Immiscibility and hybridization during progressive cooling of carbonatite and alkaline magmas (In Ouzzal terrane, Western Hoggar)

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Carbonatites and syenites from Ihouhaouene (2 Ga; In Ouzzal terrane, Hoggar, South of Algeria) have close spatial relationships. Their analogous mineral assemblages with diopside/hedenbergite (cpx), apatite, wollastonite +/- calcite and alkali-feldspar suggest that they were emplaced from a common igneous parental event. Carbonatites from In Ouzzal terrane are calciocarbonatites and form a continuous range of whole-rock major and trace element composition from Si-poor carbonatite (<20 wt.% SiO_2; 24-36 wt.% CO_2) to Si-rich carbonatite (20-35 wt.% SiO_2; 11-24 wt.% CO_2) then white syenite (52-58 wt.% SiO_2; 0.1-6.5 wt.% CO_2) and red syenite (57-65 wt.% SiO_2; 0.1-0.4 wt.% CO_2). Equilibrium calculations reveal that apatite (Ce/Lu= 1690-6182; Nb/Ta >50) and cpx (Ce/Lu= 49-234; Nb/Ta<10) from Si-rich carbonatites and white syenites crystallized from a REE-enriched carbonate melt and an evolved silicate melt, respectively. Likewise, Si-poor carbonatites have a higher REE contents in calculated apatite equilibrium melts than in their cpx and a wide range of Nb/Ta ratios with a majority of subchondritic value (<10) that reflects the segregation of the carbonate fraction from an evolved parental melt. Otherwise, red syenites have similar REE contents in apatite and clinopyroxene equilibrium melts (Nb/Ta>10) suggesting an origin from homogeneous evolved melt batches. Both mineralogical and geochemical features reveal the intimate link between carbonatites and syenites and their cogenetic signature. Immiscibility and fractional crystallization processes modelling explain the trace element contents and low Nb/Ta ratio in minerals. These processes were partly counterbalanced by intermingling of partially crystallized melt fractions and hybridization of segregated minerals during the progressive cooling of a silico-carbonated mantle melt.