

Contribution to the Attached Cyanoprokaryotes from Submersed Biotopes in Sagarmatha National Park (Eastern Nepal)

Jiří Komárek¹ and Masayuki Watanabe²

¹Faculty of Biological Sciences, University of South Bohemia,
Česke Budějovice, Czech Republic

²Department of Botany, National Science Museum,
Tsukuba, 305–0005 Japan

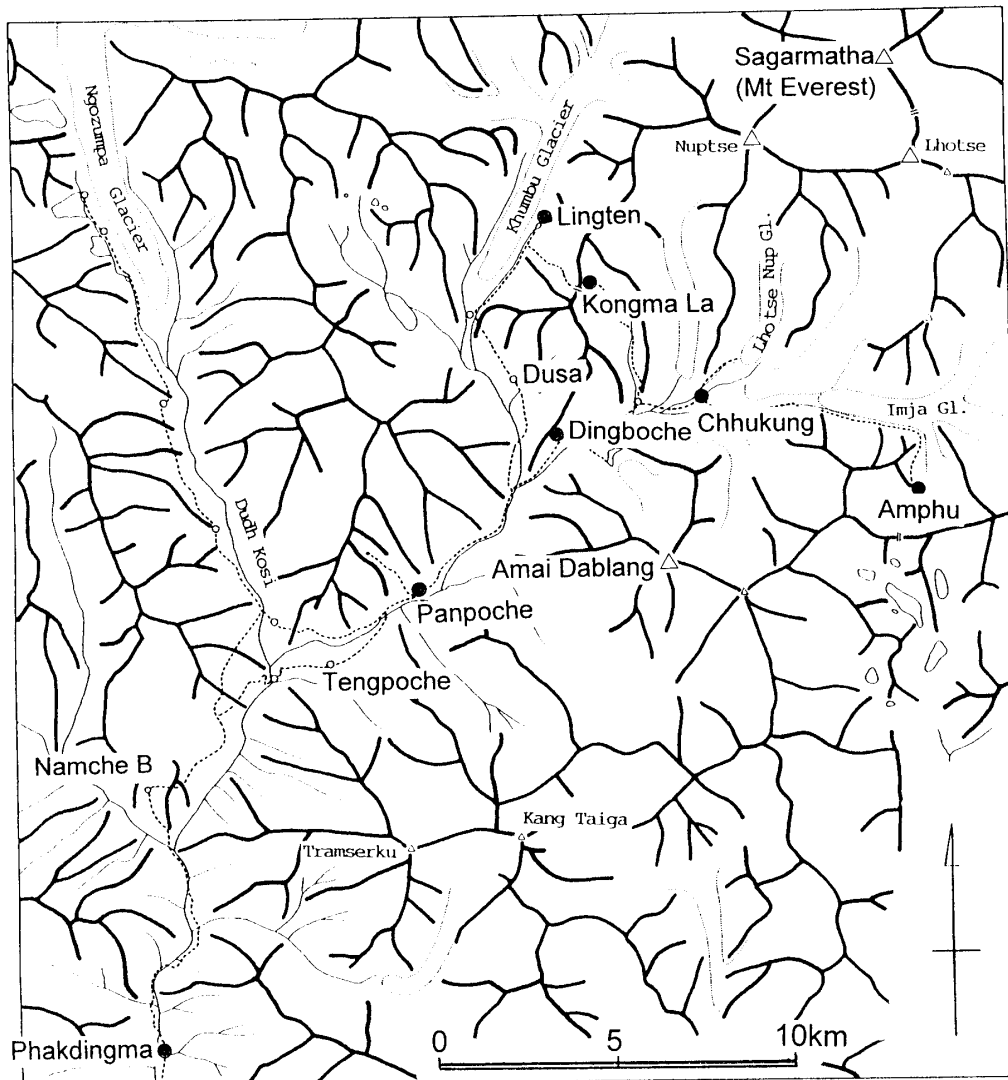
Abstract This article is our third floristic-taxonomic study of cyanoprokaryotes (blue-green algae, cyanophytes, cyanobacteria) of the Kingdom of Nepal. In previous studies (Watanabe and Komárek 1988, 1994) 84 taxa were characterized from wetland biotopes and streams from the Kathmandu Valley and Sagarmatha National Park. The present study describes those species living attached to other algae, to other submersed water plants, or to stony substrates in the same region of Nepal. Fifteen species were registered, from which seven are recognized as not yet described taxa (new species).

Key words: cyanobacteria, cyanophytes, cyanoprokaryotes, Himalaya, Nepal, Sagarmatha National Park.

The Botanical Expedition to the Himalayas was organized by the National Science Museum, Tokyo from October 1 to December 22, 1980. Samples of freshwater algae were collected by the second author (Watanabe), particularly in the region of Sagarmatha (Mt. Everest) National Park, at 2700 to 5300 meters a.s.l. in Eastern Nepal. This material was elaborated and published in several papers (Watanabe & Komárek, 1988, 1989, 1994; Komárek & Watanabe, 1990). This article reviews cyanoprokaryotic species, recognized in samples with periphytic (epiphytic and epilithic) communities from microbiotopes with streaming and stagnant water in the area mentioned.

Numerous species were found in our samples, that are not commonly known or published in previous articles. Several taxa can be compared with species known from Nepalese and Chinese mountainous areas (Kusel-Fetzmann 1969, Chu *et al.* ed., 1991). However, we did not find any species that have been recorded from the central Himalayas, e.g., by Srivastava (1967) and Jao *et al.* (1974). However, all these papers (including our results) show that the cyanoprokaryotic microflora of the Himalaya mountains have specific character and comprise numerous distinct, alpine species, of which several are probably endemic to this region.

It is interesting that several similar species such as those in samples from Sagar-



Text-fig. 1. Map of the studied area (Sagarmatha National Park, eastern Nepal).

matha National Park have been found in mountainous areas of the Hokkaido islands. For example, our population of *Chamaesiphon* cf. *minimus* corresponds well to *Chamaesiphon minutus* presented by Watanabe *et al.*, 1984, and also the morphology and dimensions of *Clastidium setigerum* (l.c.) correspond more closely to our *C. nepalense* than to the original description of *C. setigerum*.

The area, localities and collection methods are described in Watanabe & Komárek (1994; comp. Text-Fig. 1 – map of studied area). All specimens were deposited in the herbarium of the Department of Botany, National Science Museum, Tokyo (TNS), including the type specimens.

Results

1. *Aphanocapsa* sp. [cf. *Aphanocapsa muscicola* (Menegh.) Wille 1919?] (Plate I: 1–3)

Colonies microscopic up to macroscopically recognizable, with homogeneous, fine, colorless slime, diffuent or finely delimited at the margin, irregular. Cells pale grayish blue or olive-green, 1.2–3 μm in diameter, spherical, hemispherical after division, without recognizable inclusions in light microscope, sometimes with indistinct granules.

Localities: Collected in four localities in a small stream at Phakdingma (2600 m a.s.l.), in the littoral of Lake Lingten by the Khumbu Glacier (4920 m a.s.l.), and in a stream near the route from Chhukung to Amphu (4990 m a.s.l.).

Comments: This species grows benthic and epilithic in high mountain streams. It is morphologically most similar to the subaerophytic *A. muscicola* (Menegh.) Wille (= ?*A. montana* Cramer, 1862), which has, however, slightly larger cells, or to *A. rivularis* (Cram.) Rabenh. 1865. They include numerous morphotypes in mountain subaerophytic or water biotopes, and their taxonomic identity must be solved.

2. *Chamaesiphon* cf. *jaoi* Hällfors 1982 [syn.: *C. clavatus* Jao 1939] (Fig. 1, Plate I: 4)

Cells attached solitary to filamentous algae, heteropolar, more or less cylindrical, sometimes slightly narrowed to the basis and widened towards ends, grayish or pale blue-green, with exocytes in rows, 10 (13.2) μm long and 2.5–3 μm wide, rounded at the apex.

