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ESTIMATION OF ORE CONTENT FOR LOW-TEMPERATURE METASOMATITES THROUGH PALEOTEMPERATURE GRADIENTS (DATA ON LISTVENITES–BERESITES AND ARGILLIZITES)

(Fig. 1)

Abstract: The article deals with the data on paleotemperature gradients for various types of ore fields. The author arrives at a conclusion on the possibility of the estimation of ore content for listvenites-beresites and argillizites through the analysis of the above-mentioned data and their comparison with the experimental ones.

Резюме: В статье приводятся данные, характеризующие палеотермические градиенты в пределах различных типов рудных полей. В результате анализа этого материала и сопоставления его с экспериментальными данными автор приходит к выводу о возможности оценки таким путем рудоносности лиственитов-березитов и аргиллизитов.

Our recent thermobarometric study showed that paleothermal gradients vary on quite a large scale. Owing to this, they influence essentially (and sometimes decisively) metasomatites formation of a series of ore types and associated ones. In this paper an attempt is made to evaluate the influence of paleogeothermal gradients on metasomatites formations of listvenites-beresites and agrillizites and their ore-content.

As we have already mentioned, values of paleogeothermal gradients varied on quite a large scale from 50—200 °C/100 m up to 5 °C/100 m and even more. Thermal springs of Yellowstone park are characterized by maximum values gradients on metasomatites formations of listvenites-beresites and argillizites a matter of fact, from modern hydrothermal ore-bearing solutions, sulphides of a series of metals are deposited (Fig. 1; 1—3). These values vary within the limits of 50 up to 100 °C (Гибшер, 1978). Very high values of geothermal gradients are characteristic of active volcanism areas, e.g. Broadland in New Zealand (Fig. 1; 1—3), where they reach 50 °C/100 m (Гибшер, 1978). Comparable values of paleogeothermal gradients up to 70 °C/100 m (Гибшер, 1978) are stated from homogenization temperature measuring of inclusions from polymetallic Sye deposit (Kuroko type) (Fig. 1; 2). This deposit is situated in recent Cenozoic orogenic region with highly developed volcanic rocks.

Thermal conditions of polymetallic deposits formations from Altai are quite well studied. They represent a typical orogenic structure of Paleozoic age (Fig. 1; 4—7). It is stated (Щербань—Гибшер, 1976), that polymetallic deposits from Altai are characterized by quite a variety of types, associated metasomatic ones among them. We are sure to determine 4 types. Relatively high-temperature deposits quite rare to be found belong to the first type, beyond their limits amphibole (anthophyllite) metasomatites have been developed. These deposits have paleogeothermal gradient values which make up

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15—20 °C/100 m (Fig. 1; 5—6). Maximum temperatures of amphibole metasomatites formation are quite high ones, i.e. 500—550 °C. The second type associated with carbonate-free metasomatites (chloritolites and sericitolites) includes most of polymetallic deposits of the given region. They have been formed under the conditions of paleogeothermal gradients near to 25 °C/100 m (Fig. 1; 5). Maximum formation temperatures of sericitolites and chloritolites are 420 °C. The next type, being quite a wide-spread one, is of special interest since it is associated with typical listvenites-beresites. Paleogeothermal gradient values, under the conditions of which that deposits have formed, changed in broad limits from 10 to 40 °C/100 m (Fig. 1; 4—7). Maximum temperatures of these rocks' formation are ~ 330 °C. The fourth type is in association with metasomatites resembling argillizites, but different from them because of absence of caolinite. This type is not a wide-spread one and has been still established at only one deposit. It is characterized by relatively high paleogeothermal gradient values, i.e. 40 °C/100 (Fig. 1; 4). Formation temperatures of these rocks do not exceed 300 °C. It is significant, that irrespective of the preore metasomatic type, and its manifestation temperatures in particular, ores of the deposits mentioned have been formed in similar temperature conditions, polymetllic ores having been formed at temperatures lower than 250°—300 °C. Copper-pyrrhotite ores are characterized by somehow higher formation temperatures. Similar values of paleogeothermal gradients were stated in a series of gold and lead-zincous deposits of listvenite-beresite type in other regions, e.g. in Transbaikal one.

