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The Applicability of Multilevel Magnetometry for Reducing the Level of Geological Uncertainties in the Data Interpretation

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Abstract

The paper is devoted to the magnetic modeling and discussion of magnetic surveys inverse problems with use of multilevel investigations. The development of technology gives ability to measure magnetic field at different altitude levels by unmanned aerial magnetometer. It is shown, that multilevel data can determine some objects features more accurate. Mathematical upward field continuation is not correct in case of unknown remanance magnetization. So, comparing of upward continued field and real measurement at some levels, it is possible to fix remanance magnetization and solve inverse problem more adequate.

Keywords: magnetic survey, multilevel survey, computer modeling, remanance magnetization

1. INTRODUCTION

The solution of inverse problems of Geophysics is complicated from a theoretical and practical point of view, a process where the ambiguity is present at several stages. An infinite number of models can describe anomaly of any configuration. If we impose restrictions (for example, the acceptable range of properties), we can cut that number down to one model, but there is no guarantee that we approach the true model reflecting the real change of properties of rocks. Another stage associated with ambiguity, is determined by the fact that different rocks may have overlapping ranges of properties such as magnetic susceptibility. Usually this problem is solved by using integration with other geophysical methods or supplement works, drilling, surface geological information.

The development of technology and the spread of innovative shooting techniques allows us to try to use such innovations to reduce the ambiguity of solving inverse problems. Particularly in Russia (work is already underway at the level of world leaders) become available technology unmanned aerial magnetometer, which allows to perform measurements at different altitude levels, including the wrapping of the terrain. Thus, potentially we can obtain not only the values measured at a certain height on the area, but also three-dimensional field distribution. To visualize the box in the form of 3D models or as a vertical cross section of the magnetic field in the air space.

However, in these measurements there are several opinions. There is an opinion that the results of the field up recalculation are completely identical to observations at a higher level. It means to make measurements possible at the lowest altitude, and then at all higher levels to the field by resampling. Of course, this will reduce the cost of field research, but it can only be done correctly if the data at different heights are identical to the result of converting the field up. Let's look at this question in more detail.

2. WHAT MIGHT BE OF INTEREST FOR A VERTICAL CUT OF THE FIELD?

Consider the magnetic field, shown in figure 1; anomalies 1 and 3 have a similar configuration and in formal terms the field down give a similar geometry and depth of the anomaly.

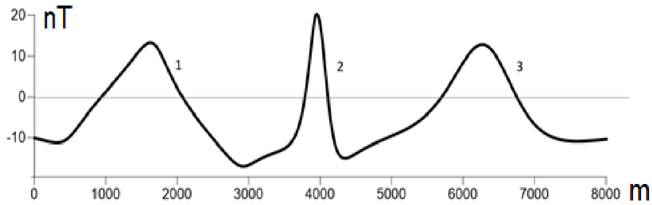

Figure 1. Consider the anomaly of the magnetic field (two-dimensional model)

It is known that the key problem of ambiguity in solving the inverse task of Geophysics is that fundamentally different objects can be formed in the same field. The problem of reducing the level of ambiguity can be relatively reliably solved in the case of additional information – geological, geophysical other.

In reality, it is a calculated field from three different objects (in GM-SYS 2D). The anomalies are obtained by calculation for the East-West trending profile with values of H=40000 NT, I=75 deg., D=0 deg.

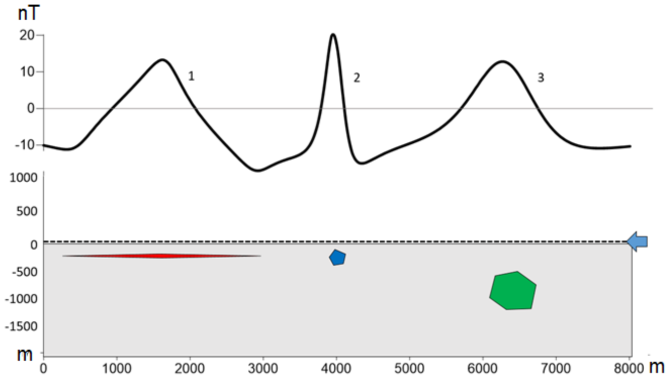

Figure 2. The scheme of location of the estimated sources of the anomalies is the true model and the calculation level fields (marked with arrow).

