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ABSTRACTS

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AUSTRALIA'S NON-RENEWABLE ENERGY RESOURCES

L.C. Ranford

Information on Australia's non-renewable energy resources was compiled at BMR in 1977 to assist the National Energy Advisory Committee (NEAC) in an assessment of the nation's energy resources. The work was conducted with the assistance and co-operation of other government organisations including the Joint Coal Board, the States Mines Departments and some oil companies.

The data on the various resources were classified into categories in terms of the certainty of occurrence and the economic feasibility of extraction using the 'McKelvey Box' as adopted by BMR. This classification system was judged to be the best available to present the data in a form suitable for national policy considerations, and to facilitate quantitative comparisons between the different energy resources.

Examination of the resource diagrams for the various energy raw materials and analysis of the data used in their compilation highlight a number of points about our energy resources and the available assessments.

On a percapita basis Australia is relatively rich in fossil and nuclear energy resources. However, we still have only very limited knowledge of our total energy resourses and in fact, petroleum is the only energy commodity for which an assessment of total resources has yet been attempted. Australia's demonstrated, economic, recoverable resources of petroleum amount to a little more than 2 percent of our total non-renewable energy resources, but petroleum currently provides between 41 and 100 percent of the energy requirements in the various Australian States, and provided 56 percent of the total Australian energy used in 1976/77.

Coal accounts for about 84 percent of the total non-renewable energy resources in the demonstrated economic category. These resources occur relatively close to the major population centres in Queensland, NSW, and Victoria.

Australia's uranium resources, if used in thermal nuclear reactors, represent about 14 percent of our recoverable demonstrated economic energy resources. About 85 percent of the uranium in this category occurs in the Northern Territory.

Oil shale deposits in Australia are subeconomic at current prices but identified resources are estimated to contain at least 500 times as much oil as has been identified in Australian oil fields to date. Some of this oil may be recovered with technology currently being developed.

J.C. ERSKINE* and E.L. SMITH

THE LOGIC THAT UNDERLIES A FEASIBILITY STUDY AND CALCULATIONS FOR MINING PROJECTS

The logical flow of information needed for a feasibility study is described, and then consideration is given to those parts of the study that can be done by computer. A flow chart is shown which puts into context those parts of the study which have to be done manually (the subjective parts) and those which the computer can handle (the objective parts).

The flow chart shows the logical flow starting with facts, going through geological, geostatistical and metallurgical studies, and ending with the formulation of several feasible conceptual plans, the detailed economic calculation and writing out of the economics of each of the plans, and the recommendation of one of the plans.

Two computer programs for use with mining feasibility studies are being designed at BMR. One is for geostatistical studies; the other, which will be described here, models (for each conceptual plan) the calculations of equipment and capital works requirements, and calculates capital costs, revenues, financial analysis and economic risk analysis. After the mining engineer has provided the basic mining and financing information, and metallurgical and location data, this program can calculate and print out the whole of the remainder of the information needed to decide on the relative economic desirability of each plan.

The steps which the program will go through are as follows:

- Access the capital cost data base. The data base is being compiled to give capital costs at the mine of all major mining equipment and capital works; it will be updated annually to take account of inflation, and of changing equipment and mining methods.

- Calculate requirements of equipment and capital works, and their capital cost. (For example, it calculates numbers of drills, shovels, trucks, and totals their capital costs).

* Speaker

- Calculate and write out detailed schedules of inflated and uninflated depreciable and tax allowable capital costs for proving-up drilling, construction camp, mine development, concentrator and support facilities, civil engineering, power supply, workshop, store and inventory, and town construction.

- Calculate total capital cost, including interest (if any) and working capital, and a cumulative total capital cost for each year.

- Calculate revenue (smelter return) from data of concentrate grades, impurities, distance from smelter, metal prices, and exchange rates.

- With the above information available, and the addition of operating costs (at present to be provided as data, but in later years to be calculated by the program) it is then relatively easy, in PROSPER computer language, to perform the financial analysis (printing out a year by year summary of the capital account, operating account, tax account, annual cash flow and discounted cash flow rate of return).

- Draw the graphs for economic risk simulation (sensitivity analysis) to show how the discounted cash flow rate of return will vary with variations in the major parameters.

THE CALCULATION AND EXPRESSION OF NATIONAL ESTIMATES OF INFERRED MINERAL RESOURCES

J.W. COTTLE

Obtaining national estimates of inferred mineral resources for particular commodities involves the preparation of individual estimates for each deposit and the aggregation of these estimates to produce a national total.

Because inferred resources refer to possible extensions or repetitions of known bodies of mineralisation their estimation is based largely on a broad geological knowledge of the deposit with, if at all, only a few samples or measurements. As a result, the components that might comprise any particular deposit estimate (e.g. grade, volume, density) incorporate varying degrees of uncertainty. Estimation of any of these components by a single value (e.g. a grade of 3.5 percent) gives no indication of the probable accuracy (uncertainty) of the estimate and leads, ultimately, to a total national estimate, the probable accuracy of which is also unknown.

