THE ORIGIN OF SELECTED GEOCHEMICAL ANOMALIES ON THE LUNAR SURFACE.

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Introduction: Analyses of the orbital geochemistry data sets have shown that some lunar regions have unusual abundances of certain elements relative to surrounding or adjacent areas, or have a surface chemistry unlike that which would be anticipated from the examination of local geologic relationships. Investigation of the formation of geochemical anomalies can provide important clues to understanding impact and volcanic processes operative during the early phases of lunar evolution as well as the lateral and vertical composition of the highlands crust (1,2,3,4).

The purposes of the present study include the following: 1) to locate and determine the extent of geochemical anomalies in selected lunar regions, 2) to determine the compositions of anomalous regions, 3) to correlate the anomalies with specific geologic units or surface features, and 4) to determine the origin of the anomalies and associated surface features.

Method: Digital versions of the various orbital chemistry data sets were obtained and utilized in this study. The Aℓ/Si values utilized were the newly revised data described by Clark and Hawke (5). The digital Fe and Ti data used were those presented by Davis (6). The Th abundances are those presented by Metzger et al. (7). In addition, images showing Fe and Ti abundances as determined by Metzger and co-workers (8,9) were kindly provided by Dr. A. Metzger. The digital data were analyzed using a variety of image processing techniques including a units mapping technique described by McCord et al. (10).

Selected Geochemical Anomalies: 1) Terrain northeast of Mare Smythii--A number of major geochemical anomalies have been identified immediately northeast of Mare Smythii. The Aℓ/Si intensity map shows that an area of relatively low Aℓ/Si values (∿1.00-.70) extends along the Apollo 16 groundtrack between 92°E and 99°E. Considerably higher Aℓ/Si values predominate in other highland areas to the east and southeast of Smythii. Previous workers (2,11) noted that relatively high Mg/Si values (MgO% = 8%) were associated with the plains material inside Babcock crater which is within the anomalous region. The deconvolution studies by Haines et al. (12) indicated that at least the northern half of Babcock exhibited enhanced Th abundances (3.4 ppm). The region also exhibits enhanced Fe and Ti values.

The geochemically anomalous region closely corresponds to a geologic province characterized by relatively young light plains mapped by Wilhelms and El-Baz (13). The province is dominated by Imbrian plains (Ip), middle Imbrian to late Nectarian plains (INp) and Imbrian-age terra mantling material (It). It is significant that areas which exhibit low Aℓ/Si values can be correlated with specific deposits of light plains or terra mantling material. In addition, Schultz and Spudis (2) mapped a high density of dark-haloed impact craters in this region. There appears to be a clear association of geochemical anomalies with light plains deposits which exhibit a high concentration of dark-haloed impact craters.

In general, the present surface composition of the anomalous region is intermediate between mare basalts and highland material. While it is conceivable that these plains could be the products of an episode of volcanic activity which emplaced material of intermediate composition, another explanation seems more likely based on the results of studies in other lunar regions (1,2,3,4). The region probably experienced an episode of mare volcanism early in lunar history. The surfaces of these basalts were subsequently contaminated by highlands material contributed by a variety of subsequent impact events.

2) Region near Langemak crater--A major farside geochemical anomaly is located in the general vicinity of Langemak crater. Hubbard et al. (14) first pointed out the rather striking variations in Mg/Si and Aℓ/Si intensity ratios which occur near Langemak. Schultz and Spudis (2) correlated the highest Mg/Si intensity ratios with two dark-haloed impact craters and suggested that the region had been the site of an early episode of basaltic volcanism. Relatively high Fe and Ti values are associated with the Langemak region (1,6). No Th or radioactivity anomaly has been identified in the region (1).

Examination of the most recent Aℓ/Si maps (5) showed that the lowest Aℓ/Si intensity values (.99 - .70) are centered on the two dark-haloed craters described by Schultz and Spudis (2). Only slightly higher values are associated with the relatively dark Langemak ejecta blanket and Nectarian light plains. Similar patterns are seen in other versions of orbital X-ray data sets [Andre and Adler (15), Hubbard et al. (16), Bielefeld et al. (17)]. Another small Aℓ/Si anomaly (.99 - .70) is located in the southern part of the Langemak region (15°-16°S, 113°-115°E) and appears to correlate with a small deposit of light plains material.

