MICROBIAL BIOMASS AND BASAL RESPIRATION OF SELECTED SUB-ANTARCTIC AND ANTARCTIC SOILS IN THE AREAS OF SOME RUSSIAN POLAR STATIONS

E. Abakumov, N. Mukhametova

Department of Applied Ecology, Saint-Petersburg State University, 199178, 16-line Vasilyevskiy Island, 29

Correspondence to: E. Abakumov (e.abakumov@bio.spbu.ru)

Abstract

Antarctica is a unique place for soil, biological, and ecological investigations. Soils of Antarctica have been studied intensively during the last century, when different national Antarctic expeditions have visited the sixth continent with the aim to investigate nature and the environment. Antarctic investigations are comprised of field surveys mainly in the terrestrial landscapes, where the polar stations of different countries are situated. That is why the main and most detailed soil surveys were conducted in the Mc Murdo Valleys, Transantarctic Mountains, South Shetland Islands, Larsemann hills and the Schirmacher Oasis. Our investigations were conducted during the 53rd and 55th Russian Antarctic expeditions in the base of soil pits, and samples were collected in Sub-Antarctic and Antarctic regions. Sub-Antarctic or maritime landscapes are considered as very different from Antarctic landscapes due to differing climatic and geogenic conditions. Soils of diverse zonal landscapes were studied with the aim to assess the microbial biomass level, basal respiration rates and metabolic activity of microbial communities. This investigation shows that Antarctic soils are quite diverse in profile organization and carbon content. In general, Sub-Antarctic soils are characterized by more developed humus (sod) organo-mineral horizons as well as by the upper organic layer. The most developed organic layers were revealed in peat soils of King-George Island, where its thickness reach, in some cases, was 80 cm. These soils as well as soils formed under guano are characterized by the highest amount of total organic carbon (TOC) between 7.22 and 33.70%. Coastal and continental Antarctic soils exhibit less developed Leptosols, Gleysols, Regolith and rare Ornhitosol with TOC levels between 0.37 and 4.67%. The metabolic ratios and basal respiration were higher in Sub-Antarctic soils than in Antarctic ones, which can be interpreted as a result of higher amounts of fresh organic remnants in organic and organo-mineral horizons. Also the soils of King-George island have higher portions of microbial biomass (max 1.54 mg/g) compared to coastal (max 0.26 mg/g) and continental (max 0.22 mg/g) Antarctic soils. Sub-Antarctic soils mainly differ from Antarctic ones by having increased organic layers thickness and total organic carbon content, higher microbial biomass carbon content, basal respiration, and metabolic activity levels.

Key words

Soils, Antarctic, Sub-Antarctic, microbial and total carbon, respiration, metabolic ratios

1 Introduction

Antarctic soils are known for being very diverse in morphology, chemistry, texture and mineralogical composition. Essential pedodiversity within the Antarctic is caused by differences in geographical locations (by latitude) as well as by existence of so-called Antarctic oasis's which are isolated from each other by ice sheets and snow masses (Gilichinskiy et al., 2010; Mergelov and Goryachkin, 2010). According to Bockheim and Ugolini (1990), there are three soil-climatic zones in the Antarctic: The Sub-Antarctic zone of tundra or tundra-barren soils (soils of this zone are the most diverse and developed); the zone of the coastal Antarctic, presented by barrens and polar deserts (here the soil diversity is lesser, and solum consist of 5-10 cm only); and finally, the zone of real continental Antarctic landscapes, where the soils are quite primitive and even presented by so-called endolithic soils of severe polar deserts (Mergelov et al., 2010, 2012). The coastal part of the Antarctic exhibits so-called Antarctic oasis's, i.e., ice- and snow-free terrestrial ecosystems. Tundra ecosystems are typical mainly for maritime or Sub-Antarctic ecosystems, where they exhibit plant communities of mosses, lichens, algaes and vascular plants – *Deschampsia antarctica* and *Colobantus quitensis*. These communities form in relatively humid and warm climates, where there are essential stocks of organic matter in soil horizons and developed soil profiles with an average thickness of about 10-30 cm. Of course, if we compare Antarctic tundras with those from the Arctic zone, they will be very different to each other. The first reason for this is the different component composition of organic plant remnants and different species, and different ecological forms in the polar zones of both hemispheres.

In contrast, the low Antarctic barrens are formed in absence of vascular plants, and are characterized by severe climatic conditions and mainly forms of consolidated debrises or their derivates. Thus, Antarctic soils are quite different in their profile organization, chemical properties, and organic compounds contents. It was shown that the TOC and organic matter humification degree are quite changeable in soils of different latitudes, which is affected by the humus precursors quality, thickness of the friable debris, and climatic conditions (Abakumov, 2010a, b).

