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Research Article

GEOCHEMICAL FEATURES OF THE ZINAK MULTI-PHASE INTRUSIVE COMPLEX WITHIN THE CHAKYLKALYAN RANGE OF SOUTHERN UZBEKISTAN

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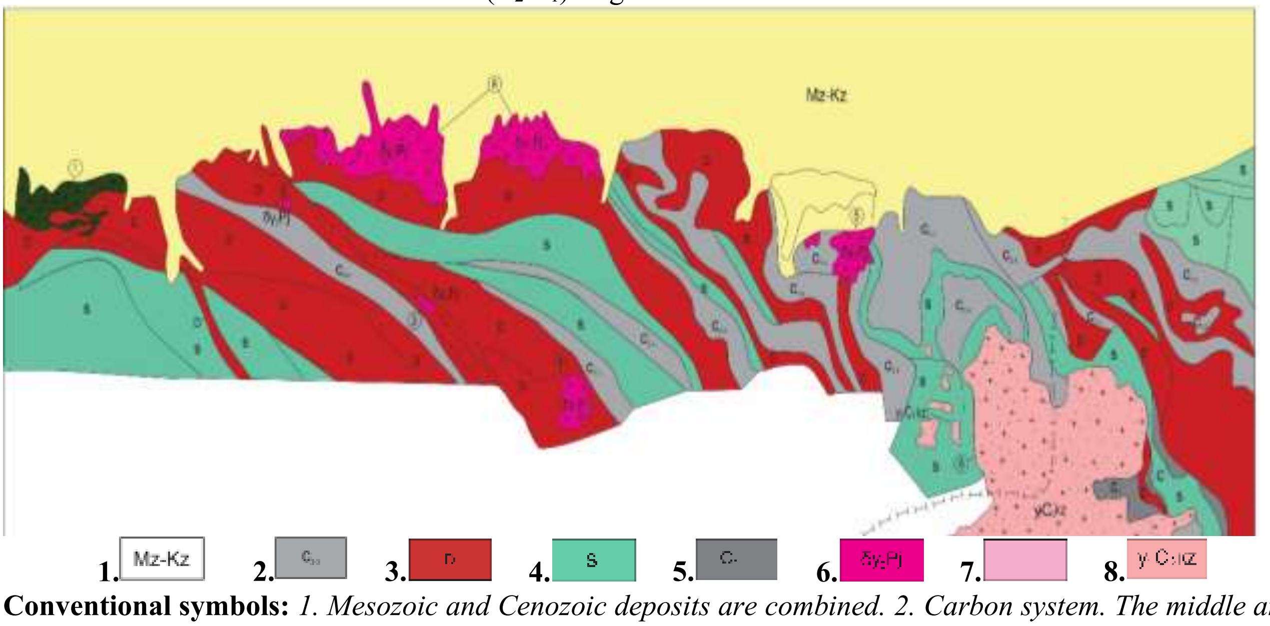
ABSTRACT
The Zinak intrusive is composed of rocks of the homodromic series and includes formations of four complexes: the Atkamara gabbro-diorite, Tyma gneissoid granites, Yakhton diorite-granodiorite, and Ketmenchin two-mica granites. The earliest representatives of this series (amphibole peridotites and pyroxene-amphibole gabbro) form under high-temperature conditions at considerable depths through the differentiation of basaltoid melt. The geochemical specialization of intrusive rocks serves as an indicator for identifying gold mineralization in granitoids.

Keywords: *Intrusive complexes, Metallogenic and Geochemical Specialization, Gold Mineralization, Zinak Intrusion, Chakylkalyan mountains.*

INTRODUCTION
The Zinak intrusive is located in the western part of the latitudinal belt of granitoid intrusions(Fig.1). The foundation of the granitoid belt consists of monoformational multi-phase intrusions composed of rocks from a single complex: the Yakhton diorite-granodiorite complex (including the Urgut, Yakhton, Chashtepa, Kamangaran, and Khodzhadyk intrusions) and the Karatyube-Zirabulak[8] adamellite-granite complex (the Akbaidzhuman intrusion). As with the entire Southern Tien Shan [1, 2], the granitoids of the Chaqilkalyan Mountains characterize the late Paleozoic (C_2-P_1) stage of the Earth's crustal evolution.



