Latest Permian–Triassic magmatism of the Taimyr Peninsula: New evidence for a connection to the Siberian Traps large igneous province

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ABSTRACT

This study presents new whole rock major and trace element, Sr-Nd isotopic, petrographic, and geochronologic data for seven latest Permian (Changhsingian)–Late Triassic (Carnian) granitoid intrusions of the northwestern and northeastern Taimyr Peninsula in the Russian High Arctic. U-Pb zircon ages, obtained using secondary ion mass spectrometry (SIMS), sensitive high-resolution ion microprobe (SHRIMP), and laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS), define the crystallization age of the Taimyr intrusions studied as ranging from ca. 253 Ma to 228 Ma, which suggests two magmatic pulses of latest Permian–Early Triassic and Middle–Late Triassic age. Ar-Ar dating of biotite and amphibole indicate rapid cooling of the intrusions studied, but Ar-Ar ages of several samples were reset by secondary heating and hydrothermal activity induced by the Middle–Late Triassic magmatic pulse. Petrographic data distinguish two groups of granites: syenite–monzonites and granodiorites. Sr-Nd isotopic data, obtained from the same intrusions, show a variation of initial (187Sr/16Sr) ratios between 0.70377 and 0.70607, and εNd(t) values range between –6.9 and 1.2. We propose that the geochemical and isotopic compositions of the Late Permian–Triassic Taimyr granites record the existence of a magma mush zone that was generated by the two pulses of Siberian Traps large igneous province (LIP) magmatism.

INTRODUCTION

The Taimyr Peninsula lies on the northern edge of Siberia between the Laptev and Kara Seas (Fig. 1A). Granite intrusions of different ages are known from the Taimyr–Severnaya Zemlya fold-and-thrust belt (Fig. 1B) and can be used to decipher the tectonic evolution of the region (Augland et al., 2019; Khudoley et al., 2018; Kurapov et al., 2018, 2020; Lorenz et al., 2007; Pease et al., 2015; Vernikovsky, 1996; Vernikovsky et al., 1995, 1998a, 1998b, 2003, 2020). Latest Permian–Triassic intrusions are less prevalent and are mainly found across the northwestern part of the Taimyr Peninsula (Augland et al., 2019; Proskurnina et al., 2019; Vernikovsky et al., 2003).

Vernikovsky et al. (2003) used U-Pb zircon geochronological data that suggested that latest Permian–Early Triassic magmatism of the Taimyr–Severnaya Zemlya fold-and-thrust belt was connected to magmatic events within the Siberian Traps large igneous province (LIP). This was recently confirmed by U-Pb zircon data published by Augland et al. (2019). The Siberian Traps is one of the largest LIPs on Earth. Recent studies suggest that the Siberian Traps LIP covered an area of up to 5 million km² and encompassed the Tungska and West Siberian basins, Taimyr Peninsula, and parts of the Kara and Laptev Sea basins (Fig. 1A) (Augland et al., 2019; Dobretsov et al., 2013b; Ernst, 2014; Reichow et al., 2005, 2009, 2016; Saunders et al., 2005; Vasil’ev et al., 2000; Vernikovsky et al., 2003). We present new petrographic, geochronologic, isotopic, and geochemical data of seven latest Permian–Triassic intrusions exposed on the northwestern coast of the Taimyr Peninsula, on several islands in the Kara Sea (Fig. 2A), and in northeastern Taimyr (Fig. 2B). Our study is focused on understanding the relationships between latest Permian–Triassic granitic magmatism within the Taimyr–Severnaya Zemlya fold-and-thrust belt and the magmatic events of the Siberian Traps LIP and its potential implications for the evolution of the continental crust.

GEOPHYSICAL SURVEY

The Taimyr–Severnaya Zemlya fold-and-thrust belt is divided into three structural domains known as the Southern, Central, and NorthernDomains (Fig. 1B). The three domains are separated by three large-scale, southeast-verging thrust faults that include the Pyasina-Faddey, Main Taimyr, and...
Diabasic thrusts (Fig. 1B) (Vernikovsky, 1996; Zonenshain et al., 1990).

The Northern Taimyr Domain is mainly composed of early Paleozoic (predominantly Cambrian and Ordovician) metasedimentary rocks that are characterized by a metamorphic grade ranging from greenschist to amphibolite facies (Vernikovsky, 1996; Makariev, 2013). These sediments were originally believed to be Proterozoic in age (Bezzubtsev et al., 1986; Pogrebitsky and Lopatin, 2000; Pogrebitsky and Shanurenko, 1998), but recent studies have revealed that they are actually Cambrian and younger in age (Ershova et al., 2015a, 2015b, 2017, 2020; Lorenz et al., 2007; Pease and Scott, 2009, Pease et al., 2015). Lower Paleozoic sedimentary rocks of the Northern Taimyr Domain are intruded by granitic plutons of Carboniferous to Triassic age (Kurapov et al., 2018; Lorenz et al., 2007; Pease et al., 2015; Vernikovsky et al., 1995, 1998b).

The Central Taimyr Domain was initially believed to represent diverse terranes accreted to the continental margin of Siberia in the Neoproterozoic (Uflyand et al., 1991; Vernikovsky et al., 2005; Zonenshain et al., 1990). However, a recent study by Priyatkina et al. (2017) proposes that these terranes have belonged to the Siberian Craton since the Mesoproterozoic and that the Central Taimyr Domain formed along the Neoproterozoic active continental margin of Siberia. Later, during latest Neoproterozoic to Late Paleozoic times, this area was transformed into a passive continental margin. This domain consists of Meso- and Neoproterozoic sediments, ophiolite fragments, and magmatic rocks metamorphosed from greenschist to amphibolite facies that are overlain by an Ediacaran to Silurian sedimentary succession (Khudoley et al., 2018; Makariev, 2013; Vernikovsky, 1996). Importantly, the Central Taimyr Domain is intruded by
Permian–Early Triassic granites and Early Triassic dolerite dykes and sills are correlated with synchronous magmatism within the Siberian Traps LIP (Khudoley et al., 2018; Vernikovsky, 1996; Vernikovsky et al., 2003). Jurassic–Lower Cretaceous sediments have a discontinuous distribution and fill local depressions in both the Northern and Central Taimyr Domains (Makariev, 2013). The Southern Taimyr Domain represents part of the Paleozoic passive margin of the Siberian Craton.

The exposed Ordovician to Triassic sediments were intruded by latest Permian–Early Triassic dykes and sills that are correlated with Siberian Traps magmatism and deformed to varying degrees (Augland et al., 2019; Vernikovsky, 1996).

