A Magnetometer Array Study in Southern Australia
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Summary

The first magnetometer array study in Australia was in operation in the second half of 1970 across the central southern part of the continent. Twenty-five three-component magnetometers simultaneously recorded disturbance fields of magnetic storms and substorms, in addition to the quiet daily variation. Curious anomalous effects were observed which showed partial consistency for horizontal fields of given polarization. Transfer functions were computed for the stations and these indicate, to first order, a long curved conductor running approximately north-south through the array and a second, more resistive conductor running east-west to the north of the array. Other structures are also present. The north-south conductor, which runs close to the Flinders Ranges, may represent a feature important in the continental tectonics of Australia.

1. Observations

Studies with two-dimensional arrays of three-component recording magnetometers enable transient induced electric currents and, by inference, electrically conductive regions to be mapped and to some extent interpreted in terms of conductive structure. Quantitative interpretation involves non-linear three-dimensional inversion and is very difficult, though appreciable progress has been made in some cases (Gough 1973). Structure in the electrical conductivity is of interest largely because this parameter is linked to temperature: anomalously hot regions of the upper mantle are highly conducting; conducting regions may be at high temperature. In parts of the western United States a correspondence between electrical conductivity, heat flow and seismic propagation parameters has been demonstrated (Reitzel et al. 1970; Porath & Gough 1971; Sass et al. 1971; Roy, Blackwell & Decker 1972; Hales & Doyle 1967).

The location of the first magnetometer array study in Australia was chosen on two hypotheses. The first was that eastern and specially south-eastern Australia is tectonically more active than the shield of west Australia and might have higher temperatures in the underlying upper mantle. The second hypothesis was that the Flinders Ranges (Fig. 1) might constitute a surface expression of the boundary between these regions. The first hypothesis has considerable support from heat flows, which are near 2 HFU (µcal cm⁻² s⁻¹) at many sites in the south-east but typically nearer 1 HFU in the western shield (Jaeger 1970); from seismicity, which is generally higher in the south-east than in the west of the continent (Doyle, Everingham & Sutton 1968); from geological evidence of recent vulcanism in the south-east (Gill 1967); and from geochronology, which indicates ages less than 400 My in the south-east and Precambrian ages in the west (Brown, Campbell & Crook 1968).

The second hypothesis was much less secure than the first. There was no evidence to indicate where the tectonic boundary, required by the first hypothesis, might be;
the facts mentioned above would in general be accommodated were the shield to extend as basement as far east as the coastal highlands. However the easternmost outcrops of pre-Cambrian rocks have a boundary roughly in line with the Flinders Ranges, which form a notable topographic feature in a flat continent. Later Cleary & Simpson (1971) suggested from seismological evidence that the Flinders might mark a boundary between sub-plates of the Indo-Australian plate, and still later seismological evidence (Cleary, Simpson & Muirhead 1972) could support a gradual thinning of the pre-Cambrian basement from the Flinders to the highlands of the east coast. This suggestion is considered below in relation to the present paper, but played no part in the choice of the array location.

On these two hypotheses the array of 25 magnetometers was placed as shown in Fig. 1, across the Flinders Ranges and far enough from the continental edge to minimize the effects of its presumed induction anomaly. Because of the uncertainty in the position of the postulated boundary the array was made some 1200 km long, with magnetometers roughly 150 km apart along three lines. The magnetometers, of a type described by Gough & Reitzel (1967), were buried near airstrips on sheep or cattle stations. Installation, servicing and retrieval were done by light aircraft and this technique proved admirable. The array recorded in 1970 from September 16 to November 30, and secured data from isolated polar magnetic substorms and from sequences of substorms during minor magnetic storms.

