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Variations of the Earth's Rotation Velocity and the Geodynamic Processes in Central Asia

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The analysis of seismic data [1, 2] shows that from 1907 to 1985, nine exceptionally strong deep-focus Hindu Kush earthquakes occurred. Six of them were followed (on average, within some months of retardation) by strong crustal earthquakes of $M \geq 7.0$ in the Central Asia region. It is easy to verify that the probability of the accidental occurrence of even a few pairs of such events within a relatively brief period is very low. The present paper is devoted to the study of this phenomenon.

Figure 1 shows a plot of variation of the Earth's rotation velocity ω_E averaged over the years from 1958 to 1988. The plot demonstrates the moments of occurrence of deep-focus and accompanying crustal earthquakes in the Central Asia region. It is seen that strong crustal earthquakes were not observed after three deep-focus events with $M > 7$ in 1962, 1965, and 1966. It is essential that these events happened against the background of a decrease of the Earth's rotation velocity, whereas the moments of occurrence of all of the remaining deep-focus earthquakes correspond to periods of increasing ω_E.

The analysis of the primary data reported in [4] shows that all three of the strongest deep-focus earthquakes, which were observed in the first half of the century (in 1907, 1909, and 1949) and were followed by the crustal earthquakes with $M > 7.0$ in the Central Asia [1], also took place against the background of decreasing planet rotation.

Hence, an important conclusion follows: at periods of increased rotation of the Earth, a certain geodynamic mechanism may be triggered, which results in a sharp increase in the level of seismicity in the Central Asia region for relatively short periods after the strong deep-focus Hindu Kush earthquakes.

Our analysis of slow crustal movements, based on tiltmeter records from the Talgar station, northern Tien Shan (20 km east of Alma-Ata), showed that periods of relatively fast increase of the ω_E value are characterized by substantial changes of the inclination rate induced by Hindu Kush earthquakes of $M \geq 5.0$.

The results obtained testify that with the increasing velocity of the Earth's rotation, the strong deep-focus Hindu Kush earthquakes are markedly reflected in crustal deformation processes even at a relatively great distance from the earthquake center. In our opinion, the reason for this phenomenon is as follows.

Previously [5], it was shown that in the Hindu Kush region, the structure of the upper mantle is radically different from that of a typical subduction zone. There are strong grounds to believe that in the deep-focus seismicity zone, two heavy blocks are submerging into the lighter mantle at a depth of about 200–400 km. This gives rise to a tension zone which is immediately intruded by mantle anomalous flows represented by a very low-viscous material with a perceptible proportion of the liquid phase and characterized by intensive absorption of S-waves. The chief reservoir of this material is at a depth of up to 100 km to the south of Hindu Kush.

In addition, there is evidence that a certain volume of the anomalous mantle enters the deep-focus seismicity zone from underneath the Tadjik depression. In this

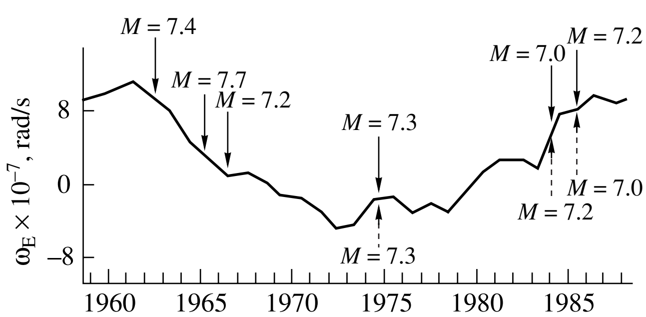

Fig. 1. Variations of the Earth's rotation velocity from 1958 to 1988 (departures from the mean value adopted from [3]) and the moments of occurrence of the strong earthquakes in Central Asia. The solid arrows designate the deep-focus Hindu Kush earthquakes; the dash-arrows indicate the crustal earthquakes.

