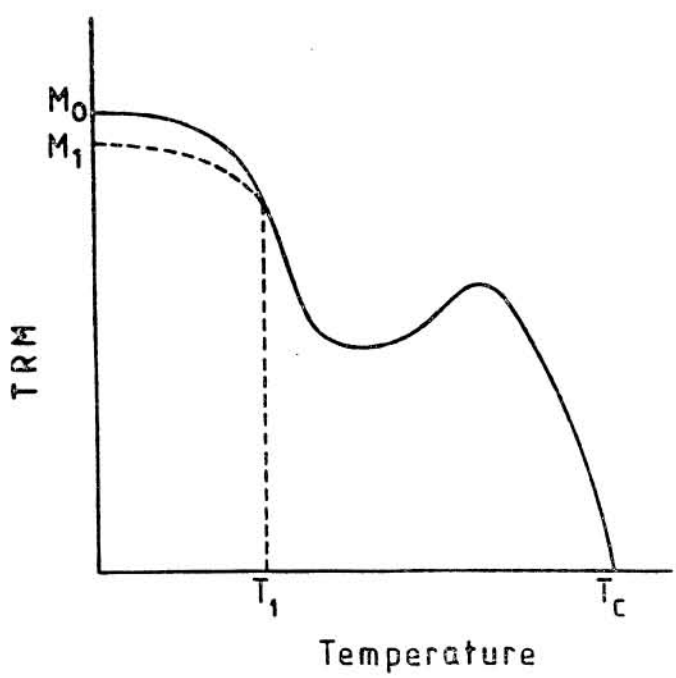
FURTHER ASPECTS OF LUNAR PALAEOINTENSITY DETERMINATIONS AND THE ORIGIN OF THE ANCIENT LUNAR MAGNETIC FIELD. S.K.Chowdhary, S.K.Runcorn, D.W.Collinson and A.Stephenson. Institute of Lunar and Planetary Sciences, School of Physics, The University, Newcastle upon Tyne, NE1 7RU, England, U.K.

Determinations of the strength of the ancient lunar magnetic field by the Thellier-Thellier (T-T) method have been plagued by problems. The major difficulties are high temperature oxidation of the magnetic carriers (iron or dilute nickel-iron grains) and an apparent magnetostatic interaction effect between iron and troilite (1). The latter is characterised by a sharp fall in the acquisition of laboratory PTRM at about 300°C followed by a rise with increasing temperature. The exact mechanism of the effect is unclear.

A crucial test for the presence of an interaction, rather than physico-chemical changes, comes from experiments on samples 10072,152 and 12018,224. These samples displayed the characteristic interaction peak in a T-T experiment but a second T-T experiment was then performed after giving the saples a TRM in a known laboratory field (equal to the field used in the T-T experiment).

In theory, the first cooling from the Curie point would give a remanence which, if continuously monitored as the temperature fell, might vary in some non-uniform way as schematically illustrated in fig. 1. M_0 is the room temperature TRM observed after cooling in the laboratory field from the Curie point. In the subsequent PTRM determination and comparison with the TRM lost, the first heating to a temperature T_1 and cooling in zero field would result in a remanence M_1 as shown, measured at room temperature. Thus the TRM lost is $(M_0 - M_1)$. The second heating to T_1 and cooling in a laboratory field should, however, always result in the room temperature remanence, M_0, being restored, irrespective of the temperature of heating, provided of course that there is no chemical change. Thus the PTRM gained is also equal to $(M_0 - M_1)$ and the laboratory field can be recovered from the second laboratory heating results even if there are interactions.



The room temperature remanence, M_0, plotted against the temperature of heating in the second laboratory experiment for samples 10072,153 and 12018,224 show that M_0 is far from constant and thus it is difficult to see how any interaction model can explain these results. It is equally difficult, however, to postulate a mechanism involving chemical changes as the PTRM not only decreases but subsequently increases as the temperature is raised. Moreover the change seems to be reversible since the effects are largely reproducible on subsequent heating. It is as if the magnetic carriers recover in some way and this suggests more than one simple chemical reaction, e.g. oxidation followed by reduction of the iron grains.

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T-T experiments have also been carried out on basalts from Disko Island (on the West coast of Greenland). Although these rocks are very glassy and probably have a whole-rock chemistry different to the lunar samples, the native iron is in the form of kamacite (low nickel) and is surrounded by troilite in many samples, similar to the situation in lunar samples. The results indicate that the interaction effect is also present in these rocks.

Whatever the true mechanism the effect does not occur in synthetic samples containing pure iron grains or unassociated iron and troilite grains. This reinforces the view that researchers should select rocks with high Fe^{o}/FeS ratios for further investigations of lunar palaeointensities; the number of such rocks, however, appears to be small.

The analysis of lunar palaeomagnetic directions, obtained by Coleman, Russell & Hood from the Apollo 15 and 16 subsatellite magnetometer surveys, is another approach for studying the primeval lunar magnetic field. From these satellite heights the magnetic anomalies observed are not from the maria lavas but from the ejecta sheets from the great impacts in which reduction of silicates apparently occurs producing iron grains and therefore magnetization intensities much greater than in the basalts. This explains the puzzling feature of the various magnetic surveys that they do not correlate with the main visible geological features.

To test the dipole hypothesis, N pole positions are calculated from the palaeomagnetic direction and they were observed (2) to fall into bipolar groups defining 3 axes (different from the present axis of rotation of the Moon). The hydromagnetic dynamo would have generated, because of the dominance of the Coriolis force, a dipole along the axis of rotation: thus the observations require the Moon to have reoriented at least 3 times with respect to its rotation axis.

The pole clusters are dated at Pre-Nectarian (4.2 by), Lower Nectarian (4.0 by) and Upper Nectarian-Lower Imbrian (3.85 by) and the multi-ring basins of these ages lie near to the palaeoequators of corresponding age and the use of the Bingham distributions shows this is highly significant. Thus it has been concluded that the Moon had at least 3 large satellites and as each was drawn in by tidal friction broke up just inside the Roche limit and a group of impacts occurred before the Moon reorientated. These conclusions are supported observationally by the direction in which the incoming bodies were travelling from the basin asymmetries as analysed by Wilhelms (to be published 1986). It has been shown that the successive movements of the pole (calculated as the mean of the palaeomagnetic poles) are in good accord with Euler's theory of the rotation of solid bodies, taking account of solid state creep (3). The concordance of the palaeomagnetic analysis and mechanics provides the strongest support for the lunar magnetic dipole hypothesis and in fact the palaeomagnetic angles of inclination plotted against angular distance to the pole fit the dipole relation well (4). These arguments are now the strongest evidence for the existence of a lunar iron core.

References:

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