why one might take the observations at face value, not least because of the very thorough job done by Coe *et al.* in discounting many possible types of artefact.

The main problem lies with assigning the origin of the magnetic changes to the Earth's core. First, given that magnetic signals must propagate the 2,900 km from the core to the Earth's surface through the electrically conducting mantle, could such a rapid signal be observed at Steens Mountain, given that the mantle's conductivity has the effect of smearing out even the sharpest impulsive change? Current experimental results for mantle conductivity indicate that field changes traversing the mantle which are dipolar (equivalent to flipping a bar magnet in the core) cannot generate changes more rapid than 2° per day. Only more complex magnetic fields with smaller lengthscales can be responsible for changes faster than this.

Second, a core origin causes problems with energetics: fast changes in the magnetic field require either rapid velocities at the top of the core (with large kinetic energies), or slower velocities and extremely small-scale magnetic fields (large time variations can be generated by moderate flows acting on magnetic fields with large spatial gradients). But even the latter picture is unattractive energetically, because small-scale fields generate a great deal of ohmic dissipation.

There is a way out of this dilemma. One thing that is universally agreed is that during a reversal the intensity of the field is greatly diminished, sometimes by an order of magnitude. So rather than an intensity of typically 50 microteslas, during the reversal at Steens Mountain it measured only 6 microteslas. At present the dipole orientation is responsible for fixing the orientation of the ring current in the magnetosphere, which usually lies at about 12 Earth radii and which is ultimately the source of magnetic storms when changes in the solar wind affect the Earth.

The effect of a weakened internal magnetic field, such as that recorded at Steens, is twofold. It causes the magnetosphere to contract (to about half its size) and consequently deliver stronger external magnetic fields to the Earth's surface, by about a factor of two. More pertinently, these external magnetic fields can have much more of an effect on the local field direction when a storm occurs, because they are of comparable size to the internal field, rather than being mere perturbations[6].

The figure on the previous page shows one of the Steens lava flows representing a time when fast changes have been observed. The magnetization direction moves rapidly through about 80° from a stable pre-jump direction to a different stable post-jump direction. But compare this with a prediction[4] for what happens to the magnetization direction when a typical magnetic storm is in progress. This can be calculated in two ways — for the case when the ring current's orientation is fixed by the pre-jump palaeomagnetic dipole axis, or for an optimized orientation. Because of the great controversy regarding the morphology of the magnetic field during a reversal (whether it remains dipolar or has a more complicated geometry), either calculation is tenable. Either way, the feasibility of the proposed mechanism as an explanation for the observations is clear.

Coe *et al.* did not neglect the possibility of a magnetic storm. But they dismissed the idea because they envisaged the external field being responsible for the entire 80° jump from pre-jump to post-jump stable directions. Ultré-Guérard and Achache's suggestion is that the post-jump direction is coincidentally in the same direction as that produced by a magnetic storm superimposed on a stable pre-jump internal magnetic field.

The proposal is not far-fetched, although it is has its shortcomings. Certainly the magnitudes are about right, but the duration required for such storms (6–10 days) is rather long by modern standards. What might seem rather improbable is the idea that two lava flows should have occurred at such unfortunate times as to have captured two magnetic storms. But set against the many lava flows that do not show signs of storms, the ratio is not too far off what would be expected from the modern frequency of storms. What does perhaps stretch the imagination is the supposed coincidence of the storm directions and the post-jump magnetization directions, which are physically unrelated.

Models of the Earth's internal dynamo, aided by increasing computing power, have now progressed to the stage of being able to generate a realistic simulation of the Earth's field for the equivalent of 40,000 years (and the latest model[7] actually exhibits a reversal). As work continues, the unravelling of palaeomagnetic data such as those from Steens Mountain will, I suggest, be crucial to the interplay between observation and theory. □

Andy Jackson is in the Department of Earth Sciences, University of Leeds, Leeds LS2 9JT, UK.

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DAEDALUS

Away with rain

"INTO each life some rain must fall", but Daedalus wants to dodge his share. His new form of rain-proofing does not intercept the falling rain drops: it deflects them. It is based on the fact that the vapour pressure of water rises rapidly with temperature. If you could make one side of a rain drop hotter than the other side, the difference in vapour pressure across it could amount to a significant fraction of an atmosphere. This unbalanced pressure would accelerate the light droplet sideways.

The DREADCO rain deflector therefore shines a powerful beam of infrared radiation up into the falling rain. The beam has a carefully designed axial intensity gradient, strongest in the centre, but declining steadily towards the outside. A rain drop falling into the beam is thus preferentially heated on the side nearest the beam centre, and is deflected sideways out of the beam.

Cunningly, the rain deflector employs a pulsed infrared laser, whose intense pulses are much shorter than the time-constant for thermal conduction within a drop. Each pulse thus imposes a strong thermal gradient across its target drops, established too quickly to be evened out by internal heat transfer.

One problem is that the rain can come from almost any angle, depending on the strength and direction of the wind. So DREADCO's pilot model has its laser on a steerable mounting. An imaging sensor detects the infrared backscatter from the illuminated drops, and continuously orients the laser to maintain an apparent circular distribution. This keeps the beam pointing into the approaching rain.

The rain deflector will be too complex and power-hungry to displace the personal umbrella. But in fixed installations it should transform the outdoor life, particularly in Britain. Pavement cafés, cheerful clothing, dry outdoor events, predictable sporting fixtures, open-topped cars, all will at last become practical. A vehicle-mounted deflector could also be used to deflect fog, which is made of smaller water droplets. The pulsed infrared beams of DREADCO's anti-fog lamp will elbow aside the swirling mists, giving clear vision in the trickiest driving conditions. In the same way, an upward-gazing, long-range, low-divergence model might even be able to deflect the clouds. The lucky user could bore a hole through an overcast sky in the direction of the Sun, and illuminate himself in a bright beam of personal sunlight. Unscrupulous evangelists will rush to acquire the apparatus, so as to demonstrate their apparent high favour with the Almighty. David Jones