Most formal methods of continuing the descending field will show a similarity for this profile in terms of effective magnetization similar to figure 3. Such methods give the result in the form of limiting the depth of the source locations of anomalies based on the allocation of the field components of different spatial frequencies and convert them to the corresponding components of the deep incision of the effective magnetization. As an illustrative example, the selected algorithm TomPoPo (author – M. B. Shtokalenko). The result of down conversion fields shown in the cut, where significant sources are highlighted in red (for the case when the field is complicated by the random noise). Currently, the tomography implies the existence of point sources, horizontal beds, and the worst-case scenario for interpretation. In addition, the two-dimensional model in the three-dimensional calculation show a larger than true depth. It can be seen, that the objects-the sources of anomalies 1 and 3 appears to receive context in a similar way, despite the large differences in baseline models. There are many algorithms for such transformations, many practical problems have grounds for their use, and yet for such forms of sources, tomographic construction is not always successful.

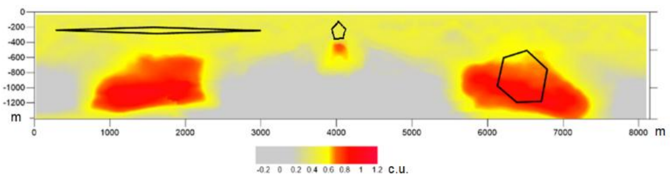

Figure 3. The result of a formal recalculation of the field down (TomPoPo algorithm, author - M.B. Shtokalenko).

What visual representation of a field can show that objects are different? Let's try to see this in a vertical section of the magnetic field. Let us calculate the magnetic field of the proposed sources for different levels, simulating a multilevel magnetometric survey. It can be seen that graphs with height are naturally flattened and reduced in amplitude. Anomalies 1 and 3 become even more similar.

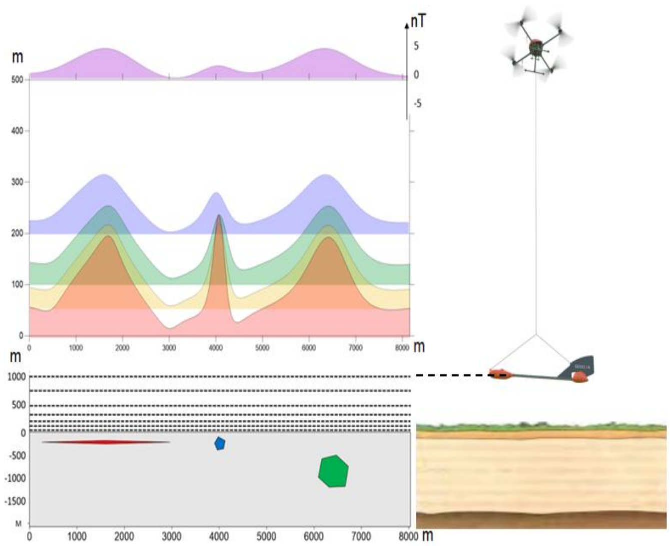

Figure 4. Altitude diagram of anomalies obtained by recalculating the model field up (to some of the levels marked above the section by a dashed line).

We obtain a vertical cut of the magnetic field of the model for heights from the surface to 1000 meters (Figure 5). Recalculation of the field up to the area of lack of sources is an unambiguous procedure. There are no third-party sources (outside the considered model) in this case. The calculation was carried out for the case of the absence of any interference and is absolutely similar for two methods of performing field upward conversion:

1) The field is set only on the surface and recalculation to higher levels is performed (imitation of ground survey and further recalculation above, by cameral processing)
2) The field at each level is obtained by solving the direct problem for a model section (simulation of multi-level shooting).

