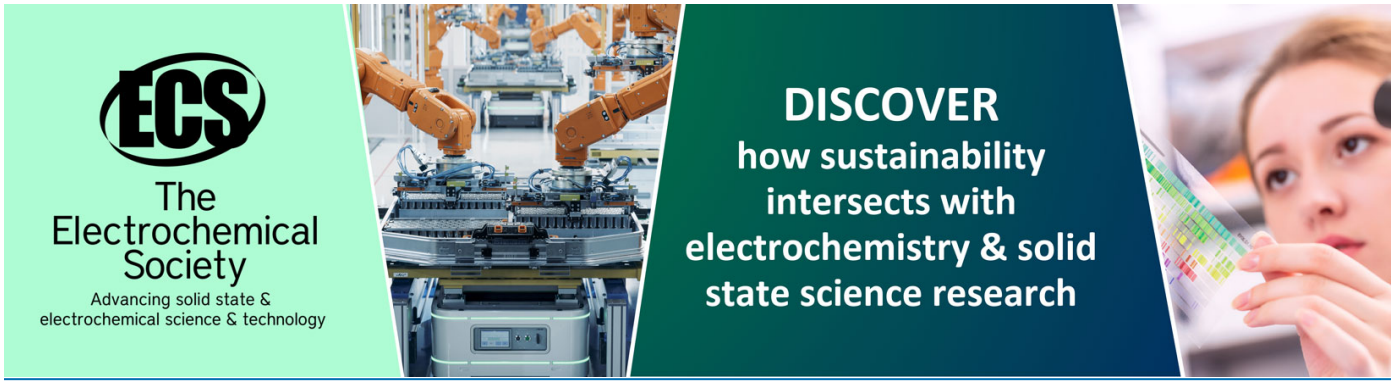
The Study of the Permeability of the Upper Crust Part on the Photo Image of the Surface in the Area of the Nalychevo Field of Thermomineral Waters (Kamchatka)



The Study of the Permeability of the Upper Crust Part on the Photo Image of the Surface in the Area of the Nalychevo Field of Thermomineral Waters (Kamchatka)

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The study of tectonic break of the upper layer of the earth's crust in the area of the Nalychevo field of thermomineral waters was made. The source material was the results of decryption of aerial- and space images. The specific length of the lineaments (SLL) of the supposed faults was determined up to the depth of 3 km and a 3D matrix was created. The voxel image of the SLL of the investigated block with areas of increased crust permeability was constructed. The Nalychevo field is located at the intersection of the north-western, latitudinal and submeridional zones of increased permeability, which are distinguished in the voxel model by the maximum values of the SLL.

Key words: decryption, lineament, model, voxel, fault.

