# Geochemical study of the Dwar Khola dolerite (1.7 Ga) in the Siwalik belt, central Nepal

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The Siwalik belt in central Nepal has been regarded as an accretionary prism mainly composed of the Middle Miocene to Pliocene molasse eroded out from the Himalaya (e.g., Jhonson et al. 1985). Recently, many dolerite sills showing 1.68 Ga $^{40}Ar/^{39}Ar$ age (Takigami et al. 2002) and the Mid-Proterozoic orthoquartzite and quartzose sandstone beds intruded by the sills were found in the Siwalik belt of the Dwar Khola area (Sakai et al. 2000). Existence of these "exotic" rocks in the belt was suggested that detachment and accretion of crustal materials stripped from the Indian shield might take place in the frontal range of a continental-continental collision orogen (Sakai et al. 2000).

The Dwar Khola dolerite has a maximum thickness of about 400 m and is more than 6 km long in the section, and show less effects of metamorphism and alteration. Plagioclase and clinopyroxene in the dolerite are commonly fresh and the igneous textures are well-preserved in spite of the Mid-Proterozoic rocks. Due to this, Gautam et al. (1996) have inferred that the dolerite sills might have intruded into the Siwalik belt during Eocene to early Oligocene on the basis of their occurrence and paleo-magnetic data. Moreover, they have pointed out that the whole rock composition has similar signature to the continental flood basalt (CFB) (e.g., Deccan Traps, Karoo and Parana basalts) but it has still remained unsolved why the CFB volcanism might occur in the frontal area of the Himalaya. In this study, major and trace elements and Nd isotope compositions of 11 samples for the Dwar Khola dolerite were determined. Using these data, we discuss petrogenesis of the Dwar Khola dolerite as well as origin and formation age of the Proterozoic mafic rocks in the Lesser

