BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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DEPARTMENT OF NATIONAL DEVELOPMENT

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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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BMR Symposia are held annually to report results or progress of projects considered particularly relevant to the Australian mining industry, and to provide a forum for industry comment on BMR's activities.

The 8th Symposium was opened by Mr W.M. Lonie, President, Australasian Institute of Mining and Metallurgy.

Most of the BMR programs reported on at the symposium and in these abstracts have involved the collaborative effort of colleagues, many of whom have assisted in the preparation of the abstract or the presentation. The abstracts are, however, attributed only to the speakers.

CONTENTS

Petroleum Prospectivity of the Australian Marginal Plateaus

Speaker - J.B. Willcox

The Australian continental margin has an area of about 5.5 10^6 km^2, which is 65 percent of the area of the continent itself. Almost half consists of mid-slope features - the sixteen marginal plateaus, terraces, and rises. These features, which are largely unexplored for petroleum, lie in medium water depths of between 500 and 2800 m; several are within range of current drilling and well-completion technology.

The western, southern and eastern margins of the Australian continent are believed to have formed in response to five discrete episodes of continental rifting, which culminated in seafloor spreading, commencing in different areas at times ranging from Late Jurassic to Paleocene. Most of the mid-slope features (hereafter termed 'plateaus') are regarded as blocks of continental crust which have foundered, mainly since the final stage of continental breakup and formation of oceanic crust in the adjacent basins.

Most of the Australian plateaus are associated with 'pull-apart basins', in which numerous normal faults trend subparallel to the continental margin. Three major sedimentary sequences can usually be distinguished: a pre-rift sequence which is extensively faulted; a rift-stage sequence which is typically fluvio-deltaic and in some areas is faulted near the oceanward margin of the basin; and a post-breakup sequence, generally comprising a marine transgressive mudstone, overlain by clastic and pelagic carbonates. Distinctive 'rift-onset' and 'breakup' unconformities generally separate these sequences. The rift-stage sediments may contain significant quantities of humic source material and reservoir sandstones. Marine incursions during the latter part of the rift stage, and the final marine transgression associated with breakup, appear to have led to the deposition of suitable petroleum source and cap rocks in many areas. Total sediment thicknesses under the Australian plateaus range from about 1000 to 9000 m, but in many areas the post-breakup sequence is thin.

Because little exploration activity has been undertaken in basins of the pull-apart type, their petroleum potential and the nature of the hydrocarbons are virtually unknown. Theoretically these basins may be expected to have had high geothermal gradients at the inception of seafloor spreading, and source rocks may well have matured with less overburden than would normally be required.

The most prospective areas - the Exmouth Plateau, and Carnarvon and Rowley Terraces - appear to be underlain by several thousand metres of mainly fluvio-deltaic rift-stage sediments, which provide reservoirs and gas-prone source beds. A transgressive marine mudstone could provide the main source beds and seal. The Queensland and Townsville Troughs, and a depocentre flanking the Marion Plateau, are also considered fairly prospective. The Ceduna Terrace is probably underlain by Aptian-Albian marine source rocks, and hence also warrants further exploration. Rift basins which may theoretically occur in the South Tasmania Rise, Lord Howe Rise, Kenn Plateau, Eastern Fields Plateau. Other areas off northeastern Australia require further surveying, as they may provide long-term prospects.

Mechanism for offshore sedimentary basin formation

Speaker -- G.D. Karner

Cross-spectral techniques have been used to analyse the relationship between free-air gravity and bathymetry of approximately 100 profiles over the continental margins of eastern USA, South West Africa, Lord Howe Rise and the Queensland Plateau. These margins are passive continental margins in the plate tectonic model, but differ in age of creation and sediment content.

The resultant filters or transfer functions have been used to evaluate the state of isostasy at these margins. The east USA coast can be best explained by a flexure model with an equivalent elastic thickness, D_e, in the range 10 to 20 kms, South West Africa can be best explained by $5 < D_e < 10$ kms. The Coral Sea-Lord Howe Rise can be equally explained by either $0 < D_e < 5$ kms or any Airy model with a depth of compensation of 30 kms. It should be noted that an Airy model is equivalent to a flexure model with a rigidity of zero.

Three factors control the degree of flexure: the age of the margin; the age and amount of sediment at the margin; and the thermal history of the margin. The observed difference between margins is explained by a simple model in which the lithosphere cools after initial rifting, increasing the elastic thickness. Thus, the overall response to the sediments at an old margin is as a relatively thick plate and at a young margin as a very thin plate or Airy model, depending on the age distribution of the sediments.