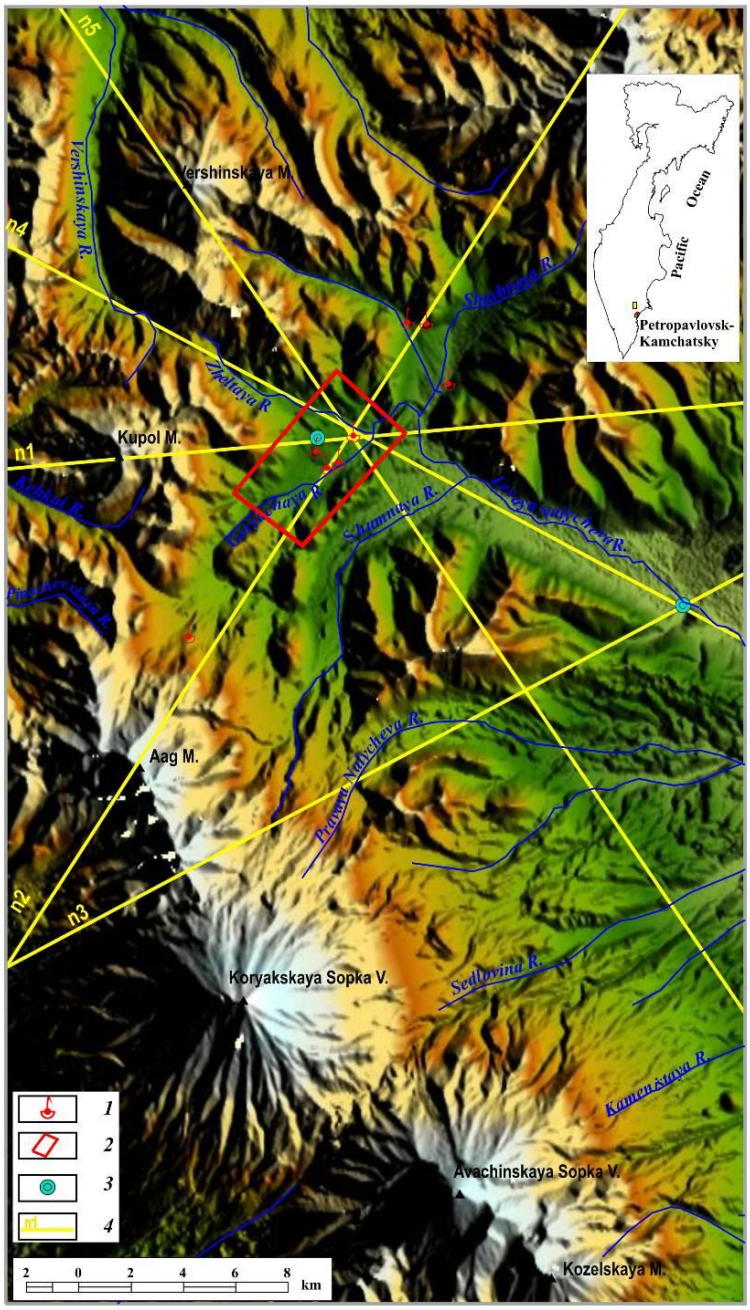
1. Introduction

It is important to know the location of areas (zones) with increased permeability to find the possible ways of deep heat-mass transfer in the earth's crust. The occurrence of increased permeability greatly depends on the activity of tectonic processes at a particular area. The permeability is determined by the cleavage and porosity of the rocks. One of the determining factors affecting permeability is faults along which cleavage zones form. The more the crust block is broken, the more permeable it is. Faults inside the crust are determined by geophysical data, on the earth surface – by geological methods and by aerial and space images. The results of a studying of crust break (cleavage) in the Nalychevo field/deposit of thermomineral waters in the upper layer up to a depth of 3 km below sea level are presented below.

The break of the geological environment can be evaluated quantitatively by the value of specific leniaments length (SLL) decrypted by the surface photoimage on the aerial and space images [1, 2]. The SLL is as a three-dimensional matrix from which a voxel image of the break of the investigated block is formed. Break presentation in the form of a voxel model gives the possibility to determine the spatial parameters of zones with increased permeability along horizontal slices and vertical sections.

2. Brief characteristics of the region, the initial data and methodology for the cleavage modeling

Nalychevo field of thermomineral waters is located in the valley of the Levaya Nalycheva River to the north of the Avacha group of volcanoes (Fig. 1). Geological and hydrogeological studies in the area were carried out from the late 1920s of XX century (Novograblenov P.T., 1928, Piip B.I., 1931-33, Ivanov V.V., 1952). In 1950s the complex hydrogeological surveys of 1:500000 scale (Izotova Ye.I., 1955), scale 1:25000 (Kovalev B.V., 1959), specialized prospecting works (Tolstikhin O.N., 1958, Mindlin V.Ya., 1960) were carried out. Four wells were drilled to the depth up to 217 m. Thermal waters are opened at 25-117 meters [3]. There are six more thermal sources in the basin of the Nalycheva River except Nalychevo source.



The region is composed by the products of Cenozoic volcanic accumulation, which occur on sedimentary and volcanic-sedimentary formations of Mesozoic-Cenozoic. In the valley of the Nalycheva River and its tributaries the volcanites are covered by loose sediments with a thickness of the first tens of meters.

In 1989-1995 years during the experimental and methodological works Sokolkov V.A. decrypted aerial and space images of various details by the method of a extensive approximation, and the scheme (Fig. 2) of the lineaments of discontinuous tectonics [4] was made, it was used to estimate the tectonic break of the described region.

Fig. 1. Overview diagram of the Nalychevo field of thermomineral waters. 1 - thermomineral springs; 2 - deposit outline; 3 - exploratory wells; 4 - lines of vertical sections of the voxel break model.

The scheme of lineaments was digitized. After that a square grid with an area of a unit cell of 1 km^2 was covered on it. Within each cell the total length of lineaments was found.

It is known that deformations of the macroscopic level of a certain volume of the earth's crust can be represented by the sum of the deformations of many elementary units (Gzovsky, 1975, [5]).

