MAGSAT ANOMALIES, CRUSTAL MAGNETISATION, HEAT FLOW AND KIMBERLITE OCCURRENCES IN AUSTRALIA

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INTRODUCTION

The Magsat map of Australia (Johnson and Mayhew, 1985) shows a good correlation between large scale tectonic structures and crustal source magnetic anomalies observed at satellite altitudes. The Precambrian cratonic blocks coincide with large positive magnetic anomalies, the largest of which is situated over the Gawler Block in South Australia. The tectonically active southeastern part of Australia is marked by low relief magnetic anomalies. The boundary between the cratonic blocks and this southeastern part of Australia is marked by a steep gradient in the anomaly field.

MAGSAT INVERSION

Inversion techniques have been applied to the Magsat data (Mayhew and Johnson, in preparation) to obtain an equivalent layer solution comprising a horizontal distribution of average vertical magnetisation for a crustal layer of constant thickness. The inversion results have a spatial resolution of the order of 100 kms and reveal features that are not easily seen in the magnetic field observed at 300-400 kms elevation. Since the earth's magnetic field inclination varies considerably through the latitude range of Australia, it is useful to compute the "reduced to the pole" magnetic anomaly from the equivalent layer solution using a vertical direction for the magnetisation.

In reality, the thickness of the magnetic layer varies from place to place largely as a function of vertical temperature gradients. In regions where the temperature gradient is high, the Curie point geotherm for magnetite is reached at depths within the continental crust. However, in regions of shallow temperature gradient, the Curie point geotherm is reached at levels below the base of the crust. We have previously argued that the mantle is essentially non-magnetic (Wasilewski et al, 1977) and therefore in such regions the thickness of the magnetic crust may be defined by the crust-mantle boundary.

XENOLITH-DERIVED GEOTHERMS

Appropriate mineral assemblages from xenoliths in basaltic and kimberlitic host rocks provide pressure and temperature measurements which can be used to define vertical temperature profiles for crustal and upper mantle depths. A range of such vertical temperature profiles, for contrasting lithospheric environments, can be used to transform the magnetic anomaly inversion results (for a constant thickness assumption) into more realistic magnetisations for a mangetic crust of variable thickness.

O'Reilly and Griffin (1985) derived a vertical temperature profile for southeastern Australia which has much higher temperatures at any given pressure than conventional continental or oceanic geotherms. The Curie point for magnetite is reached at a depth of only 12 km and substantiates the interpretation that the subdued magnetic anomalies of southeastern Australia are at least in part due to a relatively thin magnetic crust.

HEAT-FLOW MODEL

The combined interpretation of the Magsat crustal anomaly field and the geothermobarometry results leads to an exciting possibility whereby a heat-flow model for Australia may be derived which can be used to predict temperature at any location and depth. This enables the interpolation of the sparse surface heat-flow data and avoids the anomalies due to circulating artesian waters.

In addition, because P and T are constrained at depth, there is no necessity to assume arbitrarily a steady-state conductive heat-flow model which may result in misleading extrapolation of heat-flow production to high pressures. Construction of a xenolith-derived geotherm for eastern Australia, for example, predicts that there is a small field where diamond would be stable. This contrasts with the extrapolated steady-state geotherm prediction that the temperature is too high for diamond stability at all pressures.

CONCLUSION

This integrated petrological and geophysical investigation of the crust of Australia is particularly significant in the search for diamond-bearing kimberlites as it could identify likely areas for exploration targeting.

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FIGURES

Fig. 1 Magnetisations derived from inversion of Magsat crustal magnetic anomalies for a 40 km uniform thickness equivalent layer. Contours are at an interval of 0.1 A/m. Dots indicate locations of dipoles forming the equivalent layer. Heavy lines indicate a) the Tasman Line as drawn by Powell (1984) onshore and the continent-ocean boundary (Veevers, 1984) offshore western Australia.

Fig. 2 Sketch map of major structural units in Australia for comparison with Fig. 1. Ruled areas represent areas of exposed crystalline rocks, blank areas sedimentary cover. Numbers are positions of magnetisation anomalies indicated on Fig. 1.

Fig. 3 Reduced to the pole magnetic field calculated for an altitude of 325 km using a vertical magnetisation direction and the equivalent layer magnetisation intensities shown in Fig. 1.

Fig. 4 Crustal section across the Gawler Block, the Adelaide zone, the Murray Basin, and the Lachlan Fold Belt. Crustal seismic layering with P-wave velocities indicated from Finlayson et al (1984), Schackleford (1978) and Branson et al (1976). At lower right are geotherm and lower crust/upper mantle lithologies inferred from xenolith studies (O'Reilly and Griffin, 1985). Above is profile of inverted magnetisations from Fig. 1 (scale on left). Open circles are heat flow determinations (Cull, 1982) (scale on right). Grouped determinations indicated by boxes (a) enclosing a group along the craton margin and (b) enclosing a group in the Lachlan Fold belt.

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