The resulting transfer function at each margin can therefore be explained in terms of a simple thermal and mechanical model for the evolution of the margins. A model of basin formation has been constructed based on the rigidity or elastic thickness/age information for oceanic lithosphere. Using this model, speculations concerning sediment distribution, thickness, and heat flow within the forming basin can be made.

Structure, Hydrodynamics and Hydrocarbon Potential of the Central Eromanga Basin, Queensland

Speaker - B.R. Senior

The hydrocarbon potential of the Eromanga Basin sequence in southwest Queensland is evaluated in terms of source rock geochemistry, structure, and groundwater hydrodynamics. Interbedded coal, carbonaceous mudstone, and siltstone within the Jurassic and Lower Cretaceous are fair to very good source rocks for oil. Approximately half of the central Eromanga Basin sequence is marginally mature or mature, depending on thickness and variations in geothermal gradients. Linear features interpreted from LANDSAT imagery and aerial photographs indicate the probable presence of major fracture systems as some features coincide with faults delineated by seismic surveys. Groundwater flow provides a mechanism for moving indigenous (Eromanga Basin) or derived (Cooper or Adavale Basins) hydrocarbons through the region. Faults with displacements of 15 m or more, which impede groundwater flow, could trap and protect petroleum from the effects of predominantly southwesterly groundwater movement.

Diagenetic history of epeiric carbonates, Georgina Basin: the economic implications

Speaker - B.M. Radke

Porosity and permeability are significant factors influencing the economic potential of carbonates. Throughout carbonate diagenesis, the patterns of porosity and permeability are continually changing and consequently, trends in the migration of pore fluids are also modified.

Epeiric carbonates of the Ninmaroo Formation (Upper Cambrian - Lower Ordovician) in the Georgina Basin, central Australia, were modified throughout diagenesis by interaction with saline fluids. This has superimposed on the carbonate sediments, marine sabkha diagenesis, late diagenetic dolomitisation, sulphide mineralisation, and subsequent dedolomitisation during erosion.

In the Late Cambrian and Early Ordovician, a shallow sea extended into central Australia as an epicontinental embayment. Ninmaroo sedimentation was in both tidal and nontidal environments in an extensive belt adjacent to normal-marine tidal conditions, and delineated by a seaward barrier complex of carbonate sand shoals. Channels through this barrier extended weakened tidal effects to the periphery of an epeiric region, where a patchwork pattern of semi-emergent shoals was transitional with marginal emergent pavements. Indurated pavements, algal mounds and shoals of carbonate sand constituted a varied but low-relief, submerged topography.

Sabkhas developed around low-relief emergent shoals and were characterised by gypsum precipitation within, and dolomitisation of, the sediments. Nodules and laminae of anhydrite precipitated where extreme temperatures and salinities prevailed, and in areas of prolonged emergence, porosities were increased by the dissolution of sulphates and carbonates with the development of karst.

These Ninmaroo environments migrated seaward across a flat shelf, producing progradational offlap in response to a slow relative drop in sea level. With a subsequent relative rise of sea level, transgressive deposition prevailed until excessive sediment accumulation rates again produced offlap of lithofacies.

During burial and structural deformation, hydrocarbons were introduced with the updip migration of basinal brines which produced extensive dolomitisation and minor emplacement of sulphates. Where hydrocarbons had already accumulated and occluded porosity, interaction between host carbonates and dolomitising fluids was prevented. Subsequent faulting produced near-vertical conduits for the escape of deeper and warmer brines which precipitated saddle dolomite, pyrite, fluorite, galena and sphalerite in the fault zones and along the more permeable strata. Where the sequence has been exhumed by subsequent erosion, relict sulphates have been redissolved and sulphides oxidised in meteoric waters. The interaction of resultant sulphate-enriched waters has produced near-surface dedolomitisation.

Petroleum geochemistry applied to exploration

Speaker - K.S. Jackson

As petroleum exploration costs continue to soar both in onshore and offshore basins, the industry needs to consider all technical tools at its disposal. Petroleum geochemistry has emerged in the past few years as a relatively inexpensive answer to many exploration problems. Varied analytical procedures, including gas and liquid chromatography, pyrolysis, organic extraction and stable isotopes, have been developed to answer the questions of source potential, organic maturation, kerogen types, hydrocarbon migration, and hydrocarbon-source correlations. While exploration histories from Canada and the USA have shown how geochemistry has been integrated into the overall exploration program, it is now possible to report on geochemical data and their application to exploration in several of Australia's sedimentary basins. Two current geochemical projects will be discussed. A joint BMR/CSIRO/GSQ study on the Permian rocks of the Denison Trough, Bowen Basin, illustrates how source rock and maturation studies have highlighted the significance of the Cattle Creek and Reids Dome Beds as source units. A different approach was taken in a joint SADME/BMR study on the Jurassic Eromanga sequence and Triassic rocks of the Pedirka Basin. Using classical source rock methods and isotopic correlation procedures, the Jurassic and Triassic rocks in the Poolowanna well have been studied in an attempt to correlate them with the Jurassic reservoired Poolowanna oil.

