GEOCHEMICAL STRATIGRAPHY OF THE 60009/60010 CORE, APOLLO 16

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The 60009/10 core is a double drive tube collected at the LM/ALSEP site on the Apollo 16 mission. It is one of the most well studied lunar cores [1]. Previous compositional studies [2-5] were based on one to a few samples from each of the 17 stratigraphic units identified by [6]. We have analysed by INAA 121 samples from every ~0.5 cm dissection interval of the core to obtain a more detailed profile of compositional variation with depth than previously available.

Results. Stratigraphic profiles are presented for Sc (an element associated with mafic mineral phases; Fe and Cr behave similarly) in Fig. 1 and Sm (a typical incompatible trace element) in Fig. 2. The correlation between the two elements and comparison to surface soils are shown in Fig 3.

Concentrations of the Sc and Sm vary by factors of 3.8 and 4.7, making this one of the most compositionally variable cores collected on the Moon. The range in soil compositions within this 59 cm core is nearly as great as that for all 40+ samples of Apollo 16 surface soil, that were collected over a lateral distance of 7.5 km. The high-Sc, high-Sm soil (model dependent translation = "mafic, KREEPy") at 18-21 cm depth is similar in overall composition to the surface samples with the greatest concentrations of these elements, those from station 5 [7]. Among surface soils not from the North Ray crater area (stations 7 and 13), station 1 soil 61221 has the lowest Sc and Sm concentrations. All surface soils collected from stations other than 7 and 13 have compositions intermediate to 61121 and the station 5 soils, as do most of the 60009/10 soils. However, some 60009/10 soils range to much lower Sc and Sm concentrations than does 61121. The mean composition of the core (represented by dotted lines in Figs. 1 and 2) is most similar to that of soils 60051 and 64501 (based on data for all elements determined).

The stratigraphic profiles for Sc and Sm are nearly identical, leading to a strong correlation. A similar correlation exists between nearly any pair of lithophile elements analyzed. To a good first approximation (but see below), the composition of any sample in the core is equivalent to that of a binary mixture of the most Sc,Sm-rich sample (20 cm) and the most Sc,Sm-poor sample (55 cm). This conclusion was reached by previous studies and was attributed to various degrees of admixture of ferroan anorthosite such as 60025 (very low Sc and Sm) to a typical Apollo 16 soil such as that found at the surface near the landing site [2-5]. Nearly every inflection in the profiles corresponds to a break between stratigraphic units identified visually by [1,6]. There is a overall trend of decreasing Sc and Sm with depth (thus, increasing anorthosite).

Discussion. In a previous study we argued that most of the compositional variation among lithophile elements in Apollo 16 soils results from mixing of three compositionally distinct components [7]. One of these components is a soil itself, probably best represented by the station 5 soils and perhaps also by the 60009/10 soil at 20 cm depth. No common Apollo 16 rock type is identical to this soil component, but the component clearly contains a large fraction of noritic impact melt rock ("LKFM","VHA") because such rocks are the principal carriers of mafic minerals (and, thus, Sc) and incompatible trace elements (Sm) at Apollo 16. This component might be regarded as the "Cayley" component because its composition appears most similar to that of the Cayley plains (measured remotely) to the west of the landing site [7]. The second component is ferroan anorthosite. In soils where ferroan anorthosite is inferred to be an important component chemically (e.g., 51-54 cm deep in the core), coarse fragments of anorthosite and plagioclase are observed petrographically [8,9]. Most Apollo 16 soils (including 60009/10) correspond primarily to binary mixtures of the "Cayley" soil component with ferroan anorthosite. The third component is the "North Ray crater" component. North Ray crater soils contain an important rock type or types which appear to be of only minor importance at stations to the south. Compositionally, these rocks are noritic anorthosites which are distinctly different than ferroan anorthosite in being more mafic (thus, higher Sc), yet similarly low in incompatible trace elements. North Ray crater soils define a distinctly different trend on Fig. 3. Either or both of the ferroan anorthosite component and the North Ray crater component might be regarded as the "Descartes" component. (A fourth component, a mare component, was shown to be important in soils from the station 4 core [10], and is probably minor in other soils.)