The Taimyr–Severnaya Zemlya fold-and-thrust belt is considered a northward continuation of the late Paleozoic Uralian Orogen that formed in response to collision of the Kara Terrane with Siberia in the Late Carboniferous–Early Permian (Kurapov et al., 2020; Pease et al., 2015; Vernikovsky, 1996; Zonenshain et al., 1990). Compressional forces and tectonic activity ceased within the Taimyr–Severnaya Zemlya fold-and-thrust belt during the Early Permian, and it has subsequently formed the northern margin of the Siberian Craton (Kurapov et al., 2020; Vernikovsky, 1996). Various researchers (Khain et al., 1991; Saunders et al., 2005; Dobretsov et al., 2013a; Afanasenkov et al., 2016; Krivolutskaya et al., 2019) propose an extensional environment close to Siberian margins and within the West Siberian basin in the Late Permian–Early Triassic. Particularly, the development of the Yenisei-Khatanga paleo-rift (Krivolutskaya et al., 2019) suggests that synchronous extension could appear within the Taimyr–Severnaya Zemlya fold-and-thrust belt.

Previous Studies of Latest Permian–Triassic Magmatism

Vernikovsky et al. (2003) reported U-Pb zircon ages of several syenite-granite intrusions from northwestern Taimyr (Fig. 1B). These intrusions, located in the Central and Southern Taimyr Domains, yielded ages of 249 ± 5.2 Ma, 241 ± 6.5 Ma, and 241 ± 3 Ma and were correlated with Siberian Traps magmatism that took place between ca. 252–248 Ma (Burgess and Bowring, 2015; Ernst, 2014; Kamo et al., 1996, 2003). More recently, Augland et al. (2019) reported three U-Pb zircon ages (251.65 ± 0.11 Ma, 251.46 ± 0.13 Ma, and 250.6 ± 0.22 Ma) from syenite intrusions located in the Southern Taimyr Domain (Fig. 1B), while Khudoley et al. (2018) reported a U-Pb zircon age of 248 ± 4 Ma from a monzonite in the Central Taimyr Domain (Figs. 1B–2B), which further supports a connection between the Late Permian–Triassic magmatism of the Taimyr Peninsula and the Siberian Traps LIP. Proskurnina et al. (2019) reported U-Pb zircon ages of 241.0 ± 3, 236.0 ± 3 Ma, and 233.0 ± 1 Ma from three samples of Middle–Late Triassic granite intrusions in the Northern Taimyr Domain (Fig. 1B).

Latest Permian–Triassic granite intrusions occur in all three tectonic domains of Taimyr (Augland et al., 2019; Khudoley et al., 2018; Proskurnina et al., 2019).
al., 2019; Vernikovsky et al., 2003). This widespread distribution distinguishes them from Carboniferous–Middle Permian granite intrusions, which are restricted to the Northern (Kurapov et al., 2018, 2020; Lorenz et al., 2007; Pease et al., 2015; Vernikovsky, 1996; Vernikovsky et al., 1998b) and, locally, Central (Khudoley et al., 2018) Taimyr Domains.

METHODS

U-Pb dating of zircons was carried out with a sensitive high-resolution ion microprobe (SHRIMP II) at the Center of Isotopic Research, Russian Geological Research Institute (VSEGEI), St. Petersburg. Separation of zircons was performed according to the standard procedure that includes crushing to fragments of ~0.25 mm in size, a centrifugal concentration, removal of the highly magnetic minerals, and processing with heavy liquids. The handpicked zircon grains were mounted in the epoxy disc along with fragments of the zircon standards TEMORA and 91500. They were polished to expose centers of the grains. The cathodoluminescent (CL) images were used to guide the selection of analysis points. U-Pb ratios were measured following the technique described by Williams (1998) and processed using the SQUIID program (Ludwig, 2000). U-Pb ratios were normalized to the value assigned to the standard TEMORA zircon (0.6668) corresponding to an age of 416.75 Ma (Black et al., 2003). Uncertainties in single analyses (ratios and ages) were brought to conformity at a level of ±2σ. The ISOPLOT program was used to construct concordia diagrams (Ludwig, 2003). U-Pb dating results are provided in Table S1 in the Supplemental Material. Backscattered electron (BSE) CL images of dated zircons are presented in Figure S1 (see footnote 1). Laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) U-Pb zircon dating was performed in the Vernadsky Institute of Geochemistry and Analytical Chemistry of the Russian Academy of Sciences and at the UTCron geochronology facility in the Department of Geosciences at the University of Texas, Austin, USA.

In the Vernadsky Institute, grains were analyzed using UP-213 (New Wave Research) combined with an element X-ray (Thermo Finnigan LLC) ICP-MS. Each grain was ablated for 30 s using a 30 µm spot with a fluence of ~10–15 J/cm². GJ1 and 91500 were used as zircon standards following the analytical protocols of Jackson et al. (2004). Data reduction was performed using GLITTER software (van Achterbergh et al., 2001; Griffin et al., 2008).

In the UTCron geochronology facility, separate zircon grains were mounted on double-sided tape (tape mount) on a 1” acrylic or epoxy disc without polishing. All grains were depth-profiled using a Photon Machines Analyte G2 ATlex 193 nm excimer laser combined with a ThermoElement single collector, magnetic sector ICP-MS following the analytical protocols of Marsh and Stockli (2015). A total of 30 s of background was measured followed by 10 pre-ablation “cleaning” shots and then 15 s of washout to measure background prior to 30 s of sample analysis. Each grain was ablated for 30 s using a 30 µm spot with a fluence of ~4 J/cm², which resulted in ~20-µm-deep ablation pits. For U-Pb geochronological analyses of zircon, the masses 238U, 235U, 232Th, 231Pa, 207Pb, 206Pb, 208Pb, 204Pb, 208Hg, and 204Hg were measured. GJ1 was used as primary zircon standard (Jackson et al., 2004) and interspersed every three to four unknown analyses for elemental and depth-dependent fractionation. Plesioz (Slama et al., 2008) was used as a secondary standard for quality control. No common Pb correction was applied. Data reduction was performed using the Igr Pro-based (Paton et al., 2011) Iolite 3.4 software with the VisualAge data reduction scheme (Petrus and Kamber, 2012).

