Geomagnetic variation anomaly on Eyre Peninsula, South Australia

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A systematic study of the coast effect in South Australia (White & Polatajko 1978, 1985; White & Hopgood 1979) revealed the existence of a conductivity anomaly on Eyre Peninsula. Significant deflections of the transfer function vectors at periods around 1 h indicated a telluric current concentration flowing SW–NE up the peninsula. This prompted a more detailed study in the southern part of the peninsula where a total of 40 magnetometer stations have been occupied with spacing as close as 5 km (White & Milligan 1984).

Field recordings were taken between July 1982 and January 1983. Analysis of the data to produce transfer function vectors, relating the vertical to the horizontal field variations, shows that while the coast effect is present there is obvious evidence of a strong linear telluric current flow within the crust in a direction directly away from the ocean. Figure 1 displays the in-phase transfer function vectors for two periods; 2 h and 0.25 h; following normal convention the direction of the vectors has been reversed. It is apparent that both sets of vectors are responding to a telluric current flow whose axis lies close to the position indicated by the large dashed line in Fig. 1. At the higher frequency the effect is more pronounced with vectors on each side of the axis pointing almost directly towards it. Furthermore the vector amplitude reduces to very small values near the axis and the closeness of the station spacing demonstrates that the zone of enhanced conductivity in which the telluric current is flowing must be both narrow and shallow.

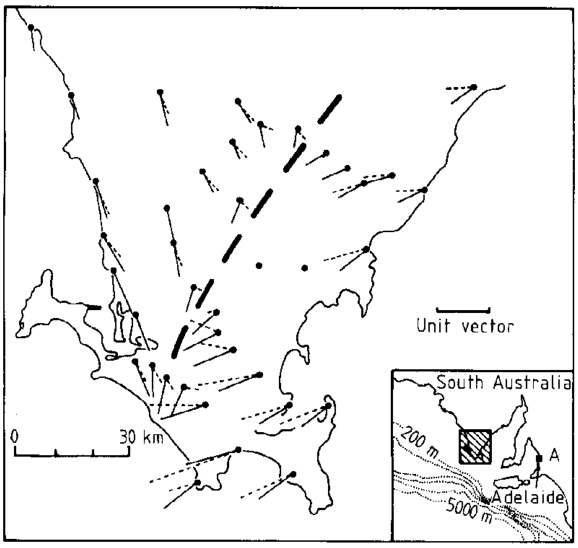

Fig 1 Transfer function vectors (in-phase) for periods of 2 h (—) and 0.25 h (---). The large dashed line indicates the axis of the proposed conducting zone.

There is a strong enhancement of the horizontal *D* field (which is almost at right angles to the direction of telluric current flow). The contours in Fig. 2a are based on data from the stations shown, and are related to the *D* field at station PL by the equation:

$$D\text{ (anomalous)} = [D(\text{total}) - D(\text{PL})]\ /D(\text{PL})$$

for 1 h. Enhancement of the *D* field is frequency-dependent; for the daily variation there is no noticeable enhancement, while for a 20 min period the enhancement for the most southerly stations overlying the conducting zone is greater than a factor of 3. Figure 2b shows contours of the vertical field derived from hypothetical event analysis (Bailey *et al.* 1974) for a 1 h period. The orientation of the unit horizontal field is parallel with the deep ocean waters and at right angles to the conducting zone, thus minimizing the coast effect and maximizing the conductivity anomaly effect. Taken together, the *D* and *Z* contours of Fig. 2 are consistent with a concentration of telluric current, channelled within a narrow zone of enhanced electrical conductivity. The axes defined by the two sets of contours do not exactly coincide, indicating that there may be some asymmetry of the zone. It appears also that the zone may broaden and/or deepen to the NE. Using a simple rectangular channel model with uniform current density as given by Wilhjelm and Friis-Christensen (1974) the best fitting model for profile AB (Fig. 3a) defines a conducting zone 12 km wide, with upper and lower bounds 6 km and 20 km deep as shown in Fig. 3b.

