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Editors in chief

(Institute of Astronomy and Geophysics, Ulaanbaatar, Mongolia)

Prof. Demberel Sodnomsambuu

Dr. Odonbaatar Chimed

Dr. Ulziibat Munkhuu

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Editors: Dr Odonbaatar Chimed
Dr Munkhsaikhan Adiya
Mrs Ankhtsetseg Dorjsuren

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ACTIVE FAULTS AND LATE CENOZOIC CRUSTAL STRESS STATE IN THE CENTRAL PART OF MONGOLIA

Sankov V.A.[1,2], Parfeevets A.V.[1], Miroshnichenko A.I.[1], Sankov A.V.[1], Demberel S.[3], Bayasgalan A.[3] and Battogtokh D.[3]

[1] *Institute of the Earth Crust of Siberian Branch of Russian Academy of Sciences, Irkutsk, Russia*
[2] *Irkutsk State University, Irkutsk, Russia*
[3] *Institute of Astronomy and Geophysics of Mongolian Academy of Sciences, Lkhagvasuren street – 42, Maakhuur tolgoi, 5 khoroo, BZD, 13343, Ulaanbaatar, Mongolia*

Contact: *sankov@crust.irk.ru*

Abstract

The new data on the active faults of the Central Mongolia have been obtained that allow one to assess the deformation character of the continental crust in the transition zone from the region with predominance of the mountainous terrain (Western Mongolia) to the less elevated and active in the Cenozoic sub-platform area of Eastern Mongolia which is classified as the Amur lithospheric plate. The western boundary of the Amur plate is fragmentarily expressed in the tectonic structure. The beginning of the neotectonic activation of the faults varies from the Miocene in the Orkhon graben and the Pliocene in the Selenga depression to the Late Pleistocene in the Hangai-Hentei tectonic saddle. The traces of the Holocene fault activity were found in many sites. The active faults of the Hangai-Hentei tectonic saddle and the Burgut block form clusters. Among them the strike-slips and strike-slips with the revers component of the displacements dominate. The faults in the Selenga depression are concentrated in the extended zones such as the releasing band. The left-lateral strike-slips and normal faults prevail here. The reconstruction of the paleostress shows that the area between the Amur plate and the Mongolian block deforms under the compression and strike-slip conditions. The conditions of the extension and strike-slip are established in the Selenga depression and within the East Hangai dome.

Introduction

The territory of Mongolia is clearly divided into two parts. The western part is characterized by high velocities of the neotectonic movements and high seismic activity. The eastern part is characterized by relatively low velocities of the vertical neotectonic movements and weak scattered seismicity. According to [Zonenshain, Savostin, 1981], the latter refers to the part of the Amur lithospheric plate. The territory of our research is located in the Central Mongolia in the band between 101 and 105 meridians where many researchers draw the western boundary of the Amur plate (Fig. 1, insert). From south to north, 3 regions are distinguished in this band, differing in the features of the topography, the prevailing strike of the Late Cenozoic structures and the level of seismic activity. The Hangai-Hentei tectonic saddle (Fig. 1, rectangle 1) is characterized by a mid-mountain topography, a weak incision of river valleys which corresponds to a low level of the vertical tectonic movements and sporadic seismicity. The topography of the Burgut block (the Orkhon-Tola interfluve) is more dissected (Fig. 1, rectangle 2). Seismic activity is high since in the western part of the block there was the epicenter of the Mogod earthquake in 1967 ($Mw = 7.0$) and its numerous aftershocks [One century of seismicity ..., 2000]. At the same time, the eastern part of the block is characterized by weak scattered seismicity. The topograhy of the uplifts around Selenga depression (Fig.1, rectangle 3) is also dissected that indicates the relatively high velocity of the vertical movements. Within the massive block of the Buren-Nuruu uplift clusters of weak earthquakes and some earthquakes with a magnitude 5 are located. The structures of the Selenga depression are seismically weak at the present stage.

