Mining production as a factor of transformation of soils and soil cover

Yulya Timofeeva[1,*] and *Elena* Sukhacheva[1,2]

[1]V.V. Dokuchaev Soil Science Institute, 109017, Moscow, Pyzhevsky lane, 7, Russia
[2]St. Petersburg University, 199034 Saint-Petersburg University embankment 7/9, Russia

Abstract. The article describes the component composition of the soil cover in the areas of mining granite material near Kuznechnoe, Leningrad region. Nonsoils formations take about 50 per cent of the study area. There are natural and varying degrees disturbed soils in this area around excavations of the quarry. Soils with Novic qualifiers are formed along the access roads to the quarry. There are stratified natural soils are diagnosed around the quarry in the direction of the rose diagram. Lithic Leptosol are formed at the crushed granite storage site. The degree of transformation of the component composition of the soil cover depends on anthropogenic activity in the territory adjacent to granite quarry has been defined. The article outlines the characteristics of the altered structure of the soil cover.

1 Introduction

The diversity of natural soils of any region depends on the well-known factors of soil formation: climate, terrain, rock formations, biota, and time. In the prevailing territory of North-West Russia, the soil cover began to form after glaciers melted about 10,000 years ago and since then it has been relatively stable for many centuries. However, in recent decades, the anthropogenic factor has become increasingly important in the formation of the soil cover. Human activities that are expanding with each decade have both a direct impact on soil and an indirect effect on soil formation factors. As a result of different types of economic activities, there are radical changes in vegetation, hydrological regime, soil-forming rocks, and the topographical relief.

Mining has one of the most powerful impacts caused by human activities. Despite the fact that quarries occupy a relatively small area, they are the most environmentally degraded areas with most disturbed functions of the soil cover [1]. Due to quarrying, vegetation and soils get completely destroyed, and it also changes hydrogeological conditions of the area [2]. New man-made forms of relief (quarries, dumps, waste piles, ravines) are formed. Therefore, the mining industry is destroying entire natural ecosystems in local areas, reducing the biodiversity of the area [3].

The influence of man on the soil cover as a result of extraction of mineral resources is manifested in the transformation of the soil profile composition, complete destruction of soil in large areas, and changes in the spatial organization of the soil cover [4].

* Corresponding author: tima204@yandex.ru

Soil areas always form a pattern of combinations of soils of varying complexity, i.e. the structure of the soil cover (SSC). Connections are formed between components of the natural soil cover, which ensure continuity, one of its most important characteristics. Physical discontinuities (e.g., rock exposures, water spaces) are, according to Vladimir Fridland, the founder of the SSC theory, only "special cases" [5]. Under the influence of human activities, functional links between the components of the natural soil cover are broken either partially or completely, which leads to the transition of soil cover from a continuum state to a discrete one.

The soil cover study around quarries was conducted in the Leningrad Region, where, on the one hand, the whole variety of glacial relief forms is represented, typical for the glacial cover areas [6] with a normal SSC, and, on the other hand, all the main economic activities characteristic of the taiga forest zone and affected soils can be found.

The current state of the soil cover of the Leningrad Region is characterized by a dynamic spatial increase in anthropogenic transformed soils and areas with a completely destroyed soil cover. Mining production is one of the major economic activities in the region that affects soils and the soil cover.

Today, the mineral and raw materials base of the region includes almost 400 deposits of solid commercial minerals accounted for by the State Register of Mineral Reserves [7].

These are large quarries for the extraction of natural building materials: crushed aggregate from eroded and metamorphic rocks (granite, gabbro, gneissogranite), carbonate rocks (dolomites, limestone), facing stone (granite, granosyenite), sand and sand-gravel material, low-melt ceramic clay, and moulding and glass-melting sand. In addition to this, limestone for metallurgy, phosphorite-rich sands, and oil shale are extracted [8].

A specific feature of the majority of SSCs in open cast mines is the presence of overburden rocks and abandoned mines, which are gradually overgrown with forest.

