

COMPOSITIONAL DATA FOR FIFTEEN FRA MAURO LUNAR SAMPLES,
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The major, minor, and trace element compositions of fifteen lunar samples (4 soils, 4 basalt rocks, and 7 breccias) collected at the Fra Mauro Formation by the Apollo 14 Mission were determined by combined semi-micro chemical, X-ray fluorescence, and optical emission techniques.

SOILS

The Fra Mauro lunar soils show a greater homogeneity than the soils from the Tranquility Base (Apollo 11 Mission) and the Ocean of Storms (Apollo 12 Mission) sites, with little variation being found in either the major, minor, or trace elements. Si, Na, K, P, Rb, Li, Ba, Be, Nb, La, and Zr display notable concentration trends characterized by Apollo 11 soils < Apollo 12 soils < Apollo 14 soils. Ti, Fe, and Sc show a reverse trend. There is also a notable increase in the Pb content of the Fra Mauro highland materials (average about 10 ppm) as compared to that found previously for the mare lunar materials (about 1 ppm). The Fe/Ni ratio of the Apollo 14 soils (218) is about one-third of that found for the Apollo 11 (661) and 12 soils (617). The Ba/Sr ratios found for the lunar soils show a trend increasing from Apollo 11 through Apollo 14 (Apollo 11, 1.6; Apollo 12, 4.3; and Apollo 14, 5.5).

BASALT ROCKS

Comparison of the Fra Mauro basalt composition with those from Tranquility Base and Ocean of Storms shows that Si, Al, Ca, Na, P, and Ni content increases from Apollo 11 through Apollo 14 with Fe, Ti, Cr, and Sc having the reverse trend. Fra Mauro basalts are highest in K, Pb, Ba, Sr, Be, Nb, La, and Y, but are lowest in Ga, Co, and V. The Fe/Ni ratios drop sharply in samples from each successive site (Fe/Ni: 21,000, 2520, 504) while Ni/Co increases (Ni/Co: 0.23, 0.98, 8.9). Fra Mauro basalts show the highest Rb/Sr, Cr/V, Ba/V and Ba/Sr ratios and the lowest Cr/Ni ratio.

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BRECCIA

The breccia samples from Fra Mauro also show the highest Si, Al, Mg, Na, K, Zn, Cu, Li, Rb, La, Ba and Zr concentrations when compared to the Tranquility Base and Ocean of Storms breccias (Apollo 14 breccias > Apollo 12 > Apollo 11). Fe, Ti, Sc and Mn show a reverse trend. Fra Mauro breccias show the lowest Cr and V content. Compared to materials returned by earlier Missions, the trace elements Ni and Y are highest in Apollo 14 breccias. The Fra Mauro breccias also have the highest Ba/V, Ba/Sr, and Rb/Sr ratios (Apollo 14 > Apollo 12 > 11). Cr/Ni and Fe/Ni ratios are lowest in Fra Mauro breccias while Ni/Co is highest.

Preliminary evaluation of these and published elemental, photographic, and mineralogic data suggests:

1. Most of the Apollo 14 samples are breccias. This strongly suggests that the breccias that characterize the Fra Mauro Formation are a gigantic ejecta blanket generated by the impact which formed the largest of the lunar seas - the Mare Imbrium.
2. Optical microscopic and photographic examination shows that the Fra Mauro highland material is more complex mineralogically than the Apollo 11 and 12 materials implying a different manner of formation or a history different from rocks returned from lunar mare regions.
3. The Ni content of the Fra Mauro fragmental rock is significantly lower than that of the regionally associated soils in contrast with Apollo 11 samples where fragmental rocks are similar in Ni content to that of the soils.
4. The Fra Mauro highland rocks differ from the mare basalts in having much lower contents of Fe, Ti, Mn, and Cr and higher concentrations of Si, Al, Na, K, Pb, Li, Rb, Be, Nb, La, and Zr.

The average major, minor and trace element composition for the basalt, breccia and soil samples we have analyzed is given in the following table:

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Average composition for Apollo 14 Samples analyzed (in %)

Constituent	Basalt ¹	Breccia ²	Fines ³
SiO ₂	47.70	47.83	47.93
Al ₂ O ₃	21.44	16.79	17.60
Fe ₂ O ₃	0.00	0.00	0.00
FeO	7.78	9.96	10.37
MgO	7.29	11.03	9.24
CaO	13.05	10.45	11.19
Na ₂ O	0.70	0.87	0.68
K ₂ O	0.48	0.56	0.55
H ₂ O ⁻	0.00	0.00	0.00
TiO ₂	1.16	1.53	1.74
P ₂ O ₅	0.42	0.55	0.53
MnO	0.11	0.13	0.14
Cr ₂ O ₃	0.25	0.21	0.25
Total	100.38	99.91	100.19

ARC 0.32 1.36 2.80

Average trace element composition (in ppm)

Pb	11	16	10
Zn	4	15	25
Cu	9.0	22	18
Ga	3.7	4.7	5.5
Li	22	25	23
Rb	14	14	13
Co	13	35	35
Ni	116	345	370
Ba	740	800	1030
Sr	170	147	189
V	37.5	50.0	55.6
Be	4.1	7.0	6.6
Nb	31.0	48.0	55.3
Sc	22.5	22.0	26.7
La	59	76	74
Y	192	253	276
Yb	16.0	22.0	25.0
Zr	615	790	813

1) Basalts: samples 14276,8 and 14310,114

2) Breccias: samples 14066,21(203), 14318,MF and 14318,27A

3) Fines: samples 14003,30;14049,37;14163,54;14240,9;
14259,12; and 14421,23