PRECAMBRIAN NONMETALLICS OF KARELIA: CLASSIFICATION AND GEOTECHNOLOGICAL ASSESSMENT

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Nonmetallics have always played an important role in the technical progress of civilizations. Both rocks and individual minerals are taken into account when classifying nonmetals.

In Karelia, which occupies an area of 172.4 X 10^3 km^2, Precambrian nonmetallics are very important. They include deposits of the minerals muscovite, feldspar, quartz, kyanite, apatite, graphite, talc, and garnet, as well as metamorphic, igneous and sedimentary rocks such as granite, marble, gabbro and gabbro-diabase (natural stone), quartz porphyry, halleflinta, talc-chloritic slate, low- and high-carbon shungite, quartzite, picritic basalt and pyroxenite (products of rock casting), and carbonatites (Fig. 1). Some of the above nonmetals are regarded as multi-purpose raw materials.

Nonmetallics continue to be in great demand. A purely commercial approach to the study of mineral products may result in flagrant errors. The study of nonmetalliferous deposits should be based on both theoretical and practical progress made in stratigraphy, tectonics, petrology, magmatism, mineralogy, geochemistry and geophysics. Furthermore, both geologic-geophysical and technological estimations of available resources are highly significant.

The polycyclic evolution of Precambrian zones is responsible for some characteristics of the geological structure of the region. It is possible to reveal the system dynamics of interaction and evolution by elucidating the developmental pattern of nonmetallics. The nonmetalliferous system is largely controlled by lithostratigraphic, magmatic, structural, metamorphogenic and metasomatic factors.

In Karelia, there are good reasons for distinguishing the Belomorian, Karelian and Ladoga geoblocks as the first-order constituents of the crust of the Baltic Shield (1). This provides a basis for the concept of the block structure of Karelia's lithosphere. Each geoblock shows a unique evolution of metamorphic processes which is indicative of various types of metamorphism. According to (5), Karelia is characterized by the following types of metamorphism:

1. Ladoga: low-pressure andalusite-sillimanite type.

2. West Karelian: moderate-pressure kyanite-sillimanite type.

3. Belomorian-Lapland: high-pressure kyanite-sillimanite type.

The latter type, characterized by high pressure and slightly increased geothermal gradient values, was responsible for the unique regional pattern of mineral formation in the Belomorian geoblock. This implies that metamorphic complexes, most sterile geochemically, are related to relatively unique metamorphism. The pegmatites of the muscovite rock association, which contain among other varieties, a type of muscovite used in TV-sets, are generally recognized as rocks indicative of the economic significance of the Belomorian geoblock. Granulite-facies metamorphism, characterized by low partial water pressure in the fluid and regarded as the earliest metamorphism, has been locally reported from the Belomorian geoblock. Increasing temperature and decreasing pressure subsequently gave an impetus to melting processes. As a result the structures of migmatite terrains were formed on a large scale within a quasi-closed geological system without a substantial addition of major rock-forming components. A general evolutionary pattern of fluid regime is characterized by the increased H_2O and decreased H_2 content of the fluid and a decline in both the H_2/H_2O ratio and the reduction coefficient.

Another example is based on the geological and technological study of kyanite ores from the Kichano-Hizovaara zone. Mineral occurrences of the Hizovaara kyanite deposit reported from the link zone of the Belomorian and Karelian geoblocks have suffered the Belomorian - Lapland kyanite - sillimanite high-pressure type of metamorphism. Three types of ores are recognized: metamorphogenic, metamorphogenic-metasomatic, and metasomatic (3).

When constructing flow charts and estimating benefication regimes for kyanite ores, the ore types have been found to be technologically heterogeneous. Variable composition and superimposed secondary processes are responsible for a difference in the physico-mechanical properties of the rocks during crushing. Hizovaara kyanites are less easily beneficiated because of graphitization. The kyanite ores of the Kichanskaya Group are more technologically usable. See Appendix 1.

Complicated flow charts and highly toxic reagents are used to beneficiate feldspathic raw materials produced from pegmatites and to isolate microcline, plagioclase and quartz concentrates. Flow charts are simplified and the quality of concentrates is increased if acid volcanogenic rocks, metamorphosed under moderate-pressure conditions in the Karelian geoblock, are used as a source of feldspathic products. A flow chart, which includes flotation of iron-bearing minerals and micas, has been employed to produce quartz-feldspathic concentrates containing no more than 0.2% Fe_2O_3. No separation of feldspars is required because the rocks show either sodic (halleflinta) or potassic (quartz porphyry) compositions when in their native states.

