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ScienceDirect
Russian Geology and Geophysics 51 (2010) 492–506
RUSSIAN GEOLOGY AND GEOPHYSICS
www.elsevier.com/locate/rgg

# Lithospheric structure and Mesozoic geodynamics of the eastern Central Asian orogen

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Received 24 April 2009

**Abstract**

The lithospheric structure of several marginal and interior units of the eastern Central Asian orogen has been explored in 2D geophysical models. The obtained constraints on effective parameters (density, resistivity, temperature) of lithospheric blocks and their boundaries allowed correlation of geophysical structures to tectonic settings. The geological and geophysical (including paleomagnetic) data were used jointly to model the present structure of the lithosphere along 126° E between 56° N and 40° N and to construct a palinspastic model of the same area for the latest Early Jurassic (175 Ma).


*Keywords:* lithospheric structure; geodynamics; paleolatitudes; palinspastic model; Central Asian orogen; Mongolia–Okhotsk paleo-ocean

## Introduction

A vast area between the East European, Siberian, and North China plates is occupied by an orogen first distinguished as the Ural–Mongolian fold belt (Muratov, 1965) and then referred to as the Ural–Okhotsk fold belt (Khain, 2001). This is an intricate tectonic collage of Precambrian continental blocks, fragments of Paleozoic and Mesozoic oceanic crust, island arcs of different ages, and young orogenic systems and continents with their active and passive margins. The Ural–Okhotsk belt consists of two units: the northwestern Ural–Siberian part between Baltica and Siberia and the southeastern part, often called the Central Asian orogen, stretching as far as the Pacific between Siberia and Tarim–Sino-Korea (Khain, 2001).

The Ural–Okhotsk belt has been largely studied (Didenko et al., 1994; Dobretsov et al., 1995; Gordienko, 2001, 2006; Gusev and Khain, 1995; Khanchuk, 2006; Kuz'min et al., 1995; Mossakovskii et al., 1993; Parfenov et al., 2003; Sengör et al., 1993; Zonenshain et al., 1990). However, despite the considerable advance in understanding its eastern part, there remains some controversy about the structure and evolution of the Mongolia–Okhotsk suture formed in place of the Paleozoic–Mesozoic Mongolia–Okhotsk ocean. The most important questionable points are (i) the oceanic structure of the Mongolia–Okhotsk zone, including the size and geometry of the basin and its southern continental border, and (ii) the mechanism and (iii) the time of ocean closure. According to geological evidence (Parfenov et al., 2003), the ocean would have closed in the Middle Jurassic, but paleomagnetic constraints place the event at the Late Jurassic–Early Cretaceous (Kravchinsky et al., 2002a) and indicate the Mongolia–Okhotsk basin to have been still over 3000 km wide in the Middle–Late Jurassic, with the paleolatitudes of its northern and southern margins of 62–65° and 22–33°, respectively (Kravchinsky et al., 2002b).

In this study we synthesize new geological and geophysical (resistivity, gravity, thermal, and paleomagnetic) data from the eastern Central Asian orogen, with implications for the present lithospheric structure and for palinspastic reconstructions.

## Tectonic division of the eastern Central Asian orogen

The tectonic division of the eastern Central Asian orogen being controversial, we outline several existing models and explain our views of the regional tectonic framework.

We call the area the eastern Central Asian orogen proceeding from the tectonic division of Central Asia according to (Karsakov et al., 2005; Khain, 2001; Khanchuk, 2006). Khain (2001) suggested the following definition: "The Ural–Okhotsk fold belt is a key tectonic unit of Northern Eurasia. It results

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1068-7971/$ - see front matter 
doi:10.1016/j.rgg.2010.04.006

from closure of the Paleoasian ocean which arose in the Late Riphean with the Rodinia breakup and existed in those limits as long as the Jurassic. The Paleoasian ocean separated East Europe and Baltica from Siberia and Siberia from the Tarim and Sino-Korean plates. The ocean stretched from the Barents Sea where it joined the Iapetus and from the Kara Sea where it met the Paleopacific as far as the present **seas of Okhotsk and Japan**, its another junction with the Paleopacific ocean. With its southwest-facing bend at Turan, the ocean joined the Paleothetys through a narrow and, possibly, discontinuous bridge, and a similar bridge may have existed also between Tarim and Sino-Korea. The bend appears to be secondary in origin, but in the present framework it divides the Ural–Okhotsk belt into the northwestern flank lying between Baltica and Siberia, the Ural–Siberian part, and the southeastern flank between Siberia and Tarim–Sino-Korea which is often called the **Central Asian belt**".