It was empirically determined that the cleavage of one face of the rock cube adequately reflects the degree of cleavage of the entire sample [1, 2]. The coefficient of tectonic break of a cubic block is determined by the ratio of the volume of all fissures in the block to its volume. The volume of fissures is defined as the sum of productions: the length (l), opening width (b) and transmission depth (h) of the fissures. For a geoblock of a cubic form with an edge ***a***, where one of the faces is a day surface, the coefficient of tectonic break will be $\Sigma l \cdot b \cdot h / a^3$. In real situation it is impossible to determine the values ***b*** and ***h*** by the photoimage of the earth's surface. But, for a specific territory, the width of the fissures (***b***) can be considered constant, and the depth of their transmission (***h***), taking into account the established rule and similarity principle, can be equaled to ***a***. Thus, determining the degree of break as the value of the specific length of the lineaments (SLL) equaled to $\Sigma l / a^2$ of the upper face of the geoblock and increasing the unit cell size step by step, it is possible to trace the break into the depth.

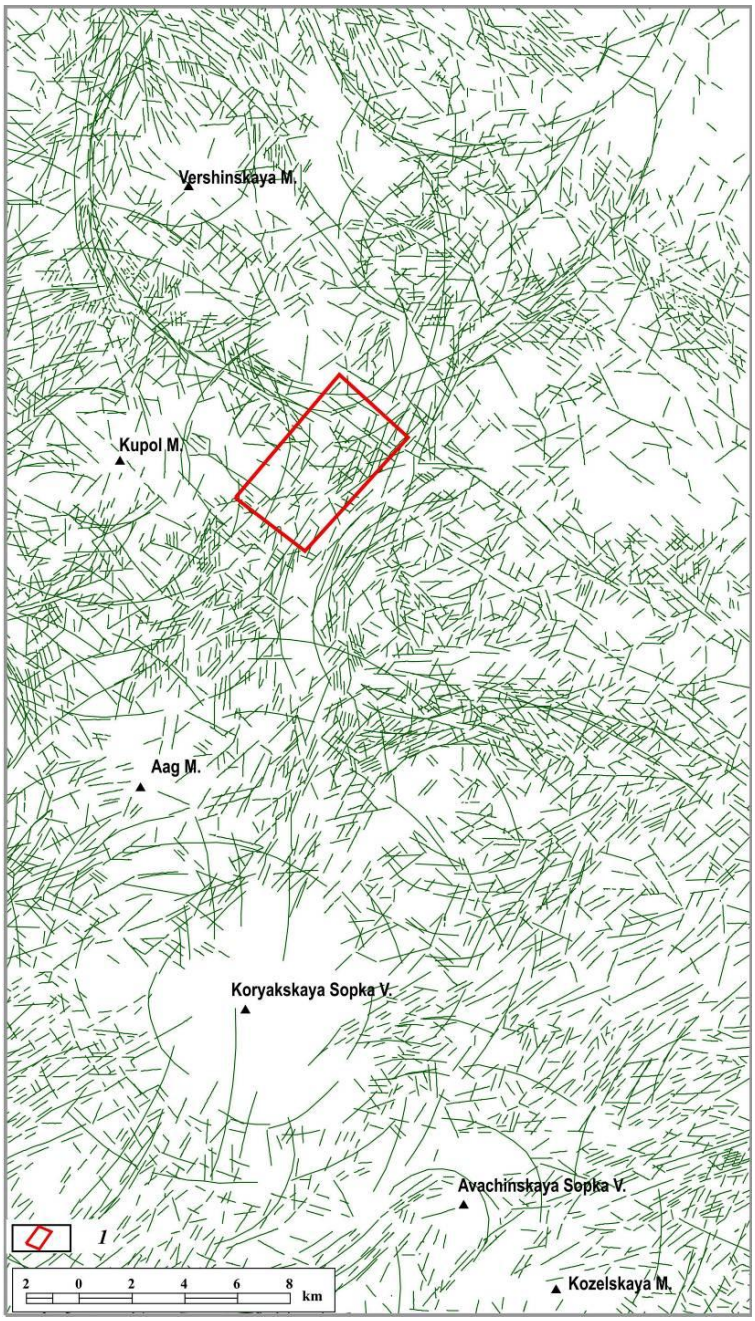


Fig.2. Map fragment of the decrypted lineament network of the Nalychevo field area by V.A. Sokolkov, [4]. 1 - deposit outline.

Considering that the rheological properties of the medium in the cell are homogeneous, the SLL values calculated in this way refer to the center of the cube at the depth ***a/2***. The algorithm was described in detail earlier in [6, 7 8]. The result was represented by a three-dimensional matrix of SLL up to the depth of 3 km, which is visualized by a voxel (three-dimensional) image (Fig. 3).

