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Succession of Soil Algae on Dumps from Strip Coal-mining in the Most Region (Czechoslovakia)

Keywords

Soil algae, Succession, Primary succession, Plant succession, Colonization of new biotopes, Vegetation on dumps, Czechoslovakia

Abstract

LUKEŠOVÁ A. et KOMÁREK J. (1987): Succession of soil algae on dumps from strip coal-mining in the Most region (Czechoslovakia). — Folia Geobot. Phytotax., Praha, 22: 355—362. — In the years 1985—1986, the primary succession of algae on dumps from brown coal mining was studied in the Most region (North Bohemia, Czechoslovakia). The colonization of sterile clayic substrates by algae (several coccal species of chlorophytes and heteroconts) and mosses (protonemata) starts before the first ecesis of higher plants (in deposits about 3 months old). Diatoms and, later, cyanophytes accompany the algal community after 1 year. Filamentous types of heteroconts and green algae occur first on 7 year old dumps. Green algae represent the commonest group throughout the succession. The number of species continuously increases with the age of the dumps and finally reaches about 40 species from the 18th to 30th year. The species composition is similar to that in grassland biotopes in Czechoslovakia.

INTRODUCTION

The large dumps from surface brown coal mining near the town of Most (North Bohemia, Czechoslovakia) are suitable for studying plant colonization and succession on new and sterile soils (comp. PRACH 1982, 1984). In 1985 and 1986, we studied the primary succession (colonization and species composition) of soil algae in this area, in relation to the age of the dumps (from 3 months to about 30 years) and to the succession of communities of vascular plants.

The dumps will cover about 400 km^2 (40 thousands hectares) in this region at the final stage. They are partly artificially recultivated, i.e., planted with trees and crop plants. However, this presents many problems. The study of the natural primary succession of microflora is important for the recognition of initial colonization by the first pioneers, and for the study of humus formation and facilitation processes.

The area is situated in the shelter of the Krušné hory mountains. It is, therefore, comparatively dry (500—650 mm of precipitations per year, 300—350 mm in vegetation season) and warm (annual mean 7 to 8.5 °C) (acc. to PRACH 1983). The substratum is composed almost uniformly of miocene clay (about 80 %), and to a small extent of sand and gravels. Usually, the substratum exhibits a scaled disintegration (cleavage) and is chemically characterized as alumosilicates with SiO_2, Al_2O_3 and H_2O, and larger or smaller amounts of Fe, Mg, and alkaline metals, pH varies slightly about 7 (TOBĚRNÁ 1973).

The higher plant succession on dumps passes through several characteristic stages (PRACH 1982, 1983, 1984) (comp. Plate 11): (1) The initial period with solitary annual plants (e.g., *Polygonum nodosum, Senecio viscosus*; up to 2nd—4th year), (2) *Atriplex nitens* community (2—8 years), (3) community with dominant *Carduus acanthoides* and *Sisymbrium loeselii* (4—12 years), (4) community with characteristic *Tanacetum vulgare* (7—20 years; during this period the soil starts to be covered continuously by plants and litter, and humus formation starts; solitary shrubs of *Sambucus nigra* are characteristic of this stage), and (5) a grassland community with dominant *Arrhenatherum elatius* and *Calamagrostis epigeios* with more solitary trees (*Sambucus nigra, Acer pseudoplatanus, Betula pendula, Fraxinus excelsior, Sorbus aucuparia*, etc.; 18—30 years). *Tussilago farfara* is the species occurring from about the 2nd year throughout the succession period, particularly on slopes.

METHODS

The soil samples were collected at the end of May and in the middle of September in the years 1985 and 1986 from the surface layer to the depth of 1—2 cm, and cultured in Petri dishes under laboratory conditions at room temperature and daylight intensity. The species composition was verified by the method of growth glasses according to LUND (1945) and by the cultivation of species from suspended soil on 1.5 % agar plates with BBM.

The sampling sites were selected in places with typically developed succession stages of higher plants as defined above. At the early stages the different types of substratum (pure clay or sand with gravel) were compared. From each sampling place several probes were collected and mixed together before cultivation.

