BULK, REE AND OTHER ABUNDANCES IN APOLLO 16 AND LUNA 20 SAMPLES,
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Abundances of the bulk elements TiO_2, Al_2O_3, FeO, CaO, Na_2O, K_2O, MnO and Cr_2O_3 and the trace elements Sc, V, Co, Hf, Th, U, Ba, Ta and nine REE, La, Ce, Nd, Sm, Eu, Tb, Dy, Yb and Lu elements have been determined by sequential INAA in Ap 15, Ap 16 and L 20 samples. An additional twelve trace meteoritic and non-meteoritic elements were also determined in soils 15041, 62281 and 22001 by RNAA. The INAA results of Ap 15 samples are already discussed (1-3). We report here our L 20 work and recent analyses on Ap 16 samples. The chondritic normalized REE patterns of Ap 16 samples are shown in Figure 1; REE patterns of L 20 samples are shown in reference 4.

Anorthosite 60025 (LM) and 60015 (Tatsumoto consortium) fall in the low K group. Of all the four anorthosites, 10085 (92% Pl), 15362 (97% Pl), 60015 (97% Pl), and 60025 (97% Pl), measured to date in our laboratory, the 60015 anorthosite has the lowest REE abundances (except Eu). The bulk and trace element composition of the 60015 anorthosite is essentially identical to 15415 anorthosite (5, 6). Likewise, REE abundances in anorthosite 60025 and in anorthosite 15362 (2) are similar. The dark clast 60015,54, an exterior glass fragment from the 60015 rock, is anorthositic gabbroic (74% Pl) in composition and relative to the 60015,63 anorthostic interior, has ~90 times more REE abundances with a negative Eu anomaly. Based on K, Ba and REE abundances, the trace element composition of the 60015,54 dark clast is matched by a mixture of ≈10% KREEP and ≈90% 60015,63 anorthosite. However, this simple combination does not satisfy the bulk elements. The bulk and trace element composition for the 60015,54 dark clast lie in the range of Ap 16 cataclastic and breccia rocks (7), and the 60015,54 composition is similar to the 68415 rock composition (8). This suggests that the 60015 anorthositic interior has been merely splashed with a molten composition very similar to 68415.

Sample 67031 (STA 11) is actually finely grounded fragments of a breccia rock and is gabbroic anorthosite (83% Pl) in composition. This breccia is also of the low K-type and has the same positive Eu enrichment like other anorthosites. The REE abundances in 67031 are ≈27 times higher compared to 60015, 63 anorthositic REE abundances.

Rake samples 60615 (59% Pl), 60625 (79% Pl) and 60636 (55% Pl) are fine grained annealed clastic rocks and were picked up at STA 10. These rake samples represent highland composition and are in the range of Ap 16 meta-igneous rocks (7). Rock 60625 is considerably lower in TiO_2, MgO, Cr_2O_3, Co, U and V relative to the other two Ap 16 rake rocks. Rock 60625 shows a positive Eu anomaly (Sm/Eu = 1.1) which is similar to the Eu anomalies previously observed in two Ap 15 rake basalts 15643 (STA 9a) and 15388 (STA 7) (1). The REE abundances of 60625 are similar to those of 15418 (1). The 60615 rock composition matches the low K-type Fra Mauro basalts (9) and is similar to L 20 meta-igneous rocks 22006 and 22007 (4). Rock 60615 shows a negative Eu anomaly (Sm/Eu = 6.2) and the REE abundances suggest ~15% norite-KREEP component. The bulk composition of the 60636 rock is similar to the average medium K-type Fra Mauro basalt (9). Rock 60636 also shows a negative Eu anomaly (Sm/Eu = 7.1).

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Based on REE abundances, the norite-KREEP component in 60636 is ≈55% (Fig. 1).

Soils: 60601, 62281, 65901, 66041, 66081, 69921, 69941, 69961. Soils 66041 and 66081 were collected from gray and whitish patches at STA 6 and they are identical in their overall bulk and trace element composition. Similarly, soils 65901, 69921, 69941 and 69961 are essentially identical in their bulk and trace element composition. In general, all these soils show a narrow range in bulk chemical composition as shown previously by LSPET (7) and this indicates a uniform composition for the Cayley Plains regolith, at least from the LM south to STA 5. These highland soils are characterized by high average Al_2O_3 (27%) and CaO (16%) and low TiO_2 (0.60%), MgO (6.4%), MnO (0.070%), K_2O (0.11%), FeO (6.0%), Cr_2O_3 (0.11%), V (25 PPM) and Sc (10 PPM). High abundances of Al_2O_3 and CaO indicate an anorthositic gabbroic composition (≈74% Pl) which is suggestive of Eu enrichments. However, the Ap 16 soils do show negative Eu anomalies (avg. Sm/Eu=5.1). REE patterns of these soils fall in a narrow range (Fig. 1). Mixing ≈8-10% of norite-KREEP to Ap 16 metaigneous rocks will satisfy a simple two component derivation of Ap 16 soils.

