FACIES	27	217-224	Pl. 45-46	2 Figs.	1 Tab.	ERLANGEN 1992

Permian Algae and Algal Microfacies from Unayzah, Quassim District, Saudi Arabia

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KEYWORDS: ALGAE – SYSTEMATIC DESCRIPTION – MICROFACIES – SAUDI ARABIA – PERMIAN

SUMMARY

Late Permian bioclastic calcarenite beds of the middle Khuff Formation were sampled for their algal constituents near the city of Unayzah, Quassim district in central Saudia Arabia. The algal flora includes two species of udoteacean algae (*Succodium difficile* and *Succodium* sp.), the dasycladacean alga *Mizzia velebitana* and two species of red algae (*Gymnocodium bellerophontis*, *Permocalculus plumosus*).

Other algal floral remains found forming isolated single layers which have generally been named algal microfacies. These include a phylloid microfacies, an oncoid microfacies and algal stromatolites. The Khuff Formation is well-known for its accumulation of non-associated gas and particularly for its oil accumulation in eastern Saudi Arabia and the Arabian Gulf states.

INTRODUCTION

In 1953 G.F. Elliott began studying the algae of the Middle East, from the Iraq and other Arabian Gulf states, as a part of his work for the Iraq Petroleum Company Ltd. (Elliott, 1968). Henbest (1957) of the U.S. Geological Survey was the first to note the presence of an algal flora in a Khuff core sample from Aramco Dammam well 43 in eastern Saudi Arabia. Rezak (1959) described the algal flora from Dammam well 43. Sampo (1969) described Permian algae in Iran. Basyoni (1984) reported algae in sections of the Khuff Formation in Unayzah (al Quassim district, Saudi Arabia). Delfour et al. (1982) and Vaslet et al. (1983) described some algal species while mapping the Khuff Formation in central Saudi Arabia.

In the course of studying microfacies of carbonate rocks, particularly those with algae (Okla, 1987, 1989, 1991) were sampled in parts of the Khuff Formation in Unayzah (Fig. 1). Khuff Formation is 264 meters thick (Manivit et al., 1986). In the middle of the formation (Duhaysan and Midhnab members) several platy bioclastic calcarenitic beds rich in udoteacean, gymnocodiacean and dasycladacean algae occur. These beds were sampled.

The carbonates of the Khuff Formation display all the characteristics of favorable source and reservoir rocks for oil and gas. They have a significant hydrocarbon potential as they become thicker to the east and northeast (Al-Laboun, 1986). More than half of the non-associated gas reserves in eastern Saudi Arabia lie within the Khuff Formation. The biggest known gas accumulation in the Khuff reservoir is the North Dome structure, offshore Qatar. Production from the Khuff Formation in the United Arab Emirates is mainly gas and condensates (Al-Sharhan & Kendall, 1986, Al Sharhan, 1989). In Oman the Permian-Carboniferous reservoirs contain oil (Beydoun, 1988).

STRATIGRAPHY

The Khuff Formation was named for Ayn Khuff (Lat. 24° 55' N, Long. 44° 43' E) near the Riyadh-Ad Dawadimi road (Powers et al., 1966). The formation includes the lowermost carbonate sequence cropping out in central Saudi Arabia. The Khuff Formation was first recognized by Steinecke & Bramkamp (1952). The succession exposed near Ayn Khuff was formally designated as type section by Steineke et al. (1958).

In the type section, the thickness of the Khuff Formation is about 194 meters. The Khuff crops out in a nearly continuous band averaging about 25 km in width for a distance of more than 1200 km from Bani Khatmah (Lat. 18° 00' N) north of the Great Nafud (Lat. 28° 10' N). At the type locality, in the vicinity of Wadi Maghib (Lat. 24° 56' N), a three-fold division of the Khuff Formation was recognized (Power et al., 1966). From base to top: the lower limestone or Khuff member, the middle shale or Midhnab member and the upper limestone or Khartem member.