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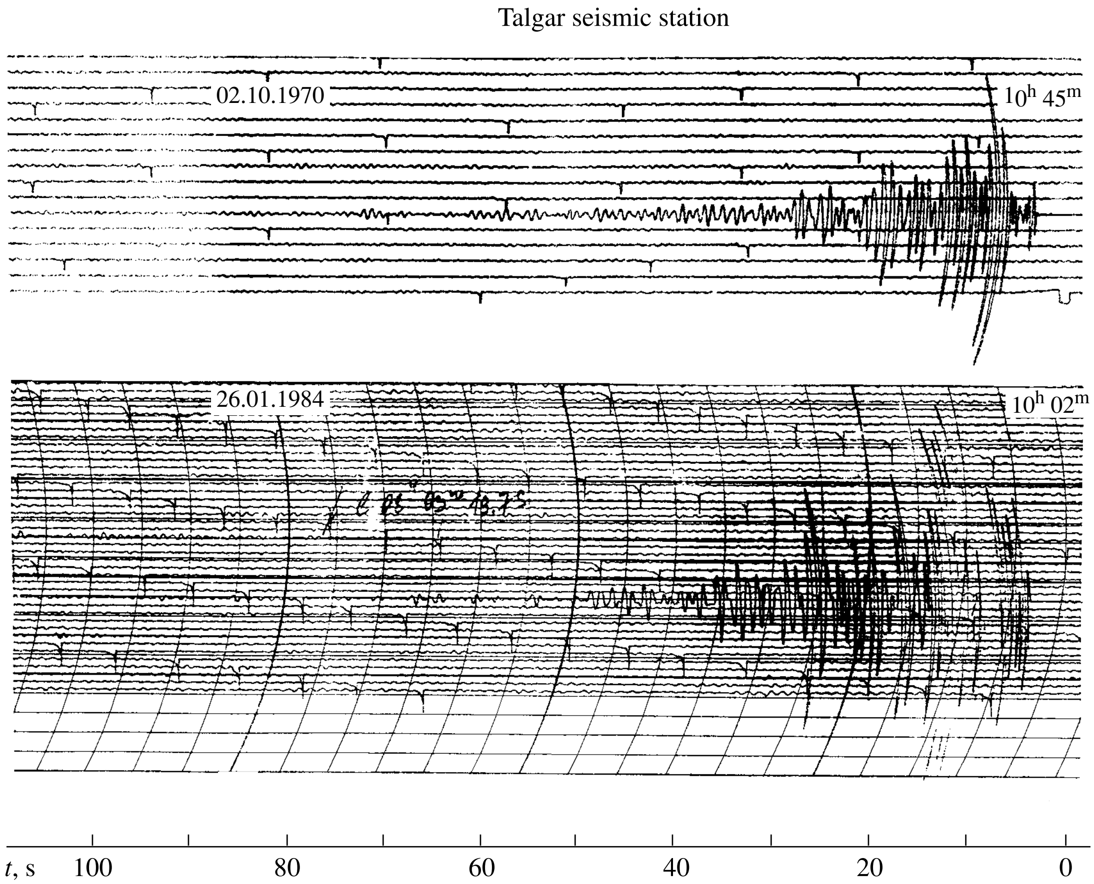

Fig. 2. Examples of the records of the Kotur-Bulak quarry explosions. Talgar station, KSE channel.

context, the deep-focus earthquakes are most likely related to phase transitions in the anomalous mantle, which are followed by a decrease in volume (possibly due to transformation of the mantle to the solid phase).

By virtue of the law of conservation of momentum, an increase of the Earth's rotation velocity should be accompanied by a decrease in the radius and, therefore, by the contraction of the surface area of our planet. However, it is believed that the contraction of the surface area is uneven, and is concentrated mainly in the weakened zones, i.e, in the tectonically active regions where the thickness of the lithosphere is reduced and the fault system is developed. This is demonstrated by the fact that in tectonically active regions, the average rate of the crustal deformation is an order of magnitude higher than in platform regions [6].

