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Mitteilungen / *Notes*

A Discussion Note on Soil Development under the Influence of Terrestrial Vegetation at two Distant Regions of the Maritime Antarctic

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Abstract: Comparative studies of two soils from the maritime Antarctic herb tundra formations (Point Thomas oasis of King George Island and Argentine Islands region) have shown a substantial difference. We did not find any distinct correlation between Antarctic herb tundra formation cover and pH measures or total content of C, N and P in soils from both regions. Soils on the Argentine Islands region were enriched with un-decomposed plant organic matter mixed with rock bed debris and probably belong to Histels, while in the Point Thomas oasis (King George Island) we found apparent Gelisols, with lower organics content. The two sites are compared and the state of the soils in relation to soil development is discussed.

Zusammenfassung: Eine vergleichende Untersuchung zur Bodenbildung von Küstentundren der maritimen Antarktis an zwei Standorten hat einen wesentlichen Unterschied in der Gesamtleistung der Prozesse gezeigt. Während die Histosole auf den Argentine Islands mit unzersetzten Pflanzenstoffen und Steinschutt des Felsbodens angereichert sind, bestehen die Cryosole des südlichen Teils der Point Thomas Oase (King George Island) unter ähnlichen klimatischen Bedingungen aus dem frosterodierten Ausgangsgestein. Dies könnte darauf hinweisen, dass die Point Thomas Oase aufgrund längerer Eisfreiheit günstigere Bedingungen für die Bodenbildung besitzt.

INTRODUCTION

The formation of soils is one of the key factors in terrestrial ecosystems fueled by the interactions of physical, chemical, physico-chemical and biological processes. The diversity of soils results from climatic conditions, state of biocoenosis, type of relief, underlying rock and the duration of soil formation processes (Allen & Heal 1970, Kowda 1973, Bölter et al. 2002, Blume et al. 2002, Campbell & Claridge 2004, Van Vilet-Lanöe 2004, Vlasov et al. 2005, Abakumov et al. 2009). Such studies are very important as they can yield data about the timing and sequence of colonization of ice-free areas by organisms, as in the case with the Arctic (Kabala & Zapart 2008). This issue is especially relevant for the maritime Antarctic where biodiversity is higher. This region of the maritime Antarctic has undergone several consecutive glaciations in the Tertiary and Quaternary (Birkenmajer) et al. 2005). Nowadays climate warming in this region has the fastest pace ever observed (Turner et al. 2005, Bracegirdle et al. 2008).

In the maritime Antarctic, especially the South Shetland Islands, several studies have concentrated around ornithogenic soils and the relationships between soil formation and the organic matter supplied by birds and sea mammals (Beyer et al. 1995, Juchnowicz-Biebrasz & Rakusa-Suszczewski 2002, Tatur 2002, Barcikowski et al. 2005, Smykla et al. 2007,). Only 5 % of the Point Thomas oasis is or has been influenced by a penguin colony (Tatur 2005). The dependence of soil formation processes on terrestrial vegetation has been reported by Kappen & Schröter 2002 and Olech 2002. Further, data are available on the role of mosses and lichens (Vlasov et al. 2005) and some vascular plants (Campbell & Claridge 2004, Abakumov et al. 2009) in soil formation, its dependence on typical plant associations of the region, namely the Antarctic herb tundra formation, in different regions of the maritime Antarctic remains poorly understood. Therefore, the aim of this note was to compare the total content of C, N, P and pH of soils from two latitudinally distant regions of the maritime Antarctic that are free of large bird colonies.

MATERIAL AND METHODS

The study was conducted during the 9th and 10th Ukrainian expeditions (2004/2005 and 2005/2006) and the 30th Polish expedition (2005/2006). Soil samples were taken from six plots in the Point Thomas oasis (King George Island / South Shetland Islands), and six plots on the Argentine Islands and the nearest archipelagos (Fig. 1).

The communities analyzed were well distinguished by the presence of two vascular plant species: *Deschampsia antarctica* Desv. and *Colobanthus quitensis* (Kunth) Bartl., as well as by a number of bryophytes and lichens. We included areas with an inflow of organic matter from aggregations of birds and seals. Also, in the Point Thomas oasis, we studied one plot without vegetation; it had been covered with ice until 2002 (Pudelko 2005).

