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THE STUDY OF GEOSYSTEM STRUCTURE, DEVELOPMENT AND FUNCTIONING IN SIBERIA

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The advancement of the theory of science elicited in the 1960s the emergence of new ideas in physical geography. They were tied to system concepts that gained acceptance in many countries in connection with the formulation of L. von Bertalanfi's general theory of system analysis. The quest of a new concept was dictated by the need to reconcile route and stationary investigations and to organize them at a new level complying with the modern trends in geography. To do this required arranging according to a system a number of theoretical postulates that took shape in landscape science and invoking additional ones from related disciplines, primarily from ecology.

The emergence of the science of geosystems goes back to 1963 when V.B. Sochava (1963) coined the term "geosystem" and introduced it into scientific usage. Subsequently the author defined this notion as follows: "...the geosystem (irrespective of its dimension) is a whole entity consisting of interrelated components of Nature that obey regularities operating in the geographical envelope or landscape sphere" (Sochava, 1974), or "...using the language of cybernetics it can be said that it is a special class of controlling systems; the terrestrial space of all dimensions where the individual components of Nature are in system linkage with one another and, as a certain integrity, interact with the cosmical sphere and with human society" (Sochava, 1978).

Initially, the new branch of science was treated as structural-dynamic landscape science (Sochava, 1967). The fundamental ideas pertaining to the science of geosystems were advanced by V.B. Sochava at the 5th Congress of the USSR Geographic Society in 1970 in his paper entitled "Geography and ecology" (Sochava, 1970), and at the 6th Congress in 1975 his paper "Science of geosystems" was presented (Sochava, 1975). The geosystem paradigm came to gain wide acceptance when V.B. Sochava's papers were published in the journals of "Izvestiya VGO" (Sochava, 1973) and "Petermanns Geographische Mitteilungen" (Sochava, 1972, 1974).

In a final form, the most important postulates of this science were set forth by the author in a monograph entitled "An Introduction to the Science of Geosystems" (Sochava, 1978). Geosystems represent a special class of open, hierarchically organized, dynamic systems. The hierarchical character of structure is their critical property because, thanks to it, both an elementary area of the terrestrial surface and the planetary geosystem constitute a dynamic entity with a special geographical organization inherent in them. Organization of geosystems includes their differentiation, integration, development, and sustaining functioning; therefore, the science of geosystems involves, as ingredients, theoretical postulates that substantiate the regularities of their classification, mapping, dynamics and evolution.

Among the basic objectives achievable on the basis of the science of geosystems, are: modeling of geosystems with consideration for their spontaneous and anthropogenic dynamics and natural regimes corresponding to them; the quest of rational techniques for quantitative assessment of geosystems and landscape-forming processes; system analysis of spatial links in the geographical envelope at the planetary and regional levels; understanding of the spatial-and-temporal regularities, and analysis of the states of geosystems; creation of graphic models of geosystems, primarily maps of the habitat in connection with problems related to its protection and optimization; study of the influence of socio-economic factors on the natural environment, and prediction of future geosystems; development of the foundations for constructive landscape science in order to generate "man-environment c-creation geosystems", one of the forms of target-oriented anthropogenic transformation of geosystems in accordance with evolution trends inherent in them (Sochava, 1978).

A very important consideration for understanding the essence of geosystems is the notion of the invariant, a totality of properties of the geosystem that remain unchanged as it is transformed under the influence of external factors. Cyclic changes of natural properties and regimes that occur for a definite time and do not leave the confines of the invariant, are called the dynamics of geosystems, while radical alterations that lead to a change of the invariant, are termed the evolution. Both dynamics and evolution represent links of the same process of development of geosystems – dynamic (quantitative) changes that accumulate in natural entities would lead to a qualitative jump, the evolution. The interaction of the components in geosystems is sustained by flows of matter and energy, and the entire totality of the processes of exchange and transformation of matter and energy is referred to as the functioning of geosystems.

The first research ground where the ideas forming the basis of the science of geosystems were tested was the Kharanorsky steppe physiographical permanent station in the South-Eastern Transbaikalia the principle objective of the work done under the guidance of V.B. Sochava was to pursue a comprehensive physiographical investigation of the steppe geosystems including the study of rhythms of natural phenomena, substantiate a classification of natural entities, and to identify structural-dynamic properties inherent in them (*Topology of Steppe…, 1970*).

