Biodiversity in space and time

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1. Contestant profile

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2. Project overview

Title:	Biodiversity in space and time
Contest:	Quarry life award 2016
Quarry name:	Pechurki quarry, Leningrad region
Prize category: (select all appropriate)	☒Education and Raising Awareness ☒Habitat and Species Research ☒Biodiversity Management

Abstract

The work was carried out to identify the main types of relief and assess the relationship between geo- and biodiversity; comparative analysis of different ecotypes of biodiversity; the inventory of soil, flora of lower and higher plants, cyanoprokaryota, epilithic lichen, microbial communities and the ants, made a comparison of plant communities in different parts of the quarry and maps of existing communities, as well as maps, taking into account the forecast succession of plant communities after the reclamation and waterlogging the quarry. During the main study of physicochemical properties of the soils, determination of environmental factors involved in the restoration of plant community considering limiting impeding recovery it was determined their influence to vegetation recovery process. After the eco-phytocenosis analysis of vegetation depending on ecotope of the quarry, it was offered effective low-budget measures that increase the speed of recovery of the quarry and reduce the negative effects of mining. It was found that in terms of biodiversity conservation and economic benefits the best option to restore quarries carbonate substrates is spontaneous succession. We highlighted key habitats of the quarry (especially valuable in terms of biodiversity). 14 protected species of higher plants were found during the research period in the quarry. Proposals have been made for remediation and further use of the Pechurki quarry in 2021, which should significant reduce technical phase of the quarry restoration.

For the first time in the territory of Leningrad region it was discovered *Anomala dubia*, that changed the picture of the area of distribution of the species and caused great interest among entomologists for studying the quarry.

After examining the level of CO2 emissions from soils of the quarry as a result of weathering of carbonates and soil respiration, and the level of CO2 sequencing from the atmosphere, it has been revealed that the establishment of certain forms of relief with optimal physical substrate properties will contribute to effective CO2 sequencing from the atmosphere and thus directly affect the decreasing of global warming. .

The educational part of the project was aimed to attract public attention, raising the level of environmental culture and responsibility for biodiversity conservation and environmental quality of the environment. It was achieved through the involvement to the project various segments of population. It has been performed through organization more than 70 eco-lessons, participation in conferences (team members made more 20 scientific reports on the subject of the project), publishing, attracting newspapers, television and other mass-media. There was a photo exhibition, press conference and scientific tour for the quarry for children. Contest for the best essay and picture was also performed. Also the first educational cartoon about biodiversity in the quarries was created, which is recommended to be used for educational and promotional activities of the company. Natural Protection Union, ITMO university, schools of St. Petersburg and the charity organization "St. Petersburg Parents" as well were involved in the educational part of the project.

Inroduction

The purpose of the work is a comprehensive study of geo- and biodiversity of the Pechurki quarry for developing methods of reclamation of carbonate rocks, as well as to attract public attention to the problems of biodiversity conservation.

To achieve the first (scientific) **goal of the project**, the **following tasks** have been established:

- to identify the main landforms of the quarry;
- to evaluate the relationship between geo- (diversity of ecotypes) and biodiversity;
- to perform comparative analysis of different ecotypes of biodiversity;
- to perform an inventory of the soil, flora of lower and higher plants, cyanoprokaryota, epilithic lichen species, microbial communities and ants;
- to compare plant communities of different parts of the quarry,
- to map the existing communities, as well as the forecast of the succession of plant communities after the remediation and waterlogging of the quarry;
- to define the basic physical and chemical properties of the soil;
- to identify the environmental factors leading to the establishment of plant communities;
- to identify the main limiting factors that prevent the restoration of ecosystems;
- to establish how environmental factors affect the process of vegetation restoration;
- to carry out eco-phytocenotic analysis of vegetation depending on ecotope of the quarry;
- to propose measures that increase the succession rate and reducing the negative effects of mining operations;
- to determine the best recovery option for post-technogenic areas in terms of biodiversity and economic benefits;
- to determine the level of CO2 emissions from soils of the quarry as a result of weathering of carbonates and soil respiration, as well as the level of sequestration of CO2 from the atmosphere;
- to propose measures to facilitate sequestration of CO2 from the atmosphere, thus contributing to reduce the rate of global warming;
- to determine the quantitative and qualitative composition of microbial communities.

Materials and methods

This investigation has been conducted on the limestone quarry Pechurki during spring and summer season of 2016. First of all it was distinguished all of relief elements of the quarry. On the most contrast ecotopes it was established thermohygrochrones for measuring of annual variation of temperature and moisture. It was selected samples from the accumulative water ecotopes for determination algae and cyanobacteria species. It was also performed analysis of species composition of higher water and coastal vegetation. At dumps filled by macrofragmental material and free of vegetation samples for moss and lichen determination have been selected. Due to significant influence of ants on soil properties and their high density on the quarry it was determined all of ant species on the key plots. On the flat and terraced relief elements it was determined soil water permeability by the tubes method (N.A. Kachinsky). On the sites with developed soil-vegetation cover we have measured changes of electrical resistivity for soil profile up to 300 cm. Vertical electrical sounding has been conducted with LandMapper-03 equipment (4-electrodes scheme of Schlumberge). Soil pits was also established here, field descriprion of soil pits was performed. It was also selected soil samples from each horizon for laboratory analisis and determination of metagenom as well. Thus 61 soil samples have been selected in total. Investigation of metagenom of soil samples has been conducted on the base of laboratory of All-Russian Institute of Agricultural microbiology with using third-generation sequenator (Junior, Roshe firm). It was created amplicor libraries v4 – variable site of 16s gen pDNA. Sequences obtained have been annotated with remote database (RDP). On the base of data obtained taxonomic analysis of microorganisms has been performed. It has been also analyzed population, estimated alfa- and beta- diversity of different key plots. On the base of laboratory of Department of Applied Ecology (SPSU) mesomorphological description of soils and determination of physical-chemical properties of soils by standard methods have been performed (annex 1).

Besides, we have tested significance of environmental factors via direct selection approach (forward selection). Using only significant variables, we have performed analysis of correspondence (CCA) in order to know how environmental factors affect distribution of plant communities. Calculations has been performed via Statistica 7 and Excel programs. Mapping of the results obtained and calculations of the area as well have been performed by ArcGIS 10.1. software: ArcMap and ArcCatalog.

Inventory of quarry flora has been contucted. On each ecotope it has been established sites 25m x 25m, within each it was determined all species of plants, on-soils mosses, total projective cover and projective cover of each species. It has been also taken into account those species which have not been decripted, but fixed by route descriptive method. It has been conducted ecological-phytocenotic analysis of vegetation. Types of living forms have been determined according to N.N. Cvelev (2000). For the purpose of estimation of species composition similarity of vegetation on different key plots it was calculated Sorensen-Chekanovsky coefficient. We have also used claster analysis (it was used Vard's method for estimation of total projective cover data for each species). For the estimation of diversity on different key plots following coefficients have been calculated:
- Simpson inverse ratio index;
- Shannon index;
- Margalef and Menhinika coefficients.

Results

Basic relief items have been identified on the quarry (Annex. 2 Fig. 2).

Eluvial ecotopes of the quarry career are quite different in their physical and chemical parameters of the substrate. Due to this, even on the same type of relief formed diverse community. For each ecotope number of selected plant species varied from 19 to 31 (annex. 3 Tab. 1). The most typical for late stages of succession dumps small-leaved forests with a predominance of Populus tremula and Betula pendula, grass-bush cover in such cases mainly presented edge-meadow and meadow species (Poa pratensis, Calamagrostis epigeios). Furthermore, coniferous forests with predomination of Pinus sylvestris and Picea abies, the herb-shrub floor, in this case, as a rule, presented by edge-forest and forest species (Convallaria majalis, Pyrola rotundifolia). Rarely mixed forests are developing, where dominants are difficult to distinguish. Tops of the dumps regardless of the length of overgrowth are quite different in their species composition, the proportion of common species is from 24 to 39% (see. Annex.4 Tab. 2). On the dumps whch are not overgrowing over 12 years, currently formed by bushes with the dominance of Rubus idaeus. On eluvial ecotopes of the quarry it was found 8 species of higher plants (Chimaphila umbellata. Dactylorhiza fushsii, D. maculata, Epipactis atrorubens, E. palustris, Equisetum variegatum, Gymnadenia conopsea, Cypripedium calceolus), protected on the territory of Leningrad region.

These areas are key habitats, they have a high value in the aspect of biodiversity, taking into account this fact, as well as the inaccessibility of dumps for people and small recreational attraction, it is not recommended to use these areas for recreational purposes.

Transit-transeluvial ecotopes are widespread in the territory of the quarry and represent different exposition slopes of dumps and pit walls. Currently,bare slopes and completely covered with vegetation slopes as well represents the quarry. Species composition of dump slopes coincides with the top of the piles (see Eluvial ecotopes). After reclamation of the quarry, it is assumed that in these areas there will be the greatest changes in the species composition, as flooding soil moisture increase. It will be formed the ecotone, which will contribute to a further increase in biodiversity and the appearance of each heap of different communities with insistence to the water regime.

Beyond the slopes, terraced areas of the quarry are transeluvial ecotopes. Mining-technical and biological reclamation have been performed on such territories, over the years pine has been planted pine here. Currently, sites are not only differ in a period of overgrowth, but also in particle size distribution of soil structure and moisture conditions. As a result, on the qaurry green moss pinery, grass pinery are represented, pine and lichen formed on a well-drained, sandy area. Species diversity of these areas is not correct to compare, since each of them represents a different type of forest, these areas are of great value in terms of preserving biodiversity. These areas are found in all Red Book species, typical for the quarries in dry areas. It should especially be noted Chimaphila umbellate, this specied is found only here. Besides, in the bright dry forests of the quarry Dactylorhiza maculate and Epipactis helleborine are grown. The well-moistened, and sometimes swampy areas are quite common inhabited with such protected species as Dactylorhiza baltica, Epipactis palustris and Equisetum variegatum.

Pine forests are also attractive for recreational purposes, the most vulnerable is a pine, growing on well-drained sandy substrate, therefore it is recommended to limit this biocenosis against the secondary human impact.

