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B70 09003

SUBJECT: A Comment on Ness's Estimate of the Interior Electrical Conductivity of the Moon - Case 340

DATE: September 2, 1970

FROM: W. R. Sill

ABSTRACT

Recent estimates of the internal electrical conductivity and temperature of the moon, made by Ness [1969c; 1969b; 1970] are based on the assumption that the response of the moon to discontinuities in the interplanetary field will lead to an increase in the risetime of the discontinuity as observed in the lunar wake. Calculations of the time domain response of the moon show that the response is characterized by a rapid increase with the same time scale as the discontinuity, followed by an overshoot and then a decay. This result is in contradiction to the interpretation of Ness.

The increase in risetime that is observed must be attributed to other effects and the estimates of the conductivity, based on this interpretation, must be discounted.

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MEMORANDUM FOR FILE

Introduction

In several recent papers, Ness [1969a; 1969b; 1970] has reported estimates of the interior lunar conductivity and temperature based on his interpretation of the response of the moon to discontinuities in the interplanetary magnetic field. Figure 1 shows the data used by Ness [1969a; 1970]. The curves show a discontinuity in the z (normal to the ecliptic) component of the interplanetary field as observed by Explorer 33 in the solar wind, and as observed by Explorer 35 in lunar orbit, when the spacecraft was in the plasma void behind the moon. The increase in the risetime of the event from 10.2 seconds at Explorer 33 to 56.2 seconds at Explorer 35 is attributed to the induction of eddy currents in the lunar interior. From this a decay time of less than 20 seconds and an interior conductivity of 10^{-4} mho/m is estimated [Ness, 1969a; 1970]. A similar discontinuity, with a risetime of 40 seconds, showed no increase in risetime in the plasma void [Ness, 1970].

The purpose of this note is to point out that calculations of the poloidal (eddy current) response of the moon to discontinuities in the interplanetary magnetic field do not support this interpretation. Neither the form nor the magnitude of the induced fields could lead to the increase in the risetime observed in Figure 1.

Induced Lunar Magnetic Field

Figure 2, taken from Blank and Sill [1969], shows the moon in the solar wind environment and the induced poloidal magnetic field. The figure illustrates the confinement of the induced field on the sunlit hemisphere by the kinetic pressure of the solar wind. This compression and amplification of the field has been confirmed by the observations of the Apollo 12 lunar surface magnetometer [Sonett et al., 1970]. On the dark side of the moon the induced field is shown expanded into the plasma void. This feature of the interaction has also been confirmed by the lunar surface magnetometer. Observations of the magnetic field during the lunar night show some inductive effects but very little amplification [Sonett et al., 1970].

The data of Figure 1 was recorded when Explorer 35 was in the plasma void behind the moon at a distance of 1.48 R_m (R_m = lunar radius). The field in the void is a summation of the solar wind field, a field due to the absence of the diamagnetic plasma and the field induced in the lunar interior. For the purposes of this paper we will neglect the diamagnetic field increase and the compression effect on the induced dipole caused by the confinement within the cylindrical plasma void. Therefore, we assume that the field at the altitude of Explorer 35 (0.48 R_m) is given by the source field and an unconfined induced dipole field.

Figure 3 shows the time domain response of a core-crust lunar conductivity model to a step function increase in the source field. The time domain response is calculated by multiplying the spectrum of the input signal by the spectrum of the poloidal response and then transforming the product back into the time domain. This is equivalent to convolving the impulse response with the input signal. The spectrum of the poloidal response in this example is calculated by a technique similar to that of Sill and Blank [1970] using the boundary conditions appropriate for an unconfined secondary field.

The interior conductivity in the model is 10^{-4} mho/m, as suggested by Ness. The top curve shows a discontinuity in the source field modeled after Figure 1; i.e., a rapid increase in the field by 7γ in 10 seconds. The second curve shows the induced field at the lunar surface. The third trace shows the total field (source plus induced) at a point 0.48 R_m above the lunar surface, assuming the induced field falls off as a dipole. We note that the response is characterized by an overshoot of small magnitude ($\sim .6\gamma$) followed by a decay. In addition the decay is not a simple exponential. For example, the inverse of the normalized slope B/(dB/dt), increases from 20 seconds at the peak, to about 35 seconds after 20 seconds.