Dating by the 40Ar/39Ar method was performed at the Sobolev Institute of Geology and Mineralogy, Siberian Branch, Russian Academy of Sciences in Novosibirsk, using the measurement technique described in Travin et al. (2009). Biotite and amphibole mineral fractions were wrapped in aluminum foil and placed into quartz ampoule with MSA-11 biotite (310.1 Ma; Travin et al., 2009), LP–6 biotite (age 128.1 Ma; Baks et al., 1996), and Bern 4m muscovite (18.51 Ma; Baks et al., 1996) standards. Irradiation was done in the cadmium-plated channel of a VVR–K research reactor at the Research Institute of Nuclear Physics, Russia. The gradient of the neutron flux did not exceed 0.5% of the sample size. Experimental stepwise heating was carried out in a quartz reactor with an externally heated oven. A blank run with 40Ar (10 min at 1200 °C) did not exceed 5 × 10–10 ncm². Purification of argon was carried out with ZrAI SAES Getters. The isotopic composition of argon was measured on a Noble Gas 5400 MS (Micromass, England). Measurement errors in the text and figures correspond to ±1σ. Ar–Ar dating results are provided in Table S2 (footnote 1).

Samples were prepared for Rb/Sr analysis at the Analytical Center for Multielemental and Isotope Research, Siberian Branch of the Russian Academy of Sciences, Novosibirsk. Samples were prepared for determining the Sm/Nd isotopic composition in cleanroom (class 10,000) of the Zavaritsky Institute of Geology and Geochemistry, Ural Branch of the Russian Academy of Sciences, Ekaterinburg. Determination of the Sm/Nd isotopic ratios of the system were carried out on a Neptun Plus ICP-MS. Accuracy and consistency of the instrument were evaluated using a Neptun Test Solution multi-element solution. The 143Nd/144Nd isotopic ratio measured in this session was 0.511725 ± 0.000014 (2σ, n=24), which is within the range of certified values for the solution (0.51171–0.51175). Determination of Rb/Sr isotopic ratios was carried out on a thermal ionization mass spectrometer (TIMS) Triton Plus in static mode. Accuracy and consistency of the instrument were evaluated using the international Sr standard SRM-987 with an 87Sr/86Sr ratio of 0.710255 ± 0.000007 (2σ, n = 18). Results of the Rb/Sr and Sm/Nd analyses are provided in Table S3 (see footnote 1).

1Supplemental Material. Table S1: Results for the SIMS SHRIMP and LA-ICPMS U-Pb zircon analysis. Table S2: Ar–Ar analytical data for studied samples. Table S3: Rb–Sr, Sm–Nd isotopic data of studied samples. Table S4: Major and trace element analyses of studied samples with the coordinates of studied samples (WGS84 projection). Table S1: BSE–CL images of zircon grains from the studied granites. Figure S2: Concordia and weighted average diagrams for studied granites. Figure S3: Ar–Ar spectra on biotite and amphibole for studied latest Permian–Triassic granites. Please visit https://doi.org/10.1130/GEOSS.16746292 to access the supplemental material, and contact editing@geosociety.org with any questions.
The whole rock geochemical studies were carried out at the Central Laboratory of VSEGEI, St. Petersburg. All samples underwent conventional crushing and grinding. The major oxide concentrations were determined on an Optima 4300DV emission spectrometer and an ELAN 6100 dynamic reaction cell MS. Geochemical data and sample coordinates are provided in Table S4 (see footnote 1). Petrographic study of rocks was performed using Olympus BX51 and Leica DM4000 P LED optical microscopes.

Petrography and geochemistry of the intrusions

Northern Taimyr Domain

East Vorontsova Peninsula

Two samples (118-6 and 118-11; locations are provided in Fig. 2) were analyzed from an intrusion on the eastern part of the Vorontsova Peninsula. The rocks examined here are coarse-grained granites according to their modal mineral contents using the quartz, alkali, plagioclase (QAP) diagram (based on Streckeisen, 1976, Fig. 3A) with equigranular texture. Quartz (35–40%) is present in subhedral grains with undulose extinction, orthoclase (30–35%) is tabular, plagioclase (20–25%) is euhedral and sharply twinned, and biotite (7–10%) occurs in laths. Accessory apatite and zircon are present. It should be noted that sample 118-11 shows signs of hydrothermal alteration that occurs as sericitization, silicification, and chloritization. These granites contain 67.7–73.5 wt% SiO$_2$, 3.31–3.88 wt% Na$_2$O, and 2.47–4.50 wt% K$_2$O and are classified as granites and granodiorites on the total alkali silica (TAS) classification diagram (Middlemost, 1994) (Fig. 3B). They are magnesian, calcic and alkali-calcic, and peraluminous (Figs. 3C–3E) (Frost et al., 2001). On a normal mid-oceanic-ridge basalt (N-MORB)-normalized diagram (N-MORB values from Sun and McDonough, 1989), the granites are characterized by an enrichment in light rare earth elements (LREE) for a comparison of granites studied with previously published data, see Proskurnina et al. (2019) and Vernikovsky et al. (2003).
and depletion in heavy rare earth elements (HREE) ($La_N/Yb_N = 17.2, 292.8$) with a negative Eu anomaly ($Eu/Eu^* = 0.53, 1.00$). On an N-MORB-normalized, multi-element diagram (N-MORB values of Sun and McDonough, 1989), the granites show enrichment in Rb, Sr, and U and depletion in Ta, Nb, and Th (Fig. 4).

**West Vorontsova Peninsula**

Two samples (192-2 and 192-3; locations are provided in Fig. 2) were obtained from an intrusion exposed on the western part of the Vorontsova Peninsula. The rocks examined here are medium-grained granites according to their modal mineral contents using the QAP diagram (based on Streckeisen, 1976; Fig. 3A) with hypidiomorphic texture. Quartz (40–45%) is present in euhedral grains, orthoclase (30–40%) is subhedral, plagioclase (15–20%) is euhedral and sharply twinned, and biotite (5–7%) occurs in laths. Accessory apatite and zircon are present. These granites contain 69.4–71.6 wt% SiO$_2$, 4.07–5.08 wt% Na$_2$O, and 2.56–3.55 wt% K$_2$O. The samples are classified as granites and granodiorites on the TAS classification diagram (Middlemost, 1994) (Fig. 3B). They are magnesian, calc-alkalic, and slightly peraluminous according to the classification of Frost et al. (2001) (Figs. 3C–3E). On an N-MORB-normalized diagram, the granites are characterized by an enrichment in LREE and depletion in HREE ($La_N/Yb_N = 8.2, 110.7$) with a negative and positive Eu anomaly ($Eu/Eu^* = 0.44, 1.07$). On an N-MORB-normalized multi-element diagram, the granites are enriched in Rb, Sr, and U and depleted in Nb and Th (Fig. 4).

