Given their high energy needs and great efficiency of acquisition and extraction of energy, why do hummingbirds spend so much time sitting? Diamond *et al.* suggest that the rate-limiting step in digestion for the birds is the time taken for the crop (the specially modified region of the oesophagus used to store food immediately after ingestion) to empty. They used a dilution technique with radioactively labelled polyethylene glycol to estimate crop contents at the start of a meal and after known intervals, and show that it takes about 4 min for the crop to half-empty after a 100-μl meal. During this 4-min period, while the bird is waiting to make space for its next meal, it sits on a perch and minimizes its energy expenditure. The observed pauses between meals are usually about 4 min, as predicted by the hypothesis of Diamond *et al.*

Are digestive bottlenecks, like the one so elegantly demonstrated by Diamond *et al.* for hummingbirds, found in other small vertebrates? It is well known that shrews spend much of their time feeding, but it is less often mentioned that during an activity period, and shortly after feeding, they frequently rest for 5 min at a time (I. Hanski, personal communication). Perhaps for these animals, like hummingbirds, rates of digestion limit rates of ingestion[5]. Optimization processes evolve under certain constraints, and rates of digestion may provide a more widespread constraint to activity patterns than previously thought. □

1. Diamond, J.M. *et al. Nature* **320**, 62 (1986).
2. Kenward, R.E. & Sibley, R.M. *J. appl. Ecol.* **14**, 815 (1977).
3. King, J.R. in *Avian Energetics* (ed. Paynter, R.A.) 4 (Nutall Ornithological Club, Massachusetts, 1974).
4. Ferro-Luzi, A. in *Energy and Effort* (ed. Harrison, G.A.) 115 (Taylor & Francis, London, 1982).
5. Hanski, I. *Ann. Zool. Fennici* **21**, 157 (1984).
6. Gibb, J. *Ibis* **102**, 193 (1960).
7. Pyke, G. *Am. Zool.* **18**, 739 (1978).
8. Carpenter, F.L., Paton, D. & Hixon, M. *Proc. natn. Acad. Sci. U.S.A.* **80**, 7259 (1983).
9. DeBenedictis, P.A., Gill, F.B., Hainsworth, F.R. & Wolf, L.L. *Am. Nat.* **112**, 301 (1978).

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Oceanography

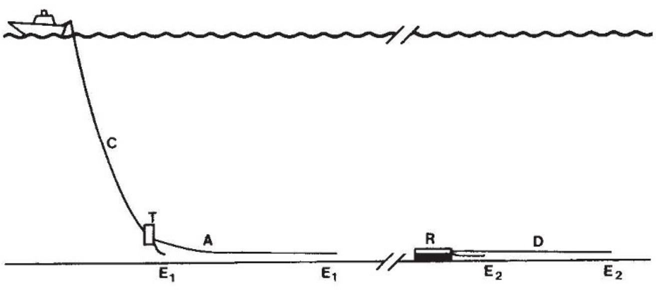
Conductivity of the sea floor

from F.E.M. Lilley

THE effort in earth science to move from observations on continents to observations on seas and sea floors has produced spectacular results; indeed, modern geology is based largely on the rewards from such adventures. The deep ocean is a remote and hostile place in which to work, requiring the development of special equipment and techniques. Once these difficulties are overcome, the deep sea floor has several advantages. Large areas of it are flat and uncluttered; it is a generally undisturbed and stable environment; equipment can be left without interference; and there seems to be little difficulty about getting owner permission — indeed there is great attraction in the internationality of seafloor science. The recent work by Cox and co-workers reported elsewhere in this issue (*Nature* **320**, 52; 1986) represents a significant step in efforts to sound the sea floor electromagnetically.

Data on seafloor seismic velocities, magnetic patterns, sediment thicknesses and heat flow, which have proved so fertile for earth science, are valuably embellished by information on electrical conductivity. At the seafloor interface this parameter relates to the porosity and thickness of the sediments; below the sediments it reflects water content in the oceanic lithosphere with implications for fracture patterns and the possibility of seawater convection, as well as the possible inclusion in the lithosphere of mineralogy of high electrical conductivity. Still deeper, at asthenospheric depths, the condition of the asthenosphere itself — is it partially molten? — should be evident from an electrical conductivity profile.

In addition to its obvious geological relevance, electromagnetic measurements promise to yield much oceanographic information, and for a correct interpretation of such measurements a good understanding is necessary of the leakage electric currents that flow through the sea floor. These currents depend in turn on the seafloor electrical conductivity.



Transmitter and receiver on the sea bed. C, Cable bringing power from ship; T, transformer housing; A, insulated wire transmitter antenna (600 m); E_1, transmitter electrode (bared wire); R receiver housing; D, receiver antenna (600 m); E_2, receiver electrodes (Ag–AgCl).

The work by Cox *et al.* reported in this issue describes a controlled-source electromagnetic experiment on the Pacific sea floor off California. The method (see figure) is an advance on the previous experiment of P.D. Young and C.S. Cox (*Geophys. Res. Lett.* **8**, 1043; 1981), in particular because of a new receiver arrangement (see Webb S.C., Constable S.C., Cox C.S. & Deaton T.K. *J. Geomag. Geoelect.* **37**, 1115; 1985). The new equipment allows a greater separation of transmitter and receiver, giving successful transmission over a distance of 65 km.

Several receivers are put out on the sea floor, and the ship steams away from them, towing the transmitting cable. The transmitted signal is rapidly attenuated in seawater, but is detected at the receivers having followed paths through the more weakly conducting sea floor (see sketch). Later the receivers are retrieved, having floated to the surface.

These pioneering results show that below a sediment layer, the crustal layer, of thickness some 5 km, has a conductivity of 10^{-3} S m^{-1}, and is underlain by a thicker region of very low conductivity — less than 2×10^{-5} S m^{-1}. In rock material, such low conductivity means dry conditions, and Cox *et al.* interpret these particular results to mean a low water content (less than 0.1 per cent by volume) in the upper mantle.

The results of further seafloor recordings will be awaited with interest not only from the Scripps team, but also from other groups with electrical techniques now under development — for example the Canadian magnetometric offshore electrical sounding (MOSES) procedure, whose name is appropriate because the technique effectively 'parts the waters' to reveal the sea floor beneath. The international EMSLAB experiment had a successful observing period last (northern) summer. EMSLAB is an electromagnetic study of the lithosphere and asthenosphere beneath the Juan de Fuca Plate and the adjacent continent, with a superarray of instruments recording natural source fields, both onshore and offshore in western North America and the Pacific Ocean. The combination of natural-source results, such as those of EMSLAB, with the controlled-source results that I have described here, will provide mutually beneficial data.

Finally, the experiment of Cox and colleagues demonstrates the reception of a weak electromagnetic signal across 65 km of deep sea floor by transmission through a resistive rock path under the ocean water. The idea of communication in this way between two sites on the ocean floor has aspects yet to be fully explored. □

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