In fact, Antarctic soils contain low soil TOC, however, their content is quite different. They vary from zero levels in ahumic regolith soils (Ugolini and Bockheim, 2008; Campbell and Claridge, 1987; Bockheim, 2013) to 3-4% in soils under mosses, lichens, cereals (Abakumov, 2010b, Simas et al., 2008), to even 30-40% of organic matter in soils formed under guano (Simas et al, 2007). The differences in C/N ratios are known as more sufficient for Antarctic soils, and change from 70 in polar deserts to 2-3 in guano-enriched soils of the maritime Antarctic (Abakumov, 2010b).

TOC is presented not only by colloidal forms of humus (humic and fulvic acids, humin), but there is also an essential portion of detrite forms that provide organic carbon redistribution (Hopkins et al, 2008) or endolitic accumulation of organic matter (Vestal, 1988; Abakumov et al., 2010b; Mergelov et al., 2012). The humification degrees are differentiated lesser between the soils of Antarctic zones. Thus, the humification index—the ratio of carbon of humic acids to fulvic acids (Cha/Cfa)—belong to the fulvate (less than 0.5) or humate-fulvate (0.5-1.0) type. Therefore, there is not a high intensity of humification or organic matter transformation in these polar soils. But we can expect essential differences caused by local conditions differing from geographical climatic gradients.

Previous works analysed changes of microbial biomass and respiration rates along the geographical gradient of polar regions. It was shown that metabolical activity is relatively higher in Sub-Antarctic soils in comparison to continental soils (Gilichinskiy et al., 2010). According to Yoshitake et al. (2007) carbon (C) and nitrogen (N) content are not considered limiting factors to heterotrophic respiration in high Arctic soils. Kumar et al. (2013) suggested that changes in soil temperature were not critically affecting arctic soils. According to Dennis et al. (2013) the effect of the warming on the soil microbial community is expected as different for soils of Sub-Antarctic and Antarctic landscapes. Soil respiration has been predicted by organic phosphorous and total nitrogen content in Sub-Antarctic soils for habitat comparison (Lubbe and Smith, 2012). Latitudinal research of different Antarctic soils shows that the temperature sensitivity of microorganisms increases with mean annual soil temperature, suggesting that bacterial communities from colder regions were less temperature sensitive than those from the warmer regions (Rinnan et al., 2009). Thus, we can summarize that there are essential changes in soil microbial activity between real Antarctic soil at high latitudes and maritime sub-Antarctic soils. These differences are caused by the temperature sensitivity of organisms, different enzymatic activity, and different pools of C, N and phosphorous. Soil basal respiration and biological activity data are very poor or absent for soils of different climatic zones in the Antarctic. These data are important for soil carbon turnover modeling, for simulation of greenhouse gases emissions and soil organic dynamics in conditions of a changing climate. That is why the aim of our investigation is to compare the microbiological activity in soils of 3 latitude zones of the Antarctic from places near Russian polar Antarctic stations. To achieve this aim the following objectives were formulated:

(i) To identify soil types and chemical characteristics in the studied areas

(ii) To determine and interpret the values of soil respiration, microbial biomass and metabolic quotients in different climatic and vegetation zones of the Antarctic.

2 Materials and methods

2.1 Study site

The study sites were situated in different climatic regions of the Antarctic: Russkaya valley (Mary Byrd land), Larsemann hills (Princes Elizabeth Lands), and King-George Island (South Shetlands archipelago, Antarctic Peninsula). These plots present the coastal-continental Antarctic, the coastal Antarctic and the sub-Antarctic climatic regions, respectively. Some data on soil diversity and its features were published by Vlasov et al. (2005), Lupachev and Abakumov (2013), Gilichiskiy et al. (2010), Mergelov and Goryachkin (2012), Simas et al. (2007, 2008), Abakumov (2013), Abakumov et al., (2013) and others. Climatic conditions are quite different in all plots investigated. The most severe conditions are in the Russkaya station, while the King-George Island is characterized by the most warm and humid conditions.

Russkaya station (R) is situated on the Berks peninsula, Mary Byrd land, Western Antarctic, $74^0 46'$ S, $136^0 48'$ W. The annual temperature, precipitation, and maximal wind velocity is -12.4 C, 2000 mm, 77 ms^{-1}, respectively. Basalts, granites and gneisses are the main components of bedrock composition (Lupachev and Abakumov, 2013). Plant cover comprised mostly of lichens, mosses and some algae, while they vegetate on the former penguin rockeries.

A Progress station is situated on the coast of the Larsemann hills (L), Princes Elizabeth Lands, Eastern Antarctic, 69° 30’ S., 76° 19’ E. The annual temperature is -9.8 C, and the mean wind velocity is 6,7 ms^{-1} with maximum about 53 ms^{-1}. The annual precipitation is about 250 mm.

