Wide compositional range of enriched continental flood basalts derived from a long-term depleted mantle source: a case from the Karoo large igneous province

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Continental flood basalt (CFB) provinces manifest anomalous large-scale mantle melting events that are associated with global mass extinction events and continental breakup. Characteristically, CFBs show considerable geochemical heterogeneity even within a single province. This heterogeneity has often been linked to heterogeneities in the mantle source, generally involving major contributions from the variably enriched subcontinental lithospheric mantle (SCLM).

The flood basalt formations of the Vestfjella mountain range represent an Antarctic extension of the Jurassic (180 Ma) Karoo CFB province that is mostly situated in southern Africa and was generated during the initial stages of the breakup of the Gondwana supercontinent. The Vestfjella CFBs and related intrusive rocks are locally well exposed and show notable variation in their chemical composition (e.g., initial ε_{Nd} from -15 to +8). Three major geochemical flood basalt types (CT1, CT2, and CT3) can be distinguished in the lavas, whereas the dikes also show rare lamproitic, ferropicritic, and MORB-like (initial ε_{Nd} = +8) compositions. The MORB-like dikes show indistinguishable Sr, Nd, Pb, and Os isotopic composition from Southwest Indian Ridge MORB, but their trace element compositions indicate melting at high pressures (below thick Gondwanan lithosphere).

Traditionally, the notable geochemical differences between the lavas have largely been attributed to variation in the subcontinental mantle source. Here we show that by selecting viable representatives for crustal and mantle contaminants (Archean and Proterozoic crust and SCLM-derived melt i.e. lamproite) and by using the energy-constrained assimilation and fractional crystallization (EC-AFC) modeling instead of traditional AFC in the case of crustal contamination, all three CT lava types can be produced from a high-pressure MORB-like parental melt with less than 5

We emphasize the following observations: 1) Vestfjella mountains are well-exposed and vegetation-free and reveal the CFBs of the area in their whole geochemical diversity. 2) The application of EC-AFC overcomes the shortcomings related to AFC modeling that often suggest superfluous degrees of crustal contamination. 3) The model parameters have not been adjusted to our needs, but present values that are representative of the geological system. Our study raises the important question whether most CFBs in other parts of Karoo and in other provinces evolved from highly depleted sublithospheric mantle melts (derived at varying pressures) that rarely reached the surface uncontaminated. The compositions of the parental melts may be difficult to assess in cases where such rocks are not known or exposed.