THE MARE HUMORUM REGION OF THE MOON: NEW OPTICAL, COMPOSITIONAL, AND GEOLOGICAL INFERENCES FROM CLEMENTINE.

P.D. Martin, P.C. Pinet, and S.D. Chevrel; UMR5562/CNRS, Observatoire Midi-Pyrénées, 14 Avenue E. Belin, F-31400 Toulouse, FRANCE.

Introduction. The present paper deals with a detailed assessment of the surface properties in the Mare Humorum region of the Moon. Spectral investigations have been made by means of the processing and analysis of Clementine UV/VIS multispectral data, at 340m spatial resolution, in order to provide new insights into both optical/compositional heterogeneities and emplacement of the geological units within the basin interior and vicinity. The spatial coverage of our image-cube (more than 2.6 million spectra) maps the western part of the basin, up to the longitude of Vitello E. An extended highland area is also mapped west of the basin, including the western portion of the mare-bounding ring. Spatially coherent spectral units have been identified with the application of a new methodology, consisting in a coupled approach of a principal component analysis and an iterative linear mixing modeling. Information on maturity, iron abundance (1), and titanium content (mare) is also considered for the selection of the successive endmembers combinations. The results of our preliminary analyses are presented below. We discuss the information derived from the abundance maps in relation with the previous interpretations of remotely-sensed data of the region and draw some new inferences that document the nature and origin of the spectrally identified materials.

Evidence for pure anorthosite. Three components located in the highlands are required to explain nearly all the variability of the surface properties of the units surrounding Humorum. The analysis of the highlands abundance maps indicates the existence of optical heterogeneities within these units. The most extended highland unit presents a concentric distribution which is found associated with the ring structure of the basin. Among these regions having low iron abundance (Fe < 8%), we have established the presence and extent of an anorthosite-bearing surface unit in the northwestern highlands. This unit, located in the close vicinity of Mersenius P and S, is interpreted to be composed of pure anorthosite on the basis of its very low Fe abundance (<3%). This conclusion corroborates those derived from analyses of spot spectra conducted by (2, 3) in the mare-bounding ring region, with the additional information of extension of this unit. Concerning variations in fractional abundances of the highland units surrounding Humorum, they are proposed to be the result of varied proportions of anorthosite.

Evidence for pyroclastic deposits. Among the three major spectral units representative of the highland materials, the area located northwest of Mersenius toward Herigonius and Letronne regions, which is low in topography, corresponds to intermediate-albedo terrains and exhibits locally mare-like subpixel contributions. Its spectral properties confirm its very specific characteristics (3, 4), with a spectrum presenting close features with spectra of Gruithuisen or Aristarchus Plateau regions (5, 6) (e.g., UV/VIS ratio < 0.9), in favor of the presence of pyroclastic deposits in this area. These deposits might be the exposed remnants of regional deposits that have been subsequently partially covered by crater ejecta (7), and might be of pre-Nectarian age.

Basin mare units and mare-highland mixing. Two major mature, Fe-rich (13-17%) basaltic units are found to be present within Mare Humorum. The unit covering the western portion of the basin (up to the longitude of Vitello) exhibits the lower 0.40/0.75 μm ratios and corresponds to a low-titanium unit (2-3%). Its UV-near infrared spectral features indicate hDS basalts (8), composed of clinopyroxene. The unit covering the eastern portion is found more recent, is higher in titanium content (5-7%), and exhibits characteristics of mIS basalts (8) bearing less abundant clinopyroxene than the Ti-rich unit. Within both these mare units, the upper regolith layer appears to be locally disturbed by the regolith reworking due to small impact craters, the 340m resolution contributing easily to depict these local lateral variations.

Besides the identification of spatially coherent spectral units, mare-highland relations have been studied and reveal the great complexity of the region at the boundary of the impact basin. The results concern the processes of physical mixing of materials throughout the geologic boundaries. These processes are found to be closely related to the lateral transport of materials due to the impacts, as shown recently in the vicinity of other impact basins by, e.g., (9), (10), and (11). The width of the mixing zone is typically several tens of km but not uniformly. The mixing gradient is also 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, and can be interpreted by a limited lateral transport of highland materials in the mare areas. More complex mixing gradients are located along the western basin rim, from the Liebig F crater to the southwest of Gassendi, and are attributed to ejecta deposition subsequent to the balistic transport of material initiated by distant (several tens of km) impacts.

Evidence for cryptomaria. Within the western highlands, between the mare-bounding ring and the next tectonic ring, the spectral features of the dark terrains located between the craters Liebig and Palmieri (23° to 28°S in latitude) indicate mare optical properties. Fractional abundances relative to the low-titanium mare endmember are of the order of 60 to 80% for these areas. The proposed interpretation for this mare-like surface unit which lies outside the Humorum basin boundary is the presence of basaltic materials mixed with or covered by higher-albedo ejecta deposits, also called cryptomaria (e.g., 12, 13). Basaltic mare areas might have formed in the southwest of Mare Humorum (25 to 100 km from the basin boundary), contemporaneously with the emplacement of the basaltic flows of Mare Humorum. The alternative interpretation could be the existence of mafic intrusions such as dikes (13) formed prior to the basin infilling, which might constitute an evidence for ancient (prior to 3.8 Gy) lunar volcanism. Subsequent impacts might have deposited ejecta materials in weak proportions and thickness, and therefore masked the greatest part of these areas.

Conclusions. These results show the existence of a great compositional diversity in the highland regions, and present new perspectives on the emplacement, extension, and chronology of ancient volcanic events in this region of the Moon. An important point is that, with the help of an extended spatial coverage at high resolution, we have been able to relate the spatial variations of the surface spectral properties with the geologic structures associated with the formation of the Humorum impact basin. A potential implication of this work could consist in the establishment of a generalized study of the geological evolution of other lunar impact basins, the Humorum basin case being just an example.

References. **1.** Lucey, P.G. et al., Science, 268, 1995; **2.** Spudis, P.D. et al., Proc. of the 15th Lunar and Planet. Sci. Conf., J. Geophys. Res., 89, Suppl., C197-C210, 1984; **3.** Hawke, B.R. et al., Geophys. Res. Lett., 20, 6, 419-422, 1993; **4.** Gaddis, L.R. et al., Icarus, 61, 461-489, 1985; **5.** Chevrel, S.D. et al., Lunar and Planet. Sci. Conf., 27th, 215-216, 1996; **6.** Pinet, P.C. et al., Lunar and Planet. Sci. Conf., 27th, 1037-1038, 1996; **7.** Coombs, C.R. and Hawke, B.R., Proc. of the 22nd Lunar and Planet. Sci. Conf., 303-312, 1992; **8.** Pieters, C.M., Proc. of the 9th Lunar and Planet. Sci. Conf., Houston, Texas, 2825-2849, 1978; **9.** Staid, M.I. et al., Lunar and Planet. Sci. Conf., 25th, 1329-1330, 1994; **10.** Fischer, E.M., and Pieters, C.M., J. Geophys. Res., 100, 23279-23290, 1995; **11.** Mustard, J.F. and Head, J.W. III, J. Geophys. Res., 101, E8, 18913-18925, 1996; **12.** Hawke, B.R. and Spudis, P.D., Geochim. et Cosmochim. Acta Suppl., 12, 467-481, 1980; **13.** Head, J.W. and Wilson, Geochim. et Cosmochim. Acta, 56, 2144-2175, 1992.