

heterogeneities are noted as well, on which scattering of PKiKP waves takes place and the coda of arc type is formed.

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5. Seismogeodynamics and seismic hazard prediction

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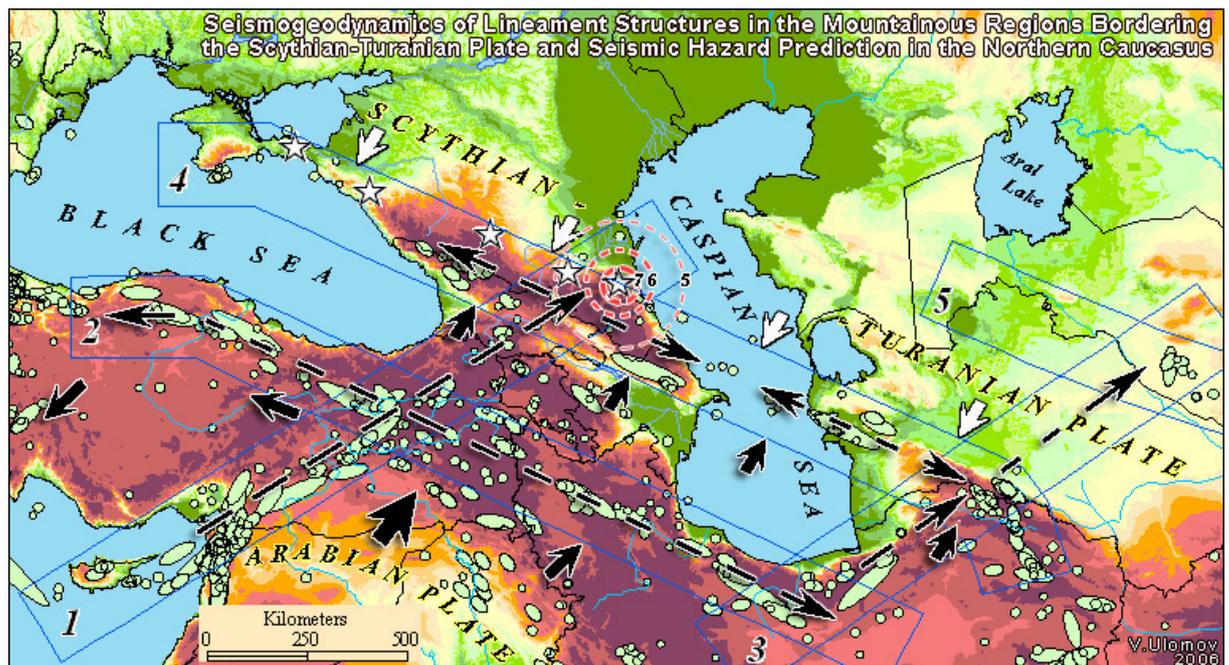


Fig. 5.1. Position of profiles (bands) covering seismic lineaments along which time-space and energy evolution of seismic geodynamic processes was studied. Profiles: 1 – Cyprus – Caucasus, length 1870 km; 2 – Anatolia – Elburs, 2270 km; 3 – Elburs – Turan, 1520 km; 4 – Crimea – Kopetdag, 2500 km; 5 – Southern Tien Shan, 2520 km. Short black arrows show the direction of geodynamic effect, white arrows show the reaction of the Scythian-Turanian platform on compressive force from the Arabian lithospheric plate (large arrow) and the Alpine structures of the Iran-Caucasus-Anatolia region. Dashed-line arrows show the direction of seismic activation migration along profiles. Stars indicate the location of earthquake potential sources of $M = 7.0 \pm 0.2$ in North Caucasus. Iseismal lines are shown around one of them.

This research continues the work on dynamic zoning of seismic hazard in North Eurasia including the territory of Russia and abutting seismically active regions (See Ulomov V.I., 1999-2002).

The major object at this stage is the Iran-Caucasus-Anatolia region, which is seismically hazardous for the south of the European part of Russia. Abutting territory of the Central Asia, which is tectonically associated with the Iran-Caucasus-Anatolia region and Scythian and Turanian platforms, was considered as well (Fig. 5.1).

