

PETROPHYSICAL PROPERTIES OF ROCKS OF THE NORTHERN LADOGA

Y. V. Taran^{*1}  and I. M. Aleshin^{1,2} 

¹Schmidt Institute of Physics of the Earth of Russian Academy of Sciences, Moscow, Russia

²Geophysical Center of Russian Academy of Sciences, Moscow, Russia

* **Correspondence to:** Yana Taran, taran@ifz.ru.

Abstract: Northern Ladoga is a region of Southeastern Fennoscandia with complex geological and tectonic structure. It is crossed by the Raakhe–Ladoga junction zone of the Karelian craton and the Svecofennian orogen. Analysis of existing data on the petrophysical properties of rocks in the region was carried out as part of a complex geophysical modelling of Northern Ladoga. Based on these data, a summary table of the properties of the rocks of the Northern Ladoga region was compiled using modern geological maps.

Keywords: Fennoscandia, Northern Ladoga, petrophysical properties, Raakhe–Ladoga zone.

Citation: Taran, Y. V. and I. M. Aleshin (2025), Petrophysical Properties of Rocks of the Northern Ladoga, *Russian Journal of Earth Sciences*, 25, ES4003, EDN: ILJGBB, <https://doi.org/10.2205/2025es001022>

1. Introduction

Structure of evolution of Precambrian complexes is one of the main problems of modern geology. Southeastern Fennoscandia is the largest area of basement rocks outcrop in Russia. It has been of particular interest for geological and geophysical research since the 1940s to the present day.

The territory of the Northern Ladoga region consists of tectonic structures of various composition and genesis. The southeastern part belongs to the Late Paleoproterozoic intracontinental orogen, the South Finland granulite belt, containing shales and gneisses of granulite and amphibolite facies with the presence of sulfides and carbon. The North-western – the Raakhe–Ladoga zone of junction of the epi-Archean Fenno-Karelian Craton and the Paleoproterozoic Svecofennian [Proterozoic. . . , 2020] This tectonic seam within the Northern Ladoga Region is also known as the Meyeri thrust zone [Baltybaev and Vivdich, 2021]. It has a length of about 40 km and a width of up to 20 km. Its complex structure is characterized by alternation of gneisses, migmatites, and crystalline schists erupted by numerous Archean granite-gneiss domes and Proterozoic intrusions [Morozov et al., 2024].

The complex structure of the region is clearly manifested in the form of contrasting anomalies of the geophysical fields. Regional and local geophysical research in the Northern Ladoga region has been conducted since the middle of the 20th century. One of the most notable results of recent years is the MT/MV soundings profile Vyborg–Suoyarvi [Sokolova et al., 2016]. In 2025 researchers from Schmidt Institute of Physics of the Earth RAS are planning an aeromagnetometric UAV survey along the part of this profile crossing the Raakhe–Ladoga zone. Geological and geophysical model of this area will be built based on these results and other previous geophysical studies, including a regional map of gravitational anomalies. Thus, in order to solve this problem, it became necessary to create a unified database of petrophysical properties of rocks of the Northern Ladoga region.

2. History of studying the petrophysical properties of rocks in Southeastern Fennoscandia

Today, despite the long history of studying the east of the Fennoscandian Shield, petrophysical data on the rocks of the Ladoga region are quite limited. This is due to the fact that the main attention of researchers was previously focused on the more developed

RESEARCH ARTICLE

Received: May 19, 2025

Accepted: June 20, 2025

Published: June 30, 2025



Copyright: © 2025. The Authors.

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

minerogenic areas of the northeast of the region [Goev *et al.*, 2023]. In addition, the process of regular sampling of rocks in this shield area is difficult due to the increased spread and thickness of sedimentary and fluvio-glacial rocks, as well as the large areas of the lakes. The results of systematic petrophysical research conducted in the Russian part of Fennoscandia since the early 60s, mainly by the forces of VSEGEI, IFZ RAS, geological institutes of the Karelian and Kola Scientific Centers of the Russian Academy of Sciences, St. Petersburg State University, St. Petersburg State University have been presented, for example, in publications [Geophysical. . ., 1968; Golod *et al.*, 1979; Petrophysics. . ., 1986; Stepanov *et al.*, 2013].

