Isotope-geochronological (SHRIMP-RG) studies of zircon from muscovite-tourmaline granites of the Kolmozero-Voronya greenstone belt: insights for sources of rare metal pegmatites

N M Kudryashov¹, O V Udoratina², M A Coble³

¹Geological Institute of the Kola Science Centre of the RAS, Apatity, Russia
²Institute of Geology of Komi SC UB RAS, Syktyvkar, Russia
³Stanford University, USA

E-mail: nik@geoksc.apatity.ru, udoratina@geo.komisc.ru, coblem@stanford.edu

Abstract. The article provides data on the U-Pb isotope (SHRIMP RG) study of tourmaline-muscovite granites of the Kolmozero-Voronya greenstone belt. The tourmaline-muscovite granites formed in the time span of 2451±60 Ma, which corresponds with the previously obtained age of tantalite from rare metal pegmatites of the Vasin-Myl’k deposit. The obtained age indicates the Paleoproterozoic formation stage of granites and, probably, associated rare metal pegmatites.

1. Introduction

Rare metal pegmatites are common on all continents in a wide age range - from Early Precambrian to Paleozoic. The bulk of the pegmatites belongs to Archean and Proterozoic rocks. A characteristic feature of rare metal pegmatites is their confinement to Precambrian greenstone belts along the zones of ancient deep faults. A clear occurrence of rare metal mineralization in pegmatite veins is established in the basic rocks. An important task of a rare metal pegmatites study is to establish their genetic relations with granites, if any, and determine the time of the ore mineralization occurrence. To address these questions, we have connected zircon U-Pb geochronology aimed at determining the formation time of both the granites ancestral for the pegmatites and the pegmatites themselves.

The Kolmozero-Voronya greenstone belt is confined to the central part of the suture zone separating the Murmansk domain from the Central Kola and Keivsky domains. The belt is represented by Late Archaean sedimentary-volcanogenic rocks (2.9-2.5 Ga). Deposits of the rare metal pegmatites (Li, Cs with associated Nb, Ta, Be) are concentrated within its limits. The pegmatite fields are located among amphibolites and gabbroic intrusions in the north-western and south-eastern parts of the belt.

The age of the pegmatites within the belt, according to the available U-Pb datings for monazite and a Rb-Sr isochronous method for bulk samples, was estimated at 2.7-2.6 Ga [1]. Up until now, there is no generally accepted view on the genetic affiliation of the pegmatites. Various authors suggest an association of the pegmatites with granitoids of all types within the region: plagiogranites, tonalites [2], amphibole-biotite granodiorites and microcline granites [3], alkaline granites, and also muscovite-tourmaline granites [4]. A connection of the rare metal pegmatites with processes of granitization has
been also suggested to be associated with a formation of microcline granites (palingenic metasomatic granites) [5].

Prior to this study, an isotope dating has been obtained for a number of rock complexes, which may be possible candidates for the role of source granites for the rare metal pegmatites. These rocks belong to the differentiated sanukitoid Porozozersky massif represented by a series of gabbrodiorite - quartz monzodiorite - granodiorite - microcline-plagioclase granite. U-Pb (ID TIMS) age of the zircon from the rocks of the series is within the range of 2.73-2.68 Ga [6]. The age of the plagiogranites and tonalites from the Murmansk block, framing the rocks of the Kolmozero-Voronya greenstone belt, is defined as Late Archaean 2.8-2.7 Ga [7]. The massifs of alkaline granites, located within the Keivsky block, have the age of 2.65-2.67 Ga [8]. Zircon in the pegmatites is overwhelmingly represented by fragments of broken crystals due to fluid processes, and cannot be reliably used as a geochronometer to determine the crystallization age of the pegmatites. The use of non-traditional minerals-geochronometers with specially developed methods of separation of uranium and lead, allow estimating the time of formation and/or alteration of the pegmatites. The isotope-geochronological studies of tourmaline (shorl) from muscovite-tourmaline allowed [9] establishing a Pb-Pb isochronous age of 2520±70 Ma. From a sample of the pegmatites taken from the Vasin-Myl’k pits, tantalite and microlite have been isolated for a U-Pb isotope-geochronological study. The grains of tantalite and microlite are characterized by intraphase heterogeneity reflecting postcrystallization processes of changes of the mineral, probably metamictization. For the tantalite, a discordant age of 2503±36 Ma has been obtained, and for the microlite, a discordant age is 2454±8 Ma [10]. The obtained age values of the tantalite and microlite possibly fix the time of crystallization of these minerals during the formation of rare metal pegmatites at the Archaean-Proterozoic boundary.

