exterior deposits are very heterogeneous in composition. The dominant highland material associated with the interior of Menelaus is noritic anorthosite [17]. However, more pyroxene-rich highland debris also occurs in the Menelaus area. No deposits of pure anorthosite have been identified in the Serenitatis Basin region. The most plagioclase-rich material in the region was exposed by Menelaus.

Small craters in the Haemus region generally expose anorthositic norites. This material was derived from relatively shallow depths and is probably dominated by Imbrium Basin ejecta. Previous studies have shown that Imbrium ejecta on the backslope west of the Haemus region is dominated by norite and anorthositic norite [2].

The Sulpicius Gallus RDMD covers ~6000 km² in the western portion of the Haemus region. Spectral studies indicate that this deposit is a mixture of orange glass and black spheres [11].

Terrain north and east of Serenitatis. Band analysis of the limited number of spectra available indicates that mare basalts are exposed in the walls of Burg Crater and that the Burg peak has a mafic assemblage dominated by high-Ca pyroxene. Anorthositic norites are exposed in the peak of Eudoxus Crater as well as the walls and peak of Romer. Dark-haloed impact craters south of Hercules and southeast of Posidonius have excavated mare basalts from beneath highland-rich surface units. At least small areas of cryptomare appear to exist northeast of Serenitatis Basin.

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THE SERENITATIS BASIN AND THE TAURUS-LITTROW HIGHLANDS: GEOLOGICAL CONTEXT AND HISTORY.

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Introduction: The Apollo 17 mission was targeted to land at the southeastern edge of the Serenitatis Basin, one of a number of large impact basins on the Moon. The choice of the landing site was influenced heavily by the desire to obtain detailed information about large impact basins [1] by constructing a composite "geological traverse" radial to a basin [2] (Fig. 1), with the Apollo 16 site (Descartes) representing the most distal regions, the Apollo 14 site (Fra Mauro) the intermediate textured ejecta unit, the Apollo 15 site (Hadley-Apennine) the basin topographic rim, and the Apollo 17 site (Taurus-Littrow) within the basin interior. The remarkable geologic exploration of the Taurus-Littrow Valley by astronauts Harrison Schmitt and Eugene Cernan provided fundamental information about processes associated with impact basin formation and evolution [3]. This information, further analysis of returned samples and other data, and subsequent exploration of the Moon have raised additional questions that can potentially be answered from the site data. The Apollo 17 site is thus a keystone to the understanding of the geology of impact basins in general and basin interiors specifically. In this contribution, the geologic setting of the Apollo 17 site is reviewed, the implications for the formation of basins from Apollo 17 results are assessed, and unanswered questions potentially addressable with existing and new data are outlined.

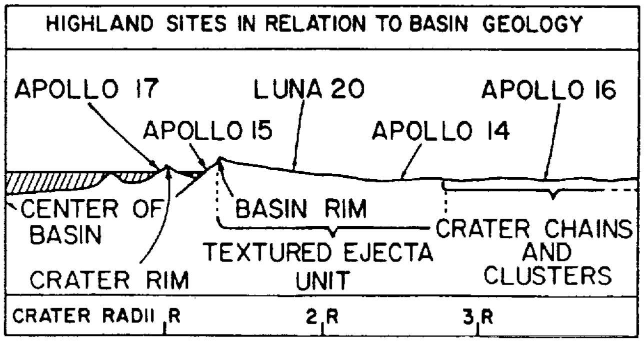

Fig. 1. Composite cross section across lunar impact basin showing relationship of Apollo landing sites to basin geology. From [2].

Geological Setting of the Serenitatis Basin: Mare Serenitatis is paradoxically one of the most clearly defined circular maria, but the basin structure itself is so indistinct, primarily due to modification by the post-Serenitatis Imbrium Basin, that some early basin studies did not even discuss it [4]. In fact, Serenitatis appears to be one of the more recent lunar basins. Stratigraphically, Serenitatis is one of 12 basins that have been assigned a Nectarian age [5]. It lies within the younger group of these basins and is immediately predated by Crisium, Humorum, and Humboldtianum, and immediately postdated by Hertzsprung. In terms of its regional setting, several pre-Nectarian and Imbrian-aged basins have had a major influence on its history.

