Continental mafic magmatism: internal versus external sources and triggers

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Away from active plate boundaries, continental mafic magmatism is manifest above inferred mantle plumes and in post orogenic and extensional environments. Heating by external (asthenospheric) heat sources and/or decompression due to far-field boundary or internal potential energy forces would appear to be the principle triggers for melting. Almost all continental mafic magmas are relatively evolved and have incompatible trace element and isotopes signatures which differ markedly from those erupted along the ocean ridges (MORB) and on ocean islands above mantle plumes (OIB). The most typical of these is the presence of negative high field strength element (HFSE) anomalies coupled with moderate to extreme enrichment in incompatible element abundances and radiogenic Sr and Pb and unradiogenic Nd isotopes. It follows either that the source regions of continental mafic magmas are located within the sub-continental lithospheric mantle (SCLM) or that asthenosphere-derived magmas interact sufficiently with continental crust or SCLM to develop these signatures. However, back-projections of incompatible trace element ratio versus isotope trends rarely point towards OIB or MORB compositions. Moreover, mass balance calculations highlight the difficulty in appealing to additions of crustal materials to explain the HFSE anomalies. Such models typically only succeed if the asthenospheric end-member is highly depleted and thus MORB-like rather than of OIB affinity usually associated with mantle plumes. Major element data often implicate a melt-depleted source region. Unfortunately, isotope signatures that are arguably unique to some melt depleted portions of the SCLM, such as sub-chondritic Os, are susceptible to even the slightest assimilation of crust and are not characteristic of all SCLM. Therefore, they do not provide a diagnostic test of SCLM source regions for continental mafic magmas. The potassic magmas that are the hallmark of many post-orogenic settings, such as the Altiplano, Betics and Tibetan Plateau often contain evidence for having formed in equilibrium with a residual potassic phase such as amphibole or phlogopite. In many cases, the onset of potassic magmatism can be linked to the onset of extension and the thus the time at which the internal potential energy of the orogenic region exceeds the driving forces imposed at plate boundaries. This association of extension with the potassice magmatism can be explained by models in which part of the lower SCLM is removed by convective instabilities and replaced by asthenosphere. The juxtaposition of asthenosphere onto the base of the SCLM will results in convective heating of the SCLM, causing metasomatised and hydrated regions of the SCLM to exceed their solidus. Resolving the source component contributions to continental mafic magas is not straightforward and arguments against SCLM sources often recourse to opinions as to whether mantle xenoliths provide a representative sampling of the SCLM and/or whether SCLM can undergo fusion and that relies on the presence of volatiles. Ways forward include detailed case studies, numerical and experimental work and the identification, or absence, of unique source mineralogy.