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MARE CRISIUM: REGIONAL STRATIGRAPHY AND GEOLOGIC HISTORY

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Abstract. Spectral reflectance measurements of five Luna 24 samples and new telescopic reflectance spectra of 10-20 km areas of seven sites in Mare Crisium have been used to calibrate multispectral images of mare units. Based on these data, three major mare units are defined in the Crisium basin and their stratigraphy is interpreted. The oldest mare unit is exposed in the ejecta of the craters Picard and Peirce and along the outer edge of the southeastern part of the basin. The next younger unit includes the Luna 24 site and generally follows a topographic annulus along the basin margin. The youngest mare unit occupies the central part of the basin. It is concluded that subsidence occurred throughout the emplacement of mare units, including extensive warping and downfaulting of the inner part of the Crisium basin.

Introduction

Multispectral images and a single telescopic reflectance spectrum were used by Pieters et al. (1976) to infer the composition of surface units in Mare Crisium. They concluded that the area for which the spectrum was available had from 2-4% TiO_2 based on the .40/.56 μm ratio (Charette et al., 1974). The area lies 70 km northwest of the Luna 24 landing site and, prior to analysis of the samples, was thought likely to be representative of material returned in the Luna 24 core. Luna 24 samples, however, have ∿1% TiO_2 (Barsukov, 1977) and the laboratory spectra (Adams and Ralph, 1977, 1978) differ from the original telescopic spectrum.

New telescopic data indicate that there exists a previously unrecognized very low (<1.5%) titanium unit in the northern part of the Crisium basin which also occurs in irregular patches at and near the Luna 24 site. In this paper we combine evidence from Luna 24 samples, new telescopic reflectance data, and radar and other topographic data to produce a regional geologic map of the Crisium basin. Preliminary stratigraphic relationships are suggested and the geologic history of Mare Crisium is inferred. In a future paper (Head et al., 1978b) we discuss evidence for the composition (chemistry, mineralogy) of the Crisium units.

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Luna 24 Samples

Visible and near-infrared (0.35 μm to 2.5 μm) diffuse reflectance spectra were measured of five samples of Luna 24 soils by Adams and Ralph (1977, 1978). The surface soils were found to have a characteristic spectral signature, thus, the laboratory spectra form a basis for interpreting the telescopic spectra (Fig. 1). Laboratory spectra of samples 24077 and 24109, the relatively mature (Morris, 1977) samples from the top of the core, show strong absorption in the UV and near 1 μm, and are similar to the relative telescopic curves (Fig. 1) of geologic unit IIa (Fig. 2).

Remote Sensing Data

Telescopic spectra were obtained for areas 10-20 km in diameter (shown by crosses on Fig. 2). We have used the spectra (Fig. 1) and the spectral vidicon images (McCord et al., 1978) to define three major units in Mare Crisium (see Table 1). Unsubdivided highland crustal material makes up the rim of the Crisium impact basin and probably underlies all mare units. Unit I, which occurs along the eastern and southeastern edge of the basin, and around the craters Picard and Peirce, is similar in spectral properties to the Luna 16 site (Pieters and McCord, 1976). Unit II occurs in a roughly annular pattern at and near the edge of the mare, and in its southern and northwestern parts is similar in spectral reflectance to Luna 24 samples. Unit III, which occupies much of central Crisium, is somewhat similar spectrally to the Apollo 12 landing site and to central Mare Serenitatis. A more detailed subdivision and characterization of these units is presented in Head et al. (1978b).

