E11 GRAVITY-GEOLOGICAL MODELING SYSTEM

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Abstract

SUMMARY

The results of gravity anomalous field modern techniques using for solution of complex geological task are described. Relationship of density values of rocs and its composition and ore perspective is shown. Some recommendations for using authors methods by finding of gold-platinum deposits are given.

Our researches show, that in a structure of ore-magma system gold-platinum of a deposit a Dry Broad Gully ore generation source are basite-ultrabasite rocks of Early Precambrian basement, with a high degree of reliability traced by gravity data in the basis of Bodaibinsky synclinorium. Such investigations of deposits of number of ores give us good results. These results were obtained in various regions of Russia: Altai, Zabaikayle (by East of Baikal lake), Voronej crystal massive, Iakutia, Sought Ural and many others area.

INTRODUCTION

The observed gravity and magnetic anomalous fields use for solution of any geological tasks. The gravity effects by oil and gas objects are no more decimal parts of milligal. The most urgent problem of using gravity data is related to elaboration of interpretation methods of field information for the concluding about the distribution features of section density inhomogeneous and for the planning of the further stages of geologic-geophysical works. Hence it follows the necessity for rigorous approach to analysis and interpretation of survey, based on modern methods and computer facility capability.

Geophysical model based on the use the seismic data; forecast (by nonlinear statistical correlations) results, information about the singular points and all the available geological data provide the first approximation for the section. The section parameters will be precise in course of gravimetric modeling of the latter.

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METHODS

Interpretation of gravitational anomalies is based to the theorems of uniqueness of a solution of inverse problems of the theory of a gravitational potential in various statements. However their practical use is hampered by that the gravity anomalies are observed on the rather limited square and contain errors of

measurements. In this connection a main problem is the selection such of reasonable classes of geological bodies, in which the solution is unique and is constructive is created on an external potential. For deriving physically interpreted solutions of inverse problems of gravity it is important, that the carrier of a solution enveloped the carrier of real distribution generating the given anomaly, or at least all singular points of a field.

By virtue of stated the greatest application among a lot of modifications of methods of the interpretation of geopotential fields data is methods of modeling. Despite of necessity of use of methods of transformations and conversion of fields, methods of singular points etc., the modeling of revolting objects, as a rule, is mandatory operation, at least, on a closing stage of constructions. The significance of modeling in geology, as one of effective means of knowledge of a structure and regularities of development, various on sizes of blocks of Earth crust, now more and more will increase in connection, as with progressive introduction of mathematical methods, and constants by thickening of problems, rising before the geologists. Geophysical modeling is understood as designing a model on base of geologic-geophysical premises of a structure of investigated geological space, and also its adjustment in connection with manifestation of the new fact data.

The study of deep levels of the Earth crust and the upper mantle requires the use of all available geological and geophysical data. The main information used in these investigations is the data of deep seismic sounding (DSS). Conventionally these data may be divided into three types of results: 1) deep sections with clear distinction of all (or almost all) the boundaries on the whole (or almost whole) profile; 2) sections with distinction of comparatively long parts of the reflecting horizons; 3) sections with only partial and rather unclear distinction of horizons. In the cases 2 and 3 at the first step of the complex interpretation the measurement data of geopotential fields were used to complete and to precise the data of DSS. Information about the physical properties of the mountain rocks being not enough sufficient, one uses methods that do not require these data: calculation of the geopotential fields irregular points coordinates and statistical methods of interpretation. To extrapolate elements of the deep DSS sections of the types 1) on domains of the types 2) and 3) were employed the forecast methods the use of nonlinear statistical correlations. Geophysical model based on the use the seismic data, forecast results, information about the singular points and all the available geological data provide the first approximation for the section in question, the parameters of the latter being precise in course of gravimetric modeling. The quantitative interpretation of approximated fields is effected in the course of frequency analysis of extreme zones by means of mathematically founded criteria which permit determination of the coordinates of the sources, causing anomalies, according to the character of a magnitude change and extreme depths of these fields with a change of appropriate parameters of transformation.

The geology-geophysical model of investigated object represents a system of abstract revolting bodies, its anomalous effects. These body series are approximate geological object with detail, necessary for the geological interpretation, reflect its structure, sizes, form, petrophysical properties and appropriate volumetric distribution of physical fields. As geological model it is possible to name approximation of the investigated crust block as aggregate of geometric bodies (three-dimensional for a volumetric model) or figures (two-dimensional for a plane model), identified with hypothetical geological structures. Graphically it is accepted for representing as a number of generalized sections (two-dimensional model) and maps of various parameters. Mathematical model is understood as a number of parameters (numerical arrays) and algorithms using to determine all points of surfaces (and other performances), bounding geological bodies. Let's underline, that the process of transition from geophysical (seismic, gravimetric) model to only geological cannot be completely formalized and strictly algorithmically is circumscribed, since it leans in many respects on knowledge, experience and intuition of the interpreter. The determination of upper edge depths of anomalous objects (without engaging an a priori information) is carried out on base of using of an analytic continuation in the lower half-space and on a number of the simple formulas, in majority representing those or other kinds of a method of tangents.

