



Mantle source heterogeneity in a Neoproterozoic back-arc basin: Geochemical and thermodynamic modeling of the volcanic section of Wadi Ghadir ophiolite, Egypt

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ABSTRACT

Wadi Ghadir ophiolite in the Egyptian Eastern Desert, which forms the northern part of the Nubian Shield, is considered as one of the best-preserved segments of the Neoproterozoic oceanic lithosphere on Earth. Primary melt calculations and thermodynamic modeling of new geochemical data for the Wadi Ghadir pillow lavas and dike complexes, integrated with comprehensive petrographic investigations, are here employed to unravel the geodynamic evolution of this ophiolitic section.

Whole-rock geochemical and clinopyroxene data indicate that the pillow lavas and sheeted dike complexes preserve geochemical signatures of N-MORB, E-MORB and OIB-like basalts. Less abundant, discrete dikes have a distinctly LILE-enriched island arc tholeiite (IAT) composition. The pillow lavas and sheeted dike complexes replicate mixed liquid lines of descent, whereas the discrete dikes exhibit a calc-alkaline differentiation trend. The pillow lavas were produced by limited (5–7%) mantle partial melting as a result of isothermal decompression over a wide pressure range (5 – 19 kbar) and restricted mantle potential temperatures ($T_p \approx 1260$ – 1300 °C), suggesting ponding of rising melts from depths of ~60 to 15 km in dry mantle. Primary melts of the sheeted dike complexes were produced by 9–11% partial melting at $P \approx 9.7 \pm 2.5$ kbar, $T_p \approx 1290$ °C, and $P \approx 14.7 \pm 1.4$ kbar, $T_p \approx 1325$ °C, suggesting a role of varying hydrostatic pressure. The magma source for the discrete dikes occurred at 10.7 ± 0.6 kbar and T_p of 1230–1300 °C by 11–13% partial melting of a metasomatized mantle region.

The calculated T_p ranges for the different melts are consistently lower than temperatures of sub-ridge ambient mantle. Together with the variable concentrations of K_2O and other incompatible elements, the estimated low temperatures of melt generation emphasize mixed sources and wet peridotite melting. The modeled primary melts designate crustal growth during back-arc basin opening and closure. During the basin opening, decompression melting of mildly enriched mantle produced high-Ti tholeiitic (pillow lavas) and transitional (sheeted dike complexes) melts, whereas subduction initiation during basin closure promoted melt-peridotite interaction. Lowering of the solidus by subduction-related components triggered melting of a spinel lherzolitic mantle and produced low-Ti calc-alkaline melts that sourced the discrete dikes. The mixed MORB and SSZ geochemical characteristics of the studied volcanic rocks, coupled with the various modeled melts and lack of significant thermal anomalies in the mantle conditions, are here interpreted as manifestations of mantle source heterogeneity in a marginal oceanic basin during the accretionary stages of the Arabian-Nubian Shield.

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