RESULTS

Altogether 46 species of soil algae were isolated from all localities studied. The actual and cumulative numbers of species (MACARTHUR et WILSON 1967) are demonstrated in dependence on the age of the dumps (Fig. 1). The actual numbers of species

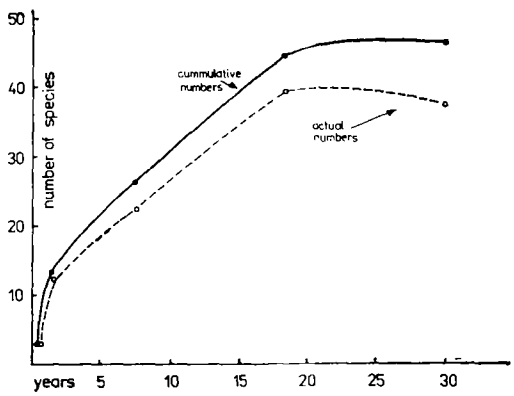


Fig. 1. Actual and cumulative numbers of soil algal species during plant succession on dumps from coal mining.

found in cultured samples gradually increase approximately to the 18th year of existence of a dump. In samples with the maximum species diversity 39 species were found, but later the actual number decreases slightly. In dumps 30 years old, the number of species decreased to 37 species on the average. The reason for this decrease is not clear; deteriorating light conditions due to the denser cover of higher plants and of plant litter on the soil surface, and a greater amount of consumers may play a certain role here.

In Fig. 2 the changes in the development of species belonging to different taxonomic groups (cyanophytes, diatoms, heteroconts and green algae) are presented, and their occurrence is related to the developed higher plant communities. The first occurrence of algal species was already recorded in the youngest successional stages of dumps 3 to 6 months old. However, these algae were only sporadic solitary cells of *Botrydiopsis* sp. and of two representatives of green algae, namely *Chlamydomonas thomassonii* and *Chlorella vulgaris*. While *Ch. thomassonii* was found only in this first

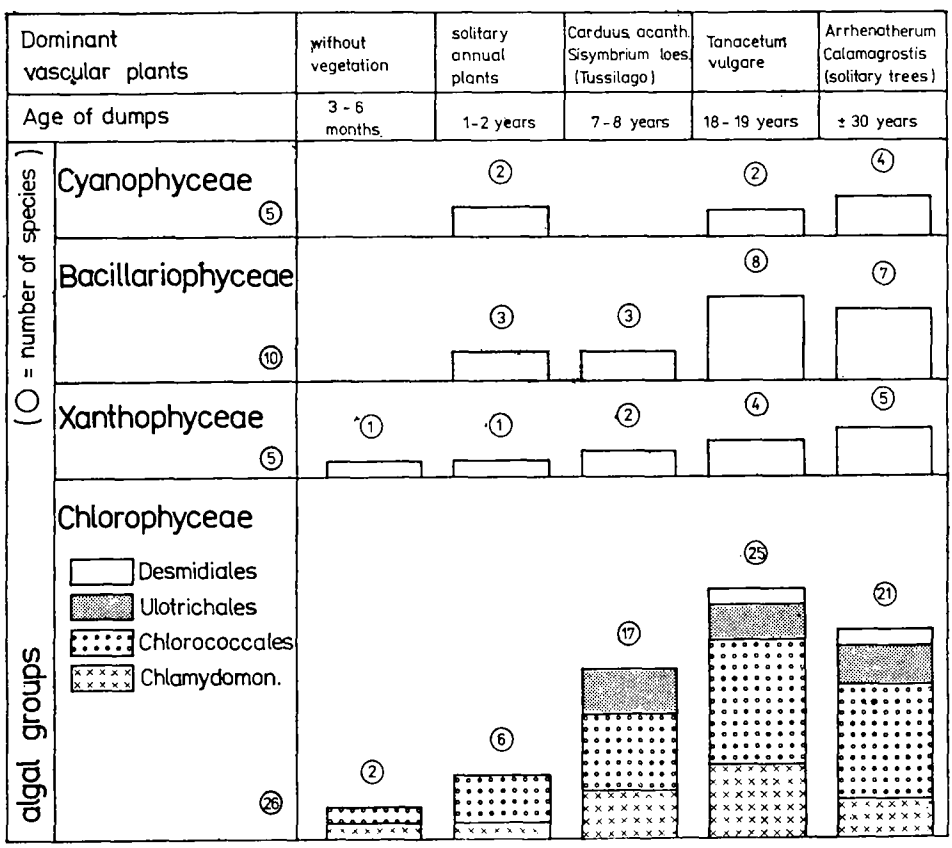


Fig. 2. Increase in the number of species in different algal groups in dependence on the age of dumps and on the succession of communities of vascular plants.

period of existence of the dumps (without higher plants), *Botrydiopsis* sp. and *Ch. vulgaris* occurred more or less sporadically throughout the further succession. It is noteworthy that protonemata of mosses were already found in samples from the first successional stage (entirely without higher plants).

