FULL PAPER

CHEMISTRY ENVIRONMENT BIOTECHNOLOGY

http://dx.doi.org/10.16926/cebj.2017.20.01

Received: 17 January 2017
Accepted: 21 April 2017
Available online: 24 April 2017

Environmental characteristic of the Kandalakshan region of the Kola Peninsula (NW Russia)

Miłosz A. HUBER,[1,*] Lesia LATA[2]

[1] Department of Geology and Protection of Lithosphere, Earth Science and Spatial Management, Maria Curie-Skłodowska University, 20-718 Lublin, 2cd Kraśnicka rd., Poland;
[2] Soil Science and Soil Protection Department, Earth Science and Spatial Management, Maria Curie-Skłodowska University, 20-718 Lublin, 2cd Kraśnicka rd., Poland

Abstract: This work is devoted to the environmental research conducted in the North of the Arctic Circle area of the Kola Peninsula. The area is located near White Sea gulf hills, and is covered with varied vegetation which has a relationship with altitudinal zonation and their geomorphology. Nearby the town of Kandalaksha is located the port with shipyard and other industrial plants situated nearby. A comparative study of lichens and rocks were provided in this study. The results showed a relationship in metals contents between rocks and selected lichens and the accumulation of other related environmental pollution.

Keywords: environmental characteristic, lichens, pollution, Kandalaksha, N Russia

1. Introduction

Kandalaksha is a town located on the White Sea, in the southern part of the Kola Peninsula, in the vicinity of Niva River. In Kandalaksha is an important railway junction with the repairer and the port and shipyard together. The city extends on the side small hills covered in most forest-tundra and tundra reaching 850 m above the sea level. There are numerous boulder fields and expose the rocks on the slopes and on the upper parts. These are classified in the part of the Lapland Granulite Belt (LGB). Due to the geographical location (proximity to the Arctic Circle) the climate in this area is raw, which makes it a relatively low altitude vegetation gives way to higher dwarf varieties of tundra with moss and lichens. The latter is particularly well grow on rocks exposing the substrate, forming sometimes extensive mats, sometimes covering entire blocks of rock. The collected samples of these lichens served as a subject of heavy metals. Theris accumulation can be connected with the ground or pollution of anthropogenic origin. The substrates belonging to Kandalakshan part of the LGB are Early Proterozoic structure of the collision near Archean Kola and Belamoryian blocks. Occurring in the area of LGB meta-volcanics and meta-intrusives have age from 2.8 to 2.4 Ga. These are the amphibolites, gneiss and amphibole-garnet [3, 5, 7, 8, 12], accompanied by various type of granulites [1–4, 11, 13].

2. Methods

Samples of basement rocks with lichen were collected in the field with photographic documentation (Figure 1). Samples of the ground have been prepared for mineralogical observation and geochemical analyzes. The polished thin sections were prepared and grinded to get ground rock samples. They were examined by microscopic methods using Optical Polarizing Microscope Leica DM2500P and Scanning Electron Microscope Hitachi SU6600 with EDS attachment. This was performed in Geology and Litosphere Protection Department on the Earth Sciences and Spatial Management Faculty of Maria Curie-Sklodowska University (UMCS) in Lublin, Poland.

Powder samples of rocks were examined using ICP-MS in the Department of Hydrology at the University of Science and Technology (AGH) in Krakow. Samples of lichens were tested using the same microscopic techniques and dried and powdered samples were analyzed using ICP-OES in the Department of Soil Science and Soil Protection UMSC.

3. Results and discussion

3.1. Morphologic-climate feature

The Kola Peninsula located in the Arctic area is exposed to the harsh climate. Murmansk is the northernmost ice-free port and the continental climate is mitigated and abounding in the rain trough the Golf Stream. The situation in Kandalaksha was found be opposite. This town even though is located on the south compared to Murmansk has a much harsher climate, which is reflected in the White Sea freezing in winter. The average temperature in the coastal zones is +1°C, and a little further from the shore 0°C, changing the upper parts especially in the central parts of the peninsula, even to −3°C. January temperatures are from −6°C to −9°C a July temperature of about +10°C. The maximum temperature in summer reaches +27°C, while the minimum in winter to −25°C. Permafrost occurs only locally in the eastern parts of the peninsula in the peat bogs and the marshes. The length of the day on the peninsula is from 0 to 24 hours. Rainfall is 450−900 mm and the number of cloudless days rarely exceeds 20. There boulder fields and there is infiltration of aqueous solutions in the rocks occure very often. On the Kola Peninsula there are numerous of rivers and about 10 000 different types of lakes. Mainly these are the type of post-glacial lakes

