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GEOGRAPHY

Modeling of Structural Types of Hazardous Morphogenetic Processes

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Previous studies of the Irkutsk district resulted in its geoecological zoning according to ecological hazards of morphogenetic processes, their classification and mapping, and assessment of their spectra and structures in different geoecological regions [1–4]. These studies demonstrated the high potential of the methodological approach used and the representativeness of spatial objects. It seems reasonable to carry out modeling of structural types of hazardous morphogenetic processes for structural–genetic zoning of geoecological regions and assessment of the synergetic balance in geomorphologic systems (GS). Therefore, we analyzed relations between hazardous morphogenetic processes in different geoecological regions of the Irkutsk district and between these processes within particular regions.

The analysis of geoecological regions in terms of the whole spectrum of hazardous morphogenetic processes (Table 1), separate spectrums (Table 2), and the number (Table 3) of principal, associated, and secondary processes revealed statistically significant similarities and/or dissimilarities of mountainous, transitional, and plain areas. The author of this communication tested tendencies outlined in the tables using polynomial trends. For this purpose, diagrams of correlation coefficients between regions according to the spectrum of processes and distribution trends of these coefficients were compiled using regression equations. In order to decrease statistical noise, autocorrelation coefficients were omitted from calculations of trends. These procedures offered the opportunity to subdivide geoecological regions into the following structural–genetic zones: (class I) regions with plain–hummocky–mountainous topography; (class II) regions with low- to medium-mountainous and upland topography; (class III) regions with medium-mountainous to upland topography; and (IV) regions with high-mountainous topography. These structural–genetic zones form a hypothetical profile from arbitrarily plain to mountainous regions.

The role of individual processes in the general structure was outlined according to ordered subdivision of all processes in the particular geoecological region based on categories: principal, associated, and accessory. The distribution plot was compiled for each of these processes along the hypothetical profile.

The data obtained made it possible to compile hierarchical series of both geoecological regions (according to their structural–genetic positions) and hazardous morphogenetic processes (according to their energy sources) and to analyze the structure of the processes inside geoecological regions for modeling their types.

The theory of synergetics of natural processes [5, 6] was used for these interpretations. The self-organization pulse represents the mechanism responsible for uniting subsystems into a system, while the influx of negative entropy and subsequent energy consumption (dissipation) provides liaison between the GS and the environment. Structures with negative entropy in the nonequilibrium region with concordant behavior of subsystems are termed dissipative structures.

The geomorphologic systems are characterized by all the main features and properties of dissipative structures. The homeostasis (high entropy) represents their equilibrium state. The energy flux that decreases entropy is provided by endogenic and exogenic geomorphologic processes. They form new links between subsystems and a new structure. Therefore, the concordant and ordered action of topography-forming factors (agents), which is reflected precisely in the formation of peculiar structural types of morphogenetic processes, represents a basis of self-organization in the GS.

The energy influx into the GS (orostasis or orostatic initial state) includes ordering that depends on the number of sources and volume of energy. The consumption of energy and its transformation by the GS (metastasis or metastatic transitional state) is always realized through the maximal number of liaison channels lead-

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Table 1. Degree of similarity/dissimilarity between geoecological regions of the Irkutsk district according to the spectrum of hazardous morphogenetic processes

Regions	Kan–Lena	Angara–Tungus	Lena–Angara	Primoríe	Cis-Sayan	Baikal–Patom	East Sayan	Khamar-Daban	North Baikal	Trans-baikal
Kan–Lena	1.000									
Angara–Tungus	0.125	1.000								
Lena–Angara	–0.263	–0.048	1.000							
Primoríe	–0.200	–0.430	0.075	1.000						
Cis-Sayan	–0.331	–0.238	0.785	0.167	1.000					
Baikal–Patom	–0.314	0.252	0.707	0.024	0.828	1.000				
East Sayan	–0.443	0.238	0.554	–0.145	0.728	0.912	1.000			
Khamar-Daban	–0.279	–0.112	0.380	–0.183	0.702	0.706	0.846	1.000		
North Baikal	–0.419	0.047	0.589	0.051	0.795	0.916	0.923	0.816	1.000	
Transbaikal	–0.439	0.091	0.529	0.020	0.787	0.923	0.953	0.840	0.971	1.000

Note: Degree of similarity/dissimilarity based on correlation coefficient *R*: (>0.9/–0.9) very high, (0.7–0.9/–0.7 to –0.9) high, (0.4–0.7/–0.4 to –0.7) medium, (0.2–0.4/–0.2 to –0.4) low, and (<0.2/–0.2) zero.