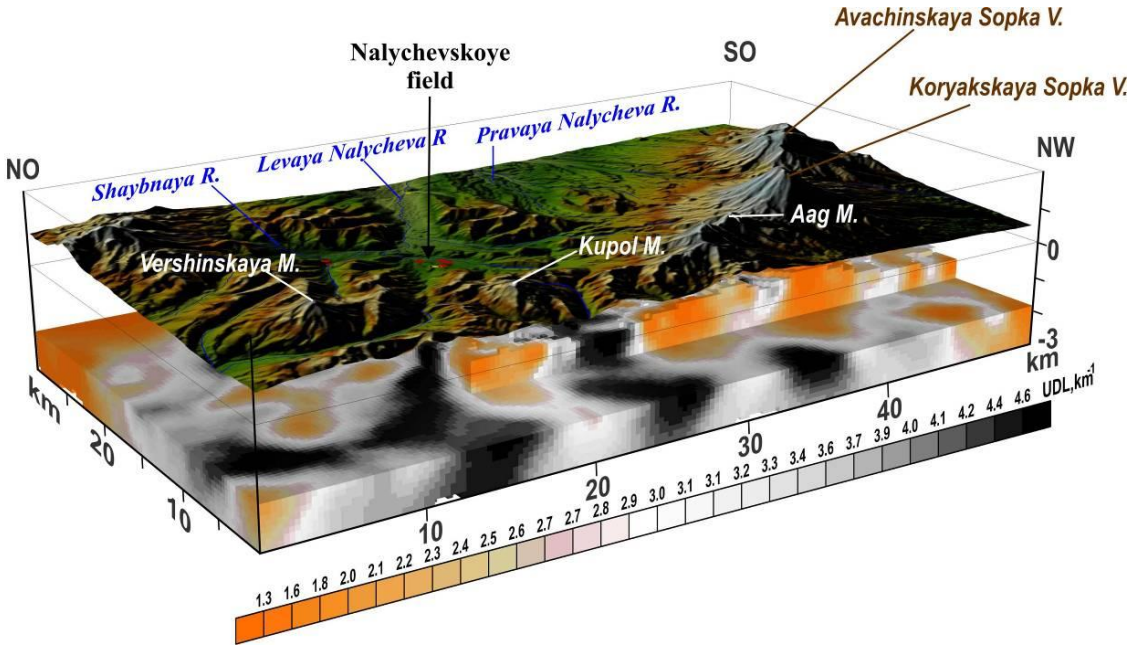


Fig.3. Voxel (3 D) model of tectonic break. The voxel cell is 0.5x0.5x0.5 km. View is from the north-west. Yellow points show wells, red ones – springs/sources of thermal waters (see Fig. 1).

3. Results

For a studied crustal block, the break varies from 0 to 10, with an average value of 2.5 in units of SLL. Figures 4 and 5 present constant time slices at a different depth of the constructed 3D model of the crustal break of the Nalychevo field of thermomineral waters, and Figures 6 and 7 show vertical slices. As it can be seen on the maps of constant time slices, Nalychevo field of thermomineral waters is located at the intersection of several zones of increased permeability.

A zone of east-west trending is some to the south from the thermal springs of the field. Zones are contoured along the contour of SLL with a value of 4 units. Inside the contours, as a rule, there are local anomalies with more than 5-6 SLL units. They form chains oriented along the trending zone. The exception is the western fragment of the east-west trending zone crossing the volcanic ridge between Kupol and Aag mountains. At a deep horizontal slice, at sea level, the zone consists of several north-eastern enchelons, within which chains of 2-3 local anomalies of the same orientation are located (Fig. 5). The enchelons form east-west line. Probably, the north-eastern orientation of cleavage is typical only for the uppermost part of the section, since at the slice of -2.5 km the anomalous cleavage is elongated strictly in the east-west direction according to the general zone trending.

The submeridional zone is observed from the south to the north, from the loop of the Pravaya Nalycheva river, "bumping" in the eastern fragment of the east-west trending zone, on the right side of

the Shumnaya river up to the confluence of the rivers Goryachaya, Porozhistaya, Shaibnaya and further (Fig. 5). At a slice of -2.5 km, in fact, there is only a fragment of a zone with 3.5-4 km wide on a segment from the Shumnaya river up to the mouth/outlet of the Goryachaya river. The width of the zone at sea level in the southern part of the area is 4.5-5 km, the northern fragment is about 2 km. The anomalous permeability of the northernmost branch of the zone is mainly concentrated above -1 km.