2. Magnetograms

Two examples of fields recorded by the array are shown in Figs 2 and 3. In each the stack of magnetograms on the left came from the northern line of the array designated line 1, and lines 2 and 3 are the central and southern lines. In each stack the magnetogram sequence from top to bottom corresponds to the station sequence from east to west. Geographic northward (X) and eastward (Y) components are shown, derived from the magnetically oriented $H$ and $D$ components originally
recorded. The vertical (Z) component amplitudes are exaggerated fourfold relative to X and Y. Times marked are GMT. Local time at the centre of the array is about 9 hr ahead of GMT. The isolated polar magnetic substorm in Fig. 2 occurred on 1970 October 23 between 13.30 and 16.30 GMT (22.30 to 01.30 local). Fig. 3 shows a 16-hr sequence in which a storm sudden commencement on 1970 November 7 at 00.45 GMT (09.45 local time) was followed by a series of substorm disturbances superimposed upon the daily variation. A well-defined midnight substorm forms the last disturbance on November 7, commencing at 13.30 GMT (22.30 local time).

The variation fields can be regarded as made up of a normal field with local anomalous fields superimposed. The normal field is the vector sum, at each instant, of the primary field from external currents and secondary fields of induced currents in an average layered conductive Earth. The internal parts of the horizontal normal field components are approximately in phase with and reinforce their external parts. Hence normal X and Y are large and local anomalies are small as fractions of the variation fields in these components. For Z the internal contribution to the normal field opposes the external contribution and local anomalies form the greater part of the recorded Z variations. These well-known facts are borne out in Figs 2 and 3, which show larger amplitudes and much greater uniformity over the array for X and Y than for Z.
FIG. 3. Magnetograms for 1970 November 7, showing a sudden commencement followed by substorms. Times are GMT. The arrangement is as in Fig. 2.
The $Z$ traces in Fig. 2 show immediately that there are local anomalies and that the situation is complicated. While $Z$ amplitudes are small at the two easternmost stations in each line, there is no simple monotonic change in $Z$ amplitude westward along the array like the increase in $Z$ found at stations east of the front range of the Rocky Mountains relative to stations in the Cordillera (Hyndman 1963; Schmucker 1964; Reitzel et al. 1970; Caner 1970; Camfield, Gough & Porath 1971; Cochrane & Hyndman 1970). The amplitude of $Z$ changes in a complicated way from station to station. Further, the waveforms $Z(t)$ vary strongly from station to station. $Z(t)$ shows some resemblance to $X(t)$ at WIL, WAL, PAR, PIM and KIN (Fig. 2) and to $Y(t)$, with phase reversal, at WER, AND and BIL. But at most stations $Z$ resembles neither $X$ nor $Y$. If induction causes a $Z$ response to some particular horizontal component, it is evident that the azimuth of the horizontal field to which $Z$ is sensitive shifts in a complicated way across the array.

The same features can be seen in Fig. 3. In addition the polarization of the horizontal field can be seen to be important in the response of local conductors, shown in the $Z$ component variations, to variously polarized normal horizontal fields. It is instructive to notice the strong $Z$ response at PIM to the north-west polarized horizontal field just after the sudden commencement, and the weak response at the same station to a north-east polarized horizontal field variation at about 10.25 GMT (Fig. 3). The next station, WYN, in line 3 shows strong response in $Z$ to the 10.25 GMT event but much less at 00.45. Frequency response also varies widely. High-frequency anomalous $Z$ fields are obvious at WAL, BIL and AND (Fig. 3) whereas at periods of order one hour QIN, MLR and WYN show stronger response, notably to the substorm which commences at 13.30 GMT.

Local anomalies can be seen in the horizontal components, on close inspection of the magnetograms. At periods of about one hour WAK shows strong enhancement of $X$ in the 13.30 substorm (Fig. 3), and $Y$ is abnormally large at EMU for the whole magnetogram of November 7 but not for the October 23 substorm.

3. Maps of Fourier transform parameters

The main advantage of a two-dimensional array of instruments lies in the opportunity to map the time-dependent physical quantity measured. In the case of a magnetometer array one can map instantaneous values of field components (Oldenburg 1969; Porath, Oldenburg & Gough 1970) but it is usually better to map Fourier transform parameters such as amplitude and phase, or sine and cosine coefficients (Reitzel et al. 1970; Camfield et al. 1971). Because time-varying magnetic fields diffuse into the Earth with (period)$^\dagger$ dependency, isolation of a definite period from the disturbance field implies a particular range of depth penetrated. Peaks in the spectra of the horizontal components of the event can be selected for mapping (Reitzel et al. 1970; Camfield et al. 1971) though there may be occasions when it is advantageous, for the sake of the horizontal polarization offered, to choose a frequency not at a spectral peak. The validity of this procedure depends on the inclusion of the whole transient event in the record (Lilley & Bennett 1972).

