MAGNETISM OF THE MOON AND METEORITES: IS IT ASSOCIATED WITH CRATERING AND COLLISIONAL PROCESSES? D.W.Collinson, Department of Physics, The University, Newcastle upon Tyne, NE1 7RU, England.

Palaeomagnetism, the study and interpretation of the natural remanent magnetization (NRM) of rocks, has played a major role in increasing our knowledge of the geomagnetic field and of the history of the Earth's surface features. The extension of the discipline to extraterrestrial materials, namely rocks from the Moon and meteorites, has also resulted in data which have important implications for lunar history and structure and meteorite evolutionary processes, and for ancient Solar System magnetic fields.

In general, the existence in the above materials of an NRM with appropriate characteristics implies both the presence of a magnetic field and an energetic process such as heating and cooling or shock, whereby the field can impress a permanent magnetism into the material. In terrestrial rocks the parallellism of the field and NRM directions has enabled the direction of the geomagnetic field at different sites and at different geological epochs to be determined, forming the basis of a powerful interpretative tool. No absolute directional information is available from the palaeomagnetism of lunar samples and meteorites, but the presence of an NRM in these materials implies the existence of a magnetic field and a suitable magnetizing process at some stage in their history.

Palaeomagnetic studies of lunar samples have shown the widespread presence of a stable NRM, with characteristics consistent with it being acquired by a thermoremanent process (TRM) during cooling after extrusion on to the lunar surface, in the presence of a magnetic field. Various lines of evidence suggest that the most likely source of this field is a dynamo process in a molten, electrically conducting lunar core, existing in the approximate interval 4.0 - 3.2 Ga ago. However, some authors have indicated that the deduced maximum field strength of about 50 - 100 μT is too large to be plausibly generated by a dynamo in a small lunar core, and considerable attention has been directed towards another possible source, impact-generated, transient magnetic fields associated with a TRM or shock magnetization. This process could occur during the extensive meteorite bombardment to which the Moon has been subjected. The importance of trying to distinguish between these two magnetization processes lies in the important implications that a dynamo and core has for lunar history and structure. Impact-generated magnetization would be a physical phenomenon of some interest, but would not be particularly informative about the Moon.

The evidence favouring a global, persistent magnetic field or impact NRM will be presented, based on results from the lunar samples and surface and above-surface magnetic field measurements. The approach is as follows. Since neither the dynamo process nor impact magnetization can currently be proved to occur or not to occur, each process is considered independently and the likely characteristics of the resulting magnetism are compared with the above observations.

The evidence shows that the most likely origin of the major features of lunar magnetism is an internally-generated dipolar magnetic field. The variation of ancient field strength with time, as deduced from the lunar samples, large regions of uniformly magnetized crust, the clustering of ancient magnetic pole positions deduced from lunar magnetic anomalies, and the existence of secondary NRMs in lunar samples are among the main lines of this evidence. However, some recently-formed and magnetized lunar breccias, and possibly some surface magnetic features, may have been magnetized by impact magnetization processes. Cratering has also been important in physically disturbing the magnetized lunar crust and thus modifying the surface and above-surface magnetic fields, and possibly also in partially demagnetizing or remagnetizing pre-existing NRM.

Meteorites also appear to be likely candidates for impact magnetization, if it occurs, but as yet there are no experimental results which point specifically to this process. A problem here, as with the lunar samples, is that there is no feature or behaviour of shock magnetization or TRM which can distinguish one from the other. A conventional magnetizing process in meteorites can provide valuable data regarding ancient Solar System magnetic fields, for example those associated with the early Solar nebula or with meteorite parent bodies.

There now, therefore, seems to be strong evidence for a lunar core and the associated implications for lunar history and structure. A problem which then arises is the nature of the energy source which maintained the dynamo for a period in excess of 500 Ma.

General References:

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