The research to reveal potential sources of strong earthquakes in North Caucasus and Ciscaucasia is based on new concepts of seismic geodynamics of seismically active regions and space-time and energy degree of order of earthquake generating structures. The term “seismic geodynamics” (SGD) proposed by V. I. Ulomov in the middle of 1960s came into active use in seismological practice. As distinct from seismotectonics, which for the major part studies the statics and the spatial relation between seismic sources and tectonics, seismic geodynamics treats the nature of seismicity as a result of movements of the Earth’s crust and of the whole lithosphere with account for their deep structure, strength characteristics, hierarchic fault-block structure, stress and strain at various scales from local sources of individual earthquakes to structures generating regional and global earthquakes. Time-space and energy evolution of seismic activation along seismic lineament structures (deformation waves, earthquake source migration and others) play a key role in this case.

It is demonstrated that transition areas from mountain structures of North Caucasus and the west of Central Asia to Scythian and Turanian platforms are a single geodynamic system that determines the features of seismic conditions on the whole area under studies. The research in time-space and energy evolution of seismic geodynamic processes along major lineament structures revealed regularities in the position of earthquake sources, in the processes of seismic activation migration and in the rate of gradual accumulation of seismic events registered by magnitude intervals. Besides, it was revealed that the development of seismic processes along the profiles under investigation is determined by their position and orientation with respect to geodynamic effects from Arabian and Indian lithospheric plates. Seismic activation migration manifests itself most vividly and in single direction on profiles that are longitudinal in relation to acting forces and in different directions on transversal profiles. Profile Cyprus – Caucasus is grouped with the former and the Crimea – Kopetdag profile belongs to the latter. The both profiles are most interesting for assessing seismic danger in North Caucasus and in the south of Russia. Vertical sections of the crust and the upper mantle of the Earth constructed along these profiles offer a clearer view of the nature of anomalous sections with deepened sources of earthquakes.

From the analysis of the accumulation process of seismic events in different intervals of magnitudes, time-intervals (years) are defined along each profile when the next large earthquake of a corresponding magnitude is most likely to occur (Fig. 5.2). On the basis of the elaboration of the primary epicenter distances method, the locations were determined of five potential seismic sources with $M=7.0\pm 0.2$ in North Caucasus. The time interval from 2013 to 2036 when they are most likely to occur was defined and the expected seismic effect was calculated that might be caused by one of them located in the eastern North Caucasus (Fig. 5.1).

A close relation was revealed between the geodynamics of the central area of the Caspian Sea represented with an active fragment of an old subduction zone and the seismic geodynamics of the whole Crimea-Caucasus-Kopetdag lineament. On the basis of the studies of the deep structure features, the lithosphere dynamics, regional seismicity and modern tectonic movements, a 3D seismic geodynamic model of the Caspian Sea region (Fig. 5.3) was proposed that accounts for the relation between the Caspian Sea level variation and local seismic geodynamics. For example, it was established that the warping of the South Caspian basin floor and the coming of water “excess” in the sea preceded the seismic activation of the Caspian Sea area. On the contrary, after large earthquakes and subsidence of crustal areas in subduction zone the general drop of water surface is noted. Assessments were obtained of the geodynamic deformation values of the southern Caspian Sea oceanic lithosphere, which cause the accumulation of elastic stresses in the lithosphere and the preparation of local earthquakes.

