ГЕОТЕКТОНИК

ACTIVE FAULTING IN MONGOLIA

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Introduction

Western Mongolia has been the site of four great (Ms >8) and many moderate sized (Ms 5.3 - 7.5) earthquakes in XX century. This activity is related to the peculiar position of Mongolia, situated between the extensional structures of the Baykal rift system and the transpressional mountain belts of Central Asia. The collision zone between India and Asia is spread over 3000 km from the Himalayas to Mongolia. The collision began about 50 Ma ago (*Beck et al., 1995*) and India has continued to move north into Asia at ~50mm/yr (*Molnar & Tapponier, 1975; Bilham et al., 1997*). Meanwhile the Baykal Rift Zone to the north of Mongolia, one of most active continental rifts, started to extend about 35 Ma ago and is currently stretching at ~4.5 mm/yr (*Calais et al., 1998*). Some of the largest earthquakes in Asia have occurred in Mongolia on strike-slip faults that are several tens, or even hundreds, of kilometers in length.

The active faulting in western Mongolia forms a pattern resembling a parallelogram of conjugate strike-slip faulting surrounding the Hangay dome (Figure 1). Right-lateral faulting on NW-SE or N-S occurs in the west (Mongolian Altay) and east (Mogod), while E-W left-lateral faulting occurs to the north (Bulnay) and south (Gobi Altay). This pattern can help accommodate the expected NNE-SSW shortening in this part of Asia. Although the Hиvsgиl graben system appears to be an extension of the Baykal rift system, the few earthquake mechanisms available in that region show strike-slip faulting.

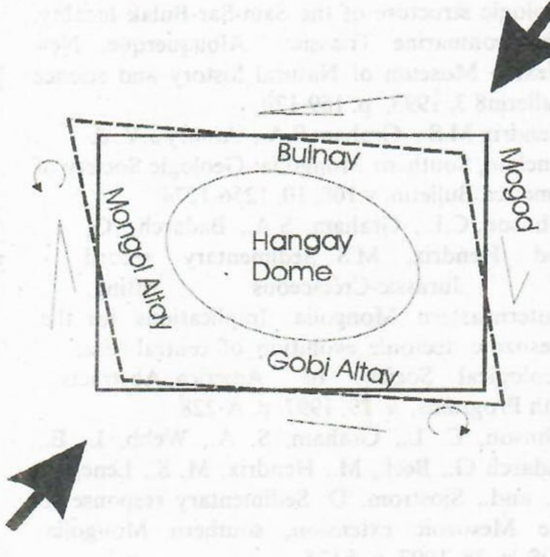

Fig.1. Deformation model of western Mongolia. Shortening processes in the region (shown by thick arrows) can be taken by rotations along conjugate strike-slip faults (modified after *Schlupp, 1996*).

The available earthquake mechanisms in Mongolia are displayed in Figure 2. These include reliable first motion solutions (those whose individual polarities were published) as well as CMT and body waveform solutions.

Mongolian Altay

Most earthquakes within the Mongolian Altay range are consistent with right-lateral strike-slip on NW-SE faults or thrusting on roughly E-W faults (Figures 3 and 4). The area has a high risk for great earthquakes. The Fu Yun earthquake of 10 August 1931 produced surface ruptures 180 km long with NW-SE right-lateral slip

