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Plagioclase from planetary basalts: Chemical signatures that reflect planetary volatile budgets, oxygen fugacity, and styles of igneous differentiation

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ABSTRACT

Plagioclase grains from 15 basalt suites from the Earth, Moon, Mars, and 4 Vesta were studied by electron and ion microprobe techniques. The results demonstrate that chemical signatures in plagioclase record three planetary aspects that affect basaltic magmatism: (1) Volatile element depletions and enrichments in the planetary bodies are recorded by the systematics of Na and K in plagioclase. Terrestrial and Martian plagioclase are enriched in the volatile elements relative to plagioclase from the Moon and Vesta, a result that mimics the overall volatile budgets of these planets. Furthermore, the volatile-depleted nature of both the Moon and Vesta imply some similarities in planetary origin and/or evolution of these bodies. (2) The overall oxygen fugacity conditions on a planet may be realized by the Eu/Sm ratios of planetary plagioclase grains. Our data show that plagioclase from the Moon and 4 Vesta has higher Eu/Sm relative to plagioclase from the Earth and Mars. These data are consistent with low oxygen fugacity conditions on the Moon and Vesta, where divalent Eu is more compatible within the plagioclase structure than other trivalent REE elements. (3) The incompatible element systematics of K, REE, Ba, Y, and Sr in plagioclase show that styles of igneous differentiation affect basaltic magmatism on planets and more specifically, within tectonic settings on each planet. Terrestrial plagioclase grains from continental flood, continental rift, and Hawaiian basalt suites are enriched in the incompatible elements K, Ce, Ba, and Sr compared with Ocean Floor and Island Arc suites. The enrichments in the former are caused by continental crust interaction with basaltic magmas, and/or derivation from undepleted (fertile) mantle sources. Lunar KREEP basalt plagioclase enrichment in incompatible elements reflect mare basalt assimilation of a KREEP component, or partial melting of a KREEP-rich source. The Martian incompatible element data show that plagioclase from Shergotty is enriched in incompatible elements relative to plagioclase from QUE 94201. The data are in agreement with the idea that most Martian shergottites (except for QUE) have assimilated an incompatible element-rich crustal component on their way to eruption on the Martian surface.