Riv. It. Paleont. Strat.	v. 99	n. 4	pp. 441-460	tav. 1-2	Marzo 1994

FOSSIL ALGAE FROM SAUDI ARABIA REVISITED

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Key-words: Cyanophycea, Dasycladacea, Permian, Jurassic, Cretaceous, Taxonomy, Saudi Arabia.

Riassunto. Nuovi campionamenti effettuati in successioni di superficie nel Distretto di Qassim (E di Unayzah) e in vicinanza di Riyadh forniscono nuovi dati sulle Alghe fossili del Permiano superiore, Giurassico medio e superiore, nonchè del Cretaceo superiore della parte centrale dell'Arabia Saudita. Sono state rinvenute l'Alga blu-verde *Girvanella* sp., le Rodoficee *Solenopora* sp. e *Archaeolithothamnium* sp., le Alghe Dasicladacee *Griphoporella* sp., *Heteroporella* cf. *H. lusitanica* (Ramalho), *Heteroporella morillonensis* Bernier, *Mizzia* cf. *M. velebitana* (Schubert) e *Trinocladus* cf. *T. perplexus* (Elliott). Sono brevemente discussi anche gli aspetti biostratigrafici e paleoambientali delle Alghe e delle loro rocce incassanti.

Abstract. New sampling of surface sections, east of Unayzah, Qassim District and in the vicinity of Riyadh has revealed new information on the occurrence of fossil algae in the Late Permian, Middle to Late Jurassic and Late Cretaceous of central Saudi Arabia. This includes the finding of the blue-green alga *Girvanella* sp., the red algae *Solenopora* sp. and *Archaeolithothamnium* sp. and the dasycladacean algae *Griphoporella* sp., *Heteroporella* cf. *H. lusitanica* (Ramalho), *Heteroporella morillonensis* (Bernier), *Mizza* cf. *M. velebitana* (Schubert) and *Trinocladus* cf. *T. perplexus* (Elliott). The biostratigraphy and the environment of deposition of the algae and the algal bearing rocks are discussed.

Introduction.

The first fossil algae that have been described from Saudi Arabia and the neighbouring countries were almost four decades ago (Elliott, 1955a, b, 1957; Rezak, 1959). In recent years attention has been focused on the algal occurrence in central Saudi Arabia (Basyoni, 1984; Okla, 1991a, b, 1992).

In central Saudi Arabia, Paleozoic, Mesozoic and younger strata crop out as curved belts bordering the Arabian Shield to the west (Fig. 1). These strata are grouped into major stratigraphic divisions of clastic and carbonate rocks (Powers et al., 1966). The oldest carbonate rocks where the fossil algae have been found are the Late Permian Khuff Formation. In the Mesozoic, the Middle to Late Jurassic Tuwaiq Mountain Limestone and the Late Cretaceous Aruma Formation were found to have fossil algae.

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The present study describes fossil algae from new samples in three different localities; the Khuff Formation east of the city of Unayzah in the Qassim District, the Tuwaiq Mountain Limestone near the top of Khashim al Giddiyah, 60 km west of Riyadh and the Aruma Formation along the Aruma escarpment at Khashim al Buwaib, Khashim al Towqi and Khashim al Hajajah northeast of Riyadh. The systematic description of the fossil algae appears in this report for the first time in central

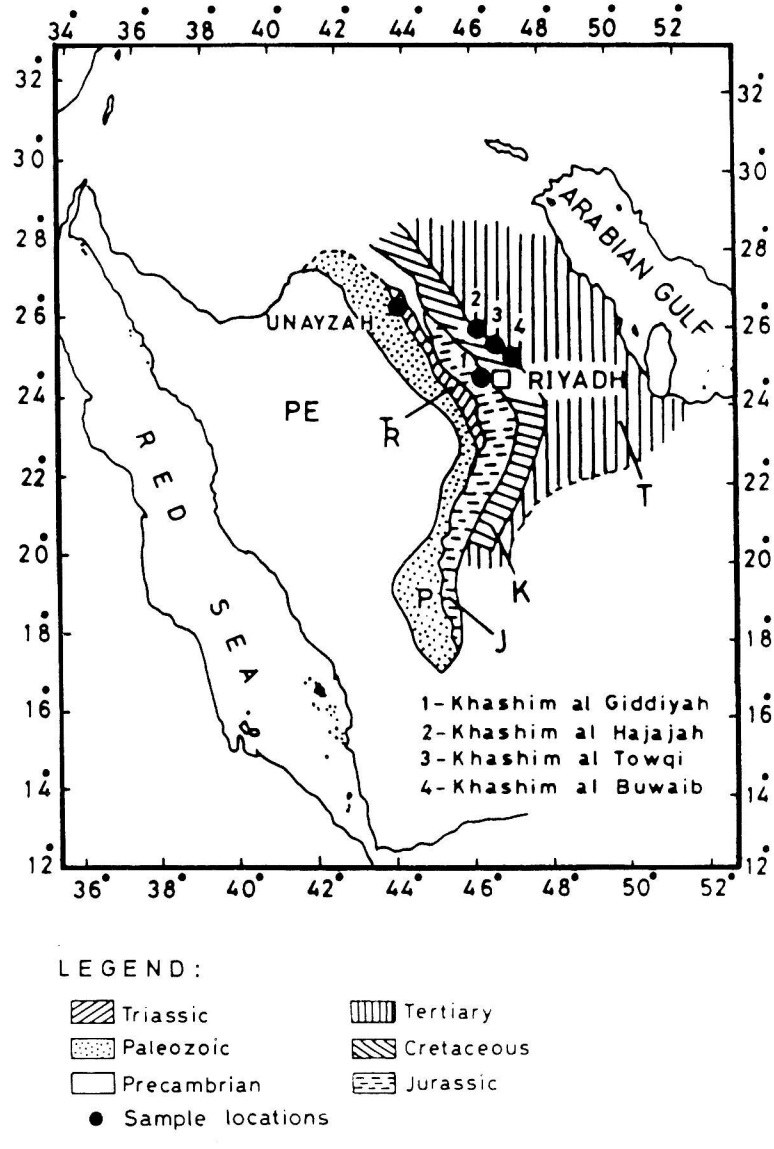

Fig. 1 - Sedimentary rocks outcropping in central Saudi Arabia (Modified from Steineke et al., 1958).

