A COMPARISON OF ANORTHOSITIC LUNAR LITHOLOGIES: VARIATIONS ON THE FAN THEME.
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Introduction: Certain anorthosites that are rare in the returned lunar samples have been identified
among lunar meteorites (e.g. [1-4]). The variety of anorthosites in the Apollo collection also is more varied
than is widely recognized. James et al. [5] identified three lithologies in a composite clast of FAN-suite
rocks in lunar breccia 64435. They further divided all FANs into four subgroups: anorthositic ferroan (AF),
mafic magnesian (MM), mafic ferroan (MF), and anorthositic sodic (AS, absent in the 64435 clast). Here we
report Sm-Nd isotopic studies of the lithologies present in the 64435 composite clast and compare the new data
to our previous data for lunar anorthosites incuding lunar anorthositic meteorites [1-4]. Mineralogy-
petrography, in situ trace element studies, Sr-isotope studies, and Ar-Ar chronology are included, but only
the Nd-isotopic studies are currently complete.

Mineralogy-petrography: We present Mg’ and An contents of lithic fragments in the same thin sec-
tions (PTSs) studied by [5,6] as well as in new thick sections prepared for in situ trace element analyses by
LA-ICPMS. Fig. 1 compares Mg’ in olivine and low-
and high-Ca pyroxene in the 64435 Coarse Troctolitic
Anorthosite (CTA) to values in the Dhofar 489 and 908
Magnesian Anorthosites (MgAN) [1]. Mg’ values for
these anorthosites are intermediate to values found
more commonly for FANs and Mg-suite rocks. Data
for the other 64435 lithologies plot at lower Mg’ values
more typical of FANs. Primary augite is present in
CTA. Sodic anorthosites (SAN) [3,7] and the hypothe-
sized “An93 anorthosite” [2,3] have slightly lower An
contents than An~95 for the AS suite of [3]. The iso-
topic data presented here are for anorthosites of more
typical An~97-98, the AF, MF, and MM rocks of [5,6].

Trace Element Geochemistry: Trace element da-
ta for individual 64435 clasts were reported by [5], and
in situ SIMS analyses by [6]. New solution ICPMS
analyses of bulk samples of CTA, CA, and two bulk
samples of FTA are shown in Fig. 2. (See [5] for clast
nomenclature). REE abundances in CA are slightly
lower than those in bulk samples of better known large
anorthosites like 60025 and 15415. REE abundances in
bulk CTA and .325 FTA are similar even though Mg’
is higher than for typical FANs. Also shown in Fig. 2
are REE abundances in fragmental breccias MIL
090034 (MIL34) and MIL 090070 (MIL70) [4]. These
two highland breccias are among the most plagioclase-
rich of lunar highland meteorites, and plot in the “tro-
cotlite” field on a diagram of FeO vs. Al2O3 [4]. Typical
highlands meteorites have Al2O3 ~26% (cf. [4]) com-
pared to ~30% for MIL34 and MIL70, and ~36% for

Figure 2. Mg’ vs. An for selected anorthosites
volume compared to these parameters for pristine rocks
(blue shaded background [3]).
“pure anorthosites like 15415 and 60025.

64435 Anorthositic Clasts & FANs 62236, 62237, Dho908 & Y86032

147Sm-144Nd data: Fig. 3 shows new data for the 64435 clasts compared to data for more larger anorthosites analysed at JSC. Internal Sm-Nd isochrons in the range ~4.3-4.5 Ga as shown in the figure were determined for several of those anorthosites. No isochron is confidently determined for the 64435 lithologies alone. However, if the fine-grained impact melt (FIM) is included, the data define a regression line (not shown in Fig. 3) corresponding to an apparent age of 4.0±0.5 Ga and initial εNd (CHUR) = 0.2±2.0 (CHUR = Chondritic Uniform Reservoir [8]). There are only minor differences in the Nd-isotopic systematics of CA, CTA, and FIM plagioclase suggesting similar source materials for anorthositic and troctolitic samples. The Nd isotopic data of the 64435 lithologies are nearly coincident with those of the “white clast” in the Dho 908 lunar highland meteorite at comparatively low 147Sm/144Nd and at higher 147Sm/144Nd with plagioclase in the “white clast” Y86032,133 in Yamato 86032 [3], as well as with the data for the MIL 3470 lunar meteorites suggesting that the petrogenetic processes are not site-specific. We note that impact resetting of the Ar-Ar ages of the MIL34/70 anorthositic breccias [4] is not apparent in their Sm-Nd data.

146Sm-142Nd data: New 146Sm-142Nd data for the 64435 clasts and the MIL34/70 meteorites are consistent with their formation within the first ~200 Ma of solar system history from an Earth-like isotopic reservoir characterized by the present day 146Nd/144Nd of the terrestrial laboratory standard, or with later formation from a CHUR reservoir (Fig. 4). More complex models do not seem justified by the data.

(T, εNd) of lunar anorthosites: Fig. 5 shows (T, εNd) values of the 64435 lithologies plotted at the average internal isochron age of troctolitic anorthosites 62236 [9] and 62237, i.e., 4.37±0.07 Ga. Also shown are data for other anorthosites and two KREEP basalts. JSC internal isochron data for 67075 and Y86032 clasts [2], and 60025 plagioclase plotted at the 4360±3 Ma age of [10] are consistent with the CHUR [8] value for an undifferentiated LMO, or one in which plagioclase dominates the REE budget. Other anorthosites contain more radiogenic Nd produced in an environment in which mafic phases dominated the REE budget, perhaps in rockbergs with variable proportions of mafic minerals forming and remelting during a protracted LMO phase. (cf. [11], Fig. 4 of [12]).


Figure 3. 147Sm-144Nd data for 64435 clasts (red circles) compared to data for ~4.3-4.5 Ga anorthosites.

Figure 4. 147Sm-144Nd data for 64435 and Y86032 clasts and MIL 34/70 lunar highland meteorites.

Figure 5. (T, εNd) diagram for lunar anorthosites.