PANEL DISCUSSION

SYNOPSIS

Taking publications into the Eighties

The panel will comprise a chairman and five members: four of whom are BMR editors; the other two represent author Branches.

The panel's presentation will start with a brief introduction by the chairman in which he will outline the historic background of BMR publishing; the philosophy and its product. It will then be shown how, in some areas, change of emphasis in BMR programs has necessitated a change in the earlier pattern of BMR publishing; and two editors will elaborate on the publisher's response to the changed demand. In contrast, another panel member will show how, while the program thrust and data to be presented by his Branch have changed little over the years, changes in presentation have nevertheless been needed. Two editors will again indicate how the publishers have attempted to achieve these changes, and at the same time, to achieve economies which maintain the price of the publications at an acceptable level. The panel's presentation will conclude with a description by an editor of BMR's attempts to reach a wider, mainly non-scientific audience through its publishing program.

The panel will answer questions and discuss points of criticism and suggestions made by members of the audience.

At the end of the discussion, the chairman will sum up and hazard some opinions as to the likely direction of BMR publishing in the next decade.

Mineral potential of the Officer Basin, Western Australia

Speaker - M.J. Jackson

The Officer Basin is an intracratonic sedimentary basin stretching from the Gibson Desert in Western Australia to the eastern part of the Great Victoria Desert in South Australia. The Western Australian portion contains a poorly exposed, little known sedimentary sequence of Proterozoic and Phanerozoic age. The area was geologically mapped by a joint BMR/GSWA party between 1970 and 1974. To complement the field work, reconnaissance gravity and airborne magnetic surveys, and a ground seismic, gravity and magnetic survey, have been carried out. This work showed that the basin contains a Proterozoic sequence up to about 10 km thick overlain by a Phanerozoic sequence (including Cambro-Ordovician, Permian, and Cretaceous rocks) up to 1.5 km thick, but the sparse information available indicated the area had very low mineral potential. For instance, although suitable structures and porous units were found petroleum source rocks and cap rocks appeared to be lacking. The Permian sequence appeared to contain little carbonaceous material.

However, drilling and field investigations by the South Australian Department of Mines and Energy in 1978 have upgraded the petroleum potential of the eastern part of the Officer Basin in South Australia. The ?Cambrian Observatory Hill Beds in Wilkinson 1 contain anomalously high quantities of organic material that is suitable for hydrocarbon generation. Based on lithological and microfossil comparisons the sequences in the eastern and western parts of the basin can now be correlated. The Observatory Hill Beds (of the Eastern Officer Basin) are probably equivalent to the Babbagoola and Browne Beds in the Western Australian part of the basin. The presence of attractive structures and good porosities in Western Australia is now complemented by at least some indications of a possible source rock.

Investigation of offshore mineral resources in the South Pacific under UN auspices

Speaker - N.F. Exon

In 1972 a number of Pacific countries formed a Committee for Co-ordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas (CCOP/SOPAC), with United Nations' support. With a small dedicated staff, a shoestring budget, and enthusiastic local support, much offshore work was done in the region, demonstrating that a larger operation was feasible and worthwhile. By late 1978 CCOP/SOPAC had nine member countries, and had produced about 30 publications on offshore geology and mineral potential. Financial support had come from the United Nations, member countries, and a number of donor countries including Australia. In January 1979 a major three-year Project - Investigation of Mineral Potential of the South Pacific - commenced with a budget of $US4 000 000 provided by member countries and the United Nations Development Program. Work is roughly equally distributed in the waters of eight member countries (New Zealand, although a member, is excluded from the Project), and will involve 6 full-time professional and technical staff, and more than 2 years of ship time.

The eight project countries can be divided into two distinct geological groups: those of island-arc origin (Papua New Guinea, Solomon Islands, New Hebrides, Fiji and Tonga), and those forming parts of seamount chains (Samoa, Cook Islands, and Gilbert Islands). The island-arc countries have a land area of 525 000 km^2, a population density averaging 7.5 per km^2, and extensive shallow seas around much of their coasts. The seamount-chain countries have a land area of 4300 km^2, a population density averaging 65 per km^2, and are surrounded by the deep ocean. The preliminary CCOP/SOPAC program showed that both groups have offshore potential for manganese nodules, phosphate, construction materials and precious corals. The island-arc countries also have potential for offshore petroleum, bauxite, detrital minerals, and perhaps metalliferous muds associated with seafloor spreading centres.

