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# EVALUATIONS OF THE RARE EARTH METALS IN THE FIELD OF KATPAR AREA, CENTRAL KAZAKHSTAN BY ANALYZING OF GEOLOGICAL - GEOPHYSICAL, MINERALOGICAL AND THERMAL GEOCHEMICAL ELEMENTS

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## ABSTRACT

Kazakhstan, the largest rare-metal province, in its lands are concentrated more than half of the world's tungsten. Reserves of molybdenum are the fourth largest in the world and the largest in Asia. In central Kazakhstan are the main rare metal deposits. Practical importances are skarn-greisens deposits katpar type, with complex molybdenum-tungsten ores and associated bismuth copper, lead and zinc.

In katpar area the stage of development of raw material framework of the Republic of Kazakhstan have practical value, deposit katpar prepared for mining open way (quarry) to a depth of 400 m within the designed quarry ore reserves and metal are calculated as the main (tungsten, molybdenum, bismuth, copper) and passing (silver, selenium, tellurium, rhenium, indium) components. In Katpar area explored deposit established large reserves of ore with an average content of molybdenum 0.071%, tungsten 0.057%, bismuth 0.005%, copper 0.042%, silver 0.71%, rhenium 0.158 g/tone.

**Key words**: Katpar, Skarn, Greisens, Tungsten, Molybdenum, Bismuth, Copper, Rhenium, Ores, Sediments, Mineralization, Veinlets, Thermodynamic, Temperature, Geochemical.

## INTRODUCTION

### Tectonic setting of the area

Katpar deposit located in central Kazakhstan, defined in Akmaya-Katpar ore zone, the rare industrial site with a spatial combination of skarn and greisens. The deposit is located in the Karaganda region, 12 Km to the east of the railway station Zharyk.

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Tectonic position defined by the position of the field in the rear of the Upper Paleozoic continental-margin volcanic-plutonic belt[2]. The field is located in the Famennian-Tournaisian carbonate-clastic sediments of the assumption of the rift, split into north-east block clastic (mainly flyschoid) and Silurian sediments, rich rare metal mineralization. The deposit is "reflected" in rare-metal mineralization, commonly manifested in the rear area of continental-margin volcanic-plutonic belt.

Geophysical data field is located in the zone of over-intrusive intrusions at a depth of 400-600 m below the surface. The main body of the array has an elliptical shape with the long axis of 10 Km with a width of 3 Km (Figs. 1, 2). Granites are geochemically specialized in W, Bi, Mo, Cu, and Sn; in the apical part, they weakly contaminated (to granodiorite) and enclosing limestone, marbles on alumino-silicate interlayer developed hornfels.

On the surface ore deposit manganese and iron clay, well-defined secondary haloes of tungsten, molybdenum and copper. Ore deposit is located in the over-intrusive zone at a depth of 400 m dissected massif weakly albitized and greisenized in exo-contact Permian granites.

In the ore-bearing ore deposits stand weathering crust and the primary ore. Above the limestone, rich skarns, the depth of the weathering crust ranges from 16 to 60 m and in fault zones-up to 200 m weathered crust is represented by clays (illite-montmorillonite and kaolinite) composition.