The coarse-grained syenites of the differentiated Yeletozero intrusion were subjected to stadial electromagnetic separation on high-intensity field separators to produce concentrates containing 0.10 - 0.15% iron. The technological value of Yeletozero raw materials is largely due to some petrological characteristics of intrusive terrains, notably higher temperature conditions. See Appendices 2 and 3.

Valuation of Karelia's graphite deposits has shown that ores represented by unaltered biotite gneisses and migmatites with alkaline metasomatites are easily beneficiated. The carbon content of concentrates is 90-95%, with 92-97% of the graphite extracted. Graphite ores from diaphthoretic (i.e., retrograde metamorphism) zones show low technological indices. See Appendix 4.

Based on the stepwise geological evolution of the Precambrian in Karelia, three distinct epochs of apatite formation (Lopian, Karelian, and Riphean) are recognized:

Lopian epoch. It has been shown by studying the Ondozero block that increased apatite concentrations are characteristic of gabbro-pyroxenite and gabbro-diorite magmatic formational types. This type of mineralization is most easily beneficiated.

Karelian epoch. This epoch is represented, for example, by apatite-bearing calcitic carbonatites of the Tiksheozero alkaline terrain. Preliminary data obtained for the above terrain corroborate the fact that relatively simple equilibrium pure mineral systems (apatite-calcite, apatite-magnetite-calcite, apatite-magnetite-phlogopite-calcite) are formed in the course of alkaline magma generation in a generally impoverished geochemical setting. Pure mineral systems substantially facilitate beneficiation. A flotation chart was used to isolate apatite concentrates (P_2O_5 content 36.0-38.8%, with 60-70% of the P_2O_5 being extracted) from carbonatites. Also, calcitic concentrates were produced. See Appendix 5.

Riphean epoch. In the Ladoga geoblock, this epoch is represented by the alkaline rocks of the Elisenvaara Group which, according to (2), belong to the potassic series. It has been shown that barium-and strontium-bearing feldspar and apatite, biotite, sphene and other types of concentrates can be produced by beneficiation.

The unique evolutionary pattern of the Earth's crust in the Karelian geoblocks is taken into consideration when evaluating nonmetallic deposits. The early Archean granite-migmatite areas of ultrametamorphism, which show increased tectono-metamorphic (metasomatic) protoactivity, are characterized by muscovite, feldspar, quartz and kyanite. Some commercial minerals such as apatite, kyanite, graphite and garnet and commercial rocks such as halleflinta and talc-chloritic slates were formed in Archean granite-greenstone complexes. The Karelian complex contains some commercial rocks, such as low- and high-carbon shungites, quartzites, dolomites and marbles. A number of nonmetallics such as apatite-bearing calcitic carbonates and barium- and strontium-bearing feldspars resulted from intrusive activity, as did building materials including granite, gabbro, gabbro-diabase and charnockite.