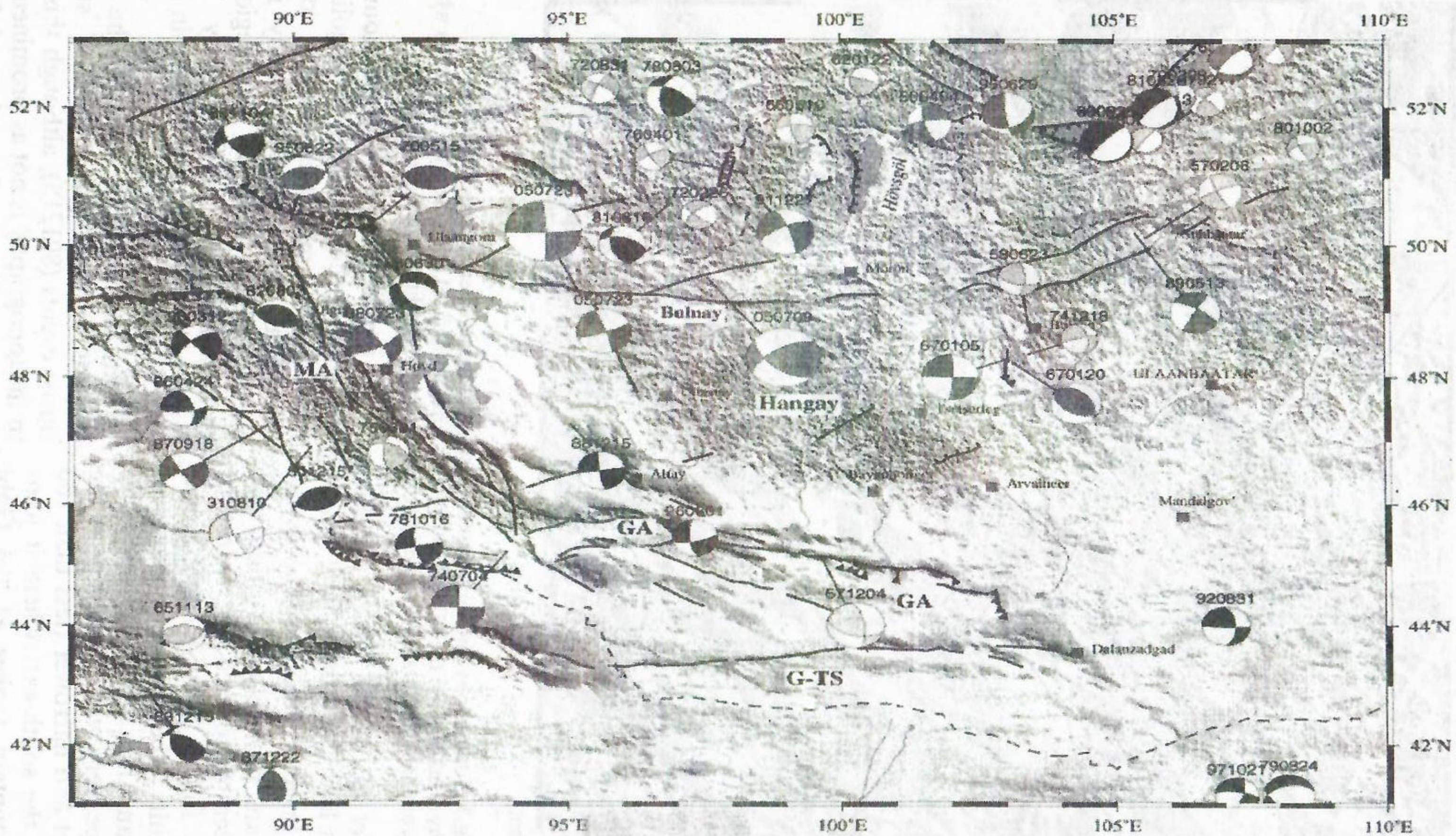

Fig.2. Fault plane solutions of Mongolian earthquakes. Earthquake mechanisms are from first motion solutions, Harvard CMT solutions and body waveform modeling results. MA □ Mongolian Altay, G-TS - Gobi - Tien Shan, GA - Gobi Altay.

Fig.3. Topography and fault plane solutions of the northern Mongolian Altay. Topography is taken from the GTOPO30 dataset, and illuminated from the SW. The faults which are most prominent topographically and well-expressed on satellite images are in black.

(*Baljinnyam et al., 1993*). There are also many known late Quaternary fault scarps produced by large earthquakes (*Baljinnyam et al., 1993*), and probably many more that have not been discovered yet. Most of these scarps follow NW-SE right-lateral strike-slip faults. The overall geometry of the Mongolian Altay mountains resembles a wedge shape, very wide (~600 km) in the northern part and narrower (less than 100 km) toward the south-east where it joins with the mountain ranges of the Gobi Altay.

In the northern part of the mountains, near the border between Mongolia and Russia, the mountain ranges of the Mongolian Altay turn gradually into a north-westerly trend. In this region the earthquakes are predominantly thrust faults (events 700515 and 950622 in Figure 3).

