

Article: IHSS18 Special Paper**Carbon Content and Macroelements Content in Cryosols****Lubica Pospisilova^{1*}, Vitezslav Vlcek¹, Vitezslav Hybler¹, and Peter Uhlík²**

¹ Mendel University in Brno, Faculty of Agri Science, Department of Agrochemistry, Soil Science, Microbiology and Plant Nutrition, Zemedelska 1, 612 00 Brno, Czech Republic

² Comenius University, Faculty of Natural Science, Department of Geology and Mineral Deposits, Mlynská dolina, Ilkovicova 6, 842 15 Bratislava, Slovakia

Abstract

Physicochemical properties of soils in Antarctica (James Ross and Deception Island) were surveyed and differences in the soil formation process were discussed. Turbic Cryosols and Leptic Andosols from volcanic tuff were mainly formed by the process of cryoturbation. Cryoturbation processes include the mixing or disturbing of soil by frost action and the freezing of the active of the permafrost during melting period. Two localities were compared: Turbic Cryosols (James Ross Island, 8 soil profiles) and Leptic Andosols (Deception Island, 2 soil profiles). Besides differences in chemical properties (mineralogy and elemental composition) we determined total organic carbon (TOC) content and humic substances (HS) quality. Results showed low TOC content ($< 10 \text{ mg g}^{-1}$), low HS quality (domination of fulvic acids), and low ratio of humic acids to TOC for the surface soil in both soil types with a larger extent for the Leptic Andosols. In elemental composition, mainly Fe, Al, Ca, Mg, S, Ti, Na, P, and K prevailed in both soil types.

Keywords: Andosols, Cryosols, elemental composition, organic carbon

Introduction

Cryosols and Andosols in ice-free area in Antarctica have been formed since the last deglaciation 9500–6000 years before present. Soil forming processes under extreme climatic conditions have not been well studied and can be an important source of information on environmental changes. Due to the specific climatic condition, scarcity of ice- and snow-free areas, mainly process of cryoturbation are taken place in soil formation (Navas et al., 2008). Mineral matrix and natural organic matter bound to mineral matrix are the main factors influencing structure of the particle network in soils. Both of them are controlled by the prevailing climatic conditions. Although the effect of humic substances on the stability, reactivity, and transport of clay minerals is complicated, the interfacial and colloidal interactions govern their existence and fate in the environment (Theng, 1979; Tombácz et al., 2004). The aim of this study was to characterize texture, physical and chemical properties,

elemental composition, and humic substances content and quality in soils in non-polluted areas of Antarctica.

Materials and Methods

Studied soils were classified according to the IUSS Working Group WRB (2006). Two localities were compared: James Ross Island (8 soil profiles) and Deception Island (2 soil profiles). Regarding soil chemistry it should be stressed that soils from J. Ross (*Turbic Cryosols*) were significantly different from soils reached from Deception Island (*Leptic Andosol*). Map of soil sampling sites is given in Fig. 1. Geographical materials are given in Table 1. Vegetation is represented by a large number of species of non-flowering plants, such as mosses, lichens, algae, and fungi. Only two species of flowering plants are known: the Antarctic pearwort (*Colobanthus quitensis*) and Antarctic hair grass (*Deschampsia antarctica*). Animals are represented mainly by birds, penguins, and seals (Gajdošova et al., 2003).