Over the following decades, the knowledge about physical properties and composition of Fennoscandian rocks was supplemented and analyzed by many researchers. One of the most significant in the framework of generalizing tasks are the works of Kischenko and Grishin [1991] and Grishin [1990] on the southeastern part of the shield. Also, the GGUP «Mineral» created a digital database for all samples taken at different times in the territory of Karelia. However, it covers only certain areas that were important for solving geological exploration tasks, and leaves a lot of blind spots for continuing systematic petrophysical research of the remaining territories of the eastern part of the shield.

The key stages in the further history of studying the physical properties and composition of rocks in this region were the construction of the Kola superdeep and Onega parametric wells [Onega. . ., 2011; Zhamaletdinov, 2020]

The petrophysical maps compiled under the guidance of N. B. Dortman [Petrophysical. . ., 1980] are still used today as the most complete generalization of the information obtained on the magnetic and density parameters of the rocks of Russian part of Fennoscandia.

N. B. Dortman's petrophysical maps were based on the materials of a long-term study of more than 200,000 rock samples from the eastern part of the shield. In addition, calculated data on the magnetization of rocks from maps of the anomalous magnetic field were used. Map legends distinguish petrophysical groups within geological formations according to the variation of the mineral or chemical composition of rocks and the percentage of rock-forming minerals.

3. Block structure of the Fennoscandian Shield according to petrophysical data

N. B. Dortman in [Petrophysical. . ., 1980] identifies crust blocks based on the differentiability of the physical properties of rocks due to the peculiarities of the manifestation of mantle and crustal movements and thermodynamic regimes. The petrophysical zoning of the shield proposed by the authors largely coincides with the generally accepted tectonic one. According to the set of petrophysical parameters, five megablocks were identified: Murmansk, Kola, Belomorsky, Karelian and Ladoga. Within the megablocks, large Archean blocks and troughs, Early Proterozoic trough structures and synclinal zones are clearly distinguished by the difference in density and magnetic characteristics. The border between the southwestern part of the Karelian and Ladoga blocks runs through the territory of Northern Ladoga region. Unfortunately, in N. B. Dortman's work, due to the limited amount of field data available to the authors, the Ladoga block of interest is characterized and dissected noticeably weaker than the others.

N. N. Kolesnik highlights another, more detailed scheme of the block structure of South Karelia in accordance with petrophysical parameters and the nature of geophysical fields in his work [Kolesnik, 1984]. He concludes that there are arched uplifts of the Moho surface up to 30–35 km within the Ladoga and Onega megablocks, suggesting further division of the latter into smaller, submerged or lowered blocks. On the territory of Ladoga region, these are: Salminsky and Vyborsky blocks of sialic type, with a thick granite layer of potassium granite massifs, including rapakivi $\sigma = 2.55\text{--}2.65\text{ g/cm}^3$; the Ladoga block of the femic type, characterized by crustal basification and a reduced granite layer of the diorite-enderbite series with $\sigma = 2.75\text{--}2.85\text{ g/cm}^3$; the Suoyarvi block of long-term uplift with a thick granite layer $\sigma = 2.58\text{--}2.62\text{ g/cm}^3$. According to N. N. Kolesnik, this structure

is confirmed by the sharp contrast of alternating positive and negative anomalies of the gravitational field and the presence of large magnetic anomalies of high intensity.

Cluster correlation analysis of anomalous components of potential fields based on 1:1,000,000 scale maps in the GISIntegro system allowed to identify 4 characteristic clusters. According to the designations in Figure 1: (1) – areas of weak negative gravitational anomalies and strong magnetic ones created by rocks of Archean tonalite complexes, heavily processed in the Proterozoic; biotite gneisses, karelian crystal shales; (2) – positive gravitational anomalies and weakly negative magnetic ones caused by gabbrodiorites and karelian potassium-granite complexes; Ludikovian volcanogenic-sedimentary rocks; (3) – strong magnetic anomalies against the background of zero gravitational effect, confined to granite and granulite karelian and metamorphosed quartzites of earlier age; (4) – weak negative magnetic and gravitational effects are observed in Archean granites and plagiogranites, as well as various rocks of Karelian age: granodiorites, monzodiorites, gabbro et al.