Saudi Arabia. The solenoporacean algae had been noted earlier (Okla, 1986) but no systematic description was given. The alga *Mizzia velebitana* (Schubert) was described earlier (Okla, 1992) but the new sections proved that the described species is much smaller than typical specimens. The occurrence of the fossil algae is then related to the occurrence of other fossils, particularly microfossils. The stratigraphy, age and paleoecology of the fossil algae and their rock units are discussed.

Stratigraphy.

Khuff Formation.

The term Khuff was defined by Steineke in 1937 for the lowermost carbonate sequence in central Saudi Arabia exposed at Ayn Khuff (Lat. 24°55'N, Long. 44°43'E,) near the old Riyadh-Jeddah road (Powers et al., 1966). In 1948, Holm and Pocock described the Khuff carbonates and subdivided them into three informal members; an upper Khartam limestone, a middle Midhnab shale and a lower Khuff limestone (Powers et al., 1966). The term Khuff Formation was first introduced and mapped by Bramkamp et al. (1956). Steineke et al. (1958) designated the succession exposed near Ayn Khuff as type section, where the formation is 255 m thick. The informal threefold division was then discarded (Powers et al., 1966; Powers, 1968). Delfour et al. (1982) re-instated the Khartam and Midhnab members and informally named Duhaysan Member, Huqayl Member and Unayzah Member in the basal part of the formation. The basal siliciclastics were excluded from the Khuff Formation and named Unayzah Formation (Al Laboun, 1982, 1986; El-Khayal & Wagner, 1985). Manivit et al. (1986) divided the Khuff Formation near Unayzah, Qassim District, into the five informal members but only the top four members are recognized in this report where the fossil algae were found (Tab. 1).

AGE	FORMATION MEMBER	ROCK TYPES	THICK-NESS
DJULFIAN	KHARTAM MEMBER	Bioclastic limestone, dolomite, sandstone and claystone.	49 m
	MIDHNAB MEMBER	Bioclastic, algal limestone and shale.	72 m
	DUHAYSAN MEMBER	Bioclastic, algal limestone and dolomitic claystone.	28 m
	HUQAYL MEMBER	Gypsiferous clays-tone, oolite and dolomite	45 m

Tab. 1 - Stratigraphic subdivision of Khuff Formation in Qassim, central Saudi Arabia.

The age of the Khuff Formation was considered by Steineke et al. (1958) to be of probable Late Permian. They listed a number of taxa that included nautiloids, brachiopods and molluscs. Some Late Permian foraminifera were reported by Vaslet et al. (1983) and Basyoni (1984) from the middle and upper parts of the formation. These included *Calcitornella* sp., *Geinitzina chapmani* (Schubert), *Globivalvulina* sp., *Glomospira* sp., *Glomospirella* sp., *Hemigordius* sp., *Langella conica* (Civrieux & Dessauvagie), *Langella* sp., *Nodosaria armeniensis* (Efimova), *Nodosaria djhulfensis* (Reitlinger), *Pachyphloria* sp., *Paraglobivalvulina* sp. and the fusulinid *Nankinella minor* (Sheng). Manivit et al. (1986) reported the occurrence of *Paradagmarita flabiliformis* (Zaninetti et al.) in the Huqayl and Duhaysan members and *Paradagmarita mondi* (Lys) in the Duhaysan Member.

Fossil algae had been used to date the middle and upper parts of the Khuff Formation (Vaslet et al., 1983). The association of the gymnocodiaceans *Gymnocodium bellorophontis* (Rothpletz) and *Permocalculus fragilis* (Pia) in the middle and upper parts of the formations suggested an age younger than Murgabian. Hill and El Khayal (1983) had reported the occurrence of a new charophyte species: *Palaeonitella terafiyensis* (Hill & El-Khayal) from the top of Midhnab Member. This species was dated Late Permian. A precise Djulfian age for the Midhnab Member had been already suggested (Vaslet et al., 1983). The early reports of the occurrence of the dasycladacean alga *Mizzia velebitana* (Schubert) from the subsurface of eastern Saudi Arabia (Rezak, 1959) and from the base of Midhnab Member in Qassim (Basyoni, 1984; Okla, 1992) also suggested Late Permian age. The occurrence of *Succodium difficile* (Korde) at the base of Midhnab Member (Okla, 1992) also suggests a Late Permian age.

Tuwaiq Mountain Limestone.

The Tuwaiq Mountain Limestone was formally defined by Steineke and Bramkamp (1952). The formation was later described in detail by Powers et al. (1966) and Powers (1968). In the type section, the formation is 200 meters thick. It was measured in the Hisyan Pass (Lat. 24°50'N) along the old Ar Riyadh-Jeddah road. Vaslet et al. (1983) subdivided the formation into three units (T1, T2 and T3). Manivit et al. (1985) redefined the Tuwaiq Mountain Limestone in a new reference section at Khashim al Qiddiyah, 60 km west of Riyadh. The fossil algae have been collected from the vicinity of the reference section (Tab. 2).

