The age, duration, and depth of a turbulent magma ocean in Mars

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One key aspect of early differentiation in terrestrial planets presently under debate is when did magma oceans (MO) form, how long did they last, and how deep were they? The heat released by accretion, short-lived radioactive elements, and core formation was likely sufficient to at least partially melt the silicate portions of terrestrial planets resulting in global-scale MO's. In order to investigate these issues for Mars, $^{142}Nd/^{144}Nd$, $^{143}Nd/^{144}Nd$, $^{147}Sm/^{144}Nd$, $^{176}Hf/^{177}Hf$ and $^{176}Lu/^{177}Hf$ data have been obtained on 9 shergottite meteorites. Shergottites fall along a mixing line between two distinct sources. This line does not pass through the chondritic point in ^{142}Nd-^{143}Nd systematics The mixing line is consequently not an isochron and this observation is independent of the initial Sm/Nd of Mars. The depleted end-member with high $^{147}Sm/^{144}Nd$ and $^{176}Lu/^{177}Hf$ is best represented by the depleted shergottites DaG476 and SaU008/094, and record differentiation ~35 Myr after solar system formation in their ^{142}Nd-^{143}Nd systematics. The enriched end-member with long-term subchondritic Sm/Nd, is preferentially sampled by enriched shergottites Zagami, Shergotty, Los Angeles, and NWA856. This end-member is likely to be late-stage quenched residual melt from the MO and differentiated ~100 Myr after solar system formation. This indicates an extended duration for the Martian MO, requiring an external process to slow down its crystallization rate, such as a primitive atmosphere acting as insulating blanket. In addition, the calculated Lu/Hf and Sm/Nd source ratios of depleted shergottites cannot be reproduced directly by cumulates crystallizing from the MO, but instead require a mixture between segregating crystals and residual melts. This is a direct consequence of turbulences in a convective MO. The Martian mantle source of depleted shergottites is the result of mixture between cumulates and ~2.5% of residual trapped melts. Finally, the Lu-Hf and Sm-Nd systematics in shergottites are consistent with a MO deeper than 1350 km.

High-Mg andesites from Glacier Peak WA, derivatives of mixing between low- and hi-Si endmembers

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Four small volume Quaternary mafic cinder cones and lava flows are present 5-10 km south of Glacier Peak, a dacitic stratovolcano in the northern segment of the Cascades magmatic arc. One of these flows, the Lighning Creek, consists of high-Mg basaltic andesite to high-Mg andesite (54.8-58 wt.% SiO_2) with Mg#s (100xMg/[Mg+Fe^T]) = 68-66, MgO = 7.8-6.3 wt.%, and 140-108 ppm Ni. The flow is isotopically heterogeneous, with ε_{Nd}=6.5-7.1; $^{87}Sr/^{86}Sr$=0.7030-0.7035; and $^{206}Pb/^{204}Pb$=18.77-18.81. The major, trace, and isotopic variations within this flow are inconsistent with fractional crystallization as the sole or dominant cause of compositional diversity. For example, Sr and La concentrations *decrease* with increasing SiO_2. Instead, chemical and isotopic trends are consistent with mixing with a Sr and La-poor felsic component, closely similar to dacites from nearby Glacier Peak (63-65 wt.% SiO_2, Mg# 47-51), to produce the high-Mg andesites of the suite. These dacites have more enriched isotope ratios than the andesites and basaltic andesites (ε_{Nd}=5.2; $^{87}Sr/^{86}Sr$=0.7036; and $^{206}Pb/^{204}Pb$=18.86), slightly higher La/Sm, but lower Dy/Yb and Sr/Y. Petrographic observations of disequilibrium textures such as xenocrysts, quenched glass inclusions, and strongly zoned and embayed phenocrysts support this conclusion of magma mixing.

All Lightning Creek samples have petrographic evidence for mixing, so the parental magma must have been less evolved (lower SiO_2) than the most primitive sample observed. Extrapolation of the mixing trend by modest amounts (removal of 10-20 wt.% dacite) predicts a parental magma composition near the basalt-basaltic andesite classification boundary. Similar relatively SiO_2-rich magnesian basalts and SiO_2-poor magnesian basaltic andesites are common elsewhere in the Cascades. Magnesian "true" andesites (SiO_2 56-62 wt.%) are not, and near Glacier Peak such magmas are products of mafic-felsic magma mixing.