In Quassim District, a composite section 30 km north of Buraydah (near Lat. 26° 30' N) was measured (Powers et al., 1966). It includes 140.5 m of the lower Khuff limestone, 70.2 m of the Midhnab shale and 81.5 m of the Khartam limestone. South of the Riyadh-Ad Dawadimi road, the Midhnab shale passes laterally into carbonates and the three-fold subdivision can no longer be recognized.

Delfour et al (1982) revised the type section for the Khuff Formation in the Ad Dawadimi quadrangle and divided it informally into the Unayzah, Huqayl, Duhaysan, Midhnab and Khartam members. These members represent alternating hard and soft limestones, dolomites and claystones, except the Unayzah member which is composed of cycles of cross-bedded fine to coarse-grained quartz sandstones, siltstones,

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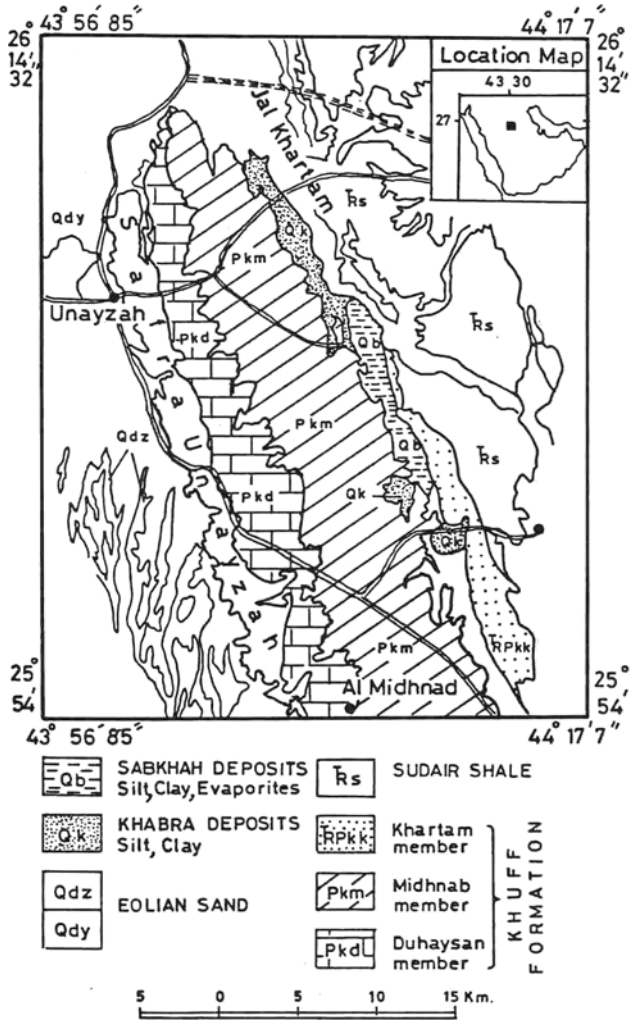


Fig. 1. Geologic map of Khuff Formation east and southeast of Unayzah, Central Saudi Arabia (redrawn from MANIVIT et al., 1986).

multi-colored claystones and thin beds of argillaceous limestones (AL LABOUN, 1982,1986, 1987). AL LABOUN (1982) regarded the cross-bedded lithologies as a separate formation and called it the Unayzah Formation:

The Huqayl member includes a lower sequence of oncolitic, lithoclastic and bioclastic limestones, dolarenite, gypsiferous claystones and burrowed dolomite (Tab. 1). The upper sequence consists of dolarenite, claystone and dolomite. The Duhaysan member displays at the base bioclastic, lithoclatic and locally calcarenitic limestones overlain by calcareous claystones intercalated by beds of bioclastic limestones. The Midhnab member consists of basal platy bioclastic limestones rich in algae overlain by a thick sequence of gypsiferous claystones and shales. The Khartam member is composed of a lower sequence of claystones and sandstones (MANIVIT et al., 1986). The upper sequence exhibits sandy dolomite and limestone.

The interval studied includes more than 76 m covering the top of the Huqayl member, the Duhaysan member and the base of the Midhnab member (Fig. 2).