The lower beds of the Tuwaiq Mountain Limestone were assigned to Middle Callovian *coronatum* zone by Arkell in 1952 (v. Steineke & Bramkamp, 1952), where a number of ammonites were found (Powers et al., 1966; Powers, 1968). Powers et al. (1966) noted that the middle and upper Tuwaiq Mountain Limestone were lacking ammonites. They reported the presence of the following foraminifera species: *Kurnubia jurassica* (Henson), *Kurnubia wellingsi* (Henson) and *Steinekella steinekei* (Redmond). Accordingly, they extended the age of the formation to Oxfordian. These species had been noted by Vaslet et al. (1983) and Manivit et al. (1985) in addition to the full development of *Kurnubia palestiniensis* (Henson) in the middle of the formations. Vas-

AGE	UNITS	ROCK TYPES	THICK-NESS
? EARLY OXFORDIAN TO MIDDLE CALLOVIAN	T_3	Light gray and white well bedded limestone with abundant algae.	10 m
		Ledge forming, bioclastic limestone and calcarenite rich in silicified corals and stromatoporoids.	90 m
	T_2	Fine-grained massive limestone with isolated corals.	60 m
	T_1	Fine-grained limestone with calcareous spicules and pellets.	30 m

Tab. 2 - Subdivision of Tuwaiq Mountain Limestone in central Saudi Arabia.

let et al. (1983) had assigned the upper Tuwaiq Mountain Limestone to Late Callovian age, where a single ammonite fragment was found in Wadi ar Rayn quadrangle, to the southwest of Riyadh. El Asa'ad (1992) reported the occurrence of Late Callovian ammonites: the Athleta-Lamberti Zone in the upper Tuwaiq Mountain Limestone in the vicinity of Al Ma'ashbah village, 200 km northwest of Riyadh. Fossil algae were first described from the upper Tuwaiq Mountain Limestone in 1991 (Okla, 1991a, b). Of the most well represented species are: *Clypeina jurassica* (Favre), *Heteroporella jaffrezoi* (Bernier), *Heteroporella lemmensis* (Bernier) and *Salpingoporella annulata* (Carozzi). These species were described from Middle and Upper Jurassic of Europe (Bassoullet et al., 1978; Bernier, 1984). They may suggest Early Oxfordian age for T3 as has been already suggested (Enay et al., 1986).

Aruma Formation.

The Aruma Formation was named for its occurrence in the Aruma Plateau, a broad upland forming the easternmost escarpment of central Saudi Arabia (Powers et al., 1966). The formation was first recognized by Steineke and Bramkamp (1952). In the type locality (near Lat. 25°38'N, Long. 46°22'E), the formation is 142 meters thick. It includes four lithologic units that were informally grouped in a basal Atj Member and an upper Lina Member (Powers, 1968). This subdivision was later regrouped into three members: Khanasir Member, Hajajah Member and Lina Member (El Asa'ad, 1977; Vaslet et al., 1988). The fossil algae were collected within the Hajajah Member (Tab. 3). Powers et al. (1966) assigned the age of the Aruma Formation to range from Campanian to Maastrichtian on the basis of a number of taxa that included ammonites and the following foraminifera: *Chrysalidina* sp., *Elphidiella multiscissurata*

AGE	FORMATION MEMBER	ROCK TYPES	THICK-NESS
Late Maastrichtian	LINA MEMBER	Yellowish to green calcareous and dolomitic claystone.	32 m
	HAJAJAH MEMBER	Pale gray bioclastic limestone with orbitoids and algae overlying olive green claystone and toped by gray dolomite.	76 m
Early Maastrichtian Late Campanian	KHANASIR MEMBER	Creen-colored nodular limestone toped by biostromal rudist beds.	23 m

Tab. 3 - Stratigraphic subdivision of Aruma Formation in central Saudi Arabia.

(Smout), *Fissoelphidium operculiferum* (Smout), *Lepidorbitoides* spp., *Loftusia* sp., *Meandropsina vidale* (Schlumberger), *Monolepiderbis sanctae pelagia* (Astre), *Omphalocyclus macroporus* (Lamarck) and *Orbitoides gensacicus* (Leymerie). El Asa'ad (1977, 1983a, b) recognized nine assemblage zones within the Aruma Formation ranging in age from Coniacian to Maastrichtian. The taxa that were used in these zones included ammonites, foraminifers and rudistids. El Asa'ad (1991) refined the earlier age assignment to include the age of Middle-Late Coniacian to Middle Campanian for the Khanasir Member and the age of Late Campanian for Hajajah Member. Other taxa that were reported in Hajajah Member (El Asa'ad, 1989 and 1990) included corals and cyclolitids.

Vaslet et al. (1988) reported the occurrence of nannoflora of Late Campanian to Early Maastrichtian age in the Khanasir Member. They included the species *Arkhangelskiella cymbiformis* (Vekshina), *Cretarhabdus crenulatus* (Bramlette & Martini), *Micula straurophora* (Gardet), *Tetralithus obscurus* (Deflandre) and *Watznaueria barnesae* (Black). Likewise Vaslet et al. (1988) reported the presence of Late Maastrichtian coccolith assemblages in Hajajah Member that included: *Cribrosphaerella erhenbergi* (Arkhangelsky), *Micula murus* (Martini), *Prediscosphaera cretacea* (Arkhangelsky), *Tetralithus obscurus* (Deflandre) and *Watznaueria barnesae* (Black).

SYSTEMATIC DESCRIPTION

Division **Cyanophyta** (Sachs 1874) Pascher 1931

Class **Cyanophyceae** Sachs 1874

Order **Nostocales** Geither 1925

Family *Oscillatoriaceae* (S. F. Gray) Dumorties ex Kirchner 1898
Genus *Girvanella* Nicholson & Etheridge 1880

Girvanella sp.

Pl. 1, fig. 1

Description. Algal nodules formed of concentrically laminated micritic coats surrounding a nucleus. The nodules are rounded to elliptical in shape. The nuclei are now replaced by sparry calcite. The micritic coats are made of algal filaments which rarely branch.