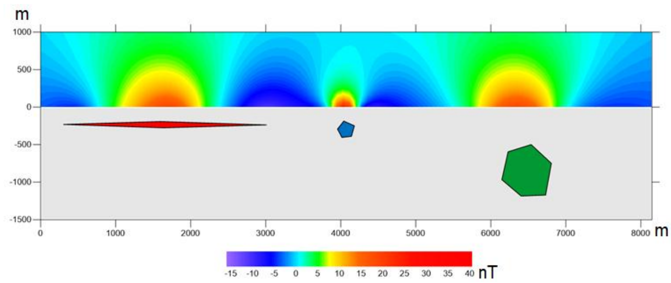

Figure 5. Vertical section of the magnetic field of the model

Next, we consider the result of the transformation of the vertical field slice, namely, the second horizontal derivative of the field. In Figure 6, the result of the calculation of this transform is shown with interpretation elements - it is visible that for anomalies 1 and 3 the features of the pattern of field variation with height are significantly different, and the problem of determining the type of source and its depth can be solved, which is used in a number of methods for quantifying the sources of anomalies (deconvolution, calculation of coordinates of singular points of the field). The interpretation elements in this case are points corresponding to field extremes at different altitude levels. Lines connect these points and point in the direction of the source. For a source that is isometric in the section (anomalies 2, 3), the lines converge at a depth almost at the same point; for an equivalent type of anomaly of a limited layer of variable power (anomaly 1), the lines are almost parallel. The indicated approach, in combination with tomographic, can give a more acceptable result of solving the inverse problem.

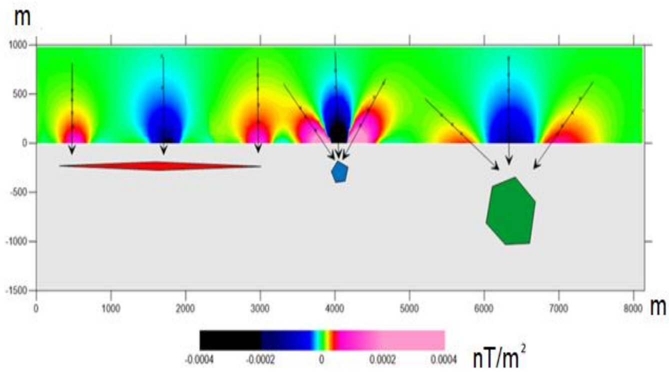

Figure 6. A vertical slice of the second horizontal derivative of the magnetic field of the model in the absence of interference and features that distinguish between anomalies 1 and 3.

It can be seen that the information on the distribution of the field in the higher levels is useful at least in order to see the differences between such objects as sources 1 and 3 of anomalies. In the case when the measurement result contains an error, and this may be the measurement error or the response from near-surface non-target objects, the task becomes more complicated and it becomes difficult to isolate the field features of interest. In this case, with a good ratio of the interference level of the survey and the required anomalies, it is possible to improve the solution of the inverse problem by not directly recalculating the field to higher levels, but by measuring it directly.

The effect of residual magnetization

It is interesting to consider the question of the equivalence of upward conversion to direct measurement in the case of the presence of residual magnetization with a direction different from the direction of the vector of inductive magnetization. We set objects - sources of anomalies 1 - 3 parameters, in accordance with the table.

Table 1. Characterization of the residual magnetization of simulated objects.

Object	Inclination, I, degrees	Declination, D, degrees
Source of anomaly 1	50	6
Source of anomaly 2	30	-10
Source of anomaly 3	-75	10

The calculation result is shown in Figure 7, where the upper cut of the magnetic field is for each level the result of solving the direct problem (equivalent to an "ideal" measurement at different levels), the next cut - for an identical field on the surface, recalculation is performed upward. It can be seen that the fields are not equivalent; the nature of the change in the field with height is noticeably different. For objects, the changes are different and depend on the characteristics of the residual magnetization. Accordingly, in the presence of objects with pronounced residual magnetization, it is not recommended to neglect multilevel measurements.

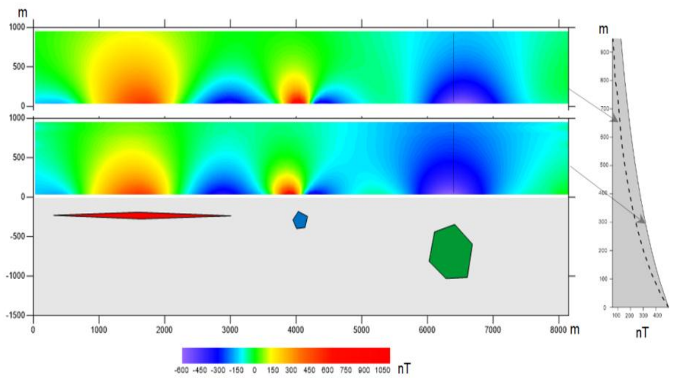

Figure 7. Vertical sections of the magnetic field of the model obtained by the algorithms (1) and (2). On the right are graphs of changes in the magnetic field, with a height for recounting and simulating measurements at different heights.

