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# Stress-Associated Synchronization and Desynchronization in Geologic and Biologic Systems

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**Abstract**—Variations in the annual numbers of representative earthquakes in three areas and six districts of the Baikal rift zone in 1964–2002 were subjected to correlation analysis. Episodes of significant correlations of shock flow rates were found against the background of chaotic seismic activity. They followed the rearrangements (catastrophes) of stresses in the lithosphere, which are also stressing factors for the whole rift geodynamic system. The episode of the late 1970s–early 1980s was particularly long and showed the maximum correlation. Therefore, it can be considered the principal event in seismic process synchronization in the Baikal Rift Zone. The same approach to data analysis revealed similar synchronization and desynchronization phenomena in the behavior of Baikalian turbellaria when they deviated from homeostasis as a result of illumination, which is a stress for this biologic system. Possible reasons for the behavior of biologic and geodynamic systems are discussed in terms of the synergetic concept of phenomena in living and nonliving nature.

*Keywords*: Baikal Rift Zone, lithosphere, seismic activity, turbellaria, correlation, synchronization.

*"Science does not still perceive clearly that life phenomena and phenomena of inorganic nature considered from the geological, i.e., global, viewpoint are manifestations of a single process."*
V.I. Vernadskii

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## INTRODUCTION

Protecting the biosphere and mankind is of increasing importance. It is done based on predicting adverse factors in space, the lithosphere, the atmosphere, the hydrosphere, the anthroposphere, the sociosphere, and the noosphere, i.e., wherever living matter comes in touch with inorganic matter and other spheres. A comparative interdisciplinary consideration of the course of various processes was undertaken during the compilation of the *Atlas of Time Variations of Natural, Anthropogenic, and Social Processes* (Atlas…, 1994; 1998; 2002) and continued in a number of studies. The following regularities are recognized in biospheric processes (Gamburtsev, 2008):

(1) Responses of the biosphere and its elements to external factors are often nonlinear and selective. Changes in these responses are caused not only by external action variations but also by features of the elements themselves.

(2) Temporal variations of several types (trends, rhythms, pulses, or noise) and amplitude variations are typical of the states of biosphere elements.

(3) Rhythms are particularly important among the major components of the ordered state of the biosphere and its elements. Their periods are broadly variable. One of the causes of a change in the dominant rhythms is desynchronization, which can result from heavy stresses. For example, a human body can experience physical and psychological stresses, and the Earth's crust can undergo severe earthquakes or nuclear explosions.

(4) Self-organization and chaotization are typical of the biosphere and its elements. In particular, self-organization manifests itself in the establishment of stable and long-term rhythmic variations, and chaotization manifests itself in sophistication of rhythmic variations up to their disappearance.

(5) Each particular biosphere element has its own variation modes within a certain time interval. At the same time, different elements of different kinds and scales occurring in different regions of the globe demonstrate common features with regard to certain processes, and these common features may be determined by global factors.

Studies of the current geodynamics of the Baikal Rift Zone (BRZ) show that the listed regularities of biosphere dynamics can be observed in inorganic matter (the regional lithosphere). The lithosphere of BRZ undergoes rearrangements of the stress state (catastrophes) which fit the scenario of nonlinear evolution with a triple equilibrium bifurcation (Kluchevsky, 2007, 2008). The rearrangements begin in lithosphere sites termed rifting attractor structures (RASs). They demonstrate a predominant 10-year rhythm accompanied by lower-amplitude trends, pulses, and noises. A rearrangement of the stressed BRZ lithosphere is typically followed by a pair of distant earthquakes whose magnitude and focus location depend on the type and speed of the bifurcation transition (Kluchevsky, 2003; 2008). The stress state of individual lithosphere blocks (northeast, center, and southwest of BRZ) is governed by the overall geodynamics of the lithosphere in the region. It is synchronous with the establishment of stable and long oscillations of the medium complicated by rapid inversions of primary stress axes (Kluchevsky, 2008). Fractal analysis detected and confirmed changes in the spatiotemporal and energetic structure of seismic activity in BRZ, which precede and accompany stress rearrangements in the BRZ lithosphere, major earthquakes, and shock series (Kluchevsky, 2006; Kluchevsky and Zuev, 2006). The uniqueness of geodynamic activation episodes in the BRZ lithosphere and their long duration hamper repeated observations and complicate a statistical analysis.

The goal of this study is to reveal manifestations of similar rhythmic processes, in particular, signs of synchronization and desynchronization, in two different systems: (1) seismic activity of the geodynamic system of the BRZ lithosphere and (2) the turbellarian population in Lake Baikal. Unlike the former, the biologic system allows the experiment to be replicated and the process to be statistically analyzed. Features of adaptation of the systems and destructive processes caused by factors producing stresses in either system were studied. The biological term *stress* was applied by H. Selye to the state of general excitement of an organism caused by a stimulus. The combination of universal symptoms reflecting attempts of the organism to cope with the situation was called *general adaptation syndrome* (GAS) or *stress syndrome* by Selye. Factors inducing GAS are called *stress factors* or *stress agents*. Internal desynchronization, or phase mismatch among system elements, which implements stress response, is a mandatory GAS component. The stress factors considered in this article are the inversion of primary and intermediate stress axes (stress catastrophe) in the BRZ lithosphere (Kluchevsky, 2008) and the action of light on Baikalian turbellaria, responded by phototaxis (Klyuchevskaya, 2007). It is shown that objects can adapt to stress if the duration and gradient of the stress factor are not too large. The biologic system is adjusted to the most conservative operation state, and the geodynamic system of lithospheric blocks relieves stresses by means of moderate earthquakes. The long-term action of a large stress factor gradient can cause internal desynchronization and destructive processes. In the lithosphere, they manifest themselves as the severest earthquakes for a particular region; in the biosphere, they can cause death.

## MATERIALS AND METHODS

Thousands of earthquakes varying in strength are recorded annually in the Baikal region. About 40 severe earthquakes with energy classes $K_p \geq 15$ ($M_{LH} \geq 6$) occurred in the 20th century. The rift zone, which includes a chain of depressions from northern Mongolia along Lake Baikal to southern Yakutia, is the most dangerous. A map of the epicenters of representative earthquakes with $K_p \geq 8$ recorded in the Baikal region from 1964 to 2002 is shown in Fig. 1. It displays the same pattern as the BRZ epicenter fields constructed for shorter time intervals, thereby pointing to the self-similar mode of epicenter distribution (Kluchevsky and Zuev, 2007).

