

RARE METAL GRANITES AND RELATED ROCKS OF THE UKRAINIAN SHIELD

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Two rare metal leucocratic granites, Perga and Kamennaya complexes, can be distinguished on the Ukrainian shield. The Perga complex consists of medium- and coarse grained, mainly porphyric, biotite, riebeckite and aegirine granites, granite porphyries, microclinites and albitites with rare metal mineralization (genthelvite, phenacite, tantalite, cassiterite and wolframite etc.). Granites from several stocks (up to 30 km²) in the northwestern part of the shield, situated along the fracture zone, restricted the large Korosten pluton of rapakivi granites to the northwest. The age of these granites (Pb-Pb and U-Pb methods on zircon and monazite) practically coincide with the age of rapakivi granites being 1750 Ma.

Within the Korosten complex of rapakivi granites we consider that zinnwaldite granites, which are characterized by fluorite and topazine mineralization, represent the final phase of pluton. These granites differ from the Perga ones by their low content of rare metals.

The Kamennaya Mogila complex lies in the southeastern part of the Ukrainian shield. It consists of biotite and muscovite-biotite, medium- and coarse-grained (also porphyric, and occasionally greisining) granites with rare metal mineralization (cassiterite, columbite, molybdenite, wolframite and beryl). Granites form several stocks (5-30 km²) situated 10-30 km to the west-northwest of the South-Kalchik gabbro-syenite-granite pluton. Granitoids in both of these complexes have similar isotopic ages (1800 Ma). Leucocratic subalkaline granites (the Novoyanisol type) are known within the pluton itself, occupying an intermediate position between the above mentioned in terms of mineral and geochemical composition.

The gabbro-syenite-granite formation of the Nearzov region has a substantial similarity to the anorthosite-rapakivi-granite formation. In this respect the relation of each of them to rare metal granites is rather remarkable. This relation is, most probably, not only spatial, but also genetic. The typical rare metal granites are situated not in the parent plutons but at some distance from them.

Key words: granites, mineral composition, chemical composition, rare earths, Ukrainian shield, Proterozoic, Ukraine.

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GEOLOGY OF THE STUDY AREA

Perga and Kamennaya Mogila complexes represent leucocratic granites. These complexes are located in the Nearazov region and in the northwestern parts of the Ukrainian shield (Fig. 1). The Perga complex is in association with the Korosten gabbro-anorthosite-rapakivi-granite pluton and the Kamennaya Mogila complex with the South Kalchik gabbro-syenite-granite pluton.

The Korosten pluton (12,000 km²) mainly consists of hornblende-biotite and biotite rapakivi granites. However, coarse layered bodies and massifs (15-1,250 km²) of anorthosites, gabbro anorthosites and gabbro-norites also occur within these rapakivi granites. The geophysical data indicates that some sub-horizontal acid and basic rocks alternate in this chonolithic intrusion (Sollogub

et al. 1968).

Granitoids of the pluton are represented by several phases. The earliest one we assign pyroxine-hornblende-rapakivi with occasional fayalite that developed in contact with gabbro-monzonites near the peripheral parts of gabbro-anorthosite massifs. The second and the main intrusive phase is represented by hornblende-biotite and biotite rapakivi granites. Several facies can be distinguished in this main phase and these facies can be differentiated from each other in terms of structure and composition. The third phase is represented by biotite granite-porphyrries and syenite-porphyrries that form stock-like bodies and dykes within exo- and endocontacts of pluton. The fourth phase can be referred to albitized fluorite-topaz-bearing biotite granites with slightly expressed rare metal specialization (the Lezniki granites).