Luna 20: metaigneous rocks 22006 and 22007, breccia 22004 and soil 22001. The bulk compositions of L 20 and Ap 16 highland rocks and soils show close similarities. Luna 20 rocks 22006 and 22007 are nearly identical in chemical composition to the Ap 16 metaigneous rocks 61156 and 66095. Luna 20 rocks are feldspathic and are similar to low K-type Fra Mauro basalts. Such rocks and anorthositic gabbros appear to be the major components present in highland soils. Luna 20 soil can be distinguished from Ap 16 soils by lower Al_2O_3,CaO and large ion lithophilic elements. Luna 20 breccia 22004 probably is compacted soil. All L 20 samples show negative Eu anomalies with Sm/Eu ratios of 5.8, 7.2, 3.9 and 3.3 for rocks 22006, 22007, breccia 22004 and soil 22001, respectively. Their REE patterns (4) suggest that norite-KREEP is insignificant, ≤1% at the L 20 site. Derivation of the L 20 soil may be explained by ≈33% of L 20 metaigneous rocks and ≈65% anorthositic gabbroic breccia rocks like 15418 (with a positive anomaly) and ≈2% meteoritic contributions.

Interelement correlations observed previously for mare samples are also found in highland samples. Luna 20 and Ap 16 soils are low in alkalies and both soils shown an apparent Cd-Zn rich component similar to that observed at the mare sites. Highland soils are considerably higher in Tl than mare soils. The Ap 16 (62281) soil contains a fractionated meteoritic component (probably ancient) of 1.5% in addition to 1.9% Cl like material, whereas L 20 soil may simply contain 1.9% Cl equivalent.

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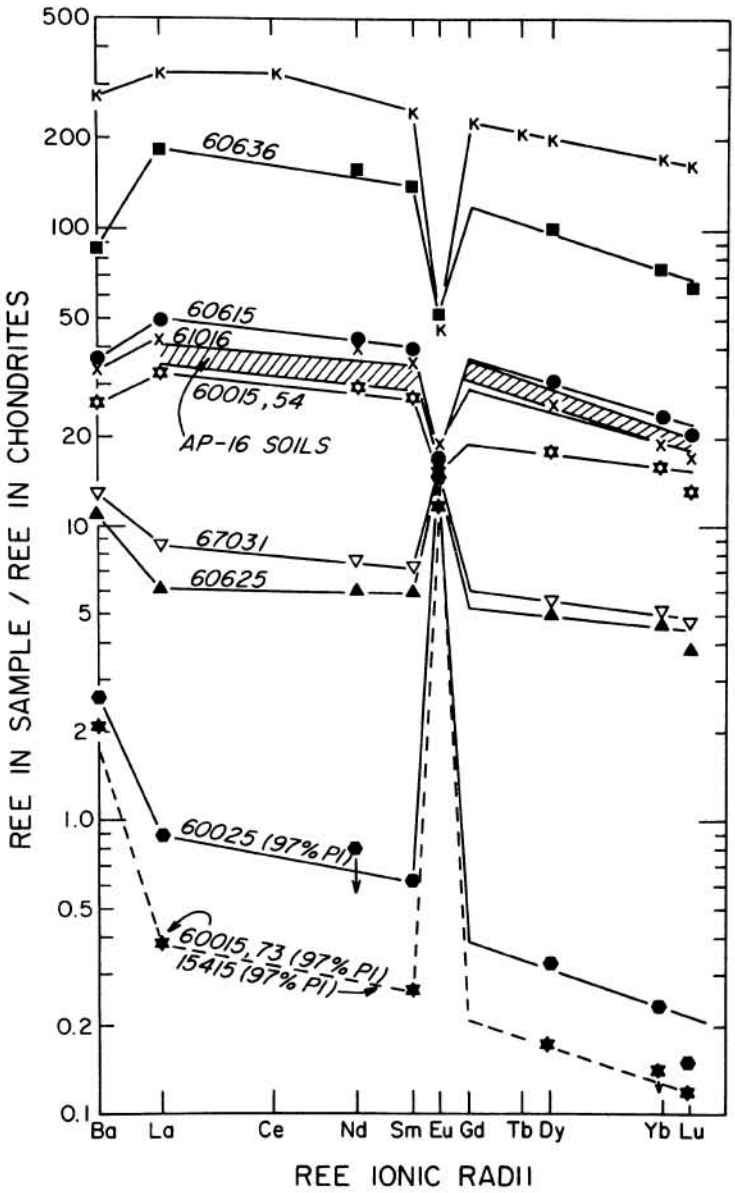

Fig. 1. Chondritic normalized REE abundances in Ap 16 samples: anorthosites 60015,73 (97% Pl) and 60025 (97% Pl); annealed clastic rake rocks 60615 (59% Pl), 60625 (79% Pl) and 60636 (55% Pl); gabbroic anorthositic breccia 67031 (83% Pl); dark clastic glass exterior sample 60015,54 (74% Pl); dark glassy fragment 61016 (70% Pl); and eight soils 60601, 62281, 65901, 66041, 66081, 69921, 69941 and 69961. Data for anorthosite 15415 is taken from Ref. 6. K equals average norite-KREEP pattern.

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