On dumps of about 1—2 years differences were found between sites on various substrata, and between sites without vegetation and those at the initial *Atriplex*-stage. On pure clay without plants only two species were found, while at clayic localities overgrown by *Atriplex* four species with dominant *Botrydiopsis* sp. were assessed. From the clay mixed with sandy particles and gravel 10 species with dominant *Botrydiopsis* sp. and *Tetracystis dissociata* were cultured. This difference also coincides with PRACH's (1983) statement that on sites with sandy deposits the first annual plants germinate and settle remarkably sooner than in places with pure clay.

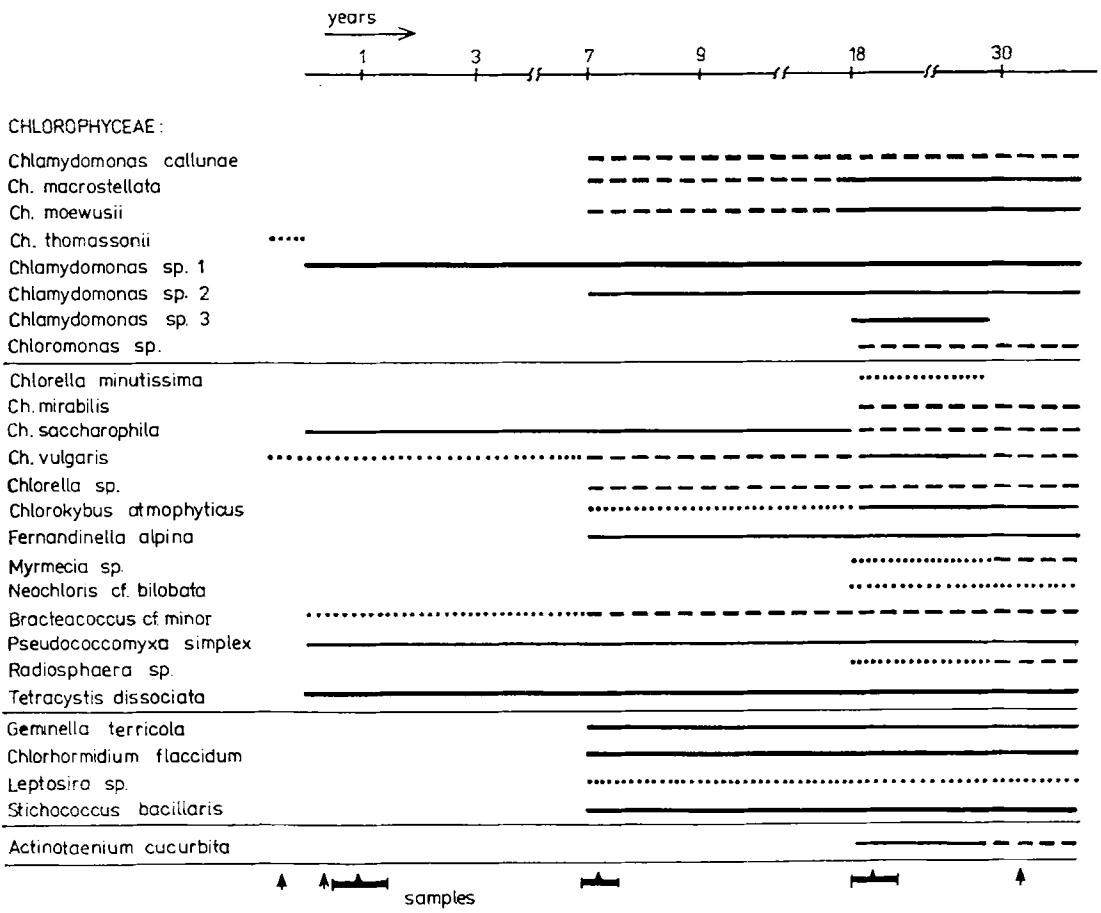
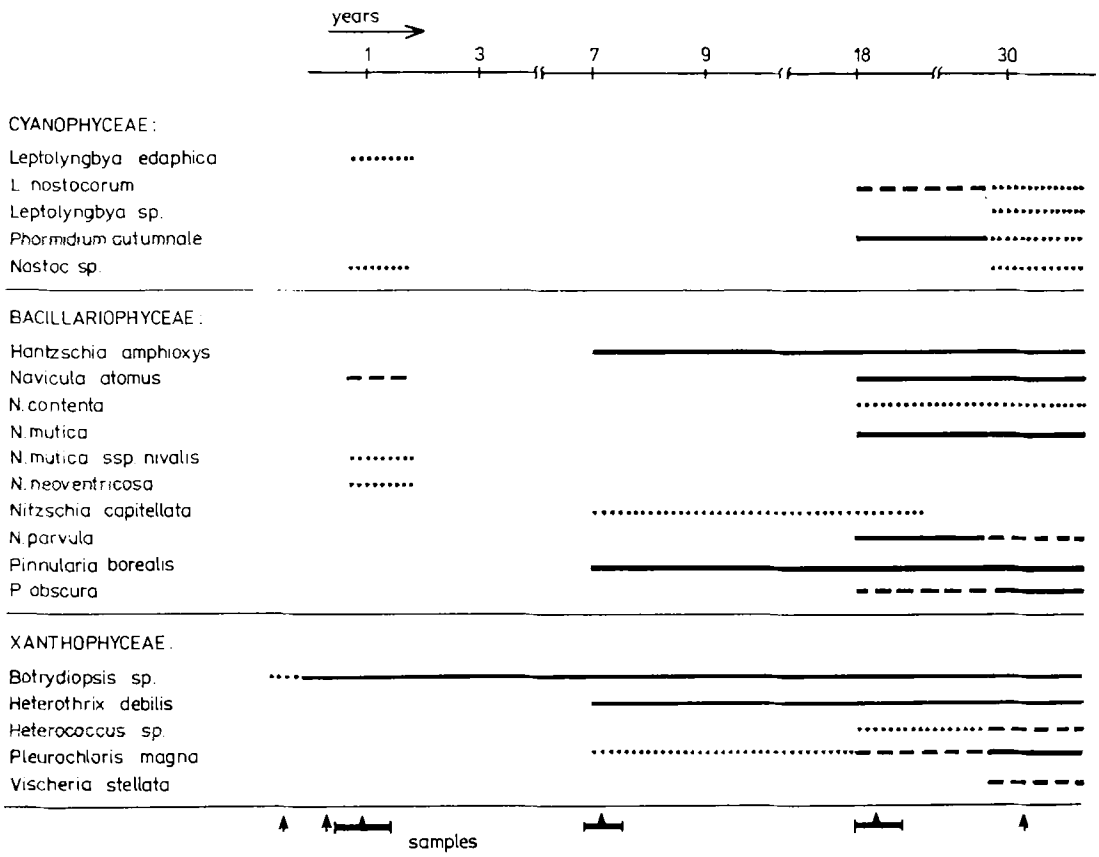


Fig. 3. Course of the occurrence of soil algal species on dumps of different ages.

No such difference was recognized between the two substrata in later successional stages in samples from sites with a more developed higher plant cover.

On dumps about 7 years old two types of communities of higher plants were studied. One with dominant *Tussilago farfara* occurring mainly on the slopes of dumps and the other with dominant *Carduus acanthoides* and *Sisymbrium loeselii*. Also in 30 year old dumps the species composition of soil algae was compared between communities with dominant *Arrhenatherum elatius* on the one hand and *Calamagrostis epigeios* on the other. In both community types, almost identical sets of algal species were found, with dominant *Chlorhormidium flaccidum* and *Pinnularia borealis*. The dependence of the algae on the substrate thus exists only at the initial stages of algal succession. At later stages, the species composition and their total number depend on the dump's age, without any noticeable relation to either the substratum



or the higher plant community. *Chlorokybus atmophyticus* (Plate 12a—d) was, however, found only on sites with a developed community of *Carduus* and *Sisymbrium*. The fact that the changes in species composition of soil algae on dumps are related more closely to the age of the dumps than to the higher plant communities also coincides with the statement of TOBĚRNÁ (1973), that the rapid development of the surface layers of dump soils soon eliminates local deviations.