Two contoured maps are needed for each component, and six to represent a variation event recorded in three components. Such sets of maps have proved useful for mapping local anomalies in the North American array studies referred to above. These anomalies appear consistently with essentially constant positions and shapes in the fields of different variation events, and can therefore be associated with internal conductive structures which are essentially two-dimensional. In this way local conductors have been mapped under the Southern Rockies, under the Wasatch Front in Utah, under the Northern Rockies and under the Great Plains through the Black Hills of South Dakota (references already quoted; Gough & Camfield 1972).

Some twenty sets of such maps have been drawn for transforms of magnetograms
from the southern Australian array. These were derived from polar geomagnetic substorms, sequences of substorms and disturbed daily variation, and most were in the period range from one-half to several hours. Of the 20 sets of maps, 14 sets (84 maps) were chosen for qualitative interpretation. The sets of maps showed great variability in anomalies, most notably for the vertical component. Studied in terms of the horizontal polarization ellipses (Lilley & Bennett 1972) however, they were found to be much more consistent; the sense of rotation of the horizontal field vector was evidently significant as well as the shape and orientation of the ellipse. Although inspection of these sets of maps did not show precisely how the anomalies were related to the various polarization parameters, the conclusion could be drawn that the variable anomaly patterns corresponded to three-dimensional structure in the electrical conductivity of the array area (Gough et al. 1972). (It is appropriate to note here that in Figs 1 and 2 of Gough et al. (1972), both ellipses of horizontal polarization have incorrect senses of rotation. The same ellipses are shown with their correct senses of rotation in Figs 4 and 5 of the present paper.)

The maps shown in Figs 4–7 have been chosen as representative of the 14 selected sets of maps. They represent the period range 35–93 min and are transformed from three substorm events, Figs 4 and 5 from 1970 October 16 15.30–22.00 GMT, Fig. 6

![Image of graphs showing Fourier transforms at period 35 min from a substorm, 15.30-22.00 GMT, 1970 October 16. The contour interval for Z phase is 5 times that for X and Y. The ellipse represents the polarization of the horizontal field.](image-url)
The $X$ amplitude maps in all four figures show a maximum elongated WSW–ENE through the station WIL. This is perhaps the most consistent feature of the maps as a whole, but is absent from three of the 14 map sets. A strong maximum in $X$ appears at WAK in the southern line in Figs 5, 6 and 7 but barely if at all in Fig. 4. This feature appears in nine of the 14 maps of $X$ amplitude.

(ii) $Y$ amplitude

The amplitude maps of the eastward component $Y$ all show a broad maximum in the eastern half of the array, with some suggestion in some maps that this branches northward. In so far as one can locate currents under horizontal-field maxima, there is some indication of a current tracing a crooked path roughly from WAK and PAR
Fro. 6. Amplitudes (in arbitrary units, equal for the components) and phases (in minutes) of Fourier transforms at period 76 min from a substorm, 13·30–16·30 GMT, 1970 October 23. The contour interval for $Z$ phase is 5 times that for $X$ and $Y$. Magnetograms are in Fig. 2. The nearly circular polarization of the horizontal field is indicated.

to AND to MLR. Substantiation for this will emerge in Section 5. In the full set of 14 $Y$ amplitude maps eleven show this anomaly. By contrast, only Figs 5 and 7 show a considerable rise in $Y$ at the west end of the array suggesting a maximum at, or west of, EMU. Fig. 6 does not show this and Fig. 4 has anomalously low $Y$ at EMU. Of 14 $Y$ amplitude maps six have a rise in $Y$ at the west end of the array and three have a low $Y$ amplitude at EMU.