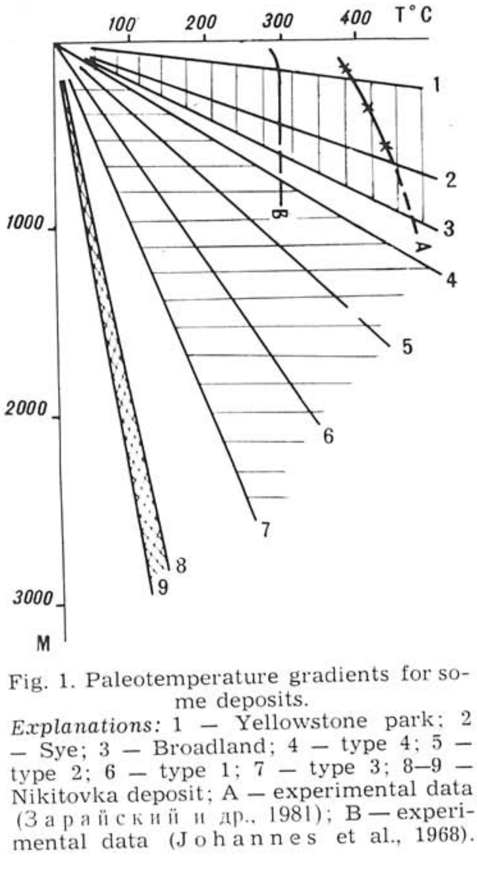

Fig. 1. Paleotemperature gradients for some deposits.
Explanations: 1 — Yellowstone park; 2 — Sye; 3 — Broadland; 4 — type 4; 5 — type 2; 6 — type 1; 7 — type 3; 8—9 — Nikitovka deposit; A — experimental data (Зарайский и др., 1981); B — experimental data (Johannes et al., 1968).

Deposits of listvenite-berezite and argillizite type, formed in platform conditions are characterized by other values of paleogeothermal gradients. Our thermobarometric studies of inclusions in quartz of Nikitovka mercury deposit associated with typical argillizites, showed that their maximum crystallization temperatures are 250—270 °C and have no essential differences, in any case in the interval of ~ 1000 m. These data indicate very small (and sometimes subtle in limited space) differences in formation temperatures of both metasomatites and a veined quartz. This provides evidence for quite small values of paleogeothermal gradients during their formation. Quite definite but small values of paleogeothermal gradients for this region are given by Golovchenko et al. (1980), who studied inclusions homogenization temperatures in quartz of Nikitovka deposit. From their results, values of paleogeothermal gradients were ~ 5° C/100 m at this deposits (Fig. 1; 8). Gorovoy et al. (1980) who studied samples selected from a reference hole bored in the central part of Nikitovka deposit, give still lower values of this parameters, which do not exceed 3.9 °C/100 m according to the results (Fig. 1; 9). Bogomolov et al. (1981) by means of geological reconstruction and other methods have evaluated the value of paleogeothermal gradients for subsalt Devonian deposits, i.e. for the deposits including a series of mercury ore manifestations, as ~ 4 °C/ /100 m. Besides that, an attempt was made to calculate the value of paleogeothermal gradient using on the one hand, maximum temperatures of cinnabar formation stated by the method of gas-fluid inclusions homogenization on the other hand, position of these deposits in the section. As soon as maximum crystallization temperature of cinnabar from ore-manifestation situated in the upper part of the section did not exceed 100 °C, and that from one located in its lower part reached 150° (sometimes even 170°), the value of paleogeothermal gradient may be evaluated as ~ 5 °C/100 m, during crystallization of cinnabar within ore-manifestations, if vertical distance between these ore manifestations is not less than 1000 m. Some gold ore manifestations in this region associated with metasomatites close to listvenites-beresites as to their composition, are characterized by small values of some degrees centigrade per a hundred metres. From the above results it is concluded that values of paleogeothermal gradients during the formation of argillizite and listvenit--beresite types in platformic conditions, were characterized by small values not exceeding 5 °C/100 m. Thus, summing up the above-stated facts we may conclude, that hydrothermal ore deposits associated with metasomatites of listvenites-beresites and argillizites formations are formed over wide range of paleogeothermal gradients from 5 (or even less) up to 40 °C/100 m.