The main features of the epicenter distribution of the earthquake are the aggregation of shocks in bands of mainly a northeastern strike and the discrete pattern of the epicenter field directed transverse to the strike of the rift zone. Plots of annual numbers of representative earthquakes are shown in insets. Inset *A* shows data for the whole Baikal region and its three areas, and inset *B* shows data for six districts of the Baikal region.

The region was subdivided according to the method commonly used in studies of a stressed and deformed lithosphere and seismic activity (Kluchevsky, 2003, 2004, 2007). The BRZ boundaries are drawn at 48.0° and 60.0° N and at 96° and 122.0° E. Three areas are established in BRZ: area 1 in the southwest ($\varphi$ = 48.0°–54.0° N, $\lambda$ = 96.0°–104.0° E), area 2 in the center of BRZ ($\varphi$ = 51.0°–54.0° N, $\lambda$ = 104.0°–113.0° E), and area 3 in the northeast ($\varphi$ = 54.0°–60.0° N, $\lambda$ = 109.0°–122.0° E). Six districts are established by a division of the areas along meridians 100.0°, 108.0°, and 116.0° E. They are numbered from 1 in the southwest to 6 in the northwest. This division makes it possible to verify the synchronization of seismic activity at various territorial ranks because the geological subdivisions—zone, area, or district—can be treated as three hierarchical levels of lithosphere heterogeneity (Sadovskii, 1979).

The plots in Figs. 1A and 1B demonstrate variations in the annual flow (number of events per unit time) of earthquakes of various amplitudes. The most notable *N* maximums were recorded in 1976, 1991–1992, and 1999. They resulted from aftershocks of corresponding earthquakes: two Busiingol ones (Apr. 1, 1976, $K_p$ = 14, $\varphi$ = 51.15° N, $\lambda$ = 97.97° E; Dec. 27, 1991, $K_p$ = 16.2, $\varphi$ = 50.98° N, $\lambda$ = 98.08° E), South Baikal (Feb. 25, 1999, $K_p$ = 14.6, $\varphi$ = 51.64° N, $\lambda$ = 104.82° E); and Kichera (Mar. 21, 1999, $K_p$ = 14.5, $\varphi$ = 55.83° N, $\lambda$ = 110.34° E). An analysis of the spatiotemporal distribution of epicenters of representative earthquakes shows an alternation of seismic activity rising and falling in the Baikal region (Golenetsky, 1990). However, little attention has been paid to the variation of seismic activity parameters characterizing these rises and falls. This fact is related to the lack of a theoretical concept and formal parameters that would

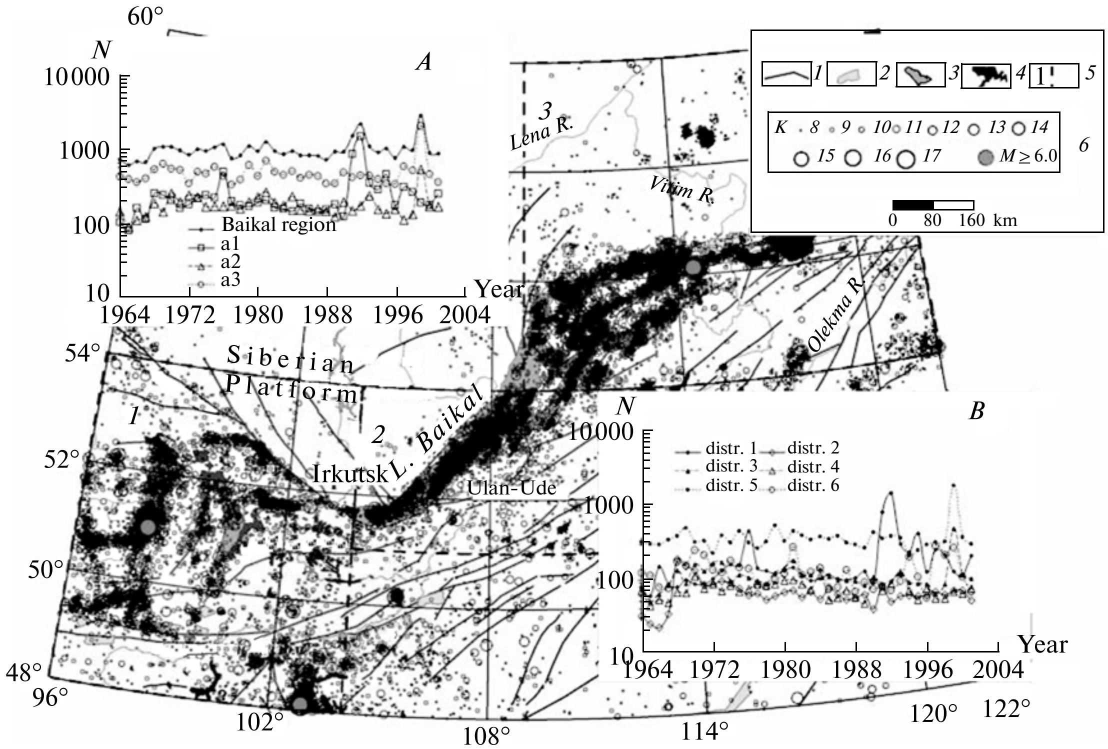


**Fig. 1.** Epicenters of representative earthquakes with $K_p \geq 8$ in the Baikal region in 1964–2002.
Insets show the plots of annual numbers N of such earthquakes in (*A*) the whole Baikal region and its three areas and (*B*) six districts. (*1*) Faults, (*2*) depressions, (*3*) lakes, (*4*) basalts, (*5*) area numbers and borders, and (*6*) energy class $K_p$ and epicenters of large earthquakes with $M \geq 6$.

make it possible to detect their correlation with variations in the stressed and deformed state of the lithosphere and the geodynamic setting in the region.

Seismic records and laboratory experiments indicate that spatiotemporal seismic activity variations preceding and accompanying geodynamic rearrangements and severe earthquakes are common (Sobolev and Ponomarev, 2003). Phenomenologically, such processes are usually associated with the approach of an unknown governing parameter (which describes the development of the stressed state of the medium) to a critical value. This approach brings the stressed object to metastability, which can end in a catastrophe. In this view, the term *catastrophe* denotes a set of pronounced changes in stress dynamics and in the rate of the seismic flow occurring within a time interval that is short in comparison with the duration of a shock series or a seismic cycle. The correlation distance at which concomitant and coherent events can be observed increases with the approach to the time of the critical value. The effect of distant pairs of severe earthquakes in Pamir and Tien Shan (Prozorov, 1990), Central and Southern Asia (Kopnichev et al., 2002), and on the flanks of the Baikal region (Kluchevsky, 2003) may be related to the increase in correlation distance. Various scales of synchronous cooperative deformations in heterogeneous media are studied in the context of physical mesomechanics, synergetics, and nonlinear dynamics of systems (Panin, 2000; Nicholis, Prigogine, 2003; Smirnov et al., 2005; Sobolev, Lyubushin, 2006).