* Corresponding author.
E-mail address: *mhuber@umcs.lublin.pl*

© 2017 Jan Długosz University, Częstochowa

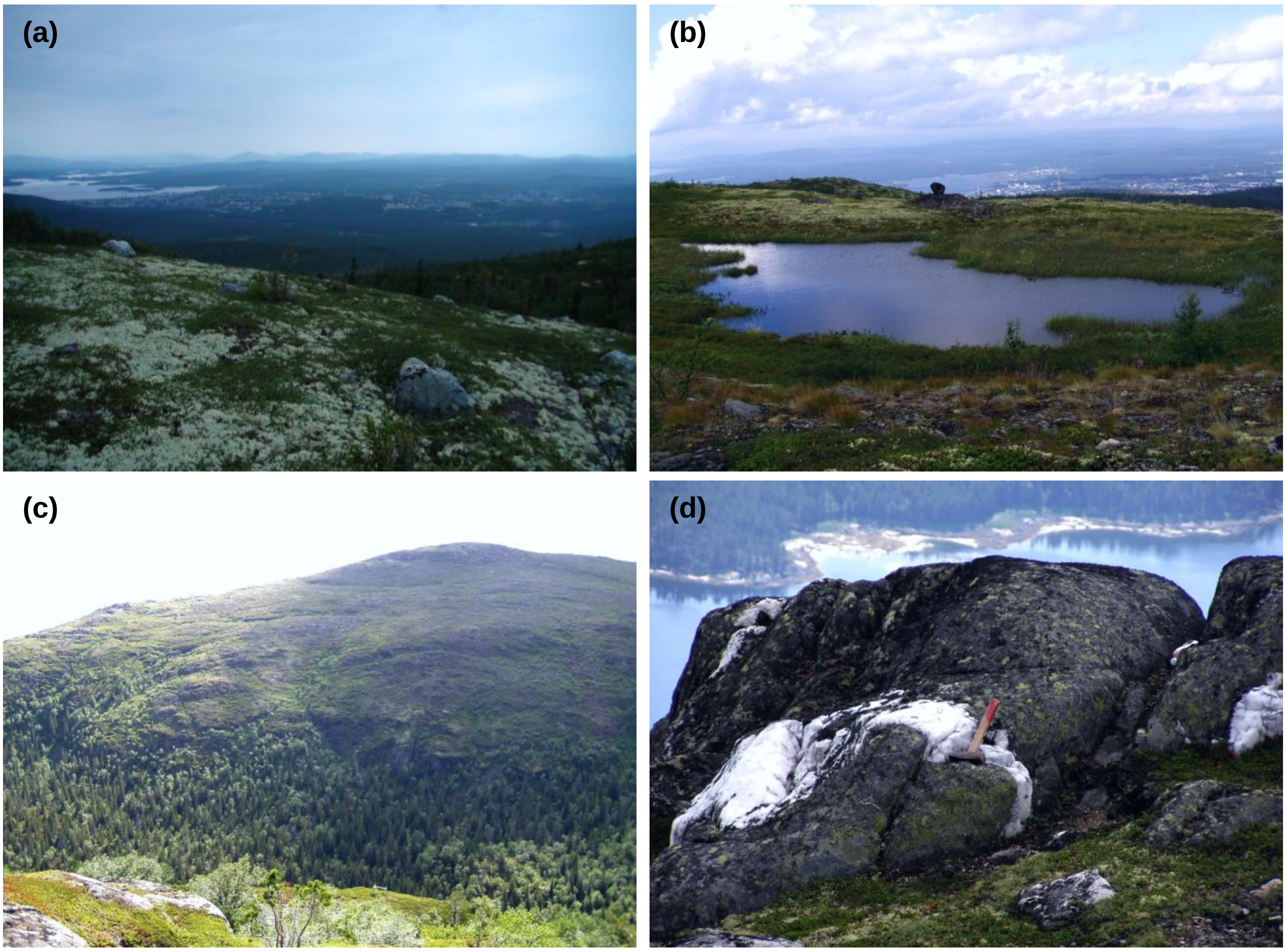

Figure 1. Photographs of the studied area: (a) view on the N-E part of the 'Kandalaksha Tundra' mountains and Kandalaksha city, (b) lakes and inselbergs erosion in the area of top Volosianaya Mt., (c) slopes of valleys with vegetation of the forest-tundra and scree in the Zhieleznaya hills, (d) Appearance rock lichen *Rhizocarpon sp*.

(moraine, gutter, melt-out) happens also fill local water wells. There are also numerous small ponds and bogs in the plateau. It is common phenomenon swamping mountain valleys (usually U-form, Figure 2). The hills located nearby Kandalaksha are typical heavily eroded with mild upper parts firmly flats and steep U-shaped valleys with numerous

