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Trace-element partitioning between immiscible lunar melts: An example from naturally occurring lunar melt inclusions

C.K. SHEARER,* J.J. PAPIKE, AND M.N. SPILDE

Institute of Meteoritics, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131, U.S.A

ABSTRACT

Evidence for liquid immiscibility on the Moon has been documented in melt inclusions in minerals that crystallized from mare basalts, within mesostasis in mare basalts and in at least one sample of a lunar plutonic rock. This study focuses on trace-element partitioning between immiscible melt pairs occurring as inclusions in plagioclase. These inclusions are blade-like in shape and range in length from 2 to 150 μm. They consist of two coexisting glasses separated by a sharp meniscus. The colorless, low-index glass (felsite) is spherical and immersed in a dark-brown, high-index glass (high-Fe basalt). The Fe-rich basaltic component of the inclusion is quartz + hypersthene normative with low Mg/(Mg + Fe) and variable SiO_2 content (between 34 and 45 wt%). The felsic component has a SiO_2 content between 72 and 82 wt% and variable K_2O (4.4 to 8.5 wt%)

In most cases, the partitioning behavior of the trace elements agrees with behavior either predicted or measured in experimental and natural systems. The high charge density elements preferentially partition into the basaltic component. High P_2O_5 and a wider solvus increase the $D^{\text{basalt/felsite}}$ for these elements. In contrast to many experimental studies and in agreement with studies of natural silicate liquid immiscibility, the $D^{\text{basalt/felsite}}$ for Ba indicates a preference for the felsic component. This difference in Ba behavior between experimental and natural samples has been attributed to differences in melt polymerization and compensation for charge unbalance within the polymerized melt structure. The apparent differences in $D^{\text{basalt/felsite}}$ for Sr and divalent Eu between the Apollo 11 high-Ti basalts and Apollo 12 low-Ti basalts may be a result of either subtle differences in bulk composition or the extent of plagioclase plating on inclusion walls. Based on our partitioning data from melt inclusions and the chemical characteristics of lunar felsites, the latter cannot be a product of simple fractional crystallization. Silicate liquid immiscibility can account for fractionation of Ba/La, K/U, and Ba/U in the lunar felsites and the limited variation in Zr/La. However, it cannot account for the REE pattern of the lunar felsites or the fractionation of U/La. These characteristics must be attributed to whitlockite crystallization prior to the onset of liquid immiscibility.