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A new possible site to study the effects of climate warming on tundra ecosystems: the Giant Mountains, Czech Republic

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Abstract In the north–south transect between the tundra areas of northern Sweden (Abisko), across southern Norway (Dovrefjell) to the Alps, one may include the summit area of the Giant Mountains (Czech Republic—Krkonoše in Czech and Poland—Karkonosze in Polish), which constitutes an isolated island of arctic-alpine tundra within the Central European Sudetes. Its area was strongly influenced, like the Scandinavian and Alps areas, by periglacial conditions during the Ice ages in the Pleistocene era. At present, the average annual air temperature of the Giant Mountains tundra area is about 2.6–5.7°C higher than that of the Abisko area and 1.8°C higher than that of Dovrefjell. The intensity of frost processes is impressively lower and special palsa-like forms have been recognized in seasonally freezing peat bogs, where some arctic-alpine plant species survive in marginal conditions in the Giant Mountains. Therefore the Giant Mountains could be used to study the effects of long-term natural climate warming on some Scandinavian tundra ecosystems. Scandinavian tundra conditions seem to be similar to those existing in Central Europe 10 000 years ago; therefore Scandinavian areas appear very interesting with regard to the beginning of postglacial development of tundra areas in Central Europe.

Key words tundra; Giant Mountains, Czech Republic; Abisko, Sweden; Dovrefjell, Norway; climate; vegetation; palsas

INTRODUCTION

Stimulated by the interest of Professor A. Rapp (personal communication, 1998), preliminary comparisons of the climatic conditions, vegetation and relief of the palsa mires and the subarctic-subalpine mires between Abisko (Sweden), Dovrefjell (Norway) and the Giant Mountains (see Fig. 1) were carried out during 1998–1999 (Kocianova & Štursova 1999).

BIOGEOGRAPHICAL SETTING

In the Abisko area of Sweden, including the sites of Rakaslako and Riksgränsen (68°21′N, 19°E), the tundra zone (low, middle and high alpine *sensu* Wielgolaski, 1998) extends up the birch treeline from about 350 to above 2000 m a.m.s.l. Considerably high numbers of palsas clearly indicate actual discontinuous and sporadic permafrost in peat bogs (Rapp, 1982). Palsas are distributed between about 360 and 940 m a.m.s.l.

The Dovrefjell area in Norway (62°20′N, 9°20′E) is one of the southernmost sites of the discontinuous and sporadic permafrost in Fennoscandia. Palsas are distributed from about 800 to 1440 m a.m.s.l. Some of the palsa bogs are situated in marginal climatic conditions and during the last 30 years have become completely extinct (Sollid & Sorbel, 1998). All three tundra zones (low, middle, high) are well developed up to 2270 m a.m.s.l.; the dominance of lichen communities is impressive.

