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СВЯЗЬ МЕЖДУ ПРОСТРАНСТВЕННЫМ РАСПРЕДЕЛЕНИЕМ ТЕКТОНИЧЕСКИХ ДИСЛОКАЦИЙ БАЙКАЛО-СТАНОВОЙ СДВИГОВОЙ ЗОНЫ И ИСТОЧНИКАМИ МИНЕРАЛЬНЫХ ВОД РЕГИОНА

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Аннотация: Статья состоит из двух частей. Первая отражает результаты комплексных исследований тектонической обстановки Байкало-Становой сдвиговой зоны. Эта высокосейсмичная геологическая структура развивается на южной окраине Сибирского кратона. Результаты комплексной интерпретации геолого-геофизических данных позволили установить, что это зона характеризуется фрагментарно проявленным главным швом, который картируется на протяжении всей зоны. Высокоразвитая сеть оперяющих и второстепенных дислокаций может быть интерпретирована с помощью теоретической модели левосдвигового эллипсоида деформаций. Во второй части приведены результаты, характеризующие необходимость учета данных тектонических исследований при проведении гидрогеологического районирования территории. Приведены результаты исследования взаимного распределения откартированных тектонических дислокаций Байкало-Становой региональной сдвиговой зоны с установленными кинематическими характеристиками и источников подземных вод региона. Было установлено, что ареалы выхода подземных вод тяготеют к областям разгрузки тектонических напряжений, в которых имеют преимущественное проявление разломы с сбросо-сдвиговой или сбросовой кинематикой. Полученные результаты актуальны для обеспечения безопасности при проведении горнопромышленных работ. Приведенные заключения привносят дополнительную информацию при проведении гидрогеологического районирования региона.

Ключевые слова: тектоника, Байкало-Становая сдвиговая зона, сдвиговые дислокации, интерпретация геолого-геофизических данных, сейсмология, фокальные механизмы, гидрогеологическое районирование, источники минеральных вод.

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A link between spatial distribution of the active tectonic dislocation and groundwater water resources in the Baikal-Stanovaya shear zone

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Abstract: The article consist of two parts. In the beginning we show the results of comprehensive research of tectonic settings in Baikal-Stanovaya shear zone. This high seismic geological structure develops in the south margin of the Siberian platform. By interpretation geological and geophysical data we suppose that the Baikal-Stanovaya shear zone has the segmented main fault which can be mapped from the lake of Baikal to the Okhotsk sea. Complex and developed net of the secondary faults can be interpreted by left-lateral theoretical model of deformation ellipsoid. In the second part of article we describes the necessity to consider the data of tectonic studies when conducting hydrogeological zoning of the territory. The results of the study of the mutual distribution of the mapped tectonic disturbances of the Baikal-Stanovaya regional shear zone with established kinematic characteristics and sources of groundwater in the region are presented. It was found that the areas of underground waters are drawn to areas of tectonic tension discharge having predominant faults with shear and thrust-shear kinematics. The results of this research are actual for improving safety in mining Forthemore, this study has additional information for hydrogeological zonation

Key words: tectonics, the Baikal-Stanovaya shear zone, strike-slip faults, interpretation of geological-geophysical data, seismology, focal mechanisms, hydrogeological zoning, mineral water sources.

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Introduction

A key role in shaping the structure of the Earth's crust and current seismological mode of the Trans-Baikal region is played by the Baikal-Stanovaya regional shear zone (BSZ) of the Neogene-Anthropogenic age [Egorov, 2015]. Up to several hundred annual earthquakes of different magnitudes occur within this geostructure [Imaev et al., 2016, Ageev, 2016]. The high level of seismic hazard of this BSZ attracts close attention of different scientists and specialists from all around the world. This shear zone has a specific interest in geological mapping of this region, which is characterized by multi-stage tectogenesis. Despite the significant structural and shaping importance, the BSZ remains understudied due to its low social infrastructure and immense territory. Along with topical scientific issues considered during the examination of the deep structure of the Earth's crust of the BSZ, the practical application is also very important. In particular, the study of the spatial distribution of mineral water sources within this geostructure is of great interest.

