REMOTE SENSING AND GEOLOGIC STUDIES OF THE NORTHEASTERN PORTION OF THE LUNAR NEARSIDE: FINAL RESULTS. B.R. Hawke[1], T.A. Giguere[2], D.T. Blewett[3], J.M. Boyce[1], J. Cahill[1], J.J. Gillis-Davis[1], J.J. Hagerty[4], P.G. Lucey[1], C.A. Peterson[1], G.A. Smith[1], P.D. Spudis[5], and G.J. Taylor[1], [1]Hawaii Institute of Geophysics and Planetology, University of Hawaii, Honolulu, HI 96822, [2]Intergraph Corporation, P.O. Box 75330, Kapolei, HI 96707, [3]Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, [4]U.S. Geological Survey, Astrogeology Program, 2255 N. Gemini Drive, Flagstaff, AZ 86001, [5]Lunar and Planetary Institute, Houston, TX 77058.

Introduction: Parts of the northeastern nearside (NEN) north and east of Mare Frigoris display light plains deposits with a variety of ages and possible cryptomare deposits [1, 2, 3]. We have selected a portion of this area for an intensive remote sensing and geologic investigation. This NEN region is centered just east of Mare Frigoris at 52º N, 40º E and includes the craters Atlas, Hercules, Thales, Gartner, Democritus, Cepheus, and Kane. The purposes of this study were to determine the locations and compositions of cryptomare deposits and to investigate the origin of light plains deposits in the NEN region.

Methods: The U.S. Geological Survey's Astrogeology Program has published on CD-ROM a Clementine five-color UV-VIS digital image model (DIM) for the Moon [e.g., 4]. Data from this DIM were mosaicked to produce an image cube centered on the NEN region. This calibrated image cube served as the basis for the production of a number of data products, including optical maturity (OMAT) images and TiO_2 and FeO maps [5, 6]. Five-point spectra were extracted from the calibrated and registered Clementine UV-VIS image cube. In addition, Earth-based telescopic near-IR reflectance spectra obtained for various units in the NEN region were utilized in the investigation [3]. Finally, a wide variety of Earth-based and spacecraft imagery was used in this study.

Results and Discussion:

Dark-Haloed Impact Craters (DHCs) and Iron-Rich Ejecta Craters (IRECs). In previous investigations, the presence of dark-haloed impact craters with iron-rich ejecta has been used as one of several criteria for the identification of buried mare deposits or cryptomaria [e.g., 3, 7, 8, 9]. While several DHCs can be identified in Earth-based photographs of the NEN region obtained at low phase angles, they are difficult to discern in the Clementine 750 nm images obtained for these high latitudes. Hence, we have used IRECs to identify possible cryptomare units in the NEN region. Numerous IRECs were identified on highland units in the NEN region and 42 were selected for detailed analysis. Earth-based near-IR spectra exist for two of these IRECs. Gartner D is a small dark-haloed crater (diameter = 8 km) which excavated material from beneath the surface of a light plains unit in the floor of Gartner crater. Two spectra were obtained for Gartner D and both have relatively deep "1 µm" absorption bands centered longward of 0.95 µm. These characteristics indicate that mare basalt was exposed by this impact event. A near-IR spectrum was also collected for Hercules J, a DHC (diameter = 8 km) south of Hercules crater. This IREC excavated mare basalt from beneath the highlands-rich ejecta blanket emplaced by Hercules crater.

Five-point spectra were extracted for 42 IRECs in NEN region. Two spectral types were identified. Type 1 spectra closely resemble those obtained for mare craters and have strong "1 µm" bands centered near 0.95 µm. The materials exposed by these IRECs have mafic assemblages dominated by high-Ca clinopyroxene and appear to contain large amounts of mare basalt. Hence, the location of Type 1 IRECs can be used to map the distribution of cryptomare deposits in the NEN region.