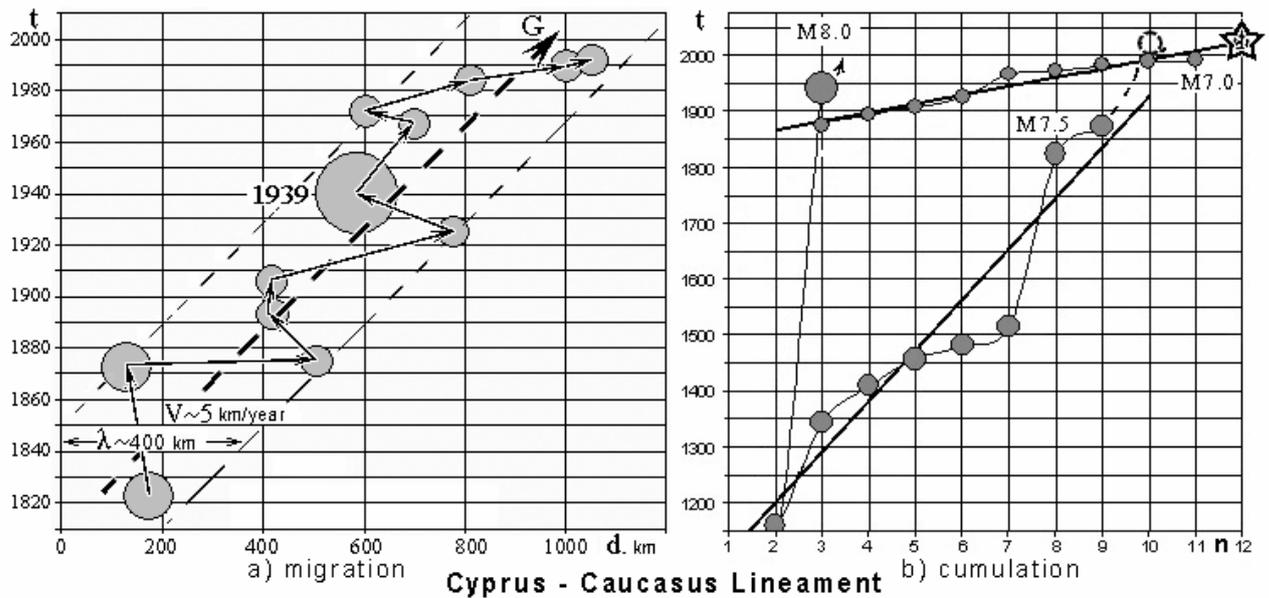


Fig. 5.2. Migration of seismic activation (on the left) and sequence of seismic events occurrence in magnitude intervals $M=7.0\pm 0.2$, 7.5 ± 0.2 and 8.0 ± 0.2 along the profile Cyprus – Caucasus. Each interval of magnitudes has a respective circle of smaller, medium or maximum diameter. Thin arrows connect events in the sequence of their occurrence; the heavy dashed-line arrow shows the generalized direction of seismic sources migration going on with velocity of approximately $V=5\text{ km/year}$ within deformation wave of a length of about 400 km. Heavy arrow is the hodograph of deformational G-wave travel. With a knowledge of velocity V of G-wave travel, it is possible to make long-term earthquake prediction in a given magnitude interval as well as to predict the most likely area of occurrence.

A sequence of seismic events accumulation in time along the profile Cyprus – Caucasus (on the right). The star shows the time of likely occurrence of the next earthquake with $M=7.0\pm 0.2$, and dashed-line circle shows events with $M=7.5\pm 0.2$.

Thus the Caspian basin being isolated from the oceans of the world is sensitive to the smallest regional deformations of the lithosphere and is a kind of indicator of local geodynamics and seismicity.

Combined research in seismic geodynamic and hydro-geodynamic phenomena offer new possibilities for earthquake long-term prediction on both regional and global scales. We revealed the correlation between the world ocean level variation and global variations of seismic conditions that testifies to this. Thus on the basis of new methods, considerable changes in seismic conditions were revealed in the time period of 1965-2005. These changes involve a threefold and more than threefold decrease in recurrence of large earthquakes ($M\geq 7.0\pm 0.2$) in the 11-year interval of time from 1982 to 1993 with subsequent intense activation on the total depth range of seismic source occurrence. These correlated phenomena are explained by the features of seismic geodynamic conditions in the subduction zones of lithospheric plates on the periphery of the Pacific and Indian oceans.

Conclusions

Traditional views on seismic regime in one or other region or in the Earth on the whole based on seismic event recurrence integral plots and concepts of seismicity developing with time based on summing up the total amount and the energy of all earthquakes that occurred make information flat and hamper the studies of seismic process nature. The results obtained by us are based on a radically new approach to seismic regime studies, in which the current of seismic events is

analyzed by magnitude intervals reflecting the hierarchic nature of the geological environment block structure.