There is a strong correlation of the conducting zone with the fault-like gradient on the western side of the Bouguer gravity anomaly shown in Fig. 3a. A simple two-dimensional model (Lockwood 1977) has been used to fit the gravity profile along AB and this is shown in Fig. 3b. The model uses a 2 km square grid with a variable density contrast ascribable to each grid square. In the model shown, a single density contrast of 0.16 g cm^{-3} was used and this gave rise to the irregularly shaped bodies as shown. The best fitting model of a rectangular conducting channel described above is superimposed on Fig. 3b for comparison.

Although these models are preliminary and conceptually simple their strong correlation indicates a major geological feature coincident with the proposed conducting zone. The basement rocks are largely granite gneisses of the Sleaford and Lincoln complexes and the denser bodies are presumably basic intrusives. They could possibly have been emplaced during the Kimban orogeny (1820–1580 Ma).

There is no direct correlation of the proposed conducting zone with mapped geology. Major parallel structures run up the eastern coastline of the peninsula. The visible deformations are due to the Kimban orogeny (Parker & Lemon 1982)

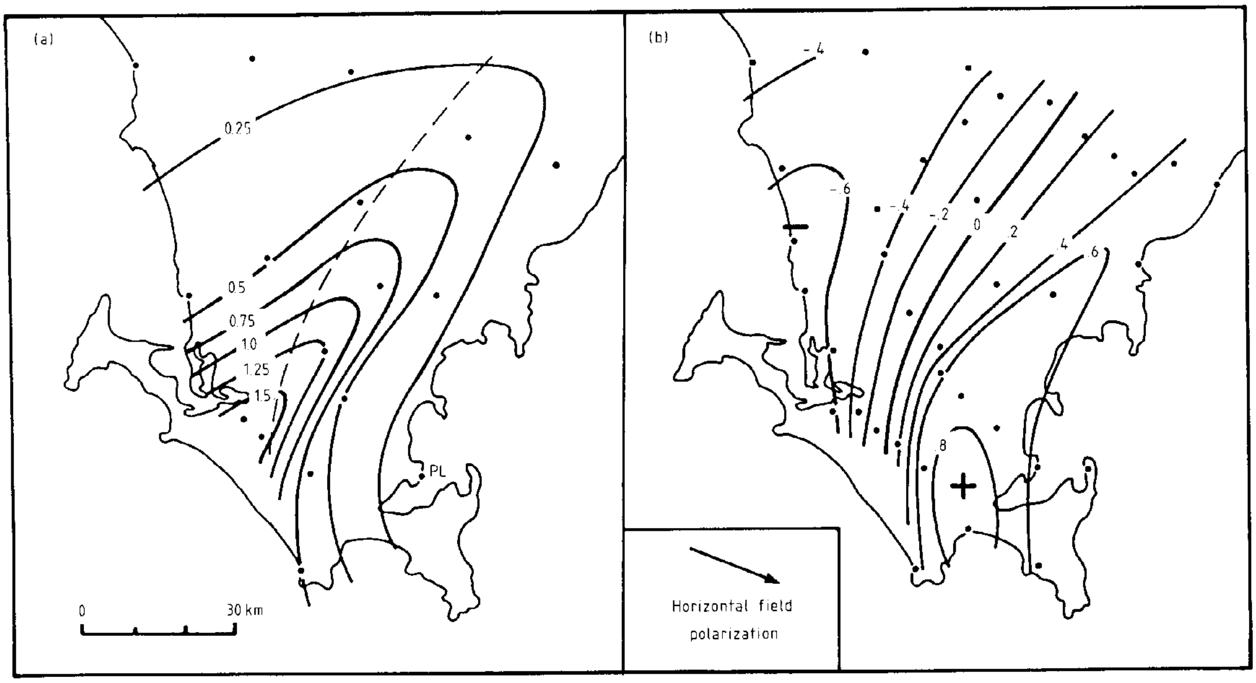

Fig 2 (a) Contours of anomalous *D* field variations relative to Port Lincoln (PL) for 1 h period. (b) Hypothetical event analysis *Z* contours for unit horizontal field in the direction shown (1 h period).

