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USING OF GEOPHYSICAL METHODS FOR ESTIMATION OF THE TECHNOLOGICAL PROPERTIES OF ORES OF PYRITE-POLYMETALLIC DEPOSITS

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The complex of well and logging methods providing efficient estimation of the technological properties of the main ore minerals and ores in process of deposits prospecting is developed basing on study of their petrophysical properties. It provides selection of representative technological probes and development on this basis of optimum methods of processing of ores. Formation of physical -geological technological model of the deposit will allow to reduce losses of metals on concentrating repartition.

The analysis of activity of the enriching enterprises on Ore Altai region has shown, that the greatest losses of metals take place at concentrating repartition. Losses of separate metals at flotation enrichment achieve 50 % [1].

It was established by research carried out in DGP «VNIIcvetmet» (Ust Kamenogorsk, Republic Kazakhstan) from 1990 till 2004, that in addition to material characteristics of ores – mineral, chemical, granulometric composition, textural-structural features, etc., electrophysical and electrochemical properties of ore minerals and ores influence on course of flotation processes, too. At this the last play a predominating role during hydrometallurgical processing of concentrates and ores.

In result the complex distribution of the main electrophysical and electrochemical characteristics of ore minerals is revealed within ore bodies. It is established, that the ores that are difficultly enriched, are characterized by:

- the big range of change of physical properties of the same minerals, and, hence, their various flotation properties;
- presence of various minerals with similar electrophysical characteristics (for example, chalcopyrites and sphalerites of metamorphized ores) in ores, that causes extraction in concentrates of alien minerals;
- presence in ores of mineral joints with sharply various physical properties forming natural microgalvanic cells, in the environments forming potential (access of water, oxygen). These elements work with electrochemical reactions that results in formation of secondary minerals [2];
- presence of identical minerals with various technological properties (for example, chalcopirites of normal and metamorphized ores, normal and ferriferous sphalerites) in the ores related to the same natural type.

Some ores containing a plenty of minerals, forming natural galvanic cells, in connection with course of electrochemical reactions in active environments , are not enriched by flotation way [3, 4]. It is expedient to enrich them by hydrometallurgical methods.

The analysis of formation of the technological probes selected at various prospecting stages, has shown, that they were selected not taking into account distribution of physical and chemical ore minerals in ore bodies. Therefore the most part of such probes appeared not representative. In result design solutions on processing ores appeared insufficiently effective. So, by results of calculation of the deposit «Maleevskoye» stocks (1987) gross extraction was projected. However at drawing up of the rules on mine arrangement taking into account electrophysical characteristics of ores two technological types of ores were selected. Their selective mining began since 1997, in result enrichment parameters have been essentially improved.

The conclusions stated above about connection of technological properties of ores with physical and chemical parameters have defined necessity of improvement of existing geological-echnological information base.

It should provide:

- display of features (heterogenities) of distributions in ore bodies and deposits of the parameters describing ***the material*** (chemical, mineralogical, granulometric and petrochemical composition, textural-structural features, etc.) and ***physical and chemical*** (electrochemical, electrophysical, gravitational, magnetic, radiometric, etc. properties) ***components*** defining processes of preliminary and flotation enrichment, as well as hydrometallurgical processing of concentrates and ores;
- continuity at transition to various hierarchical levels (preliminary – detailed – industrial – operational explorations);
- openness of the system permitting addition, correction, use of the new characteristics providing solution of particular problems.

The most rational form of representation of geological-technological information satisfying the above mentioned requirements, is the physical-geological technological model (PGTM).

One of the basic problems at formation of such model is filling its with information on physical and chemical properties of ores.

The task of studying of physical and chemical properties of ores and ore minerals can be solved with the help of combination of the field (logs, bore hole) and laboratory researches

