6 is located towards the western margin while DMR Kelgoola DDH3 and Coalex Mt Tomah DDH1 are located towards the tectonic hinge line (Harrington 1982) which forms the eastern boundary of the shelf.

The basal Lithgow and Lidsdale seams were developed within a braided fluvial environment on the Western margin but may be enclosed in paralic sediments basinwards. Upward-coarsening burrowed pro-delta and lower delta sediments above the Lidsdale seam include the Irondale and Moolarben seams. Bembrick (1981) assigned the Middle River to Katoomba seam section to a fluvial facies starting at the erosive upward-fining sandstone beneath the Middle River Seam.

Petrographic Analyses

The seams all have a low exinite content (Fig. 7) (about 5% average) with sporinite dominant, which is typical of Late Permian coals of the Sydney, Gunnedah and Bowen Basins. Vitrinite content is low for the Lithgow-Lidsdale interval, high in the overlying deltaic section and usually becomes progressively lower above the Middle River seam.

The "semifusinite ratio" (Fig. 6) (ratio of structured inertinite to other inertinite) is low to medium in the Lithgow-Lidsdale interval and medium for the overlying seams. A low semifusinite ratio is characteristic of the Lithgow-Ulan-Bayswater-Hoskisson Seam interval in the Sydney and Gunnedah Basins, and on the basis of the underlying sediments may be attributed to a setting of peat forming behind a coastal barrier. Transition from a braided fluvial to coastal facies towards the basin centre is supported by sulphur data and by sedimentological evidence in recent drill holes. A medium to high semifusinite ratio is typical of coals in fluvio-deltaic facies in the Late Permian of the Eastern Australian Permian Basins and is probably due to an autochthonous, woody peat facies.

Microlithotype composition presented in the condensed form in Fig. 5 has been related to tectonic setting (Hunt 1982). Banding of coals in DMR Kelgoola DDH3 and Wancol Mt Tomah DDH1 is generally coarser than for coals further west and this may be due to more rapid subsidence towards the eastern tectonic hinge, although high mineral matter contents also tend to produce artifically coarser banding. The relationship between microlithotype composition and depositional environment for Late Permian coals is shown in Fig. 8. Coals formed in deltaic facies are usually vitrinite rich, while those formed in fluvial facies are vitrinite poor.

Chemical Analyses

Total sulphur (daf), forms of sulphur (daf), phosphorus content (db), ash content (db) and composition of the ash are shown in Figs 1 to 4. Total sulphur (daf) tends to be medium to high (> 0.55%) for deltaic facies and low (< 0.55%) for fluvial facies in the Sydney, Gunnedah and Bowen Basins probably due to concentration of sulphate by ponding and/or access to "marine" sulphate in the deltaic facies. Total sulphur content of the Lithgow seam is > 0.55% except for one sample on the western margin of the basin, suggestive of a transition from braided fluvial to a ponded coastal facies away from the western margin. The Middle River Seam probably was deposited in an "upper delta" rather than a "fluvial" facies, on the basis of its medium sulphur content (> 0.55% daf). The sulphur is mainly organic sulphur, with the proportion of pyritic sulphate increasing in the lagoonal and deltaic facies.

Phosphorus content is variable through the sequences, with high phosphorus contents in the Lithgow-Lidsdale seams, Irondale seam and Katoomba seam. No relationship between phosphorus content and depositional environment has been found.

Shibaoka (1972) found that in the Sydney Basin, coals formed in deltaic facies generally contained high silica ashes (SiO_2/Al_2O_3 mole ratio >3.0), while those formed in fluvial facies contained less silica in the ash. Western coalfield coals all tend to have silica rich ashes due to a high proportion of probably epigenetic, fine grained (2-10 µm) angular dispersed or concentrated silica present. This material obscures any relationship between primary mineral matter and depositional environment in the west.

Conclusions

The Lithgow-Lidsdale seam interval contains generally low vitrinite, medium sulphur coals, with low to medium semifusinite ratios formed in a coastal setting away from the basin margin. The overlying Irondale-Moolarben seam interval contains high vitrinite, medium sulphur coals with high semifusinite ratios formed in deltaic facies. The Middle River-Katoomba seam interval shows a transition from high to low vitrinite and medium to low sulphur coals, with high semifusinite ratios, probably due to a transition from an upper delta to fluvial depositional environment.

Acknowledgements

F. Morris of Coalex and J. Maloney of the NSW Dept. of Mineral Resources provided access to samples analysed. Both organisations and M. Smyth of CSIRO provided access to analytical data and stratigraphic information. We also wish to thank G. Bradley, C. Bembrick, A. Crouch, A. Brakel, H.J. Harrington and M. Shibaoka who contributed to the concepts presented herein through discussion and comment.

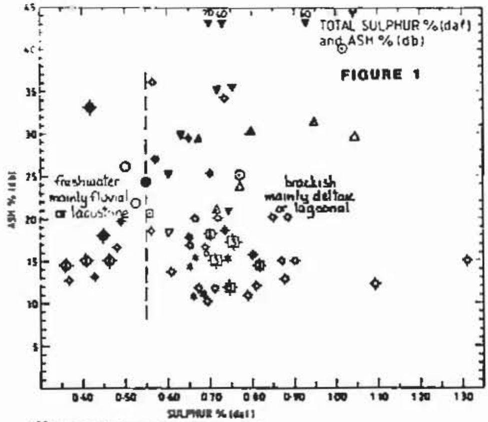
References

Bembrick, C. 1981. Stratigraphic Subdivision and Sedimentary Environment of the Illawarra Coal Measures, Western Coalfield, Abstracts of Symp. of Geology and Colliery Development in the Western Coalfield, NSW, Coal Geology Group, Geological Society 1981 Symposium 25-27 March 1981 pp. 5-6.

Harrington, H.J. 1982. Tectonics and the Sydney Basin in Abstracts for the Sixteenth Symposium on "Advances in the study of the Sydney Basin", Newcastle University, 1982, pp. 15-19.

Hunt, J.W., 1982, Relationship between microlithotype and maceral composition of coals and geological setting of coal measures in the Permian Basin of Eastern Australia in Proc. Symposium. Coal Resources Origin Exploration and Utilization in Australia (C.W. Mallett editor) Melb. 15-19 Nov., 1982 pp. 484-502.

Shibaoka M., 1972, Silica/alumina ratios of the Ashes from some Australian coals Fuel 51 pp. 278-283.



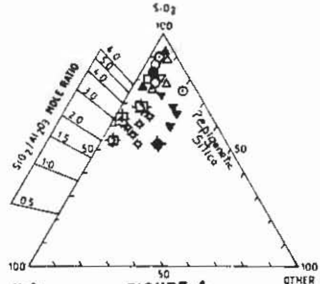


FIGURE 4
ASH ANALYSIS

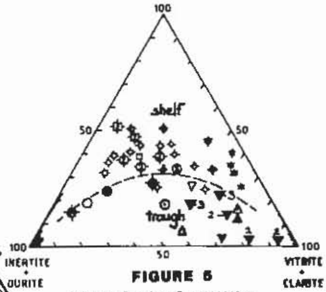
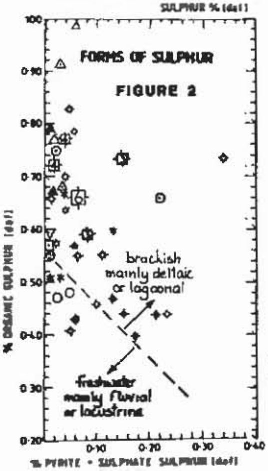
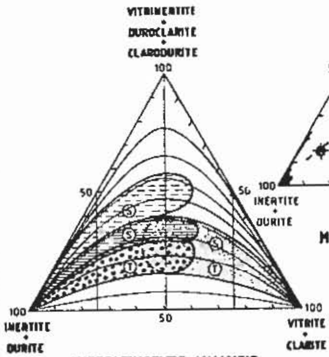


FIGURE 5
MICROLITHOTYPE ANALYSIS

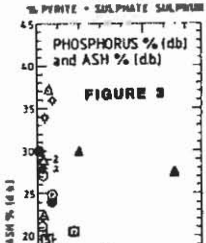




MICROLITHOTYPE ANALYSIS
Ⓢ - Shelf Ⓣ - Trough

- Upper Delta Plain - Fluvial
- Lower Delta Plain
- Braided Fluvial Piedmont
- Meandering Fluvial - Flood Basin

FIG 8 Microlithotype Composition and Depositional Environment

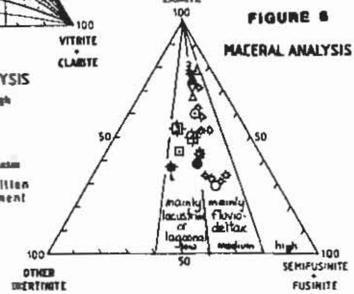


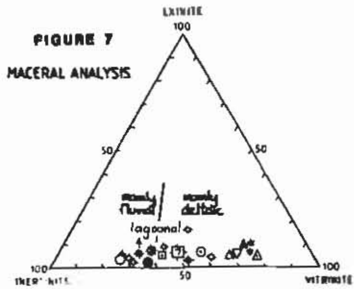
KEY TO ANALYTICAL DATA

SYDNEY BASIN
ILLAWARRA COAL MEASURES
WESTERN AREA

a/b c d
- Katoomba seam
- Unnamed seam
- Woodford seam
- Middle River seam
- Moolarben seam
- Irondale seam
- Unnamed seam
- Lidsdale seam
- Lithgow seam
- Ulan seam

a) DMR Kerrabee DDH3
b) COALEX Baal Bone DDH6
c) COALEX Mt Tomah DDH1
d) Other Western Coalfield data





STRUCTURAL CONTROL OF SEDIMENTATION OF THE COAL MEASURES IN THE RYLSTONE DRILLING AREA

G.M. Bradley, J. Moloney, N.S.W. Department of Mineral Resources

INTRODUCTION

The Rylstone Coal Drilling Area extends from about 10 km east to 40 km east of Rylstone. The area consists of approximately 320 square km of which about 290 square km are underlain by coal measures. Between August, 1980 and August, 1982, the Department of Mineral Resources drilled a total of 7,860 m in 23 drillholes in the area. The drillholes range from 100 to 670 m in depth, and are sited at 3 to 5 km centres.

GENERAL GEOLOGY

The stratigraphy of the area is:

CAINOZOIC	Olivine Basalt Flows and Plugs
MESOZOIC	Volcanic Breccia Vents
Triassic	Hawkesbury Sandstone
TRIASSIC TO LATE PERMIAN	Narrabeen Group (Sandstone, Conglomerate, Siltstone and mudstone)
PERMIAN	Illawarra Coal Measures
PERMIAN	Shoalhaven Group (Marine siltstone, sandstone and conglomerate)

Narrabeen Group sandstones outcrop across most of the drilling area except in the west, where outcrop of marine Shoalhaven Group predominates.

Basaltic plugs and volcanic breccia vents are common throughout the area. The basalt plugs commonly form prominent hills. Many of these plugs intrude Mesozoic breccia vents. Breccia vents which are not intruded by basalt plugs have subdued to negative topographic expressions. Basalt sills associated with these intrusions commonly invade the upper parts of the coal measures, but in none of the holes drilled to-date has an intruded Lithgow Coal been encountered.

STRUCTURAL CONTROL ON SEDIMENTATION

The Mount Coricudgy Anticline (Bembrick et al. 1973) extends in a northeasterly direction through the drilling area (see figures). The Stage 1 drilling in 1980 indicated that the coal measures increase regularly in thickness from west to east, and that the anticline had little or no affect on their sedimentation. The Stage 2 drilling in 1981/82 has enabled reassessment of this. The basal unit in the coal measures, the Nile Subgroup, was not fully penetrated in most drill-holes, but available data indicate an easterly increase in thickness from about 20 m in the west to over 45 m in the east. The thickness of the Coal Measures to the base of the Marrangaroo Conglomerate (the unit overlying the Nile Subgroup) increases substantially towards the east from about 120 m at Kandos, to 160 m in the northwest of the drilling area, and to 290 m in the east of the drilling area. This increase occurs at the relatively uniform rate of about 4 m/km from Kandos to about 10 km from the eastern edge of the drilling area. The thickness then increases more rapidly at about 10 m/km for the next 5 km to the easternmost limit of drilling. This indicated the presence of a north-south "hinge-line" controlling sedimentation of the coal measures. This "hinge-line" corresponds closely to an ENE-trending LANDSAT lineament extending from south of Newnes to the upper reaches of Widdin Brook, and is probably related to basement-faulting (Shepherd et al., 1981).

The isopachs of the coal measures also exhibit obvious flexures in the western half of the area. The axes of these flexures fan from E to SE-trending and cut across the trend of the Mount Coricudgy Anticline.

The isopachs of the component formations of the Illawarra Coal Measures, however, indicate a complex history of structural control of deposition. Three major structural features are evident in the isopachs of the formations (see figures). Details of these structures are summarised in the table on the next page.

The first structure is a broad NE-thickening trough in the central north of the area (see figures). The structure strongly influenced deposition of the Blackmans Flat Conglomerate, Lidsdale Coal, and Irondale Coal, but had less affect on the deposition of the Baal Bone and Farmers Creek Formations. The structure had no affect on the deposition of the Marrangaroo Conglomerate, Lithgow Coal, Long Swamp Formation, Angus Place Sandstone and The Gap Sandstone.

The second structure is an ENE-trending zone corresponding to the Mount Coricudgy Anticline (see figures). This structure is commonly characterised by thinning of formations and has a pronounced influence on the Blackmans Flat Conglomerate, Angus Place Sandstone, State Mine Creek Formation and Farmers Creek Formation. A less well developed thin zone occurs in the Marrangaroo Conglomerate. The Irondale Coal thins across the structure but also forms a SW-thickening trough along the structure. The anticlinal structure appears to have been active throughout deposition of the coal measures.

The third structure is a well defined E to NE-thickening trough in the east of the area, generally east of the "hinge-line", but extending to the west of the "hinge-line" in some cases. This feature is probably controlled by two E to ESE-trending LANDSAT lineaments. The trough is weakly developed in the Marrangaroo Conglomerate but well developed in almost all of the other formations. Towards the top of the sequence the axis of the trough swings from E-thickening to SE-thickening, then to SSE-thickening.

TABLE SUMMARISING AFFECT OF STRUCTURAL FEATURES

FORMATIONS AFTER BEMBRICK IN PREP.	TROUGH IN NORTH OF AREA	MOUNT CORICUDGY ANTICLINE	TROUGH NEAR "HINGE-LINE"
Farmers Creek Formation	ENE-thickening Open Trough	Slightly Thicker Zone	SSE-thickening
The Gap Sandstone	No affect	ENE-trending Thin zone	SE-thickening
State Mine Creek Formation	Thins to North	ENE-trending Thin zone	E-thickening
Angus Place Sandstone	No affect	NE-trending Thin zone	Thin zone west of hinge
Baal Bone Formation	Elongate N-thickening	No affect	ENE-thickening
Irondale Coal	NE-thickening	SW-thickening Trough	NE-thickening
Long Swamp Formation	No affect	No affect	Ill-defined E-thickening
Lidsdale Coal	NE-thickening	Ill-defined Slightly Thicker zone	E-thickening
Blackmans Flat Conglomerate	NE-thickening	ENE-trending Thin zone	ENE-thickening
Lithgow Coal	No affect	No affect	Thin zone
Marrangaroo Conglomerate	No affect	Ill-defined Thin zone	Weakly-defined E-thickening

Three formations are unaffected by the Mount Coricudgy Anticline. Two of these, the Baal Bone and Long Swamp Formations are major brackish incursions in the coal measures and are controlled by NNW to NNE-trending structures possibly related to growth faulting on NNE-trending LANDSAT lineaments present in the west of the area. The third formation, the Lithgow Coal, thickens generally to the east where it maintains a reasonably constant thickness along the axis of the trough in the underlying Marrangaroo Conglomerate (see figures). To the north and south of this axis the coal thickens rapidly and splits. The quality of the Lithgow Coal appears to be controlled by its relationship to the underlying Marrangaroo Conglomerate. In the west of the area, the coal is thin (see figures) where it rests on a thick depocentre of conglomerate. The coal thickens to the east of the depocentre and the quality in this zone is good (7 to 12% ash at yields of 95-100%). Further east the coal starts to split, and the quality deteriorates. At first moderate quality coal is maintained in a lower split 3 m thick (about 16% ash at yields of 96-100%). The coal then deteriorates into coal splits of less than 1.8 m thick.

