An Experimentalist View into Natural Carbonatite Complexes

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Many silica-poor carbonatite complexes occur in a predictable geometrical form of concentric rings, with calcite carbonatite at the rim, followed by dolomite or ankerite carbonatites at the core. In this association, REE mineralisation typically occurs within the Fe-rich parts of the carbonatite, whereas the calcite carbonatite is mostly barren of REE. These observations mirror experimental studies in which a carbonatite melt will fractionate calcite followed by dolomite, leading to an increase in Fe and other incompatible elements (REE included), until LREE minerals such as monazite and burbankite precipitate in the Fe-rich residual melt. Burbankite is rarely preserved and is instead altered to aggregates of LREE minerals (commonly bastnäsite and other REE-fluorcarbonates) and baryte. Exceptionally Fe-rich oxidised rocks that occur in carbonatite complexes (occasionally termed ironstones or rødbergites) contain a slightly higher proportion of HREE, and much greater overall REE contents. These ironstones are often interpreted as the weathering products of the pristine calcite, dolomite, or ankerite carbonatites with the elevated HREE explained by preferential leaching of LREE during laterite formation. However, these ironstones are ubiquitous in carbonatites of all climate regions and often juxtaposed next to outcropping and perplexing unweathered carbonatite varieties. An alternative explanation is that the ironstones are the weathered products of highly fractionated ferrous HREE-rich plutonic alkali brine-melts (“natrocarbonatites”), which are commonly observed in experiments. Due to their high alkali contents they are not stable in the geological record and undergo rapid alteration. Therefore, these HREE-rich ironstones are not a marker of protracted weathering, but instead are the inevitable magmatic fractionation outcome of carbonatite melts. As such, they are expected to occur in all silica-poor carbonatite complexes. In silica-rich carbonatites, the ferrous alkali brine-melt is unattainable because it will react to form silicates such as phlogopite, aegirine, riebeckite, and arfvedsonite, preventing the formation of HREE-rich zones.