GEOLOGY AND COMPOSITION OF THE APENNINE MOUNTAINS, LUNAR IMBRIUM BASIN. D. Ben J. Bussey[1,2] Paul D. Spudis[2], B. Ray Hawke[3], Paul G. Lucey[3], and G. J. Taylor[3]. 1. ESTEC, ESA, Noordwijk NL 2. Lunar and Planetary Institute, Houston TX 77058 3. HIG/SOEST, Univ. Hawaii, Honolulu HI 96822

The Imbrium basin is the largest well preserved basin on the Moon, also being one of the most prominent features on the lunar near side [1]. Its deposits subdivide lunar history and were considered so important, that at least 2 Apollo missions (14 and 15) were sent to directly address aspects of Imbrium basin geology and at least two others (16 and 17) have probably inadvertently done so. We have continued our work [e.g., 2-5] using Clementine data to map the composition of basin deposits, with an aim of better understanding basin formation and to probe the composition and structure of the lunar crust. Here, we present results of a study of the Apennine mountain region (10°-30°N, 10°W-10°E), an area southeast of the Imbrium basin rim, containing unambiguous basin deposits (Fig. 1). The Apennines are part of the 1200 km diameter basin defining ring of Imbrium that also manifests itself as the Montes Carpatus south of the Apennines and as the Montes Caucasus to the east. We have used the various data processing techniques (described in [3]) to make compositional maps of the highland deposits here. Comparison of these results to those derived from other techniques [e.g., 6], as well as studies of returned lunar samples [e.g., 7], enables us to make inferences on the composition of the lunar crust in this region and planetwide.

Geological Setting of Studied Area. The Apennine range is a prominent landmark on the lunar near side (Fig. 1) and displays several key morphological properties [2, 8]. The northern mountains consist of rugged, equant massifs that make up the rim crest of Imbrium (such as Mt. Hadley, near the Apollo 15 site), interspersed with knobby, upland terrain, classified as Alpes Fm. north of Imbrium [1,8,9]. The southern portion of the range shows comparable massifs, but the backslope consists of much more rugged, hilly terrain (Apenninus material) that grades into classic Fra Mauro Fm. hummocks [1] farther away from the rim crest [2,6,8]. The distribution of highland units, in conjunction with their position with respect to the prominent rim crest of the basin, suggests that both units are dominantly basin ejecta, contaminated to an uncertain extent by energetic local mixing [10] and to a mappable extent due to burial by subsequent geological units. Position, morphology, and geological relations all suggest that the Apennine backslope is made up dominantly of Imbrium basin ejecta, comparable to the Montes Rook (=Alpes) and Hevelius (=Apenninus) Fms. of the better preserved Orientale basin [1-3]. A rugged range of massifs inside the Apennine crest (Montes Archimedes) makes up one of the interior rings of Imbrium; its topographic prominence is likely to be caused by the intersection of several older basin rings [8,11]. Surrounding these mountains is a smooth, high albedo, pre-mare plains unit called the Apennine Bench Fm. [12]. Different studies have advocated both impact [1] and volcanic [12,13] origins for this unit, so we also sought to test the idea that these plains are the regional expression of the Apollo 15 KREEP basalts [12,13] and thus, volcanic in origin [12-14].

Compositions in the Apennine Region. The Apennine backslope displays several compositional units, in part caused by the presence of ponds of mare basalt and blanketing by regional pyroclastic deposits (Figs. 1,2). Restricting attention to highland units, it is apparent that the basin deposits are compositionally heterogeneous. The dominance of green and yellow in the iron map indicates that the bulk FeO content of Apennine material is on the order of 8-12 wt.% (Fig. 2). This composition is broadly that of highland basalt, the infamous “low-K Fra Mauro” composition that has previously been proposed as the dominant Imbrium basin composition [2,6,7]. Within this setting occur broad zones that are rather more feldspathic, corresponding to as little as 2-4 wt.% FeO near the crater Conon (22 km; 21.5 N, 2 E). This same crater was also interpreted by [6] as showing a more feldspathic composition, based on the weaker strength of the 1-micron orthopyroxene absorption band. In fact, a comparison between the distribution of “norite” (class 1) and “anorthositic norite” (class 2) spectra and our new iron map shows a high degree of correspondence (cf. Fig. 5 of [6] (also reproduced as Fig. 7.7 in [2]) with our current Fig. 2). Although the bulk of the Imbrium ejecta is noritic, a substantial fraction is more feldspathic, including lithologies (south rim of Conon) that approach “noritic anorthosite” (FeO ~ 2 wt.%). Thus, compositions representative of the postulated lunar crust are all present in this region.