3) The Pasteur crater region--Aℓ/Si intensity ratios in portions of the Nectarian plains in the northern floor of Pasteur (10°-12.5°S, 105°-108°E) range from 1.0 to 0.84. Similar Aℓ/Si values occur in the floor of Backlund crater on the south rim of Pasteur and correlate with a light plains unit (INp). No Ti or Th anomaly was identified but relatively high (up to 7.4%) Fe values occur on the northeast rim of Pasteur and extend into the northeastern portion of the crater floor. Relatively low Aℓ/Si values were also found to be correlated with light plains units northwest of Pasteur (17) (~9°S, 98°E). To date, no dark-haloed impact craters have been identified in the Pasteur region.

4) Region NW of Milne basin--An area of anomalously high (2.4-3.5%) Ti values occurs northwest of Milne basin. The high values are seen on both the Ti distribution maps of Davis (6) and Metzger. Fe values in the high Ti area are variable but increase systematically from the northeast to the southwest. The region contains a variety of highland units as well as a very small amount of mare material in the northernmost extension of Lacus Solitudinis. At least four dark-haloed impact craters have been identified around Lacus Solitudinis and their presence suggests that mare volcanism was more widespread in this region than is currently recognized. Two of these dark-haloed craters occur within the high Ti area. The presence of early mare basalt, thinly covered by and mixed with highland material may also be partly responsible for the anomaly.

5) Eastern Mendeleev region--Relatively high Fe abundances (5.6 - 7.4%) occur on the northeast rim of Mendeleev basin (6). Slightly lower values (4.4 - 5.6% Fe) occur in the eastern portion of the floor of Mendeleev and extend to the east of the basin. An area of high Ti values (~3.2%) can be seen on the northeastern floor and rim of Mendeleev on Metzger's unpublished Ti distribution map. The Fe anomaly is centered on a concentration of Imbrian light plains. No dark-haloed craters have been identified in the region. It seems unlikely that the high gamma-ray values are caused by detector response to mare material north of the groundtrack because the nearest significant expanse of basalt occurs over 400 km to the north on the interior of Moscoviense basin.

Conclusions: 1) These anomalies are commonly, though not always, associated with light plains deposits which exhibit a high density of dark-haloed impact craters. 2) In light of recent results of spectral reflectance studies of dark-haloed impact craters (3, 4), it seems likely that the chemical anomalies associated with light plains which exhibit abundant dark-haloed impact craters are due to the presence of basaltic units thinly covered by highlands material. The subjacent basaltic material could have been incorporated in the surface material either by local mixing during emplacement of the highlands material or by later vertical mixing. 3) In those instances where geochemical anomalies correlate with light plains without identified dark-haloed impact craters, the origin of the anomalies remains uncertain. The thinly buried basalt hypothesis is still viable but other explanations (such as highland volcanism and the impact excavation of anomalous material) must be considered. 4) The burial of pre-existing volcanic surfaces by varying thicknesses of highland material appears to have been an important process in the formation of lunar light plains.

References: 1) Hawke, B. and Spudis, P. (1980) Proc. Conf. Lunar Highlands Crust, 467. 2) Schultz, P. and Spudis, P. (1979) Lunar Planet. Sci. Conf. 10th, 2899. 3) Hawke, B.R. and Bell, J. (1981) Proc. Lunar Planet. Sci. Conf. 12th, in press. 4) Hawke, B. and Bell, J. (1981) NASA TM-84211. 5) Clark, P. and Hawke, B. (1981) Proc. Lunar Planet. Sci. Conf. 12th, in press. 6) Davis, P. (1980) JGR 85, 3209. 7) Metzger, A. et al. (1977) Proc. Lunar Sci. Conf. 8th, p. 949. 8) Metzger, A. and Parker, R. (1979) EPSL 45, 155. 9) Haines, E. and Metzger, A. (1980) Proc. Lunar Planet. Sci. Conf. 11th, p. 689. 10) McCord, T.B. et al. (1980) Lunar Planet. Sci. XI, p. 679. 11) Andre, C. et al. (1979) Proc. Lunar Planet. Sci. Conf. 10th, p. 1739. 12) Haines, E. et al. (1978) Proc. Lunar Planet. Sci. Conf. 9th, p. 2985. 13) Wilhelms, D. and El-Baz (1977) USGS Map I-948. 14) Hubbard, N. et al. (1978) In Mare Crisium: The View from Luna 24, 13. 15) Andre, C. and Adler, I. (1980) Frontispiece, PCLHC. 16) Hubbard, N. et al. (1978) Frontispiece, Proc. Lunar Planet. Sci. Conf. 9th. 17) Bielefeld, M. et al. (1977) Frontispiece, Lunar Planet. Sci. Conf. 8th.