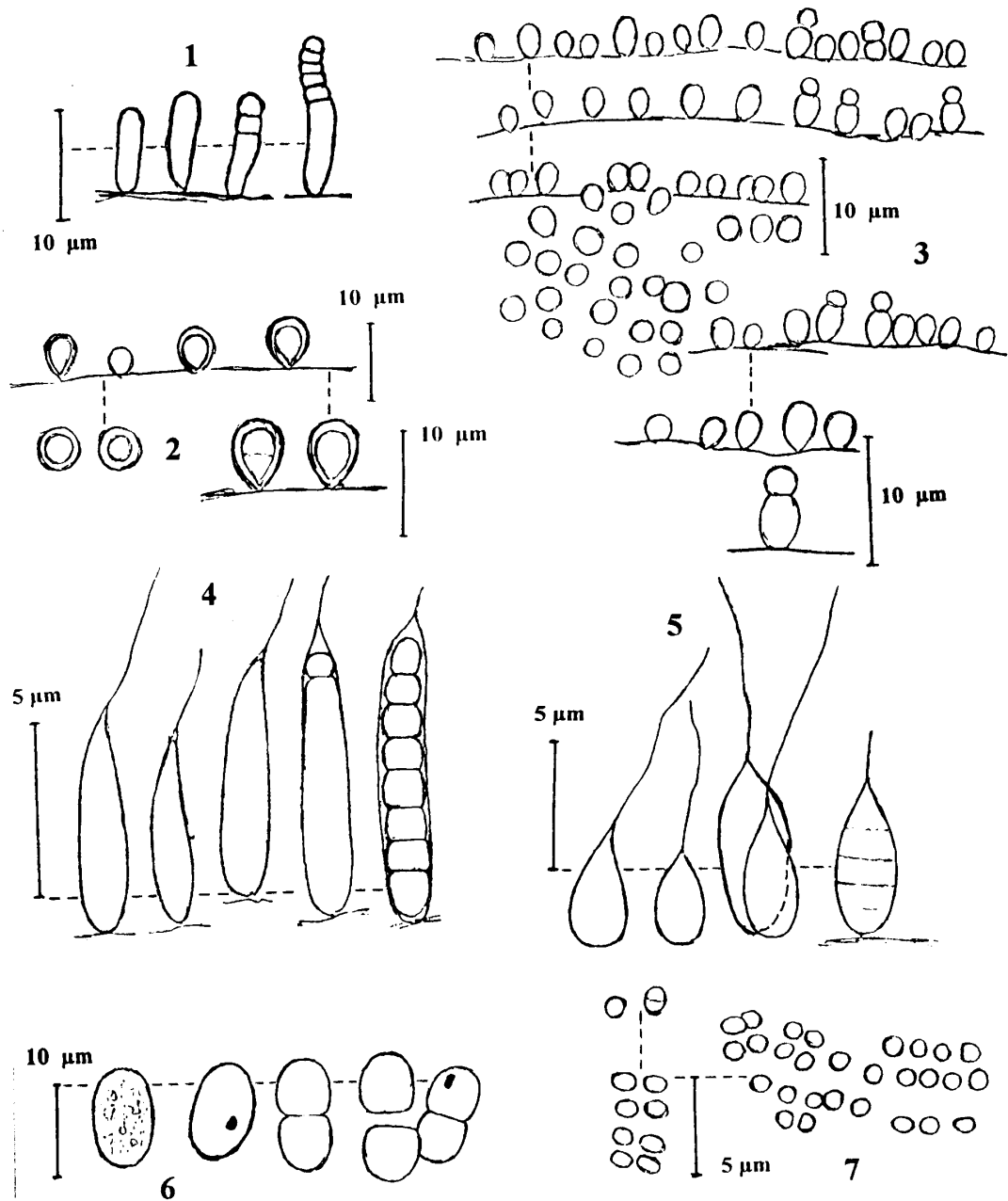
Locality: Well developed cells were found only in one locality, in a small stream above the small lake near Amai Dablang (4650 m a.s.l.).

3. *Chamaesiphon* cf. *minus* Schmidle 1902 (Fig. 2, Plate I: 5–8)

Cells attached solitary on filamentous algae, or in groups, but distant slightly one from another, small, obovoid, widely rounded at the apex, slightly narrowed to the base, spherical from above. Sheaths are a little distant from the cells, firm, thin, brownish. Cells with pale grayish-blue content, 5×3 , with sheath $6.5 \times 5 \mu\text{m}$. Reproduction was observed very rarely: the first division is horizontal, more or less in the middle of the cell, but the further development of exocytes (or baeocytes?) was not well recognized. It seems, that the daughter cells liberate completely from the sheath (the empty cup-shaped remnants of the sheath are visible on the filamentous host algae).

Localities: On filamentous algae in a small stream from above the lake situated NNW of Amai Dablang, 4650 m a.s.l., and from a pond near a stream ENE of Kongma La, 5300 m a.s.l.

Comments: The morphology of our population is very simple and resembles



Figs. 1–7. 1 – *Chamaesiphon* cf. *jaoi*, two cells with exocyste differentiation; 2 – *Chamaesiphon* cf. *minimus*, cells with distinct sheaths, but without exocyste formations; 3 – *Chamaesiphon* *palsashtiae*; 4 – *Clastidium* *nepalense*, thin and small individual cells, left cells with exocyste differentiation; 5 – *Clastidium* cf. *sicyoideum*; 6 – *Cyanobacterium* *epiphyticum*, individual cells with single backish granules; 7 – *Mantellum* *himalayense*, groups of sessile cells from above.

mainly the small *Chamaesiphon minimus*, originally described from tropical Africa. However, it has larger cells, brownish colored sheaths and absence of a pad. The ecology does not correspond to tropical waters. Reproduction was not well recognized, and the development of a few baecocytes (instead of exocytes) is also possible. In this case, classification into the genus *Dermocarpella* would seem suitable.

4. *Chamaesiphon palssahtiae* spec. nova (Fig. 3, plate II: 1–3)

Cells attached to filamentous algae and cyanoprokaryotes, sometimes in masses, but the cells are always slightly distant one from another, drop-shaped up to slightly club-shaped, rounded at the apex, 1.2–4.8 μm long and 1–2.8 μm wide, pale grayish blue-green. Exocytes develop only singly at the apex, always a little narrower than the cell, more or less 1 μm in diameter.

Localities: Common species, mainly in flowing waters; e.g., in a small stream above the lake near Amai Dablang, 4650 m a.s.l. (on *Spirogyra*), in a stream along the route from Chhukung to Amphu, 4770 m a.s.l. (on *Coleodesmium*), in a pond above a stream near Kongma La, 5300 m a.s.l. (on *Coleodesmium*), and in Lake Lingten by the Khumbu Glacier, 4920 m a.s.l.

Comments: This species is mostly similar to *Chamaesiphon minimus* Schmidle, from which it differs by having more rounded, drop-like mother cells. *Chamaesiphon minutus* and *Dermocarpa parva*, both in the sense of Chu *et al.* ed. (1991) (excluding the type), are possibly identical with our species. The species is named after the legendary Nepalese princess.

5. *Chlorogloea* cf. *microcystoides* Geitler 1925 (Plate III)

Colonies up to 1 mm in diameter, with densely agglomerated cells, in marginal parts in short, indistinct rows. Cells pale blue-green, more or less spherical to slightly irregular-rounded. 1.5–3 μm in diameter. Sheaths around cells firm, yellowish-brown.

Localities: In the littoral (epilithic) of a small pond NW of Pangpoche (4550 m a.s.l.) and in a small lake NNW of Amai Dablang (4650 m a.s.l.).

Comments: Our populations are not quite identical with this species, but particularly young colonies resemble the typical populations of *Chlorogloea microcystoides*, described from the European Alps. The old colonies are similar also to the recently described monotypic genus *Cyanoarbor* Wang (with the type species *C. rupestris*), which, however, has larger cells, forms macroscopic colonies and grows sub-aerophytically on moist rocks in China.