Conventional symbols: *1. Mesozoic and Cenozoic deposits are combined. 2. Carbon system. The middle and upper sections are undivided. Marguzor suite. 3. Devonian system. The Akbasay, Khojaqorgon, and Madmon ranges are combined. 4. Silurian system. The Kupruk, Kuturak, and Shing ranges are united. 5. Carbon system. The lower sections. 6. Biotite-amphibole granodiorite. 7. Middle-sulfur porphyritic biotite adamilliths*

(Sukarsky massif), medium-gray, slightly porphyritic Biotite leucogranites (Avgaydzhumansky massif). 8. Muscovite-biotite gneiss-like granites, cataclasite- and milonite-granites

Fig.1 *Intrusive massives and their numbers:1-Zinaksky, 2-Khodzhadyk 3-Kamangaran, 4-Yachton, 5-Chashtepa, 6-Avgaidzhuman, 7-Chinarsay, 8-Urgut*

MATERIALS AND METHODS

The study of rock characteristics from various complexes comprising the Zinak intrusive was conducted sequentially using a combination of methods: geological (mapping of intrusive formations and their contact zones), mineralogical (analysis of crushed rock samples), petrographic (optical microscopy in transmitted light), and chemical-analytical (including semi-quantitative spectral analysis, X-ray fluorescence, complete silicate chemical analysis, and ICP-mass spectrometry).

RESULTS

Within the Zinak intrusive, four complexes of rocks are manifested: Atkamara, Tyma, Yakhton, and Ketmenchi.

The most ancient (C_2) intrusive formations in the Zinak intrusive are Atkamar complex rocks represented by fine, medium, and coarse-grained amphibolithic diorites, gabbro-diorites, pyroxen-amphibole gabbro, hornblende gabbro, and amphibole peridotites. Amphibole peridotites are composed of actinolite-adenite, in places with a weak kersutitic core, highly ferruginous montichellite, diopside, enstatite, phlogopite. Gabbro, gabbro-diorites are represented by greenish-gray, dark-gray varieties. Composition: grayish-green common hornblende and actinolite, containing clinopiroksen relics, plagioclase (labrador), reddish-brown amphibole (kersutite), varying amounts of quartz, brown biotite, potassium feldspar, and a small amount of phlogopite. Accessory: sphene, apatite, rutile, magnetite, pyrite.

Petrochemical data reflect the homodromic evolution of the Atkamara complex with a slightly elevated potassium content. The rocks of the Atkamara complex are characterized by increased titanium content in the initial gabbro and high iron content. According to Z.A. Yudalevich [4], the depth of formation of the gabbroid massifs is mesoabyssal.

The Tymsky Upper Carboniferous complex of gneissic granites. The rocks of this complex have limited distribution and, within the contour of the Zinak intrusion, form two small bodies in its eastern part among the volcanic-sedimentary-carbonate strata of the Lower Silurian[8]. The complex is primarily composed of muscovite-biotite, biotite, and biotite-muscovite gneissic granites, as well as cataclastic and mylonitic granites. The bodies of the complex often exhibit a stromatolite structure due to the alternation of parallel strips of host rocks and sill-shaped bodies of gneiss-like granites and granitoid gneisses, often revealing signs of formation through recrystallization, granitization, and feldsparitization of the primary sedimentary substrate[9].

The formation of granitoids was accompanied by regional metamorphism of host rocks in high-temperature subphases of the green-shale and amphibolite facies, whose mineral paragenesis was subsequently granitized. By composition, these are acidic, low-alkali rocks of the sodium profile with high alkalinity and alumina content. Mineral composition of granites: plagioclase, quartz, kalishpat, biotite, muscovite. Accessory: apatite, tourmaline, topaz.

The Yakhton Permian diorite-granodiorite complex. The formation of the complex occurred in the following chronological sequence [3]: fine-grained weakly porphyritic pyroxene-amphibole-biotite and biotite-amphibole quartz diorites and quartz syenite-diorites; fine to medium-grained porphyritic biotite-amphibole (mesocratic) granodiorites (main intrusive phase); fine- and medium-grained porphyritic amphibole-biotite (leucocratic) granodiorites; vein rocks of the first stage: granites, aplites, pegmatites; vein rocks of the second stage: diorite porphyries; granodiorite porphyries; granite porphyries.