Correlation analysis is a common method of studying relationships among the elements of a complex dynamic system. An analysis of correlation and effects of synchronization–desynchronization of seismic flow rate (number of shocks per unit time) was performed by calculating pairwise correlation coefficients ρ for realization lengths 3 years ($L_3$), 5 years ($L_5$), and 10 years ($L_{10}$) at three hierarchical levels of lithosphere heterogeneity: BRZ, three areas, and six districts. This study comprised the time span from 1964 to 2002. The calculations were performed for 1-year intervals, and the resulting ρ values were ascribed to the middle of the time interval for each realization.

This approach reveals periods of synchronization of seismic flows in different territories, which are indicative of coherent seismic processes in these periods with high positive correlation coefficients. In this context, coherence means a coordinated course of several oscillatory processes apparent from their addition. Sums of annual correlation coefficient values $S$ normalized by the number of correlated pairs $n$ and the standard deviation $\sigma$ were calculated for the statistical evaluation of the significance of the observed correlations in seismic activity. Normalization by $n$ brings the sum of annual correlation coefficient values $S$ to the form ($-1.0 \leq S \leq 1.0$), which is appropriate for analysis. For obvious reasons, the number $n$ of the pairs considered is generally less than the possible number of combinations $N_R = n_R(n_R - 1)/2$, where $n_R$ is the number of territories. This is related to the limited volume of graphical information presented and to the necessity of investigating seismic process synchronization at various hierarchical levels of BRZ lithosphere territories. Plot intervals with high positive normalized correlations at high $\sigma$ values point to episodes of synchronization of the earthquake flow rate, and intervals with the lowest negative normalized values point to desynchronization.

To test the presence of wave processes and synchronization–desynchronization in other systems, we conducted experiments on phototaxis in a biologic system (the population of turbellaria (*Phagocata sibirica*) in Lake Baikal). The main reason for using a biosystem was the possibility of numerous replications of experiments with living objects and of statistically processing the results (Klyuchevskaya, 2007). It is known that freshwater planarians are strictly photonegative. They either keep at lower surfaces of pebbles, beneath sponges, or build envelopes of sand, silt, or debris (Porfir'eva, 1973). It makes them a suitable object for studying phototaxis. *Phagocata sibirica* is a rheophilic stenothermal species which inhabits cold rapid rivers and rivulets with clear water. It is common in continental watercourses of Far East and Siberia, including rivers emptying into Lake Baikal (Dyganova and Porfir'eva, 1990). The animals were stored in 3-l aquaria with water from Baikal. The water was changed daily, and its temperature was kept within 8–10°C, close to the temperature at sites where the animals were caught. The experiments were carried out under the same conditions.

Phototaxis experiments were conducted in 40 × 20 cm trays where one-half was shaded with dense black fabric. Mature intact worms were chosen and adapted to aquarium conditions for 24 h. Each individual was used only once. Phototaxis was recorded at several intensities of natural insolation, klx: 0, 0.005, 0.010, 0.050, 0.1, 0.5, 5, 10, 15, 20, 30, and 50. Most experiments were done with ten replications.

In each replication, 15 worms were placed in the illuminated part of a tray. Their positions were recorded at 1-min intervals for the first 5 min and then at 5-min intervals for 1 h. A worm showing neither movement nor response to touch with a brush was considered dead. The total number of individuals used in phototaxis experiments (5 min and 1 h) was $N = 1800$.

## RESULTS

Plots of variations in pairwise correlations of annual numbers of earthquakes in BRZ and three areas (a1, a2, a3) are shown in Fig. 2. With a 3-year realization length ($L_3$, Fig. 2a), the plots are complex. Correlation coefficients $\rho$ vary from $-1$ to $+1$. High positive $\rho$ values exceeding 0.8 are recorded synchronously in all the three pairs of territories under consideration in 1967–1968 and 1981–1982, and minimum values ($\rho < -0.8$) precede these maximums. With the increasing realization length, plots are shifted to positive $\rho$ values. At $L_5$ (Fig. 2b), $\rho$ values exceeding 0.7 are observed in all plots in 1966–1967 and 1981–1982. They match $S/3$ maximums. As at $L_3$, $\rho$ maximums are preceded by minimums ($\rho < -0.7$). With the realization length of 10 years ($L_{10}$, Fig. 2c), $\rho$ values exceeding 0.7 are recorded in all pairs of territories in 1968–1969 and in 1983–1984 and $S/3$ maximums are shifted: 1968–1970 and 1980–1984. At this realization length, the plots are shifted to positive $\rho$ values and the lowest correlation coefficients are no less than $-0.4$. Plots of normalized total correlation (Fig. 2d) demonstrate $S/3$ maximums at small $\sigma$ and were observed in the late 1960s and early 1980s, being preceded by minimums with high $\sigma$ values.

A study of the coordination of lithospheric processes at two hierarchical levels included a calculation of correlations between the total earthquake numbers in BRZ and the corresponding values for individual areas. Episodes of high and low correlations of this kind matched the episodes of high and low correlations of earthquake numbers in three areas shown in Fig. 2. Episodes of synchronization of the seismic process in the lithosphere of BRZ and its areas were short. They were confined to late 1960s and early 1980s, whereas short desynchronization episodes, apparent from the minimum correlation levels, preceded them. However, if the plots in Fig. 2 are interpreted as successions of maximum and minimum correlation levels, an alternation of desynchronization and synchronization episodes is apparent.

