PETROLOGY OF TWO NEW FERROAN ANORTHOSITES AND SIX APOLLO 11 BASALTIC ROCK FRAGMENTS.

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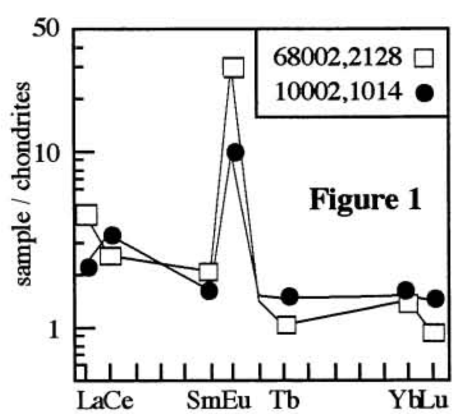
Small rock fragments extracted from lunar soil contain important and easily overlooked information about the composition of the lunar crust. This paper presents the final results of two studies: the petrology and chemical composition of two ferroan anorthosites and the petrology of 2-4 mm fragments from soil 10002. The ferroan anorthosites were collected during the Apollo 11 (10002,1014) and Apollo 16 (68002,2128 and 2131) missions and have contrasting mineral and bulk compositions. The Apollo 11 FAN has comparatively calcic plagioclase, magnesian pyroxenes, and higher Fe, Mn, Sc, Cr, Co, Ni, and Rb contents, but lower Ca, Na, K, Ba, Sr, and REE contents. These features reflect greater amounts of cumulus mafic minerals in 10002,1014 and a higher proportion of cumulus plagioclase in 68002,2128/2131. The Apollo 11 2-4 mm soil fragments are a continuation of the study reported in [1] and represent the most pristine (Ir < 4 ppb) samples from that group. Most of the samples appear to be monomict, although the presence of multiple plagioclase compositional groups in one sample indicates that it may be polymict. The ranges in plagioclase and pyroxene compositions are consistent with the prior interpretation [1] that most of these rocks are type B3 basalts.

Table 1. INAA data for ferroan anorthosite samples

Sample	10002 ,1014	68002 ,2128
Na (wt. %)	0.19	0.67
Ca	9.49	16.4
Fe	4.08	0.64
K	0.13	bdl
Mn	0.58	0.01
Sc (ppm)	6.84	1.83
Cr	893	90
Co	19.1	6.9
Ni	200	bdl
Zn	18	----
Ga	4.6	bdl
Rb	7.1	1.51
Sr	92	356
Zr	----	13.4
Cs	----	bdl
Ba	11	50
La	0.72	1.4
Ce	2.76	2.1
Nd	----	2.9
Sm	0.32	0.4
Eu	0.69	2.2
Tb	0.07	0.05
Tm	0.03	0.48
Yb	0.046	0.3
Lu	0.22	0.03
Hf	0.08	0.11
Ta	0.09	0.3
Th	----	0.08
U	5.3	bdl
Ir (ppb)	bdl	7.9

bdl =<3 ppb

FERROAN ANORTHOSITES. The two ferroan anorthosites include a fragment from soil 10002 [1] and a clast from drive tube 68002/68001 [2]. These samples are designated 10002,1014 (INAA sample and, for this paper, the probe mount), 68002,2128 (INAA sample), and 68002,2131 (probe mount). Major- and trace-element analyses are listed in Table 1, and their REE patterns and pyroxene compositions are shown in Figs. 1 and 2, respectively. Fragment **,1014** is granular and composed of plagioclase (up to 0.5 mm; An_{97}), low-Ca pyroxene (~0.1 mm; $Wo_{5-8}En_{74-76}Fs_{18}$; Fig. 2), and olivine (~0.01 mm; Fo_{80}). Sample **,2128/,2131** was described in [2], and has comparatively sodic plagioclase (An_{92}), low-Ca pyroxenes that are richer in iron ($Wo_{4-17}En_{52-58}Fs_{31-38}$; Fig. 2), and augite ($Wo_{36-40}En_{41-43}Fs_{18-19}$; Fig. 2). Sample ,2128 has considerably larger amounts of Na and Ca, reflecting the plagioclase-rich nature of this sample. Although this sample has a lower mafic-mineral component (0.64 and 4.08 wt. % Fe, respectively), it has higher REE, Ba, and Sr contents than ,1014. In contrast, 1014 is richer in Sc, Cr, Co, Ni, Zn, and Rb. The comparatively high An of ,1014 is consistent with crystallization from a more "primitive" melt than that from which ,2128 crystallized. A cumulus origin for the mafic minerals in ,1014 is suggested by the high X_{Mg} of pyroxenes and high bulk rock transition element abundances. The higher concentrations of Ba and Sr and larger positive Eu anomaly of ,2128 reflect a larger proportion of cumulus plagioclase in this sample than ,1014.