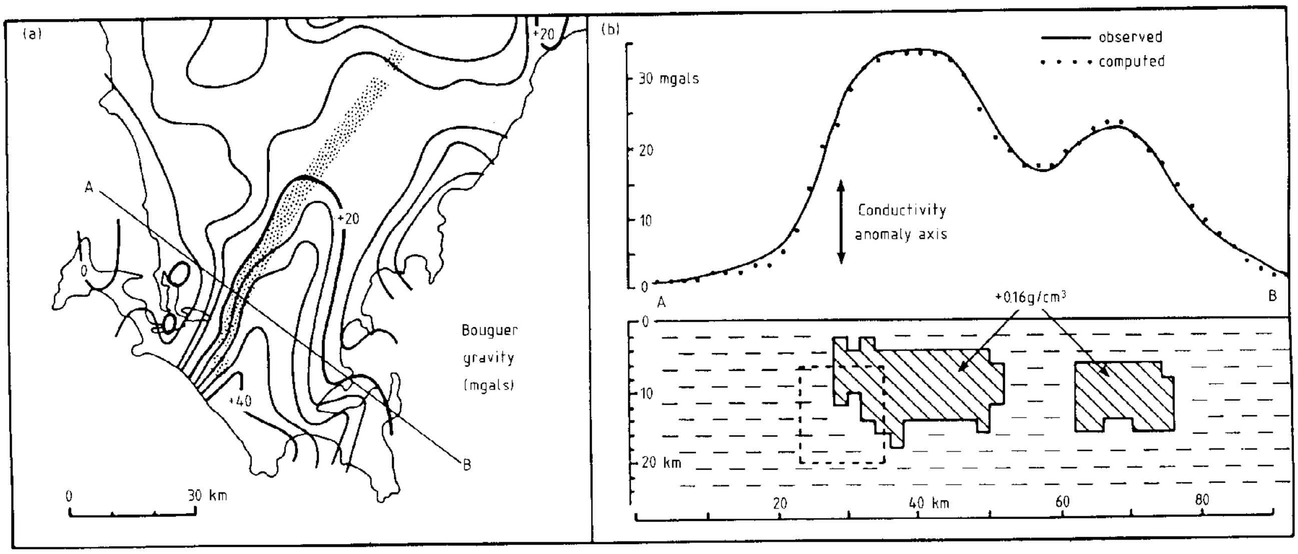

Fig 3 (a) Bouguer gravity contours. The axis of the proposed conductivity zone is shown. (b) The two-dimensional gravity model profile AB. The dashed line indicates the best fitting model of a rectangular conducting channel having uniform current density.

and lie within the metasiltstones and schists of the Hutchison group. It is possible that the conducting zone lies within a major crustal shear or fracture marking the western limit of the Kimban tectonism. Graphite occurs within the Hutchison but no significant current channelling is observed along its outcrop axis. It is more likely that the conducting mechanism is associated with strongly saline groundwaters within the proposed fracture or shear zone.

Acknowledgments

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References

Bailey R. C., Edwards R. N., Garland G. D., Kurtz R. & Pitcher D. (1974), 'Electrical conductivity studies over a tectonically active area in eastern Canada', *J. Geomag. Geoelectr.* **26**, 125–146.

Lockwood K. (1977), 'A geophysical assessment of the Outer Band Arc with emphasis on gravity measurements in Eastern Timor', unpublished MSc Thesis, Flinders University, South Australia.

Parker A. J. & Lemon N. M. (1982), 'Reconstruction of the Early Proterozoic stratigraphy of the Gawler Craton, South Australia', *J. Geol. Soc. Aust.* **29**, 221–238.

White A. & Polatajko O. W. (1978), 'The coast in geomagnetic variations in South Australia', *J. Geomag. Geoelectr.* **30**, 109–120.

White A. & Polatajko O. W. (1985), 'Electrical conductivity anomalies and their relationship with the tectonics of South Australia', *Geophys. J. Roy. Astr. Soc.* **80**, 757–771.

White A., & Hopgood D. N. (1979), 'The island and coast effect in geomagnetic variations around St. Vincent Gulf, South Australia', *J. Geomag. Geoelectr.* **31**, 479–484.