Variations of $\rho$ values for the arrays of annual numbers of earthquakes in BRZ, area 2 (a2), and districts 3 and 4 (d3, d4) are shown in Fig. 3. At $L_3$, high positive $\rho$ values (>0.6) are observed in all four pairs of territories under consideration in 1967–1968, 1978–1985, 1994, and 1998–1999. They look like maximums in the $S/4$ plot. Minimum correlation levels ($\rho < -0.8$) look in 1974–1976, 1986, 1995–1997 like minimums in the $S/4$ plot before synchronization episodes. At greater realization lengths, the plots are shifted to positive $\rho$ values and elevated correlation levels are observed in all plots in late 1960s and early 1980s (Figs. 3b, 3c). Minimum correlation levels ($\rho < -0.8$) are observed in 1976, 1987, and 1996. The synchronization of the seismic process is observed in the late 1960s and the late 1970s–early 1980s. Synchronization periods are most clearly illustrated by maximum

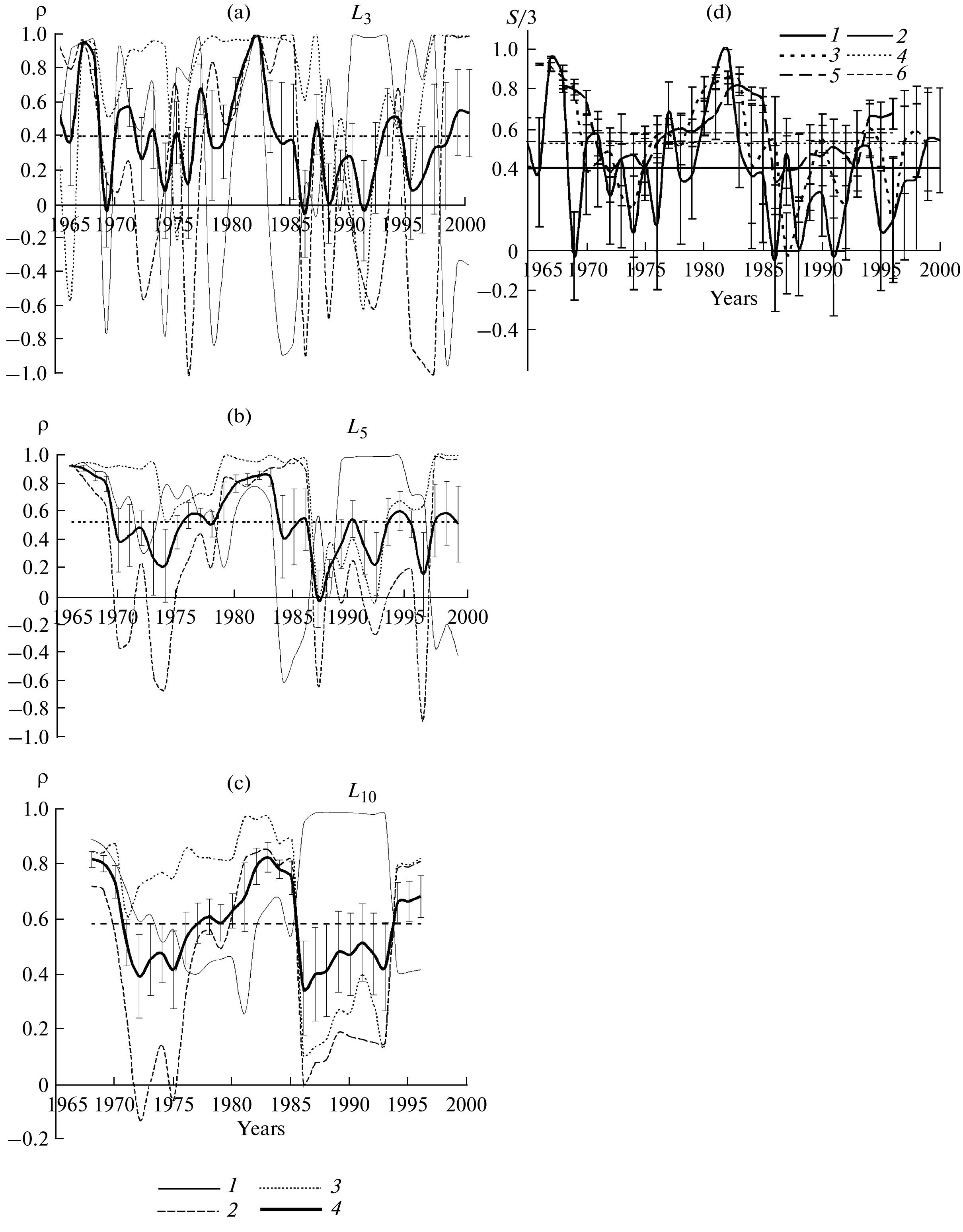


**Fig. 2.** Variations of (a, b, c) correlation coefficient ρ and (d) normalized total correlation $S/3$ of arrays of annual shock numbers $N$ for BRZ and three areas. Realization length $L$: (a) 3 years, (b) 5 years, and (c) 10 years. Curves in (a–c): (*1*) BRZ–a1, (*2*) BRZ–a2, (*3*) BRZ–a3, and (*4*) $S/3$. The dotted curve indicates the annual level. (d) Total correlation $S/3$ and its mean level at various realization lengths: (*1*, *2*) 3 years, (*3*, *4*) 5 years, and (*5*, *6*) 10 years.