Self-overgrowed bottoms (site 8 and 11) of the quarry are differ with high stoned (80%), high density and low water-holding capacity. Overgrowing by higher vegetation is slow, the first colonists inhabit nano-lowerings because here there are accumulation fine earth, seeds, slightly better moisture conditions. On the rocks large number of epilithic lichens are descripted: Arthonia fusca, Acarospora moenium, A. glaucocarpa, Candelariella aurella, Lecanora dispersa, L. crenulata, Lecidella stigmatea, Phaeophyscia nigricans, Hymenelia epulotica, Sarcogyne regularis, Verrucaria sp. Total projective cover of vegetation in these areas reaches 25%, the main

dominants here are Ceratodon purputreus and Bryum pseudotriquetum. The number of species of vascular plants over time virtually unchanged (19-20 species detected). Species composition of the bottom part of the quarry is uniform - Sërensona-Czekanowski coefficient is 92%. Vegetation are growing along the forest path way of overgrowing, the most characteristic species are Pinus sylvestris, Picea abies and Betula pendula. In the depressions it is developed Salix sarrea. Herbaceous vegetation is represented by individual parcels, some of them are typical weed species (Tussilago farfara), and representatives of edge-forestry and edge-meadow suit (Fragaria vesca, Solidago virgaurea, Calamagrostis epigeios, Stellaria graminea, Agrostis tenuis). In these areas noted 5 endangered species (Dactylohiza incarnata, D. maculata, Gymnadenia conopsea, Epipactis atrorubens, Epipactis palustris) from Orchid family, which are under protection in Leningrad region.
In general, it can be noted a low rate of development of these areas, they are a good platform for the study of the first stages of succession, the transformation of rocks by the action of moss and lichens, which prepare the substrate for plants settlement, the first stages of pedogenesis, the weathering of carbonate and early accumulation of organic matter under the parcels vegetation. Stony bottoms of the quarry represents a clear example of justice «safe sites» hypothesis in harsh habitats, and can also be a place for experiments on reclamation measures. In addition, due to the slow pace of recovery and the presence of large number of protected species, such habitats are the most vulnerable during the secondary anthropogenic influence. So recreational load reduction is needed.
On the entire quarryit was found a high density of ants, and among them there are both types of eurytopic (Formica cinerea and Lasius niger), and less common species in Leningrad region (Lasius mixtus and Lasius flavus).
In accumulative reservoirs (ponds and depressions, sites 5 and 6)of the quarry it was found about 75 species of algae and cyanoprokaryota species. Besides margins of such ecotopes are under particular interest. They are characterized by significant moisture and predomination of clay fraction in the particle size distribution. Coastal aquatic vegetation is diverse, there is a dominant Typha latifolia. In general, on these ecotopes can be found up to 20 typical of coastal aquatic species. It should be particularly noted that significant projective cover in the wetland accounts for protected species - Equisetum variegatum.

Variety of different ecotypes

According to all indices calculated the least diversity corresponds to the site 10, where on a flat surface on a soft overburden, in 1970 pine seedlings were planted (Annex 5 Table 3). This level of biodiversity is typical for pine forests of our region. The greatest level of diversity according to Margalef index, Shannon Menhinika is corresponded to the recently remediated site, where it is still not happened closure crown and typical forest species have not yet supplanted edge-meadow ones. According to the Simpson index site 12 is the greatest in sense of diversity – dump of the quarry where more than 30 years spontaneous succession without human intervention is continuing. Changes in biodiversity through time and space are connected with each other. On flat areas biodiversity over time is reduced under biological reclamation. In areas where development takes place according to the type of spontaneous succession, namely dumps over time increases the level of biodiversity. Interestingly, on a strongly rocky areas (dumps of large fragments and rocky bottoms) development takes place so slowly that for 46 years, significant changes have not occurred. The fact is that this time is too short for natural algae conversion of the substrate, lichens and mosses to settle here the higher plants. Thus, from the point of view of biodiversity best method for remediation of carbonate quarries is the creation of favorable physical conditions of the substrate and the abandonment of land for self-overgrowing. This option is also the most economically advantageous.

In total on the quarry it was found 136 species of higher plants belonging to 106 genera, 49 families, 45 orders, 5 classes and 4 divisions (Annex 6 Table 4). Families with the highest amount of species are Fabaceae and Poaceae, including 13 species (about 10% of the identified diversity) and Asteraceae and Rosaceae - 11 species (8%). A large number of representatives of the Fabacaea family is characteristic feature for disturbed habitats, Asteraceae and Rosaceae families are the leading families of the flora of Leningrad region. There were 24 single-species families. It is worth noting a rather high species richness of family Orchidaceae - 9 species (6% of the total species list), which is associated with carbonate substrate of the quarry. Also recorded 22 species of mosses from 10 families and 11 epilithic lichens of 7 families, about 75 species of algae and cyanoprokaryota species from 38 genera and 29 families (Annex 7 Tab. 5 and Annex 8 Table 6). The quarry found representatives of all the life forms of plants (Annex 9 Table 7), common in Leningrad region (according to N. Cvelev, 2000).

According to the soil wealth exactingness approach all ecological groups are presented (from oligotrophs to eutrophic and typical nitrophilic). Also species-calcicole are widespread on the quarry. On the quarry it was marked whole spectrum of representatives in relation to the water regime of soils (from xerophytes to hygrophytes). The number of species of vascular plants in areas ranging from 14 to 39 depending on ecotope. At different ecotopes of the quarry recorded 14 protected species (Annex 6 Table 4 - *they are shown in red*).

Maximal similarity of species composition are observed on the rocky bottoms of the quarry (92 %). Here there is the severest for vegetation development, it can be inhabited only for some species (Annex 4 Table 2). The lowest number of common species are related to the areas occupying different positions in the relief (site 4 and 5, and 3 and 6 are only 4% of the total of widows). Communities of 4 and 3 position occupied eluvial positions in relief, and 5 and 6 - accumulative positions. Thus there are completely different physico-chemical soil parameters. According to the results of cluster analysis (Annex 10 Figure 4) most similar communities colonize similar ecotopes.

Soils of the quarry

Description of soil profiles, their photos and results of the vertical electrical sounding is given in Annex 12 Table 9.

High diversity of soil has been found in the pits indicating multivariate model of development. Most of the environmental factors are optimal for the development of vegetation (Annex 13 Table 10). The exception was the high density and strong rock on the stony bottoms of the quarry, these properties are obstacles for the development of plant communities. All areas are characterized by extremely inhomogeneous distribution of the fractions in the profile (Annex 13 Table 10). For all sites it is typical feature large number of coarse skeletal material at a relatively low content of fine earth. The vast majority of soils are characterized by fulvic-humic type of humus, which is typical for the soils of the area. Overall, the results of mesomorphological studies show relatively high rates of pedogenic substrate conversion. The main processes of transformation of the mineral soil - chemical, biochemical and physical weathering of carbonate rocks. Intensive weathering of limestone debris contributes to a significant content of fine earth (exceptions are only rocky bottom of the quarry), this in turn increases the moisture content Embryozems and fertility. Thus, it ensures active development of plant communities, actively producing organic matter. Intensive decarbonatization are primarily reflected in a significant decrease in pH of humus horizons in comparison with parent material, we note that the forming conditions are becoming more favorable for plant growth.

Among the specific environmental 5 factors by direct selection for inclusion in the model were selected. These 5 factors have the greatest impact on the distribution of vegetation, among them - the texture of the soil, stoniness, the content of physical clay, the pH in water and humidity (Annex 14 Table 11.). The results of canonical analysis are shown in Annex 15 Figure 5. The first axis explains 65% of the variance, and the second - 23%. Areas with maximum stoniness are colonized mostly on sparse vegetation with a predominance of groups Ceratodon purpureus and Bryum pseudotriquetrum. Areas with large portion of clay fraction colonize spruce grass. Drained sandy areas are occupied by different types of pine. In areas with large number of skeletal material and relatively low content of fine earth small-leaved forests dominate.

Evaluation of CO2 emission and deposition by soils of the quarry

One of the negative consequences of mining is the high level of CO2 emissions, this is especially true for carbonate rocks. Receipt of carbon dioxide in the atmosphere due to both weathering of carbonates and soil basal respiration, in the development of soil and vegetation, emissions of carbon dioxide are changed by its deposition, the rate of the last one can be estimated on the content of organic carbon in the soil. All of these processes are given in Annex 13 Table 10. Basal respiration rate of soil of the quarry has been extremely low (from 0.015 to 0.1 g CO 2 C / g per hour), the main income sources of CO2 in the atmosphere are weathered carbonates. CO2 carbonate content varies from 0.06 to 0.5%, these values are very low compared with the content of organic carbon in the young soils (3 to 25%). The term "sequestration of soil carbon" means the removal of atmospheric CO2 by plants and storage of carbon fixed in the soil as organic matter. Surveyed levels of carbon sequencing depend on the particle size distribution and soil texture, profile. The highest levels of carbon dioxide deposition deposit are observed at 6 site. This site is accumulative ecotope with optimal moisture conditions and physical parameters of the substrate. The relatively high content of clay fractions on par with humification processes contribute to the increase of carbon content in the soil, as well as the retention of stable forms of carbon. The strategy is to increase the amount of organic matter in the soil, improving its distribution in the soil profile as well as stabilize the soil organic carbon in stable microaggregates, thereby protecting carbon from microbiological processes preventing its mineralization. In this context, management of land reclamation is an important strategy for reducing the effects of global climate change.

Ecosystem services of the Pechurki quarry

Calculation of ecosystem services on plant communities formed on the quarry have been carried out according to the formula proposed by A.G. Rosenberg (2016):

E = S (Tg + Nd * Nm * Tm), where Ei - ecosystem services; S - area of plant communities career; Nd - number of tree and shrub species; Nm - number of species of herbaceous plants at the quarry, Tm and Tg - valuation (as a assessment used taxes to calculate the size of harm to 1 hectare of herbaceous plants (Tm) - 450,000 rubles, 1 hectare of trees and shrubs (AP) -. 750 000 rub.). The total value of ecosystem services plant communities career estimated 108 480 mln. Rub. or 1,486,027,397 euros. It is worth noting that after the reclamation of the quarry and open it to discover the number of career significantly increase ecosystem services, as well as its cost.

Recommendations

According to the results of our investigation and literature as well the significant part of quarries can be successfully rehabilitate during the process of self-overgrowing. This positively affects the biodiversity level.

During the quarry exploitation dumps filled with stones (mainly sandy stones) it is recommended to warehouse this material to the horizontal or low-inclined elements of relief.

Stones with predominance of silt fractions advisably should be warehoused in figure of drum-like hills up to 2 m in altitude. In this case water erosion does not take place. Hydromorphic forms of landscapes are not developing as well.

It is recommended also to leave refigiums of natural vegetation in order to increase the speed of territories renovation, the level of biodiversity and prevent sites capture by aliens-species.

In case of big areas of the quarry and inability to leave natural vegetation it is recommended to use spontaneous lamination of litter from natural communities to material surface.

One of the main problem of recultivation of dumps full of gravel material is freeze-out of stones from rock overburden into superposed layers of soft overburden. It leads to regression of trees and abrupt decreasing of replantozems physical properties. For impact decreasing we recommend to increase the thickness of soft overburden up to 1,5-2 m. Moreover, it should be dabbed friable layer of off-corn crushing to the rock bottoms. It lets to improve physical properties of substrate and put on the overgrowing process. We also recommend to save complicated relief on the quarry. It leads to formation of diverse ecological niches and support the high biodiversity level. In order to increase the CO_2 sequestration rate from the atmosphere and for decreasing of global climate warming rates it is recommended to pay attention especially for accumulative forms of relief during the quarry designing. Here overgrowing is developing on the sites with auspicious substrate physical properties (medium-loamy soils on the soft overburden). In this exact condition it has been identified the highest rate of CO_2 sequestration from the atmosphere, highest speed of succession, highest vegetation projective cover and highest content of organic carbon in the topsoils.

Educational part of the project

The main goals of this part of the project were increasing of awareness of ecological culture among society and responsibility for biodiversity saving issue and environment quality. It was also aimed to incite children and young people for their own investigations and environmental protection events. It has been established also the goal of creating educational cartoon about biodiversity on the quarries. Since the name of our project is "Biodiversity in space and time" our goal was also cover more people different ages on the wide territory as possible.

