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MAPPING OF VOLCANIC STRUCTURES OF WESTERN-TRANSBAIKALIA PROMISING FOR THE SEARCH OF MINERAL DEPOSITS BASED ON THE ANALYSIS OF AEROMAGNETIC DATA

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Abstract. The method for analyzing the distribution of points with extreme values of the effective magnetization obtained as a result of solving the inverse problem using materials of high-precision aeromagnetic survey is presented. To study the structure of volcanic structures and make recommendations for their mapping, the processing of magnetic data was performed using the Baltika interpretation system. A feature of the algorithm for formalized calculation of the physical properties of the medium implemented in this system is the use of the gradient model. It is accepted that the physical properties of the model in the horizontal direction change according to a polynomial law, and in the vertical direction – in a piecewise linear manner. On the basis of the obtained distribution, points with extreme values of the effective magnetization and the corresponding equivalent regions were distinguished.

The results of solving the inverse problem of magnetic potential, obtained for the Naran region, are presented. These data allow us to predict the features of the geological section formed by rocks with various magnetic properties and to map volcanic-dome structures.

Keywords: aeromagnetic survey, solving of the inverse problem, interpretation system "Baltika", volcanic structures.

Introduction

In accordance with existing ideas, at the Late Paleozoic stage of development of the Western Transbaikalia territory, ore-producing and ore-bearing are intrusions of nepheline syenites of Borgoy complex (rare earths, nepheline) and granitoids of Sogotinsky and Bichur complexes (molybdenum, uranium, rare earths), associated with the volcanic-dome structures [*Makarev et al.*, 2018], that include the Altai volcanic-dome structure (VDS), located at the southern slopes of the Maly Khamar-Daban range in the interfluve of Sopsholynty, Asta and Nizhniy Asta and having (according to different sources) area from 60 to 80 km^2. The shape of the named structure is slightly elongated in the sub-lateral direction (12 by 7 km) and is composed of interleaving massive weak-fluidal and spherulitic lavas, less commonly lava breccias of trachyryolites and their tuffs (Fig. 1); the defined thickness of volcanites exceeds 500 m. In the central part of the volcanic structure trachyryolites are breached by the large (7×4 km) stock-shaped body of syenite- and granosyenite-porphyries [*Makarev et al.*, 2018]. Syenite porphyries are characterized by "clogging" with small fragments of enclosing volcanites and basement rocks of volcanic-dome structure, that indicates a possible extrusive (crater) nature of this body.