The main volume of the yacht complex is occupied by biotite-hornblende granodiorites, whose facies varieties are adamellites and porphyritic quartz diorites. Adamellites are characterized by an increased content of kalishpat and quartz, porphyritic quartz diorites by an increased melanocraticity and basicity.

Intrusive granitoids belong to the moderately alkaline series, the potassium-sodium series, highly aluminable for the main phase rocks (16-17%), with a decrease in this indicator in the dike series rocks (12.7-15.8%), with a low degree of femicity, a medium degree of iron content (Kf=60-73). The granitoid rocks of the complex are characterized by a low degree of iron oxidation (0.14-0.32) and abnormally low magnesia (MgO content 1.2-2.0%, with a decrease in the dike series rocks to 0.4%). For the middle and basic rocks of the early phases of the complex, increased natural melanocraticity, reduced alkalinity (4-6.6%), with variable type (sodium-potassium in gabbro and potassium-sodium in diorite), as well as increased magnesiality in relation to the rocks of the main phase, are characteristic [10].

The granitoids of the yachton complex are characterized by high stability of features that determine its petrochemical uniqueness. Firstly, this is the reduced acidity of the main types of rocks, which varies in the granitoids of the main phase from 62 to 66% SiO_2, secondly, the reduced overall alkalinity of the main phase rocks (7.1-8.2%) compared to the rocks of the dike series (7.7-8.7%), characterizing the calcium-sodium type of granitoids, and thirdly, a stable moderate iron content for the entire series of granitoid rocks.

The Ketmenchin complex of two-mica and leucocratic granites is considered [4] as a single-phase complex with the identification of relatively different-aged subdivisions: 1) coarse-grained leucocratic, slightly porphyritic biotite granites (the earliest); 2) medium-grained two-mica granites; 3) fine-grained two-mica granites (the latest). Among the two-mica granites, biotite-muscovite and muscovite-biotite varieties are distinguished. In certain areas, biotite tourmaline-bearing granites are found as separate occurrences.

Microscopically, the following mineral composition has been identified in the most representative varieties of granites: plagioclase (25-27%), potassium feldspar (30-33%), quartz (30-35%), muscovite (5-10%), and biotite (4-8%). Plagioclase has a tabular shape with slightly noticeable zonation; its composition varies from albite-oligoclase to andesine [6]. In some places, it has recrystallized into a finer-grained aggregate of albite. Potassium-sodium feldspar - microcline and orthoclase in porphyritic formations have a perthitic structure, while in the grains of the groundmass, they have a microperthitic structure and contain 24% albite component. Quartz forms xenomorphic grains and is observed as myrmekitic intergrowths.

The petrochemical characteristics of the granites are marked by elevated silica content (73% on average), alumina saturation, high total iron content, and increased potassium content relative to sodium (potassium-sodium alkalinity type) [9]. The accessory mineral assemblage of the granites is garnet-tourmaline-apatite with zircon.

It has been established (Table-1) that in the rocks of all four complexes, there is a pronounced presence of pervasive elements with concentrations exceeding the clarke values in all rock types (Figure-2) [10]. In the intrusion under study, rare-earth elements are present in quantities below clarke values, with the exception of neodymium in granodiorites and thulium in gabbro-diorites, whose contents are equal to the clarke value.

