THE DETERMINATION OF LUNAR MAGNETIC FIELD PALAEOINTENSITIES,

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The existence of an ancient field in which the lunar rocks cooled is now well-established because of the hard components of magnetization found in many of the lunar samples. One of the major objectives of lunar magnetic studies is the determination of the intensity of the field and this is now currently under investigation.

The standard method of determining palaeointensities is by the Thellier method by which the natural remanent magnetization (NRM) lost during thermal demagnetization from temperature T_1 to T_2 is compared with the partial thermo-remanent magnetization (PTRM) induced in a known field between the same temperatures. This method is not however always successful because of chemical changes which can occur when the samples are heated. An alternative method not involving heating is to use anhysteretic remanent magnetization (ARM).

The method used on the lunar samples involves the determination of the alternating field demagnetization curve of the NRM and the acquisition of ARM in a fixed direct field as a function of peak alternating field. This direct field was produced by 4 coplanar magnets giving a field of 1.8 Oe and this was constant to within a few percent over a volume of 1 cm^3 which was large enough to enclose the sample. The relationship of TRM to ARM may be expressed by the relation $\frac{1}{h_T}\frac{\partial I_T}{\partial H} = f'\frac{1}{h_A}\frac{\partial I_A}{\partial H}$

where h_T and h_A are the direct fields involved in producing TRM I_T and ARM I_A respectively. H is the peak value of the alternating field used to demagnetize the samples. f' is a constant greater than unity which has to be determined experimentally.

f' was determined by comparing the AF demagnetization curves of samples which had been given a TRM in a known field, with the acquisition of ARM. A plot of TRM lost against ARM gained then gave a slope from which f' could be evaluated. For a synthetic sample containing iron grains (ex carbonyl), f' was 1.28 and for a lunar basalt sample 10050,33, f' was 1.40. A mean value of 1.34 was therefore used in the calculations.

A test of the method was used on 62235,53 (basalt) on which the Thellier method had been used (1) and which gave a value of 1.2 Oe for the field. The ARM result is shown in fig. 1 where the inset diagram gives a slope corresponding to an ancient field of 1.4 Oe and is thus in good agreement with the Thellier method. The non-linearity below 60 Oe is probably explained by partial demagnetization of the NRM by solar heating of the sample on the lunar surface and this is consistent with the constant direction obtained.

An anorthosite sample (60015,49) had an extremely weak NRM (1.04×10^{-6} G cm^3 g^{-1}) and could only be demagnetized up to 90 Oe at which point the measurement errors became too large for further readings. However, the NRN-ARM plot (fig. 2) shows linearity through the origin showing that no demagnetization has taken place at the lunar surface and that there are no secondary components. There were no direction changes on demagnetization which is also consistent with this interpretation. The ancient field

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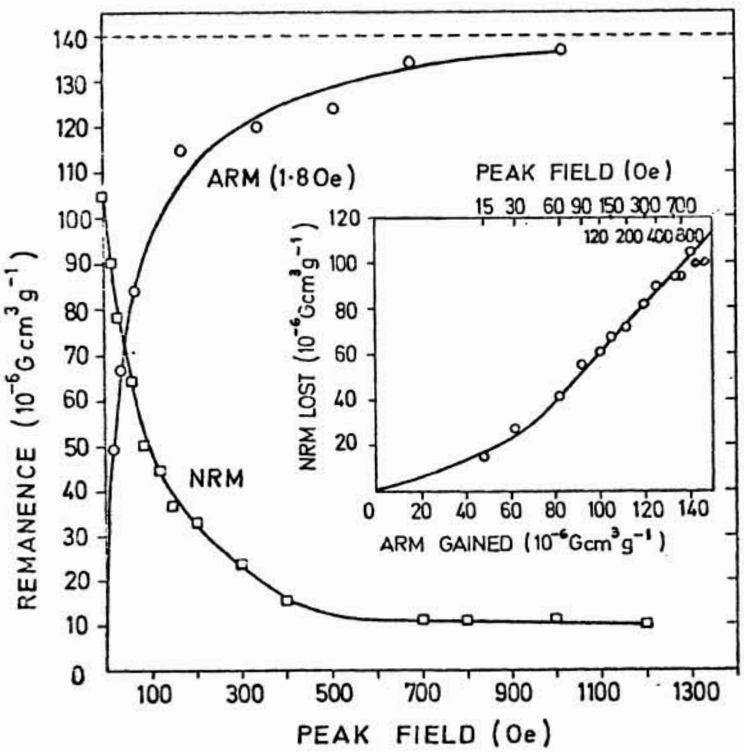