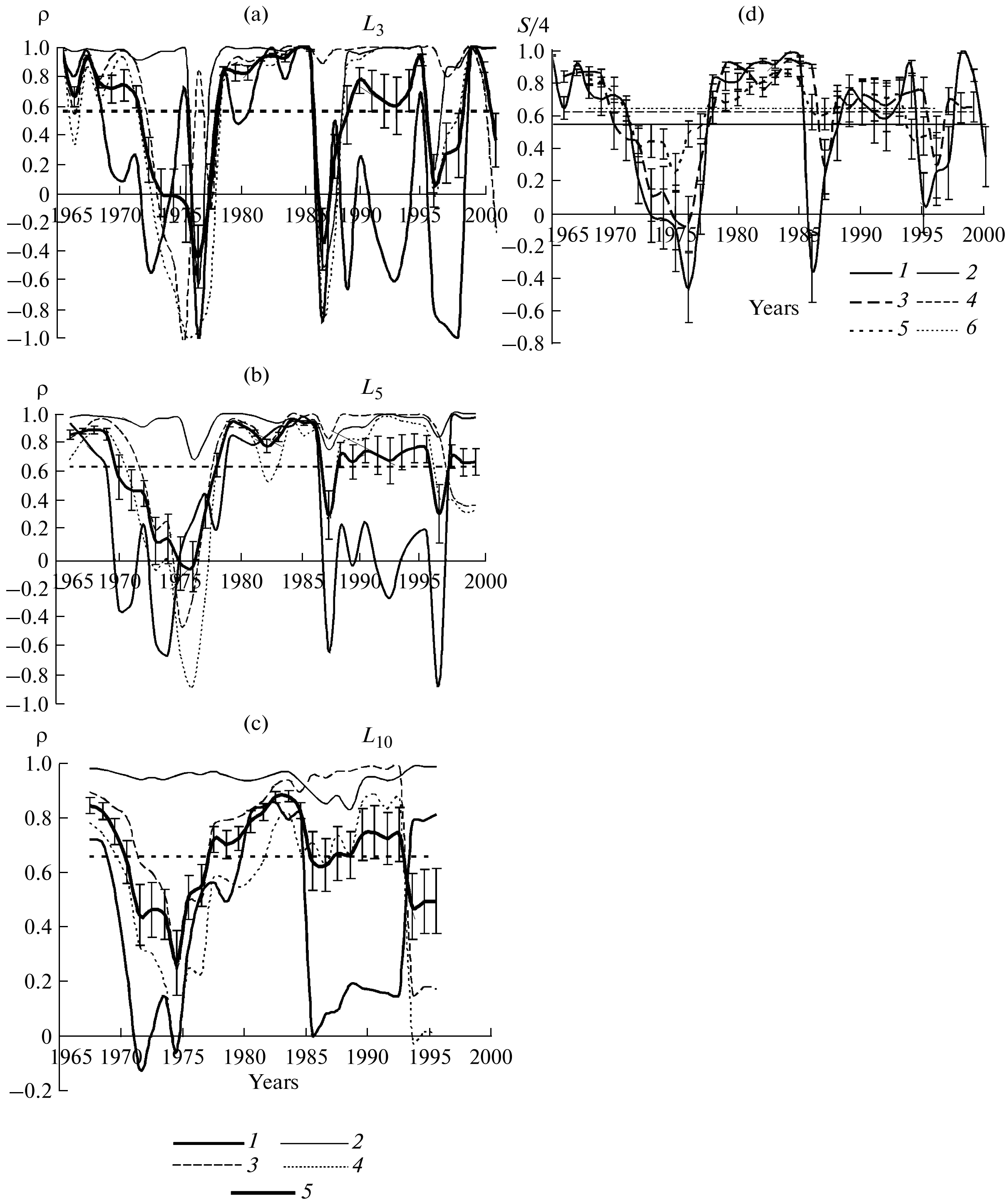


**Fig. 3.** Variations of (a, b, c) correlation coefficient ρ and (d) normalized total correlation $S/4$ of annual shock numbers $N$ for BRZ, area 2, districts 3 and 4. Realization length $L$: (a) 3 years, (b) 5 years, and (c) 10 years. Curves in (a–c): (*1*) BRZ–a2, (*2*) a2–d3, (*3*), a2–d4, (*4*) a3–d4, and (*5*) $S/4$. The dotted curve indicates the annual level. (d) Total correlation $S/4$ and its mean level at various realization lengths: (*1*, *2*) 3 years, (*3*, *4*) 5 years, and (*5*, *6*) 10 years.

values of normalized total correlation $S/4$ at small σ values (Fig. 3d), and desynchronization (in 1976 and 1987) is most clearly illustrated at large σ. Plots of ρ values of arrays of annual earthquake numbers for BRZ–a1–d1,d2 and BRZ–a3–d5,d6 slightly differ from plots in Fig. 3. However, episodes of high and low correlations of earthquake flow rates in these territories match those in Fig. 3.

Figure 4 shows variations of ρ values for arrays of annual numbers of earthquakes between BRZ and six

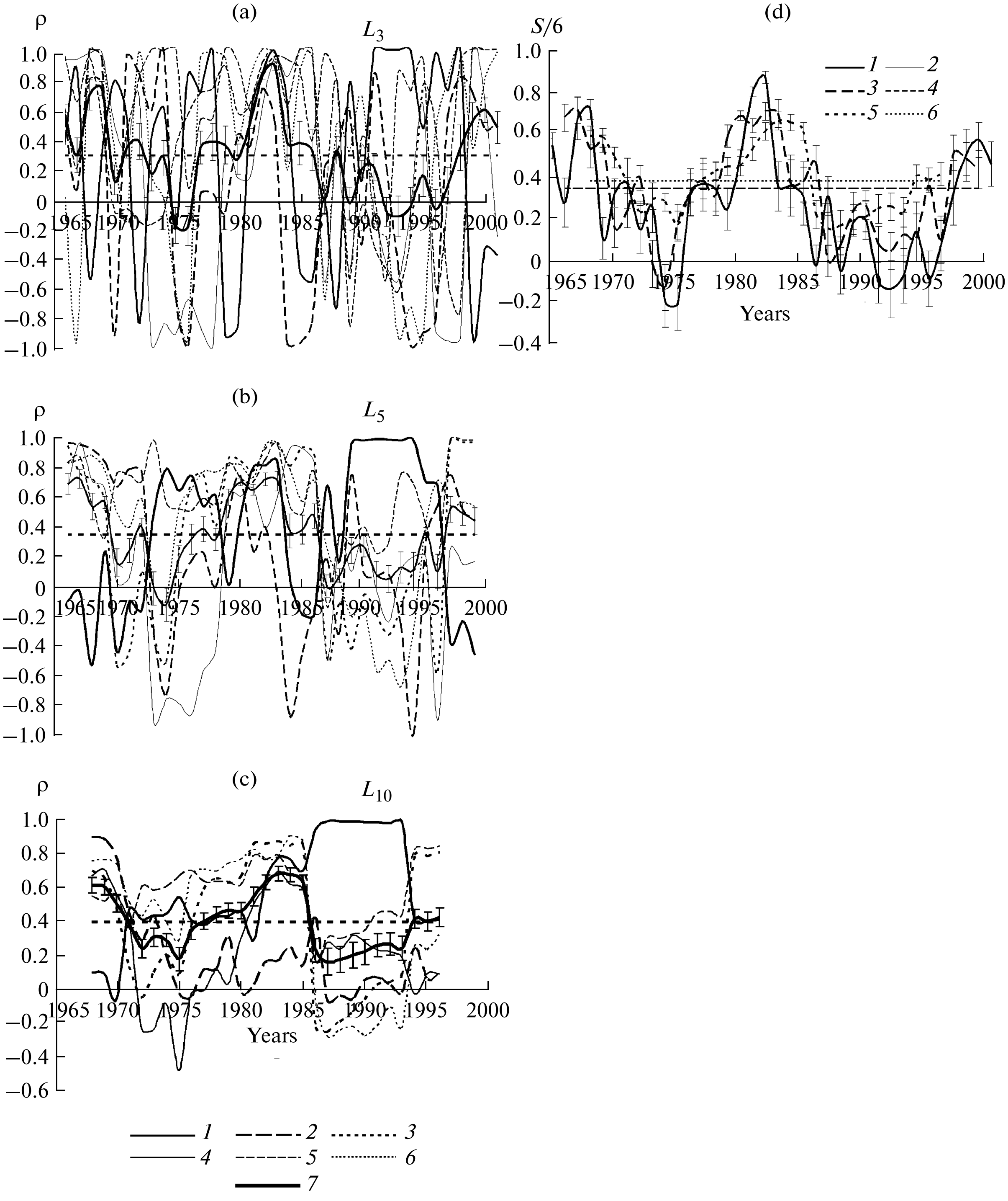


**Fig. 4.** Variations of (a, b, c) correlation coefficient ρ and (d) normalized total correlation $S/6$ of arrays of annual shock numbers $N$ for BRZ and districts 1–6. Realization length $L$: (a) 3 years, (b) 5 years, and (c) 10 years. Curves in (a–c): (*1*) BRZ—d1, (*2*) BRZ–d2, … (*6*) BRZ–d6, and (*7*) $S/6$. (d) Total correlation $S/6$ and its mean level at various realization lengths: (*1*, *2*) 3 years, (*3*, *4*) 5 years, and (*5*, *6*) 10 years.