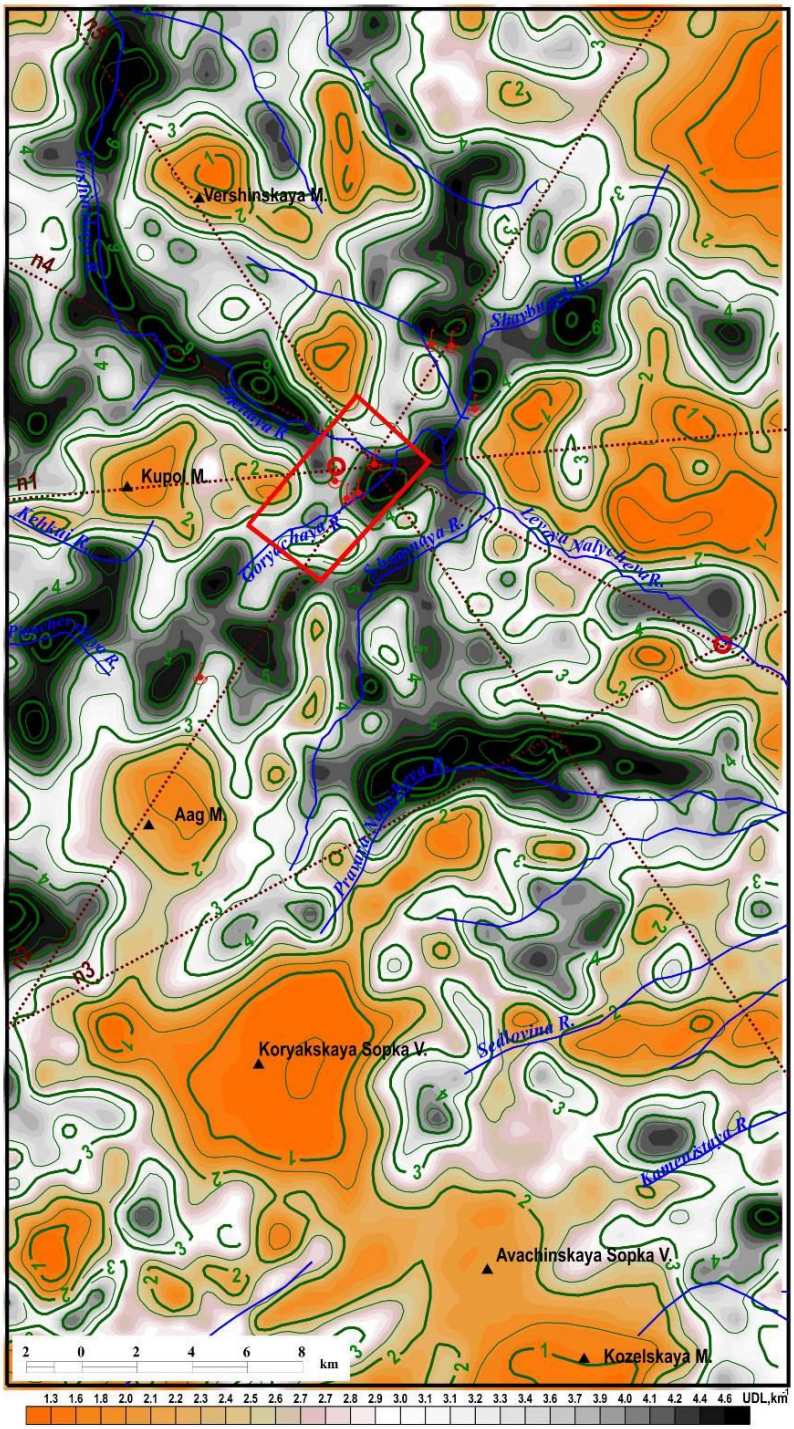


Fig. 4. Tectonic break at sea level. 1 - thermal waters sources; 2 - the contour of the Nalychevo field; 3 - wells; 4 – section lines and their numbers; 5 - isolines of SLL main (a) and intermediate (b).

