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Research Article

Organic Matter Transformation in the Shallow Soils of European Russia Depending on the Underlying Rock

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Abstract. This study undertook to map the composition and stock of organic matter in soils formed on bedrock types differing in resistance to weathering and mineralogical composition. Studies of the specific features of organic matter transformation in soils formed over bedrock have demonstrated differences depending on the parent rock characteristics. The influencing factors include the chemical composition of the rock and its weatherability. Where rocks have a rich composition – basic and ultrabasic – but are deeply metamorphosed (and, hence, resistant to weathering), there forms primitive soils with a low content of organic matter, which is mostly confined to the top organic horizon. Besides, organic matter in such soils is of fulvic nature, which is generally typical of the zonal soils. Primitive soils are not very fertile, both due to the relatively low content of organic matter and to the limited availability of mineral nutrients for plants. The fertility of shallow soils on acid parent rocks is limited by high acidity and a low content of mineral nutrients both in the parent rock eluvium and in the soil's native mineral material. The productivity of soils on basic rocks is somewhat higher. The conditions for the biota are the most favorable in shallow soils forming on carbonate rocks. They contain substantial amounts of nutrients and have comparatively low weatherability, which makes these resources available. In the organic matter of these soils, humic acids prevail over fulvic acids, even if slightly. Organic matter stores in such soils are distributed more evenly, with a substantial share concentrated in mineral horizons, in the root layer.

Keywords: soil, organic matter, parent rock

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1. Introduction

Parent rocks largely define the rate and vector of the soil formation process, as well as the soil fertility. The rate of soil formation is influenced by bioclimatic factors and rock resistance to weathering.

The mineralogical, particle-size, chemical composition, and properties of the parent rock shape the species- and, hence, the biochemical composition of plant communities, their productivity, litterfall decomposition rate, and characteristics of the decay products.

Thus, the parent rock and the soils formed thereon significantly influence the biological cycle at all of its stages and mold the biological diversity.

Ultimately, the composition, configuration and structure of parent rocks largely determine the soil fertility, and high-fertility soils never form on rocks poor in mineral nutrients [1, 2]. The material composition and properties of rocks have the most pronounced effect on the properties of young and shallow soils [3, 4].

This study undertook to map the composition and stock of organic matter in soils formed on bedrock types differing in resistance to weathering and mineralogical composition.

2. Methods and Equipment

The geological characteristics of the study area are shaped by the Baltic crystalline shield, in particular its Karelian block. It is the region's most complex structure composed of geological complexes of different ages, from the Lower Archean to the Upper Proterozoic. Like in the rest of Karelia, it is primarily made up of acid metamorphic rock. So, an area on acid crystalline rock – granitic gneiss, was taken as a reference zonal variant of pedogenesis.

Multiple intrusions of various compositions cut through the body of this rock. A set of sample plots was selected to study the early stages of soil formation thereon: on marble, dolomite, basalt, and volcanic breccias (Tab. 1).

To isolate the effect of the lithological factor on the formation of the soils sample plots were selected in forests with identical composition – pine stands of about the same age. The sample plots were also situated within the same climatic district – temperatures $+10^0$and higher annually total up to 1405^0 (1330-1480), total annual precipitation is 680 mm.

Soil pits were made in the most typical spots of the soil cover, and the morphological structure and physico-chemical characteristics of the soils were determined. Special focus was on the organic profile (humus characteristics, degree of organic material decomposition). The organic matter stock was determined for the entire soil profile; the stock was measured separately for the forest floor and then summed up with the stock in mineral horizons.

Table 1: Characteristics of parent rocks

№	Parent rocks	Time of formation	Origin	Loss on ignition	SiO_2	Fe_2O_3	FeO	Al_2O_3
						%		
1	granitic gneiss	Archean	magmatic	0,6	70,4	0,7	1,4	16,1
2	volcanic breccias	Proterozoic	magmatic	4,2	49,2	2,5	8,9	12,9
3	porphyrites	Proterozoic	magmatic	3,1	42,2	8,5	14,4	12,3
4	marble, dolomite	Proterozoic	metamorphic and sedimentary	45,3	1,6	0,4	-	-

3. Results and Discussion

All the surveyed soils can be classified into three groups.

