PETROLOGY AND CHEMISTRY OF HYPER-FERROAN ANORTHOSITE AND OTHER CLASTS FROM LUNAR METEORITE ALHA81005

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We report the results of petrographic and chemical studies of 8 clasts selected from lunar meteorite ALHA81005 (hereafter 81005) for consortium study. One of the clasts (,36) is possibly pristine. This clast is one of a "hyper-ferroan" anorthosite type from 81005. We report the first REE data for one of these clasts. Five (,33 ,52 ,53 ,54 and ,56) are fine-grained granular to cataclastic anorthositic norites that are probably polymict breccias. The other two clasts (,58 and ,60) are impact melts that are chemically similar to the bulk 81005.

Petrography: 81005,36 is a cataclastic gabbroic anorthosite, with areas up to 0.8 mm across of plagioclase that appear to have originally been single crystals. Based on the 2.4 mm^2 in our thin section, it contains 87% plagioclase (average An 96.2), 8% low-Ca pyroxene with average mg (100 X Mg/(Mg+Fe)) of 52.2, and 5% high-Ca pyroxene (average mg 62.7), with minor olivine (Fo 41), iron sulfide (as inclusions in olivine), ilmenite, and chromite. Mineral compositions are quite uniform (Table 1). The pyroxenes are unexsolved and the low-Ca pyroxenes are slightly zoned. Based on the average low-Ca pyroxene composition, this clast plots within the ferroan anorthosite field (Fig. 1). The olivine composition is unusually iron-rich and is outside the generally accepted field for pristine ferroan anorthosites (e.g. 1). Treiman and Drake (2) also reported an unusually ferroan clast (containing high-Ca pyroxene with mg 43 and low-Ca pyroxene with mg 35) from 81005. Ryder and Ostertag (3) reported a clast from 81005 containing low-Ca px with mg 40. Clast 81005,36 plots within the extended ferroan anorthosite field (Fig. 1) proposed by Treiman and Drake (2). The discovery of this clast further supports the suggestion (3) that one pristine component of 81005 is hyper-ferroan and represents a later stage in the history of the magma ocean than is represented by ferroan anorthosites sampled by the Apollo program.

Clasts ,33 ,52 ,53, and ,56 are all granular to cataclastic anorthositic norites (ANs) containing plagioclase, olivine, and lesser amounts of low-Ca pyroxene, with minor ilmenite, iron sulfide, chromite, and aluminous spinel (observed in ,52 only). Mineral compositions (ranges and averages) are given in Table 1. These clasts all plot in the gap between the Mg-rich rocks and the ferroan anorthosites in Figure 1, and are similar to feldspathic granulitic impactites from 81005 described by Ryder and Ostertag (2) and Warren et al (1).

Clast 81005,54 is a fine-grained, igneous-textured anorthositic gabbro, with a few larger, probably relict, grains. Plagioclase and olivine compositions are similar to those in the ANs (Table 1; Fig. 1). The pyroxene, however, varies continuously in Wo content from 3 to 48, with nearly constant mg (79 to 84).

Clasts 81005,58 and ,60 have similar textures, mineralogy, and mineral compositions (Table 1). They consist principally of highly shocked plagioclase with a few, probably relict, mafic grains (olivine in ,60; olivine, low-Ca pyroxene, and high-Ca pyroxene with Wo 33-42 and mg 78-81 in ,58). Much of the plagioclase in both ,58 and ,60 is pervaded by a very fine-grained (submicron size) intergrowth of mafic grains. Quasi-modes calculated from broad beam analyses of these areas indicate that the mafic grains include both olivine and pyroxene. In places in ,60 this intergrowth of plagioclase and mafics has small, lath-shaped plagioclase grains, which suggests that this texture results from shock-melting. These samples also plot within the gap in Fig. 1, but at lower mg values than the ANs.

Chemistry: Our preliminary results are consistent with previous analyses (4,5) which indicate that 81005 has low abundances of REE and the incompatible elements Zr, Hf, Ta, Th, and U (Fig.2) and high Sc/Sm ratios. Sc/Sm ratios for all the clasts except ,58 and ,60 are similar to each other (22.7 to 28.5) and to those of white clasts from 81005 studied by Korotev et al. (6). Sc/Sm ratios for ,58 and ,60 (5.1 and 7.7 respectively) are similar to, although slightly lower than those for bulk ALHA 81005 (4,5).

Samples ,58 and ,60 have patterns and abundances of incompatible elements (except for U/Th) (Fig. 2) which are similar to those of bulk 81005 (4,5). This suggests that these two clasts are impact melts with the bulk composition of the lunar regolith in the 81005 source region. Chondrite-normalized U/Th ratios are lower in ,58 and ,60 than in the bulk rock, however (<1 rather than >1). The fact that these samples have lower mg than the granulites is consistent with their being a mixture of a Mg-rich component, with Mg > 80, as suggested by (6), and a ferroan component, such as ferroan anorthosite clasts in 81005 described by (3). These two clasts also have high concentrations of the siderophile elements Ni, Co, Ir, and Au ($1.5-4\times10^{-2}$ XC1) similar to concentrations in bulk 81005 (5), which indicates the presence of a substantial meteoritic component typical of lunar regolith compositions.

The ANs all have similar abundances and ratios of REE. For clarity, only data for ,33 and ,56 are plotted in Fig. 2. The other AN samples plot between these two clasts. Their REE patterns are essentially unfractionated. These samples show more variability in ratios of the other incompatible elements: chondrite normalized Hf/Ta is <1 for ,52 and >1 for the others; chondrite-normalized U/Th is >1 for ,53 and ,56 and <1 for the others.