The Bellingshausen station belongs to the Fildes peninsula, King-George Island (KGI), $62°12'$ S, $58^0 58'$W, 40 m about sea level (a.s.l.) The parent material is comprised of andesite, basalt, and tuffs. The coastal areas are covered by maritime sands and gravels, and moraines and some fluvioglacial materials cover the periglacial plots (Peter H.-U.P., 2008). The mean annual air temperature is -2.8 °C. During the Australian summer (January and February) the mean monthly temperature rises to 5-6 °C in soil humus horizons (Abakumov and Andreev, 2010) The total annual precipitation reaches 729 mm, and the number of days with precipitation varies from 22 to 30 days per month. The wind velocity is 9.3 m/s (Petter et al., 2008) with maximum about 28 m/s. The Fildes peninsula exhibits a diverse variety of plant species (Abakumov, 2010b). Mono species plant communities are just as common as mixed ones, both in the coastal part and in plateau of peninsula. Therefore, many authors identify it as tundra or Antarctic tundra (Casanov-Kathny and Cavieres, 2012; Parnikoza et al., 2011; Bölter et al., 1997) because if compared with the Northern hemisphere this should be classified as some intermediate between tundra and barrens. Anyway, the plant communities of King-George Island are the most developed and rich throughout the Antarctic.

An indicator of biological activity within soils is the number of days where soil temperature is above zero. This value was 12-20 days on the Russkaya plot, 30-40 days on the Progress plot, and maximum 90 days in the Bellingshausen station (as is estimated by in situ termochrone loggers of humus horizons for one year). This index of biological activity is critical for mineralization and humification processes and is different in diverse zones of the

Antarctic. Thus, the KGI belongs to the Sub-Antarctic region, while the R and L plots are classified as the coastal region of the real Antarctic.

2.2 Soil sampling

The sampling of the soils and organic layers were conducted during the 53rd Russian Antarctic expedition (RAE) from 14 January 2008 to 25 February 25 2008 (samples from R) and during the 55th RAE from 4 December 2008 to 12 February 2010 (samples from KGI and L) on the scientific vessel "Academician Fedorov". Soil descriptions were partly published previously (Abakumov et al., 2008; Abakumov, 2010a, b). Briefly, soils of the King-George Islands are comprised of Gleysols, Crysols, Leptosols and Lithosols as well as one profile of Peat soils. Soil of the L plot were Gleysols on the lake coasts and exhibited one example of so-called Regolith or "Ahumic soils", according to Tedrow and Ugolini (1966). Regolith and Leptosols were typical for the landscape of the R plots. At least 3 individual samples were taken from each horizon of the soil profile. The areas of the soil pit were more or less the same for all studied plots, but differed for the KGI where soil polypedons were more or less uniform in space, and for R and L plots, where soil areas were isolated from each other due to unhomogenous vegetation distribution and non-regular soil cover character. All samples were collected during the Australian summer. Three soil samples were put into special containers with volumes of about 200 cm^3. Each sample replication was about 50 g of filed moisture weight. In some cases, while the fine earth content was to low, we collected only 10 to 15 g of soil to determine the general soil properties. The samples were stored in a freezer on the vessel to prevent transformation processes. Then the samples where stored at 0°C in the laboratory before the analyzing procedures. Weather conditions during the sampling were comparable for all the plots investigated: sunny weather, no precipitation, temperature was approximately 3-8 ^{0}C. This allows us to suggest that the microbial respiration status of the microbial community was more or less the same for all plots investigated.

2.3 Laboratory analyses

Soil samples, after being transported from the scientific vessel to the laboratory, were air dried in Petri cups, then grounded and sieved through the sieve with diameter 2 mm. It was not possible to avoid drying because only the dry soil can be homogenized, which is very important for sandy-coarse textured soils of the Antarctic. The soil color was determined with the use the Munsell color chart in the laboratory of the scientific vessel. The TOC was determined for air-dried soil by wet combustion in a solution of potassium dichromate in sulphuric acid (Tyurin or Walkley-Black method) (Walkley, 1935). The nitrogen content was assessed by the Kjeldahl method. The carbon content of the microbial biomass (Cmic) were determined in field moist samples with the chloroform fumigation-extraction method. The field moisture of soils were determined in the laboratory as a weight of water saturate soil sample minus weight of air-dried soil. A total of 5 g of soil were fumigated in chlorophom following extraction of dissolved organic matter (DOC) by 0.5 M K_2SO_4, filtration and evaluation of DOC portion by the dichromate method. The DOC of the control samples was determined in extracts without fumigation. Soil basal respiration (BR) was evaluated in laboratory closed chambers by CO_2 concentrations in an alkaline solution that was saved in a plastic container during the incubation process for 10 days. A metabolical quotient was calculated as the ratio of respirator C-CO_2 to Cmic per day of incubation (Jenkinson and Powlson, 1976; Vance, 1987). We have use the same method for basal respiration for acid (pH ‹ 7.5) and neutral soils (pH › 7.5). Because soil samples did not have a pH level more that 8.5, it is known that this pH level is caused by carbonates, which can provide the CO_2 emission under the laboratory measurements of respiration. We have determined the soil microbiological characteristics in all soil horizons, where the soil amount was enough. In some cases we were limited to general soil analyses because the soil sample amount was not enough for microbiological investigation. While the soil respiration and microbial biomass were measured in the described laboratory conditions, data obtained in this experiment cannot be interpolated directly to field conditions, but can be used only for comparison of soil microbiological activity in the same experimental conditions (temperature 20 ^{0}C, moisture 60% to initial soil weight).