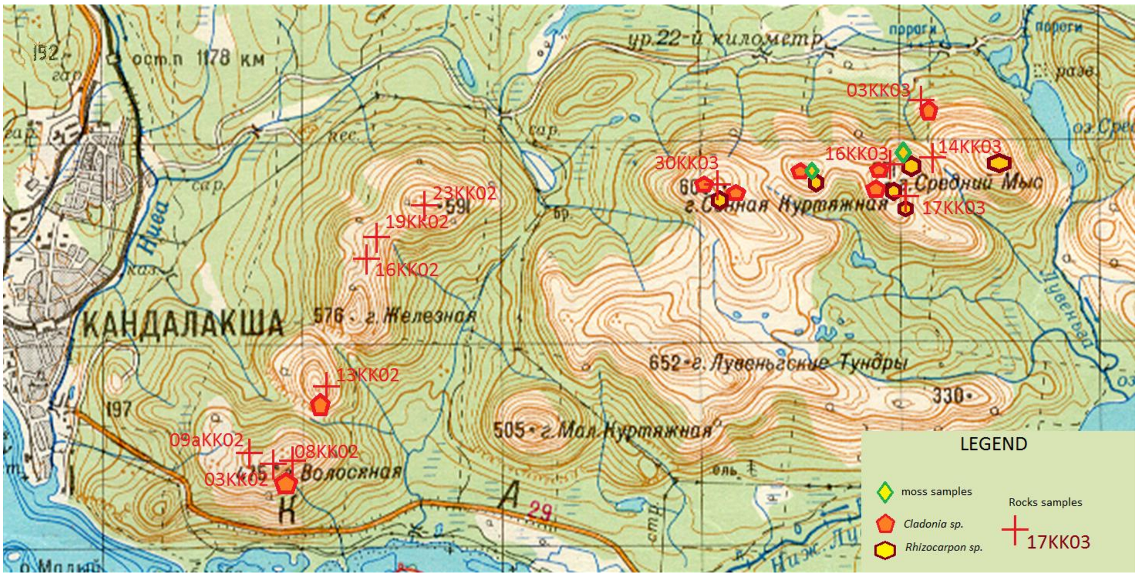

Figure 2. Studied area with samples localization marked. The maps by [15], with modifications.

 © 2017 Jan Długosz University, Częstochowa

swamps their bottoms [6, 11]. Steep slopes, steeper in the upper parts of valleys, often form a vertical wall. Above already under the peaks were visible large surfaces aligning with numerous boulders and lakes in the upper parts, like a sculpture glacial glacier Norwegian type. Frost weathering was a huge impact on such view [11]. This facilitates the observation field. Airing on the area in question is a physical (freezing) causing the disintegration of the granules. In the slopes of gullies they run with numerous rapids, also a high angle with extensive cones screes in the valley bottoms. Positive morphological forms are associated usually with old massive and dense rocks. The test area is quite abundant in water, due to the prevailing high rainfall in summer and low water storage capacity by sparse vegetation and proximity to the crystalline rocks. Due to the proximity to the sea most of the rivers with the 1−2 grade bond order by Strachler beyond the river cornfield, which is one of the major rivers on the peninsula [14].

3.2. Altitudinal zonation in the studied area

In the studied area boundary of the forest at an altitude of about 450 m about the sea level. In the taiga area is dominated by birch (*Betula Tortuosa*, *B. subarctica*) and spruce (*Picea obovata*) with an admixture of pine (*Pinus Friesia*). There is also the juniper (*Juniperus Svibice*) and rowan (*Sorbus gorodkowii*) and varieties of willow trees (*Betula nana*). The undergrowth is dominated by many species depend on the specific type of habitat (forest, meadows, swamps, etc.). In this area the humidity is relatively high and the water retention (limited) forms a plurality of aquifers due to the shallow deposits bedrock in which the cavities water may spread to form a shallow rich in water habitat of plants with sedge (*Carex bigelowii*), blueberries (*Vaccinium vitis-idaea*, *V. myrtillus*) and cloudberry (*Rubus chamaemorus*). Slightly above the taiga passes forest-tundra would eventually give way to tundra to a height of 700 m above the sea level. In this area dominated by stunted specimens of plants represented by dwarf birch (*Betula nana*), accompanied by the parties to leeward and sunny single specimens of spruce and stunted willows (*Salix nummularia*, *S. polaris*, *S. reticulata*). Above it appears vegetation typical floor grass-moss-fouling creating vast areas of deforested covering the plateau of such species as the mountain plants (*Dryas octopetala*, *Saxifraga oppositifolia*, *Juncus trifidus* or *Lycopodium alpine*). Higher floors in this area do not occur due to the rather high elevations and the impact of the White Sea, greatly mitigating climate (Figure 2) [11].