Since neither the form nor the magnitude of the calculated response could lead to the increase in risetime seen in Figure 1, I conclude that the increase in risetime cannot be due to induction of eddy currents in the lunar interior. Increasing the interior conductivity by many orders of magnitude does not alter this conclusion.

The absence of an appreciable toroidal response for the moon [Sonett et al., 1970] indicates that the observed effect cannot be due to this mode. In any event, the toroidal response is indicative of the near surface conductivity [Sill and Blank, 1970] and it also leads to a response, in the void, characterized by an overshoot. The observed effects could be due to time and/or spatial changes in the field between Explorer 33 and 35, a possibility which is dismissed by Ness [1969a].

W. R. Sill

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Attachments
References
Figures 1-3

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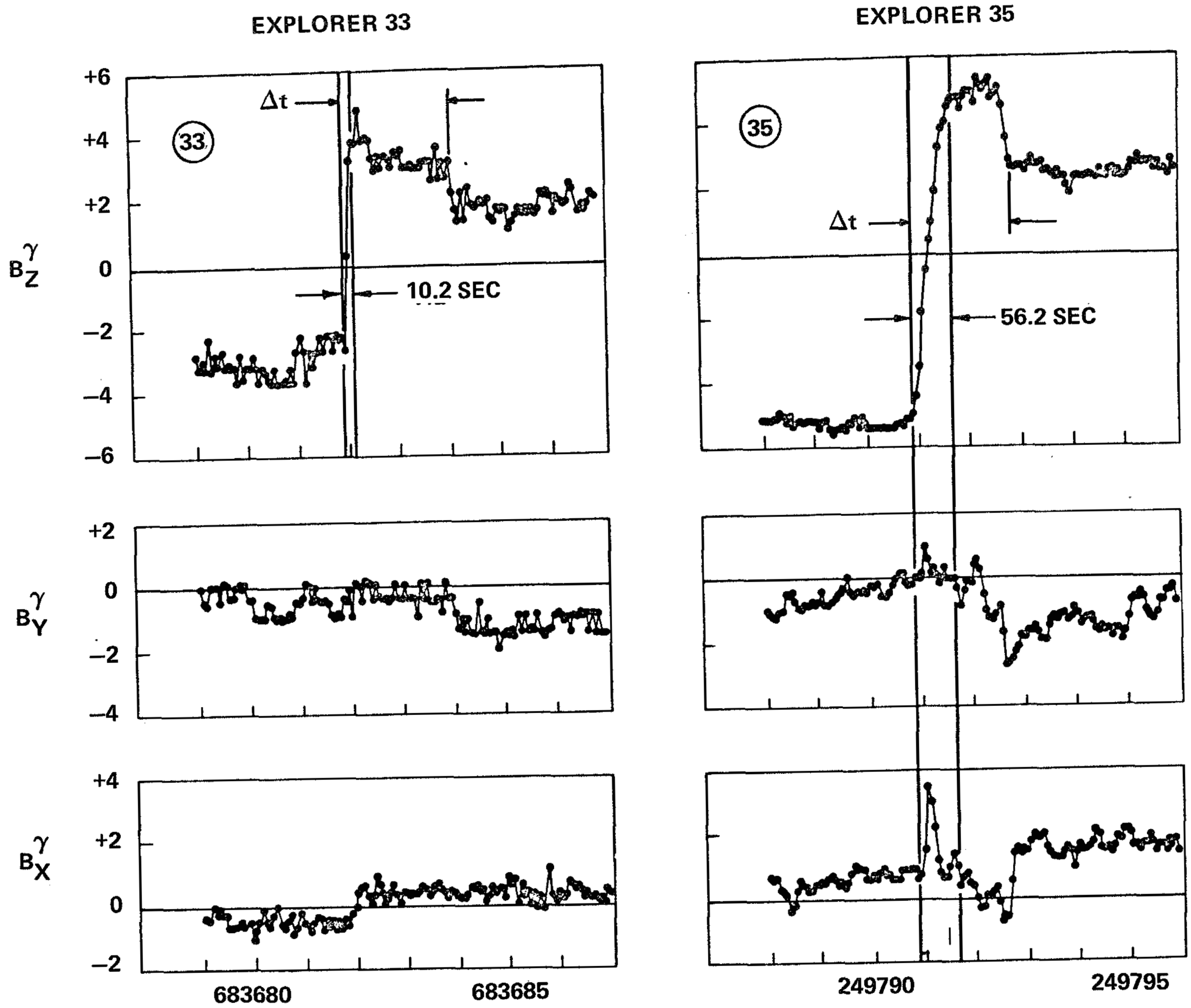

