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GEOCHEMISTRY

Mesozoic Granitoids of the Upper Amur Region: New Sr, Nd, and O Isotopic Composition Data

V. E. Strikha

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First data on the Sr, Nd, and O isotopic compositions in Mesozoic granitoids of the upper Amur region and previous data on the Sr and Nd isotopic compositions available for different-age granitoids are discussed. The upper Amur region comprises a spacious territory located between the Siberian and North China platforms. Based on literature data, the region includes the following major structural units: Aldan–Stanovoi, Baikal–Vitim, and Amur superterranes, Mongol–Okhotsk Foldbelt, and Umlekan–Ogodzha volcanoplutonic belt that unites and overlaps structures of the Amur Superterrane and the Mongol–Okhotsk Foldbelt (figure).

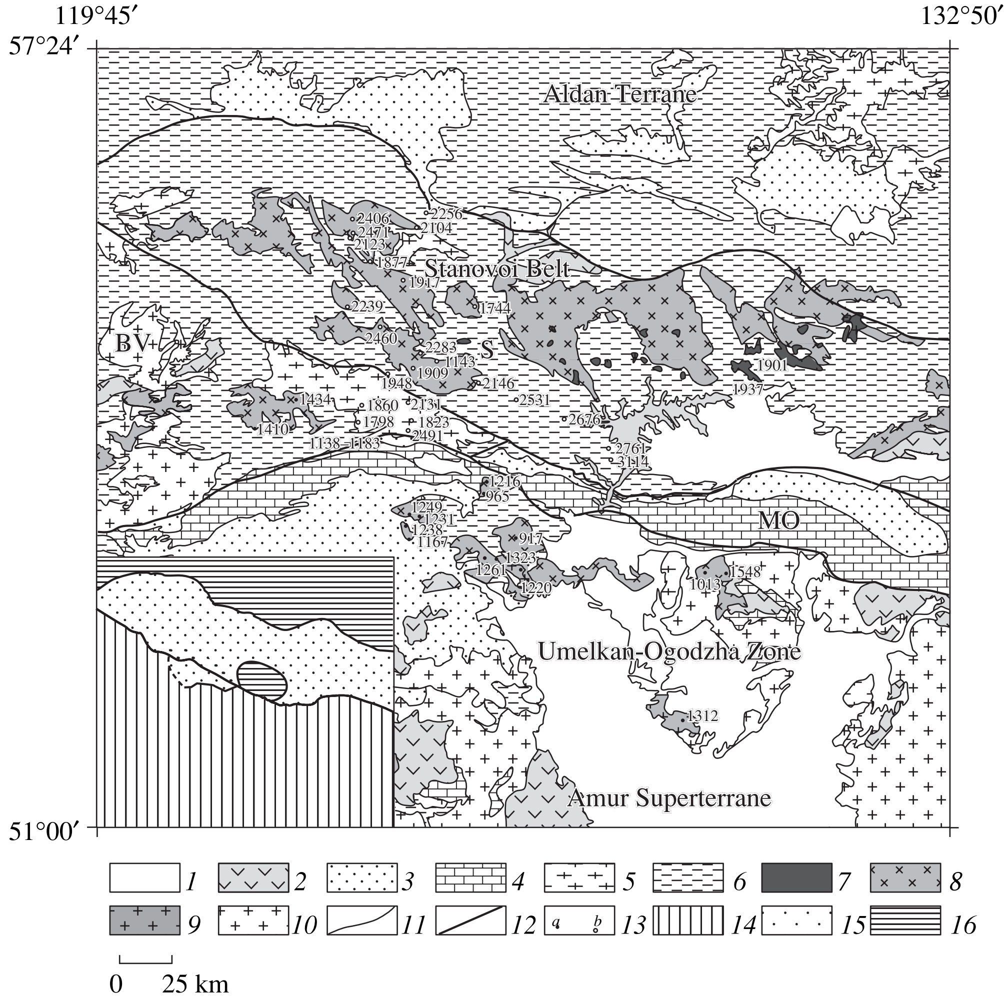
The Sr–Nd and oxygen isotopic studies were carried out with the following types of rocks: (1) Early Jurassic (210–180 Ma, Rb–Sr method [1]) granitoids of the granosyenite–granite association from the Mamyn block of the Amur Superterrane; (2) Late Jurassic–Early Cretaceous (150–130 Ma, Rb–Sr method [2]) monzodiorite–granite, Early Cretaceous (130–125 Ma, Rb–Sr method, U–Pb SHRIMP-II, unpublished data) granosyenite–granite, and Early Cretaceous (120–115 Ma, U–Pb SHRIMP-II, unpublished data) granodiorite–granite associations of the Umlekan–Ogodzha zone; (3) Early Cretaceous (135–130 Ma, Rb–Sr method [3]) granosyenite–granite association from the Baikal–Vitim Superterrane; and (4) Late Jurassic–Early Cretaceous (145–135 Ma, Rb–Sr method [4, 5]) granosyenite–granite, Late Jurassic–Early Cretaceous (150–120 Ma [6, 7]) granodiorite–granite, and Early Cretaceous (113–107 Ma, unpublished U–Pb SHRIMP-II data) granite–leucogranite associations of the Stanovoi Terrane.

