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Late Neoproterozoic adakites of the Yenisei Ridge (*Central Siberia*): petrogenesis, geodynamics, and U/Pb age

A.E. Vernikovskaya [a,b,*], V.A. Vernikovsky [a,b], N.Yu. Matushkin [a,b], P.I. Kadil'nikov [a,b], I.V. Romanova [a,b], A.N. Larionov [c]

[a] *A.A. Trofimuk Institute of Petroleum Geology and Geophysics, Siberian Branch of the Russian Academy of Sciences, pr. Akademika Koptyuga 3, Novosibirsk, 630090, Russia*

[b] *Novosibirsk State University, ul. Pirogova 2, Novosibirsk, 630090, Russia*

[c] *A.P. Karpinsky Russian Geological Research Institute, Srednii pr. 74, St. Petersburg, 199106, Russia*

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Abstract

Based on new geological, structural, mineralogical, geochemical, and isotope (Sm–Nd, Rb–Sr, and U–Th–Pb) data for igneous intrusions and metamorphic rocks of the Zimoveinyi massif, an adakite-gabbroid association was identified for the first time in the Yenisei Ridge (southwestern framing of the Siberian craton). This study demonstrates that the adakites (quartz diorites, tonalites, and plagiogranites) and associating gabbro-anorthosites of this massif formed in the interval 576–546 Ma (U–Th–Pb zircon SHRIMP-II analysis) at the final Neoproterozoic evolution stage of the active continental margin of the Siberian craton. Our results point to a genetic relationship between the adakites and the host Nb-enriched metabasites of the Zimoveinyi massif. The studied late Neoproterozoic adakites might have formed in the setting of transform strike-slip of lithospheric plates during a halt in subduction from both crustal and mantle-crustal source, similarly to Cenozoic igneous complexes of the transform margin in the eastern framing of Eurasia.

Keywords: adakites; gabbro-anorthosites; Nb-enriched metabasites; U–Th–Pb; Sm–Nd; Rb–Sr isotope data; late Neoproterozoic; active and transform continental margin; Siberian craton; Yenisei Ridge

Introduction

Studies of the petrogenesis and geodynamic settings of adakites formation, including granitoids, cause profound interest due to the similarities of their geochemical characteristics to rocks of the tonalite-trondhjemite-granodiorite (TTG) association. This is mainly the case of high Na_2O contents, Na_2O/K_2O and Sr/Y ratios as well as to depleted contents of heavy rare earth elements in the rocks (Defant et al., 1992; Drummond and Defant, 1990; Martin, 1999). By contrast with the TTG association, which characterizes the formation of continental crust in the Archean (Taylor and McLennan, 1985), the study of adakites is important for the understanding of the continental crust growth process in the post-Archean time. It is assumed that partial melting of the young hot subducting lithosphere in an elevated geothermal gradient setting was the dominating process of crust formation in the Archean. Physicochemical conditions favorable to the formation of magmas similar to TTG in composition occur in limited *P–T* modes that correspond to stable garnet conditions, which elevates the interest in finding out the geodynamic settings of their origin. In comparison to TTG rocks, adakites differ by significantly smaller volumes of rocks manifestation and a wider range of geodynamic settings. These rocks are divided into several classification types by geochemical and geodynamic characteristics, as is summarized, for example in (Xiao and Clemens, 2007; Zhang et al., 2005). Tholeitic and calc-alkaline adakites are results of melting of young and hot subducting oceanic slabs. Formation of more potassium enriched calk-alkaline variations is due to more high-temperature processes taking place at the base of the continental crust, when it is thickened in an active continental margin setting or during a collision event. The question of magmatic sources of these rocks is often debated. For potassium-enriched adakites this source can be the newly formed material of the mafic layer at the base of the lower crust or rocks similar to TTG in composition.

* Corresponding author.
E-mail address: VernikovskayaAE@ipgg.sbras.ru (A.E. Vernikovskaya)

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To understand the petrogenesis and geodynamic settings of adakites formation a large role must be given to the study of associating igneous and metamorphic rocks. For example, in the geological literature beginning with (Defand and Drummond, 1990), the origin and genetic meaning of associations of adakites with Nb-enriched basalts (NEB-type) are widely discussed (Aguillón-Robles et al., 2001; Castillo, 2006; Petrone and Ferrari, 2008; Zhang et al., 2005). In tackling these issues, in particular when dealing with ancient rocks, it is important to understand the evolution of the host tectonic structure, for example an accretionary-collisional belt, as well as the geochemical affinity of its various igneous complexes. The Yenisei Ridge orogen (Fig. 1) in the southwestern framing of the Siberian craton, is one of such regions with a long history of Neoproterozoic magmatic events. The orogen is separated in two by the latitudinal Angara fault: the Transangarian and the South Yenisei segments.

In the Yenisei Ridge, we were able to identify for the first time an association of adakites and gabbroids intruding metabasites. The latter are traditionally considered as the Zimoveinyi gabbroid massif (Precambrian…, 1986) and have been later attributed to the oldest (NA?–PP) ophiolites in the margin of the Siberian craton (Popov and Izokh, 2013). At the same time the high level of metamorphism of these rocks, their uncertain geochemical affinity, and the lack until now of age estimates for the various (from mafic to acidic) igneous formations intruding them, left unanswered the questions of petrogenesis and geodynamic settings for the formation of the igneous and metamorphic rocks of the Zimoveinyi massif. Results in this study combine geostructural, mineralogical, geochemical and newly obtained U–Th–Pb geochronological (SHRIMP-II zircon method) data indicate that a late Neoproterozoic magmatic event took place, characterizing the early geodynamic evolution stage of the Central Asian fold belt.

