GEOLOGY AND DEPOSITS OF THE LUNAR NECTARIS BASIN. P.D. Spudis[1], B. Ray Hawke[2], and P.G. Lucey[2]. 1. U.S. Geological Survey, Flagstaff, AZ 86001. 2. Planetary Geosciences, HIG, Univ. Hawaii, Honolulu, HI 96822.

The 860-km diameter Nectaris basin forms a conspicuous structural and stratigraphic marker on the lunar near side. This multiring basin was among the first recognized on the Moon [1] and its deposits were subsequently used to subdivide lunar geologic history [2]. We have undertaken studies of the geology of Nectaris basin deposits, the morphology of its ring system, and the composition of its deposits as determined by remote-sensing techniques to understand better the regional geology of the Nectaris area and the provenance of possible Nectaris ejecta collected from Apollo landing sites (Apollo 16 in particular), and to provide additional constraints on the nature of the lunar basin-forming process. This study extends our ongoing investigation of lunar basins using the methodology we have previously applied to the Orientale [3] and Imbrium [4] basins.

Nectaris basin deposits and ring system. Although the Nectaris basin is heavily modified by the superposition of crater and other basin deposits, we can still recognize several geologic units that, by virtue of their position and stratigraphic relations, appear to represent Nectaris basin units. The most conspicuous unit is the Janssen Formation (Fm.) [2,5]; this unit is exposed primarily southeast of the basin rim and consists of coarsely lineated material whose lineations are radial to the center of the Nectaris basin (at 16° S, 34° E). The Janssen Fm. is analogous to the Imbrium basin Fra Mauro Fm. and the Orientale basin Hevelius Fm.; as such, it probably consists of both Nectaris basin primary ejecta and local material reworked by secondary cratering [6]. Nectaris basin ejecta has long been considered absent around the basin where the Janssen Fm. does not appear; however, several workers [e.g., 7,8] have suggested that the hilly and furrowed Descartes material, which subtends a broad arc concentric to the Nectaris rim west of the basin, is Nectaris ejecta modified by superposed Imbrium basin secondary craters. If this interpretation is correct, the only sectors around the basin that do not have any exposed Nectaris ejecta are those that are covered by the later mare basalts (Maria Tranquillitatis and Fecunditatis). In addition to these basin exterior deposits, a knobby-textured unit crops out in the basin interior [7] that may be analogous to the knobby Montes Rook Fm. of the Orientale basin; moreover, numerous massifs delineate basin rings both within and outside the basin.

The Nectaris ring system is relatively well preserved. The main basin rim, well-defined in the west and south by the arcuate Altai scarp, is 860 km in diameter. A series of equant to rectilinear massifs, of which the Kant plateau is an example, define the main basin rim in the north and east sectors. Mare ridges and massif chains within the basin define three interior rings 240, 400, and 620 km in diameter. Additionally, several studies [e.g., 1,9,10] have recognized a large, subtle ring exterior to the Altai rim; this ring (1320 km in diameter) passes through the Apollo 16 landing site. Thus, in terms of basin size, ejecta distribution, and number of rings, the Nectaris basin may be considered analogous to the better-preserved Orientale basin.

Composition of Nectaris basin deposits. The Apollo 16 orbital spacecraft overflew portions of the northern rim of the Nectaris basin, measuring elemental conentrations of Al, Mg, Fe, Ti, and Th; these geochemical data indicate that the regional composition of these deposits range from highly aluminous (anorthosites) to less aluminous compositions, corresponding to anorthositic norite [11,12]. Such a composition is in contrast to comparable deposits of the Imbrium and Serenitatis basins [4, 12], where low-K Fra Mauro (LKFM) basalt is a major component; however, Nectaris basin deposits are less anorthositic than comparable Orientale basin deposits [3]. Results of mixing-model studies [12] indicate that LKFM basalt can constitute at most only about 25% of the deposit's composition.

We have previously reported preliminary results from the analysis of forty near-infrared reflectance spectra in the Nectaris highlands region [13]. The Nectaris highlands display mineralogical compositions rich in Fe-bearing plagioclase with minor amounts of low-Ca pyroxene, comparable to the deposits observed around the Apollo 16 site (noritic anorthosite to anorthositic norite). We have found several localities around the Nectaris region that appear to consist of shocked plagioclase with virtually no mafic mineral phase present, e.g., within Kant crater on the Nectaris main rim, within the crater Cyrillus A inside the basin, and within the crater Bohnenberger F, located on top of a highland massif that forms part of the inner (Montes Pyrenaeus) ring of the basin (620 km in diameter). We interpret these spectra to indicate the presence of shocked anorthosites, comparable to those observed within the Orientale basin [3]. Spectra obtained for a portion of the hummocky basin unit north of the basin center suggest a relatively high concentration of low-Ca pyroxene in this unit [13]; considering this, together with an observed anomalously high Mg/Al value [14], we conclude that this area consists of dominantly noritic material, either a pristine norite or a deposit rich in low-K Fra Mauro basalt. Our studies of Nectaris basin deposits indicate that the regional compositions tend to be more anorthositic than those of the Imbrium or Serenitatis basins, but more mafic than typical Orientale basin materials.

The Apollo 16 site and the Nectaris basin. Several studies have emphasized the influence of the Nectaris basin on the geologic development of the Apollo 16 landing site (see summary in [15]). Of the two main geologic units at the site, the Descartes material is most likely to be Nectaris-related; as noted above, this unit probably makes up the continuous deposits on this side of the basin, modified by the superposition of subsequent Imbrium basin secondary craters. The Descartes material at the site appears to consist of a complex megabreccia of dominantly anorthositic to anorthositic noritic composition. The overlying Cayley plains were probably emplaced by the Imbrium basin "debris surge" [6] and, as such, would consist mostly of reworked local material (the Nectaris basin Descartes material).

Numerous impact melt rocks were collected at the Apollo 16 site; although the number of melt groups present is still debated [cf. 16,17], the most abundant melt composition is that of "VHA basalt", an aluminous variety of LKFM basalt. Because the regional composition around the Apollo 16 site is more aluminous and less KREEPy than these melt rocks, they are unlikely to be the products of local impact craters [e.g.,18]. They are either melt rocks from relatively large craters (> 100 km) that occur uprange to the Imbrium basin, transported to the site during the Imbrium debris surge [19], or they may represent fragments of the Nectaris basin melt sheet [8]. Our results are consistent with either of these two models.

Discussion. The Nectaris basin impact can be modelled by the proportional-growth cratering model [e.g., 20]. For a basin main-rim diameter of 860 km, results indicate a transient cavity diameter of 470 ± 100 km, a maximum depth of excavation of 40 to 55 km, and total excavated volumes between 6.3 and 9.2×10^6 km^3 (greater than 90 percent of the excavated volume is derived from depths of less than 30-40 km). If the average crustal thickness is on the order of 70 km [21] and the crustal structure of [22] is approximately correct, then the bulk of Nectaris basin ejecta would be dominantly anorthositic in composition, as in fact is indicated by the remote-sensing data. We suggest that the Nectaris basin formed by an impact (with proportional-growth characteristics), into a grossly layered lunar crust. The ejecta from this impact are dominantly of anorthositic composition; mafic components (i.e., norite, LKFM basalt) are present in the ejecta, probably in minor (10-20%) quantitities. The bulk of the returned Apollo 16 samples are ultimately of Nectaris basin provenance; the relation of some Apollo 16 melt rocks to the Nectaris basin-forming event is possible, but has yet to be conclusively demonstrated.

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