An examination of unidentified fossil otoliths and statoliths has revealed a number of squid statoliths from North American strata. To date they have been found in the Pleistocene of California (Timms Point Silt), the Pliocene of California (Lomita Marl and Pico Formation), the Miocene of California (Olcese Sand), Florida (Chipola Formation), Jamaica (Bowden Formation), and Virginia (Yorktown Formation), and the Oligocene of Mississippi (Glendon Limestone). In one Pliocene deposit (Lomita Marl), 185 of 24,299 otoliths and statoliths recovered from approximately one ton of fossiliferous matrix represented at least three kinds of squid species. Rare fossils, very similar to modern ommastrephids *Plesioteuthis,* are known from the Upper Jurassic, suggesting that statoliths are likely to be found in strata older than the Cainozoic.

Statocysts of living cephalopods have been described by several authors[3–7] but no detailed description or comparative study of the hard calcareous statolith (= otolith) has so far been published.

M. R. Clarke (unpublished) found that the statoliths of *Ommastrephes* were composed of aragonite, and in another study attempted to relate growth to the rings seen in the statoliths of *Todarodes sagittatus.* Unaltered aragonite fossils (teleost fish otoliths, mollusc shells, and so on) are abundant throughout the Cainozoic, and sometimes afford the only method of identifying faunal components[8,9]. Indeed, fish otoliths have proved very useful in tracing the history of Recent genera, and there seems every possibility that statoliths will help clarify the relationships of Recent families, and possibly even genera, of the Cephalopoda. A study of the variation of statoliths in Recent families of cephalopods is now in progress, and it is already evident that within the limits of the general pattern the form varies considerably between and within families.

Fossil cephalopod statoliths should provide not only a means of studying phylogeny but, in addition, the relative numbers of statoliths of different families should provide an indication of the relative importance of the various families living at a particular locality and time.

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[1] Kaiser, P., and Lehmann, U., *Paläont. Z.*, **45** (1/2), 18–32 (1971).
[2] Donovan, D. T., *Symp. zool. Soc. Lond.* (in the press).
[3] Hamlyn-Harris, R., *Zool. Jb.*, **18**, 327–358 (1903).
[4] Ishikawa, M., *J. Coll. Agric. imp. Univ. Tokyo*, 7, 165–210 (1924).
[5] Ishikawa, M., *J. Morph.*, **48**, 563–584 (1929).
[6] Young, J. Z., *Proc. R. Soc.*, **B152**, 3–29 (1960).
[7] Budelmann, B.-U., *Fortschr. Zool.*, **23** (1), 84–96 (1975).
[8] Fitch, J. E., *Los Angeles Co. Mus. Contr. Sci.*, **199**, 1–41 (1970).
[9] Frizzell, D. L., and Dante, J. H., *J. Paleont.*, **39**(4), 687–718 (1965).

Electrical conductivity anomalies and continental seismicity in Australia

Where the Upper Mantle Project 'geotraverse' line in western Australia crosses seismic zones anomalous effects have been found in the vertical component of the magnetic fluctuation field[1]. A two-dimensional array study operated over a wide area of southern Australia has detected anomalous effects at the eastern edge of the seismically active Flinders Ranges[2]. Various interpretations have been suggested for the Flinders anomaly[2] and interpretations of the accompanying seismicity[3] have been given in terms of plate tectonics[4]. Independent seismic evidence[5] indicates that there is no abrupt step in crustal and upper mantle structure from west to east across the Flinders Ranges, though there may be a gradual change. A magnetometer array in south-eastern Australia has detected anomalous effects in southern Victoria[6], and the interpretation of a subsequent study has located the anomaly more exactly (F. E. M. L., unpublished), placing the conductor causing it under or near the Otway Ranges, another region of Australian continental seismicity. Consequently, all the major continental conductivity anomalies so far discovered in Australia are in regions of earthquake activity (Fig. 1).

The earthquakes plotted in Fig. 1 occurred between 1897 and 1972, and the distribution of observatories on the continent over this time has probably influenced the seismicity pattern shown. Several major earthquake zones are apparent, though on a world scale the seismicity of the Australian continent is low.

It is possible that the electrical conductivity anomalies and seismic zones are geographically related. Shallow conductivity anomalies could arise because fracturing has broken up the surface rocks, allowing continuity in saline ground waters to provide a conducting channel. This mechanism is, however, not entirely satisfactory for the Otway Anomaly, which may extend deeper than the seismic zone.

