ISSN 1028-334X, Doklady Earth Sciences, 2006, Vol. 411, No. 8, pp. 1324–1326. © Pleiades Publishing, Inc., 2006.
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GEOPHYSICS

Grouping of Strong Earthquakes in Central Asia: New Possibilities of Medium-Range Forecast of Seismic Events in the Northern Tien Shan Region

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Presented by Academician V.N. Strakhov, February 6, 2006

Received February 9, 2006

DOI: 10.1134/S1028334X06080356

We consider deep-focus Hindu Kush and crustal Altai ($M \geq 7.0$) groups of strong earthquakes in Central Asia (they can occur in the opposite order), which are followed by a northern Tien Shan earthquake ($M \geq 6.0$) with a time lag up to 1.5 yr. A total of five groups of such events occurred during the last 100 yr. The probability of their random occurrence is quite low. The last group (2002–2003) was unusual because the typical triad of events on November 8, 2005, was accompanied by one more very strong crustal earthquake ($M = 7.6$) near the Hindu Kush zone of deep-focus seismicity. We discuss the geodynamic mechanism responsible for the earthquake groups mentioned above. The obtained data can be used for medium-range forecast of earthquakes in northern Tien Shan.

In [1, 2], we distinguished pairs of strong earthquakes: the deep-focus Hindu Kush earthquakes ($M \geq 6.7$) and the accompanying strong crustal earthquake with a time lag of 4.5 months ($M \geq 7.0$) in a vast region of central and southern Asia bounded by coordinates 30°–41° N and 57°–81° E. In this work, which continues these investigations, groups of interrelated events in Central Asia are distinguished.

The analysis of seismicity in Central Asia revealed grouping of strong earthquakes in the Hindu Kush, Altai, and northern Tien Shan regions. Events in the first two regions can also occur in the opposite order, while earthquakes in northern Tien Shan always accompany events in the former regions. Table 1 presents the data on the groups of strong events over a 100-yr period (for the Hindu Kush and Altai regions with $M \geq 7.0$; for northern Tien Shan, $M \geq 6.0$). It is evident that five groups of such events occurred during the last century (Table 1; Figs. 1, 2). The Hindu Kush earthquakes were deep-focus events (h = 100–230 km), whereas other events occurred in the crust. The duration of episodes related to triplets of earthquakes vary from 1.8 to 6.9 yr. At the same time, the interval from the second to the third event in the triplets varies from 20 days to 1.5 yr. It is significant that all strong Altai earthquakes with $M \geq 7.0$ and five of the six northern Tien Shan earthquakes with $M \geq 6.0$ (excluding only the Zhalanash–Tyup earthquake on March 24, 1978, with $M = 7.0$) fall into these groups. It is worth noting that, in four triplets of the total five, the magnitudes of the northern Tien Shan events were 0.2–1.4 units lower than the corresponding Hindu Kush and Altai earthquakes. Moreover, the earthquake energy in these four groups regularly decreased from the first to the last event. We also note that the magnitudes of the northern Tien Shan events monotonously decreased from the beginning of the 20th century. One can see a tendency of an increasing time interval between the Altai and northern Tien Shan earthquakes with increasing distance between their epicenters ΔR.

Let us estimate the probability of random occurrence of the five groups of events considered here. First, we note that from 1902 to 2002, 16 Hindu Kush earthquakes with $M \geq 7.2$ occurred over a 100-yr period. On average, such events occurred approximately every seven years. Table 1 suggests that the time intervals between the Altai and Hindu Kush earthquakes vary in the triplets from 1.6 to 6.3 yr. Hence, the probability of the occurrence of five pairs of Hindu Kush and Altai earthquakes is rather high.

