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DETERMINATION OF THE SOIL-PERMAFROST BORDER IN TWO MARITIME ANTARCTIC REGIONS ON THE BASE OF VERTICAL ELECTRIC SOUNDING DATA

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Abstract. The deepness of soil-permafrost layer was measured by vertical electrical resistivity sounding. It has been revealed that the deepness of active layer on the Point Thomas oasis, King George Island is in average about 100−150 cm, while on the Argentine Islands it is 40−50 cm, which is caused by climatic conditions. Weak soils of the Argentine Islands are connected to permafrost via the massive rock, while in case of Point Thomas oasis (King-George Island) fine-coarsy gravel soils are underlayed directly by permafrost.

Key words: electric resistivity, permafrost, soils, maritime Antarctica, active layer

Визначення межі грунтової мерзлоти за допомогою вертикального електричного зондування у двох регіонах Морської Антарктики.
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Реферат. Досліджено глибину ґрунтово-мерзлотної товщі методами вертикального електричного зондування. Встановлено, що товща активного шару ґрунту в оазі Поінт Томас, о. Кінг-Джордж становить 100−150 см, у той час як на Аргентинських островах — 40−50 см, що пов'язано насамперед з рельєфними та кліматичними умовами. Малопотужні ґрунти о-ва Аргентинських островів відчувають вплив мерзлоти через скельну породу, в той час як пухкі дрібноземлисті-щебнисті ґрунти оазису Поінт Томаса о-ва Кінг-Джордж залягають переважно на товщі мерзлого ґрунту.

Определение границы почвенной мерзлоты с помощью вертикального электрического зондирования в двух регионах Морской Антарктики.
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Исследована глубина почвенно-мерзлотной толщи методами вертикального электрического зондирования. Установлено, что толща деятельного слоя почвы оазиса Поинт Томас, о-ва Кинг-Джордж составляет 100−150 см, в то время как на Аргентинских островах — 40−50 см, что связано в первую очередь с рельефными и климатическими условиями. Маломощные почвы Аргентинских островов испытывают влияние мерзлоты через скальную породу, в то время как рыхлые мелкоземисто-щебнистые почвы оазиса Поинт Томаса о-ва Кинг-Джордж залегают, в основном, непосредственно на толще мерзлой почвы.

1. Introduction

Maritime Antarctica is zone of very developed soil formation in comparison with continental Antarctica (Abakumov, 2011). But in different regions this processes have differ intensivity (Abakumov, 2010; Parnikoza et al., 2011). Active layer thickness and the depth of the permafrost layer are the basic features of soil cover of the Antarctic region, but level of study of these characteristics for Antarctic soils is not satisfactory. Additionally the depth of the permafrost can be assessed by different direct or indirect methods. The classic method is to dig the soil profile or to drill the soil mass with the aim of fixing the border of the active layer and permafrost morphologically. Nowadays, direct-current resistivity (DC resistivity) methods have to been used for the identification of permafrost depth and soil profile heterogeneity. These geophysical methods have many advantages (Scot et al., 1990, Korchagin et al., 2013) and have been widely used for permafrost identification (Hauck and Muchel, 1999). One of the main advantages of these methods is that the equipment is portable and easy to handle. The second one is the ability to detect the permafrost depth without so invasive drilling or soil-pit preparation.

The one-dimensional model is known to be effective for mapping of the permafrost depth in relatively homogenous conditions, whereas the two-dimensional approach was proposed for plots with a high degree of inhomogeneity (Hauck and Muchel, 1999; Pozdnyakov, 2008). Electric conductivity and resistance depend on soil chemical composition, especially salt content, texture of the fine earth and soil moisture content (Pozdnyakov, 2008; Magnin et al. 2015). The method of vertical electrical sounding (VES) allows us to identify contrast soil horizons and layers changes in vertical scale and provides the precise information about solum-parent material organization. On the basis of the published data (Pozdnyakov et al., 1996; Hauck and Muchel, 1999; Smernikov et al., 2008; Vanhala et al., 2009; Turu I Michels and Ros Visus, 2013) we suppose that there are essential changes in values of electrical resistance (ER) on the border of the soil and permafrost.

So this work was aimed to identify the depth of permafrost and active layer thickness in different maritime Antarctic regions by ER method.