Subsequently, the scope of stationary investigations was expanded – they incurporated the substantiation for activities aimed at transformation of the natural environment, the development of principles and methods of physiographical forecasting, and identification of potential lands of various kinds of economic utilization. To solve the problems of approaching an integral quantitative assessment of natural regimes that would open the way to settle a number of theoretical issues related to regulation and transformation of the natural environment, and to make physiographical predictions required not only estimating the parameters of flows of energy, biomass and inorganic matter but also studying the organization of subdivisions of the geographical environment. The stationary investigations were carried out, based on using the method of comprehensive ordination, the essence of which is a syntope and synchronous study of the natural regimes in transect-research areas in order to identify natural combinations as systems changeable in space (Sochava, 1967). By studying separate natural regimes and integrating them and identifying cycles of chemical elements in contiguous geosystems, it was possible to establish the major dependencies inside steppe geosystems through correlation and regression-variance analyses. They formed the basis for the creation of graphic and mathematical models of elementary geosystems, and identifying critical components of the steppe landscape: effective radiation, circulating moisture, and productivity of grass (*Topology of Steppe…, 1970*).

A large body of work done on investigating the structure and regimes of geosystems at Siberian geographical permanent field stations made it possible to determine and unravel spatial differences of the functioning of geosystems with due regards for the temporal dynamics of biotic and abiotic factors in the steppes of the South-Eastern Transbaikalia (*Topology of Steppe…, 1970*, *The Study of Steppe…, 1976*) and Yuzhno-Minusinskaya depression (*Natural Regimes…, 1976*), in the taiga of the piedmonts of the Western Sayan (*Geosystems of the Piedmonts…, 1979*), the Krasnoyarsk Angara region (*The Southern Taiga…*,1969; , *Natural Regimes…, 1975*), the

Southern Irtysh region (*The Southern Taiga…, 1975*; *Nature of the Taiga…, 1987*), and the Kondo-Sosvinskoye Ob region (*Natural Regimes…, 1877*).

A topological study of the landscape of the Upper-Chara depression (Mikheev, 1974) made it possible to carry out its detailed physiographical facies analysis with consideration for the chorological links between facies within a district and for the character of the processes which determine the formation of their factorial-dynamic series and various combinations.

Within the context of elaboration on the science of geosystems, A.A. Krauklis, on the basis of investigations from the Priangarsky taiga station, created the framework for a new working area of comprehensive physiography, experimental landscape science that is at the junction of landscape mapping, regionalization and special-purpose study of the environment using methods from exact sciences (Krauklis, 1979). The author suggested the concept of the geosystem as a set of functionally linked variable states of the natural complex, developed the landscape model in the form of a system of factorial-dynamic series of facies, and examined the prospects and avenues for practical implementation of experimental landscape research for purposes of development of the taiga.

This monograph has much in common with a book by V.V. Ryumin (1988) which, on the basis of materials from the study of the landscape structure of the surroundings of the Lensky taiga station and the Novonikolayevsky steppe station, addressed the issues related to the dynamics and evolution of geosystems and their stability, and made an analysis of the natural-resources potential of the territory.

A significant contribution to the geographers' views regarding the ordering of the structure of the landscape sphere was the concept of a three-series classification of geosystems (Sochava, 1978) that includes the typological (geomers), chorological (geochores) and dynamic (variable states and epigeomers) series. The tiniest cells of the geographical envelope are represented by elementary homogeneous (uniform) areas of the natural environment: elementary geomers or biogeocenoses. By the principle of similitude, they are combined into facies, and further, with consideration for generalization, into groups of facies, classes of facies, geoms, groups of geoms, classes of geoms, and larger taxons thus constituting a classification series of geomers. The least (as regards the number of components) territorial combination of elementary geomers represents an elementary geochore, or an elementary heterogeneous area. According to territorial contiguity and commonality of the natural properties, elementary geochores are combined into microgeochores (stows), mesogeochores (localities), topogeochores (areas), macrogeochores (districts, landscapes), provinces, etc., forming in the aggregate a classification series of geochores. These series are both interrelated, and the highest taxon of either series is the landscape envelope in general. All geosystems are subdivided into three orders of dimensions: topological, regional, and planetary. The landscape in the hierarchy of geochores occupies a nodal place – it is simultaneously a unit of both topological and regional dimension.