Results

In total, we have performed 11 scientific speech on biodiversity of the Pechurki quarry and influence of the quarries on natural environment conditions on Russian and International scientific conferences. According to the results abstracts have been published, one scientific paper is in print now. Team has created 2 lessons about biodiversity on the quarries and water resources. These materials have been send to the Natural protection community of Saint Petersburg and middle schools. By team participants it has been performed 32 lessons in the schools. Additionally at least 40 lessons created by us have been performed by volunteers and school methodists.It was organized the contest of essays on "If the quarry inhabitants could speak" among pupils of Saint Petersburg. Among children house pupils with Down syndrome and other evolution features it has been conducted the contest on the best illustration.It has been also created the first cartoon on biodiversity of the quarries adopted for children. You can watch it by the link https://www.youtube.com/watch?v=MU34-AwGf4w. Press-conference for Slantsy citizens was organized. Team represtented high conservation value of the Pechurki quarry. The meeting was attended by representatives of local radio, television and newspapers, the main results have been highlighted in the mass-media. For children local history studio it was organized excursion to the quarry. Thus, more than 2,500 people from different countries, different ages and different areas have been acquainted with our project and the importance of biodiversity.

Recommendations

Part of the quarry is planned to waterlog. After this is lands will risen from the water will rise islands. It is overgrown rock of dumps produced. Here according to gradient of humidity and soil physical and chemical properties will vary, and with them - vegetation groups. The study of the current situation in the quarry gives the reason to believe the next spatial variation of plant communities along a gradient of humidity: coastal aquatic vegetation - grassland community - thickets of willows - small-leaved, mixed or coniferous forest at the top of the dump (depending on the composition of underlayed material). The inaccessibility of these areas for humans and the lack of secondary anthropogenic load will affect the increase of biodiversity level. Many of the habitats represented in the quarry are quite rare in the surrounding natural landscape that makes the area particularly attractive for a number of Red book plants, and many other animals. At this moment, Pechurki quarry is an unique and stable system of various ecosystems, further waterlogging of part of the quarry will increase spatial heterogeneity and, consequently, biodiversity. Named ecosystem has a high conservation value, therefore in the future it is recommended to use the territory of the quarry as an object of ecological monitoring of ecosystem restoration on calcareous quarries of North-West, for environmental educational activities. It is also recommended to considerthe issue of giving the special conservation status to the Pechurki quarry. It is recommended to create a territory for environmental and biological education - "Living Encyclopedia".Taking into account high biological value before reclamation it is necessary to take measures to improve the environmental responsibility of people, such as lectures, eco-clubs, master classes, open-dors days of and excursions. Especially it should be noticed necessarity of regulari chatacter of such events, it is possible to attract local library, museum and biology teachers with their pupils. Slantsy district is poorly studied from a biological point of view, because in the past it was a developed industrial area. To this day, it is difficult to find information about the flora and fauna Slantsy district. Possible involvement of the public, including biologists and ecologists, representatives of public organizations will begin work on the creation of protected areas in the region, attracting eco-tourists to the area, increasing the attractiveness of the area, and thus have a positive impact on the socio-economic development of the region. The question of creation of specially protected area in the quarry is also relevant due to absence of such areas in Slantsy district. At the same time National program tells about increasing of such specially protected areas in 2 times.

Recreational part of the quarry should arrange so as to limit the possibility of mass gatherings of people, it is not recommended to arrange bulk beach.It is proposed to settle garden house near already formed lake. It is also necessary to organize a special place for a campfire observing the precautions of fire. At the entrance to the quarry it makes sense to establish a large information stand about how you need to behave when meeting with different animals and rare species of plants, which can be seen in the area. Information boards acquainting people with biological processes and communities, which can be seen at the site can also be installed in different ecotopes of the quarry, they will mean a key ecotrails. Some sites with less conservation value can be left for environmental experiments for reclamation measures. This quarry will be interest to all specialists: biologists - because relatively large area presents a huge number of ecological niches, environmentalists - because here you can see firsthand how all stages of succession, as well as its various directions. Also, students and local residents - because it is an opportunity to explore the natural processes not from books and pictures, but to get knowledge directly. During the organization of such measures it can be expected quite a large number of eco-tourists, for their staying it is better to mark places with possibility to install a tent (preferably meadow and open places on the quarry), and install warning signs, where not to do so.

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☒Urban ecology
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Flora:
☒Conifers and cycads
☒Ferns
☒Flowering plants
☐Fungi
☒Mosses and liverworts

Fauna:
☐Amphibians
☐Birds
☐Dragonflies & Butterflies
☐Fish
☐Mammals
☐Reptiles
☐Spiders
☒Other insects
☐Other species</td><td>Habitat:
☒Cave
☒Cliffs
☒Fields - crops/culture
☒Forest
☒Grassland
☐Human settlement
☒Open areas of rocky grounds
☒Recreational areas
☒Screes
☒Shrubs & groves
☒Soil
☒Wander biotopes
☒Water bodies (flowing, standing)
☒Wetland

Stakeholders:
☒Authorities
☒Local community
☒NGOs
☒Schools
☒Universities</td></tr>
</table>

1. The list of estimated physico-chemical and microbiological substrate properties
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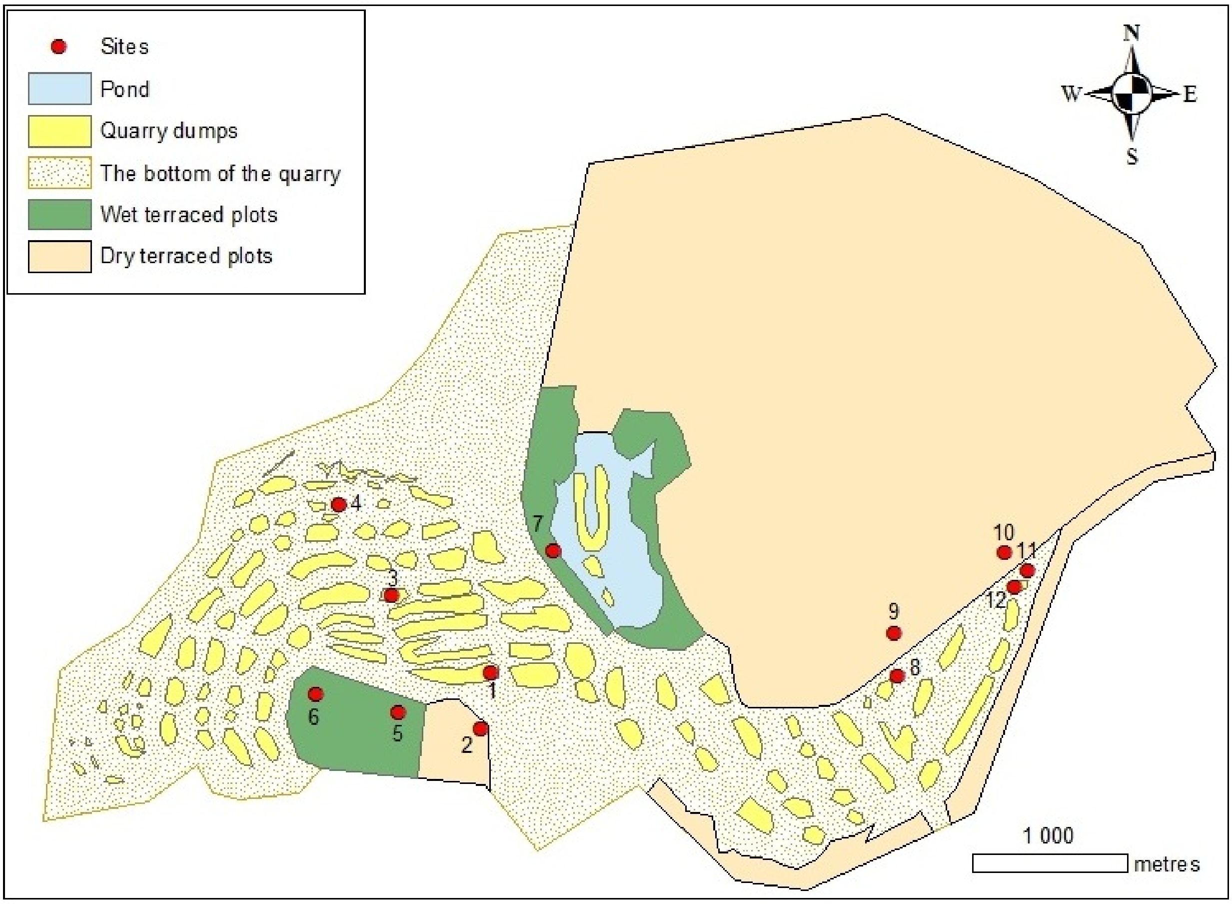
Annex 1: List of the defined physical, chemical and microbiological parameters of the substrate

The following parameters were determined in soil samples:
- Substrate-induced respiration (Ananyeva et al, 2008);
- Basal soil respiration on LED technique, but unenriched soil substrate;
- Organic carbon oxidation by bichromate - the method of Tyurin;
- PH in water and salt (1: 2.5);
- Exchangeable acidity and hydrolytic acidity;
- acidometric evaluation of CO_2 content in carbonates (Tsitovich, 1994);
- Hygroscopic humidity and maximum hygroscopic moisture;
- The total water capacity (water capacity) and the lowest moisture content;
- Soil density and the density of the solid phase of the soil;
- Structural and stoniness soil by dry sieving;
- Particle size distribution of the soil, using pipette-by Kaczynski with pirophosphate peptization of microaggregates (Rastvorova, 1983);
- Fractional-group composition of humus humus by Tyurin's scheme modified by V.V. Ponomareva and T.A. Plotnikova (1980).
- Quantitative determination of carbon of microbial biomass carbon method performed according to the formula proposed by J. P. E. Anderson and K. H. A. Domsch (1987):

