EXTENDED ABSTRACTS

Record 1985/33

14TH

BMR Symposium

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS AUSTRALIA

Canberra, 23-24 October 1985

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Exploration applications of the new large-format magnetic pixel maps of Australia

D.H. Tucker (BMR)

BMR has used image-processing techniques to produce the first of a series of grey and colour-scaled total magnetic intensity and gradient pixel maps. The maps include the Albany and Roper River 1:1 000 000 standard sheet areas which cover 4 degrees of latitude and 6 degrees of longitude. A special map from 32 to 38 degrees latitude and from 138 to 147 degrees of longitude covers the Murray Basin. Areas with no digital data are shown blank.

The pixel maps are intended for interpretation at 1:1 000 000 scale, and terminology based on visual pattern recognition in the total magnetic intensity presentation has been devised to permit a uniform approach to this. Three stages of interpretation have been adopted:

1. Separation into 'magnetic domains' - large areas of similar magnetic texture;
2. Determination of 'magnetic lithostratigraphy' - this gives detail of elements which comprise the domains; and
3. Development of strato-tectonic models.

Pixel maps of very large areas of airborne magnetics can quite easily reveal both large and small-scale features which are very difficult to recognise in conventional contour and profile presentations. The distribution of mineral occurrences and scattered geological and geophysical data of relevance in mineral and petroleum exploration can now be reviewed by overlaying on an extensive, uniform, and very evocative base. Tapes of the grids can give the option to undertake further manipulation and merging with other data.

It is evident that, for many of the sedimentary basins, extensive detailed, high-resolution airborne magnetic surveys are required to replace the 15-30 years old data presently available in government databases and unsuitable for pixel map production.

Four examples of exploration applications under investigation include: magnetic linear anomalies and spatially-associated gold and uranium; narrow curvilinear anomalies and associated nickel and gold; circular anomalies and associated tin and tungsten; and linear anomalies indicating sedimentary basin fracture systems.

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McArthur Basin: constraints on areas of deep sediment from gravity and magnetics

P. Wellman (BMR) & K.A. Plumb (BMR)

The present geological model for the McArthur Basin proposes that the Proterozoic sediments are up to 4 km thick over widespread shelves, and 4-10 km thick in the central Batten Trough and possibly to the southwest. BMR seismic refraction and magnetotelluric surveys have confirmed this model along an east-west traverse across the southern part of the basin, and identified the 10 km deep Betaloo Sub-basin in the southwest. Gravity and magnetic anomalies are used here to study the structures basin-wide. The geological model has been effectively confirmed.

Thickness variation of the preserved McArthur Basin sediments has been mapped by estimating depths to magnetic bodies, and the nature of the thick sediment has been determined from their combined gravity and magnetic signatures. The margins of the zones of thick sediment generally correspond to steep gravity and/or magnetic anomaly gradients.

Magnetic bodies within the basin succession complicate mapping of depth to basement. Selection of anomalies depends on geological constraints from surface geology. All techniques consistently define a broad zone of overall thick sediments widening from 50 km at latitute 12°S to 250 km at 17°S, and bounded by shallower shelves ($<$ 4 km) to the east and west. Separate north-south troughs cut by northwest transverse highs may be defined within this zone.

The Batten Trough lies as postulated geologically, divided by an extension of the Urapunga Tectonic Ridge. Its thickest and widest development is concealed beneath the Gulf of Carpentaria and adjacent coastal plain, between Roper River and Groote Eylandt. The concealed Beetaloo Sub-basin is outlined as a zone of thick Roper Group. A new totally concealed trough of thick carbonate rocks (McArthur Group equivalents) is suggested in the southwest of the area. Both of these troughs trend into the Tomkinson Creek Beds, north of Tennant Creek.

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G

Deformation models for country rock above intraplate mafic intrusions

P. Wellman (BMR)

A study of eastern Australian Cainozoic volcanoes shows that each volcano is associated with a large cogenetic mafic intrusive complex. The intrusive complex causes an uplift of the country rock under the volcano, and gravity and magnetic anomalies.

The mass of the intrusive complex can be calculated using the integral of the residual gravity anomaly and the mean upper crustal density. The volume of the uplift under the volcano is likely to be the volume of the intrusive complex, as this, together with the mass, gives a reasonable value of 3.0 $t.m^{-3}$ for its mean density. The gravity anomalies are consistent with a spherical shape for the intrusive complex (to a first approximation), with a centre of mass at 6-8 km. From the uplift volume the diameter must be 4-10 km. The base of the intrusive complex would be at a depth of less than 13 km. The volume of each intrusive complex is about one-third of that of the original volume of lava.

It is found that the shape of the uplift over the intrusive complex is similar to the shape of the residual gravity anomaly. This is consistent with the uplift of the country rock being given to the first approximation by deformation of an elastic half space. Uplift (u) is given by $u = k.f/(f^2+d^2)^{3/2}$, where k is a constant, d is the radial distance on the Earth's surface from above the centre of the sphere, and f is the depth of the centre of the sphere. In the examples studied, the country rock directly over the intrusion is often faulted and cut by minor intrusions.

In the above model, space for the intrusive complex is solely by uplift of the country rock above and to the side of the intrusive complex, with no crustal extension by a regional dyke swarm or faulting, and no formation of space by downward movement of the lower crust.

