EXTRALUNAR MATERIALS IN LUNAR SOILS AND ROCKS. P. A. Baedecker, C.-L. Chou, E. B. Grudewicz, L. L. Sundberg and J. T. Wasson, University of California, Los Angeles, CA 90024.

The highly siderophilic elements provide excellent indicators of the presence of extralunar components in lunar samples. We determined four siderophile (Ni, Ge, Ir, Au), three volatile (Zn, Cd, In) and one partially siderophile and volatile element (Ga) in samples collected at Apollo landing sites. In Table 1 are listed mean concentration data for soils from the Apollo-17 site, and in Table 2 data for rocks from the Apollo-16 site. Additional data are listed in a companion abstract (1).

Mean concentrations of Ni, Ge, Ir and Au in mature Apollo 17 soils are 266 μg/g, 462 ng/g, 9.6 ng/g and 3.7 ng/g. The contribution of lunar components to these concentrations are estimated to be 40 μg/g, 10 ng/g, 0.1 ng/g and 0.2 ng/g. After correcting for lunar contributions we obtained the extralunar component (ELC) in the soil by dividing by the composition of the ELC at mare landing sites of 13500 μg/g Ni, 28300 ng/g Ge, 634 ng/g Ir and 184 ng/g Au, the estimation of which we discussed earlier (2). (This composition is very similar to that of anhydrous Cl chondrites, the chief difference being that Ni concentration is about 11% higher and Ge concentration about 33% lower.) This procedure yields ELC estimates in Apollo 17 soils of 1.67, 1.60, 1.51 and 1.90%, respectively, and a mean concentration of 1.67%. As summarized in Table 3, this value is about 20 - 25% higher than that observed at the Apollo 15 and Apollo 11 sites, consistent with the relative ages of the regoliths at three sites and the "contamination" of the Apollo 15 and 17 regoliths by old regolith materials from the adjacent highlands.

Relative to mare soils higher concentrations of siderophiles are observed in highlands soils (3), and the composition of the ELC changes as well (4). In Table 3 are listed the variations in Ni/Ir, Ge/Ir and Au/Ir of the ELC observed in our data for mature soils (our Apollo-16 soil data are listed elsewhere in this volume (1)). With minor exceptions, each of these ratios shows a progressive increase with increasing ELC concentration. Based on these ratios the soils from the six Apollo landing sites fall into 3 well defined groups: the younger mare-type soils at Apollo 11 and 12, the older, highlands-type soils at Apollo 14 and 16, and the mare-type soils with highlands contamination at Apollo 15 and 17. The Au/Ir ratio undergoes the largest variation, increasing by about a factor of 2 between the mare-type locations and the Apollo-16 site. The variations in ELC composition can be understood in terms of two major populations of extralunar materials: a population with relatively constant flux which dominates during the most recent 3.7 Gyr of lunar history, and a population with a rapidly decreasing flux which dominated during

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Table 1. Mean trace-element concentrations in Apollo 17 soils.

	Ni (μg/g)	Zn (μg/g)	Ga (μg/g)	Ge (ng/g)	Cd (ng/g)	In (ng/g)	Ir (ng/g)	Au (ng/g)
72161,19	286	53.0	6.47	446	58†	4.6	10.7	4.4
72441,13	283	19.0	4.72	493	37.6	3.6	7.8	3.8
72461,9	302	20.2	4.70	431	41.5	2.9	9.6†	3.8
72701,39	317	18.4	4.45	514†	36.3	1.4	10.6	4.0
75081,20	125	26.0	5.01	207	31.8	2.0	5.0	1.4
76240,19	215	24.7	5.37	465	72.6	2.5	‡	3.2
76260,8	194	23.5	5.21	408†	36.8	3.94	‡	3.6
78421,35*	254	29.2	4.95	442	45.5	2.8	9.7	3.4
78441,15*	290	28.8	5.10	467	38.2	2.5	9.9	3.5
78461,15*	256	28.0	4.96	446	40.2	2.8	9.0	3.3
78481,32*	262§	28.8	5.19	509§	39.2	4.5	10.4§	3.6§

*Trench samples (depths): 78421 (15 - 25 cm); 78441 (ca. 10 cm); 78461 (ca. 5 cm); 78481 (0 - 1 cm). †Based on one datum only. ‡Analysis not completed. §One value only for Ni, Ge, Ir and Au; duplicate sample contained about 1.5 - 2.0 times greater amounts of these elements.

