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# Blue-green algae and their influence on development of tundra soils in Kaffiöyra, Oscar II Land, Spitsbergen

ABSTRACT: In surface horizons of Gelic Regosols, Gelic Gleysols and Gelic Cambisols from 5 sites in Kaffiöyra, 26 taxa of blue-green algae have been determined. Species of the genera *Gleocapsa, Schizothrix, Tolypothrix* and *Calothix* were the most common. In Gelic Regosols blue-green algae formed during the last 100 years the 0.5 cm thick horizon A, containing 8.6% of humus.

Key words: Arctic, Spitsbergen, blue-green algae, tundra, soil

## Introduction

Surfaces of young moraines have thin covers with organic matter. Mature tundra soils there possess continuous horizons rich with organic matter also in places free of vascuar plants, lichens and mosses. Field works proved algae from these horizons, particularly in initial soils. Tiškov (1985) stated that in Spitsbergen algae settled morainic deposits 1—2 years after a glacier retreat. In pedologic and algologic literature there is no information on algae to be the main source of organic material in fully developed soils. Connections between algae communities and soil taxonomic units have not been studied enough closely so far. Therefore investigations of algae species composition and their influence on forming surface horizons of Gelic Regosols, Gelic Gleysols and Gelic Cambisols constituted the aim of this work.

## Materials and methods

Soils were investigated in Kaffiöyra strandflat (Fig. 1, Pl. 1). Geographical environment of this area was described by Klimaszewski (1960),

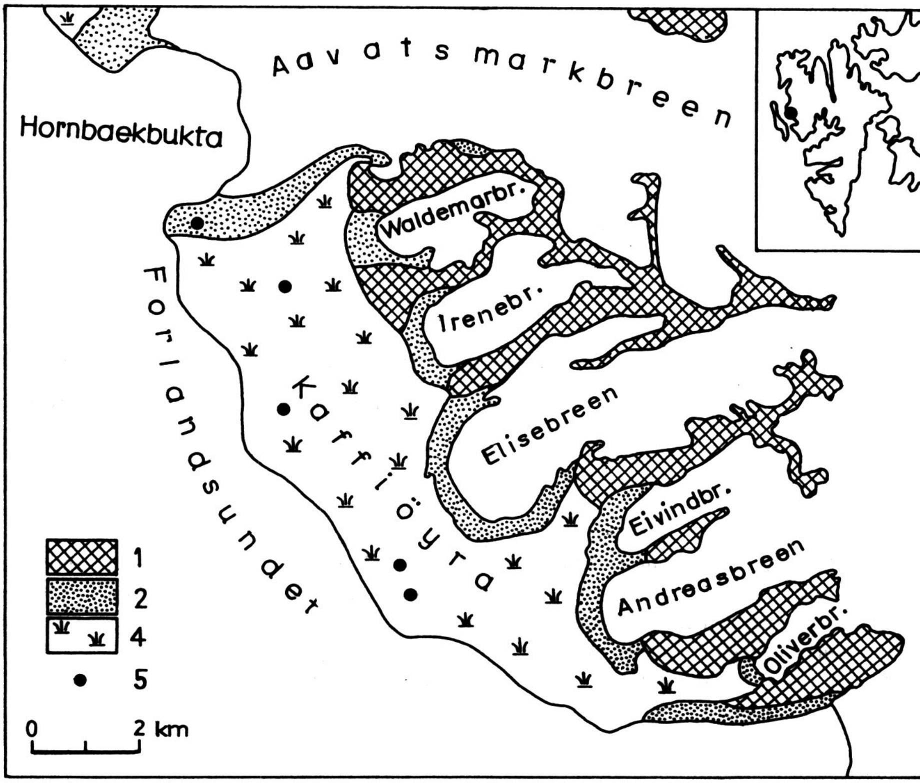


Fig. 1. Sketch of investigated area
1 — mountains, 2 — glacier morainal zones, 3 — tundra plain, 4 — studied sites

Gugnacka-Fiedor and Noryśkiewicz (1982), Niewiarowski (1982), Sinkiewicz and Plichta (1987). Samples were collected in July and August 1985 during the 7th Toruń Polar Expedition. Pedologic and algologic analyses of surface soil horizons were done for the profiles of: Gelic Regosols (site I), Gelic Gleysols (site II) and Gelic Cambisols (site III), according to the classification of FAO-UNESCO (1974). Algae from two samples of Gelic Gleysols and Gelic Cambisols (sites IV and V) were also determined but without pedologic characteristics.

