THE OCCURRENCE AND DEVELOPMENT OF PEAT MOUNDS ON KING GEORGE ISLAND (MARITIME ANTARCTIC)

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ABSTRACT

On King George Island, South Shetlands Islands, a type of peat formation has been discovered which has not previously been reported from the Antarctic. These formations are in shape of mounds up to 7x15 m in area, with a peat layer of about 1 m thick. About twenty five cm below the surface there is a layer of permanently frozen peat. The mounds are covered by living mosses (*Polytrichum alpinum* and *Drepanocladus uncinatus*), Antarctic hair grass (*Deschampsia antarctica*) and lichens. Erosion fissures occurring on the surface are evidence of contemporary drying and cessation of the mound's growth. The initial phase of the development of the mounds began with a community dominated by *Calliergidium austro-stramineum* and *Deschampsia antarctica*, and their further development has been due to peat accumulation formed almost entirely by *Calliergidium*. The location of the mounds is near a penguin rookery, which clearly conditioned the minerotrophic character of these formations, as compared with the "moss peat banks" formed by *Chorisodontium aciphyllum* and *Polytrichum alpestre*. Moreover, the peat mounds differ from the latter in several ways, e.g. rate of growth and floristic composition. Radio-carbon dating of peat from the base of one mound gave an age of 4090 ± 60 years B.P. This suggests that the age of the tundra on King George Island is about 5000-4000 years.

KEY WORDS: peat mounds, moss banks, age of tundra, South Shetlands, King George Island, Antarctic.

INTRODUCTION

The accumulation of deep peat in the Antarctic is not a frequent phenomenon. In the Subantarctic several kinds of peat formation are known, e.g. mire peat, bog peat, moss peat and tussock peat occur on South Georgia (Lewis-Smith 1979a, 1981). In the Maritime Antarctic a distinct type of peat formation occurs, referred to as "moss peat banks" or "moss banks" (Gimingham and Lewis-Smith 1970, Lewis-Smith 1979b, 1984). The best developed "moss peat banks" occur on the South Orkney Islands, particularly on Signy Island. They frequently cover wide surfaces reaching 2500 m², up to 2 m thick, and about 5000 years old (Fenton 1982, Fenton and Lewis-Smith 1982). On most of the South Shetland Islands and on the South Sandwich Islands "moss banks" are rare, because the dry porous volcanic subsoil of these islands does not create favourable conditions for peat accumulation (Fenton and Lewis-Smith 1982). However, the deepest known moss bank occurs on Elephant Island, South Shetlands (a non-volcanic island) (Fenton 1982, Björck et al. 1991), while shallower moss banks up to 1 m thick occur along the west coast of the Antarctic Peninsula to about 67°S (Fenton and Lewis-Smith 1982).

The present paper describes the structure, growth and age of a previously unrecorded type of peat formation, and compares it with the "moss banks" type. Further, the results of peat dating served as a basis for determining the age of the tundra on King George Island.

SITE DESCRIPTION

The investigations were performed during the Antarctic summer 1987-88 in the Site of Special Scientific Interest on the western side of the Admiralty Bay on King George Island (Fig. 1). This region has a relatively mild climate compared with that of Continental Antarctica. Average annual air temperature is -1.8°C while the means for summer (December-February) are 1.6-2.3°C. Annual precipitation exceeds 500 mm (rainfall equivalent) and is distributed relatively uniformly throughout the year (Rakusa-Suszczewski et al. 1993).

The peat mounds are situated at Llano Point (62° 10' S, 58° 27' W) on the west-facing slope of a small hill once occupied by a penguin rookery, about 200 m from the shore, and 36 m above sea level (Fig. 2 and 3). The bedrock of the studied area is mainly volcanic (Tertiary) basalts and andesites. In the vicinity of the peat mounds there is a transient melt stream. Ten meters away and below a rookery of the Adelie penguins there is an eutrophic mire with *Calliergidium austro-stramineum* (C. Muell.) Bartr., *Drepanocladus uncinatus* (Hedw.) Warnst. and *Prasiola crispa* (Lightf.) Menegh.

METHODS

The stratigraphy of the peat was examined in the samples taken every 5 cm in a vertical profile across the larger mound. The degree of humification was determined by means of the von Post method (Overbeck 1975) with a 10-degree

Fig. 1. Map of King George Island, showing the main locality referred to in the text. 1 – Arctowski Station, 2 – Area enlarged in Figure 3.

scale (H1-H10); H1 indicates not humified material and H10 completely humified material. The mapping of vegetation and of the terrain was made by means of the photogrammetric method, based on ground photographs. Two peat samples in the profile, i.e. the bottom layer from a depth of 90-95 cm and the top layers from a depth of 15-20 cm, were radiocarbon dated at the Radiocarbon Laboratory of the Silesian Polytechnical Academy in Gliwice.