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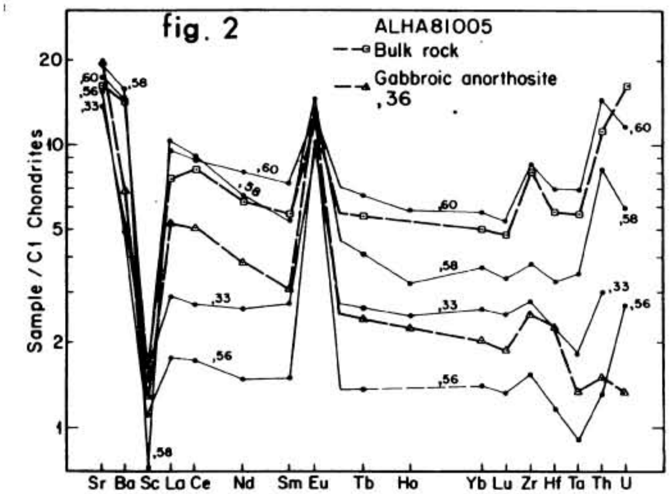
REE in 81005,36 are 2.5-10X more abundant than in typical ferroan anorthosites, but have similar relative abundances (e.g. 7). They are 5X more abundant than in the 81005 clast identified by (4) as pristine. Sr, Ba, Sc, and the other incompatible element ratios and abundances for ,36 are similar to those of the ANs. Preliminary data for siderophile element concentrations indicate that ,36 is possibly pristine. Ni, Co, Ir, and Au concentrations are close to the value of $3X10^{-4}$XC1 suggested by Warren and Wasson (8) as an upper limit for pristine rocks. 81005,36 could be an important rock because it is unusually ferroan (like a few other clasts from 81005), has higher abundances of REE than typical ferroan anorthosites, and is possibly pristine. The hyper-ferroan composition and high abundances of REE suggest that this rock crystallized very late in the history of the magma ocean.

References: (1) Warren, P.H. et al. (1983) Geophys. Res. Lett. 10, 779-782. (2) Treiman, A.H. and Drake, M.J. (1983) Geophys. Res. Lett. 10, 779-782. (3) Ryder, G. and Ostertag, R. (1983) Geophys. Res. Lett. 10, 791-794. (4) Boynton, W.V. and Hill, D.H. (1983) Geophys. Res. Lett. 10, 837-840. (5) Laul, J.C. et al. (1983) Geophys. Res. Lett. 10, 825-828. (6) Korotev, R.L. et al. (1983) Geophys. Res. Lett. 10, 829-832. (7) Norman M.D. and Ryder, G. (1979) PLPSC 10, 531-559. (8) Warren, P.H. and Wasson, J.T. (1977) PLPSC 8, 2215-2235.



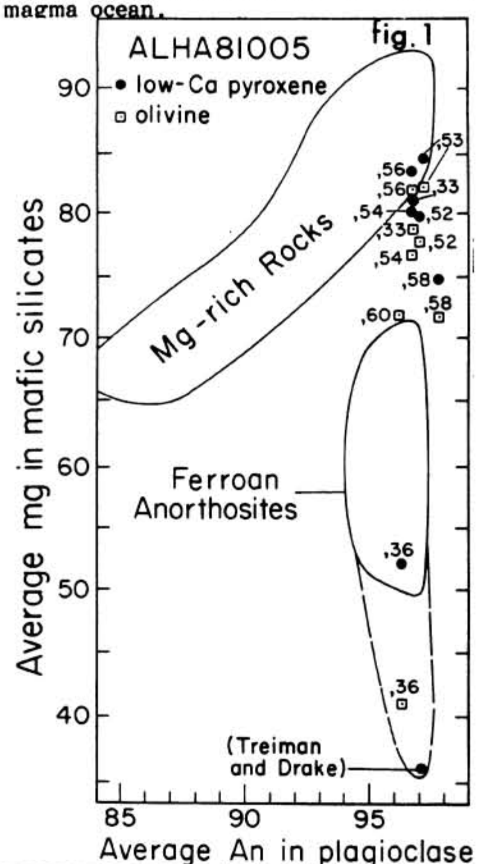


Table 1. Mineral Compositions in ALHA81005 Clasts

Sample / Mineral		,36	,33	,52	,53	,54	,56	,58	,60
plagioclase (An)		95 -97.1 avg.96.2	94.6-98 avg. 96.7	95.4-97.9 avg. 97	avg.97.2	95.8-97.2 avg. 96.7	94.8-98 avg 96.5	94.5-97 avg 97.7	95.4-97.4 avg. 96.3
olivine (Fo)		40.6 (1 point)	77.8-79 avg.78.3	76.6-77.8 avg. 77.3	81.3-82.6 avg.82	76.1-77.7 avg. 76.7	81.6-82.2 avg.81.8	70.9-71.7 avg.71.6	66.7-74.9 avg. 71.4
pyroxene	(mg)	50.4-53.9 avg. 52.2	79.9-81 avg.80.6	78.9-80 avg.79.5	84-84.3 avg.84.2	79.1-84 avg.80	82.8-83 avg.82.9	72.8-76.8 avg. 74.8	
	(Wo)	2-8	3-5	3-4	3	3-48	3-6	4	