Each horizontal component shows one prominent feature which is present in a majority of the maps, and another which is present in some maps. No local current appears in both $X$ and $Y$.

(iii) $Z$ amplitude

The $Z$ amplitude maps are rather more variable. A prominent maximum appears in or south of the array centre in Figs 4 and 6 but is absent in Fig. 5 and Fig. 7. In Fig. 7 a minimum appears west of the centre and small variations in amplitude mark the northern limit of an otherwise featureless map. The large central maximum in $Z$ appears in six of 14 $Z$ amplitude maps, disregarding quite large changes in its position. Inspection of the magnetograms shows that in some regions (notably
between WER and QIN) the change in the Z response may be too sharp for the anomaly to be well located by the instrument spacing chosen for this array.

(iv) Phases

The phase maps for the X and Y components appear to represent mainly the normal field and to be uninformative of internal structure. In contrast the Z phase maps are of considerable interest. There are large phase changes in all maps between the stations WER and QIN, listed in Table 1, which suggest the presence of a current between them. If one thinks in simple terms of a current flowing under the maximum gradient in Z phase and along the contours of the phase maps, one is led by Figs 4, 5 and 7 to place a current along an S-shaped curve from WAK, east of WER and northward between MUR and WIL, as was done by Lilley & Tammemagi (1972). Fig. 6 suggests a more complicated current system, though the Z phase values in the north-east of the array will have large errors because Z amplitudes are small there.

While the phase maps for Z offer some encouragement in the search for consistency they, like the amplitude maps, show much variability. Gough, Lilley & McElhinny (1972) have pointed out that induction, even by a linearly polarized horizontal field,
in a curved conductor or in two crossed conductors, will produce Z amplitude anomalies which are strongly dependent on the azimuth of polarization. Actual substorm fields are elliptically polarized in general, and the phase difference between X and Y components will enter the problem (Bennett & Lilley 1972), together with the phase leads which characterize the different conductors, if more than one exists.

To make further progress with the problem it is necessary to work in terms of some parameter of Earth response to incident fields, subject to the condition that phase and polarization information be preserved. Transfer functions between the components, as used by Schmucker (1964, 1970), meet the need.

### Table 1

<table>
<thead>
<tr>
<th>Figure</th>
<th>T min</th>
<th>Δφ min</th>
<th>Δφ deg</th>
</tr>
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<td>5</td>
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<td>−152</td>
</tr>
<tr>
<td>7</td>
<td>93</td>
<td>−20</td>
<td>−77</td>
</tr>
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4. **Transfer functions**

In southern Australia the normal Z component in substorm fields is small. On the assumption that the Z variation fields are mainly anomalous it is reasonable to calculate transfer functions from estimated normal horizontal components, \(X_n\) and \(Y_n\), to Z. This avoids inversion of the full transfer function matrix relating each anomalous component to each normal component, which would be justified only with separated normal and anomalous fields; though it does expose the calculations to error due to any systematic Z–H correlation in the normal fields (Schmucker 1964, p. 202). The relations used are:

\[
Z_X = \frac{S_{ZX_n}S_{Y_n} - S_{2Y_n}S_{Y_nX_n}}{S_{X_n}S_{Y_n} - |S_{Y_nX_n}|^2}
\]

\[
Z_Y = \frac{S_{ZY_n}S_{X_n} - S_{ZX_n}S_{X_nY_n}}{S_{X_n}S_{Y_n} - |S_{Y_nX_n}|^2}
\]

where \(S_{ZX_n}\) is the cross-power between the Z component (assumed anomalous) at a particular station and the estimated normal X component, and \(S_{X_n}\) is the autopower of \(X_n\). In terms of complex Fourier transforms \(C_{X_n}, C_Z\) and their conjugates, denoted *\, from time series of length \(T_0\),

\[
S_{X_n} = (C_{X_n} \cdot C_{X_n}^*)/T_0
\]

\[
S_{ZZ_n} = (C_Z \cdot C_{X_n}^*)/T_0
\]

with similar expressions for the other auto- and cross-powers in (1).

