REMOTE SENSING STUDIES OF GEOCHEMICAL AND SPECTRAL ANOMALIES ON THE NEARSIDE OF THE MOON. B. R. Hawke[1], D. J. Lawrence[2], D. T. Blewett[3], P. G. Lucey[1], G. A. Smith[1], G. J. Taylor[1], and P. D. Spudis[4], [1]Planetary Geosciences, Hawaii Institute of Geophysics and Planetology University of Hawaii, 2525 Correa Rd., Honolulu, HI 96822, [2]Los Alamos National Laboratory, MS D466, Los Alamos, NM 87545, [3]NovSol, 1100 Alakea Street, 23rd floor, Honolulu, HI 96813, [4]Lunar and Planetary Institute, Houston TX 77058.

Introduction: Lunar Red Spots make up a very important class of spectral anomalies on the lunar nearside. These features have spectra that are characterized by very strong ultraviolet absorptions, and Red Spots are generally located in the highlands. UV-IR color difference photographs were used by Whitaker [1] to identify and characterize Red Spots on the nearside of the Moon. He suggested that these anomalously red areas may have compositions that are substantially different from those of typical highlands. The identified red areas included Hansteen Alpha, Darney Chi and Tau, the Helmet, the southern portion of Montes Riphaeus, the Gruithuisen domes, and an area surrounding the anomalous craters Lassel K, G, and C.

In the immediate post-Apollo era, several workers presented evidence that at least some Red Spots were produced by highlands volcanism and suggested a connection with KREEP basalts (Medium-K Fra Mauro basalt {MKFMB}) or even more evolved highlands compositions (e.g., High-K Fra Mauro basalt {HKFMB}, dacite, rhyolite [2,3,4,5]. Malin [2] suggested that the Red Spots are the surface manifestations of pre-mare KREEP basalts. Wood and Head [3] suggested that some red material may have been involved in post-Imbrium extrusive volcanic activity prior to the emplacement of the major maria. Head and McCord [4] presented evidence that the Gruithuisen and Mairan domes represent morphologically and spectrally distinct nonmare extrusive volcanic features of Imbrian age.

In recent years, major controversies have been associated with highlands volcanism, the origin of KREEP, and the nature of Red Spots [e.g., 5,6,7]. Many questions remain unanswered. We have been using remote sensing data to determine the composition of selected Red Spots and to investigate the relationship between Red Spots and KREEP basalts and other evolved highland compositions [6].

Method: Both Earth-based and spacecraft remote sensing data were used to investigate the chemistry and mineralogy of lunar Red Spots. Chief among these were Clementine UVVIS images and Lunar Prospector orbital geochemistry data. Calibrated Clementine UVVIS data at 1 km/pixel spatial resolution were utilized to produce iron, titanium, and maturity images using the spectral algorithms of Lucey *et al.* [8.9]. Full resolution (100m/pixel) images were used to produce compositional and maturity maps of selected Red Spots. The 2° x 2° thorium data from the low-altitude portion of the Lunar Prospector mission [10] were reprojected and merged with shaded relief maps of the Red Spot regions. For the Hansteen Alpha and Gruithuisen domes regions, 0.5° x 0.5° Th maps were produced. The raw 0.5° x 0.5° thorium data have been smoothed by a two-dimensional, equal-area gaussian function with a 32 km HWHM. Telescopic near-infrared spectra were analyzed and interpreted for all of the Red Spots described below

Results and Discussion:

Helmet: This helmet-shaped highlands region lies just northeast of Mare Humorum and is about 40 km in diameter. Wood and Head [3] noted that this Red Spot is surrounded by younger mare material and consists of two terrain types: 1) a smooth plains unit which makes up about 60% of the Helmet area and 2) a hummocky to hilly unit which includes Herigonius Eta and Pi. Portions of the Helmet occur in four pixels in the Th map. These pixels exhibit the same range of Th values (4 to 6 ppm) as pixels in the surrounding region. The Helmet has FeO values of 10% to 14%, and TiO_2 values range from 0.5% to 2.0%. The higher FeO and TiO_2 values are immediately adjacent to the mare/highlands boundary and are clearly due to contamination by mare debris. FeO values of 10% to 12% are typical of the lesser contaminated portions of the Helmet.

Three near-IR spectra were obtained for the Helmet. Two spectra were collected for mature surfaces and exhibit “1 µm” absorption features (depth = 4.1% - 4.6%) that are centered between 0.95 µm and 0.96 µm. The spectrum for a small, fresh impact crater has a relatively deep “1 µm” band (depth = 11.4%) centered at 0.94 µm. A noritic composition is indicated. This uncontaminated noritic ejecta probably best represents the highlands lithology that dominates the Helmet.