Measured dimensions (in mm):

External diameter 3.36 - 10, mean 5.76 (n.=7)
Diameter of nucleus 2 - 4, mean 2.89 (n.=7)
Diameter of crust 1.2 - 6, mean 2.32 (n.=5)
Length of tubes 0.25 - 0.6, mean 0.44 (n.=5)
Diameter of tubes 0.07 - 0.13, mean 0.1 (n.=5)

Remarks. The alga *Girvanella* was first noted by Basyoni (1984) in the Khuff carbonates as algal nodules originating from the growth of blue-green algae that surrounded skeletal grains that served as nuclei. The Khuff specimens are poorly preserved. The *Girvanella* sp., however, looks very similar to the species *Girvanella subparallela* (Flügel & Flügel-Kahler) that was described from the Southern Alps (Flügel, 1979). *Girvanella* sp. is found with the dasycladacean alga *Mizzia* cf. *M. velebitana* (Schubert) and with the red alga *Gymnocodium bellerophontis* (Rothpletz) in the basal carbonates of the Midhnab Member of the Khuff Formation east of Unayzah, Qassim District. Other taxa found with *Girvanella* sp. included bryozoans and the benthonic foraminifera *Globivalvulina* sp. and *Langella* sp.

Division **Rhodophyta** Wettstein 1901
Class **Rhodophyceae** Ruprecht 1851
Order **Cryptonemiales** Schmitz in Engler 1892
Family *Solenoporaceae* Pia 1927
Genus *Solenopora* Dybowsky 1878

Solenopora sp.

Pl. 1, fig. 2, 3

Description. The thallus is rounded to tabular mass composed of calcified filaments of cells that are relatively large. Cells are not differentiated into hypothallus and perithallus. The horizontal cell walls or cross-partitions are absent.

Measured dimensions (in mm):

Length of thallus 18+
Diameter of thallus 7.2
Length of cells 0.4 - 0.65, mean 0.53 (n.=4)
Diameter of cells 0.07 - 0.1, mean 0.08 (n.=3)
Number of cells/1 mm 6 - 14, mean 10 (n.=4)

Remarks. The alga *Solenopora* was first noted in the subsurface Upper Jurassic carbonates of eastern Saudi Arabia (Powers, 1962). The occurrence of solenoporacean algae in the upper Tuwaiq Mountain Limestone was given then. Basson and Edgell (1971) reported the presence of *Solenopora liasica* (Le Maitre) in the Upper Jurassic of Lebanon but *Solenopora* sp. is slightly larger.

The alga *Solenopora* sp. is found with the foraminifera *Kurnubia jurassica* (Henson) and *Steinekella steinekei* (Redmond).

Family *Corallinaceae* (Lamouroux) Harvey 1849

Genus *Archaeolithothamnium* Rothpletz 1891

Archaeolithothamnium sp.

Pl. 1, fig. 4, 5

Description. The thallus is found as a thin crust with basal hypothallus composed of curved rows of cells and a perithallus composed of a few layers of cells. The sporangia are found in the perithallus as isolated rows.

Measured dimensions (in mm):

Thickness of the crust 0.6 - 1.45, mean 0.93 (n.=3)
Thickness of the hypothallus 0.3 - 0.35, mean 0.33 (n.=3)
Thickness of the perithallus 0.3 - 0.7, mean 0.5 (n.=3)
Length of hypothallus cells 0.02 - 0.03, mean 0.027 (n.=3)
Width of hypothallus cells 0.01
Length of perithallus cells 0.01 - 0.083, mean 0.04 (n.=3)
Width of perithallus cells 0.01
Diameter of sporangia 0.03 - 0.05, mean 0.04 (n.=4)
Number of sporangia / 1 mm 18 - 24, mean 21 (n.=4)

Remarks. The genus *Archaeolithothamnium* Rothpletz is characterized by curved layers of cells in the hypothallus, quite regular layers of cells in the perithallus and isolated rows of sporangia that are not collected in conceptacles (Johnson, 1961, 1963, 1969). *Archaeolithothamnium* sp. shows these characteristics, however, some specimens are infertile and do not show the isolated sporangia (Pl. 1, fig. 5). The measured dimensions are similar to those of a number of described Maastrichtian species from France, Italy, Spain and Algeria (Johnson, 1963). The alga is found in the upper Hajajah Member of the Aruma Formation at Khashim al Hajajah, northeast of Riyadh. It

found with *Lepidorbitoides* spp., *Omphalocyclus macroporus* (Lamarck) and *Orbitoides gensacicus* (Leymerie).

Division **Chlorophyta** Paschar 1914
Class **Chlorophyceae** Kutzing 1843
Order **Dasycladales** Paschar 1931
Family *Seletonellaceae* (Korde 1950) Bassoullet et al. 1975
Tribe *Mastoporeae* (Pia 1920) Bassoullet et al. 1975
Genus *Griphoporella* Pia 1915

Griphoporella sp.
Pl. 1, fig. 6-9

Description. Thin-walled simple cylindrical thallus with numerous thin primary branches. These branches are aspondyle and slightly vesiculiferous.

Measured dimensions (in mm):

Length of thallus (L) 2.6 +
External diameter (D) 0.8 - 1.0, mean 0.9 (n.=4)
Internal diameter (d) 0.53 - 0.7, mean 0.62 (n.=4)
Diameter of pores (p) 0.05 - 0.07, mean 0.06 (n.=3)

Remarks. Elliott (1968) reported the presence of *Griphoporella* cf. *perforatissima* (Carozzi) from Upper Jurassic and Lower Cretaceous of Iraq and Oman. One tangential section was shown with pore diameter of 0.03-0.04 mm. Elliott (1968) reported also the presence of *Griphoporella arabica* (Pfender) from the Paleocene and Eocene of Iraq and Oman. *Griphoporella* sp. has some similarity with *G. arabica* (Pfender) but the latter is not probably a dasycladacean alga (Elliott, 1968). The described species is found in lower Hajajah Member of the Aruma Formation at Khashim al Hajajah. It occurs with the foraminifer *Monolepidorbis sanctae* (Astre) and *Orbitoides* sp.

Family *Triploporellaceae* (Pia 1920) Berger & Kaever 1992
Tribe *Cylindroporelleae* Pal 1976
Genus *Heteroporella* (Cros & Lemoine 1966) Ott 1968

Heteroporella cf. **H. lusitanica** (Ramalho 1970)
Pl. 1, fig. 10, 11; Pl. 2, fig. 1

Description. The thallus is cylindrical. There are two types of branches, strongly inflated fertile branches (sporangia) and thinner sterile branches. The two types of branches are in alternating whorls, while among themselves they alternate.