In Fig. 3 the start and maximum of the occurrence of different groups of algae (differences in numbers of species) are clearly recognizable during the succession of algal vegetation. Chlorophytes are the first phototrophic pioneers on the dumps and generally the species-richest and most frequent (as the cell number could be derived from the cultures). Altogether 26 species of soil green algae were found. As for comparison with other biotopes, the chlorophytes are also commonly present in other soils in Czechoslovakia. The species composition is not substantially different, e.g., from cultivated meadows. *Chlorella saccharophila* and *Tetracystis dissociata* seem to be characteristic species of the dumps. Four species of green algae (*Chlorella mirabilis, Chlorokybus atmophyticus, Neochloris* cf. *bilobata* and *Tetracystis dissociata*) were recorded in our samples for the first time in Czechoslovakia (comp. Plates 12, 13). The heterocontic alga *Botrydiopsis* sp., which occurs commonly in all later stages, is also characteristic of the early stages of succession and is usually dominant. However, heteroconts do not occur very commonly on dumps.

The next group are diatoms, the vegetation of which starts in about 1 year old deposits. The majority of the 10 species found belong to commonly distributed soil types with the exception of *Navicula neoventricosa*, which was found in two year old sandy and gravel deposits for the first time in Czechoslovakia. *Nitzschia parvula* is a characteristic diatom of the old dumps.

The latest-occurring group in dumps are cyanophytes, with the exception of two species, namely *Leptolyngbya edaphica* and *Nostoc* sp., which were found only in one year old dump. Cyanophytes are surprisingly rare.

Figure 3 demonstrates the occurrence of all species in dumps of different ages. The early start of green algae and *Botrydiopsis* is clearly expressed. *Botrydiopsis* sp., *Chlorella saccharophila, Pseudococcomyxa simplex, Tetracystis dissociata* and one undetermined species of *Chlamydomonas* are the commonest species from one year old deposits through all later stages. Several examples of rarely occurring species of green algae found in the Most dumps, are documented in Plates 12—14.

DISCUSSION

The development (succession) of algal communities in different soil types is very little known. The colonization of sterile deposits from coal mines by phototrophic microorganisms provides a very rare opportunity to study this process under natural conditions, just as in new volcanic areas.

Our results are comparable, e.g., with the results of ŠUŠUEVA (1977) from the coal-mining dumps in Kuzbas, of TARČEVSKIJ et ŠTINA (1967) from dumps of ashes near thermic power station and deposits from metallurgic plants (both from the USSR), or of BEHRE et SCHWABE (1970), SCHWABE (1970) and SCHWABE et BEHRE (1971) from the volcanic Surtsey island (Iceland). In spite of the distance between these areas the composition of pioneer algal species

and genera with accompanying mosses is similar (*Botrydiopsis, Chlorella, Chlamydomonas, Chlorhormidium, Tetracystis* and diatoms *Hantzschia amphioxys, Pinnularia borealis, Navicula atomus, N. mutica*). The early start of diatoms in the Most dumps corresponds more with the data of SCHWABE et BEHRE (1972) than with those of TARČEVSKIJ et ŠTINA (1967), who found the start of diatoms only with the first occurrence of perennial grasses. The high amount of SiO_2 in the Most deposits probably plays an important role in the development of diatom vegetation.

The colonization of soils on Surtsey island is more rapid than on dumps. The greater number of species from Surtsey is probably the result of the greater diversity of microbiotopes; the studied localities on the dumps were much more uniform. Also our cultivation methods are, by necessity, selective, and may have eliminated some species.

In comparison with all the authors cited (cf. also MARTINOVA 1986), cyanophytes were rarely found in the Most dumps. This situation corresponds with the low nitrogen content in the Most dump soils; it increases very slightly during the years (TOBĚRNÁ 1973). The reason for this difference from the data from other localities is not clear. The early start of cyanophytes in Surtsey is probably mainly connected with the warm steam outputs from the volcanic substrate, which do not exist in the Most dumps, but may occur in other similar North Bohemian localities both natural and artificial (cf. BRABEZ 1941, KOMÁREK et ROSA 1957).

