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Paleoseismic studies of the Hustai Fault zone (*Northern Mongolia*)

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Abstract

We discuss the results of study of the Holocene seismic activity of the Hustai Fault zone, Central Mongolia. Applying seismological methods (remote, trenching, geophysics), we have revealed signs and determined the quantitative parameters of the paleoearthquake that led to the fault dissection at 3–5.5 ka. The high seismic potential of the Tola earthquake focus zone and its proximity to Ulaanbaatar confirm earlier estimates of the seismicity of the capital of Mongolia, 8 points on the MSK-64 scale.

Keywords: fault; seismic activity; absolute age; Northern Mongolia

Introduction

In this paper we consider signs of the Holocene seismic activity of the Hustai Fault zone, Central Mongolia. This fault was first marked as the most significant tectonic fracture on the neotectonic and seismic map of the Mongolian People's Republic compiled by Aprodov (1960) from the results of field studies performed next year after the intensity 12 Gobi–Altai earthquake. Seismogeological investigations of the Hustai Fault zone began only 50 years later. At the beginning of the discovery and study of the historical palaeoseismic features (1960–1970s), the Hustai Fault was paid little attention by seismic geologists because it is located in a weak- to moderate-seismicity zone at the Hentiyn spurs, near the conventional north–south striking boundary dividing the Mongolian territory into the western highly seismic and eastern aseismic parts.

The Hustai Fault is well expressed in the relief as scarp lines in massive rocks and loose deposits as well as other signs of seismotectonic activity in the base of the linear-face slope of the southeastern side of the Hustai Range. By analogy with other similar structures, we can assume tectonic activity at the ridge–depression boundary at present and throughout most of the recent epoch.

The interest to the Hustai Fault as a seismogenerating structure arose after the installation of a network of seismic stations in the vicinity of Ulaanbaatar, which recorded groups of earthquakes west and southwest of the capital of Mongolia (Fig. 1). Two of these groups are localized in the central zone of the southeastern slope and near the northeastern ending of the Hustai Range. The $M = 4$ earthquakes that took place at <100 km from Ulaanbaatar in 2008–2009 cause particular anxiety.

The next step in studying the seismic safety of the Mongolian capital was detailed onshore seismic works for revealing seismogenic dislocations and determining their major characteristics. At the same time, similar works were carried out northeast of Ulaanbaatar, in the Gunzhin Fault zone (Imaev et al., 2012).

On the general description of the territory, we presented brief information about the tectonics of both the Hentiyn and Hangayn uplands, as they have similar structure-formational complexes and history of geologic evolution. Until recent time, these uplands have been considered strongly different in the degree of seismic activity according to seismogeological and seismological data. The high seismic potential of the Hangayn was confirmed by strong earthquakes that took place in 1905 and 1967, whereas that of the Hentiyn calls for detailed complex seismogeological investigations over the large upland area. Such works began in 2007. The first results were partly published by Demberel (2010) and Ferry et al. (2010). This paper is based on the results of trenching and geophysical studies in the zone of the Hustai Fault.

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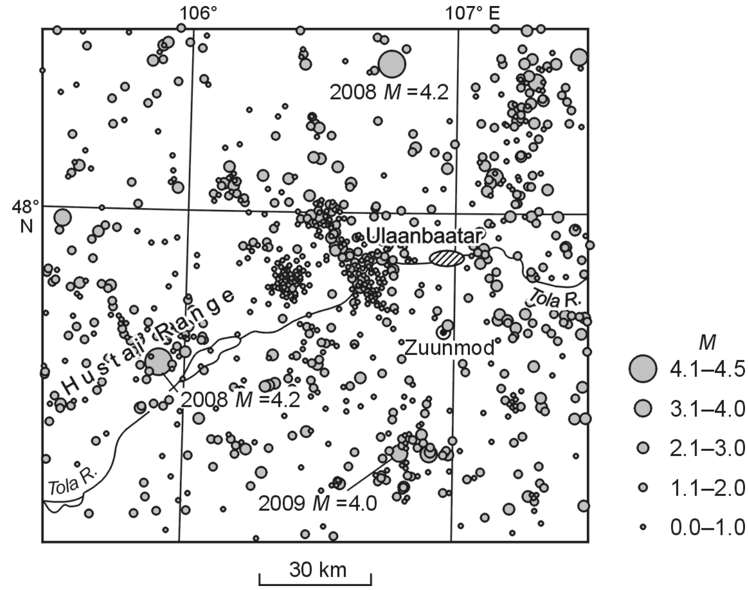