The Late Cenozoic fault tectonics and the tectonic stress field in the region have been poorly investigated. The tasks of our research include the identification of the active faults in the area, the assessment of their kinematics and the reconstruction of the paleostress state in the zones of these faults which will determine the style of the Late Cenozoic deformation of the earth's crust in the zone of the proposed interplate boundary.

Methods

Fault mapping and investigation of their kinematics was carried out using the interpretation of the space images and 3-D topography models (GTOPO-30). Field verification of the selected lineaments was carried out using the traditional geological-geomorphological and structural methods and was also accompanied by the study of the tectonic fracturing and microdisplacements in the zones of the active faults. For the paleostress state reconstruction the data on fractures and local faults with slicken slits and corrugations were collected. For the stress tensors of the tectonic paleostresses calculations we use the technology implemented in the WinTENSOR [Delvaux, 2012] software package.

Results

One of the important feature of the Late Cenozoic faulting of the area is the inheritance of the ancient linear heterogeneities by young structures. The faults of the Paleozoic and Mesozoic tectonic stages are inherited. In contrast the normal fault with the NE strike which controls the steep southeastern side of the Orkhon graben is laid regardless of the position of the main ancient inhomogeneities with NW strike [Geological map ..., 1998]. All major normal faults with NE strike widely distributed within the southern slope of the Hangai dome have the similar relationships with the main ancient structural inhomogeneities [Cunningham, 2001; Parfeevets, Sankov, 2012].

The Late Cenozoic activation of the faults in the area has signs of pronounced selectivity. Far from every zone of the mapped ancient fault, signs of deformations in the relief of the earth's surface are visible. The totality of the faults of the Hangai-Hentei tectonic saddle and the Burgut block can be classified as a cluster type of structures that represent a set of spatially proximate active faults having the similar kinematics patterns and locations in the field of the tectonic stresses. In the inner part of the Amur plate the cluster type of the active faults localization is replaced by sporadic that is represented by the randomly spatially distributed active faults.

The time of the onset of the neotectonic activation of the investigated faults is debatable. The formation of the Orkhon graben and the volcanism manifestation are observed from the end of the Miocene to the Middle Pleistocene [Rasskazov et al., 2012], it is associated with the activation of the expansion of the earth's crust. The movements along the Orkhon normal fault, as the main controlling structure, occurred from the Miocene up to the Holocene. In the Selenga depression the activation of the sublatitudinal and northeastern structures occurred in the Pliocene-Pleistocene [Khilko et al., 1985]. The fault deformations control the main forms of the topography. Several faults with the traces of Holocene activity were found. Within the Burgut block the latitudinal and northwestern faults control the Pleistocene river valleys and exhibit traces of the Holocene movements. On the Hangai-Hentei tectonic saddle deformations are often not conformal to the topography that existed in the Pliocene and even in the Pleistocene. That is, the most of the discontinuous deformations here are younger than the topography elements of the large valleys they intersect. With a certain degree of caution we can conclude that the beginning of the last stage of the activation of the movements along the faults or at least its main phase refers to the Late Pleistocene.

The kinematics of the Hangai-Hentei saddle faults and their morphogenetic types are associated with their strike. The latitudinal and WNW faults have the left-lateral strike-slip displacements with the revers or thrust vertical component. The horizontal component of the displacements as a rule exceeds the vertical one. The faults with the NW strike at the last stage of tectonic activation (Pleistocene-Holocene) are the revers fault and thrusts with the left-lateral and, in the deviation to the north, the right-lateral strike-slip component. Finally the faults with NE strike distributed mainly within the Hangai dome are represented by the normal faults (Fig. 2). The kinematics of the Burgut block faults are determined quite unambiguously. The revers movements along the NW striking faults and the right-lateral strike-slips along the faults with the submeridional strike are prevailing here (Fig. 2).