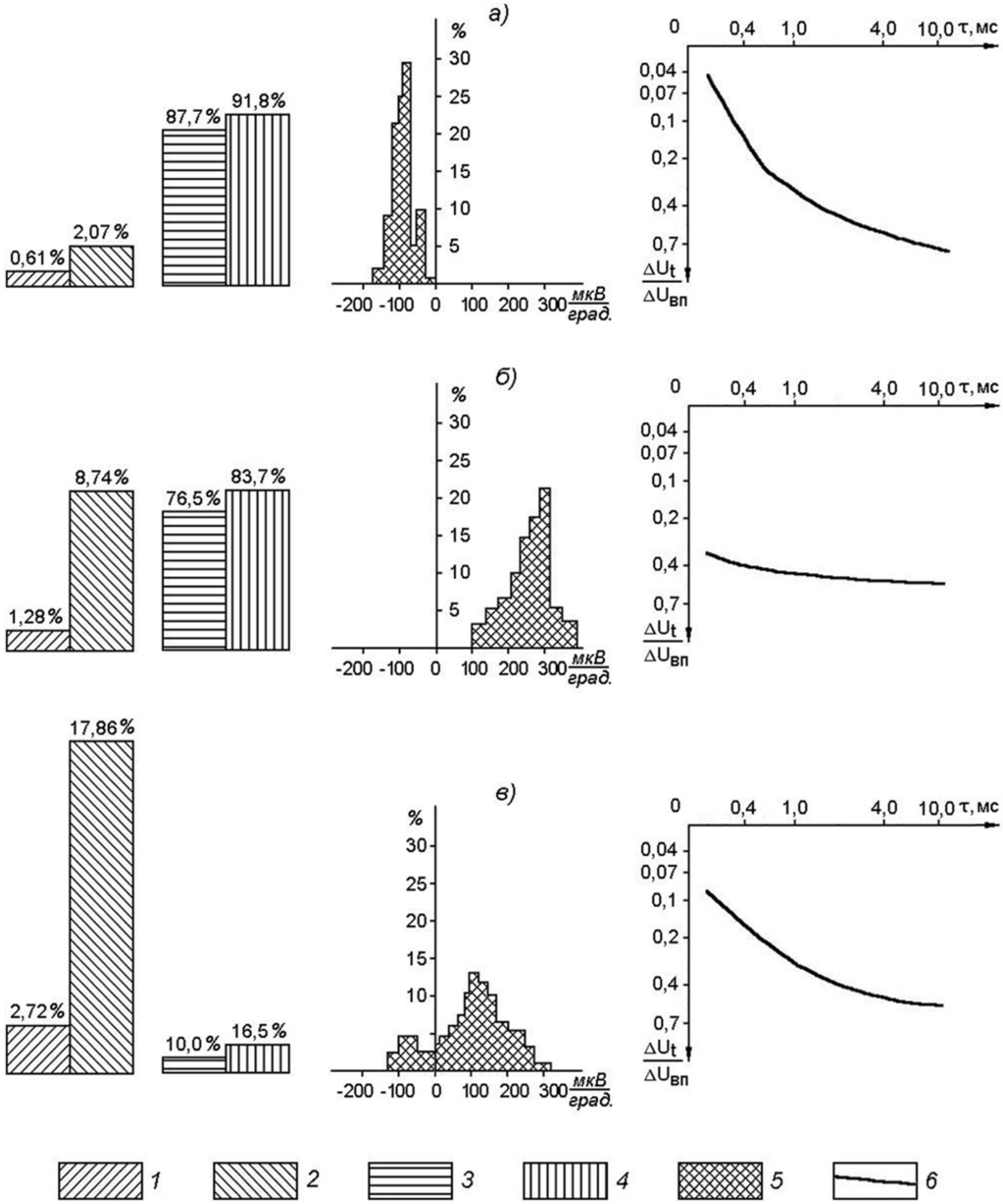

Fig. 1. *Technological properties of ores with a pyritic matrix of various type of conductivity: а, б, в – ores with a matrix described by electron (а), hole (б) and mixed (в) type of conductivity; 1) content of copper 2) zinc in initial ore, 3) extraction of copper 4) extraction of zinc in the concentrate, 5) histograms of pyrite thermo E.M.F., 6) the diagram of dependence of ESCP from* $\frac{\Delta U_t(\tau)}{\Delta U_{\text{ВП}}}$ *pyrite matrix conductivity type*

The Method of electrode potentials (MEP). In this method, in our case, the electrode potential differen-ce$\Delta U_{\text{ЭП}}$ appearing on an interface of sulfides with enclosing rocks on contact with washing liquid in wells is measured. Application of the MEP for partition of ore subsections in well by physical properties is based on the following physical-geological bases:

- differentiation of sulphidic minerals, including ones with the same name (for example, iron disulfides), on the stationary electrode potential value [5];
- close connection of thermo E.M.F. factors of sulfides – semiconductors and their electrode potentials [1];