Zonenshain et al. (1990) gave a slightly different interpretation of the Central Asian orogen which had formed as a single structure by the latest Paleozoic as a result of progressive convergence and final collision of Siberia with the Precambrian terranes of North China, Tarim, Tajik, Karakum, and Kazakhstan–North Tien Shan. They tentatively divided the USSR territory of the orogen into two segments (Kazakhstan and Tien Shan in the west and the Altai–Sayan area and northern Mongolia in the east), with the Late Paleozoic Irtysh–Zaisan suture between them.

In the recentmost tectonic map of Central Asia (Petrov et al., 2008), the area of present study comprises (from north to south): the Yankan–Amur–Okhotsk segment of the Mongolia–Okhotsk orogen, the Gobi–Hinggan folded area, the Songliao basin, and the Beishan–Solonker orogen.

The explanatory note to the geological map of the Amur region and its surroundings (Krasnyi et al., 1999) gives a similar division into the Dzhugdzhur–Stanovoi block of the Aldan–Stanovoi shield, the Yankan–Dzhagdy and Galam–Shantar zones of the Amur–Okhotsk segment of the Mongolia–Okhotsk belt, the eastern Kerulen–Argun–Mamyn terrane of the Central Asian belt, the Heilongjiang and Selemdzha segments of the Daxianling–Selemdzha orogenic system of the Central Asian belt, the Songnen–Turan terrane of the Central Asian belt, the Bureya–Jiamusi–Hanka terrane of the Pacific belt, the Jilin–Laoye Ling fold system, and the Longgang terrane of the North China plate.

With reference to the above definitions, we mean the eastern part of the Central Asian orogen as a group of Early and Late Paleozoic orogens and terranes, and several Precambrian microcontinents. The eastern Central Asian orogen borders the Siberian craton along a zone of large faults in the north and the Pacific orogen along NS and NE faults in the east (Karsakov et al., 2005; Khanchuk, 2006); in the south, its Late Paleozoic Solonker and Early Paleozoic Shara-Muren zones border the Precambrian North China plate.

The Late Paleozoic Lunjiang–Selemdzha orogen with a large superposed structure of the Mesozoic–Cenozoic Songliao basin is a central unit of the study area. A large part of Paleozoic orogenic systems is occupied by microcontinents (Argun–Mamyn, Dyagdachi, Bureya, Jiamusi, and Hanka). Most of boundaries between these units of the eastern Central Asian orogen are along systems of transcrustal faults. Other abundant structures in the area are Mesozoic and Mesozoic–Cenozoic volcanic belts and sedimentary basins (Fig. 1). The area is often referred to as the Amur superterrane.

## Methods

The integrate geophysical model of the area was constructed using seismic, gravity, magnetic, geothermal, and resistivity data. The density patterns were obtained by means of layer-by-layer 2D joint inversion of seismic and gravity data (Podgornyi, 1995) and 3D gravity (Li and Oldenburg, 1998) modeling. The former method is adapted to layered structures and yields lateral density patterns in each layer, and the latter method consists in inversion of gravity data with a minimization criterion. The 3D density models were based on digitized gravity data from the 1:2,500,000 gravity map of Russia (Stepanov and Yanushevich, 1999), on a 12.5 km × 5 km grid (horizontal and vertical dimensions, respectively). 2D modeling was for one- two-, and multi-layer lithosphere and upper asthenosphere.

MTS data were processed first in 1D as normalized longitudinal resistivity curves using the IPI-MTS program by Bobachev et al. (1995), and the 1D models were applied for reference in 2D inversion by the program of Novozhinskii and Pushkarev (2001). The 2D grid had a stepsize of 5 km in the horizontal dimension, and the vertical stepsize increased with depth. The longitudinal MTS curves were utilized in fitting the resistivity cross section parameters, and the transverse curves were used to allow for shallow crustal effects.

The thermal state of the lithosphere was reconstructed, in terms of a layered model, from measured abundances of radioactive elements and thermal conductivities of rocks, with reference to crustal density patterns. Heat production of the upper crust was estimated from abundances of radioactive elements measured in situ in exposed rocks (Goroshko et al., 2006); the lower crust abundances of radioactive elements were extrapolated from those in known granulite mafic complexes of the area. The temperature distribution in model cross sections of the crust was expressed via a 2D steady-state thermal conductivity equation for an inhomogeneous medium. The boundary conditions in the thermal model were as follows: 5 °C temperature on the Earth's surface, zero heat flow at the lateral boundaries, and heat flow equal to the mantle component at the crustal base. We reconstructed temperatures in the crust as 200, 400, 600, and 800 °C isotherms and estimated the Moho temperatures along several transects. Mean thermal conductivities according to measurements in samples of various lithologies (Gornov et al., 2009) were 1.4–1.6 W/mK for the upper crust, 1.8–2.0 W/mK for the middle crust, and 2.2–2.4 W/mK for the lower crust.

The Mesozoic paleolatitudes of Siberia and North China, which make the reference frame of the reconstructions, were derived from detailed apparent wander paths of their poles.