The modern structure of tectonic disturbances of the Baikal-Stanovaya regional shear zone

During the study of the Earth's crust of the Baikal-Stanovaya regional shear zone, the model of the lateral distribution of structural and compositional inhomogeneities was created. These operations involved the whole complex of systematized geological and geophysical information (working database) [2]. The primary task of modeling is to perform a lineament analysis (visual and automated) of the initial potential geophysical fields, their transformants and satellite images. Comparison of lineament schemes of geophysical fields and satellite images was carried out using data from neotectonic research. The next stage was the verification of selected tectonic dislocations on a geological basis. This process considered the results of many years of theoretical and experimental research aimed at studying the principles of the formation of both individual faults and their systems. The result of this multistage work was the mapping of the spatial distribution of tectonic

disturbances of the Baikal-Stanovaya regional shear zone (Fig. 1).

Comparison of linear features of geophysical fields and other maps and schemes allowed mapping and fragmentary tracking of the main fault from the axial part of the southern side of Lake Baikal in the east-northeast direction to the coast of the Sea of Okhotsk. The Main fault discordantly crosses the Barguzino-Vitimsky mega block, the Baikal-Vitimskaya suture zone and is further traced within the Stanovoy mega block. It should be noted that along the whole length the main fault does not have a single structure. Besides that, many minor faults were mapped, which often act as tectonic «bridges» between the segments of the main fault. Their echelon and in some cases a linear geometric shape is noted.

A characteristic feature of the main fault is its curved shape. In the area of this curve, numerous feathering faults are regularly mapped in accordance with the necessary tectonic and physical conditions under which their depositing and further development are possible [10].

Based on the data of tectonic-physical studies, we compared the observed pattern of tectonic dislocations distribution in the target area using the theoretical model of the ellipsoid of left shear deformations. The results of this analysis indicate that it is possible to interpret numerous feathering faults as synthetic (Riedel R-shears) and antithetic (Riedel R'-shears) faults, their location in relation to each other and the main fault is consistent with the distribution of tectonic faults in this theoretical model. At the same time, we determined the