Method of early stage of caused polarization (ESCP). Investigations of A.P. Karasev, O.V. Bumagin, R.S. Sejfullin have proved, that time characteristics of ESCP of ore minerals «... are of interest not only from the point of view of interpretation of the data received in field conditions. They allow to obtain essentially new and objective information on electrochemical activity of minerals, range and character of its change indirectly reflecting conditions of formation of sulfide deposits». The same investigations established connection of decay characteristics of early stages of the caused polarization with the sulfide mineral conductivity type. These provisions have been proved at carrying out of ESCP in the quarry «Nikolaevsky» (the deposit «Nikolaevskoye») opening an ore deposit «Kreshenskaya», and also in laboratory measurements of early stages of the caused polarization of the ore core and the samples selected from mining developments of ores of the deposits «Orlovskoye», «Maleevskoye», and «Tishinskoye».

Comparison of thermo E.M.F. of pyritic matrix pyrites making 60...80 % of volume of ores, and time characteristics of ESCP of the deposit «Nikolaevskoye» (the horizons 197, 212) ores is given on Fig. 1. Contents of other minerals (chalcopyrite, sphalerite) in ores is of the one order. As it is seen from figure, precise connection between pyritic matrix conductivity type and time characteristics of ESCP is established.

Precise distinctions in character of ESCP decay in different types of ores (pyrites in these ores are differed on electrophysical properties: in metallocolloid ores they are characterized by hole conductivity, in crystalline ores – by electron one, in transitive – by mixed type of conductivity) are established.

Mapping of ores with various electrophysical characteristics of pyrite matrixes, (visually they are practically indiscernible), is possible with the help of profiling by ESCP method on the well bore with calculation of the reduced velocity d of potential change of caused by polarization on small times.

Contact way of polarizing curves (CWPC). This method is based on studying of consistently excited electrochemical reactions on ore mineral surfaces from an electric current source [6].

Basing of results of field measurements by method **CWPC** in the quarry of the deposit «Nikolaevskoye» comparison of potentials of cathode and anode reactions with features of electrophysical properties of the basic minerals is made.

In result the following conclusions are made:

- chalcopyrites are differed on value of electrochemical reaction potential, in transitive ores two versions chalcopyrites are marked on this parameter;
- the potential of reactions on sphalerite raises from metalocolloid ores to crystalline ones, and as show geochemical researches, concentration of iron in sphalerites decreases in the same direction;
- sphalerites of transitive and crystalline ores are differed on cathodic reaction potential value;
- galena is characterized by very close values of potential – from –0,75 up to –0,8 V in all types of ores, that, apparently, is explained by imposing of lead mineralization on final hydrothermal process.

Thus, with help of **CWPC** it is possible to estimate mineral composition of ores and electrochemical properties of minerals and ores in natural bedding.

Measurement of thermoelectric properties of ores. At flotation one of the major factors determining interaction of minerals with reagents, is thermo E.M.F. of the minerals, determining the reagent sign [4];

Results of measurement of thermo E.M.F. on the horizon 182 in the deposit «Nikolaevskoye» quarry showing possibility to select metallocolloid and crystalline ores are given on Fig. 2. Pyrites make in these ores 50...80 %. In the given example the measured parameters are defined by properties of pyrite matrixes of ores. As it was noted above, they are characterized by various type of conductivity: electron one – in crystalline ores and hole one – in metalocolloid ores.

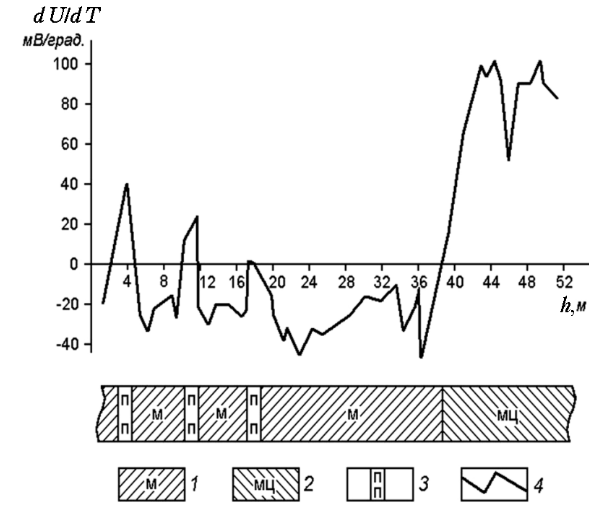

Fig. 2. *Results of thermo E.M.F. measurements on the mine Nikolaevsky in the quarry on horizon 182 (by P.S. Revyakin): 1) crystalline copper-pyrite ores; 2) metallocolloid copper-zinc ores; 3) barite-polymetallic ore veins; 4) diagrams of thermo E.M.F.*