Table 2. Degree of similarity/dissimilarity between geoecological regions of the Irkutsk district according to the spectrum of principal, associated, and secondary hazardous morphogenetic processes

Regions	Kan–Lena	Angara–Tungus	Lena–Angara	Primoríe	Cis-Sayan	Baikal–Patom	East Sayan	Khamar-Daban	North Baikal	Trans-baikal
Kan–Lena	1.000									
Angara–Tungus	0.860	1.000								
Lena–Angara	0.129	–0.396	1.000							
Primoríe	0.322	–0.207	0.980	1.000						
Cis-Sayan	–0.375	0.140	–0.964	–0.998	1.000					
Baikal–Patom	0.955	0.973	–0.172	0.024	–0.093	1.000				
East Sayan	0.964	0.692	0.388	0.563	–0.617	0.841	1.000			
Khamar-Daban	–0.371	0.984	–0.552	–0.376	0.313	0.916	0.554	1.000		
North Baikal	0.190	0.665	–0.949	–0.869	0.833	0.473	–0.079	0.786	1.000	
Transbaikal	0.969	0.960	–0.122	0.077	–0.143	0.999	0.867	0.895	0.426	1.000

Note: Degree of similarity/dissimilarity based on correlation coefficient *R*: (>0.9/–0.9) very high, (0.8–0.9/–0.8 to –0.9) high, (0.6–0.8/–0.6 to –0.8) medium, (0.4–0.6/–0.4 to –0.6) low, and (<0.4/–0.4) zero.

ing to increase in the nonequilibrium state and formation of a new structure. This is followed by dissipation of transformed energy and formation of the next structure, which tends to provide the least number of energy dissipation channels and the consequent increase in entropy of the GS (homeostasis or homeostatic final state).

The influx, transformation, and dissipation of energy in the GS are characterized by oscillatory behavior. Therefore, the initial pulse in the synergetic balance of the GS stimulates the growth of the oscillation amplitude and nonequilibrium state. Moreover, if the synergetic quotient field is sufficiently stable and long-lived, the amplitude increase is followed by a period of self-similar homologous states of the system. As soon as the quotient field ceases to send pulses, the amplitude of oscillations (self-similar homologous states) vanishes after some critical state, resulting in increase of entropy and homeostasis of the GS.

The principle points of the heuristic model of structural types and synergetic balance of hazardous morphogenetic processes (Fig. 1) are as follows.

The energy influx to the GS is provided by two sources: endogenic energy (orogeny) and exogenic energy (erosion) sources. The energy influx also has an initial structure characterized by bimodal or nearly bimodal distribution of the curve of processes and formation of orostatic geomorphologic systems with the initial structure of morphogenetic processes and energy accumulation.

This is accompanied by increase in the amplitude of self-similar oscillations in the GS, distribution of

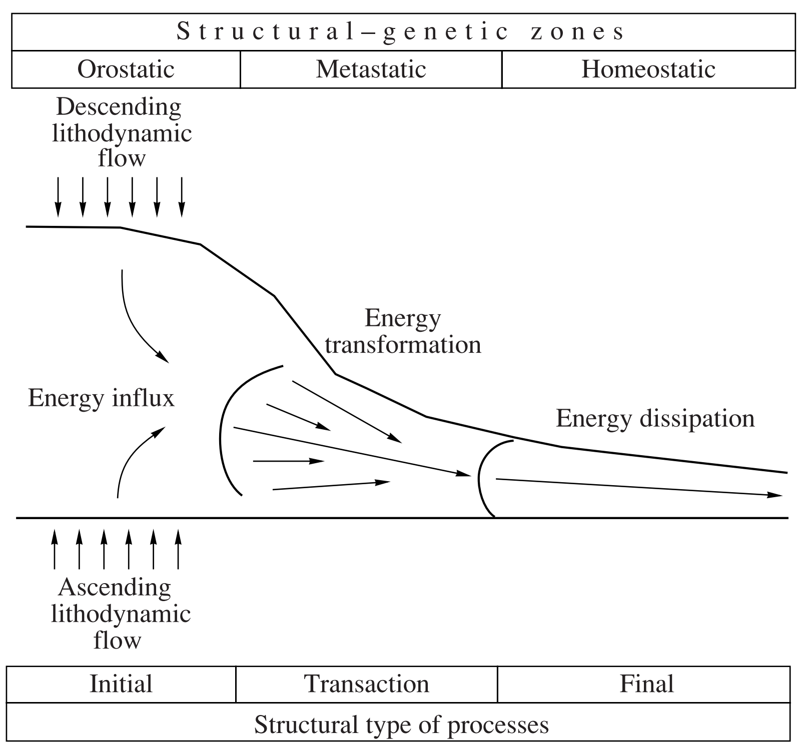
Table 3. Degree of similarity between geoecological regions of the Irkutsk district according to the number of principal, associated, and secondary hazardous morphogenetic processes