**Plavnikoye Islands**

Three samples (170-7, 171-1, and 173-1; locations provided in Fig. 2) were obtained from a granite intrusion exposed on the Plavnikoye Islands. The rocks examined here are medium-to coarse-grained granodiorites and granites according to their modal mineral contents using the QAP diagram (based on Streckeisen, 1976;
Fig. 3A) with equigranular texture. Plagioclase (35–40%) is euhedral and sharply twinned, quartz (30–35%) is present in euhedral grains, orthoclase (15–20%) is tabular, and biotite (5–15%) occurs in laths. Accessory apatite and zircon are present. The granites contain 68.0–68.4 wt% SiO₂, 3.97–4.16 wt% Na₂O, and 3.25–3.87 wt% K₂O and are classified as granodiorites on the TAS classification diagram (Middlemost, 1994) (Fig. 3B). They are magnesium to slightly ferroan and peraluminous according to the classification of Frost et al. (2001) and are alkali-calcic as defined by the modified alkali–lime index (Figs. 3C–3E). On an N-MORB-normalized diagram, the granites are characterized by a geochemical signature similar to that of the intrusions of the West Kamenny and Rastorguyev Islands with enrichment in LREE, depletion in HREE (La/Ybₙ = 28.5–43.7), and a slightly negative Eu anomaly (Eu/Eu* = 0.84, 1.02). On an N-MORB-normalized, multi-element diagram, the granites are enriched in Rb, Th, Sr, and U and depleted in Ta and Nb (Fig. 4).

### Lenivaya River

Sample 68002 (location provided in Fig. 2) was collected from an intrusion exposed along the Lenivaya River. The rock examined here is medium-grained granodiorite according to its modal mineral contents using the QAP diagram (based on Streckeisen, 1976; Fig. 3A) with porphyritic texture. Plagioclase (40%) is euhedral, quartz (35%) is present in subhedral grains, orthoclase (10%) is subhedral, and biotite (10%) occurs in laths and prismatic amphibole (5%). This granite contains 72.3 wt% SiO₂, 3.40 wt% Na₂O, and 3.43 wt% K₂O. The rock is classified as a granite on the TAS classification diagram (Middlemost, 1994) (Fig. 3B) and is magnesium, calc-alkalic, and metaluminous (Frost et al., 2001) (Figs. 3C–3E). On an N-MORB-normalized diagram, the granodiorite is characterized by an enrichment in LREE and depletion in HREE (La/Ybₙ = 28.6) with a positive Eu anomaly (Eu/Eu* = 1.24). On an N-MORB-normalized, multi-element diagram, the granodiorite is enriched in Ba and Sr and depleted in Ta and Nb (Fig. 4).

### Central Taimyr Domain

#### West Kamenny Island

Two samples (111-1 and 112-3; locations are provided in Fig. 2) were taken from an intrusion exposed on Kamenny Island. The rocks examined here are medium-grained quartz syenite and monzonte according to their modal mineral contents using the QAP diagram (based on Streckeisen, 1976; Fig. 3A) with porphyritic texture. Orthoclase (50–55%) is euhedral, plagioclase (25–35%) is euhedral, quartz (5%) is present in interlocking grains, and biotite (5–10%) occurs in laths and prismatic amphibole (7%). Accessory zircon, apatite, and rare magnetite are present. These rocks contain 60.9–62.2 wt% SiO₂, 3.86–4.13 wt% Na₂O, and 4.86–7.71 wt% K₂O. They are classified as syenites and quartz monzonites on the TAS classification diagram (Middlemost, 1994) (Fig. 3B). The syenites and quartz monzonites are magnesium and metaluminous according to the classification of Frost et al. (2001) and are alkali-calcic to alkaline as defined by the modified alkali–lime index (Figs. 3C–3E). On an N-MORB-normalized diagram, the granites are characterized by an enrichment in Rb, Ba, Th, Sr, and U and depleted in Ta and Nb (Fig. 4).

#### Rastorguyev Island

Two samples (108-1a and 194-2; locations provided in Fig. 2) were obtained from an intrusion exposed on Rastorguyev Island. The rocks examined here are medium-grained monzonites and quartz monzonites according to their modal mineral contents using the QAP diagram (based on Streckeisen, 1976; Fig. 3A) with porphyritic texture. Orthoclase (40–45%) is tabular, plagioclase (35–40%) is euhedral, quartz (5%) is present in subhedral grains, and biotite (10%) occurs in laths and prismatic amphibole (5–7%). Accessory zircon,apatite, titanite, and rare magnetite are present. These rocks contain 58.0–58.3 wt% SiO₂, 3.75–4.26 wt% Na₂O, and 5.74–6.18 wt% K₂O and are classified as monzonites on the TAS classification diagram (Middlemost, 1994) (Fig. 3B). They are magnesium, alkalic, and metaluminous to slightly peraluminous (Frost et al., 2001) (Figs. 3C–3E). On an N-MORB-normalized diagram, the syenites are characterized by a very similar geochemical signature to the intrusions of West Kamenny Island, with an enrichment in LREE, depletion in HREE (La/Ybₙ = 61.8), and a positive Eu anomaly (Eu/Eu* = 1.06). On an N-MORB-normalized, multi-element diagram, the syenites are enriched in Rb, Ba, Th, Sr, and U and depleted in Ta and Nb (Fig. 4).

### Astronomicheskiy Creek

One sample (G-2; location is provided in Fig. 2B) was obtained from an intrusion exposed along the Astronomicheskiy River (Central Taimyr Domain), which crosses both lower Paleozoic rocks and a Late Permian granodiorite intrusion (Khusnictseva et al., 2018). The intrusion contains 57.7 wt% SiO₂, 3.78 wt% Na₂O, and 4.13 wt% K₂O and is classified as a monzonite on the TAS classification diagram (Middlemost, 1994) (Fig. 3B). The sample is magnesium, alkalic, and metaluminous according to the classification of Frost et al. (2001) (Figs. 3C–3E). On an N-MORB-normalized diagram, the sample is characterized by a geochemical signature similar to that of the intrusions of the West Kamenny and Rastorguyev Islands with a high enrichment in LREE, depletion in HREE (La/Ybₙ = 88.9), and a positive Eu anomaly (Eu/Eu* = 1.13). On an N-MORB-normalized, multi-element diagram, the monzonite is enriched in Rb, Ba, U, Sr, and Th and depleted in Ta and Nb (Fig. 4).

### GEOCHRONOLOGY

U-Pb dating of zircons was carried out on seven samples (Table S1) and Ar-Ar dating of biotite and amphibole on four samples (Table S2) from the northwestern part of the Taimyr Peninsula. Concordia diagrams and Ar-Ar age spectra are provided in Figures S2 and S3 (see footnote 1), respectively.
U-Pb concordia ages and Ar-Ar ages are shown in Table 1. The U-Pb zircon date of one sample (G-2) from the Astronomicheskiy Creek pluton was previously published by Khudoley et al. (2018).