We also determined the total vegetation cover of the area (TVC) and the individual vegetative cover of separate plants as measures of the dynamics of the mass of organic matter.

Due to difficulties with transporting sufficient amounts of soil samples, we limited our comparison to basic chemical com-

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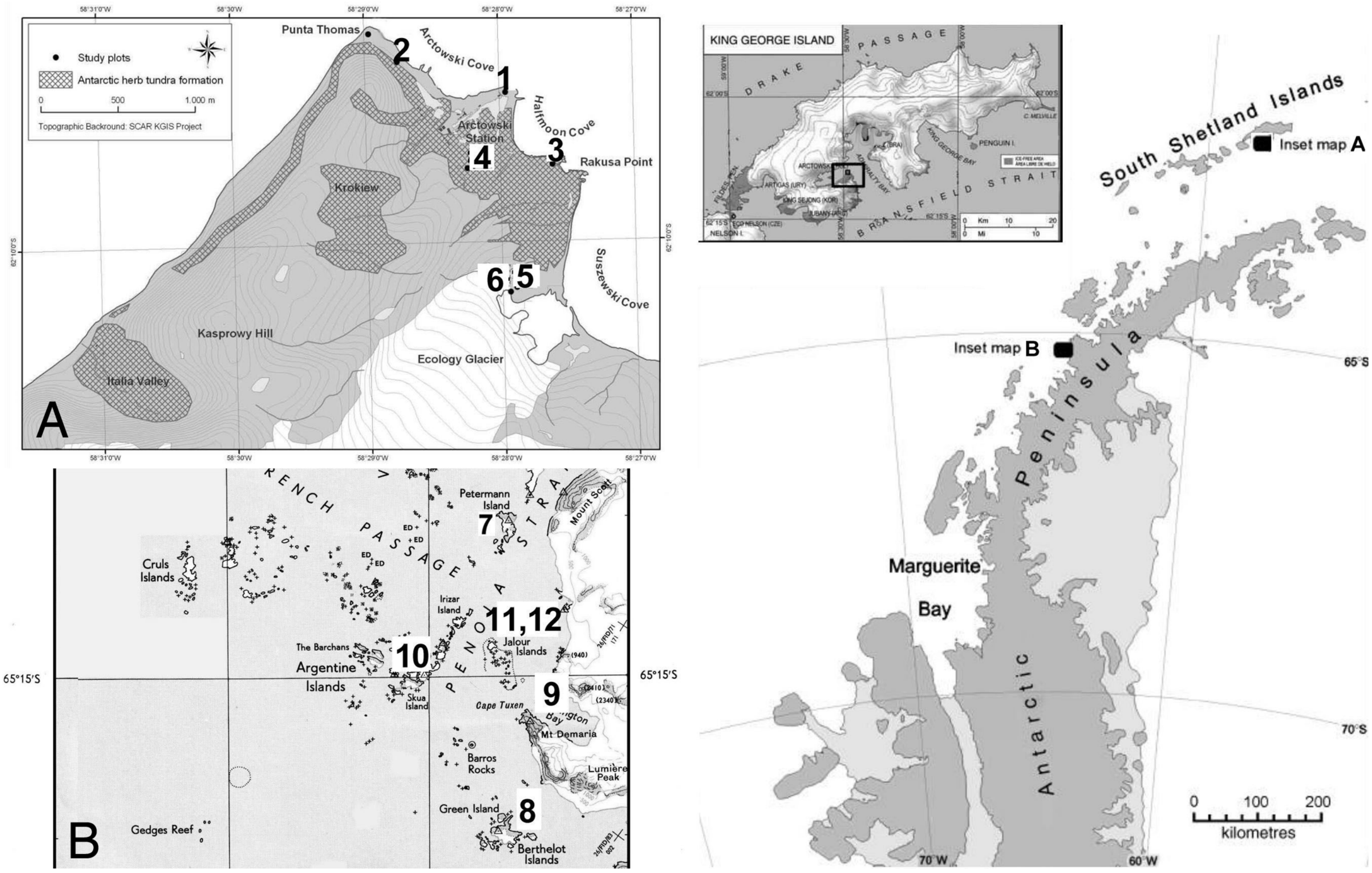

Fig. 1: The study areas at and north of the Antarctic Peninsula. A = Point Thomas oasis on King George Island, South Shetland Islands; B = the Argentine Islands and the nearest archipelagos.

