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Early Precambrian high-grade metamorphosed terrigenous rocks of granulite–gneiss terranes of the Sharyzhalgai uplift (*southwestern Siberian craton*)

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Abstract

We present results of geochemical and Sm–Nd isotope studies of high-grade metaterrigenous rocks of the Kitoi and northwestern Irkut terranes of the Sharyzhalgai uplift on the Siberian Platform in comparison with paragneisses of the southeastern Irkut terrane. The metasedimentary rocks of the first region are high-alumina garnet–sillimanite–cordierite-bearing paragneisses; their protoliths were mostly mudstones and pelitic mudstones by major-element composition. The low-alumina biotite gneisses of the Kitoi terrane formed, most likely, from magmatic protoliths similar in petrochemical features to intraplate volcanics. The major factor controlling the composition of the studied high-alumina paragneisses is precipitation of most of incompatible trace elements in the clay fraction of sediments, as evidenced from the positive correlation between trace-element and Al_2O_3 contents. The Cr and Ni contents, showing a positive correlation with MgO and no correlation with Al_2O_3, are an indicator of the contribution of the mafic-source material to the formation of high-alumina rocks. The contribution of a mafic source-derived material to the formation of terrigenous rocks increases in passing from Kitoi to northwestern Irkut terrane. The high-alumina and garnet–biotite paragneisses of the southeastern Irkut terrane are similar in trace-element patterns to the analogous rocks of the Kitoi terrane and northwestern part of the Irkut terrane but show higher Th contents and a distinct negative Eu anomaly related to the change in the composition of the felsic source. The participation of felsic potassic igneous rocks in the formation of the southeastern terrigenous sediments is consistent with their deposition after the Neoarchean collision processes (metamorphism and granite magmatism), whereas sedimentation in the Kitoi and northwestern Irkut terranes preceded them. The Sm–Nd isotope characteristics indicate that the latter sediments formed mostly as a result of the erosion of the Paleo-Mesoarchean crust, whereas the metasediments of the southeastern Irkut terrane formed with the participation of Paleoproterozoic juvenile rocks. Thus, the variations in the trace-element and isotope compositions of the high-grade metamorphosed terrigenous rocks reflect recycling and growth of the continental crust of the Sharyzhalgai uplift during the Neoarchean–Paleoproterozoic transition.

Keywords: Early Precambrian; metasedimentary rocks; trace elements; provenances; Sm–Nd isotope composition; growth and recycling of crust; Sharyzhalgai uplift

Introduction

The immobile behavior of rare-earth and some other trace and major elements during granulite metamorphism (except for migmatization and partial-melting processes) favors a detailed study of highly metamorphosed terrigenous sediments as indicators of the composition of provenance and the formation and evolution of continental crust. Analysis of the geochemical features of ancient terrigenous sediments helps to elucidate the evolution of their crustal sources, including probable variations in the trace-element and isotope compositions during the Archean/Proterozoic transition (Condie, 1993; Taylor and McLennan, 1985). Early Precambrian highly metamorphosed terrigenous rocks are widespread in the Irkut and Kitoi granulite–gneiss terranes of the Sharyzhalgai uplift in the southwest of the Siberian craton. The variations in contents of Fe, Ti, Cr, Ni, and Sc and in Cr/Th and La/Sc in high-alumina (garnet–cordierite–biotite) and garnet–biotite paragneisses of the southeastern Irkut terrane reflect different contributions of mafic rocks in the provenance, whereas the distinct negative Eu anomaly marks the contribution of felsic

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potassic igneous rocks to sedimentation (Turkina and Urmantseva, 2009). In this paper we present results of study of the mineral, geochemical, and Sm–Nd isotope composition of Early Precambrian terrigenous metasediments in the Irkut and Kitoi terranes of the Sharyzhalgai uplift. The different structural positions and timing of metamorphism of these rocks (1.85–1.86 Ga, southeastern part of the Irkut terrane, and ~2.5–2.6 Ga, Kitoi terrane) point to their different ages (Glebovitskii et al., 2011; Poller et al., 2005; Turkina et al., 2010) and make it possible to trace the change in the sediment composition from Archean to Paleoproterozoic and thus elucidate the crustal evolution of this crustal segment.

Geologic structure, composition, and age of rocks in the southeast of the Sharyzhalgai uplift

