The Tasman Project of Seafloor Magnetotelluric Exploration

J. H. Filloux, F. E. M. Lilley, I. J. Ferguson, N. L. Bindoff and P. J. Mulhearn

Introduction

This paper is based on geophysical measurements made along a line of nine recording sites crossing the deep sea floor of the Tasman. 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 the 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. Temporal fluctuations in the three components of the magnetic field were measured by magnetometers. Other instruments were used to measure fluctuations in the two components of the natural horizontal electric (telluric) field, the vertical electric field, and the ambient water temperature and pressure.

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 for 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.

Firstly, the electric field contains a significant component of signal induced by movements in the surrounding, conductive 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 MT recordings is that at the seafloor, the magnetic fluctuations at higher frequencies have been significantly attenuated from sea-surface values by the conductive 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 periods of 2 days. Depending on the actual conductivity structure this means that conductivity information will be obtained for depths from tens to possibly hundreds of kilometres.

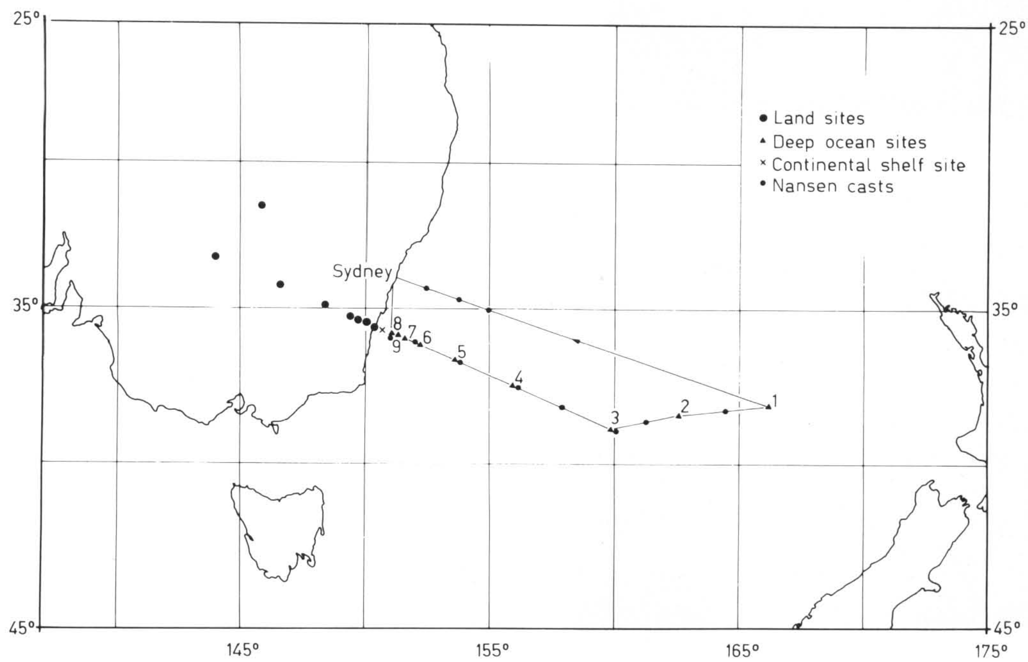

Fig 1 Map of the Tasman Project of Seafloor Magnetotelluric Exploration. Numbers mark the main seafloor recording sites.

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Previous SFMT studies have been located mainly in the Pacific Ocean. The current 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 observation period of the present experiment was approximately 114 days, lasting 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* (Fig. 2). 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 3 shows the deployment of an ocean-bottom instrument. Approximately four months later, according to a pre-set timer, the instruments released a ballast tripod and floated to the surface for retrieval, transmitting radio signals to aid in their location.

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 m.y. ago. The site also lies close to a line of seamounts that trends meridionally through the Tasman Sea.

Fig 2 The naval oceanographic ship HMAS *Cook*.

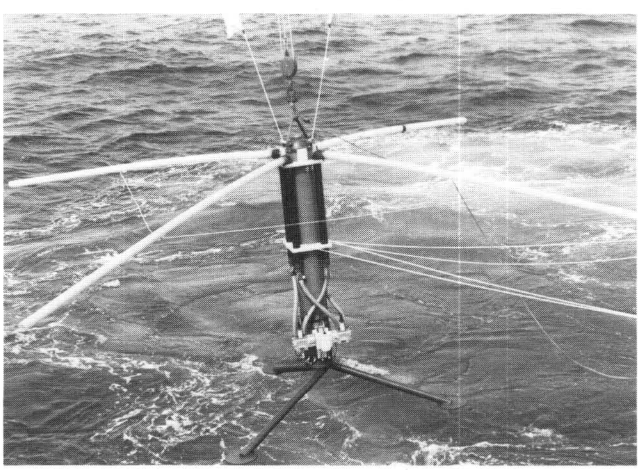


Fig 3 Deployment of a seafloor recorder. This instrument records fluctuations in the natural horizontal electric field at the seafloor, measured between the ends of the cross.