At the southern end of the range (Figure 4) there are also E-W striking thrust events (801215), although this trend in the topography is not as prominent as in the north. The configuration of faulting and especially the terminations of the

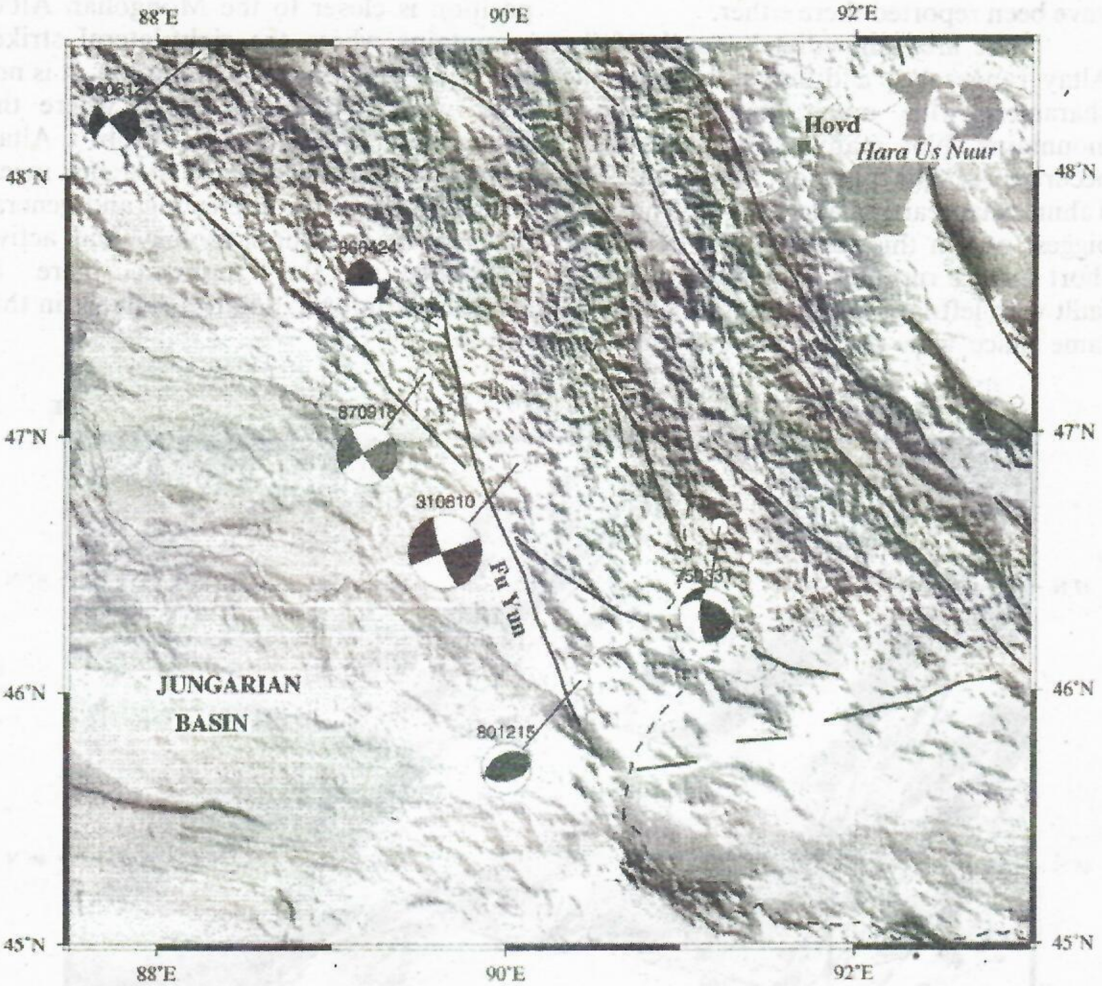

Fig.4. Topography and fault plane solutions of the southern Mongolian Altay. Topography is taken from the GTOPO30 dataset, and illuminated from the SW. The faults which are most prominent topographically and well-expressed on satellite images are in black.

strike-slip faults in the Mongolian Altay mountains might be related to rotations about a vertical axis.