CONCLUSION

Deposition of the Illawarra Coal Measures in the Rylstone Drilling Area was controlled by two dominant tectonic features:

1. the Mount Coricudgy Anticline which is characterised by a zone of thinning; and

2. a deeply subsiding trough-like feature associated with a N-S hinge line in the east of the area.

These tectonic features did not control deposition of all the component formations in the coal meausres, and the intervening units compensated in part for the stacked "thinning" and "thickening" of units associated with the two respective structures. The nett affect of this is to suppress the influence of the structures to the extent that the Mount Coricudgy Anticline is not discernibly in the isopachs of the Coal Measures and the trough-like structure merges into a rapidly thickened zone of coal measures east of the hinge-line.

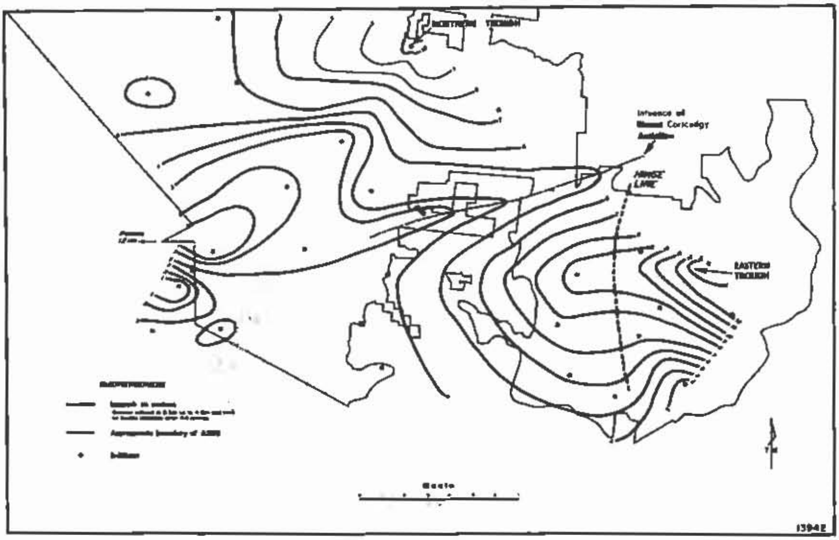
REFERENCES

Bembrick, C.S., (in prep). The Stratigraphy and Sedimentation of the Western Coalfields. New South Wales Institute of Technology M.Sc Thesis (unpubl.).

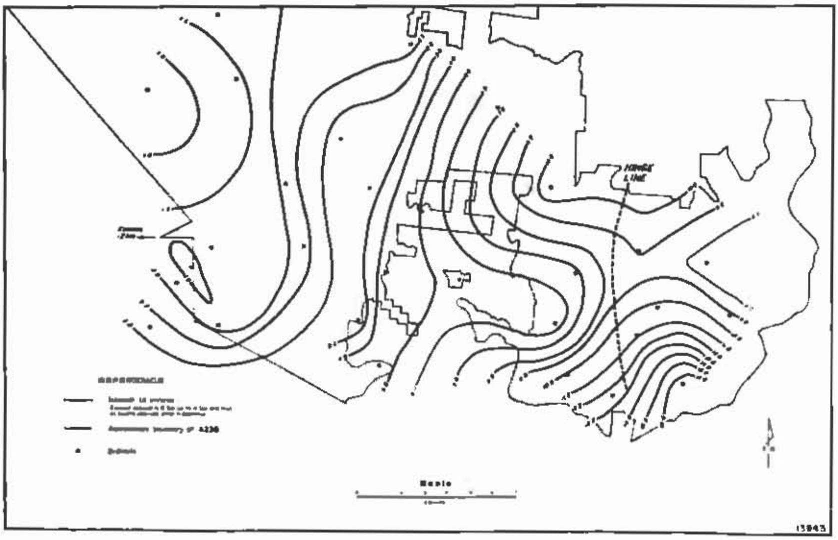
Bembrick, C.S., Herbert, C., Scheibner, E., and Stuntz, J., 1973. Structural subdivision of the New South Wales Portion of the Sydney Basin. Geological Survey of New South Wales - Quarterly Notes 11, pp 1-13.

Shepherd, J., Huntingdon, J.F., and Creasy, J.W., 1981. Surface and underground geological prediction of bad roof conditions in collieries of the Western Coalfield, New South Wales, Australia. Trans. Instn. Min. Metall. Section B (Appl. Earth Sci.) 90, pp B1-B14.

RYLSTONE COAL DRILLING AREA
ISOPACH OF BLACKMANS FLAT CONGLOMERATE



RYLSTONE COAL DRILLING AREA
ISOPACH OF LITHGOW COAL



FOURIER TRANSFORM INFRARED SPECTROSCOPY OF COALS AND TORBANITES

P.M. Fredericks, B.H.P. Central Research Laboratories

INTRODUCTION

Infrared (IR) spectroscopy has been used for many years in the study of coals and like materials[1,2]. Infrared energy is absorbed in the vibration of the chemical bonds, resulting in a wealth of information being contained in the spectra. In the case of minerals containing organic parts (coals, oil shales etc.), IR absorption bands are observed for both organic and inorganic portions. The method is quantitative in that the intensity of a single absorption band is proportional to the concentration of a particular phase or structural group. The IR spectrum of a mixture can be considered to be the sum of the spectra of the component phases each multiplied by an appropriate concentration factor.

A severe limitation to the widespread use of IR spectroscopy has been the relative inefficiency of IR spectrometers, giving rise to problems with highly absorbing, opaque samples such as coals and many minerals. These difficulties have, to a large extent, been overcome by the recent introduction of a new generation of computerised spectrometers based on the Michelson interferometer. The initial measurement of these spectrometers is an interferogram which is related to the IR spectrum by a Fourier Transformation. Hence, these instruments are called Fourier Transform infrared (FTIR) spectrometers. The advantages of the FTIR method are increased speed, sensitivity and resolution, and very high wavenumber accuracy. Additionally, the computerised nature of the method means that the data is in digital form and thus is capable of mathematical treatment to expand or contract scales, to modify baselines, to add or subtract spectra, to measure peak position and areas of absorption bands, and to store spectra on magnetic media for future retreival. Also, the signal-to-noise ratio of the spectra of difficult samples can be further improved by signal-averaging a number of spectra.

Some examples of the use of FTIR, drawn from recent work at CRL, are given below. The examples are not exhaustive, but are intended to give an idea of possible applications of the method.

FTIR OF COALS

The FTIR spectrum of a typical bituminous coal is given in Fig. 1. The Sample was in the form of a ~0.5 wt% dispersion in a pressed pellet of caesium iodide. Accepted assignments for a few of the absorption bands are shown[3]. Note that bands are observed for both the organic part and the mineral matter. The spectrum changes with coal rank because the structural group distribution changes. For example, brown coals show a large carbonyl absorption (due to carboxylic acids) and almost no aromatic C-H absorption, whereas anthracites show no carbonyl or aliphatic C-H absorption.

In order to investigate how the FTIR spectrum varies with different coal properties, a study of a wide range of Australian coking coals was undertaken. The most significant differences observed in the spectra were in the C-H stretching bands and in the mineral matter absorption bands. An FTIR parameter was measured, for each coal, representing the ratio of the absorbance of the major aliphatic C-H stretching band (~2930 cm^{-1}) to that of the aromatic C-H stretching band (~3050 cm^{-1}). Correlations were found between the FTIR parameter and the volatile matter, the C/H ratio, and the vitrinite reflectance of the coals (Figs. 2a, 2b and 2c).

Recent American work[4] suggests that the ability of FTIR to distinguish between coals means that it can be used to analyse coal blends. The method was examined at CRL using blends of varying proportions of Liddell (VM=39.3% dmmf) and TDM (VM=30.9% dmmf) coals. The results (Fig. 3a) show that this blend is readily analysed and that a standard deviation of 3% is achieved. A further test of the method was undertaken using blends of Bulli-Metropolitan and Lambton Borehole coals, containing up to 30 wt% Metropolitan, to approximate coking practice at Newcastle Works. The results (Fig. 3b) show that a good measure of the amount of Metropolitan coal in the blend can be obtained by FTIR (standard deviation 2 wt%). Much of the error is thought to be due to sampling, as very small samples are required for transmission spectroscopy. Reflectance methods using much larger samples would probably reduce sampling errors considerably.

Where a blend contains more than two components, simplistic use of an FTIR parameter will not be possible. Instead the spectra will need to be analysed by a computerised method such as factor analysis which utilises a large number of data points in each spectrum.

These results introduce the possibility of simple, fast and accurate method of coal blend analysis which does not require skilled operators and which, in fact, can be very highly automated.

FTIR OF OXIDISED COAL

FTIR is a useful tool for determining whether a coal has been oxidised because changes in the concentration of oxygen-containing structural groups are readily apparent from the spectrum. The technique is quite sensitive, but the minimum detectable level of oxidation has yet to be determined. FTIR spectra have been used to determine the chemical reactions occurring during oxidation[5]. It has been found that ketones and carboxylate groups are the initial products of oxidation, with subsequent formation of aromatic esters. A recent FTIR study of naturally oxidised coal from a Hunter Valley seam is reported elsewhere in these Proceedings[6].

FTIR OF COAL MINERAL MATTER

FTIR has been suggested as a method for the analysis of mineral matter in coal, either directly in the raw coal, or more usually, in the form of residue from low temperature radiofrequency ashing[7]. The spectrum of the mineral matter is considered to be the sum of the spectra of the component minerals each multiplied by a concentration factor. The techniques used to determine the concentration factors include spectral subtraction procedures, the method of simultaneous equations using a small number of specific absorptions, and factor analysis which uses a larger number of data points. Sub-spectra of pure samples of possible component minerals are required. The technique has the potential to be both faster and more accurate than conventional XRD methods, and is capable of being highly automated.

FTIR OF TORBANITES

Those capabilities which make FTIR useful for the characterisation of coals are equally applicable to oil shales and similar materials. Fig. 4 shows the spectrum of an Australian oil shale. Again, absorptions are observed for both organic and inorganic parts. The mainly aliphatic nature of kerogen is reflected in the sharp aliphatic C-H bands at 2950 cm^{-1} and 2850 cm^{-1} and the absence of aromatic C-H bands in the region 3000 cm^{-1} to 3100 cm^{-1}. Recent reports[8,9] indicate that oil yield by Fischer assay correlates well with the absorbance of the C-H band at 2950 cm^{-1}. This is a considerable advance as Fischer assays are time-consuming and labour intensive. A further benefit of FTIR is that the presence of any coal-like material, leading to a lowered oil yield, is readily observed. The major components of the mineral matter can also be identified and quantified.

CONCLUSIONS

FTIR spectroscopy is a new technique for the characterisation of materials. It is especially applicable to coals and oil shales. Qualitative and quantitative information is obtained for both organic and inorganic parts of the material. FTIR is both a highly sensitive research technique capable of giving much information about the chemistry and structure of materials, and also a potentially useful quality control instrument able to perform repetitive analyses automatically without requiring a skilled operator.

REFERENCES

1. Brown, J.K., "The Infrared Spectra of Coals", J. Chem. Soc., 1955, 744.
2. Bent, R. and Brown, J.K., "The Infrared Spectra of Macerals", Fuel, 1961, 40, 47.

3. Painter, P.C., Snyder, R.W., Starsinic, M., Coleman, M.M., Kuehn, D.W. and Davis, A., "Concerning the Application of FTIR to the Study of Coal: A Critical Assessment of Band Assignments and the Application of Spectral Analysis Programs", Applied Spectroscopy, 1981. 35, 475.
4. Lowenhaupt, D.E., Griffiths, P.R., Fuller, M.P. and Hamadeh, I.M. "The Characterisation of Coal by Diffuse Reflectance Infrared Fourier Transform Spectroscopy", Proc. Ironmaking Conf. 1982, 41, 39.
5. Painter, P.C., Snyder, R.W., Pearson, D.E. and Kwong, J., "FTIR Study of the Variation in the Oxidation of a Coking Coal", Fuel, 1980, 59, 282.
6. Warbrooke, P., "Natural Oxidation of Coal", Proceedings, 17th Newcastle Symposium on Advances in the Study of the Sydney Basin, Newcastle, NSW, 29th April-18th May, 1983.
7. Jenkins, R.G. and Walker, P.L. Jr., "Analysis of Mineral Matter in Coal" in "Analytical Methods for Coal and Coal Products Vol. 2", Ed. C. Karr, Academic Press, New York, 1978, p265.
8. Solomon, P.R. and Miknis, F.P., "Use of Fourier Transform Infrared Spectroscopy for Determining Oil Shale Properties", Fuel, 1980, 59, 893.
9. Cronauer, D.C., Snyder, R.W. and Painter, P.C., "Characterisation of Oil Shale by FTIR Spectroscopy", ACS Div. Fuel Chem., Preprints, 1982, 27, 122.

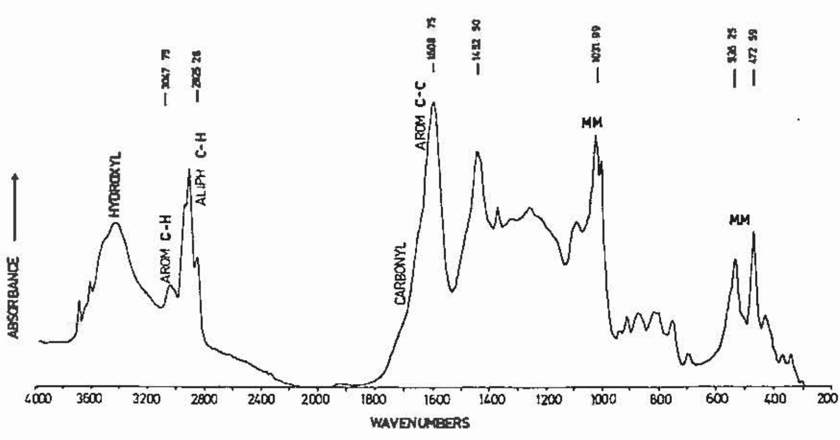


Figure 1. FTIR spectrum of a typical bituminous coal

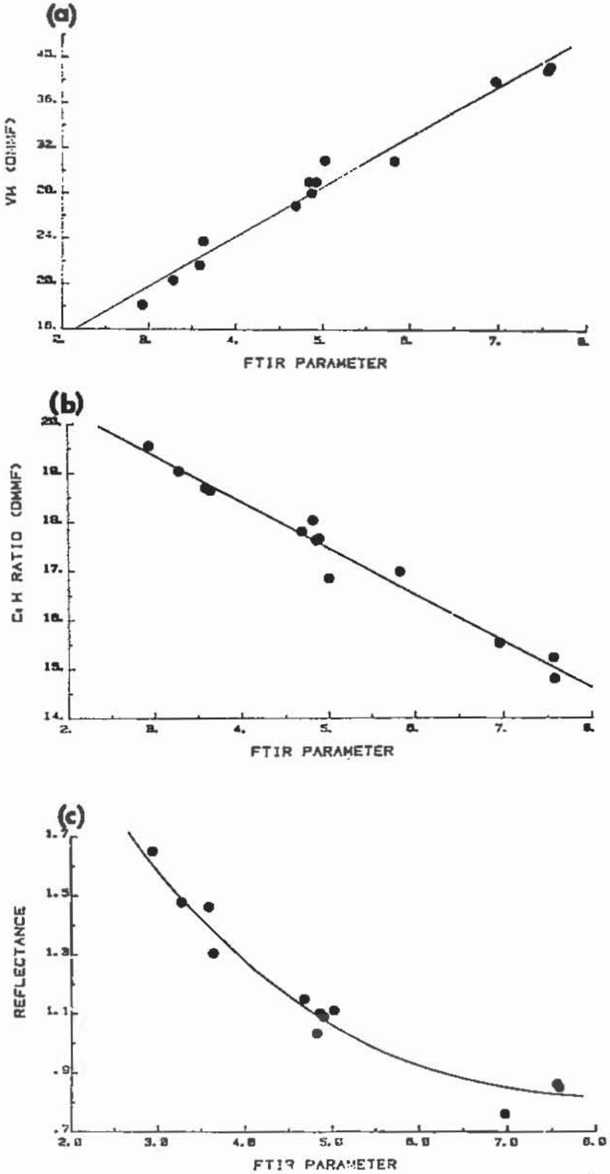


Figure 2. Correlations between the FTIR spectrum and
(a) volatile matter (dmmf),
(b) C:H ratio, and
(c) vitrinite reflectance, for 13 Australian coking coals.