Let us consider how equivalent it is to transform a field to a direct measurement based on a practical data.

3. PRACTICAL EXAMPLE

In section N, a multilevel magnetometric survey was carried out at altitudes of 50, 100, 200, and 400 m. The general characteristics of the initial data are adequate: the detail of the research decreases with height, the level of the measured anomalous field decreases (Figure 8).

The survey was performed using an unmanned aerial vehicle (UAV) quadrocopter type with electric motors. The magnetometer was located in a gondola mounted on a cord 20 meters long. There is a measurement error in the data due to non-compliance with the shooting height. Deviations of actual flight altitudes from design altitudes do not generally exceed 4 meters, but they were not taken into account during processing, nor were amendments introduced for deviation due to smallness.

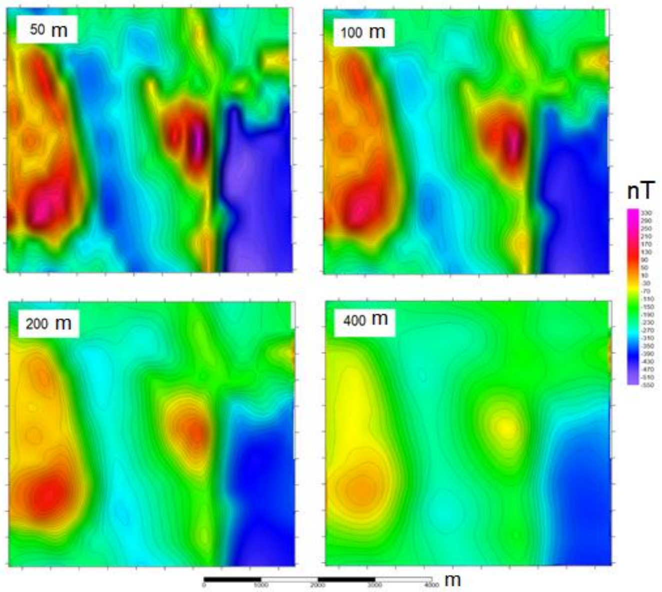

Figure 8. Maps of the measured anomalous magnetic field at heights of 50, 100, 200 and 400 m.

We will recalculate the field up for the data obtained at a height of 50 m using the Magmap module according to the Upward continuation procedure in Oasis Montaj (Figure 9) for further comparison. Figure 10 shows that the discrepancy between the calculated and measured data increases with height and, if at the level of 100 m, the effect of route anomalies (invisible in the initial field) is more likely to appear, then at higher levels, differences are likely to be associated with geological nature.

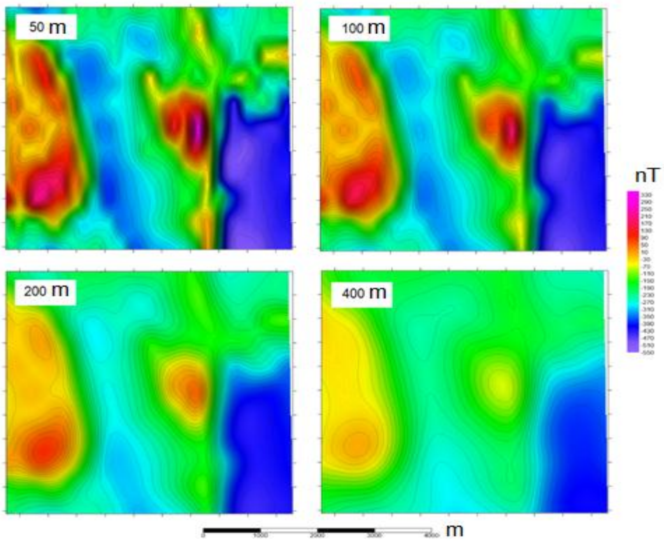

Figure 9. Maps of the measured anomalous magnetic field at an altitude of 50 and calculated fields at altitudes of 100, 200 and 400 m according to the Upward continuation procedure in Oasis Montaj (Geosoft).

