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GEOCHEMISTRY

Causes of Variations of Nd–O Isotope Ratios of Granitoids in the Tuva–Mongolia Microcontinent and Its Early Caledonian Framing

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Variations of neodymium and oxygen isotopic compositions of postcollision granitoids in the Tuva–Mongolia microcontinnet (TMM) is determined largely by different compositions of magma sources due to the mixing of two components [1, 2]. Component M is a juvenile mantle (N-MORB or similar source in isotopic composition) material ($\delta^{18}O$ ~6‰ and $^{143}Nd/^{144}Nd$ ~ 0.51235). Component C corresponds to a material with a long crustal prehistory ($\delta^{18}O$ ~12.0–12.5‰ and $^{143}Nd/^{144}Nd$ ~ 0.51186). The isotopic provinces of Phanerozoic granitoids outlined in central Asia [3] may display variable proportions of melt components depending on geological setting and emplacement age.

In the present paper, we compare Nd/O isotope ratios in the granitoid complexes of the TMM and the granitoid complexes of its Early Caledonian framing located in the Agardag–Erzin, Kaakhem, and East Tannuola zones (Fig. 1). These granitoids were previously combined into the Tannuola Complex [4]. The main aim of this study is to clarify the causes responsible for variations of isotopic systems of the granitoids.

The oxygen isotopic composition was measured on an upgraded MI-1305 mass spectrometer with an uncertainty not worse than 0.05‰. BrF_5 was used to extract oxygen [6]. CO_2 was converted on a hot coal in the presence of a Pt catalyst. The Sm–Nd and Rb–Sr isotope ratios were measured on a Finnigan MAT-261 mass spectrometer after the chemical decomposition of samples in a $HF–HNO_3$ solution following standard techniques [7]. The $^{143}Nd/^{144}Nd$ isotope ratios were recalculated to the initial values $(^{143}Nd/^{144}Nd)_t$ with the consideration of age t determined independently with the U–Pb zircon method [8] ($\lambda(^{147}Sm) = 6.54 \cdot 10^{-6}$ Ma^{-1}).

The $(^{143}Nd/^{144}Nd)_t$–$\delta^{18}O$ diagram (Fig. 2) shows average compositions of the Early Caledonian granitoids (filled symbols) from various zones of the TTM framing. The open symbols denote the previously obtained data on the late collision granites of the TTM [1] and the ophiolitic rocks in the TTM framing [2]. The lines C–M and M–O correspond to the two-component mixing in sources of granitic melts. The C–M line shows the trend of juvenile material ($^{143}Nd/^{144}Nd$ ~ 0.51235, $\delta^{18}O$ ~ 6‰) representing the mature crust ($^{143}Nd/^{144}Nd$ ~ 0.51186, and $\delta^{18}O$ ~ 12.8‰). The M–O line shows the trend of juvenile material representing ophiolites ($^{143}Nd/^{144}Nd$ ~ 0.51242, $\delta^{18}O$ ~ 12.2‰). The data points make up the following groups.

(A) Granitoids of the Kaakhem zone (451 ± 5 Ma). The average composition of the initial intrusive phase ($^{143}Nd/^{144}Nd$ = 0.51222–0.51232, $\delta^{18}O$ = 6.4–7.8‰) corresponds to the same M–C mixing line (Fig. 2) that characterizes melt sources of postcollision TMM granites [1]. A decrease in $^{143}Nd/^{144}Nd$ along with an increase in $\delta^{18}O$ toward the late intrusive phases ($^{143}Nd/^{144}Nd$ = 0.51208 and ($\delta^{18}O$ = 10.4 ± 0.7‰) may be explained, like for TTM granitoids, by magma fractionation and assimilation (AFC model).

(B) Granitoids of the Agardag–Erzin zone (~480 Ma). Their data points also fit the M–C mixing line, like for granitoids of the Kaakhem zone. However, contribution of the crustal material is lower ($^{143}Nd/^{144}Nd$ = 0.51229 and $\delta^{18}O$ = 7.0 ± 0.9‰).

(C) Granitoids of the East Tannuola zone (457 ± 2 Ma). They make up a separate trend characterized by abrupt variations of $\delta^{18}O$ from the values close to those of mantle-derived rocks (5.8–6.3‰) at the initial stage of emplacement to 8–10‰ at the late stage and an insignificant increase in $^{143}Nd/^{144}Nd$ from 0.51235 to 0.51240. This trend fits the mixing of juvenile (mantle) component M with ophiolites O in melt sources or during the magma emplacement.

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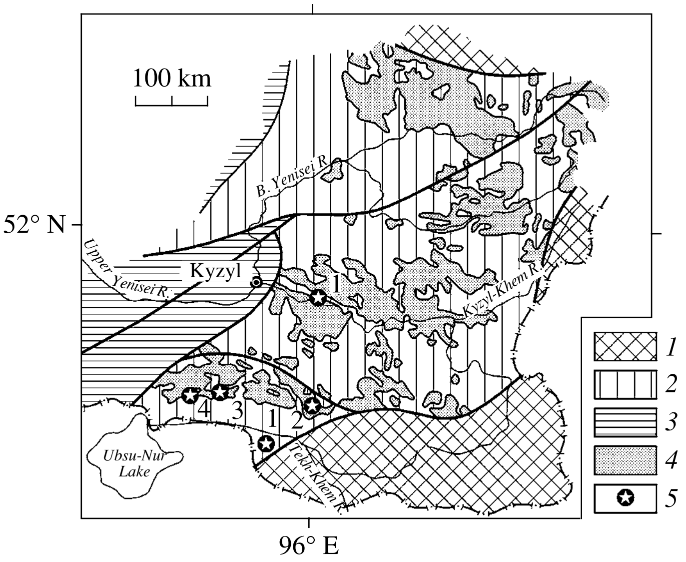

