Hybrid origin for syenite with mafic enclaves in the northeast North China Craton: in situ zircon Hf-O and apatite Sr-Nd isotopic evidence

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Whole rock geochemical composition, in situ apatite Sr-Nd and zircon Hf-O isotopes for syenites and their mafic enclaves were obtained to investigate the sources and processes of the Erhulai syenite in the Liaodong peninsula, North China Craton.

Field observations and zircon U-Pb ages reveal that the quartz syenites and mafic enclaves were coeval with identical emplacement ages of 129-126 Ma, slightly earlier than the porphyritic syenites (ca. 123 Ma). The quartz syenites show relatively high SiO₂, Na₂O+K₂O and low MgO contents, with evidently positive Eu anomalies. Their whole rock and in situ isotopic analysis show homogeneous (⁸⁷Sr/⁸⁶Sr)ᵢ ratios and εNd(t) values (–10.3 to –8.6), with variable zircon δ¹⁸O values (+4.4 to +7.0 ‰) and bimodal distribution of zircon εHf(t) values. All these geochemical features can be produced by partial melting of felsic crustal materials at relatively high pressures (>30 km), with involvement of mantle-derived materials. The mafic enclaves have relatively low SiO₂ and high MgO contents, without negative Ba and Eu anomalies. They have relatively low (⁸⁷Sr/⁸⁶Sr)ᵢ ratios, with variable εNd(t) (–11.2 to –2.0) and εHf(t) (–15.8 to –5.5) values. Combined with a large proportion of zircons in mafic enclaves display mantle-derived δ¹⁸O values, suggesting an enriched mantle source, with addition of crustal materials. The porphyritic syenites show medial Nd- and Hf-isotopic compositions between the quartz syenites and mafic enclaves, implying a mixing source between two magma components mentioned above. They all have high Si characteristics, with low Ba, Sr contents and significantly negative Eu anomalies, indicating their parental magma have experienced k-feldspar, and plagioclase-dominated fractional crystallization.

In summary, a complex, multi-stage processes involving magma mixing, fractional crystallization, and wall rock assimilation was involved in genesis of the Erhulai syenites. In situ Sr-, Nd-, Hf- and O-isotopic analysis of accessory minerals are powerful geochemical tracers that provide unique information regarding mantle-crust interaction and magmatic processes.