# Geochemical and Sr, Nd, Pb, Hf isotope compositions of the Karoo large igneous province in Botswana-Zimbabwe

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The ~180 Ma Karoo continental flood basalt (K-CFB) province in southern Africa is one of the largest CFB on Earth (> 3 x $10^6$ km²). It consists of tholeiitic lava flows, sills, and giant radiating dyke swarms related to the breakup of Gondwana. We report major and trace element and Sr-Nd-Pb-Hf isotope compositions for, respectively, 147 and 33 basaltic lava flows, sills, and dykes from Botswana, Zimbabwe, and northern South Africa, including both low- and high-Ti (< and >2 wt% $TiO_2$) rocks. Both groups display LREE/HFSE enrichment (relativlely to chondrite) with Nb depletion, but the latter has higher MREE/HREE ratios. Calculations suggest that the low-Ti basalts were generated by melting of a shallow spinel-bearing (2 % spinel) lherzolite, while the high-Ti magmas originated from a deeper garnet-bearing (2-7% garnet) lherzolite. In most isotope plots, the high-Ti lavas and picrites define a trend from BSE to compositions with strongly negative εNdi and εHfi, akin to those of some nephelinites and lamproites. The low-Ti rocks are shifted from BSE-like to more radiogenic Sr isotope compositions, indicative of some upper crustal contamination. The geochemical and isotopic signatures of the Bouvet, Shona, and Discovery hot spots are not evident in our data set and the role of a mantle plume head as direct contributor to K-CFB is speculative.

Alternatively, we suggest that K-CFB could have been produced by polybaric melting of a heterogeneous metasomatically enriched (partially veined) subcontinental lithospheric mantle (SCLM). Calculations show that mixing between a ~BSE-like component and strongly unradiogenic, with respect to Nd and Hf isotopes, nephelinite-like (vein-rich) material within the SCLM could account for the variations observed among most of the high-Ti group lavas. By contrast, the mantle source composition for the low-Ti lavas is more likely to be similar to a vein-free SCLM component. Our data do not exclude that a mantle plume may have contributed to the lithospheric melting. The spatial distribution of low-Ti and high-Ti magmas seems to match the craton-Limpopo belt positions, reinforcing the predominantly lithospheric control on K-CFB.

# Pb isotope heterogeneity between olivine-hosted melt inclusions, Eastern Snake River Plain, Idaho

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Isotopic compositions of intra-continental basalts could either under- or over-estimate the true heterogeneity of the subcontinental mantle, depending on the relative effects of blending isotopically distinct melt fractions and/or crustal contamination during ascent through the continental crust. We used a Cameca ims 1270 ion microprobe to obtain *in situ* Pb isotopic compositions of olivine-hosted MIs in basalts from the eastern Snake River Plain (ESRP), Idaho, to study early magma evolution in an intra-continental setting. Twenty-seven MIs from 21 olivine phenocrysts representative of 4 magnesian basalts (Mg#>59) were studied; the basalts are from diverse localities and span about half of the isotopic range observed for ESRP basalts. The ranges in Pb isotopic compositions obtained for the MIs are $^{207}Pb/^{206}Pb$ = 0.831-0.892 and $^{208}Pb/^{206}Pb$ = 2.058-2.17, larger than the ranges exhibited by the whole rocks (0.855-0.891, 2.107-2.201, respectively). Two samples yield isotopically homogenous MI populations. A third sample has a sole isotopically exotic MI. The same MI contains chemically distinct post-entrapment clinopyroxene (cpx) daughter crystals that require a distinct liquid line of descent. The MI population of the fourth sample is isotopically heterogenous ($^{207}Pb/^{206}Pb$ = 0.831-0.864 MSWD = 8.19, vs. 0.8491 for the groundmass). Geobarometry on cpx and glass within the same MIs yields pressures of no more than 0.5 GPa, significantly less than that obtained for cpx phenocryst crystallization (P>1.1 GPa) in another ESRP sample (Putirka et al., 2003). The somewhat greater variability in Pb isotopic compositions of these ESRP MIs than in their whole rock hosts (~factor of 2) contrasts with the 13 times greater variability of MIs than whole rocks for Cook and Society Island basalts (Saal et al., 1998). Either the ESRP source is relatively more homogeneous than that for these ocean islands or, more likely, homogenization occurs at levels at or deeper than the mid-crust prior to olivine growth and melt entrapment.