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Regional chemical setting of the Apollo 16 landing site and the importance of the Kant Plateau

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Abstract—Orbital X-ray data from the Apollo 16 region indicate that physiographic units identified before the lunar mission can be classified as chemical units as well. The Descartes Mountains, however, appear to be an extension of the Kant Plateau composition that is unusually anorthositic and resembles farside terra. The Cayley Plains have closer affinities to basaltic materials than terra materials, physically, spectrally and chemically. The Theophilus impact, 330 km east of the landing site, excavated magnesium-rich basalts from below less-magnesian flows in Mare Nectaris; but, mafic ejecta was substantially blocked from the Apollo 16 site by the Kant Plateau that rises 5 km above the level of the mare. Apollo 16 soil samples from stations selected to collect either Descartes Mountains material or Cayley Plains material were surprisingly similar. However, they do, indeed, show the chemical trends indicative of the two units as defined by the orbiting geochemistry detectors. The Kant Plateau and Descartes Mountains material may be among the rare nearside examples of a plagioclase-rich cumulate of the primordial magma ocean.

INTRODUCTION

Petrogenetic models of the lunar highland crust are based on the composition of lunar samples collected exclusively from the earth-facing hemisphere of the moon. Yet, data from numerous orbital experiments display striking physical and chemical contrasts between the lunar near and far sides. For example, the mean farside terra elevation with respect to a 1738 km radius of the lunar sphere is higher by 1.8 km, whereas, the nearside terra is lower by 1.4 km (Kaula *et al.*, 1974b). Although the average crustal thickness is calculated to be about 61 km, there is a considerable difference between the estimated thickness of the farside, 74 km, and that of the nearside, 48 km (Kaula *et al.*, 1974a). The nearside is pock-marked with large basins, most of which are filled with mare basalts. On the other hand, the farside basins have sparse accumulations of mare basalts. The chemical composition of the farside terra is substantially poorer in iron, thorium, magnesium and titanium than the nearside, and considerably richer in aluminum (Frontispiece, *Proc. Lunar Sci. Conf. 8th*). With few exceptions, physical and chemical modifications to the original lunar crust were more extensive on the nearside than on the farside. For these reasons, the hidden side of the moon is more likely to have preserved the most primitive chemical record of the early magmatic differentiation processes that formed the lunar crust.

The chemical dichotomy of the two lunar hemispheres is evident in the modes resulting from separate nearside and farside histograms of Mg/Al concentrations from the orbital X-ray fluorescence (XRF) data (Fig. 1). The farside histogram (95°E to 125°E) consists of 4,567 digital data points. The nearside histogram (20°W to 90°E) consists of 31,087 data points. The modes within the frequency distributions represent rock types, not average Mg/Al values. For instance, the nearside frequency distribution exhibits a strong, broad mode for mare basalts that peaks at 0.64 and one for terra areas at 0.39 Mg/Al concentration; whereas, the farside distribution lacks a distinct mode for mare basalts and the terra mode is displaced toward lower Mg/Al, more anorthositic, surface compositions.

Soils from the Descartes landing site are the only highland samples that were collected at considerable distances from mare-filled basins. It was expected before the Apollo 16

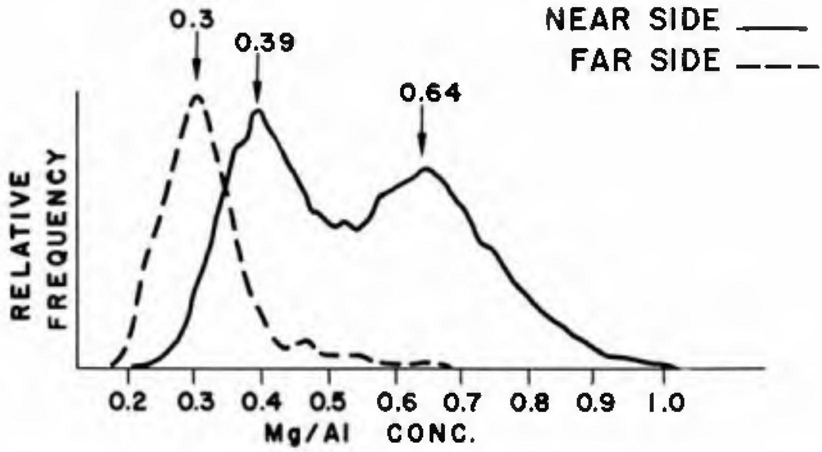

Fig. 1. Mg/Al frequency distributions. The farside terra mode is offset toward rock types with lower Mg/Al (more anorthositic) concentrations than that of the nearside. The farside lacks a mode that corresponds to the broad mare feature that peaks at a value of 0.64 in the nearside histogram.

mission that a typical terra composition could be determined from the sampling stations closest to the Descartes Mountains on the east and south sides of the site and that volcanic material would be found at the sampling stations of the Cayley light plains to the west of the landing point. Instead, it was discovered that the samples from both formations were breccias with a complicated history. Furthermore, the range of chemical compositions for these breccias was narrow and did not cluster into lithologic categories corresponding simply to the mountains or plains units. Similarly, it appeared that *soils*

