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Some little known Hydrococcaceae (Cyanoprokaryota) from Central Mexico

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With 22 figures in the text

Abstract: The little known genera of Hydrococcaceae *Cyanodermatium*, *Placoma* and *Hydrococcus* are well represented in the epilithic and epiphytic flora of central Mexico. A new marine species of *Cyanodermatium*, *C. gonzaliensis*, is established and three freshwater populations of the genera *Hydrococcus*, *Cyanodermatium* and *Placoma*, that represent new records for Mexico are studied. The morphological characteristics of the development of the thalli in several species of the three genera from populations from both marine and continental habitats are described. These genera differ among each other, in the pattern of cell division and growth that result in a characteristic organization of the pseudofilaments and therefore in the shape of the colonies.
The proposal made by KOMÁREK & ANAGNOSTIDIS (1998) to separate these genera that do not produce baeocytes from those included in the family Hyellaceae to which they are similar in their pseudofilamentous organisation is supported.

Key words: Cyanoprokaryota/Cyanobacteria/Cyanophyceae, Hydrococcaceae, *Hydrococcus*, *Cyanodermatium*, *Placoma*, taxonomy, lotic habitats, marine, new species, new report, central Mexico.

Introduction

The family Hydrococcaceae is characterised by colonies with hemispheric, irregular spherical or irregular clusters of cells disposed in pseudofilaments. Cell division occurs by irregular binary fission in different planes, but with at least one stage of development with divisions predominantly in one plane, generally parallel to the subtratum (KOMÁREK & ANAGNOSTIDIS (1998). Reproduction with release of isolated cells or groups of cells. Multiple fission is absent. Previously this family included several pseudofilamentous baeocyte forming species (KOMÁREK & ANAGNOSTIDIS 1986) that are currently included in the Hyellaceae family.

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Few reports exist for most species and in the case of *Cyanodermatium* they have not been reported since their original description. Considering the seven genera included by KOMÁREK & ANAGNOSTIDIS (1998) in this family, three of them – *Hydrococcus*, *Cyanodermatium* and *Placoma* – have been found in the epilithic or epiphytic algal flora of central Mexico.

The genus *Hydrococcus* includes four species, three of them of freshwater habitats and one marine, some of them requiring taxonomic revision (KOMÁREK & ANAGNOSTIDIS 1998). *Cyanodermatium* includes four freshwater species: *C. fluminense* for Europe, and *C. gigas*, *C. gelatinosum* and *C. violaceum* for tropical Indonesia. No marine species have been previously described. *Placoma* species are more numerous (around 10), including marine and freshwater species, some of which need taxonomic revision (KOMÁREK & ANAGNOSTIDIS 1998).

In this study we describe some freshwater populations of the genera *Hydrococcus*, *Cyanodermatium* and *Placoma*, and describe a new marine species of *Cyanodermatium* from central Mexico.

Material and methods

Specimens were obtained from FCME (Faculty of Science Herbarium, Universidad Nacional Autónoma de México). Marine and freshwater samples were examined; they were fixed in 4 % formaline freshwater or 4 % neutralised formaline seawater. Sections of *Cyanodermatium* were made with razor blades and mounted in gelatine and are deposited at FCME slide collection. Observations, photographs and measurements were made using a DIC Olympus BX51 microscope. Comparisons with descriptions and illustrations of other species of *Hydrococcus*, *Cyanodermatium* and *Placoma* were based on bibliography (GEITLER 1932, 1933, GEITLER & RUTTNER 1935, BROADY & INGERFIELD 1991, KOMÁREK & ANAGNOSTIDIS 1998).

Environmental data for some localities are detailed in GOLD-MORGAN et al. (1994) and LEÓN-TEJERA & MONTEJANO (2000). In the description of *Placoma regulare*, recorded for Los Dinamos, D.F. National Park environmental data were included. Acronyms PA, PTM and MA mean particular collections (PA = Panuco Basin; PTM = Mexican tropical Pacific; MA = Rio La Magdalena basin) deposited at FCME.