The problem of the uncertainty of the estimate can be overcome by the application of simple probability theory and simulation. This probabilistic approach embodies a flexibility that allows the uncertainty in each variable to be expressed and fully accounted for within the analysis. As will be demonstrated, this methodology ensures that the information content of the final national total estimate is greatly increased which, in turn, enables ensuing decisions to be more soundly based, because they can take account of the inherent uncertainty of the estimate.

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AN EXAMPLE OF A NATIONAL MINERAL APPRAISAL:

LEAD AND ZINC IN CANADA

D.F. Sangster (Geological Survey of Canada)

In 1972 and again in 1977, national appraisals of Canada's undiscovered lead and zinc resources were completed. The basic approach adopted was to carry out the evaluation in geological terms by deposit-type even though the reporting was in terms of commodities.

The techniques used and the problems encountered are described for two different deposit-types: (1) stratabound deposits of the "Mississippi Valley" type in carbonate rocks and (2) volcanogenic massive sulphide deposits in volcanic rocks.

Although in both cases an attempt was made to establish "type areas" and extrapolate from these to the target areas, this proved to be almost impossible for the Mississippi Valley deposit-type, largely because of lack of grade-tonnage data in the type areas.

In contrast to these difficulties, however, it was found that the distribution of volcanogenic massive sulphides was much more predictable. In seven type areas, centred around felsic volcanic accumulations, it was found that, per area, the range in numbers of deposits, total metal content, and grade were all relatively small. Furthermore, the distribution of deposits in each area conformed to a predictable pattern. Regularity and hence predictability such as this is necessary in resource estimation, and hence evaluation of undiscovered zinc and lead resources in volcanogenic massive sulphide deposits is relatively easier (and more accurate?) than in Mississippi Valley deposits.

ASSESSMENT OF 1:100 000-SCALE GEOLOGICAL MAPPING OF PRECAMBRIAN TERRAINS IN NORTHERN AND CENTRAL AUSTRALIA

Panel discussion chaired by D.H. Blake

This assessment of recent geological work in the Georgetown, Mount Isa, Arunta and Pine Creek Inliers results from an inspection made in June, 1977, by a group of twelve BMR and two GSQ geologists currently working in these areas. Several company geologists from the areas accompanied the group on various parts of the tour. Many aspects of the current 1:100 000 field-research programs were discussed and debated, especially the different mapping approaches used in each inlier, rock and stratigraphic nomenclature, recognition and interpretation of unconformities, stratigraphic correlations, aspects of geochronology, structural geology, mineralisation types and controls, and the types of information desired by company geologists.

Discussion will begin with brief descriptions, by J.H.C. Bain, G.M. Derrick, A.J. Stewart, R.S. Needham, and D.H. Blake, of the areas visited and some of the problems raised.

CONFIGURATION AND COMPOSITION OF BASEMENT OF THE PINE CREEK GEOSYNCLINE -

D.H. Tucker*, N. Sampath, and I.G. Hone

Most large uranium deposits discovered in the Pine Creek Geosyncline occur in Lower Proterozoic metasediments adjacent to granitic complexes. Accordingly, an interpretation of the regional geophysical data has been made to determine the location of shallow granitic complexes.

A study of the regional gravity data and of measured rock densities indicates that most of the gravity features can be explained by the presence of low density granitic complexes within more dense Lower Proterozoic metasediments; some features can be explained by lateral variation in density of the metasediments themselves. Anomaly analyses indicate that the granitic complexes commonly slope outwards beneath the Lower Proterozoic sediments, and can be modelled as bodies with a depth extent generally less than 5000 m. In the main there appears to be no density or magnetic contrast between the granitic complexes and the basement of the Pine Geosyncline. Hence the modelled depth extent of the granitic complexes can be used to map the thickness of Lower Proterozoic sediments and the structure of the geosyncline.

A regional model based on this hypothesis suggests that a basement high runs south from the Alligator Rivers Uranium Field, through the Jim Jim Granite, and then eastwards beneath the Kombolgie Sandstone. Another basement high fringes Van Diemen Gulf. The South Alligator Valley Uranium Field appears to lie in a basement deep.

Except in a few localities, magnetic interpretation does not help in determining the deep basement configuration. However, as most of the magnetic anomalies are caused by near-surface sources within the Lower Proterozoic section, the magnetics provide depth estimates to the base of flat-lying cover rocks and surficial cover which blankets much of the area.

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SUBDIVISION OF THE PRECAMBRIAN

K.A. Plumb

The IUGS Subcommission on Precambrian Stratigraphy is developing a world-wide subdivision of Precambrian time. The results of the Subcommission's meeting during 1977, and the prospects for achieving a satisfactory subdivision, will be discussed.

Discussion centres around the following points: geological history is episodic and essentially regional, whereas time is a continuum with no natural subdivisions; the first-order subdivision being sought is, in fact, that of time; the agreement being sought is a convention, essentially a mechanism to promote international scientific communication without undue distortion. Therefore, world-wide fundamental geological significance must not be implied by the subdivisions chosen; it should be potentially practicable to use all indices of correlation within the framework of the subdivision.