Gobi Altay

The Gobi Altay mountains consist of E-W elongated ridges about 600 km long (Figure 1). These mountains also have the potential to generate great earthquakes such as that in 1957, which produced about 260 km of surface ruptures involving left-lateral strike-slip motion with a reverse component (*Kurushin et al., 1997*). The Valley of Lakes fault system (Figure 5), the eastern part of which ruptured during the 1957 earthquake, is the most prominent active fault system within the range. There are many other late Quaternary fault scarps further west in the Gobi Altay, probably produced by earthquakes in the Holocene. There have not been many significant earthquakes within the range since 1957. Those of 881215 and 960801 both occurred in the western part and are consistent with E-W left-lateral strike-slip faulting (Figure 5). In the south the range is bounded by a very prominent fault, running NW-SE from 96°30'E, 45°15'N to 100°10'E, 44°10'N (Figure 1), well-expressed in the topography. However there has been no recent seismic activity on this fault and no late Quaternary ruptures have been reported there either.

The area immediately south of the Altay ranges has a different topographic character, with much smaller isolated mountains. Not many earthquakes have occurred in this part of Mongolia. The Tahiin Shar earthquake of 740704 is the biggest one in this century, and produced short surface ruptures on a WSW trending fault with left-lateral slip, approximately at same place with the epicentre (Figure 5). earthquakes in the Gobi Altay, but its position is closer to the Mongolian Altay mountains where the right-lateral strike-slip faults are dominant (Figure 5). It is not clear what happens in detail where the Mongolian Altay and Gobi Altay conjugate strike-slip fault systems meet. Although this is an interesting and general problem in structural geology and active tectonics, at this moment there is insufficient information to resolve it in this region. .