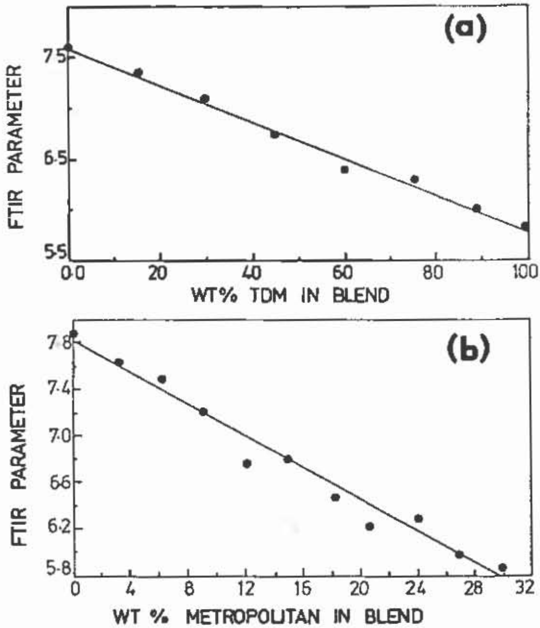


Figure 3. Coal blend analysis by FTIR,

(a) Liddell:TDM blend
(b) Bulli-Metropolitan: Lambton Borehole blend

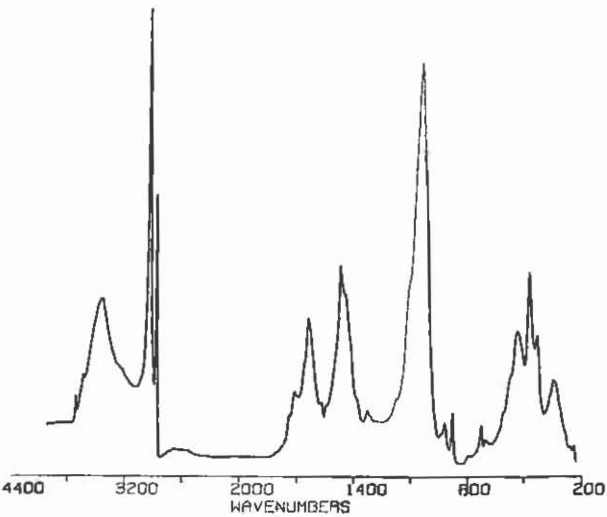


Figure 4. FTIR spectrum of an Australian oil shale

A NEW FOSSIL FISH DISCOVERY IN THE TRIASSIC OF THE SYDNEY BASIN: PRELIMINARY FINDINGS

P.S. Watson, University of Sydney

It is now well over half a century since the last major discovery of fossil fishes was made in the Sydney Basin, at Beacon Hill, Sydney. In the early 1970's fish fossils were noticed in a quarry in the hills west of Gosford. Earlier, joint collecting parties of the Australian Museum and the Mining Museum located several dozen large and well-preserved fish. In more recent times, several months of intensive excavation and collecting have yielded startling new facts.

The fish bed in question is a 2m shale lens within the Hawkesbury Sandstone at Somersby on the Central Coast. The lens is about 60m above the top of the Narrabeen Group which outcrops in nearby valleys.

FAUNAL LIST (PRELIMINARY)

Hybodontidae	Lissodus cf.africanus
Dipnoi	Gosfordia truncata
Palaeoniscidae	?Belichthys
?Birgeriidae	?Birgeria cf.groenlandica
Perleididae	Zeuchthiscus australia
Cleithrolepididae	Cleithrolepis granulatus
Hydropessidae	Hydropessum cf.kannemeyeri
Saurichthyidae	Saurichthys parvidens
	Saurichthys gigas
Parasemionotidae	Promecosomina cf.formosa

The main palaeontological significance arises from the fact that three genera are quite new to Australia. Hitherto Hydropessum and Lissodus were regarded as restricted to the Upper Karroo Beds of South Africa (Lower Triassic). Birgeria has a worldwide extent but is also found in the southern hemisphere in Madagascar. Of the other forms, the common Cleithrolepis is found in Europe and a close relative in Britain, and also occurs in Argentina and a very close relative, Cleithrolepidina, proliferates in the Upper Karroo. Similarly, Saurichthys is found in the northern hemisphere but also in Madagascar. Furthermore, the Australian parasemionotid, Promecosomina has has particularly strong affinities with the parasemionotids of Madagascar.

Thus it appears that there is a strong relationship between the Somersby fauna and those of South Africa and Madagascar. The implications of this for the Gondwana concept and for continental drift are obvious. This is an exciting possibility for previous workers (Broom, Brough and Wade) had concluded that the then existing faunas had not demonstrated any positive intercontental connections. The close affinity with the marine fauna of Madagascar is not as significant here as the affinities between the two freshwater provinces, the Upper Karroo and the Hawkesbury Sandstone.

The Somersby fish site also offers an excellent opportunity for the study of Triassic palaeoecology. No studies of Hawkesbury Sandstone shale lenses have been attempted from the palaeoecological perspective. In the past, quarrying conditions at Gosford, St.Peters, Cockatoo Island, Tambourine Bay and Woronora Dam were not favourable to such an approach. In other cases where good studies could have been made viz. Wahroonga and Beacon Hill, palaeoecology was not then in vogue and workers such as Wade concentrated on the taxonomy to the exclusion of all else. The Somersby site is ideal for such a study for the lens is not thick and the quarrying process is slow.

Previously investigation and collecting at Somersby has been confined to the rubble dumps in the western part of the quarry. Recently, excavations have been made in the lens proper and interesting observations have been recorded:

1. Fish fossils are not scattered randomly throughout the shale lens and on all levels as one might expect but are confined to certain narrowly defined zones. This contrasts with the situation at Beacon Hill where fish are found at random and on all levels.

2. There are three such zones in the western sector of the deposit. Each zone is separated by approximately a metre of barren material.

3. Each zone is up to 10cm thick and consists of two or more sub-levels with respective fish on each.

4. The concentration of fishes within each zone is so great as to suggest that each is a true mortality zone.

5. The occurrence of sand and pebbles in association with the mortality zones suggests that the death and burial of fishes was rapid and catastrophic. This contrasts markedly with Beacon Hill where mortality was apparently due to natural causes and sedimentation was more uniform.

Rapid death and burial of fishes meant that they would have died in place. The good state of preservation and lack of damage points to little transportation and consequent attrition. Therefore study of the spatial relationships of insitu fish carcases should give clues to the nature of the original living environment.

By January 1983, approximately 700 fish fossils had been found by all workers and of these 600 had been found by me. Of the 600, just over 400 have been found insitu over an area of approximately 1,500 square metres. These have all been mapped in terms of their relationship to each other and of their distance and bearing from a fixed datum point. Orientations, dimensions and relative elevations of most fish have been recorded. Other features such as laminations, pebbles, plants and sedimentary structures have also been mapped. Preliminary findings are as follows:

1. Promecosomina occurs in profusion and makes up the bulk of the fish numbers. Cleithrolepis is the second most common fish and is represented by about fifty individuals. The predators Saurichthys and Birgeria were composed of but six specimens each; there were four small unidentified palaeoniscids; three Hydropessum; and one each of the dipnoan Gosfordia and the cestraciont shark Lissodus. Zeuchthiscus is subject to confirmation but appears to be represented by about six individuals.

2. Fish are not evenly distributed among the three zones. The middle zone contains by far the greatest abundance of generally large sized fishes. Yet the variety is limited to Promecosomina, Cleithrolepis, Saurichthys and a palaeoniscid. The lowest zone contains the greatest variety and the most exacitic form viz. Lissodus, Birgeria, Hydropessum, palaeoniscoids, possibly Gosfordia and also Promecosomina, Cleithrolepis and Saurichthys. The abundance in this zone is substantial but somewhat less and the sizes moderate to large. The upper zone, thus far, consists of Promecosomina and Cleithrolepis only, the sizes are small to moderate and the occurences are sparse.

3. Fish at Somersby are on the whole larger than nay other Sydney Basin fish fossils. Several specimens of Cleithrolepis are in the vicinity of 23cm and may be the largest known. Promecosomina is generally 18-24cm and is much larger than counterparts elsewhere. This may indicate that faunas in other localities are juvenile. Small specimens do occur at Somersby but are scarce.

4. Schooling or aggregation patterns can be detected. As in the present day, schooling is size-controlled rather than species-controlled. Consequently, Cleithrolepis and Hydropessum freely intermingle with Promecosomina, the larger ones with the larger Promecosomina and the smaller ones with the smaller. Schools of larger or smaller Cleithrolepis also occur by themselves.

5. Predator-prey relationships can be established. The carnivore Saurichthys is randomly distributed horizontally and attacks its prey singly. By contrast, Birgeria attacks its prey (Promecosomina) in packs. There is little evidence of creatures higher or lower in the food chain as yet.

6. Plants are not common. They consist mainly of equisetalean stems, the leafy shrub Rienitsia, the xerophytic Xylopteris and occasional accumulations of fine plant debris. Dicroidium is conspicuous by its absence.

Study of the fish fauna at Somersby may also throw light on correlation of elements within the Hawkesbury Sandstone, such as the relationship of the distal margins to the central accumulation. Just as the Gosford/Terrigal Formation may be considered to be the distal equivalent of the Hawkesbury Sandstone, so the distal Hawkesbury Sandstone and associated shale lenses at Somersby may be the distal equivalent of the Wianamatta sedimentation in the southern part of the Sydney Basin. Comparison of the Somersby fauna with that of the Wianamatta would at first seem to suggest close parallels. In both cases the common and widespread Sydney Basin fish Cleithrolepis seems to be waning and instead Promecosomina proliferates. However there may be other local factors influencing this. Somersby lacks the exotic palaeoniscoid fauna found in the Wianamatta. Comparing the Somersby fauna with those of Gosford, Beacon Hill and St. Peters reveals that of the nine genera, four were found at Gosford, three at Beacon Hill and two at St. Peters. It would seem then that the Somersby fauna most closely approximates that of Gosford which would make it Lower Middle Triassic, however the amazing profusion of the dominant fish Promecosomina approximates mostly the Wianamatta condition. Promecosomina was not found at Gosford and was insignificant at Beacon Hill.

One further observation of the fauna may be suggestive. Birgeria and the parasemionotids are marine fish and Saurichthys and the cestraciont sharks are predominantly so. This may cause us to rethink the regime of the Hawkesbury Sandstone or at least of the margins thereof. During the Lower Triassic palaeoniscid fishes were in great decline in the oceans but a remnant flourished in the freshwater environments. Palaeoniscid fishes flourish at Beacon Hill and in the Wianamatta. Their virtual absence at Somersby may indicate that the latter was marine or partly so.

The main finding of this paper is the Gondwana connection. Palaeoecology constitutes an important supportive study. Future work on the Somersby fauna will strengthen and modify both.

A COAL RESOURCE DATA SYSTEM

O. Shiels, Joint Coal Board

Abstract not supplied.

NATURAL OXIDATION OF COAL

P.R. Warbrooke, B.H.P. Coal Geology

Since oxidised coal adversely affects marketable reserves, coal quality and washery performance, it is important to understand the nature of oxidation and to develop methods of detecting this deteriorated material.

Samples from the Great Northern seam near Killingworth show a continuous decrease in oxidation with increasing depth. The flat lying, 4.43m thick seam is oxidised over the top 2.46m and is covered by 20m of weathered conglomerate. Five hand picked samples exibiting different visual degrees of oxidation, varying from highly oxidised to unoxidised (Table 1), were subject to chemical and spectroscopic analyses. Changes in laboratory carbonisation characteristics were not considered because of the poor coking properties of this seam. Variation in coal chemistry with increasing oxidation is shown in Table 2 and illustrated on Figure 1. Basically moisture (ad) and oxygen (dmmf) increase while carbon, hydrogen, nitrogen, sulphur and specific energy (all dmmf) decrease. Volatile matter (dmmf) initially decreases slightly then increases significantly in the highly oxidised coal. Vitrinite reflectance, with the exception of the low value recorded by the highly oxidised sample, shows no change with oxidation.

Figure 2 illustrates the changes in the organic functional groups during oxidation using Fourier Transform Infrared Spectroscopy (FTIR). These changes are highlighted by subtracting the two spectra (Figure 2) and indicate that, with increasing oxidation, there is a decrease in aliphatic C-H bands, increases in hydroxyl, ketone and carboxylate ion bands while aromatic C-H and C-C bands remain unchanged. Carbon - 13 Nuclear Magnetic Resonance Spectroscopy (NMR) measures the proportions of aromatic and aliplatic carbon in the coal and shows a decrease in the aliphatic carbon with a corresponding proportional increase in aromaticity as oxidation increases (Figure 3).

The mechanism of coal oxidation is poorly understood, partially because the complex structure of coal molecules are not fully known. FTIR analysis indicates an increase in the oxygen bearing functional groups and a decrease in aliphatic groups. This is further confirmed by NMR analysis which indicates a decrease in aliphatic carbon, thus effectively increasing the aromaticity. Oxygen appears to preferentially attack the aliphatic chains, incorporating oxygen into their structures and reducing the carbon and hydrogen contents by releasing CO_2 and H_2O. Similarly sulphur and nitrogen are probably released as oxides. As the result of oxidation, the cross linked structures of the coal molecules are broken down into smaller molecules containing carboxylic acid groups (humic acids). The behaviour of volatile matter is not understood and requires further work, however it is likely that volatile matter from oxidised coal is significantly different in composition from that of unoxidised coals.

TABLE 1

Sample	Degree of Oxidation	Description
A	Highly Oxidised Coal	Soft powdery and sometimes clayey "smut". Pulverised with fingers.
B	Oxidised Coal	Direct from ground is solid but has desiccation cracks. Paritally disinitergrates after natural drying.
C	Partially Oxidised Coal	Direct from ground has no desiccation cracking but some develop after natural drying. Remains fairly solid.
D	Apparently Unoxidised Coal	No desiccation cracks after natural drying but chemical analysis indicates slight oxidation. Associated with partially oxidised coal.
E	Unoxidised Coal	Shows no visible or chemical sign of oxidation.

TABLE 2

Sample	A	B	C	D	E
Moisture % (ad)	10.8	8.4	6.4	4.3	3.4
Mineral Matter % (db)	56.9	19.4	15.5	16.0	12.1
dmmf					
Volatile Matter %	51.0	28.6	28.8	28.1	35.6
Carbon %	68.4	77.3	79.6	82.1	83.5
Hydrogen %	1.54	3.11	3.62	4.73	5.02
Nitrogen %	1.30	1.36	1.51	1.62	1.52
Oxygen (by diff.) %	28.5	17.9	15.0	11.2	9.5
Organic Sulphur %	0.29	0.33	0.31	0.37	0.44
Specific Energy MJ/kg	21.62	28.46	30.27	32.19	34.47
Ro max Vitrinite %	0.68	0.78	0.77	0.77	0.77
Aromaticity (fa)	0.75	0.72	0.65	0.63	0.61

Reasons for the decrease in specific energy are more difficult to understand. A study of the heats of combustion of organic compounds indicates that heat of combustion decrease with increasing oxygen, aromaticity and decreasing hydrogen contents. Specific energy is a measure of the energy gained from burning coal in oxygen by breaking the C-C and C-H bonds and forming CO_2 and H_2O. Since oxygen already incorporated in the molecule will not contribute to the reaction, higher oxygen contents will cause an overall decrease in specific energy. This helps explain the trend shown by specific energy with changing rank. Figure 4 shows the specific energy increasing with increasing rank as the oxygen content decreases. Aromaticity increases but not enough to outweigh the effect of the decreasing oxygen. At high ranks (above 87% carbon) the oxygen decrease levels off, aromaticity increases and hydrogen decreases. As a result the specific energy begins to decrease with increasing rank. Specific energy decrease with increasing oxidation can be explained in terms of the increasing oxygen, aromaticity and decreasing hydrogen associated with oxidation.

All of the chemical and spectral variations outlined above can be used to detect oxidised coal in samples taken during exploration and operations, or in the washed product. However consideration has to be given to the economics, practicality and accuracy of the method chosen. For example specific energy (dmmf) is probably the best measure of the degree of oxidation but requires the determination of not only specific energy but ash (or mineral matter), CO_2, moisture and sulphur. This is expensive, time consuming and not a practical solution where large numbers of samples are involved eg. drilling to detect oxidised coal near outcrop. Similarily rapid detection of oxidised coal entering a washery or in the washed product could be carried out by FTIR spectroscopy. The Crucible Swelling Number of bright coal, a traditional indicator or oxidation, is of limited use in this case because the CSN of the unoxidised coal is initially low (2-3) and bright coal is sometimes difficult to obtain in this predominantly dull coal seam.