McKay et al. [9] argue that mixing relationships among 60009/10 samples are explained by three petrographic components. Their "plagioclase single crystals" component, most prevalent at 54 cm depth, clearly corresponds to the ferroan anorthosite component. The other two petrographic components must be compositionally similar to each other or the correlation of Fig. 3 would be poorer. However, careful consideration of Fig. 3 suggests that part of the scatter from perfect correlation may result from varying ratios of the two petrographic components. The "poikilitic rocks" component is most prevalent at 20 cm depth and the "metamorphosed breccia" component is most prevalent at 58 cm depth [9]. Both of these depths correspond to peaks in the Sc and Sm profiles. Poikilitic impact melt rocks, such as 65015, have the greatest concentrations of Sm and Sc of common Apollo 16 rock types and also have higher Sm/Sc ratios than other impact melt rocks [11]. It is evident in Figs. 1-3 that the 6 samples at 18-21 cm depth (triangles in Fig. 3) have greater Sm/Sc ratios than the 3 samples at 58-59 cm (inverted triangles). Thus, the poikilitic rocks observed petrographically at 18-21 cm are the likely cause of the high Sc and Sm concentrations in the "Cayley" chemical component. (We suspect that the particularly high Sc and Sm concentrations, compared to those observed here, reported by [5] for their sample from 20 cm depth result from a unrepresentatively large proportion of poikilitic melt rock, perhaps a single large fragment, in the sample they analyzed.) It is not clear what chemical rock type corresponds to "metamorphosed breccias," which are the important petrographic mixing component in the lower (60009) portion of the core [8,9], but it must be relatively rich in Sc and Sm and have a slightly lower Sm/Sc ratio than poikilitic melt rocks. It is probably some type of "VHA basalt."

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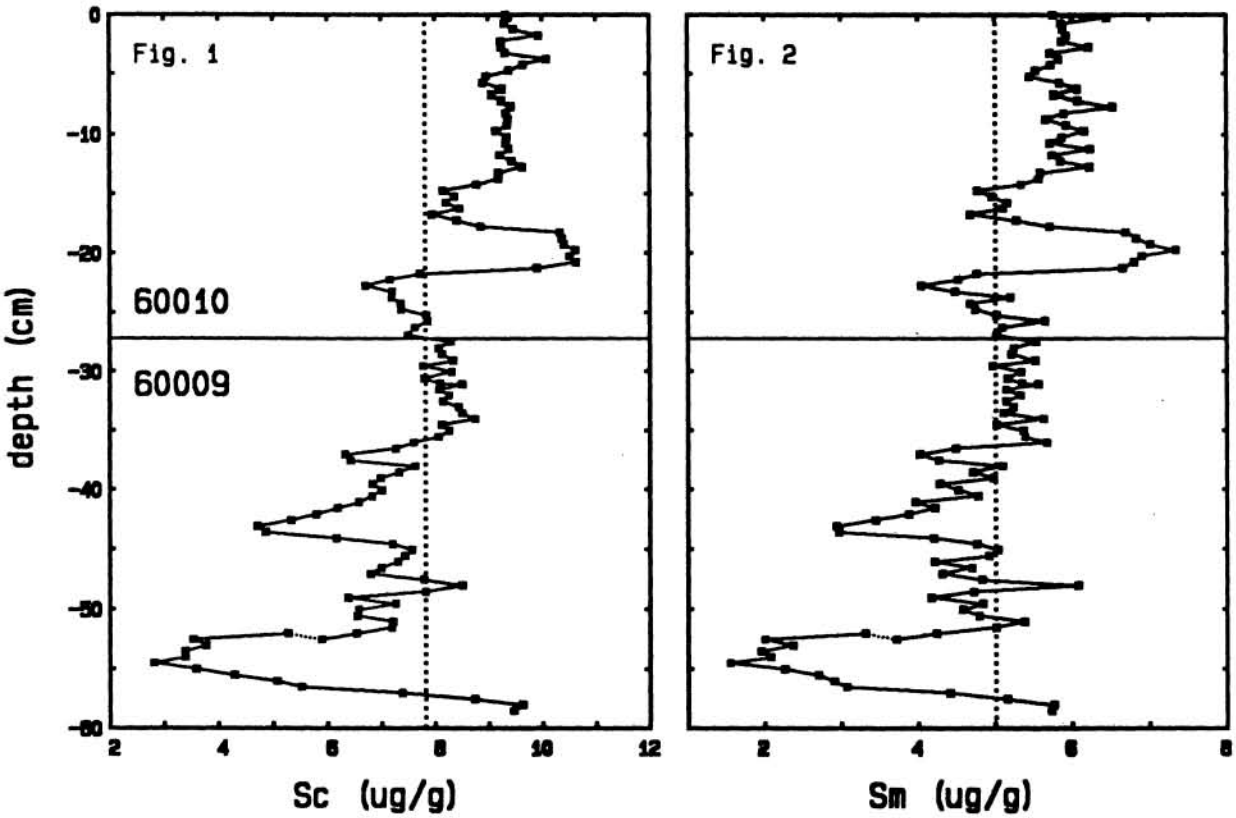
Fig. 1
Fig. 2
60010
60009
depth (cm)
Sc (ug/g)
Sm (ug/g)

