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Research paper

Lithospheric stress in Mongolia, from earthquake source data

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A B S T R A C T

Lithospheric stress in Mongolia has been studied using mechanisms of 84 $M_{LH} \geq 4$ earthquakes that occurred in the 20th century and instrumental seismic moments of 17,375 $M_{LH} \geq 2.5$ events recorded between 1970 and 2000. The $M_{LH} \geq 3.5$ earthquakes mostly have strike-slip mechanisms in southern and central Mongolia, with frequent reverse-slip motions in the west and normal slip in the north, especially, in the area of Lake Hovsgol. The principal stresses are, respectively, $S_H > S_v > S_h$ in the center and in the south; high horizontal compression with $S_H > S_h > S_v$ in the west; and a heterogeneous stress pattern with $S_v > S_H > S_h$ in the north. According to seismic moments of $M_{LH} = 2.5$ events, oblique slip generally predominates over the territory, at $S_v \approx S_H >> S_h$, while frequent strike slip motions in the west record high horizontal compression ($S_H > S_v > S_h$). Earthquake mechanisms show the principal horizontal compression S_H to be directed W–E in the east, NE–SW in the central and Gobi-Altay regions, and approximately N–S in the west of Mongolia. The patterns of principal lithospheric stresses in the territory of Mongolia have undergone three events of dramatic change for a few recent decades, and these events were synchronous with three similar events in the Baikal rift system (BRS): in the latest 1960s, latest 1970s to earliest 1980s, and in the latest 1980s to earliest 1990s. The seismicity of Mongolia has been controlled by superposition of variable stresses associated with rifting activity pulses in the neighbor BRS on the background of quasi-stationary super-regional compression.

1. Introduction

The current geodynamics and seismicity of the Mongolia-Baikal province (MBP) apparently result from interplay of regional-scale processes in the Central Asian Orogen and the Baikal rift system (BRS) and global-scale plate tectonics (Florensov, 1965; Logatchev and Florensov, 1978; Solonenko and Florensov, 1985; Baljinnyam et al., 1993; Dzhurik and Dugarmaa, 2004; Levi and Sherman, 2005; Klyuchevskii and Dem'yanovich, 2006; Dzhurik et al., 2009). Internal mechanisms play a key role in the evolution of the Central Asian Orogenic Belt (CAOB) and the Baikal Rift System (Logatchev, 1993b, 2003; Klyuchevskii, 2010a). Volcanism in BRS is due to the existence of hot asthenosphere, a sort of a "thermal trap", under the thin crust (Logatchev, 2003). The asthenospheric upwarp beneath BRS (Gao et al., 1994; Zhao et al., 2006), possibly remaining after incomplete closure of the Paleo-Asian and Mongolia-Okhotsk oceans (Goldin et al., 2006), produces gravity instability responsible for deformation in BRS. The zones of high crustal strain within the Baikal rift system revealed by Goldin et al. (2006) coincide with three zones of high strain anisotropy and predominantly vertical stress in the center and on the flanks of BRS called rifting attractor structures (Klyuchevskii, 2014). Pulse-like changes of principal stresses in these domains appear to be nonlinear responses of the system to subcrustal processes and to control the current geodynamics and seismicity of BRS.

The regional-scale internal processes interact with global-scale external effects on CAOB and other structural elements of the region from plate motion (Molnar and Tapponnier, 1975; Zonenshain and Savostin, 1981). The relative contributions of the two driving forces of the MBP evolution are hard to estimate, but it is possible to study their imprints in faulting and seismicity and in the related stress patterns. Knowledge of stress variations under mechanic, thermal, rheological, and other effects provides insights into lithospheric dynamics, as well as into the origin and location of deformation sources that maintain the current tectonic and seismic activity in continental settings. Earthquakes are a direct consequence of brittle deformation. Faults and earthquakes are often

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associated with stick-slip motions on preexisting faults. The deformation processes cover a wide range of scales from thousands of kilometers to tens of meters and generate earthquakes of different magnitudes. Most of crustal seismicity is caused by large fault systems along plate boundaries but earthquakes can also occur far from plate margins, especially in continental areas, such as the Mongolia-Baikal province, which may possess a variety of structures inherited from former tectonic episodes.

Pulse-like activity at rifting attractors in the BRS lithosphere and related stress changes trigger synchronous pulses of seismicity in the Baikal region (Klyuchevskii and Klyuchevskaya, 2009; Klyuchevskii, 2011), as well as in Mongolia (Klyuchevskii, 2010b; Klyuchevskii et al., 2010; Klyuchevskii and Demberel, 2012).

The reconstructed changes in the directions of principal stresses at rifting attractors coincide with changes in frequency of earthquakes (annual numbers *N*, correlated over 3, 5 and 10-years long periods) synchronous over the whole Baikal rift system in the late 1960s and between the latest 1970s and the early 1980s. In Mongolia, there were three such events of changing earthquake frequency or earthquake flux rates: in the latest 1960s, early 1980s, and middle 1990s. The event of late 1970s–early 1980s was the longest and best correlated among geographically dispersed areas of the Mongolia-Baikal Province, while that of the latest 1960s appeared mostly on the scale of three years. Thus, the compression pulses associated with the activity of rifting attractors can reactivate the seismic process and change coherently the earthquake frequency over the vast MBP territory. The behavior of current lithospheric stress in BRS was studied from earthquake data over the period 1968–1994 (Klyuchevskii, 2004). It is reasonable to extend the period of observations in the Baikal region and to carry out the same research for Mongolia, in order to explain the synchronicity of seismic processes in the two regions in the mid-1990s.