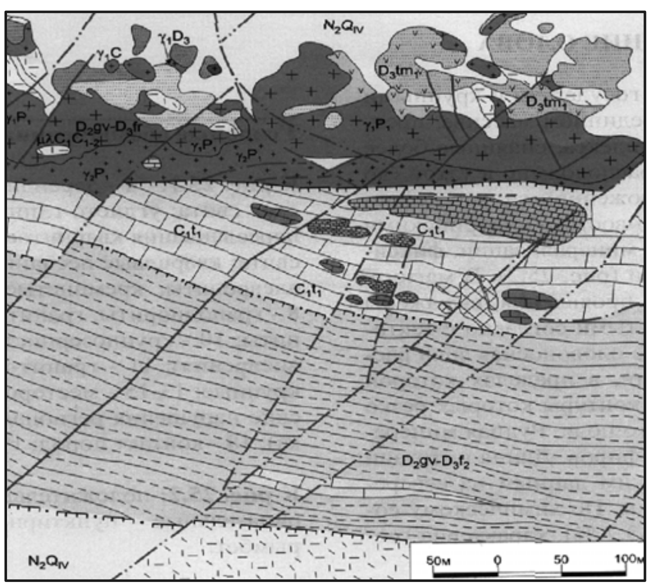



**Fig. 1: Geological map of the field Katpar**[2]

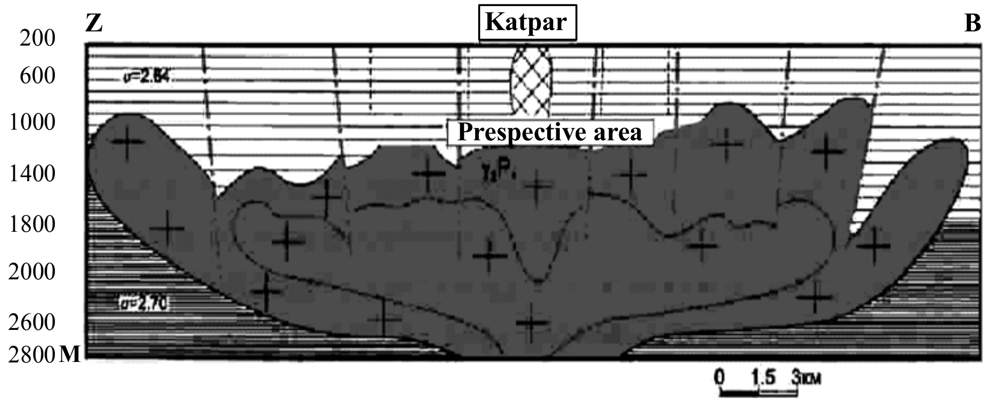



**Fig. 2: Position of the field in the "intrusion-over-intrusive zone" and geological and geophysical section of the ore-bearing massif**

Oxidized ores space weathering crust overlain ore-bearing skarns in the form of raincoat-like deposits, traced on the surface in the form of a strip width of 80-100 m for 800-850 m. The lower boundary of the oxidized ore tortuous, directly adjacent to the primary ore. Power oxidized ores than 80 m; they consist of diverse composition of clays with relics destroyed primary ore (Fig. 3).

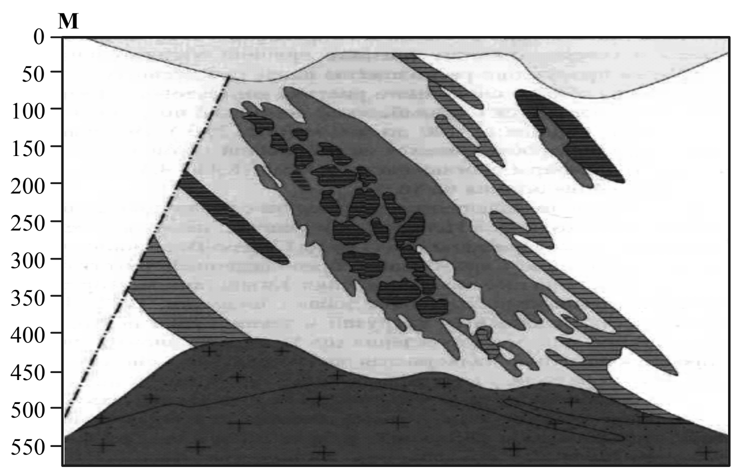
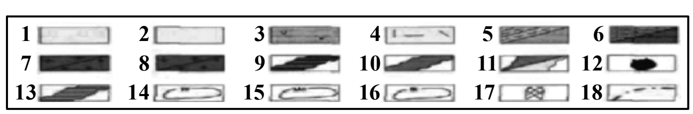



**Fig. 3: Relics of skarns in the apo-skarn-greisen molybdenum-tungsten ores**




1-gray-colored clay deposits 2-ore karst, 3-andesite, 4-andesite porphyries and their tuffs, 5-Lipari-dacite porphyry, 6-a) limestones, b) marble, 7-porphyritic granites a) medium-, b) fine-grained, 8-small-, medium-grains leucocratic granites: a) albitized, b) greisenized, 9-pyroxene-garnet skarns, 10-horizons metamorphosed ore type, 11-fluorite-scheelite ore: a) rich, b) poor, 12-relics of skarns in the rare metal ores 13-slightly skarned rocks, 14-circuit tungsten mineralization, 15-circuit molybdenum mineralization, 16-circuit bismuth mineralization, 17-molybdenum-tungsten ore body, 18-tectonic faults.