The three-year project will give a much better idea of the offshore potential of the various countries and will provide useful environmental and bathymetric information, and a much better catalogue of resources of construction materials which are important for the smaller, more densely populated islands.

Predicting the location, grade and tonnages of Australia's future tin orebodies

Speaker - D. Perkin

Models of tin deposits of specific genetic types and typical ore grades are paired with different kinds and sizes of mining operations with their characteristic costs, via a computer program. It is possible then to construct curves on price/grade graphs equating revenue at the mine with the operating cost, from which a notional cut-off-grade for any assumed tin metal price can be derived. More importantly, a curve showing the rate of return consistent with 'normal' profit (assumed to be 9% in real dollar terms) may be derived, resulting in the establishment of the desired minimum average grade for any specific type of (profitable) mining operation, given a relatively stable medium-term tin price. Conversely, for a tin deposit with known grade and tonnage, the minimum average tin price necessary for profitable operation may be derived once the general type and size of operation is specified.

Reserves are defined as identified economic resources and hence, from the graphs, it is possible to establish minimum grades and tonnages of potentially profitable tin deposits, and thus establish an aggregate tin resource inventory.

The paper concludes that there are areas within Australian tin-fields where accumulations of tin exist at grades hitherto thought too low. Because of the relative world scarcity of tin and consequent high prices coupled with Australia's natural endowment of tin mineralisation, there may be many economic tin deposits yet to be found.

Some new ideas on the age and origin of the Etheridge Goldfield, Queensland

Speaker - J.H.C. Bain

The vein deposits of the Etheridge Goldfield yielded at least 23 000 kg of gold-silver bullion between 1869 and 1940. Poorly documented and little studied, the deposits have generally been regarded as Precambrian in age, and to have been introduced directly by the Precambrian granitoids and metabasic rocks with which they are closely related spatially.

Recent field research suggests that the deposits are of late Palaeozoic age but have formed by a multistage process that began with the eruption of submarine basalts in early or middle Proterozoic times. Whilst the volcanic pile cooled on the seafloor, base and precious metals could have been leached from the pillows and deposited as sulphides in interpillow positions and in fractures in the volcanics. These would have been easily mobilised by subsequent amphibolite-facies metamorphisms (550-700°C, 3-4 kb) which were accompanied by moderate to strong deformation, the formation of penetrative foliation, and emplacement of granitoids at about 1570 m.y. and 1470 m.y. B.P. The locally high carbon content of enclosing metasediments may have helped fix the precious metals in structurally favourable sites, possibly in ore-grade concentrations. However, it was probably not until these enriched zones were locally subjected to prolonged (about 50 m.y.) and intense hydrothermal activity during the late Palaeozoic that most of the existing deposits formed. The loci of such activity appear to have been keels of Proterozoic metamorphic and granitic rocks overlying a concealed late Palaeozoic granitoid batholith. These are represented by embayments into a regional gravity low that corresponds with the extent of the late Palaeozoic igneous rocks. The thickness of the roof over the hypothetical batholith in these zones, and the presence of deep vertical or steeply dipping fractures in it, such as those in well-jointed, strained granitoids like the Forsayth Granite, could have provided mineralising hydrothermal fluids with access to higher, cooler levels and suitable depositional sites.

The formation of ore with easily extractable gold resulted from oxidation enrichment of the upper near-surface parts of the deposits during Cainozoic time.

Geology and mineral potential of Red Bed and associated environments in the Mount Oxide Region, Northwest Queensland

Speaker - G.M. Derrick

The Mount Oxide area, 200 km north of Mount Isa, links Lawn Hill and Mount Isa geology. Field investigations in 1978 established a relatively simple, unifying stratigraphy that can be traced from Lawn Hill south to Mount Isa and east to the Kalkadoon-Leichhardt basement block.

From the base, eastern Creek Volcanics and Myally Subgroup sandstones are overlain by the Quilalar Formation, a sandstone-dolomite unit equivalent to the Mary Kathleen Group to the east. A major regional unconformity separates Quilalar Formation from the Fiery Creek Volcanics, which in turn is overlain unconformably by sandstone and siltstone of the Surprise Creek Formation; the McNamara Group (broadly equivalent to Mount Isa Group) overlies Surprise Creek Formation, usually unconformably, and contains the Lady Loretta Pb-Zn deposit.

