# Geochemistry and petrogenesis of igneous intrusions within the Eocene Nisai Formation of the Muslim Bagh–Khanozai Region, NW Pakistan

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## Abstract

In NW Pakistan, the ophiolites mark the suture zone between the Indian plate and Afghan plate. These ophiolites are overlain unconformably by Nisai Formation (Eocene); the sedimentary facies hosting mafic intrusions. These mafic intrusions are discovered within the lower part of Nisai Formation of northern Balochistan, Pakistan; provide an opportunity to enhance tectono-magmatic models associated with the collision of Indian and Eurasian plates. New geochemical data allows the local tectonics and mantle dynamics during the obduction of the Khanozai and Muslim Bagh ophiolites to be further constrained, as to date, these are the youngest discovered igneous intrusions within the area (~ 55 – 35 Ma). Petrological and geochemical data is consistent with the basaltic, doleritic and gabbroic intrusions comprising alkalic series signatures, characteristic of heterogeneous asthenospheric melting associated with ocean island basalt (OIB) magmatism. The modelling for mantle source suggests that these intrusions are the result of partial melting of 1-5% of a deep, enriched, and predominantly of a depth greater than 90 km, and may be pooled a lithospheric depths of ~30 km. Variable extents of fractional crystallization and mantle melting, with low rates of assimilation, fractional crystallization and subduction-related input controlled the geochemical signatures of four sample groups within this intrusive suite - all derived from a hydrous (1 wt.% $H_2O$) related magma source. Variable degrees of melt mixing and melting infer that the intrusive suite represent sampling a melt column from a similar source. A tectonomagmatic model is proposed whereby Eocene Nisai intrusions have been generated through processes of subduction-related flux melting and localized extension through plate flexure, providing necessary deep melting of the upper asthenosphere. Residual Réunion plume material hotter than ambient mantle provided the necessary heat flux within the upper asthenosphere, contributing to enrich heterogeneous melting.