2. Materials and Methods

During 18-th Ukraine Antarctic Expedition soil-permafrost complexes has been investigated on the central Argentine Islands – Galindez and Winter Islands in the vicinities of Ukrainian Vernadsky base, S 65.245686°, W 64.257051°) and on the Point Thomas oasis, King George Island, in surroundings of the Polish Arctowski base, S 62.160250°, W 58.473882°. Argentine Islands Archipelago is situated in 5–7 km far from the western coast of Antarctic Peninsula al part (Graham Land, Kyiv Peninsula). It consist of 15 small islands with the total area about 10 km^2. The biggest islands are: Galindez, Uruguay, Skua, Winter, Grotto, Corner, Irizar with average area of every one about 1 km^2 (Govorukha, 1997). Argentine Islands presented by elevations of submarine plateau, formed by volcanic rocks. Weathering of volcanic rocks results in formation of hills relief in periglacal landscape. The most typical hill is Woozle Hill on Galindez Island (51 m height). The ridges are also places for current soil formation mainly for Leptosols or Lithosols (Kozeretska et al., 2015). It is divided each from other by permanent snow layers, were sometimes streams form in the spring. The gravel beaches aren't typical for investigated Islands, and occupied small area. The Point Thomas oasis is the area of abrasion accumulation. In front of some retreating glaciers, young lagoons occur, what are separated from the main part of the bay by underwater ridges or slightly emergent peninsulas of sand and rocks, representing frontal moraines (Rakusa-Suszczewski, 2002). There is deglaciation on the territory of oasis, new fresh sediments are colonized by plants and show the evident features of initial soil formation (see Abakumov, 2011). The main factors that influence on biological and chemical processes in both studied regions are increase of minimum winter air temperature, increase in the number of the freeze-thaw cycles, temperature limit, decrease in summer precipitation, relatively rapid deglaciation on lend, decrease in extent of sea ice (Rakusa-Suszczewski, 2002).

There were 4 and 3 VERS (vertical electric resistivity sounding) measurements in Argentine Islands and King George Island correspondingly. Study sites of the Argentine Island were presented by:

1. Winter Island, Wordie House Point, Angelica Thumb, мassive rock, covered by lichens and mosses, S 65.250210°, W 64.255630°, 8 m.a.s.l.;
2. Galindez Island, Stella Ridge northern margin near Fairy Meadow, Leptosol 5 cm deep underlayed by andesite massive rock, covered by sparse lichens, S 65.247500°, W 64.248993°, 23 m.a.s.l.;
3. Galindez Island, Sterna Point, zone of Galindez glacier retreat, coarse ground of the moraine glacial genesis with sparse lichens and mosses, S 65.251230°, W 64.251620°, 9 m.a.s.l.;

4. Galindez Island, Coarse textured Leptosol underplayed by andesite massive rock, mosses cover and *Usnea antarctica* Du Rietz formation on rock, S 65.248440°, W 64.246620°, 44 m.a.s.l.;

Study sites of the Point Thomas oasis were presented by:

1. Fresh gravel moraine in zone of deglaciation near Ecology Glacier, start of plant colonization by mosses and both vascular plants − cover not more than 1 %, S 62.166480°, W 58.468290°, 30 m.a.s.l;

2. 40 m on south-west from Puchalski grave, 90% vegetation cover of both vascular plants, mosses and lichens, Cryosol with the boulders on the surface; S 62.163660°, W 58.469710°, 28 m.a.s.l;

3. Slope of hill in W. Puchalski grave point, 90% vegetation cover of both vascular plants, mosses and lichens, Leptosol, underplayed by a granite massive rock; S 62.163660°, W 58.469710°, 28 m.a.s.l.

The ER was measured directly in the soil profiles using the vertical electrical resistivity sounding (VERS) method, which provides data on the changes in the electrical resistivity throughout the profile from the soil surface. The resistivity measurements were performed using four-electrode arrays of the AMNB configuration. A Landmapper ERM-03 instrument (Landviser, USA) was used for the VES measurements in this study. A VES modification with shorter electrode spans was used to study the upper 0 to 3-m thick layer in greater detail. The distance between the A and B electrodes ranged from 5 to 300 cm. The soils had been ‘sounded’ thoroughly and found to vary between 5 cm and 3–5 m in depth. As it was substantiated previously that the depths of VES coverage are the same as the distance between electrodes A and B, we have therefore measured the ER values at the minimum depth of 5 cm and values were collected for maximum depths of about 3 m. Field data were recalculated to the specific values following by recommendations of Pozdnyakov (1996, 2008).

3. Results and discussion

Processed data of electric resistivity measurements within the soil depth are shown in the Fig. 1 for the Argentine Islands and Fig. 2 for Point Thomas oasis correspondingly. All the soils and substrates, investigated show an increasing of specified electrical resistivity within the soil depth. This is typical for soils, underlayed by permafrost, as well as for grounds, without any features of soils formation. This fact confirms the hypothesis, that electric resistivity in high scales caused mostly by permafrost abundance that by organic matter content or other factors. The depth of the permafrost the uppermost permafrost layer is about 40–50 cm for Galindez Island. In all investigated plots the permafrost not faced with friable ground or fine textured soil. Permafrost uppermost layer is situated in massive rock, which can be separated into active layer and frozen one.