The algal communities studied are composed of special soil species, which are also distributed in other soil biotopes; however, in each case it is impossible to describe them as "mainly cosmopolitan and ubiquist" (MARTINOVA 1986).

In the dumps the contact of new sterile soils with the surrounding areas is closer than in the case of new isolated islands (comp. HALPERN et HARMON 1983). Yet the succession of vascular plants as well as microphytes proceeds very regularly in our localities. The original flora (including the microflora) is completely buried below the very deep and sterile new deposits on over large areas. The new colonization, which is fully dependent on the input of diaspores from the surrounding landscape (mainly by wind and animals), is interestingly not as rapid, spontaneous and non-selective, as one would have expected.

The number of species in 30 year old dumps is remarkably lower in comparison with old dumps, described, e.g., by MARTINOVA (1986). The restricted anthropogenic influence and different chemical conditions of the substrate in our case are probably the main reason for this difference.

The algae indicate the microecological situation very well (GOLLERBACH et ŠTINA 1969). The primary succession in dumps can therefore serve as a good example for recognition of the colonization process under given conditions.

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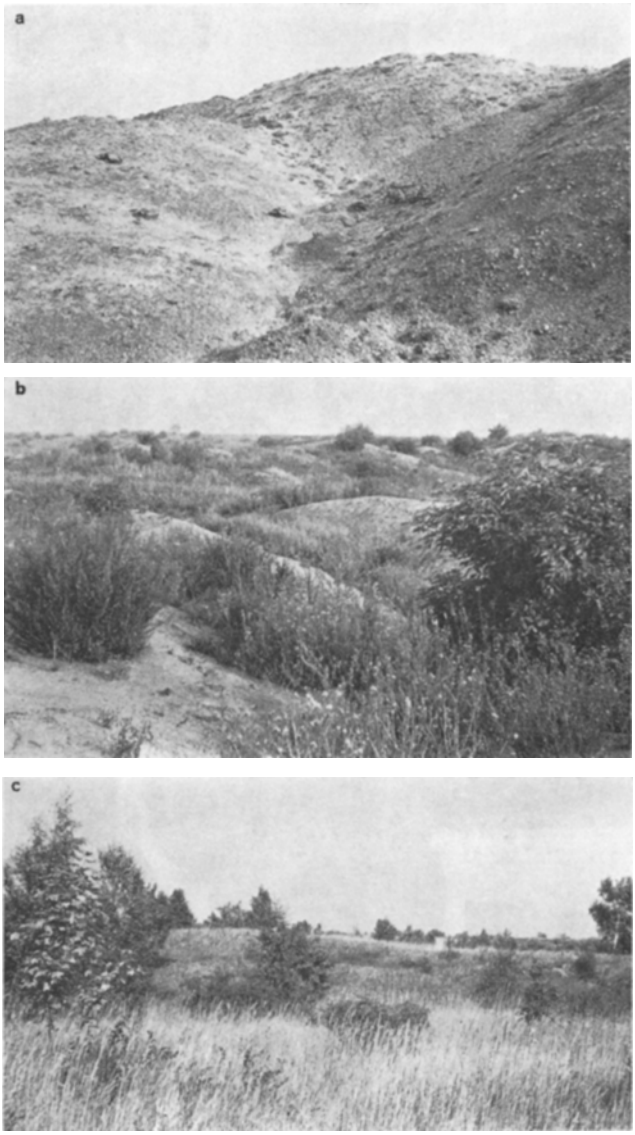
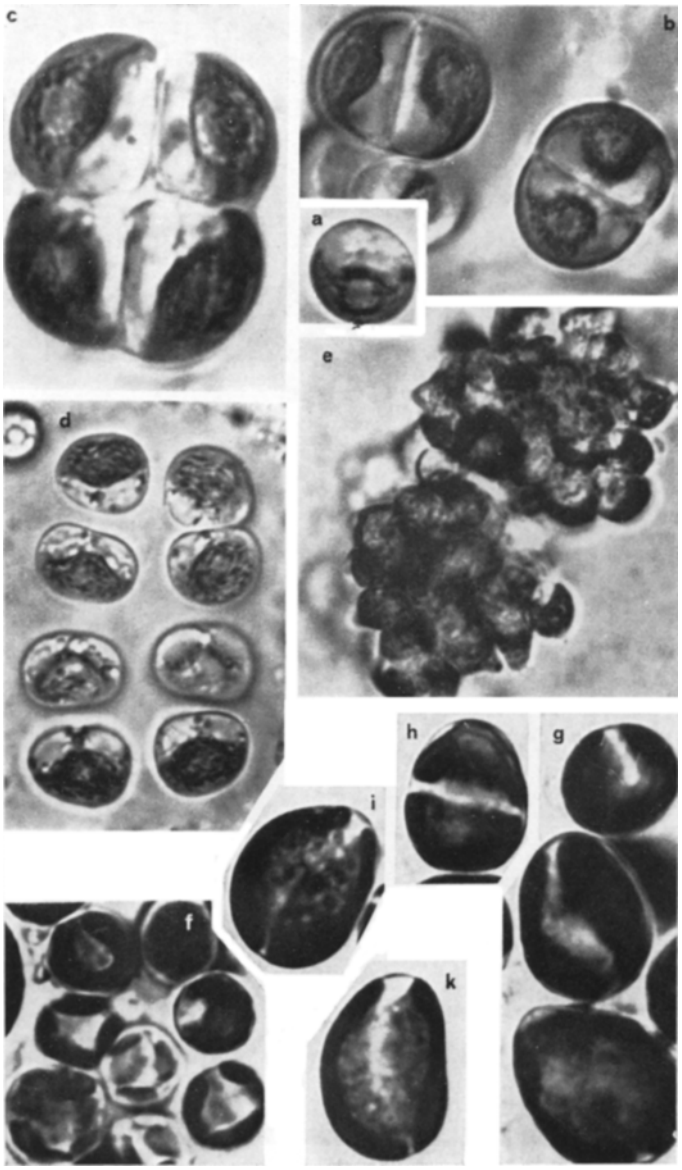
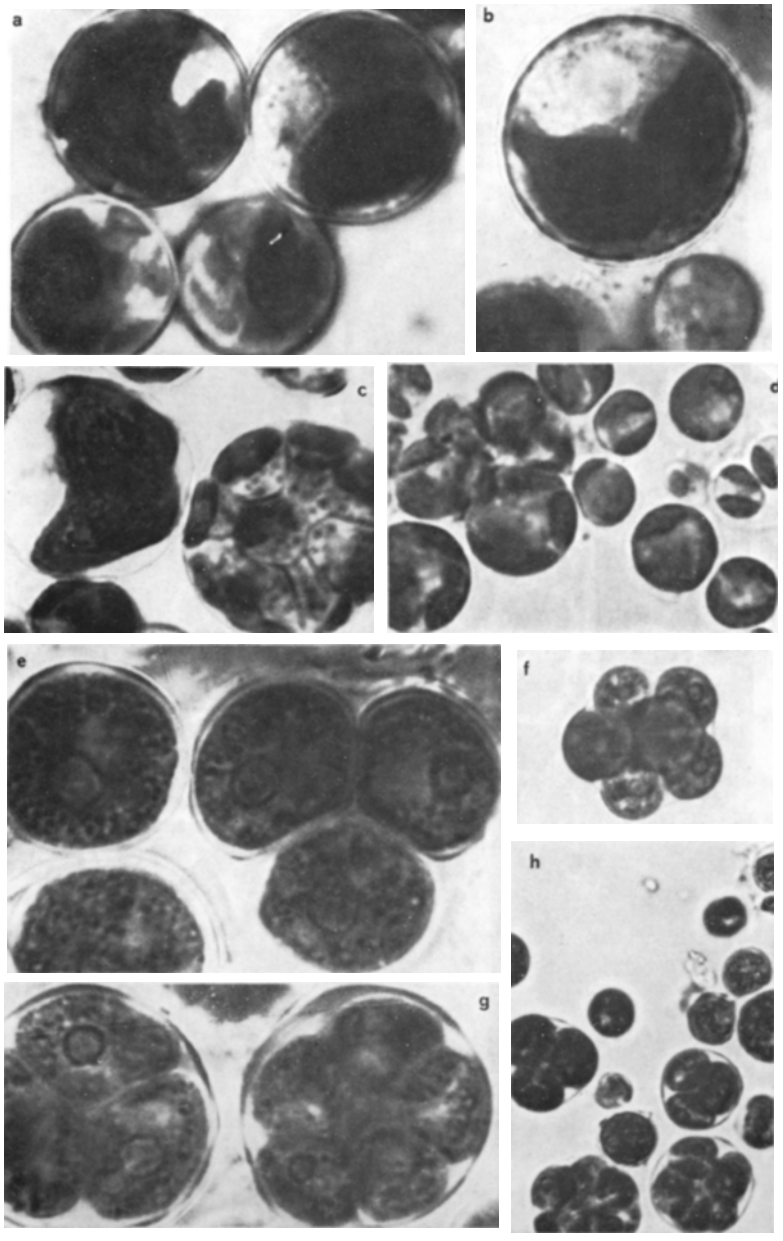
Plates 11—14