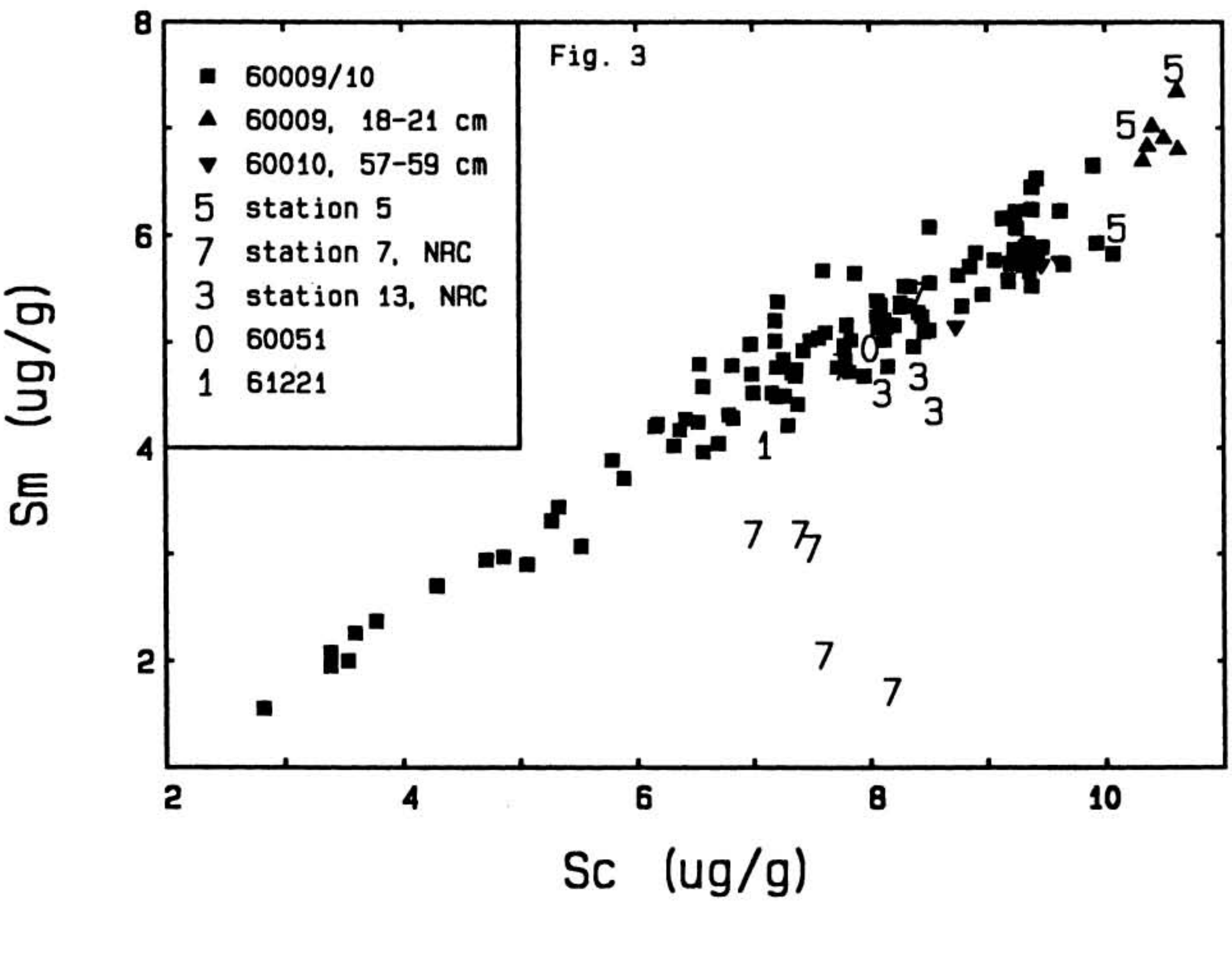
Fig. 3
60009/10
60009, 18-21 cm
60010, 57-59 cm
5 station 5
7 station 7, NRC
3 station 13, NRC
0 60051
1 61221
Sm (ug/g)
Sc (ug/g)