2 Material and methods

The soil cover in mining area was studied at survey plots represented by granite quarries located in the Leningrad Region.

The studied site is located in Priozersky district of the Leningrad Region on the Karelian Isthmus and it consists of three active quarries with the total area of more than 2.5 sq.km (Kuznechnoye quarry, Kuznechnoye-1, Rovnoye-1) for extraction of nonmetallic minerals (granite), as well as industrial facilities (crushing and sorting equipment sites). The site is located within the Baltic crystalline shield composed of Archean (granite-gneiss) and Proterozoic (rapakivi) granites.

The relief of the territory is flat-peaked ridges (selges) about 1.5 km long at the base, rising above the bottom of the trough and separated by lake-shaped depressions. The ridges are composed of massive crystalline rocks, protruding to the surface on the tops and short precipitous south-southeastern slopes. The ridges and inter-ridge depressions extend in a certain direction from north-northwest to south-southeast [9].

The natural soil cover of the site was represented by a complex combination – a mosaic of primitive soils on rock exposures on the tops and steep slopes of the hills; Entic Podzols and Albic Podzols on the ridges and slopes; Albic Luvisol and Umbric Albic Luvisol in the lower parts of the slopes; Gleyic Umbric Albic Luvisol, Histic Albic Luvisol, Histic Gleysols, Umbric Gleysol and Gleysols in inter-ridge depressions [10, 11].

The granite deposit has been in use since 1954. The process of quarrying is accompanied by the construction of crushing and sorting plants.

At the granite quarries, the survey plot of 100 m x 50 m was laid in the northwest section of the study area in the immediate vicinity of the southern quarry. The site is

crossed by an unpaved road leading to the quarry and a dirt road going to the granite chips storage ground; there is a creek, crushing facilities, and some land used for gardening.

The height difference of the survey area is 0.7 m. The natural type of the forest is pine, and modern vegetation in the area adjacent to the quarry is represented by both pine and birch forest with various grasses.

The main methods in the SSC study included the comparative geographical method consisting of the analysis of soil combinations and their comparison with anthropogenic factors of soil formation; and the extrapolation method, when part of the area is studied, with the results extended to a larger area.

The mapping of the area was carried out using Google Earth satellite images. The territory of the quarries can be identified in a satellite image by the presence of one or more rounded bright spots of considerable size (up to several square kilometers) with clear irregular boundaries and often with a radial-concentric pattern [1].

Large-scale mapping was carried out for the survey plot, relief map of the site was created. In the course of the study, eleven reference sections and 15 half-pits were laid.

3 Results and discussing

Soils, shape of soil ranges and links between components of the cover soil were radically changed by a wide range of technological operations: overburden excavation, drilling, excavation, transportation, storage, laying of trenches for working benches and access roads, creation of a system of protective ditches for stormwater and surface runoff, as well as use of the quarry for recreation purposes.

The cover soil has become much more complex and heterogeneous as a result of the transformation under the influence of human activities.

The spatial organization of the soil cover of the studied territory around the granite quarry represents a radial-concentric pattern, in the centre of which is the quarry excavation itself – non-soil formations with anthropogenic soils along the periphery.

The area of the quarry with the adjacent territory with soils transformed due to human activities is about 4.5 sq. km. Non-soil formations (NSFs) occupy the largest portion – 47% of the studied territory. NSFs are not able to provide for the growth of plants and perform the ecological functions inherent to soils.

Practically all technological operations performed at mining enterprises, such as blasting, drilling, excavation, transportation of rock mass, and storage, are accompanied by dust formation. Dust emissions into the air from blasting operation, roads, material erosion in storage areas, and soil erosion in open areas are sources of dust consisting of soil and mineral particles (during mining and storage) [12]. As a consequence, in the soil cover adjacent to the quarries, there is a large number of soil areas with stratification due to dust material formed as a result of crushing granite mass.

