Magnetic Field in Le Monnier Bay According to Data of Lunokhod 2

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The results of the first traverse measurement of the magnetic field on the surface of the Moon are analyzed. The mean value of the magnetic field in the portion of Le Monnier Bay investigated is estimated at 20–30 gammas. An anomaly of the field (10–15 gammas) was disclosed, which is confined to craters that exceed 50 meters in size.

Experiment Task

Magnetization of the lunar rocks, discovered by the Apollo missions (ref. 1), coupled with the observed absence of a uniform field on the Moon during the present (refs. 2–4), is one of the enigmas of the history of the Moon.

Investigation of the distribution of magnetic field sources from low-flying satellites is the most appropriate means of studying the global distribution of magnetic anomalies on the Moon. However, since extrapolation of the fields to the lunar surface is difficult, the necessity arises for supplementing the investigation of magnetization of the Moon from satellites with investigations on the surface of the Moon. The magnetic characteristics of individual regions, with different topographic relief characteristics (craters, faults, fields of rocks, etc.), can be studied only by a magnetic survey on the surface. Local anomalies of the field, which may be connected with these features, quickly decrease with altitude. A comparison of the magnetic data with the data of other physicochemical and geological investigations is an additional possibility in the study of the origin of the anomalies, and in understanding the nature and origin of the magnetization of the lunar rocks.

Investigation of the magnetic field on the surface of another celestial body, by means of a self-propelled vehicle, is a technical question, since a Lunokhod-type vehicle cannot be constructed without electromagnetic devices, which create interference with the operation of the onboard magnetometer. Lunokhod 2 was not intended specially to conduct magnetic studies.

Apparatus and Measurements

A three-component fluxgate magnetometer, with automatic range extension, permitting measurement of three components of the field with uniform sensitivity, in the ± 580 gamma range, was installed aboard Lunokhod 2.

The magnetometer sensors were located remotely from the body of Lunokhod by 1.5 meters. The three sources of magnetic contamination are:

a. Permanently magnetized material and circulating electrical currents
b. Moving magnetic material in the wheels
c. Thermoelectric currents, determined mainly by the heat flow in the housing and support of the magnetometer sensor.

Elimination of these sources from the onboard magnetogram data was carried out by specially planned maneuvers of Lunokhod 2 in selected sections of the traverse, on the basis of data from ground tests and the data of instruments determining the course of the Lunokhod. It was estimated that elimination of these fields was accomplished with an absolute error of ± 3 gammas for the horizontal components. The zero point of the vertical component could not be tested on the surface of the Moon. The relative error in determination of this component was about three gammas. The estimates of errors were tested by repeated measurements along the same traverse.

General Characteristics of the Field in Le Monnier Bay

A map of the route of Lunokhod 2, on which the magnetic measurements were performed, is presented in figure 1. It is clear that, geologically-morphologically, the mea-