Pedologic analyses were done by standard methods. Collected soil samples with algae for microscopic studies were water saturated in glass vessels. In samples prepared thereby algae could be determined in vivo during several following days. Determination was done with a use of keys of Elenkin (1949), Golubič (1967) and Starmach (1966).

## Results

Results of pedological and algological analyses are presented in tables (Tables 1 and 2).

Table 1

| Soil unit | Horizon | Depth in cm | Grain size content — % | | $C_t$ | $N_t$ | C/N | $CaCO_3$ | $pH_{H_2O}$ |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1.0—0.1 | <0.002 | | | | | |
| Gelic Regosols (site I) | (A)* | 0.0—0.5 | 37 | 15 | 5.0 | 0.296 | 16.9 | 10.9 | 7.5 |
| | $C_1$ | 0.5—4.5 | 38 | 15 | 0.31 | 0.032 | 9.7 | 17.6 | 8.0 |
| | $C_2$ | 24.0—38.0 | 39 | 12 | 0.25 | 0.029 | 8.6 | 15.2 | 7.9 |
| Gelic Gleysols (site II) | (O)* | 1.0—0.0 | — | — | 10.0 | 0.704 | 14.2 | — | 6.2 |
| | A | 0.0—5.0 | 37 | 8 | 1.09 | 0.104 | 10.5 | 1.5 | 7.7 |
| | C | 20.0—30.0 | 36 | 13 | 0.70 | 0.071 | 10.0 | 3.6 | 7.9 |
| | $C_g$ | 50.0—55.0 | 38 | 11 | 0.72 | 0.082 | 8.8 | 2.1 | 7.9 |
| Gelic Cambisols (site III) | (O)* | 0.5—0.0 | — | — | 8.9 | 0.334 | 26.6 | — | 4.8 |
| | A | 0.0—10.0 | 93 | 1 | 0.72 | 0.070 | 10.3 | 0.0 | 5.4 |
| | B | 15.0—27.0 | 92 | 1 | 0.29 | 0.023 | 12.6 | 0.0 | 6.7 |
| | B/C | 40.0—50.0 | 81 | 1 | 0.23 | 0.018 | 12.8 | 0.0 | 8.0 |
| | C | 60.0—65.0 | 86 | 2 | 0.15 | 0.011 | 13.6 | 7.6 | 8.3 |

* — horizons for which algologic analyses were done

Table 2

List of algae in soils of Kaffiöyra

| Species | sites | | | | |
|---|---|---|---|---|---|
| | I | II | III | IV | V |
| 1. *Gleocapsa alpina* Näg. emend Brend | | | | + | + |
| 2. *Gleocapsa kuetzingiana* Näg. | + | | | + | + |
| 3. *Gleocapsa montana* Kütz. | + | + | | + | + |
| 4. *Gleocapsa punctata* Näg. | | | | + | + |
| 5. *Gleocapsa rupestris* Kütz. | | + | | | |
| 6. *Gleocapsa turgida* (Kütz.) Hollerb. | | + | | + | |
| 7. *Gleocapsa minor* (Kütz.) Hollerb. | | | | + | |
| 8. *Nostoc microscopicum* Carmich. | | + | | + | |
| 9. *Nostoc paludosum* Kütz. | | + | | | + |
| 10. *Nostoc sp.* | + | | + | | |
| 11. *Schizothrix heufleri* Grun. f. *woronichinii* Elenk. | | | | + | |
| 12. *Schizothrix delicatissima* W. et G.S. West | | | + | | + |
| 13. *Schizothrix arenaria* (Berkeley) Gom. | | + | | + | |
| 14. *Schizothrix* cf. *arenaria* | | | + | | |
| 15. *Schizothrix* friesi (Ag.) Gom. | + | | | | |
| 16. *Microcoleus vaginatus* (Vaucher) Gom. | | | | + | |
| 17. *Lyngbya kuetzingiana* (Kütz.) Kirch. | | | | + | |
| 18. *Oscillatoria geminata* (Meneg.) Gom. | | + | | + | |
| 19. *Symploca cortilaginea* (Mont.) Gom. | | + | | | |
| 20. *Scytonema crustaceum* Ag. | | + | | + | |
| 21. *Scytonema tolypotrichoides* Kütz. | | + | | | |
| 22. *Tolypothrix elenkinii* Hollerb. | | + | | | |
| 23. *Tolypothrix elenkinii* Hollerb. f. *saccoideo-fruticulosa* Hollerb. | | + | | + | |
| 24. *Calothrix* cf. *parietina* (Nag.) Thuret f. *brevis* Ercegovic | | + | | + | + |
| 25. *Stigonema minutm* (Ag.) Hassal | | | + | | |
| 26. *Mesotaenium chlamydosporum* De-Bary [diatoms (*Navicula* sp. *Cymbella* sp., *Gomphonema* sp. — scattered)] | | + | | + | |

