Paleontología Mexicana
Volumen 5, núm. 1, 2016, p. 53-69

Cenomanian algae and microencrusters from the El Abra Formation, W Valles–San Luis Potosí, Mexico

Lourdes Omaña[a,*], José Ramón Torres[b], Rubén López Doncel[b], Gloria Alencaster[a]

[a] Departamento de Paleontología, Instituto de Geología, Universidad Nacional Autónoma de México, Ciudad Universitaria, 04510, Cd. Mx., México.
[b] Instituto de Geología, Universidad Autónoma de San Luis Potosí, Av. Dr. Nava # 5, San Luis Potosí, México.

[*] lomanya@geologia.unam.mx

Abstract

This work deals with calcareous algae and microencrusters (*incertae sedis*) from the upper part of the El Abra Formation, which crops out at the W Valles–San Luis Potosí Platform. Two assemblages of calcareous algae are recognized: one composed of rivulariacean-type cyanobacteria such as *Cayeuxia kurdistanensis* Elliott and *Garwoodia* sp. as well as the dasycladalean species *Clypeina* sp., *Neomeris cretacea* Steinmann, *Salpingoporella hasi* Conrad, Radoičić and Rey, *Trinocladus* cf. *T. divnae* Radoičić; the bryopsidales *Boueina pygmaea* Pia, *Halimeda* cf. *H. elliotti* Conard and Rioult, and the microencrusters *Lithocodium aggregatum* Elliot and *Thaumatoporella parvovesiculifera* (Raineri), and the other assemblage consisting of the gymnocodacean algae *Permocalculus irenae* Elliott and *P. budaensis* Johnson. The first assemblage is associated with the benthic foraminifera *Pseudolituonella reicheli* Marie, *Hemicyclammina sigali* Maync, *Daxia cenomana* Cuvillier and Szakall, *Merlingina cretacea* Hamoui and Saint Marc, is dated as mid-late Cenomanian on the basis of the stratigraphic distribution of the foraminifera, and suggests an oligotropic environment within the euphotic zone on the open marine platform. Over this is documented a succession consisting of a community with abundant gymnocodacean algae and a decrease in the benthic foraminifera which could be related to increased nutrient availability in mesotrophic conditions. The shallow-water association composed of the studied microfossils is typical of the Tethys Realm.

Keywords: Algae, microencrusters, El Abra Formation, Cenomanian, Valles–San Luis Potosí Platform, Mexico.

Resumen

Este trabajo trata sobre las algas calcáreas y microencrustantes (incertae sedis) de la parte superior de la Formación El Abra que aflora en la parte occidental de la Plataforma Valles-San Luis Potosí. Se reconocen dos conjuntos de algas calcáreas, uno compuesto por cianobacterias tales como Cayeuxia kurdistanensis Elliott, Garwoodia sp. así como dasycladaleans: Clypeina sp., Neomeris cretacea Steinmann, Salpingoporella hasi Conrad, Radoičić y Rey Trinocladus cf. T. divnae Radoičić, bryopsidales: Boueina pygmaea Pia, Halimeda cf. H. elliotti Conard y Rioult y los microincrustantes Lithocodium aggregatum Elliott Thaumatoporella parvovesiculifera (Raineri). La otra asociación consiste de algas gymnocodaceas como: Permocalculus budaensis Johnson y P. irenae Elliott. El primer grupo se asocia con los foraminíferos bentónicos Pseudolituonella reicheli Marie, Hemicyclammina sigali Maync, Daxia cenomana Cuvillier y Szakall, Merlingina cretacea Hamoui y Saint Marc, lo cual es datado como Cenomaniano medio-tardío sobre la base de la distribución estratigráfica de los foraminíferos. Este conjunto sugiere un ambiente oligotrópico dentro de la zona eufótica en la plataforma marina abierta. Sobre esta sucesión se documenta una comunidad con algas gymnocodaceas abundantes y una disminución en los foraminíferos bentónicos, lo cual podría estar relacionado con un aumento de la disponibilidad de nutrientes en condiciones mesotróficas. La asociación de aguas someras compuesta de los microfósiles estudiados es típica del dominio Tethysiano.

Palabras clave: Algas, microencrustantes, Formación El Abra, Cenomaniano, Plataforma Valles-San Luis de Potosí, México.

1. Introduction

The Valles-San Luis Potosí Platform (VSLPP) is part of a large carbonate platform system that rimmed the ancestral Gulf of Mexico during the Mid-Upper Cretaceous (Scott, 1990). The shallow-water deposit is represented by the El Abra Formation, which holds a rich assemblage of benthic foraminifers. Together with benthic foraminifers the calcareous algae are an important element in the Cretaceous shallow-water deposits. The term "El Abra Limestone" was first used by Garfias (1915) for the shallow-water carbonates of the Sierra de El Abra. This unit is characterized by a great variety of invertebrate fossils, mostly Albian rudists, which have been analysed and published by authors including Coogan (1973), Alencaster (1987, 1998), and Alencaster and García Barrera (2008).

The benthic foraminifers from the El Abra Formation were reported by Bonet (1956); Tavitas and Solano (1984); Omaña and Torres Hernández (2000); Ornelas *et al*. (2006). In Mexico, few studies of fossil algae have been carried out; *Neomeris cretacea* was described for the first time by Steinmann (1899) from the Cenomanian of the Cerro Escamela in the state of Veracruz. Barattolo (1983) described *Triploporella steinmanni* (probably of mid-Albian age) of the Cretaceous of Orizaba from the same locality of Steinmann (1899); later, Barattolo (1990) made a careful revision of *Neomeris cretacea*.

Other reports on Cretaceous algae have been published by Buitrón *et al*. (1995) about the Albian–Cenomanian algae from the El Abra Limestone. Hernández-Romano *et al*. (1998); Aguilera Franco *et al*. (2001) recorded algae in the Cenomanian from the Guerrero–Morelos Platform. In the Chiapas region, Michaud (1987) and Deloffre *et al*. (1985) registered the occurrence of Late Cretaceous algae. Filkorn and Scott (2011) found a late Albian algal assemblage from the Mal Paso Formation in the state of Guerrero.

The purpose of this study is to document the occurrence of rivulariacean-type cyanobacteria, calcareous algae (dasycladales, bryopsidales) and microencrusters from the upper part of the El Abra Formation in material from the west part of the Valles–San Luis Potosi Platform, and to describe and illustrate the species identified.

2. Geological Setting

The study area is located east of the city of San Luis Potosí (Figure 1). This area is situated on the western part of the Valles–San Luis Potosí Platform (VSLPP). The Early Cretaceous was a time of remarkable tectonic stability in the Gulf of Mexico Basin, characterized by decreased terrigenous influx and the development of stable shelves, ramps and platforms bordering the deep central part of the Gulf of Mexico basin, which became the site of widespread carbonate deposition, particularly during the Albian. Along the western flank of the basin in east-central Mexico, carbonate platforms were restricted to more local developments such as the VSLPP, which remained active until the earliest Late Cretaceous (Cenomanian) (Salvador, 1991).

3. Material and Methods

The material studied comes from the upper part of the El Abra Limestone. It was collected from four localities situated at the western part of the VSLPP: Llano del Carmen (LLC), Guadalcázar (G), Cerritos (C), and El Temazcal (ET). The limestone was examined in thin sections and algae and microencrusters were studied. The micropaleontological preservation is good, permitting identification. Most of the specimens are identified and illustrated from cross-sections.

The biostratigraphical framework is based on the benthic foraminiferal stratigraphic ranges. In addition, a microfacies study was carried out to infer the paleoenvironment.

4. Results

4.1. Lithology and microfacies

The samples with algae were collected east of the city of San Luis Potosí and proceed from the El Abra Formation. This unit presents two facies: the Taninul and El Abra, which are stratigraphically correlated (Aguayo, 1998). In this study from the upper part of the El Abra Formation (Taninul Facies), two main microfacies were distinguished.

Microfacies 1 is a peloidal bioclastic packstone and well sorted grainstone (Figure 2a-b).

This microfacies includes an algal assemblage composed of *Clypeina* sp., *Neomeris cretacea* Steimann, *Salpingoporella hasi* Conrad, Radoičić and Rey, *Trinocladus* cf. *T. divnae* Radoičić, *Boueina pygmaea* Pia, and *Halimeda* cf. *H. elliotti* Conard and Rioult, *Cayeuxia kurdistanensis* Elliott, *Garwoodia* sp. and the microencrusters *Lithocodium aggregatum* Elliott and *Thaumatoporella parvovesiculifera* (Raineri). In this interval we identified the following benthic foraminifera: *Pseudolituonella reicheli*, *Hemicyclammina sigali*, *Daxia cenomana*, *Merlingina cretacea*, *Cuneolina conica*, *Cuneolina parva*, *Pseudocyclammina* sp., *Nezzazata simplex*, *Peneroplis parvus*, *Dicyclina schlumbergeri*, *Minouxia inflata*, *Nezzatinella picardi*, *Spiroloculina cretacea*.

Other fossil components of this microfacies include fragments of rudists, gastropods, corals, echinoderms, and calcareous worm tubes. This microfacies was recorded at all four localities (LLC, G, C, and ET). The abundant and diversified fauna and flora and the packstone texture of the rock which characterizes microfacies 1 suggest a depositional environment within the euphotic zone on the shallow open marine platform (zone 7 Flügel, 2004; Wilson, 1975). The environmental interpretation is also supported by

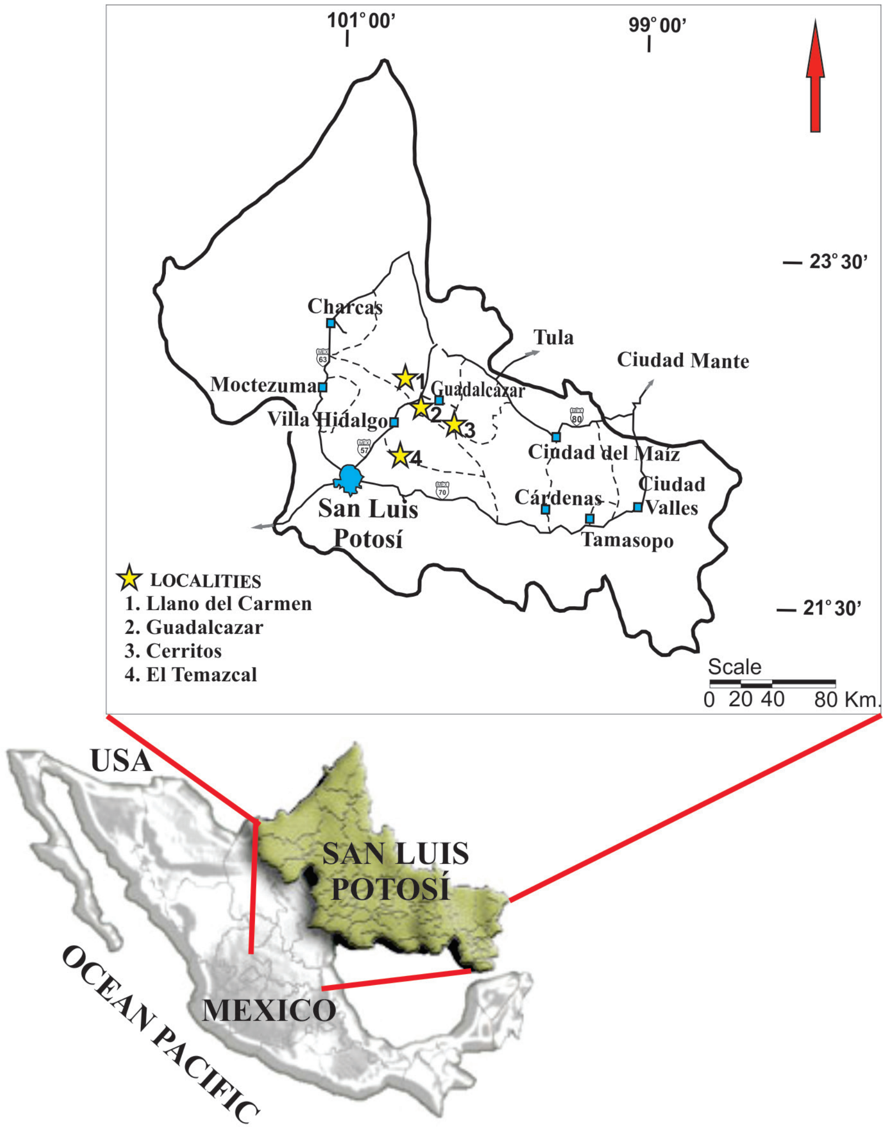

Figure 1. Geographic map with the location of the studied area.

the presence of calcareous algae and benthic foraminifera.