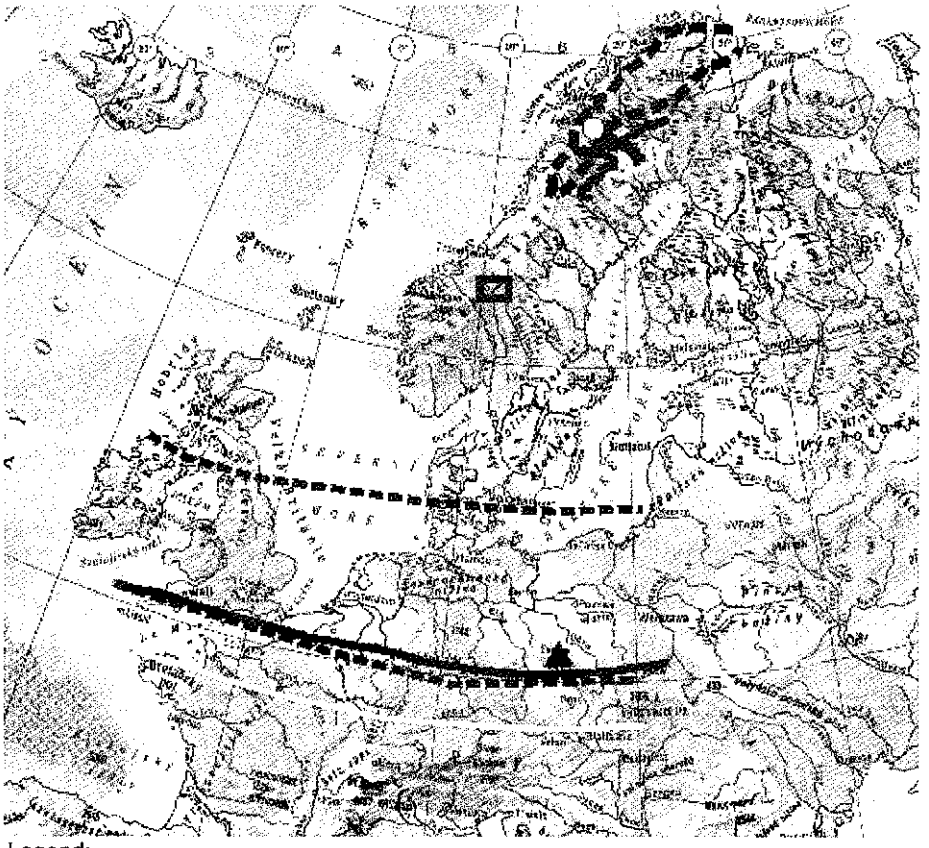

Fig. 1 Position of isotherm of mean annual air temperatures 0 and –1°C at sea level and area of discontinuous permafrost in Europe during the Younger Dryas and in Northern Scandinavia at present (based on Issarin, 1997; Rapp, 1982).

In the Giant Mountains (50°46′N, 15°33′E), the top ridge protrudes above the Norway spruce treeline from 1250 to 1602 m a.m.s.l. Three tundra zones (cryo-eolian, cryo-vegetated, niveo-glacigenic), partially corresponding to the tundra zones given by Wielgolaski (1998) for Fennoscandia, could be distinguished (Soukupová *et al.*, 1995). About 80 plant species grow in both the Giant Mountains and Scandinavia (Hadač, 1983). Some of them survive in the Giant Mountains within their live marginal conditions (only a few locations and individuals, e.g. *Rubus chamaemorus*, *Saxifraga nivalis*, *Salix herbacea*); some of them are components of Scandinavian-type plant communities (Jeník, 1961). In 1996, peat-bog forms resembling palsas were recognized (Kocianova & Štursova, 1999).

METHOD

A preliminary comparison of climatic factors is based on the literature (Josefsson, 1990; Jonasson, 1991; Glowicki, 1997; Sollid & Sorbel, 1998; Harčarik, 1999) and the data measured at Abisko Meteorological Station (360 m a.m.s.l.), and in the Giant Mountains meteorological station—Labská Bouda Chalet (1340 m a.m.s.l.)—during the period 1988–1993. The following indicators were compared: (a) maximum and minimum daily air temperatures, (b) regelation period, (c) growth period, (d) height and duration of snow cover, (e) sunshine, and (f) soil temperatures.

Each selected palsa and palsa-like form was characterized by maximum width and length, orientation, surface morphology and margin type. The plant cover variation was recorded along the line of minitransects, by means of phytosociological relévés (method of the Zürich–Montpellier school—Kent & Coker, 1992). The data were assessed by detrended correspondence analysis (DCA), detrending-by-segments (CANOCO 4 programme—Jongman *et al.*, 1995). Since the Giant Mountains are situated in an area of seasonal freezing of soil, the extent of freezing and gradual thawing was monitored in palsa-like forms during autumn, winter and spring.