The age of the Khuff Formation was considered by STEINEKE et al. (1958) to be probably Late Permian. REZAK (1959) assigned the age of Late Middle Permian to the algal flora taken from Dammam well 43 in eastern Saudi Arabia. POWERS (1968) assigned an age of Late Permian (Kungurian-Kazanian) to the Khuff Formation according to palynological dating. Similar conclusions about the age of the Khuff Formation were reached by HILL & EL-KHAYAL (1983) and HILL et al. (1985). MANIVIT et al. (1986) assigned a Djulfian age to the top of the Khuff Formation.

The gymnocodiacean and dasycladacean algae found in this study were reported from the Middle to Late Permian (ELLIOTT, 1955, 1968). The udoteacean alga *Succodium difficile* KORDE was identified from the Late Permian (BASSOULLET et al., 1983). Therefore a late Permian age for the Khuff Formation is more likely.

SYSTEMATIC DESCRIPTION

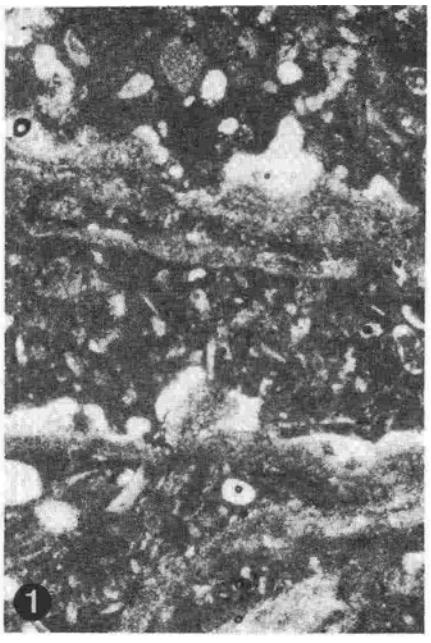
Division Chlorophyta PASCHER 1914
Class Bryosidophyleae ROUN 1963

AGE	FORMATION MEMBER	ROCK TYPE	THICKNESS
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 claystone oolite and dolomite	45m.

Tab. 1. Stratigraphic subdivision of Khuff Formation in Quassim, Central Saudi Arabia (Modified from MANIVIT et al., 1986).

Plate 45 Permian algae and algal microfacies from Unayzah, Quassim district, Saudi Arabia