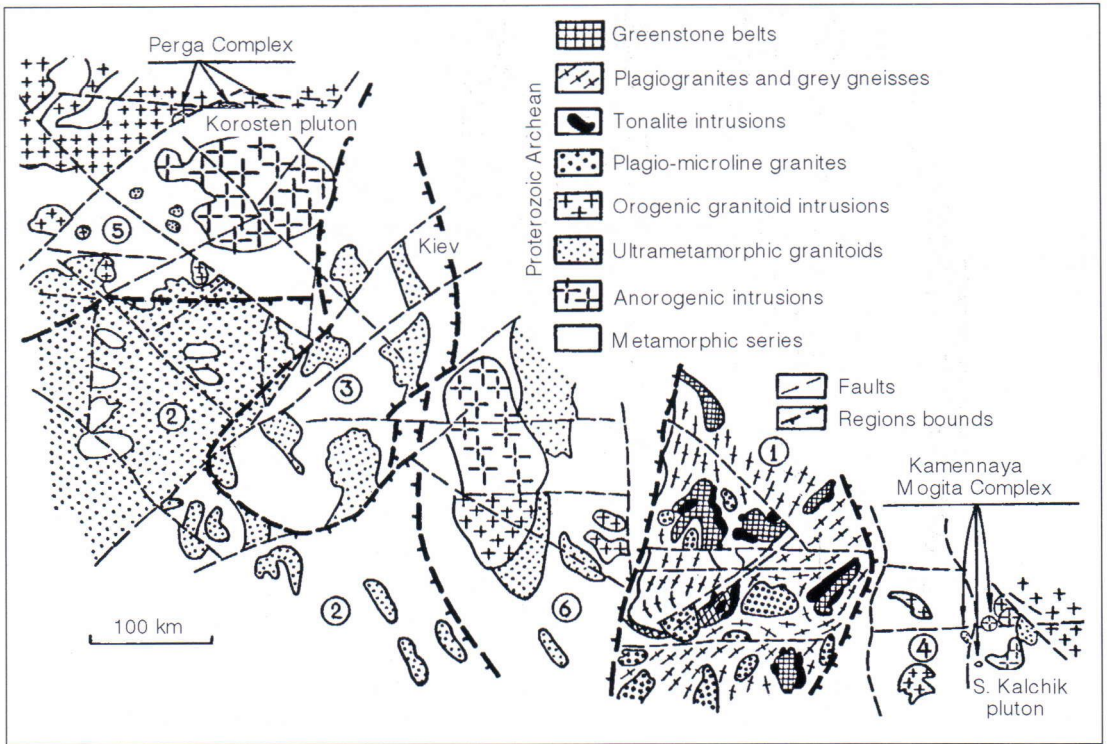


Fig. 1. Ukrainian shield, regional geological setting. Small intrusions of rare metal leucocratic granites (Perga and Kamennaya Mogila) are also indicated. Regions of the shield (numbers in circles): (1) granite-greenstone Near-Dnipro, (2) granulite-gneiss Dnistr-Bug, (3) diaphthoresic granulite-gneiss Ros-Tikish, (4) diaphthoresic granulite-gneiss Nearazov, (5) granite-gneiss North-Western, (6) granite gneiss Ingulo-Ingulets.

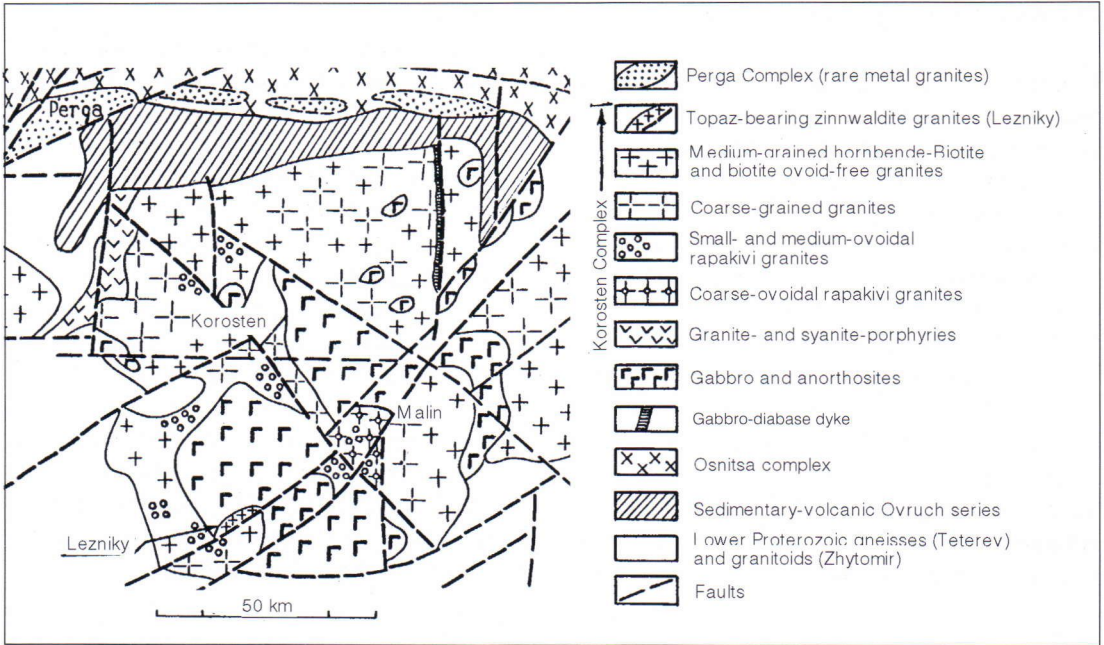


Fig. 2. Geological sketch of the Korosten pluton and Perga massifs.

Some workers consider that a typical rare metal suite of Perga granites was originated during the same phase as the rare metal suite in the Korosten complex connecting these suites with late differentiates of same magmatic source. However, considering all petrographical and geochemical data presented below the Perga granites, unlike the Lezniki ones, are an independent complex.

Granites of the Perga complex consist of several stocks in the northeast-southwest trending Sushchany-Perga tectonic zone and in the zone of the sublatitudinal South Pripyat fault (Fig. 1). The Korosten pluton and adjacent Ovruch depression, consisting of platform volcanogenic sedimentary formations (Fig. 2), restrict the fracture zones in the north. The largest and the most investigated Perga stock is a body stretching for 30 km along the fracture zone with a maximum width of 12 km and a total area of almost 20 km² (Fig. 3). The stock's northern part which is up to 5 km wide, consists of occasional leucocratic medium- and coarse-grained pegmatoid in the Khochin granites. The massifs southwestern part consists of middle- to fine-grained Lvovky granites and its southeastern parts of

porphyritic Sirnitsa granites. The Perga granites compose, in fact, the stock's central part by rather wide (thousands of metres) zones of intensively altered (ablitized, greisenized) granites of the types named above. Zones (more than 2 km wide) of cataclized granites without obvious metasomatic character are situated near the stock's periphery. Hence, gradual transition can be observed between the typical Perga granites and granites of other types that belong to this complex. This is because of superposition of tectonic and metasomatic processes. Sharp boundaries between the granites hardly exist. They are especially rare in the central part of the stock.