Group 1 is soils with humus and mineral substances distributed across the profile by eluviation and illuviation. Soils forming through podsolization were found on outcropping granites – rocks with poor chemical composition, and on the chemically richer volcanic rocks. The profile of such soils formed on a shallow layer (within 20-25 cm) of fine earth resulting from parent rock weathering. The fertility of the soils can be judged by the distribution of agrochemical parameters in the profile (Tab. 2). All horizons of the shallow Podzols have high acidity. These soils have low carbon and nitrogen content, and the distribution of the elements along the profile is due to eluvation and illuviation. Mineral horizons of the soils formed on basic rocks are much richer in these elements.

Formation of a bleached eluvial horizon is not typical of boreal soils on basic rock types, although occasional papers acknowledged such a possibility. Studies have demonstrated that profoundly altered basic rocks react differently to acid agent impact. They contain a small amount of basic plagioclases, which can be quickly fully dissolved releasing alkali and alkaline-earth cations, as well as sesquioxides into the solution. Rapid deposition of humic acids from the forest floor is therefore limited, and an eluvial horizon consisting mainly of outwashed silicate material is formed.

Group 2 comprises shallow soils on chemically rich bedrock types – pyroxenites, basic volcanic rocks, and porphyrites. The chemical composition of these rocks suggests that the soils forming thereon will contain large mineral nutrient stores. Due to high density, these rocks are quite resistant to degradation. Their weathering over the period since glacial retreat (11-12 Ka) has been minor. Soil formation is in early stages, and the entire body of soil is only 7-11 cm thick.

Table 2: Physico-chemical characteristics of the soils

Sample plot	Horizon	pH_{KCl}	P_2O_5	K_2O	C	N	C:N
			mg / 100 g		%		
Shallow soil on granites							
1	O	3,29	53,7	141,1	50,4	1,18	42,7
	E	3,32	101,9	3,6	1,05	0,06	17,5
	Bf	4,92	127,1	3,7	1,76	0,12	14,7
Shallow soil on volcanic breccias							
2	O	4,85	80,7	96,9	38,4	1,05	36,6
	Bf	4,52	99,4	41,5	1,42	0,08	17,2
	BC	4,36	134,4	5,4	2,95	0,15	19,7
Primitive soil on porphyrites							
3	O	3,04	37,6	92,4	42,8	1,41	30,4
	BC	4,93	170	1,4	0,6	0,06	10,0
Shallow Podbur on marble							
4	O	4,69	57,8	40,1	24,5	1,03	23,8
	AB	4,77	114,7	32,6	5,17	0,29	17,8
Shallow Podbur on dolomite							
5	O	4,03	42,8	78	32,6	1,39	23,5
	AB	4,56	173,7	5,6	3,1	0,25	12,4

Their nutrient content is quite high (Tab. 2). The thickness of the primitive soils and, hence, the stock of nutrients are clearly insufficient for plants to prosper. The primitive soils feature high acidity, with especially low pH value in the forest floor.

Group 3 is made up of shallow soils forming on carbonate rock. As these soils maintain a solid herbaceous ground cover, plant litter typically degrades during a year, and the forest floor is not thick – 3-4 cm. Soils on dolomites and marbles exhibit an acid reaction of the salt extract, and high carbon and nitrogen content. Their productivity is generally quite high compared to the background boreal soils.

Overall, the organic matter stock is rather low in all the studied soil types (Fig.1).

