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THE SYSTEM OF GEOLOGICAL-GEOCHEMICAL ASSESSMENT OF THE RARE-METAL ORE-BEARING IN GRANITE INTRUSIONS

(Figs. 5)

Abstract: An assessment of the ore-bearing of granitic intrusions is only possible for a Sn-W-Mo — rare-metallic mineralization whose element composition is limited by granitophile elements. The criterium of ore-bearing is combined and formed by a series of necessary but insufficient features of ore-bearing as: a) the intrusion belongs to the post orogenic magmatism stage; b) an adamellite-leucogranitic composition; c) the confinement to negative anomalies of gravity; d) a hypabyssal character; e) a granite differentiation; f) a granite rare-metallicity. The rare-metallicity of granites is the most important feature of ore-bearing which can be assessed quantitatively upon the methods of element formulas, the concentration index and the geochemical diagram of ore-bearing. The proposed system of ore-bearing assessment of granitic intrusions is good for a local prospecting of rare-metallic mineralization as well as for a division into barren and ore-bearing intrusions and the assessment of a comparative degree of ore-bearing.

Резюме: Оценка рудоносности гранитных интрузий возможна только в отношении Sn-W-Mo — редкометального орудения, элементный состав которого ограничивается гранитофильными элементами. Критерий рудоносности является комбинированным и формируется объединением необходимых, но недостаточных признаков рудоносности, такими как: а) интрузия принадлежит к посторогенной стадии магматизма; б) адамеллит-лейкогранитный состав; в) приуроченность к отрицательным аномалиям силы тяжести; г) гипабиссальный характер; д) дифференцированность гранитов; е) редкометальность гранитов. Наиболее важным признаком рудоносности является редкометальность гранитов, которая может быть оценена количественно с помощью методов элементных формул, индекса концентрации и геохимической диаграммы рудоносности. Предложенная система оценки рудоносности гранитных интрузий подходит для местной разведки редкометального оруденения, а также для разделения на безрудные и рудоносные интрузии и для оценки сравнительной степени рудоносности.

Nowadays we have to do with a certain methodical contradiction between the regional and often enough the global character of metallogenic and prognostic constructions on the one hand and the increasing detailing of geological and geologo-prospecting works on the other hand. But it is absolutely obvious that the methodical approach to the mineralization forecast must change depending on the detailing degree of geological investigations, meaning that to different scales of geological survey should correspond different methodical approaches of mineralization forecast.

The given proposition in this work is for the decision of the local mineralization forecast and goes with median and largescale geological works where the main attention does not lie with the granitic magmatism of a certain region but with separate granitic intrusions (massifs), representing this magmatism, and the forecast of the related mineralization.

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It is concluded that an objective assessment of ore-bearing of granite intrusions is only possible for the so-called rare-metal mineralization, the elements of which are limited by granitophile elements (Sn, W, Mo, Li, Be, Ta, Nb, TR, Zr and some others). These elements do form the most part of the group of lithophile elements after V. M. Goldschmidt and do concentrate in granites thereby differing sharply from chalcophile elements which are not connected with granites. Therefore, geochemical preconditions of ties with granites of the sulphide mineralization proper are absent. Therefore, methods of prediction of rare-metal and sulphide mineralization must be different.

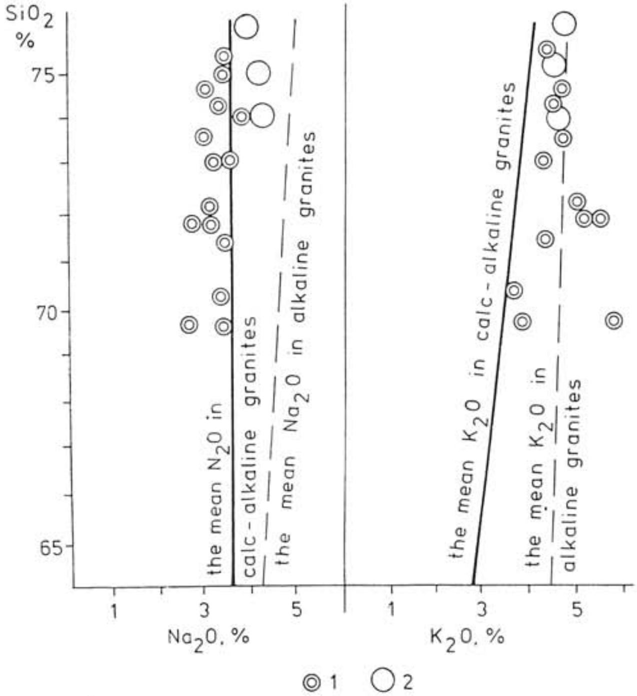


Fig. 1. Correlation of Na_2O and K_2O contents in plumasitic rare-metal granites (mean data on intrusions of different regimes).
Explanations: 1 — plumasitic rare-metal granites; 2 — subalkaline rare-metal granites;

The number of granitophile elements has been assessed (Kozlov, 1981) by the analysis of the scale of clark element concentrations in granites with rich and poor calcium after K. K. Turekyan and K. H. Wedepohl. Because of the granitophile elements concentration in leucogranites (in calcium--poor granites) the concentration ratio value of these elements in calcium-poor granites against their concentration in calcium-rich granites is always more than one.