The transfer functions \(Z_X\) and \(Z_Y\) are complex quantities. Their real parts give the in-phase responses of Z to \(X_n\) and \(Y_n\); their imaginary parts give the quadrature-phase responses where now, in contrast to the phase-lag convention of Section 3, a quadrature-phase signal is one leading an in-phase signal by a quarter of a cycle. The real parts of \(Z_X\) and \(Z_Y\) can be combined and represented as an in-phase 'induction vector': this is usually reversed and is then in the same sense as a Parkinson vector (Parkinson 1959, 1962), so that it points towards a good conductor in which current flows in phase with the normal field. The imaginary parts of \(Z_X\) and \(Z_Y\) can similarly
FIG. 8. In-phase (solid lines) and quadrature phase (broken lines) induction vectors from transfer functions at period 43 min from six 2-hr magnetogram sequences recorded at 20 stations. Both sets of vectors have been reversed: see text. AB, approximate location of in-phase current; CD, approximate location of quadrature phase current.

FIG. 9. In-phase (solid) and quadrature phase (broken) induction vectors from transfer functions at period 8.5 min from six 2-hr magnetogram sequences recorded at 20 stations. Vectors have been reversed: see text.

be combined to give a quadrature 'induction vector'. For consistency between the in-phase and quadrature-phase induction vectors the latter in this paper are reversed as well, so that all induction vectors in Figs 8, 9 and 10 should in principle point towards the related conductors. This plotting convention for the quadrature-phase vectors is opposite to that of Schmucker (1970 p. 23); though otherwise Schmucker's method for the computation of transfer functions has been followed closely.

Generally speaking, conductive structures in the Earth will show both inductive reactance and resistance, giving rise to both in-phase and quadrature-phase vectors. In the extreme case of very high reactance, arising typically when the normal field does not penetrate through the conductor, the in-phase vector will dominate. At the
other extreme, when the normal field penetrates easily, as through a thin surface conductive layer, the inductive reactance will be low compared to the resistance and the quadrature-phase vector will dominate. Were two such distinct and different structures to exist near to each other, transfer functions might distinguish between them; but there is the difficulty of showing that the in-phase vector is indeed due entirely to the 'reactive' conductor only, and the quadrature vector to the 'resistive' conductor only. Nevertheless the separation of in-phase and quadrature-phase induction effects is an important advantage in the use of transfer functions.

A second advantage, in describing multiple or three-dimensional anomalies, is that an averaged response of the structures to a number of variously polarized source fields is mapped. Interference effects, which complicate maps of individual variation events, are smoothed in a map of transfer functions.

Each cross- and auto-power used in (1) must be a mean value from a number of variation events with well-distributed polarizations. According to Schmucker (1970) more than five events should be used to give significant coherences and transfer functions. For substorm disturbances events of duration 2 hr are suitable. Ten 2-hr events were chosen which had been recorded in three components at 17 stations. These are listed in Table 2. The magnetograms of the last five listed can be seen in Figs 2 and 3. Six events, the first six listed in Table 2, had been recorded at 20 stations. At the 17 stations transfer functions were computed from 10 events and from six, and the results were closely similar at each station. In order to include all 20 stations the transfer functions from six events were used in preparing Figs 8, 9 and 10.

Table 2

<table>
<thead>
<tr>
<th>Date</th>
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<tbody>
<tr>
<td>1970 October 4</td>
<td>09:30-11:30</td>
</tr>
<tr>
<td></td>
<td>12:00-14:00</td>
</tr>
<tr>
<td>1970 October 16</td>
<td>12:00-14:00</td>
</tr>
<tr>
<td></td>
<td>16:00-18:00</td>
</tr>
<tr>
<td></td>
<td>18:00-20:00</td>
</tr>
<tr>
<td>1970 October 23</td>
<td>14:00-16:00</td>
</tr>
<tr>
<td>1970 November 7</td>
<td>01:00-03:00</td>
</tr>
<tr>
<td></td>
<td>09:00-11:00</td>
</tr>
<tr>
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</tr>
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</table>
For reasons already given $Z$ was assumed to be entirely anomalous, that is associated with induction in conductive bodies. It is indicated in equations (1) and (2) that estimates of the normal $X$ and $Y$ field transforms are required to compute transfer functions from these to $Z$. Since anomalous horizontal fields are present in the array, and must take part in the induction process, it is at least as reasonable to use mean values of $X$ and $Y$ over the array. It is also convenient. For each spectral term of each event mean $X$ and $Y$ fields were computed by taking mean cosine and sine Fourier coefficients over all stations. These were used with $Z$ coefficients from each station in substituting in (2).