Microfacies 2 is an algal-foraminiferal wackestone-packstone characterized by fragments of *Permocalculus* (*Permocalculus irenae* Elliott, *P. budaensis* Johnson), and scarce benthic foraminifera such as *Nezzazatinella picardi*, miliolids, rotalids, textularids, gastropods, and echinoderms. This microfacies was identified in the Cerritos section (Figure 2c-d). The abundant occurrence of gymnocodaceans, as well as less diverse benthic foraminifera, indicates a marine deposit associated with an increase in the flux of nutrients (mesotrophic stage) before platform flooding.

4.2. Age

The benthic foraminiferal association is used for defining the age in the succession studied. On the basis of the stratigraphic distribution of *Pseudolituonella reicheli*, *Daxia cenomana*, *Merlingina cretacea* and *Hemicyclammina sigali*, the interval that contains the algae and microencrusters was dated as mid-late Cenomanian age. This dating is reinforced by the occurrence of the *Whiteinella cretacea* Zone (latest Cenomanian–earliest Turonian) that overlies the upper part of the El Abra Formation (Omaña *et al*., 2013).

4.3. Systematic Paleontology

The thin sections that contain the algae are housed in the Paleontology Collection of the Instituto de Geología (Universidad Nacional Autónoma de México).

PHYLUM CYANOPHYTA Sachs, 1874
Order Nostocales Geitler, 1925
Family Rivulariaceae Robenhorst, 1865

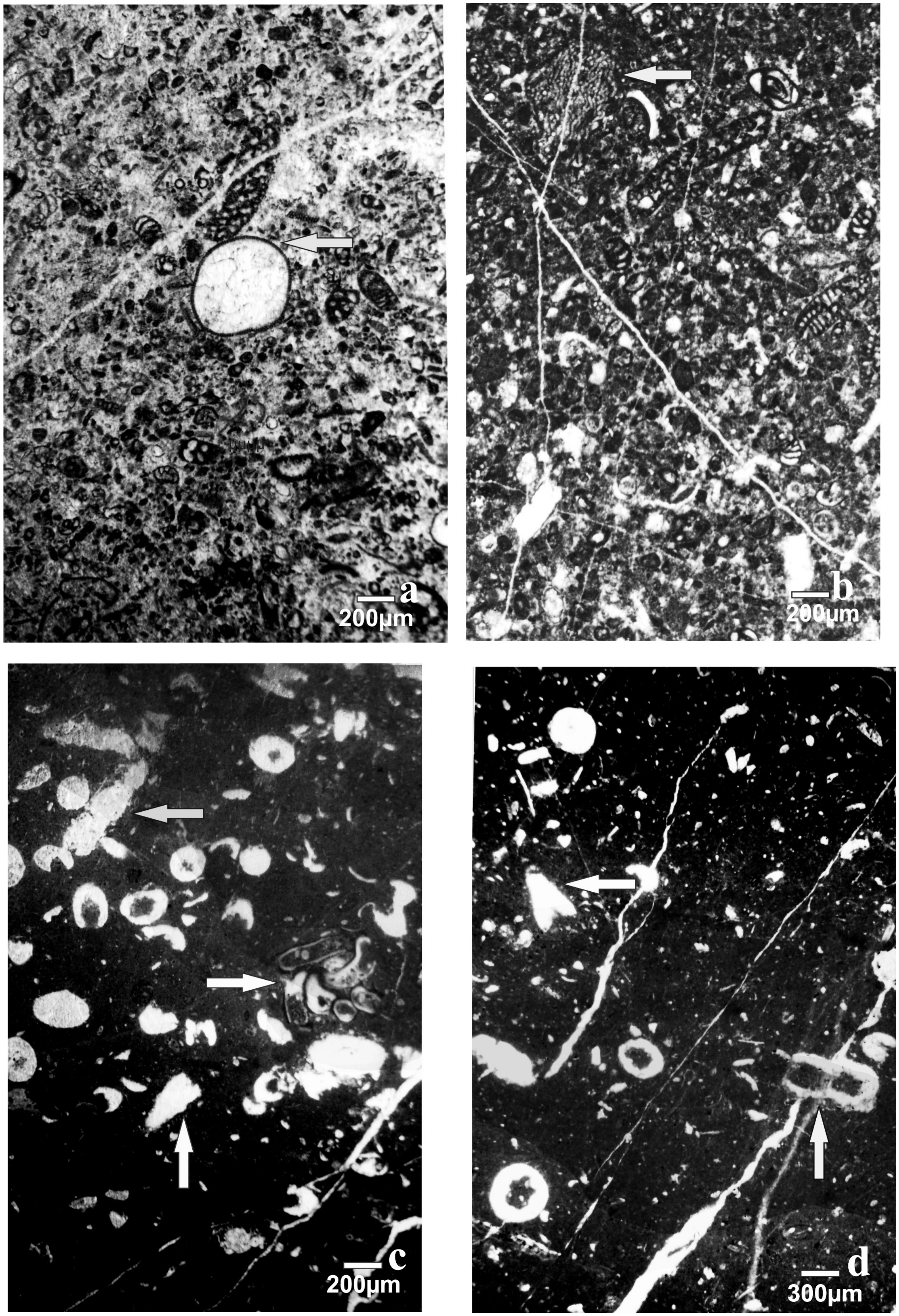

Figure 2. Microfacies with algae, foraminifers and encrusting associations. a) Foraminiferal packstone with *Thaumatoporella vesicularis* (Sample C-4). b) Peloidal bioclastic packstone with algae and foraminifers (Sample). c) Gymnocodacean algal packstone-wackestone with serpulids (Sample C-8). d) Gymnocodacean algal wackestone (Sample C-8).

The Cyanobacteria are an especially difficult group to classify. They are possibly one of the most ancient groups of organisms on earth, with some fossil representatives having very similar morphologies to present-day species (Schopf, 1974; Knoll, 2008).

Genus *Cayeuxia*

Frollo (1938) proposed the genus *Cayeuxia* with two new species, *C. piae* and *C. moldavica*, regarded as Codiaceae from the Tithonian, in East Carpathians. Dragastan (1985) transferred the genus to the cyanophyceans as a synonym of the genus *Rivularia*.

Dragastan (2008) noted that Luchinina and Shuysky in Chiuvashov *et al*. (1987) introduced other classification Phylum Cyanophyta, Family Garwoodiaceae including *Ortonella*, *Garwoodia*, *Hedstroemia*, *Cayeuxia*.

Type species. *Cayeuxia piae* Frollo, 1938.

Cayeuxia kurdistanensis Elliott, 1957
Figure 3 a, b, c

1957 *Cayeuxia kurdistanensis* Elliott, p. 790–791, pl. 25, figs. 8–10; Johnson, 1969, 37–38, pl. 26, fig. 1; Buitrón *et al*., 1995, p. 150, pl. 3, fig. 1; Filkorn and Scott, 2010, p. 182, fig. 3, 3; *Rivularia kurdistanensis* (Elliott), Dragastan, 1985, pl. 4, figs. 8–14; Mancinelli and Ferrandes, 2001, p. 538, figs. 3.4, 4.6.

Description. Fan-like thallus formed by radiating tubular filaments that diverge toward the distal margin and bifurcate from preceding tubes with an angle of divergence of about 45º, which is characteristic of *Cayeuxia*; the tubes filled with spar calcite as Filkorn and Scott (2011) have already observed.

Stratigraphic distribution. *Cayeuxia kurdistanensis* was described for the first time by Elliott (1957) from the Aptian of Iraq. This species has a wide distribution in the Jurassic and Cretaceous strata in Europe (Italy and France) as well as in the Americas (USA, Mexico, and Argentina).

Measurements.
Height 1mm

Occurrence. *Cayeuxia kurdistanensis* identified from the Llanos del Carmen (Sample LLC-1).

Garwoodia sp. Figure 3 d

Description. Thallus with tubes dichotomically branched laterally at an angle of about 90 degrees; the sheaths arranged in an irregular form; their walls are separated and the space is filled with calcite.

Remarks. The coarser tubes of *Garwoodia* have been used as an argument for assigning it to the udotacean green algae (Flügel, 2004).

Measurements.
Length 1000 µm.
Width 700 µm.

PHYLUM CHLOROPHYTA Pascher, 1914, p. 147
Class Dasycladophyceae Hoek *et al*., 1995
Order Dasycladales Pascher, 1931
Family Polyphysaceae Kützing, 1841

Genus *Clypeina* Michelin, 1845

According to Granier *et al*. (2014) the type species of *Clypeina* is *Clypeina marginiporella* (Michelin, 1845) which was originally described as an organism similar to a coral by Michelin (1840–1847; p. 177–178). The genus name derives from the Latin word "*clypeus*" for the reason that the first specimens collected by Michelin had the appearance of "perfect rings" and "half rings." In the second half of the nineteenth century, there was no consensus on the taxonomic position of these isolated "whorls" which were placed into the foraminifers by various authors as Parker and Jones (1860, p. 473–474); Carpenter (1862, p. 130–131), and Gümbel (1872, p. 262), but they were appropriately recognized as algae by Munier-Chalmas (1877) who regarded them as "*Siphonées verticillées*". Morellet and Morellet (1913) put them in the "*Acétabulariées*". In 1918, these authors proposed a new species: *Clypeina helvetica*, in addition to the two species previously identified from the Cenozoic, *C. marginiporella* (Michelin, 1845) and *C. digitata* (Parker and Jones, 1860). However, there was no record of Mesozoic forms up to the description of *Clypeina jurassica* from the Purbeckian strata (Favre and Richard, 1927).

Clypeina sp.
Figure 4 a,b,c,d, e, f, g

Description. Tallus cylindrical, euspondyl composed of one fertile whorl that consists of seven to 13 elongated primary laterals irregularly arranged containing one ovoid sporangial structure. The laterals are connected to the stem by small pores. The outer thallus diameter (D) was varying from 1000 to 625 µm; inner thallus diameter (d) 450–250 µm; pore diameter (p) 250–50 µm.