The country rocks of the Perga complex are Palaeoproterozoic gabbroids and granitoids of the Osnitsa and Zhitomir complexes and volcanites of the Klesovo series. Gabbroids and granitoids of the Osnitsa complex surround the Perga stock from the north and west, granitoids of the Zhitomir complex and volcanogenic-sedimentary rocks of the Ovruch series from the south and southwest. As a rule, direct contacts between them are tectonic. Small xenoliths of porphyrites, quartz-porphyries, felsites

and dacite-porphyrries occur in Perga granites. In the central part of the stock the isometrically-shaped body of the Yastrebits syenites, surrounded by fine-grained granites occur. Metasomatites of various compositions are also developed in the central part (feldspathic, quartz-feldspar-micaceous and mica-quartz). Usually they form vein-like, up to 1-2 m thick bodies, among gneissose granites and are confined to near contact areas of rocks of various composition. Genthelvite mineralization is related to matasomatites.

The Perga granites are accompanied by the vein

complex with dominant granite porphyries forming vein bodies up to a few metres thick. Such vein of aplites, fine-grained granites, microclinites and albitites are widespread.

The Lezniki granites form a stock (about 14 km²) in the southeastern part of the Korosten pluton approximately 10 km away from its peripheral part (Fig. 2). This stock is confined to the contact zone of rapakivi granites with the largest Volodarsk-Volynsky gabbro anorthosite massif. No large bodies of albitized and greisenized granites, like Lezniki ones, can be found in the central and

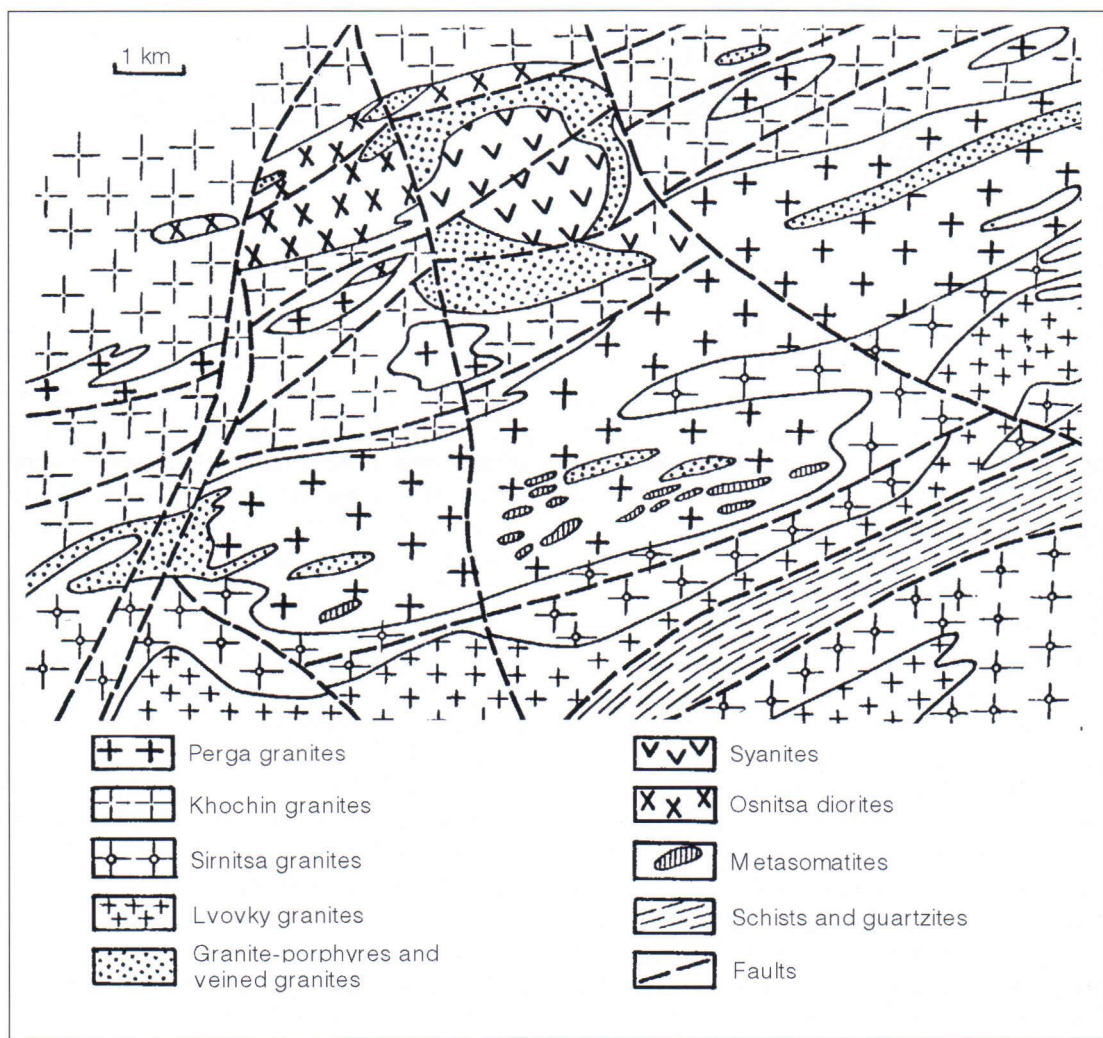


Fig. 3. Central part of the Perga massif.