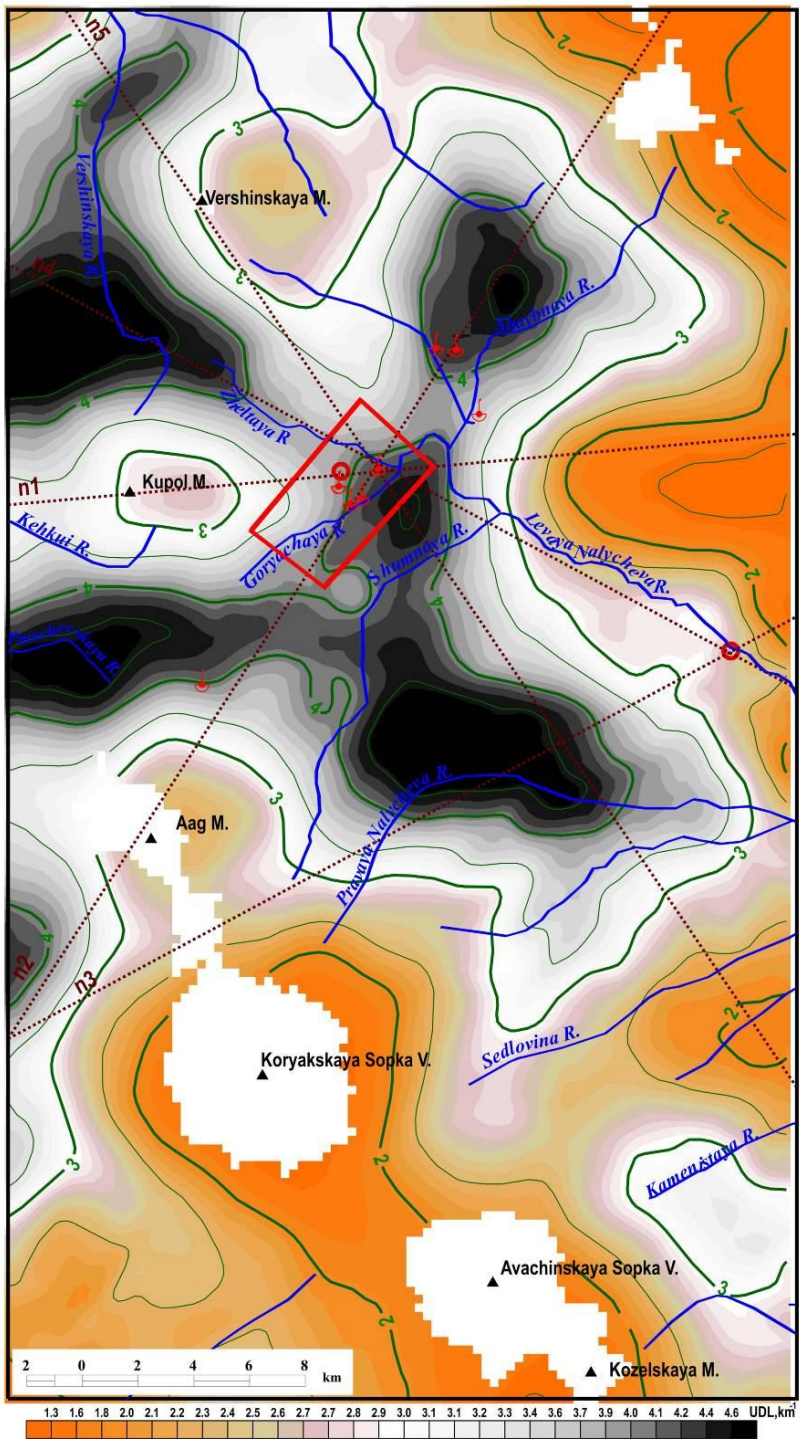


Fig. 5. Tectonic break at a depth of 2.5 km below sea level. See Fig. 4 for the legend.