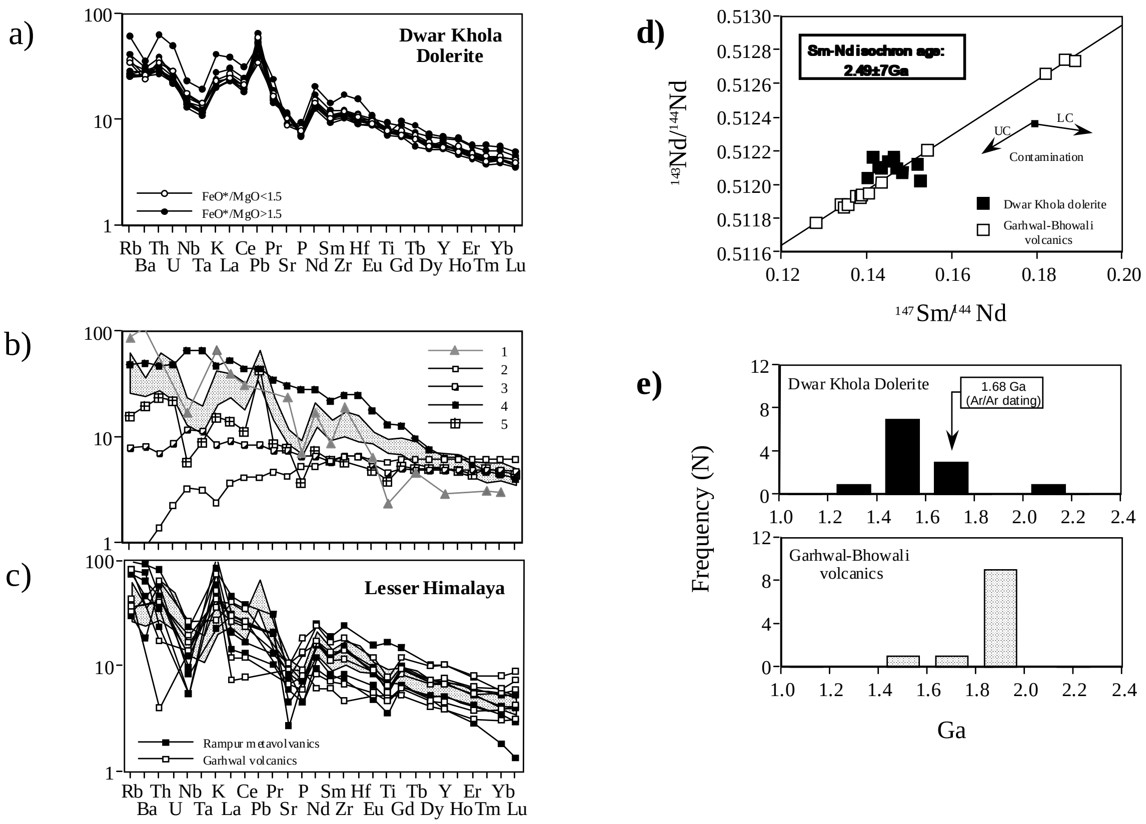


FIGURE 1. Spiderdiagrams normalized to primordial mantle value of a) the Dwar Khola dolerite (this study), b) 1: Proterozoic crust (Weaver and Tarney 1985), 2: N-MORB, 3: E-MORB, 4: OIB (Sun and McDonough 1989), 5: Deccan Traps (Mahoney et al. 2000), c) Rampur volcanics (Bhat and Le Fort 1992) and Garhwal volcanics (Ahmad and Tarney 1991) in the Himalaya belt, and d) Whole rock Sm-Nd isochron age of the Garhwal-Bhowali volcanics (Bhat et al. 1998) with the plots of the the Dwar Khola dolerite and d) Frequencys of Nd model ages of the Dwar Khola dolerite (this study) and Bhowali volcanics (Bhat et al. 1998)

Himalaya, reported by the previous studies (e.g., Ahmad and Tarney 1991, Bhat et al. 1998).

11 samples of the Dwar Khola dolerite extensively obtained from the different thrust-sheets showed very narrow variation in major and trace element abundances, i.e., 49.49–53.41 wt% in $SiO_2$, 5.36-–7.36 wt% in MgO, 2.73–3.73 wt% in $K_2O+Na_2O$, 1.58–2.04 wt% in $TiO_2$ and 188–245 ppm in Sr, and there was no regional variation among them. On the MFA diagram, all samples indicated typical tholeiitic differentiation trend, and on FeO*/MgO–$TiO_2$ diagram, they plot within intermediate area of both MORBs and OIBs. Also, spiderdiagram patterns of the Dwar Khola dolerite normalized to primordial mantle roughly showed it to be enriched in the whole spectrum of incompatible elements relative to N-MORB and plot within the middle of both OIB and E-MORB (**Figures 1a, b**), which is consistent with those of major element signature. Moreover, these patterns displayed a marked trough at Nb, Ta, P and Sr and enrichment at Pb, indicating close similarities to those in CFBs (e.g., Wilson 1989), and particularly much closer to those in Deccan Traps. Cox and Hawkesworth (1985) suggested that such a Nb and Ta trough at the pattern in CFBs might reflect the consequence of crustal contamination but the process is likely to be much more complicated on the Deccan Traps. Peng et al. (1994) concluded that two stages of mixing among T-MORB like mantle plume source, enriched lithospheric mantle, lower and upper crustal materials were required to explain the multi-isotope variation on the southwestern Deccan Traps: first stage was performed between T-MORB like mantle plume source and lithospheric mantle or amphibolite-grade lower crust with radiogenic Sr, Nd and Pb isotopic signatures, and the second stage occurred between the products of variable amounts of first stage mixing and several different upper crustal materials with relatively low Pb isotopic signature to the lithospheric mantle and/or lower crust. Geochemical characteristics for the Dwar Khola dolerite obtained in this study is likely to be explained by the first stage mixing process rather than simple contamination of the Proterozoic upper or middle crustal material. Compared to the other Proterozoic volcanics in the Himalayan belt (e.g., Rampur and Garhwal volcanics; Bhat and Le Fort 1992, Ahmad and Tarney 1991), the spiderdiagram patterns roughly displayed the similarity to those of the Dwar Khola dolerite (**Figure 1c**).

Due to the drawback, the Dwar Khola dolerite is suggested to be mainly produced by a mantle plume activity although they are more or less affected by variable degrees of crustal contamination. This means that it is convenient to put their sources as CHUR value in calculating Nd model age. The Nd model ages for the Dwar Khola dolerite showed a range from 1310 Ma to 2110 Ma of which average (N=11) was 1600±200 Ma (SD). This result agrees with $^{40}Ar/^{39}Ar$ age of 1674±74 Ma (Takigami et al. 2002) within the range of error. Whole rock Sm-Nd isochron age of the Garhwal-Bhowali volcanics determined by Bhat et al. (1998) yields an age of 2.51±0.08 Ga. However, this isochron age seems to be an "errorchron" caused by two component mixing between different initial Nd isotope ratios due to significantly wide range of $^{147}Sm/^{144}Nd$ value (0.1271 to 0.1883) among the basaltic rocks (**Figure 1d**). On the other hand, the Nd modal age for the Garhwal-Bhowali volcanics recalculated using CHUR value ranges from 1538 Ma to 1903 Ma, expect for three samples showing more than 0.18 in $^{147}Sm/^{144}Nd$ ratio. The average yields an age of 1820±100 Ma, which is consistent with those of the Dwar Khola dolerite (**Figure 1e**). These lead to the hypothesis that the Proterozoic metavaolcanic rocks in the Himalaya belt of the thrust sheets should be taken away from a surface of Indian shield, like the Dwar Khola dolerite.

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