Core value of the field is molybdenum-tungsten ore skarn-greisen type skarn-limestone with associated copper and bismuth. Mineralization is confined to the skarn-greisen veins capacity. The veins are grouped into separate stock body, stem-and columnar shape. Within stock body assaying allocated four skarn-greisen bodies. Ore minerals in the form of disseminated and scattered small sockets are concentrated mainly in the fluorite veins.

The mineral composition of skarn-greisen ores (in %): garnet-51, fluorite-5.4, wollastonite and bustamite-5.7, quartz-6, 3, carbonates-11.8, feldspar-4.3 of ore minerals is the most common, (in %): chalcopyrite (1.1), molybdenite (0.42), sphalerite (0.44), scheelite (0.37) and pyrite (0.33). As trace elements are marked (in %): Silver (0.077), tellurium (0.035), selenium (0.038), rhenium (0.025), indium (0.0287) and bismuth (0.008).

In general, the field Katpar mineralization is copper-molybdenum-tungsten and bismuth, rhenium, selenium, and tellurium. Mineralization is localized in veins and veinlets of carbonate rocks over-intrusive area, partly of granite, forming a total of ore-bearing stem. On the field three types of ore: 1-oxidized weathering crust, 2-skarn-greisen in marbled limestone, 3-quartz greisens in granite. Practical interest is the skarn-greisen ore. Ore process began at the end of the skarn, as manifested in the greisens stage and ended in the hydrothermal stage.

## The morphology of the ore bodies

Ore bodies in the form of pillars, lenses and irregular metasomatic formations are confined to zones of tectonically fractured rock. Industrial ore bodies consist of contiguous lenses, veins and veinlets, grouped into separate mineralized skarn-rich zones along the strike length of 100 to 350 m, down-dip from 100 to 600 m. Thickness of ore bodies from 10 to 200 m. Ore deposits formed in the field Katpar intrusion-over-intrusive system in which the ore-metasomatic formations most intensely manifested in over-the dome of the granite massif.

## Stages of formation of the deposit

In the formation of the field there are four stages:

First phase - The areal marbled limestone deposit is in the form of isolated sinking cool (75-80°) of ore pillar, the root part of the setting in the granites.

The second stage - The formation of infiltration skarn rich in manganese, iron, zinc and copper ore extracted from sedimentary clusters.

Third stage - Greisenization manifested in the apical part of the granites with poor Cu-Mo-Bi mineralization in skarns (skarned greisens) with the rich industrial Cu-Mo-W-Bi mineralization;

Fourth stage - The formation of the weathering crust to form the ore-rich karst manganese, fine scheelite.

## The dynamic model of the deposit Katpar

## PT conditions of mineralization

Analyzing the physical and chemical conditions of mineralization of the deposit Katpar [1,3-5] showed the following:

The main body of the center is composed of garnet skarns. Skarn process has been gradually decreasing in alkaline solution. Homogenization temperatures of gas-liquid inclusions in pyroxene (560°C), garnet (520-420°C).

With greisens in granite, limestone and associated skarns of integrated mineralization, in greisens granites are widely developed fluorite and quartz, topaz difference. In homogenization temperature of inclusions in quartz from 430-330°C, molybdenum mineralization is localized, the tungsten compound imposed in over-intrusive zone, exo-greisens for skarns and marbles formed scheelite. In the subsequent decrease in temperature and acidity of the solutions deposited sulphide chalcopyrite-bismuth mineralization. Part of native bismuth formed in the range of 270-260°C.

In the formation of deposits involved fluoride-chloride-potassium-sodium solutions enriched with hydrogen sulfide. In anions fluids played a significant role bicarbonate ion. The zoning of the field is reflected in the development of quartz-bearing facies of the roof near the granite intrusion and the predominance of fluorite fades away against her element zoning (bottom to top): molybdenum-tungsten-bismuth.