Measured dimensions (in mm):

Length of thallus (L) 1.76 +
External diameter (D) 0.6 - 0.93, mean 0.81 (n.=4)
Internal diameter (d) 0.1 - 0.2, mean 0.17 (n.=4)
Distance between whorls (h) 0.02 - 0.03, mean 0.02 (n.=3)
Length of sterile branches (1) 0.12 - 0.18, mean 0.16 (n.=3)
Diameter of sterile branches (p) 0.04 - 0.05, mean 0.045 (n.=4)
Diameter of fertile branches (sporangia) 0.12 - 0.3, mean 0.2 (n.=4)
Number of sporangia (ns.) 10-13, mean 13 (n.=3)

Remarks. The described species was found in the upper Tuwaiq Mountain Limestone west of Riyadh. Its occurrence is rather rare. The given measurements are slightly larger than those of *Heteroporella anici* (Nikler & Sokac) described by Bassoullet et al. (1978) and slightly smaller than *Heteroporella lusitanica* (Ramalho). *Heteroporella* cf. *H. lusitanica* is found with *Salpingoporella annulata* (Carozzi), *Heteroporella jaffrezoi* (Bernier) and *Heteroporella lemmensis* (Bernier). The species occurs with *Kurnubia jurassica* (Henson) and *Kurnubia wellingsi* (Henson).

Heteroporella morillonensis Bernier 1984

Pl. 2, fig. 2

1984 *Heteroporella morillonensis* Bernier, p. 468, pl. 2, fig. 6-9.

Description. The thallus is short and cylindrical. The fertile branches (sporangia) are globular. The sterile branches are thin and alternate with whorls of the fertile branches.

Measured dimensions (in mm):

Length of thallus (L) 1.1
External diameter (D) 0.9
Internal diameter (d) 0.39
Distance between whorls (h) 0.04
Length of sterile branches (1) 0.3
Diameter of sterile branches (p) 0.04
Diameter of fertile branches (sporangia) 0.13

Remarks. Only one longitudinal section was found in the upper Tuwaiq Mountain Limestone at Khashim al Giddiyah, west of Riyadh. This section, however, shows a good resemblance with the material described by Bernier (1984). Other associated species included *Heteroporella lemmensis* (Bernier) and *Salpingoporella annulata* (Carozzi). These algae occur with the species of *Kurnubia* and *Steinekella steinekei* (Redmond).

Tribe *Coniporelleae* Bassoullet et al. 1979

Subtribe *Mizziinae* Bassoullet et al. 1979

Genus *Mizzia* (Schubert 1907) Rezak 1959

Mizzia cf. **M. velebitana** (Schubert 1907)

Pl. 2, fig. 3-8

Description. The thallus is hollow, spheroidal, ovoid or elongate-ovoid, pear-shaper or pyriform with proximal and/or distal opening. The wall is perforated by about ten successive horizontal verticils. The branches are simple cylindrical or expanding cylindroids. They are arranged in alternating horizontal rows.

Measured dimensions (in mm):

Length of thallus (L) 1.55 +
External diameter (D) 0.75 - 1.33, mean 0.99 (n.=12)
Internal diameter (d) 0.42 - 0.83, mean 0.61 (n.=11)
Length of branches (l) 0.16 - 0.26, mean 0.21 (n.=7)
Diameter of branches (p) 0.09 - 0.14, mean 0.11 (n.=11)
Distance between whorls (h) 0.04 - 0.09, mean 0.07 (n.=3)
Number of branches (w) 11 - 17, mean 15 (n.=6)

Remarks. The presence of *Mizzia velebitana* (Schubert) was reported from the Permian of Saudi Arabia and Iraq (Rezak, 1959; Elliott, 1968). Rezak (1959) reported the presence of another smaller species *Mizzia bramkampi* (Rezak) from the subsurface Permian of eastern Saudi Arabia. Okla (1992) assigned some specimens from the Khuff Formation near Unayzah to *Mizzia velebitana* (Schubert). The specimens of this report are much smaller than those of *Mizzia velebitana* (Schubert) described by Rezak (1959) and Elliott (1968). It was not possible to find sections that show completely the space of the siphon or articles in connection. *Mizzia* cf. *M. velebitana* is found with *Girvanella* sp. and *Gymnocodium bellerophontis* (Rothpletz). It is found with benthonic foraminifera: *Globivalvulina* sp., *Hemigordius* sp., *Langella* sp. and *Nodosaria* sp.

Tribe *Triploporelleae* (Pia 1920) Bassoullet et al. 1979
Subtribe *Triploporellinae* (Pia 1920) Bassoullet et al. 1979
Genus *Trinocladus* Raineri 1922

Trinocladus cf. **T. perplexus** (Elliott 1955)

Pl. 2, fig. 9-13

Description. Thallus is tabular cylindrical and slightly tapering. The wall is perforated by primary branches that divide into secondary branches in the older portion of the thallus and into secondaries and tertiaries in the younger portion of the thallus.

Measured dimensions (in mm):

Length of thallus (L) 6.0 +
External diameter (D) 0.55 - 1.0, mean 0.74 (n.=9)

Internal diameter (d) 0.20 - 0.38, mean 0.29 (n.=9)
Distance between whorls (h) 0.04 - 0.09, mean 0.07(n.=6)
Length of primary branches (1) 0.05 - 0.17, mean 0.11 (n.=8)
Length of secondary branches (1') 0.04 - 0.11, mean 0.08 (n.=7)
Length of tertiary branches (1") 0.03 - 0.04, mean 0.055 (n.=4)
Diameter of primary branches (p) 0.04 - 0.08, mean 0.06 (n.=9)
Diameter of secondary branches (p') 0.02 - 0.03, mean 0.023 (n.=5)
Diameter of tertiary branches (p") 0.01
Number of primary branches (w) 13 - 15, mean 14 (n.=4)
Number of secondary branches (w') 4

Remarks. The presence of the genus *Trinocladus* was reported from the Upper Cretaceous, the Paleocene and the Eocene of Iraq and Qatar (Elliott, 1968). Okla (1991) described the species *Trinocladus radoicicae* (Elliott) in the Upper Cretaceous Aruma Formation in central Saudi Arabia. The specimens described in this study are closely related to *Trinocladus perplexus* (Elliott), however, it was difficult to document the existance of the three orders of branches which are expected to be in the older and slimmer part of the thallus. *Trinocladus* cf. *T. perplexus* is well represented in the Hajajah Member of Aruma Formation at Khashim al Hajajah, Khashim al Buwaib and Khashim al Towqi. At Khashim al Hajajah it occurs with *Lithophyllum* sp., *Lepidorbitoides* sp., *Omphalocyclus macroporus* (Lamarck) and *Orbitoides gensacicus* (Leymerie).