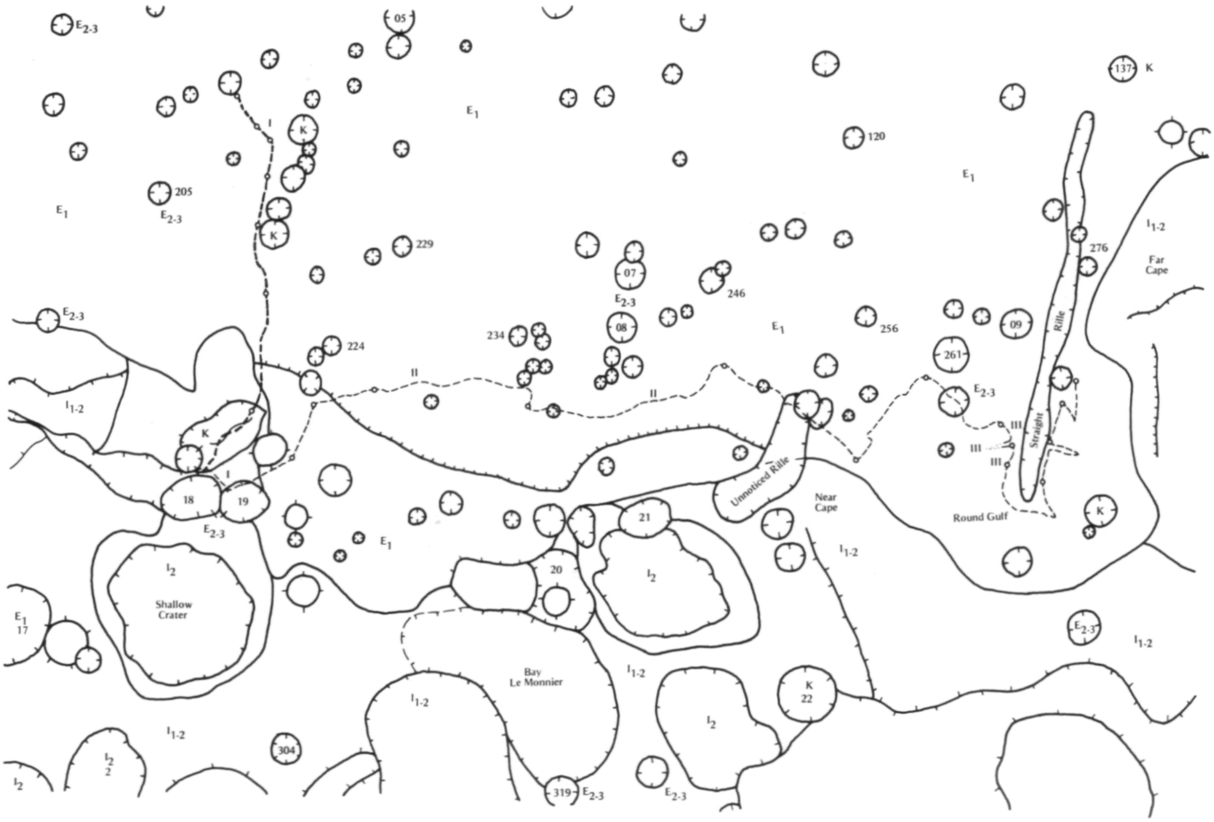

Figure 1.—*Map diagram of Lunokhod 2 route.*

surements were carried out in three characteristic types of terrain:

a. On the mare plain of the bottom of Le Monnier crater
b. In the elevated, hilly plain, which is a type of highland
c. In the vicinity of a tectonic fault crossing the bottom of Le Monnier

Examination of the magnetogram shows that the scalar value of the horizontal component of the field H changes from 2 or 3 to 30 gammas. The vertical component of the field, the absolute value of which is known no more accurately than 10 gammas, changed from − 10 gammas to + 40 gammas. Thus, the average value of the field in Le Monnier Bay is low. The value of the horizontal component, in a number of cases, was comparable to the field of the external sources: the field of the magnetic tail of the Earth, the transition zone, and the perturbed interplanetary field.

Introduction of corrections for the effect of the external sources is necessary, since such an important characteristic as the direction of the field can be strongly distorted in a number of cases. The procedure for taking account of the external sources has not yet been completely carried out.

For the measurements made in February and April 1973, the magnitude and direction of the field of the solar wind were estimated from Pioneer 8 and Pioneer 9 data (ref. 5). For a preliminary estimate of the magnitude of the field in the magnetosheath, the average characteristics of the field in the sheath were used (ref. 6), with the location of the Moon in the sheath taken into account. We hope that, as a result of the forthcoming exchange of data with Sonett and Coleman on Explorer 35, the effect of the external field in those sections of the route in which there were simultaneous measurements by Lunokhod 2 and Explorer 35 will be successfully taken into account.

In the magnetograms presented below, both the initial values of the field vectors and those corrected for the external sources are indicated.

Considering what has been reported above, it can be noted that, on the whole, the horizontal component of the field, in the portion of Le Monnier Bay investigated, is directed primarily to the southwest and south.

Concerning the vertical component, as has already been mentioned, only relative measurements could be carried out. If one assumes a zero value of this component of + 10 gammas, estimated on Earth under different measuring conditions, it can be concluded that the vertical component is directed upward, i.e., "north magnetism" acts in Le Monnier Bay.

Magnetic Field of Individual Regions

As follows from figure 1, the route of Lunokhod 2 lay across sections with different geological structures. Although the magnetic measurements were made over the entire route, data on three sections are discussed in this report. Routes over the three sections are designated by roman numerals in figure 1.

Section I–I. Lunokhod moved in the north-south direction. This section, the total extent of which is about 7 km, includes a mare-type lava plain (about 5 km) and an elevated hilly plain of the highland type (2 km). These surfaces are complicated by craters of various sizes. The average thickness of the regolith in the mare portion of the section is 2–3 m and over 5 m in the highland portion.