* Corresponding author: Tel. & Fax +420-545-133-059; E-mail: pospisi1@mendelu.cz

Table 1 Geographical information and parent material of sampling sites

Locality	Altitude (m above sea level)	Latitude	Longitude	Parent material
JR profile 1	35	S 63° 48.014'	W 57° 53.662'	Cretaceous deposits undiff.
JR profile 2	375	S 63° 48.500'	W 57° 56.923'	Hyaloclastite tuffs
JR profile 3	328	S 63° 49.270'	W 57° 56.000'	Hyaloclastite breccia's
JR profile 4	55	S 63° 48.335'	W 57° 55.082'	Cretaceous deposits undiff.
JR profile 5	53	S 63° 48.339'	W 57° 55.082'	Cretaceous deposits undiff.
JR profile 6	70	S 63° 53.135'	W 57° 57.692'	Glacial/Fluvioglacial deposits
JR profile 7	44	S 63° 53.405'	W 57° 57.661'	Fluvioglacial deposits
JR profile 8	38	S 62° 58.748'	W 60° 33.280'	Fluvioglacial deposits
DI profile 1	30	S 62° 58.715'	W 60° 33.438'	Volcanic materials
DI profile 2	10	S 62° 58.742'	W 60° 33.413'	Volcanic materials

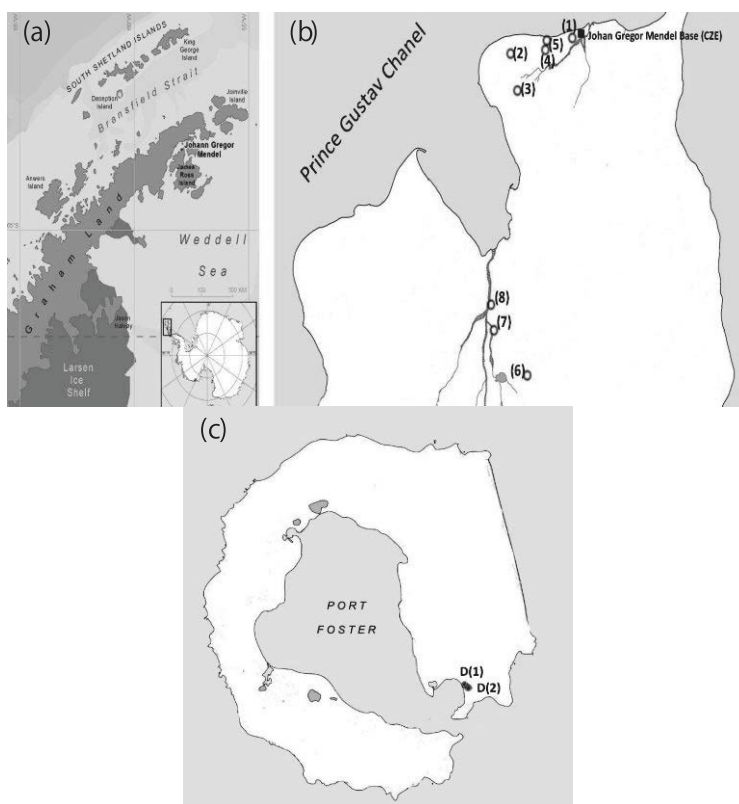


Figure 1. Left: Antarctic Peninsula, South Shetland Islands and James Ross Island (source: Zdeněk Stachoň, Masaryk University); Right: Detail of northern part of James Ross Island (source: Czech Geological Survey, 2009) with sampling places (8 soil profiles). Detail of Deception Island with sampling places (2 soil profiles).

Basic soil characteristics were determined by commonly used standard methods. Particle size distribution was determined by the pipette method (Buchan, 2001). Soil pH was determined by a potentiometric method in distilled water and in 1 M KCl solution (1:2.5). Electric conductivity was measured by a conductometer (Buchan, 2001). Contents of macro and trace elements in *Aqua regia* solution were determined by inductively coupled plasma/mass spectrometry (ICP-MS) at Bureau Veritas Commodities Canada Ltd (Majzlan et al., 2010).

Total organic carbon (TOC) content was determined by a wet digestion according to Nelson and Sommers (1982). Humic substances content was evaluated by short fractionation method according to Kononova and Beltchikova (1963) as follows: 5 g of air-dried soil sample (< 1 mm) were extracted by 100 mL of a mixture of 0.1 M NaOH and 0.1 M Na₄P₂O₇ (1:1) for 24 hours. The suspension was allowed to stand overnight and then centrifuged for 10 minutes at 2,800 g. The sediment was washed with 50 mL of the extractant and centrifuged (10 minutes at 2,800 g). Two individual

washings were combined with the extract, and an aliquot was used for the determination of alkaline extractable humus (abbreviated as “HS” here) by wet digestion. Amount of HA was also determined by wet digestion after acidification of another aliquot with concentrated H₂SO₄ (pH = 1.5). Amount of FA was calculated as difference between HS and HA. Ratio of humic acids to total organic carbon (HA/TOC) was calculated. UV-VIS spectra of HS solutions were measured using Varian Cary 50 Probe with optical fibre, within the range from 300–700 nm.