Analysis and systematization of materials on geology, geophysics, mineralogy and thermo-geochemistry possible to determine the source data, the initial and boundary conditions for the simulation of the formation of rare metal mineralization of the deposit Katpar (Table 1).

The development of the temperature of Katpar field intrusive massif in time and in space the field is located on the "blind" domes of granite massif, at the contact with carbonate rocks. Conditions of formation of skarn-greisen formations studied by various methods that exist in the field of geological research. With the use of quantitative research methods the proposed dynamic model of the deposit Katpar, includes:

- Dynamics of the thermal field in the host intrusive massif environment and the area of contact metamorphism

**Table 1: Initial data for the modeling of the thermal field of ore-bearing massif Katpar**

| **Katpar massif massif form: Ellipse** | **Geom. size of the massif Km** | **T – Formation °C** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Granites, phase** | | | **Altered rocks** | | | **Ores. min.** | **Ores. min.** |
| | | **I** | **II** | **III** | **Hornfels** | **Skarns** | **Greisen** | **Mo** | **Ше** |
| Occurrence depth massif capacity length of the massif capicity dome the width of the dome | 3,0 2,0 10,0 | 850 | 850 | 810 | | 420-560 | 380-520 | 330-430 | 250-330 |
| Ratio temperature conductivity m/s | | 12,5 $*10^{-7}$ | | 10,0* $10^{-7}$ | | | | | |

- Temperature field of ore-forming solutions when entering the zone of mineralization;
- Thermodynamic condition of crystallization of minerals and phases of mineralization;
- Gradients of temperature fields and their relationship to zoning of mineralization.

These data revealed by the example of dynamic model of mineralization[6].

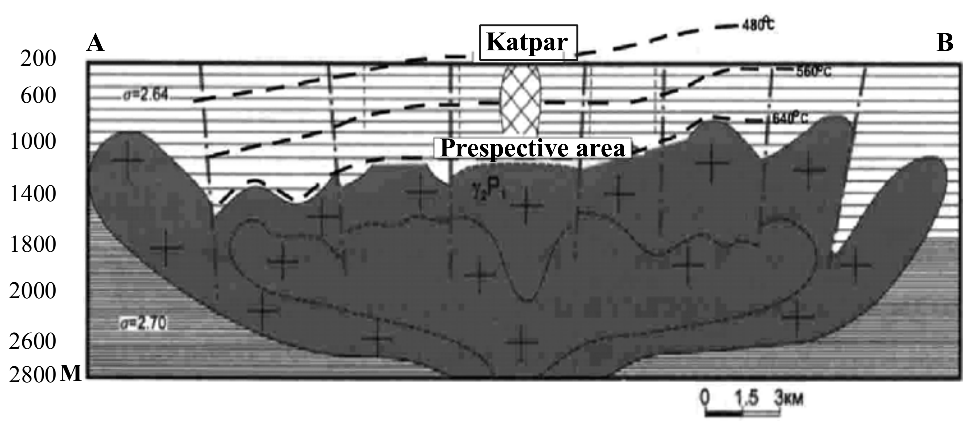
**Progressive cooling step:** Katpar granite massif is characterized by the establishment of a relatively high temperature front within the $6400^0$ C for the contact. The spread of this front in the host environment, at a distance of 1000 m from the contact granite mass, the observed temperature range 460-480°C. The estimated temperature gradient in this region is determined within the 180°C. High temperatures in the range 640-4800S, dominant in the field, developing metamorphic transformation of rocks, so that the field can accommodate limestone, marble on alumino-silicate species evolved hornfels. By apical parts granite massif is characterized by K-feldspar and albitized rock early-alkaline stage, the temperature of which is determined according to the thermometry within the 600-4500°C[7].

In the area of the contact aureole of the intrusion as a result of the interaction of alumino-silicate and carbonate rocks at passing post magmatic solutions early-alkaline stage on the field there were a number of calcareous skarns. According to initial thermometry skarned Katpar happened on the field at temperatures $5600^0$C. Mineralized main skarn process was Cl, $H_2O$, far as possible and F.