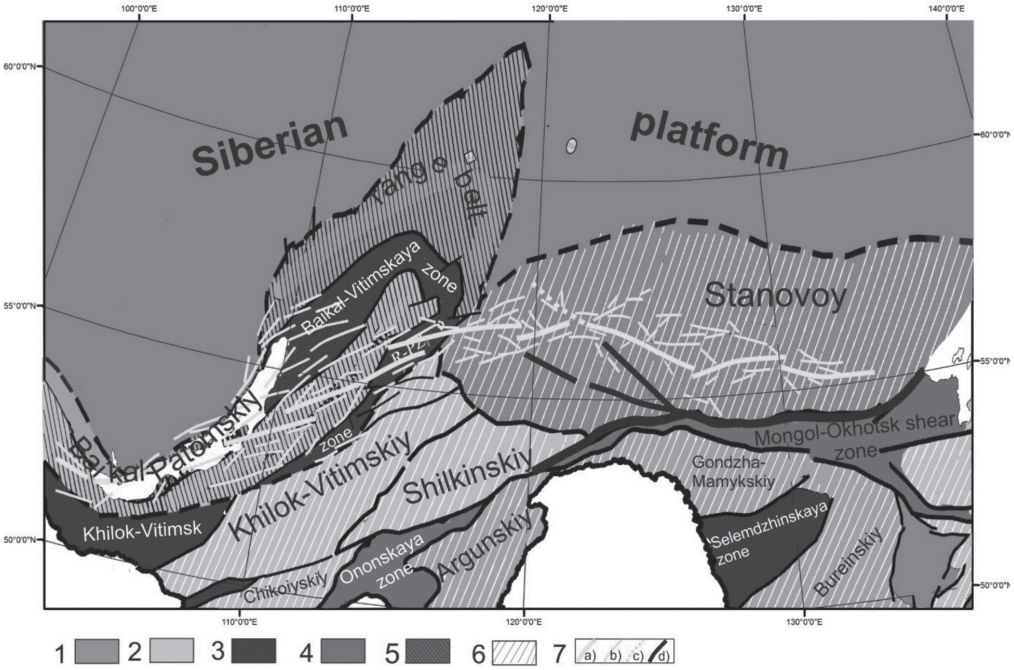

Fig. 1. Spatial distribution of faults in the Baikal-Stanovaya shear zone. The map of the main geological structures by [Egorov, 2004]. Legend: 1—2 — Terrains with old continental crust: 1 — Siberian platform, 2 — Phanerozoic folded areas; 3—4 — interblock suture zones: 3 — Caledonian and Variscan, 4 — Kimmerian; 5—6 — deformation area at the margins of terrains with old continental crust: 5 — Caledonian, 6 — Kimmerian; 7 — faults: main fault (a), secondary faults (b), inferred faults (c), faults of the Mongol-Okhotsk shear zone (d)

focal mechanism of seismic centers for the strongest earthquakes of the BSZ (Fig. 2).

The results of the focal mechanisms distribution analysis suggest that, along with the numerous manifestations of shear kinematics, normal faults and strike-slip faults are widely mapped. This is most clearly observed near Lake Baikal. When moving eastward, the number of faults with the presence of shear kinematics decreases. In this area, we mapped the faults of shear and thrust-shear kinematics. It should be noted that the above-mentioned scientific and theoretical conclusions on the kinematic parameters of faults are confirmed by similar findings of researchers of this region [7]. That conclusions correspond with results of seismology research at the west margin of North-American continent. The Walker Lane (WL) fault system and the eastern California shear zone (ECSZ) are adjacent to the San Andreas fault system — regional shear zone and the boundary between the Pacific and North-American plates at the same time [9]. Similar seismological analysis in WL shows that primary cinematics is transpression [8, 11]. Analogue research relatively ECSZ says thar the most of faults are transtensions [12].

Mapped faults of various morpho-kinematic types play a key role in controlling the seismicity of the target region. Among the variety of identified tectonic disturbances, both the faults of the ancient age (Proterozoic) and the younger ones, the Late Mesozoic and Cenozoic, are present. The age-based classification of faults is an extremely difficult task since many of the ancient ones are still active. However, it should be noted that most of the faults shown in the diagram belong to the Neogene–Quaternary period.

The analysis of the lateral distribution of structural-compositional inhomogeneities revealed an interesting feature — the