A similar uplift model appears to apply to intrusive complexes associated with carbonatite volcanism in East Africa, and should apply to other mafic and intermediate intrusions that have been forcibly injected into the upper crust.

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Tectonic development of Lord Howe Rise basins

J.B. Willcox (BMR)

The Lord Howe Rise is the major physiographic feature of the Tasman Sea region: a 'ribbon of continent' extending for more than 2000 km, with most of its crest lying in water depths of 750 to 1200 m (figure 1). Research cruises conducted by BMR and BGR (West Germany) have shown that the Rise consists of five main structural provinces (Willcox & others, 1980); Whitworth & Willcox, 1985; Roeser & others, 1985; figure 2) -

(P1) flanking sedimentary basins along the western margin, adjacent to the Middleton and Lord Howe (bathymetric) Basins.

(P2) a complex horst and graben province beneath the western half of the Rise, and generally northeast of Lord Howe Island.

(P3) a (?) rift basin southeast of Lord Howe Island.

(P4) a zone of planated basement beneath its eastern half.

(P5) An eastern flank basin, containing pre-Maestrichtian sediments of the ancient (Gondwana) continental margin.

Sedimentary accumulations of up to 4500 m have been observed, and in some areas the fault-blocks which floor them are themselves well-stratified. Modern seismic sections show some evidence of diapir-like structures in the younger basin-fill (Symonds, pers. comm.).

The origin of basins beneath the western Lord Howe Rise are still conjectural, and several scenarios for basin development need to be considered:

- western Lord Howe Rise and Dampier Ridge may constitute an entire Cretaceous rift-valley formed prior to sea-floor spreading in the Tasman Basin (Jongsma & Mutter, 1978; figure 2). Asymetric break-up along its western boundary fault would account for the narrow eastern seaboard of Australia and the absence of east coast pull-apart basins. The rift stage of the Gippsland Basin (sometimes referred to as the Strzelecki Basin) and the Lord Howe Rise basins would then have formed a triple rift junction.

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- a Lord Howe rift system overprinted the Gippsland rift; a situation that is difficult to envisage and to accommodate within the time frame.

- a basin on the western flank of Lord Howe Rise is essentially an extension of the Gippsland (Strzelecki) Basin offset by a transfer fault.

- the basins formed as a result of a major left-lateral, oblique-slip zone, between Australia and the Rise, analogous to the San Andreas Fault (Jones & Veevers, 1983).

- the Lord Howe Rise basins are not directly rift-related, but may have equivalents amongst more ancient basins, such as the Permo-Triassic Sydney Basin and Esk Trough, or the Triassic-Cretaceous Clarence-Moreton Basin.

The structural relationships of intrabasinal trends and basin margins suggest that most of the basins can be best accommodated by a modification of the first model. That is, while simple extension occurred in the Gippsland and southern Lord Howe rift systems, oblique extension took place within a northern Lord Howe rift (Symonds, pers, comm.). This oblique extension within continental crust probably continued during the first stage of sea-floor spreading in the southern Tasman Basin.

References

JONGSMA, D., & MUTTER, J.C., 1978 - Non-axial breaching of a rift valley: evidence from the Lord Howe Rise and the southeastern Australian margin. Earth and Planetary Science Letters, 39, 226-34.

ROESER, H., & SHIPBOARD PARTY, 1985 - Geophysical, geological and geochemical studies in the Lord Howe Rise region. Bundesanstalt für Geowissenschaften und Rohstoffe Report. Cruise SO36(1).

WHITWORTH, R., & WILLCOX, J.B., 1985 - Rig Seismic research cruise 1:Lord Howe Rise. Bureau of Mineral Resources Australia Report. 266.

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NOTES

WILLCOX, J.B., 1981 - Petroleum prospectivity of the Australian marginal plateaus. Energy Resources of the Pacific Region, AAPG Studies in Geology, 12, 245-272.

WILLCOX, J.B. & OTHERS, 1980 - Lord Howe Rise, Tasman Sea - preliminary geophysical results and petroleum prospects. BMR Journal Australian Geology & Geophysics, 5, 225-236.