The subdivision should: (1) be acceptable to the majority; (2) be as simple as possible; (3) not prejudice objectivity; and, (4) must contain operationally objective criteria. (5) The boundaries should have geological significance in as many regions as possible (but the significance may differ between areas); but, (6) it is unrealistic to expect the boundaries to fit all regions exactly. (7) The method by which the Phanerozoic time-scale evolved provides no useful guidelines for Precambrian subdivision.

The following methods of subdivision have been discussed and rejected by the Subcommission: Arbitrary (eg, 500 m.y. units); Stratotypes; Tectono-magmatic cycles; Biostratigraphic; Palaeomagnetic; and Theoretical Concepts of Earth Evolution.

The subdivision being sought is a geochronological subdivision of convenience, or best fit. From the analysis of presently available data, time boundaries will be selected, to pass through major breaks in the stratigraphic record which are common to as many regions as possible.

The following decisions were reached by unanimous vote:

(1) A two-fold subdivision of the Precambrian into Archaean and Proterozoic is accepted by the Subcommission.

(2) As an operational criterion, the boundary between Archaean and Proterozoic is assigned a geochronological age of 2500 m.y.

(3) The terms Archaean and Proterozoic should have status as eons, equivalent in rank to Phanerozoic, though of considerably greater duration.

By majority vote, the Subcommission accepted, as one focus of future work, the review and acceptance of Precambrian Reference Sections. Criteria and procedures are being prepared.

The principal focus of the next meeting will be the subdivision of both the Proterozoic and Archaean.

Analysis of available data indicates that the prospects for agreement on further subdivision are good. I personally anticipate that boundaries will be selected at about 1000 m.y., 1800 m.y., and 2900 m.y. The units so defined may be further subdivided at about 1400 or 1600 m.y., 2000 m.y., and at the base of the late Proterozoic glacial successions. These boundaries would be very practical for use in Australia. The units so defined sould be given new names.

I propose that no change should be made to the existing schemes in use in Australia until the Subcommission has completed its recommendations.

ADVANCES IN THE UNDERSTANDING OF THE STRATIGRAPHY OF THE PINE CREEK GEOSYNCLINE, NORTHERN TERRITORY

I.H. Crick*, P.G. Stuart-Smith and R.S. Needham

Significant uranium mineralisation in the Pine Creek Geosyncline is contained within three formations-the Cahill, Koolpin, and Golden Dyke Formations.

Because of the similar carbonate-carbonaceous rock assemblages and their association to uranium mineralisation, these three formations have been regarded as being facies and time equivalents. Recent work indicates that the Cahill Formation is older than the Koolpin Formation and that the Koolpin Formation is equivalent to the upper part of the Golden Dyke Formation. A tentative correlation is made between the lower Golden Dyke Formation which contains the uranium mineralisation in the Rum Jungle area and the lower Cahill Formation in which the large uranium deposits of the Alligator Rivers area are located.

The Cahill Formation consists of two members, a lower carbonate-carbonaceous-chlorite schist sequence and an upper quartz schist, feldspathic quartzite sequence. The formation overlies a thick sequence of continental arkose, quartzite, and conglomerate of the Mount Partridge Formation, or the Mount Basedow Gneiss-which form the base of the Lower Proterozoic succession in the Alligator Rivers area. These rocks are transitional into higher grade gneisses of the Nanambu Complex, and probably unconformably overlie Archaean granites as several granites within the Complex have Archaean ages.

The upper section of the Cahill Formation is correlated with the Mount Hooper Beds, the Coirwong Greywacke, and the Mundogie Sandstone, and is interpreted as representing a shallow marine transgressive sequence. Pebbles of silicified dolomite in conglomerates of the Mount Hooper Beds are evidence of an older carbonate sequence, probably the lower member of the Cahill Formation. The Koolpin Formation unconformably overlies the Mount Hooper Beds, Coirwong Greywacke, and Mundogie Sandstone. Changes in metamorphic grade from lower greenschist to amphibolite in the Cahill Formation can be explained simply by depth of burial.

* Speaker

Tuff has been recognised within the Golden Dyke Formation in the Burnside Granite area in the western part of the geosyncline. The Gerowie Chert in the South Alligator River valley, which was previously considered to be possibly a diagenetically altered dolomite, is composed mainly of tuff. Underlying the Gerowie Chert are iron-rich sediments of the Koolpin Formation; these are commonly chert-banded, lenticular, or nodular, ferruginous and carbonaceous siltstones; they are similar to iron-rich sediments commonly underlying the tuff in the Golden Dyke Formation.

The Gerowie Chert has previously been interpreted as interfingering to the west with the Koolpin Formation, and to the east with the Fisher Creek Siltstone, an interpretation now difficult to sustain as the Gerowie Chert is a time-stratigraphic unit.

The presence of an upfaulted Archaean basement ridge (the Stag Creek Volcanics) confining sedimentation of the South Alligator Group (the Koolpin Formation, Gerowie Chert, and Fisher Creek Siltstone) to an eastern basin, as has previously been proposed, now seems unlikely; Foy & Miezitis (1977) have found that the Stag Creek Volcanics are interbedded with sediments of the Masson Formation. We suggest therefore that the tuff and underlying iron-rich sediments of the Golden Dyke Formation are equivalent to the Gerowie Chert and Koolpin Formation.