Upon this feature to the granitophile elements belong (figures correspond with the value of the mentioned ratios): 2 — Sn, Th; 1.8—1.5 — P, F, Cl, K, Li, Rb, Be, W, Hf; 1.2—1.1 — B, Zr, Y, TR, Ta, Nb. The mentioned elements form the element composition of the mineralization, the ties of which with the granite intrusion are rather apparent.

Earlier there have been rather many criteria of potential ore-bearing of granite intrusions, but the answer to the logical questions, whether the given criterium is sufficient for the determination of an ore-bearing intrusion, usually fails. The answer is that there is no one sufficient criteria for the ore-bearing. Practically a sufficient criterium is combined and formed by several necessary but insufficient features of ore-bearing.

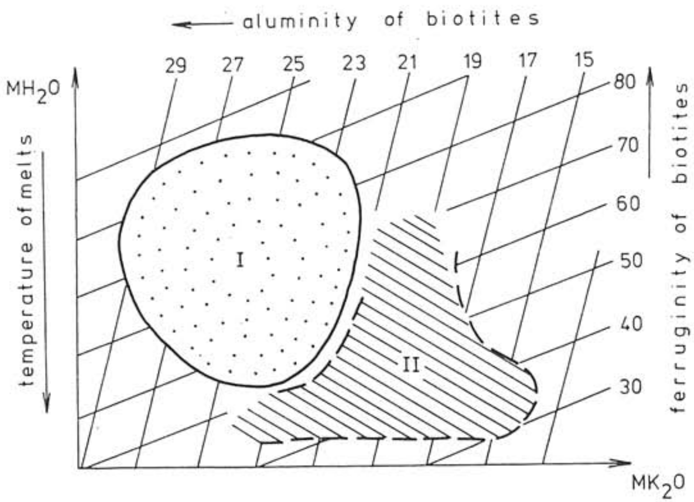


Fig. 2. Composition of biotites of plumasitic and subalkaline rare-metal granites in parameters of ferruginity-aluminity (on the diagram by V. S. Ivanov).
Explanations: I — field of biotites of plumasitic rare-metal granites; II — field of biotites of subalkaline rare-metal granites.

Some of such typical necessary features of the ore-bearing intrusion (Kozlov, 1981) are: a) the location of the intrusion in zones of deep faults, meaning that the intrusion belongs to the postorogenic (subsequent) stage of magmatism; b) the adamellite-leucogranite composition of the intrusion; c) their confinement to negative anomalies of gravity; d) the hypabyssal character of the intrusion; e) the differentiation of intrusion being a plurality of phase facial varieties of granites (differentiates); f) the granites belong to rare-metal varieties expressed by a higher concentration of granitophile elements against the clark level.

Any of these features taken separately is insufficient for the determination of a potential ore-bearing but together they do form a combined feature which is enough to diagnose the ore-bearing of an intrusion.

The potential ore-bearing intrusion is the main metallogenic factor for two types of provinces of rare-metal endogenic mineralization: the province of tin—wolfram—rare-metal (Li, Ba, Ta, Nb and so on) metallogenic profile and that of molybdenum—wolfram—rare-metal profile. There the intrusions are characteristic of the mentioned features, but differ by some petrochemical particularities (S h e r e m e t—K o z l o v, 1981). The granites of potential ore-bearing intrusions of the tin—wolfram—rare-metal provinces belong to a series of normal calc-alkali granites and are late adamellite-leucogranite intrusions of long forming granodiorite-granite intrusive series. Adamellite-leucogranites are usually with a low content of Na_2O and a high one of K_2O and abundant alumina (Fig. 1). The geochemical classification of L. V. T a u s o n represents them as a geochemical type of *plumasitic rare-metal leucogranites.*