The smooth plains of the Apennine Bench Fm. are conspicuous in the data; they possess FeO ~ 8-12 wt.%. These values are completely coincident with Apollo 15 KREEP basalts (FeO ~ 8-10 wt.%) and corroborate interpretations from the spectra, which show the plains dominated by moderate-Ca clinopyroxene (pigeonite) [6]. Thus, yet another data set supports the concept that the Apennine Bench Fm. is made up of Apollo 15 KREEP basalts and is thus, of volcanic origin [12,13]. The massifs of the Apennine Bench appear to be slightly more mafic (FeO ~ 6-10 wt.%) than the bulk composition of the feldspathic portion of the Apennine backslope (FeO ~ 2-6 wt.%), in interesting contrast with the ring massifs of the Orientale basin, which display outcrops of pure anorthosite [3]. This suggests that the deeper crust in this region of the Moon may differ from that of the Orientale basin target.

In general, our new results are highly congruent with conclusions form previous studies. The bulk composition of the Apennines is basaltic and similar to that inferred from previous remote-sensing [6] and sample studies [2, 7]. Zones of relatively feldspathic composition occur within the central Apennines and the division of the backslope into "noritic" and "anorthositic norite" terrains based on Earth-based spectra [6] is corroborated by our new map. The Apennine Bench Fm. is made up of volcanic KREEP basalts, whose well-determined isotopic ages of 3.85 ± 0.05 b.y. tightly constrain the Imbrium basin to be no younger than that age [1,2]. Pyroclastic material of very high FeO content discontinuously mantles the highland units in this region. These results suggest that previous inferences that Imbrium excavated the entire crustal column of the Moon are correct, and both postulated upper crustal (anorthositic) and lower crustal (noritic) material being present in abundance. Future data on the distribution of Th from Lunar Prospector should allow us to better refine these estimates and unravel the complex history of the Imbrium basin.

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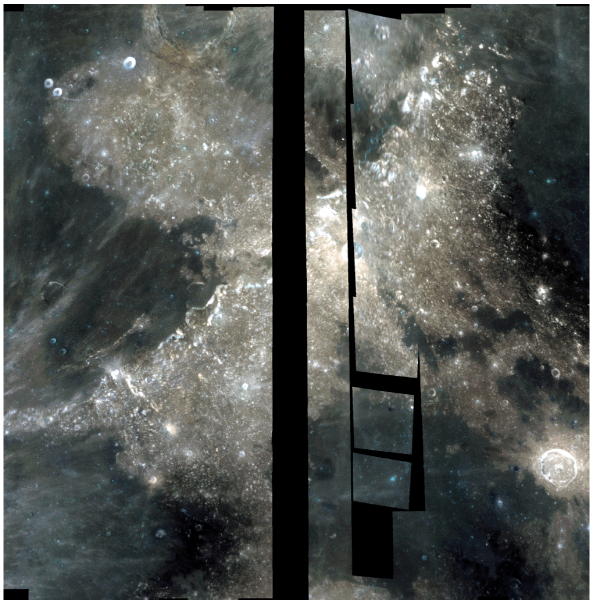

Fig. 1. A true color Clementine mosaic of the Apennine mountains.

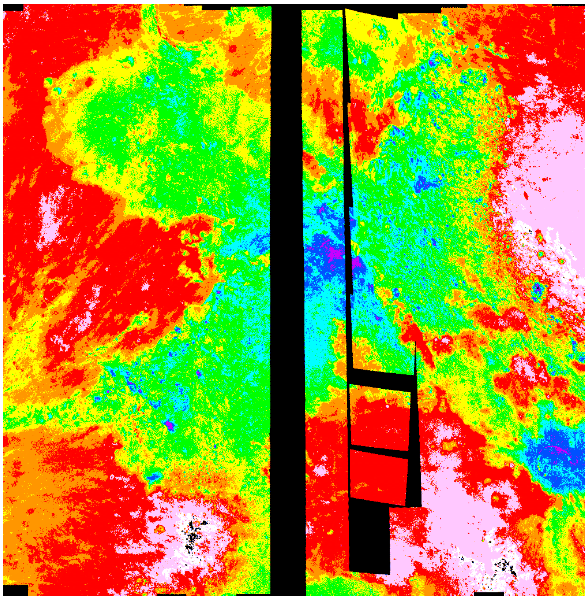

Fig. 2. Iron map of the Apennine region. Colours represent FeO content (in wt.%): black=0-2, purple=2-4, blue=4-6, cyan=6-8, green=8-10, yellow=10-12, orange=12-14, red=14-16, pink=16-18, white=>18