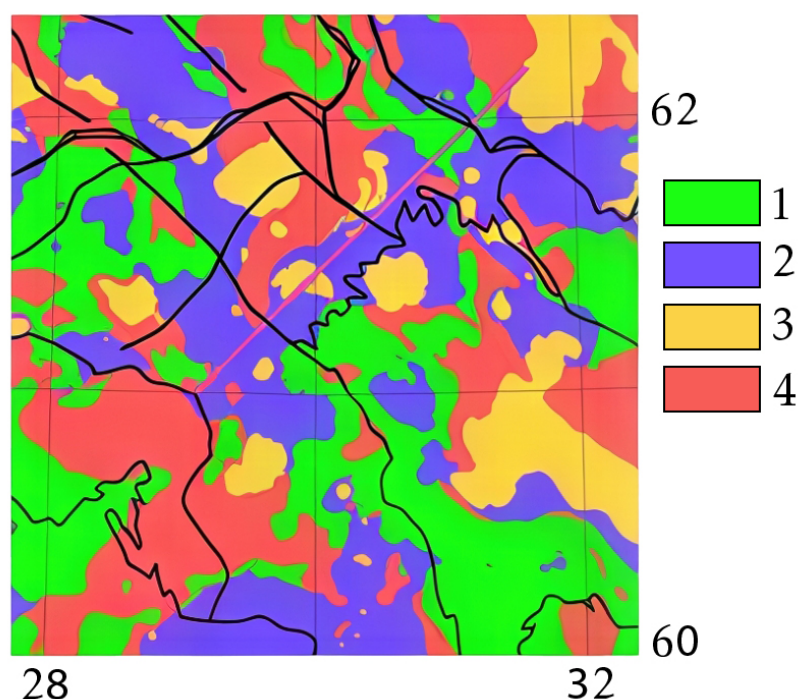


Figure 1. Cluster analysis of magnetic and gravitational anomalous fields on a scale of 1:1,000,000. The boundaries of Lake Ladoga and the tectonic and rock complexes are plotted according to [Mints *et al.*, 2020]. The clusters are described in the text of the article.

4. Petrophysical properties of rocks of the Northern Ladoga region

The patterns of formation of petrophysical groups in mapping differ to varying degrees from the patterns of actual changes in the physical properties of rocks. Therefore, the petrophysical groups identified by researchers can be characterized by fairly wide ranges of changes in magnetic susceptibility and density. Therefore, as N. B. Dortman warns, the averaging of physical characteristics over rock complexes can often be the reason for the apparent discrepancy between geological maps and maps of geophysical fields. Local gravitational and magnetic anomalies may be mistakenly attributed to deeper levels, while in reality they are caused by lateral changes in physical properties within the same group. On the other hand, the presence of structural blocks of various compositions with a high contrast of petrophysical parameters within a single geophysical anomaly may indicate the depth of the sources of the anomaly. Therefore, when conducting geological and geophysical modeling, it is extremely important to take into account both a priori literature information and measurements on field samples.

An analysis of the literature data on the physical properties of rocks in Ladoga region made it possible to compile summary working tables of the physical properties of rocks in the Ladoga region. This work is based on petrophysical and petromagnetic maps edited by N. B. Dortman, compared with modern geological concepts of the geological structure of the region [Kulikov *et al.*, 2017] and supplemented by these sources.