Magnetograms of this section are presented in figure 2 (A and B).

In the northern (mare) portion of this route, sections 1–1, 1–2, and 2–3 differ somewhat with respect to the direction of the horizontal component.

In the first section, 1–1, H has a southwest direction and a value of 20–25 gammas. The vertical component Z is of the order of 20 gammas. In the second section, 1–2, vector H is directed toward the west-southwest, and its value is about 10 gammas; the vertical component is 30 gammas.

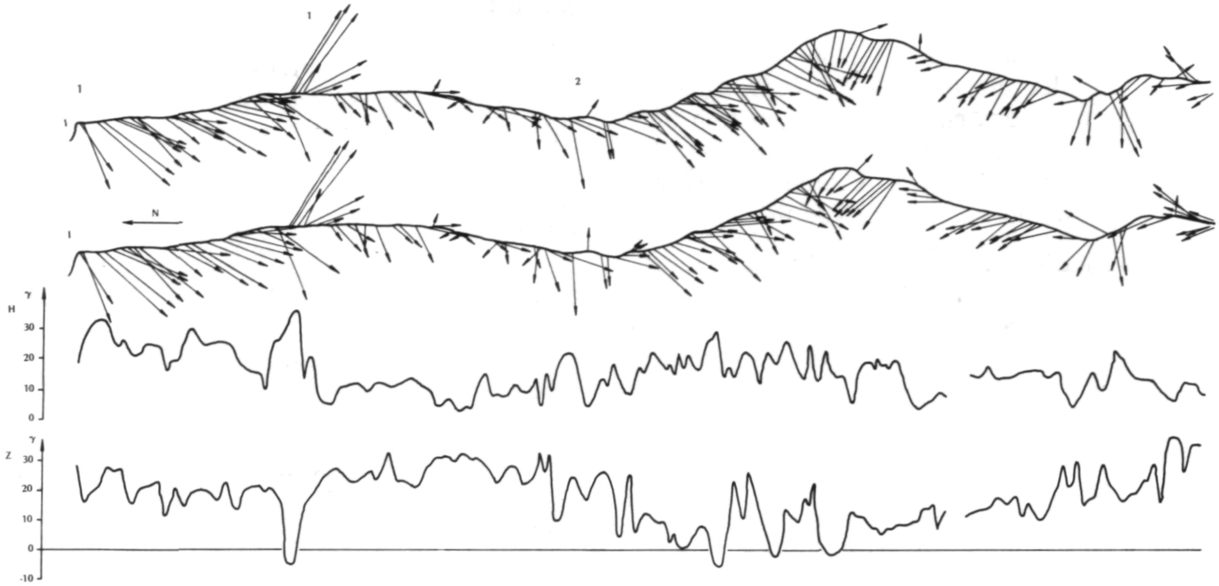

Figure 2A.—*Lunokhod 2 magnetograms in section I–I: (a) horizontal component* H *vector, taking external field into account; (b) horizontal component* H *vector, not taking external field into account; and (c) scalar value of horizontal and vertical components, taking account of external field.*

In section, 2–3, the field vector changes direction from the southwest to the northwest in a distance of 2 km. In this case, the value of H is about 20 gammas, and Z changes between 10 and 30 gammas. In this section, the route passes across a mare surface complicated by small craters which are not plotted in figure 1.

In the southern highland section of the route, 3–4, vector H is directed to the west and has a value of 10 gammas, and Z is of the order of 30 gammas. Thus, portion 3–4 is similar to portion 1–2 according to the magnetograms.

Section II–II. Lunokhod 2 moved in the west-east direction. Section II–II is located entirely on a mare-type lava plain, complicated by craters smaller than 500 m. The average regolith thickness is 2–3 m. The magnetograms of this section are presented in figure 3.

In sections where there are no craters penetrating through the regolith of the rocky base, vector H has primarily a south direction and a value of 20 gammas; Z has a value of 10–15 gammas.

Section III–III. Section III–III is on the west side of Straight Rille. Lunokhod initially moved about 500 m away from the rille to the west-southwest and then returned to the rille, approaching to within 10–20 m of the edge of the rille. The probable distance from the main tectonic fault, which formed the west side of the rille is 50–100 m. The terrain structure distant from the rille is similar to the structure of other mare-type sections. In the edge zone of the rille, the regolith thickness decreases to 1–1.5 m. Tectonic cracks, connected with the main faults, are possible here, in the rock of the basement.