Class Dasycladophyceae Hoek *et al*., 1995
Order Dasycladales Pascher, 1931
Family Dasycladaceae Kützing, 1841
Tribe Dasycladeae Pia, 1920

Genus *Neomeris* Lamouroux, 1816

According to Granier *et al*. (2012a) "The main feature of the *Neomeris* genus is a main stalk bearing regularly spaced

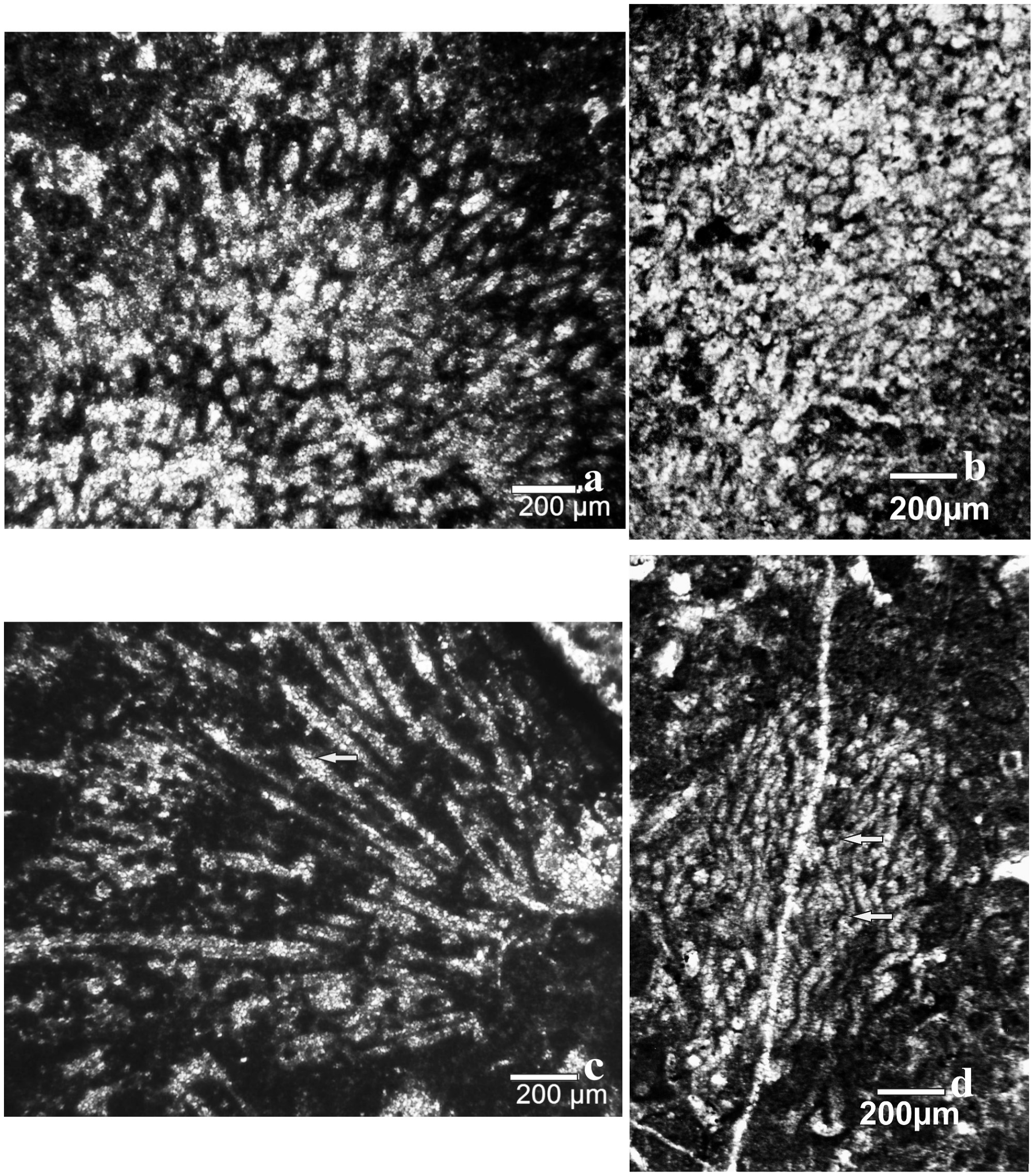

Figure 3. Cenomanian rivulariacean-type cyanobacteria from the El Abra Formation. a) Longitudinal section of *Cayeuxia kurdistanensis* (Sample LLC-1). b–c) Tangential section of *Cayeuxia kurdistanensis* (Sample LLC-1). d) Longitudinal section of *Garwoodia* sp. (Sample LLC-2).

verticils of laterals with two (exceptionally three, *e.g.*, in the living *N. stipitata* Howe, 1909) secondary sterile segments and, where they are fertile, one gametophore in terminal position (choristosporate type) per primary segment".

Neomeris cretacea Steinmann, 1899
Figure 5 a,b

Neomeris (*Herouvalina*) *cretacea* Steinmann, 1899, p. 149–154, figs. 14–20; Raineri 1922, p. 74–75, figs. 5, 6; Basson and Edgell, 1971, p. 422, pI. 5, figs. 4, 5; Kuss, 1986 b, p. 228-230, fig. 5d; Kuss and Conrad, 1991, p. 872, fig. 2.17.

Description. Cylindrical, elongated thallus with a central hollow which have two types of ramifications: primary branches each bearing two sterile secondary branches which are situate on both sides of the fertile ovoid to ellipsoidal ampulla.

Measurements.
Outer thallus diameter (D) 650 µm.
Inner thallus diameter (d) 350 µm.
Sporangia diameter (p) 50 µm.

Remarks. *Neomeris cretacea* was first described by Steimann (1899) from the Cenomanian of Cerro Escamela in Mexico.

Stratigraphic distribution. The earliest representative of *Neomeris* should have been ''born'' at the transition between the Jurassic and the Cretaceous, considering the

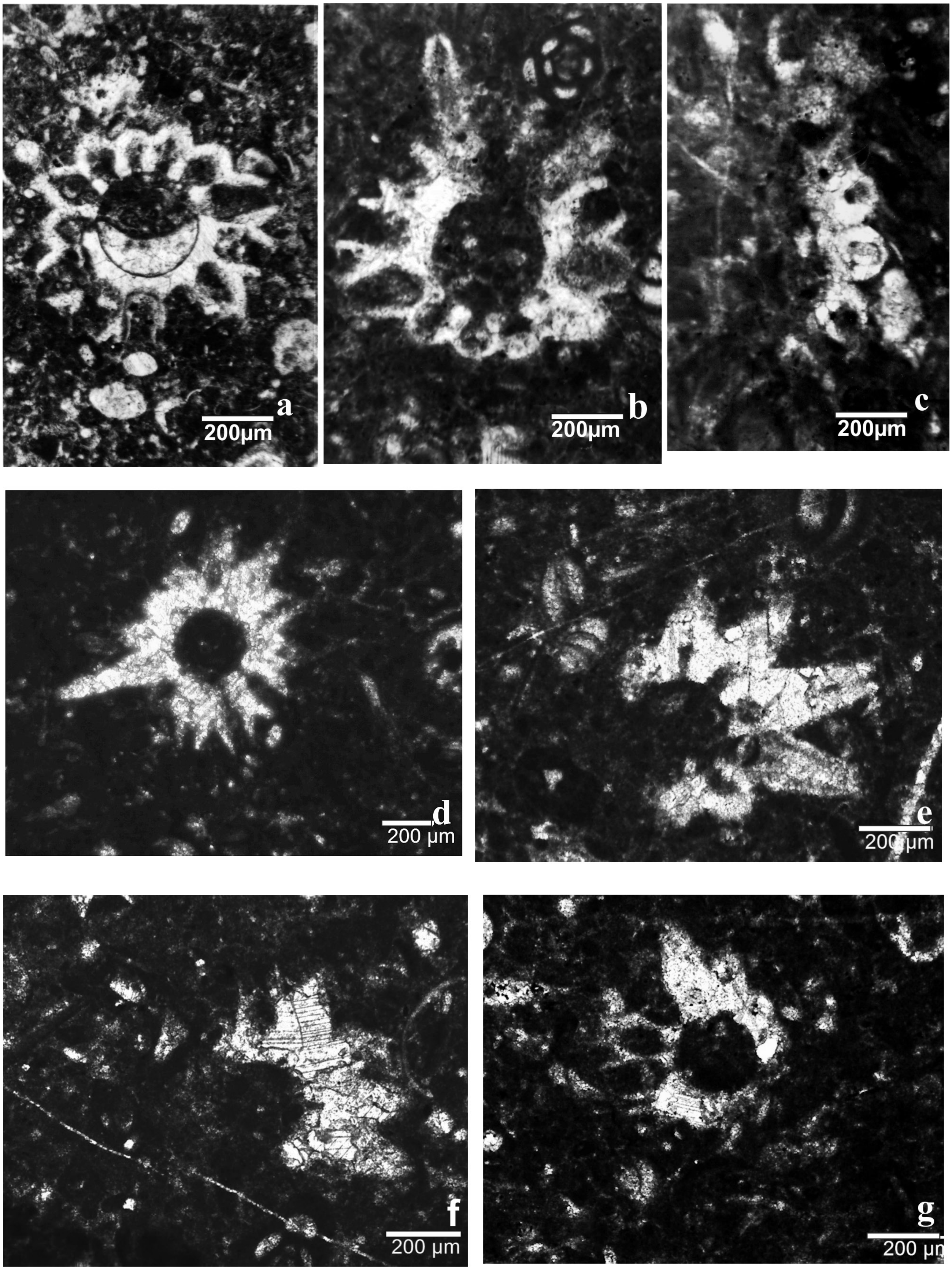

Figure 4. Cenomanian Dasycladacean algae from the El Abra Formation. a) Cross section of *Clypeina* sp. (Sample G-5). b, d, g) Cross section of *Clypeina* sp. (Sample G-5). c) Tangential section of a verticil of *Clypeina* sp. (Sample G-5). e–f) Cross section of *Clypeina* sp. (Sample G-5).

choristosporate model of reproduction, which is the main trait of the family Dasycladaceae, as emended by Granier and Bucur (Granier *et al*., 2012b).

Other reports are from the Late Cretaceous (Cenomanian-Turonian) of Iraq. In Lebanon it spans from late Aptian to Cenomanian, but the most typical specimens recorded are from Cenomanian (Basson and Edgell, 1971).

Occurrence. In our material we found this species only in the Temazcal (Sample ET-4) associated with *Daxia cenomana*, *Cuneolina pavonia*, *Cuneolina parva* and *Dicyclina schlumbergeri*.

Family Triploporellaceae Pia, 1920
Tribe Salpingoporelleae Bassoullet *et al*., 1979
Sub-tribe Salpingoporellinae Bassoullet *et al*., 1979

Genus *Salpingoporella* Pia, 1918 in Trauth, emend Carras *et al*., 2006

Type-species. *Salpingoporella muehlbergii* (Lorenz, 1902) Pia, in Trauth, 1918 emend. Carras *et al*., 2006.

Salpingoporella hasi Conrad, Radoičić and Rey, 1977
Figure 5 c

Salpingoporella hasi Conrad, Radoičić and Rey, 1977, pl. 1, fig. 5–6; Cherchi and Schroeder, 1980, pl. 1, 474; Kuss and Conrad, 1991, fig. 4.17; Radoičić, 1994, pl. 1, fig. 1; Sokač, 1996, pl. 2, fig. 1–5; pl. 8; Masse and Arnaud-Vanneau, 1999, pl. 1, fig. 11–12; Masse and Isintek, 2000, pl. 2, fig. 3–5; Radoičić, 2006, p.85, pl. 7, fig. 1

Original description. "Cylindrical thallus whose verticils are made up of a small number of branches, transversally flattened, and whose tubular proximal part is well developed. At their distal end, the branches widen out quickly and become rectangular. The nearby branches belonging to the same verticil may touch each other or not, depending on the space available, which in turn depends on their length and on the diameter of the siphon. The calcareous envelope is made up of a simple mosaic of hyaline crystals" (Carras *et al*., 2006).

Measurements.

Outer thallus diameter (D) 450 µm.

Inner thallus diameter (d) 250 µm.

Stratigraphic distribution. *Salpingoporella hasi* was described as an Albian-Cenomanian species of different localities of the Mediterranean region (Conrad *et al*., 1977). This species has been recorded in the Albian from the Karaburun Peninsula in Turkey (Masse and Isintek, 2000) and the Guyot Resolution in W Pacific (Masse and Arnaud-Vannaeu, 1999).

Occurrence. *Salpingoporella hasi* identified in the Guadalcazar site (Samples G-5).

Family Triploporellaceae (Pia, 1920) emend. Berger and Kaever, 1992
Subtribe Triploporellinae (Pia, 1920) emend. Bassoullet *et al*., 1979

Genus *Trinocladus* Raineri, 1922

Elliott (1972, p. 619) indicated that *Trinocladus* is composed of "successive verticils of radial branches, each branch showing outwardly widening primaries giving rise to several secondaries, and these in turn to bunches of tertiaries. Branches of the lower verticils may not show the full detail. Branches usually not alternate in position from verticil to verticil."