The Sharyzhalgai uplift is the exposed southern margin of the Tunguska province in the basement of the Siberian Platform (Fig. 1*A*). Four structural terranes are recognized in the uplift from NW to SE: Bulun and Onot granite–greenstone and Kitoi and Irkut granulite–gneiss. Their boundaries run along the regional faults of NW and N–S strikes (Fig. 1*B*). The Onot and Bulun terranes are formed by plagiogneisses and plagiogranitoids of tonalite–trondhjemite–granodiorite (TTG) composition and metasedimentary-volcanic deposits of greenstone belts (Nozhkin et al., 2001; Turkina and Nozhkin, 2008). The Kitoi and Irkut terranes, forming much of the Sharyzhalgai uplift, are composed of similar rock associations: intermediate and felsic orthogneisses, metabasites, garnet–biotite and high-alumina cordierite- and sillimanite-bearing gneisses, marbles, and calciphyres, metamorphosed from amphibolite to granulite facies conditions (Gladkochub et al., 2005; Nozhkin et al., 2001; Nozhkin and Turkina, 1993; Poller et al., 2005). In both terranes, two stages of metamorphism were established by zircon dating of metaigneous rocks, 2.55–2.6 and 1.85–1.86 Ga, which were synchronous with the granite emplacement (2.53–2.54 and 1.85–1.86 Ga) (Gladkochub et al., 2005; Poller et al., 2005; Sal'nikova et al., 2007; Turkina et al., 2012). Two units are recognized in the metamorphic complex in the southeast of the Irkut terrane (on the shore of Lake Baikal). The first unit includes metaigneous rocks: orthopyroxene-bearing and biotite gneisses and metabasites. Their protoliths formed mostly in the Neoarchean (~2.7 Ga) and underwent high-grade metamorphism in the late Neoarchean and in the Paleoproterozoic (Turkina et al., 2009, 2012). The sedimentary protoliths of garnet-bearing and high-alumina gneisses and calciphyres of the second unit were deposited in the Paleoproterozoic (≥1.95 Ga) and underwent metamorphism at ~1.85 Ga (Turkina et al., 2010; Urmantseva et al., 2012). Dating of accessory (monazite) and rock-forming (garnet) minerals showed that the high-alumina gneisses of the Kitoi terrane (area of the Kitoi sillimanite deposit) were metamorphosed at the Archean/Paleoproterozoic boundary, whereas the time of their sedimentation was not established (Glebovitskii et al., 2011). Metamorphism of rocks in the northwest of the Irkut terrane is also dated at ~2.6 Ga (Poller et al., 2005).

Structural position and mineral composition of metasedimentary rocks in the southeast of the Sharyzhalgai uplift

In **the southeast of the Irkut terrane** (Baikal shore, Irkut River area), garnet–biotite and high-alumina cordierite- and sillimanite-bearing paragneisses occur within the wide zones between granite–(charnockite)–gneiss domes (Fig. 1). The unit consists predominantly of garnet–biotite gneisses and is often migmatized and injected by veined garnet-bearing granites (Turkina and Urmantseva, 2009). Cordierite-bearing and orthopyroxene–biotite paragneisses occur as relatively thin interbeds. Metamorphosed carbonate and silicate–carbonate rocks (marbles and calciphyres) are spatially associated and sometimes alternate with garnet–biotite and high-alumina gneisses, which argues for the sedimentary nature of the latter (Urmantseva et al., 2012). The protoliths of paragneisses are Paleoproterozoic, 1.95–1.85 Ga (Turkina et al., 2010).

In **the northwest of the Irkut terrane** (watershed of the Kitoi and Toisuk Rivers), high-alumina gneisses containing garnet, cordierite, and sillimanite compose thin (≤50 m) "interbeds" (sheets) alternating with felsic orthogneisses containing orthopyroxene (Fig. 1, site 1). High-alumina gneisses occur in similar structural position in the junction zone of the Irkut and Kitoi terranes, in the interfluve of the Kitoi and Kholomkha Rivers, where a thin (10–20 m) sheet of garnet–cordierite gneisses occurs among felsic orthopyroxene gneisses (Fig. 1, site 2). Along with high-alumina varieties, there are garnet–biotite and garnet–orthopyroxene–biotite paragneisses at the watershed of the Kitoi and Toisuk Rivers and in the Kholomkha River area (Badashkova et al., 2011, 2013). The rocks in the northwest of the Irkut terrane were metamorphosed at 2623 ± 32 Ma (Poller et al., 2005) and intruded by collisional granites dated at 2.53 Ga (Gladkochub et al., 2005).

In **the Kitoi terrane** (Kitoi River area above the mouth of the Kholomkha River), high-alumina sillimanite–cordierite–garnet–biotitite (± andalusite) and garnet–biotite gneisses were found in the area of the Kitoi sillimanite deposit (Mt. Unyman Baron) (Fig. 1, site 3), and low-alumina leucocratic biotite gneisses, on the left bank of the Kitoi River (Fig. 1, site 4). These rocks were assigned to different metamorphic units. In the area of the Kitoi deposit, high-alumina and garnet–biotite gneisses are underlain by amphibole gneisses and amphibolites (Levitskii et al., 2010). The protoliths of paragneisses underwent metamorphism at the Archean/Paleoproterozoic boundary (Glebovitskii et al., 2011). Low-alumina biotite gneisses with thin concordant and cross-cutting leucosomes are underlain by a horizon of calciphyres containing silicate minerals (biotite, quartz, amphibole, garnet), which might argue for sedimentary nature of gneisses.

High-alumina gneisses of all studied sites of the Kitoi terrane and northwestern part of the Irkut terrane contain the similar mineral assemblage: Grt + Bt + Sil + Pl + Qtz ± Crd ± Spl ± Opx ± Kfs[1]. Gneisses of the Kitoi deposit show wide variations in contents of garnet (5–35%) and sillimanite

[1] The mineral symbols are given after Kretz (1983).