Results

Hydrococcus cesatii RABENHORST 1860

Microscopic hemispheric, nematoparenchymatous blue-green colonies, more or less circular in outline in upper view. Cells from the periphery grow radially and show an irregular arcuate shape. Central cells are generally irregular polygones. Thalli develop from a single cell, that divides perpendicular to the subtratum, and grows radially during the initial stages (Fig. 1) until a monostromatic and pseudofilamentous more or less circular colony is formed (Fig. 2). In more advanced stages the central cells of the colony, that are the oldest, begin to divide parallel to the subtratum (Fig. 3); neighbouring cells proceed with this pattern of division centrifugally. In advanced stages thalli develop a dome shape (Fig. 3).

Dimensions: colonies up to 50 µm in diameter in upper view. Cells 2–4 µm in diameter and 3–4 µm in length.
Habitat: Found growing in mountain streams, epiphytic on aquatic mosses. Altitude 1,315 m. T=16 °C, pH= 6. FCME-PA 3304 (15/11/92). Tlanchinol, Hidalgo, Mexico.

Our specimen closely resembles the description of this species by GEITLER (1932), This report widens the known geographical distribution of the species.

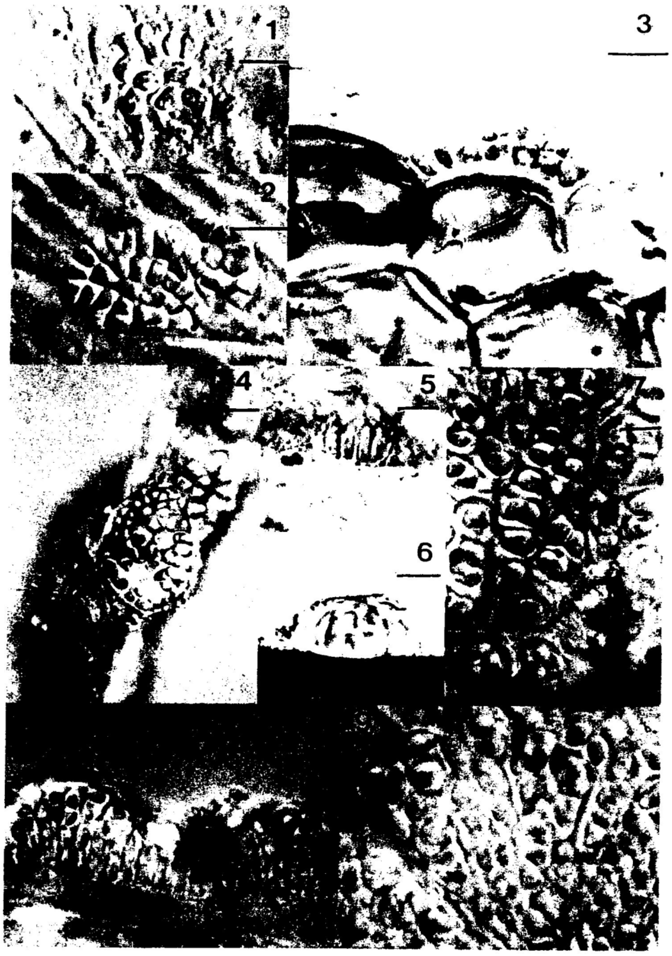
Cyanodermatium cf. *gelatinosum* GEITLER 1933

Thallus a gelatinous, flat, irregularly hemispheric compact blue-green colony (Fig. 4), micro or macroscopic, formed by irregular clusters of parallel arranged divaricated pseudofilaments with mucilaginous envelopes. Thalli developing from individual cells that divide radially, perpendicular to the subtratum in the initial stages (Fig. 5); later divisions are parallel to the subtratum (Fig. 6), forming pseudofilaments commonly divaricated. Cells are usually joined in packages (Fig. 7). The development of colonies from several aggregated cells originates a pseudofilamentous-pseudoparenchimatous thalli (Figs 7–9, 20, 21).
Dimensions: colonies up to 25 µm in height, cells 2–3.5 µm in diameter.
Habitat: Epiphytic on *Basicladia* in a stream close to a spring. T = 21 °C, pH = 7.1. FCME-PA 3919 (01/XII/2000), Huichihuayan, San Luis Potosí, Mexico (21° 33' 15" N, 98° 56' 10" W).