2.4 Statistical analyses

Data obtained were statistically analyzed with SIGMAPLOT 8.0 program (mean values, paired t-test, one way Anova. The normality of the data using a parametric test**.** Ranks of data for Sub-Antarctic and Antarctic soils were compared to determine if there were statistical differences in soil formed in different climatic conditions. Significant differences were considered as $P < 0.05$. No differences between soil horizons and their depth were assessed while the amount of soil samples was not enough to conduct this type of comparison.

3 Results and discussion

3.1 Soil morphology

All the soils investigated were identified on the type level—mainly, according to WRB (2006)—and were considered as weakly developed soils without evident differentiation into horizons (Fig. 1, Table 1). These soils are typical representatives of Leptosols at the Russkaya station and KGI, Ahumic soils of Regoliths at the R and L plots, Lithosols on KGI and Post Orhnitosol (R) and current ("active") Orhnitosol (KGI). Permanent and temporal over-moisted soils with some redoximorphic features of gleyification were characteristics for L plot.

Regoliths did not show any morphological evidence of humus accumulation and were presented by slightly different layers of mineral materials. Gleysols were determined on the base of gray-blue color of mineral part: in the upper part of solum they had organic or organo-mineral grayish horizon. Leptosols are described mostly under the lichens and mosses on the dense bedrocks. Ornhitosols (Fig. 1) should be divided on two categories: those which are currently occupied by penguins, and those which are the former penguin rockeries, invaded now by birds. We will call the latter Post Orhnitosols.

3.2 Carbon content and general soil properties

The soils investigated contained different amounts of organic carbon content. TOC values ranged from 0.05-1.22% in soils of Larsemann hills to 4-7% in organo-mineral horizons of the King-George island soil, to more than 30% in peat (turf) material (Table 2). The differences in carbon values and absorbed water were statistically significant for Sub-Antarctic and Antarctic soils: $P<0.03$ and $P<0.01$, by t-test respectively. One way Anova tests showed the same differences with P levels $P<0.01$ and $P<0.03$ for TOC and hygroscopic water. The lowest organic carbon content was fixed for regolith soil, which is not really soil, but so-called "ahumic" soil, according to Tedrow and Ugolini (1966). These ahumic soil-like bodies contain nearly entirely mineral compounds and only very small portions of organic components and were presented described in the Larsemann hills oasis. Ahumic soils are typical for severe landscapes, where soil formation is limited by low organic matter production. At the same time there are soils with essentially higher portions of carbon in this Antarctic oasis. These soils were classified as Gleysols, i.e., soils seasonally covered by water. Then, in the end of the Australian summer they were within a sub-areal environment. These soils weere called "seasonal amphibious soils" (Abakumov and Krylenkov, 2011). Soil organic carbon content values in soils of the KGI were comparable with those that have been published previously (Abakumov, 2010; Zhao, 2000). The organic carbon values agree well with the absorbed water levels. This is very important for soils which are known as soils with low fine earth content (Abakumov, 2010, Campbell and Claridge, 1987). All the soils investigated are mostly slightly acidic; there are no alkaline layers between them due to absence of effect of ocean salts accumulation and because of acid or neutral composition of parent materials. Also, there were no statistical differences between the soils investigated. The fine earth content in general is essentially higher in the soils of KGI compared to soils of the continental oasis ($P<0.04$) due to different intensity of weathering (Vlasov et al, 2005) and genesis of underlying bedrocks (Peter, 2008).

