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Evidence of fractional melting and/or metasomatism from apatite compositional variations in primitive achondrites

FRANCIS M MCCUBBIN[1], JEREMY W BOYCE[2], JESSICA J. BARNES[3], BRENDAN A ANZURES[4], THOMAS J BARRETT[5], AMANDA STADERMANN[6], ROMAIN TARTÈSE[5], KIMBERLY T. TAIT[7], NICOLE LUNNING[1] AND PROF. JAMES M.D. DAY[8]

[1]NASA Johnson Space Center
[2]NASA
[3]Lunar and Planetary Laboratory, University of Arizona
[4]Amentum/NASA Johnson Space Center
[5]University of Manchester
[6]Austin Peay State University
[7]Royal Ontario Museum
[8]University of California at San Diego, Scripps Institution of Oceanography

The Ca-phosphate mineral apatite contains bound F, Cl, and OH in its structure, which has led to its use as a mineralogical tool to probe the volatile contents of differentiated (achondrite) and undifferentiated (chondrite) parent bodies [1]. Limited work has been done, however, to constrain F, Cl, and OH abundances in apatite from primitive achondrites, which are thought to represent partial melt residues from partially differentiated asteroids. Primitive achondrites could provide valuable insights into the effects of melting on apatite X-site chemistry during planetary differentiation. In this study, we report F and Cl abundances of apatite from a broad array of primitive achondrites, and we develop a model for apatite fractional melting using known apatite-melt partitioning relationships [2-3] and the apatite fractional crystallization model of [4] to test whether apatite compositional variation can be attributed to melting processes alone.

Major and minor element compositions of apatite were acquired using a JEOL 8530 field emission electron microprobe at NASA JSC using established methods [5]. The F, Cl, and inferred OH abundances from our data are shown in Figure 1. Hydrogen was not measured directly in this study, so the missing component could be OH, other X-site anions, and/or structural vacancies.

Using the compositions of chondrite apatites as a starting point [5], we determined that the apatite compositional arrays within acapulcoites, lodranites, and winonaites are consistent with those that would arise from equilibrium or fractional melting processes, but linking lodranites and acapulcoites by fractional melting would require that the missing component in lodranites and acapulcoites is comprised predominantly of vacancies +/- O^{2-} in the apatite X-site rather than OH^{-}. Brachinites exhibit variations that are inconsistent with melting processes alone and may require open-system processes consistent with metasomatism and/or degassing.

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Figure 1

