Journal of Asian Earth Sciences 62 (2013) 79–97

Contents lists available at SciVerse ScienceDirect

Journal of Asian Earth Sciences

journal homepage: www.elsevier.com/locate/jseaes

Late Paleozoic – Mesozoic subduction-related magmatism at the southern margin of the Siberian continent and the 150 million-year history of the Mongol-Okhotsk Ocean

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ARTICLE INFO

Article history:
Available online 23 August 2012

Keywords:
Subduction
Hot spot
Magmatism
Late Paleozoic – Mesozoic
Mongol-Okhotsk Ocean
Siberian continent
Central Asian Orogenic Belt

ABSTRACT

The paper reviews geological, geochronological and geochemical data from the Late Paleozoic – Mesozoic magmatic complexes of the Siberian continent north of the Mongol-Okhotsk suture. These data imply that these complexes are related to the subduction of the Mongol-Okhotsk Ocean under the Siberian continent. We suggest that this subduction started in the Devonian, prior to the peak of magmatic activity. Studied magmatic complexes are of variable compositions possibly controlled by changes of the subduction regime and by possible input from enriched mantle sources (hot spots).

The oceanic lithosphere of the Mongol-Okhotsk Ocean had shallowly subducted under the Siberian continent in the Devonian. Steeper subduction in the Early – Late Carboniferous led to switching from an extensional to compressional tectonic regime resulting in fold-thrust deformation, to the development of duplex structures and finally to the thickening of the continental crust. This stage was marked by emplacement of voluminous autochthonous biotite granites of the Angara-Vitim batholith into the thickened crust. The igneous activity in the Late Carboniferous – Early Permian was controlled by the destruction of the subducted slab. The allochthonous granitoids of the Angara-Vitim batholith, and the alkaline granitoids and volcanics of the Western Transbaikalian belt were formed at this stage. All these complexes are indicative of extension of the thickened continental crust. A normal-angle subduction in the Late Permian – Late Triassic caused emplacement of various types of intrusions and volcanism. The calc-alkaline granitoids of the Late Permian – Middle Triassic Khangay batholith and Late Triassic Khentey batholith were intruded near the Mongol-Okhotsk suture, whereas alkaline granitoids and bimodal lavas were formed in the hinterland above the broken slab. The Jurassic is characterized by a significant decrease of magmatic activity, probably related to the end of Mongol-Okhotsk subduction beneath the studied area.

The spatial relationship of the Late Permian – Middle Triassic granitoids, and the Late Triassic granitoids is typical for an active continental margin developing above a subduction zone. All the Late Carboniferous to Late Jurassic mafic rocks are geochemically similar to subduction-related basalts. They are depleted in Nb, Ta, Ti and enriched in Sr, Ba, Pb. However, the basaltoids located farther from the Mongol-Okhotsk suture are geochemically similar to a transition type between island-arc basalts and within-plate basalts. Such chemical characteristics might be caused by input of hot spot related enriched mantle to the lithospheric mantle modified by subduction. The Early Permian and Late Triassic alkaline granitoids of southern Siberia are of the A_2-type geochemical affinities, which is also typical of active continental margins. Only the basaltoids generated at the end of Early Cretaceous are geochemically similar to typical within-plate basalts, reflecting the final closure of the Mongol-Okhotsk Ocean.

1. Introduction

Closure of ancient oceans as a result of paleo-subduction could be considered as complex process. Key information on subduction-related processes is recorded by the age of intrusions, their geochemical features and spatial relationships with respect to the active continental margin. In contrast to intra-oceanic complexes which usually are completely dismembered by subduction along the convergent plate margins, relicts of formal active continental margins frequently survive within large orogens which are formed after paleoocean's closure. Thus, dating of igneous complexes related to formal active margins provides key information on the duration of paleo-subduction processes. Our investigation focuses on the history of the subduction system of the Mongol-Okhotsk Ocean.

