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Research Article

Ambient pyroxenite mantle melting in the origin of Panjal-Qiangtang continental flood basalts: Implications for Early Permian Gondwana rifting and the birth of the Neo-Tethys☆

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ABSTRACT

Understanding the source of basalt and the conditions under which magma is generated provides fundamental insight into the composition and thermal history of the Earth's mantle, crust-mantle interactions and the origin of mantle heterogeneities. The source lithology of continental flood basalts remains a contentious issue. We evaluate a compilation of geochemical data on the Early Permian (ca. 290 Ma) Panjal-Qiangtang continental flood basalts (PQ-CFB) to constrain their source lithology and estimate the temperature and pressure conditions during magma generation. Primitive basalts and mafic dykes (MgO $>$ 7.5 wt%) from the PQ-CFB exhibit low CaO content but elevated FeO/MnO and Zn/Fe ratios at equivalent MgO contents compared to the peridotite-derived melts. Their major element chemistry is consistent with experimental pyroxenite-derived melts, distinguishing them from melts of a peridotitic source. We propose that mantle pyroxenite significantly contributed to the origin of the Early Permian PQ-CFB, like the Late Permian Emeishan and the Early Jurassic Karoo continental flood basalts. Melting temperature and pressure estimates from this study indicate that the PQ-CFB were generated under ambient mantle conditions comparable to those at which mid-ocean ridge basalts form. This raises doubts in invoking a mantle plume origin for this magmatic province. We propose that the passive continental margin of northern Gondwana underwent extension due to tensional stresses under ambient mantle conditions, leading to voluminous flood basalt eruptions sourced from readily fusible pyroxenites. Our observations support the non-plume model for the break-up of the northern Gondwana margin and opening of the Neo-Tethys Ocean during the Early Permian.

1. Introduction

Continental flood basalts (CFB) are characterized by the voluminous outpouring of lava on the Earth's surface ($>$ 1 million km^3 in volume) over a brief geological timeframe ($>$ 75 % volume within 5 million years). These events play a crucial role in forming ocean basins, driving global environmental and climate changes, causing mass extinctions, and developing economic mineral deposits, as well as oil and natural gas systems (Ernst et al., 2021). Despite extensive research, the origin of continental flood basalts remains a topic of wide debate. Competing models for their origin include (i) decompression partial melting of anomalously hot mantle plumes (e.g., Campbell and Griffiths, 1990; White and McKenzie, 1995), (ii) voluminous melt extraction from an enriched sub-lithospheric mantle in a non-plume setting (e.g., King and Anderson, 1995; Sheth, 1999), and (iii) mantle hydration (e.g., Liu et al., 2017; Wang et al., 2015, 2025; Xia et al., 2016). Besides the debated origin of the continental flood basalt provinces, the composition of primary magma, source lithology of voluminous basalts, melt generation processes, and thermal regime are not properly understood (Manu Prasanth et al., 2022, 2025). Understanding these processes is critical for elucidating the fate of recycled crustal materials in the mantle, mantle metasomatism, the origin of mantle heterogeneity, and the mechanisms that led to intense volcanism and continental break-up. Additionally, the melting conditions of the origin of continental flood basalts are crucial for constraining the thermal history of the upper mantle.

Despite significant advances in basalt petrogenesis, the source

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