5. A first-order conductivity model

From inspection of the induction vectors in Figs 8 and 9 it is immediately evident that a complicated conductivity structure is present in southern Australia. However a first-order effect can be seen where the in-phase vectors reverse direction in the region marked as the strip $AB$ (Fig. 8). This reversal may be accounted for by a highly conducting body situated under $AB$, in agreement with the suggestion of Lilley & Tammemagi (1972). Another body or bodies (not shown) is required to account for the in-phase vectors at the western stations.

The quadrature-phase vectors in Fig. 8 suggest the presence of induced currents in some region such as the strip $CD$. In the southern part of the array the quadrature-phase vector pattern is particularly well marked. While some contribution from the continental-edge anomaly associated with the south coast is doubtless present, it would be expected to appear mainly in the in-phase vectors and should tend to direct these towards the ocean. It would be an unusual coast-effect if it produced quadrature-phase vectors directed strongly inland. Some effect of current in $AB$ is to be seen in the quadrature-phase vectors at stations near $AB$. This of course reflects the fact that the currents in $AB$ are not exactly in phase with the inducing fields.

To first order, then, the transfer functions of Fig. 8 support the 'crossed-conductor' model of Gough et al. (1972).

As shown in Fig. 10 the in-phase induction vectors at period 8.5 min are remarkably consistent in direction with those at 43 min. The arrows for the shorter period are in most cases rotated inland relative to those for the longer period. This may support the hypothesis of the conductor $CD$, which would be more reactive at higher frequency. In general the short-period transfer functions are larger in magnitude.

The quadrature-phase induction arrows at period 8.5 min (Fig. 9) show more scatter in direction and magnitude than those in Fig. 8. Effects associated with dry salt lakes must enter here, but are not simple. For instance at AND the quadrature arrow suggests current in the lake east-north-east of the station, but WER has a lake to the east (Fig. 1) and its quadrature-phase induction arrow points west. In general, Fig. 9 indicates that quadrature-phase induction effects change on a distance scale smaller than the 150-km spacing of stations in this array. Detailed studies at close spacing should prove interesting.

6. The two-conductor model

The presence of two crossed but separate conductors is suggested by the transfer functions at longer periods: Fig. 8 is typical of similar maps for periods up to 64 min or more. This model, derived from study of the transfer functions, may now be checked against some of the original Fourier transform maps. For reactive $AB$ and resistive $CD$ the currents in $AB$ would affect the in-phase induction vectors, and those in $CD$ the quadrature-phase vectors. Consider the case of current in phase with $Y$ in $AB$, and leading $X$ by 80° in $CD$. The vertical fields of $AB$ and $CD$ would combine in phase to give a large $Z$ anomaly south of the centre of the array if $X$ lagged 80°
Fig. 11. Six $Z$ amplitude maps from transforms of three events. Three maps show the South Australian $Z$ anomaly strongly, one weakly and two not at all. The ellipses show the polarizations of the horizontal fields. The importance of sense of rotation is evident.