The dynamics of the simulated temperature field of the massif shows that the post-magmatic changes in the host environment and in granites correspond to the progressive phase of cooling, as the temperature of post-magmatic changes correspond to the temperatures range of the contact zone. According to the simulation of pre-ore halo changes rather wide, its vertical extent reaches up to 1200 m (Fig. 4, A and B). Pre-ore stage of development in the field Katpar fully correlated the dynamics of the progressive stage cooling massif.

**Regressive phase of cooling** granite mass corresponds to a period of productive mineralization, although ore process began at the end of skarn. Along the contact of the array over 100 thousand years after its formation the temperature drops to $4800^0$C. In the host environment, the temperature at a distance of 1,000 meters is equal to 320-$3500^0$C. This temperature zonation in the over-intrusive zone has a temperature regime of rare metal mineralization. Estimating of the temperature gradient at the beginning of a productive mineralization is about 160°C per 100 m (Fig. 4, 5, A).

Under high temperature, the hydrothermal solutions produce autometasomotic granites itself, leading to the bulk greisenization apical part of the array. Products autometasomatic greisenizations are scattered disseminations.



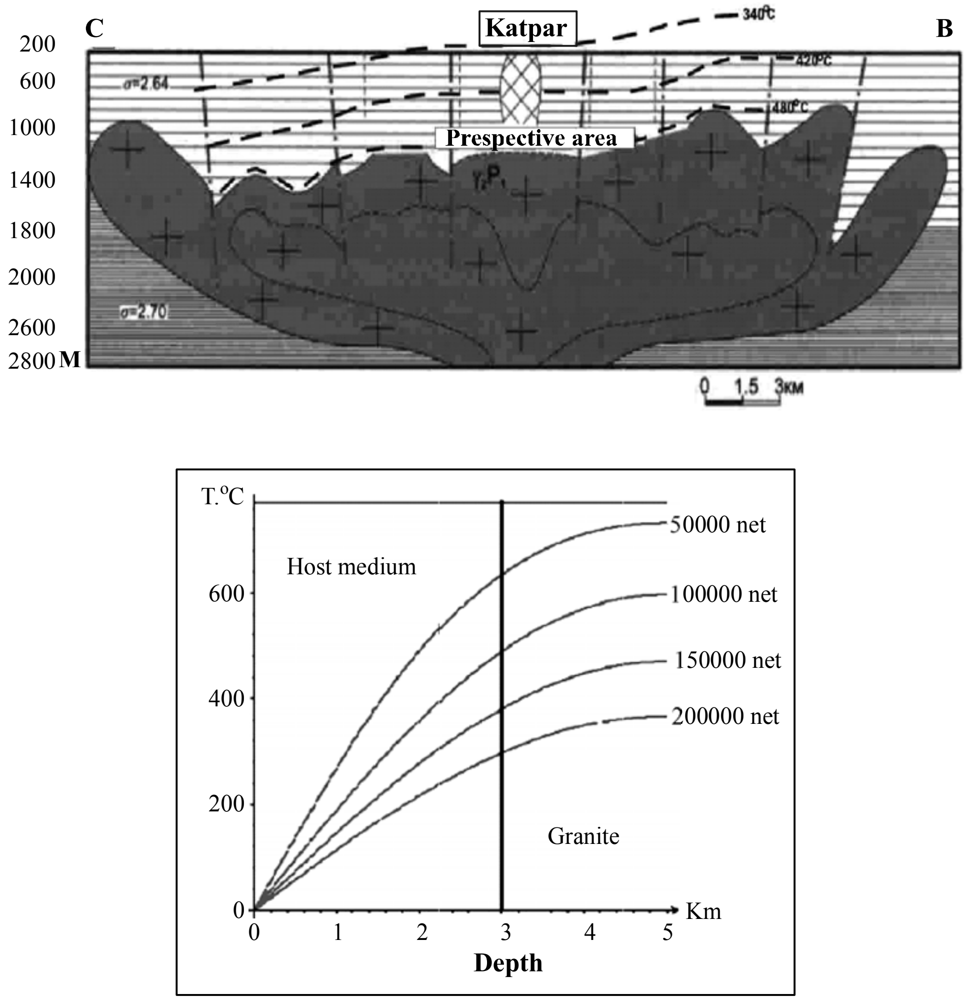