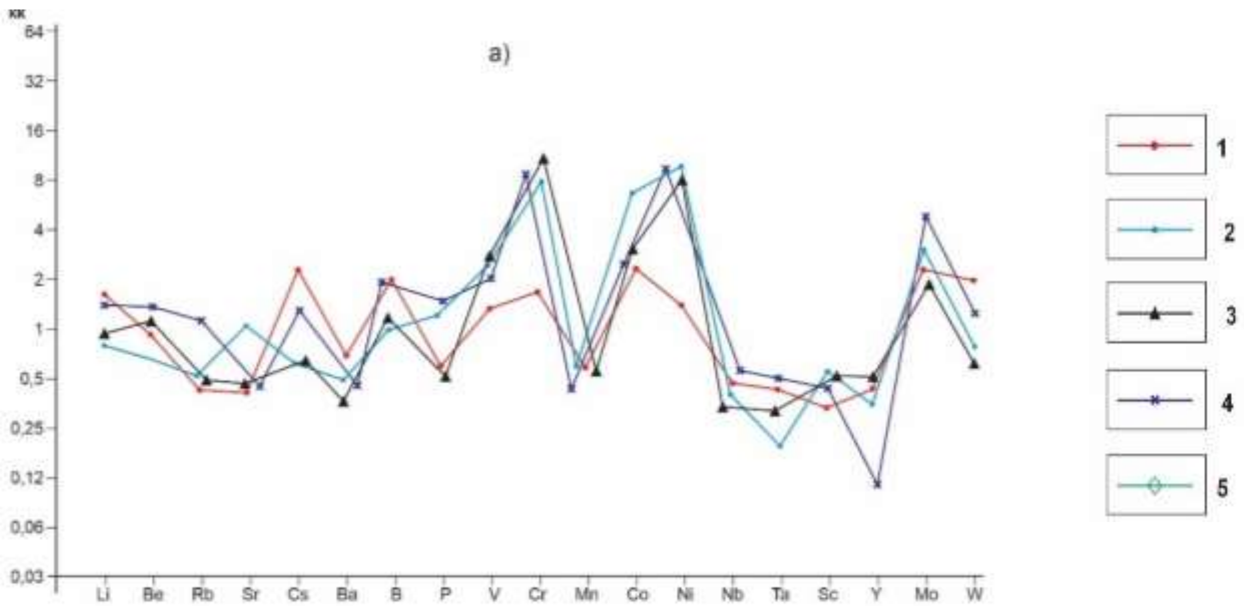
Discussion of the results. Considering the obtained materials on the intrusive magmatism of the western part of the Chaqilkalyan Mountains, which resulted in the formation of the polymorphic Zinak intrusive, it seems possible to highlight the following main characteristics [7]. The presence in the main rocks of the Atcamara complex (amphibole peridotites and pyroxen-amphibole gabbro) of intra-tellurial minerals: olivine, rhombic and monoclinic pyroxenes, basic plagioclase, allows us to assume the initial high-temperature conditions of rock crystallization corresponding to the deep zones of the Earth's crust.

Table 1: Distribution of trace elements (g/t) in the rocks of the Zinak intrusive

	Au	Ag	Bi	Nb	As	Pb	Cu	Zn	W	Cs	V	Ni	Co	Li	Ta	U	Th
Yak -7		0.177	0.130	7.03	23.8	22.7	37.8	82.2	7.31	1.47	88.0	43.0	19.3	31.1	0.471	1.23	4.18
-11		0.492	0.091	6.0	14.0	18.4	39.2	75.8	1.01	4.00	125	71.6	26.4	49.1	0.388	1.02	3.98
-23		0.243	0.088	10.1	22.1	22.1	44.1	78.8	1.44	3.12	128	58.8	13.8	43.9	0.607	1.10	5.08
-24		0.254	0.114	5.93	10.5	33.0	40.2	69.1	1.20	3.90	147	84.8	24.4	28.6	0.394	1.57	3.60
-25		0.266	0.111	8.94	21.4	17.6	52.0	82.5	1.05	4.80	147	84.3	23.1	46.3	0.508	1.39	6.15
Avg.	0.012	0.286	0.107	7.6	18.4	22.8	42.7	77.7	2.4	3.46	127	68.5	21.4	39.8	0.474	1.26	4.60
CV	4.8	4	13.4	0.4	9	2	1.1	1	2	2.3	1.4	1.4	2.4	1.6	0.4	0.6	0.5
-28		0.600	0.133	6.18	10.1	51.1	28.0	57.5	3.73	2.93	65.5	38.7	4.48	61.7	0.517	1.44	6.93
-29		0.243	0.142	9.67	11.5	28.5	36.0	66.7	1.32	2.42	95.9	49.0	6.89	4.68	0.810	0.51	4.88

