Magnetic reversals

From the core or the skies?

from J. A. Jacobs

THERE has been a flurry of papers in the past two years on reversals of the Earth's magnetic field and their possible connection with extraterrestrial catastrophic events. What has sparked this sudden interest is the reported periodicity of approximately 30 million years (Myr) in the frequency of reversals, comet/asteroid impacts on the Earth and mass extinctions.

There are many analyses of the frequency distribution of reversals of the Earth's magnetic field using statistical approaches (for example, refs 1–3) and it is not surprising that some of them disagree. Several harmonics, including one at 32–34 Myr[1] and one at 15 Myr [1,2] were reported. Later, Raup[3] claimed a 30-Myr periodicity in phase with a 15-Myr signal. The reality of a 30-Myr signal was questioned by Lutz[4] who showed that it is sensitive to the length of the time series, so that when the record is truncated by progressively omitting the most recent events, the spectrum changes. Thus, the 30-Myr peak in the spectrum seems to be an artefact of the record length, and Raup, in a *News and Views* article[5], concurred. But in the most recent analysis, Stothers[6] holds that a statistically significant periodicity of about 30 Myr does exist. Pal and Creer[7], although not suggesting a 30-Myr periodicity, claim that the palaeomagnetic record shows 'spurts' in the frequency of reversals separated by approximately 30-Myr intervals.

It is not difficult to imagine that the impact of a large body on the Earth's surface could lead to mass extinctions. Many have proposed different scenarios for the effects of such an impact, although there is consensus that it would have almost immediate consequences with the loss of many species. There are, of course, other possible causes of extinctions, and nobody proposes that they were all caused by the impacts of large bodies. The most publicized case for an extraterrestrial cause of mass extincitons occurred about 65 Myr ago at the Cretaceous–Tertiary boundary. Deep-sea limestones show marked increases in the concentration of iridium above the background level at precisely the time of the Cretaceous–Tertiary extinctions, and Alvarez *et al.*[8] claim that this iridium is of extraterrestrial origin. One of the best examples can be seen in the pelagic limestones at Gubbio in the Umbrian Apennines of Italy, which also permit detailed palaeomagnetic studies. The planktonic foraminiferal change, and hence the Cretaceous–Tertiary boundary, in this region is not coincident with any particular polarity change[9].

Quite apart from the difficulty of the absolute dating of stratigraphic boundaries, a fundamental problem arises in the culling of the database and in deciding what is mass extinction and what background extinction. Hoffman[10] showed that using different (but plausible) geological timescales and other (acceptable) definitions of mass extinctions nullifies the evidence for any periodicity. Several authors took issue with Hoffman's criticisms in a *Nature* Matters Arising exchange[11]. But Hoffman[11] answers their objections and maintains that, "although there may be a periodicity in late Permian to Quaternary extinctions, the evidence is as yet insufficient".

Despite these uncertainties, there have been several attempts to find an astronomical explanation for a correlation between mass extinctions and extraterrestrial events. One attributes the correlation to oscillations of the Sun perpendicular to the galactic plane (estimated to be 33± 3 Myr)[12]. Biological crises could arise as a result of collisions with interstellar clouds of gas and dust that are concentrated towards the galactic plane; a nearby interstellar cloud would perturb the family of comets in the Solar System, leading to an increased flux of bodies impacting the Earth[12].

The 'periodicity' in extinctions could also be controlled by an unseen companion of the Sun (Nemesis) in a highly eccentric orbit that periodically brings it into the dense inner region of the Oort cloud of comets, perturbing the orbits of many of them and initiating a comet shower resulting in several terrestrial impacts[13]. Among various objections to this hypothesis, Hut[14] estimates that irregularities in the period of revolution of the supposed 'double-star' over the past 250 Myr would be at least 10 per cent, and more likely 20 per cent. One would thus not hope for or expect perfect correlation between crater impacts and mass extinctions. Taken together with Hoffman's[11] criticisms of periodicity in the timescale of mass extinctions, correlation between periodic catastrophic extraterrestrial events and mass extinctions seems very unlikely. This does not preclude individual occurrences such as the large body impacting the Earth at the Cretaceous–Tertiary extinction.

What effect would a large impact on the Earth's surface have on its magnetic field? It is generally believed that the magnetic field results from dynamo action in the Earth's fluid outer core. But there is no consensus on what drives motions in the core. The most plausible view now seems to be 'compositionally' driven convection — freezing of material at the inner-core boundary separating a heavy fraction (mainly iron), leaving behind a lighter liquid fraction in the outer core. If events at the surface of the Earth were to lead to changes in core pressure, this would affect the role of freezing of the liquid core and modify the power supply to the dynamo. For a body of mass 10^{15} kg impacting the Earth, the change in power supply is estimated to be only 0.2 per cent[15]. There may also be a deep-mantle poroelastic shell within the Earth capable of assuming two states, inflation or deflation[16]. As the shell inflates or deflates, poroelastic stresses are redistributed in the core, modulating its solidification and affecting the polarity of the magnetic field. In this model[16], changes in pressure are again invoked to change the polarity, but pressure changes are caused by events internal to the Earth and not extraterrestrially induced.

The cause of reversals may be the result of fluctuations in the net helicity of the core (a measure of the correlation between turbulent velocity and vorticity) in response to fluctuations in the level of turbulence produced by two competing energy sources: thermal convection and growth of the inner core[17]. Helicity generated by heat loss at the mantle–core boundary has the opposite sign to that generated by energy release at the inner core boundary. The possible effect of pressure changes at the inner-core boundary caused by the impact of large bodies at the Earth's surface has been shown to be negligible — but what about changes in thermal conditions at the mantle–core boundary? It is known that the bottom 200 km of the mantle exhibits anomalous seismic properties: the basic question is whether this boundary layer is compositional/thermal. This question is still controversial. A thermal boundary

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NATURE

100 years ago

THE RECENT EARTHQUAKE IN GREECE

On the 27th inst., at 11.30 p.m., at a distance of 50 miles W. ½ S. from Cape Matapan, I felt, all of a sudden, a very strong shock, which made the ship tremble, especially the engines, for the space of about 11 seconds. At midnight I observed on our right something like a mass of thick black smoke, which, like a cone, was rising up perpendicularly from the horizon, and at intervals changing into a reddish colour. At 10 a.m. the mate, who was on watch on the bridge, reported to me that he had observed in the sea several stripes of a dark yellowish colour about one quarter of a mile long. CAPT. L. AQUILINA

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