Within the Buren-Nuruu uplift the active faults with the sublatitudinal and northeastern strike have the maximum development (Fig. 2). The former are characterized by the left-lateral strike-slip

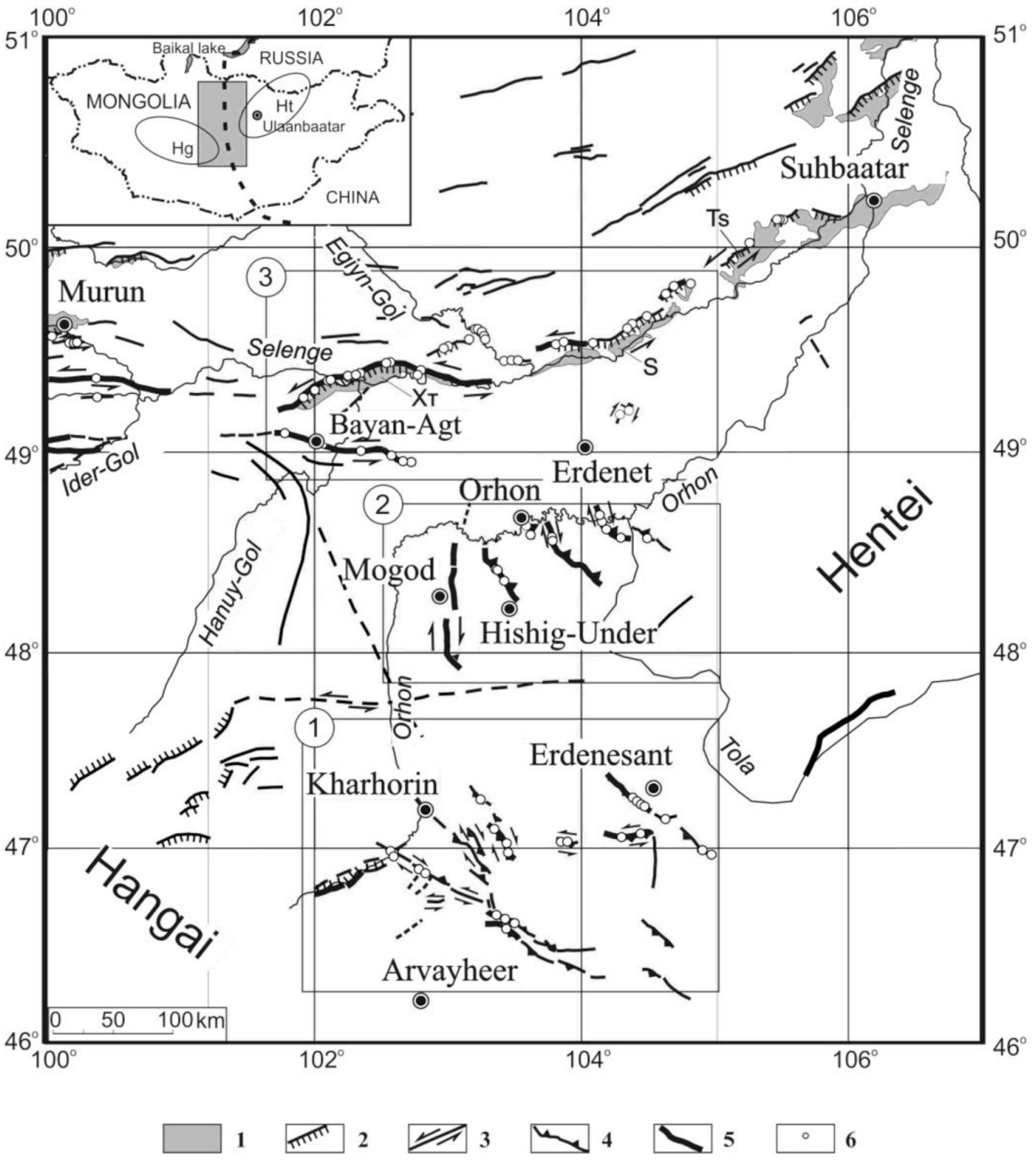

Figure 1: Scheme of faults of the Pliocene-Quaternary and Holocene activation of the central part of Mongolia. – Pliocene-Quaternary basins; 2–4– fault kinematics: 2– normal fault, 3– strike-slip, 4– revers fault and thrust; 5– faults with signs of the Holocene motions; 6– sites of observation. The shaded area in the diagram is the zone of possible position of the Amur plate boundary [Zonenshain, Savostin, 1981]. Inert: the study area (rectangle) and the position of the western boundary of the Amur lithospheric plate. Ellipses indicate the positions of the Hangai (Hg) and Hentei (Ht) domes.