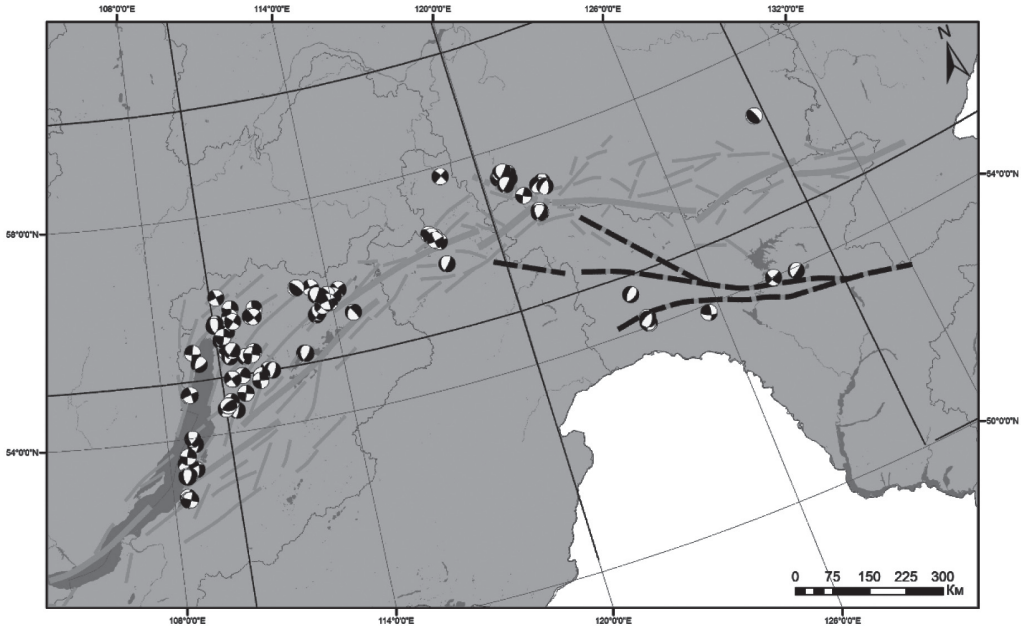

Fig. 2. Focal mechanisms of the Baikal-Stanovaya shear zone. Faults of the BSZ are colored by yellow; faults of the Mongol-Okhotsk shear zone are shown by black-dotted lines. Legend: ◐ — focal mechanism: The white zones are reflected areas of extension; the black zones are linked with areas of compression

presence of a spatial connection of the BSZ according to the system of the feathering faults with the developing southern Mongol-Okhotsk shear zone, which also has left-side shear kinematics. It was established that the juncture of these regional shear zones occurs in the area of the greatest fold of the main fault of the BSZ. Considering the above, the author assumes a similarity of features of the lateral distribution of tectonic dislocations of the BSZ and San Andreas fault. The latter has a spatial junction with parallel developing shear zones of Walker Lane Belt and the East California Shear Zone with similar shear kinematics.

The relationship of the mutual distribution of the mapped faults with the sources of mineral waters of the region

The conducted research of the deep structure of the Baikal-Stanovaya regional shear zone, along with solving scientific and theoretical problems of the structure and evolution of this region, can have practical application in a wide range of environmental management tasks. As an example, the author presents the results of a comparison of hydrothermal deposits in the target area and the geological and structural elements of the tectonic zoning of the region, summarized in the pattern of localization of mineral water sources.

The geologic-structural models are presented in the form of the fragmentary exposed main fault of the BSZ, the Mongolo-Okhotsk fault, the suture structures of these shear zones, and the system of feathering faults of the main BSZ fault. Factual information was obtained as a result of a comprehensive interpretation of geological and geophysical data, the methodological part of which is described in detail in previous articles [2, 3].

Hydrogeological data are presented as hydrogeological areas obtained from the maps of hydrogeological zoning of the Republic of Sakha (Yakutia), the Chita region and the Khabarovsk Territory [13] and mineral water sources (water points) (Fig. 3).

Traditional hydrogeological zones are based on studying several physical-geographical (geological structure, relief, climate, etc.) and hydrogeological (rebounding, groundwater dynamics, runoff rate, etc.) signs [14]. Thus, within the territory of the development of the Baikal-Stanovaya regional shear zone, several large hydrogeological regions were identified: Baikal, Selenga, Daur, and Aldan. The researchers of this region found that the crevasse-vein basement mineral waters that come to the surface directly from faults in crystalline formations or overlying sediments are mainly manifested here [13]. Along with the above features, each of the selected areas is characterized by its chemical composition of water.

The current research of localization of mineral water sources and tectonic disturbances of BSZ made it possible to identify a number of interesting patterns:

- the area along the main fault is characterized by a small number of mapped water points;
- the specific areas of occurrence of the majority of hydrothermal deposits are concentrated in the zones of feathering faults.