### Northern Taimyr Domain

#### East Vorontsova Peninsula

The zircon population of sample 118-11 is heterogeneous with elongation ratios (the ratio of length divided by width, defining the crystal morphology) ranging from 2 to 4 (Fig. S1) and a few grains containing inclusions. U content ranges from 124 ppm to 672 ppm with Th/U ratios of 0.25–1.23 (Table S1). Three of the six grains analyzed define a concordia age of 252.8 ± 3.6 Ma. One grain has a Late Carboniferous age with a high Th/U ratio of 1.23. Two are slightly younger than the inferred concordia age. They are characterized by high common Pb concentration (0.85–1.30) pointing to metamictization, so these grains were not included in age calculation. Ar-Ar dating of biotite yielded an age of 236.3 ± 4.9 Ma.

For sample 118-6, U content ranges from 248 ppm to 3285 ppm with Th/U ratios of 0.19–1.24 (Table S1). Seven of the 20 grains analyzed define a concordia age of 248.5 ± 1.8 Ma, which is very similar to the 13 grains’ 206Pb/238U weighted average age of 246.4 ± 1.3 Ma (2σ, mean square of weighted deviates [MSWD] = 0.78; 95% confidence). One grain has a Middle Permian age, and 12 are close in age or slightly younger than the inferred concordia age but show significant discordance. These grains are also characterized by high U contents (up to 3285) and high Th-U ratios (0.50–1.24), so we excluded them from the concordia age calculation. Ar-Ar dating of biotite yielded an age of 231.6 ± 3.8 Ma.

#### West Vorontsova Peninsula

The zircons from sample 192-3 are heterogeneous with elongation ratios ranging from two to six (Fig. S1), and most of the grains are characterized by visible cores. U content ranges from 160 ppm to 1549 ppm with Th/U ratios of 0.13–1.23 (Table S1). Nine grains analyzed, with one grain dated in two spots, define a concordia age of 237.8 ± 2.8 Ma. The zircons from sample 192-2 are heterogeneous with elongation ratios ranging from two to five (Fig. S1), and most of the grains are characterized by visible cores, although a few grains contain inclusions. U content ranges from 78 ppm to 877 ppm with Th/U ratios of 0.23–1.63 (Table S1). Four of the nine grains analyzed, including one grain that was dated in two spots, define a concordia age of 237.8 ± 2.8 Ma. Three grains are younger than the inferred concordia age and are characterized by high U contents (648–877) and Th/U ratios (0.52–1.63). Two grains are close in age to the inferred concordia age but show significant discordance. One grain has a Neoproterozoic age and most likely was inherited from wall rock.

#### Plavnikovy Island

U content in zircons from sample 170-7 ranges from 436 ppm to 1276 ppm with Th/U ratios of 0.32–0.62 (Table S1). Five of the 15 grains analyzed define a concordia age of 239.1 ± 2.6 Ma, which is very similar to the 12 grains’ 206Pb/238U weighted average age of 236.0 ± 2.9 Ma (2σ, MSWD = 2.3; 95% confidence). One grain is slightly younger, five are older, and four grains are close in age to the inferred concordia age, but all these grains show significant discordance and were excluded from age calculation.

#### Lenivaya River

For sample 68002, U content in the grains analyzed ranges from 506 ppm to 1372 ppm with Th/U ratios of 0.36–5.21 (Table S1). Three of the 30 grains analyzed define a concordia age of 227.5 ± 1.3 Ma. The zircons from sample 68002 have a Late Permian–Early Triassic age but do not define a concordia age.

### Table 1. Calculated U-Pb and Ar-Ar Ages for Granites from Taimyr Studied

| Sample no. | U-Pb age (Ma)* | Ar-Ar age (Ma) | Mineral dated |
|------------|----------------|----------------|---------------|
|            |                 |                | (1) U-Pb, (2) Ar-Ar |
| East Vorontsova Peninsula | | | |
| 118-6      | 248.5 ± 1.8     | 251.6 ± 3.8    | (1) zircon, (2) biotite |
| 118-11     | 252.8 ± 3.6     | 236.3 ± 4.9    | (1) zircon, (2) biotite |
| West Vorontsova Peninsula | | | |
| 192-2      | 235.2 ± 1.8     | N.D.*          | (1) zircon |
| 192-3      | 237.8 ± 2.8     | N.D.*          | (1) zircon |
| Plavnikovy Island | | | |
| 170-7      | 239.1 ± 2.6     | N.D.*          | (1) zircon |
| Lenivaya River | | | |
| 68002      | 227.5 ± 1.3     | N.D.*          | (1) zircon |
| West Kamenny Islands | | | |
| 111-1      | 235.3 ± 0.65    | 234.9 ± 2.8    | (1) zircon, (2) biotite |
| Rastorguyev Island | | | |
| 108-1a     | N.D.*           | 226.3 ± 5.6    | (2) amphibole |

*Errors are 2σ with decay constant errors. 
*N.D.—not determined.

Plavnikovy and Lenivaya Rivers. The U-Pb age of one sample (G-2) from the Astronomicheskiy Creek pluton was previously published by Khudoley et al. (2018).
Central Taimyr Domain
West Kamenny Island

For sample 111-1, U content in the granites analyzed ranges from 95 ppm to 3395 ppm with Th/U ratios of 0.52–1.69 (Table S1). Eleven of the 20 grains analyzed define a concordia age of 235.3 ± 0.65 Ma, which is very similar to the 19 grains’ 206Pb/238U weighted average age of 233.9 ± 0.96 Ma (2σ, MSWD = 1.1; 95% confidence). Nine grains are close in age to the inferred concordia age but show significant discordance and thus were not used in the concordia age calculation. Ar-Ar dating of biotite yielded an age of 234.9 ± 2.8 Ma.

Rastorguyev Island

The U-Pb zircon and Ar-Ar amphibole dating results of one sample (9113-4) from the Rastorguyev Island pluton were previously reported by Vernikovsky et al. (2003) as defining a crystallization age of 249.0 ± 5.2 Ma. Our sample 108-1a (see Fig. 2 for sample location) yielded an Ar-Ar amphibole age of 226.3 ± 5.6 Ma, which is slightly younger than the Ar-Ar amphibole age of 232.9 ± 1.4 Ma reported by Vernikovsky et al. (2003).