White A. & Milligan P. R. (1984), 'A crustal conductor on Eyre Peninsula, South Australia', *Nature* **310**, 219–222.

Wilhjelm J. & Friis-Christensen E. (1974), 'The Igdlorssuit geomagnetic variation anomaly in the rift-fault zone of northern West Greenland', *J. Geomag. Geoelectr.* **26**, 173–189.

The Tamar conductivity anomaly

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The Tamar Lineament follows an approximately straight line from near the mouth of the Tamar River to near the Tasman Peninsula. The pre-Carboniferous geology is very different on the two sides of this line. On the north-east side Devonian sediments are of deep water facies, typified by the Mathinna Beds. On the south-west side Devonian and older sediments are of shallow water origin, such as the Owen conglomerates and Gordon limestone. The granites in the north-east side are slightly older than those on the south-west side. There are also geophysical differences. The magnetic anomaly structure is smoother in the north-east and earthquakes are less frequent. This paper reports a striking conductivity anomaly coinciding with the Tamar Lineament.

Magnetic fluctuations within a certain period band are usually found to be polarized so that the vectors representing them lie in a plane. The plane is often horizontal, but if it is inclined at an appreciable angle it indicates a gradient of conductivity underground, the plane tilting upward towards the better conductor. This can be indicated on a map by an 'induction arrow' whose direction is the direction of upward tilt, and whose length indicates the angle of tilt.

Field measurements have been made in Tasmania with three-component EDA fluxgate magnetometers and Memodyne digital cassette recorders. Only two instruments are available so the technique of deriving and plotting induction arrows has been used rather than that of synoptic contour plots. It is found that all the induction arrows in eastern Tasmania point towards the Tamar Lineament, indicating that it is the location of a linear conducting body (Fig. 1).

Superimposed on the effects of such a conductor is the effect of the oceans surrounding Tasmania. At long periods of 100 min or more, the effect of the oceans dominates, and all induction arrows point towards SSE. As the period decreases induction arrows at sites to the north-east of the Tamar Lineament turn to a WSW direction and those at sites to the south-west of the Lineament turn to an ENE direction, both pointing towards the Lineament for less than 30 min periods. The effect of the oceans is more marked near the east and south coasts, where the effect is superimposed on the effect of the conductivity anomaly. Thus, for example, at Fingal, about 30 km from the east coast, the induction arrow points almost south, even for short periods.

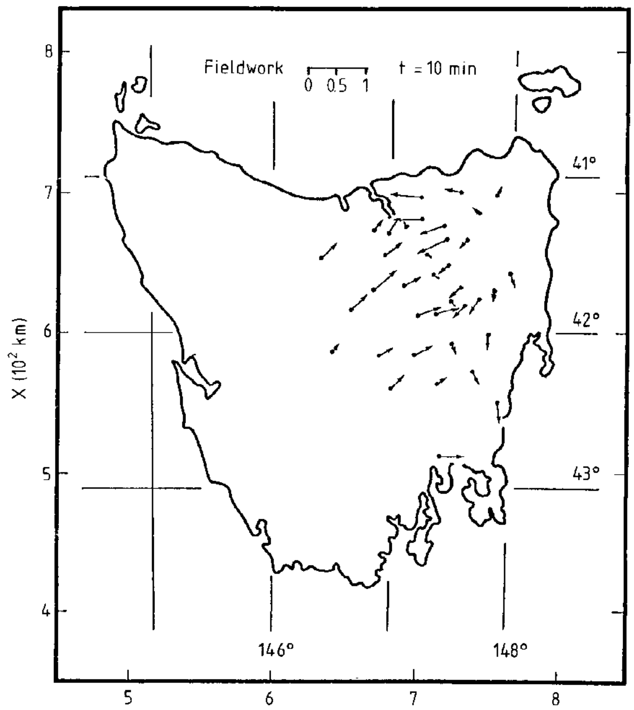

Fig 1 Induction arrows for north-east Tasmania showing the presence of the Tamar conductivity anomaly. The arrows indicate the directions of horizontal magnetic field change which cause maximum vertical magnetic field change at each site. The lengths of the arrows indicate the effectiveness of the process. The arrows point towards a zone of high electrical conductivity.