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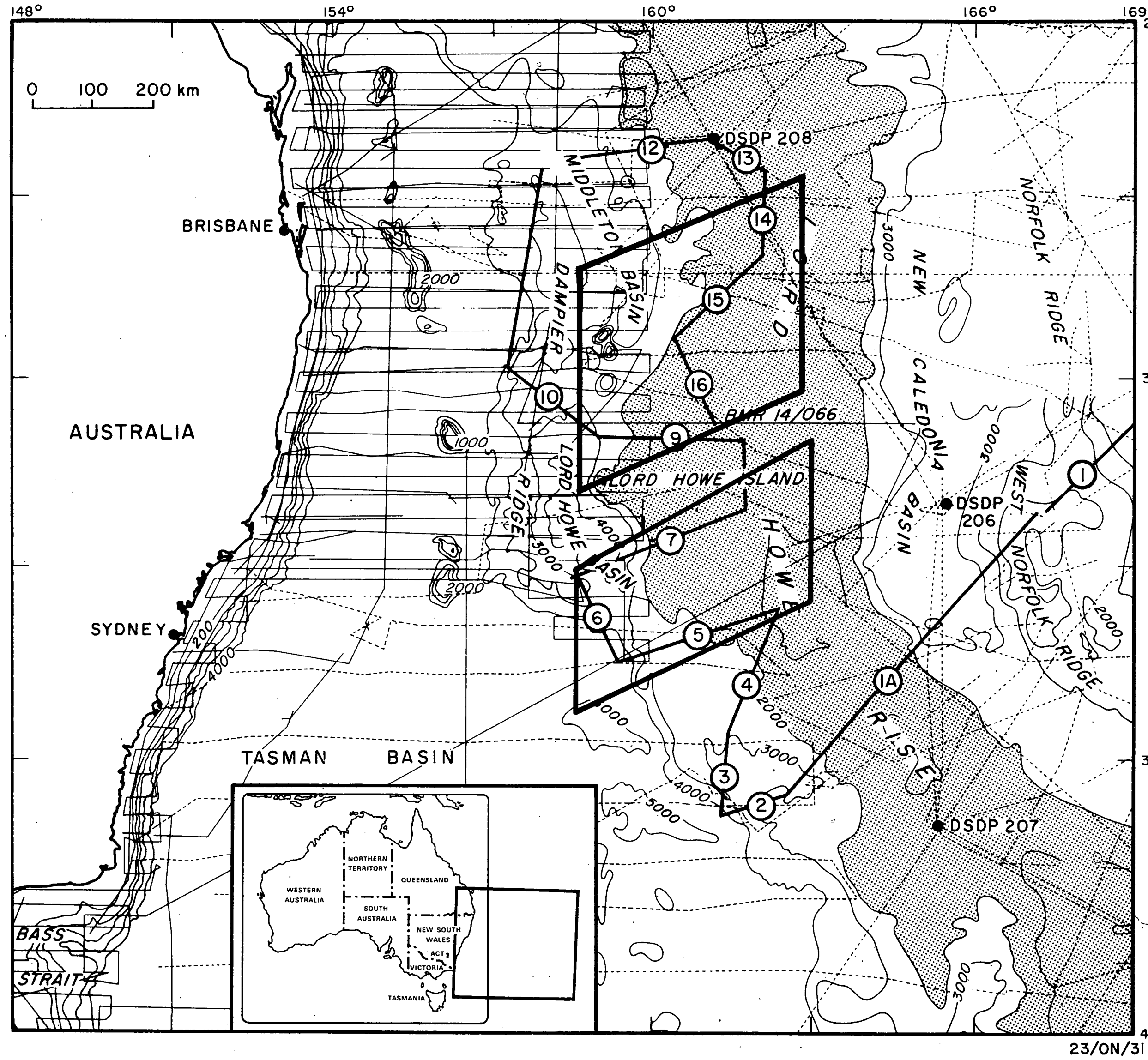

Figure 1. Bathymetry of the Tasman Sea.
After Ringis (1972), showing 1985 BMR Rig Seismic (south) & BGR Sonne (north) cruise areas, seismic reflection profiling tracks (BMR Continental Margin Survey lines solid; Sonne SO-7 lines heavy solid, 1 = Line SO7 - 01 etc), BMR Line 14/066, and DSDP sites 206, 207 and 208.

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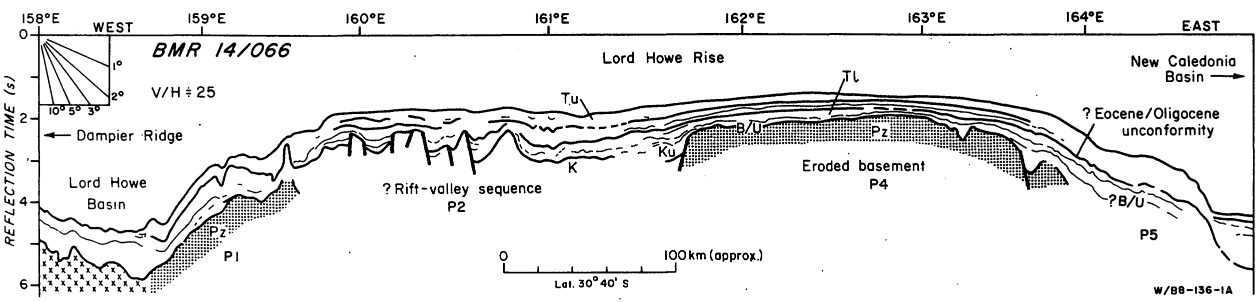

Figure 2. Structural profile across Lord Howe Rise.

Based on BMR Line 14/066 (after Willcox, 1981). Location given in Figure 1. (Tu = Miocene - Recent, Te = Paleocene - Oligocene, Ku = Late Cretaceous, Pz = Palaeozoic, B/U = breakup unconformity, crosses = crystalline basement of unknown origin).

P1 etc. are structural provinces discussed in text.

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Abiological vs biological sulphate reduction in low-temperature sulphide deposits : what is the evidence?