3.3. Soil characteristics in studied region

A short vegetation plant and the nature of the terrain make the orographic in these hills. Soil initial compositions is a regolith, resulting directly from the physical weathering of surface rocks. In the upper parts where its outflow cavities under the influence of accumulation and melting a lot of snow create numerous swamps and ponds contribute to the accumulation of silt fraction forming clay soils arise, however, in very small areas. Some of these places create communities of fens and high variety of the mountain. Among these places are the appearances of rock devoid of soil and boulders of a single relic and moraine. Other glacial deposit, which could one day spread in this place has become impossible due to the small surface area of the peak. Apart from these tracks you are also seen numerous boulder fields built with sharp-edged blocks of rock which sometimes turned in scree, free-flowing down the slopes in the couloir zones in other places overgrown with vegetation pioneer (the angle of inclination allows the relatively stable nature of the blocks). In areas of waste where there is a relatively large slope of rock and soil surfaces are reduced to small bends rock shelves fault zones where there are surfaces allowing the deposition of fine material, often supported by vegetation persistent discussed soil on bedrock. Of particular interest are moss-lichens mats often waterlogged, which, through the root system and handling make extensive surfaces directly on the stone blocks that contain a certain amount of fine material formed *e.g*. by melting snow. The slopes dominate landfalls, landslides and colluvium, rubble and ilium, especially in gullies, where there is a transport crumb of rock by the action of rainwater. In the valley bottoms there are many forms associated with post-glacial accumulation, the formation of swamping and peat bogs mainly high and the accumulation of a fluvioglacier and fluvial. They are represented by moraines along with the sands, colluvium and marsh forms.

3.4. Rocks characteristics

In this area there are two types of rocks are mainly metaintrusives and metavolcanites with small inserts of parametamorphic rocks. Metavolcanites are metamorphosed mainly in the amphibolite facies. In this group of rocks they are classified as massive amphibolites with garnets and amphibolite schists and gneisses, alternately surging and creating a continuous transition of one rock to another. Their chemical composition corresponds andesite, ryodacite, basalts [3, 6, 7, 9, 10, 11]. Metaintrusives rock outcrop in the north-eastern area a lot and are educated in the form of amphibole gneiss and granulite. In this area there are also different types of rock formations and wire having no significance for the topic of work. Different types of rocks have close different mineralogical and chemical nature. **Garnet amphibolite** are black and red color rocks (Figures 1, 3), which consist mainly of amphibole and plagioclase, quartz, garnet with ore and accessory minerals. In a thin section of whole rocks formed crystals common hornblende, often forming growths diablastic adjacent to which there are small amounts of chlorites, epidote, tremolite and biotite, with some diopside crystals. Between these plagioclase crystals are often showing deformation. The garnets and quartz are present together. Minerals are accompanied zircon, titanite, ilmenite and sulphides. Particularly sulfides and oxides and hydroxides of metals (mostly Fe, Ti, Cu) may contribute to leaching and migration under the influence of humic acids. Rocks are accompanied by a variety of massive, built almost entirely of amphibole (without garnets) and admixtures of plagioclase and quartz with admixture of magnetite, ilmenite and pyrite. These amphibolites are mixing with rocks in which the amount of minerals clear is considerably increased (Figure 3b).

These rocks are called **amphibole-garnet-quartz schists**, colored black having glomeroblasts garnets, "flowed" and emphasized by the femic minerals against quartz, and plagioclase. In thin section background rocks are basic and medium plagioclase (Figure 3c), accompanied by quartz and sometimes orthoclase. In these rocks we see a chlorite and

