Silicate-silicate immiscibility and metasomatism in the Deccan Traps SCLM: insights from mantle xenoliths of Kutch, India

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Situated in the western part of India, the end Cretaceous Deccan Traps are of the most prominent flood basalt provinces of the world, with an aerial exposure of 0.5 million km^2. Alkali basalt plugs from the north-western Deccan Traps (Kutch, Gujrat) carry small, platy xenoliths belonging to the Sub-Continental Lithospheric Mantle (SCLM). The studied xenoliths are predominantly anhydrous dunites, minor harzburgites and lherzolites. The lherzolite xenoliths possess complex primary and secondary features which suggest depletion and multi-stage metasomatism. Primary olivine is Mg-rich (Fo_{88-90}) with 0.3-0.4 wt% NiO and CaO relatively higher at the rims. Primary orthopyroxene (En_{88-90}) has high Al_2O_3 (2.4-3.6 wt%) and variable CaO (0.2-1 wt%), whereas primary clinopyroxene (Mg/Mg+Fe˜ 0.9) has high Cr_2O_3 (0.8-1.1 wt%), Ti (˜2200-3400 ppm), Na_2O (1-1.5 wt%) and Al_2O_3 (3.6-4.9 wt%). Primary Cr-spinel have low Cr/Cr+Al (˜0.19) and high Mg/Mg+Fe (˜0.76), with very low TiO_2 (0.1-0.12 wt%). Primary orthopyroxenes are partially/completely replaced by secondary orthopyroxene (En_{88-89}) having extremely low-Al_2O_3 (0.2-0.3 wt%), high-CaO (1.1-1.5 wt%), with interstitial Si-K-Al-rich glass. This secondary assemblage is subsequently replaced by a reaction zone of small secondary olivine, clinopyroxene and Mg-rich glass with low totals. Small olivines from this reaction zone have higher CaO and lower NiO than primary olivines at similar Fo contents, whereas the clinopyroxenes contain very low Al_2O_3, and lower Na_2O, TiO_2 with Cr_2O_3 and Mg/Mg+Fe similar to the primary clinopyroxenes. Another type of secondary clinopyroxene having abundant melt inclusions is found adjacent to these reaction zones around orthopyroxene. These clinopyroxene grains have high Ti (˜2300-4000 ppm), Cr_2O_3 (1-1.5 wt%) and Mg/Mg+Fe (0.91-0.93) with variable Na_2O and Al_2O_3. The melt inclusions are mostly silicate glass, and they display spectacular unmixing of immiscible phases. The two immiscible glasses are compositionally identical to the Si-K-Al-rich glass found with the secondary orthopyroxene, and the Mg-rich glass found in the orthopyroxene reaction zones. Daughter phases within these inclusions include olivine and clinopyroxene compositionally identical to the secondary phases in the reaction zones, Ti-rich phlogopite, calcite, apatite and Cr-spinel with high Cr/Cr+Al. Primary clinopyroxenes contain low Sr (˜34-53 ppm), Zr, Nb, Y and are LREE-depleted [$(La/Yb)_N$: 0.2-0.6]. The smaller, secondary clinopyroxene has similar trace elemental characteristics, whereas the melt-inclusion bearing grains have LILE, LREE enrichment [$(La/Yb)_N$: 1.9-5.7] with low Sr, and Zr. Ca-in-orthopyroxene and two pyroxene thermometry and of Brey and Köhler (1990) yield an average temperature of 800° C for the primary grains, and 1084° C for the secondary grains. Composition of the primary grains indicate that the protolith has suffered ˜ 5-10% partial melting and melt extraction. The composition of the secondary orthopyroxene is unique and usually associated with aqueous interaction. However, association with the Si-Al-K glass and higher temperature estimates suggest metasomatism with a silica-alkali rich melt. Petrographical evidence suggests that this interaction was followed by reaction with a volatile-bearing ultramafic melt and further replacement of both primary and secondary orthopyroxene. The inclusion bearing clinopyroxene formed in the final stages and it records the unmixing of these two types of metasomatic melts. This suggests that the original metasomatic melt was intermediate in composition and suffered immiscible separation upon infiltrating the protolith, resulting in multi-stage metasomatism and formation of the complex metasomatic features observed in these xenoliths.

Keywords: Mantle xenolith, Mantle metasomatism, Liquid immiscibility, Deccan Traps