A useful relationship between specific energy and moisture (ad) has practical application in exploration and mine operations. Figure 5 shows the moisture content increasing with decreasing specific energy. For Great Northern seam coal, moisture contents above 3.5% are oxidised and above 5% are highly oxidised. Determination of moisture instead of specific energy is probably an economic alternative where large numbers of samples are involved.

Another simple method of detecting oxidised coal can be carried out in the field. Humic acids formed during oxidation are dissolved by a 10% NaOH solution producing a brown colouration. The intensity of the colour increases with increasing oxidation. Unoxidised coals produce no colouration. Comparison of colour intensities can give semiquantative indications of the degree of oxidation by using known quantities of sample and NaOH.

In summary, changes in coal structure and chemistry associated with oxidation are revealed by chemical and spectroscopic analysis and these variations can be used to detect oxidised coals.

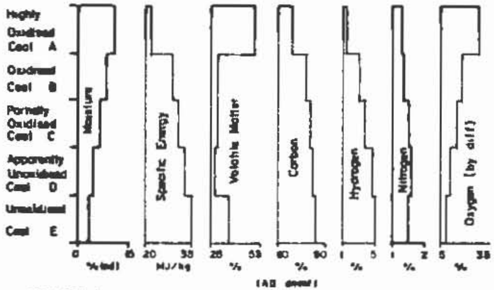


FIGURE 1

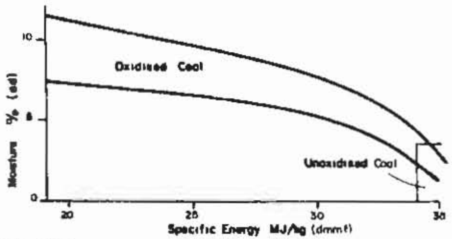


FIGURE 5

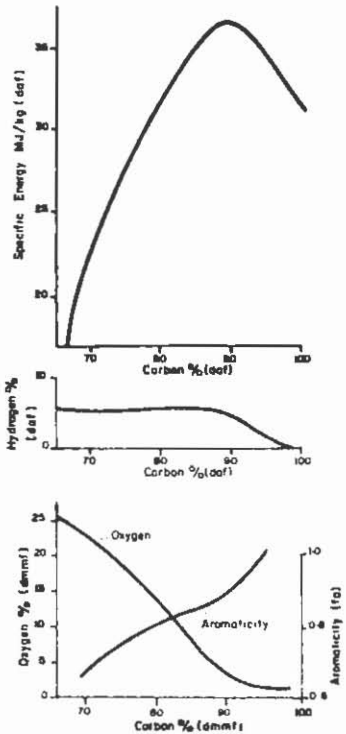


FIGURE 4

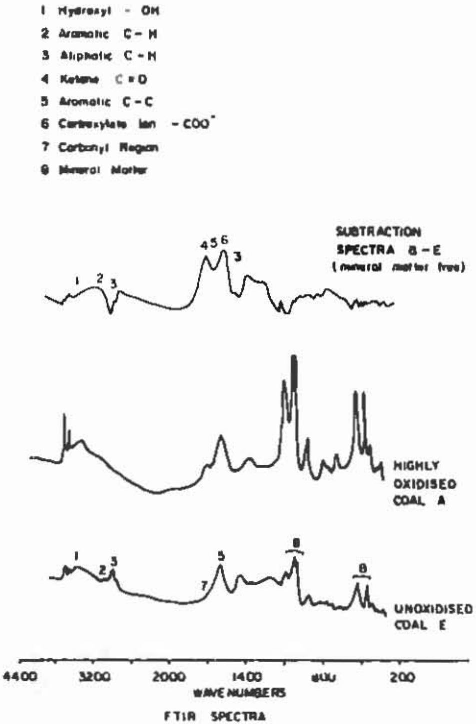


FIGURE 2

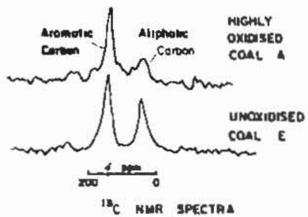


FIGURE 3

THE IMPACT OF COAL MINING ON THE GROUNDWATER RESOURCES OF THE UPPER HUNTER VALLEY

G.W.B. Gates, F.R. Kalf, Australian Groundwater Consultants Pty. Ltd.

ABSTRACT

The effects of coal mining on the occurrence movement and quality of groundwater in the Upper Hunter Valley is being studied by Australian Groundwater Consultants as part of a three year research program.

Permian Strata

Groundwater in the Permian strata: sandstone, shales and coal seams, occurs in fractures, joints and cleats and to a lesser extent in the pore spaces. Bore yields commonly range from 0.5 to 2.0 L/s but yields up to 9.0 L/s have been encountered. The coal seams are 10 to 100 times more permeable than the other rocks and are therefore the major conduits for groundwater flow. The coal seam permeability is still relatively low with a mean value of 0.11 m/day decreasing exponentially with depth. Because of this low permeability in the Permian strata water level declines around open cut and underground mines are not extensive.

One effect of mining has been to increase the permeability of the strata in the mined areas. For instance when spoil is replaced in open cut voids the broken rock has a permeability of up to 100 times greater than undisturbed strata.

Total dissolved salt concentrations of groundwater are in the range from 470 to 27,500 mg/L. Groundwater which is excessively high in salinity is generally found in areas with little structural deformation and low permeability. By contrast, those groundwaters with lower salinity occur in areas where the permeability is higher, associated with folding or faulting. The increased residence time of groundwaters in low permeability strata is considered to be a major cause for high salinities in the groundwater.

The salt pick up from runoff water over a disturbed mine surface is similar in salinity range (TDS = 200 to 1800 mg/L) to the natural undisturbed land surface. However leachate water that seeps from spoil dumps has a higher residence time in the spoil and as a result picks up more salt. Water analyses from piezometers constructed in spoil dumps indicate that while the salinity fluctuates considerably,

dependent on rainfall conditions, the overall salinity is greater than that for the undisturbed strata.

Unconsolidated Sediments

The Tertiary/Recent alluvial deposits of the Hunter River and its major tributaries are the most important groundwater resource in the valley. Aquifers under the Hunter River flats consist of shoe string channel deposits of sand and gravel capable of yielding 12 to 38 L/s to a well. The average permeability is 230 m/day for a standard thickness of seven metres. The aquifers are semi-confined and are surrounded by silt and clay overbank deposits called aquicludes, which themselves can sustain stock supplies of water to a well (supplies generally less than 2L/s).

Groundwater recharge is principally through direct hydraulic connection with the Hunter River and minor components through vertical infiltration of rainfall and side slope infiltration from Permian strata. The saturated depth of the sediments in the alluvium is governed by the river level. Under low flow conditions, the stream level is below the water table and groundwater discharges into the river. During high flows, water is recharged from the river into alluvial sediments.

Water quality in the alluvium ranges from a Total Dissolved Salt content of 285 to 2118 mg/L. Recent declines in the water table and increases in groundwater salinity are natural reactions reflecting climatic conditions and geological controls.

Mining to date has been restricted to the Permian outcrop areas and there has been no change to the flow characteristics, storage or chemical properties of the groundwater in the unconsolidated sediments.

If mining under the alluvial flats is allowed to proceed careful monitoring of the regional effects on groundwater and river flows will be necessary. Substantial pit inflows can be expected where mines cut across transmissive aquifers and this will be accompanied by a decline in the groundwater levels. The extent of decline could be up to several kilometres depending on localised hydrogeological controls such as permeability and storativity.

COMPUTER MODELS AID PLANNERS

Numerical computer models have been developed and checked against mine records to simulate the flow characteristics of the groundwater system and to make predictions on water inflows to pits, dewatering effects on neighbouring properties and changes in water quality with time. These computer methods and models provide an important aid to mine planners and environmental personnel in estimating the effects of mining on the surrounding groundwater system.

DIVERSITY, STRUCTURE AND COMPOSITION OF SOME EARLY CARBONIFEROUS BENTHIC MARINE FAUNAS IN THE SOUTHERN TAMWORTH SHELF

I.H. Lavering, Esso Australia Ltd.

A thin sequence of near-shore marine sediments of Late Visean (Early Carboniferous) age, at Mount Breakneck in the Southern Tamworth Shelf, contains twenty separate accumulations (faunas) of shelly marine invertebrates spread over three kilometres of strike. Each fauna is unique in composition but their diversity and structure varies according to sediment type and palaeoenvironments. Each fauna is unique in composition but their diversity and structure varies according to sediment type and palaeoenvironments. Each fauna consists of an in situ accumulation of shells spread over three distinct facies in the sequence; an upper, middle and lower facies.

The lower facies consists of sand and silt, deposited close to the shoreline, and this passes offshore into mud and silt. The middle facies contains a more extensive belt of near-shore sand and silt and this part of the sequence contains the most diverse faunas. The upper facies of the marine unit consists of poorly-sorted silty sand which was deposited as the seaward part of a wave-dominated delta. Low-diversity faunas are present in this part of the sequence and they consist of collections of up to four species, one of which is usually superabundant. This contrasts with faunas in the middle and lower facies of the sequence which consist of collections of up to twenty-five species where species populations are of similar size.

Faunas were sampled by collecting twenty-five kilograms of fossiliferous strata from each. Samples of the same weight were required in order to measure the composition, faunal structure and species diversity of each fauna. Composition is measured by identifying the species present and their abundance. Faunal structure is measured by the relative size of each species population present in the fauna. A fauna can consist of a large number of species with similar population sizes, or few species with very large population sizes. Few of the shells present exhibit evidence of damage prior to or after burial and preservation.

Faunas within the marine sequence do not cluster into distinct depth-limited communities. Instead a more subtle inter-grading of faunas is evident. Some species form recurrent associations, others do not. This is a pattern of faunal variation which is common to other faunas of the same age in the Southern Tamworth Shelf (Lavering, 1978). A limited number of brachiopod species are the dominant form in most communities or faunal elements. These possibly had a competitive edge compared to others. Reasons for this are not clear; better adaptation to shallow marine conditions, faster reproduction rate and greater shell stability during storms are some of the possibilities.

The pattern of faunal variation in the marine sequence is parallel to that observed by Whittaker (1970) who noted that natural environments are marked by the presence of intergrading communities of organisms whose patterns of variation and abundance are related to the changing environmental gradients.

References:

LAVERING, I.H., 1978: A palaeoenvironmental study of some Early Carboniferous sediments and faunas from the Southern New England Belt of New South Wales. University of New South Wales Ph.D. Thesis, (Unpublished).

WHITTAKER, R.H., 1970: Communities and Ecosystems. Macmillan Co., London, 158p.

A PRELIMINARY INVESTIGATION FOR THE RECONSTRUCTION OF THE NEW ENGLAND HIGHWAY OVER THE LIVERPOOL RANGE

J.R. Williams, N.S.W. Department of Mineral Resources
D.C. Starr, J.P. Harvey, Soil Mechanics Ltd.

The New England Highway crosses the Liverpool Range at Ardglen Gap, 4km north west of Murrurundi. The Murrurundi Fault passes through the Gap and forms a boundary between Tertiary Liverpool Range Basalts to the west and Carboniferous pyroclastic rocks to the east. Triassic sediments consisting of conglomerate, sandstone and mudstone also outcrop in the area south of the Gap, and are overlain unconformably by the Liverpool Range Beds.

Since construction of the present road line in 1937, there has been a record of instability of embankments constructed on steep sidelong ground south of Ardglen Gap, where the Liverpool Range Basalts outcrop. Shallow surface slides are also noted in colluvial material, and within Triassic mudstones on the south east side of the Gap towards Murrurundi.

In 1979, a site investigation was carried out by the DMR to provide preliminary data for a new alignment east of the Gap. The new alignment would involve deep cuttings in the Carboniferous pyroclastic rocks which outcrop north of the Murrurundi Fault.

The preliminary investigation comprised eighteen rotary drill-holes, the installation of standpipe piezometers, and geological mapping of the route corridor. An engineering geological survey was subsequently carried out to inspect existing road cuttings, and to relate geomorphological features to the geology. Apart from lateral variations and the presence of clay bands in both the Liverpool Range Beds and Carboniferous pyroclastic rocks, the geology is complicated by alteration and brecciation along the line of the Murrurundi thrust fault.

The geological setting is described by reference to photographs and an engineering geological plan. Results of the investigation are outlined, and the implications for cutting design discussed.

SEDIMENTOLOGY OF THE EARLY CARBONIFEROUS FLAGSTAFF SANDSTONE

I.H. Lavering, Esso Australia Ltd.

The Flagstaff Sandstone is a thick sequence of mainly-marine sediment deposited along the western margin of the Southern Tamworth Shelf during the Late Visean. Sedimentary facies in the sequence range from an offshore marine turbidite association, to a shelfal succession with some oolitic carbonates, and an upper non-marine sequence.

Depocentre for the whole sequence is located offshore where over 1000 metres of sediment was deposited in a shallowing-upwards trend. The turbidite facies comprises the basal part of this sequence and it passes upwards into shelf sediments and the Verulam Oolite Member. Nearshore areas were infilled by progradation of the non-marine facies onto the shallow marine shelf.

The shelf facies is marked by tabular sandstone units, between 10 and 20 metres in thickness, which are separated by encasing mud and silt. The sandstone units were deposited as shelf bars which were elongate parallel to the shoreline. They formed by longshore drift currents and were subject to periodic reworking by storm activity. The sand which formed the bars was derived from deltaic parts of the non-marine association.

Two major processes were active during deposition of the shelf facies, (1) fair-weather longshore drift currents, and (2) storm-generated currents which produce cross-shelf transport as well as bar erosion and reworking. Erosion of the shelf bars is evident on the central and seawards parts and is shown by the development of irregular erosion surfaces and spill-over lobes, in the form of a coarsening-upwards splay, on the shoreward side of the bar.

Sedimentation during fair-weather conditions consisted of longitudinal sand migration along the bars in the form of ripples and sand-waves. Swales developed in between the sand-waves and these received mud and silt. Cross bedding and rippling are thus the main internal features of each bar. Bioturbation is also evident but is most prolific on the shoreward parts of the back-bar.

Sedimentation during storm activity consisted of deep scouring and erosion of the upper part of the bar, and the erosion of clay drapes from the sides of the bar, to form clasts of mud encased in sand deposited as storm-lag material.

The upper part of the shelf facies covers a wide area and contains a fossiliferous marine carbonate sequence deposited as a coraline and oolite bank (Verulam Oolite Member). The middle part of the shelf sequence contains little sandstone compared to the over and underlying parts. This has been designated as the Lostock Member; it was deposited as a silt and mud-rich sequence during a period of low clastic influx. Shelly invertebrate faunas are most prolific in this part of the sequence.

Non-marine sediments are present in the southwestern extent of the Flagstaff Sandstone and consist of massive conglomeratic sandstone with some tuffs and ignimbrite bodies (Mount Rivers Ignimbrite Member). This facies provided much of the detritus which was transported onto the marine shelf and area of turbidite sedimentation. It was deposited close to the acid-volcanic source which produced all of the Flagstaff Sandstone sediments.

MACQUARIE COLLIERY, YOUNG WALLSEND SEAM, AN ANALYSIS OF STRESS RELIEF MINING

R. Turner, R. Warner, Broken Hill Pty. Co. Ltd.

1. INTRODUCTION

Macquarie Colliery is located 16km south west of Newcastle and is mining the Dudley seam with different combinations of the Nobbys seam together, making the Young Wallsend seam. Mining is at a depth of 250m to 350m below sea level. The area studied was 1 South East Headings where two continuous miner and shuttle car units operated. The major mining sequence was the right-hand side unit mining Nos. 7, 6, 5 and 4 headings, and simultaneously the left-hand side unit mining Nos. 1, 2 and 3 headings in those sequences. After and during the headings being driven, they were connected with cut-throughs. The panel of the seven headings was mapped between 19 and 47 cut-through, with the roadway conditions after mining divided into five categories ranging from very poor to very good.

With a knowledge of the sequence of mining the mapped roadway conditions revealed that each heading, when driven, would stress relieve the subsequently driven headings.