The probability of random occurrence of five northern Tien Shan earthquakes in the groups is estimated as follows. The total duration of 1.5-yr intervals, which include all such events after the corresponding pairs, is equal to 7.5 yr. The probability of the occurrence of one

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Strong earthquakes in Central Asia

Date	φ, °N	λ, °E	h, km	M	ΔT*, yr	ΔR**, km	Earthquake
July 23, 1905	49.2	96.2	25	8.2			Bolnai
July 7, 1909	36.5	69.0	230	8.0			Aivadzh
Jan. 3, 1911	42.9	76.9	25	8.2	1.5	1650	Kemin
Aug. 10, 1931	46.5	90.5	40	7.8			Mongol–Altai
Nov. 14, 1937	35.0	73.0	200	7.3			Hindu Kush (I)
June 20, 1938	42.7	75.8	21	6.9	0.6	1240	Kemin–Chuya
Mar. 14, 1965	36.6	70.8	215	7.7			Hindu Kush (II)
May 15, 1970	50.2	91.3	12	7.0			Tsagan–Shibetui
June 5, 1970	42.5	78.9	15	6.8	0.1	1280	Sarykamysh
July 29, 1985	36.2	70.9	100	7.2			Hindu Kush (III)
June 14, 1990	46.9	85.1	42	6.9			Zaisan
Nov. 12, 1990	43.1	78.0	15	6.4	0.4	700	Baisorun
Mar. 3, 2002	36.5	70.5	225	7.4			Hindu Kush (IV)
Sept. 27, 2003	50.1	86.7	20	7.3			Chuya
Dec. 1, 2003	42.9	80.4	15	6.0	0.2	975	Ketmen
Nov. 8, 2005	34.4	73.5	12	7.6			Kashmir

Note: (*) Time lag of the North Tien Shan earthquake relative to the second event in triad; (**) distance between epicenters of the Altai and North Tien Shan earthquakes.

strong northern Tien Shan earthquake during an interval of 7.5 yr (in a 100-yr period) is equal to $p = 0.075$. The probability of occurrence of five such events of the total six during this interval is determined by an elementary relation

$$P_{5,6} = C_6^5 p^5 (1-p). \qquad (1)$$

Substituting the p value, we find that $P \sim 1.3 \cdot 10^{-5}$. Hence, the probability of the random occurrence of the five groups of events considered here is negligibly small. The data presented above indicate that the sequence of earthquakes in Hindu Kush and Altai does not play a significant role. The main event is the occurrence of the pair of such events with an interval up to 6 yr, after which the probability of the occurrence of an earthquake in northern Tien Shan within the following 1.5 yr sharply increases.

The response of the northern Tien Shan region to events in the Hindu Kush and Altai regions is mainly caused by the following fact. According to the currently popular tectonic model, the stress field in the lithosphere of Central Asia is mainly governed by the collision of the Indian and Eurasian plates [3, 4]. Numerous geological and geodesic data agree with this model [3–6]. A vast region of Central Asia extending from the Hindu Kush and western Himalayas to the Altai and Sayan Mountains (approximately up to 96° E) is in a comparatively uniform stress field of submeridional compression [7]. A pair of strong earthquakes in Hindu Kush and Altai is accompanied by the redistribution of stress, naturally resulting in compression over the entire region between the sources of these events. This effect is most prominent approximately in the middle between these sources. The sources of strong earthquakes in northern Tien Shan are located precisely in this region. A significantly smaller mean energy of these earthquakes (as compared to the energy of other events in the triplets) is an additional argument in favor of the interpretation proposed above.

We note that the group of events in 2002–2003 is unusual not only because the weakest earthquake (M = 6.0) among those considered here was recorded in northern Tien Shan, but mainly because this response on October 8, 2005, was followed by another strong crustal earthquake (M = 7.6) in the Kashmir region near the Hindu Kush zone of deep-focus seismicity (Table 1, Fig. 1). This was the strongest event in the study region in the past 100 yr (at distances up to 600 km from the center of this zone).