Stratified soils are characterized by burial of the natural soil profile with a layer of dust of low thickness up to 40 cm (if soils have thickness more than 40 cm – the name of soils with Novic qualifiers). Such soils are located around excavations of the quarries, as well as along the road and rail lines (11%). The boundaries of dust-contaminated soil areas are developed consistent with the prevailing winds and the field survey results. Stratified soil areas are expressed in the western direction from the quarry for over 100 m (fig. 1).

At the storage site of crushed granite siftings, poorly developed soils are formed –Lithic Leptosol – soils formed on dense rocks.

The complex of poorly developed soils together with natural stratified soils covers 19% of the total area. These soils are found in areas between the quarries and nearby roads.

Poorly developed soils formed on loose sediments of heavy granulometric composition and on sandy sediments, including soils formed under dumps, occupy 23% in total.

Linear forms of contours dominate in the territory adjacent to the granite quarries. Natural stratified soils have slightly and medium-level dissected boundaries.

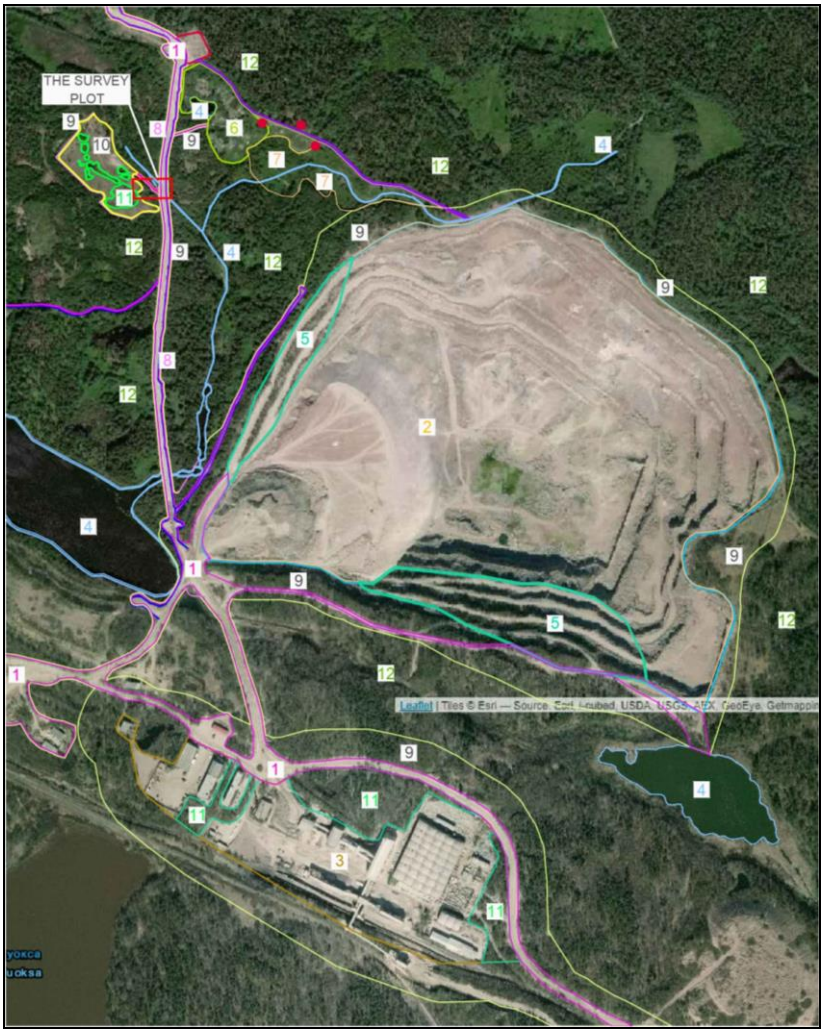

Fig. 1. Territory of southern granite quarry. Scale 1:15000.

The survey plot of 100 x 50 m was laid near the southern quarry (fig. 2). The plot is crossed by an unpaved road used for transporting the overburden material, a creek, an access unpaved road to the crushed granite storage site, and areas overgrown with forest.