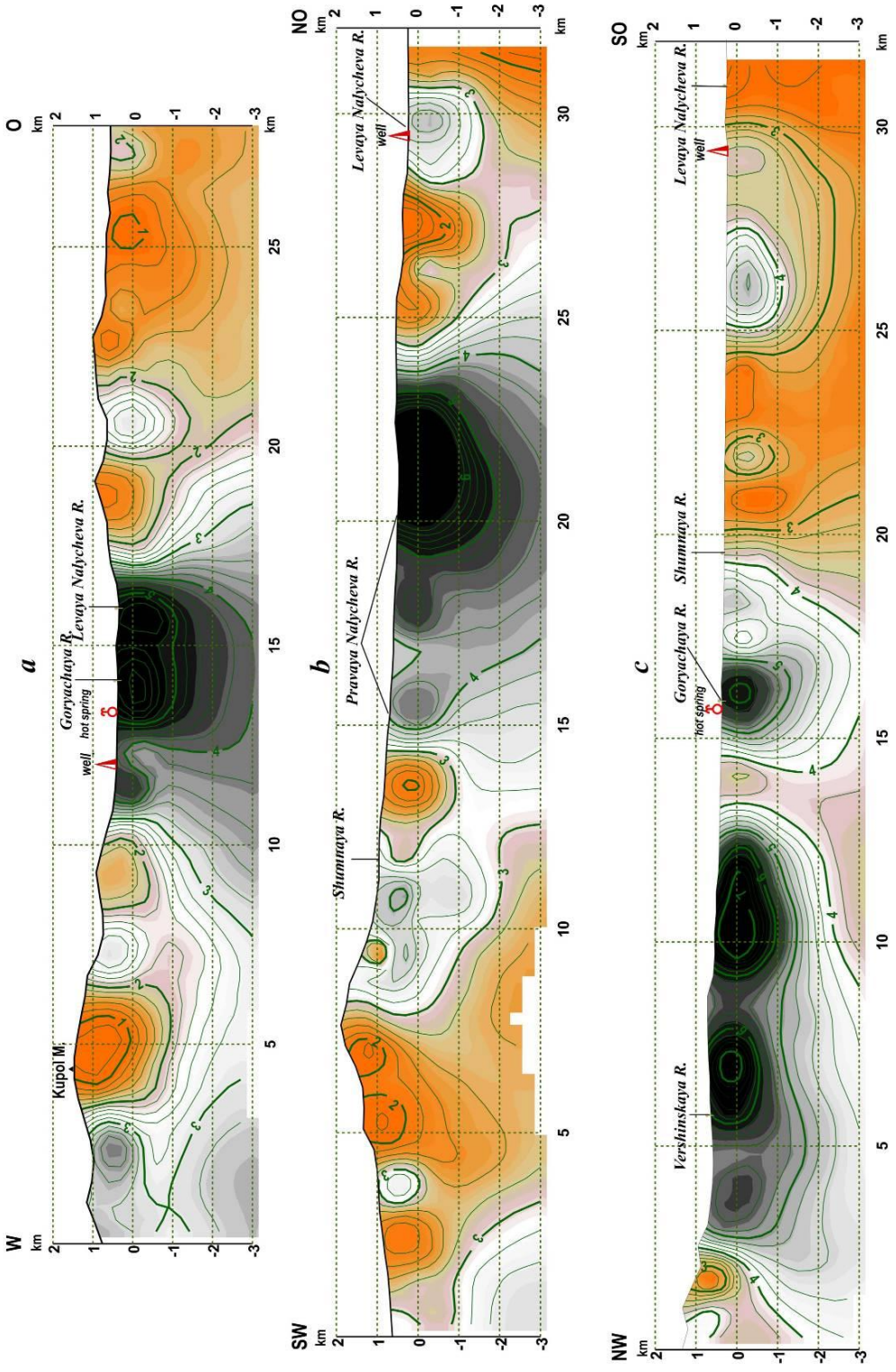


Fig. 6. Vertical sections of the model of break along the lines **n1 (*a*), n3 (*b*)** and **n4 (*c*).**