Type 2 IREC spectra exhibit moderately strong "1 µm" bands centered shortward of 0.95 µm. The areas for which these spectra were collected have mafic assemblages dominated by low-Ca pyroxene. The FeO values for Type 2 IRECs generally range between 10.5 wt% and 12.0 wt% FeO. The material exposed by Type 2 IRECs is not typical mare basalt, and the rocks may not be volcanic in origin.

Crytomaria in the NEN Region. We have used the location of Type 1 IRECs to determine the distribution of cryptomare units in the NEN region. Cryptomare deposits occur in many portions of the region and are often associated with light plains units. The mapped cryptomare deposits extend from Thales F crater in the northeast to Cepheus crater in the southeast and from the eastern boundary of Mare Frigoris to Atlas A in the east. The cryptomare deposits appear to extend both east and south of our study area. A small expanse of cryptomare was mapped immediately north of a portion of eastern Mare Frigoris (northeast of Galle C and northwest of Gartner F).

Two processes appear to be largely responsible for the formation of cryptomare deposits in the NEN region. Cryptomaria that were formed by the burial of mare units by the thick, continuous ejecta of a single impact crater are termed Copernicus-type cryptomare because the relationship was first conclusively demonstrated at Copernicus crater. In the NEN region, Copernicus-type cryptomare deposits are associated with the ejecta blankets of Atlas, Hercules, and Cepheus craters. Far away from the continuous ejecta deposits of major impact craters, mare basalt flows can still be obscured by the compound effects of discontinuous, distal ejecta deposits of several nearby impact craters that excavated highlands materials. The deposition of this high-albedo, highlands-rich distal ejecta on flat mare surfaces can convert them into light plains deposits. Such a situation was documented by Hawke and Spudis [10] and Hawke *et al.* [9] near Balmer crater on the east limb of the Moon. Most of the cryptomare deposits in the NEN regions are Balmer-type cryptomare. The evidence indicates that Imbrian-aged mare flows were emplaced shortly after the Imbrium impact event and that these basaltic surfaces were contaminated with variable amounts of highland debris emplaced by craters such as Atlas, Hercules, Keldysh, Thales, Democritus, and Cepheus. Almost all of the light plains units immediately E and SE of Mare Frigoris were demonstrated to be cryptomare deposits.

The TiO_2 and FeO maps produced from UV-VIS images were used to determine the compositions of Type 1 IRECs in the NEN region. The FeO and TiO_2 values range between 9.9 wt% and 13.4 wt% FeO and from 0.3 wt% to 2.9 wt% TiO_2. This implies that both VLT and low-TiO_2 mare basalts were emplaced in the NEN region shortly after the formation of Imbrium basin. The higher TiO_2 values are associated with cryptomare deposits immediately north and east of Mare Frigoris [11,12].

Light Plains Deposits that Exhibit Type 2 IRECs. The Type 2 IRECs are concentrated on light plains deposits north of the eastern part of Mare Frigoris. The FeO and TiO_2 values for Type 2 IRECs generally range between 10.5 wt% and 12.0 wt% FeO and from 0.3 wt% to 0.7 wt% TiO_2. These Type 2 craters expose subsurface materials that exhibit very low TiO_2 abundances, relatively high FeO values, and mafic assemblages dominated by low-Ca pyroxenes. Since mare mafic assemblages are generally not dominated by low-Ca pyroxenes, the materials exposed by Type 2 IRECs are not typical mare basalts.

Several modes of origin are possible for these light plains units. They could be FeO-rich, fluidized ejecta deposits derived from Imbrium basin. However, several workers have determined that these light plains deposits have a surface age that is younger than the Imbrium event [13,14,15]. Hence, if the material was emplaced by the Imbrium impact, the surface age of the deposits must have been reset by some poorly understood process. Alternately, a volcanic origin (mare or nonmare) for these deposits is possible [e.g., 11,13,15]. However, if these light plains are cryptomare deposits [11], the buried mare basalts have a lithology unlike that typical of mare samples returned from the Moon.

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