Magnetic soils

Magnetite *sans* microbes

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THE uppermost layers of soil are commonly magnetized many times more strongly than the layers deeper in the soil profile or the country rock upon which the soil has developed. Maher and Taylor report on page 368 of this issue[1] the successful extraction of single microcrystals of pure magnetic fractions from two types of British soil. They show convincing, if circumstantial, evidence that the greater magnetization arises as the soil is formed in a process that produces impurity-free magnetite microcrystals with perfect crystal faces which are only 10–30 nm across, and are concentrated in the topsoil.

A chain of biogenic magnetite gains identified by Petersen et al. *from deep-sea sediment cores. But not all magnetite is biogenic, Maher and Taylor show[1]. (Scale bar, 0.1 µm; from ref. 8.)*

This observation is important not only for studies of rock magnetism, but also for biomagnetic studies because, since the discovery[2,3] of similar perfect microcrystals of magnetite in freshwater bacteria *Aquaspirillum magnetotacticum*, there has been a general belief that such magnetite is produced only by biologically mediated processes.

Following the discovery of biogenic magnetite, high-quality samples of magnetite were produced in laboratory bacterial cultures and recovered from lakes, bogs and deltas. A whole volume has recently been written on such magnetite biomineralization in bacteria as well as in higher animals such as bees, birds and mammals[4]. A kind of biomagnetic bandwagon has arisen, which alarms me, by which bacterial origins have often been proposed, in the absence of direct bacterial evidence, for magnetic particles in ancient iron formations[5], hydrocarbon deposits[5] and in suboxic marine sediments[6,7]. Clear evidence of biogenic magnetite in ancient marine sediments has been found once only [8] (see figure) despite a long, hard search. The new work of Maher and Taylor in this issue[1] should halt, or at least slow, this bandwagon, because if perfect magnetite crystals can be produced inorganically in soil their presence in lake, river and ocean sediments, whether recent or ancient, need not be attributed to biogenesis. Then Earth scientists could use such crystals as tracers of past erosional, hydrological and atmospheric regimes, as they have in the past[9].

In proving their thesis, Maher and Taylor had to reject three alternatives. First, that the magnetic mineral was maghemite, which is similar to magnetite. Maghemite is found in burnt soil and is formed by decomposition of aluminium- or titanium-bearing precursors like haematite or goethite. Energy-dispersive X-ray analysis showed that maghemite was not present, as there were only trace amounts of impurities, zinc and manganese.

Second, the authors had to show the crystals were not a remnant of the country rock. Such detrital magnetite had previously been found from magnetic[10] and Mössbauer studies[11]. The authors rely on their own synthesis[12] of ultrafine magnetite under soil-forming (near-neutral-*p*H) conditions at room temperature. These synthetic magnetite grains are morphologically and magnetically similar to the magnetic extracts from soil.

Lastly, the authors had to exclude the possibility of a biogenic origin. Because the size, shape, purity and magnetic properties of the magnetic extract are similar to those of bacterially produced magnetite, how can one distinguish between biogenic and pedogenic origins? Maher and Taylor are remarkably frank in saying that on the basis of shape, purity and magnetic properties alone, the two origins are indistinguishable. But their soil magnetite does not include associated bacterial cells and a realistic laboratory simulation of pedogenesis does form very similar microcrystals of magnetite, making this the simplest explanation. □

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Daedalus

Scale model

FISH swim much more efficiently than submarines. One explanation invokes the flexible skin of the fish, which yields to local water-pressure fluctuations and damps out turbulence before it can build up. The wasteful eddies which grow around a rigid hull and stream away from it, carrying energy with them, are thus stifled at birth.

And this, says Daedalus, is why fish have scales. Each scale can yield independently to its local pressure variations, without being constrained by the different motions of its neighbours. To test his theory, Daedalus has constructed an artificial fish, with scales attached to its metal body on highly-damped polymeric mountings. Various configurations of this model are being tested in DREADCO's towing tank, to discover what size, distribution and damping of the scales gives the lowest drag. If this optimum closely mimics the scale pattern of real fish, Daedalus's theory will be confirmed. But even if it does not, like all good scientists he has a second theory up his sleeve. Fish scales may not be passive dampers at all, but active ones.

An active eddy-damping scale would sense the pressure perturbation of an incipient eddy, and then move in such a way as to cancel it perfectly. Daedalus's Mark II artificial fish will carry each of its scales on a piezoelectric element governed by a local control chip. Any pressure fluctuation on the scale elicits a pre-programmed response. DREADCO's hydrodynamicists are devising local scale strategies which should damp out eddies completely, imposing pure laminar flow around the 'fish' and giving it the lowest possible drag.

All this, says Daedalus, may only be mimicking nature. But he goes further: he wants his active-scale skin to *propel* his fish. Under central computer control, the scales will generate peristaltic ripple patterns running from its head to its tail. Imposed on the whole wetted surface of the fish, even a modest ripple pattern should produce enough reaction to propel it. A suitably-programmed active skin could generate more complex peristaltic patterns, to stabilize and steer the fish as well. This elegant integrated marine-propulsion system deserves to be scaled up. An active-skin ship, coupled to the water over its whole hull and driven silently in pure laminar flow, would be far more efficient than our present rigid, turbulent, propeller-driven monsters. It could manoeuvre in any direction, even sideways, indeed even upwards, to reduce its draught if it went aground. And barnacles and similar fouling organisms would be numbed and dislodged by the ceaseless rapid vibration of its scales.

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