RESULTS

General characteristics of peat mounds

Two mounds together cover an area of ca. 7x15 m, with the longitudinal axis running at right angles to the slope axis with gradient of ca. 15° (Fig. 4). The larger mound measured ca. 11 m in length and ca. 4 m wide, and the smaller one measured ca. 7 m in length and ca. 6 m wide. The dome-shaped surfaces of the mounds are covered with living *Polytrichum alpinum* Hedw., *Drepanocladus uncinatus* (Hedw.) Warnst., *Deschampsia antarctica* Desv. and lichens composed predominantly of *Ochrolechia frigida* (Sw.) Lynge. The surface is undulating and cut by numerous erosion grooves and fissures (Fig. 4) resulting from the now desiccated nature of the peat mounds. The thickness of the peat layer at its highest point in each mound is ca. 100 cm. About twenty five centimeters below the surface there is a permafrost layer 20 cm thick.

Development of peat mounds

The initial phase of the mounds' development began with a community formed by the hydric moss *Calliergidium austro-*

stramineum and the grass *Deschampsia antarctica*, influenced undoubtedly by the abundant inflow of nutrients from the nearby penguin rookery. This assumption is confirmed by the occurrence of feathers of these birds at the base of the mounds. The further development of the mounds progressed mainly by the growth and accumulation of dead material of *Calliergidium austro-stramineum*, which was later invaded by *Polytrichum alpinum* (Fig. 5). This change in species composition at depth of 10 cm from the top implies a change in environmental conditions, i.e. from a wet mire to a drier (mesic) community. Probably a local ice field disappeared and source of water to the site ceased. This would cause the decline of *Calliergidium* and allow the colonization of the drying and dying *Calliergidium* by *Polytrichum alpinum* and later by lichens.

At present, the mounds appear to have reached a critical height and are unable to develop further, i.e. they are in a stagnant stage. It appears that, as the mounds have increased in thickness, they have become drier and the surface vegetation has dried and became eroded. The present living mosses on the surface of the mounds suggests a more mesic habitat.

Age and growth rate

Radiocarbon dating of peat deposits have been carried out for two horizons in the profile (Fig 5). The apparent age of the bottom layer from a depth of 90-95 cm is 4090±60 years B.P. (Sample no. Gd-5333). This indicates that initial development of the peat mounds began about 4000 years B.P. The apparent age of the top layer from 15-20 cm below the surface is 2140±90 years B.P. (Sample no. Gd-2880).

These dates enabled the calculation of the approximate growth rate of the mounds. Below the level of 20 cm, it is

Fig. 2. Peat mounds at Llano Point, King George Island.

0.40 mm yr⁻¹, and for layers above this level 0.08 mm yr⁻¹. This change in the rate of growth corresponds to change in environment, from a wet to drier (mesic) conditions. The average rate of peat accumulation for the whole profile is 0.23 mm yr⁻¹.

DISCUSSION

Peat mounds in comparison with "moss banks"

Most of the semi-omrogenous "peat banks" in the maritime Antarctic are formed mainly by two tall turf-forming mosses: *Chorisodontium aciphyllum* (Hook.f. and Wils.) Broth. and *Polytrichum alpestre* Hoppe (Fenton and Lewis-Smith 1982). The peat mounds discovered at Llano Point differ basically in the contemporaneous and historical plant cover. The mounds are formed predominantly by carpet-forming mosses (Longton 1988), *Calliergidium austro-stramineum* and *Drepanocladus uncinatus* and, to a lesser extent the short turf-forming *Polytrichum alpinum*. The species which typically form moss banks (*Chorisodontium aciphyllum* and *Polytrichum alpestre*) are generally scarce in this region because of the dry and porous volcanic substrata (Fenton and Lewis-Smith 1982). Moreover, according to these authors, *Chorisodontium aciphyllum* has an increasingly restricted distribution towards the south which is correlated with reduced water availability and drier climate.