In the lithosphere of tectonically active regions, the additional compression should squeeze the liquid phase from some zones of the upper section of the lithosphere into the deeper horizons of the upper mantle and lead, in part, to acceleration of its submergence in the Hindu Kush region. It results in intensification of the phase transitions within the anomalous mantle and, therefore, in initiation of the strong deep-focus earthquakes.

The decrease in volume of a sector of the upper mantle due to a strong earthquake causes a further increase in the rate of the anomalous mantle submergence. It has been shown that in the Tien Shan region, the lower part of the Earth's crust and the upper part of the mantle are penetrated by a network of narrow "channels" of the anomalous mantle, which extend for many hundreds of kilometers from the Tien Shan depression to the northern Tien Shan [7, 8]. Information on the increasing rate of the anomalous mantle submergence in the Hindu Kush region is conveyed by this system of channels (for example, by attenuated viscous waves slowly [9]), which causes still more intensive squeezing of the liquid phase and, therefore, a sharp increase of the rate of crustal deformation above the channels.

Indicators of this process include the variations of the inclination rate of the Earth's surface in some regions of the Tien Shan. The acceleration of the liquid phase migration may also be a trigger mechanism that activates preparation of the strong crustal earthquakes in the most suitable zones. It counts in favor of this conclusion that in the Tien Shan region, the vast majority of earthquake centers with $M \geq 6.0$ are located in the channel system of the anomalous mantle [7, 8, 10].

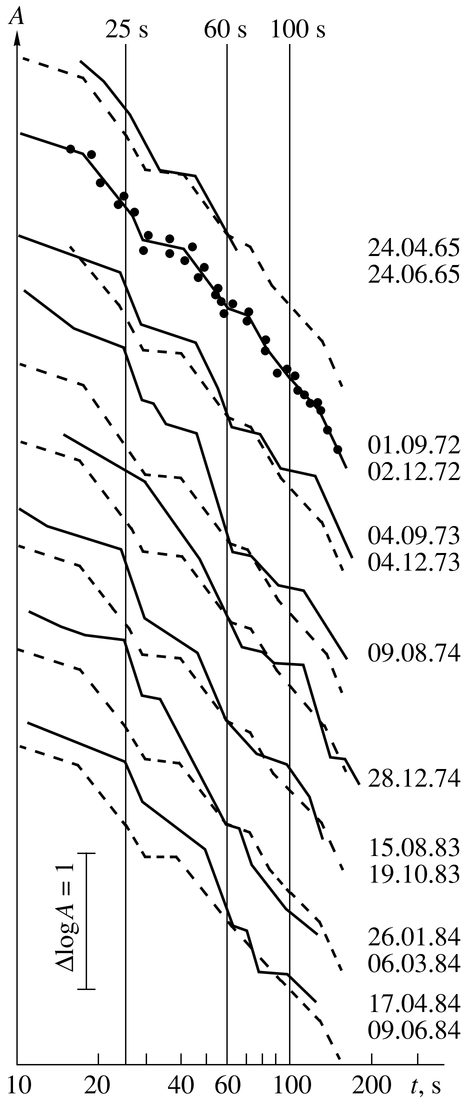

Fig. 3. Envelopes of the quarry explosion records (Kotur-Bulak quarry) in various years. Talgar station, KSE channel. The dispersion of data is demonstrated with the example of two records obtained in 1972. The dashed line is the coda envelope of 1972.

To check these conclusions, we performed a detailed analysis of variations of the enveloping coda-wave pattern on the records of the nearby quarry explosions, obtained at the Talgar station. As was shown previously [10], at a frequency of ~1 Hz, the coda of the nearby earthquakes and the quarry explosions was formed, for the most part, by transverse waves reflected from the numerous subhorizontal boundaries in the Earth's crust and upper mantle. Because of this, the coda envelope pattern serves as a reliable indicator of the presence of the liquid phase at significant depths in the zone between an epicenter and a station.

