

YTTRIUM SILICATE IN LUNAR TROCTOLITIC ANORTHOSITE 76335. J. Edmunson¹, B. A. Cohen², P. Carpenter³, R. A. Zeigler³, and B. L. Jolliff³, ¹BAE Systems/Marshall Space Flight Center (320 Sparkman Drive, VP61, Huntsville AL 35805, Jennifer.E.Edmunson@nasa.gov), ²Marshall Space Flight Center/VP62, ³Washington University in Saint Louis, St. Louis MO 63130.

Introduction: An yttrium silicate with the approximate formula $(Y,REE)_2Si_2O_7$ has been found in a thin section of lunar troctolitic anorthosite 76335 [1] along the border of an area with a mineral assemblage dominated by orthopyroxene and minor minerals such as (rare earth) RE-merrillite, chromite, and Fe,Ni metal (Figure 1, 2). The electron microprobe data obtained for the yttrium silicate appears in Table 1. The microprobe was also used to detect rare earth elements (REEs) in the weight percent range in the yttrium silicate and in RE-merrillite. Figure 3 shows the REE pattern of the yttrium silicate, the difference between the REE patterns of the RE-merrillite near the orthopyroxene, and the RE-merrillite outside the area with its typical lunar RE-merrillite pattern [2].

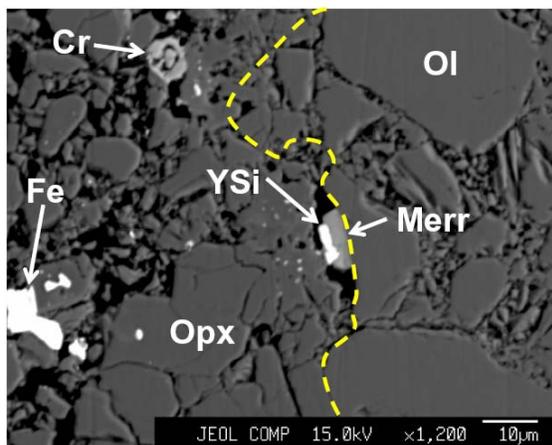


Figure 1: Backscattered electron image of yttrium silicate (white, YSi) and RE-merrillite (light gray, Merr) in lunar troctolite 76335. Yellow dashed line indicates approximate location of orthopyroxene/olivine border. Ol = olivine, Opx = orthopyroxene, Cr = chromite, and Fe = native iron nickel metal.

Background: Magnesian-suite troctolitic anorthosite 76335 is significantly cataclastized, but it is geochemically similar to sample 76535 [1,3]. Bulk geochemistry, remnant textures, and identical Sm-Nd isotopic characteristics [3] further strengthen the relationship between the two samples. These samples likely originated from the same pluton and followed the same temperature versus time path until 76335 was cataclastized [3]. This cataclasis did not occur to 76535.

Thus, it is appropriate to compare the geochemistry of the majority of 76335 to that of 76535. However, the orthopyroxene-dominated area in 76335 has significantly different REE patterns than the bulk of the sample (Figure 3).

The yttrium silicate was discovered during a study of the Sm-Nd and Rb-Sr isotopic systematics of the two troctolites. This mineral contains high concentrations (weight percent) of REEs (Table 1) and other radioactive elements (e.g., Th, U). The yttrium silicate has the approximate formula of terrestrial yttrilite ($Y_2Si_2O_7$) and keiviite ($(Y,HREE)_2Si_2O_7$). True identification of the mineral requires structural data.

Structural Data: EBSD data was obtained on the yttrium silicate by Chi Ma, but the structure proved to be amorphous, most likely metamict given the high concentrations of radioactive elements (U, Th) in the phase (Chi Ma, personal comm. 5-21-09). Raman spectroscopy for further characterization of the mineral was not attempted because the grain has a carbon coat, the size of the grain is very small, the likelihood of fluorescence, and the metamict state of the mineral.

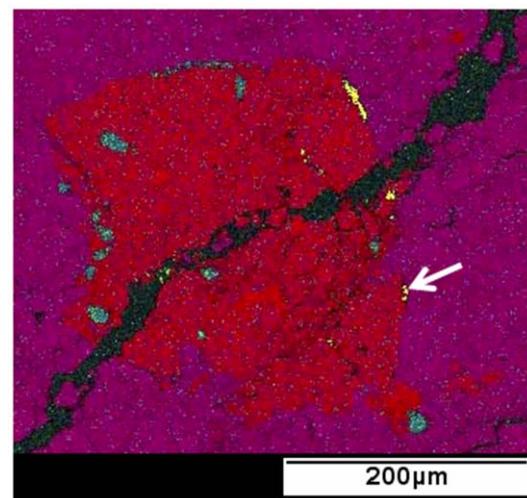


Figure 2: Energy dispersive spectroscopy phase map of the orthopyroxene area in 76335. Image obtained with the aid of J. Coston. Dark pink = olivine, red = orthopyroxene, green = chromite, yellow = RE-merrillite, black = crack within the sample. White arrow indicates the RE-merrillite next to the yttrium silicate.