Environment of deposition

The Khuff Formation represents the earliest major carbonate rocks deposited during the Late Permian transgression of the Tethys over the Arabian Platform. It formed the beginning of what is called the "Layer cake" sedimentation of the Arabian Basin (Al Laboun, 1986). The studied area represents gradual thinning of Khuff Formation from the depocenter to the east and northeast. The fossil algae are found in thin layers of calcarenites and calcarenitic limestones that were most likely transported. Basyoni (1984) interpreted an equivalent part of the studied section as back barrier beach lagoon in an open shoreline. In the studied area, west of Riyadh, the Tuwaiq Mountain Limestone has its greatest thickness (Enay et al., 1986). Le Nindre et al. (1983) interpreted the lower Tuwaiq Mountain Limestone (T1) to represent the ingress of nearshore shelf sea. T2 represents the first stage of barrier formation. T3 represents a phase of build-up reworking and progradation of the barrier as well as of internal lagoon facies. The fossil algae are found in the uppermost unit of the Tuwaiq Mountain Limestone that represented a protected environment in which lagoonal sedimentation may have taken place, as Le Nindre et al. (1983) had suggested.

In the middest of the cyclic sedimentation over central Saudi Arabia, a marine transgression that began as early as Late Turonian deposited the Aruma Formation in Late Cretaceous time. In the studied area, where the fossil algae were found, a shallow marine lagoonal or proximal-infralittoral carbonate sedimentation had been suggested (Vaslet et al., 1988).

The described fossil algae also indicate deposition of studied sections in very shallow marine environment. Recent blue-green algae prefer tidal zones, green algae are frequently found in depth down to about 20-30 m and red algae have been found living in depths down to 150 m and over, but frequently occur in water as deep as 50 m (Wilson, 1975; Wray, 1977; Flügel, 1982). Therefore green algae are most abundant in relatively shallow protected lagoons while red algae preferentially occur in reefs, shoals and banks but also range into deeper water. These findings agree remarkably with the lithological interpretation of the studied sections.

Conclusions.

This report describes the occurrence of fossil algae in surface sections near Unayzah, Qassim District, in Tuwaiq Mountain west of Riyadh and along Aruma escarpment northeast of Riyadh. The rock units that were studied included the Upper Permian (Djulfian) Khuff Formation, the Middle to Upper Jurassic (Middle Callovian to Early Oxfordian) Tuwaiq Mountain Limestone and the Upper Cretaceous (Late Campanian to Late Maastrichtian) Aruma Formation. The fossil algae included the following:

1) The blue-green alga *Girvanella* sp. and the dasycladacean alga *Mizzia* cf. *M. velebitana* (Schubert) were systematically described from the basal carbonates of Midhnab Member of the Khuff Formation near Unayzah, Qassim District.

2) The red alga *Solenopora* sp. and the dasycladacean algae *Heteroporella* cf. *H. lusitanica* (Ramalho) and *Heteroporella morillonensis* Bernier were systematically described from T3 carbonates of Tuwaiq Mountain Limestone at Khashim al Giddiyah, west of Riyadh.

3) The red alga *Archaeolithothamnium* sp. and the dasycladacean algae *Griphoporella* sp. and *Trinocladus* cf. *T. perplexus* (Elliott) were systematically described from the Hajajah Member of the Aruma Formation at Khashim al Buwaib, Khashim al Towqi and Khashim al Hajajah, northeast of Riyadh.

The ecology of the algae and the depositional interpretations of the algae-bearing rock units indicate similar paleoenvironmental setting of very shallow marine, like protected lagoons, shoals and banks.

Acknowledgment.

This research was carried out at the Geology Department of King Saud University in Riyadh. I would like to thank all those in the Geology Department that helped in bringing this paper to its final form. In particular, I would like to thank Mr. I. El Zaid, Mr. A. Sido, Mr. M. Takroni, Mr. I. Aziaz, Mr. I. Ismail and Mr. A. Saeed.

This research (Geo/1407/23) was supported by the Research Center, College of Science, King Saud University, Riyadh, Saudi Arabia.

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Received July 7, 1993; accepted December 15, 1993

PLATE 1

Fig. 1 - *Girvanella* sp. Part of nodule showing part of the nucleus to the right and small tubes in the surrounding coat. Basal Midhnab Member of the Khuff Formation, east of Unayzah; X 30.

Fig. 2 - *Solenopora* sp. Part of longitudinal section showing typical threads of cells with no cross partitions. T3, upper Tuwaiq Mountain Limestone, West of Riyadh; X 30.

Fig. 3 - *Solenopora* sp. Part of longitudinal section showing cell threads. T3, upper Tuwaiq Mountain Limestone, west of Riyadh; X 30.

Fig. 4 - *Archaeolithothamnium* sp. Part of the thallus showing the hypothallus (below) and the perithallus (above) with sporangia. Hajajah Member of the Aruma Formation, Khashim al Hajajah; X 30.

Fig. 5 - *Archaeolithothamnium* sp. Part of the infertile crust showing curved rows of cells in the hypothallus. Hajajah Member of the Aruma Formation, Khashim al Hajajah; X 30.

