Research Advances

Petrogenesis of Potassic Basalts from Northeast China: New Constraints from Trace Elements in Olivine

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This study used trace elements in olivine as a new petrogenetic indicator to further constrain the petrogenesis of potassic basalts from the Erkeshan-Wudalianchi-Keluo-Xiaogulihe potassic volcanic field (EWKX for short) in the Songliao Basin of NE China, with a combination of the previous olivine and whole-rock geochemical data. We selected representative and clean olivines which contain no crack, melt inclusions and daughter minerals from EWKX, under an optical microscope and electron probe micro-analyser (EPMA). LA-ICP-MS analysis was then done on these olivine samples at the LA-ICP-MS Laboratory of Geocycles Research Center, University of Mainz, Germany. The samples included different species, sizes and shapes, and the linear-distributed spot analyses was chosen during the LA-ICP-MS measurement due to the zonation of olivines (Fig.1). Our new data reveal the trace-element composition features of olivines, and offer new evidence for the sub-continental lithospheric mantle (SCLM) origin of the basaltic lavas from Songliao basin. In addition, the new data are helpful to further constrain the composition and magmatic process of SCLM in the study region.

We divided the olivines into two genetic groups based on their compositional and textural differences, i.e., igneous olivines (phenocrysts, melt related) and mantle-derived xenocrysts, as shown in Table 1. Integrated the newly-accquired data with the previous whole-rock data, it is inferred as follows.

The olivine-spinel mantle array (OSMA) of Cr-rich spinel ($Cr^{\#}$=70–83) and magnesian olivine phenocrysts (Fo) shows that the magma source region has undergone a high degree of melt extraction (e.g., 40%). It is thus indicated that the magma source region may contain highly refractory harzburgitic peridotite, which is especially evidenced from the high $Cr^{\#}$ (80–83) of the spinels from Xiaogulihe volcanic rocks. This inference is in accordance with the strikingly low CaO contents for the the major samples (4.5 wt%–7.5 wt%, much lower than that of the average N-MORB, ocean island tholeiite and continental flood basalts), low Al_2O_3 and FeO contents. The highly refractory character of the harzburgitic component may be explained by one or more episodes of mantle depletion.

Furthermore, later K-enrichment needs to form distinct rock assemblages in the form of metasomes (phlogopite-bearing pyroxenites) which is required to explain K-rich character of the Erkeshan, Wudalianchi and Keluo lavas, and especially ultrapotassic characters (K_2O/Na_2O > 2, MgO > 3 wt%) and lamproitic affinity of the Xiaogulihe lavas. The presence of the phlogopite in the source may be the only viable explanation for the extreme K-enrichment, which cannot be obtained otherwise. The identification of phlogopite in the source strongly implies a lithospheric mantle source, and suggests that metasomatism by volatile-rich melts occurred prior to the melting. The olivine data are in support of this view. The strikingly high Li (Table 1) concentration in both xenocrysts and phenocrysts indicates an extreme metasomatic imprint in the source (recycling of a crustal component), and the

Table 1 Summary of trace element characteristics for olivines from potassic basalts in the Songliao basin, NE China

Element	Mantle olivine (xenocryst)	Volcanic olivine (phenocryst)
Li	Two two types: ~3 ppm; 10–12 ppm	3–6 ppm
Al	40–140 ppm, scattered	50–200 ppm, mainly distributed in 50–150 ppm
P	30–70 ppm	200–600 ppm, a few are higher than 800 ppm
Ca	< 700 ppm, mainly distributed in 300–600 ppm	1000–1600 ppm
Sc	2–5 ppm	3–6 ppm
Ti	5–100 ppm	70–110 ppm
V	2–5 ppm	1.5–6.5 ppm, scattered
Cr	50–200 ppm, scattered	50–300 ppm, scattered
Mn	Mainly distributed in 1000–1400 ppm	1200–2200 ppm, scattered
Co	160–180 ppm	150–210 ppm
Ni	2800–3200 ppm, some low to 2600 ppm	A large range, 2000–3000 ppm, Some low to 1500ppm
Zn	50–240 ppm, scattered	130–300 ppm
Zr	0–0.3 ppm, scattered	0–0.3 ppm, scattered
V/Sc	< 1.5	< 1.5
Ni/Co	< 20	< 20
Fo	89–92	80–89

