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COMPLEX OF METHODS FOR STUDYING AND ESTIMATION OF GEODYNAMIC ACTIVITY

SUMMARY. This paper offers a definition of the term "geodynamic active zones" — areas of the Earth crust different in size and configuration, that are active at the present stage of neotectonic development and are characterized by reduced strength of the crust, increased cracking, permeability. As a result, they are characterized by explosive tectonics, seismicity, mass transfer of fluids and other processes. The complex heterogeneous system "relief—tectonic lineaments and structures—water solutions—substance" is studied to identify these areas. The research is determined by the scheme: modern relief—geomorphological methods of research—structural and geological conditions—geological research methods and geological results. The methods of the research are structural and geomorphological (morphometric, morphostructural, morphoneotectonic, structural-lineament-geodynamic), structural hydrogeological and structural–geochemical analysis. A complex of methods is chosen so that the shortcomings of some methods are filled by the application of other methods. The methodology has justified itself in industrial work and applied research. Hydrogeological anomalies (with a high underground chemical flow rate) have been identified within 40 of 50 identified local positive structures of the Baikit Anteclise and in 60–80% of the Volga—Ural Anteclise. Over 30 integrated geochemical anomalous zones with the surface from 100 to 700 km² (some of them with oil and gas deposits) that are spatially coincident with geodynamic active zones are identified in the southwest of the Siberian platform. In the Yenisey Ridge (the Nizhnekansky granitoid massif) an area of low geodynamic activity was recommended for building a storage for highly toxic radioactive waste instead of the initially proposed site where a zone with a high geodynamic activity had been discovered.

KEY WORDS. Complex, methods, geodynamic active zones.

The estimation of regional and local geodynamic activity is one of the crucial issues in many regions, especially the Urals, Siberia, the North, and the Far East, where with a minimum population density it is planned to build large local industrial complexes to implement technological, science-intensive and big-budget projects. At the same time, in urbanized mining and oil-producing areas the probability of environmental emergency caused by geodynamic processes, relief-forming processes in particular is enhanced every year.

Since the 1970s a new applied research area on the interfaces between geodynamics, structural geology, geomorphology, neotectonics, geochemistry, hydrogeology, geoecology, and other scientific fields has been developed—the theory of geodynamic active zones.

Object, methodology, research objectives and research procedure. Geodynamic active zones are understood as areas of the Earth crust that are different in size, configuration and area size that are active at the present stage of neotectonic development and are characterized by reduced strength of the crust, increased cracking and permeability. As a result, they are characterized by explosive tectonics, seismicity, mass transfer of fluids and other processes [1].

To identify these areas, a complex methodological approach is used. The general methodology of the research was explained in previous publications [2].

The paramount strategic objectives of the developed research area are as follows: 1) identification of geodynamic active zones of lithosphere and the geographical envelope and 2) overall assessment of geodynamic activity of the territories based on a complex of various activity rate parameters of the latest tectonic movements.

The study of geodynamic (neotectonic) activity follows the lines of research devoted to *relief—tectonic lineaments and structures—water solutions—substance* heterogeneous system. Realization of the research follows the general pattern: modern relief—geomorphological methods of research—structural and geological conditions—geological research methods and geological results. The main idea is to use the data about relief and lineaments to build geodynamic active zones models.

The study of geodynamic active zones is based on a complex of methods; among them are: structural and geomorphological (morphometric, morphostructural, morphoneotectonic, structural-lineament-geodynamic), structural–hydrogeological and structural–geochemical analyses. Modern methodology of creating geodynamic active zones models includes the following steps: 1) construction of basic morphometric maps of watercourse order, datum surfaces of different orders, coefficients of riverbed sinuosity, anomalous watercourse longitudinal profile grade, total erosional roughness; 2) construction of a digital relief model; 3) construction of maps (diagrams) of megafracture systems (local and short tectonic lineaments); 4) quantitative processing and mathematical interpretation of the results: homogenization of the environment, normalization, square averaging, calculation of indicators in equivalent values (scores), calculation of the composite score, isoline mapping, construction of the resultant map of geodynamic (neotectonic) activity; 5) construction of a geodynamic model, integration of its data with morphometric data, data of geologic structure and structural setting, geodynamic zoning, identification of geodynamic active zones; 6) assessment of the degree of accuracy of the obtained results—comparison of geodynamic activity with the data about geophysical, geochemical, hydrogeological and other fields, the assessment of the degree of local neotectonic activity (structures, areas, etc.).