Estimation of the parameters determining course of processes of preliminary enrichment, with the help of sortings and separations by geophysical methods. The main parameters determining possibilities of physical methods of sortings and separations, are:

- contrast of metal distribution of;
- correlation connection of physical dividing criteria with contents of useful components.

At estimation of contrast of useful component distribution on the well core and results of approbation of mining mountain developments the linear equivalents proposed by L.C. Puhalsky [7] are used.

Estimation of the petrophysical properties determining course of processes of preliminary enrichment is made using X-ray logging (XRL), sliding contacts (MSC). MSC and MEP Methods select intervals with pyretic and interspersed mineralization. XRL method selects the content of copper, lead, and zinc in ore intervals.

In case of application of density as dividing criterion one uses methods of density gamma-gamma logging (GGL-D), XRL and MSC. Studying of character of us-

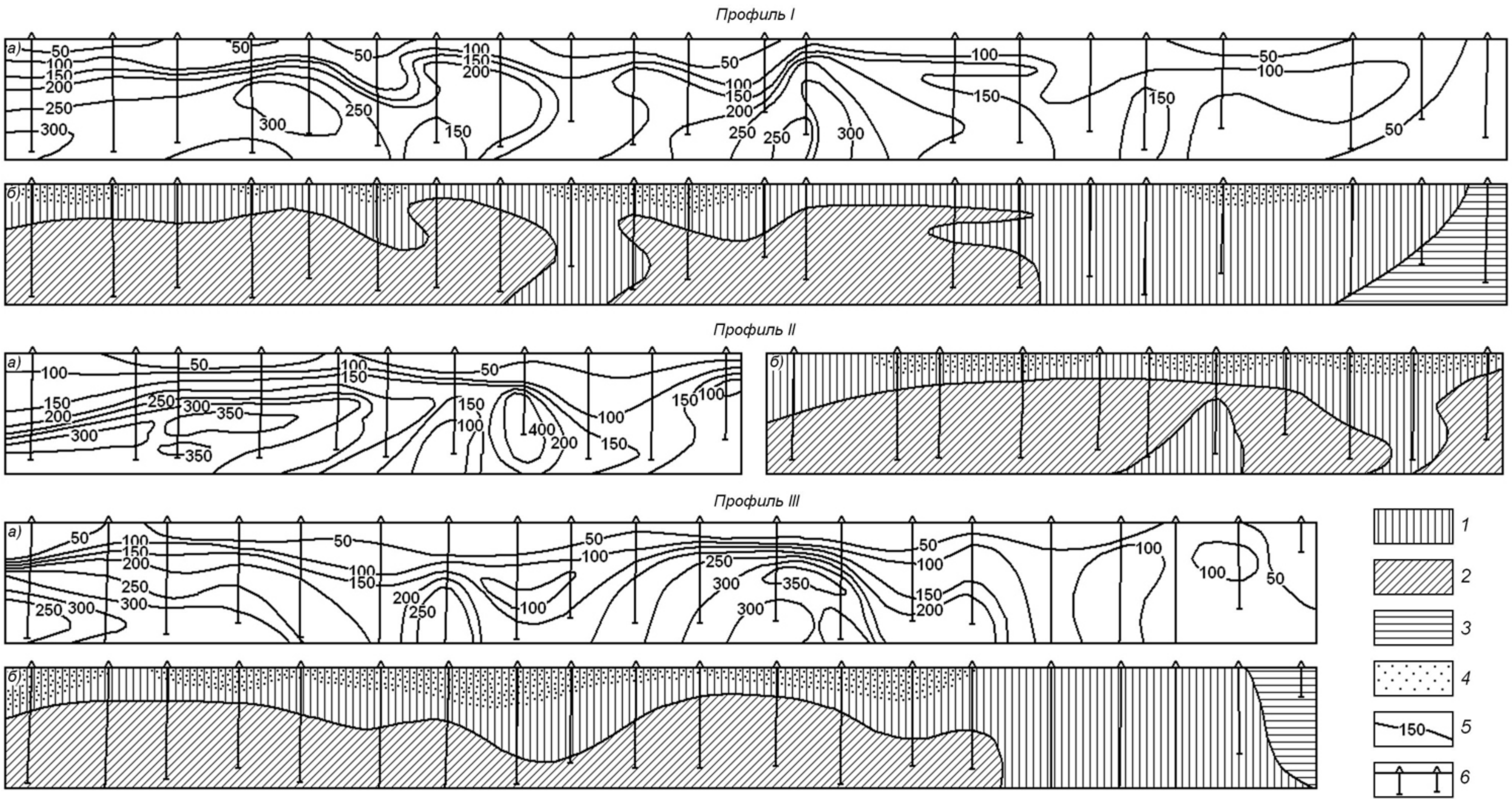

Fig. 3. *Results of induction logging of the explosive wells (the horizon 182, the block 7p): 1) metallocolloid zinc ores; 2) transitive copper-zinc ores; 3) enclosing mineralizing rocks; 4) area of disintegration of ores; 5) isolines E_α – values of radioresonant effect; 6) the explosive wells*