T.G. Powell (BMR)

Sulphide in stratabound or stratiform ore bodies have commonly been formed at relatively low temperatures (80 to 175^{o}C). The reduced sulphur species in such deposits are generally considered to have been formed by reduction of sulphate. Two mechanisms have been suggested - biological sulphate reduction and thermo-chemical sulphate reduction by organic matter. Present experimental data place the upper limit of bacterial sulphate reduction at 75^{o}C and the lower limit of thermochemical sulphate reduction at 175^{o}C, although extrapolation of kinetic data has been used to demonstrate the viability of thermochemical sulphate reduction at lower temperatures. The conditions of sulphate reduction in these two cases are sufficiently different to have profound implications for the conditions of ore genesis. Because of the impasse created by experimental data it is necessary to seek direct evidence from the deposits themselves for the conditions and mechanism of sulphate reduction.

Analysis of organic materials in association with a carbonate-hosted Pb/Zn deposit at Pine Point, Canada has demonstrated the involvement of organic matter in the production of H_2S by reaction with elemental sulphur. Isotopic evidence is consistent with the thermochemical reduction of sulphate by organic matter according to the following reaction:

$$SO_4^{2-} + 3H_2S \rightarrow 4S^o + 2H_2O + 2OH^-$$

$$10C_{30}H_{45}SO + 98S \longrightarrow (C_{30}H_{30}S_4)_{10}O_3 + 7H_2O + 68H_2S$$

Fluid inclusion data indicate that the mineralised zones represent thermal anomalies (up to 100^{o}C) compared with the host rocks which, from burial history and organic maturation considerations, have reached only a maximum temperature of approximately 60^{o}C. Mass balance considerations show that the amount and degree of alteration of the organic matter is more than adequate to account for the reduced sulphur species deposited at Pine Point. Investigation of the nature and composition of organic matter in association with low-temperature ore bodies may provide direct insight into the mechanism and timing of ore formation.

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Sedimentary phosphate deposits

P.A. Cook (BMR)

Research in Australia and overseas through IGCP Project 156 has lead to a new understanding of the genesis of sedimentary phosphate deposits (phosporites). Phosphorites form in response to a combination of conditions, operating over a wide range of scales. At the local scale, reworking of phosphate grains is essential to the formation of most economically significant deposits of grainstone phosphorite. Bacteria may play an important role: eustatic changes of sea level and changes in ocean chemistry are probably important components in global phosphogenesis. Phosphorites are most common at particular times in Earth history. The occurrence of phosphorites around the Precambrian-Cambrian and Cretaceous-Tertiary boundaries is a particularly notable feature. Faunal changes at these boundaries may be linked to perturbations in the abundance of phosphate in the photic zone of the world ocean.

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The Laser Raman Microprobe, a new tool in ore genesis studies

H. Etminan (BMR)

Raman spectroscopy investigates molecular vibrational energy and is complementary to infra-red spectroscopy. The Laser Raman Microprobe is a non-destructive technique for study of individual phases in fluid inclusions. Its main applications are in determining the bulk composition of gas and liquified gas trapped in fluid inclusions, in identifying daughter minerals, and in the partial chemical analysis of aqueous solutions.

The Laser Raman Microprobe technique (at CREGU, France) was recently applied in the study of Australian hydrothermal metallic mineral deposits. Two case studies are discussed here:

1. low-temperature, Mississippi Valley-type lead-zinc mineralisation in the Lennard Shelf reef complexes, northern Canning Basin, W.A. (Etminan and Lambert, in preparation).
2. high-temperature, tin-tungsten mineralisation at Mt Paynter, in the Lachlan Fold Belt, NSW (Etminan and Higgins, in progress).

On the Lennard Shelf, aromatic and aliphatic hydrocarbons were detected in fluid inclusions in dolomite from the Wagon Pass prospect, and in yellowish and purplish sphalerites from the Pillara prospect. These data were subsequently substantiated using the Fourier transform infra-red microprobe. Comparisons of compositions of crude oil from the Canning Basin and the hydrocarbons in fluid inclusions of the Pb-Zn prospects have commenced. This is aimed at elucidating the relationship between the genesis of petroleum and Pb-Zn mineralisation in carbonate-reef complexes.

At Mt Paynter, Laser Raman Microprobe determinations of fluid inclusions in quartz gangue associated with scheelite yielded preliminary data on the bulk composition of the ore fluid, as follows:

H_2O = 92.37, NaCl = 7.30, CO_2 = 0.30 and CH_4 = 0.03 (mol %)

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The fluids are similar to those reported from several other tin-tungsten deposits of the French Massif Central (Ramboz, 1985).

Combination of Laser Raman Microprobe and microthermometry permits the characterisation of P, T, V, X of hydrothermal fluids which can ultimately be used in numerical modelling of element transport and deposition in a wide range of hydrothermal ore deposits.

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Geochemical evolution of Archaean mafic-ultramafic volcanics, with reference to the Pilbara Block, Western Australia

A.Y. Glikson (BMR)

The magnetic evolution and environment of emplacement of mafic-ultramafic volcanics and hypabyssal bodies are relevant to considerations pertaining to exploration for Ni, Cr, V and platinum-group elements. Geochemical investigations of Pilbara, Yilgarn and Kimberley basic igneous units allow distinctions between several geochemically distinct suites, some of which show significant correlations between ferromagnesian trace-element levels and the nature of contained mineralisation.