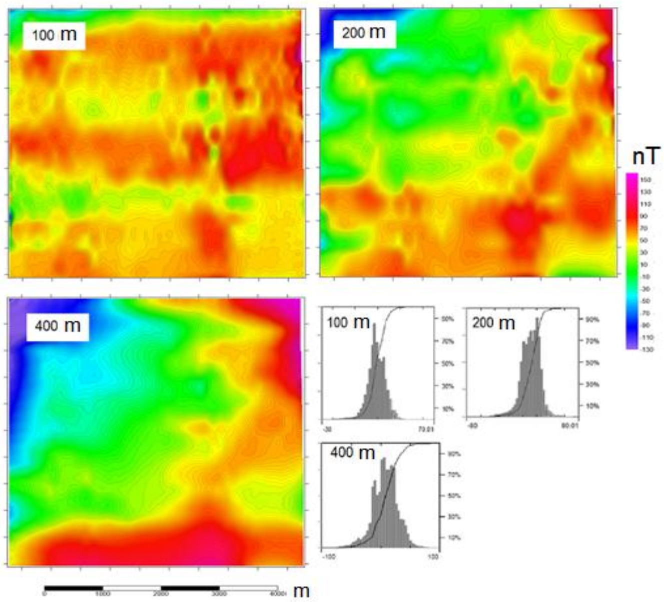

Figure 10. Maps and histograms of differences, measured and calculated magnetic prospecting data at heights of 100, 200 and 400 m.

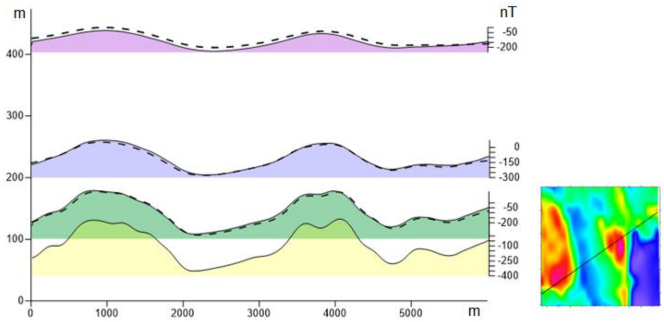

Figure 11. Graphs of measured (fill) and calculated (dashed line) fields along the profile shown in the inset.

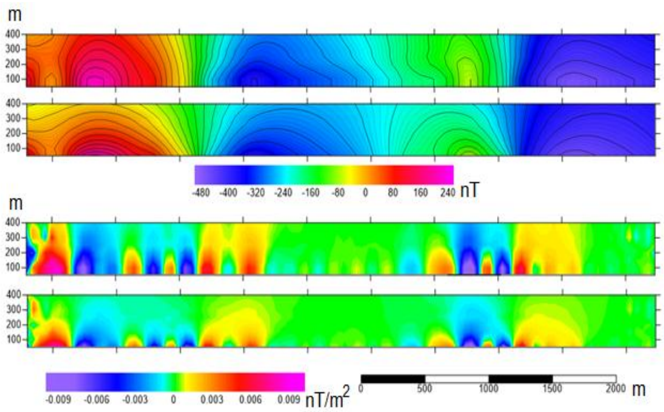

Figure 12. Above: vertical sections of the magnetic field according to measured data and calculated data. Bottom: vertical sections of the second horizontal derivative of the magnetic field according to the measured data and the calculated data (top to bottom).

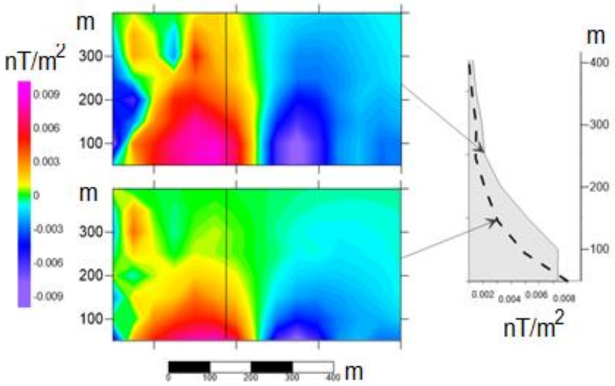

Figure 13. Vertical sections of the second horizontal derivative of the magnetic field, according to the measured (above) and calculated data (below), for the first 700 meters of the profile. On the right are graphs of changes in the second horizontal derivative of the magnetic field, for the measured and calculated options with height.