6. *Clastidium nepalense* spec. nova (Fig. 4, Plate II: 4)

Cells heteropolar, cylindrical, slightly narrowed towards ends and pointed; the sheath elongated from the apex into a very fine and short hair, which is 1–3.2 μm long. Sheaths very fine, colorless, attached to the cell. Cells with homogeneous, grayish blue-green or slightly greenish content, to 7.5 μm long (exceptionally, with differ-

entiated protoplast into exocytes, up to $8.5\ \mu\text{m}$ long), and $1\text{--}1.5\ \mu\text{m}$ wide. 1 to 8 exocytes arise from one protoplast.

Localities: Epiphytic on filamentous algae and cyanoprokaryotes, common in a small pond near Pangpoche, 4550 m a.s.l., in a pond near Kongma La, 5300 m a.s.l., and in Lake Lingten by the Khumbu Glacier, 4920 m a.s.l.

Comments: Together with *C. cf. sicyoideum* (but sometimes also in separate localities) occurs a *Clastidium*-type with more cylindrical and narrower cells. This second *Clastidium* is more similar to the cosmopolitan *C. setigerum*, but differs distinctly in the shape and size of cells (*C. setigerum* has $8\text{--}38\times 2\text{--}4\ \mu\text{m}$ large cells). We did not find the transition forms to *C. sicyoideum*. In contrast, this species corresponds habitually to *C. setigerum* sensu Chu *et al.* ed. (1991). These authors present larger dimensions ($9\text{--}15\times 2\text{--}4$), but they are very probably cited from the older identification keys (e.g., from Geitler, 1932) and do not represent the Tibetan populations. We describe therefore the very small and narrow type from the Himalayas as a new species, but the induced size variation of both related species (*C. setigerum* and *C. nepalense*) must be studied in future.

7. *Clastidium* cf. *sicyoideum* Li 1984 (Fig. 5, Plate II: 5–6)

Cells heteropolar, drop-like, ovoid to oval with narrowed and more or less pointed apex, which is elongated in a fine, filamentous hair, $0.8\text{--}6.2\ \mu\text{m}$ long, solitary, or in small groups, but distant one from another. Sheath is very fine, indistinct, attached to the cell, colorless. Cells with homogeneous, pale grayish blue content, to $7.5\ \mu\text{m}$ long, up to $8.8\ \mu\text{m}$ long before the differentiation into exospores, $2\text{--}2.5\ \mu\text{m}$ wide. From one cell maximally 6 exocytes differentiate.

Localities: Epiphytic on filamentous algae, mainly in ponds, e.g. near Pangpoche, 4550 m a.s.l., in Lake Lingten by the Khumbu Glacier, 4920 m a.s.l., etc.

Comments: Our populations correspond almost completely with *C. sicyoideum* (described from Xizang, Tibet) by the cell shape (comp., e.g., Chu *et al.* ed., 1991, fig. 37: 5), but the dimensions are slightly smaller. The populations of *C. rivulare* sensu Chu *et al.* ed. (1991) are also similar to our specimens.

8. *Cyanobacterium epiphyticum* spec. nova (Fig. 6, Plate II: 8)

Cells solitary or in small, loose groups, attached to the leaves of mosses, oval, without mucilaginous envelopes, pale olive-green, with slightly and finely granular content with indistinct striation (keritomy); cells (6.2) $7.5\text{--}12.5\times 6.2\text{--}7.3\ \mu\text{m}$. In several cells single prominent, irregularly located, dark brown granules. Cell division is always symmetrical binary fission, crosswise to the longer cell axis.

Localities: Epiphytic on mosses, studied from two samples collected under a cliff with dripping water at Phakdingma, 2700 m a.s.l.

Comments: Oval cells of this species correspond well with generic features of the recently defined genus *Cyanobacterium* (solitary oval cells, cell division, struc-

ture of protoplasts). However, the dimensions and ecology of our species differ from all species, included in this genus (comp. Komárek *et al.* 1998).

9. *Fortiea* sp. (Fig. 9, Plate IV: 3–4)

Filaments solitary or in small, loose groups, straight or simply curved, unbranched, 6.2–6.5 μm wide along the whole length. Sheaths firm, finely lengthwise striated, colorless, about 1 μm wide, open at the end. Trichomes slightly narrowed at the base, continually slightly widened towards ends, at the base cylindrical, not constricted at cross-walls, with cells shorter than wide in young trichomes, but later elongated, up to 1.7 \times longer than wide and distinctly narrower than the upper part (about 4 μm wide); the cells are towards ends more or less isodiametric or slightly shorter than wide towards ends, barrel-shaped, forming a moniliform apical part with distinct constrictions at cross-walls, 4.5–5.2 μm wide. Apical cells spherical-rounded. Cells with olive-green, very finely granular content. Heterocytes basal, more or less spherical, hemispherical or slightly elongated and rounded at the basal ends, with more or less hyaline content, usually within the sheath, 4.5–6 μm wide. Akinetes not observed.

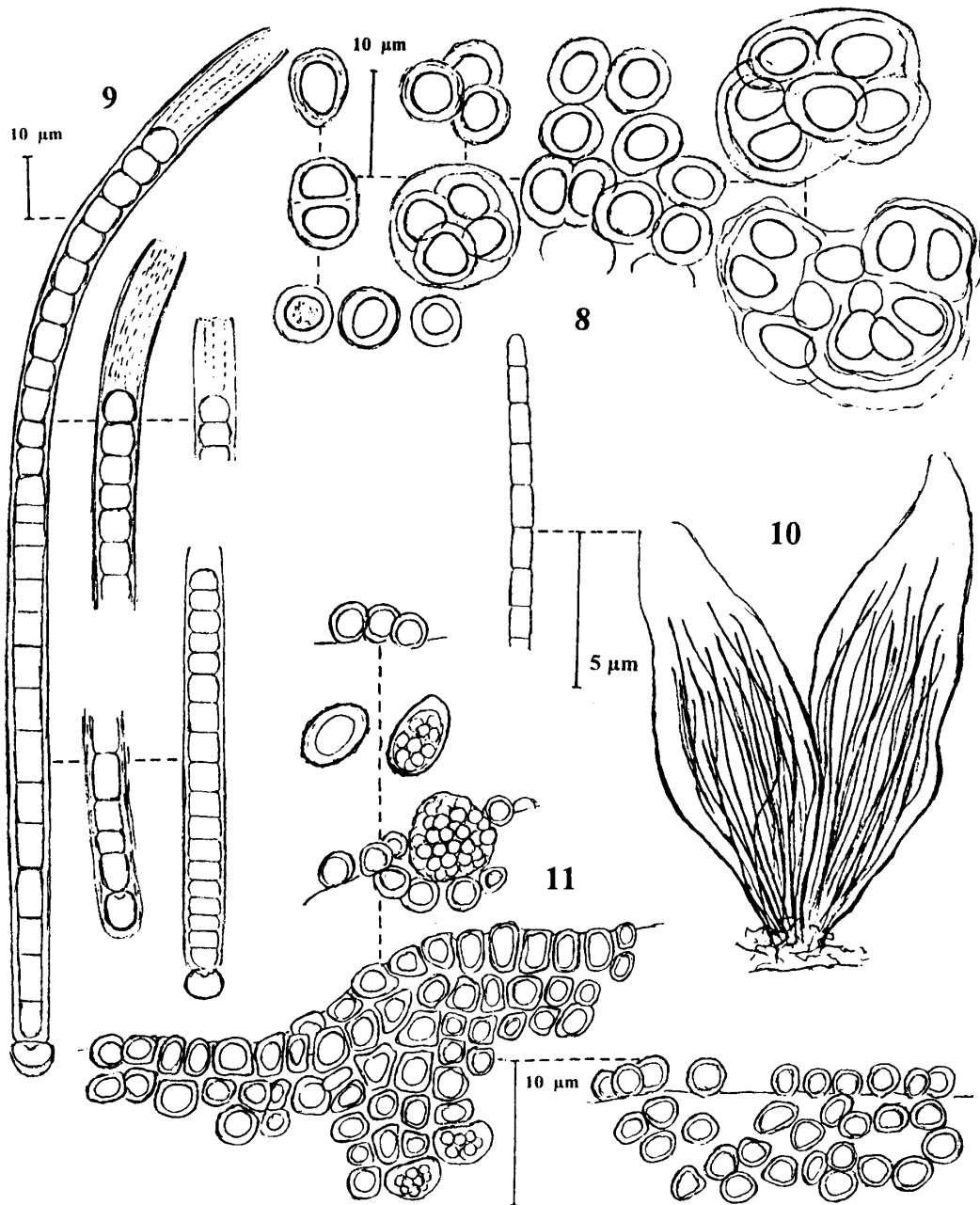
Localities: Epiphytic on leaves of subaerophytic mosses, growing on wet mountain rocks and cliffs with dripping water. Collected near Phakdingma, at about 2700 m a.s.l.