Trinocladus cf. *T. divnae* Radoičic, 2006
Figure 5 e

Description. Fragment of longitudinal section with typical *Trinocladus* organization of the laterals with inflated parts of the secondaries that are well preserved and the occurrence of small tertiaries.

Measurements.

Length of segment 1250 µm.

Occurrence. *Trinocladus* cf. *T. divnae* identified in the Guadalcazar site (Samples G-5).

Bryopsidales
Udoteaceae

The Udotaceae in the Cretaceous are represented by assemblages of dissociated segments which have been referred to three genera, *Boueina*, *Arabicodium*, and Halimedaceae *Halimeda* (Bassoullet *et al*., 1983). Although the segments are different in size and shape and internal structure, they all coincide in possessing a longitudinal medullary zone and a cortical zone which is similar to that in living *Halimeda* and closely related to it.

Steinmann (1901) stated that *Boueina* can also be differentiated from *Halimeda* based on its external character. He claimed "that *Boueina* is a cylindrical, unbranching plant, then we may emphasize that this feature is not common for the genus *Halimeda*, in spite of the similarities concerning the internal structure. All *Halimeda* species are branched and articulated."

Elliott (1965, p. 199) stated that *Boueina* "in thin-section shows a medullar zone of coarse tangled threads, and a cortex of approximately radial finer branching threads, whereas in *Halimeda* the central coarse threads are mostly longitudinally directed and the cortical threads show constrictions and swellings." This last characteristic underlined by Steinmann (1901), Elliott (1965), and Bucur (1994) has been omitted by some subsequent authors who studied algae from the *Boueina-Arabicodium-Halimeda* group.

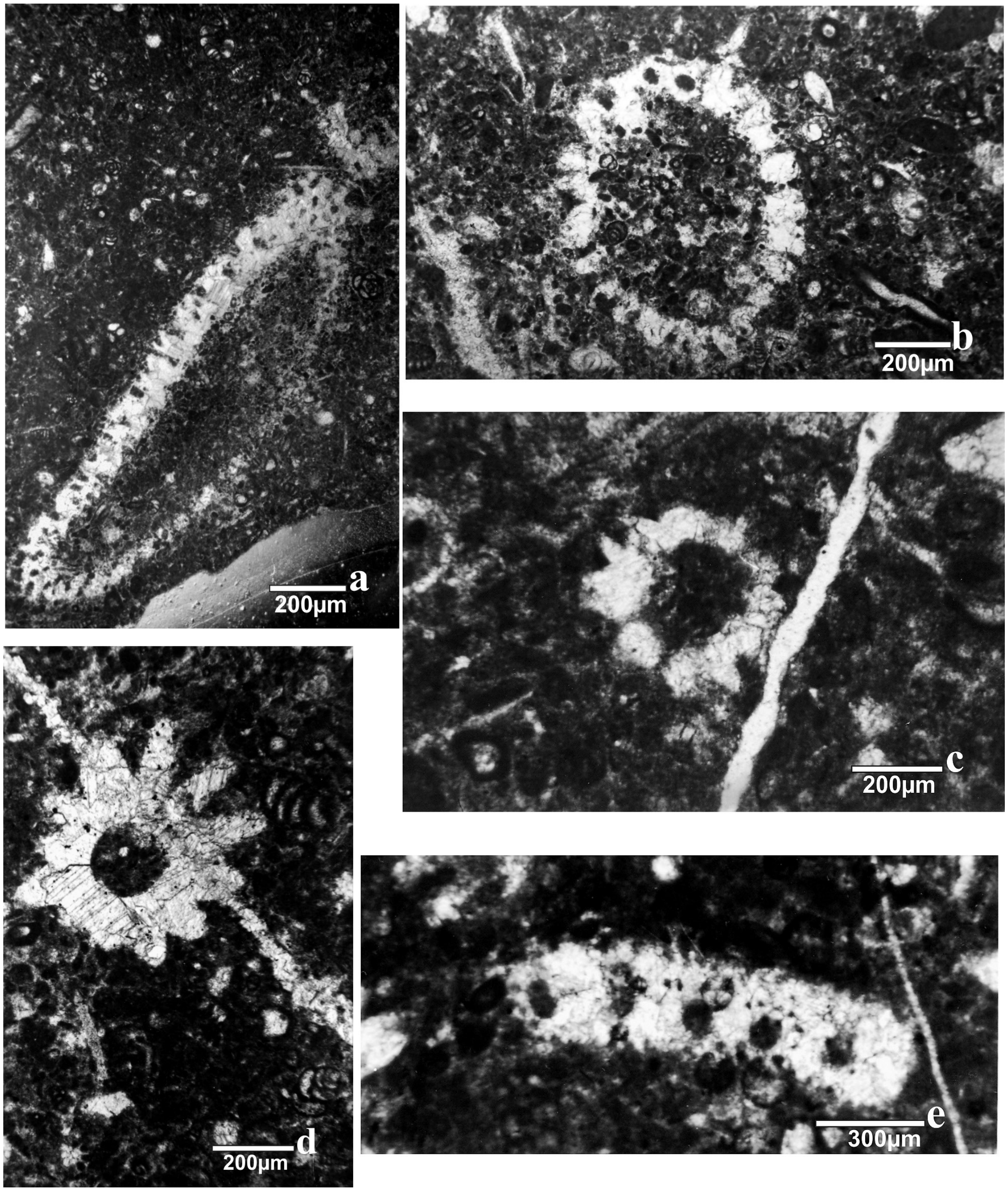

Figure 5- Cenomanian Dasycladacean algae from the El Abra Formation. a) Tangential section of *Neomeris cretacea* (Sample ET-4). b) Cross section of *Neomeris cretacea* (Sample ET-4). c) Cross section of *Salpingoporella hasi* (Sample G-5). d) Cross section of *Salpingoporella* sp. (Sample G-5). e) Longitudinal section of *Trinocladus* cf. *T. divnae* (Sample G-5).

Dragastan and Herbig (2007) indicated that "the classification of fossil-calcified-green siphonaceous algae is based on skeleton morphology. In general, internal morphology shows siphons, arranged in a central medulla and external cortex. Descriptive terms have been used with different meanings, such as tubes or filaments." Littler and Littler (1990, 1992) point out that the filament term, used by previous workers, is generally defined as a chain of cells and is incorrectly applied to siphonaceous algae such as *Udotea*, *Halimeda*, and *Penicillus*. They proposed the siphon terms for the medulla and utricle for the cortex.

Class Bryopsidophyceae Round, 1963
Order Bryopsidales Schaffner, 1922
Suborder Halimedineae Hillis-Colinvaux, 1984
Family Udoteaceae (Endlicher) Agardh, 1887–1888

Genus *Boueina* Toula, 1884

Type-species. *B. hochstetteri* Toula, 1884

Boueina pygmaea Pia, 1936
Figure 6 a

Boueina pygmaea Pia, 1936, p. 12–13, pl. 5, figs. 1–9; Elliot, 1965, p. 204, pl. 24, figs. 2, 6; Kuss, 1986, p. 231, fig. 5f-i; Kuss, 1994, p. 313, fig.9; Bauer *et al*., 2002, p. 17, pl. 4, fig. 3.

Description. Cylindrical thalli showing a strong calcification of the medullary and cortical zones. The interwoven siphons of the narrow medullary zone diverge to the cortical zone; toward the periphery where they then ramify into smaller utricules curving and diverging in all directions.

Measurements.
Height of thalli (h) 1250 µm.
Width of thalli 750 µm.
Medular zone 300 µm; cortical zone 450 µm.

Stratigraphic distribution. Pia (1936) described *Boueina pygmaea* from the Cenomanian-Turonian of Lybia. It has been recorded from the Cenomanian of France and Spain (Pfender, 1940; Ramírez del Pozo and López, 1988); Kuss (1994) found the species from the Cenomanian limestone of Gebel El Mushera in northern Sinai. Elliot (1965) reported *Boueina* cf. *B. pygmaea* from the Cenomanian of Bou-Saâda, Algeria.

Occurrence. We found *Boueina pygmaea* in the Llanos del Carmen site (Sample LLC-1).

Suborder Halimedineae Hillis-Colinvaux, 1984
Family Halimedaceae Link, 1832
Genus *Halimeda* Lamouroux, 1812

Halimeda cf. *H. ellioti* Conard and Rioult, 1977
Figure 6 b

Description. Cylindrical thalli, with elongated segments; large and thicker medullary zone crossed by tubular siphons that are extend as bifurcated cortical utricules which are inflated and constrained in their bases (Bucur *et al*., 2010).

Remarks. *Halimeda* cf. *H. ellioti* identified in our material is identical to Figure 9 (plate 6) illustrated by Radoičić (2006).

Measurements.
Length of segment 1950 µm.
Diameter of the medullary zone 400 µm.
Diameter of the cortical zone 200 µm.

Stratigraphic distribution. *H. elliotti* was described by Conard and Rioult (1977) from the Upper Cretaceous (Turonian) of southern France. Some Cenomanian-Turonian series in the Pastrik Mountain area (Kukes Cretaceous Unit) in Albania are characterized by the presence of the little-known udoteacean species *Halimeda elliotti* Conard and Rioult. “The inferences based on the data presented are that the range of *Halimeda elliotti* is from the middle Cenomanian into the middle Turonian and its maximum development is in the uppermost Cenomanian and lower Turonian” (Radoičić, 2005).

Occurrence. *Halimeda* cf. *H. elliotti* identified in the Llanos del Carmen locality (Sample LLC-1).

Family Gymnocodiacea Elliot, 1955
Genus *Permocalculus* Elliot, 1955

Type-species. *Permocalculus irenae* Elliot, 1955

Permocalculus budaensis Johnson, 1968
Figure 6 c, e

Permocalculus budaensis Johnson, 1968, p. 8, 9, pl. 1, figs. 2–5; Hernández Romano *et al*., 1998, p. 50, fig. 5d.

Description. Segmented thallus with cortical crenulations, with the sporangia in cortical or subcortical position. The weak calcification is responsible for the darker appearance of *P. budaensis* in comparison with other species of *Permocalculus* (Kuss and Conrad, 1991).

Measurements.
Height of thalli (h) 1350 µm.
Diameter of thalli 600 µm.

Stratigraphic distribution. *Permocalculus budaensis* was described and illustrated from the Buda Limestone of Cenomanian age (Johnson, 1968). Kuss and Conrad (1991) recorded the occurrence of the species in the Cenomanian of Jordan and within the Turonian of the Sinai.

Occurrence. This species was recorded from the Cerritos locality (Sample C-8).

Permocalculus irenae Elliot, 1955
Figure 6 d

Permocalculus irenae Elliot, 1955, p. 258–259, pl. 47, fig. 2, p1. 48, figs. 2–6; Johnson, 1965, p. 719, pl. 89, fig. 4; Basson and Edgell, 1971, p. 429, pl. 6, fig. 8; Kuss and Schlaginweit, 1988, p. 92, pl. 19, fig. 1; Shirazi, 2008, p. 803, pl. III, figs. 1–9.

Description. Slightly segmented thallus, segments long, ovoid or subcylindrical, irregular finger-like or pinched and swollen units with fine pores at outer zone, internal sporangia are not visible. Calcification varies from thin to thick layers to total calcification. Broken thalli fragments are often accumulated, creating the typical “algal-debris-facies” of Elliott (1958).

Measurements.
Height of thalli (h) 450 µm.
Diameter of thalli 300 µm.

Stratigraphic distribution. Elliott (1958) described *Permocalculus irenae* from the Cenomanian of northern Iraq; Cenomanian of Iran and Albian-Cenomanian of Lebanon reported by Basson and Edgell (1971). Kuss and Conrad (1991) recorded the species in the Albian from the Sinai and the Cenomanian from Jordan and northeastern Egypt.