© 2017 Jan Długosz University, Częstochowa

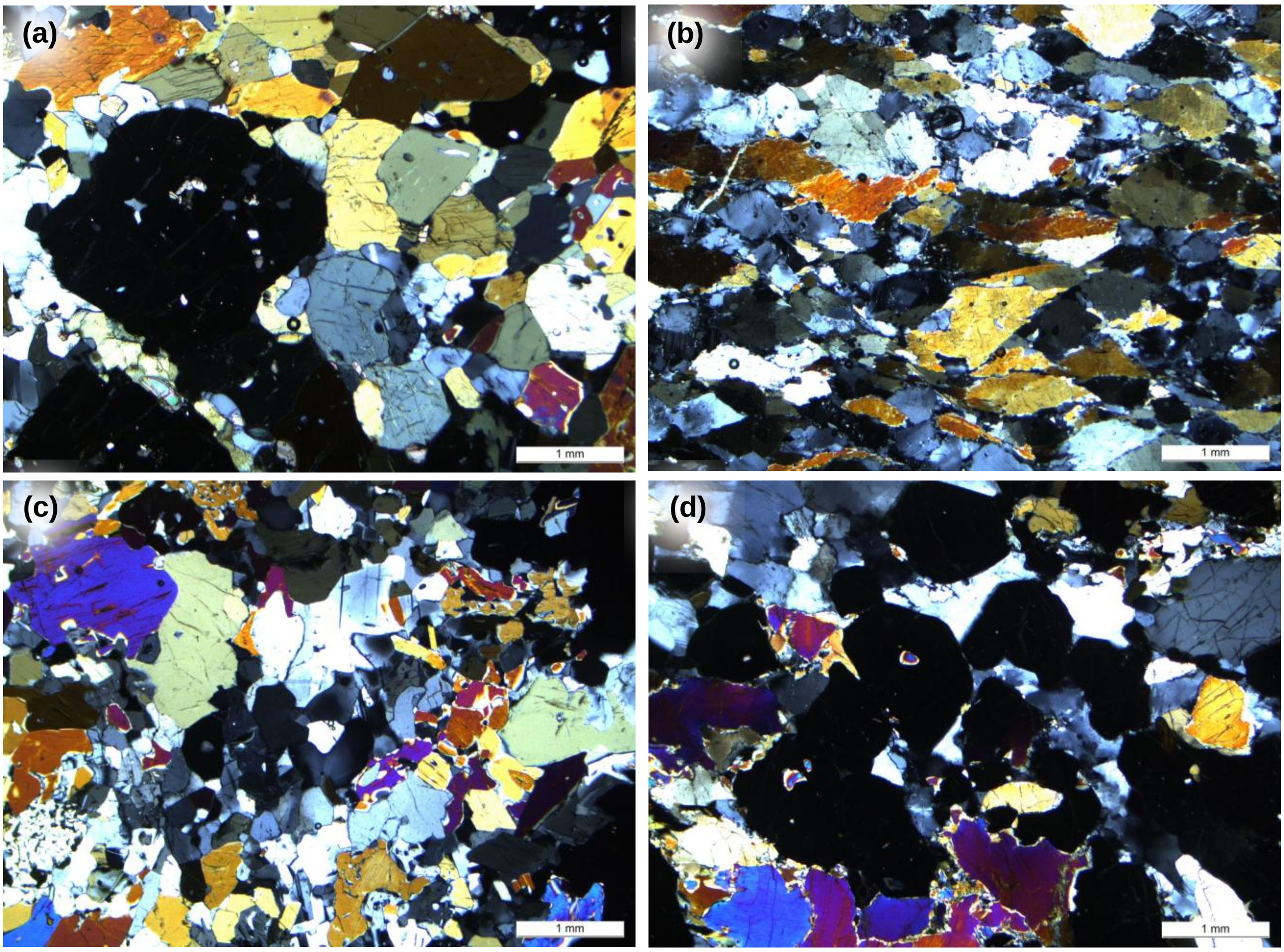

Figure 3. Microphotographs of the typical LGB rocks: (a) garnet amphibolite, (b) massive amphibolite, (c) amphibole-garnet-quartz schists, (d) granulites (transmitted light, crossed pollars).

epidote and feldspars with serycitization processes. These rocks have a structure grano-lepido-nematoblastic and adjacent to quartz veins-spindleblastic. Visible texture of slate, gneiss places, Ring. Grenades usually of up to 1 cm size have numerous inclusions and solid inclusions of quartz and titanite, rutile and ilmenite. Generally, in these rocks, the three phases of oxides and silicates of titanium co-exist. On the surface of contact with grenades plagioclases often occurs high-titanium biotite. There is also the ordinary hornblende creates dark laminae in the rock with an admixture of tremolite. In these rocks are also small amounts of amphibole gneiss and other rocks locally. In the region of the north-east in the upper parts are exposed granulites clear that there are massive rocks having the gray-pink-green color, with large pyroxenes (up to several mm) and garnets occurring against the background of quartz-plagioclases. The microscopic image is dominated by plagioclase and quartz (in varying amounts) forming a background of rock. Between these minerals are visible crystals garnets often overgrown titanite mixed with ilmenite and rutile. Appears diopside and hypersthene adjacent the garnets, especially in the transition zones is accompanied by small amounts of secondary minerals such as common hornblende, chlorite and epidote (Figure 3d). Rocks that make of the dark variety more rich in piroxenes called dark granulites. Also noteworthy are the numerous veins on the composition of granitoide, carbonatite and ore, providing both. The microforms have a thickness of up to a few mm, but are common in these rocks usually, and haves a number of ore mineral such as ilmenite, titanite, magnetite, hematite and pyrite. These can relatively easily weathering and cause migration of the solutions in the rocks, causing migration of metal substrate in the area of soil and plants.

Performed chemical analysis of the selected samples of rocks showed the presence of SiO_2 in an amount of about 50% doped with Al_2O_3 (10%) and TiO_2, respectively 0−3%, FeO 10−20%. MgO and CaO in an amount of 10−15% and P_2O_5 of up to 2% by weight. The residual ions usually measured less than 1% by weight (Figure 4). The content of the main components in the examined samples of rocks is similar due to similar processes of metamorphism of these rocks and their similar chemical composition, although there are small difference in the content of the magnesium, potassium, iron and aluminum.

The aluminum-rich shale, have a relatively low of magnesium and calcium. A relatively large number of these elements appear in the amphibolites of garnets (including garnets, pyroxene). In granulites found chromium, and titanium, also found in the amphibolites with garnets. These rocks are also have admixtures of vanadium and manganese, as opposed to shale.