displacements with the normal or revers components depending on their deviation to the north-east or north-west strike respectively. Within the Selenga depression, a combination and mutual transitions of the sublatitudinal and northeastern faults are observed. The northeast faults are represented by the normal faults and left-lateral strike-slip faults. From the west to the east of the area their number increases. Such combination of the active faults is typical for the releasing band structure formed on the latitudinal left-lateral strike-slip [Parfeevets, Sankov, 2012].

The reconstructions of the stress state with the determination of its type was carried out using

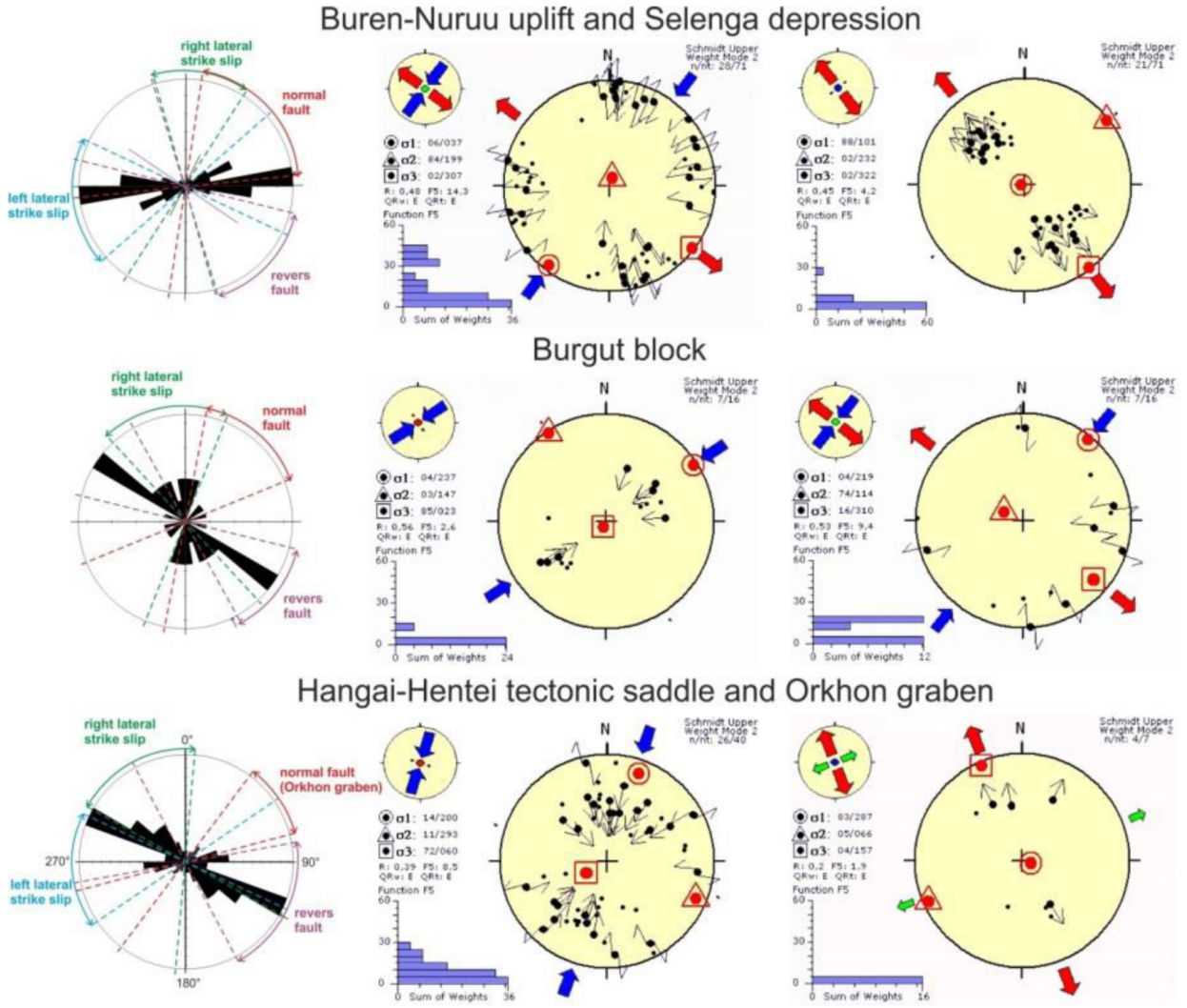

Figure 2: Faults kinematics and the results of the Late Cenozoic crustal stress reconstruction of the Central Mongolia. Left column – rose-diagrams of the active fault directions; central column – reconstructions of the prevailing stress tensor; right column – reconstructions of the secondary stress tensor.

data on the tectonic fracturing and fault displacements. Using all available solutions of the local stress tensors for the last stage of the deformations from the observations established at each site (Pleistocene-Holocene), we estimated the average stress tensor of the tectonic stress field (Fig. 2). For the Hangai-Hentei tectonic saddle the axis of maximum compression is subhorizontal and oriented to NNE. The minimal compression axis is subvertical (the compressive type of the stress tensor). For the Orkhon graben the extension axis (the minimum compression) is subhorizontal and oriented to NNW and the maximum compression axis is subvertical (the extensive type of the stress tensor).

The paleostess state of the earth's crust of the Burgut block is well described by the tensors of the compression and strike-slip types (Fig. 2), which are characterized by a subhorizontal position of the maximum compression axis oriented to the NE. The coincidence of the position of the axes of the main normal compressive stresses and the "re-indexing" of the axes $\sigma 2$ and $\sigma 3$ clearly shows that here the leading axis is the horizontal compression. This compression on the faults with the NW and submeridional strikes is realized in the thrust and strike-slip displacements respectively. The data of the palaeostresses reconstructions in the Mogod basin according to [Complex ..., 2004] coincide with the data noted above for the average direction of the maximum compression axis but more vary in the types of the stress tensors.