A rare-earth element (RE) and stable incompatible elements (Ti, Zr, Nb, P, Y) study of 3.7-2.7 b.y.-old mafic to ultramafic volcanic sequences in the Pilbara Block shows marked stratigraphic variations which are interpreted in terms of source mantle heterogeneity, fractionation processes and limited crustal contamination. The Ce_N-$(Ce/Yb)_N$ relations in the 3.7-3.4 b.y.-old group are consistent with batch melting of light RE chondritic to depleted garnet lherzolite source. The 3.4-3.0 b.y.-old basalts can be interpreted in terms of remelting of light RE-depleted mantle. The 3.0-2.7 b.y.-old basalts suggest partial melting of a light RE-enriched mantle containing a high (over 30%) alkali basalt component. Low CaO/Al_2O_3 ratios and comparisons with model fractionation trends indicate the role of clinopyroxene and plagioclase fractionation. The first and third age groups correspond to tectonically relatively stable periods during which the upper mantle was enriched in incompatible elements by liquids arising by incipient fusion of garnet lherzolite sources. The second group corresponds to a tectonically active phase, including continuous remelting and production of peridotitic komatiites. The breaks between the above phases coincided with major plutonic and volcanic felsic igneous events at 3.5-3.4 and 3.0 b.y. ago.

The relative abundance of peridotitic komatiites, chondritic RE patterns and high Ni/Mg values typical of the 3.4-3.0 b.y.-old sequences are analogous to characteristics of the approximately 2.7 b.y.-old greenstones of the Norseman-Kalgoorlie-Wiluna zone, Yilgarn Block. The high-temperature magmatic activity, involving high degrees of partial melting

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in mantle diapirs, is genetically linked to the intense tectonic activity which typifies these phases. The strong partitioning of Ni into liquids upon high-temperature partial melting, due to lowering of partition coefficients, explains the association of Ni sulphides with komatiitic assemblages in tectonically-mobile Archaean environments.

The geochemical data allow identification of long-term temporal trends in the evolution of Australian Precambrian shields. Sm/Nd ratios of basic igneous rocks tend to decrease and Ce/Y ratios tend to increase from the early Archaean to the late Archaean and early Proterozoic (fig. 1), signifying increasing light/heavy RE fractionation of the source mantle. The range of Rb/Sr ratios tends to increase in felsic igneous rocks with time. The temporally-evolving geochemical characteristics of the mantle are believed to underlie some of the principal variations in magmatic activity, tectonic style and mineralisation.

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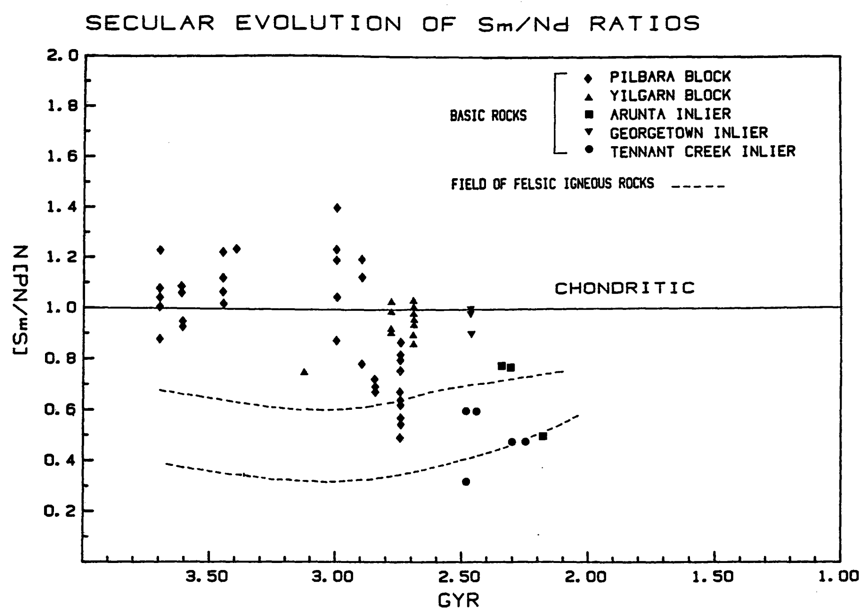
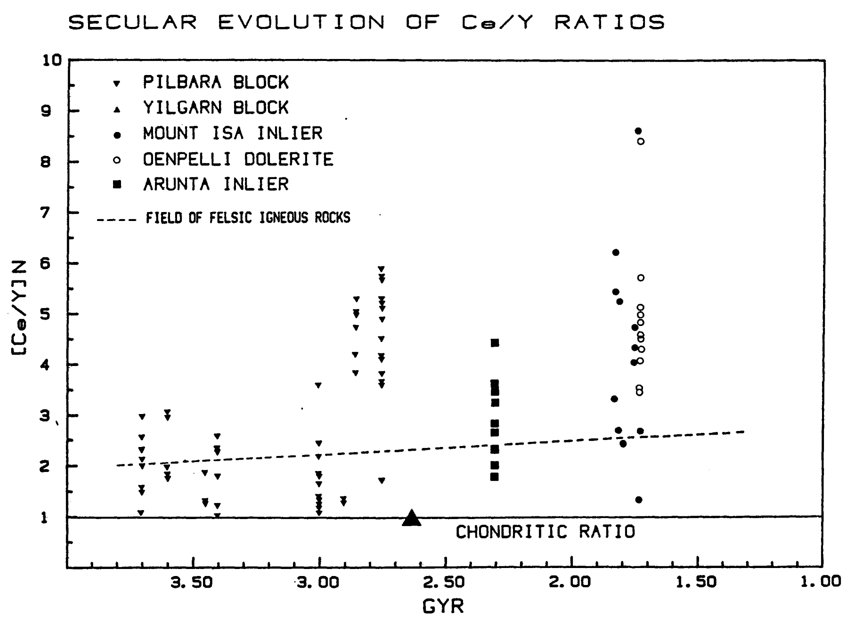
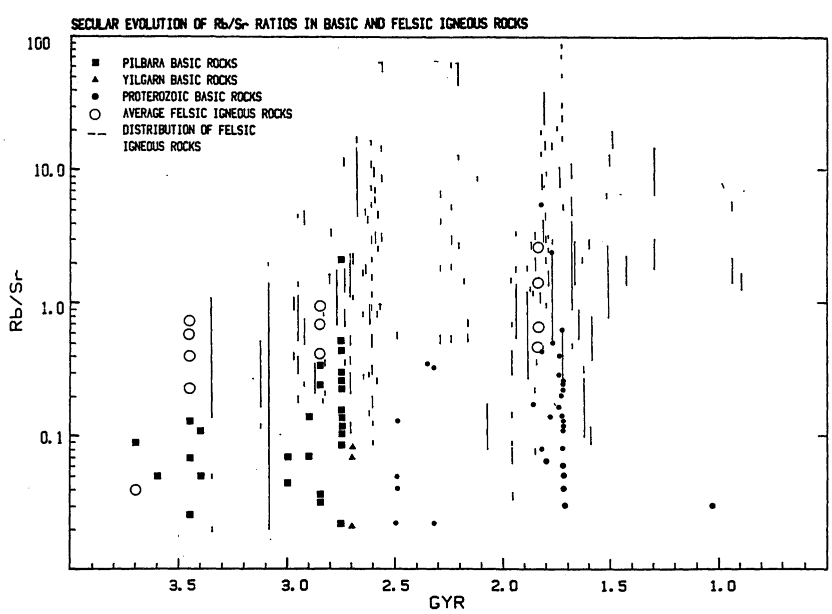