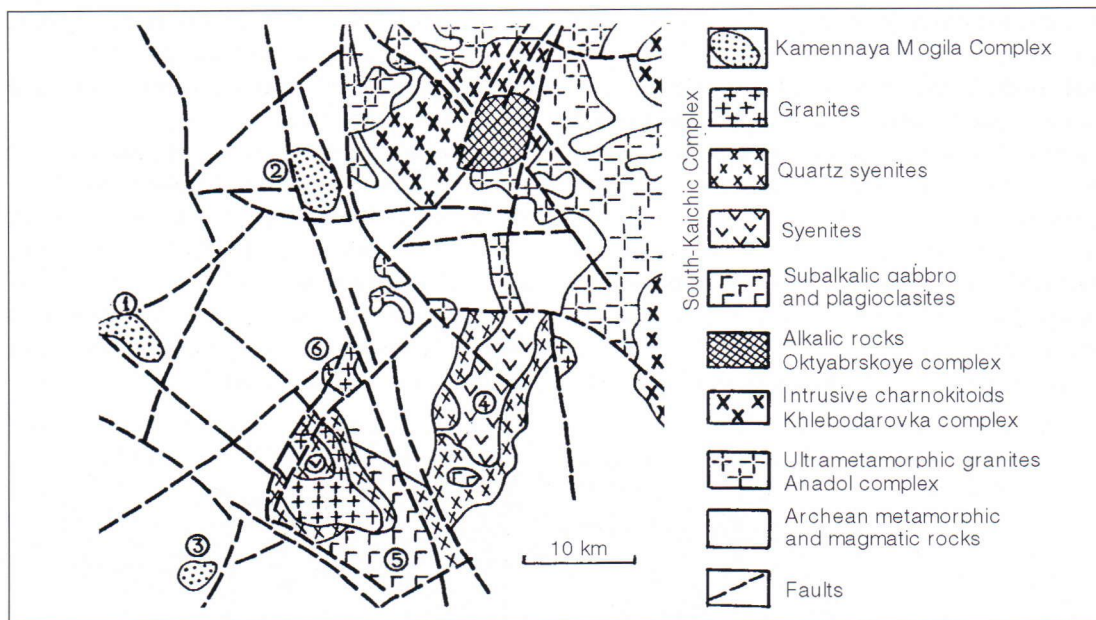


Fig. 4. Geological sketch of the Eastern-Nearazov region. Granite massifs: (1) Kamennaya Mogila, (2) Yekaterinovka, (3) Starodubovka, (4) Kremenevka, (5) Volodarskoye, (6) Novoyanisol.

northern parts of the Korosten pluton.

The South-Kalchik pluton with a total area of 330 km² consists of two intrusions. Though connected with each other, they are characterized by individual compositions (Fig. 4). Rocks of the Volodarskoye stock are represented by four phases: gabbro-syenite, syenite, granite syenite and veined rocks. These rocks are distinctly localized. Two intrusive phases can be distinguished in the Kremenevka massif, namely gabbro-syenite and granite-syenite. The small Novoyanisol stock occurs close to Volodarskoye intrusion and consists of amphibole-biotite granites with fluorite and rare metal specialization.

Granites of Kamennaya Mogilia complex form three stocks occurring at a 10-20 km distance to the west and northwest of the South-Kalchik pluton. The Kamennaya Mogila stock is a ovaly-shaped body with an area of 11 km², stretching from the southeast to the northwest along the Kamennaya Mogila fracture zones. This stock is confined to the intersection zone with sub-meridional fracture. The relationship of the granites with the country gneiss-migmatic section of the western Nearazov series

(Archean) is distinctly cross-cutting. The stock has a zonal structure: the central part is composed of coarse-grained biotite-granites with occasional pegmatite whereas the peripheral part is fine-grained and greisenized. Greisenization decreases with depth and at a depth of 80 m granites are not altered at all. At the stock's periphery aplite-pegmatoid veins are widespread.

The Yekaterinovka stock is 30 km². Its zoning is not distinctly expressed, though it can be observed that the same arrangement of zones of metasomatism and veined aplite-pegmatoid granites exists. The Starodubovka stock (4,5 km²) is slightly elongated in a sublatitudinal direction.

It is shown below that a definite difference exists between granites of the Kamennaya Mogila and South-Kalchik (Novoyanisol) types and this allowed them to be assigned to different complexes.

PETROGRAPHY AND MINERALOGY

All the granites investigated are red or pink-red of various degrees. The whole rock chemistry of

Table 1. Whole rock chemistry of granitoid samples.

