GEOLOGY AND DEPOSITS OF THE SERENITATIS BASIN Paul D. Spudis[1], B. Ray Hawke[2], Paul G. Lucey[2] 1. Lunar and Planetary Institute, Houston TX 77058. 2. Planetary Geoscience, SOEST, Univ. Hawaii, Honolulu HI 96822.

The Serenitatis basin is prominent on the near side of the Moon, just east of Mare Imbrium. Originally thought to be one of the oldest lunar basins, re-interpretation of both geological relations and Apollo 17 isotopic data suggest instead that Serenitatis is one of the youngest basins, having formed in the Nectarian Period about 3.87 Ga ago [1]. As part of our continuing effort to understand the geology of multi-ring basins on the Moon and to use basins as probes of the deep lunar crust [2], we here report results for the Serenitatis basin. Our examination of Serenitatis was stimulated in part by a new effort to re-examine the geology of the Apollo 17 landing site [3].

Geology of Serenitatis Basin Deposits The interior of the Serenitatis basin is extensively flooded by mare basalt and there are no exposures of geological units analogous to those contained within other basins. Presumably, a basin impact melt sheet underlies the basalts of Mare Serenitatis, and the terra surrounding the inner basin mare may be discontinuously mantled by the distal margins of such a melt sheet; this is postulated to have happened at the Apollo 17 landing site. The highlands east of the central Serenitatis basin are composed of two main terrain types: rugged massifs that are crudely aligned along basin-concentric circles and a knobby terrain that has been called informally the Sculptured Hills [1,4]. Rugged massifs form two distinct rings outside the flooded interior of the basin. The intermassif regions are undulating terra that has both rough and smooth facies. The hummocky intermassif deposits are gradational with the Sculptured Hills unit. All of these terra units are found near the Apollo 17 landing site.

Most investigators interpret the Sculptured Hills as an analog to the knobby, Montes Rook Formation of the Orientale basin [4,5]. In this view, the Sculptured Hills are primary ejecta from the Serenitatis basin, deposited between the main topographic rim and the intermediate rings of the basin. A key relation not consistent with a Serenitatis origin for the Sculptured Hills unit is its superposition on the rims of post-Serenitatis basin craters, such as Le Monnier and Littrow [6]. The Sculptured Hills occurs throughout the eastern rim of the Serenitatis basin and may be polygenetic, in part composed of Serenitatis ejecta where it grades into hummocky, intermassif deposits and partly Imbrium ejecta where it is gradational with radially lineated terrain found inside the main rim of Serenitatis.

The heavily cratered eastern rim of the Serenitatis basin may be a product of extensive secondary cratering from the Imbrium basin [1]; these craters are sometimes overlain by the Sculptured Hills and related highland units. Some of the large craters in the eastern Serenitatis rim region (e.g., Littrow) may be Imbrium secondaries that were formed contemporaneously with the deposition of distal ejecta from Imbrium [7]. Thus, in contrast to basin units at Orientale, all of which underlie post-basin craters, highland units on the eastern rim of Serenitatis may both underlie and overlie large, post-basin craters, producing ambiguous stratigraphy.

Ring System of the Serenitatis Basin Serenitatis displays at least four distinct rings. The inner (Linné) ring (410 km diameter) is not expressed by massifs, but its presence is inferred by the circular arrangement of mare ridges within the central basin. The ring that borders the mare is composed of rugged massifs and basin-facing scarps and is approximately 620 km in diameter. This ring passes through the Montes Taurus east of the basin and just west of the Apollo 17 landing site and intersects the northern Apennines of the Imbrium basin. Most workers [1,4,5,7] agree that the main topographic rim of Serenitatis is defined by highland scarps and isolated massifs as well as the "Vitruvius Front", a well-defined platform southwest of the Apollo 17 site, is about 920 km in diameter and corresponds to the Cordillera ring of Orientale. That no textured ejecta are evident in association with this basin ring may result from the extensive obliteration of Serenitatis ejecta by the effects of the impact forming the Imbrium basin.