3.3 Microbiological characteristics of soils

The differences between Sub-Antarctic and Antarctic soils in carbon content, soil microbial biomass, and basal respiration were statistically significant ($P<0.01$ for all indexes by both t-test and one way Anova methods). The values for microbial biomass carbon was generally the highest in Sub-Antarctic soils of KGI, especially in upper organic horizons in comparison with soils of coastal Antarctic landscapes (L, R). The same trend was found for basal respiration of soils. The metabolic soil activity was higher in Sub-Antarctic soils that can be interpreted as higher amounts of fresh organic remnants in well-developed organic horizons. Metabolic ratios were sufficiently lesser in soils of oases in the coastal Antarctic. This could be explained as a result of more severe climatic conditions as well as more homogenous composition of organic remnants with simultaneous decreased total organic carbon content. Two soils (Regolith and one of Gleysols) within the Larsemann hills showed more decreased metabolic ratios in upper layers than in deeper layers. In contrast, the second Gleysol of this oasis shows controversial distribution of these values, which can be explained by development of oxidation processes in the Gox (gleyic redoximorphic) horizon. These soils are so-called seasonal or amphibious soils (Abakumov and Krylenkov, 2011), where the sub-aquatic condition changes by air exposed at the end of Australian summer. This is the reason for intensification of microbial processes in the upper solum. Levels of microbial biomass were essentially lesser in R soils due to more severe climatic conditions. The metabolic ratios were less variable in soils near the Russkaya station than in case of Larsemann hills.

We summarize that soils of different Antarctic zones have different levels of carbon content, basal respiration, and metabolic quotient. The most homogenous group is the soils near the Russkaya station. This station had the most severe climate. Furthermore, the diversity of soils as well as the diversity of climatic conditions increases to the north. This results in increasing variability of microbial community characteristics and rate of total organic matter accumulations. Thus, our data confirm the hypothesis of Rinnan et al. (2009) that there are geographical trends in microbial communities sensitivity in latitudinal sequence in Antarctica. Also, they agree well with previous published data on metabolic activity of Sub-Antarctic and Antarctic (Gilichinskiy et al., 2010). Not only chemical properties of soil affect soil respiration levels (Lubbe and Smith, 2012), but also climatic conditions (temperature and soil moisture). This was especially important to compare the level of basal respiration in standardized laboratory conditions for soils from different natural zones (this give an opportunity to compare soils if different climate in the same experimental conditions), but not in a field, while the climatic conditions of expedition route were different. Our data shows that annual temperatures, periods of above-zero temperature, and levels of precipitation may play roles in levels of soil biological activity. Previously it was shown (Smith, 2003) that changing temperatures from 5 to 20 ^{0}C does not essentially affect soil respiration. We suppose that this is possible in case of analyzing soil in one island or oasis. While comparing soils of different natural zones these difference should be more apparent, and our data have shown these results.

4 Conclusions

Soils of diverse Antarctic landscapes were investigated to assess the microbial biomass level, basal respiration rates, and metabolic activity of microbial communities. The investigation shows that Antarctic soils are quite different in profile organization and carbon content. In general, Sub-Antarctic soils are characterized by more developed humus (sod) organo-mineral horizons and by an upper organic layer. The most developed organic layers were revealed in the peat soils of KGI, where soil thickness reaches 80 cm. These soils as well as soils under guano is characterized by the highest amount of organic carbon. Coastal and continental Antarctic soils are comprised of less developed Leptosols, Gleysols and Regolith with some Ornhitosol as well. In general, organic carbon content is less in Antarctic soils than in Sub-Antarctic soils. The metabolic activity and basal respiration were higher in Sub-Antarctic soils than in Antarctic soils due to higher amounts of fresh organic remnants in organic and organo-mineral horizons. Also the soils of KGI contain higher portions of microbial biomass than coastal and continental Antarctic soils. These data support the conclusions that Sub-Antarctic soils differ from Antarctic soils in increased thickness of organic layers and total organic carbon content, higher microbial carbon content, basal respiration, and metabolic activity levels. Thus, this short assessment of biogenic processes shows that geographical trends can cause changes in organic matter transformation indexes.

Acknowledgments

This work was supported by the Russian foundation for basic research, projects 12-04-00680, 13-04-90411 and by Saint-Petersburg State University research grant 1.37.151.2014. The authors thank V. Lukin, Head of Russian Antarctic expedition, Dr. H-U Peter and MSc Matthias Kopp, Jena University, for help in transportation of soil samples from Antarctica to Saint-Petersburg and Dr. A. Lupachev, Institute of Physico-chemical and biological problems of soil science RAS, for soil photos № 2-6 and 2-8.

References

Abakumov, E.V.: Particle-size distribution in soils of West Antarctica, Eur. Soil Sci., 43-3, 297-304, 2010.

Abakumov, E.V.: The sources and composition of humus in some soils of West Antarctica, Eur. Soil Sci., 43-5, 499-508, 2010.

Abakumov, E.V. and Andreev, M.P.: Temperature regime of humus horizons of soil of King-George Island, Western Antarctic, Transactions of Saint-Petersburg University, Ser. 3, 2, 129-133, 2011.

Abakumov, E. V., Gagarina, E. I., Sapega, V. F. and Vlasov, D. Yu.: Micromorphological Features of the Fine Earth and Skeletal Fractions of Soils of West Antarctica in the Areas of Russian Antarctic Stations, Eurasian soil science, 46-12, 1219-1229, 2013.

