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Applying phosphate halogen compositions to trace magmatic or metamorphic fluids in inner Solar System materials

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The Ca-phosphates apatite and merrillite are abundant accessory phases in rocky planetary bodies in the inner Solar System. They occur in meteorites ranging from chondrites to highly differentiated achondrites and their abundance and grain size are highly diverse, ranging from <0.1 – ~3.5 vol% and from <2 μm – 2 mm, respectively. When present, Ca-phosphates in general, and apatite in particular, are the main carrier phases for halogens (F, Cl, Br, I) due to their preferential incorporation of halogens into their crystal structure. This makes them potentially useful to (1) identify a magmatic origin, (2) constrain the volatile content and composition of any source magma, or (3) evaluate the composition of fluids and aqueous alteration processes for phosphates formed in metamorphosed rocks and/or metasomatic systems.

This study contributes to the topical discussion on the role of phosphates for the early Solar System volatile evolution [e.g., 1-3] and helps to discriminate between potential magmatic and metamorphic origin of phosphates and their halogen inventory. Calculating volatile fugacities in magmatic (e.g., as used in [4]) and metamorphic systems from the halogen composition of individual phosphate grains can be used to discriminate between these two different volatile sources. This is of particular interest for understanding early Solar System fractionation processes, such as degassing and evaporation, in respect to highly volatile elements and their compositional evolution.

We address the conditions of phosphate formation and determine the halogen signatures as a tracer for volatiles and fluids by using a comprehensive study of high-spatial analytical techniques, including SIMS (Cameca 1280 IMS). Fluorine, Cl, Br, and I concentrations of apatite and merrillite grains and their textural relationship in different meteorite groups were investigated to characterize volatile reservoirs in the early phase of the Solar System evolution and to constrain possible secondary fractionation processes. We find a strong diversity in halogen concentrations among eucrite samples including F, Cl, Br and I, whereas the variability in the halogen signature in apatite from Martian meteorites, primitive achondrites (i.e., ordinary and Rumuruti chondrites) and IAB iron meteorites is limited. Meteoritic merrillite is an additional carrier of halogens, especially Cl in eucrites, and thus should be considered for the bulk rock halogen budget.

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