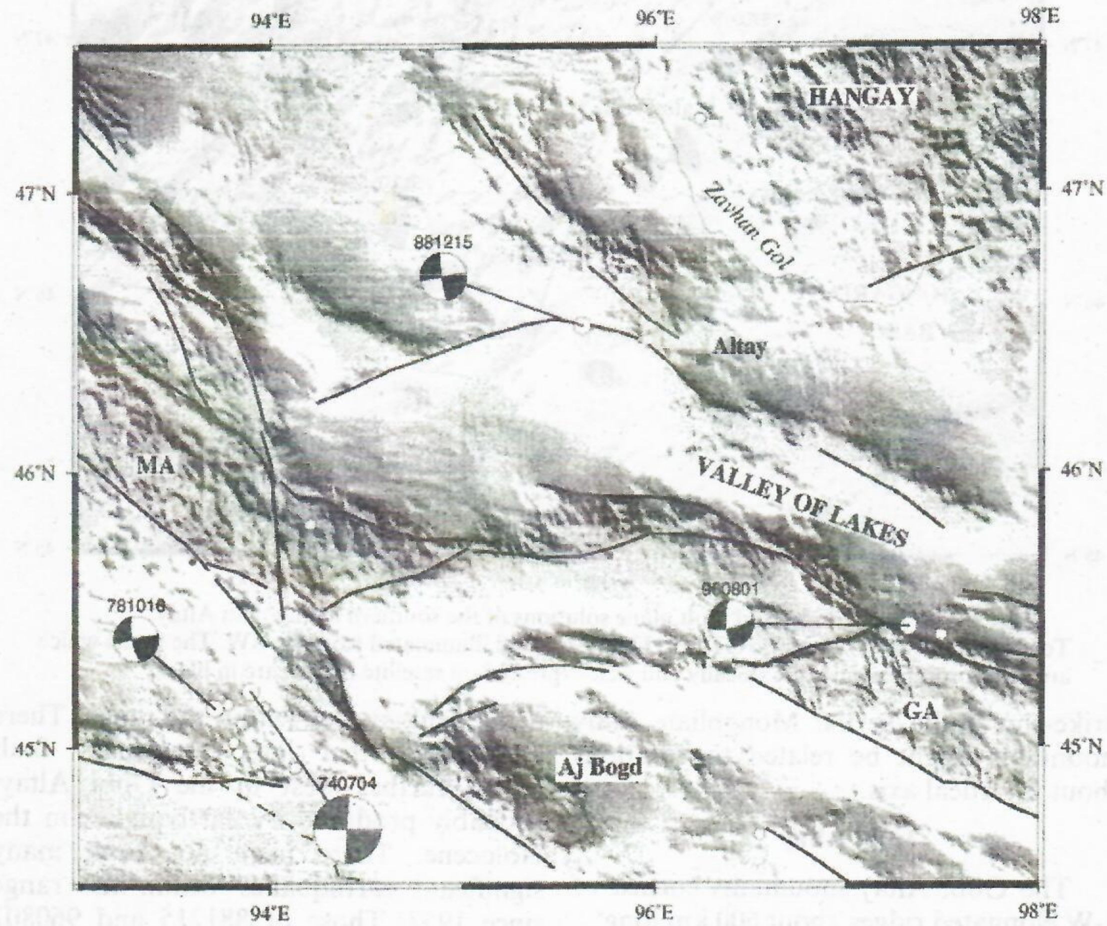

Fig.5. Topography and fault plane solutions of the junction area of the Mongolian Altay and Gobi Altay mountains. Topography is taken from GTOPO30 dataset, and illuminated from SW. The faults which are most prominent topographically and well-expressed on satellite images are in black. MA-Mongolian Altay, GA-Gobi Altay.

This event occurred south of the point where the mountain ranges of the Mongolian Altay and Gobi Altay join. It is somewhat anomalous in that it involved left-lateral slip, consistent with the

Huvsgul and the grabens of northern Mongolia

There are number of moderate-sized earthquakes recorded in the Huvsgul area of northern Mongolia. In this region three north-south grabens, known as the Hиvsgиl graben system, are the most prominent expression of recent tectonic activity. Surprisingly, most earthquakes west of lake Hиvsgиl have strike-slip fault plane solutions, such as the most recent and largest event of 911227 (Figure 6) at 13 km depth. A similar first motion solution was obtained for an earlier earthquake (760401). It is not clear whether the slip in these events was left-lateral on a north-east fault or right-lateral on a northwest fault. Both events occurred near the sharp eastern edge of the Busiin Gol graben, a prominent north-northeast rift. Southwest of Busiin Gol is the triangular-shaped Tere-Kol basin with a sharp faulted boundary on the NW side. The earthquake of 720226 may have occurred on a SW continuation of the Tere-Kol fault, involving predominantly NE-SW right-lateral strike-slip. Further west, thrusting becomes dominant (780803 and 810816). Other events in the region outside the grabens themselves mainly show strike-slip faulting or strike-slip with a significant thrust component. The events east of lake Hиvsgиl, towards Baykal, have strike-slip faulting mechanism (see events 500404 and 950629 in Figure 6).

Hangay Dome

The Hangay dome in central western Mongolia is a site of late Cenozoic volcanic eruptions. In some places these basaltic flows create the highest topography, showing that Hangay was uplifted relatively recently, from which it has been inferred that a mantle plume upwells beneath the region (*Zorin et al., 19982; Baljinnyam et al., 1993; Windley & Allen, 1993; Cunningham, 1998*). There are number of short normal fault scarps within the Hangay, although it has been quiet seismically this century (Figure 1). On the northern border of the Hangay dome, the E-W Bulnay fault produced the great 1905 earthquakes, with left-lateral surface ruptures up to 400 km long, and displacements up to 11 m (*Florensov & Solonenko, 1965; Baljinnyam et al., 1993; Schlupp, 1996*).

Central Mongolia

Seismic activity is much less in the area east of Hangay (Figure 1). The Mogod earthquake of 5 January 1967 is the biggest recent one in this region and was located near the north-east edge of the Hangay. It produced right-lateral strike-slip ruptures on north-south faults.

The 890513 event in northern central Mongolia is located near structures that appear to be eastern continuations of the large E-W left-lateral faults which bound the northern edge of the Hangay dome. However, as was noted in the discussion of the event earlier, its source mechanism implies right-lateral, not left-lateral slip on those structures, and so is enigmatic. Another event nearby on 570226 apparently had a similar mechanism (*Petit et al., 1996*).

Discussion and conclusions

The elongate mountain ranges of the Mongolian Altay and the Gobi Altay accommodate shortening related to the India-Eurasia collision. Fault plane solutions in the NW-trending Mongolian Altay show mostly right-lateral strike-slip with a minor reverse component. The southern and northern ends of this range are dominated by east-west striking thrusts. Within the Gobi Altay range faults are mostly left-lateral with a reverse component. The Hangay dome has had few significant earthquakes this century, although there are several recent fault scarps within it, most of which seem to indicate normal faulting. Several moderate-sized earthquakes have occurred west of Hиvsgиl lake, with strike-slip mechan isms.