The magnetograms of section III–III are presented in figure 4. Both traverses reveal agreement in direction (southwest) and magnitude (H = 20 gammas) of the field. The vertical component Z averages 20 gammas. The field is quite uniform overall.

Appreciable changes in the direction of H (from the southwest to the east-northeast) and magnitude of H (from 20 to 10 gammas) and of Z (from 20 to 5 gammas), are observed in direct proximity to the edge of the

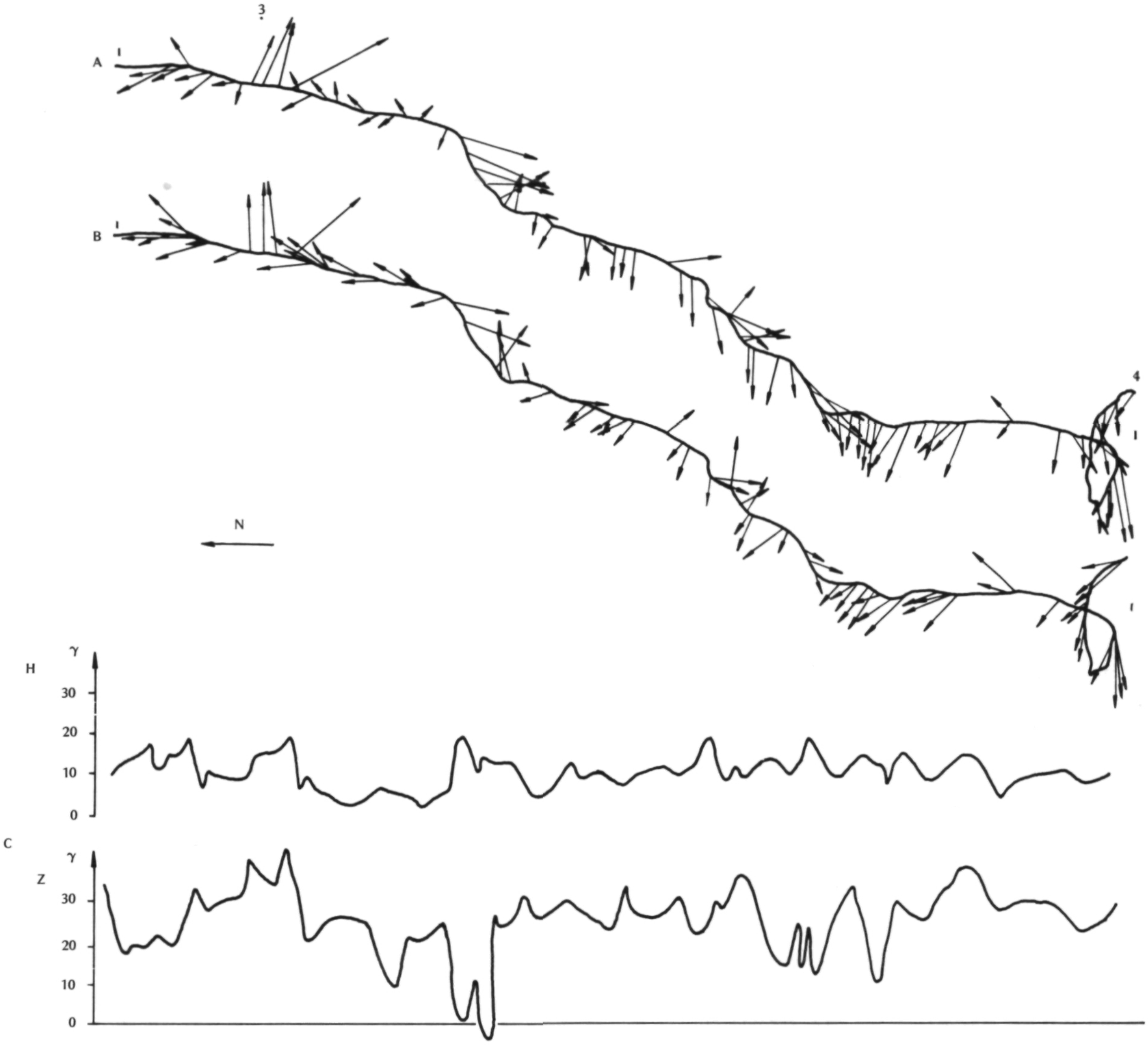

Figure 2B.—*Continuation of figure 2A.*

rille, at the beginning and end of section III–III.