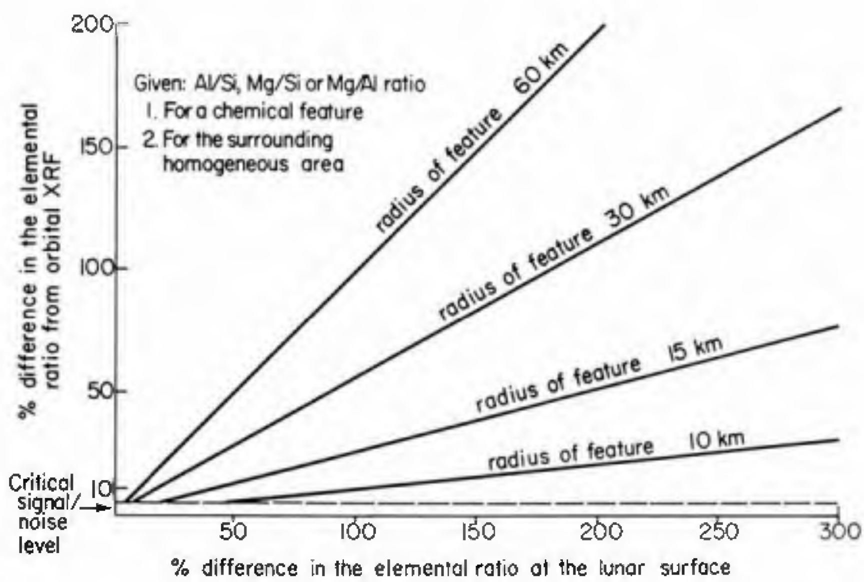

Fig. 2. The resolution graph illustrates the effect that two parameters have on the spatial resolution of the orbital X-ray data: the size of the feature observed within the center of the instantaneous field-of-view and the chemical contrast between the feature and the surrounding soils. See the text for a fuller explanation.

within the confines of the sampling site were locally homogenized by repeated meteorite impacts.

Chemical classifications were difficult and could not be correlated to the physiographic units. Although it was possible to predict from the orbital XRF data before the spacecraft landed that soils would have Al_2O_3 concentrations as high as 26 wt.% (Adler *et al.*, 1973), the spatial resolution precluded a unit by unit analysis. Since that time, refinements to correct for nonchemical solar effects and to improve the signal-to-noise ratio have been implemented (Bielefeld *et al.*, 1977; Andre *et al.*, 1977). These improvements allow a more detailed look at the Apollo 16 landing site.

At present, depending upon the size of the unit observed and the degree of chemical contrast to adjacent units, an effective field-of-view between 15 and 30 km is possible (Fig. 2). Given a circular feature within a chemically homogeneous setting, the graph indicates the percent difference in elemental ratio from the orbital view compared to the feature size and its actual ratio difference relative to surrounding soils. The plot was constructed by assuming the percent difference between ratio concentrations for a uniform chemical feature and a uniform background. The XRF detector response function centered on the feature was used to simulate the instrumental smoothing of the surface signal. The graph shows the dependence of spatial resolution upon feature size and its chemical contrast to the background signal. The relationship shown also allows one to reconstruct the ratio of the feature (in the ideal case), even when it is smaller than the instantaneous field-of-view. For instance, a feature 15 km in radius with a ratio contrast of 10% to its surroundings would actually measure a 50% difference at the surface. The improved resolution of local variations using Mg/Al, Al/Si and Mg/Si ratios crates a useful frame of reference for interpretation of the Apollo 16 samples. The data confirm the existence of chemically separable geologic units in the landing site region.

PHYSICAL SETTING OF THE APOLLO 16 LANDING SITE

There are six geologic units in the Descartes region (Milton, 1968) that could have had a strong influence on the rock and soil types found at the Apollo 16 landing site (15°31′E; 9°S). In chronological order from the earliest units are: 1) pre-Imbrian terra, modified by Imbrium sculpture; 2) materials of the Kant Plateau; 3) the Descartes Mountains; 4) Cayley Plains material; 5) Nectaris mare material; and 6) Theophilus ejecta. The landing site lies immediately west of the Descartes Mountains that extend from the base of the back slope of the most prominent ring of the Nectaris basin (Fig. 3). The uplifted block marking this third ring of the basin, the Kant Plateau, rises more than 2 km above the Apollo 16 landing site, 50 km to the west, and more than 5 km above the level of Mare Nectaris directly to the east. On the western side of the mare is the Copernican-age impact crater, Theophilus, 100 km in diameter. The floor of this crater lies 2.2 km below the mare surface (Lunar Topographic Orthophotomap 78C2). Its ejecta blanket on the west side terminates abruptly at the Kant Plateau. The landing site, on the other side of the Kant Plateau, is approximately 330 km from the center of Theophilus. West of the site, Cayley Plains and terra material are interspersed. Some of the intricate patterns of Cayley Plains are below the limits of resolution of the X-ray detector. The proportion of Cayley Plains increases with distance from the site toward Mare Nubium. Each of these physiographic units may be seen in a telescopic earth-based photograph (Fig. 3) and will be discussed in more detail below.

Kant Plateau

The Kant Plateau is an unusual nearside feature. It is distinctive topographically, spectrally and chemically in its similarity to the lunar farside. The topographic profile of this segment of the outer Nectaris basin ring shows a remarkable difference in elevation compared to the local topography (Fig. 4). The dashed line in the upper profile of the figure represents the average elevation of the farside terra (relative to a mean radius of

