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SPECIAL COLLECTION: APATITE: A COMMON MINERAL, UNCOMMONLY VERSATILE

Phosphate minerals in the H group of ordinary chondrites, and fluid activity recorded by apatite heterogeneity in the Zag H3-6 regolith breccia

RHIAN H. JONES[1,2,*], FRANCIS M. MCCUBBIN[2,3,4], AND YUNBIN GUAN[5]

[1]School of Earth and Environmental Sciences, The University of Manchester, Manchester M13 9PL, U.K.
[2]Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131, U.S.A.
[3]Institute of Meteoritics, University of New Mexico, Albuquerque, New Mexico 87131, U.S.A.
[4]NASA Johnson Space Center, Mailcode XI2, 2101 NASA Parkway, Houston, Texas 77058, U.S.A.
[5]Division of Geological and Planetary Sciences, Caltech, Pasadena, California 91125, U.S.A.

ABSTRACT

Phosphate minerals in ordinary chondrites provide a record of fluids that were present during metamorphic heating of the chondrite parent asteroids. We have carried out a petrographic study of the phosphate minerals, merrillite and apatite, in metamorphosed H group ordinary chondrites of petrologic type 4-6, to understand development of phosphate minerals and associated fluid evolution during metamorphism. In unbrecciated chondrites, apatite is Cl rich and shows textural evolution from fine-grained apatite-merrillite assemblages in type 4 toward larger, uniform grains in type 6. The Cl/F ratio in apatite shows a similar degree of heterogeneity in all petrologic types, and no systematic change in compositions with metamorphic grade, which suggests that compositions in each meteorite are dictated by localized conditions, possibly because of a limited fluid/rock ratio. The development of phosphate minerals in H chondrites is similar to that of L and LL chondrites, despite the fact that feldspar equilibration resulting from albitization is complete in H4 chondrites but not in L4 or LL4 chondrites. This suggests that albitization took place during an earlier period of the metamorphic history than that recorded by preserved apatite compositions, and chemical equilibrium was not achieved throughout the H chondrite parent body or bodies during the late stages of metamorphism. A relict igneous clast in the H5 chondrite, Oro Grande has apatite rims on relict phenocrysts of (possibly) diopside that have equilibrated with the host chondrite. Apatite in the Zag H3-6 regolith breccia records a complex fluid history, which is likely related to the presence of halite in this meteorite. The porous dark H4 matrix of Zag, where halite is observed, has a high apatite/merrillite ratio, and apatite is extremely Cl rich. One light H6 clast contains similarly Cl-rich apatite. In a second light H6 clast, apatite compositions are very heterogeneous and more F-rich. Apatites in both H4 matrix and H6 clasts have very low H_2O contents. Heterogeneous apatite compositions in Zag record multiple stages of regolith processing and shock at the surface of the H chondrite parent body, and apatite records either the passage of fluids of variable compositions resulting from different impact-related processes, or the passage of a single fluid whose composition evolved as it interacted with the chondrite regolith. Unraveling the history of apatite can potentially help to interpret the internal structure of chondrite parent bodies, with implications for physical and mechanical properties of chondritic asteroids. The behavior of halogens recorded by apatite is important for understanding the behavior of volatile elements in general: if impact-melt materials close to the surface of a chondritic asteroid are readily degassed, the volatile inventories of terrestrial planets could be considerably more depleted than the CI carbonaceous chondrite abundances that are commonly assumed.

Keywords: Merrillite, apatite, meteorite, ordinary chondrite, H chondrite, Avanhandava, Estacado, Oro Grande, Richardton, Zag