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1367-9120/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jseaes.2012.07.023

The Mongol-Okhotsk Ocean was an embayment of the Paleo-Pacific, which existed in the Late Paleozoic – Early Mesozoic between the Siberian and Mongolia–North China continents (Zonenshain et al., 1990; Zorin, 1999; Parfenov et al., 2001, 2003). The models for the formation of the Mongol-Okhotsk Ocean and the age of its related complexes are still under debate (see reviews in Kuzmin and Fillipova, 1979; Zorin, 1999; Tomurtogoo et al., 2005). The models can be divided into three types. (1) According to Zonenshain et al. (1990) and Zorin (1999) the Mongol-Okhotsk Ocean was enormous gulf of the Paleo-Pacific, which was separated after the joining of the Mongolian (Central-Mongolian) continental block and the Siberian continent approximately in the region of Khangay in Early Carboniferous – earliest Permian. (2) Parfenov et al. (2001, 2003) and Bussien et al. (2011) considered that the Mongol-Okhotsk Ocean opened in the Late Ordovician – Early Silurian as a result of large-scale displacement, which separated the southern part (in present day coordinates) of terranes accreted in the Cambrian and Early Ordovician (to the Siberian craton) from its northern part. (3) Sengör et al. (1993) named the Mongol-Okhotsk Ocean as the Khangai-Khantey Ocean and believed that it was born in Ediacaran – Cambrian time and separated the Siberian craton and the Tuva-Mongol massif.

There is no consensus about the closure time of the Mongol-Okhotsk Ocean either. Maruyama et al. (1997) suggested that the Mongol-Okhotsk Ocean closed in the Triassic. However, Zonenshain et al. (1990) believed that the western part of the Mongol-Okhotsk Ocean closed in the Triassic – Late Jurassic, whereas Zorin (1999) and Parfenov et al. (2001) considered that this happened in the Early to Middle Jurassic. However, most researchers agree that eastern part of the Mongol-Okhotsk Ocean closed later, i.e. in the Late Jurassic – Early Cretaceous (Sengör and Natal'in, 1996; Yakubchuk and Edwards, 1999; Kravchinsky et al., 2002a; Cogné et al., 2005). Relicts of this large ocean remain as fragments of metamorphosed sediments and volcanics within the Mongol-Okhotsk orogenic belt/suture, which formed during its closure. The Mongol-Okhotsk orogenic (fold) belt is the youngest segment of the Central Asian Orogenic Belt (CAOB), which is one of the largest accretionary complexes on the Earth. The CAOB or Altaids (Sengör et al., 1993; Sengör and Natal'in, 1996) is located between the Siberian craton in the north, and the North China and Tarim cratons in the south (Zonenshain et al., 1990; Kovalenko et al., 2004; Windley et al., 2007). It was formed by collision of the Siberian and North China cratons (Zonenshain et al., 1990; Windley et al., 2007, etc.) and consists of relicts of island arcs, oceanic islands, ophiolites, back-arc basins, accretionary wedges, Precambrian microcontinents and superterranes (Fig. 1).

Estimates vary for the timing of subduction of the oceanic crust of the Mongol-Okhotsk Ocean: Ediacaran – Late Permian (Sengör et al., 1993), Devonian – Early Triassic (Parfenov et al., 2003), Devonian – Permian (Gordienko et al., 2010; Bussien et al., 2011), Late Carboniferous – Late Jurassic (Metelkin et al., 2010), Early Permian – Middle Jurassic (Zhao et al., 1990; Enkin et al., 1992; Kuzmin and Kravchinsky, 1996; Zorin, 1999), Triassic – Late Jurassic (Zonenshain et al., 1990). Badarch et al. (2002) and Xiao et al. (2003) did not draw the subduction under the Siberian continent on their Devonian–Carboniferous and Permian–Triassic paleogeographic maps. Thus the timing of subduction of the Mongol-Okhotsk oceanic crust beneath the Siberian continent is still under debate.