© 2017 Jan Długosz University, Częstochowa

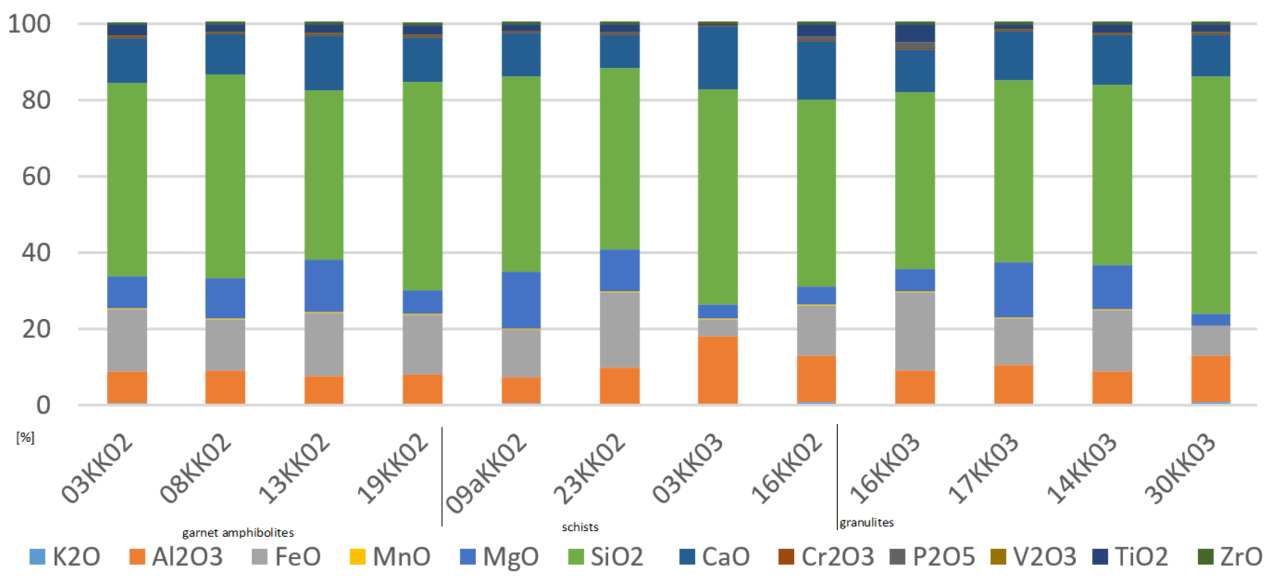

Figure 4. Chemical composition [by wt. %] of the rocks samples from the LGB.

3.5. The results of the lichens analysis

The collected samples of lichen from the surface of these rocks are mainly *Rhizocarpon sp*. and *Cladonia sp*. These are common in many areas also sometimes sites found in the valley bottoms. These in turn are relatively well protected from the wind hence sampling concentrated mainly in rocks from upper part of mountains, of this area of research. Mosses in this research area occur mainly in areas where there has been an accumulation of clastic material which may have formed relict soil. Lichens are found in the upper parts even where there appear other plants, *e.g*. in colluvium, scree and exposed rock forms.

Directly fixed to the rocks sometimes form a fairly extensive mats overgrowing almost the entire visible surface. Microscopic examination of samples dried demonstrated their diverse surface, with ridges and discoloration occurring (Figure 5). This analysis of 11 lichen and 2 moss samples showed some variation. The geochemical plants (Figure 6). Analysis of these data indicates that said samples came in accumulation of metals such as Ti, Fe and Cu, Ni, Zn, Pb, Cr. The increased amount of Ti and Fe is correlated with the ground rock wherein the element also reaches high levels. The correlation of Cu and Zn can also be combined with amphibolites and amphibolite schists that said the contents of which can be found in the southern and western parts of the studied area. The content of metals such as Cd, Ni, Cr and Mn reaches the maximum value of the samples localized in the eastern part of the study area, wherein the medium present in said rocks relatively low amounts of above mentioned elements. The highest content of Pb was found in the south-western part of the studied area.

3.6. Discussion

The present area of the Kandalaksha region is very interesting from the point of view of the natural. There is in him a great variety of plant habitats resulting from the terrain. In