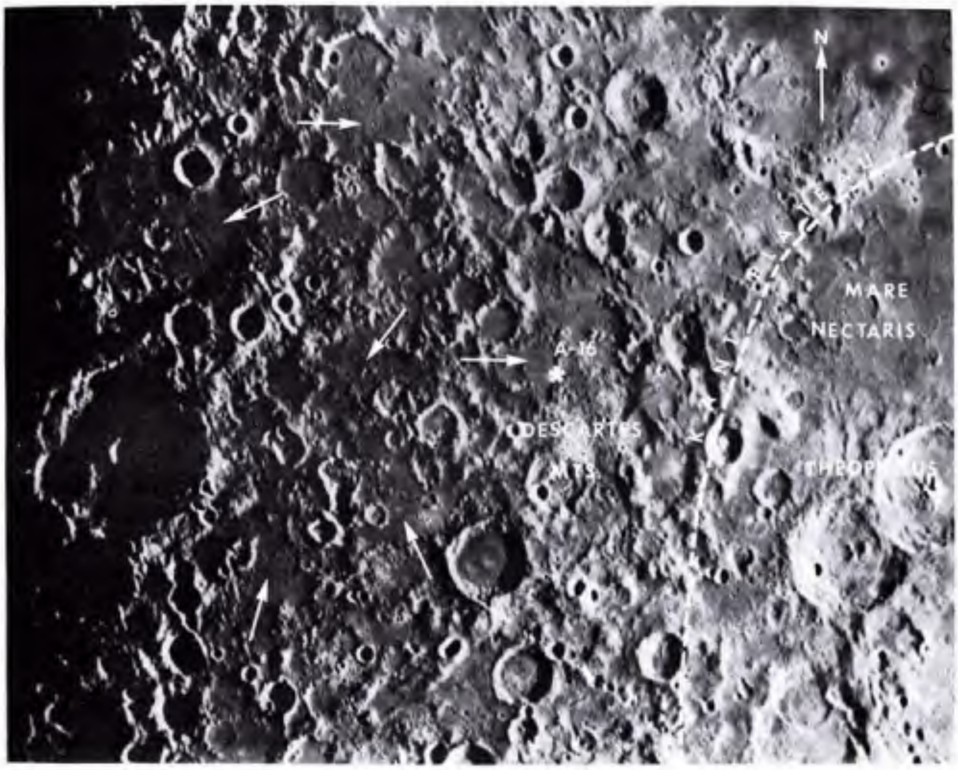

Fig. 3. An earth-based telescopic photo (Kuiper *et al.*, 1967) shows the relationship of the Apollo 16 landing site to Mare Nectaris, Theophilus crater, the Kant Plateau, the Descartes Mountains, terra material and Cayley Plains (arrows).

1730 km) that exceeds that of the nearside terra by 3.2 km (Kaula *et al.*, 1974b). The Plateau elevation is comparable to that of the farside terra and the normal albedo of the Plateau is also unusually high compared to the surrounding terrain and to the nearside terra in general. Only a very small percent of the earth-facing side of the moon has reflectivity values exceeding the 0.22 calculated for parts of the Kant materials and the Descartes Mountains (Pohn *et al.*, 1970). The elevated position, structure and physical characteristics of the Kant Plateau imply that it is subsurface bedrock mechanically uplifted during the formation of the Nectaris basin. Thus, Kant materials and perhaps the Descartes Mountains may be the best preserved and least contaminated example of the early anorthositic crust in the central lunar highlands.

Descartes Mountains

The chemical composition of the Descartes Mountains is of special interest because this rugged terrain has been mapped in a variety of ways by geologists and because geochemists analyzing soils returned from the border of the mountains are not certain whether it can be distinguished from the Cayley Plains. Milton (1968) included the mountainous area extending westward from the base of the Kant Plateau partly in the "furrowed Imbrian terra" unit and partly in the "Imbrian rugged and bright Kant material." The Apollo Field Geology Investigation Team designated the area east of the Apollo 16 landing site and west of the Kant Plateau as an extensive mountain range that curls around the east side of the Cayley unit containing the landing site. It extends south of the Descartes Crater along the west side of the Plateau. The Descartes Mountains have

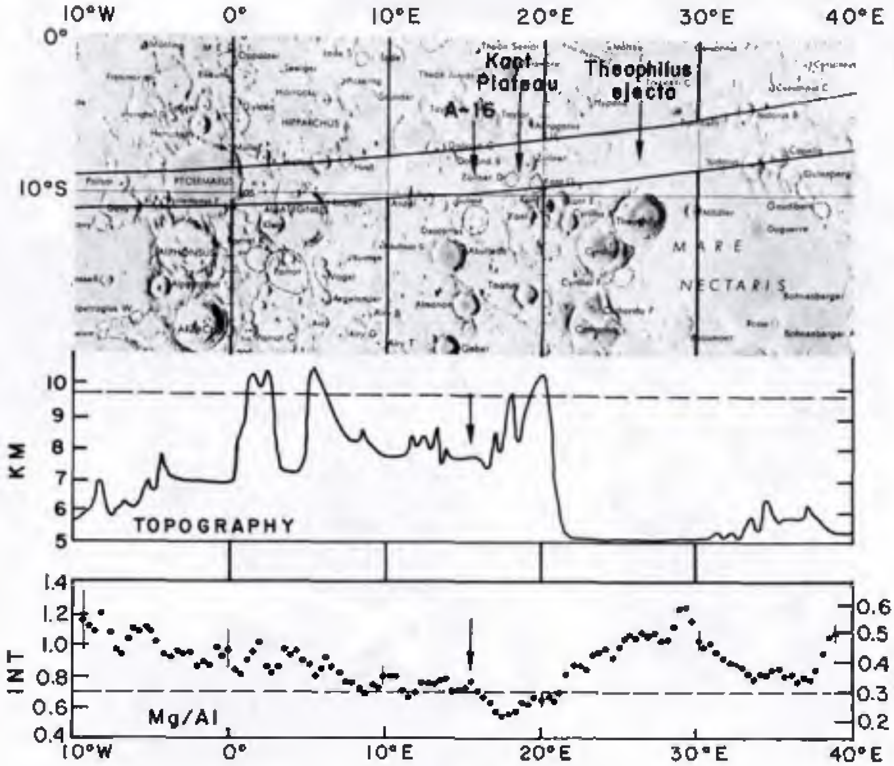

Fig. 4. The profiles show the topographic and Mg/Al intensity (and corresponding concentration) variations for the region surrounding the Apollo 16 landing site. The swath on the map represents the combined effective fields-of-view for the orbits used to construct the X-ray profiles.