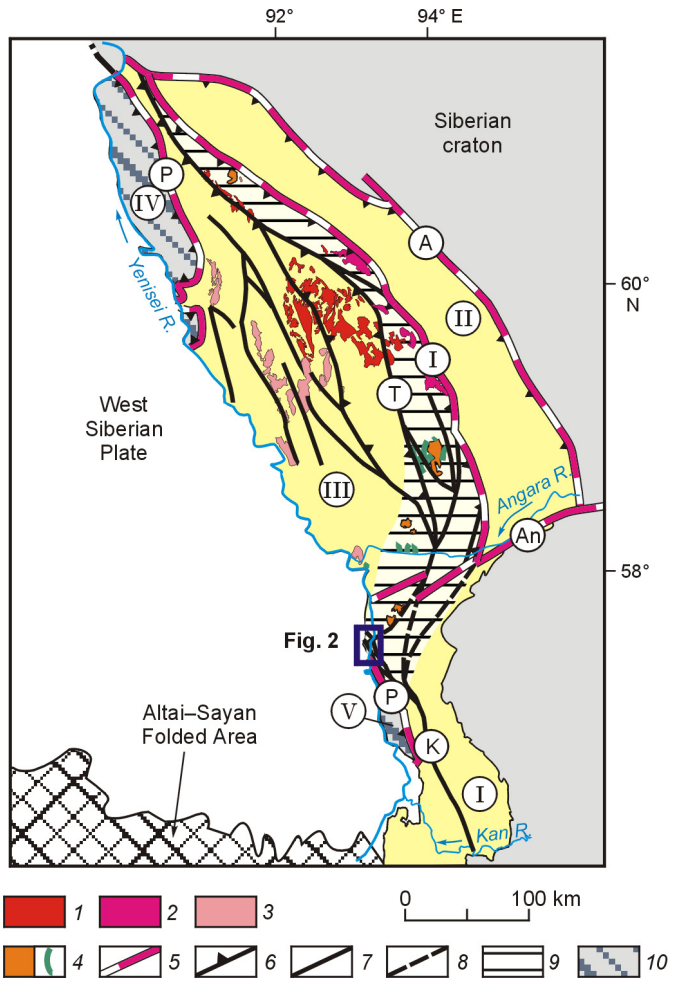

Fig. 1. Scheme of tectonics and Neoproterozoic magmatism of the Yenisei Ridge, composed using (Kachevsky et al., 1998; Romanova et al., 2012; Vernikovsky et al., 2003, 2008, 2016). *1*, Teya collisional complex granitoids (883–861 Ma); *2*, Ayakhta syncollisional complex granitoids (761–749 Ma); *3*, Glushikha postcollisional complex granitoids (752–718 Ma); *4*, alkaline and nepheline syenites, ijolites, urtites, trachytes, trachybasalts, carbonatites, and *A*-type granites of the Tatarka active continental margin complex (711–629 Ma); *5*, terrane boundaries; *6*, thrusts; *7*, identified faults; *8*, inferred faults; *9*, Tatarka–Ishimba tectonic zone; *10*, Priyenisei tectonic zone. Terranes: I, Angara Kan; II, East Angara; III, Central Angara; IV, Isakovka; V, Predivinsk. Largest faults: A, Ankinov; An, Angara; I, Ishimba; K, Kovdor; P, Priyenisei; T, Tatarka.

Regional geology and manifestation of adakitic magmatism

On the Yenisei Ridge adakites were previously discovered as part of the Teya granitoid complex aged 883–861 Ma and situated in the Central Angara terrane of the Transangarian segment of this orogen (Vernikovsky et al., 2016) (Fig. 1). Paleotectonic reconstructions for this terrane show that during the formation of the Teya complex rocks it was located far from the Siberian craton. Teya granitoids with adakite characteristics were attributed to the potassium enriched type, and their formation is linked to melting of material at the base of the continental crust caused by its extreme thickening on the final stages of the collisional process. The collision of the Central Angara terrane and the Siberian craton, during which the syncollisional Ayakhta (761–749 Ma) and postcollisional Glushikha (752–718 Ma) complexes were formed, took place only 100 Ma after the emplacement of the Teya complex rocks (Vernikovsky et al., 2003; Vernikovskaya et al., 2007). Gabbroids, trachybasalts, *A*-type granitoids, and carbonatites including contact metasomatism zones with Nb mineralization, are all typical features of the late Neoproterozoic Tatarka active continental margin complex (711–629 Ma) (Romanova et al., 2012; Vernikovskaya et al., 2013; Vernikovsky et al., 2008). These rocks are localized in the narrow band of the Tatarka–Ishimba suture zone, formed because of the collision mentioned above. The formation of carbonatite bearing igneous associations in suprasubductional complexes has been observed, for example, in the Pliocene–Quaternary magmatism of the Tyrrhenian Sea (Peccerillo and Frezzotti, 2015), which agrees with petrological modeling and numerical calculations, as well as with experimental data on the possibility of formation of carbonatite melts in such settings (Gerya and Meilick, 2011; Poli, 2015; Tumiati et al., 2013).