THE COMPOSITION OF THE PREBASIN CRUST IN THE CENTRAL HIGHLANDS OF THE MOON. RANDY L. KOROTEV, Department of Earth and Planetary Sciences, Washington University, St. Louis, MO 63130.

The Apollo 16 regolith consists of a large amount of material derived from the prebasin crust, i.e., (1) plutonic ferroan anorthosite and brecciated derivatives (>90% plagioclase), (2) a variety of noritic anorthosites (plutonic, feldspathic fragmental breccias [FFBs], granulitic breccias [GrBs], feldspathic impact-melt breccias), and (3) a minor amount of gabbronorites of highland affinity. However, the site is sufficiently close to nearside mare basins that the regolith also contains a substantial fraction of basin ejecta as well as some mare-derived materials (MDMs) delivered to the site by volcanism and impacts since filling of the basins with mare basalt. These syn- and postbasin products include (4) mafic impact-melt breccias [MIMBs, i.e., "LKFM" and "VHA"], (5) MDMS, i.e., glasses and some crystalline mare basalt, and (6) meteoritic material (largely from micrometeorites) accumulated in the regolith since basin formation ~3.9 Ga ago. The MIMBs, which are rich in incompatible trace elements, were formed during the time of basin formation by impacts large enough to penetrate the outer feldspathic crust and melt mafic underlying material, although not all of the several known varieties at the Apollo 16 site may actually have been formed by impacts that produced basins [1]. The Central Highlands, as sampled by the Apollo 16 mission, differs from highlands regions distant from mare basins in its high abundance of mafic syn- and postbasin material. For example, some feldspathic lunar meteorites (ALHA81005, Yamato-86032, MAC 88104/5, QUE93069) contain virtually no MDMS or MIMBs.

Several approaches can be used to estimate the composition of the prebasin crust in the Central Highlands. One approach involves using compositional mass balance to estimate the relative proportions of lithologies in the present regolith of the Cayley plains, the "mature Cayley soil" (MCS, Table 2, column1). Although several such models exist for the Apollo 16 regolith [2–7], all are either unrealistic in terms of the small number of components used (compared to the large number known to occur) or are heavily dependent on input assumptions about the nature and importance of certain components. We have constructed a new model that has a minimum of assumptions and that tested nearly all known components of the Apollo 16 regolith (ferroan anorthosite, 8 types of noritic anorthosite, 5 types of MIMB, 5 gabbronorites, 10 components representing MDMs, and a CI chondrite component to represent post-basin meteoritic material). Table 1 summarizes the average results for best solutions obtained from more than 3 million least-squares mixing calculations [8]. Removing the MIMB, MDM, and meteoritic components from the Cayley soil in the proportions indicated in Table 2 yields an estimate for the composition of the prebasin components (feldspathic + gabbronorite components, column 5) .

A more straightforward estimate can be obtained from the ancient regolith breccia (ARBs). The Apollo 16 ARBs represent a regolith that became closed to further input of material about the time of basin formation; they are virtually devoid of MDMs [9,10]. Compositional variation in the ARBs indicates binary mixing between MIMBs and a suite of well-mixed, feldspathic, prebasin components [11]. The average composition of the feldspathic components (column 6) can be estimated from mass balance by mathematically removing the MIMB component. For Table 2, the fraction of MIMB component removed (27% by mass) corresponds to that necessary to yield a Sm concentration equal to the average Sm concentration obtained for feldspathic clasts from ARBs [11], 0.86 μg/g. The estimates for the average composition of the prebasin components of the Cayley plains obtained from MCS and the ARBs are similar (columns 5 and 6).

The Descartes formation is represented at the Apollo 16 site by the feldspathic fragmental breccias (FFBs) of North Ray crater [2,12]. These breccias also contain MIMBs, but virtually no MDMs. Removal of the MIMBs from the FFBs yields a pre-basin composition (column 7) that is slightly more mafic that that derived for the Cayley plains and one that has a lower Mg/Fe ratio, greater Na and Eu concentrations, and greater relative concentrations of heavy REE (Fig. 1). These differences probably reflect a regional difference between the feldspathic crustal material deposited at the Apollo 16 site by the Nectaris impact (column 7) and the material influenced by the Imbrium impact (column 5 and 6). All "prebasin" estimates for Apollo 16 are similar to, but slightly more feldspathic than the most feldspathic lunar meteorites, Yamato-86032 and QUE93069 (column 8 and 9). Thus, although the present surface of the Central Highlands is more mafic than that of typical feldspathic highlands [3,13], prior to basin formation it appears to have been slightly more feldspathic.