Fig. 1. Stromatolite microfacies: Typical microstructure. Sample Pkm 49a. x 30
Fig. 2. Stromatolite microfacies: Successive laminae x30. Sample Pkm 49b. x 30
Fig. 3. Oncoids microfacies: Single and compound grains. Sample Pkm 89b. x 30
Fig. 4. Oncoids microfacies: Small oncoidal grains. Sample Pkm 89a. x 30
Fig. 5. Phylloid microfacies: Numerous broken blades. Sample Pkm 105. x 30
Fig. 6. Phylloid microfacies: Elongate thin blades. Sample Pkm 90. x 30
Fig. 7. *Mizzia velebitana* SCHUBERT 1908: Transverse section showing the wide branches. Sample Pkm 108a. x 30
Fig. 8. *Mizzia velebitana* SCHUBERT 1908: Tangential section showing the outer pores of the branches. Sample Pkm 108b. x 30
Fig. 9. *Mizzia velebitana* SCHUBERT 1908: Transverse section showing expanded branches. Sample Pkm 108c. x 30
Fig. 10. *Mizzia velebitana* SCHUBERT 1908: Transverse section showing typical branching. Sample Pkm 104. x 30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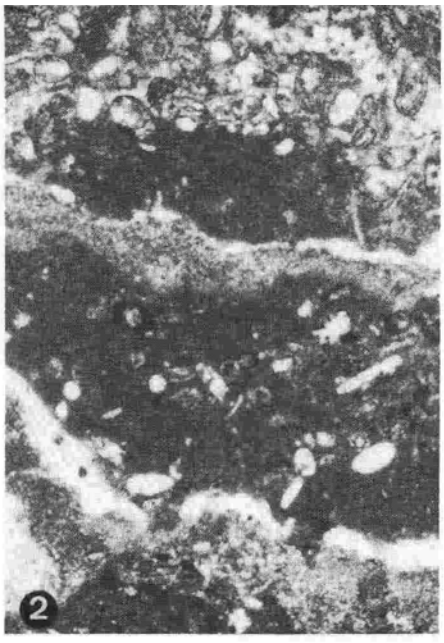
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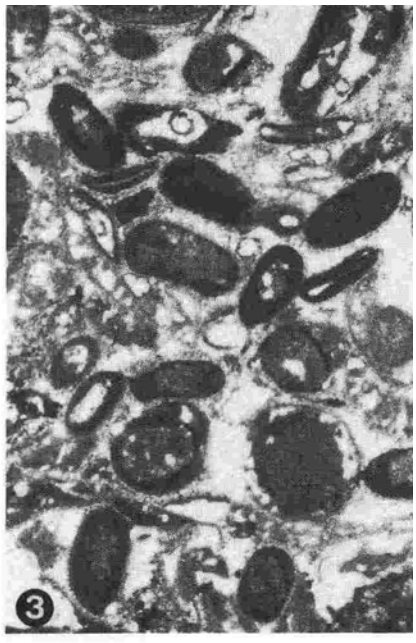
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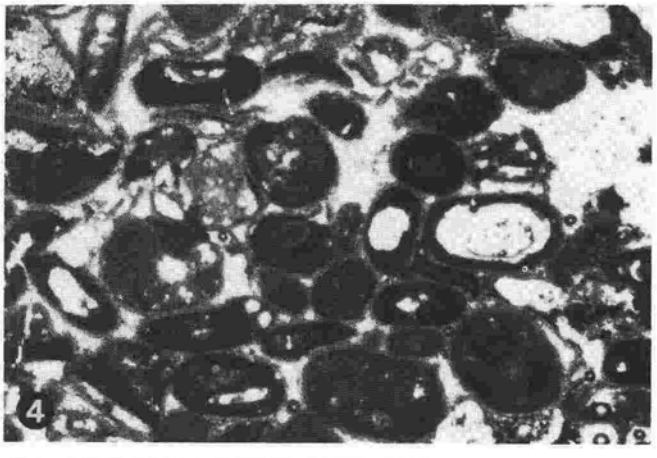
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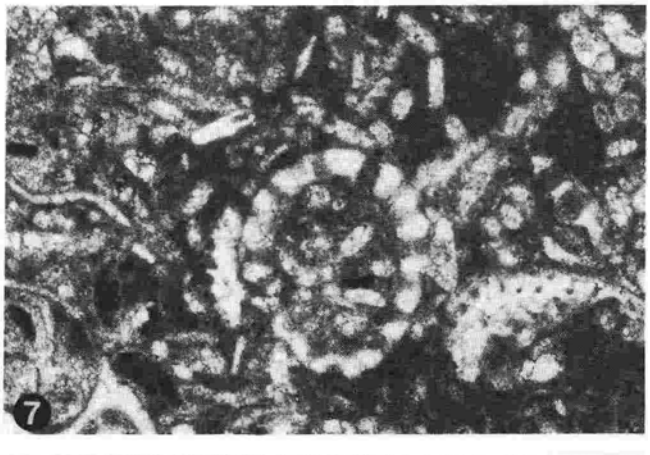
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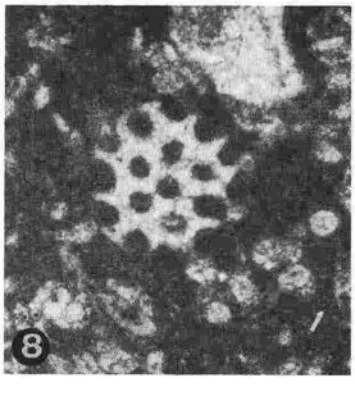
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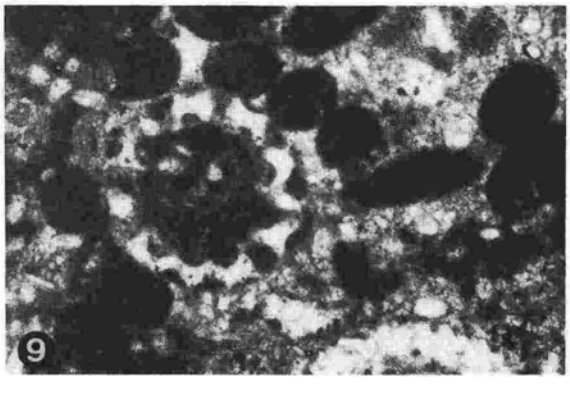
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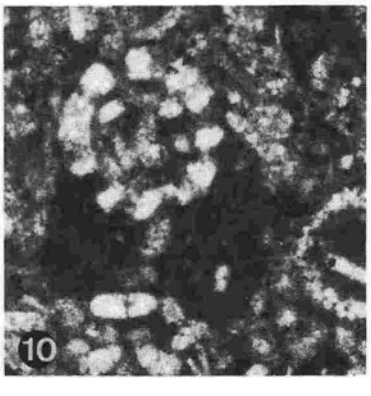
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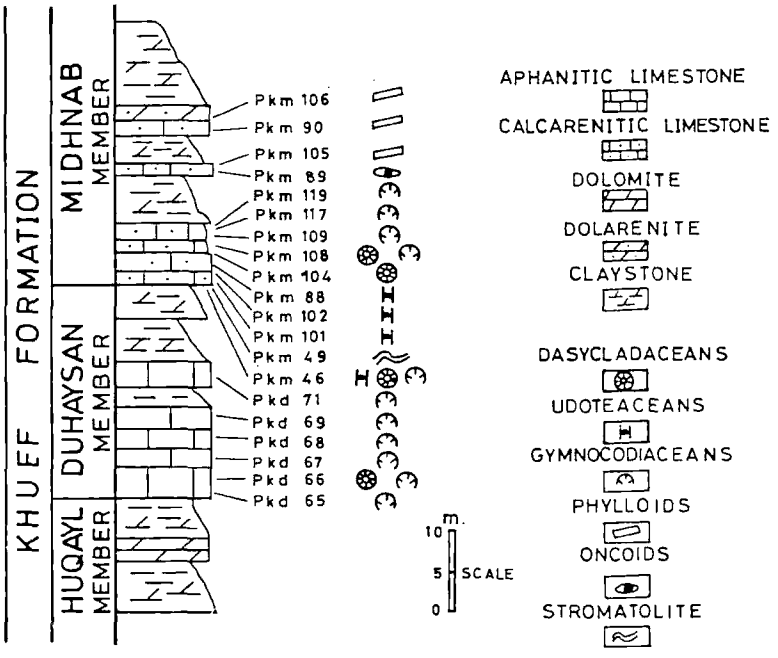