Results and discussion. As practical application of this methodology has demonstrated, the best indicators of geodynamic activity are the density of tectonic lineaments, recognized by means of structure contour interpretation of modern aerospace photographs, and total roughness of the surface. In general this methodology has been tested in the western part of the Siberian Platform and the eastern area of the East European Craton during the geological, structural geological, hydrogeological survey and oil and gas exploration [3–5]; in the Yenisey Ridge during geochemical and morphostructural examinations [6]; also in the process of geodynamic survey of the main oil and gas pipeline routes in different northern areas, Ural region, Western Siberia, etc. [7–9]. Over the last years computer interpretation technology and computer data processing have been based on ESRI software ARC GIS and its modules (Spatial Analyst Tools, Line Density, etc.).

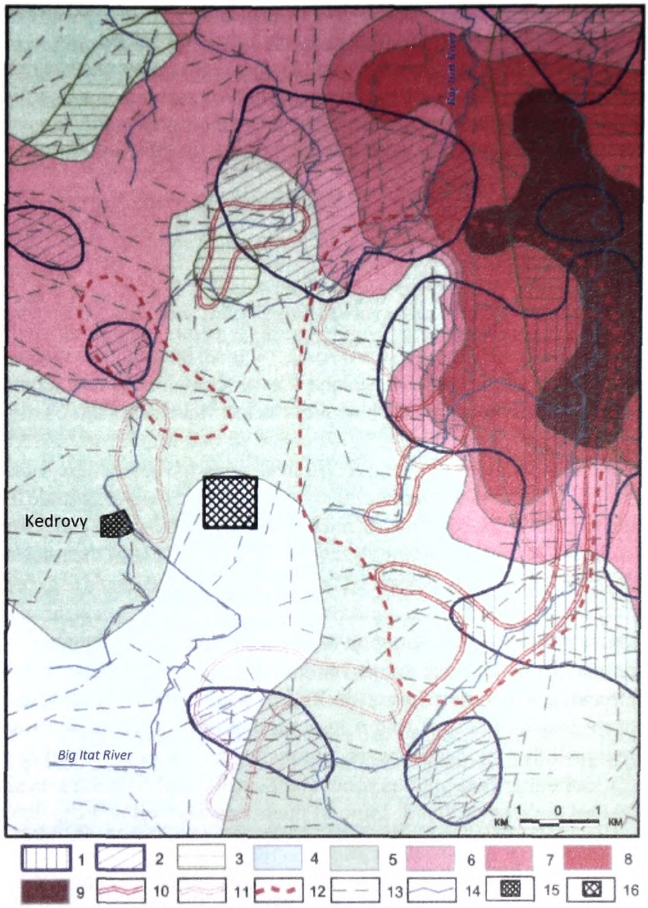
Structural–hydrogeological and structural–geochemical analyses were applied to assess the degree of accuracy of the results, creating zoning plans, estimation and prediction of geodynamic active zones. These are complex analyses and a custom solution to every case was provided, which first of all concerned establishing parameters for the estimated factors.

Structural–hydrogeological analysis is based on the following premise: structural geological conditions and neotectonic movements have an important role in forming hydrogeological conditions in an active water exchange zone. This interdependence is established in different areas of the world [10–12] and is confirmed by our research in many areas of Siberia, the Urals and the Ural region [2], [4], [13]. The following rates were used as estimate indicators for structural geological mapping: an underground flow rate, an underground chemical flow rate and a hydrocarbon flow rate. These indicators allow high-precision mapping of local positive structures and identification of geodynamic active zones. For example, in the Baikit Anteclise 40 out of 50 examined local positive structures are characterized by increased parameters of hydrogeological indicators (by 1.5–4 times); moreover, the most distinct ones are large-scale high-amplitude local positive structures with a quick limb angle. The same is typical of the Volga—Ural Anteclise where in the area of development of many positive structures (60–80% of the total number) and geodynamic active zones an increased underground flow is observed.

The analysis of geochemical fields was conducted by means of a complex of geochemical methods, each focusing on one group of basic components: waters, soils and subsoils, rock, vegetation, snow cover, air over the soil. In the Baikit Anteclise as a result of processing materials from over 15,000 geochemical sampling points, direct and indirect measures characterizing migration capacity of the Earth crust substance following tectonically weak zones were established that were activated recently. Over 30 complex geochemical anomalous zones were established with the area size between 100 and 700 km^2 have been found, some of the zones have oil and gas deposits [4–5].