Pre-Serenitatis basin geology. Serenitatis lies within the ancient pre-Nectarian Procellarum Basin, which may be as large as 3200 km diameter [5,6]. The Serenitatis impact would have occurred astride the first ring, extending westward into the basin interior and eastward to the vicinity of the second ring. The Vitruvius Front [7], a topographic scarp occurring in the area to the east of the basin, may be related to the Procellarum Basin [5]. This structure, a long, irregular, but generally north-trending scarp, occasionally rises over 2 km about the surrounding terrain and is associated with a plateau to the east. It does not appear to be directly associated with the Serenitatis Basin [5–7] and may be a remnant of the second ring (excavation rim?) of the Procellarum Basin [5,6]. If so, the Apollo 17 site would lie just within the excavation cavity and Procellarum deposits there would be dominated by impact melts and deep ejecta emplaced on a substrate thinned considerably by impact excavation.

One of the most obvious basins forming in the vicinity of the target area prior to the Serenitatis event is the 800-km-diameter pre-Nectarian Tranquillitatis Basin. The outer ring of this structure actually intersects the Serenitatis Basin in the vicinity of the Apollo 17 site and thus early site geology may be influenced by geologic structure and deposits similar to those seen along the Cordillera ring of the Orientale Basin, or the Apennine ring of the Imbrium Basin at the Apollo 15 site. Crisium is interpreted to have just predated the Serenitatis event [5]. There is no clear evidence of Crisium secondaries near the eastern Serenitatis basin deposits and some Serenitatis secondary craters are interpreted to lie on Crisium ejecta [5]. In addition to these major basins, a number of impact craters in the sub-basin size range must have occurred subsequent to Procellarum and Tranquillitatis. Continuing documentation of the presence of cryptomaria in pre-Orientale times [8–11] suggests that many ancient basins may have been floored by early mare basalts, or KREEP basalts. Thus, the substrate in the pre-Serenitatis region must have been dominated by a wide variety of impact crater and basin deposits with the likelihood of some cryptomaria in the vicinity as well.

Formation of the Serenitatis Basin. The irregular outline of the Serenitatis Basin and the characteristics of the mascon gravity anomaly are suggestive of the possiblity of two nearly superposed impact basins, with the larger one to the south [12–15]. An alternate possibility is a simultaneous impact as has been suggested for the Humboltianum Basin [5,16]. In any case, the main (southern) basin is defined by the Montes Haemus and the Littrow massifs [15]. Although there has been considerable debate, many interpret this ring as the edge of the cavity of excavation on the basis of similarities of this ring to the Outer Rook Ring of the Orientale Basin [17]. The morphologic similarity of the Sculptured Hills east of Mare Serenitatis and the Montes Rook Formation between the Outer Rook ring and Cordillera ring have been cited as further evidence in suppport of this conclusion [13–15]. According to this reconstruction, the deposits of the massifs in the vicinity of the Taurus-Littrow Valley should be composed of uplifted pre-Serenitatis upper crustal rocks overlain by Serenitatis ejecta, and modified by postbasin events. Because of the proximity of the site to the basin rim, impact melt rocks and associated breccias should be dominant.

Post-Serenitatis basin geology. The formation of the adjacent Imbrium Basin had a major effect on the Serenitatis Basin (Fig. 2), primarily due to intersection of the Imbrium ring with the northwest part of the basin and ejecta emplacement across the basin. The outer edge of the Fra Mauro Formation probably extends through central Serenitatis (Fig. 2). If the characteristics of Orientale Basin ejecta can be taken as a guide, then emplacement of ejecta from Imbrium surely heavily modified basin floor topography and caused ponding of the combined ejecta and locally excavated and eroded material in low-lying areas. Estimates of the amount of Imbrium ejecta at the Apollo 17 site based on simple assumptions of radial thickness decay [18] are in the range of 100 m, although the ballistic emplacement of ejecta at

Fig. 2. Influence of the Imbrium Basin event on Serenitatis. Black pattern is Imbrium massifs and Apennine facies, patterned areas is Alpes Formation of Imbrium age. Solid black line represents outer edge of continuous Fra Mauro Formation, the textured ejecta deposit of Imbrium. This line is extended under Mare Serenitatis along an average range from the rim of the Imbrium Basin. From [15].

this range [19] would result in the fragmentation and mixing of Imbrium ejecta with local material. Thus, any Imbrium materials in the vicinity of the Apollo 17 site should have had a mode of emplacement similar to Imbrium ejecta at the Apollo 14 or 16 site. In addition to Imbrium, several post-Serenitatis sub-basin-sized craters are seen in highlands east of Serenitatis [15]. Although none directly intersect the landing site, their presence indicates that ejecta from their formation may be emplaced in the site area. One enigmatic aspect of several of these craters, such as Littrow, is that although they appear to postdate the Serenitatis event, their rims are characterized by textures similar to the Sculptured Hills. This would imply that the formation of the Sculptured Hills texture postdates the Serenitatis event, and thus casts into doubt the interpretation of the Sculptured Hills as a Montes Rook analogue formed simultaneously with Serenitatis [20]. On the other hand, it may be that the seismic effects of the Imbrium Basin event, which must have been significant [21], caused movement that modified both the Sculptured Hills and superposed crater deposits.

