EFFECTS ON AMBIENT MAGNETIC FIELDS AND PLASMA OF THE EXPANDING VAPOR CLOUD PRODUCED IN LUNAR BASIN-FORMING IMPACTS, L. L. Hood and Z. Huang, Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona 85721.

Introduction: Previous theoretical and experimental work has shown that vaporization of projectile and target material occurring in hypervelocity (> 10 km/s) impacts results in the formation of a thermally expanding plasma cloud that may produce significant magnetic effects (1). More recent experimental studies of vapor-producing impacts (2) have established that transient magnetic fields are observed that fall into two major classes: (i) fields generated intrinsically within the plasma cloud as a result of non-aligned thermal and density gradients; and (ii) fields generated by currents induced near the surface of the cloud as it expands into the ambient geomagnetic field. Although the former class of fields may contribute substantially to the small-scale magnetization of lunar surface materials, scaling arguments indicate that their amplitudes will be reduced in large events because of decreased overall thermal gradients (1). This is consistent with the general absence of a direct correlation between lunar orbital magnetic anomalies and impact crater locations, including those of mare craters down to a few km in size (3). Interaction of the plasma cloud with ambient (e.g. solar wind) magnetic fields and plasma provides the major alternate mechanism for producing strong, large-scale fields that may have been responsible for a large component of lunar paleomagnetism.

According to a proposed model (4), external magnetic fields and plasmas may have been especially concentrated for a transient time interval in the zone *antipodal* to large impacts due to convergence of the impact plasma cloud. Shock effects (due to convergence of seismic waves and/or secondary impacts) in the presence of the enhanced magnetic fields may have produced relatively strong and coherent magnetization in basin antipode zones that could be responsible for the largest magnetization concentrations mapped from lunar orbit (5).

Model Calculations: In the work reported here, initial three-dimensional model calculations are reported of the expansion and interaction with the Moon of a basin-scale impact plasma cloud. Shown in the figure is a time sequence of plots of mass density resulting from a simplified numerical calculation of the expansion of a representative cloud using initial conditions (mass density, total mass, internal energy density) approximately appropriate for a 15 km/s normal impact of a 100 km radius gabbroic anorthosite impactor onto a gabbroic anorthosite lunar surface (6). A two-dimensional hydrodynamic code (made three-dimensional by the assumption of axial symmetry) was used in an Eulerian mode on a cylindrical grid (7). In each plot, the central circular disk represents the Moon and the outer shaded contour of the cloud corresponds to a mass density of $10^{-11}$ g cm$^{-3}$. The first plot is for a time of 64.4 seconds after impact. The second is for a time of 456 seconds. The initial vertical grid size was 21.7 km but was increased by a factor of two after expansion of the cloud to a size comparable to the lunar radius. Results are nearly insensitive to further reductions in grid size. Limitations of the calculation include the neglect of the interaction of the expanding gas with solid and liquid ejecta, neglect of radiative energy loss, and use of an ideal gas equation of state so that partial recondensation of the vapor is not accounted for. The most serious of these appears to be the latter and an effort is currently being made to account for recondensation using a more realistic equation of state. However, uncertainties regarding actual impact angle of incidence, size, velocity, and composition for a given lunar basin impactor are sufficiently large that no major qualitative revisions are expected of the current results.

As seen in Fig. 1b, the outer periphery of the cloud begins to approach the antipode after a time of 450-500 s for the chosen initial conditions. This time is of the same order as for propagation of compressive seismic waves through the Moon (400 - 500 s) and is significantly less than that for the arrival of basin secondaries (30 to 50 minutes). Thus shock effects of converging seismic waves in basin antipode zones may be a primary candidate for producing the observed magnetization, provided that a strong magnetic field enhancement occurs in the same zones. This would be consistent with a weak statistical correlation that is known to exist between electron reflection anomalies and seismically modified terrain in basin antipode zones (8).

Interaction with Ambient Fields and Plasmas: As the cloud expands, a shock wave will form between the periphery of the cloud and any ambient plasma with an embedded magnetic field. In the usual case when the Moon is in the solar wind, the interaction will resemble that between a planetary ionosphere and the solar wind except for the expansion of the obstacle in the present case. As the impact cloud expands around the Moon, the region enclosed by the bow shock will include the antipodal zone so that the external plasma and its embedded magnetic field in this zone will be relatively stagnant. For this reason, the compression of the external medium in the antipodal zone can be modeled to a first approximation by assuming that the Moon is initially surrounded by a stagnant plasma with thermal and magnetic properties similar to that of the solar wind plasma. In the actual solar wind, $\beta$, the ratio of thermal to magnetic pressure is usually less than unity but varies to values above and below unity. As an initial calculation, we make the simplifying assumption that $\beta$ is greater than unity so that a purely hydrodynamic numerical code can be used to model the external plasma dynamics in a first approximation. The change in the magnetic field is then calculated from $\partial \mathbf{B}/\partial t = \nabla \times (\mathbf{v} \times \mathbf{B})$ using the hydrocode velocity field. Although these calculations are still in progress, initial results show significant magnetic field enhancements in the antipodal zone as expected from considerations based mainly on conservation of flux (4).

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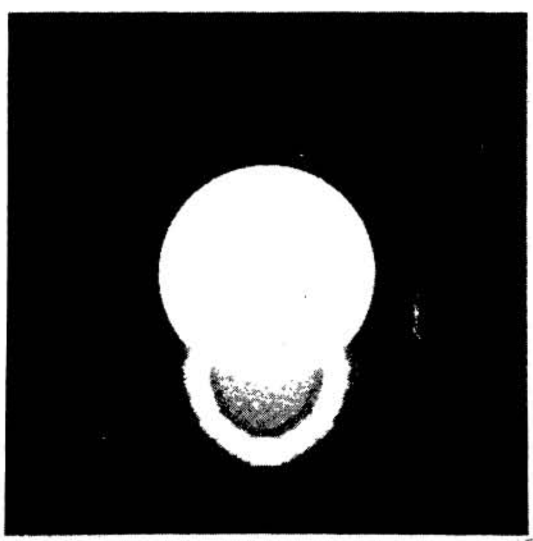
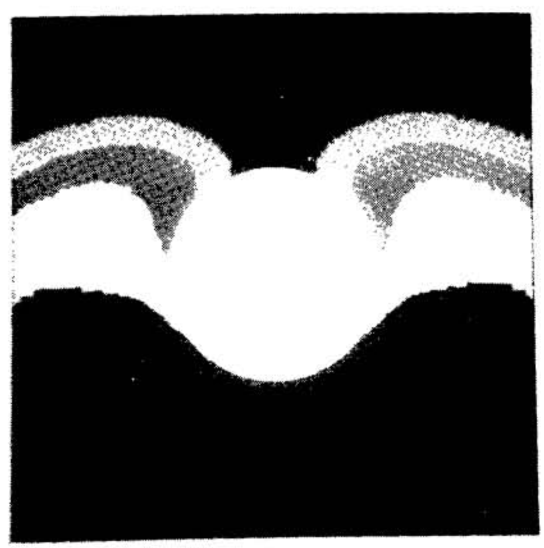


(a)



(b)