The graphic, or as V.B. Sochava said at one time, natural, model of the geosystem is represented by the landscape map summarizing results of field work. Mapping of geosystem is, in its essence, opposite to mapping of separate components of the natural environment where the primary objective is to reflect local peculiarities arising as the result of a spatial differentiation of large component formations. In the case of mapping of geosystems, however, first and foremost it is necessary to take into account the back side of the overall physiographical process – the integration of separate components into local geosystems (Sochava, 1973).

A landmark in landscape mapping was the publication of the map "Landscapes of the South of East Siberia" (Mikheev, Ryashin, 1977) compiled by V.S. Mikheev and V.A. Ryashin under the guidance of V.B. Sochava; in its legend the entire totality of mapped geoms and other geomers is subordinate to those geosystems of planetary dimension to which they pertain. The map also reflects large regional taxons to which mapped groups of geoms are subordinate, as well as dynamic categories of groups of facies.

A significant place in the science of geosystems is occupied by the problem of geographical forecasting that was treated by V.B. Sochava (1978) as a very important direction of modern geography and was defined by him as the development of ideas about natural geographical systems of the future. It is aimed at prediction of changes of geosystems in the process of spontaneous development and as a consequence of man's activity, and is intimately linked to standardization of nature management.

It is A.G. Isachenko's opinion (Sochava, 1974) that landscape forecasting is a further development of V.B. Sochava's theory of dynamics and evolution of geosystems. On the other hand, the forecasting problem is directly related to issues of information support and modeling. Therefore, the Siberian geographers' forecasting developments aimed at optimization of nature management in particular regions take into account primarily the natural and anthropogenic landscape trends that were identified as part of station-based investigations, archival and published materials, and experimental data on the determination of standard loads on geosystems.

A book by V.S. Mikheev (1974), dealing with the implementation of landscape research results in working out comprehensive problems related to development of Siberia's regions, examines a large system of support as the region of combination of the theory and practice of physiographical investigation in the development of territorial systems for scientific preparation of production operations of man in his habitat.

The beginning of studies on the influence of socio-economic factors on the natural environment in the light of the science of geosystems was marked by the appearance of a collection entitled "Topological Aspects of the Science of Geosystems" (1974). Subsequently, Siberian geographers addressed themselves repeatedly to the synthesis of economic-geographical and physiographical data in forecasting geosystems of the future in areas of intense development.

On the basis of integral usage of the science of geosystems (Sochava, 1978) and the basic postulates of landscape geochemistry (Glazovskaya, 1964; Perelman, Kasimov, 1999; Snytko, 1978), staff members of the Institute of Geography SB RAS identified a large number of aspects of differentiation, integration and development of natural entities through the study of differentiation and migration of their substance component.

Landscape-geochemical research was directed at the study of metabolism processes in geosystems (Snytko, 1978, 1983). The emphasis was on studies at comprehensive physiographical stations (Snytko, Semenov, Suvorov, 1995). The objects of observation were representative (for landscape) elementary subunits, facies, that form conjugate series in accordance with the direction and extent of flows of material. In practice, account was taken of the main forms of substance state: biogenic, solid, liquid, and gaseous.

It is possible to gain insight into each of the aforementioned substance facies of geosystems in the course of special-purpose experiments. because of the complexity of the study of the solid phase, the observations of this phase of substance had to be organized mainly in a static form. Taking into account the bulk mass of the components of geosystems provided a clear understanding of the stock of substance in solid phase, which subsequently made it possible to make various comparisons and more thoroughly represent the geosystem.

Especially noteworthy is the liquid state of matter, chiefly the transformation of moisture in soils and plants, and migration of materials dissolved in the components of geosystems. In investigating the integral role of the alkali-acid conditions, attention was paid to pH dynamics.

The organic component of geosystems as the basis for all vital processes that governs the course of most natural phenomena, has a special role. Therefore, special-purpose experiments were conducted to take into account living substance and migration of chemical elements in it. It was important to detect the dynamics of substance, its seasonal (intra-annual) variations, as well as revealing year-to-year trends of the latter.