Abakumov, E.V. and Krylenkov V.A.: Soil of Antarctic, Priroda, 3,58-62, 2011

Abakumov, E.V., Pomelov, V.N., Vlasov, D.Y., Krylenkov, V.A. Morphological organization of soils in Western Antarctica. Vestn. St.-Peterb. Univ., Ser. 3: Biol. 3 102-115, 2008. [in russian]

Bockheim, J.: Paleosols in Transantarctic mountains: indicators of environment change, Solid Earth, 4, 451-459, 2013.

Bockheim, J. G. and Ugolini, F. C.: A review of pedogenic zonation in well-drained soils of the southern circumpolar region, Quat. Res, 34, 47–66, 1990.

Bölter M., Blume H.-P., Schneider D., Beyer L.. Soil properties and distributions of invertebrates and bacteria from King-George Island (Arctowskiy station), Maritime Antarctic. Polar Biol. 18, 295-394, 1997.

Campbell, I. B. and Claridge, G. G. C., Antarctica: Soils, Weathering Processes and Environment, Elsevier, Amsterdam, 1987.

Casanov-Kathny, M.A. and Cavieres L.A.: Antarctic moss carpets facilitate growth of Deschampsia Antarctica but not its survival. Polar biol., 35: 1869-1878, 2012.

Dennis, P.G., Newsham, N.K., Rushton, S.P., Ord, V.J., O'Donnell, A.G. and Hopkins, D.W. Warming constrains bacterial community responses to nutrient inputs in a southern, but not northern, maritime Antarctic soil, Soil. Biol. Biochem., 57, 248-255, 2013.

Gilichinsky, D., Abakumov E., Abramov, A., Fyodorov Davydov, D., Goryachkin, S., Lupachev, A., Mergelov, N. and Zazovskaya, E. Soils of Mid and Low Antarctic: diversity, geography, temperature regime, World Congress of Soil Science, Soil Solutions for a Changing World , 1–6 August 2010, Brisbane, Australia. Published on DVD.

Hopkins, D.W., Sparrow, A.D., Gregorich, E.G., Novis, P., Elbering, B. and Greenfield, L.G. Redistibuted lacustrine detritus as a spatial subsidy of biological resources for soils in an Antarctic dry valley, Geoderma, 144, 86-92, 2008.

Jenkinson, D.S. and Powlson, D.S.: The effects of biocidal treatment on metabolism in soil. V. A method for measuring soil biomass, Soil Biol. Biochem., 8, 209-213, 1976.

Kumar, N, Grogan, P., Chu, H., Christiansen, C.T. and Walker, V.K. The Effect of Freeze-Thaw Conditions on Arctic Soil Bacterial Communities, Biology, 2, 356-377, 2013.

Lubbe, A. and Smith, R. V. Field Soil Respiration Rate on a Sub-Antarctic Island: Its Relation to Site Characteristics and Response to Added C, N and P, Open J. of Soil Science, 2, 187-195, 2012.

Lupachev, A.V. and Abakumov, E.V.: Soils of Marie Byrd Land, West Antarctica, Eur. Soil Sci., 46-10, 994-1006, 2013.

Mergelov, N.S. and Goryachkin, S. V.: Soils and soillike bodies of Antarctica (the Larsemann Hills oasis)," in Genesis, Geography, ad Classification of Soils and Inventory of Soil Resources, Conf. devoted to the 150th anniversary of the birth of N.M. Sibirtsev, Arkhangelsk, 38–42, 2010.

Mergelov, N. S., Goryachkin, S. V., Shorkunov, I. G., Zazovskaya, E. P. and Cherkinskii A. E., Endolithic pedogenesis and rock varnish on massive crystalline rocks in East Antarctica, Eur. Soil Sci. 45,10, 901–918, 2012.

Kumar, N., Grogan, P., Chu, H., Christiansen C.T. and Walker, V.K. The Effect of Freeze-Thaw Conditions on Arctic Soil Bacterial Communities, Biology, 2, 356-377, 2013.

Parnikoza, I., Korsun, S., Kozeretskaya, I., Kunakh, V. A discussion note on soil development under the influence of terrestrial vegetation at two distant regions of the Maritime Antarctic. Polarforchung 80 (93), 181-185, 2011.

Peter, H.U. et al.: Risk assessment for the Fildes Peninsula and Ardley Island, and development of management plans for their designation as Specially Protected or Specially Managed Areas, Research Report 203 13 124 UBA-FB 001155e. Jena, Germany, 508, 2008.

Rinnan, R., Rousk, J., Yergeau, E., Kowalchuk, G.A. and Erland, B.A.A.: Temperature adaptation of soil bacterial communities along an Antarctic climate gradient: predicting responses to climate warming, Clobal Change Biol., 15, 2615-2625, 2009.