In the Yenisey Ridge in one of the areas of Nizhnekansky granitoid massif (where the construction of a highly toxic radioactive waste storage was designed), a highly geodynamic active zone was mapped (high geodynamic activity is an unfavourable condition for engineering construction). Within the bounds of the zone a complex geochemical anomaly with a high content of helium and hydrocarbons in groundwater and snow cover and a high content of trace elements in soils was discovered. At the same time in another area, a zone of low-level geodynamic activity was mapped with low-level hydrogeological and geochemical indicators. For its geodynamic safety the zone was recommended as a location for a radioactive waste storage [6] (Figure).

In the last 30 years in the Ural region, a huge amount of geochemical data (over 300,000 samples) was accumulated in the process of regional geological–geochemical, hydrogeological, geoenvironmental research and multipurpose geochemical mapping. As a result, a large number of geochemical anomalies were identified discriminating many different components in the geological environment. Twenty-one complex lithogeochemical and thirteen hydrogeochemical anomalous zones of 1000–9000 km^2 were mapped [14]. Their location reveals proximity with geodynamic active zones.



Geodynamic active zones according to the results of lineament-geodynamic analysis, with the following lineament density: 1 — very high, 2 — high, 3 — areas with a high roughness coefficient. Areas of underground chemical flow rate, g · L / s / km^2: 4 — < 0.1, 5 — 0.1-0.3, 6 — 0.3-0.5, 7 — 0.5-0.7, 8 — 0.7-1.2, 9 — >1.2. Geochemical anomalous zones: 10 — hydrocarbon gases and helium in groundwaters and surface waters; 11 — hydrocarbon gases and helium in snow cover; 12 — trace elements in soils and vegetation (the composite score includes 25 trace elements); 13 — tectonic lineaments identified by the interpretation of aerospace photographs; 14 — a hydrographic network; 15 — a populated locality; 16 — an area with the most stable geodynamic conditions recommended for the construction of a deep radioactive waste storage

Figure: Geodynamic assessment of Nizhnekansky granitoid massif by means of geomorphological, geochemical and hydrogeological methods.

Thus, most gas, geochemical and hydrogeochemical anomalies are characterized by high estimate indicators according to some of the applied morphoneotectonic and structural hydrogeological analyses. Some areas of the anomalies' edges are geodynamically active. These data confirm the important role of neotectonic movements in geochemical anomalies formation.

Conclusions. As practical application of structural geomorphological, hydrogeological and geochemical methods has shown, the systematic use of these methods at early stages of research can effectively, with a high degree of accuracy and without big expenditure of time and money, solve the problem of quantitative (qualitative) assessment of geodynamic conditions, as well as predict modern tectonic movements and optimize the choice of areas for heavy operations like geophysical operations and drilling. This complex of methods for the estimation of geodynamic activity can be successfully used in a number of Russian regions.

These are the main spheres of application:

1) seismological problems: identification of seismogenic structures, seismic hazard zoning, earthquake prediction, prediction of other events, including disastrous ones, connected with the impact of regular distribution of both endogenous and exogenous components in lithodynamic flows;

2) engineering–geological problems: the study of geodynamic active zones' influence on engineering–geological conditions and engineering constructions; the assessment of capability for building and maintenance of any engineering constructions; the evaluation of geological risks and hazards related to design and maintenance of high responsibility constructions; the study of urban geological safety; verification of safe mine operations and commercial exploitation of mineral deposits;

3) geoenvironmental problems: identification and prediction of earth substance transfer, measurement of its speed, forecast of contamination in all the Earth's shells and territories; the study of geodynamic active zones' influence on the environment and humanity; identification of geopathic zones, caused by geodynamic activity (the theory of geopathic zones is actively formed nowadays);

4) hydrogeological problems: the study of groundwater flow patterns and the impact of geodynamic active zones on groundwater flow distribution and formation of water-abundant zones;

5) minerogenic problems: the study of geodynamic active zones' impact on the formation of mineral deposits and their exploration; explorations of hydrocarbons, ore minerals, diamonds and groundwaters are especially perspective in terms of using geodynamic parameters.

In the course of further improvement and approbation of the methodology, it can be successfully applied in other areas of scientific and practical activities.

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