been equated to the Alpes Formation located in analogous positions relative to the Imbrium basin (Head, 1974). The implication is that the Descartes Mountains represent material superposed on the pre-existing terra as a result of the Nectaris impact. Elongate furrows radial to the Imbrium basin scar the unit in a NW/SE direction. The questions posed by the geologic and sample information relating to the Descartes Mountains are: 1) does the unit have the same chemical composition as the Cayley Plains on a regional scale? 2) Is the unit a chemical extension of the Kant Plateau? 3) Does the Imbrian sculpturing indicate superposition of Imbrium ejecta onto the terrain? 4) Is the unit chemically distinct from all the other units present in the Central Highlands. The orbital X-ray data provides the spatial resolution and regional coverage necessary to address these questions.

Cayley Plains

Highland light plains, like the Cayley Formation, have many physical characteristics in common with mare basalts. However, the more confined plains deposits do not have the ridges typical of regional mare flooding; they have a more undulating surface and a higher visible albedo. Cayley Plains fill craters and irregular depressions in the central highlands, primarily west of the Kant Plateau. Within the east/west swath of orbital X-ray coverage, the proportion of plains to terra material increases with distance from the landing site toward Mare Nubium. Spectrally, these plains deposits can be clearly distinguished from the surrounding highlands. Within the largest continuous deposits, e.g., Ptolemaeus, the reflectivity drops in the visible wavelengths from the terra value of 0.14 to 0.12. This value is, however, higher than that of the most reflective mare basalts (0.09). Large Cayley deposits within the central highlands are also noticeably "bluer" than the terra in a color difference (6100 Å minus 3700 Å) photograph (Whitaker, 1972). Based on crater frequency measurements, all plains pre-date the lunar maria (Boyce *et al.*, 1974) but the Cayley Formation appears to overlie almost all other terrain in this region and is, therefore, the youngest major unit in the area (Head, 1974). Some investigators favor local derivation of plains material (Oberbeck *et al.*, 1974). Others have proposed volcanic sources (Hodges, 1973). The most recent orbital X-ray research includes several occurrences of plains units, that are widely distributed on the moon, that have chemical signatures distinct from the surrounding terrain and different from each other. Contrasts in chemical composition, like these, infer an endogenic origin (Andre *et al.*, 1979a; Maxwell and Andre, 1981). Magnesium was the distinguishing characteristic for these plains deposits, but aluminum appears to be the most effective discriminator of the Cayley Formation.

GEOCHEMICAL SETTING OF THE APOLLO 16 SITE

The Kant Plateau is easily identified on the basis of aluminum, magnesium and thorium concentrations as a singularly anorthositic unit of the lunar nearside. It is the only segment of the Nectaris ring system for which there is concentrated orbital XRF coverage. In Fig. 4, the map area covered by the X-ray data is shown and the topographic profile (Kuala *et al.*, 1974b) may be compared to a profile of variations in Mg/Al ratios. The Mg/Al ratio is a sensitive indicator for distinguishing among most members of the terra rock suite (Andre and Adler, 1980), with the exception of KREEP basalts. These basalts can have a wide range of MgO values from 3.4 to 12.5 wt.% and Al_2O_3 values from 11.2 to 18.1 wt.% (Irving, 1977) and these two elements are not necessarily anticorrelated. Therefore, profiles of Al/Si and Mg/Si data are also shown to avoid any ambiguities (Fig. 5).

The chemical profiles in Figs. 4 and 5 were constructed by averaging single data points at the same longitude from each of five orbits. A three point sliding average of the resulting values was applied to increase the signal-to-noise ratio. Spatial resolution is not compromised because the averaged points occur within the confines of the effective field-of-view. The combined fields-of-view for the orbits used is outlined on the map. However, variations along the orbits should be resolvable for distances between 15 and 30 km (approximately the distance between every other data point on the profile).

From the chemical variations, it is clear that the nearside central highlands are not chemically homogeneous and that the Kant Plateau (between about 17°E and 22°E) is more anorthositic than the landing site on the scale measured. Mg/Al values gradually increase with distance from the landing site toward Mare Nubium. Local variations are interpreted with caution west of 10°E because random variations in the X-ray data increase exponentially as the spacecraft approaches the terminator. (Notice the respresentative error bars.) However, the trend coincides with increasing amounts of plains material. The Apollo 16 site lies directly west of the sharp chemical contact that separates the Cayley Plains from the Descartes Mountains and the Kant Plateau. With a few rare exceptions, only lunar farside materials are as aluminous as the Kant Plateau/Descartes Mountain area or as low in Mg/Al ratios. Such anorthositic material on the farside is believed to exemplify a differentiated anorthositic layer of the early lunar crust (e.g., Wood *et al.*, 1970).