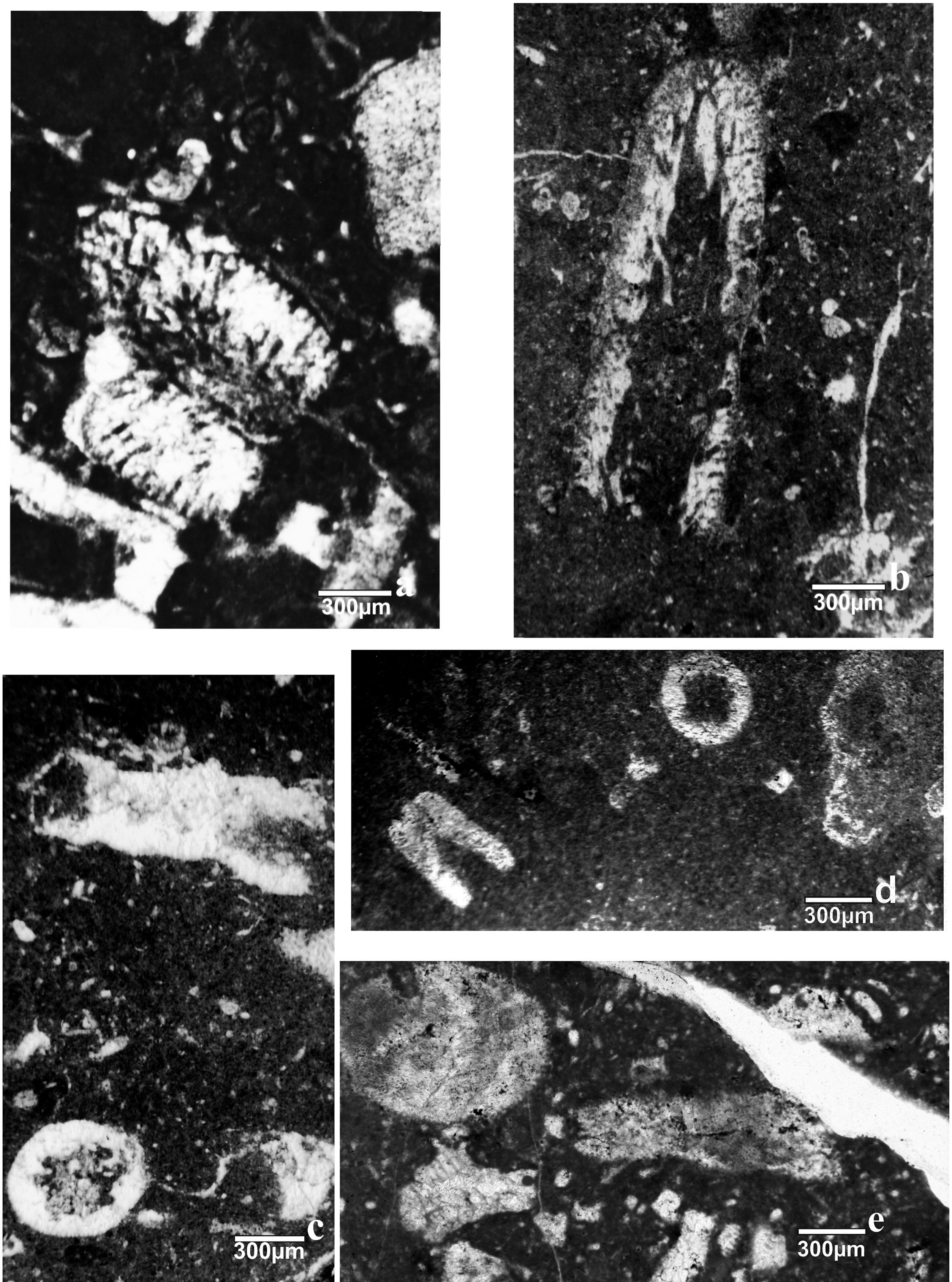

Figure 6. Cenomanian Bryopsidales and Gymnocodacean algae from the El Abra Formation. a) Longitudinal section of *Boueina pygmaea* (Sample LLC-4). b) Longitudinal section of *Halimeda* cf. *H. elliotti* (Sample LLC-1). c) Longitudinal and cross sections of *Permocalculus budaensis* (Sample C-8). d) Longitudinal and cross sections of *Permocalculus irenae* (Sample C-8). e) Longitudinal and cross sections of *Permocalculus budaensis* (Sample C-8)..

Occurrence. This species was recorded in Cerritos locality (Sample C-8).

Incertae sedis (Microencrusters)
Genus *Lithocodium* Elliot, 1956

Lithocodium aggregatum Elliot, 1956
Figure 7a, b

1956 *Lithocodium aggregatum* Elliot, p. 331, pl. 1, figs. 2, 4–5; Banner *et al*., 1990, p. 24, pl. 1, fig. 2, p. 31, pl. 4 fig. 1; Radoičić, 2005, pl. 5, figs. 1–6; pl. 6, figs. 1, 2; Schlagintweit and Bover-Arnal, 2011, p. 4, figs. 2e, g.

Description. The *Lithocodium* crusts consist of an irregular network and the periphery presents a thin alveolar system forming bifurcated filaments perpendicular to the surface.

Remarks. *Lithocodium aggregatum* was described by Elliott (1956) from Iraq. The taxonomic position of this encrusting microorganism has been controversial during recent decades. *Lithocodium aggregatum* was originally described as a siphonal (=non-septate filaments) codiacean alga by Elliot (1956) and interpreted also as a codiacean green algae by Banner *et al*. (1990). Its codiacean nature was accepted by many subsequent authors (Praturlon, 1964; Johnson, 1964; Poignat, 1968; Radoičić, 2005). Besides the assumed green algal nature, other authors such as Koch *et al*. (2002) indicated that *Lithocodium aggregatum* is more similar to sponges.

Schlagintweit (2010) and Schlagintweit *et al*. (2010) considered *Lithocodium* to be a filamentous-septate heterotrichale ulvophycean alga (order Ulotrichales?) exhibiting a heteromorphic life cycle consisting of two phases: an epilithic gametophytic stage and an euendolithic sporophytic (*Gomontia*) stage.

The taxonomic interpretation of *Lithocodium aggregatum* as sessile green algae (Schlagintweit *et al*., 2010) is accepted by Huck *et al*. (2012).

The taxon has been regarded as a foraminifer as well (Schmid and Leinfelder, 1995, 1996), which was discussed and rejected by Cherchi and Schroeder (2006) and Schlagintweit (2008); however, some authors, such as Dupraz and Strasser (2002), agree with the interpretation of Schmid and Leinfelder (1995, 1996) regarding the foraminiferal character of *Lithocodium aggregatum*. It has also been regarded as calcimicrobial colonies (Camoin, 1983). Cherchi and Schroeder (2006) showed that *Lithocodium aggregatum* is a colony of calcified cyanobacteria. This interpretation is confirmed by Conrad and Clavel (2008) who found that the *Lithocodium* crusts have a high organic content. Cherchi and Schroeder (2010, 2011, 2013) stated that *Lithocodium aggregatum* is a sponge (Entobia)-calcimicrobe consortium. They agree with the interpretation that these crusts are colonies of calcified microbes, probably cyanobacteria, which were transformed into dense, homogeneous micrite. Numerous occasionally broken needle-shaped sponge spicules and minute sedimentary particles were introduced by currents, trapped by calcimicrobial mucilage, and incorporated into the crusts.

Stratigraphic distribution. *Lithocodium aggregatum* ranging to the Late Triassic–Middle Cretaceous carbonate platforms of the Tethyan realm (Elliott, 1963; Flügel, 2004)

Occurrence. Identified from the Llanos del Carmen (Sample LLC-1).

Genus *Thaumatoporella* Pia, 1927

Thaumatoporella parvovesiculifera (Raineri 1922)
Figure 7 d–e

1922 *Gyroporella parvovesiculifera* n. sp. Raineri, p. 83, pl. 13, fig. 17–18.

Thaumatoporella parvovesiculifera (Raineri,1922): Pia, 1927, p. 69; Sartoni and Crescenti, 1962, p. 270, pl. 16; pl. 46, figs. 2–3, 5; De Castro, 2002, text-fig. 2, pl. 1, fig. 1–11; Flügel, 2004, p. 566, pl. 99, fig. 2; Senowbari-Daryan *et al*., 2011, p. 512, fig. 11–M; Schlagintweit, 2013, p. 8, figs. 8 d–e.

Description. *Thaumatoporella parvovesiculifera* (Rainieri, 1922) consists of an outer thin-walled structure with cells forming an irregular, lobed, ovoid to globular and cylindrical structure, with an internal cavity preserved as sparry calcite (Flügel, 2004).

Thaumatoporellaceans can be free-living, attached to hard substrates, or dwell as cryptoendoliths inside hollow bioclasts (Schlagintweit *et al*., 2013).

Remarks. Rainieri (1922) described *Gyroporella parvovesiculifera* from the Upper Cretaceous of southern Italy and placed it in the Dasycladacean algae. Later, Pia (1927) proposed the genus *Thaumatoporella* taking into account the differences between *Gyroporella* Raineri's genus, accepting its place within the Dasycladacean algae.

Pia (1938) observed that "the thalli were not growing in an upright position like that of the Dasycladacean but were creeping on the sea floor". This author noted the peculiarity of this genus which has no internal structure and emphasized the high variability in morphology and dimension including the width of the thallus, pore diameter, and wall thickness.

This problematic genus has been interpreted as red algae (Ramalho, 1971; Flügel, 1979), chlorophycean algae (Barattolo, 1991) and as a different group of green algae (De Castro, 1990). *Thaumatoporella parvovesiculifera* can be free-living or attached to hard substrates, as has been already observed by Schlagintweit and Velić (2012).

Stratigraphic distribution. *Thaumatoporella parvovesiculifera* successfully inhabited different shallow-water environments over a long period of more than 150 million years from the Middle Triassic (Landian) (de Castro, 1990; Flügel, 2004; Schlagintweit, 2012) to the lower Eocene (Ilerdian) in the Limalok Guyot (Central