Results and Discussion

Texture classes of studied Turbic Cryosols and Leptic Andosols varied from sandy loam to loamy sand (Table 2). Active soil reaction was weakly alkali in upper horizons. Strongly acid active reaction was determined in deeper horizons in JR profiles 5, 7, and 8. Exchangeable soil reaction varied from weakly acid to strongly acid (Table 2). Electric conductivity of the James Ross Island soils ranged from 116 to 3129 $\mu\text{S cm}^{-1}$ and thus those soils were not salty (Table 2). The

Table 2 Basic characteristics of soil samples used

Locality	Depth (cm)	Clay (%)	Silt (%)	Sand (%)	Texture class	pH(H ₂ O)	pH(KCl)	EC ($\mu\text{S cm}^{-1}$)
JR profile 1	0–10	7.8	21.0	71.2	SL	7.94	6.33	116
	10–20	14.8	36.2	49.0	L	7.89	6.54	133
JR profile 2	0–10	1.4	32.9	65.7	SL	7.90	6.65	523
JR profile 3	0–10	13.0	28.7	58.3	SL	7.85	6.50	433
JR profile 4	0–10	6.7	39.2	54.1	SL	6.35	5.17	815
JR profile 5	5–15	18.8	35.0	46.2	L	7.94	6.55	200
	25–30	2.1	52.0	45.9	SiL	7.23	6.62	1040
	38–45	9.8	18.1	72.1	SL	3.79	6.05	1480
JR profile 6	0–5	9.9	14.0	76.1	SL	7.07	5.96	430
JR profile 7	0–3	15.3	21.5	63.2	SL	7.03	6.50	2970
	3–9	23.3	22.0	54.7	SCL	7.17	6.39	1117
	12–20	3.3	60.4	36.3	SiL	4.05	3.27	2852
	32–40	8.5	29.4	62.1	SL	3.50	2.94	1692
	51–57	4.3	22.4	73.3	LS	3.64	3.12	1633
JR profile 8	0–10	14.1	25.0	60.9	SL	7.01	6.44	3129
	30–40	4.9	46.7	48.4	SL	3.77	3.24	1302
DI profile 1	0–10	2.4	22.4	75.2	SL	7.18	5.08	n.d.
DI profile 2	0–10	3.9	15.3	80.8	SL	6.88	4.91	n.d.

JR, J. Ross Island. DI, Deception Island. SL, Sandy loam. L, Loam. SiL, Silt loam. SCL, Sandy clay loam. LS, Loamy sand. EC, Electric conductivity. n.d., Not determined.

active pH, $\text{pH}(\text{H}_2\text{O})$, ranged from 3.50 to 7.94, and the exchangeable pH, $\text{pH}(\text{KCl})$, ranged from 2.94 to 6.65. Soil pH in surface layers of all the soil profiles studied was alkaline. In deeper layers, the active pH changed all the way to acidic or strongly acidic (mainly in the depth of 30 cm). Two exceptions included samples on fluvial alluvia (JR profiles 7 and 8), where the pH change occurs at 15 cm depth. This could be resulted from the transportation of water soluble salts to the surface layer within the active layers during melting period by capillary uplift and correspond with the dissolution of minerals and increase in salinization that generally occurred in surface horizons. The decreases in soil pH with depth are in opposite to the data published by Navas et al. (2008). In accordance with Amin (1993) we can conclude that typical for Antarctic soils was little chemical weathering, presence of alkalinity, and initial process of soluble salts accumulation.