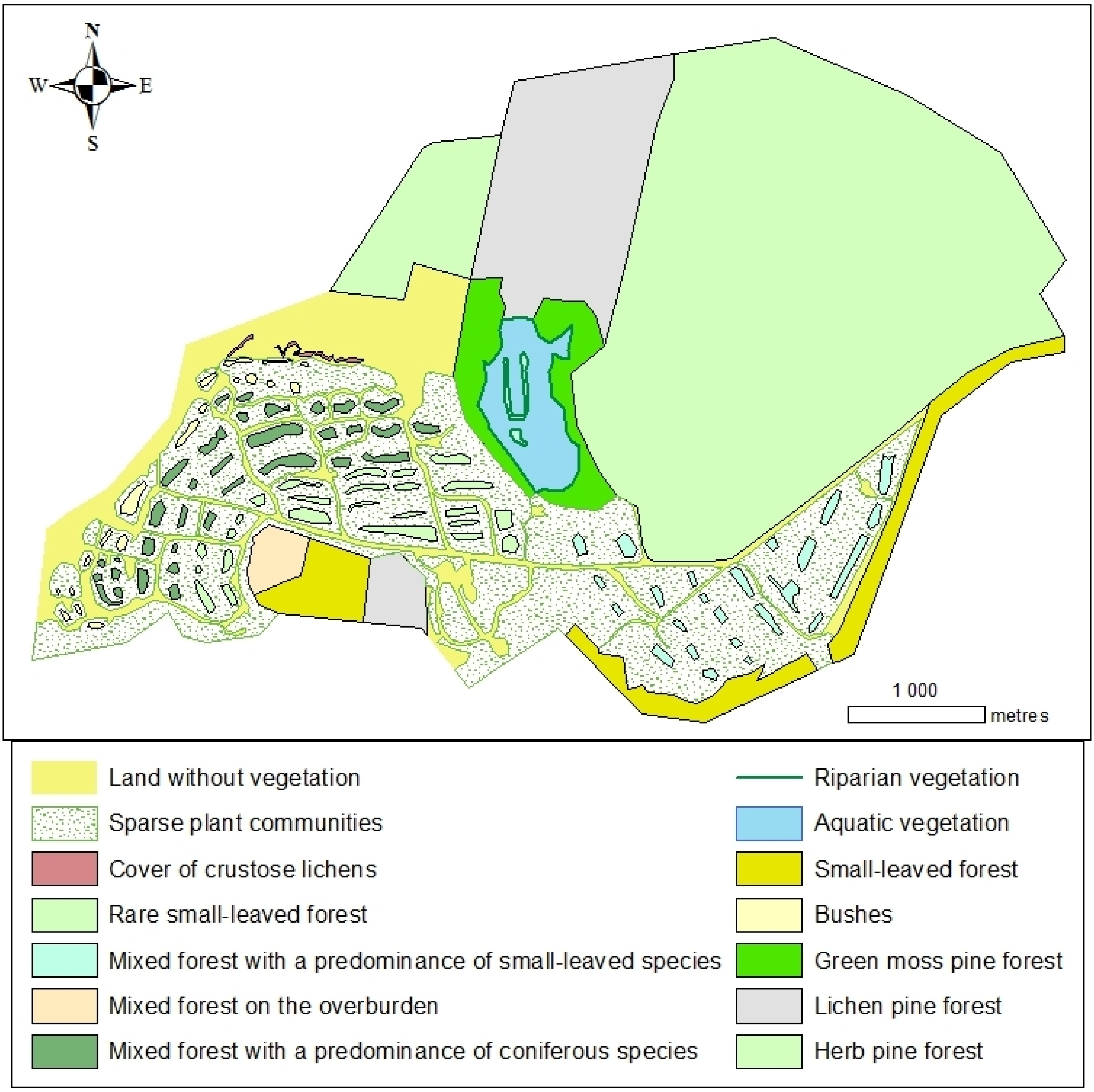
Smic (g C / g soil) = LED (L CO_2 / g soil per hour) × 40.04 + 0.37.

- Microbial metabolic rate (the specific breathing microbial biomass) is found as the ratio of basal respiration to microbial biomass carbon index: qSO_2 (g CO_2 / Smic mg / h) = DB / Smic.

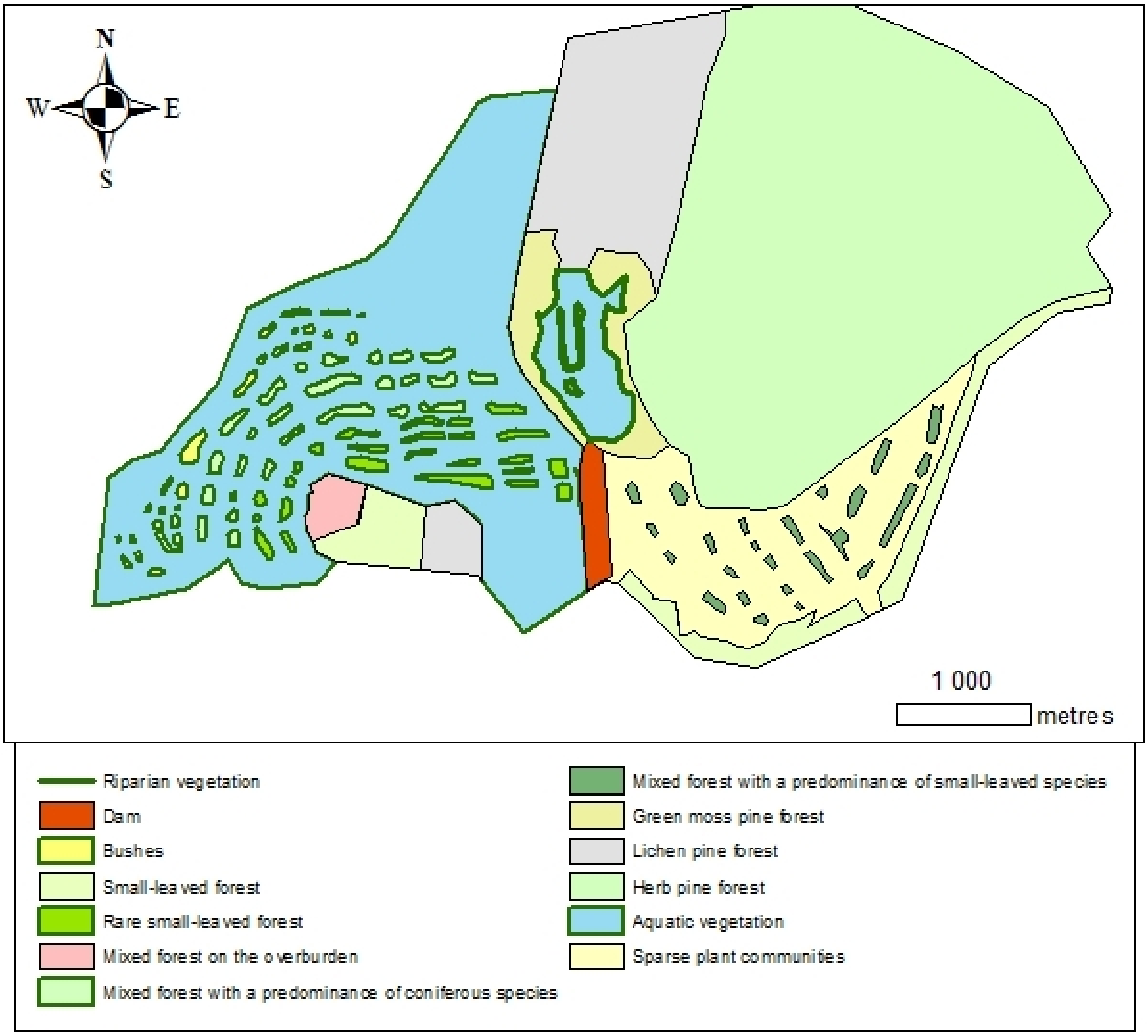
Annex 2. Figure 1. Space image of the Pechurki quarry



Annex 2. Figure 2.Schematic map of landforms on the quarry and areas of study



Annex 2. Figure 3.Schematic map of plant communities of the quarry



Annex 2. Figure 4. Schematic map of plant communities, taking into account the forecast of succession after the reclamation and quarry waterlogging

Annex 3. Table 1. The number of species of vascular plants at each site

site 1	site 2	site 3	site 4	site 5	site 6	site 7	site 8	site 9	site 10	site 11	site 12
22	30	24	19	24	23	39	20	25	14	19	31

Annex 4. Table 2. The similarity of species composition of different parts of the quarry (Sorensen-Czekanowski coefficient)**, %**

Site \ Site	1	2	3	4	5	6	7	8	9	10	11	12
1		53	39	24	13	13	29	38	46	66	43	49
2			29	24	18	11	31	44	32	45	48	42
3				37	17	**4**	15	22	28	26	27	36
4					**4**	14	10	20	31	30	21	28
5						30	29	13	20	10	19	18
6							22	13	8	16	14	48
7								44	40	37	37	31
8									26	41	**92**	47
9										61	27	32
10											42	40
11												48
12												

Annex 5. Table 3. Indices of biodiversity for different sections of the quarry

Number of site												Indices
1	2	3	4	5	6	7	8	9	10	11	12	
4,47	6,17	4,89	3,83	4,68	4,68	**8,08**	4,04	5,11	**2,76**	3,83	6,38	Margalef
2,1	2,86	2,29	1,81	2,19	2,19	**3,72**	1,91	2,38	**1,33**	1,81	2,96	Menhinik
2,41	3,13	2,29	2,21	2,83	2,98	**3,37**	2,91	2,99	**2,10**	2,83	3,31	Shennon
6,94	21,7	5,59	5,92	16	20,7	24,5	25,7	17	**5,34**	26,3	**33,4**	Reverse index of Simpson

Annex 6. Table 4: List of species of vascular plants of the quarry
Note: protected areas are in yellow.

DIVISION	CLASS	ORDER	FAMILY	GENUS	TYPE
Equisetophyta	*Equisetopsida*	*Equisetales*	*Equisetaceae*	*Equisetum*	*Equisetum arvense L.*
					Equisetum hyemale L.
					Equisetum palustre L.
					Equisetum pratense Ehrh.
					Equisetum variegatum Schleich. ex Weber & D. Mohr
Magnoliophyta	*Liliopsida*	*Alismatales*	*Alismataceae*	*Alisma*	*Alisma plantago-aquatica L.*
		Asparagales	*Convallariaceae*	*Convallaria*	*Convallaria majalis L.*
				Maianthemum	*Maianthemum bifolium (L.) F.W. Schmidt*
		Cyperales	*Cyperaceae*	*Carex*	*Carex flava L.*
					Carex pluriflora Hulten
					Carex vesicaria L.
				Scirpus	*Scirpus sylvaticus L.*
		Juncales	*Juncaceae*	*Juncus*	*Juncus articulatus L.*
					Juncus bufonius L.
					Juncus effusus L.
		Orchidales	*Orchidaceae*	*Cypripedium*	*Cypripedium calceolusL.*
				Dactylorhiza	*Dactylorhiza fuchsii (Druce) Soo*
					Dactylorhiza incarnata (L.) Soo
					Dactylorhiza maculata (L.) Soo
				Epipactis	*Epipactis atrorubens (Hoffm.) Besser*
					Epipactis helleborine (L.) Crantz
					Epipactis palustris (L.) Crantz
				Gymnadenia	*Gymnadenia conopsea (L.) R. Br.*
				Platanthera	*Platanthera bifolia (L.) Rich.*
		Poales	*Poaceae*	*Agrostis*	*Agrostis tenuis Sibth.,*
				Alopecurus	*Alopecurus pratensis L.*
				Anthoxanthum	*Anthoxanthum odoratum L.*
				Calamagrostis	*Calamagrostis epigeios (L.) Roth*
				Dactylis	*Dactylis glomerata L.*
				Deschampsia	*Deschampsia cespitosa*