Near Mount Oxide, Eastern Creek Volcanics are recorded west of the Mount Gordon Fault Zone in the cores of large domes. Thickness and facies variations in the volcanics and Myally Subgroup define the Leichhardt River Fault Trough, a rift-like feature bounded in the east by the Quilalar Arch, and in the west by the Mount Gordon Arch, a monoclinal flexure extending northwards from near Mount Isa. Westwards across the Mount Gordon Arch Myally Subgroup feldspathic sandstones grade into ferruginous dolomitic sandstone and siltstone, mudstone, and dolomite - a typical red-bed association deposited in a very shallow ?intracratonic sea. Westwards across the Mount Gordon Arch the Quilalar Formation is similarly enriched in ferruginous siltstone, mudstone and dolomite, and shallow water, possibly intertidal to supratidal, features such as stromatolites, halite casts, and possible nodular pseudomorphs after anhydrite. Around the flanks and upon the Mount Gordon Arch thin regolithic conglomerates of the Myally Subgroup, Surprise Creek Formation, and McNamara Group are preserved.

Basal McNamara Group sequences become thinner and more arenaceous adjacent to the Mount Gordon Arch, and gypsum pseudomorphs in the basal Torpedo Creek Quartzite reflect a diagenetic sulphate overprint near the palaeohigh. Younger McNamara Group sequences are less influenced by the Mount Gordon Arch, and extensive dolomitic and locally evaporitic peritidal environments characterised by an abundant stromatolite biota were formed west of the Arch.

Copper mineralisation, reminiscent of that at Redbank, is present in trachyte-rhyolite breccia and dykes which intrude the Myally-Quilalar red beds. Copper is also widely distributed in breccia zones in feldspathic ferruginous sandstone and siltstone; it infills simple vertical shears in flat-lying sandstone (e.g., near McNamara's mine), or forms in complexly faulted breccia zones, as at Mammoth.

The Mammoth deposit is located in upper Myally Subgroup adjacent to the Mount Gordon Arch, below a thick regolithic breccia of the Surprise Creek Formation and younger carbonaceous siltstone, quartzite, and dolomite. Although much of the Mammoth copper mineralisation may be related to late-stage cross-faulting, the tectono-sedimentary setting is considered favourable for syngenetic to diagenetic copper mineralisation. Synsedimentary pyrite suggests either that other red-bed zones in the area may also be pyritic at depth, or that within a mainly oxidising shallow-water environment there existed local zones of seawater sulphate reduction.

The characteristics and interpretation of geophysical anomalies in the Cobar Area, NSW

Speaker - P. Wilkes

From 1978 BMR has studied the characteristics and interpretation of gravimetric, magnetic, and electrical anomalies in the Cobar area using experimental airborne, ground and drillhole surveys, laboratory rock property measurements, data processing, and modelling. Regional gravity anomalies in the Cobar area reflect the density contrast between Ordovician basement and younger rocks. Interpretation of the regional gravity provides possible models of the Cobar trough. Detailed gravity surveys frequently highlight local lithological contrasts which can assist in mapping areas of poor outcrop. Small, discrete gravity anomalies are observed over most mineral deposits in the area, and are useful for selecting drill targets and evaluating magnetic or electrical anomalies.

Regional magnetic anomalies in the Cobar area result from basement structure, the distribution of basic volcanics, weakly magnetic zones in argillaceous rocks, and areas where extensive surficial maghemite has developed. Each of the regional anomalies has a distinctive characteristic which can be recognised on the basis of source geometry. The magnetic anomalies associated with basement structure support interpretation based on gravity modelling, and the weakly magnetic zones in argillaceous rocks may be associated with mineralised rock units. High resolution airborne and carborne surveys over discrete anomalies related to mineral deposits, basic plugs, or maghemite concentrations offer hope that 3-D modelling, spectral studies, and amplitude attenuation characteristics can aid in the discriminating between different sources. Model studies, and the results of airborne and ground TEM surveys show that a strong response to thick surface conductive zones is observed throughout most of the Cobar area. Only very small EM anomalies can be expected from bedrock conductors which do not have any expression in the weathered zone. Model and field studies indicate that discrimination of bedrock and surface conductors can be aided by a careful choice of survey parameters. A study of the application of resistivity and IP methods in the Cobar area shows that significant IP sources only occur in unweathered bedrock. However, the dilution of IP effects by the conductive overburden is marked, and meaningful interpretation of IP data in this area requires the overburden effects to be taken into account. With careful interpretation of resistivity and IP data, electrical contrasts between different rock types can be identified and used for mapping. The IP response of mineral deposits in buried bedrock is likely to be small but diagnostic - if careful attention is taken of the design and interpretation of surveys. Tests of the magnetometric resistivity method suggest that this method may prove to be an effective and rapid tool to aid mapping in areas of little outcrop.