On the scales of the route surveys on the Moon, it naturally is desirable to identify sections with fields of different characteristics and to determine their relationship to geological structures.

It is evident from what has been reported above that differences in the magnetic characteristics are small. Nevertheless, on routes oriented differently, lying on the mare sections and 5–10 km distant from each other, some similarity in behavior of the field is noted (see sections I–I, II–II, III–III).

Measurements in Craters

Magnetograms obtained while Lunokhod crossed craters penetrating through the regolith of the rocky base are presented in figure 5.

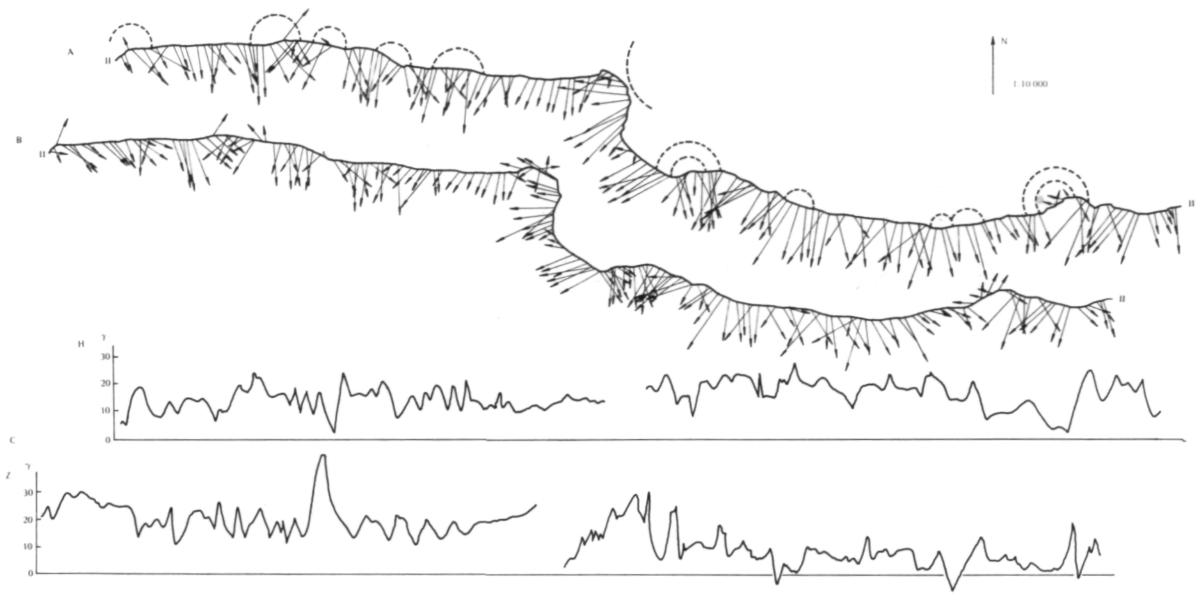

Figure 3.—*Lunokhod 2 magnetograms in section II–II: designations same as in figure 2.*

As is evident from the figure, the magnetograms are quite diverse, but some common properties can be noted:

a. The scalar value of the field magnitude T above the crater reveals noticeable changes within up to 10 gammas.
b. The greatest changes are observed above the edge of the crater.
c. The nature of changes in field components *H* and *Z* is quite diverse, but three basic types can be distinguished: *A*—above the center of the crater; *Z*—minimum; and *H*—maximum; B: above the center of the crater, *Z* is at a maximum and *H*, minimum; C: *Z* is at a maximum and *H* is at a minimum above the edge of the crater.

It should be noted that type C was observed in section II–II, where the route crossed a chain of craters located close together.

The craters discussed above have diameters of over 50 m and are in classes VS and S, i.e., their ratio of the diameter to the depth is 1/10 and 1/1.5, respectively, and the inclination is not over 7°. The effect of craters of smaller sizes, with the measurement accuracy noted, could not be detected.

The question arises, What is the origin of the field anomalies connected with the craters? All these craters are considerably younger formations than Le Monnier Bay. The change of field in the craters is close to or only a little less, in absolute value, than the average value of the field in the section of LeMonnier Bay examined. They can be connected, either with destruction of existing magnetization by impacts or with magnetization by impacts, which is proposed by Hide (ref. 7). Although details of this mechanism have not been described, it apparently cannot be effective without an external field. The existence of craters with types A and B magnetization would be easier to understand, if it is assumed that the external field was different in sign, and the magnetization was thermoremanent.

