

Nitrogen isotope compositions of the Gangdese calc-alkaline plutons, Southern Tibet: Implications for N isotope fractionation during continental arc mafic magma differentiation

PENG WU¹, LONG CHEN², YUANBAO WU³, YUNZHE CHEN⁴, YIFAN DU⁴, XUEQI LIANG⁴, AMBER JIE YU⁴
AND LONG LI⁴

¹Chengdu University of Technology

²Ocean University of China

³China University of Geosciences, Wuhan

⁴University of Alberta

Magmatic differentiation at convergent margins plays a crucial role in the formation of felsic continental crust. However, little is known about the geochemical behavior of stable nitrogen isotope systems during magmatic differentiation. To address this issue, we present whole-rock N concentrations and $\delta^{15}\text{N}$ values of two calc-alkaline plutons with compositions ranging continuously from gabbro to diorite from the Gangdese batholith, Southern Tibet. The gabbroic Numa pluton exhibits wide range of N concentrations (8.9–31.6 $\mu\text{g/g}$, average = 17.5 ± 7.3 $\mu\text{g/g}$, 1SD) with elevated $\delta^{15}\text{N}$ values (+1.5~+4.7‰, average = $+3.6 \pm 1.0$ ‰), while the more differentiated Namling pluton shows slightly lower N concentrations (6.7–18.5 $\mu\text{g/g}$, average = 10.0 ± 3.2 $\mu\text{g/g}$) and lower $\delta^{15}\text{N}$ values (+0.1~+3.6‰, average $\delta^{15}\text{N}$ = $+1.5 \pm 1.2$ ‰). Overall, the studied samples show a progressive depletion in ^{15}N (>5‰) as the mafic magmas evolve into more differentiated intermediate magmas. This depletion cannot be attributed to magmatic degassing or crustal contamination, as these processes would be expected to lead to ^{15}N enrichment. Instead, whole-rock $\delta^{15}\text{N}$ values strongly correlate with geochemical indices such as $\text{CaO}/\text{Al}_2\text{O}_3$ and Dy/Dy^* ratios, suggesting that fractional crystallization of clinopyroxene (and/or amphibole) is the most likely mechanism responsible for the ^{15}N -depletion in the residual melt. This is because inosilicates are significantly more enriched in ^{15}N than other ammonium-bearing silicate minerals^[1]. No correlation is observed between $\delta^{15}\text{N}$ values and Eu/Eu^* , suggesting that plagioclase crystallization has little effect on N isotope fractionation. On the other hand, variations in whole-rock N concentrations do not correlate with the degree of magmatic differentiation, indicating that the degassing loss of N (as N_2 in the melt) may at least counteract the enrichment of incompatible NH_4^+ (rock-fixed N species) induced by magmatic differentiation during its early stages. In summary, our study concludes that fractional crystallization of clinopyroxene (and/or amphibole) in calc-alkaline systems, overriding other processes such as magmatic degassing, would effectively fractionate the N isotope compositions of arc magmas, thereby modulating the N isotope signature during juvenile crust formation.