RESULTS

The preliminary comparison of some tundra phenomena (Table 1) indicates:

- Differences in mean annual air temperatures (*MAAT*) and mean annual precipitation (*MAP*) between all three sites: the Giant Mountains sites with palsa-like forms are warmer than the Swedish palsa bogs in rain-shadow Abisko sites, and the palsa bogs in rain-rich Riksgränsen and Rakaslako by about 2.6°C and about 3.3–5.7°C, respectively, and warmer by about 1.8°C than the Norwegian Dovrefjell Fokstua site.
- Differences in the depth of snow pack between palsa sites in Scandinavia (uneven or only some cm) and palsa-like sites in the Giant Mountains (by about 160 cm).
- Differences in duration and intensity of frost processes (permafrost in Scandinavian sites, seasonal freezing and diminution of frost action in the Giant Mountains).
- Some analogous features of the relief of palsa bogs and that of some parts of the Giant Mountains subarctic-subalpine mires (in the Giant Mountains, small oval

Table 1 Climatic data for the Abisko area, Dovrefjell and the Giant Mountains (references given in parentheses).

Site	Altitude (m a.m.s.l.)	*MAAT* (°C)	*MAP* (mm)	Years	Snow pack free area [palsas] (cm)	Active layer (cm)	Position of isotherms under the surface during the winter (cm)
Abisko	388	−0.9 −0.4 −0.9 −0.8	322 (J)	1913–1930 (A) 1931–1960 (A) 1951–1980 (J) 1961–1990 (A)	75–150 (J) [25–uneven]	40–75 (A) 34–67 (K, August 1998)	0°C: > 100 (Jo) −12°C: to 25 (Jo) −16°C: to 10 (Jo)
Riksgränsen	508	−1.5	940	1951–1980 (J)	n.d.	n.d.	n.d.
Rakaslako	970	−3.9	>1550	(M)	n.d.	n.d.	n.d.
Fokstua–Haugskardsmyra	974–1050	−0.8 0	600–800	1901–1930 (S) 1961–1990 (S)	n.d.	32–55 (K, August 1999) melted −50–75* (K, October 1999)	n.d.
Giant Mountains tundra ecosystems with palsa like forms	1350–1420	1.5 1.7 1.8	>1400	1901–1930 (G) 1931–1960 (G) 1961–1990 (G)	150–230 (H) [100–160] (K)	no detected permafrost	0°C: to 50 (H) −5°C: to 10 (H)

n.d. – not determined.

*measured on the identical sites as in August 1999.

MAAT: mean annual air temperature; *MAP*: mean annual precipitation.

Key to references:

A: Abisko Scientific Research Station, J: Jonasson (1991), S: Sollid & Sorbel (1998), G: Glowicki (1997), Jo: Josefsson (
H: Harčarik (1999), K: Kocianova & Štursova (1999), M: Åkerman & Malmström (1986).

shaped mounds protrude by about 30 cm above the waterlogged surroundings; small flat peat-bog structures with prominent cracks on the E–SE margins; small oval pools with distinct ramparts).

- Development of relationships between the vegetation of palsas in Abisko and that of some of palsa-like forms in the Giant Mountains.

CONCLUSION

The present environment of the northern and southern Scandinavian mountains seems to be very interesting with regard to the beginning of postglacial development of tundra areas in Central Europe. When we compare the position of the present isotherm of the mean annual air temperature of 0°C and −1.0°C in Scandinavia (Rapp, 1982—isotherms lie closed to the Abisko area) with that 10 000 years ago (Issarin, 1997—isotherms laid in Central Europe, the Giant Mountains were situated in the zone of evidence of discontinuous permafrost), it is obvious that the present climatic conditions of the northern and southern Scandinavian mountains could be similar to the part of the Czech basin including the Giant Mountains during the Younger Dryas (see Fig. 1).

According to the warm and wet scenario of global climate warming (Heal *et al.*, 1996), which supposes an increase of mean annual air temperature by about 2°C and increase in total annual precipitation of about 10% in the tundra and boreal sites, the present environment of the Giant Mountains tundra could be an appropriate area for

comparative studies of the effects of warm and wet climate conditions on tundra ecosystems.

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