EARTH'S MAGNETIC FIELD

Seismically Excited?

from our Geomagnetism Correspondent

THE best-known hypothesis for the origin of the geomagnetic field is that the field results from magnetohydrodynamic convective motions in the fluid outer core of the Earth. When this was proposed by Elsasser (*Phys. Rev.*, **69**, 106; 1946) nearly three decades ago, it became the first hypothesis consistent with the observed behaviour of the geomagnetic field at the Earth's surface and is still the most widely accepted view on the origin of the field today. The basic principle of core motion has rarely since been seriously questioned, although Malkus (*Science*, **160**, 259; 1968) alternatively proposed that the fluid circulation in the outer core may be due to the precessional torque on the Earth.

A basic assumption in hypotheses involving motions in the core is that the fluid is at its adiabatic gradient. Two years ago, however, Higgins and Kennedy (*J. geophys. Res.*, **76**, 1870; 1971) concluded that the adiabat for the outer core lies on the "wrong" (solid) side of the melting curve, so that if temperatures were actually distributed along the adiabat the outer core would be solid. They suggested instead that the temperature distribution in the outer core follows the melting point curve. One result of this is that the liquid in the core should be thermally stably stratified and that such stratification may inhibit fluid motion of the kind thought to generate the geomagnetic field. Subsequently, several workers claimed to have resolved this "core paradox" by suggesting that Higgins and Kennedy had miscalculated the adiabatic gradient, that they had wrongly estimated the melting curve of iron, that the outer core may not be pure iron anyway, or that the core comprises a slurry of fine iron particles in liquid suspension. But Kennedy and Higgins (*J. geophys. Res.*, **78**, 900; 1973) later refuted these suggestions, although they did concede that the lower third of the core may have temperatures distributed along an adiabat and thus be capable of sustaining free circulation.

Attempts are still being made to resolve the core paradox; and so for the time being doubt must remain as to whether or not the outer core can be set in motion by convective or precessional forces. In the meantime, however, and notwithstanding the claim by Kennedy and Higgins that their result will "impose severe limitations on any kind of circulation of the fluid in the outer core", Mullan (*Science*, **181**, 553; 1973) has proposed that earthquake waves may be sufficient to produce the motions necessary to the geomagnetic

dynamo. According to his calculations, if the total earthquake energy of 10^{26} – 10^{27} erg yr⁻¹ were transferred to the whole liquid core as kinetic energy and if that kinetic energy were entirely dissipated in one year, the resulting motions would have an energy density of 1–10 erg cm⁻³. In fact, motions should last about 100 years against viscous damping if the velocity variations have length scales of the order of 500 km or more and assuming the kinematic viscosity to be $\leq 10^6$ cm² s⁻¹. Thus the kinetic energy available at any time may be derived from more than 100 years of earthquakes, giving energy densities of 10^2 – 10^3 erg cm⁻³. Mullan suggests that energy densities in this range may be in equipartition with fields of 50–150 gauss.

Of course, all the energy from earthquakes will not reach the core in practice, although the fraction transmitted from mantle to core should presumably be greater than the 10^{-4} that Won and Kuo (*J. geophys. Res.*, **78**, 805; 1973) calculated would reach the inner core from a large earthquake. But nor need the earthquake energy be transferred to the whole fluid core. Mullan thus concludes that 10^{-4} of the earthquake energy transmitted to the outer 100 km of the outer core would still give an energy density high enough to achieve equipartition with a field of at least 5 gauss at the core-mantle boundary. As more general evidence that earthquakes have global effects, Mullan also points to recent proposals identifying earthquakes as the source of the Chandler wobble. Moreover, correlations of the length of the day with geomagnetic variations and independently with earthquake activity are claimed as indirect evidence for a correlation between geomagnetism and earthquakes.

Finally, Mullan draws attention to two possible implications of a seismic geomagnetic dynamo. The first relates to the obvious geographical correlation between the circum-Pacific seismic belt, where most of the deep earthquakes occur, and the Pacific Ocean, where the non-dipole field and secular variations are anomalously low. Could it be that the seismic excitation of core motions beneath the Pacific, being particularly intense, is sufficient to produce a "semi-permanent center of magnetic action" there with restricted drift?

Second, if the geomagnetic dynamo is excited seismically, the perturbations required to reverse the field may also be seismic. Mullan thus returns to the old idea that field reversals may be induced by the impacts of external bodies on the Earth. For example, 10^{27} erg would be transmitted to the Earth by the impact of a meteorite of mass 10^{15} g arriving at a velocity of 10 km s⁻¹, and if the density of the meteorite were 10 g cm⁻³ its radius would be 3×10^4 cm. Mullan calculates

that the average time interval between the impacts of meteorites of such a dimension is 1.7×10^5 yr. This is remarkably close to the characteristic time between field reversals (2×10^5 yr) as deduced by Cox (*J. geophys. Res.*, **75**, 7501; 1970).

ATOMIC MASS

Errors in the Chain

from a Correspondent

A DISCREPANCY with accepted atomic mass values has been observed in a recent measurement of the ⁵⁸Ni–⁵⁵Co mass difference. In their report to *Physical Review Letters* (**30**, 1255; 1973) Goss, Browne and Rollefson of the University of Notre Dame, Indiana, suggest that there is now reason to doubt all accepted values in this mass region.

Atomic masses are frequently quoted with an uncertainty of less than one part in ten million. For some, this is the result of direct measurements with a mass spectrometer; for most, it follows from an elaborate averaging procedure that takes account of a variety of nuclear reaction data. These data link together the masses of many small groups of isotopes in diverse combinations throughout the periodic table. One isotope may appear in many combinations, so the determination of its mass depends in a complex way upon the masses of its neighbouring nuclei. An error in one mass often implies more widespread problems.

By bombarding ⁵⁸Ni with 14 and 15 MeV protons and accurately measuring the energy of the outgoing α -particles, Goss *et al.* could relate the mass of the produced ⁵⁵Co atoms to that of the target atoms. Their result differs by more than three standard deviations from the value calculated from the most recent compilation of atomic masses (Wapstra and Gove, *Nuclear Data Tables*, **9**, 265; 1971). Such a discrepancy might not be particularly alarming were it not for the fact that a difficulty already exists in this mass region. Wapstra and Gove have pointed out that two sets of mass spectrometer measurements on ⁵⁷Fe disagree significantly with one another, and they warn that there could be a "rather large systematic error" in this whole region. It might well be that the Goss experiment is confirming that fear.

On the other hand, there may be a less traumatic explanation. An examination of the sources used to determine the tabulated ⁵⁵Co mass value reveals that, while several measurements are included, one has a claimed accuracy that is an order of magnitude better than the others. In effect, it is this value alone that determines the accepted ⁵⁵Co mass. The method used in that experiment was