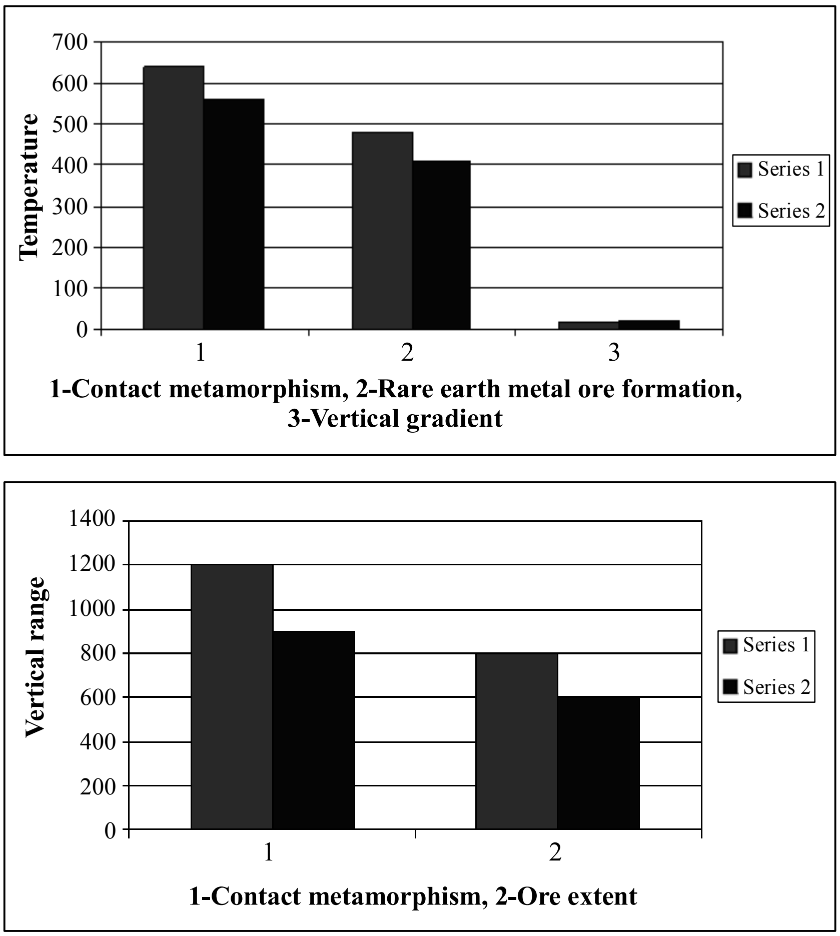

**Fig. 4: Dynamic model (temperature, formation) of the Katpar field.**

A-B-temperature field of granite massif in the period of productive mineralization, spatial temperature distribution in granites and in the host environment at different points of formation of the ore-bearing intrusions

As a product of the acid phase, in greisens granites (endo-greisens), where extensive developed fluorite and muscovite and molybdenum mineralization is localized, the temperature of its formation according thermometry defined within the 430-3300°C and can be traced to a depth of over 100 m of the intrusion.

Exo-greisens skarns and marbles in the compounds of tungsten (scheelite), the deposition of tungsten compounds in over-intrusive zone according thermometry occurred at a temperature range 330-2500°C, and deposition of native bismuth 270-2600°C.

The sequence of ore generation in the field of Katpar entirely consistent with the dynamics temperature field of the array. Front with temperature 4800S-3500$^0$C at the roof of array characterized by exo and endo - greisens processes and deposition of molybdenite in greisens granite (Fig. 5, A). Duration of these processes is determined by the duration of the existence of the front temperature. According to the calculations duration is estimated to be up to 50 thousand years.