Simas, F.N.B., Schaefer C. E. G.R., Melo V. F., Albuquerque-Filho M. R., Michel R. F.M., Pereira V.V., Gomes M. R.M., da Costa L. M.: Ornithogenic Cryosols from Maritime Antarctica: Phosphatization as a soil forming process, Geoderma, 138, 191-203, 2007.

Simas, F.N.B., Schaefer, C. E.G.R., Albuquerque, F. M. R., Francelino, M. R., Filho, E. I. F. and da Costa, L. M. Genesis, properties and classification of Cryosols from Admiralty Bay maritime Antarctica, Geoderma, 144, 116-122, 2008.

V. R. Smith, Soil Respiration and its Determinants on a Sub-Antarctic Island. Soil Biology and Biochemistry, Vol. 35, No. 1, 77-91, 2003.

Tedrow, J.F.C. and Ugolini, F.C.: Antarcic soils in: Tedrow, J.F.C. (ed.) Antractic soils and soil forming processes, Washington, 161 – 177, 1966.

Ugolini, F.C., Bockheim, J.G.: Antarctic soils and soils formation in a changing environment: A review, Geoderma, 144, 1-8, 2008.

Vance, E.D., Brookes, P.C. and Jenkinson, D.S.: An extraction method for measuring soil microbial biomass C, Soil Biol. Biochem., 6, 703-707, 1987.

Vestal, R.J.: Biomass of the cryptoendolithic microbiota form the Antarctic desert, Appl. and Env. Microbiol., 54, 957-959, 1988.

Vlasov, D.Yu., Abakumov, E.V., Nadporozhskaya, M.A., Kovsh, N.V., Krylenkov, V.A., Lukin, V.V., Safronova, E.V. Lithosols of King George Island, Western Antarctica, Eur. Soil Sci., 38-7, 681-687, 2005.

Yoshitake, S, Uchida, M, Koizumi, H and Nakatsubo T. Carbon and nitrogen limitation of soil microbial respiration in a High Arctic successional glacier foreland near Ny-Ålesund, Svalbard. Pol. Res., 26, 22-30, 2007.

Zhao, Ye. The soil and environment in the Fildes Peninsula of Kind George Island, Antarctica. China. Bejing. 2000.

Walkley, A. An examination of methods for determining organic carbon and nitrogen in soils. J. Agric. Sci. 25, 598-609, 1935.

Fig. 1. Study areas in the Antarctic: 1 - Russkaya station, 2 - Larsemann hills, 3 – King-George Island.

Fig. 2. Photos of selected soils: R: 1 – Leptosol, 2 – Regolith, 3 – Post ornhitosol surface, L: 4 – Regolith, 5 – Gleysol, Steppet Lake, 6 – Seasonal Gleysol, Reid lake, K: 7 – Lithosol, 8 – Orhnitosol, 9- Leptosol.

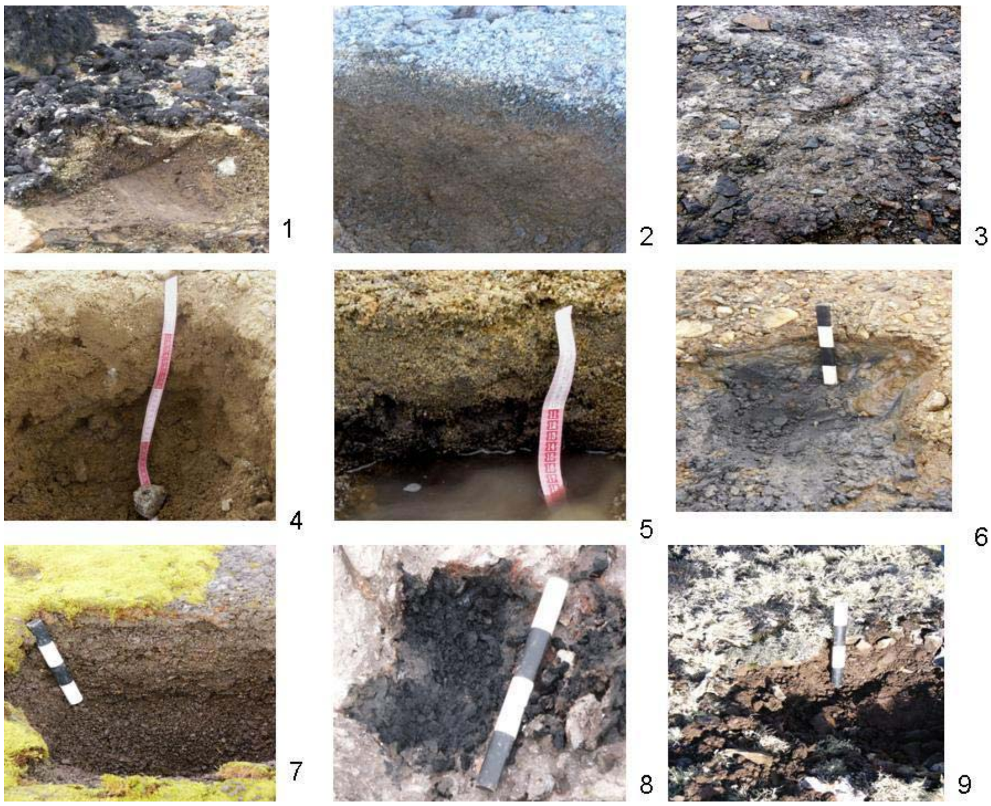

Table 1. Morphological features and chemical characteristics of Antarctic soils, ±means the standard deviation