There is independent chemical confirmation of the X-ray results. Deconvolved thorium values for the central highlands (Metzger *et al.*, 1981) and titanium variations (Davis, 1980) both show abrupt decreases in those elements related to Kant materials east of the Apollo 16 site. Thus, the Kant Plateau area is distinguished by its resemblance to the chemistry of the farside terra. We propose that the Kant Plateau/Descartes Mountains represent subsurface material, exposed during the formation of the Nectaris basin and

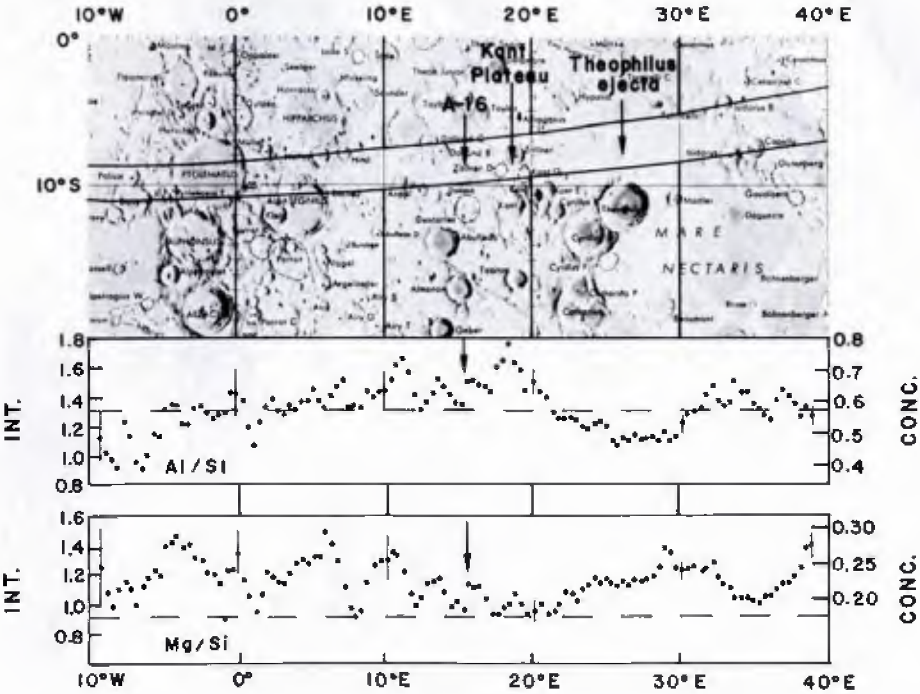

Fig. 5. Al/Si and Mg/Si profiles like the Mg/Al profile in Fig. 4.

could be one of the few nearside formations exemplifying the early anorthositic terra crust.

There is a striking chemical contrast between the Kant Plateau and the area north of Theophilus crater. A large percentage of this area within the X-ray coverage east of the Plateau (Figs. 4 and 5) is continuous primary ejecta from the Theophilus impact. This event occurred after mare basalts filled the Nectaris basin. Less than a third of the area is beyond the field of secondary ejecta (Oberbeck, 1974). Although the impact penetrated more than 2.2 km below the mare surface, the Mg/Al signal is too high to contain any significant amount of terra material. Rather, it indicates principally mare material of moderate Al and high Mg concentrations. High thorium values also suggest mare material rather than highland ejecta north of the crater (Metzger *et al.*, 1981). Unfortunately, data do not exist for the center of the crater. However, the visible albedo in the area around Theophilus is exceedingly low for a Copernican-age crater (Pohn *et al.*, 1970) and dark soils are associated with the ejecta (Milton, 1968). In addition, the continuous blanket of ejecta is more mafic than the Nectaris mare north of the ejecta unit (Fig. 6). Contours of 0.25 degree values from the most refined digital image of Mg/Al concentration ratios (Bielefeld *et al.*, 1977; Andre *et al.*, 1977) are superposed on a geologic map of the Theophilus Quadrangle (Milton, 1968). To represent units in a realistic scale relative to the spatial resolution of the X-ray experiment, only general unit categories are included. This illustration has the advantage of showing chemical variations from south to north as well as east to west, although it does not have as high statistical reliability as the averaged profiles (Figs. 4 and 5). For this reason, it was not practical to extend the data west of 10°E. It is quite clear that Mg/Al ratios increase sharply with proximity to the crater Theophilus. They correlate to strong increases in thorium with proximity to the crater itself. Mg/Al values are also high for the large Copernican-age crater northeast of

