THE EFFECT OF SHOCK ON REMANENCE IN MULTI-DOMAIN IRON GRAINS AND IMPLICATIONS FOR PALAEINTENSITY MEASUREMENTS. J. Pohl and A. Eckstaller, Institut für Allgemeine und Angewandte Geophysik, Theresienstr. 41, D-8000 München 2, FRG.

Introduction. Since the first attempts to determine the intensity of the magnetic fields in which lunar rocks were magnetized, the difficulty of this task has become increasingly apparent. There are many reasons for this. One is that the nature of the natural remanent magnetization (NRM) is not definitely known, while the usual palaeointensity methods are based on the assumption that the NRM is mainly a thermoremanent magnetization (TRM). In fact the NRM may be in many cases, at least in part, of shock or combined shock-thermal origin (e.g. 1, 2). In addition to this the remanent magnetization and other magnetic properties of lunar rocks may have been modified strongly after the acquisition of a primary ARM by several processes, the bearing of which on the determination of the palaeofield is not well known. One of these processes is again the effect of shock, which has often been discussed as a possible explanation for some unusual magnetic behaviour (e.g. 1, 2, 3). In this study we report on the effect of low level shock (<15 kbar) on the determination of palaeointensities in the case of large multi-domain iron grains.

Experimental technique. The iron was in the form of 200 μm long, approximately cylindrical grains obtained by mechanically cutting 200 μm diameter iron wire. The iron grains were annealed in a hydrogen atmosphere. The mean coercive force measured after annealing was 3 Oe, the mean remanent coercive force was 380 Oe. For the shock experiments the iron grains were embedded in an alucerta cement with very low iron content. The stress waves were generated by impacting the cement samples with 3 mm thick aluminium plates, which were accelerated in a non magnetic compressed-air gun accelerator similar to that used in (4). The peak stress was estimated from the acoustic impedance of the cement and from comparisons with similar material. This gives a value of about 5 to 6 kbar for an impact velocity of 100 m/s.

Effect of shock on hysteresis properties. Saturation isothermal remanent magnetization (SIRM), coercive force ($H_C$), remanent coercive force ($H_{Cr}$) and saturation anhysteretic remanent magnetization (ARM) in weak dc fields were measured. After shocking with impact velocities >150 m/s, all these parameters had increased values, up to 30 % at 340 m/s. Below impact velocities of 150 m/s, scatter was relatively high. SIRM and ARM produced in shocked samples also showed greater stability against af-demagnetization with an increase of the median destructive force of about 50 %.

"Palaeointensity" determinations with shocked ARM and TRM using the ARM-method. ARM and TRM were produced in a known dc-field $H_0$. Then the samples were shocked and the ARM-palaeointensity method was applied to the remaining remanence "NRM", which was generally 10 to 20 % of the remanence before the shock. The laboratory field $H_1$ used for the intensity determination was equal to the primary field $H_0$. The "palaeofield" $H_p$ is determined by $H_p=H_1\cdot "NRM"/ARM$ in the case of a primary ARM, and by $H_p=H_1\cdot "NRM"/ARM\cdot f$ in the case of a primary TRM. The magnetizing efficiency factor $f=TRM/ARM$ (in the same field $H_0$) was found to be between 0.6 and 0.8 for the multi-domain grains used in the present experiments (<1, compare to 5). Figs. 1 and 2 show experimental results.

The main effects of the shocks consist in a shifting of the intensity curves to the right and more important, in a drastic diminution of the slope.
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Fig. 2. "Palaeointensity" determination from a shocked TRM.
P 43: Slope = 0.19
P 44: Slope = 0.30

Fig. 3. Palaeointensity determination from a SRM. Peak af-field steps are similar to those in Figs. 1 and 2.
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of the more or less straight part of the intensity curve normally used for the determination of the palaeofield. It can be seen that in the present case of large multi-domain iron grains and very low shock amplitudes, errors up to an order of magnitude and more for the "palaeofield" must be expected. The determined "palaeofield" is always much weaker than the primary field $H_0$.

In lunar rocks the majority of the carriers of remanence used for palaeointensity determinations is generally of much smaller grain size and effects of shock as described above may be less important, at least in the same stress range. However, the shocks which most lunar rocks experienced, were much stronger and of much longer duration, and shock effects should not be neglected. The palaeointensities determined for lunar rocks could therefore be in many cases only minimum estimates.

Palaeointensity determination with shock remanent magnetization (SRM). SRM was produced in various dc-fields up to 10 Oe. In general an increase of SRM with increasing field and impact velocity was observed, but scatter was relatively high. Magnetizing efficiency ratios $s$ in comparison to ARM ($s=SRM/ARM$ in the same field $H_0$) were found in the range 0.15 - 0.25. For palaeointensity determinations the ARM method was used as above. The "palaeofield" $H_p$ is given in this case by $H_p=H_0 s_{ARM}$. Experimental results are shown in Fig. 3. The intensity curves tend to have a plateau at high fields, which may be characteristic for SRM. The palaeofields estimated from the slope of the intensity curves agree with the primary field $H_0$ in which the SRM was produced within 20% if the factor $s$ as determined above is taken into account.

References:
(4) Pohl J. et al. (1975) J. Geophys. 41, p. 23-41

Fig. 1. "Palaeointensity" determination from a shocked ARM.
P 17: Slope = 0.27
P 18: Slope = 0.17
P 32: Slope = 0.04
An impact velocity of 100 m/s corresponds to a stress amplitude of 5 - 6 kbar.