Darney Chi and Tau: These adjacent spectral anomalies are located in Mare Cognitum. Darney Chi is a light plains unit while Darney Tau is composed of a series of hills. These features have a Th value of ~6 ppm. This value is well within the range of Th values exhibited by the surrounding region. Both have FeO values that range between 10% and 14% and TiO_2 values of 0.5% to 2.0%. The distribution patterns exhibited by FeO and TiO_2 suggest that these small features have been heavily contaminated by the surrounding mare material. Support for this suggestion is provided by the near-IR spectra collected for Darney Chi and Tau. These spectra have spectral parameters that indicate that they were obtained for highlands/mare mixtures.

Southern Montes Riphaeus: The Riphaeus Mts. form a 170 km arc along the northwestern edge of Mare Cognitum and appear to be on the rim of an ancient impact structure [3]. Wood and Head [3] noted that the southern 50 km of this mountain are distinctively red. The Th values for this area (6 to 7 ppm) are generally similar to those exhibited by adjacent units. However, higher Th values (7 to 9 ppm) are associated with the northern Riphaeus Mts. Those portions of the Red Spot that are least contaminated with mare basalt have FeO values of 8% to 12% and TiO_2 values less than 1.5%. A near-IR spectrum for a mature surface in the southern Riphaeus Mts. exhibits a "1 µm" absorption feature with a depth of 4.5%.

Hansteen Alpha: This arrowhead-shaped highlands feature is located in southern Oceanus Procellarum just north of the crater Billy. Wood and Head [3] noted that this rough textured triangular mound (~25 km on a side) appeared distinctive in its surface texture, color, and albedo from nearby highlands and is embayed by adjacent mare deposits. The 0.5° x 0.5° Th map indicates that Th abundances range from ~4.5 ppm to ~8 ppm in the Arrowhead region. The Arrowhead itself exhibits Th values of ~6 ppm. Slightly higher values (6.0 – 6.5 ppm) are associated with the eastern portion of Hansteen crater and its adjacent ejecta deposits. Even higher Th values (6.5 - 8 ppm) are exhibited by highlands units 100 km east of the Arrowhead. Based on these preliminary results, it does not appear that the Arrowhead is composed of highly evolved highlands lithologies that are extremely rich in Th.

The central portion of Hansteen Alpha has an FeO content of 5% to 8% and a TiO_2 abundance of <1%. Nearby highlands units are much richer in FeO and TiO_2. For example, the ejecta deposits of Billy and Hansteen craters exhibit FeO values that range between 11% and 15%. If the Arrowhead was present prior to the Billy and Hansteen impact events, it should have been covered by FeO-rich ejecta from both craters. Since it was not, the Arrowhead was formed after these Imbrian-aged craters. This Red Spot was emplaced by highlands volcanism.

Two near-IR spectra were obtained for Hansteen Alpha. Both have relatively shallow (3.7% - 4.1) "1 µm" bands centered shortward of 0.95 µm.

Gruithuisen Domes: Wood and Head [3] noted that Gruithuisen Gamma and Delta were distinctive red domical features 15 to 25 km in diameter that occur at the western edge of Mare Imbrium, south of Sinus Iridum. Head and McCord [4] identified a third spectrally distinct dome just northwest of Gruithuisen Gamma as well as three red domes just west of Mairan crater. They concluded that the Gruithuisen and Marian domes represent morphologically and spectrally distinct nonmare extrusive volcanic features of Imbrian age. Support for this interpretation was recently provided by Chevrel *et al.* [7].

The 0.5° x 0.5° Th map indicates that the Gruithuisen domes have Th values of about 8 ppm. Even higher Th values (10 to 12 ppm) are exhibited by highlands units northwest of the domes. Gamma and Delta exhibit FeO values between 6% and 10% and TiO_2 values <1%. The core portions of these domes have FeO abundances of 6% to 8% and very low (<0.5%) TiO_2 values. These values are lower than those typical of MKFMB.

Near-IR spectra were collected for Gruithuisen Gamma and Delta. These spectra differ from those collected for typical highland areas in that they exhibit relatively broad bands centered at or longward of 1 µm.

Mairan Crater: Mairan (diameter = 40km) is an Imbrian-age impact structure located in the highlands about 160 km northwest of the Gruithuisen domes. While Mairan crater was never identified as a Red Spot, a local Th high appears to be associated with the crater and its ejecta deposits. Th values exhibited by Mairan and its ejecta range from 10 to 12 ppm. The surrounding highlands have Th values of 7 to 10 ppm. Mairan-related deposits exhibit FeO values of 11 – 13%. Similar FeO abundances are displayed by the surrounding highlands. Slightly lower TiO_2 values (0.5% - 1.0%) appear to be associated with Mairan ejecta.

A near-IR reflectance spectrum was obtained for Mairan K, a small (diameter = 6km) impact crater that excavated material from beneath the distal portion of the Mairan ejecta deposit. The spectrum exhibits a moderately deep (8.1%) absorption band centered at ~0.97 µm. An anorthositic gabbro lithology is indicated.

References:

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