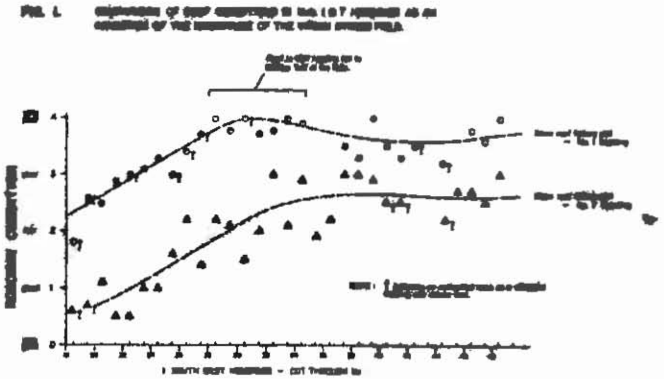
2. ROADWAY STABILITY

The stability of a roadway or series of roadways is a function of three variables.

a) Rock Properties or the mechanical strength of the varying rock types around the opening. Included in this is the pre-existing tension joints, shear joints, cleats and bedding planes which in most situations will lower the mechanical strength of the different rocks.

b) The virgin stress field that is operating at the present time. This includes magnitude and orientation of the stress ellipsoid. From strain relaxation tests on bore core the stress field in Macquarie Colliery has sigma 1 and 2 horizontal with the ratio of sigma 1, 2 and 3 approximately 1.5:1.2:1.

c) The method of mining the coal. Included in this category are the dimensions, geometry and orientation of the mined opening. The



method of cutting the coal at the face, the type of roof support used and the sequence in which the roadways in a panel were driven.

The sequence of mining was the major contributing factor to the wide variation in roadway conditions across the panel.

3. OBSERVED ROADWAY CONDITIONS IN 1 SOUTH EAST HEADINGS

a) Classification of Roadway Conditions

The classification of the mapped roadway conditions was based on distinctive features which indicated the relative degree of deformation around the roadway. The classification of roadway conditions ranged from very good to very poor with a numeral rating given to each classification. For example 0 to 0.9 for very good, 1 to 1.9 for good and so on for fair, poor and very poor. This allowed an average rating to be given to each heading over its length worked in one cycle of development.

b) Areal Variation in Roadway Conditions

Heading Nos. 1 and 7 were the first driven by each of the two units during a development cycle. These headings were subject to the initial impact of the virgin stress field and thus exhibited the poorest roadway conditions experienced over the whole panel. Figure No. 1 shows the comparison of the average magnitude of failure between these two headings indicating a stress field magnitude gradiant across the panel decreasing from No. 1 to No. 7 headings. This could be related to the dyke zone located around 200m away from No. 1 heading. A second feature is the progressive deterioration of the roadway conditions inbye of 19 cut-through. This could be a function of the increasing depth below sea level of the seam as development advance.

c) Local Variation in Roof Conditions

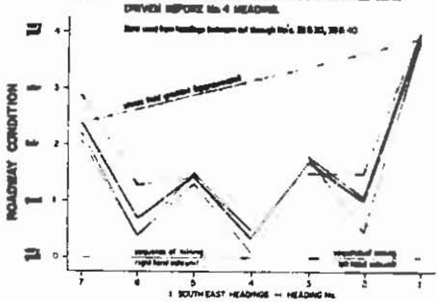
Several mining sequences were used during the development of 1 South East Headings. The dominant sequence used by the two concurrently developing units was that described in the introduction and is level mining sequence A.

Figure No. 2 illustrates the typical failure pattern manifest by this sequence in the right and left hand side units. The principle of stress relief is such that the first heading driven experiences the full effect of the virgin stress field. The failure of the first heading has a shadowing effect on the second heading driven adjacent to it and reduces the magnitude of the virgin stress field acting on the second heading.

The amount of stress relief gained from the failure of the first heading driven is shown in Figure No. 2. For example, the failure in No. 7 heading reduced the magnitude of roof failure in No. 6 heading by 68% of the expected magnitude of failure had No. 6 heading been driven first. Similarly in the left-hand side unit the magnitude of roof failure in No. 2 heading was reduced by 65% of that expected if No. 2 heading was driven first. The amount of stress relief by the second heading was found to range from 15% to 80% of the magnitude of failure that would have been experienced if it was driven first.

FIG. 2 MINING SEQUENCE A

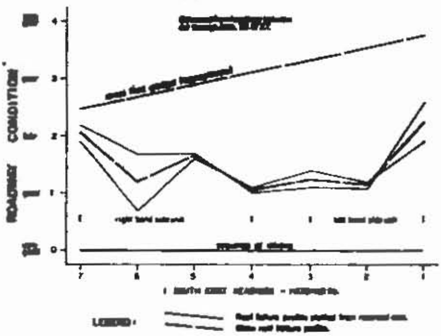
ROOF FAILURE PROFILE WHERE No's 3 & 5 HEADINGS WERE DRIVEN BEFORE No 4 HEADING



MINING SEQUENCE B

FIG. 3.

ROOF FAILURE PROFILE



The condition of the third heading driven was a function of the relationship between the first and second heading. On average, the magnitude of failure in the third heading driven is about 50% to 60% of what would be expected if the third heading was driven first.

No. 4 heading driven by the right-hand side unit was stress relieved further to 30% of its unrelieved magnitude.

d) Stress Relief Mining Principle

The first heading driven in a panel will experience the maximum effect of the virgin stress field and will, by the consequence of the failure around it, have the potential to stress relieve adjacent headings.

For example, the fourth heading driven is stress relieved by the three previously driven headings and the degree to which this heading is stress relieved is a function of:-

(i) The distance from each previously driven heading and,
(ii) the magnitude of brittle failure around each previously driven heading.

The principle behind stress relief mining is probably related to the three phases of deformation or rock failure around a heading. These occur in order of elastic, plastic and brittle deformation. The extent of brittle failure around a heading is not far enough to have a direct contribution to stress relieving an adjacent heading. However, the magnitude of brittle failure has a direct effect on the distance the elastic and plastic deformation front is propagated from a heading. Therefore, brittle deformation may extend for metres into the surrounding strata and elastic and plastic deformation extends for tens of metres beyond the extent of brittle deformation. This is the means by which stores strain energy would be partly released in the area where the adjacent heading is to be driven.

e) An Alternate Sequence of Mining

From an understanding of the principle of stress relief mining an alternate sequence of mining B was tried in the 1 South East Headings and was successful in reducing the magnitude of failure in No. 1 heading by 40% to 50%. Figure No. 3 illustrates mining sequence B where the right-hand side unit drove Nos. 7 to 4 headings followed by the left-hand side unit driving Nos. 3 to 1 headings in that sequence.

4. CONCLUSION

In high stressed areas where roadway stability is a problem to efficient mining the understanding of the principle of stress relief mining may have a contribution in increasing the overall roadway stability of a development panel.

GEOLOGICAL PARAMETERS AFFECTING SEAM GAS CONTENT & COMPOSITION IN THE COLLINSVILLE COAL MEASURES, COLLINSVILLE, QUEENSLAND

R.J. Williams, J. Giedl, Collinsville Coal Co. Pty. Ltd.

Over the past decade, the frequency and distribution of gas-related incidents in Australian collieries has significantly increased. "Gassing-out" of working places and the occurrence of instantaneous outbursts of coal and gas reflect the trend of increasing inherent gassiness and the adoption of high-volume methods of production. Gas problems are being encountered at relatively shallow depths by world standards and it is apparent that there will be an increasing need to assess seam gassiness and improve upon methods of alleviation and control.

The determination of gas content and composition is of fundamental importance in the planning of ventilation systems in coal mines and in the assessment of outburst potential. The authors believe that gas content and composition determinations should be undertaken in all prospective underground mining areas to the extent that the gas content gradient with depth or gas content distribution is reasonably well known.

Gas contents can be determined at any stage in the history of a colliery's development - from surface borecore during exploration to underground sampling at the face. There are a variety of methods available which fall into the direct or indirect categories. At Collinsville, a modification of the U.S. Bureau of Mines technique is mainly used (McCulloch & Diamond, 1976). The method determines the desorbable gas content from intact coal cores placed in sealed containers. It is the slowest of the direct methods but is among the most accurate and has the advantage of leaving the core intact for subsequent testing.

The virgin gas content of a seam is the end result of complex geological processes. Ettinger et al. (1966) showed that the sorbtion capacity of coal depended primarily on rank, but was also influenced by coal type depending upon the composition of the sorbed gas and the sorbtion pressure. The gas content and composition is also influenced by its genesis - whether a product of coalification or introduced from an external source such as igneous intrusion. The reservoir characteristics of the strata are also important.

A commonly applied indirect method determines gas content from gas pressure measurements by reference to laboratory determined gas pressure/sorbtion isotherms. From the relationship with pressure, gas contents would be expected to increase with depth due to increasing hydrostatic pressures. Gas pressures are generally below the hydrostatic pressure and it has been shown in the United Kingdom (Dunmore, 1982) and in the United States (McCulloch and Diamond, 1976) that the often measured increase in gas content with depth is the result of an increase in coal rank with depth.

At Collinsville, an extensive program of gas content determinations has been implemented primarily to define the regional outburst proneness of the potentially economic seams and as a basis for mine planning of high gas reserves. Considerable effort has been expended to assess the effect of geological parameters on gas content. Every gas content determination is accompanied by gas composition, petrographic and reflectance analyses, in addition to the normal analyses for reserves assessment from surface borecore.

The Collinsville Coal Measures are developed around the northern tip of the Bowen Basin. They are generally 200 m thick and at Collinsville dip to the south at an average of 8°. The measures contain six potentially mineable seams, the most important of which for underground mining are the Garrick and Bowen Seams. The coal measures are geologically complex with rapid changes in coal type and extensive silling by igneous intrusions.

Vertical Ro-depth factors are very high and vary over the field from 0.08%/100 m to 0.19%/100 m, reflecting the influence of igneous activity. Because of this, the Garrick seam which overlies the Bowen seam by 100 m, has a rank of 1.1% mean random reflectance (MRR) compared to around 1.25% MRR for the Bowen seam. In contrast, the rank of individual seams does not appreciably increase with depth, indicating pre-tilting coalification.

The seam gas generally is almost pure carbon dioxide with desorbable gas content values ranging from zero up to 27 m^3/t. Isotope studies by the CSIRO (Gould, Hart and Smith, 1982) show the carbon dioxide to be externally derived with isotope compositions consistent with a magmatic origin. An igneous origin is supported by the association of high gas contents and igneous intrusions.

In #2 Mine area, the desorbable gas content of the Bowen seam increases very rapidly with depth (16m^3/t per 100 m depth). Such a high increase cannot be caused by depth but is the result of extensive igneous intrusions which have produced vertical rank gradients ranging from 0.15% to 0.19%/100 m depth in this area. To the east of #2 Mine, gas contents at equivalent depths are lower by a factor of two. Igneous activity is less extensive and vertical rank gradients are lower, ranging from 0.8-0.11%/100 m. Very high desorbable gas contents (8.5-13 m^3/t) have been determined at shallow depths (127/175 m) where the seams were associated with igneous intrusions.

Discrete rank values generally showed no relationship to gas content. This does not mean that rank has no effect on gas content. Igneous intrusions dictated the gas distribution to the extent that the more subtle changes due to rank variations were not discernible. Coal type variations did appear to have a slight effect on gas content with high vitrinite coals containing more gas under equivalent conditions. Further studies on the effect of coal type and rank on gas content are in progress.

The study of gas content distributions has had a considerable impact on mine planning. Areas of varying gassiness have been defined for different seams and the quantitative results obtained have greatly improved the accuracy of mine planning in high-gas, outburst-prone areas. The policy of carrying out extensive gas content determinations in all seams will also assist mine ventilation planning.

The authors believe that geologists supervising drilling programs are in a good position to undertake these types of gas content determinations and make lease-wide assessments of the virgin gas composition and content distribution.

References:

Dunmore, R., 1982. Predicting Methane Emission Levels and Air Quantity Requirements for Longwall Workings. ("Access" magazine of the Uni. Coll. Cardiff Min. Ex. Soc.)

Ettinger, I.L., Eremin, I., Zimakov, B. and Yanovskaya, M. 1966. Natural Factors Influencing Coal Sorbtion Properties. 1- Petrography and the Sorbtion Properties of Coals. Fuel 45: 267-275.

Gould, K.W., Hart, G. & Smith, J.W., 1982 Isotopic Studies of Gas and Core Samples from Exploratory Bores Collinsville, Queensland. CSIRO Restricted Investigation Report 1361R.

McCulloch, C.M. and Diamond, W.P., 1976 Inexpensive Method Helps Predict Methane Content of Coal Beds. Coal Age, 81, 6: 102-106.

GEOLOGICAL OBSERVATIONS AND MINING CONSIDERATIONS AT ULAN, N.S.W.

M.A. Johnstone, J.S. Luxford, Ulan Coal Mines Ltd.,
K.H.R. Moelle, The University of Newcastle

The geological setting of the Ulan Seam in the northwestern fringe area of the Sydney Basin has led to particular geological and mining engineering investigations.

Upper Permian Coal Measure rocks overlie Carboniferous granite in the Ulan area and are covered by a relatively thin (approximately 100m) Triassic sequence.

The sedimentary rockmass is very gently folded about N50°-60°E trending axes, contains a number of shear zones and well developed joint systems. In addition to the diastrophic structures, several primary anisotropies have been developed.

Several sedimentological and structural aspects of the Ulan Seam and its roof- and floorstrata have been analysed with a view to assisting with the planning and layout of the two new collieries.

Coal mining operations at Ulan No.2 Colliery have proved to be valuable indicators for rockmass performance and behaviour using a variety of methods for pillar extraction. Directional roadway stability can be achieved in several parts of the colliery. Structural analyses have been combined with petrophysical and rockmechanics investigations in an effort to identify those anisotropies that control the mechanical behaviour of the roofstrata.

Sedimentological features have contributed to bed separation in the immediate roofstrata in some sections of the mine.

Structural domains have been delineated in the existing panels of the Ulan No.2 Colliery on the basis of detailed fracture measurements.

Significant differences in maceral composition have also been identified in the immediate coal roofstrata.

Comparisons between established and defined anisotropies in the current working section of the Ulan Seam and features on the surface have shown that three joint systems are common to the Permian and Triassic succession, namely:

1. WNW - ESE
2. NNW - SSE
and 3. NNE - SSW.

Prominent fracture patterns in the underlying Carboniferous granite also fit into those common systems.

A total of 1426 fracture measurements in the Ulan Seam gives the following two statistically determined mean fracture trend attitudes:

N82°W
and N21°E.

When all maxima and submaxima are considered separately, five discontinuities can be identified in the Ulan Seam with the following spatial attitudes:

1. N88°W - 80°NE
2. N70°W - Vertical (Shear)
3. N13°W - 74°NE
4. N02°E - 84°SE (Tensional)
and 5. N20°E - 86°NW (Tensional).

General fracture plane trends in the Permian sequence have been statistically determined from 2847 measurements as:

N82°W
and N19°E.

Sedimentary transport directions in the Triassic sequence have been measured as 46° and 116° respectively. The mean fracture trends in the Triassic are:

N35°W
and N51°E.

The success of future longwall mining operations will probably depend to a significant extent on the mechanical influence of folds, fracture patterns, overburden lithologies and primary sedimentary structures.

Several methodologies are currently being considered and discussed for the extraction of parts of the Ulan Seam and different layout patterns are developed for this particular geological setting.

Tectonophysical and rockmechanics data are being used to optimise layout and design parameters and to assist as much as possible in the selection of mining equipment.

The mechanical behaviour of rocks involved in future mining processes is not only "stress-strain" dependent in the conventional sense, but also "history" and "structure" dependent.

A PRELIMINARY REPORT ON IGNEOUS ACTIVITY NORTH OF MT. YENGO, N.S.W.

A.S. Ritchie, R. Evans, The Amateur Geological Society of the Hunter Valley

1. INTRODUCTION

12.4 km to the north of Mt. Yengo (Mt. Yengo 1:25000 sheet 9032-11-S, G.R. 992 483) lies Mt. Wareng or "Little Yengo". (Howes Valley 1:25000 sheet 9032-11-N, G.R. 993 607). 13.3 km further north is Mt. Poppong (Howes Valley 1:25000 sheet 9032-11-N, G.R. 999 740). Both of these elevations were reported by local residents to be capped with "black rock". Members of the society have made several trips to Mt. Wareng. Access is by road and bush-track through private property from Howes Valley. Further visits to Mt. Wareng and to Mt. Poppong are scheduled.

