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Neoproterozoic ophiolite and related high-grade rocks of the Baikal–Muya belt, Siberia: Geochronology and geodynamic implications

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A B S T R A C T

We report zircon for from ophiolitic and high-grade rocks of the Neoproterozoic Baikal–Muya belt of Siberia that occupies an arc-shaped area on the southeastern margin of the Siberian craton. It consists of arc-related plutonic, metavolcanic and metasedimentary rocks as well as fragmented ophiolites and high-grade metamorphic assemblages. Magmatic zircons from two plagiogranite dyke samples of the Mamakan ophiolite complex in the Sredne–Mamakan massif of the eastern Baikal–Muya belt yielded similar and concordant SHRIMP mean $^{206}Pb/^{238}U$ ages of 640.0 ± 4.1 and 650 ± 6 Ma, respectively, that reflect the time of dyke emplacement and from which we suggest an age of ca. 645 Ma as the most likely time of ophiolite formation.

Enderbitic gneisses of the North Baikal area, in the western part of the Baikal–Muya belt, contain complex zircon populations that reflect variable recrystallization, Pb-loss and metamorphic overgrowth during granulite-facies metamorphism. LA-ICP-MS dating of these zircons yielded inconclusive results that led us to undertake a detailed study of cathodoluminescence images combined with U–Pb SHRIMP dating. Well-preserved magmatic domains in zircons from enderbite sample 2821 yielded concordant results with a mean $^{206}Pb/^{238}U$ age of 640 ± 5 Ma, slightly higher but broadly comparable with the data obtained by LA-ICP-MS. The zircon populations of two more enderbitic gneiss samples are more complex, and their LA-ICP-MS data constitute broad swaths along concordia between ca. 840 and 600 Ma, reflecting two end-member isotopic components, namely an igneous crystallization event at ca. 800 Ma and a Pb-loss and recrystallization event at ca. 600 Ma. SHRIMP analyses of magmatic zircon domains of these samples yielded concordant data with identical mean $^{206}Pb/^{238}U$ ages of 826 ± 7.5 Ma and 826 ± 8 Ma, respectively, whereas low-U metamorphic rims crystallized at 640 ± 7 Ma. Newly crystallized ball-round metamorphic zircons in one sample produced a mean $^{206}Pb/^{238}U$ age of 640 ± 6 Ma. We suggest that the protoliths of the enderbitic gneisses crystallized at 826 ± 7.5 Ma and experienced granulite-metamorphism at 640 ± 6 Ma. The LA-ICP-MS analyses are fully compatible with this interpretation.

Our geochronological data and previously published ages for Neoproterozoic igneous rocks of the Baikal–Muya belt define two age groups at 830–780 and 650–640 Ma. We interpret that the older group reflects the evolution of a large arc system in the Baikal–Muya belt and the eastern Sayan–northwestern Mongolia region, whereas the younger group documents collision between the above arc system and the southern margin of the Siberian craton.

1. Introduction

The Central Asian Orogenic Belt (CAOB, Ural-Mongolian fold belt in earlier Russian publications) is located between the Precambrian cratons of Baltica, Siberia, Tarim and North China (Fig. 1). It consists of latest Mesoproterozoic to late Palaeozoic island arcs, ophiolites, ocean islands, accretionary complexes and