Average contents of macro elements in Turbic Cryosols (James Ross Island, JR profile 7) and Leptic Andosols (Deception Island, DI profile 1) are listed in Fig. 2. Predomination of Fe, Al, and S was typical for Turbic Cryosols. On the other hand, Leptic Andosols were rich in Ca, Mg, and Ti. Contents of micro elements were generally higher in Turbic Cryosols compared with Leptic Andosols (Fig. 3). These differences might be related to the differences in their pedogenetical process; JR profile 7 reached at about 50 cm and was most developed among JR series, while DI profile 1 reached only 10 cm. Differences in the contents of elements and quantity/quality of HS in the other James Ross Island soil and Deception Island soils were generally smaller than those between JR

profile 7 (3–9 cm) and DI profile 1 (0–10 cm) soils.

Negligible content of organic materials is general characteristics of Antarctic soils (Amin, 1993). Our results confirmed that TOC and HS contents were low in the James Ross Island and Deception Island soils even in the surface layers. Two examples of the 3–9 cm depth layer in JR profile 7 and the 0–10 cm layer in DI profile 1 are shown in Fig. 4. TOC and HS contents in the Leptic Andosols were always smaller than those in the Turbic Cryosols at similar depth (data are not shown). This may be due to the differences in vegetation and animals in the two study sites.

Quality of HS evaluated by their absorbance in UV-VIS spectral range confirmed our results from fractionation as was examples of JR profile 7 (3–9 cm) and DI profile D1a (0–10 cm) in Fig. 5. Quality (darkness of color) of HS was higher in Turbic Cryosols than in Leptic Andosols, which corresponded to the higher HA/FA ratio in HS in the Turbic Cryosols in the Leptic Andosols (Fig. 4). The HA/TOC ratio was also higher in the Turbic Cryosols in the Leptic Andosols.

Conclusions

Antarctic soils and their development differ according to the parent material, climatic conditions, and anthropogenic factors. Although both of the Turbic Cryosols in James Ross Island and the Leptic Andosols in Deception Island were characterized by low TOC content ($< 1\%$), low HS quality ($\text{HA/FA} < 1$), and low HA/TOC ratio (< 0.05), these characteristics were more conspicuous in the Leptic Andosols. In elemental composition Fe, Al, Ca, Mg,

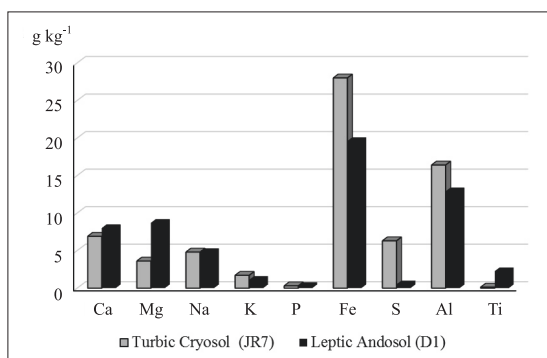


Figure 2. Comparison of macro element contents between Turbic Cryosols (JR profile 7, 3–9 cm depth) and Leptic Andosols (DI profile 1, 0–10 cm).

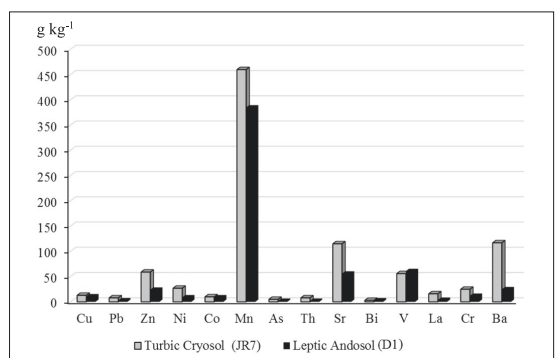


Figure 3. Comparison of micro element contents between Turbic Cryosols (JR profile 7, 3–9 cm depth) and Leptic Andosols (DI profile 1, 0–10 cm depth).

