on either the size or the rate of the increase of this change. In addition, many of the resulting features of published models are artefactual consequences of the inversion techniques used (e.g. predetermined depth or shape of the abrupt change), though this fact is invariably ignored when models are compared.

More sophisticated global three-dimensional modelling of the electrical conductivity structure of the earth would therefore appear to be inappropriate at this stage; not only because of the abovementioned lack of consistency among published studies, but also because, mathematically, the nature of the electromagnetic induction problem does not permit a tomographic decomposition of geomagnetic data in a manner being successfully applied to seismic data to determine the elastic wave properties of individual three-dimensional cells within the earth (cf. Anderson & Dziewonski 1984). This fact relates directly to the differences between the physical processes (and hence mathematical models) involved (cf. Cleary & Anderssen 1979).

An electromagnetic counterpart to the use of tomography in seismology would appear to be the use of as much data as possible to accurately determine local three-dimensional structure, which is then pieced together as a mosaic to define the global structure. Another counterpart could be based on the interpretation of the individual spectral components in a Fourier analysis of the earth's transient magnetic field.

The former approach is crucial to a better understanding of the electromagnetic induction problem for the Earth. It would help clarify to what extent the abovementioned inconsistency among models is related to the three-dimensional variation in the electrical conductivity of the earth. If the structure of the earth is as three-dimensional as recent seismic evidence suggests, then some of the inconsistency must simply reflect the geographic variability within the data used, in the sense that, locally, each data set sees a totally different electrical conductivity profile as a function of depth.

In addition, if the conclusions from seismic tomography prove to be correct, then global averaging (i.e. radial symmetric modelling) of the electrical conductivity structure is of limited use except in generating a reference model.

For such reasons, a detailed comparison of one-dimensional transfer function models derived from geomagnetic data at various geographic locations around the Earth is being undertaken.

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The Tasman Project of Seafloor Magnetotelluric Exploration

I. J. Ferguson

Research School of Earth Sciences, Australian National University, GPO Box 4, Canberra, ACT 2601, Australia.

This paper is based on geophysical measurements made along a line of nine recording sites crossing the deep seafloor of the Tasman Sea. Simultaneous measurements were also made on the Australian continent, on an extension of the seafloor line inland (Fig. 1).

The floor of the deep ocean is a remote and a technically hostile environment in which to operate. The observations described here were made possible by special highly developed instruments brought to Australia from Scripps Institution of Oceanography, California. The instruments all free-fall to the seafloor, where they record continuously for a pre-set period (acting as temporary geophysical observatories).

Several different kinds of geophysical recordings were made in this study. Magnetometers were used to measure (temporal) fluctuations in the three components of the magnetic field. A second kind of instrument measured fluctuations in the two components of the natural horizontal electric (telluric) field. In addition, a third instrument type measured fluctuations in the vertical electric field and a fourth recorded the water pressure and temperature.

The magnetic and horizontal electric field recordings enable a magnetotelluric (MT) study to be made. These data as well as those from the other instruments have many applications for oceanographic studies as well as for solid-earth geophysics.

Seafloor magnetotellurics

In the same manner as land-based MT studies, seafloor magnetotelluric (SFMT) studies involve relating fluctuations in the horizontal magnetic field to the induced horizontal electric field, in order to investigate the underlying electrical conductivity structure. There are a number of characteristics unique to seafloor magnetic and horizontal electric field recordings.

