THE DETERMINATION OF LUNAR MAGNETIC FIELD PALEOINTENSITIES,
A. Stephenson and D. W. Collinson, Department of Geophysics & Planetary Physics,
School of Physics, The University of Newcastle upon Tyne, England.

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
\[
\frac{\Delta M_r}{\Delta H} = f' \frac{\Delta M_A}{\Delta H}
\]
where \( h_r \) and \( h_A \) are the direct fields involved in producing TRM and ARM,
respectively. \( H \) is the peak value of the alternating field used to de-
magnetize 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 corres-
dponding 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 anorthosode sample (60015,49) had an extremely weak NRM
\((1.04 \times 10^{-6} \text{ G cm}^2 \text{ g}^{-1})\) and could only be demagnetized up to 90 Oe at which
point the measurement errors became too large for further readings. However,
the NRM-ARM plot (fig. 2) shows linearity through the origin showing that no
demagnetization had 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

© Lunar and Planetary Institute • Provided by the NASA Astrophysics Data System
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.
LUNAR MAGNETIC FIELD PALAEOINTENSITIES

Stephenson A. et al.

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.

REFERENCES


