IMPACT PROCESSES AND THEIR EFFECT ON LUNAR MAGNETISM; S. Cisowski and M. Fuller, Dept. Earth and Planetary Sci., Univ. Pittsburgh, Pittsburgh, Pa., M. F. Rose, Naval Weapons Lab., Dahlgren, Va., and P. J. Wasilewski, The George Washington Univ., Washington, D.C.

The natural remanent magnetization (NRM) of a particular lunar sample is predominantly controlled by three factors; the magnetic characteristics of the carriers of NRM, the mechanism of magnetization and the ambient field in which the magnetization was acquired. Each of these three factors may in certain instances be affected by impact processes. We have undertaken a variety of experimental studies to assess the probable importance of the effect of shock upon the magnetic characteristics of the carriers of lunar NRM and to calibrate field and shock level dependence of the shock remanent magnetization (SRM).

In order to characterize the magnetic carriers of remanence in lunar samples, we have relied primarily upon their saturation magnetization (J_s), saturation remanent magnetization (IRM_s), initial susceptibility (χ_0), coercive force (H_c) and remanent coercivity (H_{RC}). In particular we have found that plots of IRM_s/J_s against χ_0/J_s reveal a progressive increase of grain size of the ferromagnetic iron from that in the soils and unannealed breccias, through annealed breccias to that in igneous rocks. Thus in assessing the effect of shock upon the magnetic characteristics of the ferromagnetic material, we compare shocked material with its unshocked analogue in terms of these hysteresis parameters. To describe the shock remanent magnetization (SRM) acquired in the experiment, its alternating field (AF) and thermal demagnetization characteristics have been determined.

Three types of material have been used in the study. First, artificially shocked lunar samples were used to provide the calibration of shock effects. Second, individual hand-picked soil particles, which can be compared magnetically with large samples of similar rock type have been used to obtain an estimate of the magnetic effects of the comminution process. Third, samples from the LONAR impact crater have been used to provide naturally shocked and control basaltic material.

1. Artificial Shock Experiments. In earlier experiments soil samples were shocked to 50, 75, 100 and 250 kb using a modified flying plate technique and the magnetic characteristics of the samples were found to be markedly changed. In the 50, 75 and 100 kb samples the coercive force (H_c) and saturation remanence (IRM_s) increased substantially. In the 250 kb sample these parameters did not change but additional fine iron was produced. These experiments were carried out in the earth's field and remanence of 10^{-3} to 10^{-4}gauss cm^3g^{-1} was generated. This remanence exhibited alternating field (AF stability) similar to partial thermal remanence (pTRM). The shock remanence (SRM) however had more distributed blocking temperatures, suggesting inhomogeneous heating.

Powdered samples prepared from 12053, have now been subjected to 75 kb shock. A spectacular increase in saturation remanence and remanent coercivity was observed when these parameters were compared with those of the starting material. The remanent magnetization acquired is relatively soft and hence unlike that of the pTRM-like shock remanence acquired by the soil. It may be

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distinctive of an isothermal type of shock remanence. The characteristics exhibited by the powdered rock are not unlike those of a number of lunar samples. The simplest explanation of the difference between the shock remanence of the soil and that of the powdered rock is related to the presence in the former only of near superparamagnetic iron with low blocking temperatures. Thus, it alone acquires pTRM in the low temperatures to which the samples are heated in the shock experiment. These experiments are being continued with solid rock samples. With the use of an air gun they will be extended to calibrate field and stress dependence of shock remanence in the low stress, low field region.

2. Hand-picked Soil Particles (10086,30). The study of individual soil particles permits a direct observation of the magnetic effects of the comminution process or by comparison of igneous soil particles with their parent type. It also makes available such interesting particles as glassy agglutenets and orange soil glasses for magnetic studies. Individual fine basalt, coarse basalt, breccia, microbreccia, and glassy agglutinate particles varying in mass from .0001 to .003g were separated by Dr. G. Eglinton and were studied in our laboratory. Critical magnetic characteristics were observed and the NRM of individual particles studied. All particles exhibited strong saturation isothermal remanence and high remanent coercivity (H_{RC} varied from 350 to 900 oe). Even igneous fragments exhibited remanent coercivities as high as 700 oe which is far greater than those of the parent rock type. All particles carried NRM. The intensity varied from 10^{-3} to 10^{-6}gauss cm^3g^{-1}. The AF stability of NRM was very variable with one microbreccia almost untouched by demagnetization to 900 oe, while other samples decreased sharply in low fields of 100 oe, so that demagnetization had to be terminated. Although complete thermal demagnetization remains to be carried out, it is already clear that the remanence is not entirely a low temperature pTRM. It therefore appears that the process of comminution which gives rise to soil profoundly alters the characteristics of the carriers of NRM in the individual particles. It is possible that the process actually generates magnetization since the NRM of igneous fragments in the soil appears to be large compared with those of equivalent igneous rock samples. Such remanence would add another lunar magnetic puzzle, since unless it was generated during the early history of the moon, the origin of the necessary magnetic field is obscure.

3. Lonar Samples. Lonar crater is in the Buldana District of Maharashtra India in the Deccan traps. It is 1800m across and 150m deep. Samples have been obtained from the crater rim basalts, from drill holes within the crater and from trenches cut in ejecta material within 100m of the crater rim. Many of the samples were obtained for us by Dr. J. Fredriksson. The majority of the rim basalts studied carry stable NRM which appears to be the primary NRM of the lava and unaffected by the impact. They serve as control samples. In contrast, a basalt from the drill hole exhibited soft NRM similar to the isothermal-like shock remanence carried by the powdered lunar sample 12053,35. A breccia from the drill hole had a low intensity of NRM which was unstable in direction. Glass from the ejecta exhibited strong and stable NRM. The NRM of the basalts from the trench in the ejecta had rather low NRM compared with the control basalts, although some carried NRM indistinguishable from

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that of the control samples. The ejecta from this crater carries a wide variety of NRM; some samples such as the glass have NRM which is clearly due to the impact, but the NRM of some basalts is apparently unaffected by the impact. The directions of magnetization within the ejecta are not coherent, but vary from sample to sample. Work is continuing to assess the effect of shock upon the characteristics of the carriers of NRM in these rocks. At this point it is clear that a variety of rocks are available at this site which may throw light on lunar impact processes. An important preliminary indication is that the ejecta material is not coherently magnetized, so that individual large fragments carry a record of earlier history and the ejecta does not give rise to a substantial magnetic anomaly.

These studies reveal that impact related shock can have a profound effect on the magnetic characteristics of carriers of NRM and that in some instances it can generate NRM. In the lunar samples, the major effect appears to be an increased capability to carry remanence and hardening of the carriers. The increase of remanent coercivity of the 12053,35 powder on shocking to 75 kb was particularly remarkable, as was the magnitude of SRM it acquired. The AF demagnetization of the SRM of the sample is similar to that of a number of lunar samples. Individual soil particles exhibit magnetic characteristics which suggest that the process of comminution involves similar effects to those of the experimental shock. For example, the remanent coercivity (H_{RC}) and saturation remanence (IRM_s) of igneous fragments in the soil is large compared with those of the parent rock types. These samples also appear to have anomalously large NRM. The samples from Lonar crater gave evidence of the softer isothermal type of shock remanence in basalts. Ejecta shows very variable NRM in individual large fragments and is not coherently magnetized. These results suggest that the role of shock in determining the magnetic characteristics and indeed the NRM of certain lunar samples may have been seriously underestimated in the past.

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