ABSTRACT

Ultramafic and mafic xenoliths are the direct samples of the lithospheric mantle which provide insights into the composition and evolution of the cratonic lithosphere. This study reports petrography, mineralogy, major and trace-element compositions of both ultramafic and mafic mantle xenoliths, and first detailed hydrogen concentrations in peridotites and olivine xenocrysts from Mesoproterozoic Wajrakarur kimberlite field, Eastern Dharwar craton (EDC), India. These xenoliths provide a unique opportunity to investigate the origin and geodynamics of the Dharwar cratonic lithosphere. The ultramafic xenoliths consist of olivine (modal 74-82 vol. %) with Fo_{92-93}, clinopyroxene, orthopyroxene, spinel, garnet, and/or ilmenite whereas the mafic xenoliths are classified into bimineralic and kyanite eclogites based on mineralogy. Calculated equilibrium pressure and temperature conditions range from 2.5 to 5.0 GPa and 710-1179 °C for peridotites and 3.1 to 4.7 GPa and 789.1 to 1159.3 °C for eclogites equilibrating at depths of ~165 kms and lie on a 40 mW/m^2 Dharwar geotherm. Garnet in ultramafic rocks [with Mg# = molar (Mg/(Mg+Fe^{total}) × 100 of 80-88] displays either sinuous LREE-enriched patterns with depletion in Gd and Er for harzburgites or “normal” LREE-depleted, HREE-enriched patterns for lherzolites. Two groups of peridotitic clinopyroxenes (group-I and group-II) were also observed with high LREE ($La_N > 10$) and low LREE ($La_N < 10$), respectively. The Yb vs. Zr contents in peridotitic garnet are characterized by two distinct trends: one with low-T metasomatism for harzburgitic garnets and the other with high-T metasomatism for lherzolitic garnet, which suggests metasomatism from fluids circulating within the continental lithospheric mantle, resulting in refertilization from harzburgite to lherzolite. REE concentration of hypothetical melts in equilibrium with the peridotitic garnets display low volume carbonated silicate melts similar to the natural kimberlites and orangeites

of the Dharwar craton. Modeling suggests that peridotites are the residues of ~35-50% of melt extraction at ~1500-1540 °C and ≤2.0 GPa (≤60 km depth) and were formed by shallow and a hot plume melting environment.

Eclogitic garnets ($Py_{26-50}Alm_{18-35}Grs_{21-46}$) display LREE depleted patterns along with pronounced positive Eu anomaly whereas clinopyroxenes [with Mg# =molar (Mg/(Mg+Fe^{total}) × 100 of 82-90] in these mafic rocks exhibit LREE enriched patterns and are treated as the counterparts of the garnets in these mafic rocks. These mafic rocks have originated as low-pressure gabbroic cumulates and are formed by subduction of ancient oceanic crust. These eclogites samples show $Ce/Yb_{NMORB} \geq 1$ and $La_N/Yb_N > 1$ which have undergone melt metasomatism. Clinopyroxene is the primary carrier of metasomatism evidenced by the clinopyroxene-garnet trace element distribution coefficients. Hypothetical melts in equilibrium with the eclogitic clinopyroxenes exhibit ultramafic carbonated silicate melts metasomatism similar to the natural kimberlites and orangeites of the Dharwar craton. Trace element modeling suggests eclogites of the Wajrakarur cluster have encountered progressive fractional melting compared to the higher degree of batch melting in the Kalyandurg cluster.

Calculated hydrogen concentrations in peridotites and olivine xenocrysts are, on average, 18 ppm H_2O wt in olivine, 70 ppm H_2O wt in orthopyroxene, and 207 ppm H_2O wt in clinopyroxene, while garnet has highly variable hydrogen concentration ranging from 0 to 258 ppm H_2O wt. The reconstructed hydrogen bulk concentrations of Dharwar peridotites yields 40 (+10,-8) ppm H_2O wt and is two to five times lower than the estimated hydrogen concentration in the lithospheric mantle, and agree well with the lower range of hydrogen bulk concentration from the current database for the upper mantle minerals transported by kimberlites from other cratons (e.g., South Africa, Siberia). These observations, valid to a depth of ~165-km, suggest that the cratonic lithosphere beneath the Dharwar craton may not be particularly indicative of an abnormal hydrogen-rich southern Indian lithosphere in the late Archean and that hydroxylic weakening in olivine would induce a negligible effect on the mantle viscosity of Indian subcontinent.

Keywords: Eclogite xenolith, peridotite xenolith, Wajrakarur kimberlite, Eastern Dharwar craton, plume, melting of eclogite, metasomatism, hydrogen.