Within the shear development zone, three areas of increased concentration of water points are clearly distinguished. The first area is situated near Lake Baikal. Here, the faults, to which water points are drawn, are trended mainly in the north-northwest direction. The second area develops in the region at 1200 east longitude and is also trended in the north-northwest direction. The third area is located east (at 1250 east longitude) with a similar strike of tectonic disturbances. The results of the analysis of the theoretical model of the left-shear ellipsoid deformation and the mechanisms of seismic centers indicate

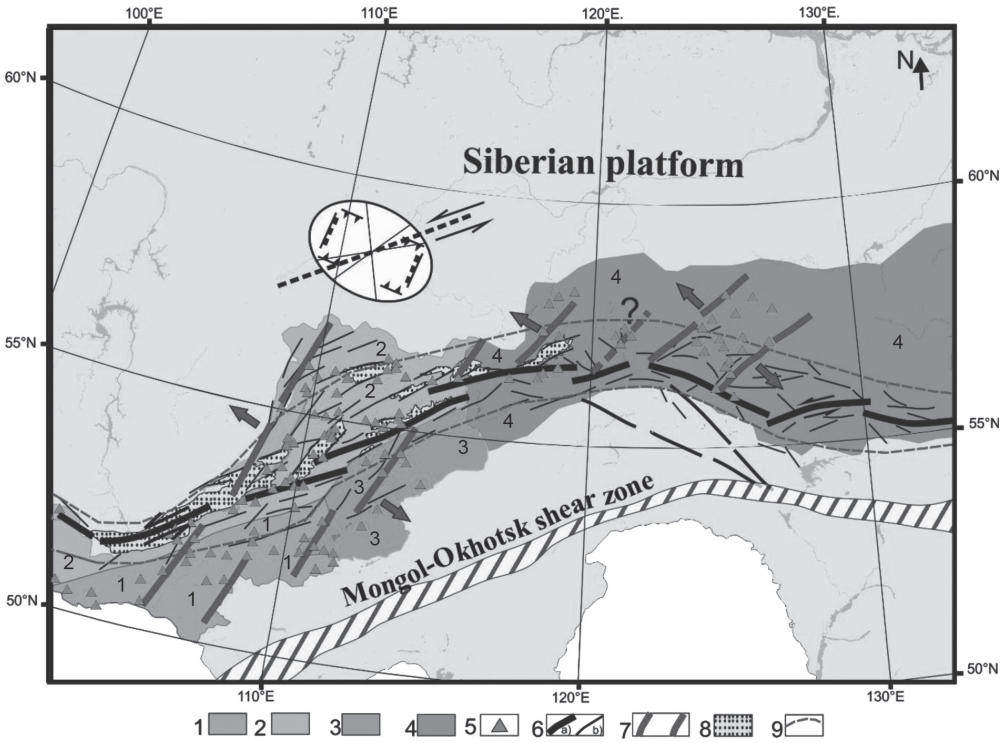

Fig. 3. Features of localization mineral water sources in the Baikal-Stanovaya shear zone. Legend: 1 — 4 — Hydrogeological areas: 1 — Selenginskaya, 2 — Baikal, 3 — Daurskaya, 4 — Aldan; 5 — Mineral water sources; 6 — Mapping faults: a) — main fault, б) — secondary faults; 7 — Areas of extension; 8 — Depressions (Quaternary); 9 — Contour of Baikal-Stanovaya shear zone

that within the selected areas the faults along with the shear component have a significant fault displacement, thus forming areas of tension.

Discussion

The study of the relationship between the chemical composition of water and the tectonic situation did not reveal any correlation. The obtained information may indicate the dependence of the chemical composition of water directly on the composition of the host rocks.

The research results allow making fundamental scientific and theoretical conclusions that the general laws of localization of mineral water sources correspond to the direction of the strike of the shear zone. However, upon detailed examination, it was established that the predominant localization of the latter is observed in the areas of the feathering faults. Tectonic disturbances, to which water points are drawn, are characterized by a significant fault displacement component. These areas form tension zones in which current tectonic stresses are discharged and, accordingly, sources of mineral waters are localized.

Thus, the results of the study reflect the need to consider the deep structure of the earth's crust of the regional shear zone during hydrogeological zoning of the territory. Along with this, the results of this study can improve safety in mining processes. The object for further research is establishing the relationship between the chemical composition of water and the tectonic dislocations, which may be a subject for further study.

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