Available online at www.sciencedirect.com

ScienceDirect

RUSSIAN GEOLOGY AND GEOPHYSICS

Russian Geology and Geophysics 57 (2016) 773–789

www.elsevier.com/locate/rgg

Late Paleozoic granitoid magmatism of Eastern Kazakhstan and Western Transbaikalia: plume model test

S.V. Khromykh [a,b,*], A.A. Tsygankov [c,d], P.D. Kotler [a,b], O.V. Navozov [e,†], N.N. Kruk [a], A.G. Vladimirov [a,b], A.V. Travin [a], D.S. Yudin [a], G.N. Burmakina [c], V.B. Khubanov [c,d], M.D. Buyantuev [c], T.N. Antsiferova [c,d], G.S. Karavaeva [e]

[a] *V.S. Sobolev Institute of Geology and Mineralogy, 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] *Geological Institute, Siberian Branch of the Russian Academy of Sciences, ul. Sakh'yanovoi 6a, Ulan-Ude, 670047, Russia*
[d] *Buryat State University, ul. Smolina 24a, Ulan-Ude, 670000, Russia*
[e] *Topaz Geological Exploration Company Ltd., ul. Geologicheskaya 1, Ust'-Kamenogorsk, 070001, Kazakhstan*

Received 8 July 2015; accepted 24 September 2015

Abstract

We present results of a comparative study of Late Paleozoic granitoids of Eastern Kazakhstan and Western Transbaikalia composing the large Kalba–Narym and Angara–Vitim batholiths. We have established that despite the different geologic history of these regions, granitoid magmatism there proceeded nearly synchronously at the Carboniferous/Permian boundary (330–280 Ma) and was accompanied by mantle magmatism. The regularities of its evolution are considered in terms of the plume model and different stages of interaction of mantle plumes with the lithosphere. The major principles of plume–lithosphere interaction in accretion–collision fold belts have been formulated: (1) Plume–lithosphere interaction results in large-scale melting of sublithospheric mantle, lower lithosphere, and crustal substrates warmed by the preceding orogenic processes; (2) The processes last 30 to 50 Myr and produce large volumes of igneous rocks, mostly granitoids; (3) The sequence of formation of granitoid and basic igneous complexes and the metallogenic specialization can be different and depend on the lithosphere structure and preceding geologic history of the region.

Keywords: granitoid batholiths; large igneous provinces; plume–lithosphere interaction; Central Asian Orogenic Belt

Introduction

Recent geological, petrological, and isotope–geochronological studies have revealed manifestations of mantle plumes and superplumes in the Earth's Phanerozoic evolution and have shown their important role in the evolution of the continental crust and in the formation of ore deposits (Dobretsov et al., 2010; Yarmolyuk and Kovalenko, 2003; Yarmolyuk and Kuzmin, 2012). Analysis of plume manifestations permitted defining indicator large igneous provinces (LIP) within Phanerozoic fold systems. In these provinces, widespread granitoids of different types form large batholiths. The following plume-related LIP are recognized in Central Asia: Barguzin (Transbaikalia), Hentiyn and Hangayn (Mongolia), and Tarim (western China, Mongolia, and Eastern Kazakhstan) (Dobretsov et al., 2010; Yarmolyuk et al., 2013, 2014).

Importantly, Western Transbaikalia and Eastern Kazakhstan are similar in the widespread occurrence of granitoid magmatism, peaking at the Carboniferous/Permian boundary (Kotler et al., 2015a; Tsygankov, 2014; Tsygankov et al., 2007; Yarmolyuk et al., 1997). These events resulted in the formation of large granitoid batholiths—Angara–Vitim (Transbaikalia) and Kalba–Narym (Eastern Kazakhstan). Till the late 20th century, this process was conventionally attributed to accretion–collisional events on the margins of the Siberian paleocontinent, whereas the small-scale basic magmatism accompanying the granitoids was regarded as a result of post-collision extension (Bulgatov and Gordienko, 1999; D'yachkov et al., 1994; Gordienko, 1987; Litvinovsky et al., 1993; Lopatnikov et al., 1982). However, in recent years, evidence

* Corresponding author.
E-mail address: serkhrom@mail.ru (S.V. Khromykh)
† Deceased.

1068-7971/$ - see front matter © 2016, V.S. Sobolev IGM, Siberian Branch of the RAS. Published by Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.rgg.2015.09.018

has been obtained for the synchronous occurrence of large-scale mantle magmatism accompanied by indicator mineralization and represented by basaltoids of trap associations, alkaline basic intrusions, gabbrosyenite–granite series, and belts of composite dikes (Burmakina and Tsygankov, 2013; Khromykh et al., 2013; Khubanov, 2009; Pirajno et al., 2009; Xu et al., 2014; Yarmolyuk et al., 2014). Analyzing the recent data on the composition and age of the granitoids of the Kalba–Narym and Angara–Vitim batholiths, the authors made the conclusion that their genesis should be considered in terms of plume–lithosphere interaction. With regard to the different geologic structures and evolutions of Eastern Kazakhstan and Western Transbaikalia, the present work is aimed at the analysis and correlation of sequence of magmatism and the evolution of its composition; also, it is concerned with the testing of "the plume model" whether it can explain Late Paleozoic magmatism in these two regions.

