GEOCHEMICAL, MINERALOGICAL, AND VOLCANOLOGICAL CONSTRAINTS ON THE PETROGENESIS OF KOMATIITES

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Komatiites are ultramafic volcanic rocks that occur primarily in Archean greenstone belts and that are inferred to have had very high liquidus temperatures (1640-1360°C), a very large interval between the liquidus and solidus (460-180°C), very low viscosities (0.1-1.0 Pa s), high densities (2800-2700 g m⁻³), and high specific heats (1800-1700 J kg⁻¹ °C⁻¹). Because of these unusual geochemical, thermal, and physical characteristics they are interpreted to have erupted very rapidly and superheated, formed very voluminous and very mobile flows that may have traveled great distances from their eruptive sites, become channelized within seafloor depressions, and cooled and solidified slowly. Depending on the degree of channelization, they may have also thermomechanically eroded wall rocks and/or substrates. As such, they provide critical information regarding the composition and structure of the Archean mantle and the nature of volcanism on the young Earth. The high MgO contents (up to 30%) of least-altered aphyric and fine random spinifex-textured komatiites and the high Fo contents (up to 94) of relict igneous olivines require derivation from a mantle source. Very low abundances of HILE relative to MILE and positive eNd values in most komatiites worldwide indicate derivation from depleted sources. Although it has been suggested that komatiites were water-rich (up to 4%) and were generated by hydrous melting, this is inconsistent with the lack of enrichment of HILE in most komatiites, suggesting that the rare komatiites that do contain igneous amphibole or abundant vesicles incorporated water during emplacement. Low abundances of MILE in most komatiites suggest moderate to high degrees of partial melting, depending on the composition of the source and the degree of prior melt extraction. Individual komatiite sequences commonly grade upwards from massive or differentiated cumulate units derived from
high-Mg komatiites to massive or differentiated non-cumulate units derived from low-Mg komatiites, suggesting that the lava pile evolved by fractional crystallization during emplacement in a regressive lava flow field. Crustal contamination occurred on large scales during ascent through the crust, typically in the late stages of eruptive cycles, or on very localized scales during emplacement, typically in the early stages of eruptive cycles. Although crystallization of spinifex zones and accumulation of olivine has been proposed to have occurred during inflation, textural, mineralogical, whole-rock geochemical, and mineral chemical variations indicate that inflation must have occurred early, that the excess olivine in the cumulate zones crystallized during emplacement, and that the spinifex zones crystallized after the flows ponded. Because of their unique thermal and physical characteristics and propensity to fractionate and crystallize olivine's chromite and to assimilate country rocks, the emplacement and crystallization history of komatiites must be carefully evaluated prior to making any inferences about magma generation processes.