The similar situation is observed within the Buren-Nuruu block and Selenga depression (Fig 2). The strike-slip conditions with NNE direction of the maximum compression axis are dominated here.

The extension type of the stress field with NW direction of the minimum compression axis is the secondary. Both tensors have the same direction of the minimum compression axes. The vertically directed $\sigma 1$ and $\sigma 2$ axes have close values and replace each other.

Conclusions

The boundary between the Amur plate and the Mongolian block (according to [Sonenshain, Savostin, 1981]) is fragmentarily expressed in the tectonic structure and represents the marginal part of the active deformation zone. The faults of the territory inherit the ancient linear inhomogeneities of the Paleozoic and Mesozoic ages. The normal faults of the Orkhon graben that are laid independently of the ancient structures are the exceptions.

The beginning of the neotectonic activation of the faults varies from the Miocene in the Orkhon graben and the Pliocene in the Selenga depression to the late Pleistocene in the Hangai-Hentei tectonic saddle. The traces of the Holocene fracture activity were found at many sites.

The active faults of the Hangai-Hentei tectonic saddle and the Burgut block form clusters. Among them the strike-slips and strike-slips with the revers component of the displacements dominate. The kinematics of the strike-slip displacement depends on the strike of the fault. The faults of the Selenga depression are concentrated in the extended zones such as the releasing band. Here the left-lateral strike-slips and normal faults prevail.

The reconstruction of the paleostress shows that the area between the Amur plate and the Hangai block is deformed under the compression and strike-slip conditions. We can note a change from south to north of the strike of the maximum horizontal compression axis from NNE to NE. The conditions of extension and strike-slip are established in the Selenga depression and within the East Hangai uplift.

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