Differences are seen in the ratio of organic matter stores in the top organic horizon and in the mineral body. In soils on poor parent rocks the transformation of incoming plant litter is very slow, and organic matter is therefore accumulated on soil surface. Its stores in the forest floor predominate over the stores in mineral horizons. The situation in soils forming on dolomite and marble is somewhat different. The ground cover in the samples plots with these soils is dominated by herbs, whose litter is decomposed quite rapidly. As a result, mineral horizons receive substantial amounts of organic matter. Pine

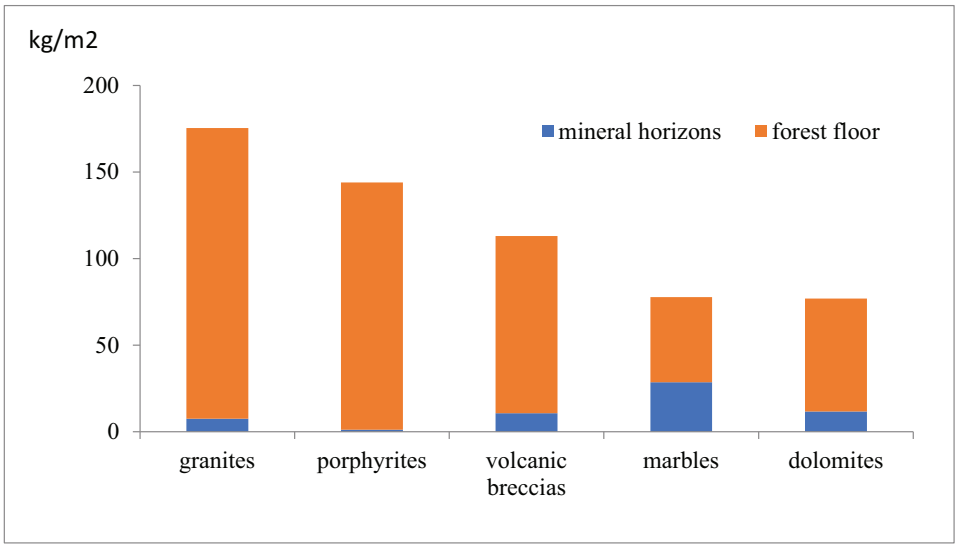

Figure 1: Organic matter stock in the surveyed soils.

stand on carbonate rocks are far more productive than on rocks where other primitive soils form.

4. Conclusion

Studies of the specific features of organic matter transformation in soils formed over bedrock have demonstrated differences depending on the parent rock characteristics. The factors of influence are both the chemical composition of the rock and its weatherability. Where rocks have a rich composition – basic and ultrabasic, but are deeply metamorphosed (and, hence, resistant to weathering), there form primitive soils with rather low content of organic matter, which is mostly confined to the top organic horizon. Besides, organic matter in such soils is of fulvic nature, which is generally typical of the zonal soils. Primitive soils are not very fertile, both due to the relatively low content of organic matter and to the limited availability of mineral nutrients to plants. The fertility of shallow soils on acid parent rocks is limited by high acidity and low content of mineral nutrients both in the parent rock eluvium and in the soil's native mineral material. The productivity of soils on basic rocks is somewhat higher.

The conditions for the biota are the most favorable in shallow soils forming on carbonate rocks. They contain substantial amounts of nutrients and have comparatively low weatherability, which makes these resources available. In the organic matter of these soils humic acids prevail over fulvic acids, even if slightly. Organic matter stores in such soils are distributed more evenly, with a substantial share concentrated in mineral horizons, in the root layer.

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References

[1] Heckman K, Rasmussen C, Welty-Bernard A, Schwartz E. Geologic controls of soil carbon cycling and microbial dynamics in temperate conifer forests. Chemical Geology. 2009;267(1-2):12-23.

[2] Samec P, Voženílek V, Vondráková A, Macku J. Diversity of forest soils and bedrock in soil regions of the Central-European highlands (Czech Republic). Catena. 2018;160:95-102.

[3] Djukic I, Zehetner F, Tatzber M, Gerzabek MH. Soil organic-matter stocks and characteristics along an alpine elevation gradient. Journal of Plant Nutrition and Soil Science. 2010;173(1):30-38.

[4] Kammer A, Hagedorn F, Rigling A et al. Treeline shifts in the Ural mountains affect soil organic matter dynamics. Global Change Biology. 2009;15(6):1570-1583.