Table 2. Mean trace-element concentrations in Apollo 16 rocks.

	Ni (ug/g)	Zn (ug/g)	Ga (ug/g)	Ge (ng/g)	Cd (ng/g)	In (ng/g)	Ir (ng/g)	Au (ng/g)
60255,38	391	21.0	5.23	912	60.8	15	12.2	5.6
61016-light*	3.4	1.8	3.46	23	180	256	0.25	0.94
61016-dark†	569	0.52	3.69	641	7.8	4.0	15.0	9.7
65015,63-wr‡	582	0.82	4.57	504	16.2	0.32§	12.9	9.9
65015,63-sph‡	56700	3.2	1.15	37800	≤94	≤0.78	990	1070
66075,32	249	12.2	4.49	1650	97	72	6.0	4.2
68415,68	140	1.47	2.99	98	≤1.1	12	5.6	2.8

*portion 161 †portion 183. ‡wr = whole rock; sph = metallic spherule (one determination, all elements). §±factor of 3.

Table 3. Concentration of extralunar component in lunar soils and ratios of Ni, Ge and Au to Ir, normalized by dividing ratios in CI carbonaceous chondrites (1).

	ELC (%)	Ni/Ir	Ge/Ir	Au/Ir
12070	1.18	0.76	0.61	0.84
10084	1.32	0.80	0.60	0.88
15 soils	1.37	0.95	0.71	1.20
17 soils	1.67	1.05	0.68	1.19
14 soils	2.44	0.99	0.77	1.35
16 soils	3.69	1.24	0.98	1.72

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the earlier period of lunar history. The composition of the latter is poorly defined for several reasons. Even in a regolith as old as that at the Apollo 16 site an appreciable portion of the ELC results from the recent long-lived population. We can attempt to correct for this by substracting siderophile concentrations observed at Apollo 11 from those in mature soils at Apollo 16 (the 10% younger age at the Apollo-11 site is more-or-less compensated by the greater mixing depth in the unconsolidated surficial materials at the Apollo-16 site). This exercise yields net concentrations of the short-lived extralunar materials at Apollo 16 of 312 μg/g Ni, 726 ng/g Ge, 7.18 ng/g Ir and 6.57 ng/g Au, and CI-normalized Ni/Ir, Ge/Ir and Au/Ir ratios of 1.78, 1.45 and 2.97, respectively. The simplest interpretation appears to be that the short-lived population was depleted in Ir; primordial meteorite groups with similar ratios include the E4 (enstatite) chondrites (5) and the group IA irons (6). The Au/Ni ratios are slightly higher than observed in these groups, which lends support to the idea that a portion of the Au in highlands soil samples is of lunar origin.

Each of our Apollo 16 rocks (with the exception of the anorthositic portion of 61016), has a high ELC concentration, indicating that they include large amounts of regolith materials. The rocks are marked by large variations in siderophile ratios, though the range is not appreciably greater than observed in known groups of primordial meteorites. Rock 66075 has a Cl normalized Ge/Ni ratio of 2.3, higher than those in primordial meteorites with the exception of the low-Ni portion of the IA-irons (6). Rock 68415 has siderophile ratios roughly comparable to those in ordinary chondrites. We isolated an 8-mg metal spherule from our sample of the metal-rich breccia 65015 (7) which had siderophile ratios similar to those observed in the high-Ni portion of iron-meteorite group IIIA; the absolute concentrations suggest a dilution of about 20% relative to such irons. In addition to the remarkably low siderophilic content of the light portion of 61016, it has incongruously high enrichments of Cd and In whereas the content of a third volatile, Zn, is quite low.

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