Table 3

<table>
<thead>
<tr>
<th>Date</th>
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<th>$T_{\text{min}}$</th>
<th>$Z$ anomaly</th>
<th>$\Delta \phi$</th>
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<td>$+51^\circ$</td>
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<td></td>
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<td>48</td>
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<td></td>
<td></td>
<td>73</td>
<td>Yes</td>
<td>$+128^\circ$</td>
</tr>
<tr>
<td>October 23</td>
<td>13:30-16:30</td>
<td>76</td>
<td>Yes</td>
<td>$+99^\circ$</td>
</tr>
<tr>
<td>November 7</td>
<td>09:30-13:00</td>
<td>46.5</td>
<td>No</td>
<td>$-56^\circ$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>93</td>
<td>No</td>
<td>$-166^\circ$</td>
</tr>
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behind $Y$ in phase. Since the fields would still interfere constructively if they differed in phase by $50^\circ$ or so, one would expect $X$ to lag, say, $30^\circ$ to $130^\circ$ behind $Y$ in an event giving a large $Z$ anomaly. The corresponding sense of rotation of the horizontal field is counterclockwise.

The four $Z$ amplitude maps of Figs 4–7 are repeated in Fig. 11, with two more $Z$ amplitude maps, for similar periods, derived from similar events. Three maps in Fig. 11 show prominent $Z$ anomalies, one a weak $Z$ anomaly and two none at all.
It is easy to find the phase lag of $X$ behind $Y$ corresponding to each $Z$ amplitude map, as the $X$ and $Y$ phases are mapped. Table 3 shows the phase lags of $X$ behind $Y$ for the six $Z$ maps of Fig. 11. The three transforms showing well-developed $Z$ amplitude anomalies have phase lags in the range $+51^\circ$ to $+128^\circ$ and the weak $Z$ anomaly corresponds to lag $136^\circ$. The two transforms from November 7 have large phase leads of $X$ with respect to $Y$, and no $Z$ anomaly.

Fig. 11 and Table 3 show again the dependence of the $Z$ response upon the azimuth and sense of rotation of the horizontal polarization. To first order they support the two-conductor model, which is one way of accounting for the presence of horizontal-field maxima above $AB$ and $CD$ in various maps not associated with $Z$ anomalies (Figs 7 and 5 are examples). Even so, the two-conductor model is only a first approximation: it does not account for the $X$ anomaly often present centred at WAK, nor for the $Y$ anomaly centred at EMU, in both cases in roughly half of the map sets drawn. An exhaustive quantitative study would involve three-dimensional numerical modelling.

7. Tectonic significance

The conductor $AB$, since it responds mainly in-phase to horizontal normal fields, is very probably a large body of high electrical conductivity. It could hardly represent a thin crustal layer and must therefore be sought in the lower crust or upper mantle. This interpretation is in accord with the preliminary modelling of Lilley & Tammemagi (1972) and the magnetotelluric evidence of Tammemagi & Lilley (1973).

Tectonic interpretations of the conductor fall into two categories. Either the conductor arises from recent tectonic activity or else it might represent the relic of some tectonic activity of the geological past. Lilley & Tammemagi (1972) have already pointed out that the seismic zone suggested by Cleary & Simpson (1971), which lies at the boundary between two sub-plates, is in the general proximity of $AB$ (Fig. 12), though rather distinctly to the west of the conductor. The conductor may thus be associated with high mantle temperatures under the postulated plate boundary,
possibly arising from an upwelling of the mantle into the lower crust. Such an interpretation, in association with the seismic evidence, would suggest this to be a nascent stage in the development of a rift system. The seismic zone and conductor also coincide with a feature postulated by Cook (1966), Wilson (1968) and Crawford (1970) to be an ancient fracture zone. Cleary & Simpson (1971) observe that the continuity of this feature with oceanic fracture zones depicted by Heirtzler et al. (1968) off southern Australia supports the view of Wilson (1965) that transform faults originate on lines of weakness within continents. An alternative explanation therefore is that the conductor is associated with a fracture zone. A third suggestion proposed by Tammemagi & Lilley (1973) is that the conducting region lies in the crust, and could represent an easterly remnant of the Adelaide geosyncline in the form of a trough filled with saline sediments.

The first two possibilities outlined above are distinguishable from the third in that the conductor AB would not be isolated in the crust but would extend to greater depths into the upper mantle. The extension of this study to the longer periods of the daily variation and its harmonics may help in distinguishing between the two cases.

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References


Magnetometer array study