Comments: The slightly widened and moniliform trichome ends and narrowed bases classify this species as the genus *Fortiea*, in which the species *F. monilispora* Kom. 1984 from tropical swamps in Cuba is morphologically mostly related. However, it differs slightly by smaller dimensions, narrower and colorless sheaths, and by ecology. The widening towards ends is not very distinct in Nepalese populations. Our samples represent probably a separate species, but we have studied only few specimens and the final taxonomic solution remains open. The taxonomy of this species must be solved together with specimens, designated by us previously like *Microchaete* cf. *aequalis* and *Fortiea* sp., found in the same area (Watanabe & Komárek, 1994).

10. *Gloeocapsopsis ferruginea* spec. nova (Fig. 8, Plate II: 7)

Cells always enveloped by firm sheaths, solitary or in aggregated irregular groups, attached to the filamentous algae. Cells more or less spherical, irregularly rounded, after division more or less hemispherical, pale grayish blue-green, with finely and indistinctly granular content, (2) 3–5 (6.3) μm in diameter. Sheaths thick, firm, distinct, smooth from outside, usually intensely yellowish-brown; cells with sheaths 5–9.5 μm in diameter: usually arise packet-like colonies to 20 μm in diameter. Cell division irregular.

Localities: On filamentous algae in a small lake NNW of Amai Dablang, 4650 m a.s.l.



Figs. 8–11. 8 – *Gloeocapsopsis ferruginea*, small groups of ensheathed cells; 9 – *Fortiea* sp.; 10 – *Schizothrix flammea*, with detail of a trichome (terminal part); 11 – *Xenococcus luteo-violaceus*, with cells differentiating in baeocytes.

Comments: The morphology and structure of colonies correspond with the genus *Gloeocapsopsis*. It is, up to now, the only species of this genus with sheaths with ferric precipitates.

11. *Mantellum himalayense* spec. nova (Fig. 7, Plate IV: 2-arrows)

Cells solitary or agglomerated in one layer, attached to the substrate, more or less spherical; arranged in short, irregular rows, pale grayish-blue, 0.5–1 (before division up to 1.3) μm in diameter. Cell division by binary fission, perpendicularly to the substrate, in two planes in successive generations.

Localities: Epiphytic on filamentous algae in a stream along the route from Chhukung to Amphu, 4770 m a.s.l.

Comments: The third species of this genus. Differs from the marine *M. adherens* by ecology and by smaller dimensions, and from the reddish *M. rubrum* from volcanic lakes in Mexico by color of cells and ecology.

12. *Schizothrix flamma* spec. nova (Fig. 10, Plate IV: 1, 5)

Filaments nearly fusiform, up to 125 μm long, attached to the substrate by basal ends, enveloped by firm, delimited, yellow-brown sheaths, which are colorless at the apical ends. Trichomes fasciculated, more or less parallel, cylindrical, very thin, 0.5–0.8 μm wide, pale grayish-blue, not constricted or very slightly constricted at the cross walls. Cells 1.2–2 times longer than wide, apical cells cylindrical, rounded at the ends.

Localities: Epiphytic and metaphytic among other algae in Lake Lingten by the Khumbu Glacier, 4920 m a.s.l.

Comments: Very fine species, which does not correspond either morphologically or ecologically to any other known *Schizothrix* species.

13. *Stigonema* sp. (Plate IV: 6–9)

Old filaments up to 140 μm wide, branches only 34–40 μm wide. Heterocytes were not developed, sheaths around cells intensely yellow-brown, lamellated. Cells (3.7)–5–(7.5) μm in diameter.

Localities: Periphytic in a small pond NW from Pangpoche, 4550 m a.s.l. and on mosses growing on rocks in a stream ENE of Kongma La, 5300 m a.s.l.

Comments: This species seems to be characteristic for submersed localities in the central Himalayas. However, it does not correspond precisely to any described *Stigonema* species. The taxonomic position is not identifiable and is complicated by the absence of heterocytes in our samples. The taxonomic classification of this species remains to be solved by future studies.

14. *Tolypothrix* sp. (Plate V)

Filaments cylindrical, more or less 7.5 μm wide. Trichomes not constricted at cross walls, sparsely branched, more or less 5.5 μm wide. Cells always shorter than wide. Sheaths yellow-brown, slightly lamellated. Heterocytes more or less isodiametric, quadratic, more or less 7.5 μm wide, intercalary or in basal position and rounded at the basal end.

Localities: Periphytic and among algae in a small pond NW of Pangpoche, 4500 m a.s.l.

Comments: Similar situation as the previous *Stigonema*. Not identifiable, slightly different from well described species. More material is needed for resolving the taxonomic position.

15. *Xenococcus luteo-violaceus* spec. nova (Fig. 11, Plate VI)

Cells in groups or densely aggregated, forming monolayer on the surface of filamentous algae, arranged irregularly, rarely in indistinct rows. Cells rounded or polygonal rounded, pale grayish blue-green or slightly violet, with homogeneous or slightly and finely granular content, 1.5–3.8 (5) μm in diameter, enveloped by firm, thick, yellow-brown sheaths; cells with sheaths 3.7–6.3 (7) μm in diameter. Reproduction by irregular binary fission and with baeocytes; the cells increase before the baeocyte formation up to the diameter 8.8 (10) μm ; baeocytes are small, more or less spherical, about 1–1.5 μm in diameter, clusters of baeocytes inside the mother sheath up to 15 μm in diameter.

Localities: Common species, growing epiphytically in submerge biotopes with stagnant water. It was found in two samples from a small pond NW of Pangpoche, 4550 m a.s.l., in a pond near the stream, situated ENE of Kongma La, 5300 m a.s.l., and in Lake Lingten by the Khumbu Glacier, 4920 m a.s.l.

Comments: The generic features of the genus *Xenococcus* were revised by Gold-Morgan *et al.* (1994). Our new species corresponds well to their generic diagnoses, but differs greatly from all species described to date by morphology (particularly, yellow-brown sheaths) and by ecology.

Diagnoses

Chamaesiphon palssahtiae spec. nova: Cellulae cyanoprocaryoticae solitariae vel seriatis et in grupos laxos aggregatae, heteropolaris, basim ad substratum adherentes, obovoideae vel guttaeformis, apice late rotundatae, basim paulum attenuatae, ad 4.8 μm longae, ad 2.8 μm latae, cum vagina tenui, hyalina; cellulae contentu pallescente aeruginoso, homoganeo. Divisio cellularum in parte apicali; exocytas solitariae subsphaericae, pulse minusve 1 μm in diametro. – Typus: lamina vitrea no. 51792 (TNS); icona typica figura nostra 3. – Habitatio: Epiphytice ad cyanoprocaryotis algisque, praecipue in aquis fluentibus; locus classicus: rivulus prope Amai Dablang, Montes Emodi, Nepalia.

Clastidium nepalense spec. nova: Cellulae cyanoprocaryoticae solitariae, basim ad substrato adherentes, plus minusve cylindraco-ovoideae, basim rotundatae, ad apices subacutae et cum filo hyalino elongatae, ad 3.2 μm longo; cellulae ad 7.5 (8.5) μm longae, ad 1.5 μm latae, contentu pallescente griseo-aeruginoso, homoganeo. Teg-

mentum tenue, hyalinum. Propagatio exocytis seriatim dividuntur. – Typus: lamina vitrea no. 51782 (TNS); icona typica: figura nostra 4. – Habitatio: Epiphytice ad cyanoprocaryotis algisque submersis; locus classicus: lacus prope Pangpoche, Montes Emodi, Nepalia.

