Indigenous ghost apatite in lunar melt inclusions

DAN ZHU[1,*], YINGKUI XU[2], HUIMING BAO[1,3], YUN LIU[1]
JIANZHONG LIU[2], XIONGYAO LI[2] AND SHIJIE WANG[2]

[1]State Key Laboratory of Ore Deposit Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences, Guiyang 550081, China. *Correspondence Email: zhudan@vip.gyig.ac.cn

[2]Lunar and Planetary Science Research Center, Institute of Geochemistry, Chinese Academy of Sciences, Guiyang 550081, China

[3]Department of Geology and Geophysics, E235 Howe-Russell Complex, Louisiana State University, Baton Rouge, LA 70803, USA

Unusually high H_2O and F contents have been measured in some of the lunar melt inclusions in primitive olivine phenocrysts (Chen et al., 2015; Hauri et al., 2011), which is in an apparent contrast to the notion of a volatile-poor Moon. Here we show that the anomalously high H_2O and high F melt inclusions can in fact be produced by very dry melt. Our boundary-layer indigenous ghosts (BLIGs) model quantitatively reproduces these observed high H_2O melt inclusions by trapping the boundary layer of a dissolving H_2O- and F-rich apatite, a mineral phase that can grow out of a dry melt (Boyce et al., 2014) and precipitate initially within the boundary layer of a rapidly growing olivine. A necessary condition for our BLIGs model is an initial rapid cooling followed by a later reheating of a melt, a situation commonly existing during thermal evolution of a primitive magma (Annen et al., 2006). Our model also reproduces the geochemistry observed in lunar melt inclusions. For example, (1) The dichotomy of H_2O and F contents in melt inclusions is due to the first release of H_2O during the dissolution of BL ghost apatite owing to H_2O's greatest imcompatibility (McCubbin et al., 2015) and high diffusivities of F and H_2O in apatite (Brenan, 1993); (2) The higher CaO and Eu contents in lunar glassy melt inclusions comparaed to those in the whole rock are also related to the dissolution of BL apatite; (3) Some lunar glassy melt inclusions with higher contents of high-field strength elements, such as Nb, Hf and Zr (Chen et al., 2015), can be generated by trapping the ilmenite (or armalcolite), another ghost mineral. These ghost ilmenites had been completely remelted within these melt inclusions at the reheating stage. Our BLIGs model suggests that unusually high H_2O and F contents in some of the lunar melt inclusions are not necessarily in contrast with a dry lunar interior, as supported by many lines of evidence (Albarède et al., 2015; Sharp et al., 2010; Xu et al., 2014).