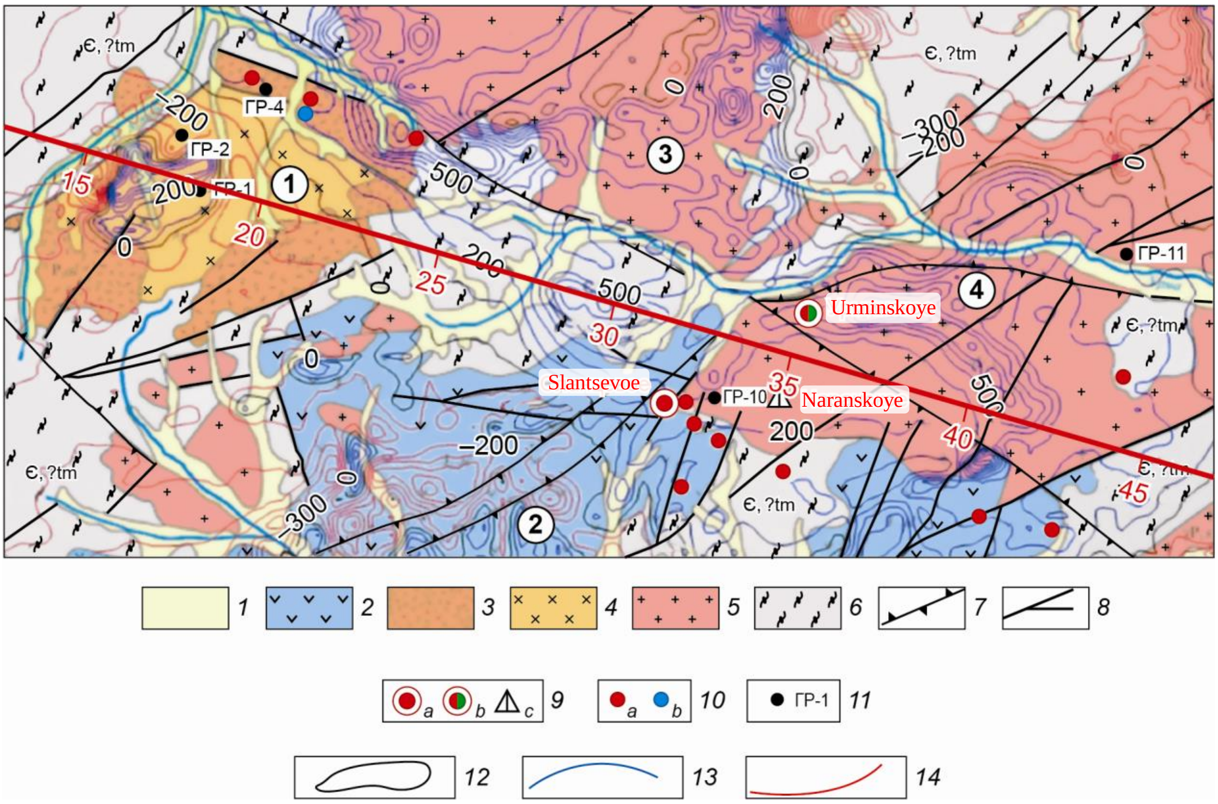

Fig. 1. Fragment of the geological map of the Naryn area (sheet M-48-X) by [Makarev et al., 2018]), is combined with a map of magnetic field contours ΔT, nTl. Red line is interpretation profile 1 (figures – distance along the profile R, km).

1 – unconsolidated quaternary deposits; *2* – Ichituiskaya series of strata: conglomerates, tuff gravelstone, trachyandesite (J1-2ič); *3–5* – Aleutuy-Sogotinskaya volcano-plutonic association: Aleutuiskaya series of strata (*3*): trachyrhyolite, trachyte and their lavabreccia (P1al); subvolcanic formations (*4*): syenite-porphyries, montsonit-porphyries (ξπP1al); Sogotinskiy plutonic complex, the third phase (*5*): granites, leucogranite, granosyenite (γP1s); *6* – Temnikskaya geological series of strata: crystal slates, marbled limestone (Є1?tm); *7* – regional breaks; *8* – other explosive violations; *9* – deposit of uranium (*a*), beryllium and uranium (*b*), fluorite (*c*); *10* – ore occurrences of uranium (*a*) and polymetals (*b*); *11* – places of selection of geochronological tests with the indication of number; *12–14* are magnetic field contours: zero (*12*), positive (*13*), negative (*14*). Circles with numbers 1–4 are the main volcano-plutonic structures of the explored territory: Astayskaya (1), North Borgoyskaya (2), Urminsky massif (3), Naransky array (4)

To study the structure of volcanic structures and develop recommendations for their mapping, the aeromagnetic survey data were processed using the Baltika interpretation system [*Goryachev*, 1998]. Feature of the formalized calculation of physical properties of the medium implemented in this algorithm system is the use of gradient model of lower half-space structure. It is accepted that the physical properties of the model in the horizontal direction change according to a polynomial law, and in the vertical direction – in a piecewise linear manner. In the general view the problem is reduced to minimizing the system of smoothing functionals

$$M^{\alpha}\left[z_l,\tilde{u},\tilde{A}\right]=\left\|\tilde{A}\bullet z_l-\tilde{u}\right\|^2+\alpha*\left\|z_l\right\|^2, \qquad (1)$$

$$M^{\alpha}\left[z_n,\tilde{u},\tilde{F}\right]=\left\|\tilde{F}\bullet z_n-\tilde{u}\right\|^2+\alpha*\Omega, \qquad (2)$$

where $M^{\alpha}\left[z_l,\tilde{u},\tilde{A}\right]$ and $M^{\alpha}\left[z_n,\tilde{u},\tilde{F}\right]$ are residual functionals of the solution of linear and non-linear inverse problem solution; z_l and z_n are the vectors of required parameters of linear and non-linear inverse problem, respectively; α is regularization parameter; Ω is stabilizing functional; $\tilde{A}$, $\tilde{F}$ are linear and non-linear operators, respectively; $\tilde{u}$ is the vector of measured potential field. Values of z_l and z_n calculated for the assumed model are called the "effective" magnetization (J_{eff}).

