Deposits of the Imbrium Basin: Montes Alpes and Caucasus Paul D. Spudis[1], D.B.J. Bussey[2], B. R. Hawke[3] 1. Lunar and Planetary Institute, Houston TX 2. ESTEC-ESA, Noordwijk NL 3. PGD/HIG, Univ. Hawaii, Honolulu HI (spudis@lpi.jsc.nasa.gov)

Introduction. We continue our ongoing study of the composition of basin deposits by examining the northern ejecta of the Imbrium basin. Prior to Galileo and Clementine, remote sensing data for these units were available only through earth-based observation. We now have both Clementine and Lunar Prospector coverage of this area [1,2], allowing us to characterize the mineral and chemical composition of Imbrium ejecta in this region of the Moon. This work builds and expands on our results reported last year for the Apenninus region of the Imbrium basin [3]. The Alpes are part of the 1200 km diameter basin defining ring of Imbrium that also manifests itself as the Montes Carpatus in the south, the Apennines in the southeast, and the Montes Caucasus to the east. We have used the various data processing techniques (described in [4]) to make compositional maps of the highland deposits here. Comparison of these results to those derived from other techniques [e.g., 5], as well as studies of returned lunar samples [e.g., 6], enables us to make inferences on the composition of the lunar crust in this region and planetwide.

Geological setting of studied area. The Alpes and Caucasus ranges make up highland blocks north and northeast of Mare Imbrium (Figure 1) and display several key morphological properties [5,7]. The Montes Caucasus and Alpes consist of rugged, equant massifs that make up the rim crest of Imbrium basin. The knobby Alpes Formation, a unit with wide distribution around the Imbrium basin [5,7,8], is found along the backslope of the basin rim crest in the north and east of the basin. In the western segment of the basin exterior, hummocky to radially lineated Fra Mauro Fm. material makes up the backslope deposits [5]. This fundamental dichotomy of ejecta facies was remarked on by [5,8], but its significance is not known. The crater Plato (Fig. 1) is post-basin, but pre-mare; its ejecta is a renowned "red spot", one of many that are found in the Imbrium-Procellarum region. In the western portion of the Alpes, basin relations are obscured by the deposits that created the Sinus Iridum crater. This feature is a post-Imbrium basin about 250 km in diameter. The distribution of highland units, in conjunction with their position with respect to the prominent rim crest of the basin, suggests that both Alpes and Fra Mauro deposits are dominantly basin ejecta, contaminated to an uncertain extent by energetic local mixing [9] and of limited extent due to burial by subsequent geological units.

Basalts of Mare Frigoris cover Imbrium basins deposits north of the basin rim at radial distances of 300-700 km from the rim crest. Mare Frigoris has complex stratigraphy and is made up of several different basalt units. Most of the mare is of low or very low Ti-basalt [7,10]. Basalts filling Plato appear to be close in composition to mare basalts found in Imbrium, although Wilhelms [9] maps them as temporally correlated with the basalts of Frigoris. Smooth, high albedo, pre-mare plains occur along the base of the Alpes. Some of these plains are similar to the Apennine Bench Fm., a pre-mare unit made up of volcanic KREEP basalt near the Apollo 15 landing site [11,12].

Composition of deposits A map of iron derived from Clementine data is shown in Figure 2. There appear to be two principal compositional units associated with the Imbrium basin deposits: most of the ejecta have a mafic highland composition, comparable to that seen in the Apennines south of this area [3]. This unit, which encompasses massifs and both the Alpes and Fra Mauro units has FeO contents between 8-12 wt.% with TiO_2 ~1 wt.%. This composition corresponds to the generally 'basaltic' (e.g., "LKFM" – see [8]) composition seen in elsewhere. Such a basaltic composition is also evident in the deposits exposed north of Mare Frigoris, which is dominated by Fra Mauro Fm. material. Another distinct compositional province is seen in the eastern backslope of the Caucasus, which is made up solely of Alpes Fm. Material. This unit is significantly more feldspathic, with FeO content ~ 4-8 wt.% and less than 0.5 wt.% TiO_2 (Figure 2). It is comparable to the feldspathic deposits that occur in the Apennine backslope around the crater Conon [3]. Its occurrence here suggests that this feldspathic component is indeed part of the Imbrium basin ejecta and that feldspathic rocks (anorthosites and anorthositic norites) make up part of the basin ejecta. However, the bulk composition of the Alpes and Fra Mauro support our previous results that Imbrium basin ejecta is the most mafic of all lunar basins [5,8].