Table 1. Summary table of the properties of rocks in the Northern Ladoga region in accordance with the petromagnetic and petrodense maps [Petrophysical. . ., 1980] with the use of other research results and modern ideas about the geological structure of the region [Kulikov *et al.*, 2017]. ρ – resistivity, χ – magnetic susceptibility, σ – density

		Rock types	Petrophysical properties			
			ρ , Ω m	χ , 10^{-5}	σ , g/cm ³	
PR	Upper Riphean	Tagamites	50–400	0–40	2.7–2.75	
	Lower Riphean	Rapakivi granite, wiborgite	1000–10,000	0–40	2.55–2.65	
	Vepse	Montzogabbro, syenites, granites, potassic ultrabasites	5000–10,000	240–550	2.6–2.65	
		Biotite gneiss, crystalline schist	1000–5000	0–40	2.6–2.65	
		Potassic granites	1000–10,000	600–1200	2.7–2.8	
		Enderbites, charnokite, granulites	5000–20,000	1200–2400	2.7–2.75	
		Diorites, gabbrodiorite, tonalites	5000–20,000	240–550	2.85–2.9	
		Monzodiorites, granodiorites, granites	5000–20,000	0–120	2.6–2.7	
		Kalevi	Tonalites, diorites, gabbro-diorites	6000–20,000	1200–2400	2.8–2.85
	Kalevi	Montzodiorite, gabbro, pyroxenites	5000–10,000	0–120	2.65–2.7	
		Granite, migmatite-granite, gneissogranite	10,000–20,000	120–550	2.65–2.75	
		Quartzites, sandstones, and their metamorphic rocks	1200–3000	10–1400	2.6–2.65	
		Lyudikovian	Undifferentiated volcanic-sedimentary rocks	0–500	40–120	2.9–2.95
			Yatulian	Anhydrite-magnesite	10,000–100,000	0–100
	Dolomite, sandy dolomite	1000–10,000		0–100	2.82–2.9	
	AR	Mesoarchean	Archean complexes, intensively processed in the Paleoproterozoic, tonalites, granodiorites	3000–10,000	0–40	2.6–2.65
Neoarchean			Ferruginous quartzites	10–200	40–120	2.65–3
Mesoarchean			Tonalites, granodiorites	6000–20,000	0–120	2.6–2.7
			Diorites, tonalites, magmatic-plagiogranites	1000–10,000	0–120	2.6–2.65
AR	Mesoarchean	Phyllites, sulfidized rocks, graphitized rocks	10–100	3–128	2.6–3	

5. Conclusion

Petrophysical studies of the Northern Ladoga region in Fennoscandia have a long history. In the 20th century, significant data was accumulated on measurements of rock samples. However, due to the limited possibilities for sampling and the concentration of attention on metallogenic sites, it is still quite limited. Nevertheless, the available data allowed to compile a fairly complete table of the characteristic values of petrophysical properties for all stratigraphic units.

These data will help not only to more accurately solve inverse problems and build starting models. Thanks to the available petromagnetic and petrodensity maps and models of block structure, it is possible to carry out a more accurate separation of structures in the geological interpretation of the obtained geophysical models.

Additional sampling of the studied structures may be required to refine and expand the database of petrophysical properties, in particular, to build a complex geophysical model along the Vyborg-Suoyarvi profile.

Acknowledgments. This work was conducted in the framework of budgetary funding of the Geophysical Center of RAS and Schmidt Institute of Physics of the Earth RAS, adopted by the Ministry of Science and Higher Education of the Russian Federation.

