The Apollo and Korolev basins and the stratigraphy of the lunar crust, Donald A. Morrison[1] and D. Ben J. Bussey[2], 1-SN4, Johnson Space Center, Houston, TX, 77058, 2.-Lunar and Planetary Institute, Houston, TX, 77058

Introduction: The Apollo and Korolev basins on the lunar far side offer an opportunity to examine the stratigraphy of the lunar crust. The pre-Nectarian, 505 km diameter Apollo Basin, located in the northeast quadrant of the South Pole-Aitken Basin (SPA) apparently excavated rocks from the lower lunar crust-upper mantle [1]. The floor of the SPA has elevations of -6 to -8 km below the mean lunar datum [2] in the Apollo area (centered at 36S, 151W). Apollo would have excavated SPA ejecta and underlying material bringing up rocks from depths as great as 30 km.

In contrast, the 404 km Korolev event (centered at 5S and 157W) 900 km due north of the Apollo basin, excavated material from the region of thickest lunar crust and highest elevation, 2-3 km above the mean lunar datum [2], perhaps exposing rocks from as deep as 10 to 12 km. Comparison of the two will help to determine the stratigraphy and structure of the crust.

Methods: We have investigated the two areas using Clementine imagery. Clementine data were reduced with ISIS software (September, 1996 version) developed by the USGS-Flagstaff, [3], and calibration parameters developed by the USGS [4] and the Clementine science team e.g., [5].

All bands were coregistered with the 750 nanometer band. 250 m/pixel mosaics and color composites were produced by ratioing the 415/750 bands for blue, the 750/415 bands for red and the 750/950 for green.

FeO and TiO_2 values were estimated following the method of Lucey et al. [6 and 7]. Values for the Apollo calibration sample 62231 [8] and reflectance values generated from the Apollo 16 calibration sites were used for calibration in the calculations to determine wt.% FeO.

Results: Figure 1 illustrates the characteristics of the Apollo basin and the terrain to the south towards the center of the SPA. Three major units are present within the Apollo Basin. They are 1.) a pre-Nectarian [9] basin floor unit (1 in fig. 1) cut by grabens in places, 2.) massifs of the same age forming the basin rings, (2 in fig. 1), and, 3.) Imbrium age [9, 10] basalts in the center of the basin and between the inner and outer rings. (3 in fig, 1). Subordinate units such as NE trending rays that converge at the Orientale Basin also occur. Apollo ejecta and younger overlying units [9] form rough, typical highlands topography on the basin periphery (4 in fig, 1).

The basin floor material represents an average of the target material. Representative spectra (fig. 2) fall between typical highlands and basaltic soils. FeO content is 6 to >10 wt. %. Material least effected by younger unit deposition is ~10%.

The discontinuous inner ring massifs stand approximately 3 km above the floor of the basin. They have spectra like those of the floor materials. They are heterogeneous, ranging in FeO content from 4 to ~9%. Post-Apollo craters, Dryden and Chaffee, for example, including one that is younger than the basalts, have very red spectra, although their FeO content is the same as other areas of the massifs. The reddening is not a compositional function therefore, and suggests that the rocks that make up the massifs and at least part of the floor have an unusually high glass content.

The basalts (3 in fig. 1) in the topographic lows of the basin [cf. 10] and in areas between the inner and outer rings [cf. 10] are Fe-rich, averaging 16 % FeO. TiO_2 values are uncertain as yet because of incomplete photometric calibration and a latitude dependence [7] but preliminary data indicate approximately 10% TiO_2 [6,7]. This is consistent with Galileo data [10] which show that these basalts have medium to high TiO_2 contents.

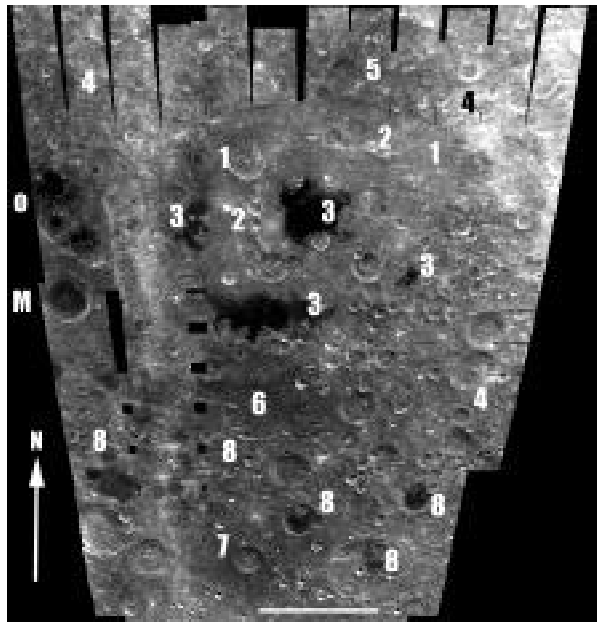

Figure 1: 750 nanometer band mosaic compiled from 1st and 2nd month orbits illustrating the geology of the Apollo basin and the South Pole-Aitken basin to the south. The lower part of the figure is near the center of the South Pole-Aitken basin. Top left is at 25.508S, 191.15W, bottom right is at 59S, 221.89W. Scale bar is 200 km

The terrains immediately north, northwest and southeast of the outer ring, (4 in fig. 1), presumably dominated by Apollo ejecta, have FeO contents generally of 8-10%. The floor of the crater Barringer (5 in fig. 1), which excavated massifs of the outer ring, is 8-10% FeO, its central peak approaches 13% and part of its northern crater wall has 13 to 16% FeO.