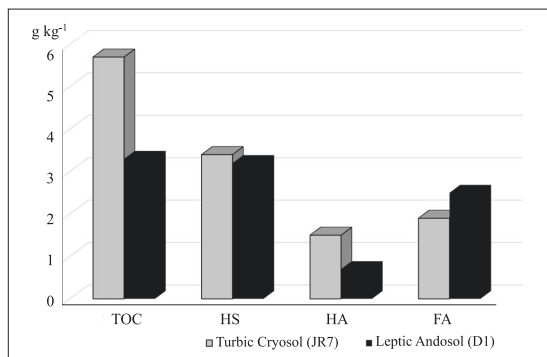


Figure 4. Average contents of total organic carbon content (TOC), alkali-extractable humic substances (HS), humic acids (HA), and fulvic acids (FA) in Turbic Cryosols (JR profile 7, 3–9 cm depth) and Leptic Andosols (DI profile 1, 0–10 cm depth).

S, Ti, Na, P, and K prevailed in both soil types.

Acknowledgment

This work was supported by Grants-in-Aid for Scientific Research from the Czech Ministry of Agriculture (NAZV QJ 1210263), Czech Republic.

References

- Amin, Z. M. (1993) In: Heavy Metal Pollution in Antarctic Soils. Diploma Thesis. University of Canterbury (UK).
- Buchan, G. D. (2001) In: Soil and Environmental Analysis, Physical Methods, 2nd ed, Marcel Dekker, New York – Basel, Switzerland, pp. 281-314.
- Gajdošová, D., Novotná, K., Prošek, P. and Havel, J. (2003) In: Separation and characterization of humic acids from Antarctica by capillary electrophoresis and matrix-assisted laser desorption ionization time-of-flight mass spectrometry Inclusion complexes of humic acids with cyclodextrins. *J. Chromatogr. A*, **1014**, 17-127.

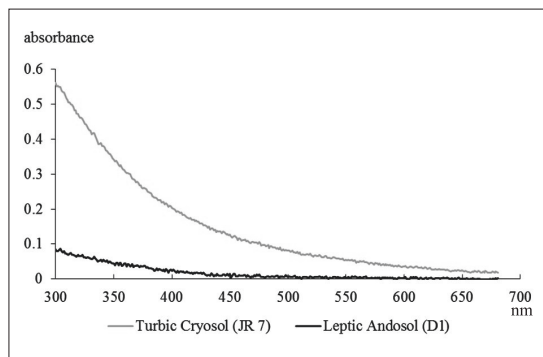


Figure 5. UV-VIS spectra of alkali-extractable humus in JR profile 7, 3–9 cm depth (Turbic Cryosols) and DI profile 1, 0–10 cm depth (Leptic Andosols).

- IUSS Working Group (2007) World Reference Base for Soil Resources 2006. First update 2007, World Soil Resources Reports 103, FAO, Rome. Italy.
- Majzlan, J., Brecht, B., Lalinská, B., Chovan, M., Moravanský, D. and Uhlík, P. (2010) Elemental and mineral inventory of tailing impoundments, near Pezinok, Slovakia and possible causes of action for their remediation. *Mineralogia*, **41**, 55–74.
- Kononova, M. M. and Beltchikova, N. P. (1963) In: Soil Organic Matter, Moscow State University Eds., Moscow, Russia, pp. 228-234.
- Nelson, D. W. and Sommers, L. E. (1982) In: Methods of Soil Analysis, Part 2, Page, A. L., Miller, R. H. and Keeney, D. R. Eds., ASA and SSSA, Madison, WI, USA, pp. 539–579.
- Theng, B. K. G. (1979) Formation and properties of clay-polymer complexes. *Dev. Soil Sci.*, **9**, 227–236.
- Tombácz, E., Libor, Z. L., Ille, E., Majzik, A. M. and Klumpp, E. (2004) The role of reactive surface sites and complexation by humic acids, in the interaction of clay mineral and iron oxide particles. *Org. Geochem.*, **35**, 257–267.