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The February 1, 2011 M_w 4.7 earthquake: Evidence of local extension in western Transbaikalia (Eastern Siberia)

Valentina I. Melnikova [a,b,*], Alena I. Seredkina [a,b], Yan B. Radziminovich [a], Aleksander I. Melnikov [a], Nadezhda A. Gilyova [c]

[a] Institute of the Earth's Crust, Siberian Branch of RAS, 664033, Lermontov Street, 128, Irkutsk, Russia
[b] Diamond and Precious Metal Geology Institute, Siberian Branch of RAS, 677891, Lenin Ave., 39, Yakutsk, Russia
[c] Baikal Branch of the Geophysical Survey, Siberian Branch of RAS, 664033, Lermontov Street, 128, Irkutsk, Russia

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ABSTRACT

We consider the rare February 1, 2011 earthquake M_w 4.7 that occurred in the low active region of western Transbaikalia, Russia. Its epicenter relates to the Zagan metamorphic core complex (MCC). From geological data, MCCs are characterized by signs of regional extension. We calculated earthquake source parameters (hypocentral depth, moment magnitude, scalar seismic moment and focal mechanism) from the data on amplitude spectra of surface waves and the first body-wave arrivals recorded on regional stations. The results obtained show that the focus of this event was formed in the conjunction zone between the low-angle dipping zone of plastic flow (detachment) included in the structure of the Zagan MCC and the listric fault related to the adjacent basin. A normal fault focal mechanism proves the processes of horizontal extension near the MCC, with one nodal plane being low-angle dipping (dip 35°) that agrees with the dip of the detachment zone. As long as this zone is characterized by high rates of tectonic deformation, we suppose that normal-fault displacement in the earthquake origin is carried out along the low-angle dipping rupture plane. Taking into account that in the territory of western Transbaikalia, compression and strike-slip regimes of seismotectonic deformations dominate, we suppose that the extension in the focus of the earthquake under study has a local character, and is caused by the structure of the Zagan MCC.

1. Introduction

Western Transbaikalia in Eastern Siberia is located on the periphery of the Baikal rift zone (BRZ) and represents a large geotectonic province (Fig. 1). Compared to the high seismic and tectonic activity of the BRZ, here a dramatic decrease in seismicity can be observed. This phenomenon is related to another neotectonic pattern as Transbaikalia is assigned to the area of moderate orogenic movements (Solonenko, 1977). Despite the weak seismicity of the investigated region, the magnitudes of some local earthquakes may exceed M 4.5 (Solonenko, 1977; Ulomov, 2014). According to historical data, rather large earthquakes with magnitudes sometimes as high as M ~ 6.2 occurred in western Transbaikalia during the 19th Century (Kondorskaya and Shebalin, 1982).

One of the most significant and rare seismic events in the investigated area was the February 1, 2011 M_w 4.7 Zagan earthquake that had occurred in a previously aseismic area of the mountain range of the same name. During the instrumental observation period (1951–2016), it became the second-most important seismic event after the October 2, 1980 mb 5.0 earthquake located near the Orongoi basins (Golenetskii et al., 1982, 1983; International Seismological Centre, 2016). Geologically, the structure to which the epicentral area of the Zagan earthquake is related is the metamorphic core complex (MCC). It falls within the contours of the Khilok zone of the Eravna terrain (Fig. 2). It should be noted that the geological structure of western Transbaikalia is represented by different size blocks formed by heterochronous structural and compositional complexes (Sklyarov et al., 1997; Zorin et al., 1995). Here, we mark the terrains mainly composed by the Archean and Archean-Paleoproterozoic rocks related to the active margin of the Siberian platform (Fig. 2). The earliest structural and compositional complexes are relics of microcontinents with the Paleoproterozoic-early Riphean crust at their basements (Barguzin). The remainder of the terrains (viz. Khamar-Daban, Dzhida,

* Corresponding author at: Institute of the Earth's Crust, Siberian Branch of RAS, 664033, Lermontov Street, 128, Irkutsk, Russia.
E-mail address: vimel@crust.irk.ru (V.I. Melnikova).