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TABLE 1. Results of mass balance model for mature Cayley soil (MCS).

component	%
ferroan anorthosite	27 ± 5
noritic anorthosites	36 ± 7
mafic impact-melt breccias (MIMBs)	30 ± 3
mare-derived materials (MDMs)	6.1 ± 1.5
gabbronorites	0.9 ± 1.6
meteoritic (volatile-free), in excess of that contributed by the rocks	0.9 ± 0.2

TABLE 2. Mean compositions of mature soils from the Cayley plains (MCS), ancient regolith breccias from the Cayley plains (ARB), and feldspathic fragmental breccias from the Descartes formation at North Ray crater (FFB), with estimates of the composition of their prebasin components and comparison to two lunar meteorites.

	mean (observed)			prebasin components of				meteorites	
	MCS	ARB	FFB	MCS	MCS –CI	ARB	FFB	QUE 93069	Yam.- 86032
	1	2	3	4	5	6	7	8	9
TiO_2	0.60	0.51	0.44	0.20	0.20	0.30	0.39	0.25	0.18
Al_2O_3	26.7	28.4	29.1	31.3	31.5	31.3	29.9	28.9	28.4
FeO_t	5.51	4.21	3.78	2.64	2.42	2.66	3.41	4.44	4.28
MgO	6.14	5.49	4.26	3.19	3.06	3.37	3.61	4.53	5.26
CaO	15.3	16.1	16.4	17.3	17.4	17.5	16.8	16.5	16.4
Na_2O	0.46	0.49	0.54	0.43	0.43	0.48	0.54	0.35	0.44
Sc	9.64	6.6	7.0	4.3	4.3	4.55	6.5	7.75	8.3
Cr	775	525	445	370	345	270	370	600	680
Co	31.7	21.8	9.8	12.9	8.2	7.0	6.5	22.0	14.5
Ni	454	296	94	177	72	36	41	295	134
Ba	146	118	63	38	38	34	43	41	26
La	13.3	11.2	4.20	2.19	2.20	2.02	1.96	3.35	1.26
Sm	6.18	5.10	1.90	1.00	1.00	*0.86*	*0.86*	1.62	0.62
Eu	1.20	1.21	1.18	0.97	0.98	1.05	1.14	0.83	0.93
Yb	4.37	3.49	1.63	0.84	0.84	0.64	0.94	1.21	0.60
Lu	0.608	0.49	0.23	0.13	0.13	0.113	0.135	0.17	0.09
Th	2.22	1.76	0.67	0.40	0.40	0.28	0.31	0.52	0.21
Mg'	66.5	70	67	68	69	69	65	64.5	68.7

Oxides in %, others in μg/g. *Mg'* = bulk mole % Mg/(Mg+Fe). (1) Mean of 22 samples of mature surface soil from the Cayley plains [this work and 14]. (2) Mean of 10 bulk samples of ancient regolith breccia [9,10,15,16]. (3) Mean of feldspathic fragmental breccia samples 67015, 67016, 67035, and 67915 [16–21]. These 4 samples are similar in composition and represent the middle of the wide range of *Mg'* observed among FFBs. (4) Data of column 1 after removal MIMB and MB components in proportions of Table 2. (5) Like column 4, but meteoritic (CI) component also removed. (6) Column 2 after removal of 27% MIMB (groups 1M, 1F, and 2DB of [1]). (7) Column 3 after removal of 8% MIMB [group 2NR of 1]. (8) Lunar meteorite QUE93069 [22 and update]. (9) Lunar meteorite Yamato-86032; mean based on data of [23,24, and this lab].

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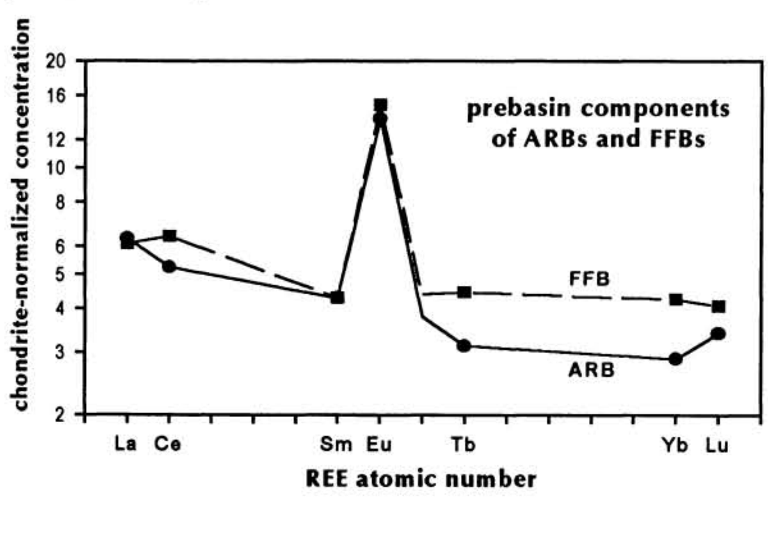

Figure 1. Chondrite normalized concentrations of REEs in the prebasin components of the ARBs and FFBs. Absolute concentrations are probably correct to within 50%; this plot shows relative concentrations assuming the Sm concentration is 0.86 μg/g in both (Table 2).