districts (1–6). At $L_3$, high positive correlation coefficient values ($\rho > 0.6$) are observed synchronously in all six pairs of territories in 1968–1981. Maximums in the $S/6$ plot occur in the same years (Fig. 4a). At greater $L$, the plots are shifted to positive ρ values, and elevated correlation coefficients are generally observed in 1966–1968 and 1980–1983 (Figs. 4b, 4c). Minimum correlation values are observed in the $S/6$ plot before synchronization episodes. It is apparent that the earthquake flow rate synchronization and desynchroniza-

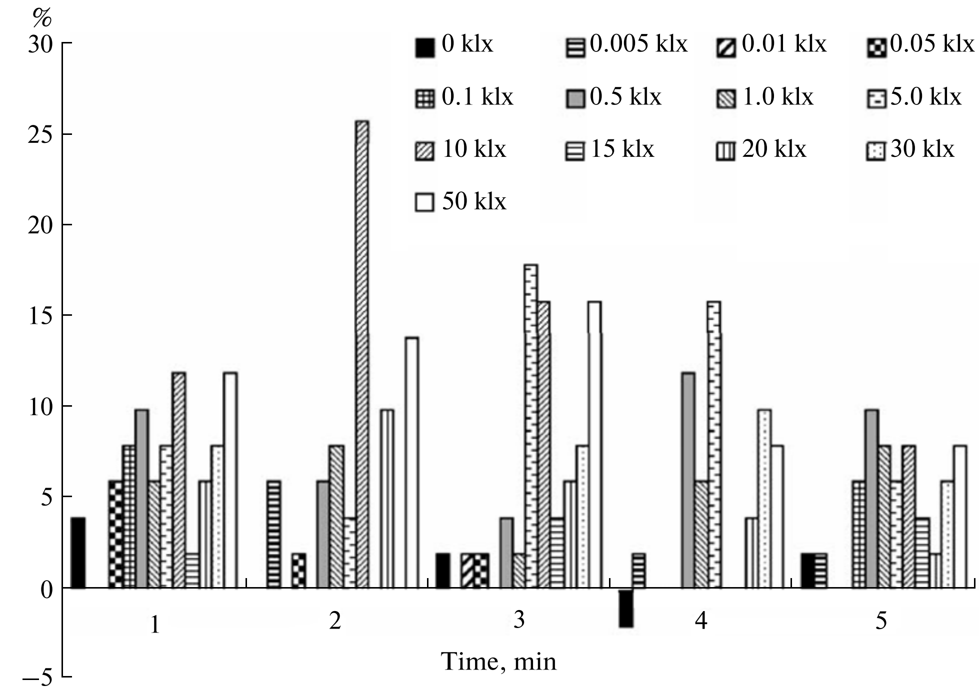


**Fig. 5.** Distribution of the number of turbellaria moving to the dark areas of the trays within the first five minutes of phototaxis experiments.

tion episodes in the lithosphere of BRZ and six districts are short. In all $S/6$ plots, the coherence of the seismic process is apparent in the late 1960s, early 1980s, and late 1990s.

As was described in Materials and Methods, at the first stage of the phototaxis study, turbellaria were placed in the illuminated part of a tray and their movement was recorded at 1-min intervals for 5 min. Figure 5 presents time distributions of the numbers of turbellaria in the dark parts of the trays at various illuminances.

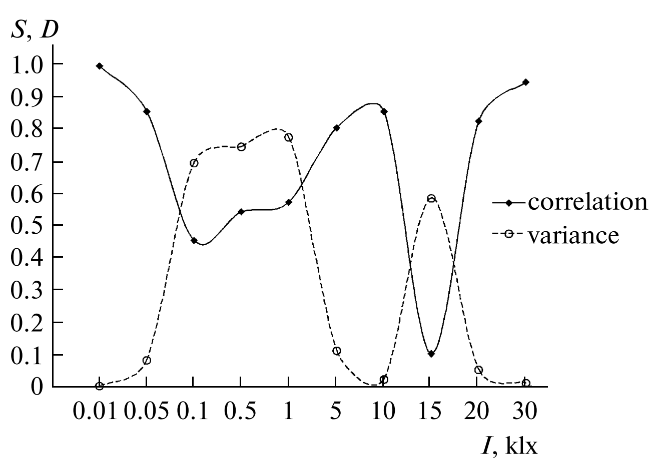


**Fig. 6.** Phototaxis experiment. Coefficients of normalized total correlation $S$ and variances $D$ of the number of turbellaria remaining in the illuminated parts of trays at various illuminance values after the first 5 min of exposure.

At the first minute of the experiments, three maximums of the number of worms escaping from light are observed: at 0.05–0.5, 1–10, and 15–50 klx. This illustrates oscillatory processes depending on illuminance. At the second minute, the weak coordination of migrations disappears and the maximum at 10 klx points to the formation of one resonance transition. At the third minute, the system shows weakly coordinated behavior again, but at a weaker illuminance: 5 klx. At the fifth minute, weakly coordinated behavior is observed only at intense illumination: 20–50 klx.

The coefficient of normalized total correlation $S$ of the number of turbellaria remaining in the light at various intensities was calculated as above: as the mean pairwise coefficient between the realizations of three light intensities at one intensity intervals, the arrays of the 1st, 2nd, 3rd, 4th, and 5th minutes being correlated. The normalized total correlation value was ascribed to the median light intensity in the realization, and variance $D$ of $S$ was calculated to describe the fluctuation level (Fig. 6). This zonal averaging of data allows the recognition of the most intense resonance transitions in the system. Three normalized total correlation maximums ($S > 0.8$) are observed at the least variance ($D < 0.1$): at weak light intensity $I = 0.05$ klx, medium intensity $I = 5–10$ klx, and high intensity $I \geq 20$ klx.