Fig. 6 - *Griphoporella* sp. Oblique-longitudinal section showing thin-walled segment with inclined small pores. Hajajah Member of the Aruma Formation, Khashim al Hajajah; X 30.

Fig. 7 - *Griphoporella* sp. Oblique-longitudinal section showing close-set pores widening at the surface. Hajajah Member of the Aruma Formation, Khashim al Hajajah; X 30.

Fig. 8 - *Griphoporella* sp. Oblique-longitudinal section showing relatively long segment. Hajajah Member of the Aruma Formation, Khashim al Hajajah; X 30.

Fig. 9 - *Griphoporella* sp. Oblique section showing thin walled segment. Hajajah Member of the Aruma Formation, Khashim al Hajajah; X 30.

Fig. 10 - *Heteroporella* cf. *H. lusitanica* (Ramalho 1970). Oblique section showing thin sterile branches and large fertile branches. T3, upper Tuwaiq Mountain Limestone, Khashim al Giddiyah; X 30.

Fig. 11 - *Heteroporella* cf. *H. lusitanica* (Ramalho 1970). Part of oblique longitudinal section showing thin sterile and large fertile branches. T3, upper Tuwaiq Mountain Limestone, Khashim al Giddiyah; X 30.

PLATE 2

Fig. 1 - *Heteroporella* cf. *H. lusitanica* (Ramalho 1970). Oblique section showing sterile and fertile branching. T3, upper Tuwaiq Mountain Limestone, Khashim al Giddiyah; X 30.

Fig. 2 - *Heteroporella morillonensis* Bernier 1984. Longitudinal section showing typical long and thin sterile branches and short and circular fertile branches. T3, upper Tuwaiq Mountain Limestone, Khashim al Giddiyah; X 30.

Fig. 3 - *Mizzia* cf. *M. velebitana* (Schubert 1907). Oblique-longitudinal section showing expanding rays and polar opening. Basal Midhnab Member of the Khuff Formation, east of Unayzah; X 30.

Fig. 4 - *Mizzia* cf. *M. velebitana* (Schubert 1907). Oblique-longitudinal section showing ramification and polar opening. Basal Midhnab Member of the Khuff Formation, east of Unayzah; X 30.

Fig. 5 - *Mizzia* cf. *M. velebitana* (Schubert 1907). Tangential section showing peripheral hexagonal pores. Basal Midhnab Member of the Khuff Formation, east of Unayzah; X 30.

Fig. 6 - *Mizzia* cf. *M. velebitana* (Schubert 1907). Small transverse section showing ramification. Basal Midhnab Member of the Khuff Formation, east of Unayzah; X 30.

Fig. 7 - *Mizzia* cf. *M. velebitana* (Schubert 1907). Nearly transverse section showing simple unbranched rays. Basal Midhnab Member of the Khuff Formation, east of Unayzah; X 30.

Fig. 8 - *Mizzia* cf. *M. velebitana* (Schubert 1907). Oblique-longitudinal section showing pyriform segment. Basal Midhnab Member of the Khuff Formation, east of Unayzah; X 30.

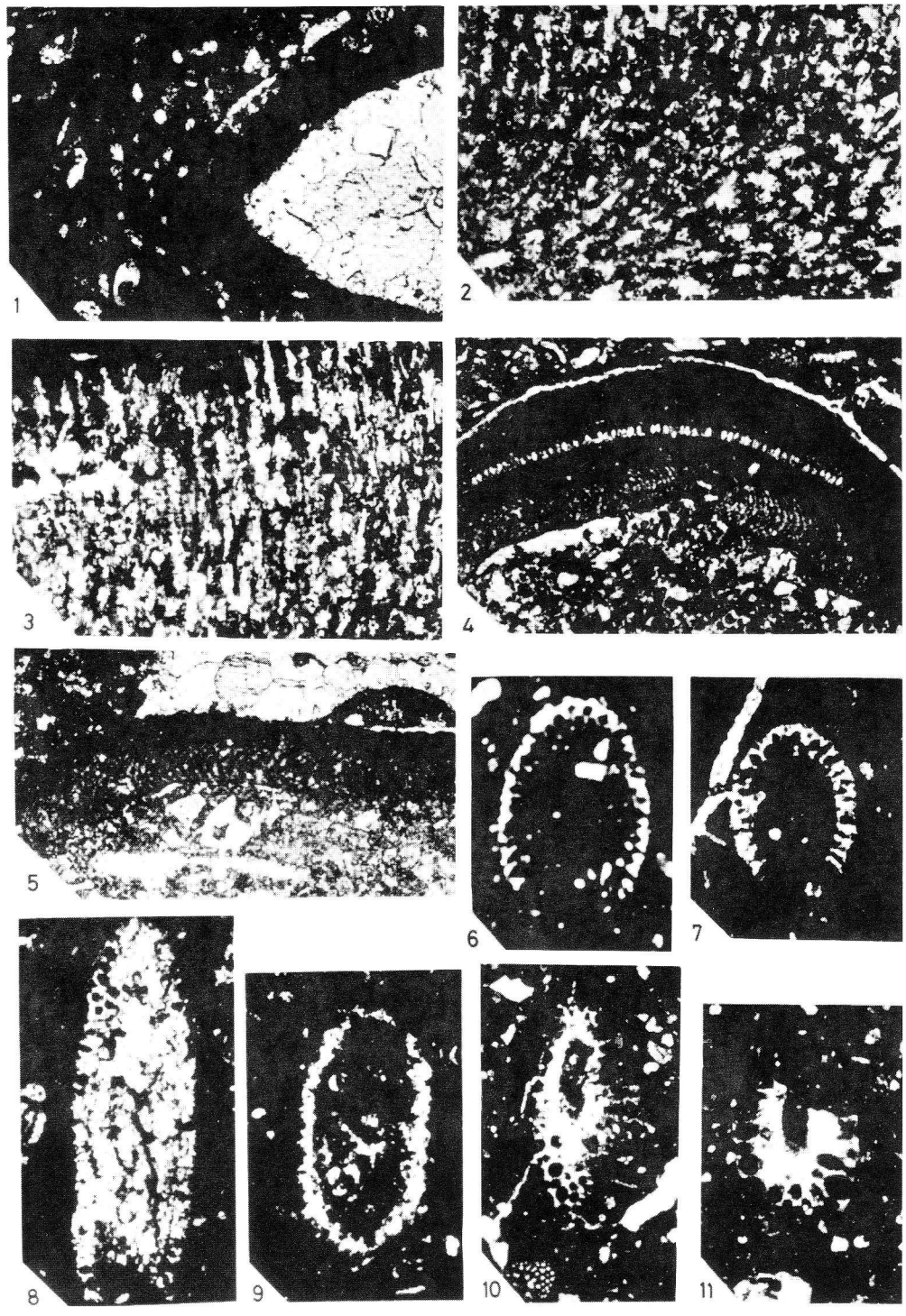
Fig. 9 - *Trinocladus* cf. *T. perplexus* (Elliott 1955). Oblique section showing short thick primaries and thinner secondaries. Hajajah Member of the Aruma Formation, Khashim al Hajajah; X 30.