As is shown in Table 1, the spectral vidicon

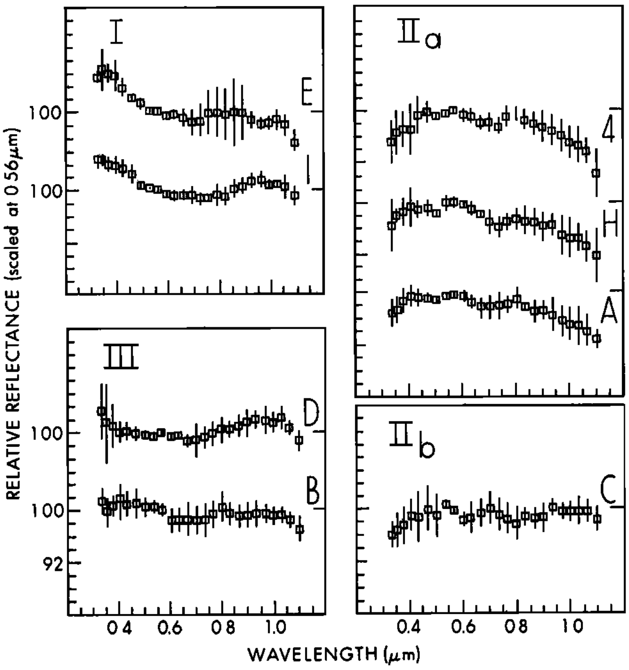

Fig. 1. Telescopic reflectance spectra for the Mare Crisium region divided by the spectrum for the Mare Serenitatis standard. Roman numerals indicate units; letters and numbers refer to specific spectra. Locations shown in Fig. 2.

and albedo data suggest that there is highland material in the craters Picard and Peirce. This interpretation is tentative as it is based only on the vidicon data, and we feel that spectra are needed for confirmation. Orbital x-ray fluorescence data do not show an increase in Al/Si over Picard (Andre et al., 1977; Hubbard and Vilas, 1977) as might be expected if highland material were exposed; however, the crater interiors are close to the limit of the orbital x-ray spatial resolution.

The x-ray data do show a significant increase in Mg/Si associated with the ejecta of Picard and thus with our unit I. Based on the principle of inverted stratigraphy on crater rims, we conclude that Picard (and Peirce) excavated unit I from depth. Hubbard and Vilas (1977) report an increase in Mg/Si just east of the Luna 24 landing site, where unit I also occurs, which further supports the spectral data which were used to correlate the eastern parts of unit I with the Picard and Peirce ejecta.

The regional topography (Head et al., 1977; Brown et al., 1974; Zisk, 1978) of Mare Crisium has a distinctive annular appearance. There is an outer shelf about 50 km wide around the basin except in the southwest. The inner margin of the shelf generally corresponds to the location of a mare ridge system. Basinward of the shelf is an annular topographic depression ranging up to 100 km in width. The most extensive low region in the basin (unrelated to craters) occurs in the northeast part of this band. The central part of the basin is a broad topographic high over 150 km in diameter centered on a narrow north-south ridge.

Mare surface slopes and the annular nature of unit boundaries suggest that the present topographic configuration of the mare is not simply the result of continued accumulation of lavas on the Crisium basin floor. The mare floor appears to have subsided by at least 400 m in a belt between the outer shelf and the inner elevated portion. A series of scarps and mare ridges generally marks the inner boundary of the outer shelf. Relationships between the style of mare emplacement and the topographic evolution of the basin floor have been observed in other mare regions (Howard et al., 1973; Boyce, 1976; Pieters et al., 1977; Whitford-Stark and Head, 1977). Thus, coincident with the phase of volcanic emplacement of the mare, the topography was not only shallowing due to fill, but also changing due to subsidence and associated activity.

Unit I is the earliest mare unit that is presently visible at the surface. Its relative age is indicated by its presence in the ejecta deposits on the rim of the large craters Peirce and Picard. This ejecta overlies units II and III. Unit I also is exposed around the southeast edge of the basin, where it is bounded on the mare side by an extensive set of mare ridges and a topographic drop of over 200 meters. Unit I appears to have been emplaced originally over a large part of the basin, on the basis of its distribution and its presence in Peirce and Picard ejecta deposits. Low albedo rims on the craters Greaves and Swift suggest that this unit may exist under the present surface of the mare shelf in the southwest and northern parts of the basin.