The first $S$ maximum corresponds to illumination in the turbellarian habitat in Lake Baikal and reflects the homeostasis of the system. The second and third $S$

maximums point to stress-induced synchronization episodes of turbellarian movement related to the coherent behavior of worms at elevated illuminance *I*. These maximums are separated by *S* minimums with high variances, which point to the desynchronization of the worm behavior between two synchronization episodes.

During the second stage of the phototaxis experiments, the positions of turbellaria were recorded for 1 h at 5-min intervals. The worms tried to move to the shade at 0.01–50 klx. They usually did not respond to weak illumination (<0.005 klx), probably because it was close to that in their natural habitat. The worms showed different responses to different illuminance values. At low values (0.010–0.1 klx), no more than 40–50% of worms migrated to the dark zone, which may be related to their random distribution over the tray and the insufficient intensity of the stress factor. Obviously, small deviations in illumination from the homeostatic conditions do not affect the rhythmic regime of processes occurring in living organisms very much. At high illuminance values (>0.500 klx), over 80% of worms migrated to the shaded zone within the first five minutes of the exposure. The increase in light intensity gradient induces the rapid development of the stress syndrome, which makes the worms move to the shade rapidly. It is known that the prolonged severe action of a stress factor can induce the destruction of objects or organs (Aptikaeva et al., 2008). In our experiments, 50-klx illuminance often induced the intense migration of turbellaria to the dark zone within a few minutes; then the worms died. This behavior of turbellaria agrees with the statement that intense external factors can be fatal for an organism: its response becomes so vigorous that it causes irreversible changes. On the other hand, if the duration and strength of the factor are not fatal, objects can adapt to them. The periods of predominant rhythms remain, but their amplitudes can change (Aptikaeva et al., 2008). With the increasing stress factor gradient, the rhythmic character of processes changes, shifting to longer periods.

Thus, the oscillatory processes and episodes of synchronization–desynchronization of the seismic process in the course of stress rearrangements in the BRZ lithosphere are somewhat similar to the wave processes and synchronization–desynchronization effects observed in the phototactic behavior of a system of biologic populations exemplified by Baikalian turbellaria (a sample of 1800 individuals) in response to a deviation in the homeostatic conditions mimicked by light exposure. In both cases, stress factors induce complex responses of the turbulence type, which illustrates the basic trend to dynamic chaos evolution in many natural systems under certain conditions (Nikolis and Prigozhin, 2003).

## DISCUSSION

The discovered coherent behavior of seismic flow rate patterns in various BRZ territories in the course of lithosphere stress rearrangements and of the biologic system of turbellaria (*Phagocata sibirica*) in experiments on phototaxis is indicative of spatiotemporal desynchronization–synchronization in the geodynamic macrosystem and the turbellaria population. This self-organization type is known as synergy (Haken, 1985). It takes place in this formation in laser coherent light. It was also observed by many scientists in various nonequlibrium macroscopic systems producing spatiotemporal dissipative systems, concentrational autowaves in oscillatory chemical reactions of the Belousov–Zhabotinsky type, etc. In this context, studies of the parameters of a system exposed to external factors are of great interest, because an organism or a system produces a stress response in reply to any external influence, even small. Such a response can manifest itself in the form of a phase mismatch of system components that are well coordinated under normal conditions.

An analysis of the earthquake rate revealed no significant variations in the numbers of earthquakes in periods of geodynamic activity in the lithosphere of BRZ, three areas, or six districts. A correlation analysis at various realization lengths of earthquake numbers demonstrates a synchronous increase in the seismic flow rate in the Baikal region, three areas, and six districts after geodynamic activation. Major episodes of the synchronization of the earthquake number flow are observed in the late 1960s and late 1970s–early 1980s. They follow episodes of geodynamic activation of the lithosphere mediated by stress catastrophes. The synchronization episode in the early 1980s stands out in regards to duration and degree of correlation. Thus, it may be considered the predominant factor in the BRZ lithosphere in 1968–1994. In our interpretation, episodes of spatiotemporal seismic flow rate desynchronization correlate with stress catastrophes and they precede synchronization episodes. Outside these episodes, seismic activity in three areas and six districts of BRZ is poorly correlated due to the chaotic character of the seismic process. It is conjectured that the episode of geodynamic activation of the BRZ lithosphere is determined by the increase in Earth's rotation velocity in 1978–1980 (Kluchevsky, 2001). As was reported by Gamburtsev et al. (1991), changes in the stressed state of the Earth's crust occurred in Kirgizia and Turkmenistan at the same time. They were also supposed to be related to the dramatic increase in the Earth's rotation velocity, i.e., a cause of interplanetary nature. The observed synchronization indicates that geodynamic rearrangements in the lithosphere and seismic activation episodes occur practically simultaneously in various BRZ territories as a regional phenomenon, forming a short-term increase in the earthquake flow rate in the chaotic spatiotemporal distribution of regional seismic activity. It manifests itself in the flow rates of severe (Kluchevsky, 2003) and weak shocks.

We could suggest that the results also reflect different modes of the behavior of seismic activity at various hierarchical levels if we knew the mechanism by which some seismic activity parameters characterize the regional state of the system and others characterize a certain part of this state. This mechanism is obvious in the mechanical stress system: weak shocks (stress adjustment events) dominate in the whole rift zone. As a result, generally only one attractor is observed at any level. It corresponds to stresses of this type at all hierarchical levels of lithosphere heterogeneity (Kluchevsky, 2007). Seismicity lacks such a mechanism, because shocks of different fault types are statistically equivalent and differences or similarities arise only at the level of assemblies. However, the results reported in (Kluchevsky, 2003) indicate that the numbers of shock series and swarmed earthquakes increase in this time in attractor structures, illustrating the nonlinear mode of the spatiotemporal coherence of the phenomena that are observed. This mode is related, most likely, to the increase in the number of weak swarmed shocks, which, in turn, result from stress rearrangements in the BRZ lithosphere due to self-organization and changes in the fluid regime. Seismicity desynchronization may be related to the successive disclosure and closure of variously directed faults during the inversion of stress axes in the BRZ lithosphere.