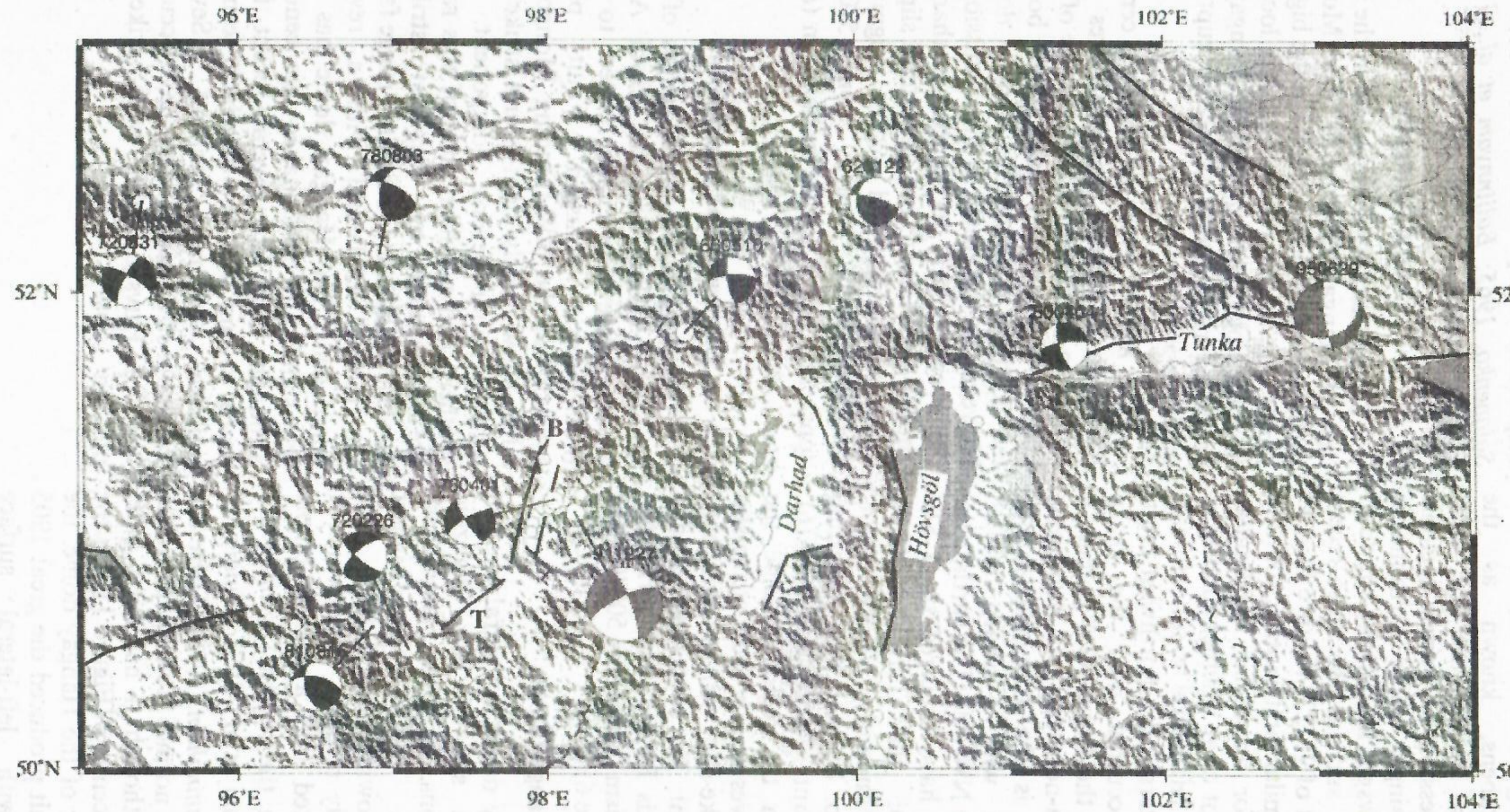

Fig. 6. Topography and fault plane solutions of the Hıvsgıl graben system. Topography is taken from the GTOPO30 dataset, and illuminated from S-W. The faults which are most prominent topographically and well-expressed on satellite images are shown in black. B -- Busiin Gol graben, T -- Tere-Kol.

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