Maskelynite-hosted apatite in the Chassigny meteorite: Insights into late-stage magmatic volatile evolution in martian magmas

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ABSTRACT

Apatite-hosting maskelynite and alkali maskelynite within regions interstitial to cumulus olivine differ compositionally from that found within melt inclusions in the Chassigny martian meteorite. Feldspar glass compositions within the interstitial regions evolve along a high-temperature crystallization path. Within the melt inclusions, feldspar glass shows evolution to low temperatures, extending into the subsolidus regime. Coupled with these differences in maskelynite compositions are differences in volatile abundance in apatite included within the maskelynite. Apatite found within the large olivine-hosted polyphase melt inclusions is uniformly fluorapatite, whereas that interstitial to cumulus olivine is chlor-fluorapatite.

We propose that the differences in maskelynite and apatite compositions within the melt inclusion and interstitial regions arose primarily from different crystallization conditions. Melt-inclusion maskelynite and apatite are consistent with nearly closed-system buildup of magmatic volatiles during crystallization within the melt inclusions, exsolution of a Cl-bearing fluid phase, and retention of this fluid phase within the melt inclusions into the hydrothermal regime. For the interstitial regions, however, the higher solidus temperatures of the interstitial melts, the early crystallization of feldspar with significant ternary component, and the Cl-rich nature of the apatite, all suggest open-system fluid migration through the cumulus pile, ingress of Cl-rich, H₂O-poor brine from a hotter, less evolved portion of the magma plumbing system, and interaction of this Cl-rich fluid with melt prior to the crystallization of feldspar. Such processes of fluid migration through a cumulus pile have been suggested on Earth in layered intrusions, and apatite is the primary recorder of this process.

Keywords: Magmatic volatiles, chlorine, water, fluorine, Chassigny, Mars, SNC meteorite, apatite

INTRODUCTION

The Chassigny martian meteorite is representative of the Chassignite class of SNC meteorites. It is a cumulate dunite (Floran et al. 1978; McSween and Treiman 1998; Nekvasil et al. 2007) with cumulus olivine and spinel, and intercumulus pyroxene, maskelynite, apatite, ilmenite, and sulfides. Olivine-hosted polyphase “melt” inclusions (MI) contain augite, low-Ca pyroxene, kaersutite, pyrrhotite, chromite, pentlandite, Ti-biotite, apatite, rhyolitic glass, maskelynite, ilmenite, and rare Al-rich chromite (Floran et al. 1978; Johnson et al. 1991; Nekvasil et al. 2003, 2007; McCubbin et al. 2006a). Although the Chassigny meteorite has been extensively studied (e.g., Mason et al. 1975; Floran et al. 1978; Johnson et al. 1991; Wadhwa and Crozaz 1995; Varela et al. 2000), the cumulate nature of the meteorite has made it difficult to constrain the chemical characteristics of the melts associated with its formation. The unknown volatile contents of these liquids and uncertainties regarding volatile evolution during crystallization further complicate petrogenetic interpretations.

Volatiles play a critical role in magmatic systems by controlling many physiochemical processes such as thermal stabilities of minerals and melts, melt density and viscosity, magma eruptive processes, and transport of economically important metals. Three common volatiles in terrestrial magmas are water, fluorine, and chlorine, and the literature contains extensive information concerning the effects of these volatiles in magmatic systems (e.g., Candela 1986a, 1986b; Webster 1992b, 1992a, 1997a, 1997b, 2004; Burnham 1994; Carroll and Webster 1994; Webster and Rebbert 1998; Webster et al. 1999; Webster and De Vivo 2002; Halter and Webster 2004; Mathez and Webster 2005). Evidence for the presence of volatiles in martian magmas is preserved in the volatile-bearing mineral phases of the martian meteorites. In the Chassigny meteorite, it is preserved in apatite of the melt inclusions and in regions interstitial to the cumulus phases, and in the kaersutite and biotite of the melt inclusions (e.g., Floran et al. 1978; Johnson et al. 1991). These minerals contain F⁻, Cl⁻, and OH⁻, suggesting the likelihood of elevated amounts of dissolved volatiles in the trapped melt. The effect that these volatiles may have had on the mineral assemblages depends not

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