-30		0.296	0.071	9.66	30.1	33.7	17.0	67.1	1.29	2.53	112	45.9	6.63	23.0	0.576	1.04	10.5
-31		0.210	0.061	10.9	15.2	35.2	23.5	89.9	1.36	4.27	122	47.9	7.00	29.6	0.570	1.39	15.0
-32		0.189	0.041	9.25	29.6	36.9	9.66	73.9	1.11	2.99	129	49.4	7.83	32.6	0.638	1.26	10.1
Cp.	0.015	0.308	0.089	9.13	19.3	37.1	22.8	71.0	1.76	3.03	105	46.2	6.57	30.3	0.622	1.13	9.48
CV	6	8	9	0.4	13	2	2.3	1.8	0.8	0.6	2.4	10	7	0.8	0.2	0.4	0.6
-33		0.260	0.348	6.28	28.1	26.2	26.8	26.8	2.56	2.37	131	31.7	1.31	42.0	0.840	0.72	7.19
-34		0.275	1.06	8.17	11.2	48.6	45.9	45.9	0.85	3.59	144	36.6	3.36	42.5	1.01	1.38	10.1
-35		0.235	0.274	7.36	11.0	46.8	54.1	54.1	0.72	2.73	142	39.0	4.37	13.4	0.500	1.21	9.92
-36		0.338	0.390	7.53	10.1	38.1	21.4	43.8	0.75	3.35	131	40.0	3.34	17.7	0.786	0.60	5.09
Avg.	0.02	0.277	0.518	7.34	15.1	39.9	37.0	42.6	1.22	3.01	137	36.8	3.10	28.9	0.784	0.98	8.08
CV	8	8	52	0.35	11	2	3.7	1	0.6	0.6	3	8	3	0.8	0.3	0.3	0.5
-37		0.204	0.206	12.7	9.51	39.9	19.6	62.1	2.27	7.64	122	39.2	2.24	57.2	1.06	3.01	14.0
-38		0.308	0.436	13.2	10.7	37.6	13.8	49.3	1.70	6.72	125	30.6	1.45	61.3	1.30	2.87	12.1
-39		0.266	1.18	11.5	12.4	26.5	26.8	53.7	3.47	7.59	134	35.8	2.22	78.9	1.08	2.12	13.4
-40		0.358	0.819	10.4	3.07	34.0	61.6	57.3	3.35	6.36	26.8	69.7	3.16	68.0	1.99	2.61	9.90
41		0.367	0.673	11.3	6.79	34.0	54.9	65.6	3.26	4.76	29.0	69.6	3.17	48.8	1.22	2.81	12.2
Avg.	12	0.301	0.663	11.8	8.49	34.4	35.3	57.6	2.81	6.61	87.4	49.0	2.45	62.8	1.33	2.68	12.3
CV		8	66	0.6	6	2	3.5	1.5	1.3	1.3	2	11	2.4	1.6	0.5	0.9	0.7

Notes. 7-25-gabbro-diorites; 28-32-gneiss-like granites; 33-36-granodiorites; 37-41 - two-mica granites.