First, the electric field contains a significant component of

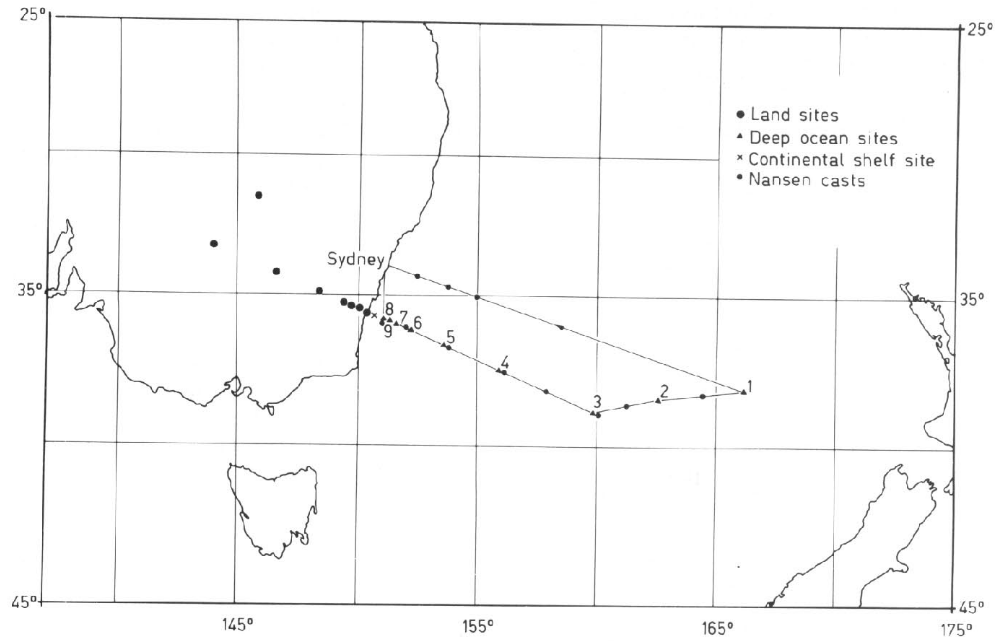

Fig 1 Map of the Tasman Project of Seafloor Magnetotelluric Exploration. Numbers mark the main seafloor observation sites.

signal induced by movements in the surrounding, conducting sea water. This signal is present at a wide range of frequencies; at long periods the signal is induced by eddies and ocean currents, at diurnal and semidiurnal periods it is induced by tides and at shorter periods it is induced by internal waves and ocean turbulence. The second difference from land recordings is that at the seafloor, the magnetic fluctuations at higher frequencies have been significantly attenuated from sea-surface values by the conducting sea water.

These effects limit the possible range of frequencies that may be used in SFMT. Even under optimum recording conditions this window extends over only 2.5 decades, from periods of 10 min to 2 days. Depending on the actual conductivity structure this means conductivity information will be obtained for depths of tens to possibly hundreds of kilometres.

Previous SFMT studies have been located mainly in the Pacific Ocean. These studies commenced around 1970 and have produced valuable information regarding the presence and depth of an asthenospheric layer. Such a layer is believed to be characterized by a partially molten region of high electrical conductivity.

The Tasman experiment

The observing period of the present experiment was approximately 114 days, from early December 1983 until the end of March 1984. The instruments were deployed and retrieved during two cruises of the naval oceanographic ship HMAS *Cook*. The instruments were lifted overboard using a crane, released, and then allowed to fall through water depths of 4000–5000 m to the seafloor. Figure 2 shows the deployment of an ocean-bottom instrument. Approximately 4 months later, according to a preset timer, the instruments released a ballast tripod and floated to the surface for retrieval, transmitting radio signals to aid in their location.

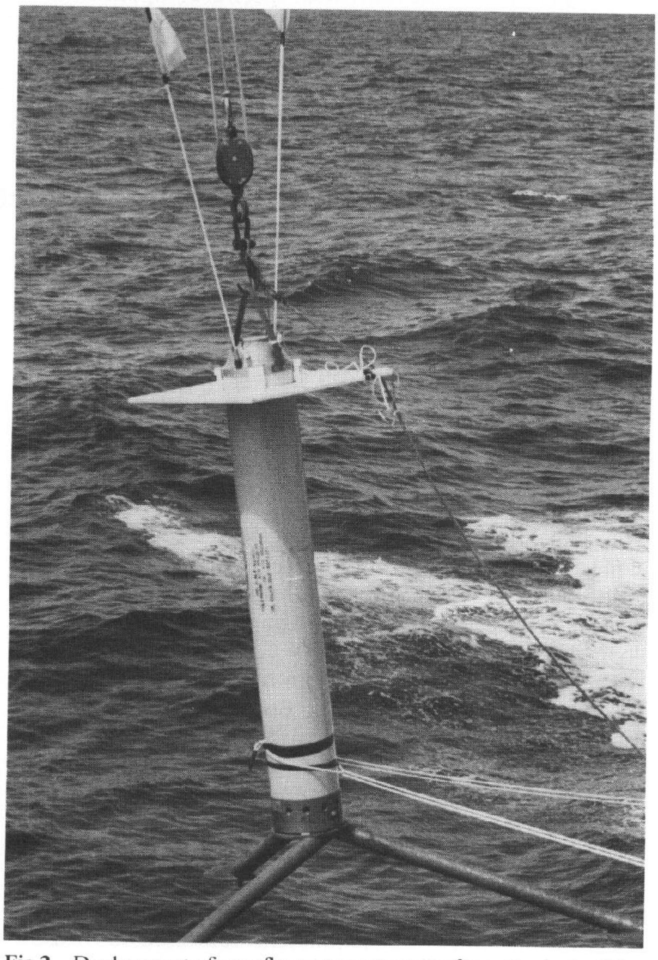

Fig 2 Deployment of a seafloor magnetometer from the deck of the naval oceanographic ship, HMAS *Cook*. This instrument, developed by J. H. Filloux of the Scripps Institution of Oceanography, measures fluctuations in three components of the natural geomagnetic field, recording unattended on the seafloor for periods up to 4 months.

This paper is concerned particularly with the SFMT data from site 4 in the Central Tasman Sea (Fig. 1). This site lies near the fossil spreading ridge that produced the Tasman Sea 80–60 Ma ago. The site also lies close to a line of seamounts that trends meridionally through the Tasman Sea.

