Research Note

Diatoms from an ice-wedge furrow, Ungava Peninsula, Quebec, Canada

LIISA KOIVO and MATTI SEPPÄLÄ

Koivo, L. & Seppälä, M. 1994: Diatoms from an ice-wedge furrow, Ungava Peninsula, Quebec, Canada. *Polar Research 13(2)*, 237–241.

The first recorded information about living fresh water diatoms on an ice-wedge furrow is presented. One sample has been analysed and two species, *Cymbella aequalis* and *Tabellaria flocculosa*, formed almost half of the diatom population. Some rather rare species for the Canadian Eastern Arctic were identified: *Fragilaria constricta*, *Eunotia lunaris*, *Eunotia microcephala*, *Pinnularia gibba*, *Anomoeoneis zellensis*, and *Cymbella aspea*. Of the 37 species identified, most are common elsewhere in the Arctic.

Liisa Koivo, Lahnaruohontie 4 C 37, SF-00200 Helsinki, Finland; Matti Seppälä, Laboratory of Physical Geography, P.O. Box 9, FIN-00014 Helsinki University, Finland

Introduction

In conjunction with a study of low-centred ice-wedge polygons in August 1986, on the northern Ungava Peninsula, Quebec, Canada, (Seppälä et al. 1988) a water sample was collected from an ice-wedge furrow for algal analysis. The bottom of the shallow water body was totally covered by a brownish red layer formed mainly by Oscillatoria and Desmidiaceae green algae (Seppälä et al. 1991). The sample was also enormously rich in diatoms.

Because of the remoteness of the location and the lack of information in the literature about fresh water diatoms in ice-wedge furrows, it was considered worthwhile to identify the species more carefully. The results were then compared with other investigations from the eastern Canadian Arctic as well as from Greenland, Fennoscandia, Spitsbergen and Alaska.

It is well known that diatoms live on, in and under the sea ice in the Arctic (e.g. Meguro et al. 1966; Horner & Schrader 1982; Horner et al. 1988; Syvertsen 1991) and in Antarctic waters (Meguro 1962). One of the main questions raised in these studies has been how the algae survive the winter: Do they remain inactive in the ice or do they produce resting spores for winter survival in the water or on the sea floor. Another question is whether or not diatoms penetrate into the sea ice pores. Answers to these questions are also fundamental when considering the diatom contents of permafrost ice. Although this study has not been able to provide the answers, we would like to point out that in the continuous permafrost zone a rich diatom flora can be found in shallow waters which are unfrozen for only a few months and frozen to the bottom for about ten months of the year. These diatom-rich waters may affect the permafrost layers underneath, at least through the frost cracks.

Sampling site, material and methods

The polygon field is situated in the northernmost Ungava Peninsula on the flood-plain terrace of the Rivière Déception 62°07′30″N, 74°17′30″W, about 50 m a.s.l. and 35 km from the present coast of Hudson Strait. The field lies in the immediate vicinity of a large sub-aqueous glacio-marine outwash fan described by Gray et al. (1985) and Ricard et al. (1987), some seven metres above the normal summer level of Rivière Déception.

The region is 500 km north of the timber line and belongs to a zone of continuous permafrost (Fig. 1). The permafrost may attain a thickness of 600 m (Taylor & Judge 1979). The main annual air temperature is −8°C. Precipitation data are not available. Snow depths range from 20 to 40 cm in general (Seppälä et al. 1991).

The low-centred ice-wedge polygons with 70–80 cm high marginal banks form tetragonal pat-

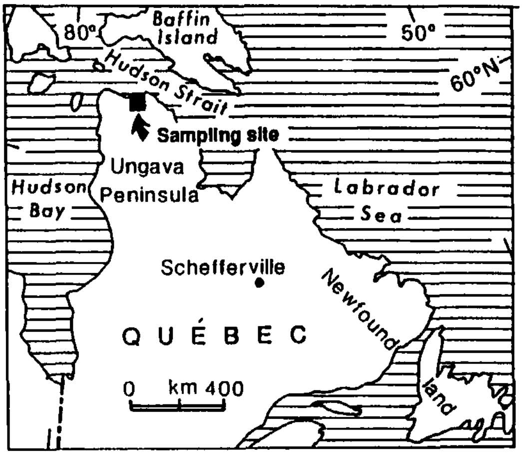

Fig. 1. General location of the sampling site.

terns averaging 20 m in diameter (Seppälä et al. 1991). The maximum width of the polygon banks on each side of a deep fissure is about 2,5 m.

Ice-wedges exist in the middle of the banks on average 24 cm below the active layer (Seppälä et al. 1988). On the active layer above the ice-wedge up to 1,5 m wide furrows are located which could be filled with standing fresh water formed by melting and rain. The bottom layer on the algal mat from one of these furrows was sampled for diatom analyses on 12 August 1986. The depth of that water body was 25 cm with a pH value of 6.6.