As was noted earlier, important information on subduction-related processes can be obtained by studying igneous complexes of active continental margins. A huge-scale of magmatic activity occurred since the Late Paleozoic to Late Mesozoic within eastern Siberia (Transbaikalia, Russia), and northern and central Mongolia (Wickham et al., 1995; Koval et al., 1999; Parfenov et al., 2001; Kovalenko et al., 2004; Jahn et al., 2009; Kuzmin et al., 2010; Yarmolyuk and Kuzmin, 2011). Numerous intrusions as well as

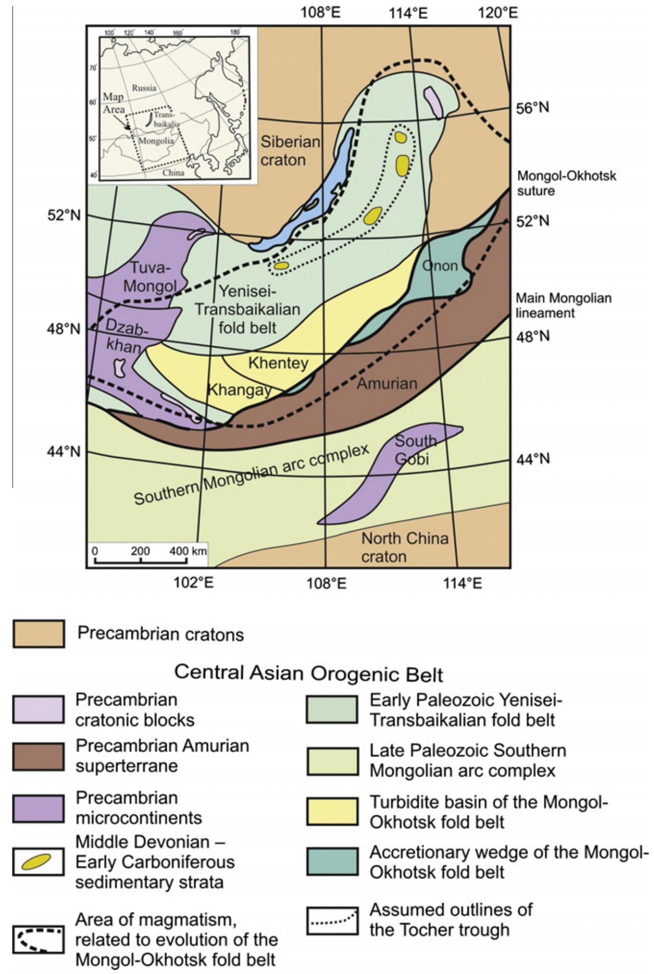

Fig. 1. Simplified tectonic map of the Central Asian Orogenic Belt and adjacent Precambrian cratons (compiled and modified from Mossakovsky et al. (1993), Badarch et al. (2002), Parfenov et al. (2003), Belichenko et al. (2006), Volkova and Sklyarov (2007), Donskaya et al. (2008), Mazukabsov et al. (2010), and Rojas-Agramonte et al. (2011)). Area of magmatism, related to evolution of the Mongol-Okhotsk Ocean is shown after Zorin (1999).

voluminous lavas are located northward from the Mongol-Okhotsk suture and formed before the closure of the Mongol-Okhotsk Ocean. However, there are a few different points of view on the geodymanic setting of formation of the Late Paleozoic – Late Mesozoic granitoid batholiths and volcanoplutonic belts in eastern Siberia (Transbaikalia, Russia), and northern and central Mongolia, including the Angara-Vitim, Khangay and Khentey batholiths, in the Western Transbaikalian, Northern Mongolia and Mongolian-Transbaikalian belts. Zorin (1999), Parfenov et al. (2001) and Tomurtogoo et al. (2005) suggested that the above mentioned granitoid batholiths and volcanoplutonic belts were related to subduction of the Mongol-Okhotsk Ocean beneath the continental margin of the Siberian continent. However, these authors never used any geochemical proxies to confirm their geodynamic conclusions. Wickham et al. (1995) suggested that the same granitoid batholiths and volcanoplutonic belts were related to an anorogenic intracontinental setting that had no connection to the evolution of the Mongol-Okhotsk Ocean. Yarmolyuk and Kovalenko (1991), Yarmolyuk et al. (1997, 2000, 2001, 2002), Kovalenko et al. (2004), Kuzmin et al. (2010) and Yarmolyuk and Kuzmin (2011) proposed that the granitoid batholiths and volcanoplutonic belts could have formed along an active continental margin above hot spots (mantle plume tails). Jahn et al. (2009) and Reichow et al. (2010) concluded that the alkaline magmatic complexes in the