

AMPHIBOLE AND PHLOGOPITE FORMATION ON THE R CHONDRITE PARENT BODY: AN EXPERIMENTAL INVESTIGATION

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Introduction: Rumuruti (R) chondrites are unique in that they include metamorphosed members that experienced hydrous metamorphism and ones that record predominantly anhydrous metamorphism [1-4]. R chondrites are the only chondritic meteorites known to contain high-temperature hydrous minerals (amphibole and/or phlogopite mica), and only three R chondrites are known to contain one or both of these hydrous minerals: Miller Range (MIL) 07440, MIL 11207, and LaPaz Icefield (LAP) 04840 pairing group [1-3].

There is not a consensus about how amphibole formed on the R chondrite parent body. McCanta et al. [1] proposed that the amphibole found in LAP 04840 (the only R chondrite in which amphibole had been identified at the time of their study) formed by a reaction between high-Ca pyroxene, plagioclase, low-Ca pyroxene, and H₂O that preferentially consumed high-Ca pyroxene leaving LAP 04840 depleted in high-Ca pyroxene relative to other R chondrites. In contrast, Rubin [3] proposed that the amphibole in these R chondrites formed by a reaction between the same phases as [1] listed above, but instead preferentially consumed low-Ca pyroxene because the lack of high Ca-pyroxene found in LAP 04840 is not observed in the subsequently identified amphibole-bearing R chondrite MIL 11207. In this study, we experimentally investigate conditions at which amphibole and phlogopite may form from an anhydrous R chondrite precursor under H₂O-saturated conditions, and the contributions of high-Ca and low-Ca pyroxene to formation of amphibole.

Methods: Our experiments were conducted in a horizontally oriented cold-seal apparatus at the Smithsonian Institution (SI). Its pressure vessel is composed of a Ni-alloy that results in an intrinsic experimental oxygen fugacity (f_{O_2}) around one log unit greater than the NNO buffer (~FMQ+1.6). Water is used as our pressurizing medium. Our experiments were run for ten days at temperatures of 670, 770, and 870°C, and at pressures of 25 MPa and 40 MPa. These pressure and temperature ranges and f_{O_2} are broadly consistent with those calculated for LAP 04840 by McCanta et al. [1]. The experimental charges consisted of powdered anhydrous R4 chondrite LAP 03639 with H₂O inside welded Au-capsules. Compositional data presented in this abstract are either energy dispersive x-ray (EDS) analyses collected with the FEI Nova NanoSEM 600 at the SI or wavelength dispersive x-ray (WDS) analyses collected with the JEOL 8900R EMP at SI.

Results and Discussion: New minerals are distinguished from materials found in the starting material by their small overall sizes and generally faceted appearance. Phlogopite grew in our two coldest experiments (670 and 770°C) conducted at 25 MPa. Amphibole grew in our experiment at 670°C and 40 MPa; this amphibole appears to be forming directly from decomposing high-Ca pyroxene. Phlogopite grew on surfaces of orthopyroxene crystals and was also occasionally observed on olivine. We have not found phlogopite or amphibole in our experiment conducted at 770°C and 40 MPa or any experiment conducted at 870°C. These findings confirm the calculations of [1] that hydrous silicate phases can form at pressure and temperature conditions of planetesimal interiors. Amphibole forming from degrading high-Ca pyroxene supports the proposed chemical reaction of [1] that consumes high-Ca pyroxene. However, this model does not explain why MIL 11207 does not appear to be modally depleted in high-Ca pyroxene [3].

Our charge from the experiment conducted at 870°C and 40 MPa contains glass, which preserves the composition of a quenched silicate melt. The alkali-rich (10.5 wt.% Na₂O + 1.89 wt.% K₂O) and Si-rich (55.6 wt.%) composition of this glass (n=5 analyses) captures that of a minimum (or near minimum) melt from an R chondrite under H₂O-saturated conditions. Although Na-rich silicate melts can form by low degrees of partial melting of R chondrites under anhydrous conditions; melting occurs at much higher temperatures ($\geq 1080^\circ\text{C}$) [5]. The occurrence of hydrated high-temperature minerals, such as amphibole, opens up the possibility that melting may have occurred on some planetesimals under hydrated conditions. The melt in our 870°C experiment suggests that small degrees of partial melting, under H₂O-saturated conditions, could have occurred at temperatures below the Fe,Ni-FeS cotectic (950-980°C), which is generally thought to be the initiation of melting on planetesimals [e.g., 6].

Future Work: We plan to conduct additional experiments to investigate potential conditions at which amphibole and phlogopite co-exist, as observed in LAP 04840 and MIL 11207. Alternatively, the co-existence of these two minerals may record retrograde metamorphism. We also plan to undertake additional analytical work and to determine mineral modes for our experiments.

References: [1] McCanta M. C. et al. (2008) *Geochimica Cosmochimica Acta* 72:5757 [2] Ota K. et al. (2009) *Journal of Mineralogical and Petrological Sciences* 104: 215 [3] Rubin A. E. (2014) *Meteoritics & Planetary Science* 49: 1057 [4] Bischoff A. (2011) *Chemie der Erde* 71:101 [5] Lunning et al. (in revision) *Geochimica Cosmochimica Acta* [6] McCoy et al. (1997) *Geochimica Cosmochimica Acta* 61: 623