MAGNETIC PERMEABILITY AND IRON ABUNDANCE OF THE MOON FROM MAGNETOMETER MEASUREMENTS, C.W. Parkin*, P. Dyal**, and W.D. Daily**.
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The relative magnetic permeability of the Moon is calculated from properties of global lunar hysteresis curves obtained using measurements of two Apollo lunar surface magnetometers (LSM) and the Explorer 35 orbiting magnetometer. The permeability is then used to estimate ferromagnetic content, and in particular the iron abundance, of the outer region of the Moon where temperatures are below Curie temperature of the magnetizable material.

During times when the Moon is located in quiet regions of the geomagnetic tail, the total magnetic field $\underline{B}_A$ measured at the lunar surface by an Apollo LSM is expressed $\underline{B}_A = \underline{B}_E + \underline{B}_u$, where $\underline{B}_E$ is the extralunar geomagnetic tail field measured by Explorer 35 and $\underline{B}_u$ is the magnetization field induced in permeable lunar material (here the steady remanent magnetic field local to the surface site has been subtracted out). For the spherically symmetric case, the magnetization field $\underline{B}_u$ is dipolar, and its magnetic moment is proportional to $\underline{B}_E$, i.e., $\underline{m}_u = k' \underline{B}_E$; the proportionality constant k' in turn depends upon the permeability and the dimensions of the permeable region of the Moon.

The radial component of the surface field is expressed $B_{Ar} = (1 + k)\, B_{Er}$. A plot of B_{Ar} versus B_{Er} is in effect a plot of a global B-H hysteresis curve for the Moon. For cases where the ratio B_{Ar}/B_{Er} is a constant, i.e., for low field B_{Er} (~ 10 gammas for the geomagnetic tail) the hysteresis curve should take the form of a straight line; the slope of the hysteresis curve is proportional to permeability and dimensions of the permeable region of the Moon.

Hysteresis curves are obtained using tail data from five lunations at the Apollo 12 LSM and two lunations at the Apollo 15 LSM. Least-squares fit and slope calculations determine slopes, from which the bulk relative permeability of the Moon is determined to be 1.03 ± 0.02. Slope and permeability calculations from both Apollo sites agree to within experimental error, indicating that the hysteresis effect is a global phenomenon. Furthermore the relative permeability is above 1.0 for both extremes of the error limits, indicating that when immersed in a uniform, steady geomagnetic field, ferromagnetic materials in the lunar interior are magnetized along the direction of the tail field, causing the Moon as a whole to have properties similar to a weakly magnetized paramagnetic sphere.

The magnetization field $\underline{B}_u$ is due to ferromagnetic materials in regions of the Moon where the temperature is below the material Curie point. For a spherically symmetric Moon of temperature increasing monotonically with depth, the contributing magnetized material will lie in an outer shell of the Moon, and the relative permeability of the shell will be higher than the calculated bulk value. Permeability is calculated for shell configurations based on various temperature models of the lunar interior.

Iron abundance in the portion of the Moon above the Curie temperature is also estimated from the lunar hysteresis curve, using various compositional models of the lunar interior. Lunar iron abundance values are discussed with reference to theories of lunar origin.