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Mineralogy, Geochemistry and Palaeomagnetism of Mafic Dykes from Kumaun Lesser Himalaya: Implication on Petrogenesis, Tectonic Setting and Timing of Mafic Magmatism in Northern Part of Indian Lithosphere

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Occurrence of mafic dykes in Himalaya has been intriguing and debated since long because of its difficulty to ascent and emplacement through a thickened crust. Mafic dykes in Kumaun Lesser Himalaya (KLH) of central Indian Himalaya occur abundantly in three major tectonic segments intruding the Krol-Tal Formation of Nainital region (ND) between Main Boundary Thrust (MBT) and South Almora Thrust (SAT), Almora crystalline in Khunt region (AD) between SAT and North Almora Thrust (NAT) and Mandhali-Deoban Formations of Pithoragarh region (PD) between NAT and Main Central Thrust (MCT). Mineralogical, geochemical and palaeomagnetic investigations of dykes (ND, AD, PD) from KLH have been carried out in order to recognize sources, magmatic processes and timing of dyke magmatism, and further to understand extensional regime prevailing in northern part of Indian lithosphere. Modally PD and ND correspond to leucogabbro to gabbro whereas AD represent olivine gabbro to gabbro. Plagioclase in PD (An10-An65), AD (An12-An58) and ND (An17-An61) is normal zoned. Olivine (Fo61 to Fo33) in AD corresponds to crysolite to mostly hortonolite type of olivine. Clinopyroxene varies from Wo36 En36 Fs10 to Wo46 En51 Fs27 in PD, Wo40 En36 Fs15 to Wo46 En42 Fs23 in AD and Wo35 En32 Fs14 to Wo44 En45 Fs25 in ND, which exhibit distinct evolutionary trends along Di-Hd join crystallizing in tholeiitic to mildly alkaline magmas within a range of T=1050o-1200oC at P<3kbar.

Whole rock Mg# (Mg/Mg+Fet) ranges from 0.48 to 0.69 in PD and 0.57 to 0.64 in AD suggesting evolved nature of dyke magmas whereas Mg# (0.29 to 0.69) of ND suggests moderately evolved nature. Rb and K are depleted in ND, AD and PD, which may be account to crustal contamination. Strong positive Sr-anomaly in ND and AD suggests differential degrees of fractional crystallization of dyke magmas. Small negative Nb anomaly however indicates a low degree of contamination with lower crust. A strong positive correlation between Zr/Y and Zr of ND, AD and PD could be a reflection of source region or contamination with crust. HFSE-based tectonic diagrams firmly suggested that ND, AD and PD magmas belong to tholeiitic basalts of continental affinity which formed in intraplate rift condition. Tholeiitic to mildly alkaline nature of parental dyke melts could be either due to changing degrees of partial melting of a common source or parental tholeiitic melt might have undergone slight crustal contamination.

Trace and REE patterns of the ND and AD are identical, and hence similar processes should have been involved in their evolution. Enriched LILE and observed elemental variations suggest that the AD magma can be generated by partial melting of an enriched mantle source which subsequently experienced fractional crystallization involving olivine, plagioclase and clinopyroxene. LREE enrichment over the HREE may account to slightly LREE enriched basaltic magma. Trace and REE patterns of PD are different from ND and AD, which signify a different origin for PD magma. Enriched and fractionated LREE to HREE and observed elemental variations suggest that the PD magma is generated by partial melting of an enriched mantle source subsequently experiencing synchronous fractional crystallization and assimilation. Slight positive Sr and Eu anomalies of PD indicate derivation of basalt from plagioclase peridotite or a feature caused by plagioclase accumulation. AD and ND dyke magmas appear derived from enriched mantle source whereas PD dyke magma may have been derived from depleted mantle source.

Pearce Element Ratio (PER) have suggested that ND, AD and PD follow the same evolutionary trend having

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same slopes but different intercepts, which indicate that they have experienced the same fractionation mechanism but their parentages are different. Some of the data scatter observed on PER diagrams may be due to slight contamination or assimilation and/or could be sorting effect of crystallized phases. Based on batch melting models, it has been concluded that 1 to 3% melting of garnet peridotite can produce the observed LREE variations of precursor ND and AD melts whereas LREE contents of PD melt can be produced by 5 to 7% melting of a garnet-spinel peridotite at relatively shallower depth as compared to mantle source of ND and AD magmas.

ND provide distinct initial 87Sr/86Sr ratios (0.7071, 0.7112 and 0.7066) at different Rb/Sr values, which suggest that mantle-derived ND magma has experienced low to moderate degrees of contamination probably with lower crust. PD exhibit initial 87Sr/86Sr ratio (0.7051) which is close to the mantle-derived mafic melt but slightly contaminated with crust. One AD sample represents uncontaminated mantle-derived mafic melt (initial 87Sr/86Sr ratio = 0.7039) whereas another AD sample (initial 87Sr/86Sr ratio = 0.7084) appears moderately contaminated with crust.

Palaeomagnetic parameters of AD yielded palaeo-location (3.82oN-295.2oE) constraining the age of magmatism ca 120 Ma, almost equivalent to the ages of Rajmahal-Sylhet traps and dykes. PD yielded palaeo-location (76.58oN-336.2oE), indicating the age of ca 1000 Ma, which most likely relate to the attenuation of Rodinia supercontinent to a maximum size at about 1000 Ma i.e. much later than the initiation of amalgamation at ca 1300 Ma. However, ND could not provide any stable directions and thermal demagnetizations, which might be because of altered and weathered nature of block samples. ND postdate the Krol-Tal Formations of Early Cambrian (ca 570 Ma), and therefore ND magma must have emplaced after 570 Ma. AD are intrusive into garnetiferous mica-schist (ca 475 Ma) of the Saryu Formation, and the suggested palaeomagnetic-based age of ca 120 Ma for AD is geologically valid and acceptable. PD intrude the carbonate rocks and carbonaceous slate of Deoban Formation (ca 1200 Ma) of the Tejam Group, and therefore suggested palaeomagnetic age of ca 1000 Ma can be considered geologically valid and acceptable. We conclude that ND, AD and PD magmas were formed episodically during pre-Himalayan time having distinct geological, petrographic and, to some extent, geochemical and Rb-Sr isotopic signatures, contributing partly in the growth of northern part of Indian lithosphere, which are now tectonically juxtaposed in Kumaun Lesser Himalaya of central Indian Himalaya.

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