FIGURE 1 - SIMULTANEOUS MEASUREMENTS OF THE MAGNETIC FIELD AT EXPLORER 33 IN THE SOLAR WIND AND AT EXPLORER 35 IN THE PLASMA VOID BEHIND THE MOON

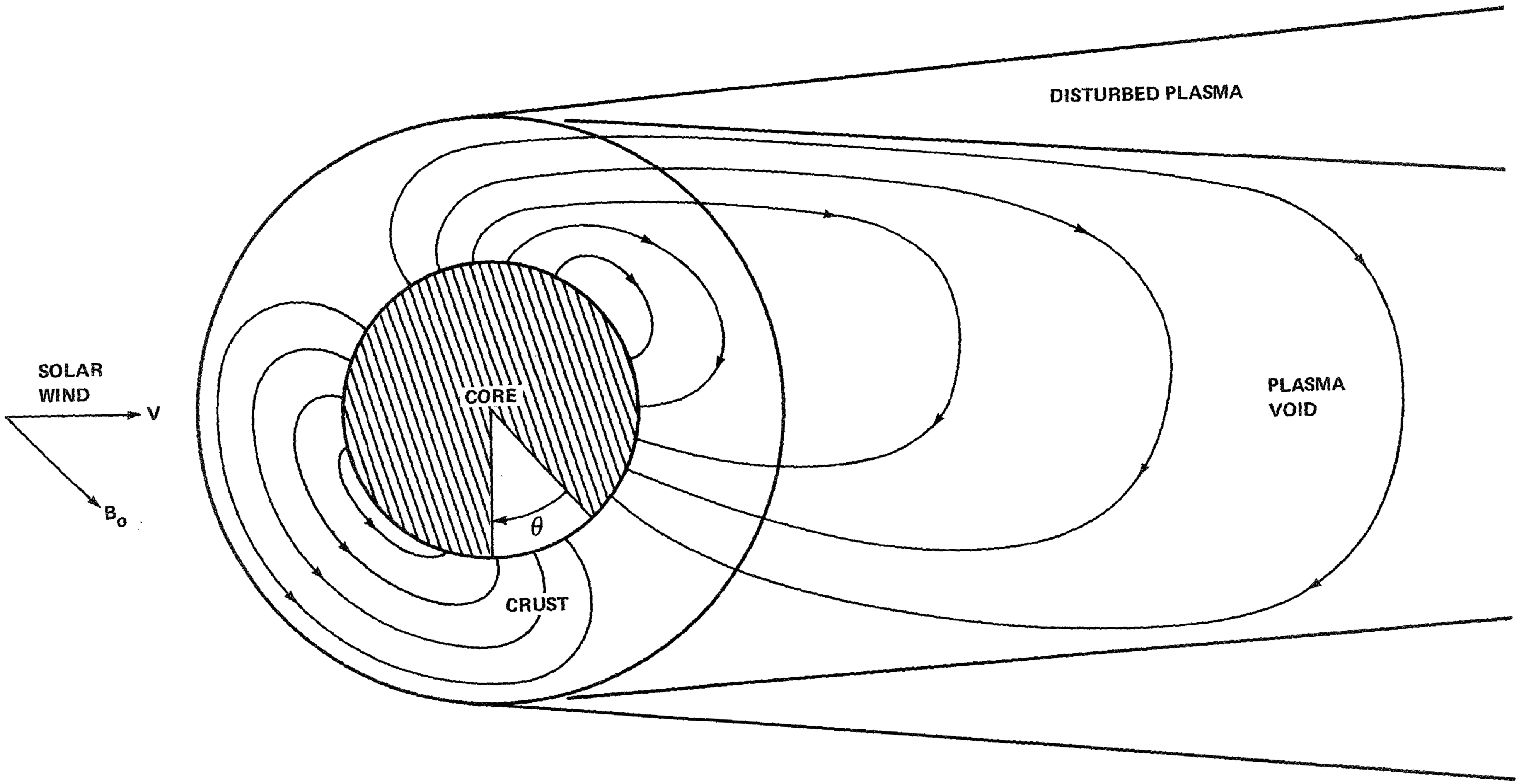

FIGURE 2 - SCHEMATIC ILLUSTRATION OF THE CONFINEMENT BY THE SOLAR WIND OF A HARMONIC COMPONENT OF THE INDUCED LUNAR MAGNETIC FIELD

