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Low-degree Mantle Melting beneath Tibet: Signals of Heterogeneous Lithosphere Erosion

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The nature of the geodynamic processes which have formed the Tibetan Plateau and continue to drive its evolution remain a matter of debate. Models which invoke the convective removal of the lower lithospheric mantle following distributed shortening are a currently popular means of explaining the plateau's apparently rapid uplift, magmatic history and extensional deformation [1]. The further development of such models is limited by a lack of information regarding the past thermal and compositional structure of the mantle lithosphere. Potassic, post-collisional magmatism across Tibet arguably represents low-degree melting of lithospheric mantle following convective removal [2,3], and as such provides a window for investigating the nature of Tibetan mantle lithosphere and melting processes. We present new ^{40}Ar-^{39}Ar ages, major, trace element, Sr, Nd and Pb isotope data for Tibetan dykes and lavas, which highlight spatial-temporal variations in melting processes, and the presence of contrasting mantle sources.

The erupted lavas are shoshonitic to ultrapotassic with extreme incompatible element and LREE/HREE enrichment, negative Nb, Ta, Sr and Ti anomalies, high $^{87}Sr/^{86}Sr_{(i)}$and low εNd. Lavas from Southern Tibet have more primitive isotopic compositions and are further distinguished by the presence of negative Ba anomalies. Within these regional groups, K_2O remains relatively constant over a wide range of SiO_2, implying buffering by residual phlogopite/pargasitic amphibole. Modelling the relative compatibility of trace elements [4] in these lava suites confirms the presence of K-bearing residual phases and suggests that small degrees of melting (<1%) of a metasomatised, garnet-free source at depths less than 100 km are required to explain their petrogenesis.

When compared at 8wt% MgO, the southern group shows a striking displacement to lower TiO_2, Fe_2O_3, CaO and higher SiO_2 with respect to the northern volcanics. These variations are interpreted in terms of the contrasting nature of their respective source regions and melting processes. The excellent correspondence between the data arrays and experimental data fields for fertile and depleted peridotite melting [5,6] suggest that the northern and southern lavas were derived from fertile and depleted mantle sources, respectively.

Fundamental differences in time-integrated source history are further supported by the co-variation of major element data with Sr, Nd and Pb initial isotope ratios, which provide constraints on the timing of incompatible-element enrichment in these sources. The observed isotopic ratios suggest that enrichment was an ancient event, or that an ancient component was introduced into the source in a more recent episode of metasomatism. Nd model ages record a Proterozoic event, with maximum depleted mantle model ages of 0.8-1 Ga (εNd -8 to -10) and 1.5-2 Ga (εNd -13 to-16) for the northern and the southern groups, respectively. Pb isotopes are characterised by a range of $^{207}Pb/^{204}Pb$ (north, 15.68-15.71; south, 15.76-15.85) and $^{208}Pb/^{204}Pb$ (north, 39.00-39.32; south 39.53-39.97) at more restricted $^{206}Pb/^{204}Pb$ (north, 18.68-18.78; south 18.76-18.88), leading to vertical arrays. Interestingly, Pb model ages require an Archean component in the sources of both groups, suggesting decoupling from Nd isotope systematics. The contrasting incompatible-element enrichment and major-element depletion of the two lava groups can be reconciled with different multi-stage source histories, in which depletion by melt extraction is followed by several enrichment events. The negative Nb, Ta and Ti anomalies suggest that metasomatism is related to subduction processes, while positive Pb anomalies indicate a component of recycled oceanic crust. The broad differences between the southern and northern Tibetan sources are spatially related to the boundaries between ancient arc terranes which comprise the modern plateau.

The melting of ancient lithospheric mantle across Tibet allows further refinement of geodynamic models for the formation and evolution of high plateaus following continent-continent collision. The lavas require a significant perturbation of the thermal structure of the lithosphere beneath Tibet from at least 24 Ma, and models which invoke thinning or erosion of the lithospheric mantle provide the most plausible mechanisms for generating the high temperatures (ca. 1100-1150 ºC) required to trigger melting. However, the spatial distribution and diachroneity of magmatism are more plausibly explained by gradual, localised lithospheric erosion than by catastrophic convective removal or delamination processes.

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