The described techniques were used for mapping of geological object closely connected about gold-platinum deposit.

INTERPRETATION

Slate deposit a Dry Broad Gully is located within the limits of a large regional structure – Bodaibinsky synclinore. This structure is derivate by big capacity of folded Proterozoic beds.

The square of localization of a deposit is characterized by confined to sub latitude anticline by second order, which is a part of larger structure – Marakano-Tungusky syncline. There are some suites in this structure section. Its composition is similar and it includes greenstone-metamorphic terrigene and terrigene-carbonate deposits. Ore bodies of a deposit as a whole have a stratiform character. They represent zones of various on intensity gold and platinum content of quartz-pyrite and quartz-carbonate-pyrite mineralization. The magmatic rocks exposure in area of a Dry Broad Gully is advanced slightly. They are represented by small granitoid massive “Konstantin” and also accompanying to it some dykes of granite-porphry. Massive is located in 6km to a southwest from a deposit.

Fig.1. Geological-density model of section across Dry vally deposit. Density value - g/cm^3 .

The problem solving of decoding of a depth structure of area of a deposit was based to the interpretation gravimetric and petrodensity data by reason of essential deficiency of geological information observed on a surface. The anomalous gravitational field distinguishes by sub latitude zonal: northern part is characterized by reduced significances of a field, southern – rather increased. The indicated zones are divided by a precisely expressed gravitational step. Local gravity minimum “Ugachan” is selected on this background in area of a rather reduced field. Massive “Konstantin” and deposit a Dry Broad Gully are dated to it boundaries. Local gravity maxim “Kropotkin” places in the area of an increased field.

Zone of increased significances of a gravitational field and complicating it a maxim “Kropotkin” are not only local feature of considered area. It represent only small fragment of a continuous band of linear positive anomalies and local gravity maximum, located inside them. Its extended on a distance more 2000km along a southern edge of the Siberian platform. This band by a breadth up to 50km and more in east coincides with a zone of juncture of a shade “Aldan” and fold area “Stanovoy”. It intersects by Bodaibinsky synclinore being bent to north, and further to a southwest, extended along lake of Baikal. The anomalous created bodies in zone its come out to the day, it are represented by ultrabasite, gabbroids, orthoamfibolities and crystalloslates of basic and ultra basic consistency,

Archean and early Proterozoic age. The significant manifestations of platinum are detected in original bedding just in connection with such rocks located on the commissure of a shade "Aldan" and source area. The platinum minerals represented by non rolled crystals are founded in to placers of gold confining to these rocks.

Fig.2. Schematic model of the Baikal rift crustal structure based on gravity modelling. The cross-section along the seismic line 11 (Hatchinson et al., 1992). Red points - earthquake hypocenters. Density values - g/cm³. — Blocs borders — Faults

As the gravity minimum "Agaschan" is negative anomaly, it is doubtless, that the gravitating body, which has caused it, is characterized by a smaller denseness, than containing late Proterozoic sedimentary beds. The technique (above described) of calculation of upper edge depths was used for determination of position depth of a roof of this object. The calculations were carried out on four

inter correlation lines, that has allowed to accept obtained evaluations missed no more than on 200m, as rather authentic. The determined evaluation of upper edge depth has made 3-3.2km. The density of considered gravitating object could be no more 2.60g/cm^3 as the average density of the above-mentioned containing rocks makes $2.68\text{-}2.70\text{g/cm}^3$. Such significance of density has only normal granite among rocks enough widely developed in Bodaibinsky synclinore area. It is obvious, that the gravity minimum "Ugaschan" is stipulated by the latent granite body described by the density 2.60g/cm^3 (pluton), which is referred to also "Ugaschan". The visual analysis of an anomalous gravitational field allows with a high degree of probability to determine a pluton position in the plan: it is fixed by negative ellipse anomaly by amplitude near 6-7mGal. For clarification of a configuration of granite body and determination of other parameters of a section the gravimetric modeling in an interactive mode is made on those to the above-stated lines (with use indicated density values). In an outcome is established, that in the plan pluton "Ugaschan" (cryptobatholyte) represents a geological body of the oval form close conterminous on a configuration to the of the same name local gravity minimum. As the pluton density is determined is independent extremely because of geological information, and the position of depth of a roof is calculated on gravity data completely distinct from modeling by a method, the described determination of the pluton form because of modeling is represented univalent. The gravity modeling univalently has shown, that rocks of a large density – 2.80g/cm^3 combine large part of the basement on investigated area. It is most probably, that these rocks are metamorphic and metavolcanic rocks of high basicity, composing by early Precambrian basis of region. The subisometric body with density value = 2.94g/cm^3 , located inside the basement, corresponds to a gravity maximum. It corresponds to basite intrusion – serpentinous ultrabasite by magnitude of an average density and a structural stand. The roof of the basement, according to conducted accounts, is loaded up to depth 5-9km, in the area of a reduced gravitational field (fig. 1). Late and postmagmatic activity of pluton, in turn, has caused concentration of gold-platinum mineralization in upper; there are enough horizons distant from it of a containing medium. Deposit a Dry Broad Gully is distant by granite cryptobatholyte roof near 3km distance. By this attitude, with a high probability-taking place along southeast side contact of pluton "Ugaschan", it is represented by the main pervious channel for passing of the ore contain solutions that have generated a deposit.