					(L.) Beauv.
				Festuca	*Festuca ovina L.*
					Festuca pratensis Huds.
					Festuca rubra L.
				Melica	*Melica nutans L.*
				Phleum	*Phleum pratense L.*
				Phragmites	*Phragmites australis Cav.*
				Poa	*Poa pratensis L.*
		Trilliales	*Trilliaceae*	*Paris*	*Paris quadrifolia L.*
		Typhales	*Sparganiaceae*	*Sparganium*	*Sparganium erectum L.*
			Typhaceae	*Typha*	*Typha latifolia L.*
	Magnoliopsida	*Adoxales*	*Sambucaceae*	*Sambucus*	*Sambucus racemosa L.*
		Araliales	*Apiaceae*	*Aegopodium*	*Aegopodium podagraria L.*
			Apiaceae	*Angelica*	*Angelica sylvestris L.*
		Aristolochiales	*Aristolochiaceae*	*Asarum*	*Asarum europaeum L.*
		Asterales	*Asteraceae*	*Achillea*	*Achillea millefolium L.*
				Artemisia	*Artemisia vulgaris L.*
				Carduus	*Carduus crispus L.*
				Centaurea	*Centaurea phrygia L.*
				Cirsium	*Cirsium vulgare (Savi) Ten.*
				Crepis	*Crepis paludosa (L.) Moench*
				Hieracium	*Hieracium umbellatum L.*
				Leucanthemum	*Leucanthemum vulgare Lam.*
				Solidago	*Solidago virgaurea L.*
				Taraxacum	*Taraxacum officinale Wigg.*
				Tussilago	*Tussilago farfara L.*
		Balsaminales	*Balsaminaceae*	*Impatiens*	*Impatiens noli-tangere L.*
		Boraginales	*Boraginaceae*	*Echium*	*Echium vulgare L.*
				Pulmonaria	*Pulmonaria obscura Dumort.*
		Campanulales	*Campanulaceae*	*Campanula*	*Campanula patula L.*
		Caryophyllales	*Caryophyllaceae*	*Coccyganthe*	*Coccyganthe flos-cuculi (L.) Fourr.*
				Oberna	*Oberna behen (L.) Ikonn.*
				Stellaria	*Stellaria graminea L.*
			Chenopodiaceae	*Atriplex*	*Atriplex latifolia Wahlenb.*
				Chenopodium	*Chenopodium album L.*
		Corylales	*Betulaceae*	*Betula*	*Betula pendula Roth*

		Dipsacales	*Caprifoliaceae*	*Lonicera*	*Lonicera xylosteum L.*
			Dipsacaceae	*Succisa*	*Succisa pratensis Moench.*
		Ericales	*Ericaceae*	*Chimaphila*	*Chimaphila umbellata (L.) W.P.C. Barton*
				Orthilia	*Orthilia secunda (L.) House,*
				Pyrola	*Pyrola rotundifolia L.*
				Vaccinium	*Vaccinium vitis-idaea L.*
		Fabales	*Fabaceae*	*Anthyllis*	*Anthyllis vulneraria*
				Lathyrus	*Lathyrus pratensis L.*
					Lathyrus sylvestris L.
				Medicago	*Medicago lupulina L.*
				Melilotus	*Melilotus albus Medik.*
					Melilotus officinalis (L.) Pall.
				Trifolium	*Trifolium hybridum L.*
					Trifolium medium L.
					Trifolium pratense L.
					Trifolium repens L.
				Vicia	*Vicia hirsuta (L.) Gray*
					Vicia sepium (L.) Moench
					Vicia sylvatica L.
		Geraniales	*Geraniaceae*	*Geranium*	*Geranium sylvaticum L.*
		Hypericales	*Hypericaceae*	*Hypericum*	*Hypericum perforatum L.*
		Lamiales	*Lamiaceae*	*Galeopsis*	*Galeopsis speciosa Mill.*
				Origanum	*Origanum vulgare L.*
				Prunella	*Prunella vulgaris L.*
				Stachys	*Stachys palustris L.*
		Myrtales	*Onagraceae*	*Chamaenerion*	*Chamaenerion angustifolium (L.) Scop.*
				Circaea	*Circaea alpina L.*
		Oleales	*Oleaceae*	*Fraxinus*	*Fraxinus excelsior L.*
		Oxalidales	*Oxalidaceae*	*Oxalis*	*Oxalis acetosella L.*
		Papaverales	*Fumariaceae*	*Corydalis*	*Corydalis bulbosa (L.) DC.*
		Polygalales	*Polygalaceae*	*Polygala*	*Polygala amarella Crantz*
				Rumex	*Rumex acetosella L.*
					Rumex obtusifolius L.
		Primulales	*Primulaceae*	*Trientalis*	*Trientalis europaea L.*
		Ranunculales	*Ranunculaceae*	*Caltha*	*Caltha palustris L.*
				Hepatica	*Hepatica nobilis Mill.*

				Ranunculus	*Ranunculus acris L.*
		Rhamnales	*Rhamnaceae*	*Frangula*	*Frangula alnus Mill.*
				Rhamnus	*Rhamnus cathartica L.*
		Rosales	*Rosaceae*	*Filipendula*	*Filipendula ulmaria (L.) Maxim.*
				Fragaria	*Fragaria vesca L.*
				Geum	*Geum rivale L.*
					Geum urbanum L.
				Padus	*Padus avium Mill.*
				Potentilla	*Potentilla anserina L.*
					Potentilla erecta (L.) Raeusch.
				Rubus	*Rubus caesius L.*
					Rubus chamaemorus L.
					Rubus idaeus L.
				Sorbus	*Sorbus aucuparia L.*
		Rubiales	*Rubiaceae*	*Galium*	*Galium album Mill.*
		Salicales	*Salicaceae*	*Populus*	*Populus tremula L.*
				Salix	*Salix starkeana Willd.*
					Salix caprea L.
		Sapindales	*Aceraceae*	*Acer*	*Acer platanoides L.*
		Scrophulariales	*Plantaginaceae*	*Plantago*	*Plantago major L.*
			Scrophulariaceae	*Melampyrum*	*Melampyrum nemorosum L.*
					Melampyrum pratense L.
				Scrophularia	*Scrophularia nodosa L.*
				Verbascum	*Verbascum nigrum L.*
				Veronica	*Veronica longifolia L.*
		Solanales	*Solanaceae*	*Solanum*	*Solanum dulcamara L.*
		Urticales	*Ulmaceae*	*Ulmus*	*Ulmus glabra Huds.*
					Ulmus laevis Pall.
		Viburnales	*Viburnaceae*	*Viburnum*	*Viburnum opulus L.*
		Violales	*Violaceae*	*Viola*	*Viola canina L.*
Pinophyta	*Pinopsida*	*Cupressales*	*Cupressaceae*	*Juniperus*	*Juniperus communis L.*
		Pinales	*Pinaceae*	*Picea*	*Picea abies (L.) H. Karst.*
			Pinaceae	*Pinus*	*Pinus sylvestris L.*
Polypodiophyta	*Polypodiopsida*	*Blechnales*	*Woodsiaceae*	*Gymnocarpium*	*Gymnocarpium dryopteris L.*
	Polypodiopsida	*Dicksoniales*	*Dennstaedtiaceae*	*Pteridium*	*Pteridium aquilinum (L.) Kuhn*
Всего: 4	5	45	49	108	136

продолжение таблицы	
Мохообразные	
Семейство	Вид
Hylocomiaceae	Rhytidiadelphus triquetrus
	Hylocomnium splendens
	Pleurozium schreberi
Dicranaceae	Dicranum scoparium
	Dicranum polysetum
Bryacea	Bryum pseudotriquetum
	Pohlia nutans
Mniaceae	Mnium marginatum
	Plagiomnium cuspidatum
Polytrichaceae	Polytrichum commune
	Pogonatum urnigerum
Pylaisiaceae	Calliergonella lindbergii
Pylaisiaceae	Campylium stellatum
Amblystegiaceae	Ceratodon purputreus
Brachytheciaceae	Brachythecium mildeanum
Thuidiaceae	Thuidium recognitum
Leucodontaceae	Leucodon sciuroides
Disceliaceae	Discelium nudum
Pylaisiaceae	Ptilium crista-castrensis
Peltigeraceae	Peltigera aphtosa
Climaciaceae	Climacium dendroides
Blasiaceae	Blasia pusilla

Annex 7. Table 5. Taxonomical summary of algae and cyanoprokaryota of accumulative ecotopes of the Pechurki quarry

DIVISION	ORDER	FAMILY	GENUS	AMOUNT OF SPECIES
Bacillariophyta	*Cymbellales*	*Cymbellaceae*	*Cymbella*	2
		Gomphonemataceae	*Gomphonema*	1
	Fragilariales	*Fragilariaceae*	*Fragilaria*	1
		Fragilariaceae	*Synedra*	1
	Naviculales	*Naviculaceae*	*Navicula*	7
		Pinnulariaceae	*Pinnularia*	3
	Rhopalodiales	*Rhopalodiaceae*	*Epithemia*	1
	Stephanodiscales	*Stephanodiscaceae*	*Cyclotella*	1
	Tabellariales	*Tabellariaceae*	*Tabellaria*	1
Charophyta	*Desmidiales*	*Desmidiaceae*	*Staurastrum*	6
		Desmidiaceae	*Cosmarium*	9
	Zygnematales	*Zygnemataceae*	*Mougeotia*	2
Chlorophyta	*Chlamydomonadales*	*Sphaerocystidaceae*	*Sphaerocystis*	1
		Volvocaceae	*Eudorina*	1
	Sphaeropleales	*Hydrodictyaceae*	*Pseudopediastrum*	1
			Stauridium	1
			Tetraedron	1
		Scenedesmaceae	*Dimorphococcus*	1
			Scenedesmus	4
		Selenastraceae	*Ankistrodesmus*	2
			Monoraphidium	4
Cyanoprokaryota	*Chroococcales*	*Microcystaceae*	*Microcystis*	3
		Chroococcaceae	*Chroococcus*	3
		Microcystaceae	*Gloeocapsa*	1
	Nostocales	*Nostocaceae*	*Cylindrospermum*	1
	Oscillatoriales	*Microcoleaceae*	*Trichodesmium*	1
		Oscillatoriaceae	*Lyngbya*	1
			Oscillatoria	2
	Synechococcales	*Coelosphaeriaceae*	*Snowella*	1
		Leptolyngbyaceae	*Planktolyngbya*	1
		Merismopediaceae	*Merismopedia*	2
			Aphanocapsa	1
		Pseudanabaenaceae	*Jaaginema*	1
		Synechococcaceae	*Rhabdoderma*	1
			Synechococcus	1
Euglenophyta	*Euglenales*	*Euglenaceae*	*Trachelomonas*	1
Miozoa (Dinoflagellata)	*Peridiniales*	*Peridiniaceae*	*Peridinium*	1
Ochrophyta	*Chromulinales*	*Dinobryaceae*	*Chrysococcus*	2
Всего: 7	17	29	38	75