A major revision of the Lower Proterozoic stratigraphy of the Pine Creek Geosyncline is required.

PETROLEUM RESOURCE ASSESSMENT METHODS

D.J. Forman

For most companies the purpose of petroleum resource assessment is to determine the likely amount of undiscovered petroleum in an area so that management may decide whether or not the petroleum is worth exploring for. Industry and government also require petroleum resource assessments for long-term planning.

A number of publications are available on methods of estimating the amount and value of discovered petroleum resources. In recent years there have also been a number of papers on methods of estimating undiscovered petroleum, but the methods presented are extremely diverse, some of them are invalid, and many are not applicable to Australian conditions.

Estimation of undiscovered resources requires that geological and historical data and inference are applied both objectively and subjectively, either in theoretical models or in comparisons, to solve two problems. One is to calculate the probability that hydrocarbons exist; the other is to estimate the volume of hydrocarbons that may exist.

The probability that a basin, play, or prospect does contain hydrocarbons is determined by risk analysis. The prospect-by-prospect, play methods, or volumetric methods may all be used to estimate the volume of petroleum that is likely to be discovered. Selection of the method or methods depends on how much is known about the geology of the area, the time available for the study, and access to the necessary data and methodology. It is important to consider the location and field-size distribution of the undiscovered resources so that the economies of producing them may be assessed.

MATURATION OF PETROLEUM SOURCE ROCKS IN AUSTRALIA: RESULTS OF THE BMR-CSIRO STUDIES, 1977

J.D. Gorter

The aim of the continuing joint project was to provide basic data for petroleum resource assessment of Australian basins for BMR basin studies groups, and provide a stimulus for industry. Emphasis was placed on previously written-off areas, and basins from which source rock work had not been done. An attempt to sample all geological periods, from late Precambrian to early Tertiary, and diverse sedimentary environments, was made.

The primary controlling factors determining the hydrocarbon potential of a basin are the total amount of organic carbon, type of organic material-whether of plant or animal origin-and the thermal history of the rocks. Recently developed techniques relating to hydrocarbon generation enable integration of these data into basin evaluation. Five parameters were selected to provide the basic data: total organic carbon content, solvent extractable organic content, hydrocarbon content, extract chromatography, and vitrinite reflectance.

During 1977 BMR submitted over 300 core samples to CSIRO, representing some 106 wells in 20 onshore basins. Subsidised wells, and BMR and State Survey stratigraphic drilling provided the bulk of the core samples submitted. This paper discusses the more interesting results, some of which are summarised below.

1. In the Canning Basin vitrinite reflectance data and moderately high total organic carbon values suggest that the Permian Noonkanbah Formation is a good source rock in the southeastern Fitzroy Graben. Reservoir and structure are expected to be present. Similarly, Ordovician rocks on the northeastern Broome Arch are at present mature, and of excellent source potential; however disappointing results were obtained from wells in the same structural province. Oil in the Permian Grant Formation at Thangoo 1 is probably derived from the immediately underlying Ordovician.

2. Data from the Clarence-Moreton Basin suggest that the play is a gas prospect, with a source in the Triassic coal measures. It would have unnamed Upper Triassic sands (if permeable) as a reservoir and be sealed by the Walloon Coal Measures in post-Jurassic structures at a depth of no greater than 2000 m in the north and 1000 m in the south of the basin.

3. In the Hillsborough Basin very high total organic carbon values, low vitrinite reflectance values, and the chromatograph patterns, indicate typical oil-shale extracts.

4. Moderate total organic carbon values and submature reflectivities from the non-marine Lower Permian glacial sequence in the Murray-Darling Basin suggest that these rocks may be a potential gas source, if more deeply buried.

5. In the Laura Basin a large divergence between Lower Jurassic and Permian reflectivities is evident. This can be interpreted either as due to the removal of some 3500 m of Triassic rock before the Jurassic, or to a change in heat-flow regime.

ENHANCED RECOVERY: A GENERAL DISCUSSION WITH POSSIBLE APPLICATION TO AUSTRALIAN OILFIELDS

B.A. McKay

In the next ten years, many Western industrialised nations will be major importers of crude oil because of their imbalanced demand/indigenous supply situation. In 1990 for instance Australia will have to import about four times her currently projected production to meet her supply gap. Because of prolific discoveries in the North Sea, Great Britain is one of the fortunate few and will have crude for export in the 1980's.

In some undersupply situations, the problem is one of productivity and recovery efficiency. This is exemplified by the United States, where over 300 billion barrels of liquid crude resources exist (sufficient for 50 years supply at current usage), but only about 10 percent of this is currently recoverable.

At projected crude oil prices of US$20/Bbl in 1990, the drain on foreign reserves for these imports will be a major economic concern for many nations in the same relative position.