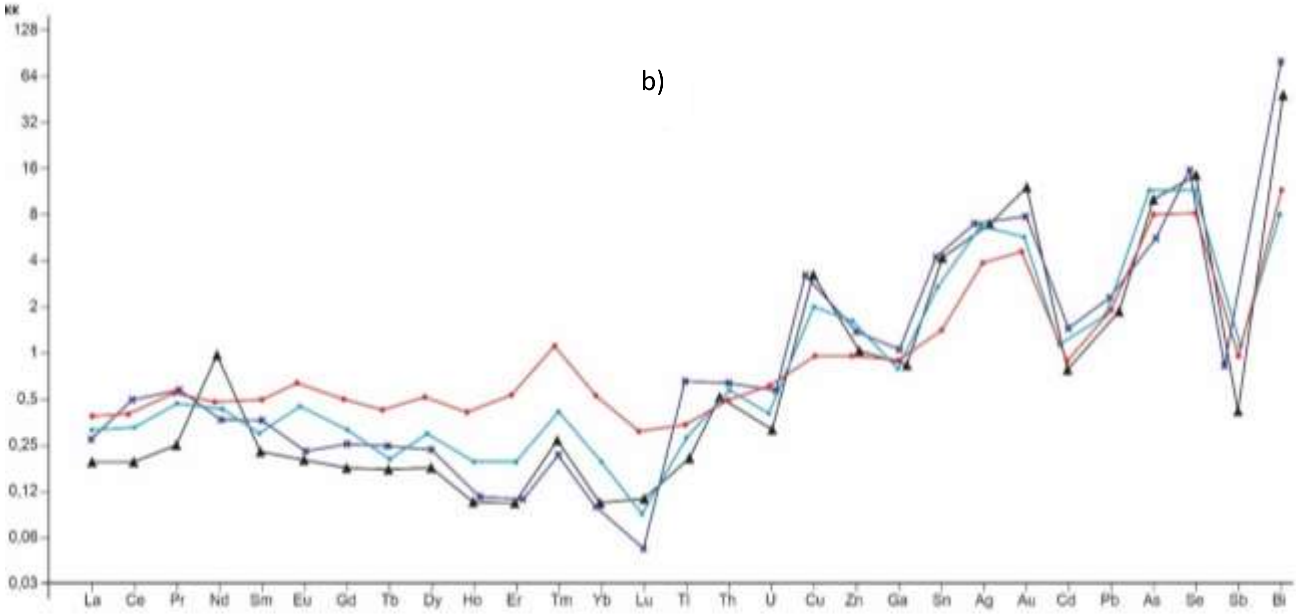
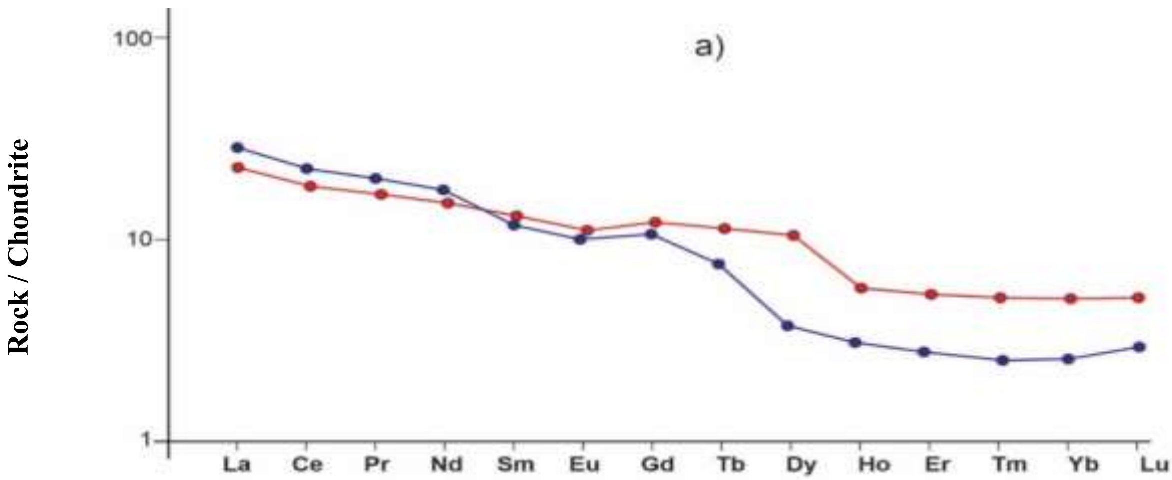


Figure 2: Variation diagram of ore-forming element distribution in the rocks of the Zinak intrusive. 1 - gabbro-diorites; 2 - gneissic granites; 3 - granodiorites; 4 - two-mica granites; 5 - Yakhton camptonites. *a) Li, Be, Rb, Sr, Cs, Ba, B, P, V,Cr, Mn, Co, Ni, Ta, Sc, Y, Mo, W; b) La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Tl, Th, U, Cu, Zn, Ga, Sn, Ag, Au, Cd, Pb, As, Se, Sb, Bi.*