In fact, the problem is reduced to determining the coordinates of points with extreme values of effective magnetization in the lower half-space and their equivalent regions.

The results of the inverse problem solution for the interval 10-28 km of profile 1 (see the profile position in Fig.1), intersecting the volcanic structure are shown in Fig.2. According to geological data, in the central part of the volcanic structure was identified a large stock of syenite- and granosyenite-porphyries [*Makarev et al.*, 2018]. Inversion data allow to consider the vent part of the structure as a body with dimensions not more than 3×1 km, that is more magnetic in comparison with host rocks.

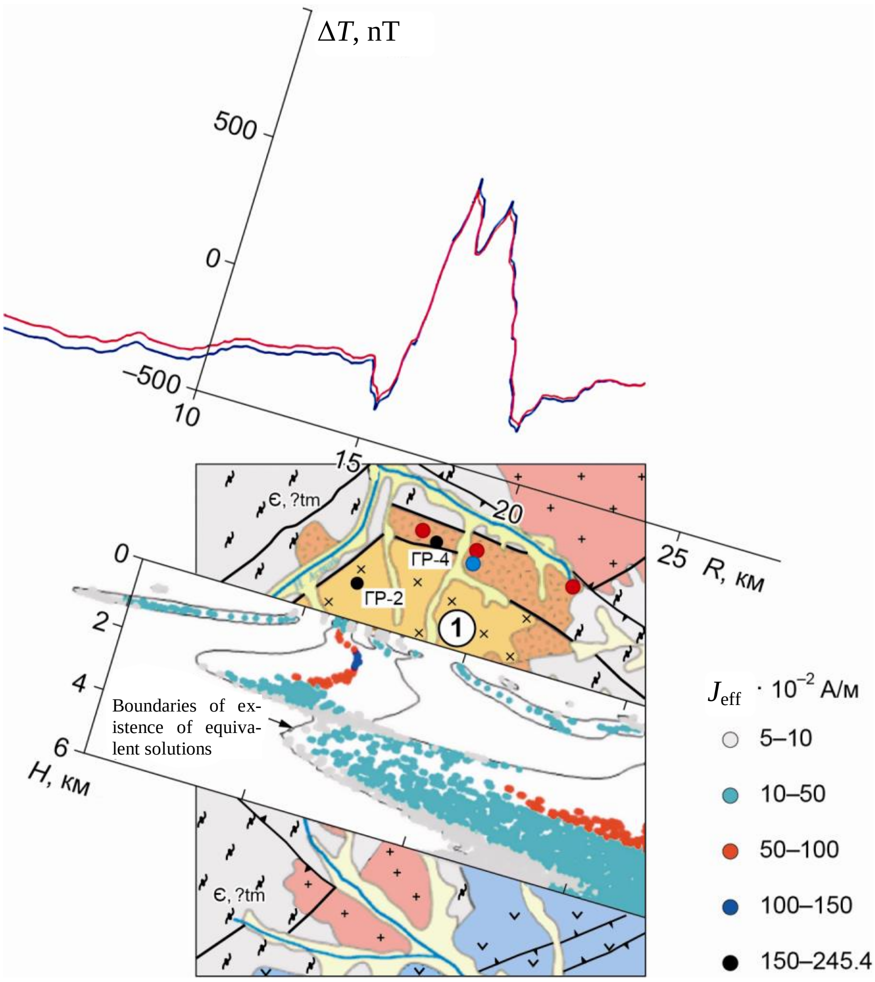

Fig. 2. Results of the solution of the inverse problem in the interval of 10–28 km of profile 1. Color of points on the section corresponds to different values of effective magnetization. Above the section are plots of observed (blue curve) and matched (red) anomalies of magnetic field (Δ*T*, nT). Notations to the geological map see in Fig. 1

For convenient comparison of results, in Fig.2 a geophysical section represented by points with extreme values of effective magnetization and the boundaries of existence of equivalent solutions is superimposed on a fragment of the geological map. Above the section, there are plots of magnetic field anomaly (ΔT, nT) – observed (blue curve) and matched (red). Geometrically discussed magnetic body in section represents a crescent object curved in the east direction; its most eastern part lies at the depth from 0.8 to 1.3 km and has the largest values of effective magnetization in the range of $(100–150)\cdot10^{-2}$ A/m.