Fig. 1 Field determination on basalt sample 62235, 53 (1.4 Oe).

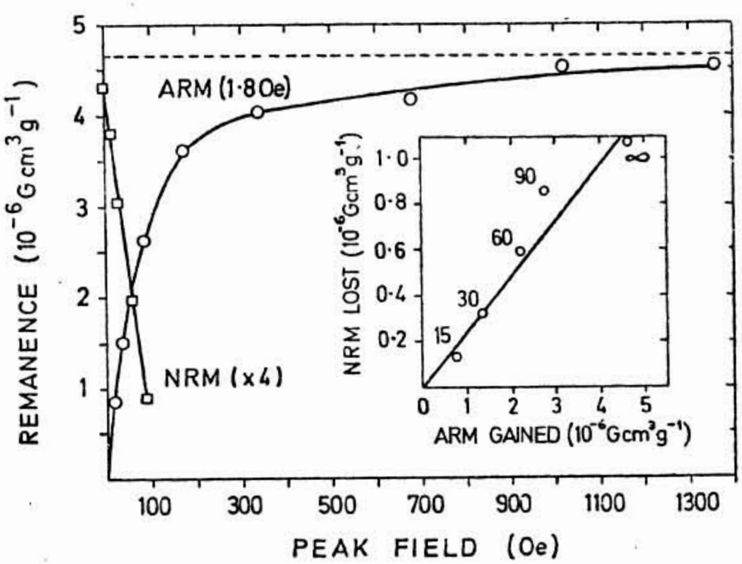

Fig. 2 Field determination on anorthosite sample 60015, 49 (0.33 Oe). Figures courtesy *Nature*.

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determined from fig. 2 is 0.33 Oe.

Other Apollo 16 samples investigated were 68416,23 (gabbroic anorthosite) and 66055,10 (breccia). The former sample yielded a complex curve and from the direction changes which took place on demagnetization clearly contained several components, the hardest of which was isolated above a demagnetizing field of about 150 Oe where the direction remained constant and where the NRM-ARM plot yielded a slope corresponding to a field of about 1.2 Oe. The latter sample yielded a field value of about 0.13 Oe but this must be regarded with caution since large direction changes occurred.

Apollo 11 samples 10050,33 and 10057,7 showed evidence of secondary components both from the NRM-ARM plot and also from the direction changes of the demagnetization curves of the NRM. The field values determined from the curves were 0.38 and 0.14 Oe respectively.

Dated samples are 60015,49 (2) which gave a well determined field of 0.33 Oe and 10057 (3) which gave a field of 0.14 Oe. The crystallization ages for these two samples are 3.58 and 3.63 x 10^9 years respectively.

It is not yet possible to decide whether the variations in field, have occurred smoothly or more randomly. A surface field of the same order as that of the earth's would mean that if a lunar core were responsible it would have a higher moment per unit volume than the earth's core by a factor of more than 15 if its radius were less than 1/5th the radius of the moon. Permanent magnetism of the moon however (4) would require an average lunar magnetization higher than typical values of the saturated remanent magnetization of lunar basalts. More information regarding the time variation of the field is clearly required before the mechanism responsible can be positively identified from these and other possibilities.

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