Next, the data is compared on the field slices. A limited set of heights leads to the fact that the resulting distributions do not look smooth, however, the nature of the field change can be traced and seen that in the practical case the nature of the field changes with height also differs. The effect may be due to the underestimation of up-sided objects located outside the survey area, with the presence of interference in the measured field, however, the main effect is attributed to the assumption that the effective magnetization is equal and the induced one, without taking into account the residual magnetization vector in a possibly different position. Accordingly, the interpretation of the results of recalculation of the field up may be incorrect, in contrast to the results obtained taking into account real accurate measurements at different heights.

4. CONCLUSIONS

Thus, at the theoretical and practical level it is shown that recalculation of the field up does not always correspond to the actual measurement at height. Additional information in the form of data from several shooting levels will allow better tracking of objects with residual magnetization. As a result, the interpretation of the data will be better and more reliable. The authors currently do not know the software that allows you to automatically take into account such differences. However, the algorithmization of the procedure seems feasible and, for a number of tasks, relevant.

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REFERENCES

[1] Alekseev S. G., Shtokalenko M. B., Senchina N. P., Bochkov P. A. The Indication in the Potential Fields of Structures Controlling Diamondiferous Magmatism. / Practical and Theoretical Aspects of Geological Interpretation of Gravitational, Magnetic and Electric Fields -45th Uspensky International Geophysical Seminar/Kazan: Kazan University, V 1, 2019. pp. 331 - 338.

[2] Alekseev S.G., Senchina N.P., SHatkevich S.YU., SHtokalenko M.B. Dostoinstvainedostatkitomografiipotencial'nyhpolej // Voprosyteoriiipraktikigeologicheskojinterpretaciigravitacionnyh, magnitnyhielektricheskihpolej: Materialy 43-j sessiiMezhdunar. nauch. seminaraim. D.G. Uspenskogo. Voronezh: OOO IPC «Nauchnayakniga», 2016. S. 10-13. (In Russian).

[3] Balk, P.I., Dolgal, A.S., Pugin, A.V. et al. Effective algorithms for sourcewise approximation of geopotential fields. Izv., Phys. Solid Earth 52, 896–911 (2016). https://doi.org/10.1134/S1069351316050025

[4] Dolgal A.S. Effect of earth sphericity on the results of aeromagnetic measurements over platobasalts (on the example of Norilsk region) / Bulletin of the Tomsk Polytechnic University. Geo Assets Engineering. 2019. V. 330. 11. 26–33

[5] Dolgal A.S., Kosticyn V.I., Novikova P.N., Pugin A.V. Algoritmyapproksimaciigeopotencial'nyhpolejistokoobraznymifunkciyami // Geofizika. № 5. S. 4-10. (In Russian).

[6] Dolgal A.S., Voroshilov V.A., Novikova P.N. Povyshenietochnostitransformaciimagnitnogopolya s ispol'zovaniemistokoobraznyhfunkcij. Voprosyteoriiipraktikigeologicheskojinterpretaciigeofizicheskihpolej: Materialy 47-j sessiiMezhdunarodnogonauchnogoseminara D. G. Uspenskogo-V. N. Strahova. S. 110-114. (In Russian).

[7] Dolgal, A.S., Pugin, A.V., Simanov, A.A., and Batyreva, P.N., Application of analytical approximations to geopotential fields modeling and interpretation, *Ros. Geofiz. Zh.*, 2011, no. 49-50, pp. 42–51.

[8] Prostolupov G.V. Modifikaciyametodapolyarnojtransformaciivektorovpotencialaprityazheniya // Strategiyaiprocessyosvoeniyageoresursov. Sb. nauchnyhtrudov. Vyp. 9. Perm': GI UrO RAN, 2011. S. 132-134. (In Russian).

[9] Pugin A.V. Istokoobraznyeapproksimaciigeopotencial'nyhpolej. Otteorii k praktike // Geofizicheskieissledovaniya. 2018. T. 19. № 4. S. 16-30. (In Russian).

[10] Shtokalenko M. B., Shatkevich S. Y., Senchina N. P., Alekseev S. G. Areas of Negative Excess Density of the Earth's Crust as Sources of Energy for Ore Formation:/ Practical and Theoretical Aspects of

Geological Interpretation of Gravitational, Magnetic and Electric Fields/Kazan: Kazan Federal University , V 1, 2019. pp. 279 - 284.

[11] Tarantin M.V. Prostolupov G.V. Polyarnayatrans formaciyaproizvodnyhgravitacionnogopotenciala // Geofizika. 2013. № 2. S. 13-18. (In Russian).