The initial phase of development of typical "moss banks" commences in moist, sometimes flooded communities with *Calliergidium austro-stramineum*, *Calliergon sarmentosum* (Wahlenb.) Kindb. and *Drepanocladus uncinatus*, which are later colonized by *Chorisodontium aciphyllum* and *Polytrichum alpestre* (Lewis-Smith 1972, Collins 1976). The development of the peat mounds at Llano Point had been initiated also with a mire community dominated by *Calliergidium austro-stramineum* and *Drepanocladus uncinatus*. *Deschampsia antarctica*

was also present. However, the further growth of the mounds, up to 95 cm, was mainly due to *Calliergidium*. Such a thick peat layer formed entirely by this species is exceptional in the maritime Antarctic. On other islands, e.g. on Signy Island, the carpet-like communities including this species are usually able to accumulate a thin layer of organic matter, up to 15 cm, because of the relatively rapid rate of decomposition (Gimingham and Lewis-Smith 1970, Collins 1976, Christie 1987). The results of the present study suggest that in the maritime Antarctic *Calliergidium austro-stramineum* may accumulate thick peat under favourable topographic and ecological conditions (sheltered slope with slight inclination and short-lasting snow cover, abundant water enriched with nutrients, particularly nitrogen and phosphorus).

The moss banks with *Polytrichum alpestre* and *Chorisodontium aciphyllum* in the maritime Antarctic are regarded as semi-omrogenous or predominantly ombrotrophic, i.e. they derive water mostly from precipitation (Fenton and Lewis-Smith 1982). The dominance of *Calliergidium austro-stramineum* in the peat mounds at Llano Point indicate that they have more minerotrophic character than moss banks. This hypothesis is confirmed by the results of Christie (1987) from Signy Island. He found that the moss turf was more acidic (pH 4.3) and had lower concentrations of nitrogen, phosphorus and potassium than the wet carpet community dominated by *Calliergon sarmentosum*, *Calliergidium austro-stramineum* and *Drepanocladus uncinatus*, where pH was 5.0. Further, the minerotrophic character of peat mounds at Llano Point is also confirmed by the occurrence of *Deschampsia antarctica* and feathers of birds (probably penguins) in the bottom layers. This indicates a considerable nutrient inflow from the nearby penguin rookery, at least in the early stages of mound development. Thus, apart from the geological and climate factors described above, the higher trophic status appears to be the main determinant of species composition of this unique peat formation on King George Island. This contrasts markedly

Figure 3. Part of Admiralty Bay showing the location of moss banks. 1 – Ice-free areas, 2 – Permanent snow and ice, 3 – Moss banks, 4 – Arctowski Station, 5 – Contour lines.

with the general absence of such biotic enrichment during the formation of moss banks within the maritime Antarctic botanical zone.

A characteristic trait of the moss peat banks is the occurrence of permafrost reaching the bottom, where the thickness of the peat layer exceeds 20–30 cm (Fenton 1980). Permafrost also occurs in the peat mounds at Llano Point, but only as a layer, above and below which the peat remains unfrozen. It is interesting, considering that peat profile was taken across and near the center of the mounds, and during the Antarctic summer.

The mean estimated growth rate of the mounds – 0.23 mm yr^{-1} – is not high as compared with moss banks in the maritime Antarctic, calculated by Fenton (1980) to $0.9\text{--}1.3 \text{ mm yr}^{-1}$. Such a low growth rate is striking, considering that *Calliergidium austro-stramineum* in carpet-like communities has an annual increment of 4 cm, whereas for *Chorisodontium aciphyllum* and *Polytrichum alpestre* it is only $0.3\text{--}0.7 \text{ cm}$ (Collins 1976). This can be explained by the lower upward growth of *Calliergidium* in peat mounds conditions, and the higher decomposition rate of organic matter (Christie 1987). Further, the rate of upward growth of older peat layers in mounds (0.40 mm yr^{-1}) on King George Island corresponds well with data for the exceptionally deep moss bank on Elephant Island (Björck et al. 1991). Relating peat depth and age the rate of accumulation appears to be from 0.1 to 0.3 mm yr^{-1} . In the latter case, however, the rate of accumulation in the younger layers (ca. 2000 years B.P. to present) was more rapid, with a value of 0.5 mm yr^{-1} . In peat mounds at Llano Point the converse has been observed, i.e. the rate of peat accumulation in younger layers (above 20 cm, Fig. 5) was much lower – on the average 0.08 mm yr^{-1} . A distinct decrease of growth rate of peat mounds may be explained by less favor-

able moss growth conditions, e.g. decrease in availability of nutrients and water which would have reduced the annual shoot increment of *Calliergidium austro-stramineum*. In addition, the apparent rate of increase was reduced by increased compression (Fenton 1980). Alternatively, such low rate of peat accumulation of younger layers may also be explained by influence of biotic agents. The age of peat at 15–20 cm below the surface is ca. 2100 years B.P. This may suggest it ceased development a long time ago. The site might have been broken due to trampling by penguins from the nearby rookery. A similar effect has been reported from Elephant Island (Allison and Lewis-Smith 1973).