As points with extreme values of effective magnetization approach the surface and with the increasing depth, the magnetization decreases to $(50–100)\cdot10^{-2}$ A/m, amounting to no more than $30\cdot10^{-2}$ A/m in the surface part. Maximum sizes of stock estimated by the area of equivalent solutions, in the upper part of the section do not exceed 2.5 km.

On both sides of the crescent vent magnetic body in the upper part of the section are mapped flat lying weakly magnetic objects distinguished by extreme values of effective magnetization $(10–50)\cdot10^{-2}$ A/m. Supposedly, they represent interleaving massive weak-fluidal and spherulitic lavas, trachyrhyolite lava breccias and their tuffs.

The nature of distribution of points with extreme values of effective magnetization in the section corresponds to the image of volcanic-dome structures that allows to use the obtained results as mapped feature for allocation of such objects of interest in connection with the confinement of a number of minerals to them.

Results of the solution of the inverse problem for the interval of 35–46 km of profile 1 are given in Fig.3. This part of the profile intersects the Naran massif composed in its southern part mainly by leucogranites of the third phase of Sogotinsky complex. Subvertical magnetic intrusive body located at the top of the section, as it can be seen, is mapped with points with extreme values of effective magnetization from $50\cdot10^{-2}$ A/m to $100\cdot10^{-2}$ A/m.

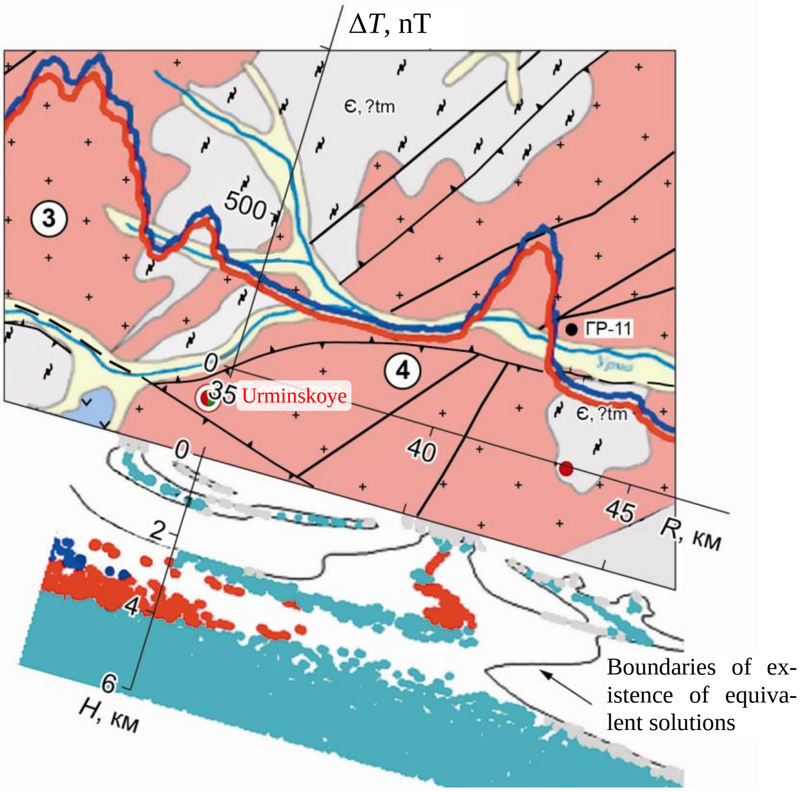

Fig. 3. Results of the solution of the inverse problem in the interval of 35–46 km of profile 1. Notations and comments see in Fig. 2

Significant difference in geophysical sections shown in Fig. 2, 3, is that for Astayskaya volcanic-dome structure points with extreme values of effective magnetization (10–50)$\cdot10^{-2}$ A/m are grouped in the depth range of 2–3 km, as if forming the basement of the volcanic-dome structure (see Fig. 2), and for the Naran massif (see Fig. 3) these points are located at substantially greater depths. In the wing parts of the structure given in Fig. 2, location of points with extreme values of effective magnetization is similar to the observed for the Astayskaya volcanic-dome structure. The noted can serve as a basis for classifying the considered part of the Naran massif as dome-type structures (see Fig. 3).