Summary

It should be noted that for three of the seven samples (118-11, 192-2, and 68002), the number of zircons used for concordia age calculation is limited to three or four grains but still with reasonable MSWD that doesn’t exceed 1.8. Furthermore, the calculated age of these samples is confirmed by the age of the samples (118-6 and 192-3) dated in close proximity (East Vorontsova Peninsula, West Vorontsova Peninsula, Plavnikoye Islands, and Lenivaya River). The other group incorporates syenites, monzonites, and quartz monzonites (West Kamenny Island, Rastorguyev Island, and Astronomicheskiy Creek). Whole rock geochemistry of the granites–granodiorites is characterized by Sr contents with an increasing 87Sr/86Sr ratio but show no age dependence (Fig. 5B). The mafic rocks from Taimyr display a broadly inverse relationship between 87Sr–Nd isotopic compositions and SiO2 content, and thus the most isotopically depleted samples are characterized by the highest SiO2 contents (Figs. 5C–5D).

WHOLE ROCK Sr-Nd

Calculated 206Pb/238Sr, ratios of latest Permian–Early Triassic granites (East Vorontsova Peninsula, Astronomicheskiy Creek) are 0.70377 and 0.70587 with εNd(t) values of 1.2 and −5.5 and two-stage Nd isotopic model ages of 0.97 and 1.61 Ga. Middle Triassic (Ladinian)–Late Triassic (Carnian–Norian) granites (Plavnikoye Islands, West Kamenny Island, and Rastorguev Island) have calculated 206Pb/238Sr, ratios ranging from 0.70461 to 0.70607, εNd(t) values ranging from −5.5 to −0.2, and two-stage Nd isotopic model ages ranging from 0.82 to 1.15 Ga (Fig. 5; Table S3). Samples are characterized by εSr contents with an increasing 206Pb/238Sr ratio but show no age dependence (Fig. 5B). The mafic rocks from Taimyr display a broadly inverse relationship between Sr–Nd isotopic compositions and SiO2 content, and thus the most isotopically depleted samples are characterized by the highest SiO2 contents (Figs. 5C–5D).

DISCUSSION

Petrogenesis and Source of the Taimyr Granites

The samples can be divided in two groups based on petrographic and geochemical data. One group includes granites and granodiorites (East Vorontsova Peninsula, West Vorontsova Peninsula, Plavnikoye Islands, and Lenivaya River). The other group incorporates syenites, monzonites, and quartz monzonites (West Kamenny Island, Rastorguyev Island, and Astronomicheskiy Creek). Whole rock geochemistry of the granites–granodiorites is characterized by peraluminous, alkali-calcic, and calc-alkalic signature, while the syenites–monzonites group has metaluminous alkalic character (Figs. 3D–3E; Table 2). In addition, granites–granodiorites are lower in REEs than syenites–monzonites. Granites–granodiorites have generally lower 206Pb/238Sr, ratios and higher εNd(t) values than syenites–monzonites (Fig. 5A; Table 2).

Furthermore, relative to the granites–granodiorites, the syenites–monzonites are enriched in compatible elements Ba, Sr, Zr, and Eu (Fig. 6) and are also characterized by a positive Eu anomaly. Deering and Bachmann (2010) showed that high Zr concentration in addition to the Zr/Hf ratios may indicate a cumulate residue. On the Zr/Hf–Zr diagram, syenite–monzonite samples correspond to cumulate residues. This geochemical composition suggests that the syenites–monzonites represent the products of residual crystal concentration (silicic cumulates) (Bachmann and Bergantz, 2004, 2008a; Schaen et al., 2017, 2018). Silicic cumulates must be formed through the extraction of rhyolite melt (Schaen et al., 2018). The Taimyr granites–granodiorites are depleted in rare earth elements Ba, Sr, Zr, and Eu, which is typical of extracted rhyolite melt (Bachmann and Bergantz, 2004, 2008a). Such depletion occurs due to the extraction of interstitial melt from crystal-rich mush systems (Bachmann and Bergantz, 2004, 2008a; Bachmann and Huber, 2016; Hildreth, 2004; Schaen et al., 2017, 2018).

The residual crystal concentration is also supported by the textural features of the syenites–monzonites, which are characterized by porphyritic texture (Table 2) containing euhedral minerals (plagioclase, orthoclase, and amphibole) that may represent crystallization of the melts in the cold mid- to upper crust. However, recent studies show that these textural features, combined with the trace element distribution described above, indicate cumulate origin (Deering and Bachmann, 2010; Irvine, 1982; Schaen et al., 2018; Vernon and Collins, 2011; Wiebe et al., 2002).

Previously described latest Permian–Triassic syenite-granite intrusions from Taimyr (Proskurnina et al., 2019; Vernikovsky et al., 2003) were interpreted in the perspective of the genetic classification. Vernikovsky et al. (2003) considered the syenite-granite intrusions of northwestern Taimyr as A-type granites, while Proskurnina et al. (2019) interpreted the northern Taimyr intrusions as SH-type (shoshonitic) granites. The geochemical compositions of these syenite-granite intrusions cluster close...
to the syenites–monzonites described in this study (Figs. 3–5). They are also enriched in trace elements and compatible trace elements (Ba, Sr, Zr, and Eu), which suggests they are composed of silicic cumulate as well. However, samples described by Proskurnina et al. (2019) generally have a slightly negative Eu anomaly that is uncommon for silicic cumulate (Bachmann and Bergantz, 2004; Deering and Bachmann, 2010). At the same time, Schaan et al. (2017) note that a positive Eu anomaly is not required in silicic cumulates if accumulation has occurred from a magma with low Eu concentration. Overall, we find that the Taimyr silicic intrusions have textural characteristics and compositional trends that are consistent with complementary crystal accumulation (i.e., formation of silicic cumulates) and melt segregation (Bachmann and Bergantz, 2016; Fiedrich et al., 2017; Laurent et al., 2020; Schaan et al., 2017, 2018; Tavazzani et al., 2020). The isotopic composition of Taimyr syenite–granite intrusions (Table S3; Fig. 5) suggests that they were derived from an open magmatic system with a heterogeneous source (Fig. 5A) that is characterized by varying degrees of mixing of mantle and crustal components. The unfractonated HREE distribution implies an insignificant garnet content or its absence in protolith (Tikhomirov et al., 2008), which indicates the origin of parental magma from garnet-free complexes that could present in the lower continental crust (amphibolites or pyroxene gneisses) (Tikhomirov et al., 2008; Wilson, 1989). Enrichment in LREE and depletion in HFSE (Nb and Ta) indicate the substantial assimilation of crustal material (Barth et al., 2000; Green, 1995). Assimilation of the older crustal material is supported by the Neo-Mesoproterozoic Nd model (TDMt) ages (Table 2). Our data correlate well with previously published isotopic data from the syenite-granite intrusions of northwestern Taimyr (Vernikovsky et al., 2003), which suggests a similar crustal contribution for all intrusions. A heterogeneous source is typical of LIPs, where mixing of depleted mantle, enriched mantle, and continental crust often occur (Haapala et al., 2007; Pietruszka et al., 2009; Sharma et al., 1992; Vernikovsky et al., 2003).