One of the most important results of this study is the similarity between major behavioral features of inorganic matter by the example of the BRZ lithosphere and processes observed in living systems, such as the turbellarian population in Lake Baikal. The biosphere includes not only living systems but also matter involved in biotic circulation, which also displays some features of a living system, e.g., self-regulation. These features are determined by feedbacks among system components. The unique biologic properties indicated in (Kompanichenko, 2008) draw a distinct boundary between the living and nonliving realms of nature, whereas nonunique properties can be considered links between them. Unique properties first manifested themselves during the origin of life, whereas nonunique ones "moved" from the original geologic environment and acquired some life-related features. It is suggested that nonunique properties can provide grounds for a description of processes in the geologic cradle of life. In this regard, the following biologic properties are most notable: thermodynamic and chemical inequilibrium, integration by means of cooperative phenomena, and the capability for self-organization. The demand for inequilibrium conditions relates the origin of life to a wide range of specific phenomena resulting from bifurcations and the formation of dissipative systems. Evolution is an ecosystemic process, and it cannot be interpreted as a mere succession of adaptive changes. Being driven by internal and external factors, evolution does not occur synchronously throughout the biosphere but only in certain areas. The emergence of such areas, refugia, requires specific conditions. During speciation in a refugium, crises with ecological imbalance and desynchronization alternate with time intervals characterized by relatively stable conditions and associated with an increasing number of available licenses and milder competition and selection.

It is known that the adaptation, self-organization, and self-regulation of a dynamic system imply a gradual change of averaged parameters in its stochastic environment (Tyurin and Terekhov, 2008). Adaptation is defined as the ability of a system to alter its structure to fit the changed environment. Such systems belong to the class of nonlinear dynamic systems, which cannot be implemented by using common linear methods of control theory. Adaptation and self-organization are close in their basics and results. Adaptation, which involves an assessment of ambient parameters and their changes, is based on dissipative elements, which allow the damping and smoothing of fast variations to reveal trends to which the system has to be adapted. On the other hand, dissipative systems as common examples of self-organization are also related to energy dissipation by spatial smoothening processes: diffusion, viscosity, and heat conduction. Usually, adaptation and self-organization produce similar results: better fitness to environmental changes due their better reflection in the properties and/or the structure of the system and lesser energy dissipation in the new state.

Knyazeva and Kurdyumov (2003) present a philosophical viewpoint in which the understanding of the regularities governing the evolution and self-organization of complex nonlinear systems or media reveals the intrinsic isomorphism between living and nonliving matter and the uniformity of evolutionary phenomena and structures in the realms of living and nonliving nature. This uniformity is explained by the fact that the nonlinear properties of these media carry ranges of structures, or ranges of evolutionary organization forms, which can arise at advanced asymptotic stages of processes. A search for the range of structures is one of the basic problems referred to in synergetics as a search for the eigenfunctions of a nonlinear medium. It implies the detection of stable ways to process the organization in a medium which would be adequate for this medium and to which all other states of the medium would eventually approach. Only the internal properties of the medium determine what relatively stable structures can self-sustain as metastable in the system and how many they are. We recognized three major RASs in the BRZ lithosphere, but some minor ones may also exist (Kluchevsky, 2008).

Nonlinear positive feedbacks are common in nature. They determine the development of systems in the blow-up regime, which points to their limited lifetime (Knyazeva and Kurdyumov, 2003). The term *blow-up regime* denotes superfast processes in which characteristic values, e.g., temperature, energy, concentration, or monetary capital, go to infinity at a finite time, called *blow-up time* (Knyazeva and Kurdyumov, 2002). If the factor responsible for inhomogeneities in the medium (the action of nonlinear extensional sources) operates more intensely than the dissipating factor, this brings about localized processes and combustion waves converging within the localization volume. We identify such a localization volume as an RAS in the BRZ lithosphere. This process develops with the increasing intensity within a decreasing area in the vicinity of a maximum. This is the so-called blow-up *LS* regime. In an analysis of the stress state of the BRZ lithosphere from seismic activity data (regardless of the temperature, pressure, or volume), it is apparent from an abrupt decrease in the vertical component of the primary stress $S_V$.

The existence of two opposite complementary regimes has been shown for a wide range of equation classes with highly nonlinear sources (Kurdyumov, 2006). It is conjectured that the destruction of a complex system developing in the blow-up *LS* regime (temperature growth) can be avoided by timely switching to the *HS* regime by means of a fluctuation or chaos. The *HS* regime implies a decrease in intensity (temperature), an infinitely divergent wave, and the resumption of processes following "old traces," which follows stress catastrophes in the BRZ lithosphere in the *LS* regime. Destruction gives way to integration; the maximum development of inhomogeneities gives way to their smoothening. By now, only a switch from *HS* to *LS* has been simulated in silico (Kurdyumov, 2006). The reverse switch, from *LS* to *HS*, is still a hypothesis as a result of theoretical modeling on the base of an analysis of the phase plane obtained by averaging. Nevertheless, the reverse switch has been actually observed in the BRZ lithosphere since the early 1980s. In geophysical terms, it is explained by an increase in the number of shocks (stress adjustment events) as a result of a slow increase in the vertical component of the primary stress $S_V$ (Kluchevsky, 2008).

## CONCLUSIONS

Variations in the annual numbers of earthquakes from 1964 to 2002 in the Baikal rifting zone and its three areas and six districts were subjected to correlation analysis. An analysis of the arrays of annual numbers $N$ of representative earthquakes in these territories showed that a high correlation of the earthquake flow rate, pointing to the synchronization of the seismic process in the region, was observed for the late 1960s and late 1970s–early 1980s and was preceded by stress rearrangements in the BRZ lithosphere. These rearrangements are considered a stress factor for the geodynamic system of the rift. Synchronization episodes are typically preceded by the chaotization of the seismic process when the seismic flow correlation coefficient fluctuates close to zero and seismic process of desynchronization are at minimum correlation levels. These synchronization episodes indicate that seismic activation occurred practically synchronously throughout BRZ. Seismic activation episodes formed the short-term coherent elevation of shock flow rate in the spatiotemporal seismic process. The synchronization episode of the late 1970s–early 1980s is prominent in duration and has the highest correlation level. Thus, it can be considered the primary phenomenon in the seismic process synchronization in the region. The synchronization and desynchronization episodes during stress rearrangements in the BRZ lithosphere are nonlinear, as are the similarly revealed synchronization and desynchronization effects in the behavior of a model biologic system (a sample of 1800 Lake Baikalian turbellaria in experiments on the phototactic response to deviation from homeostasis). It was shown that the object could adapt to stress after a short-term exposure with a small gradient. Long-term exposure to high gradients of a stress factor can produce destruction, manifesting itself as an earthquake of outstanding strength for a particular region in the case of lithosphere or, in the case of biologic objects in the biosphere, manifesting itself as death.

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