Site I is located on a terminal-lateral moraine of the Aavatsmark Glacier (Aavatsmarkbreen). The moraine was formed at the end of the 19th century (Niewiarowski 1982). Gelic Regosols are composed there of medium heavy loam (soil textural groups according to the Polish Standard BN – 7819180-11). Ground surface is overgrown by scarce vegetation, mainly *Saxifraga oppositifolia* L., *Saxifraga caespitosa* L., *Cerastium alpinum* L., *Cerastium regeli* Ostenf., *Draba alpina* L., as well as mosses and lichens. No vegetation occurred in places where samples were collected.

In upper part of the soil profile the 0.5 cm thick horizon rich with humus (4.9% of organic carbon) occurred. The sample from this horizon contained blue-green algae of *Gleocapsa kuetzingiana* forming scarce but large thalluses surrounded with periderma as well as densely tangled filaments of *Schizothrix friesi.* These species were the most common among all 4 species of blue-green algae determined in this sample. Because no other autotrophic plants in this site occurred, blue-green algae seem to be a main source of humus in surface soil horizon (A).

The sample of the Gelic Gleysol (site II) was collected from a fresh moss tundra. This soil is composed of light loam on medium heavy loam. The most common plant species in the place comprise *Salix polaris* Wahl, *Saxifraga oppositifolia, Oxyria digyna* (L.) Hill., *Draba oblongata* R. Br., *Luzula arctica* Blytt., *Cetraria hiascens* (Fr.) Th. Fr. and many other moss and lichens. On the ground surface irregular stone rings covered by 10 cm thick organic horizon (O) were distinguished (Pl. 1). Inside the rings a thickness of organic horizon decreases to about 1 cm only. Organic horizon is usually black and strongly folded (Pl. 2). It contains about 10% of organic carbon. Macro and micromorphologic analyses indicated this horizon to be mainly composed of algae remains. This sample from the organic horizon from the inside of a stone ring contained 14 taxa of blue-green algae. The most common were thalluses of *Tolypothrix elenkinii* and *T.e.f. saccoideo — fruticulosa.* Numerous colonies of *Gleocapsa* and *Nostoc* were also found between filaments of *Tolypothrix.* After water saturation thick mucilaginous sheaths of blue-green algae formed few millimeter thick layer between scarce moss remains. In this sample single individuals of *Cymbella, Navicula* and *Gomphonema* have been also found.

Gelic Cambisols (site III) are composed of loose sand of ancient coastal forms. They are covered by lichen tundra. Species of *Saxifraga oppositifolia, Saxifraga caespitosa, Luzula arctica, Cerastium alpinum, Oxyria digyna, Equisetum scirpoides* Michx., *Cetraria hiascens, Cetraria nivalis* [L.] Ach., *Stereocaulon alpinum* Laur. and *Drepanocladus uncinatus* [Hedw.] Warnst. are the most common there. Organic horizon is 0.5 cm thick and contains 8.9% of organic carbon. In this horizon 6 species of blue-green algae were distinguished between moss and lichens remains. Scarcity of blue-green algae species and individuals seems to result from a low pH of a soil equal 4.8.

Composition of blue-green algae species in two other samples was also determined but without pedologic characteristics. These samples were collected from Gelic Gleysols on fresh moss tundra (site IV) as well as from Gelic Cambisols on lichen tundra with prevailing *Stereocaulon alpinum* (site V).