Increased exploration may be the answer in some undersupply nations; however, improving recovery efficiency may offer the most viable means for(economically) increasing reserves and oil production. Currently, there are a number of enhanced recovery pilot schemes underway in various nations, foremost of which are in the USA. Techniques have been tailored to certain reservoirs, e.g., steam injection and in situ combustion for increasing production from heavy oil reservoirs, surfactant-micellar injection techniques for reservoirs benefiting from a lowering of interfacial tensions).

Many enhanced recovery schemes overseas are considered after using secondary techniques such as waterflooding in reservoirs having finite boundaries. Many Australian oil fields (particularly Bass Strait) have primary active water drive which affords good displacement efficiency, but being "open ended", have little scope for control or use of enhanced recovery.

The Moonie oil reservoir in Queensland is in a somewhat similar position as Bass Strait, with a strong edge-water drive; however, the high residual oil saturation at depletion (65% of oil in place) makes Moonie a tempting prospect. The Petroleum Technology Laboratory of the BMR is currently investigation the use of polymer displacement in core samples from this field with the hope of assisting improved economic recovery.

However, Barrow Island may be the vest candidate for enhanced recovery in Australia because of its finite reservoir system, low oil viscosity, and high oil saturation, although problems may ensue with low formation permeability.

WESTERN VICTORIA, A GEOTHERMAL ENERGY PROSPECT ?

J.P. Cull

All heat contained within the Earth can be described as geothermal energy. However a geothermal resource can be defined only if heat can be extracted from crustal rocks and concentrated at the surface by fluid migration.

There are no hydrothermal fields in Australia but hot springs have been found in regions of recent volcanism. In addition there are many bores producing hot water in sedimentary basins. Resources of this type are conduction dominated, and maximum rates of heat extraction can be calculated only if heat flow is determined.

The Otway Basin is defined as a low enthalpy geothermal energy prospect. Large volumes of hot water can be readily obtained from high-yield aquifers. Flow rates of 70 L/s and temperatures greater than 50^{o}C have been recorded. Heat can be extracted for process and space heating using existing bores near Portland. Additionally, steam may be made available from centres of recent volcanism within the basin. At Mount Gambier heat flow is 91.8 $\pm$ mW m^{-2}. An anomalous source of heat is indicated close to the crater.

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A SEISMIC INVESTIGATION OF THE EASTERN MARGIN OF THE GALILEE BASIN, QUEENSLAND

J. Pinchin

Beneath the southeastern margin of the Galilee Basin lie the Drummond and Adavale Basins. The structural relationships of these three basins have an important bearing on the hydrocarbon potential of the area; gas has been discovered in the Adavale Basin and there have been gas and oil shows within the Galilee Basin. In addition, Permian coal measures of the Galilee Basin subcrop along the eastern margin and their depth and extent is of economic interest.

In 1976, BMR shot four six-fold c.d.p. seismic reflection traverses covering 219 km across the eastern margin of the Galilee Basin in areas where there had been no previous seismic coverage. The first two traverses, about 50 km east of Hughenden, were to investigate the structure of the basin's northeastern margin with relevance to the extent of the coal measures, and Traverses 3 & 4 were to investigate the underlying Adavale and Drummond Basins in the Galilee-Jericho area.

The results from Traverse 1 showed that the northeast margin of the Galilee Basin has been affected by faulting as recently as Tertiary times, and a possible fault-bounded anticline probably trending parallel to the basin margin was crossed. Drummond Basin rocks thicken to 800 m at the west end of the traverse, where they are overlain by 2000 m of Galilee Basin sediments. No structures of any kind were intersected by Traverse 2, although a steep basin margin was expected from interpretation of aeromagnetic data; the observed magnetic anomaly is probably caused by intrabasement changes in rock type. The Permian coal measures dip gently from a depth of 750 m at the northwest end of the line to 1000 m at the southeast end. The Galilee Basin sediments are underlain by 600 m of Early Carboniferous Drummond Basin sediments, hence the Drummond Basin is seen to extend further northwest than previously thought.

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Traverse 3 extended a BMR 1971 seismic traverse to provide continuous seismic coverage from Lake Galilee 1 well eastwards to the outcrop of the Anakie Metamorphics. Results indicate that sedimentary rocks of the Drummond Basin, in particular the Mount Hall and Telemon Formations, extend westwards below the Galilee Basin; it is unlikely that the Adavale Basin extends this far north. The traverse crosses a prominent gravity high, the Donnybrook Gravity High, and this is thought to be caused by a dense intra-basement block rather than basement uplift. An alternative explanation for the gravity high, involving a reversed density contrast of dense sediments over less dense volcanics, is being considered. Results from the fourth traverse also show that Drummond Basin sediments extend far westwards beneath the Galilee Basin, and that the Adavale Basin, which is the more prospective of the two pre-Galilee basins, is restricted to the south.

