Thermal migration effect in the lunar anorthosites

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The absence of Na enrichment of plagioclase in the lunar anorthosite crust (LAC) (Gross et al., 2014; Warren, 1993) is still elusive, because it is in an apparent contrast to that of Apollo Mg-suite rocks and terrestrial basaltic rocks, and cannot be reproduced by experiments (Charlier et al., 2018; Rapp and Draper, 2018), although possible explanation has been proposed (Nekvasil et al., 2015). Here we show that the very restricted composition of plagioclase (An_{94-98}) is a natural consequence of thermal migration effect (TME), which is referred to as by Lesher and Walker (1988) when thermal gradient acting on crystal mush. During the formation of the LAC from the lunar magma ocean (LMO), there must be a large temperature gradient between the base of the LAC (cold end) and the top of the LMO (hot end). According to the experimental results (Lesher and Walker, 1988), the interstitial melt at the base of the LAC was depleted in Na and K and enriched in Ca as a results of TME, and a consequent increase in An content of the plagioclase. For example, using the experimental date from Walker and Delong (1982) and the model of Grove et al. (1992), our calculations indicate that the melt ON/04-1.5 in equilibrium with plagioclase (An=83) from Charlier et al. (2018), can equalibrate with plagioclase with An=98 after separation by TME. Supporting evidence for TME in the LAC is: (1) silica phases (e.g., quartz) are almost absent in the feldspathic lunar meteorites (Korotev et al., 2003) and the anorthositic Apollo samples (Papike et al., 1998), which is in contrast with the experimental results (Charlier et al., 2018; Lin et al., 2017; Rapp and Draper, 2018). We suggest that the TME impedes silica phases to be saturated in the interstitial melt of the LAC because Si is depleted in the cold end (Walker and Delong, 1982); (2) the REE (rare earth elements) compositions of the LAC parent melt calculated using the recent partition coefficients from Sun et al. (2017), are even higher than those of the KREEP basalts (K, REE, and P) (Warren, 1989). We also attribute this to TME, because it also lead the cold end enriched in REE concentrations (Lesher, 1986). The TME in the LAC supports the existance of the LMO.