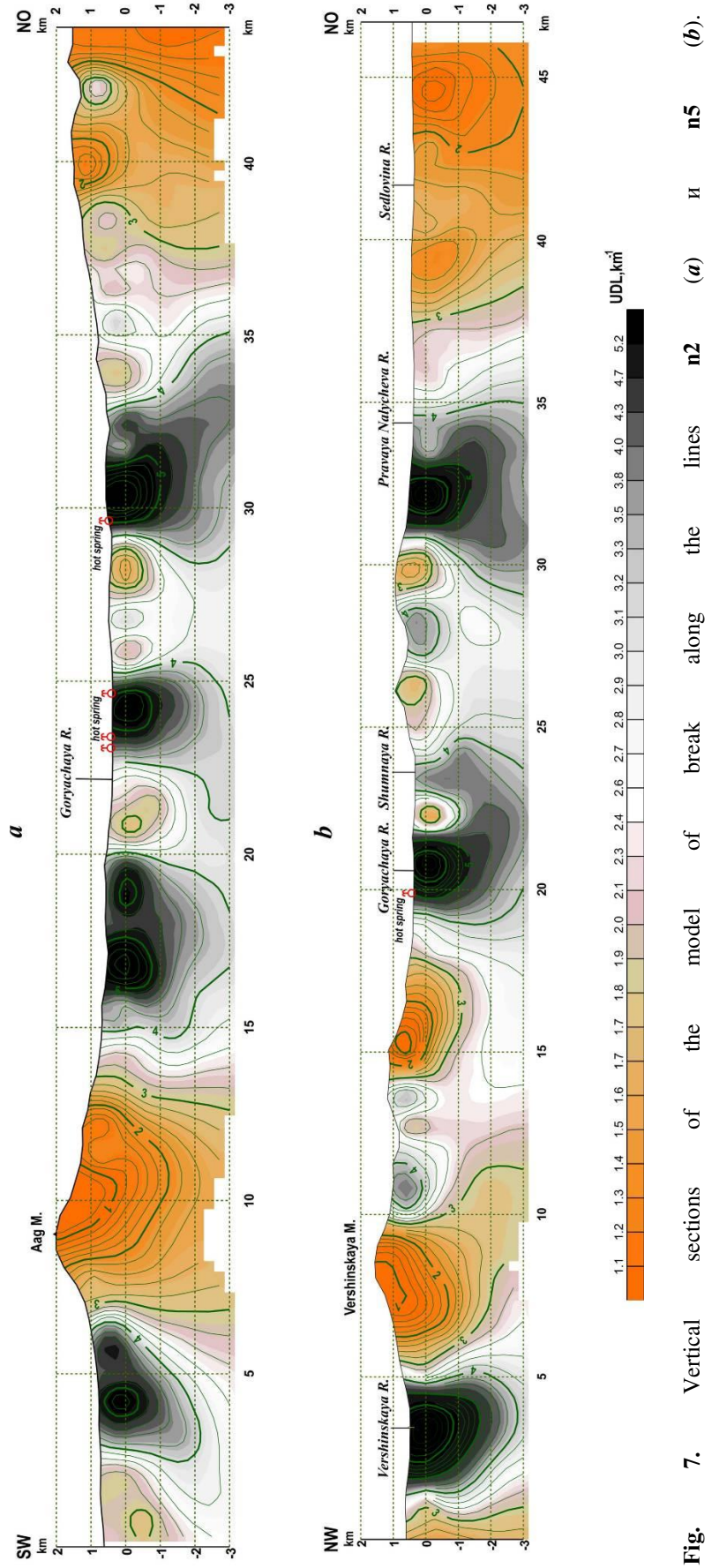


Fig. 7. Vertical sections of the model of break along the lines **n2** (***a***) и **n5** (***b***).

The north-western zone is confined to the valleys of the rivers Levaya Nalycheva, Zheltaya and Vershinskaya, in its upstream. The width of the zone at sea level is 2-2.5 km. At a depth of -2.5 km and more an anomalous break of more than 4 units of SLL remains only in the heads of the Vershinskaya river. In the valley of the Levaya Nalycheva river a high break is noted only at a depth of less than -1 km.

The boundary of the ring structure to the north from the field has clearly developed as an arc-shaped chain of local maxima of the SLL, in the layer above sea level. 7 units. Anomalies with the intensity of 5–7 units and width of about 2 km form an arc along the valleys of the rivers Vershinskaya-Zheltaya-Shaibnaya (Fig. 5). The structure diameter is about 15 km. The break of the geo-environment decreases with the depth.

Faults intersection of different strike near the Nalychevo field leds to the appearance of a node with an anomously high cleavage. In this place there is the highest values of the SLL. It can be clearly seen on the sections that the anomalous permeability can be traced to a depth of more than 3 km (Figures 7a, 8).

Around Nalychevo permeable node in the deep part of the section a high cleavage occurs else in some places: in the upstream of the Vershinskaya river, Pinachevskaya river and middle reaches of the Shaibnaya river, Pravaya Nalycheva river, Shumnaya river. These nodes form a circle, in the center of which there is the Nalychevo field. Another feature is that known sources of thermomineral waters are located at the nodes edges of a high permeability (Figures 4-7).

Thermal springs characterize the "open" cleavage, however, by the surface photo-image, faults, which cracks were filled with mineral matter after their occurrence, are also decrypted. We can assume that the model also reflects the once closed ore-forming (for example, gold-silver) hydrothermal systems. Therefore, areas with anomalous permeability should be considered as promising not only for mineral waters, but also for metallic minerals.

Conclusions

Nalychevo deposit of thermomineral waters is located at the intersection of linear (north-western, latitudinal and submeridional) and arc-shape zones of increased permeability, which are distinguished in the voxel model of SLL on horizontal slices by anomaly chains.

On the examined territory the greatest break of the geoenvironment is noted from the surface to a depth of 1-1.5 km below sea level. At the field and around it an anormalous cleavage can be traced to a depth of more than 3 km below sea level.

Outlets of thermal waters are located on the edge of blocks with anomalously high break.

The cones of active volcanoes Koryakskaya Sopka, Avachinskaya Sopka and massifs of Kozelskaya, Aag, Kupol and Vershinskaya mountains are of relatively small break.

Zones and nodes of increased break directly indicate the possible areas of circulation of hydrothermal mineral solutions and can be used as a structural factor in predictive estimates for metallic minerals.

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