Soil	Horizon	Depth, cm	Color	TOC, [%]	Hygroscopic water, [%]	pH in water	Fine earth, [%]
Leptosol, R	W	0-7	10 YR 5/3	4.67±0.23	2.58±0.014	5.90	Nd
Post ornithosol, R	O	0-10	10 YR 5/3	0.60±0.03	2.41±0.08	5.80	11
Regolith, R	C_1	2-15	5YR 6/1	0.52±0.03	1.00±0.08	5.40	5
	C_2	15-30	5YR 6/1	0.87±0.05	1.98±0.15	3.30	9
Regolith, L	C_1	0-10	5YR 6/1	0.08±0.01	0.22±0.01	6.39	7
	C_2	10-20	5YR 6/1	0.05±0.01	0.31±0.02	7.77	16
Gleysol, coast of the Steppet lake, L	G	0-2	7,5 YR 6/1	1.22±0.05	0.36±0.02	3.57	53
	G	2-8	5YR 6/1	0.83±0.09	0.41±0.03	5.70	26
Gleysol, coast of the Reid lake, L	Cox	0-12	5YR 6/2	0.37±0.04	0.23±0.01	6.80	28
	G	12-20	5 Y 4/4	0.50±0.06	0.33±0.02	7.04	21
Lithosol, KGI	O	0-3	10 YR 5/3	6.34±0.19	6.34±0.25	5.60	Nd
	AУ	3-6	5YR 6/1	1.73±0.07	4.73±0.15	6.50	18
	C		5YR 6/1	0.80±0.07	-	6.60	34
Lithosol, KGI	O	0-3	10 YR 4/2	11.25±045	9.00±0.74	4.74	Nd
	AУ	3-13	10 YR 5/2	1.20±0.04	4.66 ±0.25	6.10	56
	C	13-21	5YR 6/1	0.95±0.09	7.42±0.32	4.85	56
Organic Gleysol, KGI	O	0-3	10 YR 4/2	14.02±0.74	8.41±0.12	6.33	Nd
Peat soil, KGI	O	0-20	7,5 YR 5/6	33.7±0.98	9.57±0.58	5.25	Nd
Ornhitosol, KGI	Ocopr	0-10	2,5 YR 4/4	7.56±0.12	0.65±0.04	6.01	Nd
Ornhitic Leptosol, KGI	Ocopr	0-10	2,5 YR 4/4	7.22±0.21	13.25±0.85	7.30	9
Leptosol, KGI	W	0-5	10 YR 5/3	1.32±0.05	0.75±0.04	5.40	47

Table 2. Microbial biomass, basal respiration, and metabolical quotient in soils, ±means the standard deviation

Soil	Horizon	Cmic, [mgg^{-1}]	Basal respiration, [$mgg^{-1}day^{-1}$]	Metabolical quotient
Leptosol, R	W	0.11±0.01	0.006	0.06
Post ornithosol, R	O	0.17 ±0.01	0.011	0.07
Regolith, R	C_1	0.11±0.01	0.006	0.06
	C_2	0.22±0.02	0.012	0.06
Regolith, L	C_1	0.26±0.02	0.005	0.02
	C_2	0.14±0.02	0.020	0.14
Gleysol, coast of the Steppet lake, L	G	0.20±0.03	0.004	0.02
	G	0.20±0.02	0.014	0.07
Gleysol, coast of the Reid lake, L	Cox	0.23±0.02	0.014	0.06
	G	0.17±0.01	0.002	0.01
Lithosol, KGI	O	0.49±0.03	0.060	0.10
	AУ	0.16±0.01	0.010	0.06
Lithosol, KGI	O	1.20±0.05	0.100	0.08
	AУ	0.23±0.01	0.003	0.01
Organic Gleysol, KGI	O	0.41±0.02	0.040	0.10
Peat soil, KGI	O	1.54±0.09	0.080	0.05
Ornhitosol, KGI	Ocopr	0.92±0.07	0.050	0.05
Ornhitic Leptosol, KGI	Ocopr	0.74±0.06	0.090	0.12
Leptosol, KGI	W	0.34±0.04	0.009	0.03