Приложение 8. Table 6. Taxonomical summary lithobiotic algae and cyanoprokaryota

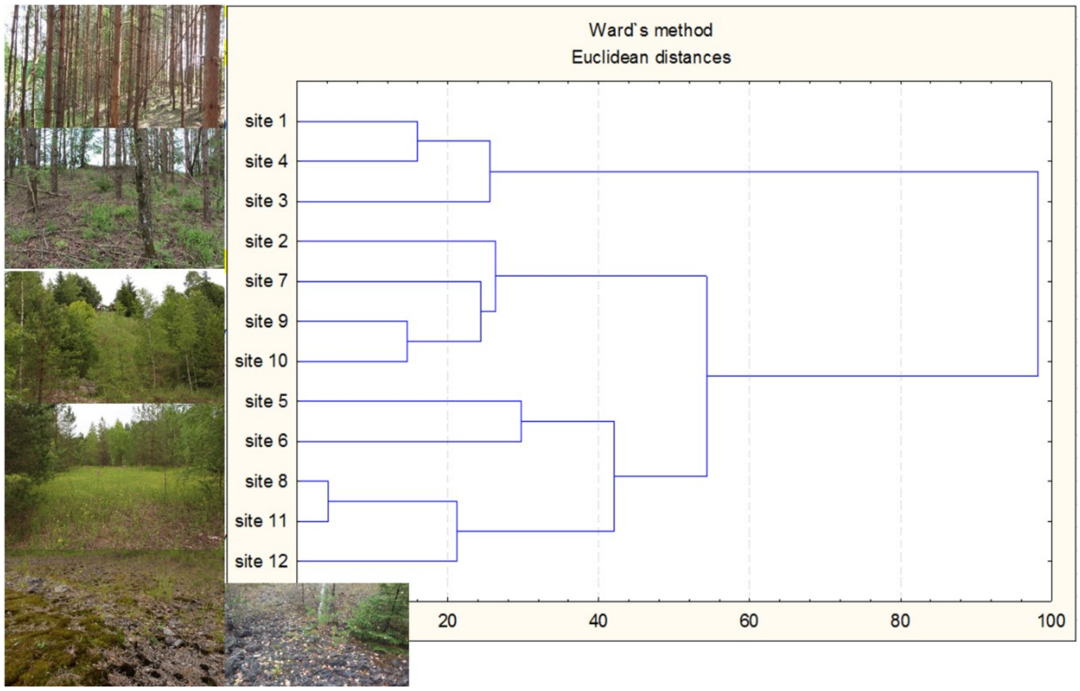
DIVISION	ORDER	FAMILY	GENUS	AMOUNT OF SPECIES
Bacillariophyta	*Naviculales*	*Naviculaceae*	*Navicula*	1
		Pinnulariaceae	*Pinnularia*	2
Charophyta	*Desmidiales*	*Desmidiaceae*	*Cosmarium*	1
	Zygnematales	*Zygnemataceae*	*Mougeotia*	1
			Zygnema	1
Chlorophyta	*Chlorellales*	*Oocystaceae*	*Oocystis*	1
	Sphaeropleales	*Microsporaceae*	*Microspora*	1
	Trentepohliales	*Trentepohliaceae*	*Trentepohlia*	2
Cyanoprokaryota	*Chroococcales*	*Microcystaceae*	*Microcystis*	1
		Aphanothecaceae	*Gloeothece*	1
		Chroococcaceae	*Chroococcus*	2
		Microcystaceae	*Gloeocapsa*	3
	Nostocales	*Nostocaceae*	*Isocystis*	1
		Rivulariaceae	*Calothrix*	2
	Oscillatoriales	*Oscillatoriaceae*	*Lyngbya*	2
			Oscillatoria	3
			Phormidium	5
	Pseudanabaenales	*Schizotrichaceae*	*Schizothrix*	1
	Synechococcales	*Coelosphaeriaceae*	*Coelosphoerium*	1
		Merismopediaceae	*Merismopedia*	1
			Synechocystis	1
		Synechococcaceae	*Synechococcus*	1
Ochrophyta	*Tribonematales*	*Tribonemataceae*	*Tribonema*	1
Всего: 5	12	19	22	36

Annex 9. Table 7. List of epilithic lichen species of the Pechurki

DIVISION	ORDER	FAMILY	GENUS	TAXON
Ascomycota	*Arthoniales*	*Arthoniaceae*	*Arthonia*	*Arthonia fusca* (A. Massal.) Hepp
Ascomycota	*Lecanorales*	*Acarosporaceae*	*Acarospora*	*Acarospora glaucocarpa* (Ach.) Körb.
Ascomycota	*Lecanorales*	*Acarosporaceae*	*Acarospora*	*Acarospora moenium* (Vain.) Räsänen
Ascomycota	*Lecanorales*	*Acarosporaceae*	*Sarcogyne*	*Sarcogyne regularis* Körb.
Ascomycota	*Lecanorales*	*Candelariaceae*	*Candelariella*	*Candelariella aurella* (Hoffm.) Zahlbr.
Ascomycota	*Lecanorales*	*Hymeneliaceae*	*Hymenelia*	*Hymenelia epulotica* (Ach.) Lutzoni
Ascomycota	*Lecanorales*	*Lecanoraceae*	*Lecanora*	*Lecanora dispersa* (Pers.) Sommerf.
Ascomycota	*Lecanorales*	*Lecanoraceae*	*Lecanora*	*Lecanora crenulata* Hook.
Ascomycota	*Lecanorales*	*Lecanoraceae*	*Lecidella*	*Lecidella stigmatea* (Ach.) Hertel et Leuckert
Ascomycota	*Lecanorales*	*Physciaceae*	*Phaeophyscia*	*Phaeophyscia nigricans* (Flörke) Moberg
Ascomycota	*Verrucariales*	*Verrucariaceae*	*Verrucaria*	*Verrucaria* spp.
Всего: 1	3	7	9	11

Annex 10. Table 8. Analysis of species composition of vegetation of different parts of the quarry

LIVING FROMS	SITES											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Evergreen trees	2	2	1	-	1	-	2	2	1	1	1	2
Summer-green trees	4	5	1	1	3	4	4	3	4	3	1	3
Evergreen bushes	-	-	-	-	-	-	1	-	-	-	-	-
Summer-green bushes	-	-	-	-	-	-	1	-	1	-	1	2
Summer-green root-proliferous semi-shrubs	-	-	1	1	-	-	1	-	-	-	-	-
Evergreen long-rhizome shrubs	-	1	-	-	2	4	2	1	-	-	-	-
Perrenial semi-shrubbed	-	1	-	-	-	-	-	-	-	-	-	-
Perrenial long-rhizome	8	5	7	3	7	5	7	2	8	6	2	5
Perrenial short-rhizome	3	5	3	7	3	1	4	1	7	5	3	5
Perrenial rod-rooted	1	2	-	-	-	-	-	-	3	1	-	1
Perrenial rod-brushrooted	1	1	-	-	1	-	3	-	2	1	-	2
Perrenial loose-bushed turf	1	4	-	1	1	-	-	1	2	1	5	-
Perrenial dense-bushed turf	-	-	-	-	-	-	1	1	-	-	-	-
Perrenial ground-creeping	-	-	-	-	1	1	-	1	-	-	-	-
Perennial stolon-froming	-	-	-	-	1	1	-	-	1	-	-	-
Perennial rosette	-	-	-	-	1	1	1	1	2	-	-	-
Perennial tuberous	-	-	-	-	-	1	5	4	3	-	-	-
Perrenial short-rhizome overground-stolone	-	-	-	-	-	-	1	1	1	1	-	-
Perrenial long-rhizome overground-stolone	-	-	-	-	-	-	1	-	1	-	-	2
Annual and perennial herbs	1	2	4	1	-	-	1	-	-	2	-	1
Annual root semiparasites	-	2	-	-	1	1	-	-	-	-	-	-
Group in regard to soil wealth												
Oligotrophs	-	3	2	2	-	-	-	1	1	-	2	1
Oligomesotrophs	-	-	-	1	3	3	7	4	5	2	4	1
Mesotrophs	17	19	8	12	13	11	22	14	23	9	7	16
Mesoeutrophs	-	4	1	-	5	3	4	-	4	6	-	2
Eutrophs	-	1	1	2	1	2	2	-	3	-	-	1
Groups in regard to soil water regime												
Xerophytes	-	1	-	-	-	-	-	-	-	-	-	-
Xeromesophytes	-	-	-	-	1	-	-	-	2	3	-	4
Xeromesohygrophytes	-	1	1	-	-	-	1	1	1	1	1	1
Mesophytes	18	19	6	11	12	13	24	11	22	17	7	13
Mesohygrophytes	-	3	-	2	9	4	7	3	9	-	4	4
Hygrophytes	-	1	-	1	1	-	3	2	2	-	2	-

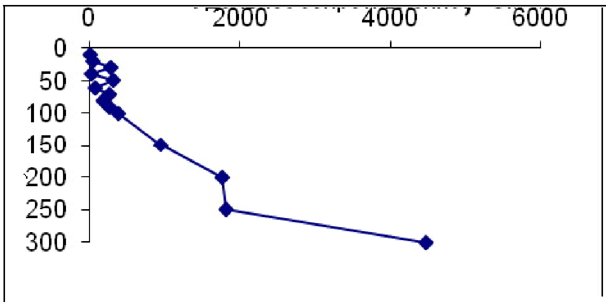
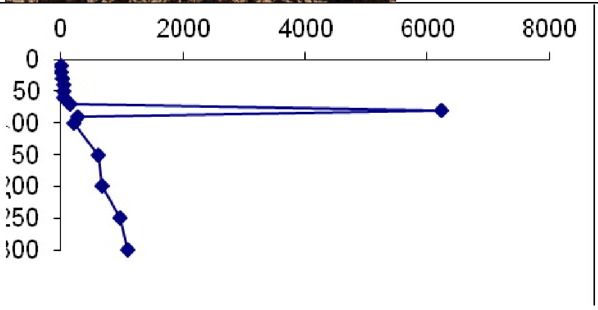


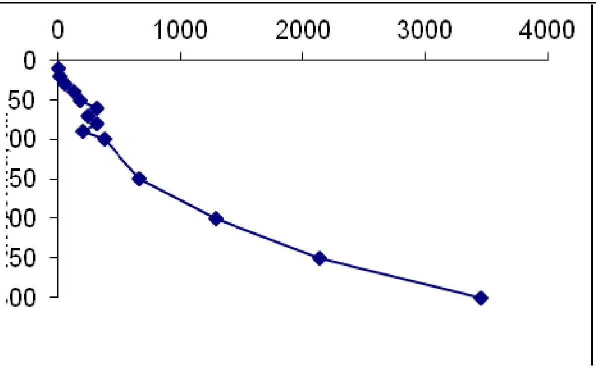
Annex 10. Figure 5. The results of cluster analysis

Sites 1, 3, 4 are self-overgrowing quarry dumps. Sites 2,7,9 and 10 are terraced (currently pine forest have formed here). Sites 5 and 6 are accumulative self-overgrowing territories. Sites 8 и 11 are rocky bottoms of the quarry.

Annex 12. Table 9. Soil profiles of the quarry and vertical electrical sounding

	**Site 1.** Self-overgrowing dump. Overgrowing duration - 28 years. Total projective cover of vegetation– 68 %. **Grey-humus embryozem** **O** (0-4 cm) – litter, sandy loam, densely permeated by roots, dark, not greasy. **AY** (4-33 cm) – sandy loam, roots, washed quartz grains, lighter than previous. **C** (33-48 cm) – sandy, light, power plants spread out, the inclusion of clay particles and quartz grains, roots. **[C]** (48 cm) – consists of quartz grains and stones, large sand, darker than the previous one, a smooth transition (everywhere), fragments of limestone found.