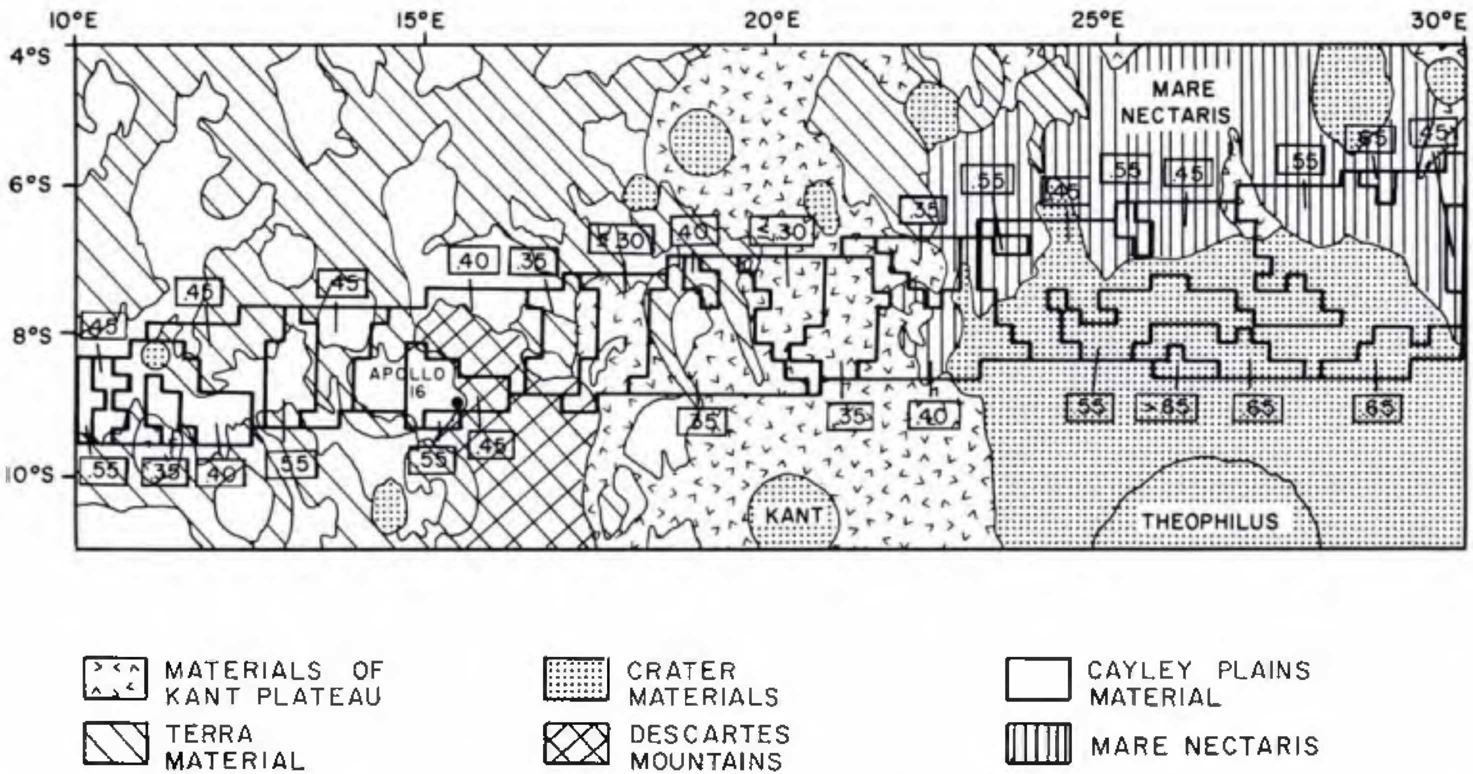

Fig. 6. Contour map of variations in Mg/Al concentrations for the Apollo 16 landing site region. The key below the map indicates the meaning of the map units, each of which combines all the related subunits of U.S.G.S. Map I-546 (Milton, 1968) and includes the Descartes Mountains from Hodges *et al.* 1973). The concentration values show above and below the X-ray data coverage outline indicate the highest concentration found between those contour lines. Mg/Al values up to 0.45 are contoured at 0.05 intervals and the higher values are at intervals of 0.10.

Theophilus. Thus, these craters, like many other post-mare craters in nearside maria appear to have excavated magnesium-rich basalts from beneath the surface flows (Andre *et al.*, 1979b). However, the early magnesium-rich basalts excavated in Mare Nectaris have made a negligible contribution to the Apollo 16 landing site. The Kant Plateau, with high concentrations of aluminum and low concentrations of magnesium and thorium, chemically separates the two units (Figs. 4 and 5). This implies that the steep eastern scarp of the Kant Plateau occluded Theophilus ejecta west of the crater. The orbital data indicate that primary ejecta is apparently minimal, even though a few secondary craters are traceable to Theophilus (Hodges *et al.*, 1973). The Kant obstruction most likely emphasized the asymmetrical ejecta pattern noted by Milton (1968) and preserved the anorthositic nature of both the Kant Plateau, including the Descartes Mountains, and the landing site soils.

This map representation of Mg/Al variations (Fig. 6) also clarifies the strong correlation between Kant materials and very low Mg/Al ratios. Low values (up to 0.35) to the far left of the figure nearly coincide with Kant materials within the crater Andel M. A similar Al/Si map (Fig. 7) shows that increases in aluminum are also associated with this feature. Likewise, low values of Mg/Al follow the northeastern-most extension of the Plateau.

It is significant to note that the western edge of the Plateau shows a chemical extension. Low Mg/Al values (Fig. 6) continue west across the Descartes Mountains, to the landing site where concentrations increase to 0.55 in conjunction with the Cayley deposit there. The relationship between the Kant Plateau and the Descartes Mountains is most obvious in Fig. 7. Calculated Al_2O_3 concentrations increase strikingly from 19 wt.% just west of the site at 14°30′E to 29 wt.% at 16°E at the center of the Descartes Mountains east of the site. This is important to the question of whether the Descartes Mountains are, in fact, chemically identical to the Kant Plateau material, there are no further increases of aluminum values east of the Descartes Mountains. This strongly implies that the anorthositic composition of the Kant Plateau is shared by the Descartes Mountains. Although the method of emplacement for these geologic units may not be the same, they have a common composition. The gamma-ray detector does not provide the high-resolution that the X-ray detector does. However, the chemical difference between Cayley and Descartes material is sufficient to observe the northwest/southeast trend of the Descartes Mountains, even on a two degree map. Two low values of thorium occur west of the Kant Plateau—one east and the other north of the landing site (Etchegaray-Ramirez *et al.*, 1981).

