ON THE INTENSITY OF ANCIENT LUNAR MAGNETIC FIELDS, S.M. Cisowski, M. Fuller, and C. Hale, Dept. of Geological Sciences, UCSB, Santa Barbara, California 93106.

Despite the efforts of the various magnetism groups, there is still little agreement on the nature of the magnetic fields in which the lunar samples were magnetized, nor indeed upon the roles of different mechanisms of magnetization. There is however some agreement that fields of between 1000\(\gamma\) and 1 oe have been recorded by the samples. The significance of such magnetic fields early in the history of the moon and of the solar system is considerable, so that it is important to refine these estimates and determine the nature of the fields.

The absence of oriented bedrock samples from the moon makes the problem of understanding lunar paleomagnetism much harder than it might otherwise be because the possibility of internal consistency tests for individual rock units is lost. Moreover the process of formation of the regolith from which the samples are collected may generate magnetic contamination. The Thellier-Thellier intensity determination technique is therefore of great potential importance because it reveals in an ideal case that the sample carries thermo-remanent, in addition to giving the estimate of field intensity. A major part of our recent experimental work has been aimed at the development of a microwave heating technique so that the necessary heating for the Thellier-Thellier method can be carried out without bringing about the irreversible changes generated by conventional heating of lunar samples.

Microwave induction heating seems initially promising because the \(I^2R\) losses are predominantly in the highly conducting metallic iron and iron nickel particles which carry the lunar magnetism. Thus the magnetic carriers are heated while their chemical environment is minimally disturbed. Moreover, other iron bearing minerals, such as ilmenite and troilite, are less severely heated because of their lower conductivity and are less likely to generate new iron by reduction (1). Preliminary experiments have been carried out with a commercial microwave oven providing 650 watts to a 33 liter cavity at 2.45x10^9 Hz. They have revealed that in synthetic lunar analogues the bulk heating is dependent upon the concentration of metallic iron and that it is also grain size dependent. A lunar sample carrying saturation isothermal remanent magnetization (IRM\(_s\)) was demagnetized to 10% of its original magnetization by a 210 secs. exposure. We have modified the commercial oven, adding a waveguide, so that the samples can be heated and cooled away from the magnetically noisy environment of the oven, in field controlled space. In this way we plan to carry out a Thellier-Thellier type of progressive heating experiment.

In the absence of definitive identification of the mechanisms of magnetization of lunar samples, the determination of magnetic intensity becomes in part a petrological problem because one needs petrological control on the nature and history of the origin and history of the samples. In principle analysis of the NRM of rock samples can help solve petrological problems by showing whether or not samples have been heated to their Curie points. However the type of evidence which has been used in such studies, with terrestrial rocks, is simply not available in the lunar case, so that such applica-
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...tions must be viewed with caution. For example, schemes of breccia origin which assume all breccias were heated above their Curie point at the time of their formation because they carry stable remanence (2) are extremely misleading and neglect other possible mechanisms of lithification besides sintering. It is therefore important to establish the nature of the magnetization carried by the various lunar rock types both to carry out intensity work and to clarify the origin of rock types.

Our experimental studies have demonstrated that impact related shock can generate agglutinate like particles and soil breccia analogues, which carry primary natural remanent magnetization due to impact related phenomena. They have also demonstrated that the primary remanence of solid rock samples can be modified by shock in a manner which is dependent upon the magnetic hardness of the rock and the level of shock. The magnetism of soil breccias and agglutinates may therefore not be a simple thermo-remanent magnetization and should not be used directly for intensity determinations. Moreover, it is also clear that even the magnetization of crystalline rocks and high temperature breccias must be examined carefully to detect shock demagnetization before it can be assumed to give reliable field estimates.

To help unravel the field intensities implied by lunar magnetism, we have studied the magnetism of samples from a variety of terrestrial impact craters. At Lonar Crater in India impactite glass, high and low temperature breccias and basalts showing a variety of shock effects are found. The magnetic response of the Lonar basalts to shock is controlled by their magnetic hardness, the extreme variation of which is due to the presence or absence of exsolution lamellae in the titanomagnetite grains. We have been able to simulate the NRM of these basalts by exposing samples carrying stable remanence to a variety of shock levels from 10 to 20 kbs. The magnetic characteristics of the breccias can be used to place limits on the temperatures to which they have been exposed. Similar studies have been conducted with samples from Meteor Crater. In both these cases the magnetic studies have been able to utilize control petrological studies which indicate the levels of shock experienced by the samples (3).

In our experimental studies we have not found convincing evidence for the types of zero field magnetization processes which have been reported or suggested by others (4,5) and we suspect that though these effects may be real they are small. The predominant effects of shock appear to be, to magnetize in the presence of a field, and to demagnetize in the absence of a field. The magnetic effects depend then upon the ambient field, the level of shock, the mechanical and magnetic hardness of the material and the remanence it carries. It is possible to make crude estimates of the field during soil breccia formation, which seems to be of the order of \(10^3\) or \(10^4\) y. It may eventually be possible to take account of shock demagnetization of the primary remanence of crystalline rocks by an independent estimate of shock.

It is our conclusion that we are coming close to the point where we may be able to see through the effects of shock to obtain improved estimates of the ancient field intensities in which the lunar samples acquired their NRM. If this does prove feasible then it will also be possible to make more realistic tests of the various models proposed for these fields.

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