	According to the results of the vertical electrical sounding to 100cm in the soil contains large amounts of clay fractions. Considerable increase of the resistance indicates a large amount of coarse limestone material at a depth of 150 cm.
	**Site 2.** Self-overgrowing dump. Overgrowing duration - 16 years. Total projective cover of vegetation– 45 %. **Abra(Al-Fe)humus embryozem** O (0-3 cm) - brown, turn rocks, quartz grains, a large number of roots, undecomposed pine litter. BF (3-13 cm) - the presence of roots, lighter previous, large rocks, wet, sand inclusions, quartz grains. C (13 cm) - stones, wet, gray, moving with streaks.
	According to the results of mesomorphological studies loam fraction predominates up to 100 cm. Significant incresing of electrical resisrtivity (Ra) value on 100 cm is connected with limestone plate.
	**Site 3.** Self-overgrowing dump. Overgrowing duration - 30 years. Total projective cover of vegetation– 56 %. **Grey-humus hydrometamorphic embryozem** O (0-7 cm) - loamy sand, brown, lumpy structure, a large number of roots. AY (7-15 cm) - lighter than the previous, red streaks of oxidized iron, the presence of roots. Gox (15-46 cm) - lighter than the previous one, sand, roots, clay pellets. G (46 cm) - gray with accents of clay, iron concretions, rare roots, sand, decomposed organic residues.

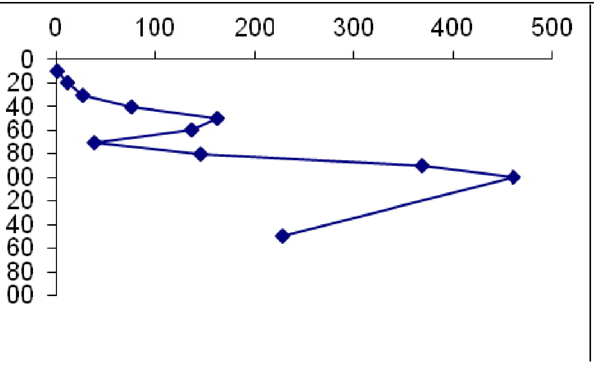


Increased soil resistivity with depth indicating a significant increase in the content of coarse material down the profile. Pronounced predominance of fine clay fractions at a depth of 70 cm.

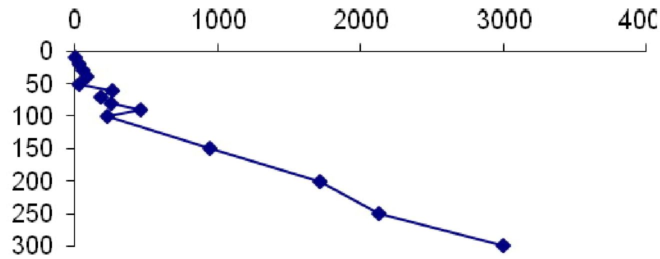
Site 4. Self-overgrowing dump. Overgrowing duration -8 years. Total projective cover of vegetation– 60 %.

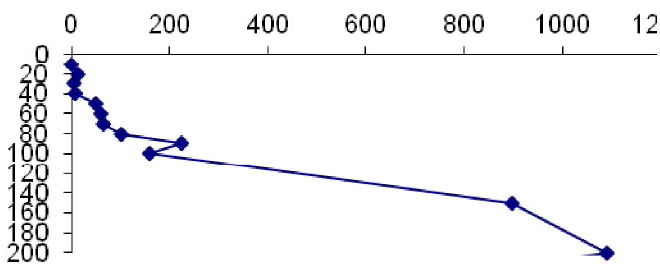
Grey-humus replantozem

AY (0-26 cm) - sandy loam with inclusions of sand and clay, lumpy structure, incorporating stone, permeated with roots, ferruginous sand
AC (26 cm) - the sand, lighter previous boundary layer along the rocky, ferruginous, permeated with roots, dark organic inclusions, a large number of stones.



This plot is characterized by non-uniform distribution of the profile fractions of sand and clay.

	**Site 5. Accumulative self-overgrowing ecotope.** Overgrowing duration - 35 years. Total projective cover of vegetation– 90 %. **Grey-humus stratozem** O (0-13 cm) - badly decomposed woody debris, dark. AY (13- 25 cm) - the sand, the inclusion of stones, humus dark inclusions, the transition color, permeated with roots, minerals, grains. C1 (25-37 cm) - gray, sand, roots. C2ox (37 cm) - red sand with roots, ferruginous.
	In this plot to a depth of 70 cm soil contains a large amount of fine fractions, the content of coarse material increases with depth.
	**Site 5. Accumulative self-overgrowing ecotope.** Overgrowing duration - 35 years. Total projective cover of vegetation– 90 %. **Grey-humus stratozem** O (0-4 cm) - litter, decomposing organic debris, roots are present. AY (4-28 cm) - brown, a large number of roots, wood particles, loose, lumpy structure. C (28 cm) - sandy, light, moist, contains inclusions of iron root zone

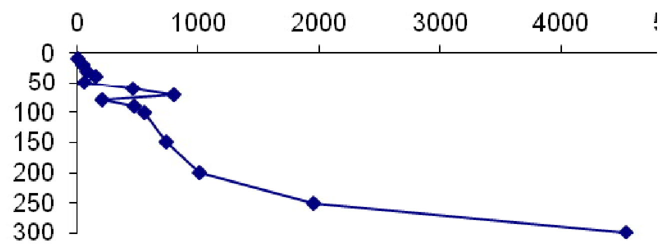


At a depth of 150 cm we observed sharp increasing in Ra values, which may indicates a finding here limestone plats.

Site 7. Recultivatioal plot of the quarry. Site 5.
Overgrowing duration - 29 years. Total projective cover of vegetation– 57 %.

Grey-humus replantozem

O (0-7 cm) - moss litter, poorly decomposed pine needles, half-decayed wood with plenty of mycelium.
AY (7-9 cm) – humus-accumulative layer, gray, sand, a large number of roots.
C (9+ cm) yellow, iron inclusions root zone, the inclusion of coal, a significant number of large stones.

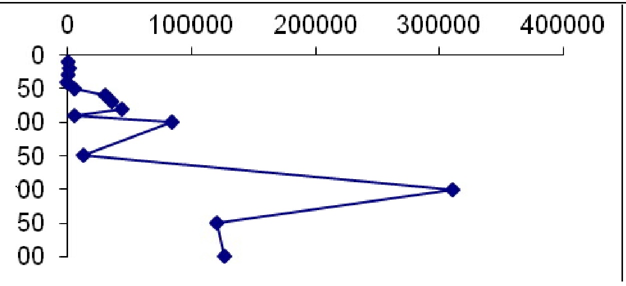
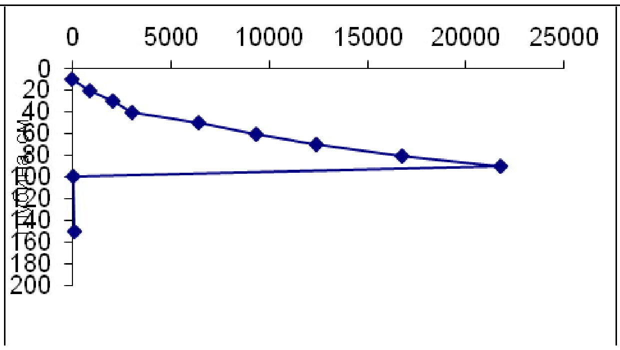


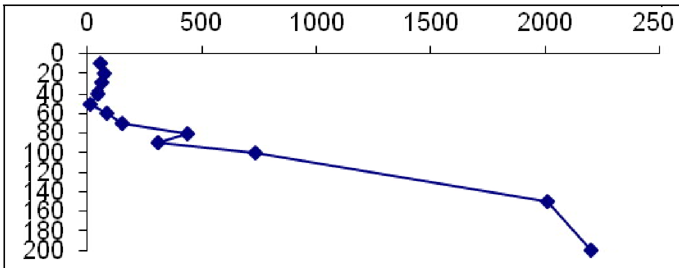
Results on vertical electric sounding indicate non-uniform distribution of clay and sand fractions, the presence of debris and changing soft rock overburden material at a depth of 100 cm.

Site 8. Self-overgrowing bottom of the quarry. Site 5.
Overgrowing duration - 29 years. Total projective cover of vegetation– 10 %.

Petrozem

C (0+ cm) - gray, with a lot of stones, very dense.

	На данном участке зафиксированны аномально высокие значения электрического сопротивления, стоит отметить, что на участке № 10 (скальное днище карьера значения сходны) In this plot anomalously high values of electrical resistivity are registered, it is worth noting that on the site 10 (rocky bottom of the quarry) values are similar to these in site 8.
	**Site 9. Recultivatioal plot of the quarry.** Overgrowing duration - 46 years. Total projective cover of vegetation– 50 %. **Grey-humus replantozem** O (0-3 cm) - moss-hards, there are cereals. AU (3+ cm) loam, brown, turn rocks, roots, clay particles
	According to values of electrical resistivity at depths 40-100 limestone plate lies.
	**Site 10. Recultivatioal plot of the quarry.** Overgrowing duration - 56 years. Total projective cover of vegetation– 50 %. **Grey-humus replantozem** O (0-7cm) - moss-hards, there are cereals. AU (7+ cm) loam, lumpy structure, incorporating stones, roots, clay particles



Increasing of soil resistivity with depth is indicating a significant increase in the content of coarse material down the profile. It is manifested predominance of fine clay fractions at a depth of 60 cm.

Site 11. Self-overgrowing bottom of the quarry. Site 5. Overgrowing duration - 29 years. Total projective cover of vegetation– 10 %.

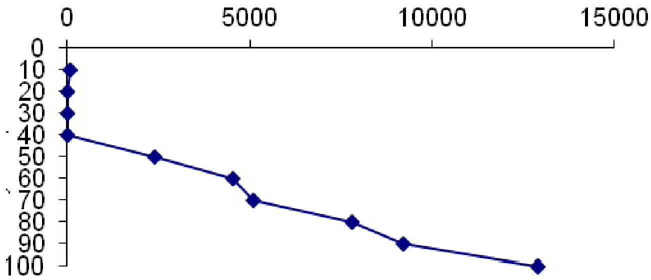
Petrozem

AU (0-0.5) - poorly decomposed plant residues
C (0,5+) gray, with a lot of stones, very tight.

Site 12. Self-overgrowing dump. Overgrowing duration - 46 years. Total projective cover of vegetation– 70 %.

Grey-humus embryozem

O (0-7sm) - moss-hards, there are cereals.
AY (7-14sm) loam, brown, turn rocks, densely permeated by roots
AC (+ 14 cm) loam, lumpy structure, incorporating stones, roots, clay particles



According to the data on vertical electrical resistivity sounding clay fraction is predominanced up to 40 cm. With the depth Ra values are sharply increasing. It testifies significant amount of coarse material down the profile.