Fig. 3. Geology-density model across Urengoy deposit (West Siberia). Variant 1.

In especially difficult geological circumstances the gradients of anomalies of a field narrow ambiguity of the decision of the inverse problem of gravity. A good example is a density section through a southern part by northern hallow of Baikal rift, where the extremely high gradients of change of gravitational and magnetic fields are observed (fig. 2). To achieve concurrence of gradients of observed and calculated fields it was possible only by inclusion in western part of Barguzin horst in the top part of a section of high-density block, imbeded in immediate proximity from incompact sites of a section. On the geological data to the specified block corresponds gabbro rock mass, directly observable on a land surface.

Gravity modeling on Baikal rift area for a number of profiles has shown, that the earthquakes zone corresponds by incompact zones, which were obtained by gravity modeling.

Concrete model of depth structure of deposit area (down 10-12km) on base careful quantitative analysis of gravity data is present. Conclusion of mechanism of deposit formation is done on this base.

Fig.4. Geology-density model across Urengoy deposit (West Siberia). Variant 2.

Not always geology-density models construction gives possibility in satisfactory results. For a profile "25" at the center of Western Siberia the gravitational modeling is carried out; two variants of density model received with the account of incompact in the region of crossing by Urengoy deposit are created. As a rule, the large oil deposit is incompact zone in a section. The results of transformations of abnormal geopotential fields clearly specify on the incompact site in an interval of depths from 1 up to 5km. The borders of an incompact zone coincide with borders of a deposit, and the initial values of density characteristics are chosen on the available literary data. The final meanings of effective density are received by means of gravity modeling by criterion of affinity, both size of gravitational effect, and it's gradient (fig. 3). As it is visible on the submitted model, to obtain a observed gradient of gravity field for east branch of a gravitational minimum it was possible with the help of use of essential differentiation of incompact for western and east of areas of a deposit (down to insignificant excess of the density characteristic for upper Cretaceous formation).

Probable, within the framework of an available seismic given variation of a situation of a roof of Paleozoic base, have not allowed to satisfying with an observed gravity field. The essential rise of east branch of the diagram of a field is the party of an intensive maximum with the center near to a super deep well "SG-6", settling down hardly to the east of a zone of the submitted line. The carried out accounts depths of surface top of gravity objects with use gravity and magnetic fields have given close

to seismic results. In this connection the variant of model on a profile "25" with abnormal condensation of rocks of a Paleozoic complex in area "SG-6" was designed. On available seismic constructions and materials "SG-6" the lowering of a Paleozoic rocks roof in this area does not leave other opportunity of the coordination of parameters of a section with anomalies of a gravitational field (fig. 4). The received thus sizes of incompact are represented unreal for a platform area. Any geological interpretation of the given results yet is not found. Thus, the carried out research has revealed discrepancy of all geology-seismic data to observed gravity field.

Fig.5. Geology-density model across regional line 1 (Bashkiria). Density values were obtained using some formulas for conversion velocity-density (minimum value by formulas number)..

The construction of similar model in a submeridional direction is represented rather interesting to us. The coordination of these structures in a point of their crossing in this or that measure would confirm, or has denied the constructions, made by us.

Almost always success in a geology-density modeling of a section is reached by means of application of a complex of technique. In the central part of a regional profile in northern Bashkiria on the first sight there is an obvious contradiction: the essential rise of a number of high-speed borders is not reflected in a gravitational field. Even at practically unreal minimization of the density characteristics the divergence calculated and observed of curves is very great. The satisfactory decision is received by means of 1) differentiation of the density characteristics on the basis of conversion velocity-density, 2) updating of a structure section on a basis some other correlation of seismic data.

Essential differentiation by an abnormal curve specifies a high degree of density heterogeneity of the top part of a section. The differentiation of the density characteristics of carboniferous deposits corresponds by local extremes of a gravitational field characterized by the insignificant sizes in the plan and sharp gradients. The received model is characterized by good convergence of calculated and observed data – not only the amplitude of a divergence has decreased, but also, that is more important, gradients of curves on all extent of a fragment of a line practically have coincided.

CONCLUSION

Thus, the conducted researches show, that in a structure of an ore-magma system gold-platinum of a deposit a Dry Broad Gully a ore generation source are basite-ultrabasite rocks of Early Precambrian

basement, with an high degree of reliability traced by gravity data in the basis of Bodaibinsky synclinorium. The main ore mobilization, undoubtedly, is Paleozoic granite cryptobatholyte "Ugaschan". Its hydrothermal activity has caused transposition and concentration of gold-platinum mineralization that in the issue has reduced in shaping a deposit. At last, ore enclosing medium are late Proterozoic carbon-bearing slates of Homolhynski formation.

Fig. 6. Geology-density model by regional line 1 (Bashkiria). Model were obtained using seismic data new correlation and density variation.

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