The distribution of rare earth elements in the rocks of all four complexes comprising the Zinak intrusion is characterized by the predominance of light lanthanides over heavy ones (Table 1, Figure 3). In the rocks of the entire homodromic intrusive series, there is a distinctive flattening of normalized concentration lines in the light part of the rare-earth spectrum from La to Sm [9]. However, significant differences are observed in the medium and heavy lanthanide regions, allowing for the identification of two associations of intrusive rocks: early (gabbro-diorites of the Atkamar complex and gneissic granites of the Tym complex) and late (granodiorites of the Yakhton [10] complex and two-mica granites of the Ketmenchin complex). It is important to note the consistent absence of geochemical specialization for tungsten in the rocks of all four complexes.



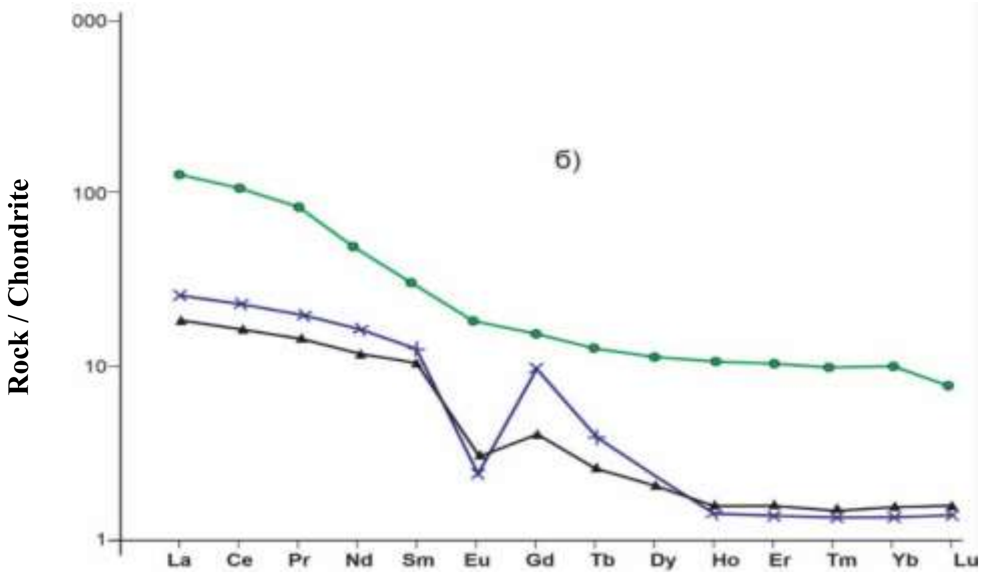


Fig. 3. *Distribution of rare earth elements normalized to chondrite in the rocks of the Zinak intrusive*
a) gabbro-diorites and gneiss-like granites;
b) granodiorites, dimica granites, and Yachton camponites Boynton standardization, 1984.

CONCLUSION

1.The polymorphic Zinaks intrusive is formed by rocks of two magmatic associations: the middle-late Carboniferous gabbro-diorite-plagiogranite and the early Permian granodiorite-leucogranite. The early magmatic association corresponds to the collisional regime of the region's geodynamic development, while the later one corresponds to the autonomous tectono-magmatic activation regime under intraplate conditions.
2. Magmatic associations are represented by a homodromic series of intrusive complexes, the early representatives of which (peridotites, gabbro and gabbro-diorites) are formed in high-temperature conditions, at considerable depths, by the differentiation of basaltoid melt, which is clearly recorded by the behavior of rare earth elements (the predominance of light lanthanides over heavy ones and the absence of a europium minimum).
3. Subsequent granitoid complexes are formed under conditions of crustal substrate melting, initially as a syntonic complex of magmatites and anatectites, represented by gneiss-like granites with a high degree of their discontinuity, cataclasis, and milonitization.
4. The influence on the formation of the heterochronous series of intructural complexes of the primary focus is clearly expressed by the transverse accumulation of the same elements (Au, Bi, As, Se, Ag) in the constituent rocks, which are part of the typomorphic productive association of gold mineralization in the granitoids of the Yakhton deposit, located 15-17 km southeast of the Zinak intrusive.

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