Results of solving the inverse problem for the entire profile 1 are given in Fig. 4. In the central part of the profile between the Astayskaya volcanic-dome structure and the Naran massif (interval 22–35 km) is mapped the structure of synclinal type by the points with relatively low extreme values of effective magnetization – (10–50)$\cdot10^{-2}$ A/m. Above the structure (to the depth of 0.8 km from the surface) there is an alternation of areas filled with the points with relatively high extreme values of effective magnetization – (50–100)$\cdot10^{-2}$ A/m and (100–150)$\cdot10^{-2}$ A/m.

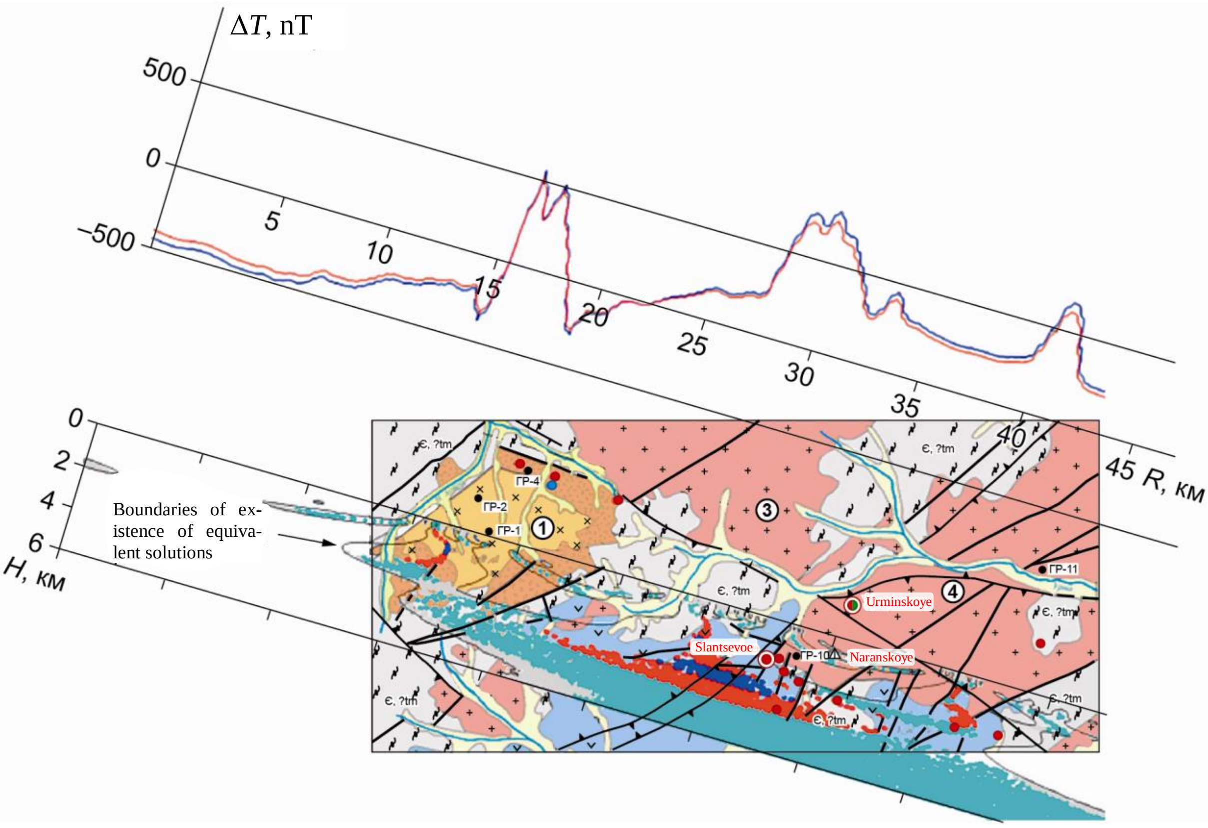

Fig. 4. Results of the solution of the inverse problem for the entire profile 1. Notations and comments see in Fig. 2

The marked alternation may be due to the existence of plutonic rock associated with the considered intrusions of Astayskaya volcanic-dome structure and the Naran massif.

Thus, analysis of geometric features of distribution of points with extreme values of effective magnetization, equivalent regions and values of effective magnetization make it possible to predict the presence of the volcanic-dome structures in the studied areas. With these structures can be associated intrusions of nepheline syenites of Borgoy complex, granitoids of

Sogotinsky and Bichur complexes, perspective for such minerals as nepheline, molybdenum, uranium, rare and rare-earth metals, etc.

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