AN ACCEPTABILITY CRITERION OF LUNAR SAMPLES FOR PALEOINTENSITY DETERMINATION. K. Hoffman, S. K. Banerjee and J. P. Mellema, Department of Geology and Geophysics, University of Minnesota, Minneapolis, Minnesota 55455.

A significant physical constraint to models of lunar origin and evolution-and, therefore, to the present internal structure--is the time-variation of magnetic paleointensity as obtained from magnetic measurements of lunar samples. It is now clear that not all samples are suitable for this kind of experiment. We intend to show that a new, additional criterion should be employed for acceptability of lunar samples.

A phenomenon commonly encountered when demagnetizing lunar rocks by the alternating field (AF) method is that the resulting natural remanent magnetization (NRM) is not reproducible for a given AF peak intensity. We have previously reported (1) on sample 15535,28 (weight 6 gms.), an olivine basalt, which dramatically illustrates this problem. Specifically, we found that, upon step-wise demagnetization of the NRM of this sample, a zig-zag pattern of remanence intensities was observed with values ranging from 2×10^{-6} to 1.6×10^{-5} emu. In addition, when demagnetized with a peak AF$\leq$100 Oersteds, the magnetization vector was seen to move essentially within a plane. We have since extended our investigation of this sample. AF demagnetization, as before, was carried out in a triple μ-metal-shielded environment where the residual dc field was $\sim$10 gammas. The AF frequency was 400 Hz and was checked to be free of any dc bias or distortion.

AF demagnetization to a peak AF of 1000 Oe of a 0.1 oersted ARM shows zig-zag behavior similar to that of the original NRM. In addition, repeated demagnetizations carried out in peak AF's of 50, 300 and 900 oersted show similar fluctuations and suggest that, in fact, application of an AF to a peak value of 1000 oersteds <u>cannot demagnetize</u> this sample. An earlier attempt to thermally demagnetize the sample was carried out on the original NRM. Although little change in the NRM was observed after cooling from 50°, 75° and 100°C, approximately a 75% increase in the intensity was seen upon cooling from 125°C. The moment remained in the "preferred plane".

The normalized AF demagnetization curve for a saturation (16 K Oe) IRM is shown in figure 1. The mean distructive field is seen to be <100 Oersteds. Although the sample was then AF demagnetized to a peak field equal to that of the saturation IRM (by spinning the sample within the pole pieces of an electromagnet while slowly decreasing the field strength to zero), some IRM remained. Repeated demagnetizations from a peak AF of 1000 Oe in the shielded AF device also failed to destroy this remanence, but certainly randomized, as well as possible, grains with coercivities $\leq$ 1000 Oersteds. From this point on only AF-demagnetization experiments to peak fields not exceeding 100 Oersteds were conducted.

For the following experiment the (1000 Oe AF demagnetized) sample was demagnetized twenty-five times along its Z-axis each time with a peak AF strength of 100 Oe and measured after each run. Zig-zag behavior was observed superposed on the residual IRM. Figure 2 shows the 25 vector orientations as seen in the XY ans ZY planes; the mean X, Y, and Z values ($\bar{X}$, $\bar{Y}$ and $\bar{Z}$) were calculated and subtracted out in order to show only the zig-zag fluctuations. These measurements were seen to be highly reproducible (to within 2 x 10^{-7} emu), hence, confirming that the zig-zag behavior is indeed solely due to the application of the AF. Best fit lines were calculated of the form $X-\bar{X} = c_1(Y-\bar{Y})$ and $Z-\bar{Z} = c_2(Y-\bar{Y})$ which minimize the sum of the absolute values of the normal distances from these lines to each point. These lines are also shown in the figure and correspond closely to the direction of the original NRM planar behavior. The sample was then demagnetized (100 Oe peak AF) once along its X-axis and once along its Y-axis. Following this procedure several demagnetizations along the Z-axis were carried out, again measuring after each run. The resulting data indicated that the average X, Y and Z values had shifted (by $\leq$ 8 x 10^{-6} emu) after the demagnetizations along the X and Y axes. Hence, applied AF's along axes orthogonal to the Z-axis "reset" the initial state of the total magnetic moment.

Viscous acquisition in 3.0 Oersteds and decay experiments were conducted on this sample and are shown in figure 3. Acquisition times (t_a) and decay times (t_d) varied from a few minutes to >1000 minutes. The value taken for the initial magnetization was that acquired after application of the 3 Oersted field for <<1 sec. The 3 Oersted IRM acquired in this manner was considerable and amounted to 5.6 x 10^{-6} emu--approximately the same value as the VRM acquired for t_a = 1140 minutes. In addition, the acquisition coefficient $S_a = dJ/d \log t_a$ and the initial decay coefficient $S_d = (dJ_{vr}/d \log t_d)_0$ are not equal; we calculate $S_a \simeq 3/2|S_d|$ indicating that some of the acquired VRM behaves as would an IRM.