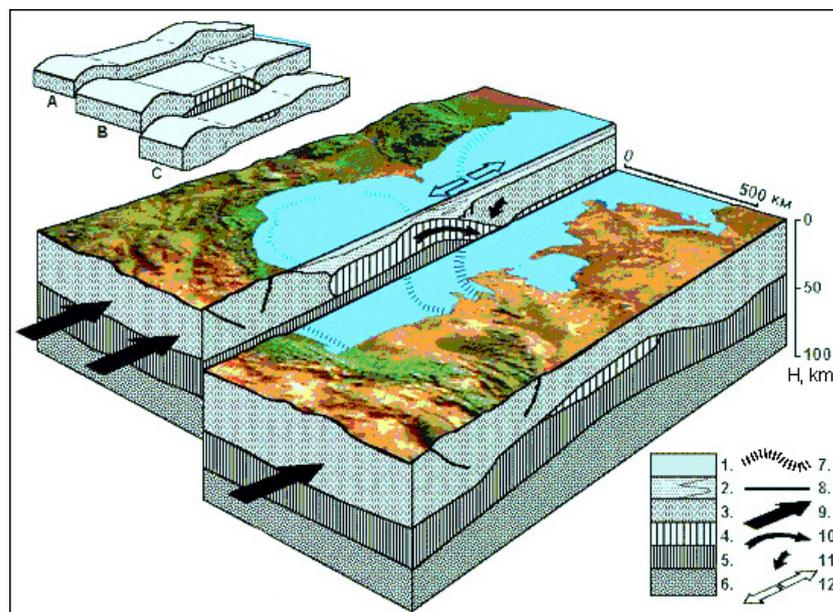


Fig. 5.3. 3D seismic geodynamic model of the Caspian Sea region (scaled up vertically). 1 – water mass; 2 – sedimentary bed and dislocated sediments in the central area of the Caspian Sea; 3 – continental crust; 4 – oceanic crust relics; 5 – sub-crustal layer of the lithosphere; 6 – asthenosphere; 7 – maximums of isostatic anomalies gradient; 8 – large tectonic dislocations (faults); 9 – pressure direction from Iranian and Arabian lithospheric plates; 10 – the direction of the oceanic lithosphere subduction of the Southern Caspian Sea under Scythian-Turanian plate; 11 – the direction of drawing in the subsidence of the northern Caspian Sea lithosphere; 12 – local horizontal extension in the bending lithosphere of the northern Caspian Sea. The upper figure is a conventionalized model of the dynamics of three blocks: A – Caucasus – Talyshskii, B – Elburs – Caspian, C – Kopetdag – Turanian.

Self-organization is characteristic of the Earth, which develops in strongly non-equilibrium conditions. Global oscillation regimes of the lithosphere are caused by the processes of the geological environment volumes adjusting to prolonged force effects of planetary scale. In this context, the alternation of elastic stresses and their subsequent discharge in the form of small deformations and rapid decrease of stress in earthquake sources is the most economical self-organization regime of geodynamics because it involves successive repetition of an event of the same type. Though geodynamic system is changing continuously, the Earth on the whole is in dynamic equilibrium and the observed periodicity contributes to it.

Processes of accumulation and release of geodynamic stresses alternate and thus reflect discrete and continuous nature of the dynamics of the Earth's crust and the whole lithosphere. These processes and phenomena are reflected in both global and regional seismic geodynamics. They should be taken into account in research in strong earthquake long-term prediction.

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6. Seismic Risk Assessment and Management in the Russian Federation

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In the Russian Federation more than 20 million peoples live in the regions characterized by moderate and high level of seismicity. Earthquake prone areas, where earthquakes with intensity 7 (MMSK-86 scale) and higher may occur, occupy about 20% of the Russian Federation territory. The most seismically active regions are the Northern Caucasus, Altaj, Sayany, the Baikal area, Yakutiya and the whole Far East, including Kamchatka, Sakhalin and Kuril Islands. In order to secure the population safety in earthquake-prone regions the assessment of seismic risk level and possible consequences due to scenario events should be carried out in advance.

During the past years much attention was paid in Russia to seismic risk assessment and reduction. New approaches for seismic hazard, vulnerability and risk assessment were developed under the Russian Federal Programs "Safety of Population, Buildings and Structures against Natural