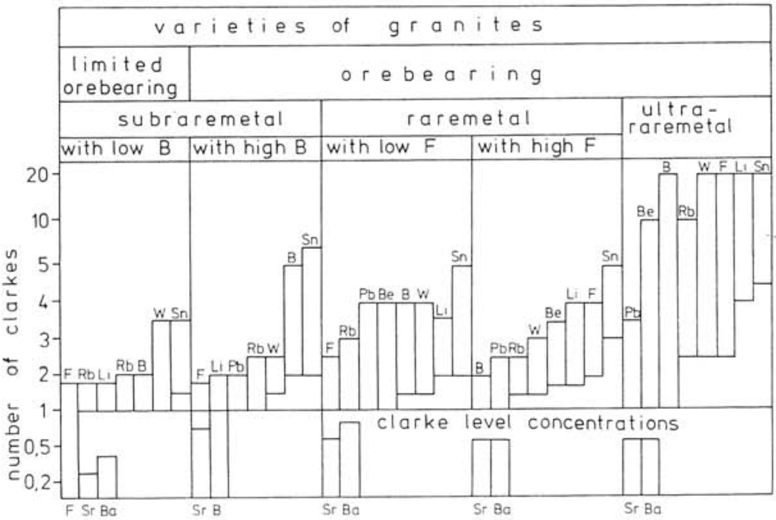


Fig. 3. Varieties of granites for the degree of their ore-bearing and rare-metal capacity.

The granites of potential ore-bearing intrusions of the molybdenum—wolfram—rare-metal provinces are represented by the geochemical type *of rare--metal leucogranites of the alkaline series.* They form late intrusions of subalkaline granitoid series represented by monzonite-granosyenite-subalkaline granite-alaskite. The subalkaline leucogranites are of alkaline feldspar and quartz having a higher quantity of accessory magnetite and are characteristic of a higher concentration of Na_2O and K_2O (Fig. 1).

The apparent difference between plumasitic rare-metal leucogranites and rare-metal leucogranites of the alkaline series is the composition of their mica (Fig. 2). The biotites of plumasitic rare-metal leucogranites are represented by high-alumina and low-magnesium varieties, the composition of which reflects the high activity of water and acid components in the initial melts. The biotites of most intrusions of subalkaline rare-metal granites are with a high concentration of magnesium or rarely with iron at a low content of aluminium. The biotite composition shows the low activity of water and the high one of alkalies in the initial melts of the subalkaline intrusions.

An important feature of ore-bearing of granites is the rare-metalness, unstable for different intrusions. The rare-metalness is defined by the principle of combined concentrating of granitophile elements at a different degree of accumulation. Therefore, the degree definition of ore-bearing of granites on the concentration of but one or two ore-forming elements is methodically wrong.

The division of ore-bearing granites on the concentration degree of a part or all granitophile elements makes subrare-metal, rare-metal and ultrarare-metal ones (Kozlov, 1981; Fig. 3), the ore-bearing of which is generally correlated with the rare-metalness. Intrusions of subrare-metal granites with a low concentration of boron have usually a limited ore-bearing. Rare-metal granites with moderate-high and higher concentrations of fluorine and subrare-metal granites with a high content of boron form the majority of potential ore-bearing intrusions. Finally, the highest ore-bearing have ultrarare-metal granites with a high degree of accumulation (more than four clarks) of fluorine and some granitophile elements. The real ore-bearing of the intrusions (or their probable ore productivity) is not only defined by the degree of rare-metalness of forming granites but also by their volume. Therefore, the greatest potential productivity have intrusions of a considerable size formed by ultrarare-metal granites. This means that large ore-bearing intrusions, the granites of the main intrusive stage which make up the basic volume of the intrusions, are represented by ultrarare-metal varieties. Such examples are really very rare.

Another independent factor of the potential ore productivity of the intrusion is the erosion cut with the growth of which the productivity falls.

As the rare-metalness of granites is highly inductive, so methods of a quantitative assessment of rare-metalness have been made up with the help of *element formulas* of granites and an *index of concentration* of granitophile elements (Kozlov, 1984), (Fig. 4).

The element formula is a result of fixing the concentrations of trace elements in the given variety of granite against the clark concentration in granites. Elements with a higher concentration than the clark level form a series in the numerator of the formula and the elements with concentration lower than clark are excluded. Figures before the element are coefficients of concentrations of each element as to its clark; elements in the formula are given with a dash.

The concentration index is a sum of anomalous, as to clark level, concentrations of granitophile elements expressed by clark units.

The element formula of typical rare-metal granite (Transbaikalia) and the assessment formula of the index concentration is given in Fig. 4 ($INC = CC_1 + CC_2 + CC_3 + \ldots + CC_n - n$, where CC_1, CC_2 = concentration coefficients of each granitophile element, $_n$ = number of granitophile elements).