Both coal and oil exploration in this area are going to prove difficult. The steep and faulted northeast margin of the Galilee Basin provides only a narrow strip where coal is likely to be found at mineable depths, and the pre-Galilee sediments below the basin's eastern margin look unprospective for petroleum because of their fluviatile origin. However, an area between Traverse 1 and Traverse 3, known as the Koburra Trough, contains a thick sequence of Permo-Carboniferous sediments, and its eastern margin is probably bounded by structures such as that crossed by Traverse 1; these structures could provide petroleum traps and it is on this area that exploration should now concentrate.

LEAD AND ZINC IN CARBONATE ROCKS - PROSPECTS IN GEORGINA BASIN, NORTHERN TERRITORY AND QUEENSLAND

J.J. Draper

The Georgina Basin contains a thick sequence of carbonate rocks, of Early Cambrian to Early Ordovician age, deposited in a series of subtidal to supratidal environments on an epicontinental shelf. These carbonate rocks unconformably overlie Vendian to Lower Cambrian glacigene and marine rocks in the southern part of the basin, and pre-Adelaidean rocks elsewhere (except where rare Lower Cambrian basalt is present). Lower to Middle Ordovician shallow marine siliciclastic rocks overlie the carbonate rocks in the southern part of the basin. During the Devonian, deformation of the basin was accompanied by dominantly freshwater sedimentation. Mesozoic and Tertiary rocks and Recent sediments obscure much of the basin. There are a number of prospective targets for lead and zinc mineralisation in the carbonate rocks, but two targets of particular importance are the Arrinthrunga Formation, together with its partial equivalent the Meeta Beds, and the post-Devonian to Mesozoic unconformity.

The Arrinthrunga Formation and Meeta Beds comprise subtidal to supratidal limestone and dolomite containing large quantities of algal material. Minor mineralisation occurs in the units at Box Hole (galena, barite, sphalerite) and BMR Huckitta No 7 and 8 (minor scattered sphalerite), and anomalous values of lead, barium, and zinc are present in Alliance Mulga No 1 at about the same stratigraphic level as at Box Hole. Fluorite is present in the unit, but is probably formed in an early stage of diagenesis. The Box Hole and Mulga No 1 occurrences, as well as an occurrence of galena in the overlying Tomahawk Beds, coincide with positive gravity features. Part of the Arrinthrunga Formation was deposited in an arid supratidal environment, so that brines would be present and gypsum (often preserved as pseudomorphs) would provide a potential source of sulphur. Hydrocarbons are also present. One area of particular interest is around Alliance Mulga No 1, where the Meeta Beds are (?)disconformably overlain by the Ninmaroo Formation which is strongly jointed (NE-SW). Another region worthy of consideration is the Marqua to Toomba Range area where shallow water, shoaling sediments pass laterally into fetid, dark, subtidal sediments; there is a good possibility of stratigraphic traps.

The post-Devonian to Mesozoic unconformity is a well developed karst surface which transects various shallow-water Lower Palaeozoic carbonate rock units. The Mesozoic sequence overlying the unconformity is initially freshwater, overlain by a transgressive marine sequence. (In the Camooweal-Undilla area, apparently marine shales directly overlie the unconformity.) The post-Devonian to Mesozoic unconformity provides a suitable conduit for mineralising fluids and suitable ore traps. Pseudomorphs of pyrite are often associated with the unconformity. One feature of the present karst surface in the basin is the presence of manganese and iron concentrations with zinc values up to 0.65 percent and barium to 1.14 percent - this weathering concentration may be a suitable mechanism for pre-concentrating metals for later redeposition as Mississippi Valley Type deposits. Areas worthy of closer consideration are the Camooweal-Undilla area, Glenormiston-Alderly area and the eastern Burke River Structural Belt.

GRAVITY EVIDENCE FOR ABRUPT CHANGES IN MEAN CRUSTAL DENSITY AT JUNCTIONS OF AUSTRALIA'S CRUSTAL BLOCKS

P. Wellman

The major gravity anomalies in central and Western Australia occur as elongate dipoles, either in isolation or in a series. Each dipole can be explained by an abrupt change in mean crustal density across the junction of crustal blocks, and by the associated isostatic compensation. Typically a block has an anomalously high mean density in the upper or whole crust; this slowly reverts to normal away from the block boundary. Some dipoles are enhanced in amplitude by low density sediments and their compensation. The observed anomalies are consistent with the anomalous masses being isostatically compensated by variations in thickness of the crust; the variations are gradual, and extend to about 100 km from the boundaries of the anomalous bodies.

The crustal block boundaries inferred from dipole anomalies correspond in position with the crustal block boundaries inferred from geology, and approximately with the position of those inferred from the gravity trend pattern. At boundaries between younger and older blocks there is a tendency for the younger block to have high density material forming its block edge, and for the older block to be covered with sediment; these features are likely to be caused by the process of formation of the younger block, or the joining of the younger block to the older block. The dipole anomalies on the Australian Precambrian crust are similar to those recognised at Precambrian province boundaries in Canada, and have similar tectonic positions.

THE USE OF MICROFOSSILS IN PRECAMBRIAN CORRELATION: PROBLEMS AND PRINCIPLES.