2. STRUCTURE

Mt. Wareng is capped by about 122 m (400 ft.) of fine to coarse basic intrusive rock, lying on Hawkesbury sandstone but having no cover rock. The sandstone is ferruginous near the contact which, however, is obscured by the igneous rock talus. Vegetation and talus, in general, obscure definite outcrop rock on the slopes.

Distinct textural and mineralogical variations indicate the presence of

(a) a fine-grained rock from a lower basal selvedge.

(b) A fine to medium grained olivine-rich rock and

(c) a coarser plagioclase-rich rock constituting the bulk of the igneous mass.

To some extent, then, the structure corresponds to that reported of Mt. Yengo (see Abstracts, Newcastle Symposium, 1981), but the total thickness is only about two-thirds of that at Mt. Yengo.

There is a slight thinning out of the igneous body (133.5 m (438 ft.) at the southern and 127.4 m (418 ft.) at the northern end) to the north.

3. PETROGRAPHY

The mineralogy comprises

(a) Plagioclase: fresh twinned laths, weakly oriented - approximately 55% by volume,

(b) Titanaugite: small sub-hedral grains, weakly sub-ophitic in places, strongly zoned to pink rims, approximately 25% by volume,

(c) Olivine: small and less frequent, larger sub-hedral grains. All are zoned but the smaller grains more strongly so. The composition is forsteritic - approximately 13% by volume.

(d) Titaniferous Magnetite: scattered equant grains, 20% by volume.

(e) There are patches of interstitial alkaline mesostasis comprising zeolite (probably natrolite), ilmenite, alkali feldspar, green acmitic clinopyroxene, aenigmatite, apatite and analcime. The mesostasis constitutes about 5% by volume of the whole rock.

Variations in mineral proportions and textures occur suggesting some degree of layering. The mineralogy, however, is typical of the crystallisation of an "alkali-olivine-basalt" magma in a shallow crustal setting.

A more comprehensive report on igneous activity in the Howes Valley district is envisaged in a future communication.

4. ACKNOWLEDGEMENTS

Generous assistance from the staff of the Department of Geology, University of Newcastle is gratefully acknowledged.

THE LONGITUDINAL GRAVITY HIGH OVER THE SYDNEY BASIN AND ITS GEOLOGICAL SIGNIFICANCE

I.R. Qureshi, University of New South Wales

THE MEANDARRA GRAVITY RIDGE

West of the broad gravity lows over the New England granites, the Gravity Map of Australia shows three distinct linear anomalies that run north-south along the major structural trend of the region. The Namoi Gravity High lies over the Tamworth Foldbelt. The Gwydir Gravity Low runs to the west in proximity and parallel with the Hunter-Mooki Thrust and the Meandarra Gravity Ridge runs further west over the Gunnedah Basin. The three anomalies form a continuous feature for a length of over 500 km from the Liverpool Range in the south to Meandarra in Queensland.

THE WOLLONDILLY-BLUE MOUNTAINS GRAVITY GRADIENT ZONE

South of the Liverpool Range, in the Sydney Basin proper, the most prominent feature of the Gravity Map is the Wollondilly-Blue Mountains Gravity Gradient Zone. This zone lies over the Lapstone Monocline, the Kurrajong Fault and the 'hinge line' (Bembrick et al., 1980). The zone runs as a single entity for a distance of 140 km from Moss Vale to Bilpin, where it splits into two branches, one runs northwards in a subdued form up to the Liverpool Range while the other heads north-eastwards towards the Lochinvar Anticline. A gravity high is placed between the two branches, north of the junction, whilst to the south a high parallels the main gradient zone to the east. The high is succeeded eastwards by a gravity low. The placement of the high over a broad synclinal feature in the Sydney Basin and the low over the Kulnura Anticline represents an apparent contradiction with geology (Mayne et al., 1974).

NEW GRAVITY MEASUREMENTS

New gravity measurements partly reported earlier (Qureshi, 1981) now amount to over 500. These were made along selected profiles at a spacing of 2 to 3 km. Terrain corrections have been applied and these amount to as much as 6 mgal in rugged areas. The accuracy of reduced Bouguer anomalies is estimated at better than 1 mgal.

A QUANTITATIVE STUDY OF THE GRAVITY ANOMALIES

A quantitative study of the anomalies has been carried out along the longest profile between Bathurst and Mona Vale, along which 87 gravity stations have been observed. An Airy-type isostatic model has been constructed for the Blue Mountains and the transition zone between the continent and the ocean. This model predicts a smooth eastward increase in gravity from a minimum of -70 mgal over the mountains to +13 mgal at the coast. The effect of the Sydney Basin sediments is computed on the basis of the seismic data and this shows a steady decrease, east of the "hinge line" with a maximum gradient over the Lapstone Monocline. The effect reaches a minimum of -41 mgal over the thickest part of the basin and increases only slightly (-39 mgal) over the Kulnura Anticline which obviously represents a gentle flexure. When these effects are accounted for, the residual anomalies show a prominent, nearly symmetrical gravity high centred at the same position as in the uncorrected Bouguer anomaly profile and a small eastward increase in gravity. The latter may reflect a deep fault or an eastward thinning of the crust at a slightly greater rate than what is allowed in the isotatic model.

THE RESIDUAL GRAVITY HIGH

The resolved gravity high turns out to be the more important feature than the gradient zone as the latter is largely explainable by the isostatic effect. A branch of the high probably continues in a north-easterly direction to meet a similar feature over the Lochinvar Anticline revealed in a previous study (Qureshi & Nalaye, 1977). Its northerly extension ends south of the Liverpool Range some 40 km to the east of the southern end of the Meandarra Gravity Ridge. It is suggested that the gravity high in the Sydney Basin is most probably a displaced continuation of the Meandarra Gravity Ridge.

The gravity high almost completely masks the expected negative effect of the Sydney Basin sediments and this explains the apparent contradiction with surface geology. The high has an amplitude of about 49 mgal, a base width of about 60 km and a half-width of 32 km. Preliminary two-dimensional modelling based on the assumption of a uniform density contrast,suggests the source width to be about 41 km and a thickness varying from 2.5 km at the margins to about 8 km towards the axis, the entire source lying within the upper 10 km of the crust. Models favour a density contrast of 0.2 gcm^{-3} and give shallow depths to top, ranging from 3 km at the margins to only 600 m at the axis. It seems highly probably that the density of the source increases towards its axis. Models based upon variable density contrast are likely to give greater minimum depths and less variation in thickness.

THE NATURE OF THE SOURCE

The preliminary quantitative analysis of the gravity high suggests a source that has a density of about 2.9 gcm^{-3}(2.7 gcm^{-3} being the assumed density of the Lachlan Foldbelt rocks), lies probably immediately at the base of the Basin sediments and has a thickness of 4-5 km. Basalts of the Allandale and Lochinvar Formations (penetrated in Kurrajong Height No. 1, see Mayne et al., 1974) could possibly meet these requirements. A larger and deeper 'Lochinvar Anticline' with an intrusive gabbroic core (see Nalaye, 1977) may be a possible candidate. A thickness exceeding 600 m of basic volcanics of Permian and possibly older age, has been penetrated in exploration wells at depths of as much as 1500 m below sea level in Gunnedah Basin (E. Scheibner, personal communication). These rocks would probably account for the Meandarra Gravity Ridge. Considering the great linear extent of the gravity high, it may well mark a buried volcanic arc which was presumably active in the Carboniferous times. The possible sources mentioned here, should not be considered to be exclusive of each other.

The isostatic model, used in the interpretation, does include thinner crust under the Sydney Basin than under the Blue Mountains, but the gravity high has its source largely within the upper crust (c.f. Qureshi, 1975).

REFERENCES

Bembrick, C., Herbert, C., Scheibner, E. & Stuntz, J., 1973. Structural subdivision of the New South Wales portion of the Sydney-Bowen Basin. Q. Notes geol. Surv. N.S.W., 11, 1-13.

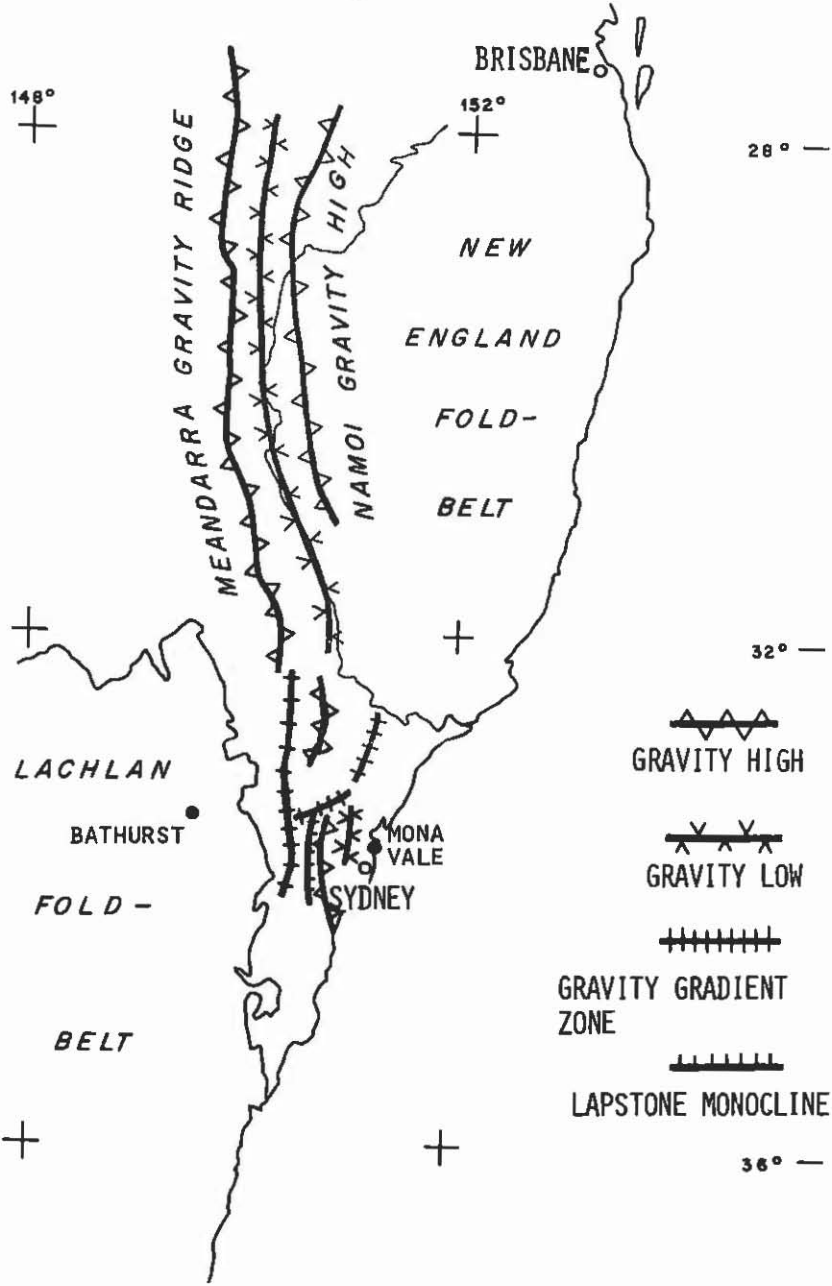
Mayne, S.J., Nicholas, E., Bigg-Wither, A.L., Rasidi, J.S. & Raine, M.J., 1974. Geology of the Sydney Basin - A Review, B.M.R. Bulletin No. 149.

Nalaye, A.M., 1977. A geophysical study of the Sydney Basin. M.Sc. Thesis, University of New South Wales.

Nalaye, A.M. & Qureshi, I.R., 1977. A geophysical study of the north-eastern part of the Sydney Basin. Eleventh Symposium on "Advances in the Study of the Sydney Basin", Department of Geology, University of Newcastle.

Qureshi, I.R., 1975. The crust beneath the Sydney Basin. Tenth Symposium on "Advances in the Study of the Sydney Basin", Department of Geology, University of Newcastle.

Qureshi, I.R., 1981. New gravity measurements over the western flank of the Sydney Basin. Fifteenth Symposium on "Advances in the Study of the Sydney Basin." Department of Geology, University of Newcastle.


BRISBANE
148°
152°
28°
32°
36°
MEANDARRA GRAVITY RIDGE
NAMOI GRAVITY HIGH
NEW ENGLAND FOLD-BELT
LACHLAN FOLD-BELT
BATHURST
MONA VALE
SYDNEY
GRAVITY HIGH
GRAVITY LOW
GRAVITY GRADIENT ZONE
LAPSTONE MONOCLINE

ORIGIN OF THE COASTAL VALLEYS IN THE SYDNEY REGION

R. Coenraads, University of British Columbia

A number of coastal valleys are cut into the Triassic Hawkesbury Sandstone and Narrabeen Group and filled with Quaternary alluvium. They are found on Sydney's northern coastline between North Head and Palm Beach.

The bedrock topography and sediment fill of these valleys have been determined by geophysical methods and borehole data, in order to draw firm conclusions as to their origin.

The results strongly suggest that the northward flowing, entrenched meandering river system proposed by Taylor (1958) is unlikely and that much smaller, independent stream systems, flowing in a south-easterly direction were responsible for the present observable features. The coastal valleys are very similar in nature because they are structurally controlled by the predominant orthogonal joint set in the rocks of this part of the Sydney Basin.

PETROLEUM SOURCE ROCK STUDIES OF THE PERMO-TRIASSIC SEQUENCE INTERSECTED IN DM HOWES HILL DDHI AND THEIR RELEVANCE TO THE PETROLEUM PROSPECTIVITY OF THE GUNNEDAH BASIN

L. Etheridge, N.S.W. Department of Mineral Resources

Petroleum source rock studies have been conducted on specimens sampled from the Department of Mineral Resources coal exploration hole DM Howes Hill DDHI, sited in the southwestern corner of the Gunnedah Basin. DM Howes Hill was chosen as a reference hole for future regional petroleum source rock studies as:

1. the complete Permo-Triassic sequence was intersected.
2. No major intra Permian unconformities were present.
3. The sediments were thought to be minimally heat affected.

Results of the above studies are summarised in table I.

Coal from the Maules Creek Formation ("Lower Coal Measures") was found to be relatively high in exinite (12 per cent), and resinous vitrinite (16 per cent). Related organic rich sediments are therefore considered likely to be "oil prone". Vitrinite reflectance at this level, near basement at a depth of 719m, was measured at 0.53%. This value may be anomolously low due to the high percentage of resinous material present in the vitrinite.

The overlying marine Porcupine Formation, comprising pebbly, silty sandstone analysed at 0.5 to 0.7 per cent total organic carbon (TOC) suggesting these sediments have a poor to marginal source rock rating.

The prodelta sediments of the overlying Watermark Formation, comprising mainly claystone and silty claystones, give TOC's ranging from 1.3 per cent to 2.5 per cent. These levels are indicative of good to excellent hydrocarbon source rocks, a TOC of 0.5 per cent being considered the minimum acceptable limit for a claystone source rock. The prodelta sequence of the Watermark Formation contains both "gas prone" and "oil prone" sediments. Dispersed organic matter (DOM) ranges from 6 per cent (gas prone) to 40 per cent (oil prone) exinite in reflected light, and 20 per cent (gas prone) to 90% (oil prone) amorphous and finely disseminated material plus exinite and biodegraded terrestrial material in transmitted light. Spore colour ranged from yellow-orange (Thermal Alteration Index = 2.4) at the top of the sequence to orange (Thermal Alteration Index = 2.7) at the base of the sequence, indicating that the sediments are at a maturation level which is transitional-mature to mature with respect to the "oil generation window". Laminated siltstone/sandstone of the "delta front facies" was found to be "oil prone" (42% exinite DOM) and sub-mature (spore colour yellow; Thermal Alteration Index = 2.3). A significant acritarch population, bimodal in distribution, was noted within the Watermark Formation.

Petroleum source rock geochemical studies comprising EOM analyses and kerogen elemental composition determinations confirm that the Watermark Formation contains both "oil prone" and "gas prone" sediments.

Both organic-rich sediments and coals within the Black Jack Formation ("Upper Coal Measures") are relatively low (mainly between 0-7 per cent) in exinitic material, although the marine influence of the Arkarula Sandstone Member is reflected in an increase in DOM exinite from 7 per cent near the base of the "lower delta plain" to 31 per cent within the Arkarula Sandstone. The Black Jack Formation is therefore overall gas prone. The marine influence of the Arkarula Sandstone is also marked by the presence of acritarchs. TOC's are typically between 1.0 and 5.5 per cent. Two major organic maturation anomalies occur within the Black Jack Formation. The vitrinite reflectances of these anomalies range from a base level of 0.65% to peaks of 1.22; and 1.30% respectively. Both peaks directly correspond with a loss of volatiles from the coals and are symmetrically positioned about a 22m thick basic intrusion. It is probable that some local hydrocarbon accumulations have been generated as a result of these anomalously high maturation levels.