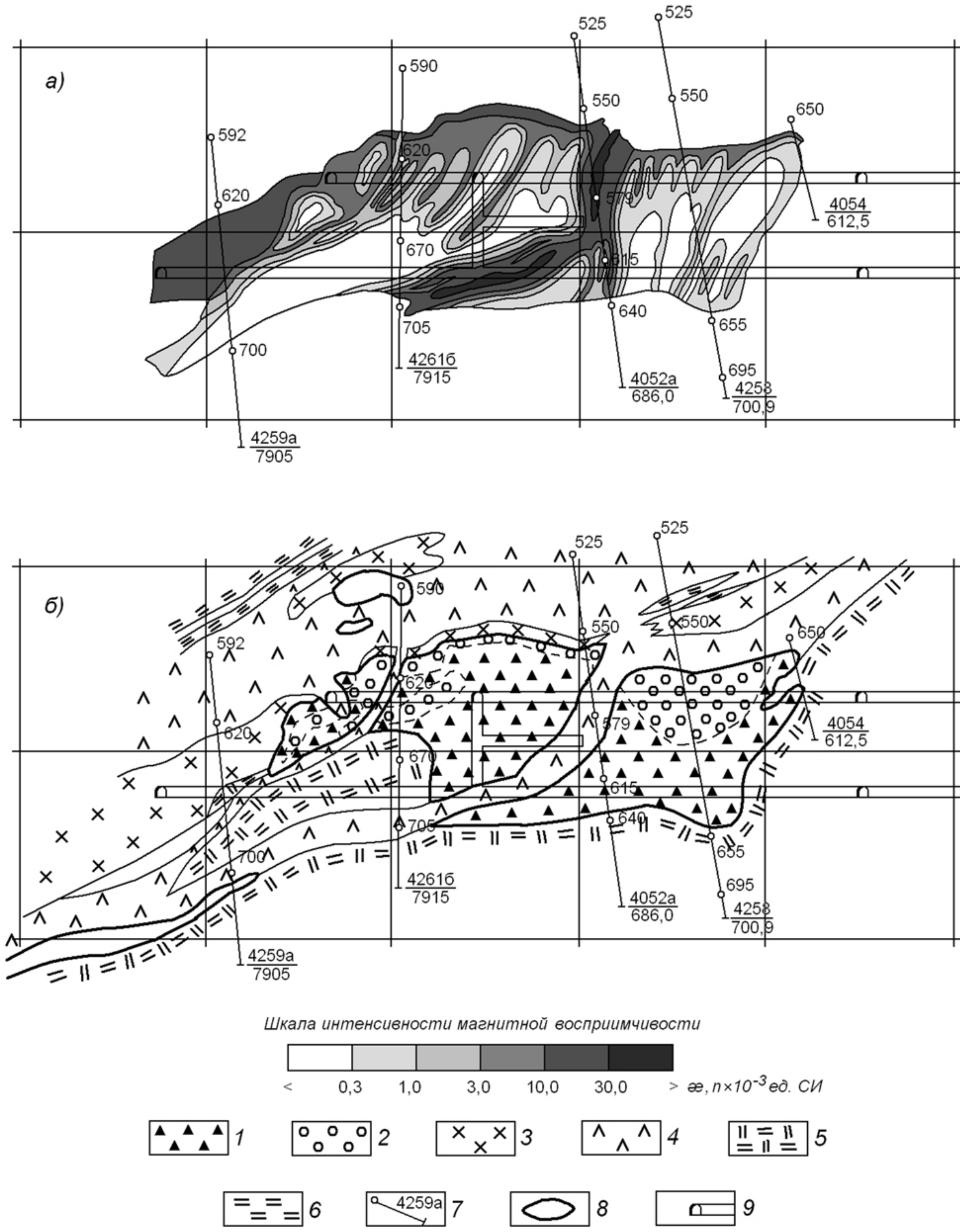

Fig. 4. *Magnetic properties of ores of the deposit Maleevskoye: a – distribution of a magnetic susceptibility; б – geological cut alongside the profile 190; 1–2) ores: copper-zinc (1), polymetallic (2); 3–6) containing enclosing rocks: quartz porphyries (3), porphirites of basic composition (4), quartzites (5), aleurolites (6); 7) projections of prospecting wells; 8) contours of ore bodies; 9) mining developments*

eful component distribution within the selected versions on rocks density is carried out with help of XPL. In total this information allows to select such factors preventing gravitational enrichment, as presence of dykes of the basic composition which density is commensurable with density of ores in ore bodies.

At using of electric resistance (a radioresonant method of separation) as dividing criterion one applies methods of electric logging: MSC, resistance logging (RL), induction logging. Geoelectric cuts by the measurements, carried out in explosive well on the horizon 182 of the quarry «Nikolaevsky» with the help of induction logging are given on Fig. 3. Estimation of metal contents within each of the selectef zones with the help of XRL method allows to define factor of contrast of useful components distribution in view of ore zone differentiation on conductivity.

At selection of the ores enriched by such magnetic minerals, as pyrrotines, melnikovites, melnikovites-pyrites, ferriferous spalerites which influences negatively on course of flotation processes, it is expedient to use magnetic susceptibility logging (MSL) and kappametry in mining developments.

On the deposit «Nikolaevskoye» it is established, that ferriferous spalerites of metallocolloid ores are characterized by increased magnetic susceptibility (up to $500 \cdot 10^{-5}$ SI units).

The example of metamorphized copper-zinc ore mapping in the zone of their contact with dykes on the deposit «Mallevskoye» with help of kappametric method is shown on Fig. 4.

