REMOTE SENSING STUDIES OF PYROCLASTIC DEPOSITS IN THE MARE HUMORUM REGION.
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Introduction: In recent years, interest in lunar dark mantle deposits of pyroclastic origin has greatly increased. In part, this interest is due to the results of intensive studies of lunar pyroclastic glasses [e.g., 1, 2], as well as remote sensing investigations of both localized and regional pyroclastic deposits [3, 4]. Laboratory analyses of pyroclastic spheres from several regional deposits show that this volcanic debris had a greater depth of origin and lesser fractional crystallization than mare basalts [e.g., 1, 5]. These data indicate that pyroclastic glasses are the best examples of primitive materials on the Moon, and they are of critical importance both in characterizing the lunar interior and as a starting place for understanding the origin and evolution of lunar basaltic magmatism [4]. Interest in regional dark mantle deposits has also been increased by the suggestion that pyroclastic debris would be an excellent lunar resource, and that pyroclastic deposits would be prime sites for the establishment of lunar bases [6]. Additional remote sensing and geologic studies are needed to assess the full resource potential of regional pyroclastic deposits and address key scientific issues concerning their origin. We have used a wide variety of remote sensing data to investigate pyroclastic deposits in the Mare Humorum region. The purposes of this study are to: 1) identify and map the extent of pyroclastic deposits, 2) determine the composition and degree of contamination of the regional deposits, 3) measure deposit thicknesses, and 4) assess their resource potential.

Methods: The U.S.G.S. has published on CD-ROM a Clementine 5-color UV-VIS digital image model for the Moon [e.g., 7]. Data from this model were mosaicked to produce an image cube for the Humorum region. This calibrated image cube served as the basis for the production of a number of data products, including optical maturity (OMAT) images and FeO and TiO_2 maps [8, 9]. In addition, Earth-based telescopic near-IR reflectance spectra obtained for various units in the Humorum region were utilized in this investigation. Finally, the depolarized 12.6-cm and 70-cm radar images recently obtained by Campbell *et al*. [10, 11] were used to investigate the surface textures and block populations of pyroclastic units in the Humorum region.

Results and Discussion:

Deposit Location, Characteristics, and Geology. A very large pyroclastic deposit of regional extent has been identified in the southwestern portion of Mare Humorum [12, 13]. The elongate deposit extends from Liebig F in the NW to Doppelmayer G in the SE and has an area of ~ 1475 km^2[4]. The SW Humorum (SWH) pyroclastics largely overlie older mare basalt deposits. The eastern portion of the SWH unit is embayed by younger mare basalts. The 12.6-cm and 70-cm radar data indicate that the pyroclastics are thickest (>10m) in an area that extends for ~15 km on each side of Rima Doppelmayer I. To the west, the SWH deposit becomes much thinner. The thick portion of the SWH unit exhibits a low albedo, high FeO values (16-18 wt%), and very low OMAT values. The thinner SWH deposits have slightly higher albedo values and lower FeO abundances. The depolarized 12.6-cm and 70-cm radar images were used to characterize centimeter- to decimeter-scale rock abundances over a range of depths within the thickest portion of the SWH deposit. The low returns in both of these data sets indicate a rock-poor area that would be well-suited for resource exploitation. The association of the thickest portion of the SWH deposit with Rima Doppelmayer I suggests that the source vents for SWH may be located along this rille. A number of possible vents have been identified.

A second very large regional pyroclastic deposit has been identified in and SE of Doppelmayer crater [12, 13]. The thickest portions of this deposit are located on the NE floor and rim of Doppelmayer. Dark mantling materials were also identified on the NW and SE flanks of the crater. The Doppelmayer pyroclastic deposit extends to the SE and occurs in and around Vitello crater. The thickest portions of the Doppelmayer deposit exhibit low albedo values, high FeO abundances (16-18 wt%), and low OMAT values. The depolarized 70-cm radar returns from these thick pyroclastic deposits are attenuated but are not as low as those measured for the SWH unit. The relatively high depolarized 70-cm returns from the dark material on the flanks of Vitello indicate that the pyroclastic deposit is thin (<7m) in this area. No well-defined source vents have been identified in the Doppelmayer region.

Other dark mantle deposits of pyroclastic origin have been identified in the Mare Humorum region. These include the small, localized pyroclastic deposits on the floor of Mersenius crater [4, 14], the dark mantle deposit NE of Liebig [12], the pyroclastic unit NE of Loewy, and a small dark mantle deposit on Rupes Kelvin.

Deposit Composition. In order to determine the compositions of the regional pyroclastic units in the Mare Humorum region, five Earth-based near-IR reflectance spectra were obtained for these deposits using the University of Hawaii 2.24-m telescope at the Mauna Kea Observatory. Spectra were collected for three portions of the SW Humorum deposit and two spots on the Doppelmayer deposit. The spectra of these five areas share similar spectral characteristics. They all exhibit steep infrared continua, low albedoes, and very broad absorption bands (>0.4 µm) centered longward of 1 µm. Similar parameters were determined for the spectra collected for the pyroclastic deposits on the Aristarchus Plateau [3, 15, 16]. Numerous workers have attributed these characteristics to Fe^{2+}-bearing pyroclastic glass [3, 4, 15, 16]. We also attribute these spectral characteristics to the presence of Fe^{2+}-bearing glass in the SW Humorum and Doppelmayer regional pyroclastic deposits. It is important to note that all portions of both of the very large pyroclastic deposits of regional extent in the Mare Humorum region are dominated by Fe^{2+}-bearing pyroclastic glasses. Minor spectral differences among the various spectra appear to be due to varying amounts contamination by non-pyroclastic debris. We are currently conducting spectral mixing studies of the Humorum region using Clementine UV-VIS imagery which should provide information concerning the degree of contamination of the regional pyroclastic deposits.

Wilcox et al. [17] have recently presented the results of a radiative transfer modeling study of a high quality Earth-based spectrum obtained for the SW Humorum regional pyroclastic deposit. This technique uses the measured optical constants of glasses to predict the bidirectional reflectance of a particulate glass surface as a function of Fe and Ti concentration, particle size, and maturity in order to find the best spectral match to the remotely observed deposits. Wilcox et al. [17] found that model spectra of pure glass provided a good match to the SW Humorum spectrum and indicated that the glasses in the deposit had very low TiO_2 abundances and an iron content of 20 wt% FeO.

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