Fig. 1. Schematic map of the earthquake epicenters in the vicinity of Ulaanbaatar in the period 1994–2009 (from data of RCAG, Mongolia).

Brief characteristics of the history of evolution and present-day geologic and tectonic structure of the study area

The Hangayn and Hentiyn uplands occupy vast areas within the Caledonian folded basement of Northern Mongolia. Their similar geologic and tectonic structures and history of evolution are due to their belonging to the same Hangayn–Hentiyn structure-formational zone formed by intricately dislocated shale units of Late Riphean and Early Paleozoic age (Fig. 2). In the Middle and Late Paleozoic, thick (up to 10–11 km) terrigenous Devonian–Carboniferous series of sediments with local intermediate and felsic volcanics formed on continental crust in this zone. Active sedimentation ended in the Carboniferous. Deformation of Paleozoic rock units began as early as their accumulation, as evidenced from numerous signs of the turbidite sedimentation regime. In particular, the Hentiyn synclinorium evolved under prolonged lateral contraction. The rock beds are intensely dislocated and occur almost vertically (Yanshin, 1974).

The next step of evolution of newly formed folded structures within the Hangayn–Hentiyn zone was the formation of bar-like uplifts bounded by longitudinal faults and dissected cross faults and reverse faults. The ascending movements were accompanied by the intrusion of Mesozoic granitoids. Late Jurassic and Early Cretaceous deposits accumulated in intermontane troughs. The largest area of exposure of Mesozoic sediments, 43 km in length and 6 km in width, occupies the northern half of the present-day Tola basin (Fig. 3). The wide occurrence of Mesozoic sediments beyond the Hangayn–Hentiyn zone and their fragmentary presence within the zone evidence that the recent uplifts in Northern Mongolia have existed as positive tectonic structures since post-Hercynian time.

The recent stage of tectonic activity, when the subsequent growth of the Hangayn and Hentiyn uplands proceeded, is subdivided into two main substages. At the first (Miocene–Early Pliocene) substage, new areas around the growth centers (cores of synclinoriums) were involved in the uplifts. Slow vertical movements led to the formation of huge arched structures with a large radius of curvature (Yanshin, 1974). The second substage, which began in the Early Pliocene, is characterized by the intensified differentiation of motion along old and new tectonic fractures. Horsts and grabens of NE strike formed within the Hentiyn upland. The maximum rates of motions were in the Late Pliocene–Early Pleistocene, and the total amplitude of uplifting in the Central Hentiyn varies from 1500 to 2500 m (Kozhevnikov et al., 1973).

Deformations in the Hustai Fault zone

The Hustai Fault inherits the position of a fragment of the extended tectonic contact between Lower–Middle Devonian and Lower Carboniferous rocks, which are flysch associations ~3500 and 2500 m in thickness, respectively (Geological..., 1998). The fold-nappe structures along the northwestern boundaries of the Hentiyn synclinorium, revealed by L.P. Zonenshain, and Lower Paleozoic strata thrust over the synclinorium deposits with an amplitude of up to 5–10 km also determine deformations in the Devonian and Carboniferous strata of the synclinorium, including the NW vergence of the deposit folds (Yanshin, 1974). One else specific feature is the presence of quartz dikes and tectonic fractures of NW dip at the boundary between the Devonian and Carboniferous deposits.

The ~100 km long Hustai Fault serves as a boundary between two tectonic structures, the Hustai Range and Tola basin. They are located in the southwestern Hentiyn, near the