Based on the above data, the most significant source rocks within the Gunnedah Basin occur in the Watermark Formation, especially the shallow marine shelf and delta front claystone and laminated sandstone/siltstone facies. Further, a comparison can be made between the dispersed organic matter contained within the Watermark Formation and equivalent facies within the Back Creek Formation of the Bowen Basin in Queensland.

Except for locally high paleo-geothermal anomalies within the Black Jack Formation, caused by intrusions, only the Watermark Formation, and strata lower in the sequence are likely to be found at a maturation level which could have resulted in the generation of hydrocarbons within the Basin.

Acknowledgements a) M.Smyth and J.Hunt (CSIRO) for reflected light petrographic determinations.

b) A. McMinn for transmitted light petrographic determinations.

Depositional Environment and Facies Type	Formation	Lithology	Sample Depth (m)	TOC
Shallow marine (bay) tidal to intertidal mud flats.	Napperby Formation	Thin-bedded claystones, siltstones & calcareous sandstone	4 DOM Samples 33.6-155.3	-
Fluvial/Alluvial fans	Digby Formation	Polymictic to quartzose conglomerate, quartzose and sublabile sandstone	5 DOM Samples 33,6-155.3	-
Gorran Conglomerate Member & upper delta plain facies	Black Jack Formation	Conglomerate, coal seams, interbedded siltstone and lithic sandstone, quartz-rich sandstone and tuffaceous claystone	7 Coal Samples 3 DOM Samples 305.5-442.2	Coal (1.8)
Hoskinson Seam				1.5-2.1
Shallow marine shelf	Arkarula Sandstone Member	Silty sandstone	448.7	-
Prograding lower delta plain facies		Siltstone, claystone, quartz-lithic sandstone, interbedded siltstone, sandstone coal	4 Coal Samples 3 DOM Samples 456.4-493.3	Coal (2.5) 1.0-5.5
Delta front facies	Watermark	Laminated siltstone/ sandstone	505.7	1.4
Pro delta facies and Marine shelf facies	Formation	Siltstone, claystone and silty claystone and laminated siltstone and sandstone	5 DOM Samples 518.1-579.3 590.8 7 DOM Samples 598.0-627.3	(1.9) 1.3-2.2 2.5 (1.6) 1.3-1.9
Marine shelf facies	Porcupine Formation	Silty sandstone and pebble conglomerate with minor siltstone	664.7 680.7	0.7 0.5
Upper delta plain	Maules Creek Formation	Conglomerate, lithic sandstone, siltstone claystone. Coals.	718.8	Coal
Colluvial	Leard Formation	Pelletoidal claystone	721.0	4.7

1a. Amorphous and finely disseminated material
1b. Exinite and biodegraded terrestrial material
2. Woody material 3. Opaques and semi-opaques

Macerel Types[#] Reflected Light			Organic Types[#] Transmitted Light				T I Spore color	Source Rating Organic Maturity
Exinite	Vitrinite	Inertinite	1a	1b	2	3	(Ro mean)	
17	68	14	(7)	(33)	(15)	(45)	2.0	gas-oil prone;
			0-20	25-45	5-30	20-70	(0.3equ)	immature
15	11	74	80	10	5	10	pale yellow	
(4)	(58)	40	(0)	(20)	(5)	(75)	2.0-2.7	
3-5	26-88	(9-71)	0-5	10-35	0-35	40-85	pale yellow	gas prone;
							-	mainly immature
							orange	
(4)	(40)	(56)					(0.67-1.30)	fair to good
0-7	10-65	10-84						gas prone;
								mature due to
								influence of
								basic intrusive
(1)	(27)	(72)	(8)	(19)	(3)	(70)	2.5-3.5	
0-2	0-60	38-100	5-15	5-20	0-5	50-90	Or-dk brn	
							2.4	gas-oil prone;
31	0	69	0	30	10	60	yel - Or	submature
(1)	(65)	(34)					(0.65-1.22)	fair to good
0-3	45-88	12-55						gas prone;
								mature due to
(13)	(11)	(76)	(15)	(30)	(10)	(45)	2.5-3.0	influence of
7-18	3-24	62-86	0-30	20-40	5-15	25-65	Or-brn	basic intrus.
42	5	53	50	40	5	5	2.3	good-oil prone
							Yellow	sub-mature
(18)	(4)	(78)	(11)	(30)	(5)	(54)	2.4	good-oil prone
6-24	0-12	64-94	0-25	20-45	0-10	35-70	Yel - Or	and fair to
40	3	57	70	20	0	10	2.5	good gas prone
(25)	(6)	(69)	(3)	(23)	(8)	(65)	2.5-2.7	transit.mature
15-34	0-12	58-82	0-5	20-30	5-10	60-70	Yel or Or	- mature
14	14	72	0	25	5	70	2.7	Poor-fair gas
								and oil prone
38	0	62					Orange	mature
12	25*	63	-	-	-	-	-	good-oil prone
(29	9)							transit.mature
*resinous vitrinite incl. in exinite classification							(0.53)	(refer text)
0	21	79	0	0	0	100	-	Poor gas prone
								mature

[#] after Beckett et al Geological Survey of New South Wales, Quarterly Notes No.51

[#] average value given in brackets

HYDROCARBON SOURCE ROCKS IN THE SYDNEY AND GUNNEDAH BASINS

M. Smyth, C.S.I.R.O. Division of Fossil Fuels

The potential of some Permian sediments in the Sydney and Gunnedah Basins as source rocks for hydrocarbons has been assessed using organic petrology. Petrographic analyses on samples of the Denman Formation and Mulbring Siltstone from the Sydney Basin and Black Jack and Watermark Formations from the Gunnedah Basin, show that the volume of dispersed organic matter in the four ranges between 2 and 26%, as follows:

Denman Formation	2-26%; average 8% (13 samples)
Mulbring Siltstone	3-6%; average 4% (7 samples)
Black Jack Formation	2-8%; average 4% (8 samples)
Watermark Formation	2-5%; average 3% (13 samples)

The dispersed organic matter is inertinite-rich (>50%); vitrinite is less than 30%, down to nil; and the exinite content varies between nil and about 40%.

More than half of the exinite is sporinite, with liptodetrinite and cutinite abundant in only a few samples. Traces of alginite are present through the samples.

Inertodetrinite makes up more than 70% of the inertinite macerals, the bulk of the remainder being semifusinite and fusinite.

The quantity of dispersed organic matter in all the sediments is sufficient to classify them as having good to excellent potential as source rocks for hydrocarbons. The quality, or type, of the dispersed organic matter, being inertinite-rich, may not appear to have good source potential for hydrocarbons, especially oil, when viewed by conventional wisdom. However, extensive studies of the Permian sediments in the Patchawarra Trough of the Cooper Basin have shown that the dispersed organic matter is just as inertinite-rich as that in the Sydney and Gunnedah Basins, with an even lower exinite content, less than 20%.

The Patchawarra Trough has both gas and oil fields being developed now to the production stage.

On the basis of quantity and type the Denman, Mulbring, Black Jack and Watermark Formations have as good a potential as source rocks for oil and gas as the sediments in the Patchawarra Trough. The maturity of the sediments is the remaining factor to be considered for determining the potential of the rocks. In areas where this is suitable, the formations should produce hydrocarbons.

THE SIGNIFICANCE OF SULPHIDE PSEUDOMORPHISM OF PLANT REMAINS IN ARENITES

R.A. Creelman, Macquarie University

The 1000 known 'Red Bed' or Sandstone-Copper deposits and prospects of the Southwestern United States are distributed through New Mexico, Arizona, Texas, Colorado, Oklahoma and Kansas. One characteristic common to all is a close association of sulphides with coalified plant remains. The present study was designed to document the petrology of this sulphide-coal association. Metal sulphides can be deposited during sedimentation, diagenesis or after diagenesis. Organic remains are sensitive to diagenetic and post-diagenetic change so the coal-sulphide association is potentially useful for timing the entry of metals into a sediment.

Chalcocite is the predominant sulphide found in the sandstone-copper deposits, but some contain significant amounts of chalcopyrite and bornite. Pyrite, marcasite, nickel and cobalt bearing thiospinels, galena, sphalerite and uraninite are accessory minerals. Sulphides are either intimately associated with plant remains or are interstitial to sand grains. The latter can be demonstrated as secondary, the result of redeposition, and frequently contain sulphur-rich bornites. There is little evidence to support the contention that iron sulphides as either masses, framboids or cell pseudomorphs were the major precursors of copper minerals. It is more consistent with the observations to argue that copper-bearing minerals and pyrite were deposited together, and there has been a degree of interaction between the two. Chalcocite owes its existence to the replacement sequence chalcopyrite→bornite→chalcocite. Blaubleibender (blue remaining) covellites are common, and are the product of copper leaching by slightly oxidizing solutions from chalcocite.

Chalcopyrite, bornite and chalcocite all pseudomorph wood structures. The most delicate details are preserved, the best examples being casts and molds of tracheid pits. Wood is totally pseudomorphed by sulphides when both the cell lumen is filled and the cell walls replaced. The sulphide-filled cells have many openings, and enclose slivers of coal. The openings are usually along the join of two cells, and between the cell walls and lumens. Sulphide replacement has originated from these openings and some examples show that the lumen may have been pyrite filled, but the cell wall replaced by copper bearing minerals. Sulphide recrystallization has in some instances obliterated cell structures.

Coal with the sulphides is at high to medium volatile sub-bituminous rank. It is a light (Rm_{oil} 0.68% - 1.04%) and dark (Rm_{oil} 0.44% - 0.66%) variety of vitrinite. As the reflectivity (rank) increases the light and dark vitrinites become increasingly more difficult to distinguish, and at Rm_{oil}-1.15% they are indistinguishable, and the coal is a single variety anisotropic vitrinite. Coal microfractures are sulphide free at lower rank, but as rank increases are filled by remobilized sulphides. This implies that there may be a relationship between the oxidation process that has remobilized the sulphides and the rise in coal rank. There are examples of copper bearing sulphide phases filling lumens only. When all the lumens are filled in a specific area, but the cell walls are not pseudomorphed, the cells have gone through gelification without swelling. If the lumen infill is scattered, swelling has occurred. Cells that have had only their lumens filled by sulphide form the 'pseudotextinite' texture and show that cell wall 'replacement' by sulphides can only proceed when geochemical conditions allow the gradual removal of organic matter to permit sulphide deposition. Some wood is detrital and has been charred or weathered and has been converted to either semifusinite or fusinite on coalification. Fusinites have had open lumens at all times in their history, and consequently have filled with silt or clay as well as sulphides.

Four conditions necessary for sulphide pseudomorphism of wood are:

1. The wood structure must be intact at the start of the process. Biochemical change of organic remains begins early in coalification so metal sulphide deposition must occur before there is any modification even from the peat stage.

2. The wood must be in an aqueous medium which preserves the necessary low Eh conditions and allows the delivery of metals and sulphur into the depositional sites. Oxidation/reduction conditions must be finely balanced. If reducing conditions prevail, then there is sulphide void filling only, but not the replication of cell walls. On the other hand, oxidizing conditions will preclude sulphide deposition as well as degenerating the wood structure. The optimum conditions for replacement are an Eh low enough to deposit sulphides, but not low enough to preclude the gradual removal of organic matter.

3. There is a source of metal. The aqueous medium that deposits the sulphides must have metals enough for deposition which implies there is a geochemical anomaly. The causes can be diverse, but the simplest explanation is that the source is local, that is, the host sediments are in direct contact with a metal bearing rock. The sulphides from the sandstone-copper deposits have the characteristic negative $\delta^{34}Ss^{2-}$ with a limited dispersion generated by biogenic activity in a system open to sulphate.

4. The wood structures are preserved through diagenesis if there is a framework or block of sulphide that supports the mass through diagenetic compaction.

The study has not shown any evidence of sulphides replacing coal. Small sulphide atolls are seen in coal, but they are the remnants of cell lumen fills, or small patches of pseudomorphism that did not form a continuous support framework when compaction began. Consequently they are fractured and rotated.

Wood structures in sulphides are important primary textures that are evidence of sulphide deposition before diagenesis. In the course of the study examples were found of uraninite pseudomorphism of wood structures which, using the criteria defined here, indicates uranium entered the sediment before diagenesis, which implies it to be syn-sedimentary.

The Long Reef native copper deposits near Sydney are all examples of microfracture filling. The coal is at low volatile sub-bituminous rank (Rm_{oil}~1.3%). Such associations imply that the copper is a post diagenetic mineral, possibly generated by _in situ_ leaching of a tuffaceous component present in the sediment, and subsequently deposited in the spaces provided by the coal microfractures.

PREPARATION OF A PHOTOGRAPHIC GUIDE TO THE CORED ROCKS OF THE SYDNEY BASIN

G. Skilbeck, University of Sydney
G. Bradley, N.S.W. Department of Mineral Resources

INTRODUCTION

With the long term increase in demand for coal, and Australia's recognised capacity to fill this need (see WORLD COAL STUDY), increasingly more sophisticated techniques, are required for exploration, reserve estimation, and mine planning. However, the value of these techniques will be considerably diminished if the methods used in initial data collection are inadequate. A case for standardisation of the basic lithological data of Australian coal-bearing successions has recently been argued by Mallett and Ward (1982).

Problems arising from the imprecise recording and communication of data have long plagued the geological fraternity. Not the least of these originate from generalised rock-classification schemes, and the ambiguously-defined terminology that accompanies them. The major shortcomings of most classification schemes stem from attempts to categorise continuous natural series, and to incorporate within this structure all possible future contingencies. By highlighting selected key charateristics, to the exclusion of others deemed to be less significant, such schemes are divested of their objectiveness. For the conclusions of any geological study to be scientifically valid, they must be based on objectively assembled data. Previously, if a classification scheme did not allow for a particular variation of rock-type, it was suitably amended (as was the terminology), or, a new scheme was created with emphasis on different distinguishing factors. Such a solution only transfers problems, rather than resolves them.

Melton and Ferm (1978) proposed an alternative solution, that overcomes the inevitable flaws of generalised classifications. Their initial premise was that only a finite number of rock-types will be commonly present in any one geological area, the overall sequence being made up of various combinations of these. Therefore, by identifying all of these basic rock-types before data collection commences, a scheme can be erected that will have universal application within the designated area. Further, if colour photographs of the lithological reference series so identified are compiled into a keyed catalogue then the problem of equivocal descriptions can also be lessened. The emphasis in their solution is on the naturally occurring rock assemblage. The advantage of these catalogues is that they promote the rapid, efficient, and consistent collection of basic lithological data.

REFERENCES

Branagan, D.F., Herbert, C., and Langford-Smith, T., 1979, The Sydney Basin. Science Press, Marrickville, 60p.

Ferm J.C. and Weisenfluh, G.A., 1981, Cored rocks of the Southern Appalachian Coal Fields. Department of Geology, University of Kentucky, Lexington, 93p.

Mallett, C.W. and Ward, C.R., 1982, Standardisation of Geological Data in Coal Measures, in Mallett, C.W. (ed) Coal Resources: Origin, Exploration and Utilization in Australia. Geol. soc. Aust. Coal Geology Group Symposium, Melbourne, November, 1982, p 400-412.

Melton, R.A. and Ferm, J.C., 1978, Photo-book construction and computer assisted proceedures for assimilation and preparation of core data. Proc. 2nd Symposium on Geology of Rocky Mountains Coal, Colorado geol. Surv., p 143-148.

Middleton, G.V., 1978, Facies in Fairbridge, R.W. and Bourgeois, J. (eds), Encyclopedia of Earth Sciences, Dowden, Hutchinson and Ross, Penns. p323-325.

AUTHOR INDEX

NOTES

THE UNIVERSITY OF NEWCASTLE

N.S.W.

DEPARTMENT OF GEOLOGY

SEVENTEENTH NEWCASTLE SYMPOSIUM

ON

ADVANCES IN THE STUDY OF THE SYDNEY BASIN

29TH/30TH APRIL, 1ST MAY, 1983

***

ADDITIONAL PROGRAMME INFORMATION

***

The Chairmen for the individual technical sessions are as follows:

<u>SATURDAY, 30th APRIL, 1983</u>

<u>MORNING TECHNICAL SESSION</u>
(Lecture Theatre E01)

<u>CHAIRMAN</u>: Mr. A.J. Rigg,
Geological Manager,
Esso Australia Ltd.