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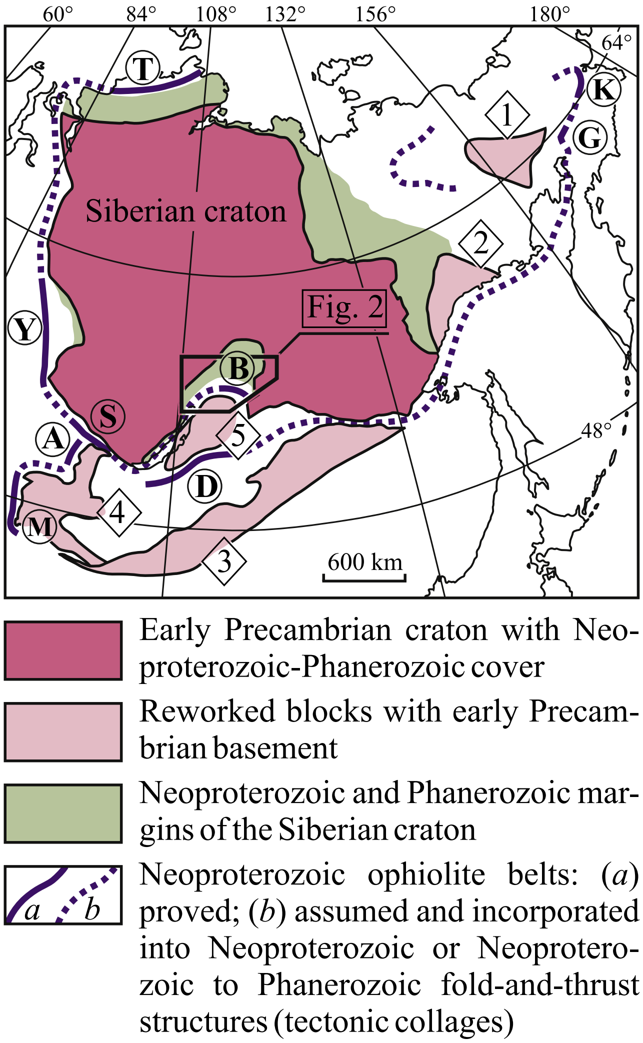

Fig. 1. Neoproterozoic (NP) ophiolite belts surrounding the Siberian craton (boundaries of the craton, continental blocks with early Precambrian basement and passive continental margins are mainly after Parfenov et al. (2010). Ophiolites incoporated within Neoproterozoic (NP) tectonic collages: T – Taimyr (Vernikovsky, 1996; Vernikovsky and Vernikovskaya, 2001), Y – Yenisey Range, Borisikha Massif (Kuzmichev et al., 2008); within NP-early Palaeozoic tectonic collages: S – Dariv-Shishkhid-Gargan zone in East Sayan Range: Dunzhugur Massif (Khain et al., 2002; Kuzmichev and Larionov, 2013), Shishkid Massif (Kuzmichev et al., 2005), M – the same zone in western Mongolia, Dariv and Khantaishir Massifs (Khain et al., 2003; Jian et al., 2014), A – Agardagh Tes-Chem ophiolite zone (Pfänder et al., 2002), B – Baikal–Muya zone (this paper); within Neoproterozoic-Palaeozoic structure: D – Dzhida (Gordienko et al., 2012) and Shaman complexes (Gordienko et al., 2009); within Mesozoic structures of the West-Koryak belt – K: Ust'-Bel'sky ophiolite complex (Tikhomirov, 2010) and related ultramafic rocks (Ledneva et al., 2012; Nekrasov and Bogomolov, 2015), and G – Ganychalan complex (Nekrasov and Makeev, 2003). Numbers in diamonds denote reworked blocks with early Precambrian basement: 1 – Omolon; 2 – Okhotsk; 3 – Argun; 4 – Central Mongolian; 5 – Barguzin.

more or less strongly reworked fragments of Archaean to Proterozoic continental massifs some of which preserve Neoproterozoic passive continental margin sequences. Many of these assemblages were tectonically dismembered during accretionary processes in the large archipelago-type Palaeo-Asian Ocean that ended in the late Palaeozoic when the numerous ocean bsins closed and collision occurred between the North China and Tarim cratons and the accreted terranes south of the Siberian craton (for reviews of the tectonic history see Wilhem et al., 2012; Kröner et al., 2014; Kröner, 2015).