The water temperature in the ice-wedge furrow was not measured. For comparison we can tell that the maximum water temperature (+15.6°C) of the river Rivière Déception was recorded on 1 August 1986. This is higher than the temperature of the water just above the permafrost. The study period from the 1–16 August was warm with the highest recorded air temperature of +26.8°C. On 5 August 1986 at five o'clock in the morning the lowest air temperature of −4.7°C was measured. During the following days the air temperature ranged between +1.7 and +12.7°C.

The sample was taken from the green algae mucus into a 500 ml plastic bottle. Before the preparation of the diatom slide the sample was kept cold and 5 ml of strong formaldehyde was added for preservation. Normal decanting techniques and centrifugation were used in the preparation of the sample.

Two hundred diatom frustules were counted in the systematic quantitative analysis, and after that an overall view of the sample was taken and the quality of all species were identified. A paper by Ross (1947) on freshwater diatoms in the eastern Canadian Arctic was used as the main reference. Other valid references are Cleve (1864), Cleve & Grunow (1880), Hustedt (1930), Patrick & Freese (1961), and Seidenfaden (1947).

Results

Quantitative analysis of diatoms

Two species, *Cymbella aequalis* and *Tabellaria flocculosa*, constituted almost half of the diatom population in the sample (Table 1). Other common species were *Fragilaria constricta*, *Nitzschia amphibia*, *Cymbella argustata v. hybrida*. In total these five species formed 65% of the 200 counted frustules.

Twenty-three species were found in the quantitative analysis (Table 1). Four of these were recognised just once.

Ecology of the species

Most of the identified species are classified as halophobe or oligohalobe, and according to Foged (1981), the pH of their living habitat is circumneutral, indifferent, or they are acidophilous species. Some alkaliphilous species (*Achnanthes minutissima* var. *cryptocephala*, *Cymbella aspera*, *C. turgida*, *Nitzschia amphibia*, *N. frustulum*) were also identified (cf. Foged 1981). The life habitat of these species seems to be truly benthic because the maximum water depth was only 25 cm and the sample was collected from the bottom.

Discussion

Distribution comparisons

Six species (*Fragilaria constricta*, *Eunotia lunaris*, *Eunotia microcephala*, *Pinnularia gibba*, *Anomoeoneis zellensis*, *Cymbella aspera*) found from the Ungava Peninsula were not mentioned by Ross (1947) as coming from the eastern Canadian Arctic.

Fragilaria constricta is the third most common species in this sample from Ungava Peninsula, but it is mentioned in Arctic literature only as a rare species from Varanger Peninsula, Norway

Table 1. Quantitative analysis of freshwater diatoms, Ungava peninsula, northern Quebec, Canada (62°07'30"N, 74°17'30"W). Comparable distribution data: CEA (Canadian Eastern Arctic; Ross 1947); PL (Peary Land, northern Greenland; Foged 1955); WG (West Greenland; Foged 1958); SP (Spitsbergen; Foged 1964); V (Varanger Peninsula, Norway; Foged 1968); FL (Finnish Lapland; Seppälä 1971); A (Alaska; Foged 1981).

	n	%	CEA	PL	WG	SP	V	FL	A
1. *Nitzschia amphibia* Grunow	11	5.5	+	+	+	+	+		+
2. *N. frustulum* (Kütz.) Grunow	3	1.5	+	+	+	+	+		+
3. *Pinnularia mesolepta* (Ehrenb.) W. Smith	6	3.0	+	+	+	+	+	+	+
4. *P. microstauron* (Ehrenb.) Cleve	9	4.5	+	+	+	+	+	+	+
5. *P. gibba* Ehrenberg	1	0.5		+	+	+	+	+	+
6. *P. borealis* Ehrenberg	3	1.5	+	+	+	+	+		+
7. *P. divergentissima* (Grunow & Van Huerck) Cleve	2	1.0	+	+	+	+	+		+
8. *Tabellaria flocculosa* (Roth) Kützing	40	20.0	+	+	+	+	+	+	+
9. *T. fenestrata* (Lyngb.) Kützing	6	3.0	+	+	+	+	+	+	+
10. *Cymbella aequalis* W. Smith	51	25.5	+						
11. *C. turgida* Gregory	4	2.0	+	+	+		+		+
12. *C. aspera* (Ehr.) Cleve	2	1.0		+	+		+	+	+
13. *C. angustata* v. *hybrida* (Grunow ex. A. Smith)	10	5.0	+			+	+		+
14. *Anomoeoneis zellensis* (Grun.) Cleve	2	1.0			+	+	+		+
15. *Stauroneis phoenicenteron* v.x (Nitzsch) Kützing	8	4.0	+	+	+	+	+		+
16. *S. anceps* v. *amphicephala* (Kütz.) Cleve	5	2.5	+						
17. *Eunotia septentrionalis* Østrup	5	2.5	+		+	+	+		+
18. *E. lunaris* (Ehr.) Grunow	8	4.0		+	+	+	+		+
19. *E. monodon* Ehrenberg	1	0.5	+	+	+	+	+		+
20. *E. praerupta* Ehrenberg var.x	3	1.5				+	+		+
21. *E. tenella* (Grunow) Hustedt	1	0.5	+	+	+	+	+		+
22. *E. pectinalis* var. *minor* (Kütz.) Rabenhorst	1	0.5	+		+		+		+
23. *Fragilaria constricta* Ehrenberg	18	9.0					+		
Total	200	100%							
In addition to the species above the following taxa were determined in the *qualitative* analysis:									
24. *Synedra tabulata* var. *delicatula* (Grunow) Cleve & Grunow			+				+		
25. *Eunotia praerupta* var. *genuina* Grunow & Van Huerck			+						
26. *Eunotia exigua* (Bréb. ex Kütz.) Rabenhorst			+	+	+	+	+		+
27. *Eunotia pseudoparallela* A. Cleve-Euler			+						
28. *Eunotia microcephala* Krasske							+		
29. *Achnanthes minutissima* var. *cryptocephala* Grunow & Van Huerck			+	+	+	+	+		+
30. *Navicula variabilis* var *gomphonemacea* Grunow & Van Huerck			+						
31. *Navicula rotaeana* Grunow & Van Huerck			+	+	+	+	+		+
32. *Neidium iridis* var.? (Ehrenb.) Cleve			+	+	+	+	+		+
33. *Stauroneis perpusilla* var *obtusiuscula* Grunow			+						
34. *Gomphonema micropus* Kützing			+						
35. *Cymbella microcephala* Grunow & Van Huerck			+	+	+	+	+		+
36. *Cymbella stauroneisformis* Lagerstedt			+	+	+	+			+
37. *Cymbella botellus* (?) (Lagerstedt) A. Schmidt			+						