<u>CONCURRENT SESSIONS</u>

AFTERNOON TECHNICAL SESSION
(Lecture Theatre E01)

<u>CHAIRMAN</u>: Mr. B.W. Vitnell,
Chief Geologist & Exploration Manager,
Coal & Allied Industries Ltd.

AFTERNOON TECHNICAL SESSION
(Lecture Theatre OG08)

<u>CHAIRMAN</u>: Mr. K.J. Brown,
District Geologist,
Joint Coal Board.

<u>SUNDAY, 1st MAY, 1983</u>

<u>CONCURRENT SESSIONS</u>

MORNING TECHNICAL SESSION
(Lecture Theatre E01)

<u>CHAIRMAN</u>: Mr. W.E. Beath,
Superintendent of Collieries,
The Broken Hill Proprietary Coy. Ltd.

MORNING TECHNICAL SESSION
(Lecture Theatre OG08)

<u>CHAIRMAN</u>: Dr. D.L. Marchioni,
Principal,
Marchioni & Associates.

******

Two papers have been added to the technical sessions on Sunday, 1st May. 1983. The revised programme now reads as follows:

SUNDAY, 1st MAY, 1983

COFFEE $08^{30}-09^{00}$ in the DEPARTMENT OF GEOLOGY

CONCURRENT SESSIONS

Theatre E01	Time	Theatre DG08
MACQUARIE COLLIERY, YOUNG WALLSEND SEAM, AN ANALYSIS OF STRESS RELIEF MINING R. Turner & R. Warner B.H.P. Coal Geology Dept.	$09^{05}-09^{40}$	A PRELIMINARY REPORT ON IGNEOUS ACTIVITY NORTH OF MT. YENGO, N.S.W. A.S. Ritchie & R. Evans Amateur Geological Society of the Hunter Valley
RELATIONSHIP BETWEEN SEAM GAS PARAMETERS AND GEOLOGY R.J. Williams, J. Giedl, Collinsville Coal Co. Pty. Ltd.	$09^{40}-10^{15}$	THE LONGITUDINAL GRAVITY HIGH OVER THE SYDNEY BASIN AND ITS GEOLOGICAL SIGNIFICANCE I.R. Qureshi, University of N.S.W.
GEOLOGICAL OBSERVATIONS AND MINING CONSIDERATIONS AT ULAN, N.S.W. M.A. Johnstone, J.S. Luxford Ulan Coal Mines Ltd. K.H.R. Moelle, The University of Newcastle	$10^{15}-10^{50}$	ORIGIN OF THE COASTAL VALLEYS IN THE SYDNEY REGION R. Coenraads, University of British Columbia

MORNING TEA $10^{50}-11^{15}$ in the GEOLOGY DEPARTMENT

Theatre E01	Time	Theatre DG08
PETROLEUM SOURCE ROCK STUDIES IN THE GUNNEDAH BASIN L. Etheridge, Dept. of Mineral Resources	$11^{15}-11^{40}$	THE SIGNIFICANCE OF SULPHIDE PSEUDOMORPHING WOOD IN SANDSTONES R.A. Creelman, Macquarie University
HYDROCARBON SOURCE ROCKS IN THE SYDNEY AND GUNNEDAH BASINS M. Smyth, C.S.I.R.O.	$11^{40}-12^{10}$	PREPARATION OF A PHOTOGRAPHIC GUIDE TO THE CORED ROCKS OF THE SYDNEY BASIN G. Skilbeck, University of Sydney G. Bradley, Dept. of Mineral Resources
THE GEOLOGICAL INVESTIGATION FOR THE SYDNEY SUBMARINE OCEAN OUTFALLS N.V. Jensen et al., M.W.S.D.B.	$12^{10}-12^{40}$	EARLY PERMIAN STRATIGRAPHY & PALAEOGEOGRAPHY, SOUTHERN SYDNEY BASIN P.R. Evans et al., University of N.S.W.
SUMMARY AND VOTE OF THANKS	$12^{40}-12^{45}$	BY THE CHAIRMEN

LUNCH $12^{45}-14^{00}$ at the STAFF HOUSE

POSTER PAPER

DETAILED GEOLOGICAL MAPPING IN THE UPPER HUNTER VALLEY
G.R. McIlveen, Dept. of Mineral Resources

THE GEOLOGICAL INVESTIGATION FOR THE SYDNEY SUBMARINE OCEAN OUTFALLS

N.V. Jensen, G.S. Thomas, G.C. Hawkins, Metropolitan Water Sewerage & Drainage Board

The present method for the disposal of the greater quantity of Sydney's sewage is to release it to the sea via short length, near shore outfalls after primary treatment at severage works at North Head, North Bondi and Malabar. To meet the increasing demand and to reduce the effect of pollution on the environment, a decision was taken by the Sydney Water Board to carry the effluent from the existing treatment works and discharge it into deep water several kilometres from the coast. An investigation was initiated into the feasibility of constructing submarine tunnels to carry the effluent to be discharged from diffusers at near sea bed level.

The factors which led to the decision to adopt this method of sewage disposal will not be discussed as they are outside the scope and purpose of this paper, which is concerned with a description of the geological investigation that was carried out in relation to the feasibility study and to provide engineering geological data required for the design and construction of the tunnels, diffusers and associated on shore structures. In addition, the results of the investigation will be summarized together with a discussion of the effects the geological information had on engineering decisions.

In order to assess geological feasibility for the proposal and to enable the selection of suitable routes and diffuser locations for preliminary design to proceed it was first necessary to define the off shore parameters of water depth, sediment cover and distribution, broad stratigraphy and the presence and spatial relations of major structures. The Geological Survey of N.S.W. in conjunction with the Public Works Dept., was engaged to do this work by geophysics. They provided water depth and sediment information with a high level of confidence and stratigraphy with lesser confidence.

Water depth at the proposed diffuser sites is of the order of 60m at North Head and North Bondi and at Malabar is 80m. The offshore area at North Head was found to be relatively free of sediment cover but two large intersecting inferred dyke zones posed problems. Deep-water magnetometer surveys showed the major anomaly to be due to two smaller dykes separated by some 40m. The geophysical work at Bondi delineated a paleodrainage network and no major structures likely to interfere with the proposals. A large inshore sediment lobe was defined at Malabar with rock outcrop offshore in the proposed diffuser location. The possibility of sediment movement was thus raised for latent rationalisation.

Onshore drilling was undertaken at each site to locate stratigraphic formation boundaries to assist the geophysical interpretation and to determine the order of magnitude of localised dips of the strata. Physical testing of cores was also done to assist preliminary design.

The need for offshore control for the investigation had become apparent and the U.K. contractor Wimpey Laboratories Ltd. was engaged to bore 5 vertical holes near to each proposed tunnel route.

The offshore drilling was undertaken from Wimpey's drillship "Geodrill". The drilling platform was not stabilized, heave compensations being achieved by a system of counterweights and pulleys.

The major problems encountered during the drilling were due to marine rather than geological conditions.

Of 15 scheduled boreholes 12 were drilled.

The offshore drilling generally confirmed the stratigraphic boundaries inferred from the marine geophysics. At North Head a borehole intersected an inferred dyke at a depth of 28.5m below the seabed and at this level it was unweathered.

Water pressure testing of the holes was carried out whenever possible. Low flows were recorded at the majority of the test locations. The highest flows recorded were interpreted as occurring from discrete joints rather than uniformly over a length of borehole.

Geophysical logging of boreholes was adopted as an insurance against loss of information due to possible core losses and as a method of confirming borehole depths. As core recovery was very high the geophysical logging proved to be largely superfluous. Routine laboratory tests of representative core samples was carried out.

Machineability studies were undertaken independently by Wimpey Laboratories and Professor Roxborough of the University of N.S.W. and both studies indicated that roadheader TBM performance would be marginal in much of the expected rock sequences, and the use of a full face machine was indicated.

The Geological Survey of N.S.W. and the P.W.D. were engaged to resolve the sediment movement problem. Their studies are still in progress.

Detailed side scan sonar work and sea bed inspections using the D.A.R.F. remote control T.V. camera has revealed what is now thought to be non-magnetic dykes in the Malabar area and further work to resolve this problem is in progress as the unpredicted intersection of dykes in the tunnel drives would pose added engineering problems.

It is accepted that due to economic and technical limitations the offshore investigation, particularly the drilling programme, could not be exhaustive. The investigations have largely satisfied the requirements for establishing the feasibility of the tunnel proposal and providing the engineering geological data required for design purposes. The good correlation between the results of the geophysical investigations, the offshore and the onshore investigations have given confidence to the prediction of the detailed geology in the immediate vicinity of the tunnel routes. Estimates of the lengths of the various stratigraphic types to be expected in the tunnel drives, rock stability including stand up times, water ingress and its mode of entry and machineability of the various lithogical types have contributed to the making of decisions regarding the selection of tunnelling machines and the mode of progress to be adopted.

The ingress of water, a major consideration, remains an area of uncertainty and a rigorous programme of probing ahead of the drive will be essential. It will also give advance warning of unpredicted problems.

EARLY PERMIAN STRATIGRAPHY & PALAEOGEOGRAPHY, SOUTHERN SYDNEY BASIN

Evans, P.R., Seggie, R.J. Oil Co. Aust., Sydney
Walker, M.J., University of New South Wales

INTRODUCTION

Gostin & Herbert (1973) divided the Lower Permian of the southern Sydney Basin to the west and south of Ulladulla between the Talaterang Group at the base, consisting of the Pigeon House Creek Siltstone, Yadboro Conglomerate and Clyde Coal Measures, and the Conjola Subgroup of the Shoalhaven Group. The Conjola Subgroup consists of the Wasp Head Formation at the base the Pebbley Beach Formation and the Snapper Point Formation. McElroy & Rose (1962) recognised a depression in pre-Permian basement that they termed the Talaterang Low and that was considered by subsequent authors to be the remnants of a glacial valley draining from a western highland. Gostin & Herbert recognised that the low was infilled mainly with the Talaterang Group.

Exposures of the Talaterang Group and Conjola Subgroup are largely confined to steep cliff faces of inland mesas up to 300m high and to coastal headlands. Much of the region is part of the forested Morton National Park or a military firing range. Thus most of the terrain is inaccessible and interrelationships between facies and formations on the coast with those inland have remained questionable. Nevertheless, checks of the microfloral content of available outcrops and re-mapping of the upper Clyde River region have resulted in a modified view of the stratigraphy and palaeogeography of the southern Sydney Basin.

STRATIGRAPHY

Microfloras were extracted mainly from coastal outcrops to the south of the Termeil Essexite: the geotemperature of the terrain to the north of Snapper Point was at some time in the past too high for such fossils to survive coalification.

A distinct assemblage change at the top of the Pebbley Beach Formation coincides with the diastem evident in outcrop between that formation and the overlying Snapper Point Formation at Clear Point. The Wasp Head and Pebbley Beach Formations contain assemblages that are assignable to Early Permian Stage 3a.

Microfloras from the type section of the Snapper Point Formation are highly coalified and cannot be assigned to a specific subdivision of the palynological scales with a great deal of certainty, but seems best assigned to Stage 4. No microfloras have been extracted from the formation between Pretty Beach and Ulladulla.

Inland, assemblages have been obtained from the Jindelara lithofacies (discussed below) and the type Clyde coal Measures. The Jindelara lithofacies was sampled in Jindelara Creek and yielded a Stage 3a microflora. The type Clyde Coal Measures in the upper Clyde river provided upper Stage 4 assemblages. No microfloras could be found in outcrops of the Pigeon House Creek siltstone and Yadboro Conglomerate. Microfloras from the Pigeon House Creek siltstone reported by Helby & Herbert (1971) are interpreted here as part of Stage 3a. Glossopteris sp. was located within the Yadboro Conglomerate, suggestive of an age no older than Stage 3.

The Pigeon House Creek Siltstone at the base of the Talaterang Group achieves a maximum thickness of 50m and consists of mudstone and siltstone with stringers of boulder conglomerate and lithic sandstone. Usually regularly bedded, the formation bears ripple marks in places. Comminuted plant debris is also present. The bulk of the Talaterang Group is composed of the Yadboro Conglomerate (up to 240m thick), an unsorted, massive greywacke conglomerate with rounded quartzite pebble boulders up to 1m in section, angular pebbles and boulders of phyllite, rounded pebbles of gneiss, chert and volcanic rocks and an immature matrix.

The Jindelara lithofacies consists of sandstone, minor pebble stringers, shale and thin coals that lie between the Yadboro Conglomerate and the overlying Wandrawandrian Siltstone. It forms the high cliffs around the Clyde River gorge at Yadboro, where it is 150-200m thick. Gostin & Herbert referred this sequence to the Snapper Point Formation. The lithofacies is poorly sorted and immature at the base and more mature, better sorted towards the top: its matrix varies from about 30% in basal sediments to 10% in upper levels. The facies extends well beyond the limits of the Yadboro Conglomerate onto Ordovician basement. Mapped by Seggie (1978) and Walker (1980) as "Jindelara Sandstone", the unit is termed here a lithofacies because of presently unsolved problems in recognising the lateral limits of the sequence as if it were a formation in terms of the International Stratigraphic Code.

The Jindelara lithofacies is typified by upwards grading sequences, 50-100cm thick, with basal pebble bands and pebble to fine gravel stringers throughout. Dune cross-bedding, scour and fill and shallow channel structures are evident in places. Carbonaceous shale, siltstone and thin coals form lenses up to 1.5m thick. Such beds were previously regarded as Clyde Coal Measures, but they cannot be mapped as a distinct formation. Plant debris within the coal seams and shales is usually comminuted.

Re-mapping of the pre-Permian unconformity has confirmed the presence of the Talaterang Low, but showed the axis of the depression to the north of Yadboro is N-S rather than E-W. On a local scale topographic variations in basement are very marked. In order to understand the original attitude of the depression the effects of post-Permian movements have to be discounted. Isopach maps of the interval pre-Permian basement to base of Nowra Sandstone show thickening westwards (Seggie, 1978). Most of the thickening takes place within the Yadboro Conglomerate. The Talaterang Low thus did not originally dip eastwards as depicted by McElroy & Rose.

PALAEOGEOGRAPHY

Isopach maps of the Yadboro Conglomerate and the interval between the basement unconformity and the base of the Nowra Sandstone resemble in general shape such maps of an alluvial fan. Viewed in cross-section, if the Yadboro Conglomerate alone was the product of a fan, the sediment pile could not have been in isostatic equilibrium. In order to have been in equilibrium the conglomerate would have had to have been in part a correlate of sections of the Jindelara lithofacies.

The palaeogeographic model envisaged on the basis of this mix of evidence is that of an alluvial fan delta complex centred at or near Yadboro and that spread eastwards to merge with a rising Early Permian sea.

Prior to onset of sedimentation the terrain was strongly dissected. The progressive rise in sea level during the Early Permian initially drowned the irregular topography. The Pigeon House Creek Siltstone probably represents a landwards extension of the typically fine grained facies of the more estuarine Pebbley Beach Formation.

Deposition by mass flow, braided stream and sheet flow dumped the Yadboro Conglomerate lithofacies towards the head of the fan and the Jindelara lithofacies towards the toe. The source of detritus from which the fan was built was high ground to the west that remained from the effects of the intra-Carboniferous Kanimblan Orogeny. Nevertheless, more local sources provided the phyllitic components of the clasts and mass flow deposits such as the breccia bands in the lower Wasp Head Formation. The Clyde Coal Measures and similar lithofacies formed in swamps at the foot of the fan complex adjacent to the Permian coastline.

Basement warped under the load, initiating the Talaterang Low. As the time passed, the fan delta was drowned by the advancing Permian sea and was overlain by the marine facies of the Snapper Point Formation and Wandrawandrian siltstone.

REFERENCES

GOSTIN,V.A. & HERBERT.C.,1973:J.Geol.Soc.Aust.,20(1),49-70.
HELBY, R.J. & HERBERT,C.,1971:Quart.Notes Geol.Surv.N.S.W.
McELROY.C.T. & ROSE,G.,1962:Geol.Surv.N.S.W.Bull.,17.
SEGGIE, R.J.,1978: University of N.S.W. Hons Thesis (unpubl.).
WALKER, M.J.,1980: University of N.S.W. Hons Thesis (unpubl.).