Abb. 1: Lage der Untersuchungsgebiete : A = Point Thomas-Oase auf der König-Georg-Insel / Südshetland-Inseln, B = Argentine Islands und Umgebung.

pounds, such as total nitrogen, phosphorus and total organic carbon contents. In both oases we also analyzed the contents of some other elements. However, due to the different volume of the sampled soils, comparison was not possible for these chemicals. The soils from the Point Thomas oasis were taken by a shovel, in 10 x 10 x 4 cm^3 samples. The samples from the Argentine Islands were half the size.

Determination of the chemical characteristics was done according to BULYGIN et al. (1999) in the Laboratory of Agricultural Ecology and Analytical Research of the Institute of Agriculture of the National Academy of Sciences of Ukraine. We studied pH (KCl), Turin’s organic carbon content, total nitrogen and phosphorus contents after treating the soil with concentrated sulfuric and chloric acids. All of the listed techniques are described in more detail in PARNIKOZA et al. (2007).

In order to ensure that the studied soils had not experienced possible ornithogenic influence, we compared the obtained chemical compositions with data from TATUR (2002) on the chemical characteristics of two layers of the ornithogenic horizon from the Point Thomas oasis (see Tab. 1).

To assess the degree of decomposition of plant material, we present data (Tab. 1) on the content of the analyzed chemical in plants that constitute the Antarctic herb tundra formation according to FABISZEWSKI & WOJTUN 2000.

RESULTS

Analysis of the presented data (Tab. 1) reveals significant differences between soils from the two studied regions. In particular, soil samples were very different morphologically. Samples from the Point Thomas oasis were darker and their mechanical properties were similar to mineral soils. These soils had two horizons, the upper one being brown, and the lower being, actually, a zone of interaction with the native rock or an active permafrost layer (the zone of frost-driven erosion). Hence, according to the USDA soil taxonomy, this type of soil can perhaps be recognized as Gelisol. This kind of soil has yet been reported from this region (ZARZYCKI 1992).

Samples from Galindez and Jalur islands (No 12) and Rasmussen Cape were blends of organic matter of plant origin, which resembled incompletely formed peat, mixed with fine pieces of rock. Four other samples from the Argentine Islands consisted solely of organic matter represented by brownish partially decomposed organic remnants. Thus, according to the USDA soil taxonomy, soils from the Argentine Archipelago can be related to the most organic-rich type of Gelisols – Histels (Histosols according to FAO systems, BEYER et al. 1995).

DISCUSSION

The analyzed samples from both locations are dissimilar in pH and biogenic contents. In general, soil pH varied from 3.60 to 6.85, i.e. within the range of mineral and organogenic soils. But at 5 plots in the Point Thomas oasis the pH was almost neutral or slightly acidic, and only at 1 plot (No 4, Uplaz slopes) it was strongly acidic. Soils from the Argentine Islands were mostly strongly acidic, and only on Galindez Isl. and Rasmussen Cape the pH was close to neutral (Tab. 1). This acidification resembles that observed by Vlasov et al. (2005) for soil formation under moss-lichen communities and may indicate a common direction of the soil formation processes in the maritime Antarctic. Overall, our analysis shows mostly acid-driven decomposition in soils on the Argentine Islands and a less aggressive environment in the Point Thomas oasis. Still, analysis of the TVC percentage in coenoses with different pH values within the same region (for example, the Argentine Archipelago and King George Island) revealed no relation between vegetation phase and pH. This can be explained, among all, by different pH sampling techniques.