Terrain further north of the northern edge of Mare Frigoris becomes more feldspathic (Figure 2). Some of this is undoubtedly a phase effect (note the low iron zones in association with crater shadows at northern edge of mosaic), but much of the Alpes terrain north of Frigoris in the eastern sector of the mosaic has a broadly feldspathic composition, like the Alpes in Caucasus backslope.

The very red ejecta blanket of Plato is seen to be relatively low in iron (FeO 4-8%; Figure 2) . This is somewhat at variance with the composition of a similar red spot on the south rim of Archimedes, which we determined last year to have higher iron contents (FeO ~ 6-10%; [3]). The origin and cause of red spots remains a mystery.

Lunar Prospector has recently determined the contents of Th in this region [2]. Th contents in general are elevated around the Imbrium basin, but particularly high levels of Th are associated with mare basalts west of the Sinus Iridum crater and centered around Aristillus crater [2]. Th levels associated with the "basaltic" highlands of the western Alpes are on the order of 4-6 ppm, consistent with that of the LKFM composition seen in the southern Apennines [3]. A Th "low" (<2 ppm) is found in the eastern Caucasus, coincident with the feldspathic zone described previously, supporting its interpretation as feldspathic rocks.

Conclusions Compositional mapping of the northern half of Imbrium confirms the mafic nature of Imbrium basin ejecta. Our compositional provinces to not correlate very well with morphologically defined geologic units, suggesting that differences between the two ejecta facies are related to physical properties of deposition, rather than composition [cf. 5]. Imbrium basin ejecta is broadly highland basaltic in composition, although specific areas are significantly anorthositic. KREEP is abundant in the region, although its specific distribution appears to be not directly related to the distribution of Imbrium basin deposits [cf. 13]. Our results suggest that the distribution of KREEP, tracked by Th content, is not directly correlated with Imbrium basin ejecta, but has had a complex, multiphase history involving both impact and volcanic processes.

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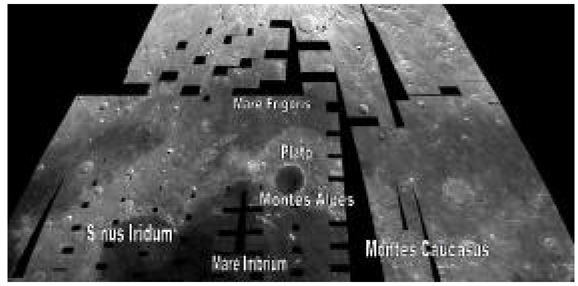

Figure 1. Index map of study area.

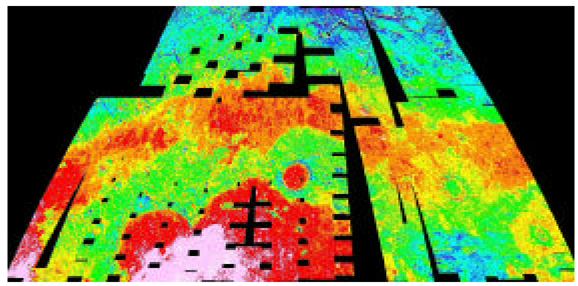

Figure 2. Iron map of the Alpes-Caucasus region. Colors represent FeO content (in wt.%): black=0-2, purple=2-4, blue=4-6, cyan=6-8, green=8-10, yellow=10-12, orange=12-14, red=14-16, pink=16-18, white=>18