HIGHLAND CRUST DIVERSITY AND MARE-HIGHLAND MIXING RELATIONSHIPS IN THE MARE HUMORUM REGION OF THE MOON: A CLOSER LOOK WITH UV/VIS CLEMENTINE MULTISPECTRAL IMAGES:

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Introduction: Following the results issued from Clementine UV/VIS multispectral analyses at 340m per pixel spatial resolution (1,2), we present in Figure 1 three schematic cross sections through mare-highland boundaries, which give insights into the stratigraphic properties within the Humorum basin area. Regions of particular interest are the mare-highland western boundaries, the northwestern highlands, and the low-albedo unit in the highlands west of the basin. Spatially coherent spectral units have been identified, characterized, and mapped according to combined specific spectral characteristics such as iron and titanium content, soil maturity, and fractional abundance with respect to selected spectral end-members (1). The spatial identification, which is consistent with previous interpretations of the area (3,4), is much improved by the high spatial resolution available. As described below, the results emphasize the complex relationships that exist between surface materials at regional or local scale, particularly at the basin boundaries, and lead to some implications on the nature, emplacement, and contamination of the identified units.

Highland crust diversity: The neighboring western highland region, relatively mature, exhibits FeO contents typical of a feldspathic crust (below 8%), with spatial variations which can be attributed to slight changes in the feldspathic composition. The concentric pattern found associated with the ring structure of the basin (2) indicates that the emplacement processes of the highland surface materials, at least westward of the basin, have been strongly influenced by the Humorum event. Variations in spectral properties of the materials that have been excavated, transported and deposited at variable radial distance from the basin center during the impact, might then reflect the changes in pre-impact crustal stratigraphy. In addition, a large portion of this area of the highlands exhibits spectral characteristics and FeO values (6 to 8%) indicating that the materials could be either of noritic composition or slightly more mafic and resemble LKFM rocks (e.g., 5). A significant presence of LKFM rocks nearby the boundaries of Humorum would seem to be a reasonable interpretation, since these lunar rocks are suggested to represent crustal rocks formed during basin-forming impact events. Within this major western highland unit, Figure 1a shows the presence of a pure-anorthosite unit located along the northwestern mare-bounding ring (2), which mostly corresponds to fresh craters, crater rims, and very bright ejecta (e.g., Mersenius C, P, S, Liebig, or the Gassendi E&K complex). Figure 1a also shows an area of materials located northwest of Mersenius toward Herigonius, Letronne, and Billy regions, which is lower in topography compared to the mare-bounding ring. This intermediate-albedo, highly mature unit, which exhibits locally mare-like contributions (2), might indicate the presence of cryptomaria, in consistency with the conclusions of (6), or materials partially covered by crater ejecta or basaltic flows, such as exposed remnants of regional deposits. Measurements acquired in the infrared would allow to bring answer elements for confirming the presence of such undefined deposits. The low radar returns obtained in this area might indicate a deficit of fragments of size 1 to 50-cm on or near the surface, or the presence of materials having a dielectric constant different from those of typical highland materials (4,7).

The cross-section in Figure 1b indicates the presence of potential cryptomare (e.g., 8) materials located between the craters Liebig and Palmieri (2). Spectral features of these terrains of lower albedo than the surrounding highlands indicate mare optical properties, with FeO contents ranging from 9.5 to 13%. According to (2), two processes of formation are proposed, as shown in Fig. 1b: the existence of mafic intrusions such as dikes (9) formed prior to the basin infilling, or a contemporaneous emplacement with Mare Humorum basaltic flows.

The southwestern portion of the highlands, of positive elevation, reveals very fresh, spectrally heterogeneous, high-albedo materials (Fig. 1c). This region might reflect a local reworking of the soils relatively recently, responsible for the optical heterogeneity at the subpixel scale. This reworking process might be related either to the residual cratering process (balistic redistribution of ejecta and regolith modification) or to instabilities of the slopes due to gravity which could be indirectly implied by the impact processes.