It is known that development of listvenitization-beresitization process in rocks of acidic composition leads to formation of the following paragenesis:

An unchanged rock of acid composition ⟶ quartz + feldspar + chlorite ⟶ ⟶ quartz + muscovite + chlorite ⟶ quartz + muscovite + carbonate ⟶ ⟶ quartz + muscovite ⟶ quartz.

Such rocks are transformed in argillization conditions as follows:

unchanged rock of acid composition ⟶ feldspar + quartz + chlorite ⟶ ⟶ montmorillonite (or hydromica) + Mg-Fe carbonate + quartz ⟶ caolinite + Mg-Fe carbonate + quartz ⟶ caolinite + quartz ⟶ quartz.

In cases when initial rocks are represented by ultrabasites development of listvenitization-beresitization and argillization process lead to the similar results, i. e.:

unchanged or serpentinised ultrabasite ⟶ talc ⟶ talc + carbonate ⟶ ⟶ quartz + carbonate.

It is obvious that some of the minerals and parageneses mentioned may be used in evaluation of formation temperatures of the rocks studied. To such minerals belong first of all Mg-Fe carbonates including those associated with quartz, which were studied by Iohanes (1968), Winkler et al. (1969), by means of thermodynamic calculations and experiments. According to their results (see Fig. 1; A) stability of carbonates depends both on total pressure in the system and on water/carbon dioxide ratio in it. From the group of Mg-Ca carbonates magnesite has the minimum stability temperature which decreases essentially, if the former is associated with quartz, i. e. an association corresponding to the inner zone of metasomatic column of listvenites-beresites. Formation temperature of this association does not exceed 250—300° under moderate total pressure and relatively small content of carbon dioxide in the fluid. We may expect from preliminary results that other things being equal, still lower stability temperatures are characteristic of magnesio-ferruginous and magnesio-ferruginous-calcic carbonates wide spread in the rocks studied. Formation temperatures of ores from listvenite-beresite type rocks, e. g. Pb-Zn ones, do not exceed 250—300 °C from direct and indirect results.

From minerals forming a part of argillizites besides Mg-Fe carbonates, argillaceous minerals are characterized by the lowest temperatures, caolinite being the most studied one in this sence. Its dehydration reactions were studied in different time by Alhaus (1966), Hemly (1959), Zaraisky et al. (1981) and by other scientists. Minimum stability temperature of this mineral at $P = 1000$ atm got by Zaraisky is 290 ± 10 °C (Fig. 1; B). Other scientists' data are comparable with the given ones. Works are also known showing that caolinite associated with magnesian carbonate, i. e. in association found quite frequently in argillizites and especially in those replacing rocks in the main composition, are characterized by a still lower temperature stability limit not exceeding 250 °C at $P = 1000$ atm. Ores associated with metasomatites of argillizite formation are also low-temperature ones. If we consider mercury ores, their formation temperatures got by homogenization of inclusions in cinnabar do not exceed 150—170 °C.

Thus provided the decrease of mineral formation process for a given type of deposit occurred at 50 °C, the vertical span of metasomatic columns of listvenites-beresites may vary from 5—6 km in platforms to 1 km in orogenic zones, and that of argillizite columns ranging from 4—5 km to 750—800 m. Ore intervals in these columns located in their upper parts are 2.5 km—500 m for mercury ores and from 3—4 km to 500—700 m for gold and polymetallic ones.

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