MAGNETIC EFFECTS OF LARGE-SCALE IMPACTS ON AIRLESS PLANETARY BODIES, L. L. Hood, Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona 85721.

Background: Analyses of available lunar orbital magnetic field measurements have previously indicated that the largest concentrations of strong crustal magnetization occur antipodal to 4 relatively young large impact basins (1). Weaker magnetization is observed peripheral to Imbrium in association with the Fra Mauro and Cayley formations (2). In contrast, fields over the nearside maria are nearly absent and anomalies are not correlated with impact crater locations in either the highlands or the maria (3). Experimental and theoretical studies of vapor-producing impacts have shown that transient magnetic fields are generated both within the plasma cloud above the impact point and also near the surface of the cloud as it expands into an ambient magnetic field (4). A model for an especially large field amplification antipodal to lunar basin-forming impacts has been proposed to explain the largest magnetization concentrations observed from orbit (5).

Model Calculations: In previous work, we have reported two-dimensional axially symmetric model calculations of the expansion and interaction with the Moon of a basin-scale impact plasma cloud (6). In this paper, the results of these calculations are applied to determine expected field amplitudes both within and external to representative expanding impact plasma clouds for several possible initial conditions.

Fields Within the Plasma Cloud: Transient electrical currents are generated in the plasma cloud itself by strong temperature and density gradients combined with the basic difference in ion and electron mobilities (4). A scaling analysis of the governing equations yields an estimate for the saturation magnetic field amplitude,

$$| B_s | \sim (ck/e)(\Delta T/VL)$$

where c is the speed of light, k is Boltzmann's constant, e is the electron charge, $\Delta T/L$ is a typical cloud temperature gradient, and V is a representative gas expansion velocity. Although generated field amplitudes can be large for laboratory-scale events, $| B_s |$ decreases as L increases while ΔT and V remain relatively constant. In the basin-scale impact plasma cloud calculation described in ref. 6, after 64 seconds the size of the cloud is comparable to half the lunar diameter. Maximum temperatures near the impact point are $\sim 10^4$K and decrease to much smaller values in a distance of $\sim$ 1000 km. Typical expansion velocities are $\sim$ 10 km s^{-1}. Substitution into the above expression yields $| B_s | \sim 10^{-6}$ G. Even at times of < 10 seconds after the impact, the estimated field amplitudes remain $< 10^{-4}$ G. It is therefore concluded that large-scale impacts on airless planetary surfaces are unlikely to produce significant large-scale magnetizing fields within the impact plasma cloud itself. This result is generally consistent with the absence of correlations between lunar orbital magnetic anomalies and impact crater locations noted above.

External Fields: At least three initial plasma and magnetic field environments of an airless planetary body may be considered. First, the body may have no large-scale intrinsic magnetic field but may be exposed to the solar wind plasma and its embedded magnetic field (e.g. the present-day Moon for most of its orbit). Second, the body may possess an intrinsic field and be exposed to plasmas in its own magnetosphere (e.g. Mercury). Third, the body may have no intrinsic field but may spend part or all of its time within the magnetosphere of a planet (e.g. satellites of the outer planets). In any of these cases, the external medium consists of a plasma with an embedded magnetic field. A magnetohydrodynamic shock wave will therefore develop ahead of the expanding impact plasma cloud. Within the shocked layer, the field is amplified while outside the shock wave, the plasma and field environment is unperturbed. A simple example is illustrated in the figure. The inner dashed line represents the outer boundary of the impact plasma cloud and the outer dashed line represents the external shock. In this example, the external plasma medium is stationary relative to the Moon and the ambient magnetic field is uniform and oriented parallel to the impact symmetry axis. The shock velocity is assumed to be about 10% larger than the gas expansion velocity. The largest field amplification occurs antipodal to the impact point and can reach values of several hundred times the ambient field amplitude (5). Although other initial plasma and field conditions result in different compressed external field configurations, antipodal field compression is found to occur in most cases. This result combined with observational evidence for magnetization concentrations antipodal to lunar impact basins suggests that external field compression is the most important magnetic field effect of large-scale impacts on airless planetary surfaces. Heating and weak shock effects of converging seismic waves in basin antipode zones provides one plausible mechanism for imparting magnetization to crustal materials (5).

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