Mare-highland mixing relationships: We discuss here physical mixing processes that imply lateral and vertical transport and mixing of materials throughout geologic boundaries, resulting from impacts in the vicinity of impact basins (6,10,11). In our study of the Humorum area, the width of the mixing zone is typically several tens of km but the mixing gradient is not uniform, with sharp transitions in some areas along the basin rim. Narrow mixing gradients are found southwest of the basin, in the Doppelmayer region (Fig. 1c), and can be interpreted by a limited lateral transport of feldspathic materials in the mare areas. More complex mixing gradients are present along the western basin rim, from the Liebig F crater to the southwest of Gassendi (Fig. 1b), and are attributed to ejecta deposition subsequent to the balistic transport of material initiated by distant (several tens of km) impacts (2). Contamination by feldspathic materials is essentially present near mare-highland boundaries, which can result from both vertical mixing from below and lateral transport of materials along crater rays and ejecta blankets (e.g., 12). However, mare basalts within the basin are found little contaminated or affected by highland debris. Much of this mixing appears to have occurred laterally along the western border. Given the fractional variations of highland abundance across the mare-highland boundary, the mixing gradient is found progressive, and can be considered as a moderate mixing gradient, according to the definition given by (6) (Fig. 1a).

Conclusions: By the light of these conclusions, we propose a revision of the optical, compositional, and stratigraphic properties of the Humorum region. The diversity in crustal stratigraphy proves the complexity of processes which occurred consequently to the impact. The study of mare-highland contacts also reveals a significant complexity of emplacement of the materials, with variable mixing gradients suggesting varied processes of physical mixing of materials throughout the geologic boundaries of the basin. In order to confirm this complexity, a next step would consist in studying these regions of interest at a more local scale and, if possible, integrate the information provided by the Clementine near-infrared channels and future lunar missions.

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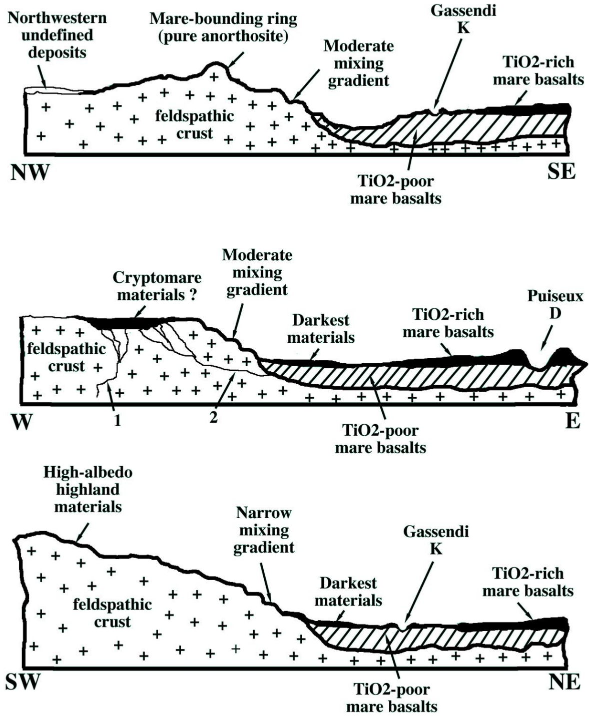

Figure 1: Several schematic cross sections resulting from the spectral units identification, taking into account the regional and local topography. From top to bottom: (a) through the NW-SE highland-mare boundary, crossing Mersenius P and Gassendi K. (b) through the W-E highland-mare boundary, crossing Puiseux D. (c) through the SW-NE highland-mare boundary, crossing Gassendi K. Variations in topography indicate that the southwestern highlands exhibit more relief, and that the northwestern part of the basin is lower than other basaltic areas of Mare Humorum. The difference between the two basaltic units is also shown, with the TiO$_2$-rich unit which covers the eastern part of the TiO$_2$-poor unit.