In general our populations coincide with most of the species features. However, our material differs in the cell aggregation in packages (Figs 7, 9, 20) that is not evident in the material described by GEITLER (1933) and GEITLER & RUTTNER (1935) for Java and Sumatra. This species, as far as we know, has not been reported since it was originally described for Indonesia (S. Sumatra) (GEITLER 1933), therefore we can consider that this report confirms the validity of the species and extends its known geographical distribution.

***Cyanodermatium gonzaliensis* spec. nova** (Figs 10–13)

Diagnosis: Thallus coloniis planis gelatinosis quasi microscopicis 60–75 µm crassitudine, viridicaeruleis formans, ex numerosis pseudofilamentis ad substratum perpendiculariter dispositis formatus. Pseudofilamenta uniseriata, vaginis hyalinis incoloribus manifestis instructa, confluentia, 8–9.3 µm crassitudine, ex ad 12 cellulis sphaericis vel ovoides formata, cellulis magnitudine variabilibus, locum secundum, vagina individuali manifesta. Cellulae strati basalis spheroideae, 3–6 µm diametro majore. Cellulae apicales cylindricae, apice superiore rotundato, inferiore plano, 6–8 µm longae, 3–5 latae. Cellulae intercalares (intermediae) subspheroideae vel ovoideae vel irregulariter pyriformes, 4–7 µm longae, 3–5 µm latae. Cellularum divisio plerumque ad substratum parallelis, interdum perpendicularis.
Habitatio: alga epilithica, supra petras umbrosas supra aestum, ca. 6–7 µm supra libram maris crescens. Ad roris casum subjecta.
Locus classicus: San Agustín, Oaxaca, Mexico.
Figurae nostrae: 10, 11, 12, 13, 18, 19.
Holotypus: FCME PTM 6300 (6/IX/97).



Figs 1–3. *Hydrococcus cesatii*. **1** – Initial phase of development in upper view. **2** – Later phase of colony development in upper view. **3** – Section of a colony in an intermediate phase of development.

Figs 4–9. *Cyanodermatium* cf. *gelatinosum*. **4** – Upper view of a young colony. **5** – Initial phase of colony formation: cells dividing only perpendicularly to the subtratum. **6** – Cells beginning to divide parallel to the subtratum initiating the formation of pseudofilaments. **7** – Superfical cells of a developed colony in upper view. **8** – Section of a nearly fully developed colony showing pseudofilamentous arrangement. **9** – Section of a fully developed colony showing pseudofilaments and cell packages.

[Scale bars: **1** = 4 µm; **2, 3** = 5 µm; **4, 5, 6, 8** = 4 µm; **7, 9** = 2 µm]

Flat mucilaginous blue-green to light green colonies or crusts, micro or macroscopic, 60–75 µm in height. Thalli formed by numerous parallel pseudofilaments oriented perpendicularly to the substratum (Figs 10, 11). Pseudofilaments generally uniseriate with oval to polygonal-rounded cells that generally divide parallel to the subtratum (Figs 12, 13, 18). Occasionally some intercalary cells divide perpendicularly to the subtratum, originating a divarication (Figs 12, 13 thick arrow). Pseudofilaments with fine hyaline confluent mucilaginous envelopes are up to 8-9.3 µm wide and 8-12 cells in length (Fig. 12). Cells from the basal stratum ovoid with 3–6 µm maximum diameter (Figs 12, 13 double arrows, 19). Intercalary cells spherical, piriform to rounded polihedrical 4–7 µm long and 3–5 µm in diameter (Figs 12, 13). Apical cells very distinctive by cylindrical shape, rounded at the apex, 6–8 µm long and 3–5 µm in diameter (Figs 12, 13 long arrow). All cells with evident individual sheaths (Figs 11, 12). Colony development apparently initiates from a single cell that divides perpendicularly to the substratum in several planes, originating a flat unistratose layer of cells. Later these cells apparently change their division plane to parallel to the subtratum in a more or less synchronous manner, originating a pseudofilamentous-pseudoparenchymatous thallus where all the pseudofilaments have the same length (Figs 10, 11, 13. The initial development stages have not been observed

Type locality: San Agustin, Oaxaca, Mexico. Figs 10, 11, 12, 13, 18, 19. Epilithic, growing on shady supralittoral rocks, around 6–7 m above sea level. Subject to marine breeze.