Cyanobacterium epiphyticum spec. nova: Cellulae solitariae vel laxa aggregatae, substrato irregulariter adherentes in strato uno, ovaes, apicibus late rotundatis, sine mucilage, $6.2\text{--}12.5 \times 6.2\text{--}7.3 \mu\text{m}$, perpendiculariter in partes aequales et perpendiculariter ad substrato dividuntur, contentu pallescente olivaceo-verdoso vel aeruginoso, longitudinaliter indistincte striato, saepe cum granulis solitariis. – Typus: lamina vitrea no. 51774 (TNS); icona typica: figura nostra 6. – Habitatio: Ad muscos subaerophyticis; locus classicus: prope Phakdingma, Montes Emodi, Nepalia.

Gloeocapsopsis ferruginea spec. nova: Coloniae microscopicae, irregulares. Cellulae rare solitariae, praecipue in coloniis irregularibus multicellularibus aggregatae, subsphaericae vel irregulariter rotundatae, $6.2\text{--}12.5 \mu\text{m}$ in diametro, contentu pallescente griseo-aeruginoso, paucim granuloso. Tegumenta mucilaginosa firma, lata, luteo-brunescentes. Divisio cellularum irregulariter in partes duas. – Typus: lamina vitrea no. 51790 (TNS); icona typica: figura nostra 8. – Habitatio: Epiphytice ad algas submersas lacu prope Amai Dablang, Montes Emodi, Nepalia.

Mantellum himalayense spec. nova: Cellulae cyanoprocaryoticae, plus minusve sphaericae, $0.5\text{--}1.3 \mu\text{m}$ in diametro, contentu pallescente aeruginosae, homogaeo, substrato adherentes in strato uno, plus minusve ad lineas curtas ordinatae. Divisio cellularum fisione in partes duas, perpendiculariter ad substrato, in planos duas perpendiculares in generationis successivis. – Typus: lamina vitrea no. 51797 (TNS); icona typica: figura nostra 7. – Habitatio: Epiphytice ad algas filamentosas in aquis fluentibus prope Chhukung, Montes Emodi, Nepalia.

Schizothrix flammea spec. nova: Filamenta ad $125 \mu\text{m}$ longa, fusiforme inflata, lata, ad apices attenuata et plus minusve acuta, cum trichomatibus numerosis, plus minusve dense paralleliter consociatibus, paucim irregulariter flexuosis. Vaginae mucilagosae paucim amplae, limitatae, luteo-brunescentes. Trichoma simplia, cylindracea, ad dissepimenta not vel paucim constricta, pallescente griseo-aeruginosa, $0.5\text{--}0.8 \mu\text{m}$ lata. Cellulae cylindraceae, ad $2 \times$ longiores quam latae, contentu homogaeo. – Typus: lamina vitrea no. 51813 (TNS), icona typica: figura nostra 10. – Habitatio: Epiphytice metaphyticeque inter algas submersas lacu Lingten, Montes Emodi, Nepalia.

Xenococcus luteo-violaceus spec. nova: Thallus sessilis, cellulis saepe aggregatis, subsphaericis, plus minusve in strato uno compositis. Cellulae ad $1.5\text{--}5 \mu\text{m}$ in di-

ametro, contenu pallescente griseo-olivaceo, griseo-aeruginoso vel paucim violascente, paucim granuloso. Vagina firma, lata, luteo-brunescens. Divisio cellularum perpendiculariter ad substratum, plus minusve asymmetrica; propagatio baeocytis; cellulae matricaliae cum vaginas ad $15\ \mu\text{m}$ in diametro, baeocyta sphaeroidea, $1\text{--}1.5\ \mu\text{m}$ in diametro. – Typus: lamina vitrea no. 51804 (TNS), icona typica: figura nostra 11. – Habitatio: Epiphytice ad cyanoprocaryotis algisque in aquis stagnantibus; locus classicus: lacus prope Kongma La, Montes Emodi, Nepalia.

References

- Chu, H., W. Zhu, & Y. Li, 1991. Chroococcophyceae. In H. Chu (ed.), Flora algarum sinicarum aquae dulcis II, 161 pp. Science Press.
- Desikachary, T. V., 1959. Cyanophyta. Indian Counc. Agric. Res. Monographs. 686 pp. New Delhi.
- Geitler, L., 1932. Cyanophyceae. In Rabenhorst's Kryptog.-Fl. **14**: 1196 pp. Leipzig.
- Jao, C.-C., 1939. Studies on the freshwater algae of China IV. Subaerial and aquatic algae from Nanyoh, Hunan. *Sinensia*, **10**: 161–239.
- Jao, C.-C., H.-Z. Zhi & Y.-Y. Lee, 1974. Algal flora of the Mt. Jolmo Lungma region, Tibet. Rep. Results Exped. Jolmo Lungma Region in 1966–1968, pp. 91–126. Science Press.
- Gold-Morgan, M., G. Montejano, & J. Komárek, 1994. Freshwater epiphytic cyanoprocaryotes from central Mexico II. Heterogeneity of the genus *Xenococcus*. *Arch. Protistenk.*, **144**: 383–405. Jena.
- Hällfors, G. & R. Munsterhjelm, 1982. Some epiphytic Chamaesiphonales from fresh and brackish water in southern Finland. *Ann. bot. Fennici*, **19**: 147–176.
- Komárek, J., 1984. Sobre las cianoficeas de Cuba 1, 2. *Acta bot. cubana*, **18**: 1–30.
- Komárek, J. & M. Watanabe, 1990. Morphology and taxonomy of the genus *Coleodesmium* (Cyanophyceae/Cyanobacteria). In M. Watanabe & S. B. Malla (eds.), Cryptogams of the Himalayas 2. Central and Eastern Nepal, pp. 1–22. Tsukuba.
- Komárek, J., J. Kopecký & V. Cepák, 1998. The background of taxonomy of the simplest cyanoprocaryotic genera *Cyanobium*, *Cyanobacterium* and *Synechococcus*. *Cryptogamie/Algologie*, Paris, in press.
- Kusel-Fetzmann, E., 1969. Einige Algen aus Nepal. In Khumbu Himal, **6** (1): 37–56. Innsbruck-München.
- Srivastava, P. N., 1967. On some blue-green algae from central Himalayas. *Phykos*, **6**: 110–114.
- Wang C. Z., 1989. *Cyanoarbor*, a new genus of the Entophysalidaceae (Cyanophyta). *Acta Phytotax. Sinica*, **27** (2): 129–131.
- Watanabe, M., M. Haga & T. Ioriya, 1984. Algae in the mountain streams of the Satsunai River 2. Notes on blue-green algae. *Jap. J. Phycol.*, **32**: 60–64.
- Watanabe, M. & J. Komárek, 1988. Blue-green algae from Kathmandu. In M. Watanabe & S. B. Malla (eds.), Cryptogams of the Himalayas 1. The Kathmandu Valley, pp. 1–20. Tsukuba.
- Watanabe, M. & J. Komárek, 1989. New *Blennothrix*-species (Cyanophyceae/Cyanobacteria) from Nepal. *Bull. Nat. Sci. Mus., Tokyo*, Ser. B, **15**: 67–79.
- Watanabe, M. & J. Komárek, 1994. Several Cyanoprocaryotes from Sagarmatha National Park, Nepal Himalayas. *Bull. Nat. Sci. Mus., Tokyo*, Ser. B, **20**: 1–31.

