



Research Paper

Decoding the tectonomagmatic evolution of the Ladakh Magmatic Arc, NW Himalaya: A multi-proxy geochemical and isotopic approach

Irfan M. Bhat^{a,*}, H. Chauhan^b, T. Ahmad^b, T. Tanaka^c, Tehseen Zafar^d, Y. Asahara^c^a Centre for Disaster Risk Reduction, IUST, Kashmir 192122, J&K, India^b Wadia Institute of Himalayan Geology, Dehradun 248001, Uttarakhand, India^c Graduate School of Environmental Studies, Nagoya University, Nagoya 4648601, Japan^d College of Energy, Chengdu University of Technology, Chengdu 610059, China

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ABSTRACT

Magmatic arcs are the active locus of crustal formation, and their knowledge of spatiotemporal geochemical variation is vital for understanding the evolution of collisional systems. Here, we compare geochemical and isotopic results from the precollisional Dras-Nidar Island Arc Complex (DNIAC), pre- to syn-collisional Ladakh Batholith (LB) that formed the part of the well-known Kohistan-Ladakh Batholith, and post-collisional mafic dykes. It is observed that the long-term magmatic evolution was controlled by the Neo-Tethyan Ocean geodynamics. The Ladakh magmatic arc records three distinct magmatic stages through its geochemical and isotopic evolution. The pre-collisional DNIAC (160–110 Ma) shows tholeiitic to calc-alkaline melts with depleted mantle signatures ($\epsilon_{\text{Nd}} > +5$ and $^{87}\text{Sr}/^{86}\text{Sr} < 0.704$), transitional to syn-collisional LB granitoids and associated Khardung volcanics (103–45 Ma) reflecting enriched signatures ($\epsilon_{\text{Nd}} +2$ to -4 , $^{87}\text{Sr}/^{86}\text{Sr} = 0.704\text{--}0.708$, $\text{La}/\text{Sm} > 3$, $\text{Th}/\text{La} > 0.2$) due to sediment subduction and crustal assimilation. While post-collisional mafic dykes (< 45 Ma) reflect lithospheric mantle metasomatism (enriching incompatible trace elements including rare earth elements) with limited crustal interaction ($\epsilon_{\text{Nd}} +1$ to $+3$). This demonstrates a progressive evolution from a fluid-dominated mantle wedge melting to a sediment-driven crustal influence and finally to an enriched mantle melting, highlighting the critical role of slab dynamics and crustal recycling in continental growth during arc-continent collision. Thus, we concluded that the contribution from the sediment subduction is more pronounced in the KLB compared to the DNIAC.

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1. Introduction

India-Eurasia collision and Himalayan orogeny are part of a long-term subduction and accretionary history (Searle et al., 1998). Numerous magmatic activities have been recognized in the Himalaya and adjoining areas, recording the rapidly changing tectonic scenario prevailed during the convergence time (Thakur and Mishra, 1984). The Himalayan orogenic cycle commenced with the opening of the Neo-Tethys Ocean in the Permo-Triassic, situated between the Cimmerian micro-continent to the north and the Indian Plate to the south. Early Permian tholeiitic to alkaline basalts, similar to continental flood basalts, such as the Panjal volcanics in the Kashmir Himalaya and the Bhote Kosi basalts of Tibet, are linked to the Permo-Triassic rifting phase (Bhat et al., 1981;

Garzanti et al., 1999; Chauvet et al., 2008; Shellnutt et al., 2015; Chen et al., 2023). Afterwards, during the Middle Jurassic (~168 Ma), the supercontinent Gondwanaland began to break-up into different plates whereby India started its northward movement (Metcalf, 2021). The closure of the Neo-Tethys Ocean and the collision of the approaching margins of the Indian and Eurasian plates were accommodated along at least two northward subduction zones: the intra-oceanic and ocean-continental subduction zones, currently corresponds to the Indus Suture Zone (ISZ) and the Shyok Suture Zone (SSZ), respectively (Rolland, 2002; Ahmad et al., 2022; Sivaprabha et al., 2022). The intra-oceanic subduction of the Neo-Tethys Ocean began along the ISZ during the Late Jurassic Period (~161 million years ago), leading to the formation of the Dras-Nidar Island Arc Complex (DNIAC; Bhat et al., 2019a, 2021a; Walsh et al., 2021). This was followed by the development of a calc-alkaline Kohistan-Ladakh-Gangdese Batholith during Cretaceous to Eocene (Honegger et al., 1982; Ahmad et al., 1998;

* Corresponding author.

E-mail address: irfan.maqbool@iust.ac.in (I.M. Bhat).