On the basis of above-stated the complex of geophysical researches of wells (GRW), solving problems of studying of material structure and technological properties of pyrite-polymetallic deposit ores is developed. At this GRW complex is considered as uniform system of geophysical researches of well, surfaces and mining developments, including:

- a set of well and logging methods being necessary for studying of natural and technological types of ores;
- technology of carrying out of GRW: scales, stage of carrying out of researches;
- a methods for GRW interpretation.

The set of GRW methods at search-estimated and exploration stages is subdivided on groups:

<u>The first one</u> includes the method of the charged body, measurement in wells EP, WL, XRL. Scale of researches by the charged body method is 1:5 000 – 1:10.000, researches by WL and XRL methods – 1:500. The general problem is selection, specification of the ore interval site, mapping of structures containing ores. These methods cover all wells. Basing on the obtained data one builds individual petrophysical model of the first approximation which is used for preliminary quantitative interpretation of the charge method.

<u>The second one</u> is presented by the methods providing coordination of ore intervals, definition of wedging out zones, contouring of near-well and inter-well spaces – by MSC and ESCP methods. Scale 1:1000. The petrophysical model of the first approximation is specified by these data, it is used for calculation of the following variants of charge method interpretation. Correction of the petrophysical model is made in a dynamic mode in process of carrying out of researches by MSC and ESCP methods.

<u>The third one</u> provides estimation of material structure, contents of useful components, textural-structural features in the selected ore intervals – XRL, MSC, MEP, remote fotometry. Measurements are carried out in scales 1:500 – 1:50. It is recommended to use the CWPC method. In this case it is possible to obtain information on mineral structure of ores, electrophysical properties of ore minerals composing them, as well as to make preliminary estimations of useful component stocks. Basing on the obtained data one makes the model of natural ore type distribution.