Intra-landscape transformation patterns of the gaseous phase of matter were considered in the example of soil air carbon dioxide as an indicator of the course of long-term natural processes. The study revealed its variations within definite geosystems, and transformations in their conjugate series.

A study of the vertical differentiation of substance of conjugate facies made it possible to determine the dynamic trends of landscape caused by the distribution of substance in connection with surface nonuniformity. The study demonstrated the intra-secular differentiation of substance in geographical facies on the basis of studying the series of macro- and microelements.

Geochemical investigations into landscape form part of physiographical research to ascertain the structural-functional organization of geosystems. Appropriate routine observations of the variability of substance provide not only spatial but also temporal regulararities. Results of seasonal and year-to-year observations of the particular indices at the transect-research site (conjugate series of facies) were plotted as a graph that was regarded as a spatial-temporal model of the facies.

Investigations of radial migration of material with water flows at stations used the lysemetric, chromatographic and micromorphological methods.

An outline is given of the experience gained from investigating the dynamics of taiga geosystems (by considering an example of the West-Siberian region) using informative landscape-geochemical indices. Calculating the relative parameters of the major natural processes (biogenic and water migration of chemical elements and their differentiation in the soil thickness) is treated as the quest of the form of expression of the landscape dynamics (Nechayeva, 1985).

An analysis was made of the entry of technogenic material into landscapes, and of the processes of its transformation and distribution in the components of environment. The functioning and transformation of landscapes evolving in technogenic conditions were studied (Volkova, Davydova, 1987).

Station-based landscape-geochemical investigations furnished an opportunity to study the course of intra-annual and, partly, long-term dynamics of some of landscape indices. The studies revealed their slight spatial variability (within an elementary geosystem), which motivated the need for temporal observations with a large proportion of objectiveness. The dependence of the series of soil-geochemical indices on hydrothermal factors was emphasized. Time-coincident observations in doublet geosystems revealed substantial differences of soil-geochemical data obtained fro anthropogenically transformed geosystems, on parameters inherent in their natural counterparts (Snytko, Semenov, Martynov, 1987).

Possibilities were demonstrated for using the synthesis of data from landscape-geochemical investigations in order to gain insight into the regularities of differenttiation, integration and development of natural entities. Methods were developed for landscape-geochemical prediction and assessment of geosystems (Semenov, 1991).

Station-based investigations of the behavior of substance in conditionally natural and anthropogenically modified geosystems that have been carried in different regions of Siberia, together with landscape-geochemical mapping and experimental research made it possible to create the technique for landscape-geochemical substantiation of regional systems of nature management. It includes such pivotal elements as diagnostics of the state of geosystems by analyzing long-term series of observations of migration of material, determining the stability of natural entities to technogenic impacts, and establishing allowable technogenic loads, predicting the behavior of material on the basis of temporal prolongation of experimental data, and spatial extrapolation of results obtained at a local level, with due regard for restrictive ecological factors.

Thus the emergence of the science of geosystems, the development of the princeples of geosystem approach, and its use in tackling ecological-geographical problems, together with the landscape-geochemical approach, betoken a constant quest and the emergence of new ideas in geographical science. The system paradigm has given us the chance to revise the logical foundations of the science of landscape environment and draw a clear distinction between problems in physiography and sectoral geographical disciplines (Sochava, 1978). The science of geosystems has become the "core" of physiography that evolved into a modern science treating of natural systems and taking full advantage of the system approach, while sectoral sciences, primarily so-called "through" sciences: landscape geophysics, and landscape geochemistry, based on exploiting its theoretical base and its own quantitative methods, allows an understanding of the functioning of natural entities.

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SUMMARY

In the sixties, the development of the science theory has caused an appearance of new ideas in physical geography. These ideas were concerned with the system approach. In the year of 1963 V.B.Sochava introduced the term "geosystem", and in 1978 had published the monography "Introduction into doctrine of geosystems". The system paradigm had given possibility to revise the logic bases of the doctrine of landscape sphere, and to differentiate accurately the problems of physical geography and branch geographical disciplines. On the basis of combined use of doctrine of geosystems and primary postulates of landscape geochemistry, the employees of the Institute of geography of the Siberian Branch of the Russian Academy of Science have revealed many aspects of differentiation, integration and development of natural objects by means of studying of differentiation and migration of their material component.