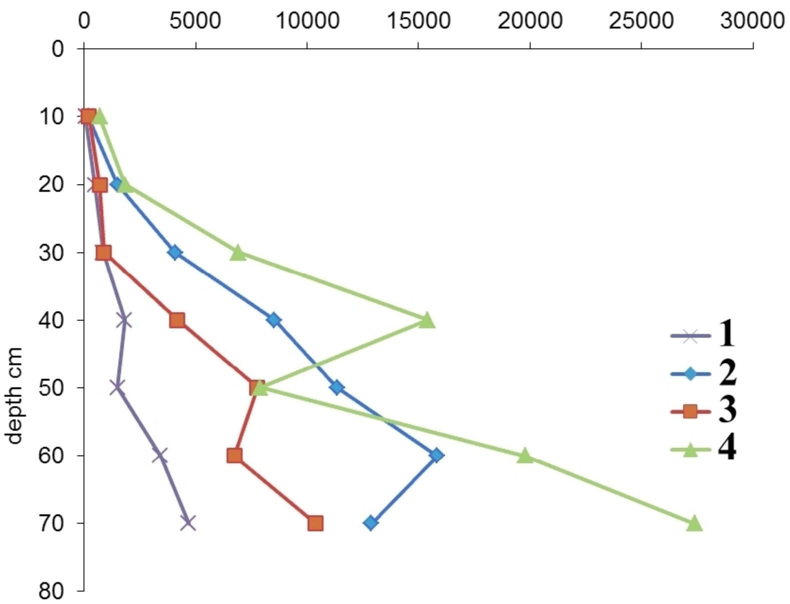

Fig. 1. The vertical electrical resistivity sounding results for Argentine Islands study sites,

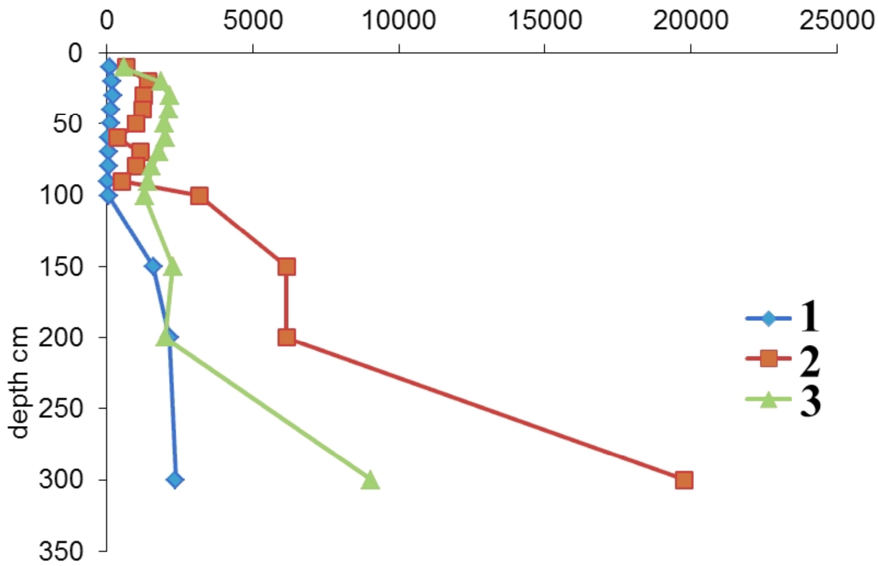

Fig. 2. The vertical electrical resistivity for Point Thomas oasis study sites, Specific Electric Resistivity, Om*m

Soils of Point Thomas oasis show the same trends of rapid increasing of resistance within the ground depth. The main difference of the Point Thomas oasis sites from Argentine Islands one is the higher thickness of the active layer — 100–150 cm. Geological (thick layers of friable ground) cause this and climatic conditions, namely, King George Island situated in relatively warm zone of maritime Antarctica near 400 km on north from Argentine Islands. In previous studies was shown that soil formation processes in King George Island go ahead in comparison with Argentine Island area (Korsun et al., 2008; Parnikoza et al., 2011). Analyzing the curves of resistance in Point Thomas oasis study sites was shown that first increasing is deeper that 100 cm, after what the second maximum is possible deeper than 200 cm. This can be interpreted that zone between 100–200 cm are dynamic layer, changed from year to year, with cracks, accumulated melted soil materials and spots of not degraded permafrost. This hypothesis supported by those facts that in case of massive rock there are not 2 peaks of permafrost.

4. Conclusions

Field measurements of VERS allow assessing the depth of the soil and base material active layers in conditions of Antarctic Peninsula. It was shown, that on the area of Argentine Islands the soils generally not contact directly with permafrost layer and they are fenced off from permafrost by not frozen massive rock. Thus they can be classified like Leptosols or Lithosols, but not Cryosols, because there is no mass turnover in soil profile. In opposite, in case of Point Thomas oasis there is both type of soil — permafrost layer. The first is typical for Argentine Islands where friable soil is sub laid by rock. The second one is while friable soil faced to permafrost without transitional massive layer. In general, the average deepness of the active layer is about 40-50 cm in Argentine Islands, while it is 100–150 cm in Point Thomas oasis, King George Island.

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