Beneath fracture zones, motion along fault planes presumably occurs by some type of ductile flow. Such ductile shearing of rock may increase greatly its electrical conductivity and produce a deep electrical conductivity anomaly, either by causing a change in rock fabric[7] (for example the presence of a graphite schist has been postulated to explain a major conductive structure in North America[8]), or simply by heating. The rheological process of ductile flow beneath continental earthquake zones may involve the conversion of considerable quantities of mechanical energy to heat.

Magnetic fluctuations may in future be observed over the more northern centres of Australian seismicity (see Fig. 1) which have not yet been covered by magnetometer array studies. Because of present interest in the thermal balance of active faults[9], heat flow data are being collated, although heat flow values would not necessarily be expected to be high: increased conductivity could result from quite a minimal increase in temperature at depth were that temperature already near the melting point, thus forming a partial melt.

If a general relationship between seismic activity and electrical conductivity anomalies is established there may be several implications for projects of earthquake prediction. The first is that deep electrical conductivity may vary both before and after an earthquake, as a consequence of associated variations in the ductile flow. (I do not mean to imply that such variations would be detected by a magnetometer array; perhaps controlled-source, electrical methods would be most suitable.) The second implication is that any observations of magnetostrictive changes in the Earth's static magnetic field may need to be corrected for non-uniform magnetic fluctuations arising from local conductivity anomalies. Such corrections may be possible if magnetostrictive observations are taken on an array basis, and full geomagnetic induction tensors[10] are estimated for each observing site.

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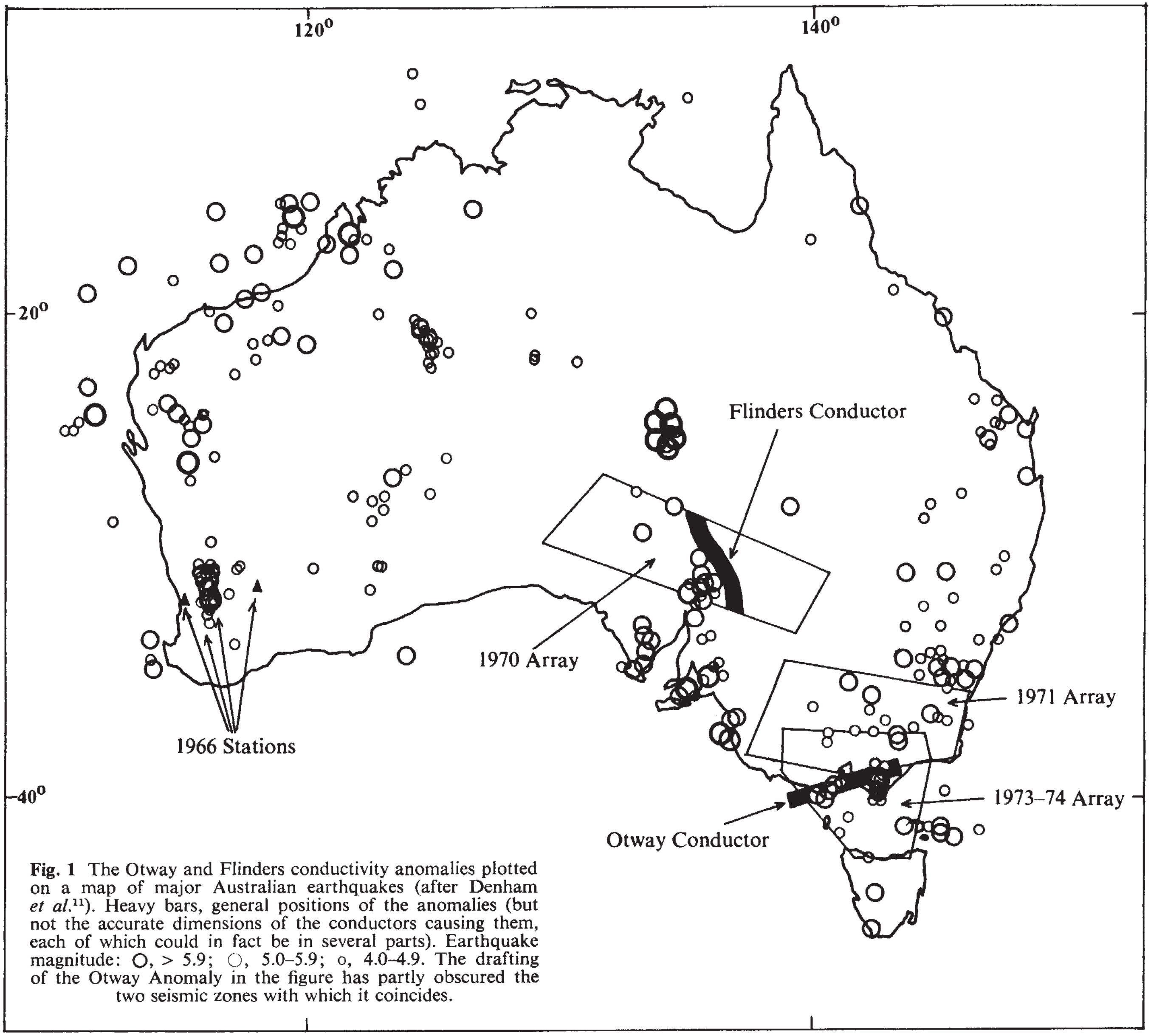