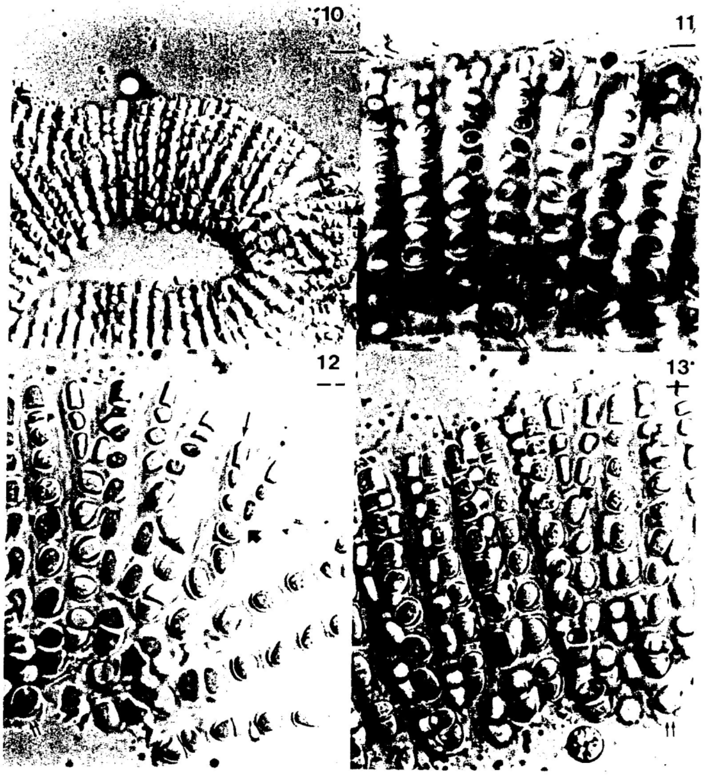
Holotype: FCME-PTM 6300 (6/IX/97).

This species is dedicated to Dr. JORGE GONZÁLEZ GONZÁLEZ, professor and friend of the authors, who consecrated most of his professional life to the development of a national phycological project.

Two types of growth pattern were observed in the *Cyanodermatium* populations examined. In the freshwater material, cells that form the basal stratum divide in several planes originating pseudofilaments whose cells apparently have also the potential for division in several planes; in this case pseudofilaments are generally divaricated or may be several cells wide. In the marine pseudofilaments are generally uniseriate, but occasionally some intercalary cells change their plane of division from parallel to perpendicular to the substratum originating a divarication, commonly located close to the apical part of the pseudofilament.

We consider that the marine epilithic populations of *Cyanodermatium* constitute a new species characterized by crusts with mostly uniseriate pseudofilaments very homogenous in aspect and height contained in evident sheaths. Cells are evidently differentiated in shape from obvoid to rounded polygonal at the base and intermediate parts to rounded cylindrical at the apex. Such homogenous pseudofilaments length may be originated to synchronization of cell division, but we have to consider that all the observed material was well developed; being an epilithic species, young colonies are difficult to observe.