GRANITOID COMPLEX	PERGA							KOROSTEN		KAMENNAYA MOGILA			SOUTH-KALCHIK	
GRANITE TYPE	Biotite	Aegirin	Riebeckite		Biotite		Granite-porphry	Biotite		Biotite			Hornblende-biotite	
LOCALITY	Perga	Perga	Perga	Lvovky	Khochin	Simitsa	Perga	Lezniky		Kamennaya Mogila			Kalchik	
OXIDES, %														
SiO ₂	75.66	73.53	75.34	74.15	76.90	73.32	74.83	74.77	76.08	71.80	75.22	74.11	71.30	76.84
TiO ₂	0.18	0.18	0.21	0.19	0.10	0.29	0.24	0.22	0.16	0.13	0.03	0.07	0.33	0.04
Al ₂ O ₃	11.55	13.63	12.30	12.57	12.20	13.04	12.45	12.02	11.78	14.10	13.50	13.60	13.53	12.21
Fe ₂ O ₃	1.37	0.64	0.70	1.02	0.24	1.01	0.55	1.21	0.81	1.10	0.45	0.25	0.53	0.19
FeO	1.08	1.42	1.58	1.82	1.29	1.70	1.89	1.08	1.00	2.40	0.35	1.08	2.88	0.72
MnO	0.02	0.03	0.03	0.01	0.02	0.03	0.00	0.02	0.02	0.04	0.01	0.02	0.03	0.00
MgO	0.20	0.17	0.40	0.32	0.01	0.21	0.00	0.00	0.24	0.20	0.16	0.16	0.08	0.24
CaO	0.48	0.54	0.34	0.13	0.47	1.31	0.45	0.79	0.90	0.90	0.68	0.68	1.56	0.34
Na ₂ O	2.90	3.74	3.76	2.79	3.39	2.80	3.30	3.10	3.18	3.70	5.16	4.52	3.52	3.14
K ₂ O	5.34	5.19	4.53	6.25	4.70	5.23	5.26	5.76	4.82	3.70	3.30	3.90	4.96	5.48
P ₂ O ₅	0.06	0.02	0.06	0.02	0.06	0.16	0.06	0.00	0.00	0.10	0.08	0.00	0.15	0.06
H ₂ O-	0.00	0.22	0.00	0.00	0.11	0.25	0.02	0.00	0.00	0.00	0.00	0.00	0.10	0.00
l.d.t	0.59	0.54	0.64	0.59	0.23	0.47	0.30	0.69	0.50	1.30	0.64	0.87	0.16	0.36
TOTAL	99.43	99.83	99.89	99.86	99.72	99.82	99.35	99.66	99.49	99.47	99.58	99.26	99.13	99.62
TRACE ELEMENTS, ppm														
V	3	5	3	25	10	5	10	7	3	4	3	3	3	6
Cr	7	0	6	30	30	10	6	5	5	6	8	5	5	12
Co	3	0	3	2	0	1	0	3	3	3	0	3	3	3
Ni	5	5	5	5	40	2	5	5	5	5	5	5	0	5
Cu	8	15	5	10	10	10	30	5	5	5	30	7	5	5
Zn	50	215	100	20	30	100	100	30	80	100	30	30	30	10
Pb	24	95	52	10	60	20	40	66	52	70	70	76	76	13
Sn	34	40	21	1.5	20	6	100	3	5	37	14	21	14	7
Mo	3	30	3	0	10	10	2	3	4	1	21	1	210	170
Li	180	300	190	10	400	85	600	110	46	960	66	97	180	40
Rb	580	650	590	260	1200	400	1000	270	380	830	450	520	600	90
Sr	40	30	40	100	15	50	20	50	50	120	30	30	400	200
Ba	80	15	50	400	20	400	20	250	130	110	30	50	40	40
Zr	585	860	600	500	500	1000	100	440	450	150	120	-	20	30
Nb	135	120	150	10	50	30	100	45	50	50	60	-	4	1
Y	160	185	200	0	150	100	150	80	85	90	100	-	5	3
Be	6	20	6	0	1	7	10	6	6	20	4	8	10	3
F	1700	5000	2000	200	1600	1040	5000	1800	1800	3000	2400	1500	220	90

ganitoid samples are presented in Table 1. Granites have medium- to coarse-grained porphyric structure and massive texture. However, in some varieties of the altered Perga granites the texture is banded. The typical Perga granite has the following mineral composition: microcline-perthite 45-50%, albite or albite oligoclase 5-10%, quartz 33-37%, mica up to 8%. Depending on the composition of dark-coloured minerals, annite, siderophyllite (the most widespread), aegirine, arfvedsonite and riebeckite can also be distinguished in the Perga granites. Secondary minerals are muscovites, apophyllites, cryolites and kaolinites.

The Lvovky granite, represented in marginal facies of the Perga massif, is predominantly fine- and medium-grained. The Sirnitsa granite is characterized by porphyric structure and massive texture with a lesser degree of abtization whereas the Khochin granite is coarse grained and pegmatoid here and there. Bluish, bluish-grey and lilac quartz can be observed in all of the above mentioned granites; constantly in the Sirnitsa and Khochin granites, sporadically in the Lvovky granites whereas in the Perga granites only within small

parts adjacent to the zones of ore-bearing metasomatites.

The Lezniki granite (see fig. 1 for location) is rather homogeneous in its composition and structure. In comparison with Perga one, the Lezniki granite is characterized by the higher content of microcline-perthite (up to 60%) with very low content of dark-coloured minerals, represented almost entirely by annite (up to 20%).