We processed the seismograms of explosions at the Kotur-Bulak quarry, which is located at a distance of approximately 20 km from the station [11]. The records of the narrow-band KSE channel with maximum amplification in the 1 Hz zone were analyzed.

Figure 2 presents typical examples of the explosion records from the Kotur-Bulak quarry. The explosion performed in 1984 is marked by the following feature: at a period of increased rotation velocity of the Earth, amplitudes in the coda of the span $t \sim 25$–70 s dampen some 4 times as fast as those in the explosion of 1970, which is marked by the interval of ω_E decrease (parameter t is measured from the moment of onset of the seismic energy emission in the center).

Figure 3 shows the summary enveloping codas of various years from 1965 to 1984. It is seen that in the span $t = 25$–60 s, which corresponds to the depths from 45 to 125 km in the model of single reflections of the traverse waves [10], the mildest coda damping was observed in 1972, when large local minimum of the Earth's rotation velocity was noted (Fig. 1). In the coda envelopes of 1972, two parts are distinguished with relatively fast damping of amplitudes in the ranges of 17–30 and 40–60 s, which correspond to the depths of 30–55 and 80–125 km. In these depth ranges, the quality factor values Q_S (estimated from the formula: $A(t) \sim \exp(-\pi t/Q_S T)/t$, where T is the period of oscillation [10]) are equal to 40 and 100, respectively. In the explosion records of 1965, against a background of deceleration of the Earth's rotation within 1–3 months after the largest Hindu Kush earthquake on March 14 ($M = 7.7$), the coda envelopes are little different from the curve plotted on the basis of the records of 1972.

At the same time, at periods of increasing value ω_E the envelope pattern is essentially changed. Already in 1973, the steep slope sectors shifted to the spans of 25–29 and 45–62 s (depth ranges of 45–52 and 90–130 km, respectively); for these spans, the values Q_S decreased to 19 and 45, respectively. Within ten days after a Hindu Kush earthquake with $M = 7.3$ (July 30, 1974), in these depth ranges, the quality factor decreased still further ($Q_S = 17$ and 30). After the Markansui earthquake on August 11, by the end of 1974, the sector of the relatively steep decrease of amplitudes shifted to the span of 30–70 s and the quality factor increased up to 70. In late 1983, at the depth intervals of 45–52 and 90–125 km, the quality factor became equal to 16 and 45, respectively. After the deep-focus Hindu Kush earthquake on December 30, 1983, when the most rapid increase of ω_E began, within more than two months, the high absorption zones corresponded to the depth intervals of 45–52 and 65–115 km ($Q_S = 15$ and 50). By the middle of 1984, after the Gazli earthquake on March 19, the roof of the lower zone subsided to the depth of 95 km and the quality factor of the medium decreased up to 35 in this zone and increased up to 25 in the upper zone.

Note that, as well as in the other regions [5, 8, 12], all the envelopes show very low-angle sectors with a duration of up to 20 s (for the time values $t \le 100$ s); within many of them, the damping of amplitudes in the coda is even slower than that derived from the law $A \sim t^{-1}$ which corresponds to the model of single reflections of traverse waves. This is due to the very low absorption of the traverse waves in the respective layers due to the migration of liquid phase into other horizons [8].

Our data obtained testify that the essential change in the form of the coda envelopes due to the submergence or uplift of the high-absorption layers by up to some tens of kilometers may occur over a period of 1–2 months. Hence, the liquid phase migration may be equal to some millimeters per second.

Thus, it is established that in the lower part of the crust and the upper parts of the mantle, the high-absorption zones shift with time; in some regions of the lithosphere and asthenosphere, during the intervals of rapid increase of the Earth's rotational velocity, the values of Q_S are observed to decrease, which is particularly perceptible within the first months after the strongest earthquakes in Hindu Kush. This supports the conclusions made above that the vertical migration of the liquid phase in the crust and upper mantle serves as one of main mechanisms of conservation of the Earth's angular momentum and explains the previously noticed relation between the strongest deep-focus Hindu Kush earthquakes and the crustal ones in the Central Asia region.

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