In the site IV moss remains are covered partly by $CaCO_3$ efflorescence. In this place 13 taxa of blue-green algae were determined. Different development stages of *Gleocapsa alpina* were the most common as: a) nannocites with cells equal 1—2 $\mu$m in diameter and colonies about 30 $\mu$m in diameter, b) cells equal 5—7 $\mu$m in diameter and big colonies reaching 350—500 $\mu$m in diameter, c) cells equal 5—7 $\mu$m too but forming smaller colonies, only about 80 $\mu$m in diameter. In this sample blue-green algae which seem to be of the genus *Calothrix* (probably *Calothrix parietina* f. *brevis*) were common. Determination was difficult due to their mutability.

In the sample of Gelic Gleysols many different species and a great number of individuals have been found.

In the sample from the site V with Gelic Cambisols, 6 species of blue-green algae were determined. In this place blue-green algae covered moss remains which build organic horizon. *Schizothrix delicatissima* and colonies of *Gleocapsa montana* of different sizes were the most common.

## Recapitulation

Blue-green algae which can occur under a vide variety of habitat conditions, can form a pioneer community in a non-soil material (Round 1984, Tiškov 1984). In this process blue-green algae capacity to fix nitrogen from the atmosphere makes them independent on a presence of nitrogen compounds in a soil substrate (Stewart 1971, Grandhall and Lid-Torsvik 1975). Heterocystous species are the best known blue-green algae which fix $N_2$ aerobically. Several non-heterocystous species have been also investigated, using thick mucilaginous sheaths, boundles of filaments as well as in different unknown ways they could create local micro-aerobic conditions and fix $N_2$ aerobically (Stewart 1972). According to Alexander (1974, after Holding 1981) blue-green algae which are lichen components, free-living, symbiotic or as epiphytes on mosses create the main nitrogen source in tundra areas.

In the site I in Gelic Regosols developed on morainic material deposited about a hundred years ago, blue-green algae formed 0.5 cm thick horizon with 8.6% humus content. In this horizon nitrogen supply is equal 0.025 $kg \cdot m^{-2}$ whereas humus supply is equal 7.1 $kg \cdot m^{-2}$. Forming a shallow horizon but rich in humus and nitrogen creates favorable conditions for the following succesion stages. In other sites with mature tundra soils abundance and diversity of blue-green algae are greater.

In wet and rich with carbonates Gelic Gleysols (site II and IV), 15 taxa of blue-green algae were determined. Field observations show that in wet places with scarce vascular plants, mosses and lichens, the blue-green algae form thin (1—2 cm) organic horizons. Development of organic horizons in Gelic Cambisols (site III and V) composed of sand and shingle, with well drained surface horizons is less influenced by blue-green algae. Presence and development of blue-green algae in these soils are limited by acidic reaction and low water content. Acidic reactions of a habitat with pH equal 4—5 is the factor limiting the occurrence of blue-green algae (Brock 1973).

In a surface layer (0—2 cm) of tundra soils in Alaska, 59 algae species from different taxonomic groups (*Chlorophyta*, *Cyanophyta*, *Chrysophyta*) have been found (Cameron *et al.*, 1978). Amongst them the most of a biomass was formed by blue-green and green algae. On the other hand the Kaffiöyra soils contained blue-green algae only.

## Conclusions

In samples analyzed from surface horizons of tundra soils from Kaffiöyra the alge communities consisted mainly of blue-green algae. Presence of 26 taxa of blue-green algae was noted, predominantly of *Gleocapsa*, *Schizothrix*, *Tolypothrix* and *Calothrix* genera. In wet Gelic Gleysols a number of species is greater than in dry and acidic Gelic Cambisols. In Gelic Gleysols the organic horizon composed mainly of blue-green algae is often black and folded.

On a terminal-lateral moraine of the Aavatsmark Glacier blue-green algae formed 0.5 cm thick horizon rich with humus during about a hundred years. They are the pioneer community in a phytocenosis succesion on morainic formations.

