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Transformation of ijolite into (silico-)carbonatite by reaction with carbonatite melt – a case study from a megaxenolith of the Dicker Willem Complex, Namibia

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The Eocene (49 Ma) Dicker Willem complex (S Namibia) is a 5 km^2 subvolcanic carbonatite intrusion that comprises several stages of coarse-grained calcite carbonatite, fine-grained calcite carbonatite, ferroan carbonatite dykes, nepheline silico-carbonatite and carbonatite breccia. Ijolite and nepheline syenite are exclusively found as xenoliths of various sizes in carbonatite. Nepheline silicocarbonatite was considered to play an important role in the formation of the complex and has been interpreted to represent parental magmas. Accordingly, fractionation of this melt should have produced carbonatite and silicate cumulates.

Detailed observations of a sample profile through a silicate-rich carbonatite xenolith (Ø 7 m) enclosed in fine-grained calcite carbonatite suggest a different genetic relationship, namely the reaction of a carbonatitic melt with earlier ijolites to nepheline silicocarbonatites. The observations revealed systematic textural, mineralogical and mineral compositional variations, transforming the xenolith from central calcite ijolite → calcite syenite → (±nepheline) silicocarbonatite → marginal coarse-grained calcite carbonatite. From the center to the margin, clinopyroxene composition changes from augite to aegirine. Systematic whole rock and $\delta^{13}C/\delta^{18}O$ variations ($\delta^{13}C$ -5.1→-4.0; $\delta^{18}O$ 8.1→11.4) support the petrographic and textural observations, indicating a progressive transformation of the xenolith. Under late-stage, carbo-hydrothermal conditions, nepheline was progressively replaced by orthoclase, while late-magmatic conditions lead to its replacement by cancrinite. Biotite crystallized at the expense of orthoclase and clinopyroxene near the contact to the carbonatite host rock.

These results indicate that nepheline silicocarbonatite represents a transitional lithology and disprove its position as the product of a parental magma. This study also introduces a new process for the formation of silicocarbonatites. While classical models suggest silicocarbonatite formation due to increased SiO_2-contamination directly in the carbonatite magma, or crystallization from a parental melt of immiscible silicate-carbonate melt pairs, the present study provides an alternative process through **carbonatitization** of pre-existing silicate rocks. This involves in-situ dissolution-reprecipitation of silicates and replacement by calcite, and concomitant, significant silica introduction into the carbonatitic magma. Hence, numerous silicocarbonatite occurrences worldwide need to be reevaluated.