MAGNETIC PROPERTIES OF LUNAR ROCKS AND FINES.
S.K. Runcorn, D.W. Collinson, W.O'Reilly and A. Stephenson,
Department of Geophysics and Planetary Physics, School of
Physics, The University, Newcastle upon Tyne, England.

1. Remanent Magnetism. This has been investigated in one
sample of crystalline rock and several samples of the
fragmental material (Apollo 14) and a further sample of Apollo
11 crystalline rock. Intensity of NRM is in the range 2.0 -
220 \times 10^{-4} \text{ emu/g}, the highest value being observed in the
crystalline sample 14053,35.

Alternating field demagnetization of the NRM reveals
an apparently complicated history of magnetization, with two
components present, and possibly more. All samples show a rapid
initial decay of NRM in fields of up to 75 Oe (with the
exception of 10020,4F, which was highly stable) and changes of
direction of several tens of degrees. Higher fields indicate
the presence of a harder component both through a change of
slope in the intensity curve and a more persistent direction
of NRM. In 14053,35 and a fragmental sample (14305,56) a rise
of intensity occurs around 150 Oe, followed by a region of
low and variable intensity but essentially constant direction up
to peak fields of 500 Oe. The intensity of the harder component
in the four samples tested is \(1 - 5 \times 10^{-4} \text{ emu/g}\). The NRM of
14053,49 during thermal demagnetization shows a steady decrease
up to 800°C, which suggests that the hard component is carried
by iron; the heating was done in a vacuum of \(10^{-5}\) torr, and no
oxidation was detected.

Growth of viscous magnetization has been measured in
several samples and is significant in all of them; 14053,35
shows the most rapid growth (\(s = 3.0 \times 10^{-4} \text{ emu/g/Oe}\)), but in
no sample can the observed NRM be attributed to a VRM acquired
in any reasonable time and field on the moon. Rather low fields
are required to give the samples an isothermal remanence equal
to their NRM, varying from 7 to 22 Oe; however, the stability
of this IRM to both thermal and A.F. demagnetization is
significantly less than that shown by the NRM of the rocks.
Some samples easily acquire a 'shock' magnetization in a weak
field (\(< 1 \text{ Oe}\)); very moderate mechanical shocking of 14053,35
produces a magnetization of about \(10^{-4} \text{ emu/g}\) along the ambient
field direction.

All samples tested show that magnetic particles are
present which are capable of carrying a hard magnetization,
by demagnetization of the saturated IRM.
The properties of single magnetic particles extracted from both fragmental and crystalline rock have been examined, using a new small-scale magnetometer. Two groups of particles are distinguishable in 14053, 35, both of which have high susceptibility averaging about $4 \times 10^{-5}$ and $3 \times 10^{-5}$ emu/g/0e; only the latter group appear to possess any NRM (typically 0.1 emu/g) which, in the particles measured, is very soft and can be removed in less than 100 Oe. Saturation IRM of this group averages 1.5 emu/g and is acquired in 500 Oe or less. The particles are not generally homogeneous and are not easy to identify. They do, however, rust in a moist atmosphere, and this feature, combined with their strong magnetic properties, is evidence that they consist at least partly of native iron. This work is proceeding, but it now seems probable that the hard and soft component of NRM is carried by iron in this rock.

2. Rock Magnetism. The Apollo 14 fines have properties very similar to those returned from previous missions. A single Curie point of 775°C is observed, an initial susceptibility of $3.0 \times 10^{-5}$ emu/g/0e, and the magnitude of induced and isothermal remanent magnetization and saturating field again indicate the presence of a range of fine-grained iron particles which contribute the magnetic properties.

The Apollo 14 rock samples have initial susceptibilities in the range 120 - 650 x $10^{-5}$ emu/g/0e, the highest value being in the crystalline sample; all the values are considerably higher than in the Apollo 11 and 12 rocks. 14053, 35 is remarkable in having rock magnetic properties comparable with the fines, which is presumably due to its possessing a similar range of fine-grained iron. The Curie temperatures of all samples so far measured indicate native iron to be the most important magnetic mineral present.

Electron microprobe analysis is being carried out on a selection of the 'metallic' grains present in the rocks to establish any correlation between composition and magnetic properties. The analysis of 9 such grains from 14306, 63 shows that they are homogeneous and predominantly of iron, with nickel content of 1 - 18%.

Low Temperature measurements. Some rock chips have been cooled to -196°C in zero field to observe any changes in NRM. Sample 10049, 1 (crystalline) showed a reversible increase by a factor of 2.7, whereas 14053, 35 showed an irreversible decrease to about 50% of the original NRM. A similar result occurred when the saturated IRM acquired at room temperature was cooled in zero field to -196°C. The decrease produced by this treatment was 6%, but on warming to room temperature a further decrease of 6% was observed. This behaviour was also seen in 14318, 38 and is tentatively ascribed to
irreversible domain wall movement, presumably in multi-
domain iron grains.

The TRM acquired on cooling to $-196^\circ$C in a field
of 1.2 Oe has been investigated in 14053,35 and 14318,38. The
TRM in the former showed a sharp decrease at about $-150^\circ$C
during re-warming to room temperature, almost certainly
indicating the presence of ulvöspinel; the fragmental sample
(14318,38) showed a much weaker TRM, with no discontinuity on
warming, suggesting a much smaller quantity, or absence of
ulvöspinel. The behaviour of saturated IRm between $-196^\circ$C
and $20^\circ$C shows the absence of detectable amounts of magnetite
in these rocks.

3. Discussion. Native iron, with or without small
amounts of nickel, is confirmed as the dominant magnetic
mineral in lunar rocks, and it appears to carry the NRM.

A great variability of stability of the NRM of the
rocks has become increasingly apparent, but several samples
do possess a component of remanent magnetization which is
stable in the range 300 - 500 Oe and of $1 - 5 \times 10^{-6}$ emu/g
in intensity. Thermal demagnetization of the NRM and A.F.
demagnetization of laboratory-produced TRM is consistent
with the origin of the hard component being thermoremanent
acquired in a weak field on the moon.

The additional soft component which is usually
present may be attributed to one or more of several processes.
In the rocks examined, its direction is within the same octant
as that of the hard component, which may have some significance;
a puzzling feature is the decay of the NRM on moderate
heating ($\sim 150^\circ$C), since this component would be expected to
be eliminated by thermal cycling on the moon. Although it
seems unlikely, it is perhaps necessary to consider a soft
component of NRM being acquired by the rocks during or after
their return to Earth, in addition to a lunar origin.

In the absence of knowledge about the effects of
such lunar features as prolonged thermal cycling, radiation,
and meteoritic shocks, the evidence from the Apollo 14 rocks
is that they possess a weak, stable NRM with properties
suggesting a thermoremanent origin in a weak field of
probably less than 0.1 Oe. They subsequently acquired a
substantial component of soft magnetization, for which the
most likely origin seems to be a shock or isothermal remanent
process associated with meteoritic impact(s) which distrib-
uted the rocks over the lunar surface.