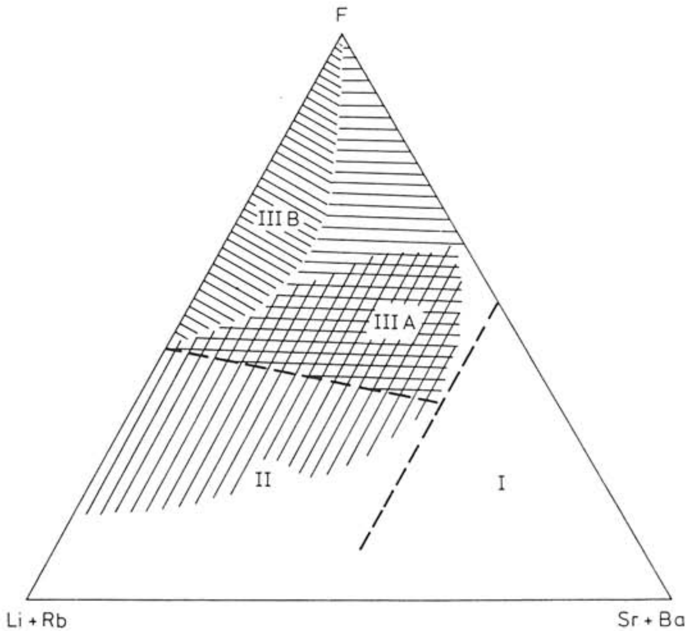
The element formulas show the typical geochemical particularities of rare-metal granites being the combined concentrating of granitophile elements there in (numerator) and the constantly lowered concentrations of strontium and barium (denominator) as to the clark level. The element formulas and the volume of INC fix the apparent difference of separate ore-bearing intrusions upon the degree of rare-metalness of the forming granites. For a constant group of taken granitophile elements (F, Li, Rb, Be, B, Sn, W, Pb) the value of INC in subrare-metal limited-ore-bearing granites makes 4—6 clarks, in

elements	%			ppm									
	Na	K	F	Li	Rb	Be	Sr	Ba	B	Sn	W	Zn	Pb
clarke concentrations	2.8	3.3	0.08	40	170	3	300	800	15	3	1.5	50	20
plumasitic rare-metal leucogranite of Transbaikalia	2.6	3.7	0.15	100	290	6.5	170	450	31	9.3	2.8	47	31
element formula of rare-metal leucogranite of Transbaikalia	$\frac{\text{Sn } 3.1 - \text{Li } 2.5 - \text{Be } 2.2 - \text{W } 1.9 - \text{F } 1.8 - \text{Rb } 1.7 - \text{B } 1.5 - \text{Pb } 1.5}{\text{Sr } 0.6 - \text{Ba } 0.6}$												
calculation formula of the INC	$INC = CC_1 + CC_2 + CC_3 + \ldots + CC_n - n$												
calculation of INC of rare-metal leucogranite of Transbaikalia	$INC = 3.1 + 2.5 + 2.2 + 1.9 + 1.8 + 1.7 + 1.5 + 1.5 - 8 = +8.2$												

Fig. 4. The estimation of element formulas and INC.

rare-metal ore-bearing granites 8—12 and in ultrarare-metal of highly ore-bearing granites the value is more than 20 clarks (20—50).

There is also a graphic variant of assessment through a triple diagram, using concentrations of F, Li+Rb and Sr+Ba (Kozlov, 1914), (Fig. 5). The sum of strontium and barium is taken as an indicator of the differentiation degree



Fng. 5. Geochemical diagram of ore-bearing capacity of granitoids.
Explanations: I—III — fields of granites; I — non-ore-bearing; II — limited ore-bearing; III — ore-bearing (IIIa — potential ore-bearing, IIIb — rarely ore-bearing).

of granites sharply decreasing from the early mafic differentiates to the late leucogranites in any granite series. The sum of lithium and rubidium shows best the concentration degree in granites of most typical granitophile elements (Sn, W, Be, etc.). The fluorine content is usually taken as a strong indicator of a rare-metal ore-bearing of granite intrusions. Statistically there are distinguished fields of non-ore (1), limited-ore-bearing (II) and ore-bearing granites (III). The field III is divided into a field IIIa of potential ore-bearing granites and IIIb of rarely ore-bearing ones. The use of the diagram require a preliminary analysis of the geological structure of the intrusion and the determination of the stage-facial characteristic of the granite varieties (as main, late stage or facies, etc.).

It is understood that with the system we may not only subdivide granites into non-ore and ore-bearing ones but also determine the degree of a probable potential ore-bearing.

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