CHARACTERIZING THE EFFECT OF SHOCK ON ISOTOPIC AGES II: Mg-SUITE TROCTOLITE MAJOR ELEMENTS.

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Introduction: Two troctolites from the lunar magnesium suite (Mg-suite), 76335 and 76535, have 147Sm-143Nd and 87Rb-87Sr ages that do not indicate the same age for their respective sample. In the case of 76335, the 147Sm-143Nd age is 4278 ± 60 Ma [1], but the 87Rb-87Sr data does not reveal an isochron [2]. For 76535, the 147Sm-143Nd age is significantly younger (4260 ± 60 Ma [3]) than the 87Rb-87Sr age (4570 ± 70 Ma, λ = 1.402x10^-11 [4]). This study was designed to discover why the 147Sm-143Nd and 87Rb-87Sr ages did not match for each individual sample.

Observations: Sample 76335 is composed of anorthite (An_{98}Ab_{2}) and olivine (Fo_{88}), with minor orthopyroxene (En_{87}Fs_{12}Wo_{1}) and various trace phases (including chromite, baddleyite, zirkelite, metal, and merrillite). Microprobe analysis indicates that 76335 Fe-Ni-Co metal has Ni and Co abundances indicative of pristine rocks, supporting the conclusions of [5] and the status of 76335 as a monomict breccia.

Troctolite 76535 is unlike 76335 in most physical features, but is very much like 76335 in geochemistry. Sample 76535 is a coarse-grained annealed rock complete with 120° triple grain junctions [6], while 76335 is a cataclastite. Investigations are ongoing to determine if 76335 is part of the 76535 parent pluton, but with at least one subsequent cataclastic event that 76335 did not experience. There are a few points of evidence that would imply a shared origin. First, their geochemical pairing [7]. Second, their almost identical bulk trace element pattern [8, 9]. Third, the overlap of 76335 and 76535 in 147Sm-143Nd age versus ε^143Nd space [1]. Lastly, remnant 120° triple grain junctions and small linear inclusions of pyroxene [10] in the anorthite of cataclastized 76335 match those observed 76535. These shared features may indicate that the samples originated from the same parent pluton. Thus, the near identical 147Sm-143Nd ages may indicate the true age of both troctolites, while the subsequent cataclastic event experienced only by 76335 may have disturbed the 87Rb-87Sr isotopic systematics sufficiently to prevent an isochron.

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76335 Yttrium Silicate

A yttrium silicate with the approximate composition Y$_2$Si$_2$O$_5$ was observed in 76335. This silicate contains high concentrations (weight percent) of REEs (see figure at right) and other radioactive elements. The composition Y$_2$Si$_2$O$_5$ is the formula for the mineral yttrolite. The yttrium silicate in 76335 was not verified as a structural match for yttrolite because an electron backscatter diffraction (EBSD) pattern was not obtainable. Multiple efforts by Chi Ma to obtain an EBSD pattern from the mineral only proved that the structure was amorphous, likely due to the significant radiation damage the mineral experienced during its long life on the Moon (Chi Ma, personal comm. May 21, 2009).

A REE pattern was produced using detailed analysis using the microprobe at Washington University by Paul Carpenter and Ryan Zeigler. The yttrium silicate in 76335 has a strikingly similar REE pattern to yttrolite thought to be a result of breakdown of zircon [10] (see figure at right). Accessory phases baddeleyite and zirkelite are also present in 76335 and 76535.

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Implications to Geochronology

The breakdown of zircon via particle and defect volume diffusion implies that 76335 experienced temperatures of approximately 750°C [11] long enough to create an entirely new mineral. This temperature is higher than the $^{147}$Sm-$^{144}$Nd closure temperature [12] and the temperature for cation ordering [13], and thus likely occurred during a long-term cooling history in which the textures noted in the above figures were imparted to both 76335 and 76535. Therefore, the parent pluton of 76335 and 76535 existed prior to the age recorded by the $^{147}$Sm-$^{144}$Nd isotopic system, and a yttrolite phase should be found in 76535.

Comments can also be made on the $^{87}$Rb-$^{86}$Sr isotopic system of these two samples based on the comparisons above. Rubidium loss was measured in a sample experimentally heated to 800°C [14] and long-term heating of the parent pluton may be responsible for producing an older $^{87}$Rb-$^{86}$Sr “pseudo-isochron” for 76335 [15]. In fact, Rb loss can be easily seen in two of the olivine mineral fractions from 76335 (ol and ol ox). Given the observed severity of Rb loss, and the resulting relatively low $^{87}$Sr/$^{86}$Sr ratios, it is likely that the Rb loss event occurred very early in the history of the sample. Volatility of Rb during cataclasis/meteorite bombardment likely promoted Rb loss in 76335 over 76535 (e.g., [16]).