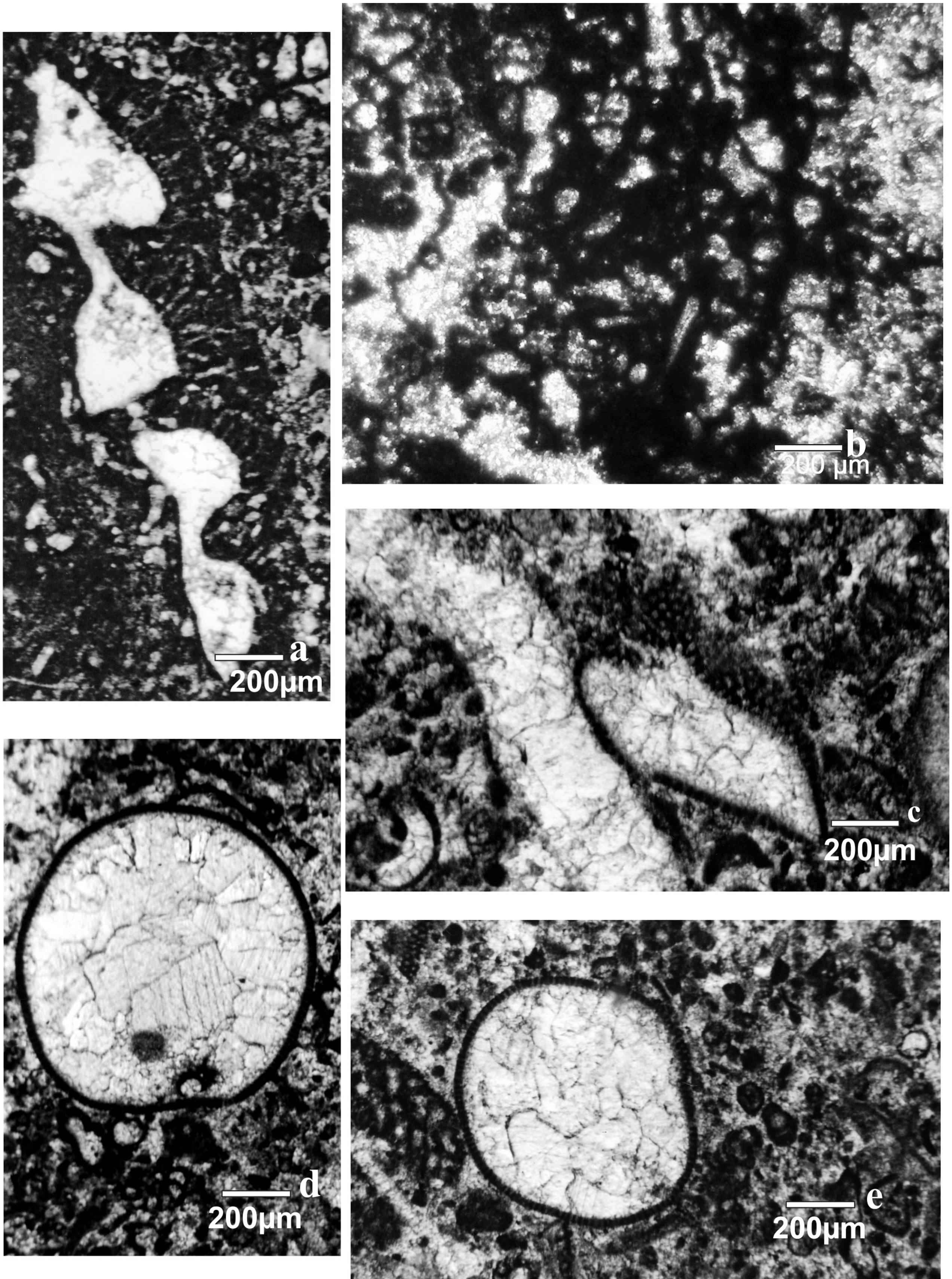

Figure 7. Cenomanian incertae sedis (microencrusters) from the El Abra Formation. a–b) *Lithocodium aggregatum* (Sample LLC-1). c–e) *Thaumatoporella parvovesiculifera* (Samples C-5, 6).

Pacific). At this site it was observed in younger sediments of middle Eocene (Lutetian) (Nicora *et al*., 1995). Later, Vecchio and Barattolo (2006) and Vecchio and Hottinger (2007) recorded thaumatoporellacean algae in southern Italy in the same interval; from these published data the occurrence of this fossil ranged to the Eocene (uppermost Ypresian–lowermost Lutetian).

Measurements.

Diameter 600–800 µm

Occurrence. *Thaumatoporella parvovesiculifera* was living free or on a hard substrate, as was already observed by Schlagintweit and Velić (2012). In our material it is very common in the Cerritos locality (Samples C-5, C-6).

5. Conclusions

The deposit of the upper part of the El Abra Limestone (Taninul Facies) contains a diverse algal and benthic foraminiferal assemblage. It is dated as mid-late Cenomanian based on the occurrence of *Pseudolituonella reicheli*, *Daxia cenomana* and *Merlingina cretacea*.

The textural features and the microfossil association allow for two different depositional environments to be inferred. The first is characteristic of a warm shallow-water carbonate platform with open circulation and medium-high hydrodynamic energy with a great diversity of benthic and algal species in an oligotrophic stage, and the other represents a reduction of the benthic foraminiferal assemblages associated with the gymnocodacean algae such as *Permocalculus irenae* and *P. budaensis*, which could be related to increasing nutrient availability in mesotrophic conditions.

The algal association is typical Tethysian, similar to Mediterranean localities.

Acknowledgements

This work was supported by DGAPA-PAPIIT IN119208 project grants. We are greatly indebted to Dr. Rafael Barboza Gudiño (Director of the Geology Institute of the Universidad Autónoma de San Luis Potosí) for logistical assistance.

The authors gratefully acknowledge the valuable feedback and suggestions contributed by Dr. Ioan I. Bucur (Department of Geology, Babeş-Bolyai University, Romania) which were very helpful to improve the manuscript. We are thankful to Dr. Bruno Granier (Université de Bretagne Occidentale, Brest, France) for the useful corrections. We thank Joaquín Aparicio for preparing numerous thin sections, and Carlos Jiménez for the photos he took.

References

Agardh, J.G., 1887–1888, Till Algernes Systematik, VIII. Siphoneae: Lund´s Univ. Arsskr., 23, 1–174.

Aguayo, C.E., 1998, The middle Cretaceous El Abra limestone at its type locality (facies, diagenesis and oil emplacement): Revista Mexicana de Ciencias Geológicas, 15, 1–8.

Aguilera-Franco, N., Hernández-Romano, U., Allison, P., 2001, Biostratigraphy and environmental changes across the Cenomanian and Turonian boundary, Southern Mexico: Journal of South American Earth Sciences, 14, 237–255.

Alencáster, G., 1987, Fauna arrecifal del Albiano Tardío de la región de Jalpan, Querétaro, México: Universidad Autónoma de Nuevo León, Actas de la Facultad de Ciencias de la Tierra 2, 111–119.

Alencáster, G., 1998, New Caprinid rudist genera *Guzzyella* and *Muellerriedia* (Bivalvia Hippuritacea) from the Albian (Cretaceous) of Central Mexico: Revista Mexicana de Ciencias Geológicas, 15, 91–105.

Alencáster, G., García-Barrera, P., 2008, Albian Radiolitid (Mollusca-Bivalvia) from East-Central Mexico: Geobios, 41, 571–587.

Banner, F.T., Finch, E.M., Simmons, M.D., 1990, On *Lithocodium* (Calcareous algae): its paleobiological and stratigraphical significance: Journal of Micropaleontology, 9, 21–36.

Barattolo, F., 1983, Observazioni su *Triploporella steinmannii* n.sp. (alghe verdi, Dasicladali) del Cretacico del Messico: Bollettino della Societa dei Naturalisti in Napoli, 91 (1982), 35 p.

Barattolo, F., 1990, Remarks on *Neomeris cretacea* Steinmann (Chlorophyta, Dasycladales) from the Cretaceous of Orizaba (type locality), Mexico: Bolletino della Società Paleontologica Italiana, 29 (2), 207–221.

Barattolo, F., 1991, Mesozoic and Cenozoic marine benthic calcareous algae with particular regard to Mesozoic Dasycladaceans, *in* Riding, R. (ed.), Calcareous Algae and Stromatolites: Spring Berlin Heidelberg, New York, 504–540.

Basson, P.W., Edgell, H.S., 1971, Calcareous algae from the Jurassic and Cretaceous of Lebanon: Micropaleontology, 17 (4), 411–433.

Bassoullet, J.P., Bernier, P., Conrad, M.A., Deloffre, R., Genot, P., Jaffrezo, M., 1978, Les Algues Dasycladales du Jurassique et du Crétacé: Geobios Mem. Sp, 2, 1–338.

Bassoullet, J.P., Bernier, P., Conrad, M.A., Deloffre, R., Génot, P., Jaffrezo, M., Vachard, D., 1979, Essai de classification des Dasycladales: Bulletin des Centres de Recherches Exploration-Production Elf-Aquitaine, 3 (2), 429-442.

Bassoullet, J.P., Bernier, P., Deloffre, R., Génot, P., Poncet, J., Roux, A., 1983, Les algues Udoteacées du Paleozoique au Cenozoique: Bulletin Centre Recherches Exploration-Production Elf-Aquitaine, 7, 449–621.

Bauer, J., Kuss, J., Steuber, T., 2002, Platform environments, microfacies and systems tracks of the upper Cenomanian-lower Santonian of Sinai, Egypt: Facies, 47, 1–26.

Berger, S., Kaever J., 1992, Dasycladales. An illustrated monograph of a fascinating algal order. Thieme, Stuttgart, 247 p.

Bonet, F., 1956, Zonificación microfaunística de las Calizas Cretácicas del Este de México: Boletín de la Asociación Mexicana de Geólogos Petroleros, 8, 389–489.

Bucur, I.I., 1994, Lower Cretaceous Halimadaceae and Gymnocodaceae from southern Carpathian and Apuseni Mountains (Romania) and systematic position of the Gymnocodaceae: Beiträge zur Paläontologie, 19, 13–37.

Bucur, I.I., Nagm, E., Wilsem, M., 2010, Upper Cenomanian-Lower Turonian (Cretaceous) calcareous algae from the Eastern desert of Egypt: Taxonomy and significance: Studia Universitatis Babeş-Bolyai, Geologia, 55 (1), 29–36.

Buitrón, B.E., Carrillo-Martínez, M., Rosales-Domínguez, M.C., Aguilera-Franco, N., 1995, A middle Albian biota (Algae, Foraminifera and Gastropoda) from Ahuacatlán State of Queretáro, Mexico: Revista Mexicana de Ciencias Geológicas, 12 (2), 145–156.

Camoin, G., 1983, Plate-formes carbonatées et récifs à rudists du Crétacé de Sicile: Travaux du Laboratoire de Géologie Historique et de Paléontologie, Université de Provence, Marseille 13, 244 p.

Carpenter, W.B., 1862, Introduction to the study of the foraminifera: Hardwicke, R., London, 174–183.

Carras, N., Conrad, M.A., Radoičić, R., 2006, *Salpingoporella*, a common genus of Mesozoic Dasycladales (calcareous green algae): Revue de Paléobiologie, 25 (2), 457–617.

Cherchi, A., Schroeder, R., 1980, Presenza de clasti cenomaniani a Prealaveoline nella formazione del Cixerr (Serdegna SW): Bolletino della Società Sarda di Scienze Naturali, 20, 27–36.

Cherchi, A., Schroeder, R., 2006, Remarks on the systematic position of *Lithocodium* Elliott, a problematic microorganism from the Mesozoic carbonate platforms of the Tethyan realm: Facies, 52, 435–440.

Cherchi, A., Schroeder, R., 2010, Boring sponges (ichnogenus *Entobia*) in Mesozoic *Lithocodium* calcimicrobial crusts: Rivista Italiana de Paleontologia e Stratigrafia, 116, 351–356.

Cherchi, A., Schroeder, R., 2011, Revision of the holotype of *Lithocodium aggregatum* Elliott, 1956 (Lower Cretaceous, Iraq): new interpretation as sponge-calcimicrobial consortium, *in* Bucur II, Sasaran E (eds.), 10th International Symposium on Fossil Algae, Cluj-Napoca, Abstr vol, 17 p.

Cherchi, A., Schroeder, R., 2013, Revision of *Lithocodium aggregatum* Elliot, 1956 (Lower Cretaceous, Iraq): new reinterpretation as sponge-calcimicrobe consortium: Facies, 59, 49–57.

Chiuvasohv, B.I., Luchinina, V.A., Shuysky, V.B., 1987, Isko-paemîie izvestkvîie vodorosli (morfologhia, metodî izucenia): Trudî Instituta Geol. i Geofiziki, vîpusk 674, Acad. Nauk SSSR Sibirskoe otdelenie, 5–109.

Conard, M.A., Rioult, M., 1977, *Halimeda ellioti* nov.sp. algae calcaire (Clorophyceae) du Turonien des Alpes-Maritimes (SE France): Géologie Mediterranéenne, 4 (2), 83–98.

Conrad, M.A, Clavel, B., 2008, A *Lithocodium* and *Bacinella* signature of a late Hauterivian, local microbial event: the Urgonian limestone in south-east France: Geologia Croatica, 61, 239–250.

Conrad, M.A., Radoičić, R., Rey, J., 1977, *Salpingoporella hasi*, n. sp., une Dasycladale de l'Albien et Cénomanien du Portugal: Compte rendu des séances de la Société de physique et d'histoire naturelle de Genève, 11 (1–3) 99–104.