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 the coast of 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 disturbance on the site 4 horizontal electric field recording. For site 4 the impedance tensor is highly skewed and anisotropic. However, the skewness is 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. 4. 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 respective-

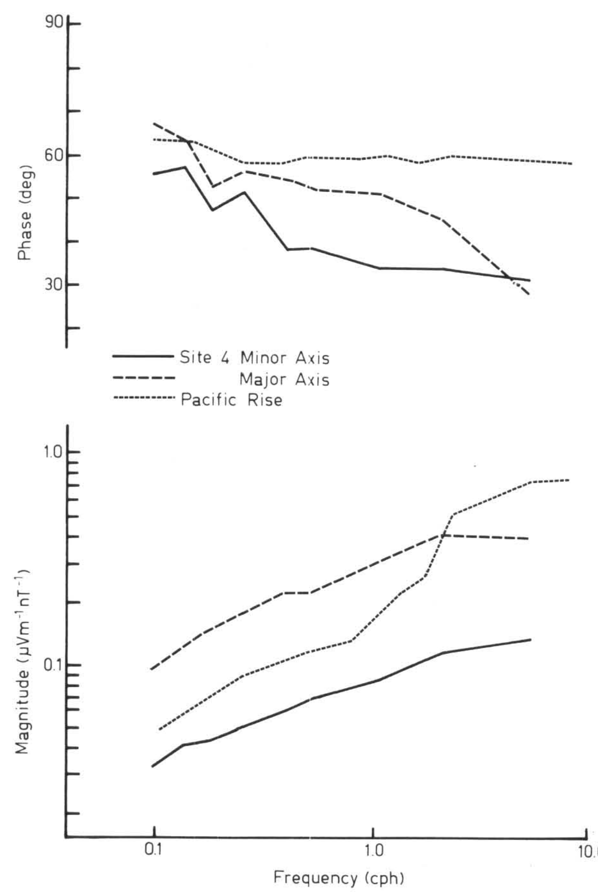


Fig 4 Impedance tensor results for site SIO 4 Tasman Sea, and for the Pacific Rise at 12°N off Mexico.

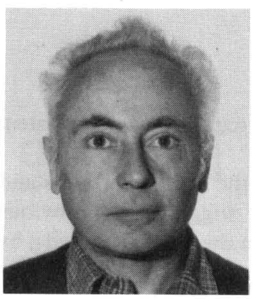
ly). The phase differences between the two components suggest that this anisotropic conductivity varies with depth.

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 the site 4 data is of comparable magnitude to the impedance near the Pacific Rise. Furthermore at higher frequencies, the site for impedance is significantly lower than the impedance near the Pacific Rise.

Interpretation

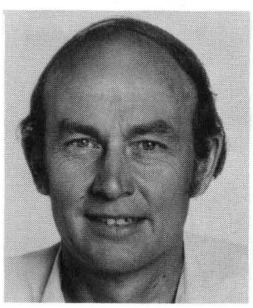
The similar magnitude of the impedance at site 4 in the Central Tasman Sea with that near the Pacific Rise suggests comparably large electrical conductivities in the earth's mantle. In addition the lower impedance of site 4 components at higher frequencies (as well as the very low values for phase at 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.



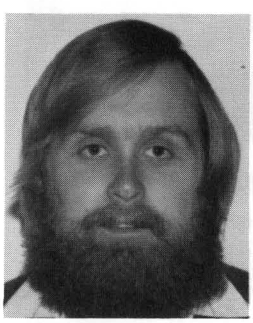
Dr Jean Filloux is a Research Oceanographer at the Scripps Institution of Oceanography (SIO), which is a part of the University of California, San Diego. He moved to the United States from France, where he had received his schooling and first degrees in engineering. At SIO in California he graduated MS and PhD in physical oceanography. He has worked particularly on the development of oceanographic instruments for the deep-water measurement of geophysical quantities, especially electric, magnetic, and pressure fluctuations on the ocean floor. The former data have given pioneering results for the electrical conductivity of the oceanic lithosphere and asthenosphere, determined by the magnetotelluric method. The latter data have given pioneering measurements of open ocean tides and tsunami. Jean Filloux is a member of AGU.