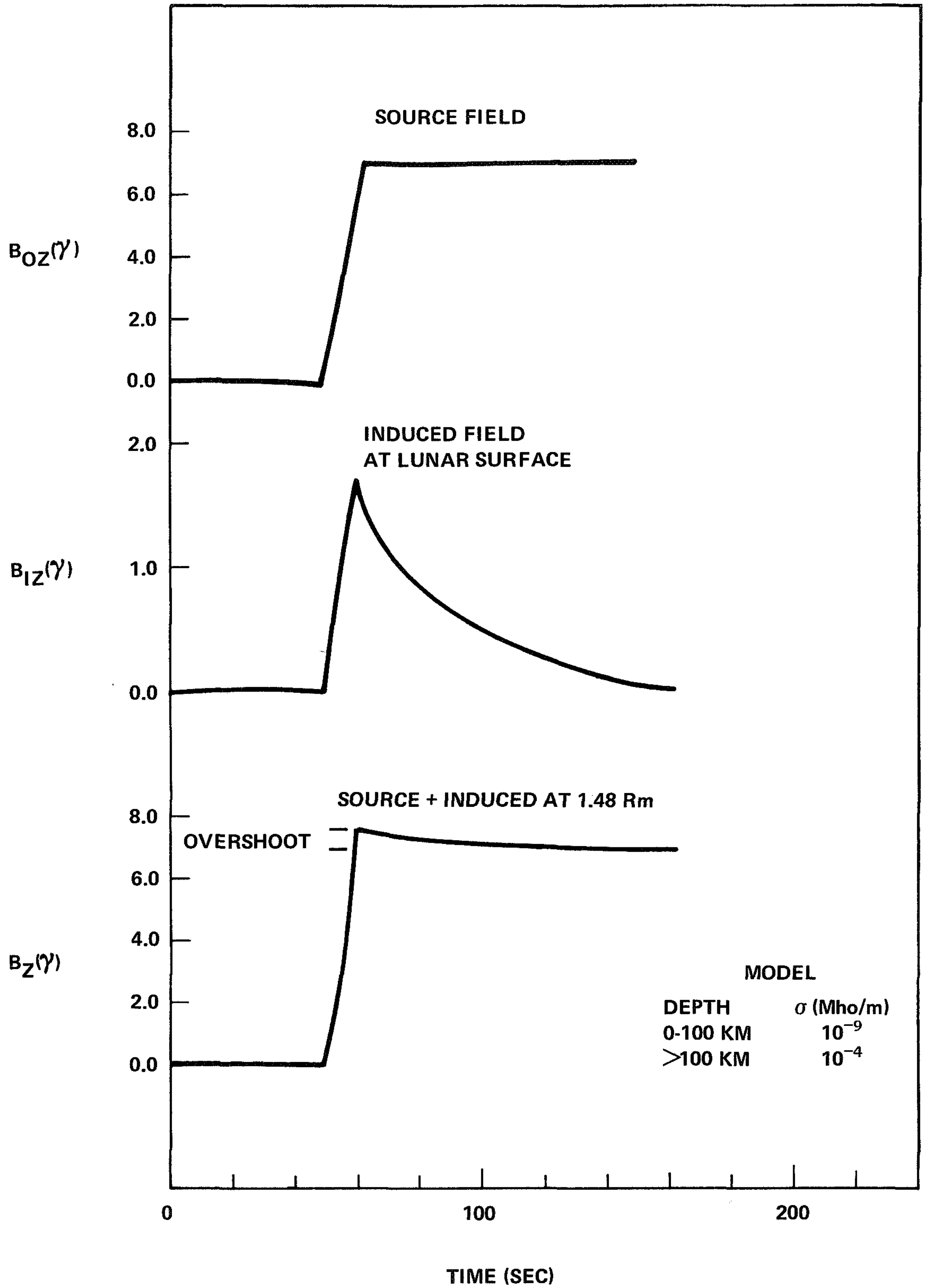

FIGURE 3 - TIME DOMAIN RESPONSE OF A LUNAR CONDUCTIVITY MODEL TO A DISCONTINUITY IN THE SOURCE FIELD

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