Crustal profiles in the Lachlan Fold Belt from explosion seismology, and the Palaeozoic evolution of southeastern Australia

Speaker - D.M. Finlayson

Since 1976 BMR has made seismic recordings along four profiles radiating from the Dartmouth Dam site in northeastern Victoria; Dartmouth to Merimbula, Dartmouth to Marulan, Dartmouth to Dubbo, and Dartmouth to Condobolin. Interpretation of the data to satisfy both the kinematic and dynamic characteristics on the seismic record sections indicates a) that the crust under the Lachlan Fold Belt is neither uniform nor homogeneous, b) that velocity-depth functions are characterised by transitions rather than discontinuities, c) that the crust may contain one or more low-velocity zones, d) that the crustal thickness may exceed 50 km in places, and e) that the greatest crustal thickness is under the highest topography, decreasing towards the Murray Basin.

Geological and geochemical evidence now suggests that a thick continental-style crust must have existed prior to the Palaeozoic evolution of the Lachlan Fold Belt. It is suggested that the crustal structure evolved during more than one tectonic episode and may have analogues in the Appalachians and western South America, rather than in the oceanic island-arc regions of the western Pacific.

Strangways cryptoexplosion structure NT - terrestrial or extra-terrestrial origin?

Speaker - John Ferguson

The Strangways cryptoexplosion structure comprises a circular feature containing abundant evidence of shock metamorphism. The core consists of granite gneiss about 5 km radius, surrounded by a collar of Proterozoic quartzite and siltstone. No definitely coherent bedrock is exposed in the core: exposures are breccia, commonly highly shocked, or melt rock rich in clasts. In different areas the clasts may be all of gneiss, or a mixture of gneiss and sediments. In the collar, which is about 5 km wide, quartzite forms ridges of steeply dipping, outward-facing strata, which commonly extend outward into overturned flaps, presumably lying on poorly exposed siltstone. In one sector the outermost quartzite forms a flap of nearly horizontal overturned beds 4 km wide, making the diameter of the disturbance about 22 km. The innermost quartzite is mainly breccia both in the strike ridges and flaps; breccia is minor in the outer quartzite ridges. Shatter fracturing - more commonly intersecting sets of striated cleavage surfaces than well-formed cones - is well developed in the inner quartzite of the collar, but rare toward the outside. Anomalous features are small patches or house-sized blocks of at most weakly shocked quartzite resting on gneiss up to 1.5 km inside the normal contact, and rare blocks of shocked gneiss as far as 0.5 km outside. In the northwest corner of the structure a flat-lying carbonate unit is found which appears to post-date the explosive event and is possible Cambrian Tindall Limestone.

The basic structure is similar to the Vredefort Dome in South Africa, but the melt rock and the flaps indicate a shallower level of exposure. The occurrence of the flaps at about the same elevation as the base of the melt layer is surprising. It is not clear whether they represent features of the collar rocks outside the central uplift or of the floor inside.

The presence of shatter-cones, diaplectic glass and planar decorations in quartz indicate a high-degree of shock metamorphism. Extrapolation of static experimental data suggest pressures could have been as high as 100 kb. To achieve pressure on this scale at high levels in the crust would require the impact of a meteorite or comet; the chemistry of the shattered and melted rocks is however enigmatic. Relative to the undisturbed rocks they show enrichment in the compatible elements Ni, Co, Cr and V and in the incompatible elements Ba, La, Ce, P, and Ti. Large-scale introduction of K has also taken place. Although the compatible elements could be attributed to volatilisation of a meteorite during impact, the introduction of K and the incompatible elements would not support such an origin. If the shock-metamorphism observed is to be attributed

to a terrestrial origin a violently explosive crypto-volcanic event would be the most likely cause. The chemical changes recorded would suggest involvement of a volatile-enriched alkaline ultramafic magma. From a terrestrial argument the biggest difficulty would be in the generation of excessively high overpressures, as suggested by the experimental work.

The excessively high overpressures suggested by the experimental work represent the greatest difficulty to a terrestrial origin for the structure.

The state of stress in the Australian continent

Speaker - D. Denham

Evidence from earthquake focal mechanisms, overcoring measurements, and surface deformations indicates that the Australian continent is in a state of substantial compression.

Reliable focal mechanisms are now available from twelve earthquakes that have occurred in several parts of the continent since 1967. Each of these mechanisms indicates that the faulting associated with the earthquakes was caused by compressive stress acting close to horizontal.