Fig. 1 The Otway and Flinders conductivity anomalies plotted on a map of major Australian earthquakes (after Denham *et al.*[11]). Heavy bars, general positions of the anomalies (but not the accurate dimensions of the conductors causing them, each of which could in fact be in several parts). Earthquake magnitude: ◯, > 5.9; ○, 5.0–5.9; o, 4.0–4.9. The drafting of the Otway Anomaly in the figure has partly obscured the two seismic zones with which it coincides.

The Bureau of Mineral Resources provided maps of Australian earthquakes.

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[1] Everett, J. E., and Hyndman, R. D., *Phys. Earth planet. Interiors*, **1**, 24 (1967).
[2] Lilley, F. E. M., and Tammemagi, H. Y., *Nature phys. Sci.*, **240**, 184 (1972).
[3] Doyle, H. A., Everingham, I. B., and Sutton, D. J., *J. geol. Soc. Aust.*, **15**, 295 (1968).
[4] Cleary, J. R., and Simpson, D. W., *Nature*, **230**, 239 (1971).
[5] Cleary, J. R., Simpson, D. W., and Muirhead, K. J., *Nature*, **236**, 111 (1972).
[6] Bennett, D. J., and Lilley, F. E. M., *Geophys. J.*, **37**, 191 (1974).
[7] Stesky, R. M., and Brace, W. F., *J. geophys. Res.*, **78**, 7614 (1973).
[8] Gough, D. I., and Camfield, P. A., *J. geophys. Res.*, **77**, 3168 (1972).
[9] McKenzie, D., and Brune, J. N., *Geophys. J.*, **29**, 65 (1972).
[10] Lilley, F. E. M., *Phys. Earth planet. Interiors*, **8**, 301 (1974).
[11] Denham, D., *et al.*, *Search*, **6**, 34 (1975).

Tyndall figures at grain boundaries of pure ice

LIQUID figures produced by internal melting in ice are called Tyndall figures (see refs 1–3). I report here the formation and morphology of Tyndall figures at grain boundaries in pure ice.

I produced Tyndall figures at grain boundaries by focusing radiation from a small lamp into an area of 2×2 mm^2 in an ice specimen which had grown from degassed, distilled and deionised water in stainless steel containers, and which had reached melting point as indicated by veins of water forming along the intersections of three grain boundaries[4].

Two Tyndall figures with a vapour cavity were formed at a grain boundary (Fig. 1*a*). The vapour cavities—the black parts in Fig. 1*a*—are produced because of the density difference between ice and water[1]. The Tyndall figures are inclined to the plane of the figure. The dashed arrows and the solid arrow (Fig. 1*a*) show the veins of water and the intersection of the melt grain boundary and the specimen surface, respectively. The surface of the melt boundary is not flat.

Fig. 1*a* shows that small perturbations are formed at the periphery of the Tyndall figures. Such perturbations were observed at the periphery of disk-shaped Tyndall figures formed in the basal plane. When the figures in the basal plane developed to a certain size, they became truncated cones and the perturbations began to be nucleated at the edge where the side face and the planar plane of the figures intersected[5]. On the other hand, the perturbation of