The highlands on the northeast limb of the Apollo basin have FeO contents of 4-8%, lower than in the other quadrants. This terrain has morphologies indicating overprinting by younger ejecta, primarily from Orientale.

The post-Apollo crater Oppenheimer (O, fig. 1) is immediately to the west of the Apollo structure. Pyroclastics occur within the Oppenheimer structure but apparently flows do not. The crater Marsukov, (M in fig. 1) to the south of Oppenheimer, in contrast, is floored by basalt that is equivalent in FeO content (and elevation) to those in Apollo , as was mapped by [9], and similar to younger volcanics that flood terrain to the south.

Immediately south of the outer ring of Apollo, (6 in fig. 1), between the craters White and Grissom [cf. 9], is an area that may be "cryptomare" - a volcanic unit that is older than the interior basalts but younger than the Apollo event. It is shown as Inp by [9] who suggests that it may be related to Imbrium and/or Nectarian ejecta. FeO values for this unit are about 13% FeO.

Further to the south of the Apollo basin at approximately 55-59S, (7 in fig. 1), is another area of smooth terrain that may also be cryptomare, or a fluidized ejecta sheet. FeO wt% values range from 10 to 12%. This region is flooded by a younger volcanic unit (8 in fig. 1) that fills topographic lows and embays and floods and/or fills pre-existing structures. FeO values (15%) are comparable to the basalts of the interior of the Apollo structure and distinctly higher than the surrounding unit(s), including the putative cryptomare. These basalts and those within the Apollo basin, apparently equivalent in age, may mark a hydrostatic datum in this area of the Moon during Imbrium time with an elevation approximately 6 km below the mean lunar datum.

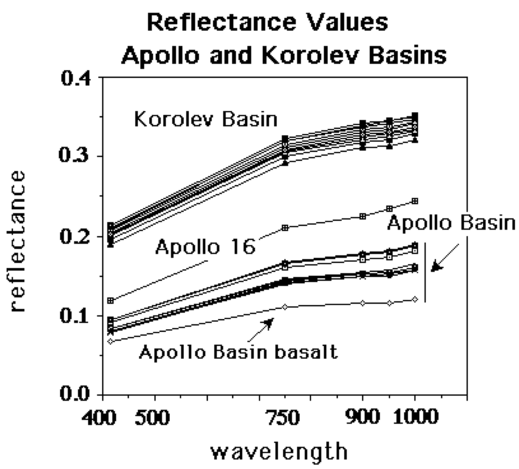

Figure 2: Representative reflectance spectra for Apollo and Korolev basin units compared to Apollo 16 sample 62231. Wavelength in nanometers. Spectra are calibrated using ISIS values as of Sept. 1996, and the photometric parameters of Lucey and Blewett [7].

In contrast to Apollo, the Korolev basin materials are brighter, less red, and have much lower FeO abundances. Representative spectra are shown in fig. 2. The Inp unit of [9] is 4-6% FeO (A in fig. 26 of [10]). This unit is dated by crater frequencies at 4.04 b.y. by [10], and it may be representative of Korolev target materials although it is not uniquely defined by either the FeO abundances nor units defined by spectral ratioing. In general, the area within the inner ring of Korolev is 4-6% FeO. The massifs of the outer ring and materials on the periphery of the basin have 2-4% FeO. These units may correspond to the regional Th value of 1.29 ppm derived by Metzger et al, [12] from the Apollo gamma ray data, significantly enriched relative to Apollo ejecta.

Conclusions: Apollo and Korolev represent two points in a stratigraphic column through the lunar crust. The material forming the floor of Korolev averages 5 wt% FeO. Korolev could have sampled and averaged crust from +2 km to -6 km, The latter near the current elevation of the Apollo basin, and 5% FeO represents some summation of this material. Apollo, on the other hand, averaged material from -6 km to ≥-20 km with respect to the mean lunar datum, and its bulk FeO abundances, on the order of 10-12%, may represent an averaging of this lower section of the crust, although the material excavated by Apollo probably was dominated by SPA ejecta. Two points so broadly defined are not enough to draw conclusions concerning a chemical or petrologic gradient in the crust. Basins of various sizes and contexts must be sampled [13].

It is evident that the Apollo basin excavated an FeO-rich heterogeneous terrain. The range of FeO values within the basin and of its ejecta is equivalent to that observed in the SPA by Lucey et al. [1]. Whether or not mantle rocks are represented is model dependent [1]. The FeO abundances observed are broadly consistent with predictions of lower crustal LKFM-like compositions of various models including, for example, Spudis and Davis [11]. The degree of heterogeneity (≥ 6% FeO to ≥13% FeO) suggests that a variety of rock types were excavated by the 505 km Apollo event. Metzger et al. [12] derived Th values of 0.42 to 0.64 ppm (areas 12H and 12G in table 7 of [12]) for the terrain to the north of Apollo. Because the gamma ray experiment had a large footprint and measured a mixture of SPA, Apollo, Korolev and younger crater ejecta, the correlation with the FeO values we observe is unclear.

Estimates of the bulk composition of the SPA terrain are complicated by the presence of younger FeO-rich flows and pyroclastics. Cryptomare (and/or ejecta sheets deposited as fluidized units) with 12-13% FeO and younger flows with ~ 15-16% FeO occupy a significant fraction of the terrain - perhaps 10% or more for the younger flows labeled as 8 in the area illustrated in fig. 1.

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