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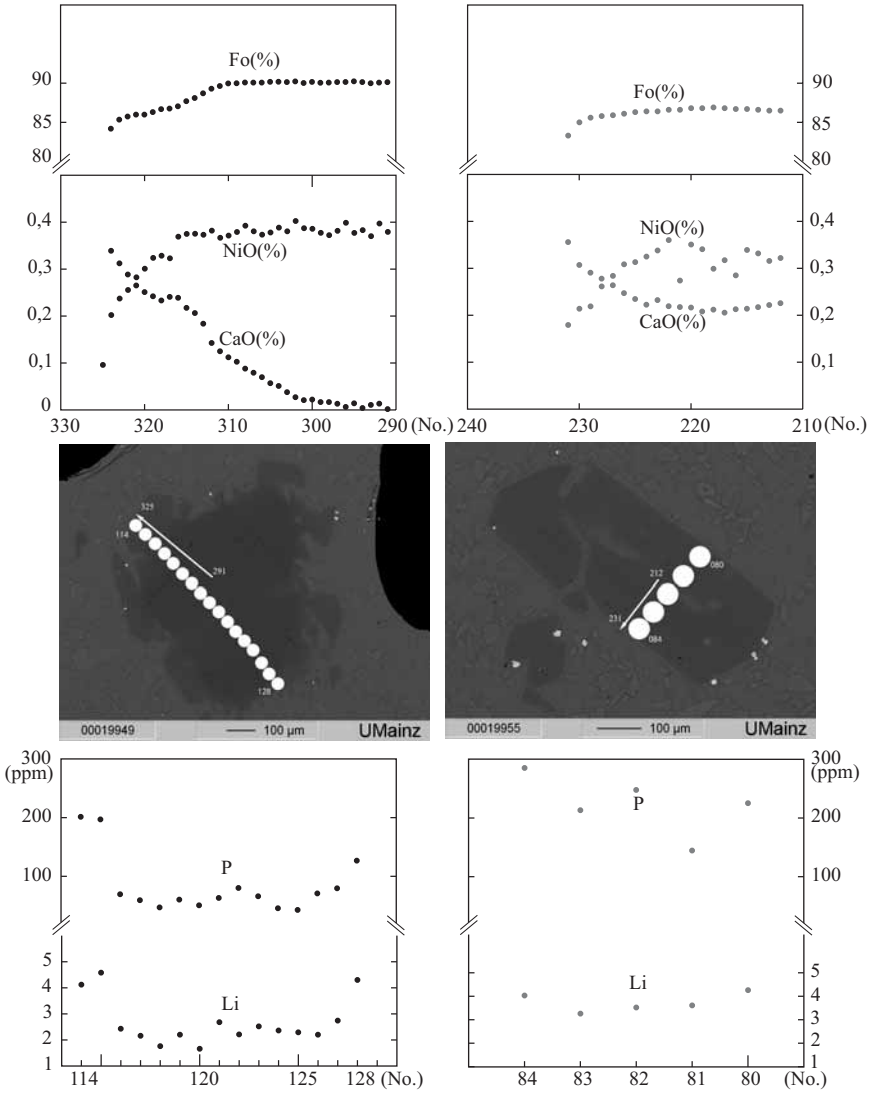

Fig. 1. Representative major and trace element line analyses of two type of olivines from sample LHS (Laoheishan) in the Wudalianchi area. The arrows, points and plotting show the location of troughs carved by line analysis and the compositional variation tendency along.

striking P (Table 1) in phenocrysts indicates the metasomatism or the extreme partitioning influence during the magmatic process. Experimental studies also suggest that most hydrous minerals tend to occur in low heat-flow lithosphere, rather than high-temperature asthenosphere. Contrarily, phlogopite stability in the lithosphere is possible given its lower temperature, reflecting lower conductive heat transfer.

The Sc-Zr and Al-Cr covariance plots of the olivine xenocrysts suggest two different types of xenolith (spinel peridotite from Keluo area and garnet peridotite from Wudalianchi area) entrained in the basalts. The Ni/Co value (< 20) and Fo-NiO plot of igneous olivine suggest that magmatic source, which presents the oxidation state (indicated by V/Sc value, < 1.5), has undergone normal fractional crystallization. The aluminum-in-olivine thermometer is used to determine the minimum crystallization temperatures of primitive melts, and the crystallization temperature calculated for different olivines from the same area is very close, with an error range < 90℃. It is therefore reliable to use the temperatures to indicate the thermal state beneath the three areas. The average temperatures from three mentioned areas are 1258℃ (Erkeshan), 1224℃ (Wudalianchi) and 1203℃ (Xiaogulihe), respectively.

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