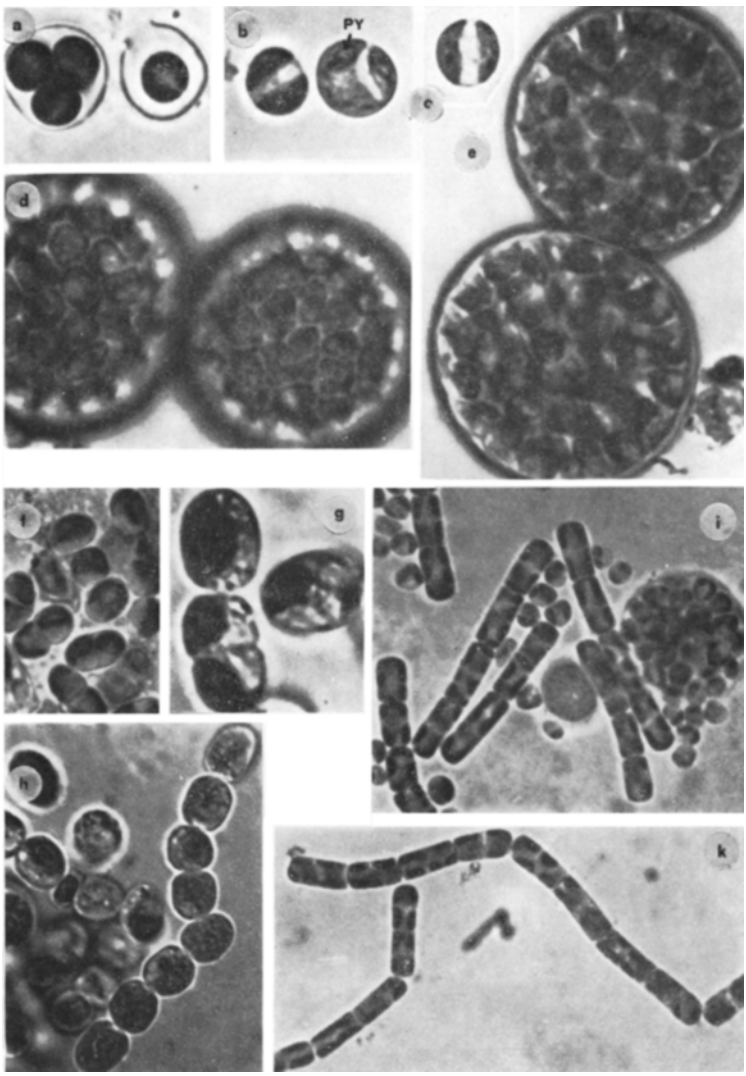
Dumps from coal-mining in the Most region (Czechoslovakia): a — 1 year old, b — 8 years old, c — about 30 years old; (photo PRACH).



Rare species of coccal green algae found in dump soils: a—d — *Chlorokybus atmophyticus*, e — *Fernandinella alpina*, f—k — *Myrmecia* sp.



Rare species of coccal green algae found in dump soils (cont.): a—d — *Neochloris* cf. *bilobata*, e—h — *Tetracystis dissociata*.



Characteristic species of algae in dump soils: a—e — *Bracteacoccus* cf. *minor*, f—h — *Geminella terricola*, i—k — *Heterothrix debilis* (i — with *Botrydiopsis* sp., liberating of autospores).