Geologic position

The granitoids of the Kalba–Narym batholith occupy at least half the Kalba–Narym turbidite terrane (KNTT), belonging to the Altai collision–strike-slip system of Hercynides, which formed in the western Central Asian Orogenic Belt during the interaction between Siberian and Kazakhstan continents (Vladimirov et al., 2003). The Kalba–Narym terrane is part of a continent-marginal basin on the oceanic basement, whereas its sedimentary filling might have accumulated on the slopes and in the axial part of a deep-sea trench at the edge of the Siberian paleocontinent. The results of studies of the sedimentary strata (Kotler et al., 2015b) testify to slight changes in composition from Middle Devonian to late Early Carboniferous and show that the Kalba–Narym sediments formed from substrates of low maturity (probably, the Devonian volcanic complexes of the Altai active continental margin of the Siberian continent). Collision interaction between Siberian and Kazakhstan continents caused the deformation of the sediments and their compression in NW-striking near-isoclinal folds (Berzin and Kungurtsev, 1996). The southwestern boundary of the Kalba–Narym terrane is the Terekty strike-slip fault, which separates it from the Char zone, whereas the northeastern part of the Kalba–Narym terrane belongs to the Irtysh shear zone. All along this zone, tectonic sheets of rocks of the amphibolite and granulite facies are mapped, which make up the metamorphosed great-depth part of the basin, according to the latest isotope–geological data (Ermolov, 2013).

The Kalba–Narym granitoid batholith stretches from northwest to southeast, forming a linear structure–compositional complex together with the host rocks. Systematic geological studies here were carried out in connection with the development of rare-metal (Li–Rb–Cs, Ta–Nb, Sn–W, and Au) deposits till the late 1980s. As a result, several detailed schemes for correlation of magmatism were compiled (D'yachkov et al., 1994; Lopatnikov et al., 1982). Recently, in the additional geological studies of areas of scale 1:200,000 (additional site exploration, ASE-200) in the West Kalba and Kalba–Narym zones by Topaz Geological Exploration Company Ltd. (Navozov et al., 2011), it has been determined more precisely in what sequence the intrusive complexes of the Kalba–Narym batholith formed (Fig. 1).

The Kalguty complex is composed of NW-trending dike belts and intrusive massifs, concentrated in the southern Kalba–Narym batholith. It consists of three intrusion phases: (1) fine- and medium-grained garnet–biotite and biotite–hornblende granodiorites, (2) fine- and medium-grained biotite–hornblende granites, and (3) dike granite–granodiorite porphyry.

The Kunush complex includes small intrusions in the northwestern and central parts of the batholith and numerous NW-striking dike belts all along. The Kunush complex consists of three phases: (1) plagiogranite-porphyry and granite-porphyry dikes, (2) fine- and medium-grained biotite plagiogranites and plagiogranodiorites, and (3) aplitic granites and pegmatites.

The Kalba complex. Granitoids, the most widespread rocks in the batholith, form large sheet-like plutons up to 4–5 km thick. Their origin reflects the main stage of batholith formation. The complex is made up of three phases: (1) medium- and coarse-grained porphyritic biotite granodiorites and melanocratic granites, (2) medium-grained biotite granites passing into fine-grained biotite and muscovite–biotite granites, and (3) vein granites, aplites, granitic aplites, and granitic pegmatites. The rare-metal granitic pegmatites forming the largest rare-metal (Ta, Nb, Li, Be, and Cs) deposits (D'yachkov, 2012) and ongonite dike belts (Khromykh et al., 2014a) are related to the granitoids of the Kalba complex.

The rocks of the *Monastyri complex* form a chain of isolated large (≤100 km^2) multiphase intrusions, mainly in the southwestern part of the batholith. The complex includes (1) coarse-grained leucocratic two-mica granites (often, porphyritic), (2) medium- and fine-grained leucocratic granites, and (3) vein granites, aplites, and chamber quartz–feldspar pegmatites.

The rocks of *the Kaindy complex* make up several large multiphase subisometric intrusions with a concentrically zoned structure, which predominantly form a NW-striking chain in the outer, southwestern, part of the Kalba–Narym batholith. The complex formed in the following sequence: (1) medium- and coarse-grained porphyritic biotite granites, (2) medium-grained porphyritic biotite granites and fine-grained biotite granites, and (3) aplites, aplitic granites, and aplite–pegmatites.

Endogenic activity terminated with discontinuous belts of "postbatholith" dikes controlled by the NE fault system and belonging to the Mirolyubovka complex (Lopatnikov et al., 1982). The complex includes groups of mafic, intermediate, and felsic dikes, tentatively divided into three phases: (1) olivine dolerites and dolerites, (2) variegated rocks from diorite porphyry and lamprophyres to quartz monzonites, and (3) granodiorite porphyry and granite-porphyry.

Basic magmatism. Most of the Late Paleozoic basic–ultrabasic magmatism within the Altai collisional system is manifested in the adjacent Char structure–facies zone (Fig. 1,