Beyond these speculations, we do not have the experimental data available which would permit a choice between possible mechanisms of magnetization. It is possible that the most important result is proof of confinement of the anomalies to craters of such sizes.

The SG–70 magnetometer with automatic range extension, installed aboard Lunokhod

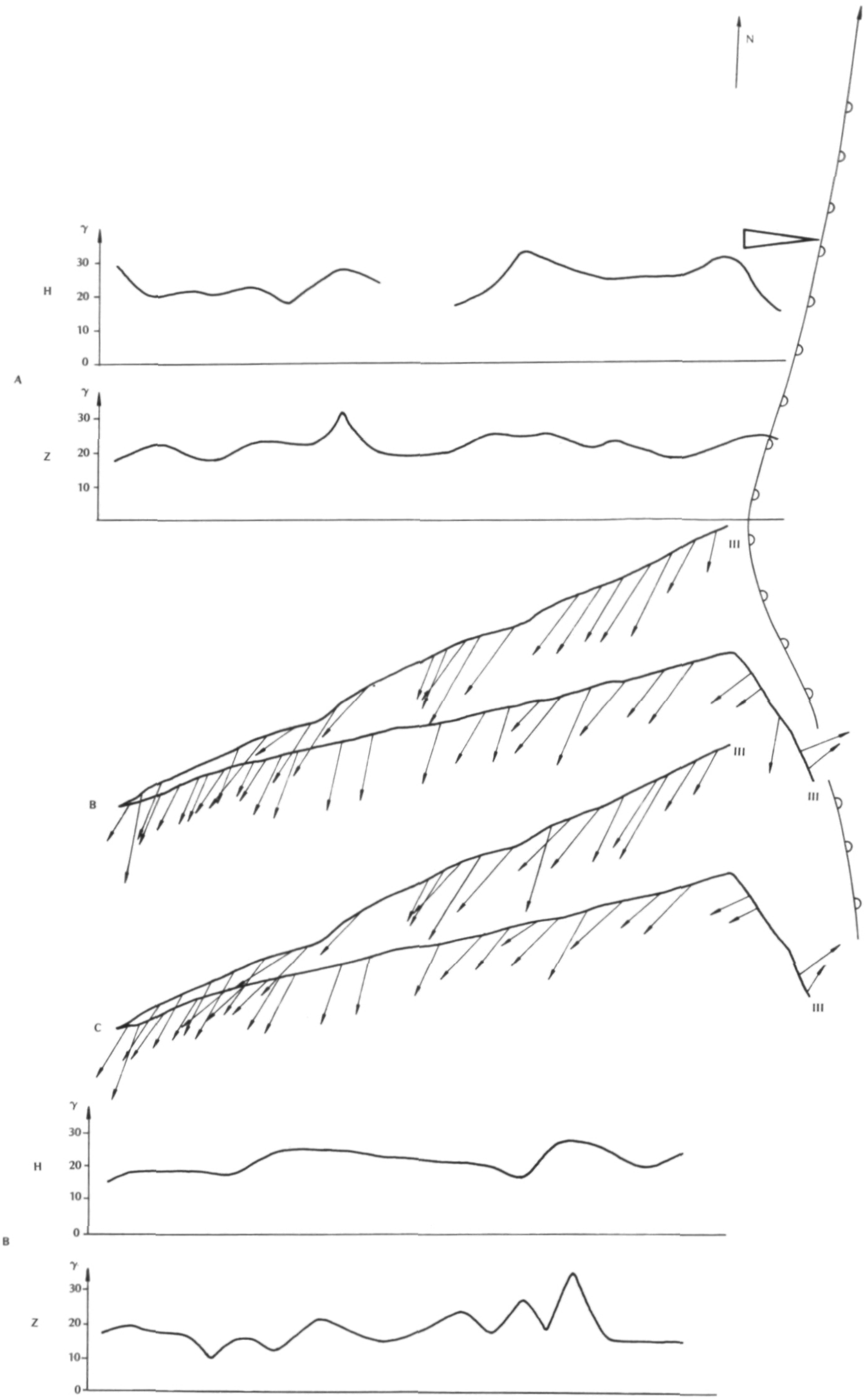

Figure 4.—*Lunokhod 2 magnetograms in section III–III at Straight Rille: (a) scalar values of* H *and* Z*, taking account of external field during departure from rille; (b) horizontal component* H *vector, taking account of external field; (c) horizontal component* H *vector, not taking account of external field; and (d) scalar values of* H *and* Z*, taking account of external field in approaching rille.*