Magnetotelluric analysis

The horizontal magnetic and electric field components from site 4 were Fourier transformed, band averaged, and analysed to produce an impedance tensor. The band averaging was arranged such that spectral lines near tidal frequencies were grouped and then omitted from further analysis. Further examination of coherences between components, indicated that the impedance tensor was only accurately resolved for periods between 10 h and 20 min.

This narrow frequency range is due to the active nature of the ocean off eastern Australia. Large-scale warm water eddies are carried down by the eastern Australian ocean current and propagate across the line of the sites. The passage of such an eddy may be visually correlated with the commencement of a long period of disturbance on site 4 horizontal electric field recordings.

For site 4, the impedance tensor is highly skewed and anisotropic. The skewness is however frequency independent, and as such, could be produced by a near surface distortion of electric currents. A simple differential rotation of the electric data with respect to the magnetic data produces a 'corrected' tensor that is consistent with a two-dimensional electrical conductivity structure.

The magnitude and phase values for the principal axes of this tensor are shown in Fig. 3. Considerable anisotropy exists between the two axes, suggesting significant differences in electrical conductivity in the directions of the major and minor axes (10° and −80° clockwise from magnetic north respectively). The phase differences between the two components suggest that this anisotropic conductivity varies with depth.

For comparison with the Tasman data, the impedance tensor derived for a site near the Pacific Rise, an active spreading ridge off Mexico, is also shown. It may be noted that for longer periods an 'average' impedance for site 4 data is of comparable magnitude to the impedance near the Pacific Rise. Furthermore at higher frequencies, site 4 impedance is significantly lower than the impedance near the Pacific Rise.

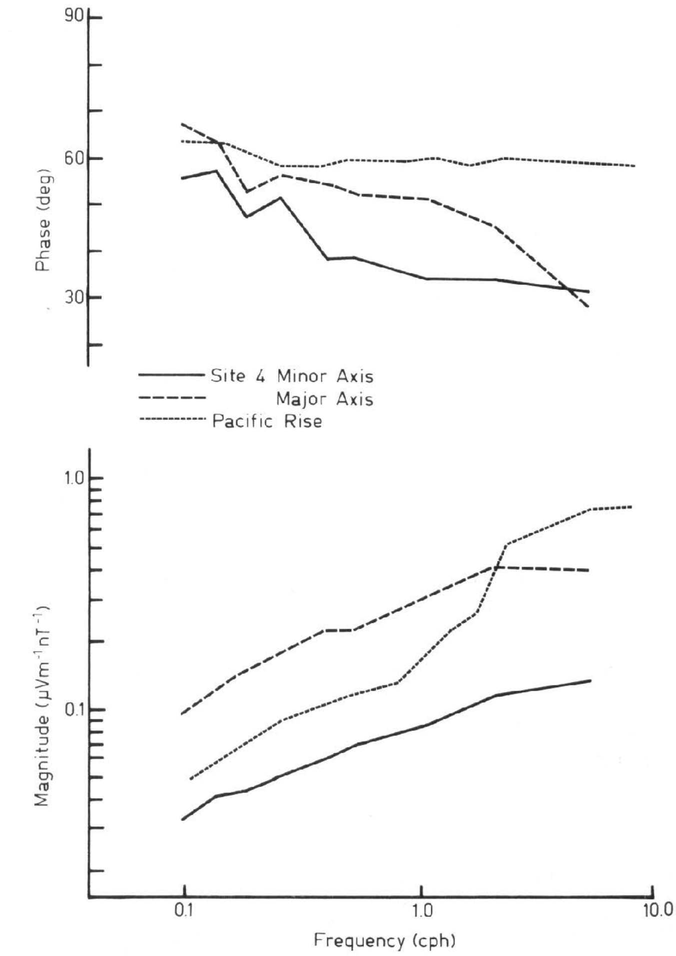

Fig 3 Impedance tensor results for site 4 in the Tasman Sea, and for the Pacific Rise at 12° N, off Mexico.

Interpretation

The similar magnitude of the impedance at site 4 in the central Tasman Sea to that near the Pacific Rise suggests comparably large electrical conductivities in the earth's mantle. In addition the lower impedance of site 4 components at higher frequencies (as well as the very low values for phase at these frequencies) suggests that at some relatively shallow depth (< 80 km) the conductivity in the central Tasman is higher than beneath the Pacific Rise.

Such an electrical conductivity value for the mantle beneath the Tasman Sea is unexpectedly high. One would generally expect such high conductivities to be associated with more tectonically active regions. The apparent two-dimensionality of the conductivity at site 4 means that for a more complete understanding of the conductivity structure the data analysis for the surrounding sites will need to be completed. The high value of electrical conductivity may be a result of thermal effects associated with the seamount chain passing near the site.