Granites of Perga complex are characterized by a wide spectrum of accessory minerals. The following minerals are among them: zircon, fluorite, cassiterite, thorite and ferrithorite, molybdenite, columbite, bastnaesite, haematite, martite, leucocoxene, galenite, sphalerite, phenacite, genthelvite, gahnite etc. The most widespread are metamictic zircon, fluorite and thorite but their distribution is extremely irregular. The coarse-grained pegmatoid granites are poor in accessory minerals but areas of intense albitization, greisenization and silicification are highly enriched in such minerals.

In microcline of the Perga granites the abundance of anorthite component is not more than 1% and

Table 2. Biotite analyses.

LOCALITY	Perga			Kamennaya	Yakater-	Lezniky	South-
SAMPLE NR	18	21/1	1	Mogila km-16	inovka y-1	Lz-5	Kalchik wp-1
SiO ₂	36.38	36.90	37.14	36.20	34.30	34.20	33.92
TiO ₂	2.02	2.90	2.68	1.10	1.20	2.10	3.31
Al ₂ O ₃	14.02	14.00	11.64	20.10	20.60	16.40	15.87
Fe ₂ O ₃	5.38	5.10	10.01	9.00	6.00	5.90	2.13
FeO	25.89	25.20	21.45	18.00	23.30	25.90	30.03
MnO	0.32	0.30	0.36	0.40	0.30	0.20	0.35
MgO	0.43	1.00	1.12	0.70	0.50	0.50	2.61
CaO	1.23	0.10	0.05	0.10	0.01	0.00	0.42
Na ₂ O	1.10	1.10	0.40	0.90	0.20	0.20	0.15
K ₂ O	7.21	7.90	8.71	8.00	8.70	9.10	7.60
H ₂ O	4.98	3.80	4.04	3.60	3.90	3.70	3.55
F	1.09	2.30	3.10	2.10	0.80	2.40	0.08
Total(-0.42F)	99.59	99.63	99.40	99.32	99.37	99.59	99.99

albite ranges from 18% to 35%. An elevated abundance of albite is related to alkaline metasomatism. Microcline in Perga granite is extremely high in Rb (2550 ppm) and Cs (4 ppm) compared with microcline in Lezniki granite (Rb 890 ppm, Cs 2 ppm).

Micas of rare metal granites are represented first of all by the annite-siderophyllite series (Table 2) and characterized by high Fe / (Fe+Mg). Micas in the Perga biotite granites are typical annite with Al_2O_3 abundances of 11.64%-14.02% and iron oxide totals of 30.30%-31.27%. In the aegirine and riebeckite-arfvedsonite Perga granites, the micas have lower Al_2O_3 (7.18%-10.26%) but higher TiO_2 (3.0%-3.42%) content (Buchinskaya and Nachayev 1990). In the Sirnitsa, Khochin and Lvovky granites, and also in granite porphyries, biotites have the lowest Fe / (Fe+Mg) for these rock series, similar to that of micas in granitoids of the Korosten complex (Lichak 1983).

Micas of the Kamennaya Mogila are represented mainly by siderophyllite with Al_2O_3 contents of more than 20%. More ferruginous biotite was separated from granites of the Yekaterinovka massif (Table 2). The South-Kalchik granites contain the most magnesian mica (up to 2.61% MgO), it is also characterized by an elevated content of TiO_2 (3.31%), low content of K_2O (7.60%) and low F (0.08%) abundances.

The metasomatically altered Perga granites quite often contain lithium micas (protolithionite and lithium phengite-muscovite) (Buchinskaya and Nachayev 1990). Inside large bodies of the Perga metasomatites and also in greisenized areas of pegmatites of the Kamennaya Mogila and Yekaterinovka massifs lithium micas, ferruginous lepidolite and zindwaldite occur. The biotites are also characterized by very high abundances of Rb (over 6000 ppm in Perga and up to 5000 ppm in the Kamennaya Mogila granites) and Cs (more than 200 ppm). Contents of these two elements in biotites from the Lezniki granites are 3000 ppm and 40 ppm, respectively.

All three massifs of Kamennaya Mogila complex are composed of the same type of coarse- to medium-grained porphyritic granites of the following

mineral composition: microcline and microcline-perthite 30-40%, albite and albite-oligoclase 25-30%, quartz 32-35%, biotite 2-7% and muscovite 2-10%. In greisenized varieties of granites muscovite abundance increases up to 15-20% and in quartz-muscovite-fluorite greisens up to 50-80%. Porphyritic phenocrysts up to 3-4 cm form microcline and microcline-perthite with incomplete lattice structure of the chess-spotted type. Microcline from all types of rare metal granites are characterized by very low natural and X-ray thermoluminescence (Rokachuk 1988). Rb and Cs abundances in microcline from the Kamennaya Mogila granites are much lower (Rb 1640 ppm, Cs 1.2 ppm) than in microcline of the Perga granites. Abundances of these elements in alkalic feldspar from the South-Kalchik granites are also very low (Rb 500 ppm, Cs 1 ppm). One special peculiarity of the South-Kalchik granites is the presence of high-ferruginous amphibole related to ferrohastingsite. Amphibole is absent in the Kamennaya Mogila granites.