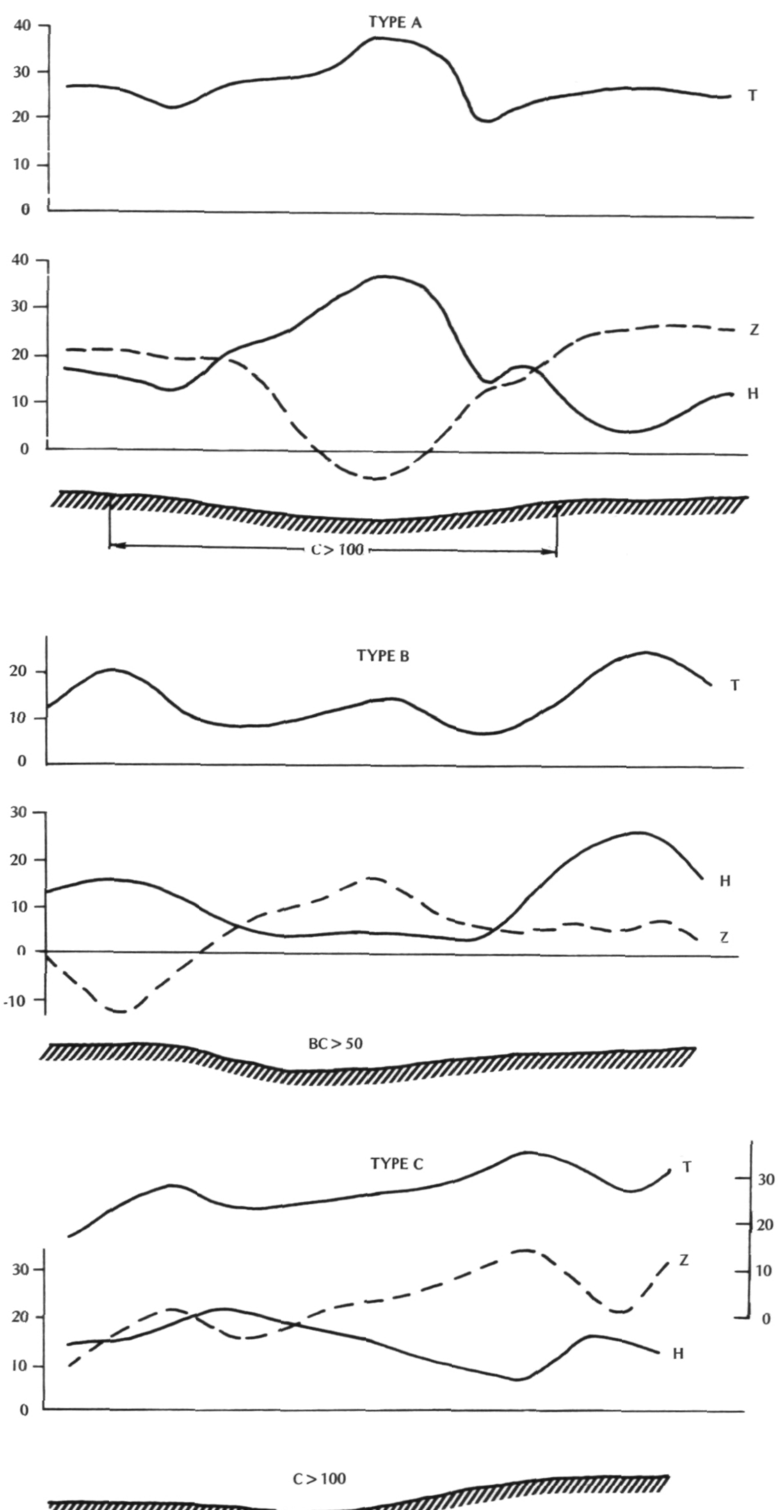

Figure 5.—*Magnetograms of horizontal* H *and vertical* Z *components above craters; angular dimensions in crater profiles given in scale.*

2, was designed and built in the Special Construction Brigade "Geologorazvedka," Ministry of Geology, U.S.S.R.

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