**A - Temperature histogram, B - Vertical histogram amplitude processes**

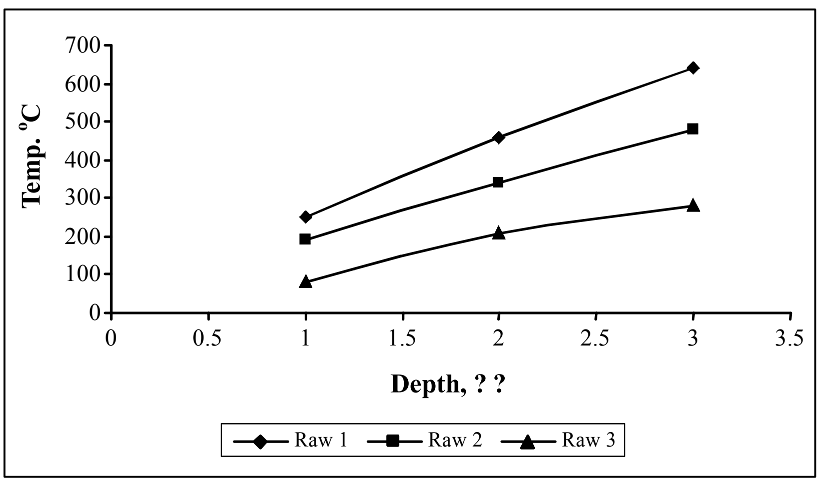
No. 1 - The simulation results, and No. 2 - The results of thermometry

**Fig. 5: Comparative analysis of the quantitative method of modeling and analysis of the field Katpar**

In the over-intrusive area where formed tungsten deposits and bismuth deposits, a temperature range between 350-2800$^0$C has a duration of between 100 thousand years in the period of regression cooling array. Over 200 thousand years after the implementation of the front of the array with the minimum temperature 2800$^o$C, which necessary for rare metal mineralization reaches the roof of the array (Fig. 5, Row 2, 3).

On the field three types of ores, but the main value is the molybdenum-tungsten ore skarn-greisen type, skarned limestone over-intrusive zones with associated copper and bismuth. Geological data on the actual vertical scale of mineralization not exceed 600 m (Fig. 5, B). The zoning of rare metal ores is complicated by the fact that they are superimposed on early stratiform ore. Calculation of cooling intrusive massif to evaluate the duration pre-ore and ore at the deposit stage of Katpar field within 200 thousand years. Quantitative parameters of the modeling method in the field correspond to the temperatures of Katpar field rare metal mineralization, where results are shown in Fig. 6.

**Post-ore stage of the deposit** is characterized by hydrothermal-vein stage. According[8] apo-phyllite, fluorite, zeolite, calcite, calcite mineral associations of the post-ore stage formed at temperatures of 160-900$^o$C. Thermometry data of gas-liquid inclusions in minerals show that the gap in the temperatures of ore formation and post-ore stages of 110-1200$^o$C.




Row 1 - During the processes of contact productive mineralization,
Row 3 - The end of mineralization metamorphism, Row 2 – The beginning of

**Fig. 6: Changes in temperature of the host medium at different stages of mineralization of the deposit Katpar**

**Summary**

**Deposit Katpar**: Copper-molybdenum-tungsten and bismuth, rhenium, selenium, and tellurium. Molybdenite, which has caused the concentration of rhenium in this field is located in areas of greisenization, feldspar granites and quartz and quartz-feldspar veins, as well as skarn-greisen bodies. Ore zoning in the field shows that the molybdenite is localized in the apical parts of the granite and can be traced to a depth of over 100 m of the intrusion. Skarn-greisen body length of 800 m, 5-200 m capacity can be traced to a depth of 400 m.

The spatial position of ore veins with molybdenite in the field Katpar suggests that in the apical parts of the granites are crystallized in thermal equilibrium, due to the proximity of the heat and the ore-forming fluids and appeared in the form of molybdenite - 2H modification. In the skarn-greisen bodies molybdenite were crystallized in thermal equilibrium.

**Crystallization in thermal equilibrium**: It was contributed by the forming morphology of the ore body, giving rise to the anomaly in the thermal field of the intrusion. In this case, molybdenite appears as third modification, most adapted to isomorphic substitution. In this regard, one can explain the cause of rhenium in the mineral composition of skarn-greisen bodies within the field Katpar to 0.025%.

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