Descriptions to Plates

- Plate I. 1–3 – *Aphanocapsa* sp. (1=young colony, 3=detail of cells); 4 – *Chamaesiphon* cf. *jaoi* (cells with single exocytes); 5–8 – *Chamaesiphon* cf. *minimus*.
- Plate II. 1–3 – *Chamaesiphon palssahtiae*; 4 – *Clastidium nepalense*; 5–6 – *Clastidium* cf. *sicyoideum*; 7 – *Gloeocapsopsis ferruginea*; 8 – *Cyanobacterium epiphyticum*.
- Plate III. *Chlorogloea* cf. *microcystoides* (comp. also with the genus *Cyanoarbor*, 1=detail of a young colony, 5=old colony, 6=situation of cells inside of a colony).
- Plate IV. 1, 5 – *Schizothrix flamma*, attached colonies with numerous secondary epiphytes; 2 – *Mantellum himalayense*, colonies from the top view (arrows); 3–4 – *Fortia* sp., the identical trichome with various focusing; 6–9 – *Stigonema* sp., parts of branched filaments in various magnification (5=young branch, 8=habit of the branched filament).
- Plate V. *Tolypothrix* sp., details of terminal and intercalary parts of filaments (4 and 9 =characteristic branching).
- Plate VI. *Xenococcus luteo-violaceus*, rich agglomerations of epiphytic cells (5= cells differentiating in baeocytes are marked by arrow).