In order to estimate the composition and age of granitoid melt sources, the Sr and Nd isotopic compositions of rocks was studied in line with the standard procedure using a TRITON (Thermo) multicollector mass spectrometer at the Center of Isotopic Studies of the Karpinsky All-Russia Institute of Geology (St. Petersburg). The procedure blank was 0.01, 0.2, 0.01, and 0.05 ppm for Rb, Sr, Sm, and Nd, respectively. The average accuracy of isotopic ratio determinations (2σ) was as follows (%): $^{87}Rb/^{86}Sr$ 0.7, $^{87}Sr/^{86}Sr$ 0.002, $^{147}Sm/^{144}Nd$ 0.3, and $^{143}Nd/^{144}Nd$ 0.005. The isotopic composition of the NIST 987 standard was $^{87}Sr/^{86}Sr = 0.710244 \pm 0.000011$. The isotopic composition of the Jndi-1 Nd standard was $^{147}Nd/^{144}Nd = 0.512106 \pm 0.000002$. The modern values of CHUR ($^{143}Sm/^{144}Nd = 0.512638$, $^{147}Sm/^{144}Nd = 0.1967$) [8] and DM ($^{143}Nd/^{144}Nd = 0.513151$, $^{147}Sm/^{144}Nd = 0.2136$) [9] were used for calculations of $\varepsilon_{Nd}(T)$ values and T_{Nd}(DM) model ages. The average crustal $^{147}Sm/^{144}Nd$ value of 0.12 [10] was accepted for calculating two-stage T_{Nd}(DM-2st) model ages.

The oxygen isotopic composition of the majority of the Mesozoic granitoid samples was determined at the Institute of Geochemistry, Mineralogy, and Ore Formation (National Academy of Sciences of Ukraine, Kiev) in line with the standard technique using a MI-1201V mass spectrometer (V.N. Zagnitko, analyst). Late Jurassic–Early Cretaceous granitoids of the Stanovoi Terrane were examined at the Institute of Geology, Far East Division of the Russian Academy of Sciences (Vladivostok) using a Finnigan MAT-252 mass-spectrometer (T.A. Velivetskaya, analyst). The $\delta^{18}O$ values (‰) are normalized relative to the international SMOW standard. The accuracy of isotope measurements is ±0.2‰.

The figure shows the spatial distribution of Sm–Nd model ages obtained for granitoid massifs under consideration. The T_{Nd}(DM-2st) values obtained for granitoids of the upper Amur region vary from 917 to 3114 Ma and demonstrate correlation with tectonic zoning of the region. Based on the Sm–Nd model age, values of the upper Amur region can be subdivided into three isotopic provinces: Archean (2531–3114 Ma), Early Proterozoic (1744–2471 Ma), and Riphean (917–1548 Ma).

Amur Complex Research Institute, Far East Division, Russian Academy of Sciences, Relochnyi per 1, Blagoveshchensk, 675000 Russia; e-mail: strikhav@mail.ru



Schematic geological structure and distribution of Mesozoic granitoid massifs. (*1*) Neogene–Quaternary sediments; (*2*) Upper Jurassic–Cretaceous volcanogenic rocks; (*3*) Mesozoic sediments; (*4*) Paleozoic igneous and sedimentary rocks; (*5*) Proterozoic igneous and metamorphic rocks; (*6*) Archean metamorphic and igneous rocks; (*7*) Early Cretaceous granite–leucogranite association; (*8*) Late Jurassic–Early Cretaceous granitoid associations; (*9*) Early Jurassic granitoid associations; (*10*) Early Paleozoic intrusive rocks; (*11*) geological boundaries; (*12*) major fractures; (*13*) sampling sites: (*a*) our data, (*b*) literature data (numbers designate T_{Nd}(DM-2st) values, Ma); (*14–16*) isotopic provinces of crustal granitoid protoliths in the inset: (*14*) Riphean (0.9–1.6 Ga), (*15*) Early Proterozoic (1.6–2.5 Ga), (*16*) Archean (>2.5 Ga). (S) Stanovoi Terrane; (BV) Baikal–Vitim Superterrane; (MO) Mongol–Okhotsk Foldbelt.

