PALAEOMAGNETISM

Another Transition Zone

from our Geomagnetism Correspondent

ONE of the classic pieces of evidence for reversals of the Earth's magnetic field is the existence of transition zones—sets of rocks apparently magnetized when the field was actually reversing from one polarity to the other. Unfortunately, the time the field spends in the process of reversing is but a few per cent of the time spent in the fully normal or reversed states, which is why only a handful of well defined transition zones have been recorded.

The migration of the ancient geomagnetic pole from normal to reversed states, as determined from Indian sediments.

A newly discovered transition zone is thus good news for palaeomagnetists in general and proponents of field reversal in particular. Such a zone has now been reported by Pullaiah and Verma (*Phys. Earth Planet. Interiors*, **2**, 158; 1970) in the Tirupati sandstone formation (Lower to Middle Cretaceous) from Godavary Valley, India. To be sure, there are only two samples within the transition zone proper, which means that the new zone is not the best known example. On the other hand, the stability of the magnetizations of the two samples has been studied in great detail, which cannot be said of some of those transition zones discovered when palaeomagnetism was in its infancy. Thermal and a.f. demagnetization thus leave no doubts that the observed magnetizations are primary; and petrographic examination revealed no evidence of mineralogical differences between normal and reversed samples, and thus no hint of self-reversal.

PLASMAS

Instabilities in the Solar Wind

from our Magnetosphere Correspondent

AN outstanding problem in dealing with the solar wind concerns the temperatures of the electrons and protons, which are observed to differ considerably (electrons are hotter by a factor of about 2.5), but not as much as they would according to the crude theoretical model.

The plasma is cooled by adiabatic expansion as it flows away from the Sun, and thermal conduction which is important is much more effective for electrons than protons. Collisions are barely important and so the standard transport coefficients are of dubious validity, a conclusion which also follows the fact that the thermal velocity of the electrons exceeds the wind speed, while the proton thermal velocity does not. Collisions are insufficiently frequent to make the temperature isotropic, and the anisotropy is aligned with the magnetic field.

It seems that heat must be transferred from the electrons to the protons by means of some unstable waves, since the collisional transfer is negligible, and this is confirmed by the observed ratio of temperatures. Such a transfer reduces the temperature gradient of the protons and increases that of the electrons. Forslund (*J. Geophys. Res.*, **75**, 17; 1970) has shown that heat conduction in the electrons is itself a source of instability for several plasma wave modes. Associated with the heat flow is a skewing of the proton and electron distribution function (integrated over $v_{\perp}$ to give a reduced distribution over $v_{\parallel}$). The outgoing electrons have a bigger velocity spread than those ingoing and consequently the peak of the distribution occurs at a lower outward velocity than the mean velocity. If there is no electric current, the mean velocity of the protons is the same as that of the electrons, and then the peaks of the proton and electron distributions are separated and waves may be amplified in essentially the same way as when a current flows in a plasma of uniform temperature.

Forslund estimates growth rates for the various modes at various distances from the Sun. Ion acoustic waves have high growth rates and the magnetic field is weak enough to be neglected here, but the waves are damped if the temperature ratio approaches unity. They probably start at ten solar radii and dominate until the temperature ratio drops to the critical value. The resulting heating of the protons occurs in the tail of the proton distribution.

Where the temperature ratio is not large other modes involving the magnetic field may be important, and their stability depends also on β , the ratio of plasma pressure to magnetic pressure, which increases with distance from the Sun. The first to go unstable may be the less familiar electrostatic ion cyclotron mode, the growth rate of which is also proportional to $\partial f / \partial v_{\parallel}$ at the parallel phase velocity. These waves may heat the protons a little farther out by gyroresonance. Far out, at about one astronomical unit where β is high, the fast magneto-acoustic mode may be amplified at frequencies near the proton gyrofrequency. The stability condition is complicated by the importance of the magnetic force. More general electromagnetic waves, the stability of which depends on cyclotron harmonic resonances, should also be considered.

A quantitative quasilinear treatment of the energy transfer remains to be carried out and it may well be necessary to use a more detailed model of the distribution, but the way seems clear for the construction of an adequate theoretical model. It is already clear that macroscopically the rate of heat transfer from electrons to protons increases with the magnitude of the electron temperature gradient and this could have interesting dynamic effects.