Journal of Asian Earth Sciences 145 (2017) 494–511

Contents lists available at ScienceDirect

Journal of Asian Earth Sciences

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

Full length article

Tectonostratigraphic evolution of the Mohe-Upper Amur Basin reflects the final closure of the Mongol-Okhotsk Ocean in the latest Jurassic–earliest Cretaceous

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ARTICLE INFO

Keywords:
Mohe-Upper Amur Basin
Mongol-Okhotsk Ocean
Latest Jurassic–earliest Cretaceous
Tectonostratigraphic evolution
Northeast Asia

ABSTRACT

The Mohe-Upper Amur Basin to the south of the eastern Mongol-Okhotsk Suture Zone contains important stratigraphic records for understanding the closure of the eastern Mongol-Okhotsk Ocean. The basin is crossed by the Russia/China border, and its Chinese and Russian parts are known as the Mohe Basin and Upper Amur Basin, respectively. Using most up-to-date data on stratigraphy, sedimentology, petrography, and detrital zircon U-Pb geochronology, this study establishes the stratigraphic correlation between the two, Mohe and Upper Amur parts of the basin, and analyzes depositional ages, provenance, and paleogeography of their Jurassic–Lower Cretaceous strata. The adopted Middle–Late Jurassic ages for the Xiufeng, Ershierzhan, Emuerhe, and Kaikukang formations in the Mohe Basin, are revised and constrained to late Kimmeridgian, Tithonian, Berriasian–early Valanginian, and late Valanginian ages, respectively. During the late Kimmeridgian–Tithonian, extension occurred in the Mohe-Upper Amur Basin, and sediments were mainly sourced from areas to the south of the basin. Later, in the Berriasian–early Valanginian, the northern margin of the Mohe-Upper Amur Basin was uplifted and started furnishing sediments into the basin. In the late Valanginian, regional uplift of the northern part of the Mohe-Upper Amur Basin transformed the basin into a compressional intermountain basin, with sedimentation localized in its southern part. After the Valanginian, extension and associated volcanism occurred in the basin. We suggest that the evolution of the Mohe-Upper Amur Basin reflects the gradual closure of the eastern Mongol-Okhotsk Ocean and associated collision of the Siberia Craton and the Amuria Block, that occurred from the Kimmeridgian–Tithonian, to the west of the basin through to the Berriasian–Valanginian, to the north and northeast of the basin. The final closure of the Mongol-Okhotsk Ocean to the north of the Mohe-Upper Amur Basin in the earliest Cretaceous significantly affected the sedimentological, structural and tectonic evolution of Northeast Asia.

1. Introduction

The Central Asian Orogenic Belt (CAOB), located between the Siberia Craton to the north and the Tarim and North China cratons to the south, is one of the largest Phanerozoic accretionary collages on earth (Zonenshain et al., 1990; Sengör et al., 1993; Sengör and Natal'in, 1996; Xiao and Santosh, 2014), and is considered to have evolved over about 720 million years from the late Proterozoic to the Mesozoic (Kröner et al., 2007, 2014; Windley et al., 2007). The Mongol-Okhotsk Suture Zone, extending over 3000 km from the Central Mongolia in the southwest to the Sea of Okhotsk in the northeast, is one of the youngest orogenic divisions of the CAOB (Zonenshain et al., 1990) (Fig. 1). The closure of the Mongol-Okhotsk Ocean along the suture zone and associated collision of the Siberia Craton and the Amuria Block in the late Mesozoic significantly affected the stratigraphic, structural and tectonic evolution of the Central and East Asia, involving paleogeographic transformation, folding, thrusting, metamorphism, and magmatism (Zonenshain et al., 1990; Zorin, 1999; Yang et al., 2015a,b). However, two main controversial issues related to the closure of the Mongol-Okhotsk Ocean still remain unresolved.

First, how wide was the Mongol-Okhotsk Ocean in the Late Jurassic? Based on stratigraphic, structural, and magmatic data, geologists suggested that its western part to the west of longitude 120°E closed either in the Late Triassic–Early Jurassic (Zonenshain et al., 1990; Zonenshain and Kuzmin, 1997) or at the Early/Middle Jurassic boundary (Zorin, 1999), leaving to the east a remnant oceanic expanse

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http://dx.doi.org/10.1016/j.jseaes.2017.06.020
Received 13 April 2017; Received in revised form 25 June 2017; Accepted 25 June 2017
Available online 27 June 2017

