WATER ON ASTEROIDS: THE CURIOUS CASE OF R-CHONDRITE MILLER RANGE 11207.

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Introduction: Understanding the origin, distribution, and behavior of volatile-rich material in the Solar System provides crucial constraints on planetary evolutions as well as the availability of magmatic fluids for any potential occurrences and sustenance of life. The discovery and recovery of volatile-bearing meteorites, thus, plays a fundamental role in placing such constraints on the origin and distribution of water throughout our Solar System, highlighting the crucial importance of the ANSMET field expeditions. The Miller Range (MIL) 11207 meteorite was recovered during the 2010-2011 ANSMET field season at the Miller Range, Antarctica. It is a shocked R-6 chondrite [1,2] and contains ~12 vol% OH-bearing minerals – amphibole, biotite, and apatite [2]. This is the second R-chondrite reported to contain abundant OH-bearing minerals, the other being La Paz Icefield (LAP) 04840 [3]. However, MIL 11207 is petrologically distinct from the LAP 04840 pairing group (including finer grain size, and stronger effects of shock), and thus, elevates LAP 04840 from a unique odd-ball to the first find of a distinct subclass or grouplet of chondrites [2]. The importance of this grouplet lies in the elevated pressure of water vapor required to stabilize its amphibole and biotite [2,3]. Here we report updated mineralogy and petrography of MIL 11207 and discuss the implications of our results for the geological history of the R-chondrite parent body.

Sample and Methods: Data here on MIL 11207 are from two polished sections; one thin (,14) and one thick (,13). BSE and cathodoluminescence images and mineral chemical analyses were performed with a CAMECA SX100 microprobe at the American Museum of Natural History and the JEOL-8200 at Rutgers University. Modal mineralogy was calculated similar to [4,5].

Mineralogy/Petrology: MIL 11207 is composed of relict chondrules and poikilitic feldspar, pyroxene, and amphibole, set in a crystalline ground mass of olivine and sulfides, with minor apatite, biotite, and chromite [2]. It contains no metal, indicative of relatively high oxidation state similar to LAP 04840 [2,3]. *Olivine* is homogeneous at Fo_{58-61}, with NiO ranging from 0.3-0.6wt%. *Sulfides* are present as pyrrhotite and pentlandite. *Feldspar* in MIL 11207 is poikilitic in texture and albitic in composition. *Pyroxene* is poikilitic in texture and is augitic clinopyroxene (augite to diopside). *Amphibole* grains are strongly pleochroic in polarized light. Chemically amphibole is magnesio-pargasite and is hydroxyl rich (1.98sfu OH). *Apatite* forms large grains and contains up to 0.72sfu OH. *Biotite* is phlogopite and hydroxyl-rich (3.91sfu OH). *Chromite* is commonly associated with sulfides.

Geothermometry: MIL 11207 is similar to LAP 04840 in containing amphibole, biotite, and apatite. These hydrous phases appear to have formed during a metamorphic episode. By combining mineral exchange thermometry and the locations of mineral reactions, we calculated peak metamorphic conditions, at which MIL 11207 equilibrated, to be between 20-700 bars H_2O vapor pressure and ~720ºC.

Discussion and Conclusion: Achieving and maintaining the inferred H_2O vapor pressur (20-700 bar) on the R-chondrite parent body are problematic because of its presumed size (hence lower gravity) and high permeability. One way to achieve and maintain such high P_{H2O}, is that the R-chondrite parent body was sealed by water ice [6,7]. In this scenario, asteroid disruption followed by re-assembly and consolidation [e.g., 3] would burry near-surface hydrogen-bearing rocks deep inside the reassembled asteroid. The water would be remobilized and released as vapor via sublimation and mineral dehydration reactions [3], which are driven by internal heat from differentiation, radioactive decay, and gravitational reassembly. The water vapor would diffuse through the pore space and flow outward until it became cold-trapped as ice, creating an ice shield layer inside the asteroid parent body that would seal off the interior and isolate it from the vacuum of outer space [7]. Once the ice shield was in place, the pressure within the parent body could increase, even at shallower depths, and thus explain the high water pressure recorded in MIL 11207 and similar R-chondrites. Such ice shields have been proposed in the past for Mars, Ceres, and main-belt comets (e.g., 6-8). Findings such as the amphibole bearing R-chondrites MIL 11207 and LAP 04840 highlight the importance of the ANSMET expeditions to recover invaluable samples that are necessary for our understanding of early Solar System processes including the origin, distribution, and behavior of volatile-rich material throughout the Solar System.

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