Silicic cumulates are known to be found in extensional environments (Bachl et al., 2001). In the Late Permian–Triassic, extension caused by the Siberian Traps LIP activity (Krivolutskaya et al., 2019; Saunders et al., 2005) affected the Taimyr–Severnaya Zemlya fold-and-thrust belt. Thereby, we propose emplacement of the Late Permian–Middle Triassic Taimyr syenite–granite intrusions to be the result of Siberian Traps LIP magmatic activity as was suggested by Augland et al. (2019) and Vernikovsky et al. (2003). In addition, the magmen, calc-alkaline, meta- to peraluminous signature of these intrusions is characteristic of extensional environments (Bea et al., 2007; Frost et al., 2001). Overall, textures, geochemical and isotopic compositions demonstrate that syenites–monzonites
TABLE 2. TEXTURAL, GEOCHEMICAL, AND ISOTOPIC PARAMETERS OF THE TAIMYR GRANITIC INTRUSIONS

| Texture                        | ASI / MALI indexes (Frost et al., 2001) | ∑ REE (ppm) | 87Sr/86Sr(i) | εNd(t) | TDM1 |
|--------------------------------|----------------------------------------|-------------|-------------|--------|------|
| Granites–granodiorites         |                                        | 29–194      | 0.70377–0.70467 | +1.18–−1.0 | 1.01–0.81 |
| Equigranular, hypidiomorphic   |                                        |             |             |        |      |
| Peraluminous/alkali-calc-calci calc-alkalic                |             |             |             |        |      |
| Syenites–monzonites            |                                        | 203–396     | 0.70561–0.70607 | −3.9–−6.9 | 1.24–1.09 |
| Porphyritic                    |                                        |             |             |        |      |
| Metaluminous/alkalic           |                                        |             |             |        |      |

Note: ASI—aluminum saturation index; MALI—modified alkali lime index.

and the granite–granodiorites are complementary magmatic units that represent the end-member, crystal-rich versus liquid-rich equivalent of the same initial evolved melt (Bachmann and Bergantz, 2004, 2008a; Tavazzani et al., 2020). The incidence of plutonic masses with clear crystal accumulation zones suggests the presence of mush zones within the crust (Bachmann and Huber, 2016) in the Siberian LIP. The existence of mush zones (mush model; Bachmann and Bergantz, 2004, 2008b; Bachmann and Huber, 2016; Hildreth, 2004) implies the emplacement of Siberian Traps LIP mafic magmas into the lower crust, which underwent assimilation and fractional crystallization that produced voluminous mafic to intermediate and silicic mush reservoirs in lower crustal, mid-crustal, and upper crustal levels, respectively (Fig. 7) (Bachmann and Huber, 2016). Fractionation and melt extraction in upper crustal silicic mush led to the formation of the syenites–monzonites (silicic cumulate) and the granites–granodiorites (extracted melt counterpart).

Geochronological Record of Siberian Traps LIP Magmatic Pulses in Taimyr

Our new geochronological data allow us to determine two magmatic events within the Taimyr–Severnaya Zemlya fold-and-thrust belt during the latest Permian–Early Triassic and during the Middle–Late Triassic. U-Pb zircon ages of the studied intrusions range from ca. 253–228 Ma (Fig. 8; Table 1) and define the crystallization age of the plutons studied.

Our data from the East Vorontsova Peninsula (ca. 248.5 Ma and 252.8 Ma), which agree with previously published U-Pb zircon ages (Augland et al., 2019; Khudoley et al., 2018; Vernikovsky et al., 2003), allow us to determine that plume-related syenite-granite bodies were emplaced in the Taimyr–Severnaya Zemlya fold-and-thrust belt between ca. 253 Ma and ca. 249 Ma (latest Permian–Early Triassic). These ages strongly correlate with the main pulse of Siberian Traps LIP magmatic activity between ca. 252–248 Ma (Burgess and Bowring, 2015; Ernst, 2014; Kamo et al., 1996, 2003). The ca. 242–241 Ma syenite intrusions of the Central and

Figure 6. Whole-rock major and trace element variation diagrams for granites studied are compared with previously published data (Proskurnina et al., 2019; Vernikovsky et al., 2003): (A) Ba (ppm) vs. Sr (ppm); (B) Zr/Hf (ppm) vs. Zr (ppm); (C) Zr (ppm) vs. SiO$_2$ (wt%); (D) Eu (ppm) vs. SiO$_2$ (wt%).
Southern Taimyr Domains described by Vernikovsky et al. (2003) are also considered to be associated with the main magmatic pulse of the Siberian Traps LIP (Fig. 8). Furthermore, Walderhaug et al. (2005) reported ca. 248 Ma (plagioclase Ar-Ar) basalt flow from the Southern Taimyr Domain and related it to the Siberian Trap magmatism.

However, Siberian Traps LIP magmatic activity encompassed a duration of 22–26 m.y. with a series of minor pulses continuing into the Middle–Late Triassic (ca. 240–230 Ma) (Ivanov et al., 2013; Puchkov, 2009, 2010; Walderhaug et al., 2005). Our U-Pb zircon ages from the West Vorontsova Peninsula, West Kamenny Island, and Plavnikovye Island plutons yield ages between ca. 239.1 Ma and 235.2 Ma, which correlates with the timing of these Middle–Late Triassic magmatic pulses (Fig. 8).

Syenite-granite intrusions of a similar age (ca. 241–233 Ma) from the Northern Taimyr Domain have been described by Proskurnina et al. (2019). However, the Lenivaya River granodiorites are notably younger and were emplaced at ca. 227.5 Ma, although a coeval (229.0 ± 0.4 Ma) granite intrusion

Figure 7. Latest Permian–Triassic large igneous province magmatic system scheme for Siberia and Taimyr is shown. Emplacement of Siberian Traps large igneous province mafic magmas in the lower crust produced mush reservoirs at all crustal levels, which led to the formation of the Taimyr granitic intrusions.