Annex 13. Table 10. Physical and chemical properties of the substrate

Sites	**Horizon**	Depth, cm	pH in water	pH in salt	Hydrolitic acidity	Exchangeable acidity	CO2 %	W,%	C, %	Cha/Cfa	Basal respiration gCO2/r soil in g	Substrate-induced respiration	Cmic (vkg C/g soil)	qCO2(mkg CO2 C/mg C mic/h)	Field capacity	Field water capacity	Density	Stoniness, %
1	O	0-4	5,02	4,24	0,04	0,12	0	6,14	8,16	0,85	0,066204	0,071296	3,224704	0,02053	-	-	-	13,1
	AY	4-33	4,40	3,07	0,20	0,80	0,06	5,35	6,79	-	0,030556	0,033102	1,695398	0,018023	44,66	38,29	2,9	
	C	33-48	5,72	4,40	0,25	1,00	0,1	5,75	1,19	-	0,02037	0,02037	1,18563	0,017181	37,98	32,26	3,01	
	[C]	48	7,45		0,01	0,07	0,17	2,56	0,86	-	0,025463	0,028009	1,491491	0,017072	45,26	37,2	2,6	
2	O	0-3	5,26	3,68	0,20	1,90	0	6,08	1,69	0,76	0,112037	0,11713	5,05987	0,022142	-	-	-	30,5
	BF	3-13	6,35	5,48	0,20	0,70	0,24	5,89	5,73	-	0,040741	0,043287	2,103213	0,019371	62,11	59,31	3,05	
	C	13	6,55	6,12	0,65	1,00	0,08	2,14	2,05	-	0,0352	0,035648	1,797352	0,019834	43,19	39,32	2,97	
3	O	0-7	6,36	4,53	0,20	0,30	0,1	6	3,27	0,78	0,040741	0,045833	2,205167	0,018475	-	-	2,87	6,9
	AY	7-15	5,86	4,34	0,30	0,50	0,1	4,85	7,85	-	0,022917	0,028009	1,491491	0,015365	46,99	37,69	2,8	
	G	15-36	6,43	4,69	0,30	0,50	0,07	5,01	0,65	-	0,061111	0,066204	3,020796	0,02023	73,25	68,29	2,87	
	Gox	36-45	6,12	4,52	0,15	0,50	0,08	4,44	1,94	-	0,038194	0,040741	2,001259	0,019085	66,84	60,88	3,09	
	C	45	6,50	4,78	0,03	0,08	0,09	3,69	5,45	-	0,015	0,015278	0,981722	0,015562	46,74	43,25	2,9	
4	AY	0-26	5,22	4,50	2,00	2,00	0,21	6,06	3,94	0,91	0,040741	0,045833	2,205167	0,018475	49,37	42,05	2,52	29,5
	AC	26	6,34	5,48	0,15	0,40	0,16	3,98	6,32	-	0,01522	0,015278	0,981722	0,015562	51,77	36,42	2,9	
5	O	0-13	5,64	3,61	4,10	5,50	0	5,98	14,40	0,65	0,043287	0,045833	2,205167	0,01963	55,87	51,63	-	28,0
	AY	13-25	6,05	5,06	0,20	1,00	0,35	5,34	2,13	-	0,063657	0,066204	3,020796	0,021073	73,25	68,22	2,7	
	C1	25-37	5,76	5,00	0,15	0,70	0,08	5,66	0,67	-	0,0223	0,025463	1,389537	0,018325	47,53	40	3,1	
	C2ox	37	6,10	5,14	4,00	4,00	0,52	3,27	3,33	-	0,030556	0,035648	1,797352	0,017	58,2	54,81	3,23	

	O	0-4	6,57	6,28	0,10	0,90	0	5,43	24,81	-	0,061111	0,078111	2,816889	0,021695	-	-	-	13,8
6	AY	4-28	6,53	5,09	0,01	0,03	0,13	5,38	13,25	0,76	0,035648	0,040741	2,001259	0,017813	141,15	116,05	2,4	
	C	28	5,40	4,60	0,20	0,25	0,27	3,43	4,47	-	0,035648	0,038648	1,797352	0,019834	43,51	39,69	2,55	
	O	0-7	5,98	4,90	1,70	2,00	0	5,89	8,24	-	0,066204	0,076389	3,428611	0,019309	-	-	-	4,5
7	AY	7-9	6,90	5,87	1,25	1,25	0	5,06	9,46	0,68	0,033102	0,038194	1,899306	0,017428	52,69	49,31	2,45	
	C	9	7,35	7,20	0,95	2,20	0,09	4,13	3,89	-	0,035648	0,038194	1,899306	0,018769	42,38	36,19	2,69	
8	C	0-5	6,70	6,35	3,60	3,60	0,52	5,17	3,24	-	0,045833	0,04838	2,30712	0,019866	-	-	2,4	80,0
9	O	0-3	5,96	5,30	0,35	0,60	0	5,81	8,80	0,57	0,071296	0,073843	3,326657	0,021432	-	-	2,45	22,4
	AC	3	6,70	5,95	3,40	5,50	0,36	3,13	3,75	-	0,040741	0,043287	2,103213	0,019371	33,15	32,11	2,4	
10	AY	0-18	6,5	5,25	0,90	0,53	0,04	5,73	12,64	0,62	0,023571	0,107379	4,669462	0,005048	-	-	2,4	22,4
	C	18+	6,5	6,24	3,45	5,52	0,07	3,68	12,5	-	0,036667	0,083808	3,725686	0,009842	34,05	31,97	2,5	
11	AC	0-3	6	5,40	3,00	3,00	0,91	5,92	16	-	0,031429	0,081192	3,620914	0,00868	-	-	2,5	80,0
	C	3+	6,3	5,54	3,50	3,60	1,03	5,14	15,58	-	0,018333	0,086429	3,830624	0,004786	-	-	2,4	
12	AY	0-25	6,15	4,70	0,3	0,8	0,23	5,30	17,68	0,80	0,02095	0,096904	4,250043	0,004929	44,55	37,90	2,7	30,0
	C	25+	6,11	5,34	0,25	1,2	0,22	5,65	10	-	0,018333	0,068096	3,096557	0,005921	38,02	32,28	2,8	

Annex 14. Table 11. Texture class of soils of the Pechurki quarry

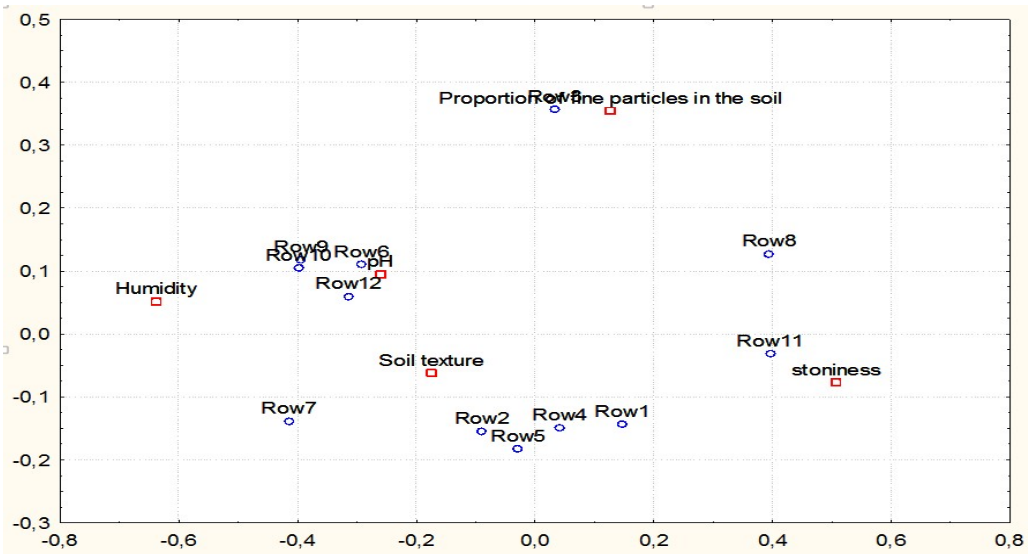
Sites	Horizons	Content (%) of air-dry aggregates to dry soil, mm					Content (%) of texture classes to abs. Dry soil, mm						
		>7,00	7,00-1,00	1,00-0,50	0,50-0,25	<0,25	1,00-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0001	<0,001	<0,01
1	AY	13,1	22,4	9,7	18,1	36,7	29,7875	49,7875	12,05	1,925	1	5,45	8,375
	C	18,9	16,6	5,1	9,1	50,3	26,783	54,967	12,425	1,35	0	4,475	5,825
	[C]	33,9	44,1	12,5	3,6	5,9	55,3945	29,1805	2,925	2,45	1,925	8,125	12,5
2	BF	30,5	45,0	10,2	6,2	8,1	49,386	36,189	8,1	0	2,45	3,875	6,325
	C	9,1	81,7	7,0	0,6	1,6	37,45	38,825	14,7	2,25	0	6,775	9,025
3	O	16,1	21,2	6,9	12,1	43,7	1,031	82,444	8	3,025	1	4,5	8,525
	AY	6,9	10,1	5,7	24,5	52,8	10,325	83,8	1	0	1	3,875	4,875
	G	11,6	8,6	4,5	23,3	52,1	4,1935	84,4565	6,6	0	0,75	4	4,75
	Gox	14,4	13,7	4,1	17,4	50,4	12,4595	75,2655	1	7,775	0,725	2,775	11,275
	C	5,1	16,8	5,5	9,8	62,8	16,24	73,06	5,6	0,225	1,55	3,325	5,1
4	AY	29,5	52,6	6,5	3,8	7,6	5,0925	72,4575	12,8	1,075	2,975	5,6	9,65
	AC	31,5	44,6	8,3	5,3	10,3	2,646	77,204	10,825	1,625	3,325	4,375	9,325
5	AY	28,0	28,4	13,8	15,9	13,9	4,077	47,848	26,25	4,95	7,8	9,075	21,825
	C1	15,8	11,4	2,8	13,3	56,7	7	72,825	16,425	0	0	3,75	3,75
	C2ox	8,1	11,6	5,8	11,8	62,8	28,15	54,275	12,625	0,25	1	3,7	4,95
6	AY	13,8	35,5	13,3	10,7	26,7	12,044	55,631	14,9	4,05	5	8,375	17,425
	C	8,1	22,3	4,9	14,2	50,5	5,6665	88,2035	2,325	0,08	0,05	3,675	3,805
7	AY	4,5	9,9	4,0	14,0	67,6	14,333	78,417	3,075	0	0,375	3,8	4,175
	C	5,2	7,3	3,1	12,9	71,5	2,723	83,627	7,9	0,325	1,6	3,825	5,75

8	C	28,6	44,9	5,9	4,9	15,6	3,403	44,097	15	8,1	12,925	16,47 5	37,5
9	O	6,8	65,4	8,9	7,7	11,2	16,296	49,254	19,875	1,825	6,625	6,125	14,57 5
	AC	22,4	50,4	8,1	6,6	12,4	10,9575	57,0175	18,45	0,75	5,075	7,75	13,57 5
10	АУ	5,7	66,5	9,0	7,5	11,3	19,25	55,5	12,5	2,5	5	5	12,5
	C	23,5	52,3	7,3	6,5	10,4	15,2	55,8	12,5	4	5	7,5	16,5
11	A	29,0	39,6	6,4	3,1	21,9	10,9	26,6	27,5	32,5	0	2,5	35
	C	30,1	43,5	5,9	5,8	14,7	26,3	31,2	17,5	10	5	10	25
12	АУ	12,9	24,6	9,0	19,3	34,2	18,55	63,95	12,5	0	2,5	2,5	5
	C	17,4	18,5	5,1	9,3	49,7	7,85	72,15	10	2,5	0	7,5	10

Annex 15. Table 12. Significant variables selected by direct selection

Significant variables	Cumulative adjusted R2	F	P
Soil texture	0,035	11,2	<0,001
Content of physical clay fractions	0,05	5,3	<0,001
Moisture	0,098	3,9	<0,001
pH_{H20}	0,105	2,5	<0,002
Stoniness	0,114	2,7	<0,003

Annex 16. Figure 6.Canonical correspondence analysis.



Note: Blue circles - plant communities; red squares – environmntal factors