Coogan, A. H., 1973, Nuevos rudistas del Albiano y Cenomaniano de México y Sur de Texas: Revista del Instituto Mexicano del Petróleo, 5, 51–83.

Cros, P., Lemoine, M., 1966, Dasycladacées nouvelles ou peu connues du Lias inférieur des Dolomites et de quelques autres régions mediterranéennes (1re partie): Revue de Micropaléontologie, 9 (3), 156–168.

De Castro, P., 1990, *Thaumatoporelle*: conocenze attuali e approcio all'interpretazione: Bolletino della Società Paleontologica Italiana, 29 (2), 179–206.

De Castro, P., 2002, *Thaumatoporella parvovesiculifera* (Raineri) typification, age and historical background (Senonian, Sorrento Peninsula-southern Italy): Bolletino Società Paleontologica Italiana, 41, 121–129.

Deloffre, R., Fourcade, E., Michaud, F., 1985, *Acroporella chiapasis* algue dasycladacea Maastrichtienne du Chiapas (SE Mexique): Bulletin des Centres de Recherches Exploration-Production Elf-Aquitaine, 9 (1), 165–217.

Dragastan, O.N, 1985, Review of Tethyan Mesozoic algae of Romania, *in* Toomey, F.D., Nitecki, N.H. (eds.), Palaeoalgology: Contemporary Research and Applications, Berlin, Heidelberg, Springer Verlag. 101–161.

Dragastan, O.N., 2008, Mesozoic and Cenozoic calcareous algae precursors of Family Codiacea: Acta paleontologica Romaniae, 6, 83–95.

Dragastan, O.N., Herbig, H-G., 2007, *Halimeda* (green siphonous algae from the Paleogene of (Morocco)-Taxonomy, phylogeny and paleoenvironment: Micropaleontology, 53 (1–2), 1–72.

Dupraz, C, Strasser, A., 2002, Nutritional modes in coral-microbialite reefs (Jurassic, Oxfordian, Switzerland): evolution of trophic structure as a response to environmental change: Palaios, 17, 449–471.

Elliot, G.F., 1955, Fossil calcareous algae from the Middle East: Micropaleontology, 1, (2), 125–131.

Elliot, G.F., 1956, Further records of fossil calcareous algae from the Middle East: Micropaleontology, 2, 327–334.

Elliott, G.F., 1957, Algues calcaires codiacées fossiles d'Iraq, nouvelles et peu connues: Bulletin de la Société Géologique de France, 6 (6), 789–795.

Elliott, G.F., 1958, Algal debris facies in the Cretaceous of Middle East: Palaeontology, 1 (3), 254–259.

Elliott, G.F., 1963, Problematic microfossils from the Cretaceous and Paleocene of the Middle East: Palaeontology, 6, 293–300.

Elliott, G.F., 1965, The interrelationships of some Cretaceous Codiaceae (calcareous algae): Palaeontology, 8, 199–203.

Elliott, G.F., 1972, *Trinocladus exoticus*, a new dasycladacean alga from the Upper Cretaceous of Borneo: Palaeontology, 15 (4), 619–622.

Favre, J., Richard, A., 1927, Étude du Jurassique Supérieur de Pierre Châtel et de la cluse de la Balme (Jura méridional): Mémoires de la Société Paléontologique Suisse, 46, 1–39.

Feldman, J., 1946, Sur l'heteroplastie decertaines siphonales et leur classification: Compte Rendu Académie des Sciences, 22, 752–753.

Filkorn, H., Scott, R.W., 2011, Microfossils, paleoenvironments and biostratigraphy of the Mal Paso Formation (Cretaceous, upper Albian): Revista Mexicana de Ciencias Geológicas, 28 (1), 175–191.

Flügel, E., 1979, Paleontology and microfacies of Permian, Triassic and Jurassic algal communities of platform and reef carbonate from the Alps: Bulletin des Centres de Recherches Exploration-Production Elf-Aquitaine 3, 569–587.

Flügel, E., 1988, *Halimeda*: Paleontological record and paleoenvironmental significance: Coral Reefs, 6, 123–130.

Flügel, E., 2004, Microfacies of Carbonate Rocks. Springer, Berlin, 976 p.

Garfias, V.R., 1915, The oil region of northeastern Mexico: Economic Geology, 10, 195–224.

Frollo, M.M., 1938, Sur un nouveau genre de Codiacée du Jurassique supérieur des Carpates Orientales: Bulletin de la Societé Géologique de France, Ser. 5, 8, 269–271.

Geitler L., 1925, Cyanophycea, *in* Pascher A. (ed.), Süswasserflora 12, Gustav Fischer Verl., Jena., 481 p.

Granier B., Dias-Brito, D., Bucur, I.I., 2012a, A mid Cretaceous *Neomeris* (dasycladacea alga) from Portiguar Basin, Brazil: Facies DOI 10.1007/s10347-012-0322-4.

Granier B., Dias-Brito D., Bucur I.I., Tibana P., 2012b, *Brasiliporella*, a new mid-Cretaceous dasycladacean genus: the earliest record of the Tribe Batophoreae: Facies, doi:10.1007/s10347-012-0312-6-14.

Granier B., Dias-Brito, D., Bucur, I.I., 2014, *Clypeina tibanai* (Polyphysacea, Dasycladales, Chlorophyta) mid Cretaceous green alga from Portiguar Basin, Brazilian margin of the young South Atlantic Ocean: Geologica Acta, 12 (3), 227–237.

Gümbel, C.W., 1872, Die sogenann ten Nulliporen (*Lithothammnium* und *Dactylopora*) und ihre Betheiligung an der Zusammensetzung der Kalkgesteine Zweiter Theil: Die Nulliporen des Thierreichs (Dactyloporideae) nebst Natchtrag zum ersten Theile: Abhandlungen der königlich bayerischen Akademie des Wissenschaften, (CII) XI (I), 231–290.

Hernández-Romano, U., Aguilera-Franco, N., Buitrón, B.E., 1998, Late Cenomanian fossil association from Morelos, Mexico Stratigraphic implications: Revista Mexicana de Ciencias Geológicas, 15 (1), 46–56.

Hillis-Colinvaux, L., 1984, Systematics of the Siphonales, *in* Irvine Deg, John, DM (eds.), Systematics of the green algae: Academic Press, New York London, 271–286.

Howe, M.A., 1909, Phyco1ogical studies, IV. The genus *Neomeris* and notes on other Siphonales: Bulletin of the Torrey Botanical Club, 36, 75–104.

Huck, S., Heimhofer, U., Immenhauser, A., 2012, Early Aptian algal bloom in a neritic proto-North Atlantic setting: Harbinger of global change related to OAE 1a?: Geological Society of America Bulletin, (doi 10.1130/B30587).

Johnson, J.H., 1964, The Jurassic algae: Quarterly of the Colorado School of Mines, 59 (2), 1–129.

Johnson, J.H, 1965, Three Lower Algae to the Americas: Journal of Paleontology, 39 (4), 719–721.

Johnson, J.H., 1968, Lower Cretaceous algae from Texas Part 1, Fossil algae from the Buda Limestone of Texas: Professional Contributions of the Colorado School of Mines, 4, 1–28.

Johnson, H.B., 1969, A review of the Lower Cretaceous algae: Professional Contributions of the Colorado School of Mines s, 6, 180 p.

Knoll, A.H., 2008, Cyanobacteria and earth history, *in* Herrero, A., Flores, E. (eds), The cyanobacteria: molecular biology, genomics and evolution, Caister Academic Press, Norfolk, 1–19.

Koch, R., Moussavian, E., Ogorelec, B., Skaberne, D., Bucur, I.I., 2002, Development of a *Lithocodium* (syn. *Bacinella irregularis*)-reef mound-A patch reef within Middle Albian lagoonal limestone sequence near Nova Gorica (Sabotin Mountain, W-Slovenia): Geologija, 45, 71–90.

Kuss, J., 1986, Upper Cretaceous calcareous algae from the Eastern Desert of Egypt: Neues Jahrbuch fir Geologie und Palaontologie, Monatshefte, 223–238.

Kuss, J., 1994, Cretaceous (Albian-Turonian) calcareous algae from Egypt and Jordan-Systematics, stratigraphy and paleogeography: Abhandlungen der Geologischen Bundesanstalt, 50, 295–317.

Kuss, J., Conrad, M.A., 1991, Calcareous algae from Cretaceous carbonates of Egypt, Sinai, and southern Jordan: Journal of Paleontology, 65 (5), 869–882.

Kuss, J., Schlanginweit, F., 1988, Facies and stratigraphy of Early to Middle Cretaceous (Late Aptian-Early Cenomanian) strata from the northern rim of the African Craton (Gebel Maghara-Sinai, Egypt): Facies, 19, 77–96

Kützing, F.T., 1841, Die Umwandlung niederer Algenformen in höhere, so wie auch in Gattungen ganz verschiedener Familien un Klassen höherer Cryptogamen mit zelligem Bau: Natuurkundige Maatschapij Wetenschappen, Haarlem, 120 p.

Kützing, F.T., 1843, Phycologia generalis: Perhes Leipzig, 458 p.

Lamoroux J.V., 1812, Extrait d'un mémoire sur la classification des Polypiers coralligènes non entièrement pierreux: Nouveau Bulletin des Sciences par la Société Philomathique, Paris, 3, 181–188.

Link, H.F., 1832, Uber die Pflanzenthiere uberhaupt und die dazu gerechneten Gewachse besonders: Abh. Konigl. Acad. Wiss. Berlin, Phys. Kl., 1830, 109–123.

Littler, D.S., Littler, M.M., 1990, Systematics of *Udotea* species (Bryopsidales, Chlorophyta) in the tropical western Atlantic: Phycologia, 29 (2), 206–252.

Littler, D.S., Littler, M.M., 1992, Systematics of Avrainvillea (Bryopsidales, Chlorophyta) in the tropical western Atlantic: Phycologia, 31 (5), 375–418.

Lorenz, T., 1902, Geologische studien im Grenzbebiete zwischen helvetischer und ostalpiner Facies: Ber. naturfosch Gesellschaft Freiburg Breisgan, 12, 34–62.

Mancinelli, A., Ferrandes, D., 2001, Mesozoic cyanobacteria and calcareous? algae of the Apennine platform (Latium and Abruzzi, Italy): Geobios, 34 (5), 533–546.

Masse, J.P., Arnaud-Vanneau, A., 1999, Algues calcaires du Crétacé Inférieur du Pacific Ouest: Revue de Micropaléontologie, 42 (1), 57–69.

Masse, J.P. Isintek, I., 2000, Algues Dasycladales de l'albien de la Péninsule de Karaburun, Turquie: Revue de Micropaléontologie, 43 (3), 365–380.

Michaud, F., 1987, Stratigraphie et paléogeographie du Mesozoique du Chiapas (Sud Est du Mexique. Académie de Paris Université Pierre et Marie Curie: Mémoires de Sciences de la Terre, 87, 298 p.

Michelin, H., 1840–1847, Iconographie zoophytologique. Description par localités et terrains des Polypiers fossiles de France et pays environnants. P. Bertrand, Paris, 348 p.

Morellet, L., Morellet, J., 1913, Les Dasycladacées du Tertiaire parisien: Mémoires de la Société Géologique de France (Paléontologie), XXI (I), 47, 1–43.

Morellet, L., Morellet, J., 1918, Observations sur le genre *Clypeina* Michelin: Bulletin de la Société Géologique de France, (4o Série), 18 (1–2), 102–105.

Munier-Chalmas, E.P., 1877, Observations sur les algues calcaires appartenant au groupe des Siphonées verticillées (Dasycladées Harv.) et confondues avec les foraminifères: Compte Rendu de l'Académie des Sciences, 85 (18), 814–817).

Nicora, A., Premoli Silva, I., Arnaud Vanneau, A., 1995, Paleogene larger foraminifer biostratigraphy from Limalok Guyot, Site 871, *in* Haggerty, J.A., Premoli Silva, I., Rack, F., McNutt, M.K. (eds.): Proceedings of the Ocean Drilling Program, Scientific Results, 144, 127–139.