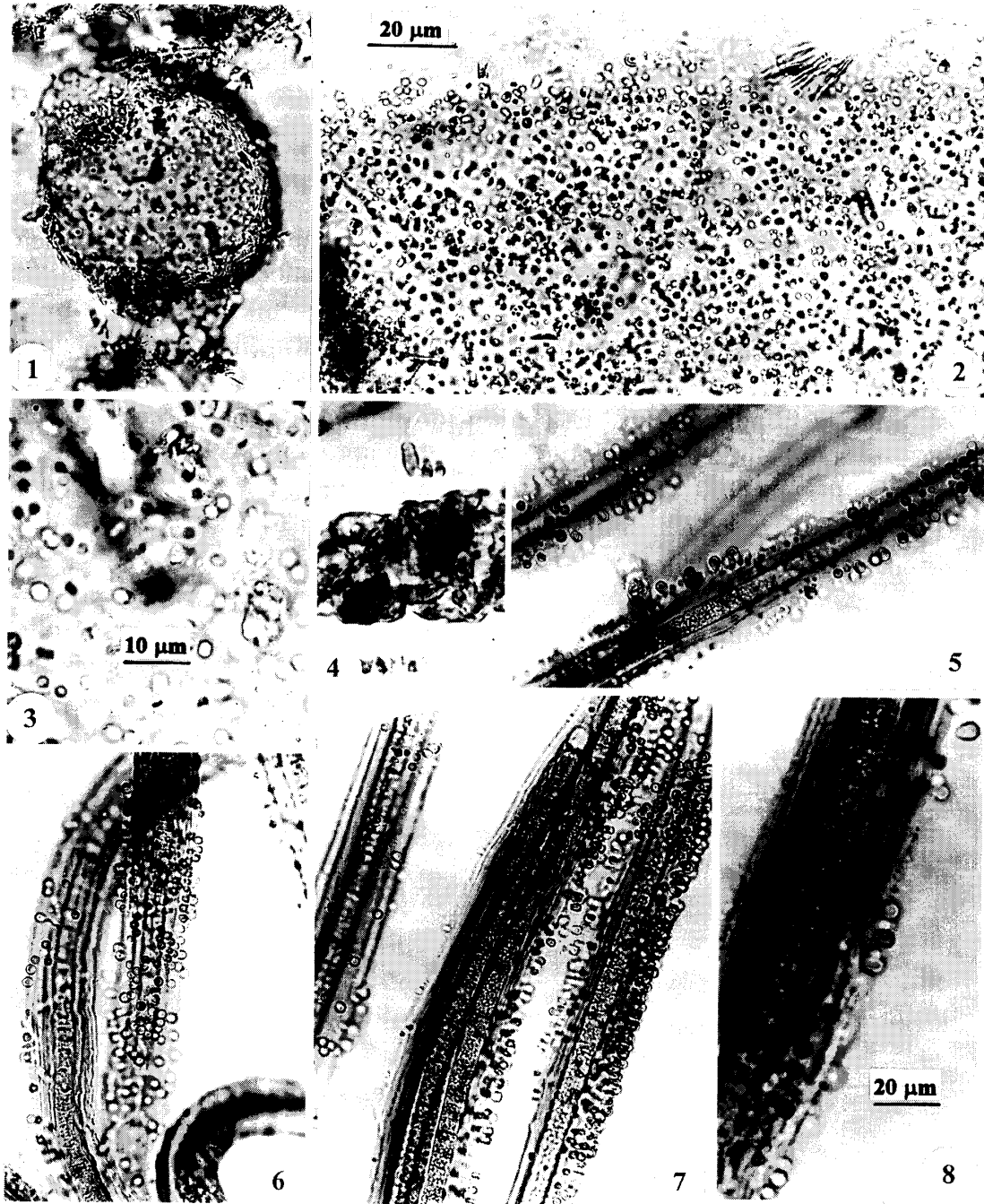


Plate I

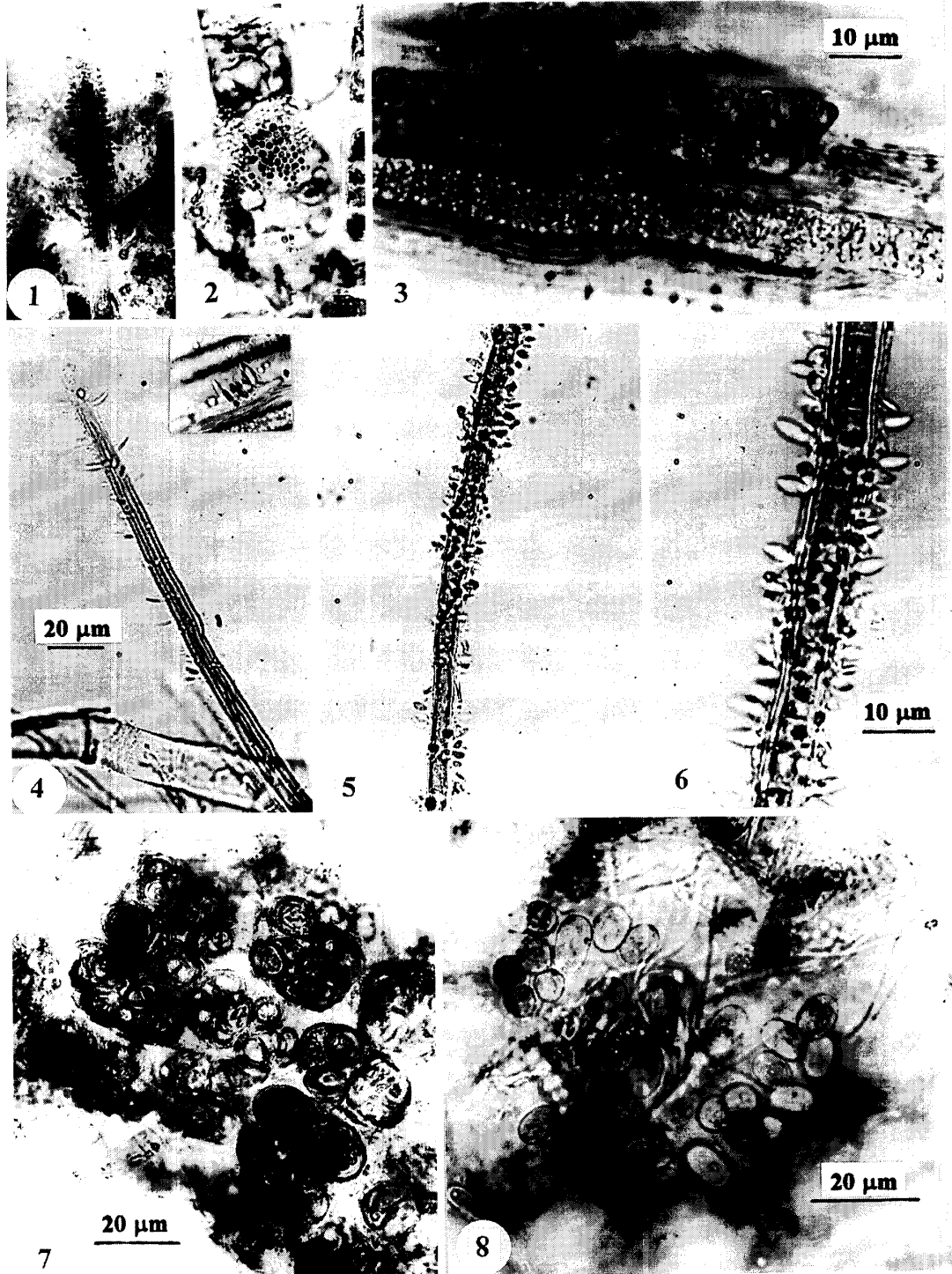


Plate II

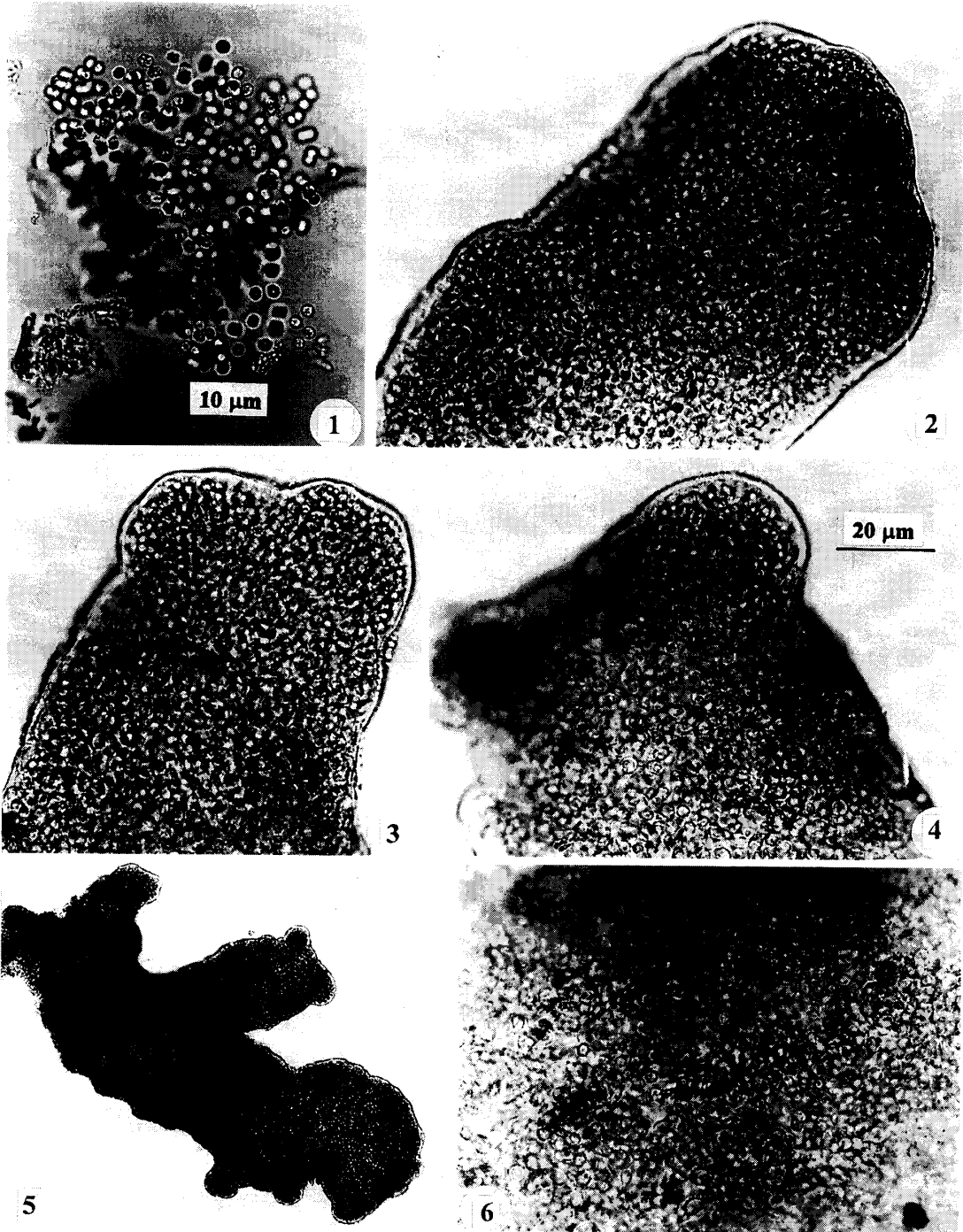


Plate III