Space-time stress patterns controlled by large-scale lithospheric processes are used for medium-term earthquake prediction and seismic risk mapping (Turcotte and Schubert, 2002). The distribution of stresses is commonly inferred from parameters of earthquakes originated within the brittle seismogenic crust, which is 15–20 km thick in continental areas (Zoback, 1992). The stress pattern of Mongolia was studied, to the first approximation, from source parameters of large earthquakes and few composite solutions for small events in the area of Lake Hovsgool (Solonenko and Florensov, 1985). The earthquake data show predominant compressive strike-slip motions over the Mongolian territory and mixed slip geometries with a significant amount of rifting-related normal slip in the north, near Hovsgool (Golenetsky and Misharina, 1978). The boundary between the zones of super-regional compression and regional extension was suggested to follow the Bulnay fault, as typical rift basins are absent south of it (Logatchev and Florensov, 1978). However, no sharp boundary appears in earthquake mechanisms (Doser, 1991). Single events show predominantly strike-slip faulting, while the mechanisms of

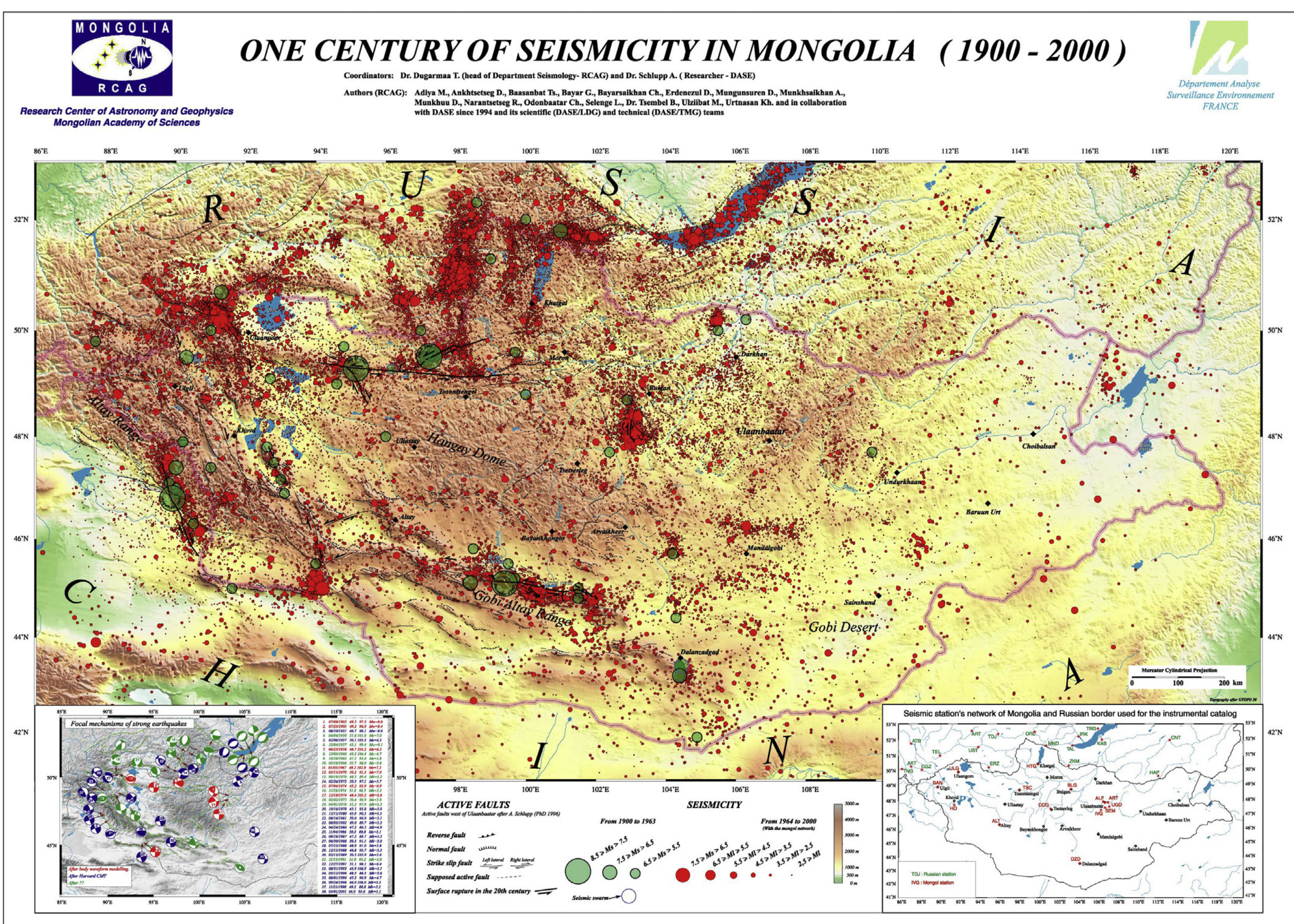

Figure 1. Map of one century of seismicity in Mongolia (1900–2000) (Dugarmaa et al., 2002).

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