Letter to the editors

Comment on 'Generalized thin sheet analysis in magnetotellurics: an extension of Price's analysis' by R. P. Ranganayaki and T. R. Madden

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In their paper Ranganayaki & Madden (1980) state 'oceanic crustal resistivity values of $10^6$ or even $10^5 \Omega \cdot m$ are probably unrealistic, but until these values are better known one must be careful interpreting oceanic measurements'. Furthermore, they say 'the ocean crust is probably less resistive (than $10^6 \Omega \cdot m$) but we have yet no direct measurements of its electrical properties'. These statements are rather surprising since, to the contrary, both direct and indirect data are available in the open literature that suggest that the ocean crust does indeed have a low resistivity. The following discussion uses only data that were available to Ranganayaki & Madden (1980) before they re-submitted their paper.

Stesky & Brace (1973) presented resistivity data for a suite of serpentinized rocks dredged from the floor of the Indian Ocean. Some samples showed very low resistivities ($< 100 \Omega \cdot m$), owing to a combination of high porosity (and hence fluid conduction) and conduction in highly conductive minerals such as magnetite. Such data are not necessarily representative of the ocean crust since serpentinized ultramafics are discounted as a major constituent of the crust on the basis of their high Poisson's ratio (Drury 1979).

Hyndman & Ade-Hall (1974), Drury (1976, 1978), Hyndman & Drury (1976) and Christensen et al. (1978) have published data on the electrical resistivity at room temperature of laboratory samples of oceanic basalts drilled from a large number of oceanic sites by the Deep Sea Drilling Project. Many of the samples were from sites of deep (several hundreds of metres) penetration into basement. The data show that oceanic basalts saturated with low resistivity seawater (approximately $0.25 \Omega \cdot m$) have generally low resistivities, arising from their high porosity. The geometric mean resistivity of 86 samples collated from the above works is approximately $200 \Omega \cdot m$, and the mean porosity approximately 7 per cent. Gabbros have a higher resistivity ($\approx 2000 \Omega \cdot m$) and lower porosity of about 1 per cent (Drury 1979). The resistivity of both basalts and gabbros is lowered significantly at $200^\circ C$, the estimated temperature at the base of the ocean crust (Drury 1979).

Using these data, Drury (1979) constructed resistivity models of the oceanic crust, and predicted that the mean resistivity of the crust of thickness 7–10 km would be in the range $400–600 \Omega \cdot m$, with very much lower resistivities, as low as $1 \Omega \cdot m$, in the sediments of layer 1 and pillow basalts and volcanic rubble of layer 2A. These values are in good agreement with the observations of Bostick, Cox & Field (1978) who concluded, from an electro-
magnetic propagation experiment, that the effective resistivity of the suboceanic propagation path was not greater than 1000 Ω m.

Direct measurements of the electrical properties of the upper ocean crust have also been made. Kirkpatrick (1979) found, from downhole geophysical logging at Deep Sea Drilling Project site 396B near the mid-Atlantic ridge, that the resistivity of the upper few hundreds of metres is in the range approximately 5–90 Ω m. All indications are, therefore, that the ocean crust has a low resistivity, of the order of 100 Ω m.

The model used by Ranganayaki & Madden should more reasonably have, as part of the 'resistive' layer between the surface sheet (ocean) and mantle, 10 km of material of resistivity 100–1000 Ω m, giving a resistivity-thickness product of $10^3–10^4$ kΩ m². The conductivity-thickness product for a 5-km deep ocean of conductivity 4.0 S m⁻¹ of 20 kS then gives an 'adjustment distance' of approximately 140–450 km, much less than the 1000 km suggested by Ranganayaki & Madden (1980). The authors point out the importance of taking into account this 'adjustment distance' effect in modelling. In this sense, the smaller the adjustment distance the more potentially tractable is the determination of local resistivity structure. In particular, the adjustment distance is important when one considers magnetotelluric data obtained from the sea-floor. For example, the data obtained by Filloux (1967) in the Pacific Ocean were from a site 630 km off the coast of California. Ranganayaki & Madden (1980) would have this site within the 'adjustment distance' whereas the available resistivity data indicate that it would be beyond the adjustment distance.

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References


