REMNANTS FROM THE ANCIENT LUNAR CRUST III: NORITE 78236.
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Norite 78236 was sampled from the same 0.5 m boulder at the base of the
Sculptured Hills that produced norites 78235 and 78238. Petrographic exami-
nation of 78236 by Nyquist et al. (1) reveals that this sample closely resembles
78235 as described by McCallum and Mathez (2) and 78238 as described by Jackson
et al. (3). These samples are coarse-grained cumulates, containing approxi-
mately equal proportions of orthopyroxene and plagioclase with a small amount
but wide variety of accessory phases, including phosphates and metal. The
samples have been strongly shocked, as indicated by conversion of much of the
plagioclase to maskelynite and shock melting along many grain boundaries.

Sample 78236 has been the focus of a consortium of workers examining
pristine lunar norites (L. Nyquist - leader). We have analyzed for FeO and
trace elements a representative aliquant of the whole rock sample prepared for
consortium study by grinding and homogenizing a 1.75 g chunk (Table 1), magneti-
cally separated and handpicked pyroxene and plagioclase samples, and 10 indi-
vidual chips. In addition, we have analyzed a representative split of whole
rock for major elements by XRF (Table 1).

Work is continuing, but we are confident of several conclusions:

1. 78236, 78235, and 78238 are all samples from the same rock. In
addition to the petrographic similarities noted above, trace element abundances
for mineral separates from 78236 are identical to those reported for 78235 by
Winzer et al. (4), as shown in Figure 1.

2. These samples crystallized from an evolved, fractionated liquid with
REE abundances greater than 100X chondrites, LREE much enriched over HREE,
and a deep negative Eu anomaly. This conclusion is in essential agreement with
that of Winzer et al. (4). We have calculated the REE abundances for the
liquid that was in equilibrium with the pyroxene, plagioclase, and whole rock.
The plagioclase calculations are well constrained by the very low FeO content
(< 0.3%) of the plagioclase fragments and separate, limiting contamination from
trapped liquid (estimated FeO ~ 10%) or pyroxene (FeO ~ 13%) to less than 3%.
The pyroxene calculations are constrained by the very low Eu content (< 0.05 ppm)
of the pyroxene fragments and separate, limiting contamination from trapped
liquid or plagioclase (both ~ 1.4 ppm Eu) to < 4%. Results of these calcula-
tions indicate a parent liquid having ~ 100X chondritic LREE, with HREE strongly
depleted relative to LREE. Results of the whole rock calculation are in
general agreement with the mineral calculations. Even assuming up to 10%
trapped liquid (McCallum and Mathez (2) estimate less than 5% trapped liquid
for 78235), the equilibrium liquid still must be well over 100X chondrites in
LREE abundances, depleted in HREE, with a deep negative Eu anomaly.

3. An appreciable fraction of the REE in this sample is contained in a
LREE-enriched phase other than pyroxene and plagioclase. Mass balance calcu-
lations indicate that mixtures of pyroxene and plagioclase separates fail to
reproduce both the overall REE abundance level and the degree of LREE enrich-
ment observed for the whole rock. However, a mixture of REE-enriched plagi-
oclase particle B with pyroxene A nearly perfectly matches the whole rock
composition. Pyroxene A is essentially identical to the pyroxene separate.
Plagioclase B differs from the plagioclase separate in that it is enriched in
LREE and is depleted in FeO (0.10%). Thus, the enriched LREE are associated
with a Fe-poor phase. Whitlockite or apatite, which were observed to contain
up to 6.5% REE in 78235 (2), are likely candidates.
Additional evidence for the presence of a minor phase enriched in LREE comes from the equilibrium liquid calculations. Calculations based on the whole rock abundances indicate a liquid with a sloping, light-enriched LREE pattern, while mineral calculations indicate a liquid with a flat or light-depleted LREE pattern. This result does not depend strongly on the values assumed for distribution coefficients, because the same set of values was used for all calculations. The result suggests the presence of a LREE-enriched minor phase with which plagioclase and pyroxene equilibrated after the trapped liquid became chemically isolated from the parent liquid. Competition for REE between the major silicate minerals and the LREE-enriched phase would leave the former anomalously low in LREE, resulting in low estimates for LREE in their "equilibrium" parent liquid. Isotopic systematics detailed by Nyquist et al. (1) for 78236 give ample evidence for a re-equilibration episode after the rock solidified. Redistribution of REE among major cumulate phases and minor phases may well have occurred at that time.

References:
(1) Nyquist, L.E. et al. (1981) This volume.

Table 1. 78236,3 Bulk Rock

<table>
<thead>
<tr>
<th>Element</th>
<th>Abundance</th>
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<tr>
<td>SiO₂</td>
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<tr>
<td>TiO₂</td>
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<tr>
<td>Al₂O₃</td>
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<tr>
<td>FeO</td>
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<tr>
<td>MnO</td>
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<td>MgO</td>
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<tr>
<td>CaO</td>
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<tr>
<td>Na₂O</td>
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<tr>
<td>K₂O</td>
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<tr>
<td>P₂O₅</td>
<td>0.08</td>
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<td>S</td>
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Total 99.45
Figure 1: Whole rock and minerals from 78236,3. Closed symbols are Px from 78235 and open symbols are Plag from 78235, both from Winzer et al. (4).