M.D. Muir

The intensive study of Precambrian microfossils is a comparatively recent development in palaeontology, and the use of Precambrian microfossils for stratigraphic correlation is in its infancy. At this early stage, there are few workers in the field and most of them lack experience in biostratigraphy. It is important to try to avoid making the kinds of mistakes that, because of excesses of enthusiasm, have characterised the early stages of other branches of palaeontology. Useful lessons can be learned by examining the development of ideas on the biostratigraphic application of palynology (the study of spores and pollen and other organic walled microfossils).

The problems that were encountered in the early days of stratigraphic palynology and that now face us in Precambrian stratigraphic micropalaeontology are strikingly similar. Correlation is required for kilometres of both outcrop section and of drillcore, on both regional and local scales. The morphology of the fossils is simple and they are very small, and require fairly sophisticated microscopical techniques for their understanding. Physical and chemical changes during incorporation into and diagenesis of the sediment can grossly alter the fossils' morphologies. The present day equivalents are poorly known morphologically, and in terms of their ecological significance. The fossil assemblages are barely known. There may be large numbers of taxa in a single sample and extremely numerous individuals in a single microscope preparation, all of which makes the serious study of samples very time consuming.

One way of tackling the problem is to make a conscious effort <u>not</u> to try to identify fossils with living species, but to try to group fossils, as objectively as possible, into small units which are delineated by severe morphological and dimensional restraints. This will inevitably produce a very much larger number of 'taxa' than conventional palaeontological treatment, but it does produce data that can be treated numerically. Similar

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techniques were applied to the almost intractable problems of the stratigraphic palynology of the tropical Tertiary (Germeraad, Hopping, & Muller, 1968) with excellent results. Zonations on various scales of refinement were produced, and it proved possible to determine the controls over these zonations. Universal, long-ranging zones are probably a result of plant evolution, while fine-scale basinal zones are controlled by local ecological and edaphic conditions.

At present the outlines of broad, evolutionary zones in the Precambrian can be detected. Basin studies, currently in progress, will form the basis for local zonations which can be used for intra and eventually inter-basinal correlation. Because the Precambrian time scale is so long, a solid framework of isotopic age determinations is an essential substrate for biostratigraphy, as is also a thorough understanding of lithostratigraphy, facies analysis, and diagenesis. The microfossils are organic walled, and can be used colorimetrically as sensitive indicators of thermal diagenesis, and depth of burial. Microfossils have been recovered from rocks of biotite grade, so the possibilities for correlation in metamorphic terrains are available. This could be of considerable interest in the correlation of, say, the McArthur Basin, and the Mount Isa region.

Thus although the problems involved in such studies cannot be underestimated, they are not insuperable, provided a commonsense approach is taken.

Germeraad, J.H., Hopping, C.A., & Muller, J., 1968. Palynology of Tertiary sediments from tropical areas. Review of Palaeobotany and Palynology, 6, 189-348.

CRUSTAL STRUCTURE IN AUSTRALIA FROM EXPLOSION SEISMOLOGY

D. Denham* and D.M. Finlayson

All our mineral resources lie in the Earth's crust, and all of the crust is derived from the mantle, so it is important to look at the structure and physical properties of the crust and upper mantle.

Studies using man-made explosions show that in oceanic regions the crust is comparatively thin (10-15 km) and simple, whereas in continental areas the crust is thicker (30-50 km) and often extremely complicated. This situation arises because oceanic crust is ephemeral - at most lasting only 200 m.y. - and is generated in only one way. Hot mantle rises under mid-ocean ridges to form new oceanic lithosphere and this cools with a crust on top as it spreads away from the ridge.

In a continental environment we have to contend with several complicated and interactive processes, such as erosion, intrusion, granitisation, metamorphism and subduction, and on a much larger time scale - some continental rocks are at least 3800 m.y. It seems that once material is accreted to a continent it mostly stays in a continental environment in one form or another, almost indefinitely. In most of Australia we have no knowledge of intra-crustal structure below crystalline basement.

Because of the complications on land it is a difficult problem to determine the intra-crustal structure there. The most successful techniques have been those which use man-made explosions. These involve using refractions and wide-angle reflections from large explosions (3-500 t) and vertical reflection techniques developed for oil search purposes.

BMR has been involved in several crustal studies using explosions since the Maralinga atomic blasts of the 1950s. The results show that the upper crustal velocities beneath the sediments are very variable, ranging from 5.7-6.4 km/s. We always observe crustal velocities in this range. In the

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lower crust sometimes we observe velocities in the 6.5-7.5 km/s range, and sometimes we don't. This and other evidence suggest that there is great heterogeneity throughout the crust. Recent work in southeast Australia casts doubt on the simplistic two-layer crust formerly proposed, and suggests the possibility of local low-velocity layers and lower crustal velocities of 7.3-7.4 km/s before reaching normal mantle, which has a velocity of about 8 km/s.

The seismic structure of the upper mantle appears to be less variable, but seismic recording programs in recent years have demonstrated that the fine structure of the upper mantle is no less difficult to determine than that in the crust. In the western and central part of the continent reconnaissance surveys show the velocity of the upper mantle immediately beneath the crust falls in the range 8.2-8.3 km/s, while in the east the velocities range from 7.8-8.1 km/s. This change in velocity correlates well with the heat flow rates, which are low in the Archaean cratons of the west (40 mW/m^2) and high in the east (80 mW/m^2), and the ages of the crust which range from about 3500 m.y. in the west to about 400 m.y. in the east.