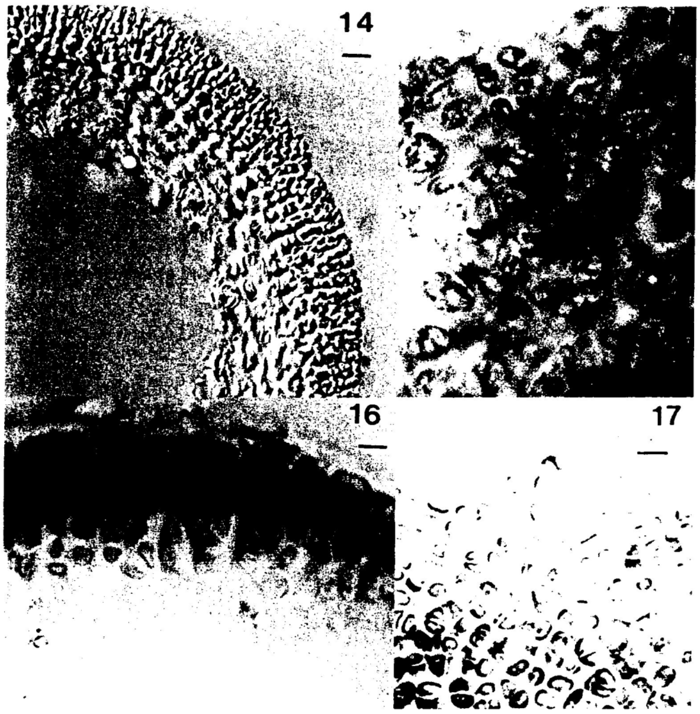
Our marine specimens have pseudofilaments of homogeneous length similar to *C. fluminense* (FRITSCH) KOMÁREK et ANAGNOSTIDIS 1995, *C. violaceum*



Figs 10–13. *Cyanodermatium gonzaliensis.* **10** – Section of the thallus showing pseudofilamentous arrangement. **11** – Section showing mostly uniseriate pseudofilaments and cell size variation from the base to the apex. **12** – Section showing divaricated pseudofilaments, apical cell differentiation and change in the pattern of cell division. **13** – Section showing divaricated pseudofilaments and differentiation of basal and apical cells. [Scale bars: **10** = 12 μm; **11, 12, 13** = 5 μm]

GEITLER 1933 and *C. gelatinosum* GEITLER 1933, and different from *C. gigas* (GEITLER) KOMÁREK et ANAGNOSTIDIS 1995. In *C. gigas* the crust height is apparently homogeneous but the cells in the upper part of the crust are very scarce and distant among themselves. This may be caused by an abundant secretion of mucilaginous substances and/or the liberation of upper cells.

Our material differs from *C. fluminense* in the irregular apical margin of the crust that coincides with the presence of solitary, or in short rows, spherical or slightly elongate reproductive cells (monocytes) that are absent in *C. gonzalien-*



Figs 14–17. *Placoma regulare*. **14** – Section showing pseudofilamentous arrangement and evidently widened basal strata. **15** – Basal strata aspect with heterogeneous disposition of cells. **16** – Section of thallus showing pseudofilamentous arrangement and intercalary and apical cells. **17** – Upper view of thallus with superficial cells.
[Scale bars: **14** = 5 μm; **15** = 7 μm; **16, 17** = 2 μm]

sis. This newly described species also differs from *C. fluminense*, *C. violaceum* and *C. gelatinosum* in the presence of a very evident and characteristic apical cell, with a cylindrical shape rounded at the apex and flat at the base, that is generally thinner and sometimes longer than the rest of cells. This peculiar shape and size is probably due to its continuous division and growth (Figs 12, 13). In *C. gonzaliensis* the division of the apical cells is probably asymmetrical, with the apical cells always maintaining its characteristically thin and long size compared to the other cell produced from same division (Figs 12, 13). In this material almost all cells have the capacity to divide by binary fission starting from those at the base (Figs 11–13, 18) to those at the apex (Figs 12, 13). In most cases for each pseudofilament there is an evident decrease in cell size towards the apex (Fig. 11), probably related to the higher frequency and/or speed of cell division in the upper portions of the crust compared to the frequency and speed of cell division at the basal part. Basal cells are found generally at the same distance from the base of the crust, resembling *C. fluminense*, *C. violaceum* and *C. gelatinosum* and differing from *C. gigas* where cells are, according to the original drawings, more distant from each other and from the base of the crust. For each cell and pseudofilament there is a sheath apparently diffluent (Figs 12, 13).