The data map representation of the Mg/Al orbital X-ray variations (Fig. 6) also clarifies the general trend seen in the profiles (Figs. 4 and 5) toward higher Mg/Al values with increasing amounts of Cayley Plains material from the west side of the landing site to Mare Nubium. The data track narrows toward the west and thus contour lines run generally north/south. Contoured areas with the largest proportion of plains, however, also have high Mg/Al ratios compared to the older terra unit or Kant materials. The Cayley unit immediately west of the Apollo 16 site has distinctly lower Al/Si values. Although it is difficult to assign the Cayley unit a specific Al_2O_3 value because of the varying sizes and shapes of the deposits, it has lower aluminum content than the terra, which in turn has lower Al than the Kant/Descartes Mountains materials. The best estimate of the Cayley Plains patch adjacent to the landing site is 19 wt.% Al_2O_3, assuming 21 wt.% Si (45 wt.% SiO_2). This is considerably higher than the concentration of aluminum in mare basalts but only one wt.% less than the most aluminous KREEP basalt composition (Irving, 1977). Coupled with the sharply increasing thorium values toward the largest unit of plains that fills the Ptolemaeus crater, it is conceivable that this Cayley Plains unit is, at least in part, an early thorium-rich basalt (KREEP basalt?) emplaced much as the maria were. This explanation, although certainly not the only one, would explain the similarity to the physical characteristics of mare basalts, with the exception of the higher albedo and more extensive reworking. Aluminous, magnesium-rich, pre-mare material in the south and west of the Smythii basin also has visible albedo values clearly higher than those of mare basalts and somewhat lower than terra areas. Yet, magnesium

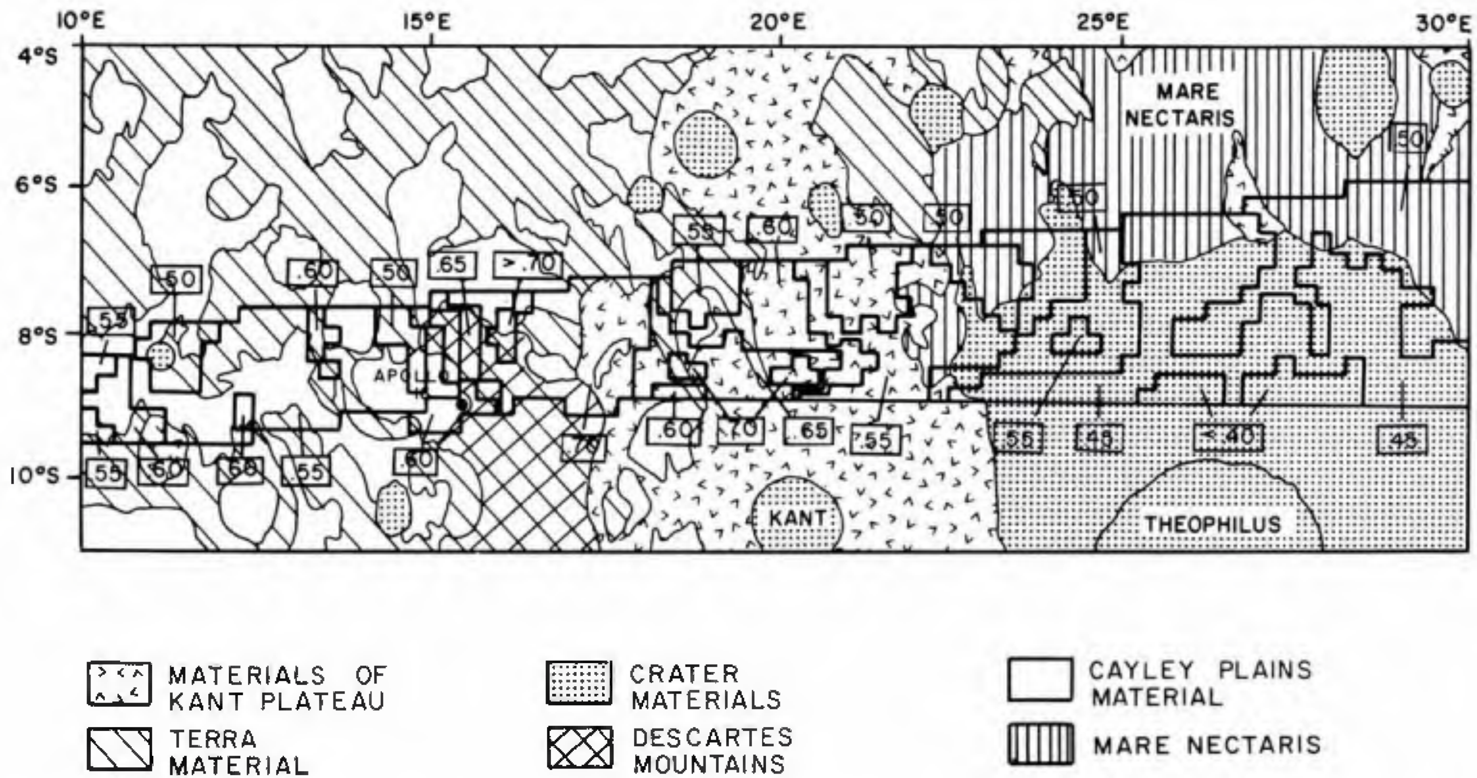

Fig. 7. Al/Si concentration contour map like Fig. 6. The highest value within the contours is shown. The interval between contoured areas is 0.05. The corresponding Al_2O_3 wt.% for each Al/Si concentration, assuming 45 wt.% SiO_2, is as follows: 0.40 = 16, 0.45 = 18, 0.50 = 20, 0.55 = 22, 0.60 = 24, 0.65 = 26, 0.70 = 28.