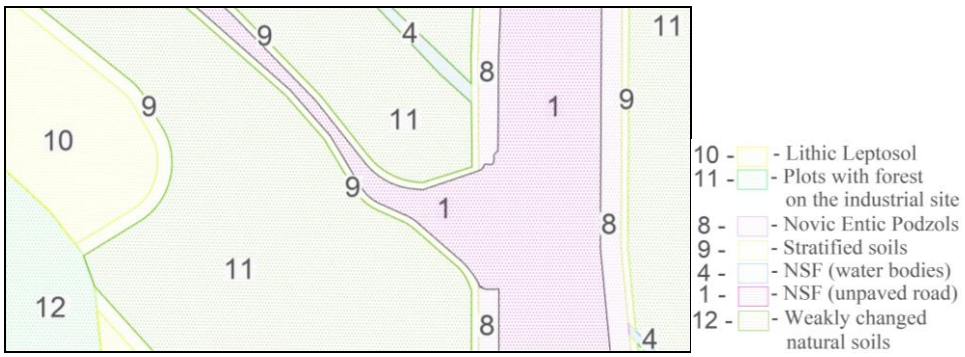

Fig. 2. Survey plot of the granite quarry. Scale 1:700.

The survey plot is located in the prevailing winds zone, which contributes to the transfer of dust from the unpaved road into the forest depth. The soil cover studied at the plot is characterized by dust concentration in the upper horizon. Dusting of the area along unpaved roads and rail lines occurs as a result of the lack of use of dust control means.

The functioning of the mining complex leads to the formation of quarry-dump forms with a complex technogenic relief, numerous surface dumps, and soils transformed due to human activities.

The NSFs on the site are represented by a dirt road, about 12 m wide, an access road to the site previously used for crushed granite storage, and a creek.

Novic Entic Podzols are formed along the roads. These soils have the biggest share of the profile represented by humus stratified thickness over 40 cm. They represent elevations from 0.2 to 0.9 m high and up to 3 m wide.

Poorly developed soils are formed at the crushed granite storage site, they are Lithic Leptosol consisting of bedding-peat horizon, which lies on the fine-soil-rubble formation.

The site has areas with undergrowth consisting of aspen, pine, and birch. Overgrowth develops very slowly: sparse birch trees, moss and lichen patches, single herbaceous plants begin growing in such areas [11]. Under such undergrowth, humus Lithic Leptosol are formed.

The largest part of the survey plot is occupied by slightly altered natural soils (52% of the total area). NSFs occupy 20%. The ratio of the areas is presented in the table 1.

Table 1. Distribution of areas in the survey plot at the granite quarry.

Contour	Sq.m.	% of the survey-plot area
Lithic Leptosol	544	11
Plots with forest on the industrial site (humus Lithic Leptosol)	260	5
Novic Entic Podzols	270	5
Stratified soils	329	7
Weakly changed natural soils	2 613	52
NSF (water bodies)	40	1
NSF (unpaved road)	944	19

The site consists mainly of undisturbed contours. Slightly distorted contours are characteristic for stratified soils and soils with Novic qualifiers. In addition, the contours of these soils are also linear in shape. The other contours are either elongated or isomorphic in shape.

4 Conclusion

The formation of anthropogenic soils is the result of human activity. In this case, the soil cover represents soil combinations with partially disturbed inter-component links.

The soil cover structure of granite quarries with adjacent areas dramatically differs from the natural one. As a result of human activity there is an increase of contrastive features of the soil cover structure and development of new soil combinations.

Both targeted interventions and indirect factors cause transformation of the soil cover structure.

The targeted interventions include activities related to mining operations. The development of the territory for quarries leads to a complete or partial destruction of the topographic forms, soils and vegetation. Dusting has a significant impact on the environment. The soil cover adjacent to quarries, roads and railroads experiences stratification by dust carried from the quarry site during drilling-and-blasting and excavation works, as well as during transportation of crushed material, stockpiling, and waste disposal. The soil cover structure becomes more complicated.

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