SECULAR EVOLUTION OF Sm/Nd RATIOS
BASIC ROCKS
PILBARA BLOCK
YILGARN BLOCK
ARUNTA INLIER
GEORGETOWN INLIER
TENNANT CREEK INLIER
FIELD OF FELSIC IGNEOUS ROCKS
CHONDRITIC
[Sm/Nd]N
GYR


SECULAR EVOLUTION OF Ce/Y RATIOS
PILBARA BLOCK
YILGARN BLOCK
MOUNT ISA INLIER
OENPELLI DOLERITE
ARUNTA INLIER
FIELD OF FELSIC IGNEOUS ROCKS
CHONDRITIC RATIO
[Ce/Y]N
GYR


SECULAR EVOLUTION OF Rb/Sr RATIOS IN BASIC AND FELSIC IGNEOUS ROCKS
PILBARA BASIC ROCKS
YILGARN BASIC ROCKS
PROTEROZOIC BASIC ROCKS
AVERAGE FELSIC IGNEOUS ROCKS
DISTRIBUTION OF FELSIC IGNEOUS ROCKS
Rb/Sr
GYR

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Geochemical evolution of igneous rocks of the Mount Isa Inlier and significance for mineralisation

L.A.I. Wyborn (BMR) & R.W. Page (BMR)

With time, the igneous rocks of the Mount Isa Inlier show a change in composition, with the change at 1800 Ma being quite marked. The oldest major suite of igneous rocks is composed of the Kalkadoon Granodiorite, Ewen Granite and Leichhardt Metamorphics emplaced between 1865-1840 Ma. There is evidence of felsic volcanics which pre-date this, but they are volumetrically insignificant. The 1865-1840 Ma suite is I-type, and shows little evidence of fractionation, and there are no zoned plutons or major bodies of leucogranite. There is no significant mineralisation associated with this suite.

Rift phase I commenced around 1790 Ma with the bimodal volcanics of the Magna Lynn Metabasalt and the Bottletree and Argylla Formations. After some sedimentation, these were followed by continental tholeiitic volcanism of the Eastern Creek and Marraba Volcanics. The felsic volcanics of rift phase I are chemically distinct from any found in the 1865-1840 suite, containing higher Zr and Nb and lower Sr, and they are true A-types. The Soldiers Cap Group may or may not correlate with rift phase I.

Intruding the Corella Formation of sag phase I is a bimodal granite-gabbro suite of the Wonga Belt of which the Burstall Granite and the Lunch Creek Gabbro are parts. This suite, which is dated at 1740 Ma, may signify the start of rift phase II. The granites of this suite contain free fluorite, and have high contents of Th (up to 150 ppm), U (up to 30 ppm), Nb (up to 60 ppm), and Y (up to 120 ppm). Rift phase II igneous rocks, from 1700-1678 Ma, include the Carters Bore Rhyolite, the Fiery Creek Volcanics, and the Weberra Granite. They are characterised by unusually high K_2O, which is due in part to alteration, but the primary K_2O may also have been high. High K tuffs in sag phase II (Mount Isa and McNamara Groups) show similar chemical features.