Omaña, L., Torres-Hernández, J.R., 2000, Cenomanian–Turonian foraminiferal assemblage from the El Abra Formation in the Santa Isabel Region, San Luis Potosí Mexico: VIII Congreso Nacional de Paleontología y I Simposio en el Noreste de México, Linares, Nuevo León, México, Libro de Resúmenes, 53.

Omaña, L., López Doncel, Torres Hernández J.R., Alencaster, G., 2013, Biostratigraphy and paleoenvironment of the Cenomanian-Turonian interval based on foraminifera from the western part of the Valles–San Luis Potosí Platform, Mexico: Micropaleontology, 58 (6), 457–485.

Ornelas-Sánchez, M., Franco-Navarrete, S., Granados-Martínez, M., Segura-Treviño, A., Torres-Estrada, C., Ruíz-Ruíz, H., 2006, Análisis y evolución de las facies arrecifales de la Formación El Abra (Aptiano-Cenomaniano) de la Cuenca Tampico-Misantla: Memoria X Congreso Nacional de Paleontología, Universidad Nacional Autónoma de México, Instituto de Geología Publicación Especial, 5, 123–124.

Parker, W.K., Jones, T.R., 1860, On the nomenclature of the foraminifera: Annals and Magazine of Natural History, Journal of Natural History 3rd Series, 30, 466–477.

Pascher, A., 1914, Über Flagellaten und Algen: Berichte der deutsche botanischen Gesellschaft, 32, 136–160.

Pascher, A., 1931, Systematische Übersicht über die mit Flagellaten in Zusammenhang stehenden Algenreihen und Versuch einer Einreihung dieser Algenstämme in die Stämme des Pflanzenreiches: Beihefte zum Botanischen Centralblatt, 48, 317–332.

Pia, J. von., 1918, Dasycladaceae, *in* Trauth, F. (ed.): Das Eozänvorkommen bei Radstadt im Pongau und seine Beziehungenzu den Gleichalterigen Ablagerungen bei Kirchberg am Wechsel und Wimpassing am Leithagerbirge Akademie der Wissenschaften, 95, 171–278.

Pia, J. von., 1920, Die Siphoneae verticillatae vom karbon bis zur Kreide: Abhandlungen der Zoologisch-Botanischen Gessellschaft in Wien Band XI, Heft 2, 259 p.

Pia, J. von., 1927, Tallophyta, *in* Hirmer, M, Handbuch der Paläonbotanik, Oldenburg, 31–136.

Pia, J. von., 1936, Calcareous green algae from the Upper Cretaceous of Tripoli (North Africa): Journal of Paleontology, 10 (1), 3–13.

Pia, J. von., 1938, Über *Thaumatoporella parvovesiculifera* Ranieri Spec und ihr Auftreten auf der Insel Naxos: Praktika tès Akàdemias Athènon, 13, 491–495.

Poignat, A.F., 1968, Les algues des calcaires aptiens et albiens de l'Aquitaine méridionale: Revue de Micropaléontologie, 10, 271–276.

Praturlon, A., 1964, Calcareous algae from Jurassic-Cretaceous limestone of central Apennines (Southern Latium-Abruzzi): Geologica Romana, III, 171–203.

Praturlon, A., 1966, *Heteroporella lepina*, new dasyclad species from upper Cenomanian-lower Turonian of central Apennines: Bolletino Società Paleontologica Italiana, 5 (2), 202–205.

Radoičić, R., 1959, Nekoliko problematičnih mikrofosila iz dinarske krede (Some problematic microfossils from the Dinarian Cretaceous): Bulletin du Service de Géologie et Géophysique, Republique de Serbie, 17, 87–92.

Radoičić, R., 1994, On some successions of the Pastrik Mountain (Kukes Cretaceous Unit, Mirdita): Annales Géologiques de la Péninsule Balkanique, 58 (2), 1–16.

Radoičić, R., 1998, *Halimeda elliotti* Conard and Rioult, 1977 (Udoteacea, Green Algae) from the Kukes Cretaceous Unit (Mirdita Zone): Bulletin of Natural History Museum, A 47–50, 181–188.

Radoičić, R., 2005, New Dasycladales and microbiota from the lowermost Valanginian of the Mirdita Zone: Annales Géologiques de la Péninsule Balkanique, 66, 27–53.

Radoičić, R., 2006, *Trinocladus divnae Montiella filipovici*- a new species (Dasycladales, green algae) from and the Upper Cretaceous of the Mountain Paštrik (Mirdita Zone): Annales Géologiques de la Péninsule Balkanique, 67, 65–87.

Raineri, R., 1922, Alghe sifonee fossili della Libia: Atti della Società italiana di Scienze naturali e del Museo civico di Storia Naturale in Milano, 61 (1), 72–8.

Ramalho, M., 1971, Contribution à l'étude micropaléontologique et stratigraphique du Jurassique Supérieur et du Crétacé Inférieur des environs de Lisbonne (Portugal): Memórias de Serviços Geológicos de Portugal, 19, 1–212.

Ramírez del Pozo, J., López Martínez, J., 1988, Estratigrafía del Cretácico Superior en las cabeceras de los Valles de Ansó y Roncal (Pirineo occidental): Revista de la Sociedad Geológica de España 1 (1–2), 37–52.

Rabenhorst, L., 1865, Flora europaea algarum aquae dulcis et submarinae. Section II. Algas phycochromaceas complectens. Lipsiae [Leipzig]: Apud Eduardum Kummerum, 1–319, 71 figs.

Round, F.E., 1963, The taxonomy of the Chlorophyta: British Phycological Bulletin, 2, 224–245.

Ruprecht, F.J., 1851, Tange des Ochotskischen, *in* A. Th. von Middendorff's Reise in der aussersten Norden und Osten Sibiriens während der Jahre 1843 und 1844: St. Petesburg, Buchdrucherei der Kaiserlichen Akademie der Wissenschaften, 1, 191–435.

Sachs, J., 1874, Lehrbuch der Botanik, 4th ed., W. Engelmann, Leipzig.

Salvador, A., 1991, Origin and development of the Gulf of Mexico basin, *in* Salvador, A., (ed.), The Gulf of Mexico Basin: The Geology of North America, Volume J., p. 389–444.

Sartoni, S., Crescenti, U., 1962, Ricerche biostratigrafiche nel Mesozoico dell´Appennino meridionale: Giornale di Geologia, 29, 153–302.

Schaffner, J.H., 1922, The classification of plants XII; Ohio Journal of Science, 22, 129–139.

Schlagintweit, F., 2008, Bioerosional structures and pseudoborings from Late Jurassic and Late Cretaceous-Paleocene shallow-water carbonates (Northern Calcareous Alps, Austria; SE France) with special reference to cryptobiotic foraminifera: Facies, 54, 377–402.

Schlagintweit, F., 2010, Taxonomic revision of the Late Jurassic "*Lithocodium aggregatum* Elliot" sensu Schmid and Leinfelder 1996: Jahrbuch der Geologischen Bundesanstalt, 50, 393–406.

Schlagintweit, F., 2013, *Thaumatoporella* ladders unraveled: Studia Universitatis Babeș-Bolyai Geologia, 58 (1), 5–9.

Schlagintweit, F., Bover-Arnal, T., Salas, R., 2010, New insights into *Lithocodium aggregatum* Elliott 1956 and *Bacinella irregularis* Radoičić 1959 (Late Jurassic–Lower Cretaceous): two ulvophycean green algae (?Order Ulotrichales) with a heteromorphic life cycle (epilithic/euendolithic): Facies, 56, 509–547.

Schlagintweit, F., Bover-Arnal, T., 2011, The morphological adaptation of *Lithocodium aggregatum* Elliott (calcareous green algae) to cryptic microhabitats (lower Aptian, Spain): an example of phenotypic plasticity: Facies doi: 10.007/s 10347-011-272-2, 201.

Schlagintweit, F., Velic, I., 2012, Foraminiferan test and dasycladalean talli as cryptic microhabitats of thaumatoporellacean algae from Mesozoic (Late Triasic-Late Cretaceous) platform carbonates: Facies, 58, 79–94.

Schlagintweit , F., Hladil, J ., Nose, M., Salerno, C., 2013, Paleozoic record of *Thaumatoporella* Pia, 1927: Geologia Croatica, 66 (3), 155–182.

Schmid, D.U., Leinfelder, R.R., 1965, *Lithocodium aggregatum* Elliot n'est pas une algue mais un foraminifère encroutant, commensalisées par le foraminifère *Troglotella* incrustans Vernli et Fookes: Comptes Rendus de l'Académie des Sciences, Paris sér, IIa 320, 531–538.

Schmid, D.U., Leinfelder, R.R., 1966, The Jurassic *Lithocodium aggregatum-Troglotella incrustans* incrustant foraminiferal consortium: Palaeontology, 39, 21–52.

Scott, R.W., 1990, Models and Stratigraphy of mid-Cretaceous reef communities, Gulf of Mexico, *in* Lidz, B.H (ed.), SEPM Concepts in Sedimentology and Paleontology, 2, 1–99.

Schopf, J.W., 1974, The development and diversification of Precambrian life: Origin of Life, 5, 119–135.

Scott, R.W., 1990, Models and Stratigraphy of mid-Cretaceous reef communities, Gulf of Mexico, *in* Lidz, B.H (Ed.), SEPM Concepts in Sedimentology and Paleontology, 2, 1–99.

Senowbari-Daryan, B., Rashidi, K. Saberzadeh, B., 2011, Dasycladalean green algae and some problematicum algae from the Upper Triassic of the Nayband Formation (northeast Iran): Geologica Carphatica, 62 (6), 501–517.

Shirazi, M.P.M., 2008, Calcareous algal from Cretaceous of Zagros Mountains (SW Iran): World Applied Sciences Journal, 4 (6), 803–807.

Sokač, B., 1996, Taxonomic review of some Barremian and Aptian calcareous algae (Dasycladales) from the Dinaric Karst regions of Croatia: Geologica Croatica, 49 (1), 1–79.

Steinmann, G., 1899, Über fossile Dasycladaceen von Cerro Escamela, Mexico: Botaninisch Zeitung, Berlin, 57, 137–154.

Steinmann, G., 1901, Über Boueina, eine fossile Alge aus der Familie der Codiaceen: Ber Naturforsch Gesell Freiburg i Br., 11 (for 1890), 62–72.

Tavitas, G.J., Solano, M. B., 1984, Estudio bioestratigráfico del subsuelo en el oriente de la Plataforma Valles-San Luis Potosí: Memoria del Tercer Congreso Latinoamericano de Paleontología, 225–236.

Toula F., 1884, Geologische Untersuchungen im westlichen Theiledes Balkan und in den angrenzenden Gebieten (X). Von Pirot nach Sofia, auf den Vitos über Pernik nach Trn und über Stol nach Pirot: Kaiserliche Akademie Wissenschaften in Wien Sitzungsberitsche Mathematisch-Naturwissenschaftlichen Classe 88, 1279 p.

Van den Hoek, C., Mann, D.G. Jahns, H.M., 1995, Algae: An Introduction to Phycology, Cambridge University Press, United Kingdom.

Vecchio, E., Barattolo, F., 2006, *Periloculina* (?) *decastroi* n. sp. a new foraminifer from Eocene (uppermost Ypresian-lowermost Lutetian) Trentinara Formation (southern Apennines, Italy): Bollettino della Società Paleontologica Italiana, 45 (1), 147–158.

Vecchio, E., Hottinger, L., 2007, Agglutinated conical foraminifera from the Lower–Middle Eocene of the Trentinara Formation (southern Italy): Facies, 53, 509–533.

Wilson, J.L., 1875, Carbonate facies in Geologic History. Spring-Verlag, NewYork, 470 p.

Manuscript received: March 7, 2016.
Corrected manuscript received: April 16, 2016.
Manuscript accepted: April 18, 2016.