(Foged 1968) and from Adak Island, Aleutian Islands (Hein 1990, p. 52).

Two of the common species (*Cymbella aequalis* and *Stauroneis anceps* var. *amphicephala*) and six of the rare species (*Eunotia praerupta* var. *genuina, E. pseudoparallela, Navicula variabilis* var. *gomphonemacea, Stauroneis perpusilla* var. *obtusiuscula, Gomphonema micropus*, and *Cymbella botellus*) from the Ungava Peninsula have been found elsewhere in the eastern Canadian Arctic by Ross (1947), but these have not been mentioned in other checked studies from the Arctic.

Most of the species (except *Cymbella aequalis*, and *Stauroneis anceps* v. *amphicephala*) mentioned in the quantitative analysis (Table 1) have been found and are also common on the Varanger Peninsula, northern Norway (Foged 1968). Seven of the additional species identified in the qualitative analysis are missing from the Varanger Peninsula (Table 1).

Twenty-four species listed from the Ungava Peninsula have also been found in West Greenland by Foged (1953; 1958). Twenty-one species are also mentioned from Peary Land, northernmost Greenland (Foged 1955), 26 species from

Alaska (Foged 1981), and 23 species from Spitsbergen (Foged 1964) (Table 1).

Picinska-Faltynowicz (1988), in her study from southern Spitsbergen, mentioned twelve of the diatom species listed in this article from the Ungava Peninsula, including *Cymbella turgida* which Foged (1964) did not find in the small lakes of Spitsbergen (Picinska-Faltynowicz 1988, table 3).

On Adak Island in the northern Pacific, Hein (1990) mentioned only two of our mentioned species as common (*Eunotia pectinalis* var. *minor* and *Tabellaria flocculosa*). He found thirteen other species listed in this study as rare, very rare or infrequent on Adak Island. All had already been found by Foged (1981) in Alaska (Table 1).

As a small comparison to subfossil material from Finnish Lapland, one sample is listed as coming from the bottom of a mire (Table 1) which was formed some 8000 years ago from a small pond (Seppälä 1971, fig. 37, table 14). Six species from this Lappish sample have also been found in the Ungava Peninsula.

Many fresh water diatoms in our sample are cosmopolite and can be found throughout the Arctic regions. Our analysis confirms that even small water bodies which are deeply frozen most of the year can be very rich in diatom flora. As little is known about the diatom flora of small seasonal water bodies on permafrost, it is hoped that this study will serve as an impetus to further diatom studies from permafrost ice.

The survival strategies of diatoms in permafrost environments should be studied with the aid of year-round observation. We do not know if any of the dominating species of this study produce resting spores or resting cells, one possible way of surviving the winter. Another open question arising from our observations is the length of the summer season (=thawing season) needed for the development of such a rich diatom flora.

The comparisons of diatom floras in Ungava and Lapland correspond well with the supposition that the climate of northern Fennoscandia after deglaciation has not been as severe as that in the Canadian Arctic today. Only six species were found in both regions. Based on studies of diatoms in the literature, the climate of northern Fennoscandia at the end of Boreal time need not have differed greatly from the present-day climate which is subarctic in this southern margin of the discontinuous permafrost zone.

Acknowledgements. – The sample was collected during the 1986 expedition organised by J. Gray, Université de Montréal. Green algae were determined by V. Hosiaisluoma. The travel costs of M. Seppälä were financed by the National Council of Natural Sciences, Finland. We are also very grateful to two anonymous referees for comments which improved the manuscript and to N. O'Donoghue for checking the English language.

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