

Apatite U-Pb dating, trace element, *in-situ* Sr-Nd isotope insights into petrogenesis and tectonic setting of the niobium-rich Saima alkaline complex in NE China

MR. BO LIU, PHD^{1,2,3}, NAN JU^{2,4}, YANAN GONG¹,
MINGYI JIANG¹, KUNFENG QIU⁴, ZHE NAN², YUE WU²,
LU SHI², XIN LIU² AND HAOHENG WANG¹

¹Northeastern University

²Shenyang Center of China Geological Survey (Northeast Geological S&T Innovation Center)

³Stockholm University

⁴China University of Geosciences (Beijing)

The Saima alkaline rock-type Nb deposit in eastern Liaoning (NE China) provides a valuable opportunity to link alkaline rocks and niobium mineralization. Petrographic studies show the Saima deposit occurs in aegirine nepheline syenite, with loparite, columbite-tantalite, fergusonite, fersmite, betafite, and bastnaesite as the main ore minerals, consistent with typical alkaline rock-hosted Nb deposit. Apatites associated with Nb mineralization exhibit uniform, concentric, and oscillatory zoning in CL images, high (La/Yb)_N ratios (124.62–11440.84) and insignificant Eu anomalies ($\delta\text{Eu}=0.68\text{--}0.85$). These data suggest that the main Nb mineralization occurred during the early crystallization stage of the alkaline magma. LA-ICP-MS apatite U-Pb dating yields lower intercept ages of $232\pm 7\text{Ma}$ and $224\pm 17\text{Ma}$ for the aegirine nepheline syenite. These ages agree with previously reported zircon U-Pb and biotite Ar-Ar ages, suggesting early Late Triassic Nb mineralization. *In-situ* Sr-Nd isotope analyses of apatite reveal elevated $^{87}\text{Sr}/^{86}\text{Sr}$ values (0.70835–0.70879) and negative $\epsilon_{\text{Nd}}(t)$ values (–17.21 to –10.71), indicating that the mineralized alkaline rocks were derived from partial melting of a metasomatized Nb-enriched lithospheric mantle. Based on regional geology, we interpret the Saima deposit's ore-bearing syenite as a product of post-closure extensional tectonics. Recycled ancient Yangtze craton continental crust played a key role in the generation of the Triassic Nb-rich alkaline rocks in eastern Liaoning, as demonstrated by the Saima alkaline complex. The entire Triassic alkaline complex within the eastern North China Craton exhibits Nb metallogenic potential and justifies further prospecting and exploration efforts.

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