THE EFFECT OF LOCAL MAGNETIC FIELDS ON THE LUNAR PHOTOELECTRON LAYER WHILE THE MOON IS IN THE PLASMA SHEET; W. J. Burke
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The Charged Particle Lunar Environment Experiment (CPLEE) at the Apollo XIV site has been used to investigate the interactive effects of the plasma sheet and the lunar photoelectron layer. Under quiet time plasma sheet conditions the electron and proton densities are about $0.1 \text{cm}^{-3}$ with temperatures $T_e = 200 \text{eV}$ and $T_i = 2 \text{keV}$ (1). In situ measurements show that between 5eV and 200eV lunar photoelectrons have a power law spectral distribution (2, 3). Laboratory observations of photoelectrons emitted from lunar fines suggest that the spectrum has a maximum between 1 and 2eV (4). The three sets of data have been combined to fit the photoelectrons to a "kappa" distribution

$$f_\nu(v) = \frac{n_\nu \Gamma(K+1)}{(\pi K)^{3/2} \Gamma(K-1/2) w^3} \left[ 1 + \frac{v^2}{K w^2} \right]^{-(K+1)}$$

with $K=3$, $n_\nu=240 \text{ cm}^{-3}$ and $w$ the most probable velocity corresponding to a most probable energy of 1eV.

To calculate the surface potential of the sunlit side of the moon while immersed in the plasma sheet, it is necessary simultaneously to conserve charge and current and to satisfy the Poisson equation. These calculations have been made using models developed by Grobman and Blank (5) and by Guernsey and Fu (6). Ignoring local magnetic fields, these models predict a surface potential of between 12 and 20 volts. Thus, the CPLEE analyzer that looks toward the local vertical should see no downwelling photoelectrons whenever the moon is in the plasma sheet. This prediction is contradicted by CPLEE data which show that the counting rates of the energy channels centered at 40eV, 50eV, and 65eV are substantially the same in the plasma sheet and the high latitude lobes of the magnetotail. It is only under conditions of enhanced plasma sheet, characteristic of magnetic storms, that the counting rates of these channels vanish, indicating a modulation of the surface potential.
In order to resolve the apparent contradiction between theory and observation we have investigated the effects of: (a) other sources of current, and (b) local magnetic fields. The most likely source of current that was not included in the original calculations comes from secondary electrons produced by the plasma sheet particles as they impact the lunar surface. However, only those secondary electrons with a "vertical component" of kinetic energy greater than the surface potential can escape the moon and contribute to the return current. Laboratory studies of secondary electrons from lunar fines, generated by primary electrons with plasma sheet energies, have maximum energies of less than 50eV (7). Protons with energies of a few keV are very efficient producers of energetic (up to 100eV) secondary electrons when they bombard some dielectric and metal surfaces (8). Unfortunately, the secondary spectrum of lunar fines due to ion bombardment has never been attempted. Our calculations show that the plasma sheet protons would have to produce 0.78 secondary electron with kinetic energy greater than 70eV per incident proton in order to bring CPLEE's observations in line with simple electrostatic theory. Such an efficiency is most unlikely. Other particle sources such as the photoelectrons and secondary electrons produced from dust particles in the lunar atmosphere (9) have been found several orders of magnitude too small to explain observations.

In order to estimate the effect of local magnetic fields on electrons reaching CPLEE it was first necessary to estimate the magnetic field in the vicinity of the Apollo XIV experiments. Dyal et al. (10) have reported the exact positions of two vector magnetic field measurements made by the Apollo XIV Lunar Portable Magnetometer. These measurements were fit to the field of a magnetic dipole of strength $10^5$ gauss·m$^{-3}$, centered at about 0.6km beneath the surface of the moon. At CPLEE's position the field strength is 45 gamma and pointed almost due east. This field falls to a value of 10 gamma (the ambient magnetotail strength) at about 600m above CPLEE. The trajectories of photoelectrons in this field and under various surface potential conditions have been computed. Our calculations show that indeed the magnetic field strongly influences the flux of photoelectrons returning to the lunar surface. By comparing quiet and storm time plasma sheet data we have calculated that the scale height of the field needed to turn back a 50eV electron, with a surface potential
of 25 volts, is about 400m. A more general result is to express a caveat in the use of surface models that ignore local magnetic fields.

References