2. Methods
Zircons for geochronological studies were extracted from 3–5-kg rock samples, which were disintegrated in an iron mortar, sieved (sieve size of 0.25 mm), washed, dried, and separated on magnetic and nonmagnetic fractions. The nonmagnetic fraction was further divided in bromoform and heavy nonmagnetic fraction was cleaned manually under a binocular microscope. The isotopic–geochronological studies of zircons were carried out at the SUMAC Center of Stanford University and US Geological Survey (http://shrimprg.stanford.edu). The zircon monofraction and standards were mounted in epoxy resin. The U–Pb age of zircons was analyzed on a SHRIMP-RG ion multicollector microprobe. The cathodoluminescent images of crystals most suitable for dating were taken on a Jeol 5600 SEM.

3. Results and Discussion
The isolated zircon from the tourmaline-muscovite granite sample (KV-76) is represented by slightly modified brownish crystals of zircon type with the size of 100-150 mcm. The internal structure is characterized by the phase heterogeneity expressed both as an alternation of dark and light zones in marginal parts of the grains, and as diffused dark spots in the center of the grains. Contours of the zones are blurred, rectilinear and, apparently, reflect the growth of the crystals from the melt (Fig. 1).
Figure. 1. Cathodoluminescence images of zircon grains from the sample KV-76. Circles on the grains show the location of U–Pb age measurement.

Table. 1. Results of U-Pb dating of zircons (KV-76)

| Grain   | 206Pb, % | 206Pb common, ppm | 206Pb* common, ppm | Content, ppm | 235Th/238U | Corrected ratios ± 1σ (1 σ) | Age ± 1σ, Ma | D, % |
|---------|----------|-------------------|--------------------|--------------|-------------|-----------------------------|--------------|------|
| 76-6.1  | 0.132    | 351               | 2810               | 107          | 0.04        | 0.089±5.0, 1.79±9.2         | 0.145±7.7    | 0.8  |
| 76-3.1  | 0.154    | 530               | 3054               | 66           | 0.02        | 0.120±9.6, 3.35±11.1        | 0.202±5.5    | 0.5  |
| 76-5.1  | 0.249    | 399               | 1590               | 25           | 0.02        | 0.141±3.9, 5.70±11.7        | 0.293±11.0   | 0.9  |
| 76-11.1 | 0.158    | 468               | 2077               | 40           | 0.02        | 0.141±0.2, 5.11±4.6         | 0.262±4.6    | 1.0  |
| 76-10.1 | 0.053    | 559               | 2232               | 34           | 0.02        | 0.150±1.2, 6.04±3.8         | 0.292±3.6    | 0.9  |
| 76-8.1  | 0.050    | 551               | 1947               | 45           | 0.02        | 0.150±7.5, 6.83±14.1        | 0.330±12.0   | 0.8  |
| 76-1.1  | 0.073    | 350               | 1900               | 462          | 0.25        | 0.151±1.9, 4.47±6.5         | 0.214±6.2    | 1.0  |
| 76-2.1  | 0.305    | 575               | 2425               | 23           | 0.01        | 0.153±2.7, 5.83±5.5         | 0.276±4.9    | 0.9  |
| 76-12.1 | 0.051    | 478               | 1789               | 65           | 0.04        | 0.154±0.2, 6.62±3.1         | 0.311±3.1    | 1.0  |
| 76-9.1  | 0.069    | 546               | 2930               | 99           | 0.03        | 0.161±13.5, 4.81±16.6       | 0.217±9.6    | 0.6  |
| 76-4.1  | 0.074    | 621               | 2161               | 54           | 0.03        | 0.168±2.2, 7.74±3.7         | 0.334±3.0    | 0.8  |
| 76-7.1  | 0.039    | 506               | 1513               | 12           | 0.01        | 0.178±0.2, 9.55±3.7         | 0.389±3.7    | 1.0  |