We found significant differences in total content of biogenic material between soils from two regions of the maritime Antarctic separated from each other by long distances from north to south. The biogenic content in soils from the Argentine Islands was 10-100 times higher than those from the Point Thomas oasis; the measured quantities were uncharacteristic of mineral soils. Carbon and nitrogen content in samples from the Argentine Islands region were relatively high, possibly due to the aggregation of *D. antarctica* tufts rich in C and N (Fabiszewski & Wojtun 2000, Juchnowicz-Bierbasz & Rakusa-Suszczewski 2002, Abakumov et al. 2009). The phosphorus content approached that of bird guano and plant

Plot No	Habitat conditions	N (%)	P_2O_5 (%)	C (%)	pH_{KCl}
Point Thomas oasis (King George Island)					
1	S 62°09.480', W 58°27.953' 4 m to fresh-water lake Wujka in a rock cavity; TVC* 63 %, *D. antarctica* 30 %, *C. quitensis* 3 %, Bryophyta 30 %	0.13	0.72	0.30	5.70
2	S 62°09.366', W 58°28.757' Between a fuel oil tank and a freshwater lake on a rock slope; TVC 58 %, *D. antarctica* 5 %, *C. quitensis* 3 %, Bryophyta 1 %, Lichens 49 %	0.05	0.32	0.10	5.20
3	S 62°09.734', W 58°27.611' Rakusa Point region, under peat tuft in split rock; TVC 80 %, *D. antarctica* 25 %, *C. quitensis* 25 %, Bryophyta 10 %, Lichens 10 %, *Prasiola crispa* 10 %	0,06	0,1	1,64	5,80
4	S 62°09.735', W 58°28.253' Uplaz slopes, at the bank of a glacial stream; TVC 100 %, *D. antarctica* 50 %, *C. quitensis* 10 %, Bryophyta 40 %	0.10	0.57	2.92	3.60
5	S 62°10.161', W 58°27.893' Outskirts of the Ecology Glacier, 50 m from its edge ice-free since 1979; TVC 56 %, *D. antarctica* 3 %, *C. quitensis* 3 %, Bryophyta 50 %	0.04	0.22	0.22	5.80
6	S 62°10.161', W 58°27.893' Outskirts of the Ecology Glacier, flat surface of a small hill to the north-east from the glacier's edge, ice-free since 2002; no vegetation	0.03	0.26	0.22	6.60
Argentine Islands region					
7	Petermann Isl., S 65°10.453', W 64°08.452' Middle part of an eastward-oriented steep slope; TVC 60 %, *D. antarctica* 5 %, Bryophyta 5 %, Lichens 50 %	3.16	0,86	29,6	3,90
8	Berthelot Isl., S 65°19.731', W 64°08.613' Steep slope oriented westwards; TVC 50 %, *D. antarctica* 20 %, Bryophyta 30 %	2.80	0.93	16.6	3.90
9	Cape Rasmussen, S 65°14.819', W 64°05.156' Acclive slope oriented westward; TVC 40 %, *D. antarctica* 10%, Bryophyta 30 %	4.69	8.75	8.98	6.85
10	Galindez Isl., S 65°14.783', W 64°14.799' Height's point; TVC 25 %, *D. antarctica* 15 %, Bryophyta 10 %	3.40	7.81	8.15	5.70
11	Jalour Isl., S 65°14.139', W 64°09.330' Top of an elevation, oriented westwards; TVC 45 %, *D. antarctica* 20 %, Bryophyta 25 %	4.50	1.60	>30	3.80
12	Jalour Isl., S 65°14.039', W 64°09.761' TVC 45 %, *D. antarctica* 20 %, Bryophyta 25 %	3.13	9.75	10.20	4.60
Point Thomas ornithogenic soil sample, profile A 0-2 sm depth	by Tatur (2002)	2.33	6.80	13.85	-
Point Thomas ornithogenic soil samples profile A 2-15 sm depth	by Tatur (2002)	0.94	8.83	3,91	-
D. antarctica overground shoots	by Fabiszewski & Wojtun (2000)	1.40-3.37	-	31.30-41.98	-
C. quitensis overground shoots	by Fabiszewski & Wojtun (2000)	1.47-1.98		33.17-37.43	-

Tab. 1: Contents of N, P, C and exchange acidity (pH_{KCl}) of soil from plots with different characteristics of vegetation in the Point Thomas oasis and on the islands of the Argentine Archipelago region. *TVC = total vegetation cover

