

An Overview of Hydrous Lunar Magmatism, with an Emphasis on the Possible Role of Dissolved Molecular Hydrogen in Lunar Basalts.

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The increasing pace of observations of endogenous H₂O in high temperature lunar materials represents an exciting challenge to understanding of a range of important processes associated with the origin and differentiation of the Moon. Measurements of lunar materials combined with appropriate models and experimental partition coefficients will presumably document a range of H₂O concentrations in lunar magmatic products and their reservoirs. As I am not engaged in any of these measurements, my purpose is to take a larger perspective on how small to modest H₂O concentrations in lunar magmas may influence our understanding of lunar processes and petrogenesis.

Modest concentrations of H₂O in the lunar interior will undoubtedly influence understanding of delivery and retention of volatiles in the early Earth-Moon system. To date, the largest H₂O concentrations that have been considered in the lunar interior by Saal et al. (2009) that at least some lunar basalt source regions have H₂O concentrations similar to the terrestrial oceanic mantle. Such high concentrations are not easily reconciled with the strong depletions of other volatile elements (Ag, Zn, Sn, In, Br, Cd, Bi, Tl) in lunar basalts, which are 50 X lower than MORB (Wolf and Anders, 1980). If the comparatively high concentrations inferred by Saal et al. (2009) are robust, then either most lunar H₂O must be from a highly fractionated (cometary?) source or the behavior of a wide range of volatiles in lunar petrogenesis require reexamination.

The relatively modest concentrations of H₂O apparent in lunar basalts will likely have relatively little effect on their petrogenesis, except that they may account in part for the vesiculation and eruption dynamics. As is true for MORB, source concentrations as high as 100 ppm H₂O will have modest influence on the region from which small degree (< 1%) melts can be extracted, but little effect on larger degree partial melt source regions. Only modest influences on the major element compositions of basalts is expected, except that effective mean melt fractions will be reduced by extraction of significant hydrous small degree partial melts.

One important consideration is that the comparatively reduced conditions in the lunar interior dictate that much of the dissolved hydrous magmatic component is likely molecular hydrogen rather than H₂O or hydroxyl. Preliminary solubility measurements of molecular H₂ under reduced conditions made at the University of Minnesota (Ardia et al. in prep), analyzed by both FTIR and SIMS, indicate appreciable H₂ solubilities. Combining these results with established dependences of H₂O (OH) solubility on H₂O fugacity, T, and P allows estimation of the relative concentrations of different dissolved hydrous species. For example, at conditions of 1 GPa and 1400 °C and an oxygen fugacity similar to 1.5 log units below iron wustite, as much as 2/3 of the hydrogen, on a molecular basis, can be H₂ rather than H₂O. However, relative proportions of hydrogen and hydroxyl are highly sensitive to oxygen fugacities, absolute concentrations, and pressure. In particular, whereas concentrations of OH vary with the square root of H₂O fugacity, those of dissolved H₂ vary with the H₂ fugacity. Thus, there is a strong possibility of redox reactions between dissolved species on decompression, with magmas driven to more reduced conditions.