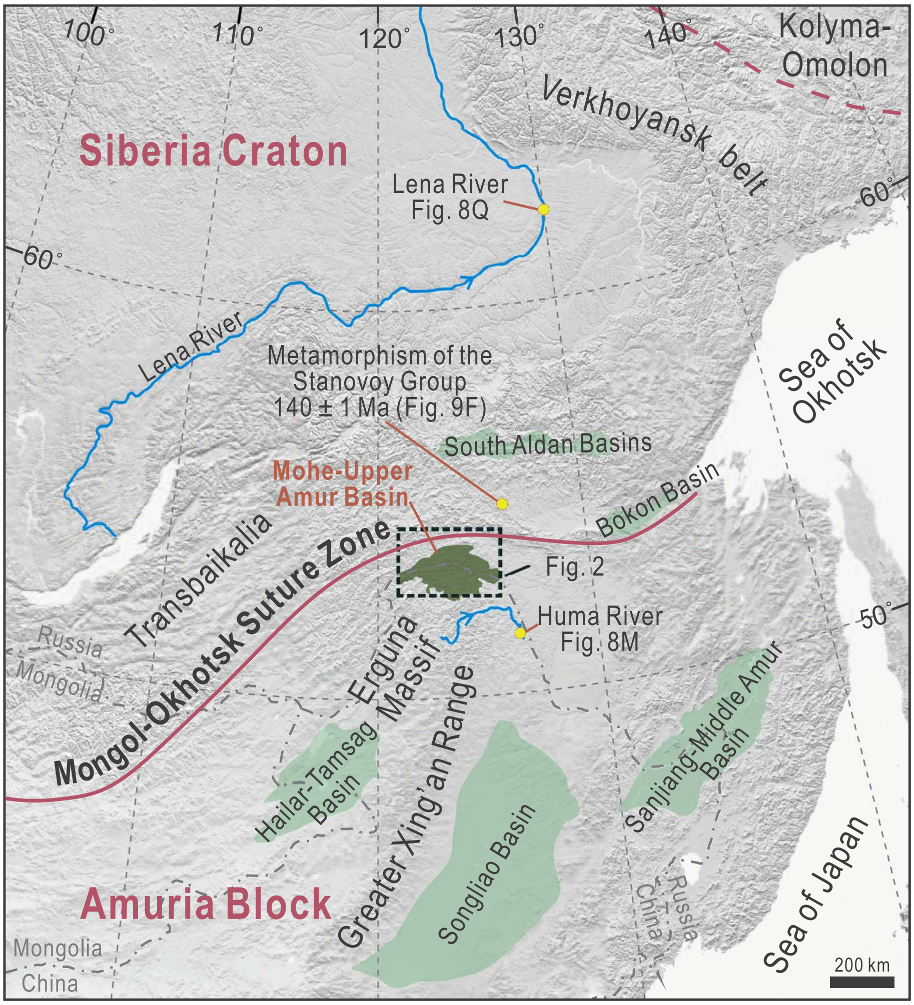

Fig. 1. Topographic and tectonic map of Northeast Asia, showing main geographic regions in the Northeast Asia, Mongol-Okhotsk Suture Zone, Mesozoic sedimentary basins, study area, and other features mentioned in the text.

~300 km wide until the Late Jurassic (Zonenshain et al., 1990) (Fig. 1). However, paleomagnetic data demonstrate that the Late Jurassic to Early Cretaceous convergence between the Siberia Craton and the Amuria Block reached 1000–3000 km, indicating that the ocean remained considerably wide in the Late Jurassic (Enkin et al., 1992; Halim et al., 1998; Cogné et al., 2005; Metelkin et al., 2010; Pei et al., 2011; Van der Voo et al., 2015; Ren et al., 2016).

Second, when did the Mongol-Okhotsk Ocean finally close? As Upper Jurassic thick marine sandstone and shale are widespread in the eastern Mongol-Okhotsk Suture Zone and its neighboring areas where syn-collisional folding, metamorphism, and magmatism occurred in the earliest Cretaceous (Figs. 1 and 2), it was assumed that the eastern part of the ocean closed in the Early Cretaceous (Zonenshain et al., 1990; Zonenshain and Kuzmin, 1997; Nokleberg et al., 2000; Parfenov et al., 2010). Yang et al. (2015a) suggested that the Mongol-Okhotsk Ocean closed rapidly during the latest Jurassic–earliest Cretaceous, which resulted in the formation of a giant fold-and-thrust belt in the northern China and Mongolia. However, geochemical (He et al., 2005) and petrographic (Zhang et al., 2014) studies of the Middle–Upper Jurassic sandstone from the Mohe Basin to the south of the Mongol-Okhotsk Suture Zone indicated that the suture zone was a provenance area, implying that the Mongol-Okhotsk Ocean had closed before the Middle Jurassic, and the neighboring Mohe Basin was either a foreland basin (He et al., 2005; Hou et al., 2010; Zhang et al., 2014) or an inter-mountain basin (He et al., 2008) (Fig. 2).

The Jurassic–Early Cretaceous Mohe-Upper Amur Basin to the south of the eastern Mongol-Okhotsk Suture Zone (Figs. 1 and 2) is supposed to contain valuable stratigraphic data recording the evolution of the basin as well as the eastern Mongol-Okhotsk Ocean. However, the evolution of the basin has never been investigated in detail, clearly understood, and linked to the final closure of the Mongol-Okhotsk Ocean. As the Mohe Basin and Upper Amur Basin are located in China and Russia, respectively, the stratigraphic correlation between them has not been explored, and the evolution of the basin as a solitary unit remains ambiguous. In this study, we review the stratigraphic and sedimentological characteristics and establish a regional stratigraphic framework for the Mohe-Upper Amur Basin. On the basis of petrographic and detrital zircon U-Pb geochronological analyses of sandstone samples from the Mohe Basin, we re-assess the depositional ages and provenance locations for its Middle Jurassic–Lower Cretaceous deposits. Ultimately, we propose a new model for the tectonostratigraphic evolution of the Mohe-Upper Amur Basin linked to the closure of the eastern Mongol-Okhotsk Ocean.

2. Geological setting, stratigraphy and sedimentology of the Mohe-Upper Amur Basin

The Jurassic–Early Cretaceous Mohe-Upper Amur Basin is situated in the northern Erguna Massif, just to the south of the eastern Mongol-Okhotsk Suture Zone and to the north of the Greater Xing'an Range (Fig. 1). The Erguna Massif, the northernmost part of the Amuria Block, has a Precambrian basement composed of amphibolite, gneiss, schist, granulite, marble, and migmatite (Wu et al., 2012; Zhou and Wilde, 2013) overlain by Paleozoic–Mesozoic clastic and volcanic rocks (Zhang et al., 2008). The stratigraphy and sedimentology of the Mohe-Upper Amur Basin are briefly summarized below.