Tab. 1: N-, P- und C-Gehalte sowie Austauschazidität (pH_{KCl}) der Böden aus Untersuchungsflächen mit unterschiedlichen Charakteristika der Vegetation in der Point Thomas-Oase und im Gebiet der Argentine Islands matter. The C and N contents in soils from the Point Thomas oasis were close to natural mineral soils (see, Juchnowicz-Biebasz & Rakusa-Suszczewski 2002). Based on these results, it seems that the denser vegetation in the Point Thomas region does not cause increased biogenic contents in the soils compared to the Argentine Islands. Variation in TVC and the specific vegetation cover of individual higher plant species do not significantly influence the basic biogenic levels within the chosen region. This suggests that plant communities are not responsible for the aforementioned difference in the biogenic contents of the soils. Based on the available data on bird numbers in both regions (Loparev and Trivelpiece pers. com.), the expected volumes of ornithogenic organic matter influx must be comparable in both regions.

In addition, it should be noted that in each of the regions values varied dramatically. The main reason must have been that the soil ecosystems of the maritime Antarctic are relatively young and, due to the thin and fragmented soil cover, their buffering capacities must be low. In such conditions, even a slight local change of some ecological factors will lead to a very mosaic pattern of soil cover. At Rasmussen Cape and on Galindez and two plots of Jalur Island, pH of soil samples was higher (closer to neutral) than at the other three studied plots on the Argentine Islands, just as were the rates of organic matter mineralization and P contents.

The more developed soils from the Point Thomas oasis (plot No 4, Uplaz slopes) have both strongly acidic pH and the highest levels of organic carbon, i.e. lower rates of organic matter mineralization. It is yet another proof that the soil formation processes in the maritime Antarctic follow common directions due to similar climatic conditions, relief, rock types, and characteristics of coenoses. But at the same time, there are striking differences in soil morphology and chemistry, which have been discussed above and possibly stemming from temporal differences in soil formation near the Point Thomas oasis and on the Argentine Islands.

The existence of relatively poorly developed soils (mostly half-decomposed plant matter) on the Argentine Islands compared to more developed soils from the Point Thomas oasis is itself not a sufficient evidence of a shorter time of soil formation on the Argentine Islands. Because of the short summer, the Antarctic herb tundra formation occupies more elevated locations, often peaks of coastal rock ranges that are the first to appear from the snow, but cannot be considered as the best for soil formation. Comparison of these habitats with those where conditions resemble the Point Thomas oasis (Plot 4, Uplaz slopes) reveals a higher development of soils in the oasis.

So, can the above-mentioned features support the idea of a longer duration of the soil formation processes in the Point Thomas oasis? In this regard, we obtained interesting data on the soil cover occurring as patches on territories that are gradually becoming free of ice. Samples of soils at plots No 5 and No 6 were located in a post-glacial area (by now only plot No 5 is covered with vegetation). Chemically and morphologically, these are analogous to other plots in the oasis, which indicate uniformity of their genesis.

Some data that may be indicative of better conditions and longer time of soil formation in the Point Thomas oasis compared to the more southerly located Argentine Islands are known from literature. Thus, there is an assumption that the Point Thomas oasis, among some other coastal territories near King George Island, remained free of ice even during strongest glaciations of the Pleistocene maximum. The possibility of the existence of oases on King George Island that, due to various reasons, remained free of ice has been confirmed by Marsz (2001). Besides, Tatur (2005) with reference to Clapperton (1990) demonstrates that during the Pleistocene glacial maximum there were ice-free areas on King George Island, namely in the Admiralty Bay. However, the idea that vegetation of Bryophyta, and probably vascular plants, persisted in the Point Thomas oasis, and thus soil formation continued, requires further research.

CONCLUSION

Comparative analysis reveals well-defined differences in some morphological characteristics, like the total biogenic content and pH, between soils from two regions of the maritime Antarctic. Soils on the Argentine Islands covered with the Antarctic herb tundra formation are rich in primary organic matter and belong to Histels, while in the Point Thomas oasis there are Gelisols characterized by lower organic contents. No distinct correlation between Antarctic herb tundra formation cover and pH measures or total content of C, N and P was found for soils from either of the two regions.

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