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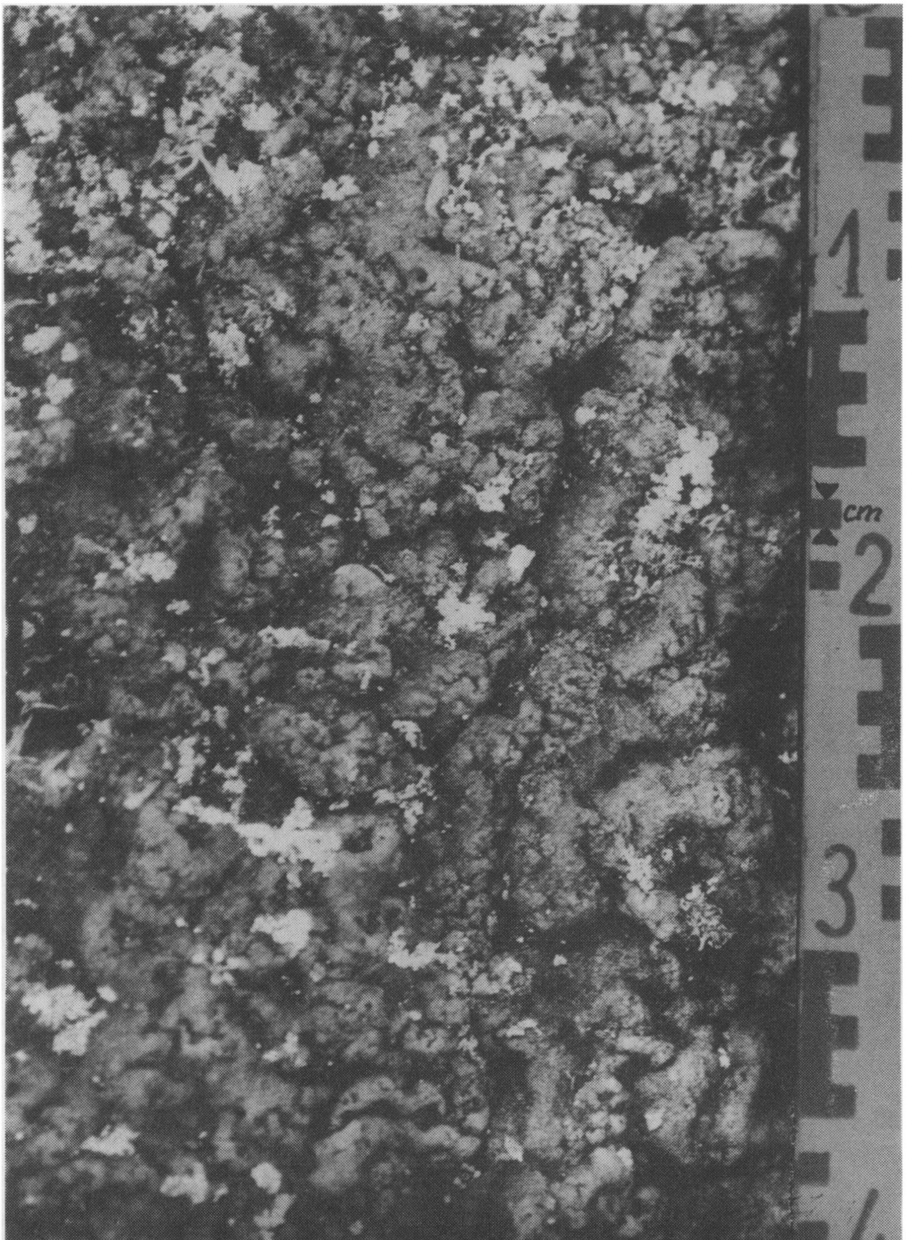
## Streszczenie

Badania glebowe i algologiczne przeprowadzono na równinie nadmorskiej Kaffiöyra, Spitsbergen (fig. 1, pl. 1). Analizowane poziomy powierzchniowe gleb (A) i (O) zawierały głównie sinice (tab. 1 i 2). W Gelic Regosols są one organizmami pionierskimi. W glebie tej, w czasie około 100 lat, sinice utworzyły 0,5 cm poziom zawierający 8,6% próchnicy i 0.30% azotu. Sinice w Gelic Regosols należą głównie do rodzajów *Schizothrix* i *Gleocapsa*. Na dojrzałych glebach tundrowych Gelic Gleysols zawierających węglany stwierdzono największą różnorodność gatunkową zbiorowisk sinic (13—15 gatunków). W Gelic Gleysols były one prawie jedynym źródłem próchnicy w poziomie organicznym (pl. 2). Ubogie natomiast w gatunki są kwaśne (pH 4,8) poziomy organiczne Gelic Cambisols.




Kaffiöyra tundra plain with Gelic Gleysols

Folded organic horizon on the surface of Gelic Gleysols, mainly composed of blue-green algae