Outside the main basin rim, two additional rings are evident, with diameters of 1300 and 1880 km, respectively [7,8]. Parts of these rings can actually be traced inside the Apennine ring of the Imbrium basin, helping to constrain the size of the transient cavity for that basin [2]. The rings of the Serenitatis basin display a crudely polygonal outline that reflects interaction with topography both older and younger than the basin. The Vitruvius ring is missing where the Serenitatis basin intersects the Tranquillitatis basin in the south and is truncated by the Apennines of the Imbrium basin to the west. In addition, the Vitruvius ring becomes highly irregular northeast of the central basin and a tangential structure is evident near the crater Atlas.

Composition of Serenitatis Basin Deposits The composition of highland deposits associated with the Serenitatis basin appears to be more mafic than is typical for other basins we have studied [2]. Orbital chemical data indicate a low-alumina composition, noticeably less feldspathic (Al_2O_3 = 20 wt.%) than typical lunar highlands (Al_2O_3 = 26 wt.%) [9]. Such a chemical composition suggests that Mg-suite noritic rocks and polymict, highland basaltic compositions dominate the deposit. Earth-based spectra indicate that the Taurus-Littrow region, the highlands in Montes Haemus (southwestern basin rim), and terrain north of Mare Serenitatis all contain anorthositic norite. The interior of the crater Menelaus shows noritic anorthosite, but significantly more mafic compositions also occur within and near this crater [10]. Many of the highlands areas contain contaminating mixtures of post-basin mare volcanics, both basalts and pyroclastics; however, some ancient basaltic debris is probably included within the Serenitatis ejecta [6,7].

The Apollo 17 site is near large massifs that are probably close to, if not making up, the rim of the basin transient cavity [1,4,5]. Two classes of impact melt breccias from the Taurus massifs are the poikilitic and aphanitic impact melts [6]. The poikilitic melts are LKFM in composition, form a tight compositional cluster, and have been postulated to represent the impact melt sheet of the Serenitatis basin [11]. The aphanites are also LKFM, but show diffuse chemical grouping and diverse clast populations [6]; this may indicate that they come from a different large impact event [6], but others hold that the aphanites are also from the Serenitatis basin impact [1,4,7,12]. Clastic debris from the site is almost exclusively Mg-suite norites, troctolites, and dunites (in accord with the orbital chemical data [9]), but the ferroan suite is represented by granulitic breccias of unknown precursors. Several chips have been proposed as pristine ferroan rocks from the site [13], but such samples are extremely small and may be unrepresentative pieces of larger samples of uncertain provenance and origin.

Discussion The impact that formed Serenitatis basin probably occurred 3.87 Ga ago [1] and excavated a large fraction of the crustal column in this region of the Moon [7,14]. The main rim diameter of Serenitatis is 920 km; thus, Serenitatis is a basin nearly identical in size to Orientale [4]. On the basis of our previous results for Orientale and other lunar basins [2], we estimate that the Serenitatis basin had a transient cavity diameter of about 500-600 km, a maximum depth of excavation of 55-60 km, and an excavated volume of about 7.5×10^6 km^3 [7]. In contrast to Orientale, where the average pre-impact crustal thickness was about 100 km [15], the crustal target in this region of the Moon was on the order of 60-70 km thick [15]. Thus, the maximum excavation depth of Serenitatis nearly reached the lunar mantle and a significant amount of lower crustal material may make up the basin ejecta. Consistent with this concept, the Serenitatis ejecta appears to be more mafic than other lunar basin deposits. The impact melt sheet of the Serenitatis basin was sampled at the Taurus massifs at the Apollo 17 landing site; it is unclear whether multiple events are represented by the Apollo 17 impact melts. We will continue to acquire new spectral data of Serenitatis basin deposits to better characterize its ejecta and to constrain models of basin excavation.

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