Overcoring measurements made in underground mines and close to the surface in quarry floors or on rock outcrops also indicate compressive stress in all areas.

Near the site of the 1968 Meckering earthquake, shallow overcoring measurements (< 10 m) were carried out to compare the in-situ observations with the earthquake focal mechanism and the surface faulting. The measurements were made in competent granite at seven locations along a 200 km north-south traverse. The results indicate a high regional compressive stress acting about 77°E of N which agrees well with the 91°E of N direction for the pressure axis obtained from the earthquake focal mechanism. The highest stress (23 MPa) was measured at the site furthest north from the epicentre and the lowest stress close to the epicentre, where the maximum principal stress was about 4 MPa.

During 1978 five sites in NSW were tested at depths ranging from 3-9 m. At each site the stress measured was compressive. Near the coast at Milton and Moruya the axes of maximum compression were north-south, but at the other sites the maximum stress was close to east-west. The highest values ($\sim$ 20 MPa) were obtained in Silurian granite at Tocumwal and Berrigan.

Basement evolution and mineral potential of the Alice Springs area

Speaker - R.D. Shaw

A simplified model is presented of the stratigraphic and tectonic evolution in the basement rocks in the Alice Springs 1:250 000 Sheet area based on the concept of three broad lithological groupings, termed Divisions.

In this model Division I consists chiefly of basic and acid granulites and is interpreted as a bimodal sequence of volcanics and intrusives introduced during a phase of arrested east-striking rift development on an ensialic crust.

Later widespread subsidence resulted in two, possibly connected, east-trending troughs flanking the metavolcanic belt represented by Division I rocks. The southern trough was filled by acid volcanic and volcaniclastic rocks, now represented by well-layered quartzofeldspathic gneisses, tentatively assigned to units of the lower part of Division II. In contrast a more argillaceous sequence containing only minor volcanic rocks, and more typical of the upper part of Division II, was deposited in the northern trough. The quartzofeldspathic gneisses of lower Division III appear to be much thinner.

The sedimentary cycle was completed by deposition of more mature quartz sandstone and argillite belonging to Division III.

Tectonism at about 1800 m.y. resulted in metamorphism up to granulite grade, widespread migmatisation, and minor granite emplacement. Metamorphism and deformation re-occurred at 1700-1600 m.y., possibly at 1500-1400 m.y., at 1100-1000 m.y., and at 400-300 m.y. Granites were emplaced during the 1700-1600 m.y., and some granite emplacement accompanied the 1100-1000 m.y. metamorphism. Overthrusting, possibly at 1600 m.y., and certainly at 300 m.y., was synchronous with metamorphism.

The Woolanga Lineament, which cuts the main east-west tectonic trend at a high angle, is thought to be a deep-crustal fracture responsible for localisation of the potassic-ultramafic Mordor Igneous Complex and the Mudtank Carbonatite during periods of stability about 1090 m.y. and 730 m.y. ago, respectively.

Arunta rocks have some potential for Oonagalabi-type Zn-Pb-Cu deposits. Various schist zones are prospective for gold, lead, copper, and possibly uranium. The zone alongside the Woolanga Lineament is a possible locus for kimberlite, which may contain diamonds, and for carbonatite which may contain economic concentrations of niobium, rare earth elements, zircon, apatite, and vermiculite. Other minerals of interest in the region include mica in the Harts Range pegmatites, and ruby, some of which is of gem quality, occurring in amphibole-plagioclase pods in the Mount Riddoch Amphibolite.

New developments in geochronology

Speaker - L.P. Black

In only the simplest of geological terrains will different dating techniques yield the same age for a particular rock. With increasing knowledge, however, this apparent disadvantage is generally proving to be a help rather than a handicap, for it makes possible the identification and dating of different events during the history of that rock.

In the Mount Isa region, for example, detailed studies have shown that Rb-Sr total-rock ages for igneous rocks are generally significantly younger than U-Pb zircon ages, which usually represent the time of primary crystallisation. The two methods thus provide a stratigraphic framework for the area. Farther east, in the Georgetown Inlier, it has been shown that different Rb-Sr total-rock ages can be derived from rocks of the same stratigraphic age. These ages correlate with temporally distinct deformational-metamorphic events spread over at least 1000 m.y. The data indicate that the critical structural requisite for resetting Rb-Sr total-rock ages is the development of a penetrative schistosity. This resetting is independent of metamorphic grade - e.g., it occurs in granulite rocks in the Arunta Block, in amphibolite-facies rocks in the Georgetown Inlier and the Arunta Block, and in greenschist facies rocks in western Tasmania and the Tennant Creek and Mount Isa regions. Elsewhere in the world it has been documented in rocks which have not even reached greenschist conditions.