The thickness of crustal rocks seem to lie mostly within the range 30-40 km, compared with a range of 25-50 km in North America and USSR. However thicknesses of over 40 km have been interpreted from reconnaissance surveys in southwest Australia and beneath the Snowy Mountains. Refinements in instrumentation and interpretation methods within the last 10 years will undoubtedly lead to a revision of the current simplistic models of intra-crustal and upper mantle structure which no longer stand up to detailed examination.

TECTONIC SETTING OF KIMBERLITES IN SOUTHEASTERN AUSTRALIA

John Ferguson* and L.P. Black

Recent discoveries have established the existence of fourteen areas where kimberlitic rocks occur in southeastern Australia, in the States of New South Wales, Victoria, Tasmania and South Australia (Ferguson & Sheraton, 1977, and Stracke & others, 1977). One or more intrusives are found in each area, the maximum being twenty-seven. Rb-Sr dating on whole-rock samples and on phlogopite separates have established Permian and Jurassic ages for kimberlitic occurrences in northwestern New South Wales and South Australia, respectively. Field relations indicate that all the occurrences postdate the Proterozoic, and that some are as young as Tertiary.

In an attempt to relate the kimberlites and their associated rock types to a structural framework the following features were investigated: on and off-shore structures, igneous activity, earthquake activity, general tectonics, gravity, and magnetics. Postulated continental extensions of transform faults, stemming from both the Antarctic and Tasman Sea Ridges, appear to have played the major role in the location of the kimberlitic intrusives in southeastern Australia. The South Australian kimberlitic occurrences all lie on the continental projection of the oceanic fracture zone arising from present-day spreading associated with the Antarctic Ridge. This feature is in accord with the postulate that the sites of transform faults are probably dictated by pre-existing structural weaknesses in the pre-breakup continental crust. On the eastern seaboard, this southern spreading ridge is also thought to be responsible for the projected continental fracture zone which lies coincident with a broad belt of Cainozoic igneous activity, and is also approximately the edge of Cainozoic epeirogenic uplift and the Cainozoic mean line of hot-spot migration. All the kimberlitic

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occurrences near the eastern seaboard of Australia fall within this broad zone of activity. Their location also appears to have been governed by fracture patterns developed initially during pre-breakup times, which later became the sites of continental extensions of transform faulting during the Tasman Sea opening; this spreading commenced 80 m.y. ago, and aborted 60 m.y. ago. A number of the kimberlites on the eastern seaboard of Australia are located at the intersections of the projected continental transforms stemming from the two spreading centres.

Ferguson, J. and Sheraton, J.W. (1977) - Petrochemistry of kimberlitic rocks and associated xenoliths of south-eastern Australia. Extended Abstracts, Second International Kimberlite Conference, Sante Fe, New Mexico, October 3-7, 1977.

Stracke, K.J., Ferguson, J., and Black, L.P. (1977) - Structural setting of kimberlites in south-eastern Australia. Extended Abstracts, Second International Kimberlite Conference, Sante Fe, New Mexico, October 3-7, 1977.

LANDSAT FOR GEOLOGY - A REVIEW OF CURRENT TECHNIQUES AND ACHIEVEMENTS

C.J. Simpson

The extensive research into satellite data technology that followed the launch of LANDSAT-1 (ERTS-1) in 1972 has resulted in progressive improvements to product quality and digital data analysis techniques. Improved image quality has direct significance to the many mineral and petroleum exploration organisations that are now routinely applying conventional photogeological interpretation techniques to LANDSAT multispectral scanner imagery.

Considerable effort has been directed to detection and analysis of LANDSAT lineaments. The USGS, for example, includes the results of LANDSAT lineament analysis in the synthesis of mineral resources assessment. To date, the only reported mineralisation discovery based solely on LANDSAT, resulted from visual interpretation of imagery.

Photogeological techniques will continue to be the main means of LANDSAT interpretation; however, even the best quality imagery may contain less than one quarter of the total information recorded. LANDSAT imagery is produced electronically from digital data recorded on magnetic tape. Each scene of each of the four spectral bands imaged by LANDSAT is composed of about 7.5 million picture elements (pixels). The ground brightness of each pixel (representing an effective area of 79 m x 56 m) is recorded by the scanner system on a scale which cannot be completely represented in a photographic image. Computer analysis techniques offer the only adequate means of analysing all the data in a LANDSAT scene.

Considerable progress has been made with computer analysis of LANDSAT digital data, and some techniques have definite application to mineral and petroleum exploration. Various computer enhancement techniques have been employed to reveal structural and lithological information not visible on conventional LANDSAT imagery or aerial photography. In specific environments direct detection of iron-weathering products associated with hydrothermal alteration has been achieved. Many techniques which are showing promise overseas have yet to be tested in the Australian environment.