The Archean province comprises the Dambuka block of the Stanovoi Terrane with widespread Lower Archean rocks. The terrane represents probably the microcontinent within the Early Proterozoic province.

The Early Proterozoic province includes the remainder of the Stanovoi Terrane and eastern part of the Baikal–Vitim Superterrane located between the Dzheltulak and Mongol–Okhotsk suture zones.

The T_{Nd}(DM-2st) value varies from 2.5 to 2.1 Ga in the phase I granitoids of the Late Jurassic–Early Cretaceous granosyenite–leucogranite association (Chubachin Massif) in the Stanovoi Terrane ($\varepsilon_{Nd}(T)$ ranges from –18.5 to –14.0). These values indicate a mixed source of the parental melt composed largely of Early Proterozoic juvenile crust material with an insignificant admixture of the Archean crustal component [5, 11]. The primary Sr isotopic composition $(^{87}Sr/^{86}Sr)_0$, which characterizes the isotope property of the substrate during magma melting, is 0.7038 for phase I granosyenites. The $\delta^{18}O$ values determined for phase I granosyenites, phase II binary granites, and phase III binary leucogranites are +6.9, +5.8, and 5.9‰, respectively. The low $\delta^{18}O$ values obtained for phase II granitoids are probably explained by postmagmatic greisenization of rocks.

The Sm–Nd model age obtained for granitoids from the Late Jurassic–Early Cretaceous granodiorite–granite association (Tynda–Bakaran complex) of the Stanovoi Terrane is even more variable: T_{Nd}(DM-2st) = 2.2–1.1 Ga and $\varepsilon_{Nd}(T)$ ranges from –15.7 to –2.4 [11]. These data imply that, in addition to the Early Proterozoic crust, the Riphean crust also contributed to the composition of this rock association. The $(^{87}Sr/^{86}Sr)_0$ value of 0.7065–0.7088 [7] suggests isotopic heterogeneity of the protolith. The $\delta^{18}O$ value in phase III granodiorites is +4.7‰, which is characteristic of mantle rocks [12]. Phase II granites and phase III leucogranites from the Early Cretaceous association of the Stanovoi Terrane (Tok–Sivakan Massif) are characterized by similar $(^{87}Sr/^{86}Sr)_0$ and $\varepsilon_{Nd}(T)$ values (0.7065–0.7067 and –11.77 to –12.20, respectively), which suggest isotopic uniformity of melt sources. The T_{Nd}(DM-2st) value is 1937–1901 Ma. The $\delta^{18}O$ value measured for rocks of this association decreases from +5.36‰ in phase I quartz monzodiorites to +5.23 and +5.00‰ in granites and leucogranites, respectively. This is probably explained by the influence of meteoric hydrothermal fluids with low $\delta^{18}O$ contents.

The Riphean province comprises the Amur Superterrane, Mongol–Okhotsk Foldbelt and western part of the Baikal–Vitim Superterrane. Granitoids of the Riphean province are characterized by a more radiogenic Nd composition as compared with their counterparts from the Early Proterozoic province.

The Early Jurassic granosyenite–granite association from the Mamyn block of the Amur Superterrane has low $(^{87}Sr/^{86}Sr)_0$ and $\varepsilon_{Nd}(T)$ values (0.7059–0.7060 and –3.87, respectively). The T_{Nd}(DM-2st) value is 1312 Ma. The $\delta^{18}O$ values estimated for phase I quartz monzodiorites (+6.30%) and phase II subalkaline granitoids (from +7.13 to +7.50‰) indicate a mantle source for these rocks.