<u>The fourth one</u> estimates the physical and chemical properties defining course of processes of flotation, hydrometallurgical processing and methods of preenrichment on the basis of sortings and separations. These measurements are carried out within the selected natural types of ores. To study electrophysical (electrochemical) properties of ores one carryes out point measurements by the ESCP method or the method of thermo E.M.F. measurement. Under favorable conditions (pH of drilling mood, differentiation of ore minerals on thermo E.M.F.) these methods are replaced by the MEP logging method. Scale of record of curves is 1:50 – 1:100.

Additional methods at an estimation of the parameters causing course of preliminary enrichment processes with the help of sortings and separations, are defined by the chosen dividing criterion.

Thus, with the help of geophysical methods, besides solution of traditional problems – geometrization of ore bodies and definitions of useful component content – it is possible to solve problems of technological mapping. At the exploration stage it is possible to estimate objectively efficiency of flotation enrichments of ores, hydrometallurgical processing of concentrates, and also methods of preliminary enrichment.

Application of modern computer technologies to process results of measurements and volumetric division into districts of the established parameters will allow to form and to modify physical-geological technological model in dynamic mode in process of information accumulation [8]. It will provide volumetric mapping of ores within the ore bodies and deposits on natural and technological properties. The problem of selection of representative technological probes and, accordingly, development of optimum technologies of enrichment of pyrite-polymetallic ores will be solved.

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THE MAIN GEOLOGICAL FACTORS INFLUENCING ON FORMATION OF INDICES OF COAL QUALITY (on the example of the coal deposit «Neryungrinskoye»)

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Genetic and epigenetic factors influencing on formation of a coal bed (its characteristics expressing by means of morphology, petrographic composition, degree of reducing, metamorphism, oxidation, and dislocation, physical properties and indices of coal quality) are considered. The main task of this research consisted in establishing of the significant factors influencing of the coal bed quality indices to a greater extent. Solution of the set task from positions of a system approach at study of rock massifs consisting in revealing and studying of many interconnected elements and estimation of their influence by means of alternate normalization of the main bounds is shown.

The study was carry out in conditions of the bed «Moshny» of the coal deposit «Neryngrinskoye» of the Southern-Yakutia basin. The experimental data were treated with use of the correlation-regression methods.

Results of researches allow to use geological information and geophysical methods for operative planning of geologic prospecting process and mining works in more total way.

Indices of coal bed quality are the most important characteristics which define the industrial – economical value and competiveness of coal deposits.

The coal deposit «Neryungrinskoye» is located in the southern-eastern part of the Aldan-Chulman coalfield. The deposit area is 45 km^2. The deposit is localized in brachysyncline fold. The industrial coal reserves are connected with the neryngrikanskaya suit of high jurassic age.

The suit is characterized by quick change of granulometric composition of rocks in cut and on area. Suit rocks are presented mainly by varigrained sandstones which content is 65...78 %. The dominating sandstones are fine-grained (27...39 %) and medium-grained (20...21 %) ones, the share of large-grained ones is 18 %. Aleurolites have subordinate value (10...17 %), argillites are very rare (0,5...0,9 %), content of gravelites and conglomerates is up to 9,5 %.

The main coal bed is the bed «Moshny», developed on the area about 20 km. The bed thickness is changed from 8...10 m up to 60 m with average thickness about 24 m. At analysis of the bed «Moshny» it is noted the good expressed sequence of changing of petrographic types of coal from bright ones to semi-matt and matt ones. Increase of coal ash content at transition from the low layers to high ones occurs according to this change. Heterogeneity in the bed structure is kept on all the area of the deposit that allowed, having applied geophysical methods, to reveal bundles of petrographic complexes inside the bed layer.

This feature of the bed «Moshny» is of great importance at carrying out of prospection, operation and processings of coal. Correlation bundles are widely used for coordination of geological cuts, making of special plans and maps, division of coals by their quality indices. There petrophysical cuts of the deposit «Neryungrinskoye» on Fig. 1, *a*, *б*. The cut is divided in the interval 100...500 m into 2 lithologic-geophysical steps 100...200 and 200...500 m (from above – downwards) within which limits change of physical properties – speed of distribution of longitudinal waves V_p, specific electric resistance ρ_n, factor of porosity K_n, density of the saturated rocks $\delta_н$ – with depth does not exceed accuracy of their definition by geophysical methods [1].