Fig. 1. Location of granitoids in structural–facies zones of Tuva [5]. (*1*) Tuva–Mongolia massif (TMM); (*2*) Early Caledonides; (*3*) Late Caledonides; (*4*) granitoid batholiths of the Middle Ordovician Tannuola Complex; (*5*) location of samples in the Early Caledonian framing of TTM: (1) Kaakhem batholith; (2–4) East Tannuola batholith: (2, 4) tonalite of the main intrusive phase, (3) two-feldspar granite of the Agardag–Erzin zone.

The table shows compositions of the inferred melt sources for different TMM granitoid complexes. They were calculated taking into account compositions of the inferred mixing components and their proportions in the melt sources.

Thus, we can make the following conclusions. Three components prevailed in magma sources of granitoids localized in both the TTM and its Early Caledonian framing: (1) relatively old crustal component C, which is close in neodymium and oxygen isotope ratios to the metaterrigenous rocks of the TTM; (2) juvenile component M, which is close to MORB in isotopic compositions (this component may be related to the Early Paleozoic magma reservoir); and (3) juvenile component O, which is similar to the Vendian ophiolites of the Agardag–Erzin zone and the MORB (in the Nd isotope ratio), but differs in elevated $\delta^{18}O$ values. Upon mixing with juvenile material, the relatively old crustal component makes up magma sources of granitoids within the microcontinent. The crustal component is also recorded beyond the TTM at its junction with the framing (the Kaakhem and, to a lesser extent, Agardag–

Calculated compositions of granitoid magma sources

Zone	x*	$^{143}Nd/^{144}Nd$	$\delta^{18}O$, ‰	SiO_2	TiO_2	Al_2O_3	FeO	MgO	CaO	Na_2O	K_2O
Erz	0.9–1.1	0.51195	9.3	59.4	1.1	14.7	7.5	5.2	7.0	2.4	1.4
Bnk	0.5–0.6	0.51203	7.9	56.7	1.2	14.8	8.3	5.9	8.3	2.5	1.0
Tsk	0.4–0.6	0.51205	7.7	56.3	1.3	14.8	8.4	6.0	8.5	2.5	1.0
Bsk	0.05–0.2	0.51226	6.2	51.9	1.5	14.9	9.8	7.2	10.8	2.6	0.4
Kkh	0.1–0.2	0.51222	6.4	52.6	1.5	14.9	9.6	7.0	10.5	2.6	0.5
Tnl	1.2**	0.51234	6.0	55.7	1.3	15.2	9.6	5.3	5.7	4.0	0.7
Agz	0.05–0.1	0.51229	7.0	51.5	1.5	15.0	9.9	7.4	11.0	2.7	0.3
Inferred mixing components in melt sources											
M		0.51235	6.0	50.2	1.6	15.0	10.3	7.7	11.7	2.7	0.13
C		0.51186	12.8	68.6	0.6	14.3	4.6	2.7	2.2	2.1	2.6
O		0.51242	12.2	60.0	1.0	15.2	8.9	3.3	0.7	4.9	1.2

Note: (*) Ratio of crustal and juvenile (mantle) components (C/M) in magma sources; (**) M/O ratio in melt sources. Major oxide contents are given in wt %. Granitoid plutons in TMM: (Erz) Erzin, (Bnk) Bayankol, (Tsk) Teskhem, (Bsk) Bashkymugur; granitoids in the TMM framing: (Kkh) Kaakhem, (Tnl) East Tannuola, and (Agz) Agardag–Erzin.

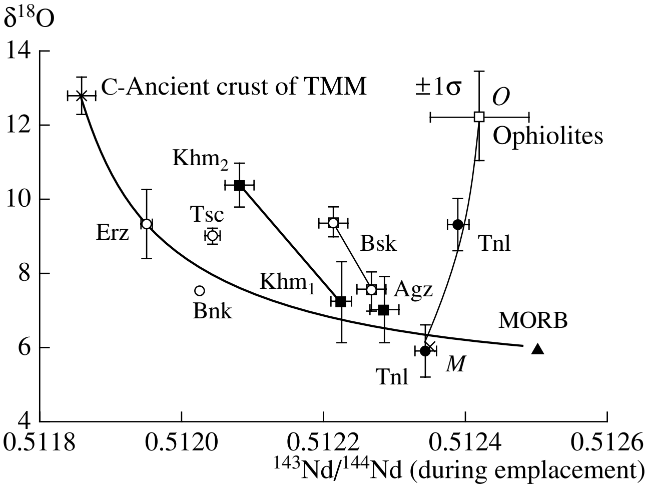

Fig. 2. $\delta^{18}O$ vs. $^{143}Nd/^{144}Nd$ (initial values) diagram. Symbols are as in the table. The solid line shows the MORB-C mixing line.

Erzin zones). However, the sources of the bulk of granitoids of the East Tannuola zone in the Early Caledonian framing is dominated by the Early Paleozoic juvenile component M in combination with the ophiolitic material. Thus, variations of Nd and O isotope ratios in granitoids of the TTM and its framing are caused by proportions of particular components in melt sources. Less significant changes of isotope ratios from the older granitoid phases to the younger phases within the same complex are related to assimilation and fractional crystallization.

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