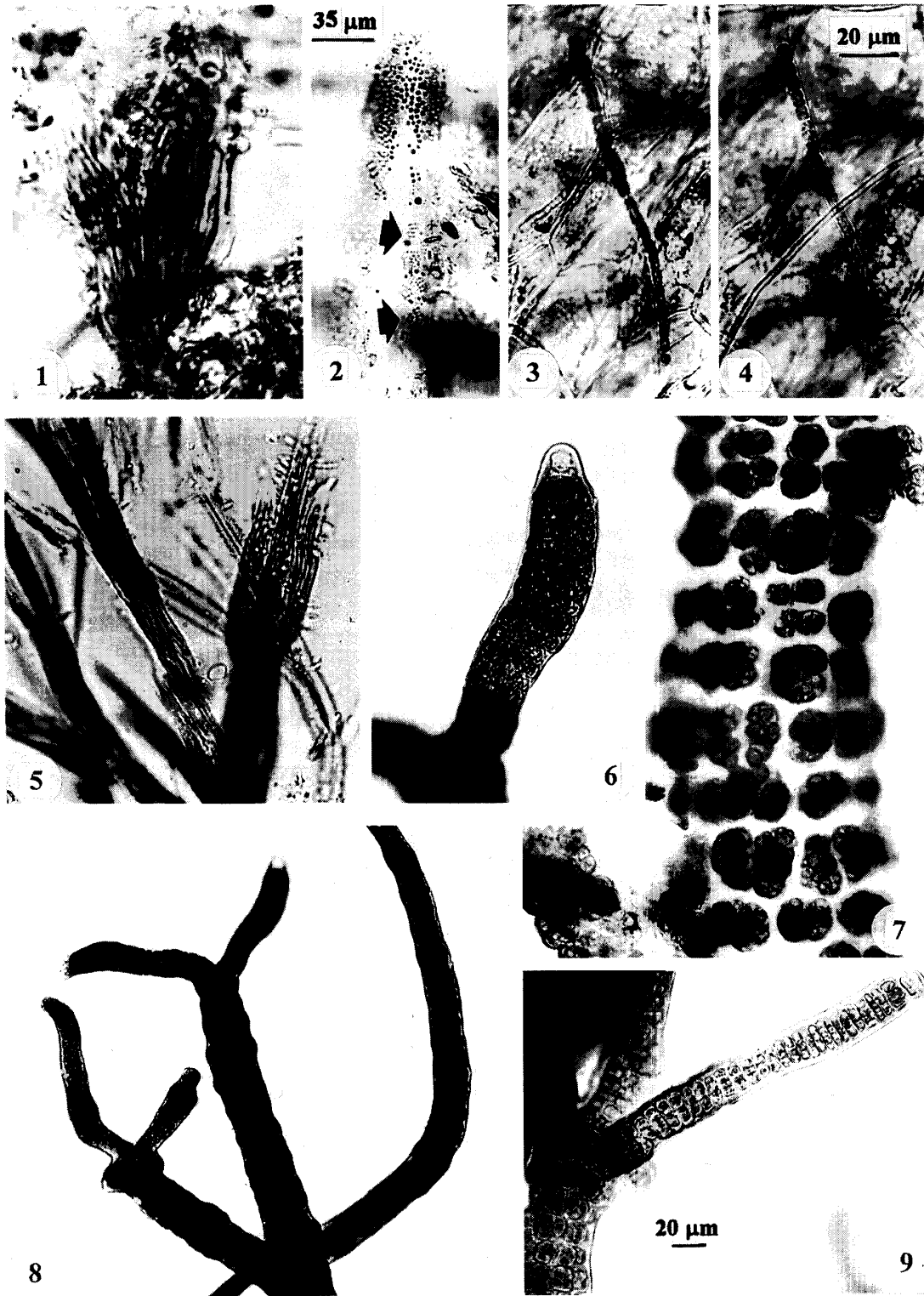


Plate IV

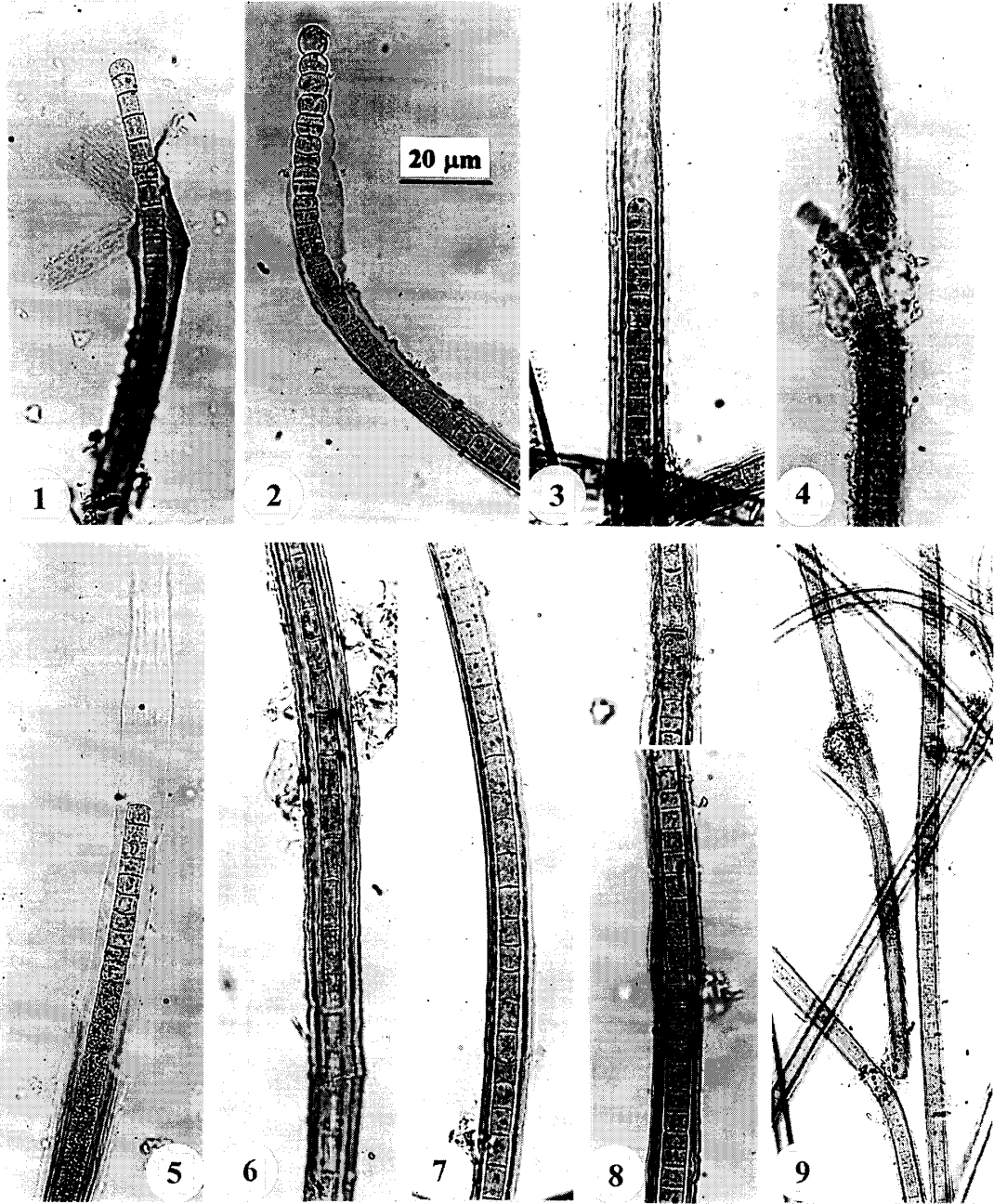


Plate V

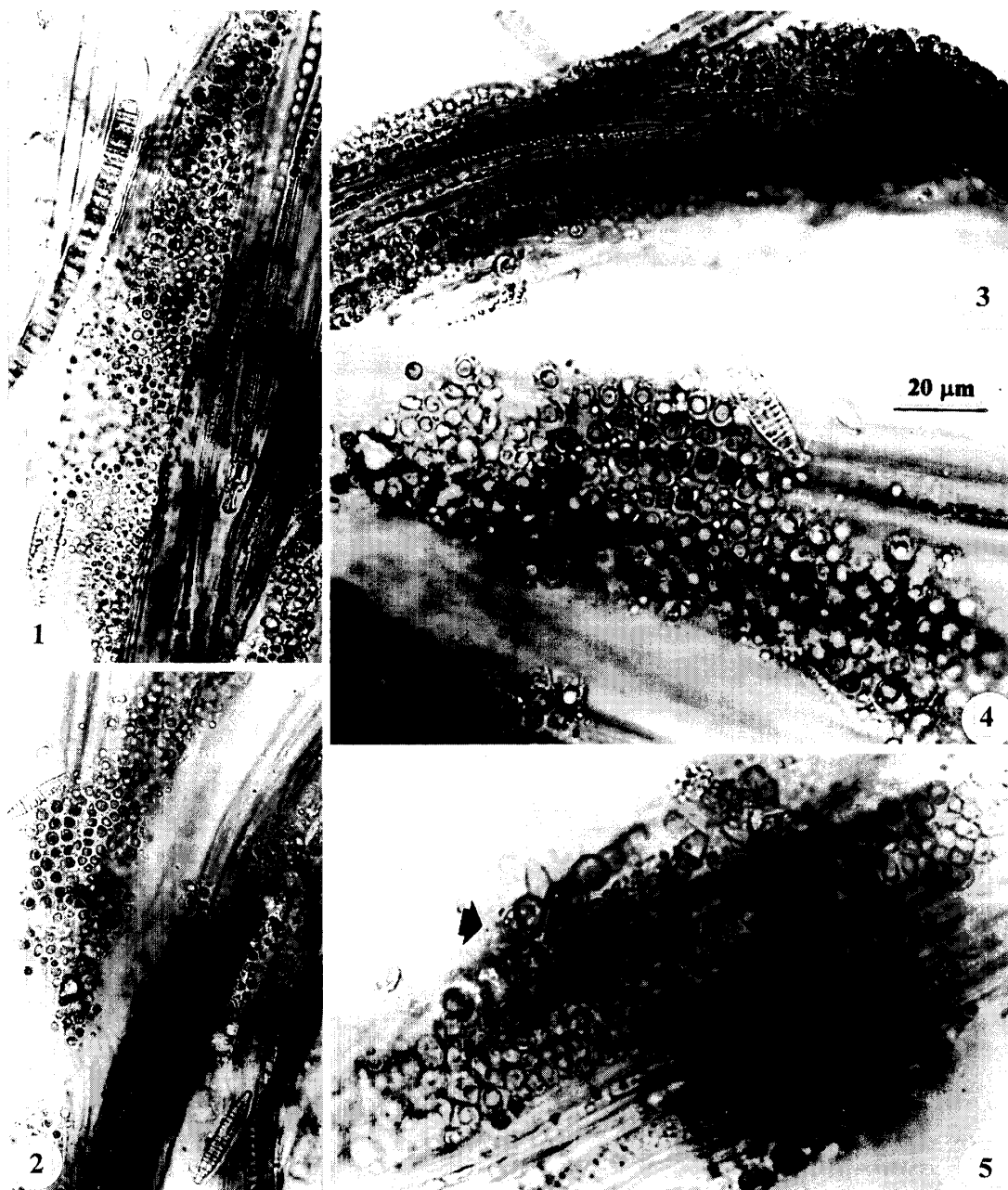


Plate VI