Unit II is complex, with two major subdiv-

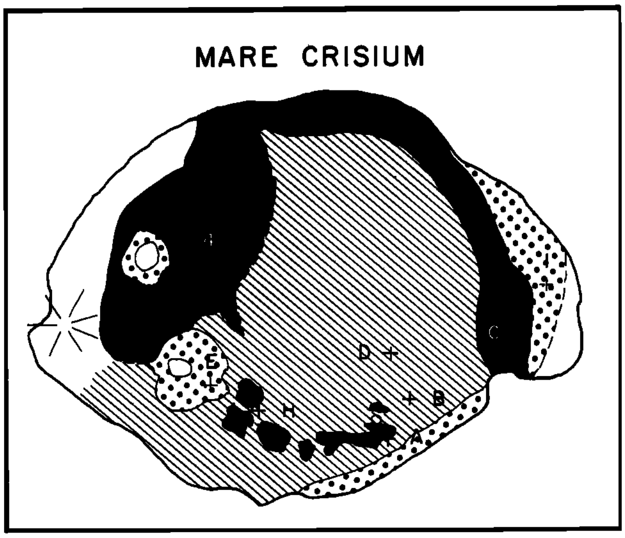

Fig. 2. Preliminary map of geologic units of Mare Crisium. Units are defined and distinguished on the basis of a variety of data derived from remote sensing techniques (see Head et al., 1978a). Unit I, dots; II, black; III, ruled. Crosses indicate position of spectra indicated in Fig. 1. Unpatterned areas within Mare Crisium have not been mapped except for the floors of Peirce (circular feature just west of 4) and Picard (circular structure just west of E), which appear to be highlands material. Luna 24 site located approximately at the cross indicated at A. Small circle above A is Fahrenheit crater.

Table 1. Units in Mare Crisium as defined by spectral reflectance properties.

Units	Defining Spectral Properties	Locations of Units	Available Data*
highlands	high albedo weak 1 μm absorption	a) highlands surrounding Crisium basin b) centers of craters Picard and Peirce	a) .56 μm and .95/.56 μm images b) .56 μm and .95/.56 μm images
I	low albedo high .40/.56 μm ratio weak 1 μm absorption	a) ejecta of Picard and Peirce b) topographically high mare region at eastern edge of basin c) topographically high mare region along southeastern edge of basin	a) spectrum E (Picard) and .45 μm and .40/.56 μm images; low radar backscatter b) spectrum I and .56 μm and .40/.56 μm images c) .56 μm and .40/.56 μm images; also one poor quality spectrum suggestive of I (above)
II	intermediate albedo low to intermediate .40/.56 μm ratio strong 1 μm absorption	a) Luna 24 landing site and mottled areas in southern part of basin b) extensive areas in northwestern Crisium c) topographically high mare shelf in northern and eastern parts of basin	a) spectrum A; spectrum H; .56 μm and .40/.56 μm images b) spectrum 4 c) spectrum C; .56 μm and .40/.56 images; also .6-.4 μm color difference image (Whitaker, personal communication)
III	intermediate albedo intermediate .40/.56 μm intermediate 1 μm absorption	a) central Crisium basin	a) spectrum D and spectrum B; .56 μm and .40/.56 μm images

*.56 μm and .40/.56 μm images are published in Pieters et al. (1976) and McCord et al. (1978). Locations of spectra are shown in Fig. 2.

isions. Although it can be shown locally that unit II is younger than unit I, these two units may have been emplaced in part contemporaneously. Unit II appears to have been deposited over much of the basin; it underlies unit III, as is evidenced by the topographic elevation and annular nature of much of unit II and its patchy nature between the Luna 24 site and Picard. Continued downwarping of the basin after the emplacement of unit II further deformed the older mare units. Unit III was emplaced primarily in the central portion of Crisium and appears thicker in the east central part of the basin. Continued subsidence was concentrated in the east within the annulus, which is today one of the lowest parts of the basin.

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