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The 1670 Ma Sybella Granite is enigmatic. It may pre-date the Mount Isa Group and be part of rift phase II, or it may post-date it and signify another rift phase. Like the 1740 Ma Wonga granites, the Sybella Granite contains fluorite and high values of Th, U, Nb, Y, as well as high Zr and Pb.

The last major felsic event was the emplacement of the Williams Batholith and Naraku Granite at about 1500 Ma. These granites are petrographically distinct, containing sphene+magnetite+clinopyroxene but no fluorite. Chemically they are also enriched in Th and U (up to 30 ppm), but unlike the earlier granites they contain less K_2O, Pb, and Zn. Of all the Mount Isa granites, those of the Williams Batholith show the best evidence for crystal fractionation; some plutons are zoned, and some have small deposits of Cu, Au, Ag, and U both within and around the margins.

Although no major ore deposits appear to be directly associated with igneous processes, some of the igneous rocks would have been suitable source rocks during deformation metamorphic events; e.g. between 1600-1480 Ma. The mafic volcanics were probable source rocks for Cu, Co, and Au deposits, whilst the felsic igneous rocks, particularly those younger than 1800 Ma, are in places associated with deposits of U, Th, La, Ce, Sn, and Be.

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Basement in the Mount Isa Inlier : field and geochronological evidence

D.H. Blake (BMR) & R.W. Page (BMR)

The extent and age of basement rocks underlying Proterozoic cover-sequences of the Mount Isa Inlier are currently being investigated. The oldest cover-sequence rocks are considered to be the felsic Leichhardt Volcanics which, together with comagmatic granites of the Kalkadoon Batholith, are dated at between 1850 and 1880 Ma (U-Pb zircon). The earliest regional deformation and metamorphism known to affect these rocks is dated at about 1620 Ma, 50 Ma after the deposition of the Mount Isa Group. Units which can be snown to have been deformed and regionally metamorphosed before 1620 Ma are regarded as basement or possible basement. One such unit, a suite of migmatitic rocks, is exposed along the west side of the Kalkadoon-Leichhardt Belt, and another, the Yaringa Metamorphics, crops out west of Mount Isa.

The migmatites in the west of the Kalkadoon-Leichhardt Belt include metasediments, dacitic to rhyolitic metavolcanics, and gneissic granites. They are intruded by Kalkadoon Granite and mafic and felsic dykes and are overlain unconformably to the west by the 1790 Ma-old Bottletree Formation. Field evidence shows that migmatitic metadacite containing zircon dated at 1850±16 Ma was intensely deformed before being cut by granite veins containing zircon dated at 1860±35 Ma. The geochronological data suggest that the migmatisation took place between 1850 and 1860 Ma, although regional considerations favour an older age.

The Yaringa Metamorphics west of Mount Isa consist mainly of partly migmatitic paragneiss retrogressed to schist, but have also been taken to include schistose felsic porphyry. The paragneiss contains a complex population of zircons, with a minor multi-age component (2.1-2.5 Ga) and a major younger component (ca. 1.9 Ga) which forms rims around older cores. Three possible interpretations are (1) the 1.9 Ga zircons are detrital igneous grains; (2) the 1.9 Ga zircon grew authigenetically during migmatisation; (3) the migmatites are late Archaean and were retrogressed at 1.9 Ga.

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Structure and tectonics of the Precambrian Mount Isa Inlier, northwest Queensland

G.S. Lister (BMR), M.A. Etheridge (BMR), & A.J. Stewart (BMR)

This paper summarises the present working hypothesis for the tectonic evolution of the Mount Isa Inlier.

The youngest structures are strike-slip faults, with 0-40 km relative displacement, oriented so that the region must have undergone simultaneous north-south extension and east-west shortening. Individual strands of the strike-slip systems diverge or converge, as do fault strands on major wrench faults much as the San Andreas system. As a result, these later movements (some of which persisted into the Mesozoic) are associated with important transpressional or transtensional effects. Transpression led to significant ductile deformation, and locally thrusting and/or high-angle reverse faulting took place. Transtension led to normal faulting.

Prior to this, the region was subject to east-west shortening in the order of 40-80% during the D_2 deformation. As the crust is now only 40-50 km thick, we must assume a crustal thickness prior to D_2 of only 20-25 km. D_2 caused penetrative deformation, during which km-scale upright folds developed, defining elongate domes and basins. Regionally significant vertical ductile shear zones (with vertical extension lineations) were formed. These zones may have localised later strike-slip faults. Relations of the D_2 shear zones with economically significant mineralisation are discussed.

However, prior to D_2 there was a considerable history of deformational events. This includes the major thrusting event already recognised, but in addition, there were at least two periods of major crustal extension, possibly some strike-slip faulting, and a period in which upright folds formed. The most interesting of these events is that which led to the formation of gneiss bodies such as those exposed in narrow elongate doubly-plunging antiforms in the Wonga Belt, since these may be related to mid-crustal extension phenomena analogous to those in modern extensional terranes.

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Alteration styles in the western Mount Isa Inlier
and their significance for Cu and U mineralisation

L.A.I. Wyborn (BMR) & G.S. Lister (BMR)

This paper compares the styles of alteration in five geochemical collections in the western Mount Isa Inlier; one is of a granite, another is of the western uranium deposits, and three are of metabasalts.