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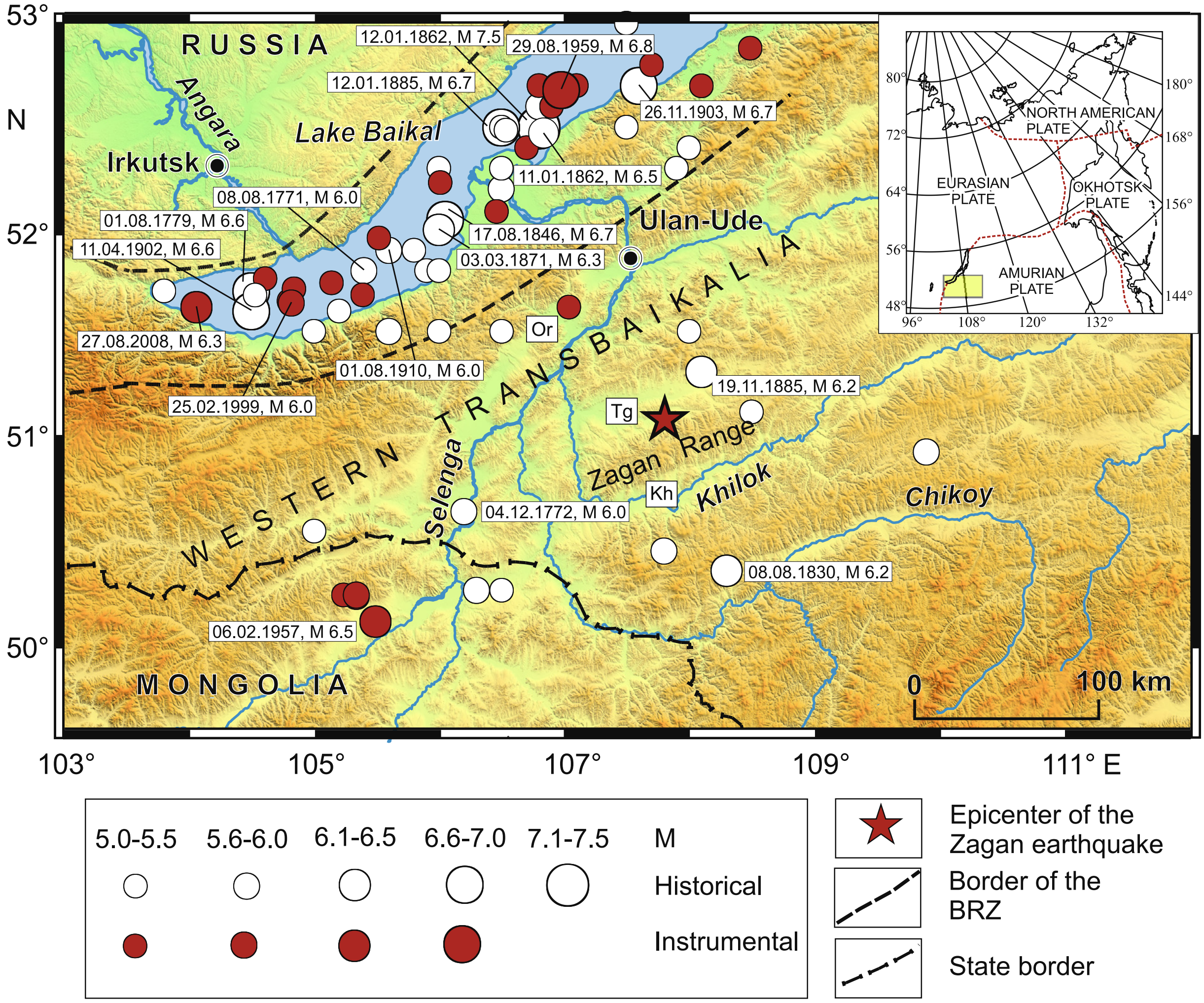

Fig. 1. Map of epicenters of strong earthquakes in the SW part of the BRZ and Transbaikalia over historical (1771–1950) and instrumental (1951–2016) observation periods. Dates and magnitudes are presented for earthquakes with $M \geqslant 6.0$. Abbreviated names of Mesozoic basins: Or – Orongoi, Tg – Tugnui, Kh – Khilok. Location of the investigated area is marked with a yellow square in the inset. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Eravna), which adjoined the Siberian continent at the end of Late Paleozoic time (Belichenko et al., 1994), are composed of heterochronous rocks (from Riphean to late Paleozoic). A distinguishing feature of the Eravna terrain (Fig. 2) is the existence of MCCs and adjacent rifting basins comprising a unified NE-striking belt (Mazukabzov et al., 1995, 2011; Sklyarov et al., 1997). The MCCs play an important role in the modern pattern of western Transbaikalia (Sklyarov et al., 1997). The peculiar features of their geological structure and seismotectonic position have been described in numerous publications (e.g. Donskaya et al., 2008; Mazukabzov et al., 2011; Sklyarov et al., 1997; Wang et al., 2011) that focus primarily on the age and composition of the MCCs and kinematics of displacements on the faults. The relationships between these complexes and seismicity are very poorly presented in the literature because of their low activity.

Thus, the occurrence of a significant earthquake in a geologically well-investigated area (Donskaya et al., 2008; Sklyarov et al., 1997) determined the topic of our research, aiming to elucidate the relation between the source parameters of this event and tectonic features of its epicentral zone. The obtained data further contribute to the development of models of the modern structural evolution in Transbaikalia.

2. Major parameters of the Zagan earthquake

The major parameters of the Zagan earthquake were determined by different seismological agencies (Table 1). In our study, we used the data obtained by the BYKL agency, as the errors of the epicenter location are minimal. Assessments of the hypocentral depth range from 12.7 km (ISC) to 26 km (BYKL); values of the body wave magnitude vary from mb 4.1 (IDC) to mb 4.7 (NEIC) (Table 1).

To calculate the source parameters (viz. focal mechanism, scalar seismic moment and hypocentral depth) of the Zagan earthquake, we applied the inversion of surface wave amplitude spectra, based on the method described in Bukchin (1990) and Lasserre et al. (2001). The reliability of this method in focal mechanism determination of large ($M_w \geqslant 5.2$) and medium ($M_w \geqslant 4.3$) seismic events occurring in different regions has already been demonstrated (Bukchin et al., 1994; Gomez et al., 1997a, 1997b; Lasserre et al., 2001; Seredkina and Melnikova, 2014; Seredkina et al., 2015). The main assumptions of the method, i.e. instantaneous pure double-couple point seismic source with known origin time and epicentral location (Bukchin, 1990) and medium with weak lateral inhomogeneity (Babich et al., 1976; Woodhouse, 1974), allow us to define