References

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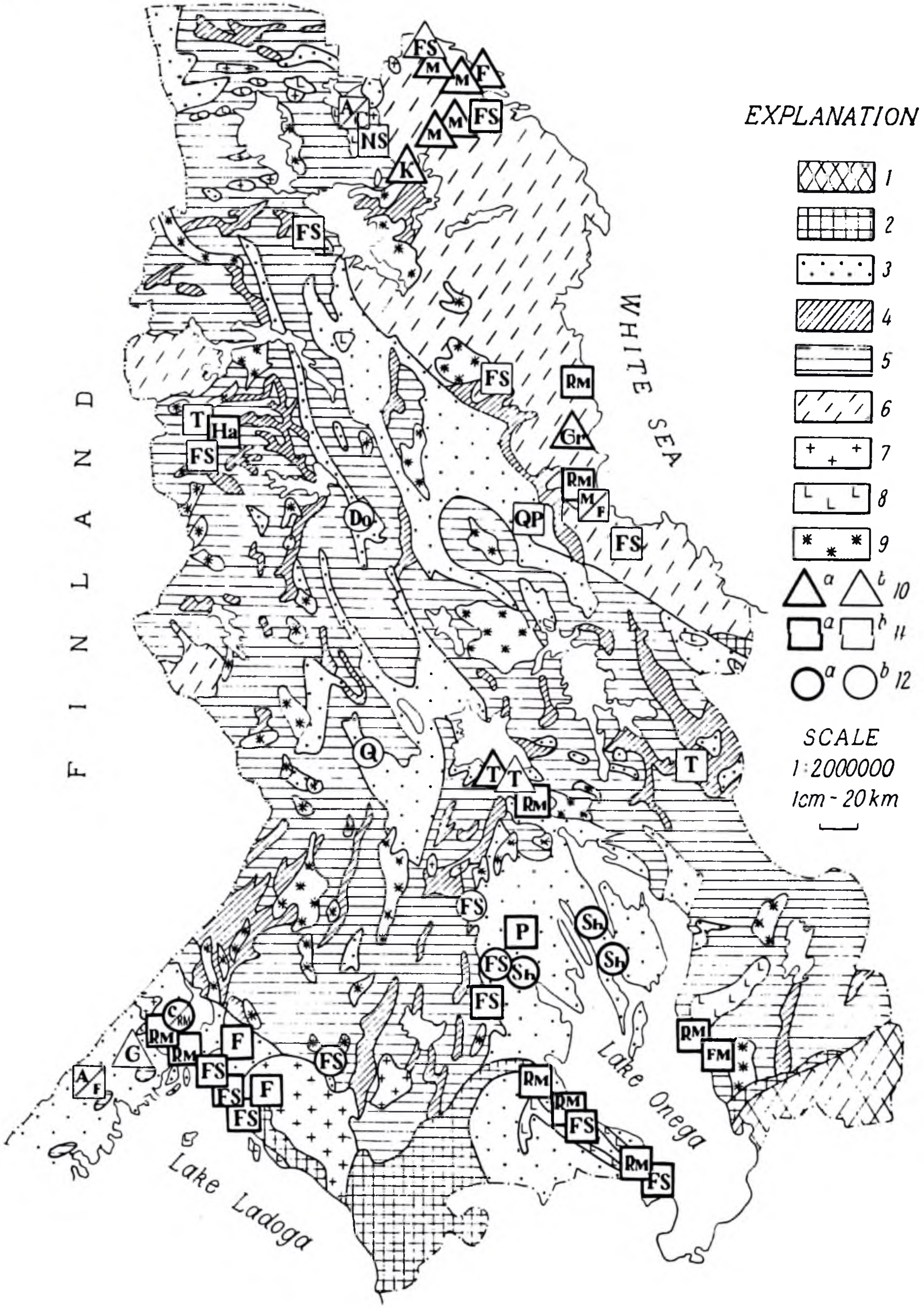
EXPLANATION
1
2
3
4
5
6
7
8
9
a
b
10
a
h
11
a
b
12
SCALE
1:2000000
1cm - 20km
FINLAND
WHITE SEA
Lake Onega
Lake Ladoga

Figure 1. Distribution of major Precambrian nonmetallics in Karelia (Geologic sketch map modified from Stenar, 1989)

1 - Phanerozoic rocks. Precambrian strata: 2 - Vendian and Riphean; 3 - Karelian; 4 - Lopian; 5 - non-divided Lopian and Saamian; 6 - Saamian. Intrusive complexes: 7 - Proterozoic granitoids; 8 - basalts and ultrabasic rocks; 9 - Archean intrusions. Deposits: 10 - metamorphic and ultrametamorphic genesis (a - mined or proven resources, b - potential resources); 11 - magmatic genesis (a - mined or proven resources, b - potential resources); 12 - sedimentary genesis (a - mined or proven resources, b - potential resources). Industrial minerals: K - kyanite, M - muscovite, F - feldspar and quartz-feldspar, Gr - garnet, T - talc, G - graphite, A - apatite, C - calcite. Industrial rocks: Ha - halleflinta, QP - quartz porphyry, NS - nepheline syenite, Q - quartzite, SH - shungite, Do - dolomite, FS - facing stone, RM - road metal, P - pyroxenite.

