
With the return of the Apollo 14 rocks it has been necessary to closely examine the magnetization in breccias since most samples were of this type. In general, the breccias have the possibility of carrying a significant viscous remanent magnetization when exposed to magnetic fields. The two samples which we have studied in detail, rocks 14313 and 14321, appear to exemplify two limiting cases which can be clearly related to the iron distribution present. The VRM of sample 14313 (Fig. 1) has a definite spectrum of relaxation times associated with a sharp cutoff between 100 and 1000 minutes. The shape of the decay curve of the magnetization is that expected for a uniform distribution of grain sizes. The cutoff corresponds to a grain diameter of about 150μ and coincides with the transition from superparamagnetic to stable single domain size. These extremely fine-grained particles probably occur in the matrix of the breccia.

A different kind of VRM which follows the classical log t relationship is found in sample 14321 (Fig. 2). The time dependence of this VRM is typical of multidomain iron with a wide distribution of relaxation times and is probably related to the larger interstitial iron blebs greater than a few microns in size seen under the microscope. Igneous rocks, on the other hand, acquire little or no viscous magnetization (Fig. 1, sample 14310) suggesting that the spherical iron particles which are usually associated with troilite and are typically around 1 micron in size behave almost like single domain particles. This agrees with the very stable remanence found in these rocks.

The grain size distribution inferred from the VRM tests is well substantiated by hysteresis loop measurements. Typically, igneous rocks have a ramp like hysteresis curve (Fig. 3) indicative of equant multidomain grains. The breccias, on the other hand, generally have rounded hysteresis curves reflecting superparamagnetic and equant single domain particles.

Furthermore, the analysis of hysteresis loops yields the concentration of metallic iron. Fig. 4 shows a histogram of the iron concentrations in igneous and fragmental rocks as well as in soils. The values represent our data as well as data from the literature obtained by magnetic and Mossbauer effect methods. The igneous rocks generally have a metallic iron concentration of about 0.1 wt% as compared to about 0.5 wt% for the soils and breccias. This five fold enrichment is more than can be accounted for by simple addition of meteoritic iron. Experiments with simulated lunar glass indicate that heating to about 900°C in a strongly reducing environment - conditions to be expected during impact - is an effective mechanism to produce native iron in quantities and grain sizes such as found in many breccias.
There is an indication that the time dependence of the magnetization of the breccias can be correlated with their metamorphic grade. In sample 14313, a low grade metamorphic sample, the VRM is dominated by superparamagnetic grains; the VRM of sample 14321, which is of medium metamorphic grade, is mainly carried by multidomain grains a few microns in size. Sample 14312 is of high metamorphic grade and magnetically totally unstable indicating a dominance of rather large multidomain grains.

In spite of the viscous effects there seems to be little question that some of the breccias carry a stable remanent magnetization and can therefore be used to reconstruct the history of the lunar magnetic field.
ON THE MAGNETIC PROPERTIES OF LUNAR BRECCIAS

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Figure 3

Figure 4