Fig. 10 - *Trinocladus* cf. *T. perplexus* (Elliott 1955). Oblique section showing branches and pores. Hajajah Member of the Aruma Formation, Khashim al Hajajah; X 30.

Fig. 11 - *Trinocladus* cf. *T. perplexus* (Elliott 1955). Longitudinal section of long tabular thallus showing primary and secondary ramification. Hajajah Member of the Aruma Formation, Khashim al Hajajah; X 30.

Fig. 12 - *Trinocladus* cf. *T. perplexus* (Elliott 1955). Oblique-longitudinal section showing branching and central cavity. Hajajah Member of the Aruma Formation, Khashim al Hajajah; X 30.

Fig. 13 - *Trinocladus* cf. *T. perplexus* (Elliott 1955). Longitudinal section of part of tabular thallus showing branches. Hajajah Member of the Aruma Formation, Khashim al Hajajah; X 30.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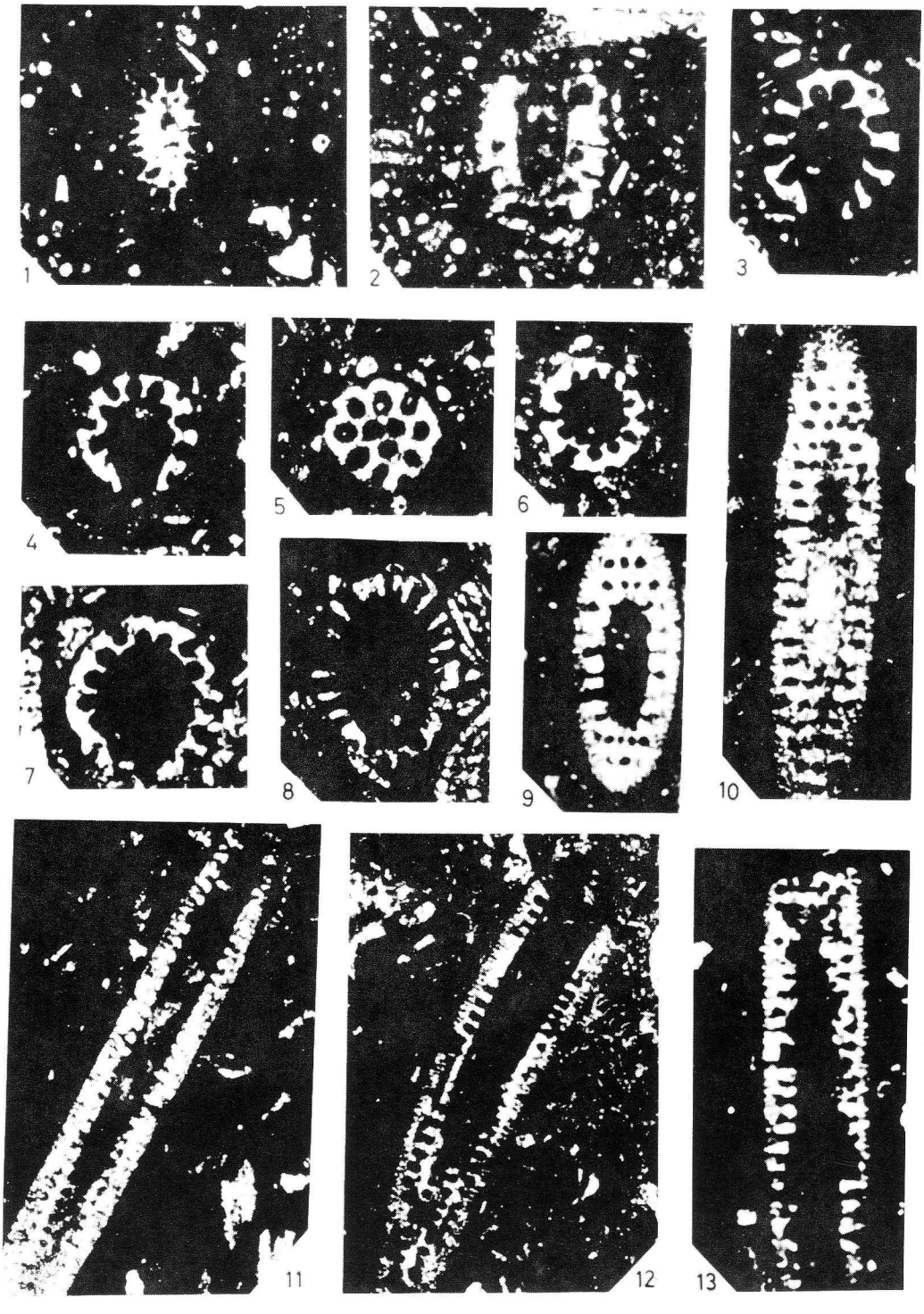
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