Type of metamorphism	Genetic variety	Feature of technological processes	Concentrates, % Content of Al_2O_3	Content of kyanite	Extraction of kyanite	Example of deposit
kyanite-sillimanite high-pressure	metamorphogenic	flotation	52-55	82-88	55-60	Northern lense
kyanite-sillimanite high-pressure	metamorphogenic metasomatic	flotation	56-57	88-90	65-70	Southern lense
kyanite-sillimanite high-pressure	metasomatic	magnetic flotation	53-55 52-54	84-87 82-87	60-61 58-60	Eastern and Fuksite
kyanite high-pressure	metamorphogenic	magnetic flotation	57.5-58.5	91.5-92.5	73-74	Kichan-skaja group

Appendix 1. Kyanite ores of Karelia

	1	2	3	4	5	6	7	8	9	10	11
SiO_2	57.26	57.18	57.98	59.40	59.06	59.14	60.00	57.18	56.78	59.59	59.69
TiO_2	0.82	0.64	0.64	0.86	0.82	0.77	0.90	0.45	0.85	0.90	0.85
Al_2O_3	19.45	19.60	19.60	16.22	16.82	16.43	18.20	20.77	19.77	18.03	17.80
Fe_2O_3	6.17	7.76	5.17	7.60	7.18	6.38	4.50	4.50	5.78	5.20	5.11
CaO	2.52	1.26	2.38	1.68	1.82	3.50	2.59	1.47	2.52	2.43	2.48
MnO	0.17	0.19	0.14	0.15	0.16	0.15	0.13	0.12	0.17	0.17	0.16
MgO	0.85	0.30	0.60	0.70	0.80	1.00	0.73	0.42	0.80	0.69	0.81
Na_2O	6.45	6.17	6.45	6.17	5.71	5.77	6.31	8.15	6.66	6.08	6.15
K_2O	6.06	6.54	6.55	6.70	7.00	6.07	5.84	6.29	6.05	6.40	6.22
H_2O	0.06	0.41	0.13	0.26	0.24	0.30	0.10	0.12	0.27	0.13	0.09
L.o.i.	0.77	0.56	0.60	0.33	0.51	0.46	0.55	0.69	0.56	0.73	0.69
Total	100.58	100.61	100.24	100.24	100.12	99.87	99.85	100.10	100.21	100.35	100.04
Na_2O+K_2O	12.51	12.71	13.00	12.87	12.71	11.84	12.15	14.44	12.71	12.48	12.37
$K_2O:Na_2O$	0.94	1.06	1.02	1.09	1.23	1.05	0.92	0.77	0.91	1.05	1.01

Appendix 2. Chemical composition of alkaline syenite of Eletozero massif (wt. %)

N	Output	Content			Na_2O+K_2O	$K_2O:N_2O$
		Fe_2O_3	Na_2O	K_2O		
1	62.28	0.25	7.40	6.71	14.11	0.91
2	69.80	0.30	7.40	7.46	14.86	1.01
3	63.51	0.27	7.43	7.32	14.75	0.99
4	64.61	0.20	6.94	7.04	13.98	1.01
5	61.40	0.27	6.57	7.42	13.99	1.13
6	64.40	0.26	6.94	6.67	13.61	0.96
7	67.40	0.23	7.40	6.53	13.93	0.88
8	75.10	0.34	8.94	6.53	15.47	0.73
9	65.90	0.20	7.00	6.31	13.31	0.90
10	69.70	0.16	7.00	6.90	13.90	0.99
11	66.80	0.10	7.00	6.67	13.67	0.95

Appendix 3. Technological indices of concentrates from alkaline syenite of Eletozero massif

Type of metamorphism	Feature of technological processes: Fraction of grinding before the main flotation	Quantity of purifications	Quantity operations of additional grinding	Main indices of concentrates, percent: Degree of separation of graphite aggregates	Content of carbon	Extraction of carbon
unaltered	50-60%	3-5	1	75-80	92.43	91.57
Biotite gneisses	class-0.07 mm					
retrograded	"	5	2	65-70	90.51	87.58
Migmatites	"	3-5	1	75-78	95.00	94.58
Alkaline metasomatites	"	3-5	1	70-75	86.65	94.23

Appendix 4. Graphite ores of Karelia

N	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	H_2O	L.o.i.	P_2O_5	S	Total	CO_2
1	4.87	0.39	0.61	3.05	3.12	0.20	3.55	42.85	0.47	0.39	0.18	35.15	4.90	0.19	99.63	34.0
2	4.56	0.31	2.19	3.51	3.23	0.093	3.28	45.36	0.49	0.38	0.12	31.02	4.48	0.02	00.62	29.84
3	3.62	0.16	3.18	3.75	2.72	0.215	3.78	43.76	0.31	0.57	0.19	33.21	4.32	0.17	99.78	30.34

Appendix 5. Average chemical composition of carbonatites of Tiksheozero massif