References

- Baltybaev Sh. K. and Vivdich E. S. Evolution of the Meyeri Thrust Zone of the Northern Ladoga Region (Republic of Karelia, Northwest Russia): PT Conditions for the Formation of Mineral Parageneses and Geodynamic Reconstructions // *Geotectonics*. — 2021. — Vol. 55, no. 4. — P. 502–515. — DOI: [10.1134/S0016852121040038](https://doi.org/10.1134/S0016852121040038).
- Geophysical studies of Precambrian formations of Karelia / ed. by M. I. Golod. — Petrozavodsk : Karelian Book Publishing House, 1968. — P. 100. — (In Russian).
- Goev A., Fedorov A., Fedorov I., et al. The Present State of the Kola Peninsula Broadband Seismic Network // *Russian Journal of Earth Sciences*. — 2023. — ES6003. — DOI: [10.2205/2023es000872](https://doi.org/10.2205/2023es000872).
- Golod M. I., Klabukov B. N. and Grishin A. S. Electrical conductivity of Karelian rocks // *Petrophysical studies of the Karelo-Kola region*. — Petrozavodsk : Karelian Branch of the USSR Academy of Sciences, Institute of Geology, 1979. — P. 124–134. — (In Russian).
- Grishin A. S. Geoblocks of the Baltic Shield. — Petrozavodsk : Karelian Branch of the USSR Academy of Sciences, Institute of Geology, 1990. — P. 112. — (In Russian).
- Kischenko N. T. and Grishin A. S. Petrophysics of structural and material complexes of the southeastern part of the Baltic Shield. — Petrozavodsk : KarSC RAS, 1991. — P. 70. — (In Russian).
- Kolesnik N. N. Typification of block structures in South Karelia based on the analysis of geophysical and petrophysical data // *Petrophysical studies on shields and platforms*. — Apatity : AS USSR, 1984. — P. 97–100. — (In Russian).
- Kulikov V. S., Svetov S. A., Slabunov A. I., et al. Geological map of Southeastern Fennoscandia (scale 1:750,000): A new approach to map compilation // *Proceedings of the Karelian Research Centre of the Russian Academy of Sciences*. — 2017. — No. 02. — P. 3–41. — DOI: [10.17076/geo444](https://doi.org/10.17076/geo444). — (In Russian).
- Mints M. V., Glaznev V. N., Muravina O. M., et al. 3D model of Svecofennian Accretionary Orogen and Karelia Craton based on geology, reflection seismics, magnetotellurics and density modelling: Geodynamic speculations // *Geoscience Frontiers*. — 2020. — Vol. 11, no. 3. — P. 999–1023. — DOI: [10.1016/j.gsf.2019.10.003](https://doi.org/10.1016/j.gsf.2019.10.003).
- Morozov Yu. A., Terekhov E. N., Matveev M. A., et al. Sheeted Intrusions in the Svecokareliides of the Ladoga Region: Structural Control, Petrogenesis, Geochemical Analysis of Rocks, and Geodynamic Setting // *Geotectonics*. — 2024. — Vol. 58, no. 6. — P. 575–610. — DOI: [10.1134/S0016852124700419](https://doi.org/10.1134/S0016852124700419).
- Onega Paleoproterozoic structure (geology, tectonics, deep structure and minerageny) / ed. by L. V. Glushanin, N. V. Sharov and V. V. Shchiptsov. — Petrozavodsk : KaSC RAS, 2011. — P. 431. — EDN: [QKKKSZ](https://www.edn.ru/0QKKKSZ) ; (in Russian).
- Petrophysical maps of geological formations of the eastern part of the Baltic Shield (petrodense and petromagnetic). Explanatory note to 1:1,000,000 scale maps / ed. by N. B. Dortman and M. Sh. Magid. — Leningrad : Aerologiya, 1980. — (In Russian).
- Petrophysics of ancient formations / ed. by V. A. Turemnov. — Apatity : Kola Branch of the USSR Academy of Sciences, 1986. — P. 113. — (In Russian).
- Proterozoic Ladoga Structure (Geology, Deep Structure and Mineral Genesis) / ed. by N. V. Sharov. — Petrozavodsk : KarSC RAS, 2020. — P. 434. — (In Russian).
- Sokolova E. Yu., Golubtsova N. S., Kovtun A. A., et al. Results of synchronous magnetotelluric and magnetovariational soundings in the area of Ladoga conductivity anomaly // *Journal of Geophysics*. — 2016. — No. 1. — P. 48–61. — EDN: [VOITNT](https://www.edn.ru/VOITNT) ; (in Russian).
- Stepanov K. I., Sanin D. M. and Sanina G. N. State Geological Map of the Russian Federation scale 1:200,000, second edition, Karelian series sheets P-35-XXIV, P-36-XIX. — Moscow : VSEGEI, 2013. — P. 230. — (In Russian).
- Zhamaletdinov A. A. Fiftieth Anniversary of the Kola SG-3 Superdeep Borehole // *Izvestiya, Atmospheric and Oceanic Physics*. — 2020. — Vol. 56, no. 11. — P. 1401–1422. — DOI: [10.1134/S0001433820110110](https://doi.org/10.1134/S0001433820110110).