ON THE INTERPRETATION OF THE NRM OF LUNAR SAMPLES. S.M. Cisowski, M. Fuller and Yeeming Wu, Dept. Geological Sciences, UCSB, Calif. 93106, M. F. Rose, Naval Weapons Lab., Dahlgren, Va. 22448, and P. J. Wasilewski, NASA, Goddard Space Flight Centre, Greenbelt, Md. 20771.

The continued aim of our work in the past year has been to clarify the origin of the lunar NRM, so that reliable estimates of the intensity of the fields in which the NRM was acquired can be made. A major part of our work has been concerned with establishing the effects of impact related shock upon NRM of lunar samples. We consider that these effects are critical to any understanding of lunar NRM. The effects can be conveniently divided into two categories depending upon whether the NRM is essentially due to a primary shock associated remanence, or whether the shock effects are giving rise to secondary magnetization or demagnetization which modifies a primary NRM. The shock lithified soil like breccias (1,2) afford examples of rocks which probably carry a primary shock associated NRM. Almost all samples collected have experienced some shock history so that their NRM will tend to be modified. It is with this second aspect of shock which our work is now principally concerned.

To study the effects of shock upon the magnetism of rocks requires different techniques from those used in the powder experiments, because shocking rock foils to the levels in which we are interested destroys the samples. We have therefore used impacts of projectiles into the rocks of interest as an experimental approach. We were able to obtain samples from blocks of rock into which artillery shells had been fired. Cores were drilled from the centre of the impact crater and at several distances away from the crater. AF and thermal demagnetization was carried out and the samples characterized by their hysteresis properties. The AF demagnetization curves for all samples taken from a block of diorite were all similar and highly stable in direction and magnitude. Thus the shock appeared to have had little effect on these samples, although the NRM was noticeably harder than a thermo-remanent magnetization given to the sample in the laboratory and may have been shock hardened. The remanent coercivity of this sample was approximately 450 oe - the sample is magnetically hard. In contrast to the behaviour of the diorite, the remanence of a magnetically softer granite was clearly strongly affected by the shock. The samples furthest from the crater exhibit hard and stable NRM similar to a laboratory TRM, while those nearer to the impact point display progressively greater instability in direction and magnitude. Upon demagnetization the directions of the unstable samples migrate towards that of the stable

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samples, which probably represents the primary NRM direction of the sample. The directional changes appear to be due to the demagnetization of a soft shock remanent magnetization acquired at the time of impact. Thermal demagnetization of a sample from near the impact point also revealed a gradual migration of the direction of NRM towards that of the stable samples. Measurements of saturation isothermal remanent magnetization (J_r) along the three orthogonal directions of the various granitic samples revealed an apparent decrease of J_r approximately parallel to the wave front resulting in a shock induced anisotropy of up to approximately 10%. No such anisotropy was seen in the diorite samples. These two samples reveal very different response to shocks which were probably of comparable strength to order of magnitude. It seems that the remanence of the diorite was virtually unaffected, or possibly weakly shock hardened, but the magnetism of the softer granite was profoundly affected.

In addition to the experiments described in the previous paragraph, we have also studied naturally shocked material from the Lonar crater as a means of establishing the effects of shock upon the NRM of rocks. In these samples, there is a marked correlation between low field instability in direction and intensity upon AF demagnetization, and low remanent coercivity. In this instance the rock types are all similar, being tholeitic flood basalts, but the presence of ilmenite exsolution from the titanomagnetites brings about an increase of coercivity from 125 oe to as much as 550 oe. It appears that these samples afford a natural example of the variation in shock response being determined by the hysteresis properties of the ferromagnetic carriers.

The returned lunar soil exhibits a great variety in the shock levels to which the individual particles have been subjected. There are fragile glass spheres and agglutinates which are unlikely to have sustained strong shock, and basalt fragments which were shocked so strongly that comminution to a rock powder ensued. By measuring the NRM of individual soil particles one can take advantage of this range of shock levels to attempt to assess the effects of shock. To investigate the NRM of material which is relatively unshocked and hence should therefore carry a primary remanence, we have studied glass spheres from the orange soil and glass splatter. If the NRM after 100 oe demagnetization is normalized by the saturation isothermal remanence, one finds inducing fields of the range 0.1 to 0.5 oe for the glass spheres. Although one should be cautious in asserting that these fields are very accurate, the results from about ten samples are all consistent which suggests that the magnetization was probably acquired in fields of the order of 10^{-1} oe. In marked contrast the NRM of glass splatter from 64435,29 when normalized in the same manner gives an estimate of

order $10^2\gamma$. The glass splatter result implies one of the weakest inducing fields for NRM, which we have encountered. However, this glass is extremely young and the estimate of the inducing field is comparable with the present fields at the Apollo 16 site. In addition to the NRM of the glass spheres from the soil and the splatter from 64435,29, we have also determined the NRM of many rock fragments from the soil. In general, their normalized NRM implies fields smaller than that of the glass spheres, but the majority are of the order of $10^3\gamma$.

We conclude from this work that some of the observed variation in lunar NRM and the inducing fields which the NRM implies may be due to varying degrees of shock demagnetization of primary NRM. It appears that the orange soil spheres were probably magnetized in a field of at least some tenths of an oersted. The NRM of rock samples of intermediate remanent coercivity, such as the Mare basalts, is probably shock demagnetized to varying degrees depending upon the shock experienced by the rock and the coercivity of the samples. It therefore appears that impact related shock not only affects NRM by generating primary remanence in shock lithified breccias, but may also account for some of the variation of NRM in rocks carrying primary NRM of thermal origin.

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