Figure 8. Dating results for the intrusions using U-Pb and Ar-Ar methods are shown. Taimyr granitic intrusion ages correlate well with the Siberian large igneous province (LIP) main and minor magmatic pulse ages. Error bars are 2σ. T1—Lopingian, T2—Lower Triassic, T3—Middle Triassic, T4—Upper Triassic. Dashed lines show the epoch boundary.

This study Previously published

d. Sample location
g. Ar-Ar amphibole age
h. Khudoley et al., 2018
i. Augland et al., 2019
j. Vernikovsky et al., 2003
k. Proskurnina et al., 2019

(a) East Vorontsova Peninsula b. West Vorontsova Peninsula c. Plavnikovye Islands d. Lenivaya River e. West Kamenny Island f. Rastorguyev Island g. Khudoley et al., 2018 h. Vernikovsky et al., 2003 i. Augland et al., 2019 j. Proskurnina et al., 2019
has been described in the Noril'sk-Kharaelakh region (Kamo et al., 2003).

It is notable that silicic cumulates of different ages (West Kamenny Island, Rastorguyev Island, and Astronomicheskiy Creek) generate a cluster on isotopic plots (Fig. 5A) as well as their extracted melt counterparts (East Vorontsova Peninsula and Plavnikovo Islands). This dependence likely indicates that the silicic cumulate accumulation–melt extraction magmatic process was repeatedly induced by Siberian LIP magmatic pulses.

In addition, the age distribution of detrital zircons in Mesozoic sedimentary and volcano-sedimentary rocks from the northeastern part of the Siberian Craton (Grahamov et al., 2013, 2015; Letnikova et al., 2014) encompasses both the latest Permian–Early Triassic and Middle–Late Triassic magmatic pulses of the Siberian Traps LIP.

Ar-Ar ages match the U-Pb zircon ages for samples 118-6 (East Vorontsova Peninsula) and 111-1 (West Kamenny Island), which suggests rapid cooling. However, the Ar-Ar mica age is significantly younger for sample 118-11 (East Vorontsova Peninsula) than the U-Pb zircon age (Fig. 8), and there is a similar discrepancy of Ar-Ar amphibole age described for Rastorguyev Island syenite-granite intrusion by Vernikovsky et al. (2003). These ages match the crystallization ages of younger intrusions (Fig. 8), so we suggest that the emplacement of the younger intrusions supplied sufficient heat to reset the Ar-Ar system in the samples. However, the East Vorontsova rocks are so close in proximity that heat flow from the younger magmatic pulses would have likely affected both biotite ages. Therefore, we propose that there must have been localized heating via hydrothermal activity associated with the younger magmatic pulse of Siberian Traps magmatism to reset the biotite age of sample 118-11. This is supported by the signs of hydrothermal alteration in sample 118-11; sample 118-6 does not appear to be hydrothermally altered.

**Thermal Effect of Siberian Traps LIP Magmatic Pulses on Taimyr**

The thermal effect of magmatism related to the Siberian Traps LIP and its influence across the Taimyr–Severnaya Zemlya fold-and-thrust belt remains insufficiently studied. Recently published apatite fission track (AFT) dating results (Khudoley et al., 2018; Zhang et al., 2018) only provide information on early Mesozoic thermal events in the region. AFT ages from the Central and Northern Taimyr Domains range between 245.7 + 12.6 Ma and 197.6 + 8.8 Ma (Zhang et al., 2018). They can be divided into three age groups that include those reheated by Siberian Traps LIP magmatism during the Early–Middle Triassic (ca. 245–230 Ma), inversion/uplift triggered by LIP volcanism in the Late Triassic with an average age of ca. 217 Ma, and shallow burial of rocks during the Late Triassic–Early Jurassic (Zhang et al., 2018). On the other hand, (Khudoley et al., 2018) argue that the latest Triassic–earliest Jurassic tectonic event led to a complete resetting of AFT ages in some samples in the Northern and Central Taimyr Domains. In addition, the 198 Ma Ar-Ar plagioclase age from dolerite sill (Southern Taimyr Domain) was also attributed to the fold-deformation episode (Walderhaug et al., 2005). Our data correlate with the Early–Late Triassic AFT data (Zhang et al., 2018) and support a geothermal effect of Siberian Traps LIP magmatism in the region studied. At the same time, our data indicate that heating associated with Middle–Late Triassic granite intrusion emplacement was limited. Therefore, further research is required to better understand the relationship between Siberian Traps LIP magmatism and latest Triassic–earliest Jurassic tectonic events within the Taimyr–Severnaya Zemlya fold-and-thrust belt.

**CONCLUSIONS**

1. Our new U-Pb zircon age data define the crystallization age of the Taimyr intrusions studied as ca. 253–228 Ma, which ranges from latest Permian (Changhsingian) to Late Triassic (Carnian). The U-Pb zircon age distribution suggests that two magmatic pulses spanned the latest Permian–Early Triassic and the Middle–Late Triassic.

2. Some of the Ar-Ar ages suggest rapid cooling of the intrusions studied. However, younger Ar-Ar ages of a few samples were reset by the second heating and hydrothermal activity associated with the emplacement of Middle–Late Triassic syenite-granite intrusions.

3. Textural features and compositional trends observed in Taimyr granitic rocks suggest accumulation (i.e., formation of silicic cumulates) and melt segregation in a silicic system. The syenites–monzonites represent the products of residual crystal concentration within the silicic mush (silicic cumulates). The granites–granodiorites were formed via extraction of rhyolite melt from mush (melt-rich counterparts).

4. Emplacement of Siberian Traps LIP mafic magmas in the lower crust produced mafic reservoirs in the lower-, mid-, and upper crustal levels. Fractionation and high silica melt extraction in upper crustal silicic mush led to the formation of the Late Permian–Triassic Taimyr granitic plutons.

5. We propose that the formation of the mush zone that generated the latest Permian–Early Triassic and Middle–Late Triassic granitic intrusions of Taimyr was associated with the two pulses of Siberian Traps LIP magmatism. The main magmatic pulse between ca. 253 Ma and 248 Ma was followed by a series of minor pulses between ca. 239 Ma and 228 Ma. Large silicic magma chambers are often considered to be upper crustal bodies that are predominantly kept at high crystallinity (e.g., “mush” model; Bachmann and Huber, 2016; Hildreth, 2004; Tavazzani et al., 2020) and episodically recharged by injections from lower crustal reservoirs (Annen et al., 2015; Bachmann and Huber, 2016). Our work characterizes the Taimyr granites as silicic cumulates and elaborates on the connection between silicic magma chambers (crystal mush zones) and large igneous provinces and thereby elucidates the magmatic processes that facilitate the evolution of the continental crust.

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