Placoma regulare BROADY et INGERFIELD 1991

Thalli formed by spherical, subspheric, sac to lobulated visible, brown colonies (Figs 14, 22); hollow, with a smooth cartilaginous texture. Superficial layers formed by two types of cells, small and pigmented in the outer part of the colony (Figs 14, 16, 17) and bigger and unpigmented in the lower layers (Figs 15, 16). Superficial cells are polygonal-rounded to slightly square, disposed in radial rows of up to 10 cells (Figs 17, 23) that diminish in size from the base towards the surface of the colony (Figs 14, 16). At the base there is a layer of large unpigmented cells that divide first perpendicularly to the substratum forming a basal stratum that is several cells wide (5–7 μm). In more developed stages basal stratum cells do not have a definite arrangement (Fig. 15). In transverse sections, pseudofilaments of 5 to 7 cells long are evident (Fig. 23). Cells are spherical to rounded or irregular polyhedrical

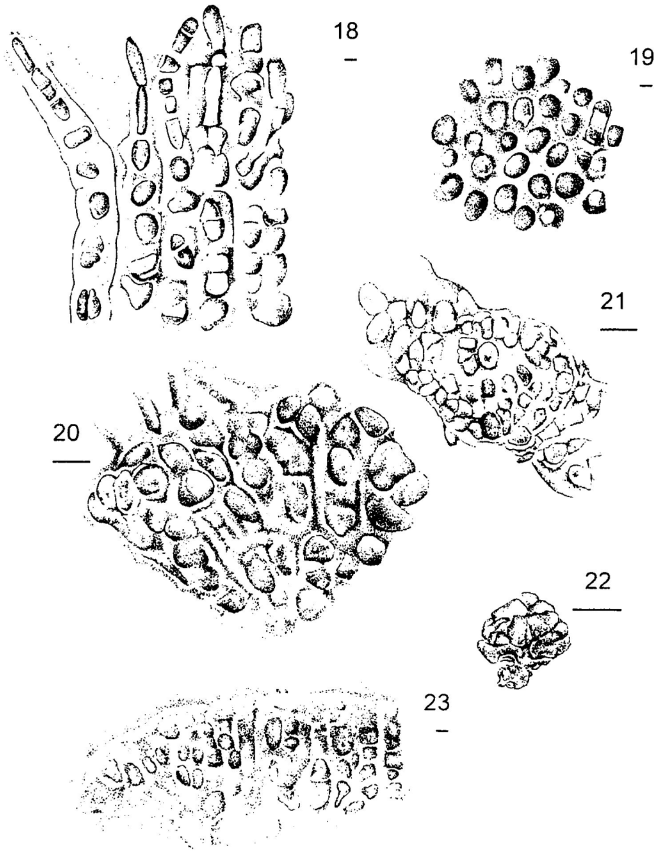
Dimensions: Colonies 2–15 mm in diameter (Fig. 22). Superficial cells 1.9–2.8 μm in diameter; intercalary cells 3.8–4 μm in diameter. Basal cells 2.8–3.8 μm in diameter.

Habitat: Epilithic in mountain streams of *Pinus* and *Quercus* forests. Altitude: 3.200 m. T = 7–11 °C. pH = 6.6- 7.3. FCME MA 142, 155 (16/03/2001). Rio La Magdalena, Distrito Federal, Mexico (19° 16' 00" N, 99° 18' 22" W).

Placoma regulare was described originally from New Zealand mountain streams, and as far as we know has not been reported elsewhere. Our material corresponds in general with the description of the species made by BROADY & INGERFELD (1991). In particular the radial arrangement of cells, the gradual increase of size from the periphery to the base and the cell dimensions are similar. Habitat is also relatively equivalent as our material grows on stream rocks subjected to low speed currents or at the edges of streams where it is permanently wet and shaded. A conspicuous difference however is the colour of the colony: red in the New Zealand material and brown in the Mexican specimens.

Discussion

The populations described in this study show the distinctive characters of three genera of Hydrococcaceae. This includes evident polarity, pseudofilamentous tendency and the absence of baeocytes. Cells have the capacity to divide in several planes, but in developed stages a pseudofilamentous thallus is originated by



Figs 18–19. *Cyanodermatium gonzaliensis.* **18** – Transverse section of the thallus showing pseudofilaments arrangement and characteristic apical cells. **19** – Upper view of thallus with superficial cells.
Figs 20–21. *Cyanodermatium* cf. *gelatinosum.* **20** – Transversal section of thallus showing pseudofilamentous arrangement. **21** – Upper view of a young colony.
Figs 22–23. *Placoma regulare.* **22** – Fully developed thalli. **23** – Transversal section of thalli showing pseudofilamentous arrangement.
[Scale bars: **18–21, 23** = 3 µm; **22** = 5 mm.]

a predominance of divisions parallel to the subtratum. The species from tropical Mexico, confirm the distinctive characteristics of these genera.