J. Filloux, Scripps Institute of Oceanography, USA.



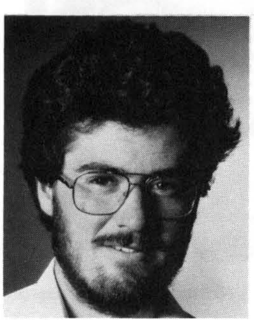
After secondary school in Hobart, Ted Lilley was awarded a cadetship in geophysics by the Australian Atomic Energy Commission and graduated BSc(Hons) from the University of Sydney. Following experience in airborne surveying with the Bureau of Mineral Resources he undertook graduate study in geophysics at the University of Western Ontario, Canada, where he graduated MSc and PhD. Postdoctoral work at Cambridge, England followed before he returned to the Australian National University, where he is now a Fellow in the Research School of Earth Sciences. He has worked particularly on measurements of geomagnetic induction using magnetometer arrays. Lilley recently served a three-year term as ASEG editor. He is also a member of GSA and AGU.

F. E. M. Lilley, Research School of Earth Sciences, Australian National University, GPO Box 4, Canberra, ACT 2601.



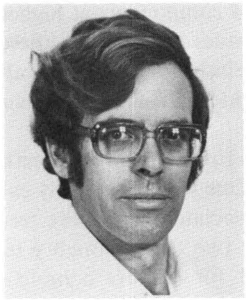
Ian Ferguson received a BSc(Hons) degree from Australian National University in 1981 after studying geology and then geophysics. During 1982 he was employed by the BMR as geophysicist at the Macquarie Island Geophysical Observatory. Since 1983 he has been a PhD student at ANU where he is engaged in research on magnetotelluric investigation in the Tasman Sea. He is a student member of ASEG, AGU, and AMSA.

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



Nathan Bindoff graduated in 1984 with an honours degree in geophysics from the University of Tasmania. He is currently enrolled for a PhD at the Australian National University. The main subjects of his research are the geomagnetic induction effects of continental margins and ocean water movements. This work is being carried out as part of the Tasman Project of Seafloor Magnetotelluric Exploration. Nathan Bindoff is a student member of the ASEG.

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



Dr Mulhearn is a Senior Research Scientist at the RAN Research Laboratory, Sydney, and a Research Affiliate in Sydney University's Department of Geology and Geophysics, and in its Ocean Sciences Institute. He is a member of the Australian Marine Sciences Association. Principal research interests are the behaviour of large scale oceanic fronts and eddies, and their real-time analysis.

P. J. Mulhearn, Research School of Physical Sciences, Australian National University, GPO Box 4, Canberra, ACT 2601.

Geophysical investigations of dolines* in lateritic terrain

J. E. Haigh and R. G. Nelson

Introduction

The detection of cavities in the near ground surface assumes vital enconomic significance when the area is subject to major engineering construction. Such is the case where the route of the proposed Alice Springs to Darwin railway crosses the Wiso Basin, between Tennant Creek and Katherine. Although the presence of dolines in the Wiso Basin was well documented, the overnight collapse of the Buchanan Highway into a sinkhole in 1982 highlighted the potential danger and dictated a full scale investigation.

Regional geology

The Wiso Basin formed during the Early Cambrian, with deposition of the Antrim Plateau Volcanics in a shallow marine environment, on a flat eroded surface of Proterozoic rocks. The volcanic activity was followed by Middle Cambrian deposition of the Tindall and Montenjinnie Limestones, which reach a thickness of 150 m in the area of interest. The next recorded deposition is that of the Cretaceous Mullaman beds, a sequence of quartz sands and silts bonded by clay cement, which were deposited in shallow lacustrine and marine conditions. The beds reach a thickness of 100 m and are characterized by strong lateral facies changes. During preliminary drilling, free-flowing sands, and clay-filled voids were encountered.

It has not been positively established, but it is presumed that erosion and karstic topography development occurred between the Cambrian and Cretaceous. Extensive weathering during the Tertiary resulted in laterite formation and strong preferential weathering along vertical joints. The Quaternary is represented by minor alluvial and aeolian sediments.

Doline distribution

Photo-interpretation infers that regional and local geological conditions exert some control on doline formation. An observed correlation of doline locations with lineation patterns and centres of drainage, implies that the regional fracture system has exerted significant control.

The stratigraphic juxtaposition of the Mullaman Beds and the karstic Cambrian limestone suggests an obvious mechanism for formation of dolines in the Mullaman Beds; by

Fig 1 Dolines on the Buchanan Highway formed late wet season, 1982 (courtesy of Dr R. W. Twidale).

* The generic term 'doline' is defined to include: broad, shallow depressions; deep, steep-sided sinkholes; piping structures or cavities which may lead to sinkhole formation (Fig. 1).