The most ancient ophiolites and arc-related complexes of the CAOB surround the Siberian craton in the north (Taimyr Peninsula), southwest (Enisey Range), southwest (southern part of the East Sayan Range) and southeast (Baikalian mountain area) and constitute the Neoproterozoic Circum-Siberian Belt (Khain et al., 1997; Fig. 1). An eastern extension of this oceanic archipelago was discovered within the Cenozoic – Mesozoic domain of the northeastern margin of Asia, where remnants of Neoproterozoic ophiolites were identified (Khain et al., 1997). For example, the Ust'-Belaya ophiolite in the Koryak uplands (K in Fig. 1) contains tectonic blocks and sheets of different ages and origin. Plagiogranite from small veins in gabbro yielded a SHRIMP zircon age of 556 ± 17 (Tikhomirov, 2010), and amphibole gabbro from the same unit was dated at 799 ± 15 Ma (SHRIMP zircon age; Ledneva et al., 2012). Olivine pyroxenite from an adjacent thrust slice yielded a Sm–Nd mineral isochron age of 885 ± 83 Ma (Nekrasov and Bogomolov, 2015). The Ganychalan ophiolite complex is situated about 400 km to the southwest of the Ust'-Belaya terrane (G in Fig. 1) and contains amphibolites and gneisses from which zircons were dated at 532 ± 5 Ma (TIMS; Nekrasov and Makeev, 2003).

Neoproterozoic passive margin sequences are exposed along the present-day margins of the Siberian craton in the southwest (Enisey Range and the northern part of East Sayan Range, Sovetov et al., 2007; Sovetov, 2011), south and southeast (Baikalian mountain area, Patom uplands, Stanevich et al., 2007), and in the east (Yudoma-Maya area and Sette-Daban Range, Khudoley et al., 2001) (Fig. 1). These clastic-carbonate sequences unconformably overlie a Palaeoproterozoic metamorphic basement in the northern East Sayan Range (Sovetov, 2011) and in western Cisbaikalia (Gladkochub et al., 2013). They are mainly composed of clastic sedimentary rocks interlayered with carbonates and calcareous schists, mafic volcaniclastic rocks and glacial deposits. These successions reflect passive continental margin settings and tidal deposition on broad shelves recognized in detail on the southwestern margin of the Siberian craton between ca.750 and 540 Ma (Sovetov et al., 2007).

The Neoproterozoic history of the Circum-Siberian belt is recorded since about 1 Ga. A supra-subduction zone assemblage with an age of ca. 1020 Ma was revealed in the Dunzhungur ophiolite of East Sayan (Khain et al., 2002; Kuzmichev and Larionov, 2013), and by a 1017 ± 47 Ma subduction-related tonalite–trondhjemite suite identified in the Arzybey Complex in the northern part of East Sayan (Turkina et al., 2004). Metamorphosed N-MORB basalts (now amphibolites) were recognized in the roof zone of the Angaro-Vitim Batholith (Fig. 1) where an amphibolite was dated at 918 ± 15 Ma, a plagiogranite-gneiss associated with these amphibolites yielded an age of 972 ± 14 Ma (SHRIMP zircon studies, Nekrasov et al., 2007; Ruzhentsev et al., 2010), and a gabbro from this area yielded a SHRIMP zircon age of 939 ± 11 (Gordienko et al., 2009, 2010). Arc-related volcanic and ophiolitic sequences, formed at about 830–780 Ma ago, constitute an extensive belt in northern Mongolia and East Sayan (Kuzmichev et al., 2005; Kuzmichev and Larionov, 2011), and metavolcanic rocks, granites and gabbroic rocks with similar ages and with supra-subdution zone affinities occur in the Baikal–Muya belt (Izokh et al., 1998; Rytsk et al., 2001a,b) (Fig. 2). A Neoproterozoic active margin was also recognized in the Priolkhonie region (Fig. 1), based on zircon ages from a high-grade metamorphic complex (Gladkochub et al., 2010).

The Baikal–Muya belt consists of Neoproterozoic arc-related magmatic, metavolcanic and metasedimentary rocks, ophiolites and carbonates. It occupies an arc-shape area located between the margin of the Siberian craton (Baikal–Patom belt), and the Barguzin block (Fig. 2). It is situated in the northern part of the Baikal area and represents a Neoprotorozoic terrane that was slightly reworked during Palaeozoic magmatism. The geological events preserved in this belt provide data for the time interval