Species of *Hydrococcus* differ from those of *Cyanodermatium* in the shape of the colony, that is related to the pattern of cell division. In *Hydrococcus* divisions parallel to the subtratum take place first in the older and central cells of the unistratose colony, originating a dome shaped colony, whereas in *Cyanodermatium*, once a unistratose layer is formed, cells divide parallel to the subtratum in a more or less synchronous manner developing pseudofilaments of similar aspect and length. In the case of *C.* cf. *gelatinosum* the arrangement of the colony is more irregular probably due to the fact that each colony is originated by several initial cells. In *C. gonzaliensis* pseudofilaments are very regular and colonies probably develop from a single initial cell.

According to the descriptions and illustrations of type material (in GEITLER & RUTTNER 1935 and KOMÁREK & ANAGNOSTIDIS 1998), the species of *Cyanodermatium* have a slightly different pattern of cell division that generates uniseriate pseudofilaments (although occasionally divaricated) in the case of *C. gonzaliensis* and *C. gigas* and evidently divaricated pseudofilaments or cell packages in *C.* cf. *gelatinosum*. A diversity in the degree of the apical cell differentiation is also evident within the genera, specially in the long and rounded cylindrical apical cells of *C. gonzaliensis*. Differences are also clear concerning basal and intercalary cell shape and arrangement and the general aspect of cells within the crustous colony. In some species such as *C. gonzaliensis* there is an almost homogenous cell disposition in the pseudofilaments whereas in other species it is very heterogeneous.

Placoma differs from *Cyanodermatium* and *Hydrococcus* in the form and texture of the colony, that is a hollow sac where most of the basal stratum is detached from the substratum and peripheral cells have a radial arrangement. In the case of *Placoma regulare* the pseudofilamentous arrangement is very clear with a conspicuous differentiation in cell size between basal and peripheral strata. In this material we have found the formation of a basal stratus originated by a layer of cells that divide perpendicular to the substratum and remain adhered to it. These cells then divide parallel to the substratum originating pseudofilaments. Later, cells from the first layer continue to grow and divide forming a basal stratum several cells thick, where cells are bigger than intercalary or apical cells. This potential for division in several planes probably causes parts of the basal stratum to detach from the substratum forming hollow or semi-hollow, globous colonies. Species included in genus *Placoma* differ considerably among themselves. *P. regulare* differs from the rest of the species in its clearly pseudofilamentous organization and the decrease of cell size from the base to the surface. In other species of *Placoma* the cell arrangement is more irregular.

Conclusions

From these results the information on both distribution and patttern of development of *Hydrococcus cesati; Cyanodermatium* cf. *gelatinosum* and *Placoma regulare* are expanded. We describe a new species: *C. gonzaliensis* based on characterisitc cell differentiation, habitat and pattern of cell division. All these data corroborate the validity of the family Hydrococcaceae.

We agree with the proposal of KOMÁREK & ANAGNOSTIDIS (1998) that states that the main differences among the genera of the Hydrococcaceae are the pattern of cell division and growth, and the synchronicity of cell division along the pseudofilament. We also agree with the separation of the Hydrococcaeae family from those genera where baeocytes occur and that are currently included in Hyellaceae (KOMÁREK & ANAGNOSTIDIS 1998).

In our material some colonies of *Cyanodermatium* and *Hydrococcus* were similarly shaped in spite of differing in their developmental pattern, therefore we consider that it is necessary to study the patterns in all members of this family.

The scarce information on species of these genera is probably related to their apparently specific habitat conditions and the low number of studies on cyanoprokaryotes developed in little known regions, particularly in tropical countries. The distribution of some species recognised for other areas will probably be modified with the development of further studies of this type.

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