Geological Setting of the Apollo 17 Site: Apollo 17 surface exploration provided an excellent sampling of the different massifs and deposits in the Taurus Littrow Valley [22]. The sample materials consist of fragment-laden impact melts showing a diversity of textures (poikilitic, ophitic, subophitic, aphanitic) and a rather narrow range of chemical composition [23,24]. These characteristics have been generally interpreted to indicate that the majority of the rocks were derived from cooled melt rocks containing lithic clasts (primarily granulite breccias and Mg-suite cumulates) and representing Serenitatis ejecta and impact melt. Although the characteristics of the sample suite support this view, the outline of events in the Serenitatis region in addition to the Serenitatis event itself (e.g., Procellarum, Tranquillitatis, Imbrium, post-Serenitatis craters, etc.) all suggest that there may be other candidates for many of the materials sampled [20]. In addition, recent work on the formation of impact basins and new multispectral imaging data on basins [11,24] have provided a basis for the reinterpretation of the Apollo 17 site region. In December 1992 the Galileo spacecraft will obtain multispectral images of the north polar nearside region, including the Serenitatis Basin, and these data will provide an excellent framework for reanalysis of the Serenitatis Basin. Among the important questions to be addressed are (1) What is the role of Procellarum and Tranquillitatis Basin ring deposits at the Apollo 17 site? (2) What are the correct ring assignments for the Serenitatis Basin? (3) How many impact events are recorded in breccias? (4) How can we provide a better link of sample data to impact crater environments? (5) What is the true age of the Sculptured Hills and what represents them in the sample collection?

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THE ANCIENT LUNAR CRUST, APOLLO 17 REGION.

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Introduction: The Apollo 17 highland collection is dominated by fragment-laden melt rocks, generally thought to represent impact melt from the Serenitatis basin-forming impact. Fortunately for our understanding of the lunar crust, the melt rocks contain unmelted clasts of preexisting rocks. Similar ancient rocks are also found in the regolith; most are probably clasts eroded out of melt rocks.

The ancient rocks can be divided into groups by age, composition, and history. Oldest are plutonic igneous rocks, representing the magmatic components of the ancient crust. Younger are granulitic breccias, which are thoroughly recrystallized rocks of diverse parentages. Youngest are KREEPy basalts and felsites, products of relatively evolved magmas. Some characteristics of each group are given below.

Plutonic Igneous Rocks: All large Apollo 17 samples of plutonic igneous rocks are members of the Mg-suite. They are troctolites, norites, one gabbronorite, and one dunite. Detailed investigations of smaller samples (breccia clasts, coarse fines, and rake samples) have identified additional samples of the first three of these rock types, plus several samples of ferroan anorthosites.

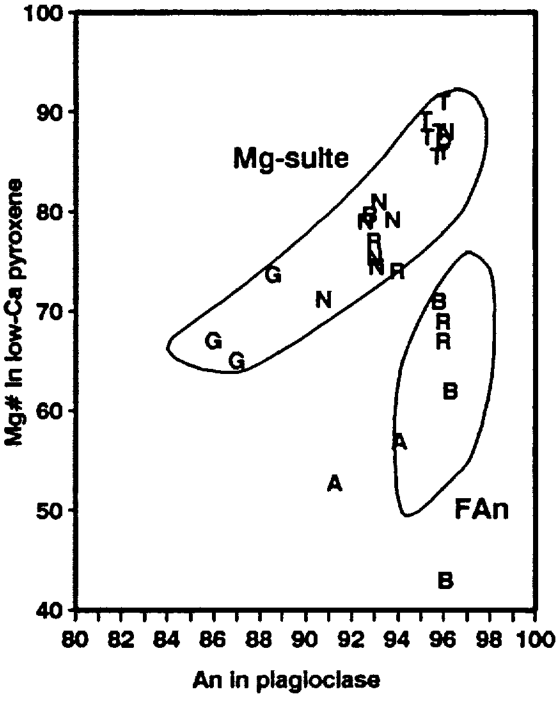

Fig. 1. Content of An in plagioclase vs. mg# in low-Ca pyroxene in some Apollo 17 ancient crustal rocks. Symbols are as follows: T, troctolite; D, dunite; N, norite; G, gabbronorite; A, anorthosite with relict igneous texture; B, anorthosite or norite with granulitic texture; R, granulitic breccia. Lines enclose the fields of compositional variation of minerals in all lunar Mg-suite rocks and in ferroan-anorthosite-suite rocks from sites other than Apollo 17.