Muscovite in rare metal granites has an elevated Fe content (Fe + Fe_2O_3 more than 9%) with predominance of Fe^{2+} over Fe^{3+} . In muscovite from greisenized granites and greisens Fe^{2+}/Fe^{3+} is reversed and the total Fe contents are moderate. Zircon in Kamennaya Mogila granites is semi-transparent, yellow and it forms prismatic bipyramidal crystals of zircon type with proelongation close 2. Zircon usually has zonal structure metamict core. Metamictic zircon of the Perga granites forms rather coarse crystals of prismatic and bipyramidal habit and also irregular yellow, brown reddish brown and grey grains. High HfO_2 (3-5%) and heavy REE contents are characteristic of its composition.

Fluorite is represented by several generations. Green fluorite, forming irregular separations (up to 0.5 mm) between grains is characteristic of the early stages of metasomatic transformation; the distinctive feature of this fluorite is predominance of heavy rare-earth elements in its composition. In greisens and pegmatites purple-violet fluorite exists, and in the most low temperature metasomatites and hydro-thermolites a light violet-pink with predominance of light REEs in its composition.

PETROCHEMISTRY, GEOCHEMISTRY AND GEOCHRONOLOGY

According to the chemical composition rare metal granites of the Ukrainian shield are assigned to subalkaline leucocratic granites of K-Na series. They are characterized by high SiO_2 contents (71.80-76.90%), sums of alkaline oxides in the range of 7.40-10.12%, predominance of Fe over Mg ($\text{Fe}/\text{Mg} = 0.81-0.95$) and low CaO abundances (0.34 - 0.90%). As a rule, K_2O predominates over Na_2O . According to the general chemical composition these granites do not differ particularly from granites of the final stages of the Korosten (Lezniki) and South-Kalchik complexes. However, their difference concerning abundances of trace elements is rather noticeable.

First of all, all rare metal granites, apart from Lvovky granites, are characterized by high F contents (up to 5000 ppm). In the Lezniki granites of the South-Kalchik complex F contents are 1800 ppm, and in granites of the South-Kalchik complex it ranges from only 90 to 220 ppm (see Table 1). Granites of the Perga and Kamennaya Mogila complexes are distinguished by high contents of Sn (31-100 ppm), high abundance of Li (600-690 ppm), Be (up to 20 ppm), Y (up to 200 ppm) and Rb (up to 1200 ppm). In the Lezniki granites of the

Korosten complex contents of Sn is 3-5 ppm, Li 46-110 ppm, Be 6 ppm, Y 80-85 ppm and Rb 270-380 ppm. The South-Kalchik granites are distinguished by high contents of Mo (up to 210 ppm), high Sr abundances (200-400 ppm) and low contents of Zr (20-30 ppm), Nb (1-4 ppm) and Y (3-5 ppm).

High abundances of rare metal elements (REE) are characteristic of the rare metal granites investigated. In granites of other complexes (especially the gabbro-syenite-granite of the South-Kalchik complex) REE abundances are much lower (Table 3). The rare metal Perga granites have the highest abundance of heavy lanthanoids that differ them from the Lezniki granites of the Korosten complex. Chondrite-normalized REE plots (Fig. 5) show very large negative anomalies in the rare metal Perga and Kamennaya Mogila granites whereas in the Lezniki granites and especially in the South-Kalchik granites these anomalies are much lower.

Skobelev (1987) investigated lead isotope content in some samples of zircon from metasomatically altered granites and quartz-feldspar metasomatites of the Perga zone. According to his data, an age of 1675 ± 45 Ma was obtained reflecting the time when metasomatic process took place. Shcherbak *et al.* (1989) dated zircon from the Perga granites and obtained an age of 1760 Ma that practically coincides

Table 3. Rare-earth elements in granites (ppm)

GRANITE TYPE	Perga	Kamennaya Mogila	Lezniky	South-Kalchik
SAMPLE NR	6	111	2Lz	Sk
La	95	119	110	7.6
Ce	150	152	201	15.0
Sm	9.1	24	17.1	2.2
Eu	0.2	0.18	0.4	0.2
Tb	2.6	3.46	0.8	0.3
Yb	23	27	7.8	0.5
Lu	3.2	3.00	1.7	0.3

with the age values of rapakivi-granites (1760 Ma) and granite-porphyrries (1770 Ma) of the Korosten complex. The U-Pb dating for zircon from the Kamennaya Mogila granites obtained an age of 1800 ± 20 Ma that is approximately the same age obtained for granitoids of the South-Kalchik complex (Esipchuk *et al.*, 1992).

CONCLUSIONS

On petrographical and geochemical grounds the Perga and Kamennaya Mogila granites are assigned to the typical rare metal granites of lithium-fluoric

type (Kovalenko 1977). Ore mineralization in the Kamennaya Mogila granites is represented by quartz-fluorite veins with cassiterite and also by metasomatites with columbite, monzanite and beryls. One can find molybdenite in pegmatite and quartz veins, albitized granites and silicified migmatites. In greisenized granites, veined pegmatites and aplite-like granites columbite, tantalite, zircon and beryl also occur.