The Sm-Nd dating technique, which has recently been developed overseas, is currently being established in the joint ANU-BMR laboratory. Like the U-Pb zircon method, this technique can also provide the primary crystallisation age of an igneous rock in a geologically complex terrain. Provided the samples are properly collected, metamorphism, and even alteration, weathering, erosion, and deposition as sediment apparently do not disturb the original Sm-Nd systematics. Consequently, the technique will become increasingly important in Australia. Its main limitation is that it can be applied only to relatively old rocks - i.e., older than about 1000 m.y.

Late Palaeozoic ignimbrite volcanism and mineralisation in northeastern Queensland

Speaker - B.S. Oversby

During Carboniferous and Permian time the Georgetown-Chillagoe district of northeastern Queensland was the site of an extensive post-orogenic (or transitional) calc-alkaline volcanic field (Newcastle Range-Featherbed Field). This was characterised by eruptions of voluminous, mainly rhyolitic, ignimbrites. Similar fields also occurred in northern Cape York Peninsula and Torres Strait (Janet Ranges-Torres Strait Field), and in the Bowen area (Bulgonunna Field). Ignimbrite eruptions in these fields were commonly accompanied by the development of subsidence structures which appear to have been represented at the surface by relatively gentle depressions. Structural form was emphasised at depth as underlying magma chambers stoped their way upwards; further emphasis occurred as a consequence of late-stage settling-in when magma chambers solidified. Some of the subsidence structures are large, and irregular in plan; these structures, which are commonly composite, are regarded as volcano-tectonic features. Smaller second-order features are more-or-less circular to elongate in plan.

Uranium, tin, and porphyry-copper-like deposits are associated with late Palaeozoic ignimbrites in northeastern Queensland. Undiscovered deposits, possible of large size, should occur preferentially in the more complex and longlived parts of subsidence structures. One area in the postulated Featherbed volcano-tectonic structure is considered to be especially prospective. However, most deposits will not be easy to find; their discovery will depend on fuller understanding of the relative importance of different subsidence structures, so that those with suitable characteristics can be selected for detailed exploration in preference to others. Fuller understanding can be achieved in part by relating ignimbrite units to their source eruptive centres, and by elucidation of the structure of volcanic sequences at the surface, and at depth.

Revised Proterozoic stratigraphy and economic potential of the western Georgetown Inlier, north Queensland

Speaker - D.E. Mackenzie

Geological work by White & others in 1956-58 resulted in the division of the Precambrian sequence of the western Georgetown Inlier into four Proterozoic units Robertson River Metamorphics, and Bernecker Creek, Etheridge, and Langdon River Formations, and a possibly Archaean basement (Einasleigh Metamorphics).

More recent joint BMR-GSQ field work has shown that all of the previously named units form a continuous sequence, the Etheridge Group, which is made up of the Bernecker Creek, Robertson River, Townley, Heliman, Candlow, Langdon River Formations and the Einasleigh Metamorphics. The Robertson River Metamorphics is the high-grade (eastern) part of the more extensive, dominantly pelitic Robertson River Formation. The Einasleigh Metamorphics contain higher grade equivalents of the calcareous Bernecker Creek Formation and also grades into the lowermost(?) part of the Robertson River Formation, but the stratigraphy of the Einasleigh Metamorphics is incompletely resolved. A marked angular unconformity separates the Etheridge Group from the overlying Malacura and Yarman Formations (new units), which are in turn separated from the Proterozoic (previously considered to be Permian-Carboniferous) Croydon Volcanics - partly by faults, and partly by an angular unconformity. Each unit is described briefly.

The Einasleigh Metamorphics contain stratabound Pb-Zn and Cu deposits spatially related to a change from calcareous to pelitic lithologies; thus the Bernecker Creek Formation-Robertson River Formation contact, as well as calcareous parts of the latter unit, may also be prospective. Maximum development of volcanic rocks is in the middle Robertson River Formation, where metabasalts and metadolerites are locally associated with minor Cu-Ag-Au mineralisation. The overlying more quartzose Townley Formation may contain some volcanic detritus, and, as well as several Ag-Pb-Zn mines and prospects, there are signs of apparently stratigraphically controlled Pb-Zn geochemical anomalies. Parts of the Candlow Formation, a shallow-water siltstone - fine sandstone unit, are very carbonaceous, also commonly pyritic, and locally dolomitic, all reminiscent of evaporitic conditions. The unit is very poorly exposed, but several minor Pb-Zn gossans, generally associated with intraformational(?) breccias, are known.