The Queen Elizabeth pluton of the Sybella Batholith was sampled in detail to assess the marginal concentration of Th, U, and Sn found by Towsey & Patterson (1984). The new results suggest that these elements, as well as La, Ce, Be, Nb, Zr, Y, V, Pb, and Cr were mobile during amphibolite-grade metamorphism, which occurred during both D_1 and D_2. The elements La, Ce, Th, and Sn tend to move within or concentrate at the margins of the pluton, whilst Be and Nb have concentrated in metamorphically derived pegmatite adjacent to the pluton. The remaining elements, U, Pb, Zr, Y, V, U, and Cr, moved further and are believed to be concentrated in the western uranium deposits, some of which have up to 5000 ppm Zr, 2500 ppm V, and 1400 ppm Y.

The three collections of metabasalts come from the Mammoth Mines area (Derrick & others, 1985), immediately east of Mount Isa (Glikson & Derrick, 1978), and the Smith & Walker (1971) analyses of the greenstones under the 1100 ore body, particularly the V26E drill hole. The surface samples can be subdivided into massive and cleaved alteration types. The massive alteration occurred either syn- or pre-D_1, and these rocks contain albite+actinolite+chlorite+magnetite+ilmenite+sphene+adularia+epidote+biotite. Chemically this type is the least altered and has moderate Fe^{3+}/Fe^{2+} ratios. It contains higher K_2O, and locally has high Cu content. The alteration of the cleaved metabasalts occurred syn-D_2, and these rocks contain albite+chlorite+epidote+sphene+actinolite or albite+chlorite+calcite+magnetite+rutile. Chemically the rocks have the highest Fe^{3+}/Fe^{2+} ratios and contain more Na_2O, Zr, Y, and less Cu, K_2O, and Ba than the massive metabasalts. The greenstones under the mine show similar igneous fractionation trends for TiO_2 and P_2O_5 as the surface metabasalts, and are thought to form from the cleaved metabasalts in another

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alteration event probably synchronous with D_3. They contain albite+quartz+chlorite+calcite+rutile and have the lowest Fe^{3+}/Fe^{2+} ratios. The greenstones are enriched in SiO_2, MgO, H_2O, Y, Zr, and V, and depleted in Cu, CaO, MnO, Ba, Sr, Ni, with most of these appearing to concentrate in the adjacent silica dolomite, as was suggested by van den Heuvel & O'Toole (1965).

It is argued that the greatest mobility of Cu and U occurred during D_2, with the development of the regional north/south cleavage. This fluid was oxidising and capable of moving high field strength cations such as U, Zr, V and Y, but incapable of moving gold. During D_3 there was further, but more limited fluid circulation, with suitable dilation sites forming in transpressional fault zones. We suggest the Mount Isa copper ore body is formed by the interaction of D_3 on a pre-existing D_2 ore concentration.

References

Derrick, G.M., Wilson, I.H., & Perkin, D.J., 1985 - BMR Journal, 9, 917-328.

Glikson, A.Y., & Derrick, G.M., 1978 - BMR Record 1978/48.

Smith, S.E., & Walker, K.R., 1971 - BMR Bulletin 131.

Towsey, C. & Patterson, D., 1984 - Journal of Geochemical Exploration, 22, 71-82.

van den Heuvel, H.B., & O'Toole, A., 1965 - 38th ANZAAS Congress, Hobart, 1965.

NOTES

The significance of transpressional strike-slip faulting in the Lake Julius area, Mount Isa Inlier

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Field relationships suggest that at least two (possibly related) periods of strike-slip faulting have affected the Proterozoic rocks of the Mount Isa Inlier. A field study in the Lake Julius area, 60 km north-northwest of Mount Isa has revealed the presence of a north to northwest-trending left-lateral strike-slip fault system. This is truncated by younger strike-slip faults of the Mount Remarkable fault system, which generally trend north to northeast with right-lateral displacements. These faults produce structures that are referred to as D_3 and D_4 respectively, in the locally established deformation scheme. Movements on the D_3 faults are strongly transpressional in the area of Lake Julius, and are associated with significant ductile deformation. D_2 folds were tightened considerably by D_3, and some folds have been partially dismembered. In places, shallow-dipping fractures were created which then dilated, producing vertical fibre lineations. Locally D_3 transpression appears to have led to thrusting, producing "flower" structures typical of wrench-fault regimes, and rotations of the upper plate of up to 60-90° about vertical axes. The D_3 event in the transpressional zones involved east-west shortening and vertical extension. The Lake Julius D_3 event may be correlated with the D_3 event in the Mount Isa mine. Since Perkins (1984) associates major hydrothermal Cu mineralisation with the mine D_3 event, some attention should be given to other localities in which significant transpressional strike-slip faulting appears to have taken place. D_3 fluid-migration was relatively localised, and dilational traps in transpressional zones may have remobilised pre-existing ore concentrations formed during previous events when more pervasive fluid systems of different geochemical character were migrating. Gold prospects in the area occur near or in dilated thrusts where the D_3 strike-slip faults are strongly transpressional because they have rotated from northwest-trending orientations to be parallel to north-south-trending D_2 ductile shear zones.