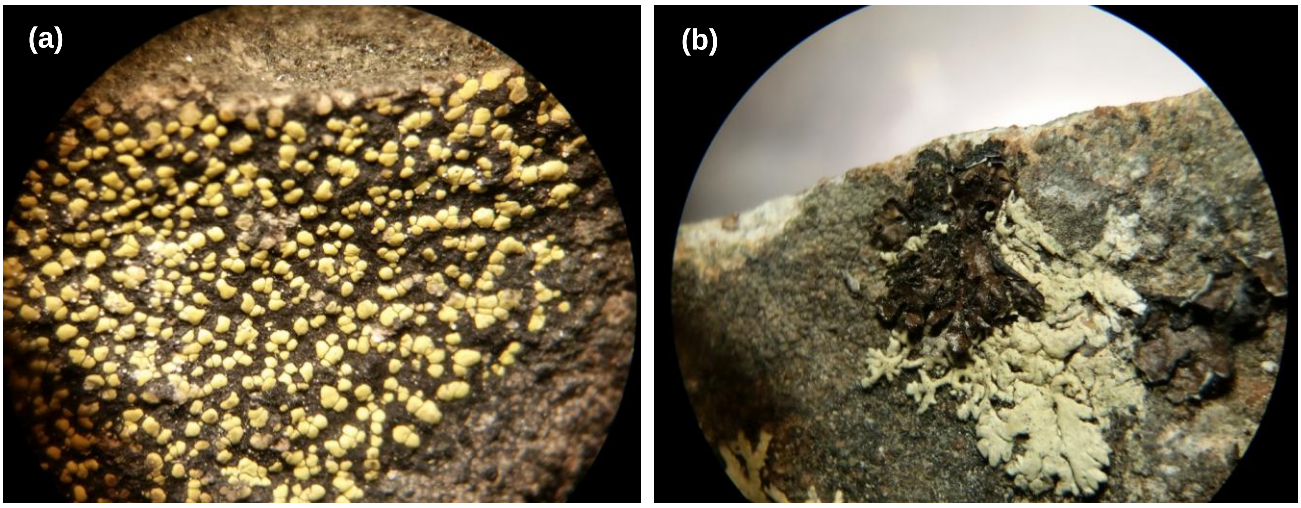

Figure 5. Photographs of the typical lichens from LGB (*Rhizocarpon sp*. – in left, *Cladonia sp*. – in right).

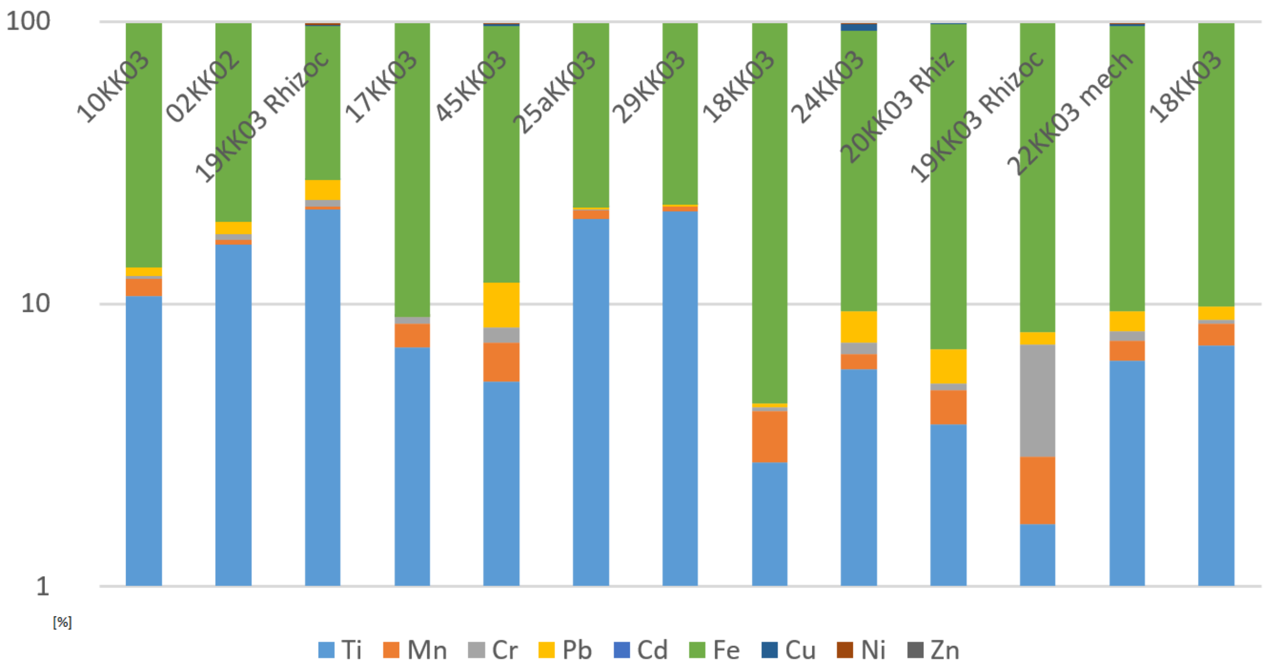

Figure 6. The diagram of the chemical analysis of lichens samples from LGB [by wt. %]. The number of these samples is the same just like the host rocks (number without name are *Cladonia sp*. sample, number with 'Rhizoc' name are *Rhizocarpon sp*. sample, 'mech' are moss sample).