and thorium values indicate that the unit is probably an early volcanic fill, not Crisium basin ejecta (Conca and Hubbard, 1979; Andre, 1981). Early geologic studies of the Smythii basin interior include evidence of several episodes of pre-mare volcanism characterized by higher albedos than the later mare flows (Stewart *et al.*, 1975; Wolfe and El-Baz, 1976). Thus, the albedo difference between mare material and Cayley Plains may be attributable to the age and higher aluminum content of the thorium-rich basalts. One other occurrence of thorium-rich plains material is located within a newly discovered ancient basin and has the physical and chemical characteristics of early volcanic fill (Maxwell and Andre, 1981). The extrusion of KREEP, based mainly on isotopic evidence, is estimated to have started about 4.4 b.y. ago (Schonfeld and Meyer, 1972). It predates mare volcanism as does all plains emplacement. If the Cayley Plains are a volcanic unit, the long history of meteorite bombardment may have caused the higher reflectivity, chemical homogeneity of lithologic boundaries and obliteration of igneous texture.

DISCUSSION

Orbital X-ray data indicates that both the Kant Plateau materials and the Descartes Mountains bear a strong resemblance to terra soils of the eastern farside. This observation is supported by thorium data from the orbital gamma-ray experiment. Within the coverage of the orbital geochemistry, these materials, representative of subsurface crustal material exposed by the Nectaris impact, are rare on the lunar nearside. The other occurrences of unusually anorthositic material on the nearside also represent material from below the crustal surface. High resolution XRF data from the Smythii basin area indicate that the chemical patterns formed by the basin impact persist, although Smythii is one of the oldest basins on the moon (Andre, 1981). A circular ring of low Mg/Al values correlates with a rim ring that represents material from the deepest levels of excavation. Similarly, Langrenus crater, 130 km in diameter, 600 km west of Smythii exposes equally anorthositic material comparable to the farside terra. We suggest that the Nectaris basin is exhibiting a similar pattern at the Kant Plateau and the Descartes Mountains. The Kant Plateau marks the third topographic ring of the basin, 850 km in diameter, that may be the boundary of excavation. The striking low-magnesium, low-thorium and high-aluminum pattern that coincides with this ring supports this hypothesis. According to orbital geochemical data, the hummocky material of the Descartes Mountains and the Kant Plateau have a common lithology that forms a segment of a chemical pattern that has survived since the formation of the Nectaris basin. If our interpretations are correct, then materials like those of the farside terra comprise the Descartes Mountains and the Kant Plateau. They are almost certainly in the sample collection. Either ballistic transport to the site by meteorite impacts or excavation from below the Cayley Plains are viable mechanisms to explain their presence.

The orbital X-ray data also indicate that the Cayley Plains unit can be chemically identified as the least aluminous in the landing site region. Whereas Al_2O_3 values can be as high as 29 wt.% for the Descartes Mountains and the Kant Plateau, Al_2O_3 values for the Cayley Plains immediately west of the site can be as low as 19 wt.%. If both these units of different lithologies are at the Apollo 16 site, it raises the question of why the samples do not fall into distinct chemical populations. With the exception of Theophilus ejecta, orbital data indicate that Al_2O_3 values are the most diagnostic of the geologic units present at the site. The greatest chemical change over the smallest distance is centered at the landing site. Within a distance of 45 km, Al_2O_3 values increase 10 wt.% from the Cayley unit to the Descartes unit. Yet, there is no dramatic contrast between sample populations. Korotev (1981) calculated mean soil compositions of Apollo 16 sampling stations. Al_2O_3 averages for all stations differ by only 2.7 wt.% Al_2O_3 (26.2 at Station #5 to 28.9 at Station #11). MgO values range from 4.3 wt.% at Station #11 to 2.4 wt.% at Stations #6 and #8. Although there are limited differences related to sample location, all soils from stations at the south end of the traverse at elevations less than 7900 m are less anorthositic and have a larger KREEP component; whereas, soils from Stations #11 and #13, on the side of

Stone Mountain, are most anorthositic, with only a minor KREEP component. Perhaps the limited contrast is to be expected. The disparity between rock and soil variance may be characteristic of the lunar highlands. At the Apollo 17 site, there was a surprising degree of homogeneity of south massif soils that does not indicate the distinct compositional difference between the noritic breccias and anorthositic gabbros, the two major massif rock types (Rhodes, 1977). Within the restricted areas of sample collection, gardening by meteorite impacts has apparently homogenized the compositional extremes and disguised petrologic histories.

At North Ray Crater, samples were clearly more anorthositic (Korotev 1981). Considering the more anorthositic nature of the Descartes Mountains, this crater, 230 m deep, may have excavated Descartes/Kant-type material from beneath the Cayley Plains surface unit, according to the mission plan. Furthermore, the feldspathic fragmental breccias (light matrix breccias) from North Ray crater area, that have old highland ages, 4.1 to 4.5 aeons (Taylor, 1975, p. 217–218), and that are chemically like anorthosites may be remnants of the earliest anorthosites to form the primitive lunar highland crust.

SUMMARY

The following points are the results of our study of the Apollo 16 region based primarily on orbital geochemical data:

1. Geologic units in the Apollo 16 region can be separated by orbital geochemical data.
2. Cayley Plains have closer affinities to basalt volcanism than terra materials, physically, spectrally, and chemically.
3. The Theophilus impact excavated magnesium-rich basalts from below less-magnesium flows in Mare Nectaris, but the orbital view indicates that the mafic ejecta was substantially blocked from the landing site by the Kant Plateau.
4. The Kant Plateau and Descartes Mountains have common lithologies and may be among the rare nearside examples of a plagioclase-rich layer evolving from the "primordial magma ocean."

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