The above results confirm out initial conclusion, that the zig-zag planar behavior is due to the presence of a few, large, aligned, disk-shaped multi-domain grains which carry a substantial fraction of the total remanence. Moreover, it is now clear that, for some as yet unexplained reason, these "super-grains" do not demagnetize--neither by AF demagnetization to 1000 Oersted nor by heating to lower temperatures. Their magnetic moments on the other hand, appear to rotate retaining a direction within a preferred plane.

Apart from the interest this behavior generates from the viewpoint of rock magnetism, it may interfere with the attainment of a meaningful time-variation of paleointensity. Since the most satisfactory paleointensity technique, the Thellier-Thellier method, involves the ratio of the amount of NRM lost to the amount of TRM gained in a known field after repeated heatings to various temperatures, any strong non-demagnetizable low-coercive component could quite easily make any such determiantion of little value.

Thus far, the more dramatic examples of zig-zag AF demagnetization behavior have been reported for lunar crystalline rocks (see Hargraves and Dorety, 2 and Strangway et al, 3); hence, we strongly suggest that, apart from well-behaved breccias, only crystalline rocks totally devoid of such unorthodox behavior be utilized for the purpose of paleointensity determination.

References: (1) Banerjee, S.K., Hoffman, K.A. and Mellema, J.P. (1972) Difficulties in separating the stable component of natural remanent magnetization of lunar rocks. In "The Apollo 15 Lunar Samples" pp. 420-424. The Lunar Science Institute, Houston. (2) Hargraves, R.B. and Dorety, N. (1972) Remanent magnetism in four Apollo 15 igneous rock fragments. Ibid. pp. 438-439. (3) Strangway, D.W., Pearce, G.W., Gose, W.A. and Timme, R.W. (1971) Remanent magnetization of lunar samples. Earth Planet. Sci. Lett., 13, pp. 43-52.

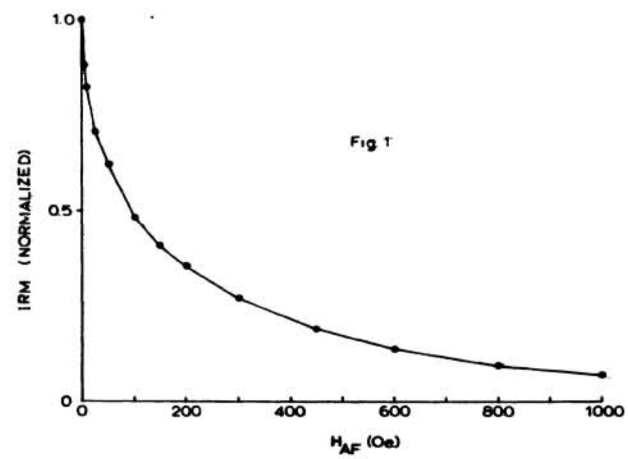

Fig. 1. AF-demagnetization curve of 16 KOe IRM.

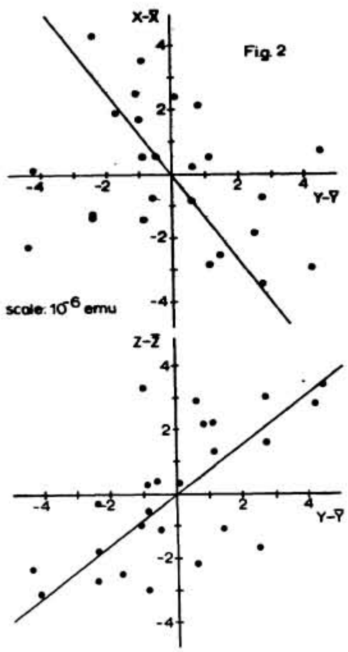

Fig. 2. Random addition of remanent magnetization in a preferred plane.

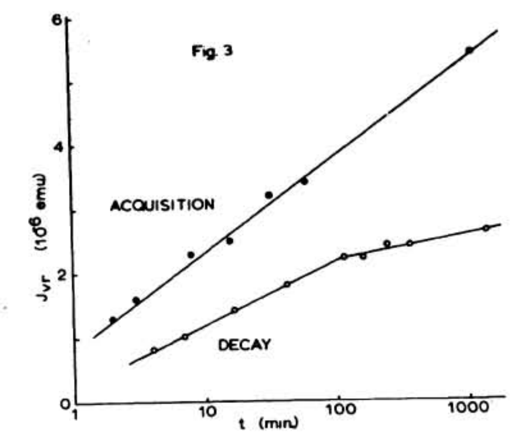

Fig. 3. Acquisition and decay of VRM in 3 Oe.