the valleys at the foot of the hills dominated boreal forests and wetland habitats forming mold sometimes marshy bog. In the zones of slope appear plants growing on and pioneering colluvium, rock shelves or places with milder slope. Vegetation but it varies depending on the location of the slope with respect to the prevailing winds and sunlight and altitude. In the slopes of the southern exposure altitudinal zonation of plants it reaches higher levels than in the north. The peak areas devoid of the taiga is the volatility underscored boulder fields and marsh and weathering forms forming niches in which sometimes may be single individuals dwarfed trees. Only the most resistant vascular plants, mosses and lichens can be sustainable in the wasted poor soil of the peak areas. The latter, however, attacking even exposed rocks appearances and the 'island mountains' type are covered with erosion also blocks colluvium boulder fields and entering in the place practically inaccessible to other plants. Chemical studies show a correlation with the test ground lichen. This primarily concerns the content of metals such as Ti, Fe, relatively common in these amphibole rocks, like the contents of Cr and Cu. With sequential way Pb content differs from the concentration measured in the rocks. Elevated amounts of Pb were found in the southwestern portion of the studied area, which is relatively busy road Kandalaksha-Umba not far from the city. Probably the increased number of metals such as Ni, Cu, Cr can also be correlated with anthropogenic activities that could contribute to pollution in this area adjacent to the city. The rocks of the substrate concentration of these metals are not so high in Kandalaksha is the heavy industry and shipbuilding facilities of rolling stock, which may be the issuer of these pollutants. In the north-west direction in the vicinity of these hills, there is a military base which can also be a source of pollution in the area. These data can also confirm the samples examined mosses, which also have an increased content of metals such as iron, lead, copper, nickel and zinc.

4. Conclusions

Environment of the Kandalaksha region is a diverse area of arcto-alpine and boreal plants habitats, resulting from terrain and geomorphological diversity. Rocks located on East of Kandalaksha are a complex amphibolites, including shale and granulite gneisses and admixture, accompanied by numerous wire pieces. They are characterized by a relatively high content of iron oxides and titanium additions of metals such as Cr, V, Mn and associated with its protolith and secondary processes. Lichen samples examined indicate a degree of correlation with rocks substrate, indicating increased in iron, titanium. Increased concentrations of metals such as Pb, Zn, Cu, Ni, likely to be associated with their accumulation as a result of pollution caused by increased human activity (the nearby city of heavy industry, the road and the military unit).

References

[1] V.V. Balagansky, J.S. Daly, *Svekalapko Lanmmi Finland*, **2000**, 9.
[2] D. Bridgwater, D. Scott, V.V. Balagansky, M.J. Timmerman, M. Marker, S.A. Bushmin, H. Alexeyev, J.S. Daly, *Dokl. Russ. Sci. Acad.*, *Geology*, **1999**, *366*, 664−668.
[3] M. Huber, *Miner. Slov.*, **2001**, *2*, 17−31.
[4] M. Huber, *J. Biol. Earth Sci.*, **2013**, *3*, 39−46.
[5] M. Huber, *J. Biol. Earth Sci.*, **2014**, *4*, 1−15.
[6] M. Huber, E. Blicharska, L. Lata, S. Skupiński, ***Wpływ podłoża na zawartość metali w wybranych roślinach, w aspekcie ochrony środowiska***, Science Publisher, Lublin, **2016**, p. 255.

 © 2017 Jan Długosz University, Częstochowa

[7] N.E. Kozlov, A.A. Ivanov, *Geological Survey of Norway, NGU Biuletin, Trondheim, Norway*, **1991**, *421*, 19−32.

[8] N.E. Kozlov, N.E. Kozlova, *Вестник МГТУ*, **1998**, *1*, 43−52.

[9] N.E. Kozlov, A.A. Avedisyan, J.A. Balashov, A.A. Iwanov, A.D. Kamienskaya, I.W. Mukhamedova, W.A. Polkanova, W.A. Pripachkin, J.A. Rispolozhensky, L.L. Tarnovetsky, *Geological Survey of Norway, NGU Biuletin, Trondheim, Norway*, **1995**, *spec. 7*, 157−166.

[10] N.E. Kozlov, A.A. Ivanov, L.I. Nyerovich, ***Лапландский Гранулитовый Пояс–первичная природа и развиme***, RAN, Apatity, Russia, **1990**, p. 139.

[11] M. Huber, ***Geology of Lapland Granulite Belt of Kandalaksha region, Kola Peninsula, Russia***, TMKarpinski Publisher, Suchy Las, **2014**, p. 135.

[12] F.P. Mitrofanov, ***Prekambryjska tektonika północno−wschodniej części Tarczy Bałtyckiej***, Wyd. Nauka, St. Petersburg, **1999**, p. 111.

[13] F.P. Mitrofanov, V.V. Balagancky, Y.A. Balashov, F.G. Gannibal, V.S. Dokuchaeva, L.I. Nerovich, K. Radchenko, G.I. Ryungen, *Norges Geologiske Undersøkese*, **2000**, 179−183.

[14] M. Ozga-Zielińska, J. Brzeziński, ***Hydrologia stosowana***, PWN, **1997**, p. 287.

[15] Sample localization maps were making on the topographic base: Maps of the Kola Peninsula M.O.O.O. и P. Rosokhotryblobcoyuz, ВГУ, 1994, in scale 1:100 000, arc. Kandalaksha.

 © 2017 Jan Długosz University, Częstochowa