Age of the tundra on King George Island

Birkenmajer et al (1985) suggested the age of tundra on King George Island was 4900 years, based on a radiocarbon age for buried peat at Penguin Point. The present study confirms this view, and the difference of 800 years between Penguin Ridge and Llano Point may have resulted from the absence of suitable ecological conditions for plant colonization at the former site. The age of the tundra on Signy Island, South Orkney Islands is similar, about 4800 years (Lewis-Smith 1984). Initial development of an extensive moss bank on Elephant Island began about 5500 years B.P. (Björck et al. 1991). The difference of about 1000 years may result from the earlier deglaciation of this island, and the accessibility of the habitats for colonization. This assumption is confirmed by the slight difference in the age of the younger peat layers from the level of about 20 cm which, for the Elephant Island and King George Island sites is 1890 ± 50 and 2140 ± 90 years B.P., respectively. Thus, it is suggested that the narrow coastal belt on King George Island was free of ice and available

Fig. 4. Vegetation map of peat mounds and their close surroundings at Llano Point, King George Island. 1 – *Drepanocladus uncinatus*; 2 – *Ochrolechia frigida*; 3 – *Polytrichum alpinum*; 4 – *Bryum pseudotriquetrum*; 5 – *Deschampsia antarctica*; 6 – *Prasiola crispa*; 7 – Unvegetated peat; 8 – Eroded peat; 9 – Eutrophic mire; 10 – Erosion fissures; 11 – Stones; 12 – Contour lines.

Fig. 5. Vertical section through a peat mound (scale 1:5) at Llano Point, King George Island. Radiocarbon dates are given for two positions in the profile. 1 – Present vegetation, 2 – Peat with *Polytrichum alpinum*, 3 – Peat with *Calliergidium austro-stramineum*, 4 – Peat with *Deschampsia antarctica*, *Calliergidium austro-stramineum* and sand, 5 – Permanently frozen peat.

for colonization by vegetation about 5000-4000 years ago. The decisive factors in early plant migration were probably the extent of the ice free terrace and its early emergence from the sea and glaciers (Fabiszewski and Wojtuń 1993). The present study indicates a more extensive glaciation before 5000 to 4000 years B.P. than today on King George Island and may suggest a major ice recession (warmer climate) between ca. 6000 and 4000 years ago (Lewis-Smith 1990, R. I. Lewis-Smith, personal communication).

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WYSTĘPOWANIE I ROZWÓJ PAGÓRKÓW TORFOWYCH NA WYSPIE KRÓLA JERZEGO (ANTARKTYKA MORSKA)

STRESZCZENIE

Na wyspie Króla Jerzego odnaleziono utwory torfowe, które dotychczas nie były znane z Szetlandów Północnych. Mają one kształt pagórków o wymiarach 7x15 m. Grubość pokładu torfu wynosi około 100 cm. Poniżej powierzchni na głębokości 25 cm występuje warstwa zmarzłego torfu. Pagórki porośnięte są przez mchy *Polytrichum alpinum* i *Drepanocladus uncinatus*, trawę *Deschampsia antarctica* oraz porosty. Występujące na powierzchni bruzdy erozyjne świadczą o współczesnym przesuszeniu i przerwaniu wzrostu pagórków. Faza inicjalna rozwoju pagórków zaczęła się od zbiorowiska z *Calliergidium austro-stramineum* i *Deschampsia antarctica*, a dalszy ich przyrost odbywał się dzięki *Calliergidium*. Rozwój pagórków pozostawał w ścisłym związku z pobliską kolonią pingwinów, co warunkuje minerotroficzny charakter tych utworów, w porównaniu do moss peat banks. Ponadto pagórki torfowe różnią się od tych ostatnich wieloma cechami, np. tempem wzrostu i składem florystycznym. Datowanie metodą radiowęglową szczątków organicznych z warstwy spongowej dało wynik 4090 ± 60 B.P. Wynik ten wskazuje, że wiek tundry na Wyspie Króla Jerzego wynosi około 4000-5000 lat.

SŁOWA KLUCZOWE: pagórki torfowe, moss banks, wiek tundry, Szetlandy Południowe, Wyspa Króla Jerzego, Antarktyka.