Table 1: Electron microprobe analyses of 76335 yttrium silicate.

Oxide	YSi 1	YSi 2	YSi 3	Average
SiO ₂	26.55	30.10	30.43	29.03
TiO ₂	0.23	0.22	0.23	0.23
Al ₂ O ₃	0.06	0.03	0.01	0.03
FeO	1.20	1.05	1.16	1.14
MgO	1.29	0.93	0.92	1.05
CaO	5.12	2.07	2.54	3.24
PbO	1.02	0.71	0.53	0.76
Na ₂ O	0.04	0.08	0.06	0.06
HfO ₂	0.14	<0.09	<0.09	0.05
ThO ₂	0.84	0.77	0.68	0.76
UO ₂	0.07	0.04	0.05	0.05
Y ₂ O ₃	39.18	39.40	40.60	39.73
La ₂ O ₃	2.09	2.12	2.41	2.20
Ce ₂ O ₃	3.47	3.37	4.13	3.66
Pr ₂ O ₃	0.07	0.09	0.08	0.08
Nd ₂ O ₃	0.27	0.26	0.34	0.29
Sm ₂ O ₃	0.21	0.18	0.18	0.19
Gd ₂ O ₃	0.69	0.64	0.73	0.69
Tb ₂ O ₃	0.27	0.27	0.27	0.27
Dy ₂ O ₃	3.84	3.50	3.73	3.69
Ho ₂ O ₃	1.13	0.99	1.12	1.08
Er ₂ O ₃	4.86	4.44	4.41	4.57
Tm ₂ O ₃	0.57	0.63	0.51	0.57
Yb ₂ O ₃	2.80	2.61	2.19	2.53
Lu ₂ O ₃	0.33	0.36	0.26	0.32
P ₂ O ₅	5.36	2.40	2.89	3.55
Total	101.7	97.3	100.5	99.8

Eu₂O₃ and ZrO₂ were not found in the yttrium silicate. All values in oxide weight percent.

Rare Earth Element Patterns: Figure 3 shows REE patterns for comparable phases inside the orthopyroxene-dominated area and outside the area. Note that the yttrium silicate, RE-merrillite, and pyroxene in the orthopyroxene-dominated assemblage have LREE enrichments as well as HREE enrichments when compared to the REE patterns of RE-merrillite and pyroxene outside the orthopyroxene-dominated assemblage. There is a noticeable MREE depletion in the RE-merrillite in the orthopyroxene-dominated assemblage compared to RE-merrillite outside the assemblage. A similar pattern to the RE-merrillite in the assemblage is observed in the yttrium silicate.

Further Study: Currently, the mechanism for formation of the orthopyroxene-dominated assemblage is unknown, and no identical phase has been observed in 76535. The REE pattern for the RE-merrillite in the orthopyroxene area does not match the REE pattern for the RE-merrillite from other areas of 76335 (Figure 3).

Thus, more study is necessary to find out (1) the relationship, if any besides location, between the orthopyroxene-dominated area and the rest of 76335, (2) the source of the orthopyroxene-dominated assemblage and the yttrium silicate, and (3) what effect these minerals may have on the isotopic geochemistry of the sample.

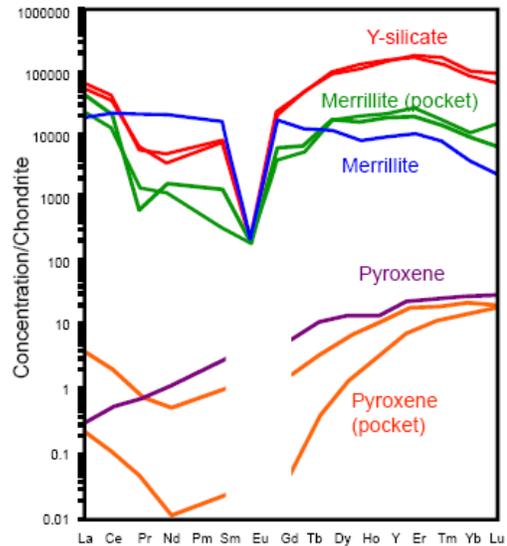


Figure 3: Rare earth element patterns for 76335 yttrium silicate, RE-merrillite, and pyroxene. The term “pocket” refers to those minerals within the orthopyroxene-dominated assemblage. Those without the “pocket” notation occur outside the orthopyroxene-dominated assemblage. Pyroxene results obtained using secondary ion mass spectrometry (SIMS) by C. Floss. Note that Eu was not detected by the electron microprobe or analyzed by SIMS for 76335 – the depth of Eu anomaly in RE-merrillite and the yttrium silicate was estimated from a zirkelite phase.

References: [1] Warren P. H. and J. T. Wasson (1978) *LPS IX*, 185-217. [2] Jolliff B. L. et al. (2006) *Am. Min.* 91, 1583-1595. [3] Edmunson J. and B. A. Cohen (2009) *Met. Planet. Sci.* 72, 5300E (Abstract).