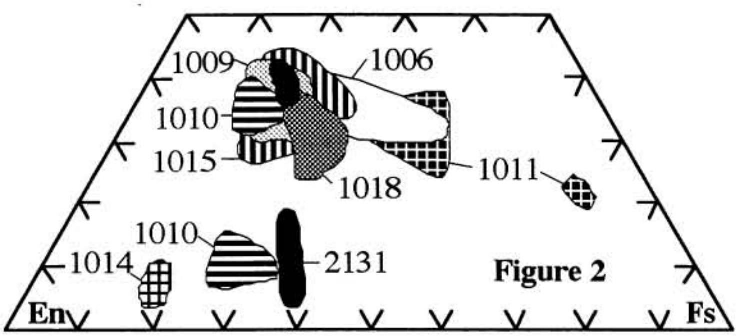


Figure 2

APOLLO 11 BASALTIC FRAGMENTS. The chemical compositions of 2-4 mm fragments from soil 10002 were previously reported in [1]. Based on trace element contents, most rocks were grouped as B3 basalts except for ,1006, which was believed to be a group D basalt . We have completed a petrographic (reflected light) and mineral-chemical investigation to better characterize these samples. All samples contain less than 30% plagioclase. Pyroxene composition fields are shown in Fig. 2.

Sample **,1006** is a small and granular, and composed of plagioclase (~0.2 mm), augite to ferroaugite (~0.2 mm; $Wo_{31-38}En_{24-38}Fs_{26-44}$), ilmenite (0.1-0.3 mm), and cristobalite (~0.1 mm). Two plagioclase populations have been identified: ~An_{84} and ~An_{94}. These two groups may reflect a polymict nature. Fragment **,1009** is composed dominantly of augite (~1 mm; $Wo_{31-41}En_{40-49}Fs_{15-28}$), with lesser amounts of tabular to blocky plagioclase (0.1-0.2 x 0.4-0.5 mm), ilmenite (~0.1 mm), and cristobalite (0.1-0.3 mm). Plagioclase compositions vary considerably between grains (averages range from An_{83-92}) and within grains (up to 11 mol. % An). Despite these variations, the texture of this sample does not appear to indicate that it is polymict. Fragment **1010** is an ilmenite-rich rock (15-20 vol. %; 0.1-0.4 mm) that also contains plagioclase (0.2-0.4 mm), augite (up to 0.5 mm; $Wo_{33-38}En_{45-59}Fs_{15-21}$), pigeonite (up to 0.5 mm; $Wo_{8-13}En_{45-66}Fs_{15-32}$), and cristobalite (~0.15 mm). Plagioclase is typically ~An_{92}, although one grain was found to be zoned from An_{94} at the core to An_{85} at the rim. Sample **,1011** is also ilmenite-rich (~40 vol. %), but in contrast to the relatively small round grains of 1010, the ilmenite in 1011 is large (~ 1 mm) and skeletal. Clinopyroxene falls into two compositional groups: ferroaugite (0.1-0.6 mm; $Wo_{29-36}En_{22-34}Fs_{35-48}$) and subcalcic ferroaugite (<0.1 mm; $Wo_{20-22}En_{9-10}Fs_{69-70}$). Both form discrete grains and ferroaugite also occurs as thin, long inclusions (0.05 x 0.5 mm) within ilmenite. Plagioclase (0.2 x 1 mm) is typically ~An_{92}, but one grain varies irregularly from An_{80} to An_{92}. Anhedral grains of cristobalite (~0.15 mm) are also present. Fragment **,1015** has an interstitial texture, with laths of ilmenite (~0.01-0.05 x 0.5 mm) and plagioclase (0.05-0.2 x 0.4 mm) that are separated by smaller ilmenite grains, augite (0.2-0.5 mm; $Wo_{28-42}En_{36-52}Fs_{16-30}$), and cristobalite (~0.2 mm). The composition of plagioclase laths varies little, from An_{89} to An_{92}, with an average of ~An_{91}. Fragment **,1018** is composed of laths of plagioclase (up to 0.8 mm long), large interstitial augite (0.35-0.8 mm; $Wo_{25-36}En_{32-46}Fs_{22-36}$), and large skeletal ilmenite (up to 1 mm long). Plagioclase grains are normally zoned, with An_{90-95} cores and An_{80} rims.

For several reasons, we believe that the majority of these samples are small fragments of mare basalts. First, most of the compositions of plagioclase in all the fragments analyzed for this study are within the range (~An_{84-95}) for Apollo 11 high-Ti, low-K basalts listed in [3]. A few of the samples described above have grains or rims on grains that are slightly more sodic than this range, which suggests that lower limit of this range can be extended down to ~An_{80}. Second, pyroxene compositions are also consistent with those analyzed from other mare basalts [3]. Finally, as reported in [1] and mentioned earlier, all samples except for ,1006 have trace-element concentrations that are similar to group B3 basalts. Although ,1006 was reported to be a group D basalt, the presence of two plagioclase populations suggests that it may be polymict.

References: [1] Snyder et al. (1994) *LPSC XXV*, 1301-1302; [2] Snyder et al. (1994) LPSC XXV, 1313-1314; [3] Papike et al. (1991) in Heiken et al. (eds.), *Lunar Sourcebook*, 121-181.