Within the framework of the suggested mechanism of seismic response formation, the effect of this earthquake in northern Tien Shan should be similar to the effect of the deep-focus Hindu Kush events. It is natural to suppose on the basis of the obtained data that the group of strong earthquakes in 2002–2005 can be followed by another strong tectonic event ($M \geq 6.0$) in northern Tien Shan. The most probable interval of its occurrence is 1.5 yr after the Kashmir earthquake, i.e., approximately before April 2007. In [8], based on the analysis of the totality of geophysical and geological data, it was suggested that the Kirgiz Ridge area located

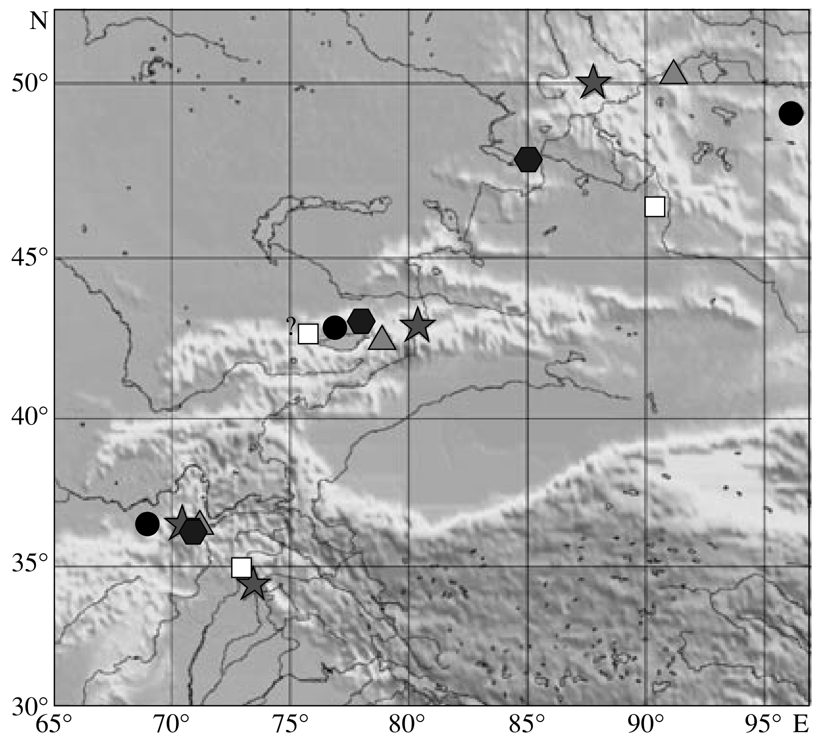

Fig. 1. Chart of the study region with epicenters of strong earthquakes. Groups of strong events: 1905–1911 (circles); 1931–1938 (boxes); 1965–1970 (triangles); 1985–1990 (hexagons). Asterisks denote the group of strong earthquakes in 2002–2005. The question mark denotes the region of expected strong event in Northern Tien Shan according to [8].

southeast of Bishkek is one of the regions of preparation of such earthquake. We note that two relatively strong events ($M \sim 5.0$, $h \sim 20$ km) in this region on January 16, 2004, and June 2, 2004, possibly, can be considered as foreshocks of earthquakes related to the expected triad, since relatively deep events frequently become percursors of strong crustal earthquakes [9, 10].

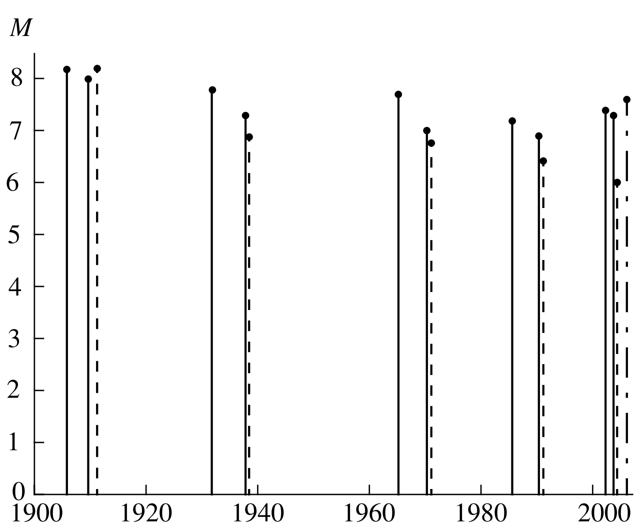

Fig. 2. Earthquake magnitude vs. time relationship. Dashed lines denote events in northern Tien Shan; dashed-dotted line, the Kashmir earthquake.

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