n the calibration standard is 0.29%. 206Pbc and 206Pb* – common and radiogenic lead; b.d. – below the limit of determination (≤0.04). Corrected ratios and 206Pb content are corrected for 204Pb. D is discordance: D = 100 × [age (207Pb/206Pb)/age (207Pb/235U) – 1].
Figure 2. Diagram with concordia for the tourmaline-muscovite granites. Gray ellipses - analytical data included in the calculation of the discordia; transparent ellipses - not included in the calculation.

The Pb-U isotope results of the analyzed zircon grains are shown in Fig. 2 and Tabl. 1. The discordant age, calculated for 8 analyzed points of zircon, was 2451±61 Ma, MSWD=1.6. As Fig. 1 shows, the analytical points are strongly discordant, which indicates that the original U-Pb system is not in equilibrium. The zircon is highly enriched in uranium - 2500-3000 ppm and has low U/Th=0.01-0.04, which possibly indicates metasomatic processes. Thus, the upper intersection of the discordia with an intercept age of ~2.45 Ga likely reflects the crystallization time of zircon during the formation of the tourmaline-muscovite granites, and the high discordance is associated with a subsequent change in the zircon. The obtained age is close to the age estimates for the tantalite and microlite from the rare metal pegmatites of the Vasin-Myl’k deposit. On the basis of the obtained isotope-geochronological data, it can be concluded that the tourmaline-muscovite granites, located in the immediate vicinity of veins of the rare-metal pegmatites, are their most probable source.

Acknowledgments
These studies were carried out according to the project GI KSC RAS No. 0226-019-0053.

References
[1] Pushkarev Yu D, Kravchenko E V and Shestakov G I 1978 Geochronological reference points of the Precambrian of the Kola Peninsula (Leningrad: Science) p 136
[2] Ginzburg A I, Timofeev I N and Feldman L G 1979 Basics of the geology of granite pegmatites (Moscow: Nedra) p 296
[3] Sosedko A F 1961 Materials on the geology and geochemistry of granite pegmatites (Moscow: Gosgeoltekhiizdat) p 152
[4] Gordienko V V 1970 Mineralogy, geochemistry and genesis of spodumene pegmatites (Leningrad: Nedra) p 240
[5] Vetrin V R 1985 Magmatic formations of Precambrian North-Eastern part of the Baltic Shield (Leningrad: Nauka) p 176
[6] Kudryashov N M, Petrovsky M N, Mokrushin A V and Elizarov D V 2013 Neoarchaean sanukitoid magmatism of the Kola region: geological, petrochemical, geochronological and isotope-geochemical data Petrology 21 351-374

[7] Kozlov N E, Sorokhtin N O, Glaznev V N, Kozlova N E, Ivanov A A, Kudryashov N M, Martynov E V, Tyuremnov V A, Matyushkin A V and Osipenko L G 2006 Geology of Archean Baltic Shield (St. Petersburg: Nauka) p 345

[8] Zozulya D R, Bayanova T B and Eby G N 2005 Geology and Age of the Late Archean Keivy Alkaline Province, Northeastern Baltic Shield Journal of Geology 113 601-608.

[9] Kudryashov N M, Gavrilenko B V and Apanasevich E A 1999 Age of rocks of the Archean Kolmozero-Voronya greenstone belt: new U-Pb data Geology and minerals of the North-West and the Center of Russia: proceedings of X conf. K. Krats Apatity 66-70

[10] Kudryashov N M, Lyalina L M and Apanasevich E A 2015 Age of Rare_Metal Pegmatites from the Vasin_Myl’k Deposit (Kola Region): Evidence from U–Pb Geochronology of Microlite Doklady Earth Sciences 461(2) 321-325