The Perga granites are first of all characterized by the development of quartz-feldspathic and quartz-micaceous metasomatites with particular mineralization of cassiterite, phenacite, columbite, zircon, bastnaesite, wolframite, molybdenite,

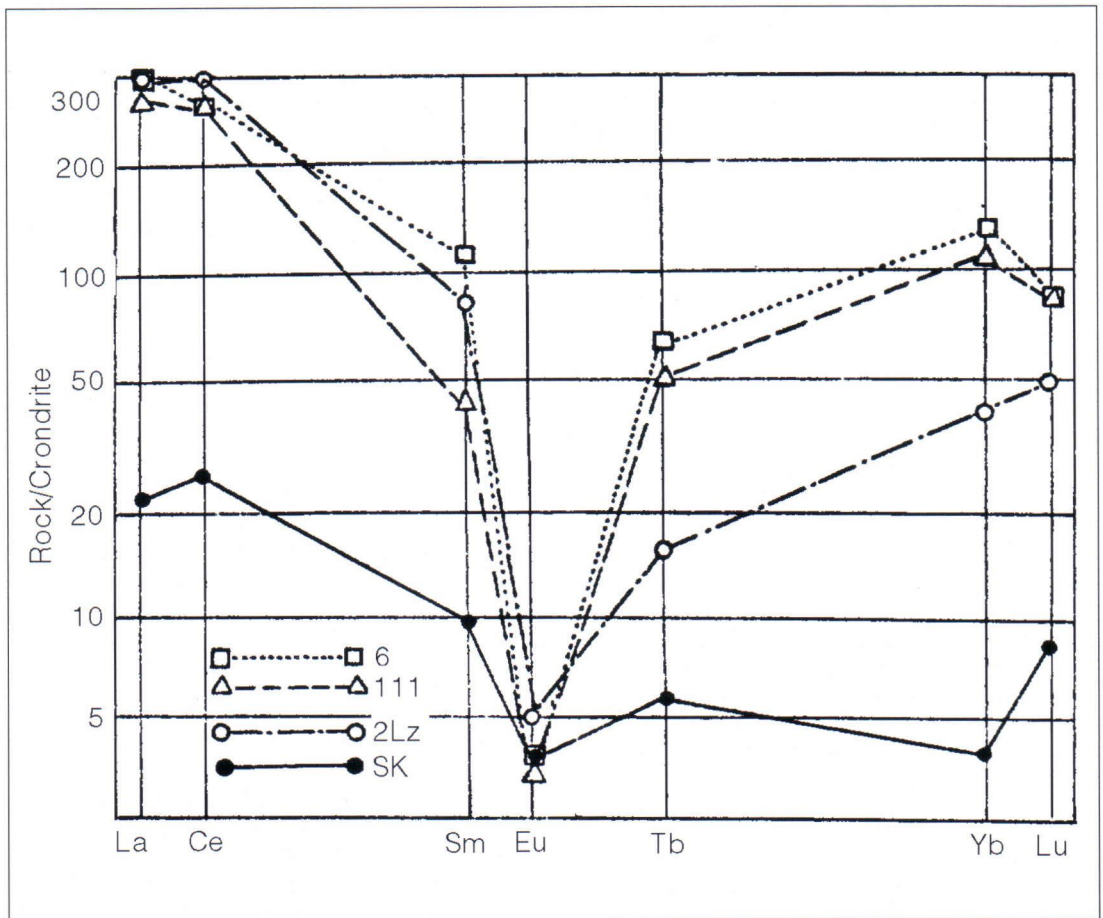


Fig. 5. Chondrite normalized REE patterns for granites investigated. Samples: 6 = Perga, 111 = Kamennaya Mogila, 2Lz = Lezniky, SK = South-Kalchik.

genthelvine. Sn and W occurrences of cassiterite-quartz ore formation and alluvial cassiterite placers were also discovered within the Sysychany-Perga zone (Metalidi and Nechayev 1983). There are several hypothesis on the genesis of the granites of metasomatic origin which we do not discuss in this paper. However, we consider that these granites are undoubtedly magmatic formations.

Kovalenko (1977), who investigated rare metal granites of Zabaikalye, Mongolia, Nigeria and also other regions, considered that rare metal granites were derived from crustal granite magmas of alaskitic composition. F abundance in them plays an important role. During crystallization magmas unsaturated with F generate rare metal granites of standard geochemical type but F-saturated magmas develop rare metal granites of the lithium-fluoric type. Crystallization of lithium-fluoric granites mainly took place under hypabyssal and near-surface conditions during repeated deroofing over the magmatic source, pressure lowering and changes of acidity-alkalinity. During magma crystallization residual melts were enriched in Li, Rb, Sn and some other elements. Afterwards elements such as W, Pb

and Zn were transferred to the fluid phase. During the whole crystallization process of lithium-fluoric granites Nb, Ta and Hf, abundances in the melts were high. The composition of residual fluid was enriched in H₂O, Li and K and silica, e.g. in those components which later took part in granitic greisenization.

We share the opinion of those researchers who consider rare metal granites of lithium-fluoric type (to which referred granites of Perga and Kamennaya Mogila complexes belong on the basis of geological, petrological, mineralogical and geochemical characteristics) to be derived from high-fluoric granite magmas, generated in the continental crust under the influence of abyssal fluid heat flows, and crystallized in an anorogenic situation. Formation of anorogenic gabbro-anorthosite-rapakivi-granite and gabbro-syenite-granite plutons predates their formation, although primary magmatic sources of them both were different.

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