In granitoids from the Late Jurassic–Early Cretaceous monzodiorite–granite association of the Umlekan–Ogodzha zone, the $(^{87}Sr/^{86}Sr)_0$ value varies from 0.7057 to 0.7073 ($\varepsilon_{Nd}(T)$ ranges from –0.18 to –3.75). The T_{Nd}(DM-2st) value ranges from 917 to 1249 Ma. In rocks of the Dzhalinda Massif located between structures of the Mongol–Okhotsk Belt and Baikal–Vitim Superterrane, the $\delta^{18}O$ value varies from +7.58 to +8.24‰. In rocks of the Igak Massif located in the eastern area located between structures of the Mongol–Okhotsk Foldbelt and Amur Terrane, the value is lower (from +7.0–+7.22‰) due to the presence of metapelitic matter in the source of the Dzhalinda Massif.

Phase I granosyenites from the Early Cretaceous granosyenite–granite association of the Umlekan–Ogodzha zone are characterized by the lower $(^{87}Sr/^{86}Sr)_0$ values as compared with phase II subalkaline granites (0.7070 versus 0.7074–0.7079) and similar $\varepsilon_{Nd}(T)$ and T_{Nd}(DM-2st) values varying from –2.7 to –4.59 and from 1167 to 1323 Ma, respectively. The $\delta^{18}O$ value is +5.24‰ in phase I granosyenites and ranges from +8.0 to +9.97‰ in phase II subalkaline granites. This fact, along with geochemical differences [13], indicates their origination from autonomous sources: mantle source for phase I granosyenites and mantle source with an admixture of metapelitic matter for phase II granitoids.

Phase II granosyenites and phase III granites from the Early Cretaceous granodiorite–granite association of the Umlekan–Ogodzha zone (Elna Massif) differ in the $(^{87}Sr/^{86}Sr)_0$ ratio (0.7059 and 0.7066, respectively) and $\varepsilon_{Nd}(T)$ values (–0.95 and –7.39, respectively). Different T_{Nd}(DM-2st) values obtained for granodiorites and granites (1013 and 1548 Ma, respectively) indicate their formation from autonomous magmatic sources due to partial melting rather than from fractionation of granodiorite melt.

Granitoids from the Early Cretaceous granosyenite–granite association of the Baikal–Vitim Superterrane (Khaikta Massif) are characterized by higher $(^{87}Sr/^{86}Sr)_0$ values (0.7075–0.7083), a less radiogenic Nd isotopic composition ($\varepsilon_{Nd}(T)$ varies from –5.64 to –5.93), and an older model age (T_{Nd}(DM-2st) = 1410–1433 Ma) as compared with rocks from the similar association of the Umlekan–Ogodzha zone. The $\delta^{18}O$ value in granitoids ranging from +7.37 to +8.57‰ indicate a presence of metapelitic matter in the source.

The cited data on the Sr isotopic composition in granitoids are generally similar in different structures of the upper Amur region. Hence, they characterize the compositionally similar and isotopically heterogeneous source in the lower crust. The $(^{87}Sr/^{86}Sr)_0$ values are characteristic of intracontinental basic and intermediate volcanics with elevated alkalinity. Hence, the protoliths of both Early Proterozoic and Riphean provinces were probably dominated by metamagmatic materials with different contents of dark-colored and feldspar components. The rocks from all the studied granitoid associations belong mainly to high-alkali varieties of the first type. Taking into consideration experimental data [14], the high K_2O content in granitoids suggests high K concentration in the protolith owing to the presence of biotite and/or potassic feldspar, which implies its high alkalinity. Along with geochemical [13] and isotopic–geochemical signatures, the petrochemical properties of Mesozoic granitoids indicate different compositions of sources. Both petrochemical properties of rocks and experimental data [15] suggest that rocks of monzodiorite–granite and granodiorite associations and phase I granosyenites from the granosyenite–granite association originated probably from partial melting of garnet-bearing biotite amphibolites with different contents of garnet, dark-colored minerals, and feldspars [13]. The relatively high $\delta^{18}O$ content indicates that the source for phase II granitoids of the granosyenite–granite association was of a mixed amphibolite and metamorphic graywacke composition with admixture of the metapelitic component.

The obtained geochemical and isotopic–geochemical data suggest that compositional differences of Late Mesozoic granitoids in the upper Amur region are largely explained by regional compositional differences of the parental Early Proterozoic and Riphean crustal substrate. These differences were responsible for longitudinal and transverse petrochemical zoning of Late Mesozoic granitoids in the upper Amur region.

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