Regions	Kan–Lena	Angara–Tungus	Lena–Angara	Primoríe	Cis-Sayan	Baikal–Patom	East Sayan	Khamar-Daban	North Baikal	Trans-baikal
Kan–Lena	1.000									
Angara–Tungus	0.982	1.000								
Lena–Angara	0.984	0.933	1.000							
Primoríe	0.945	0.866	0.988	1.000						
Cis-Sayan	0.982	1.000	0.933	0.866	1.000					
Baikal–Patom	0.327	0.500	0.156	0.000	0.500	1.000				
East Sayan	1.000	0.982	0.984	0.305	0.982	0.327	1.000			
Khamar-Daban	0.891	0.961	0.797	0.632	0.961	0.721	0.891	1.000		
North Baikal	0.982	1.000	0.933	0.866	1.000	0.500	0.982	0.961	1.000	
Transbaikal	1.000	0.982	0.984	0.305	0.982	0.327	1.000	0.891	0.982	1.000

Note: Degree of similarity based on correlation coefficient *R*: (>0.9) very high, (0.8) high, (0.6–0.8) medium, (0.4–0.6) low, and (<0.4) zero.

energy through the maximal number of liaison channels, and its simultaneous transformation. Such energy fluxes in the nonequilibrium zone show the polymodal distribution of the curve of processes and are responsible for the formation of metastatic geomorphologic systems with the transaction structure of morphogenetic processes and energy transformation.

This is followed by the growth of entropy, ordering of the energy flux (minimization of liaison channels), and by its subsequent dissipation. Such energy fluxes show the unimodal or nearly unimodal distribution of the curve of processes and produce homeostatic geomorphologic systems with the final structure of morphogenetic processes and energy dissipation.



Synergetic model explaining the formation of structural types of hazardous morphogenetic processes (profile from mountainous regions to piedmonts and plains).

Table 4. Synergetic classification of geoecological regions in the Irkutsk district

Geoecological regions	Distribution of processes	Synergetic balance	Structural–genetic zone	Structural type of processes
East Sayan, Khamar-Daban, North Baikal, Transbaikal	Bimodal	Energy influx	Orostatic	Initial
Lena–Angara, Baikal–Patom	Transitional from bimodal to polymodal	Transition from energy influx to its transformation	Transition from orostatic to metastatic	Transitional from initial to transaction
Kan–Lena, Primoríe, Cis-Sayan	Polymodal	Energy transformation	Metastatic	Transaction
Angara–Tungus	Unimodal	Energy dissipation	Homeostatic	Final

All these processes lead to the formation of three structural–genetic zones: (1) the influx zone (orostatic state of the GS); (2) the transformation zone (metastatic state); (3) the dissipation zone (homeostatic state). Ultimately, three (initial, transaction, and final) structural types of morphogenetic processes are formed.

In order to test the proposed heuristic model, plots of the modal distribution of hazardous processes were compiled for each geoecological region arranged successively according to sources of energy for the GS or agents of morphogenesis. The geoecological regions appeared to be arranged with respect to the structural type of processes, synergetic balance, and structural–genetic position or zoning of the GS (Table 4).

Thus, transitional structural–genetic zones are characterized by the maximal transformation of energy of morphogenetic processes, a decrease in entropy, and an increase in the number of liaison channels between the GS and the environment.

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