Fig. 2. Measured composite section east and southeast of Unayzah, Central Saudi Arabia.

Order Caulerpales SETCHELL 1929
Family Udotaceae (ENDLICHER) AGARDH 1888
Genus *Succodium* KONISHI 1954

Succodium difficile KORDE 1965 (Pl. 46/6-7)

Succodium difficile KORDE 1965 – BASSOULLET et al. 1983, Plate15, figures 6 and 7, pages 570-571.

Description; Dendroidal codiacean alga consisting of articulated segments with weakly calcified central medulla, conspicuously calcified subcortical parts of irregularly interwoven utricles and thin outermost cortical layer outlining outlets of the tapering utricles. It typically has large sized assimilator threads and utricles.
Measured dimensions (in mm): Length of thallus (L) = 12+; Width of thallus (D) = 2.2-3.8; Width of medulla (d) = 1.12-1.8; Diameter of medullar filaments (dtm) 0 0.03-0.06; Diameter of cortical filaments (dtc 1) = 0.02-0.03; Dimensions of pilules (dtc 2) = 0.16-0.6; Diameter of terminal outlets (p) = 0.01-0.02
Occurrence: *Succodium difficile* is found in the basal calcarenitic limestone of the Midhnab member (Samples Pkm 88, Pkm 101 and Pkm 102). It occurs with *Gymnocodium bellerophontis* and bryozoans.

Succodium sp. (Pl. 46/8-9)

Description; Disconnected segments, cylindrical in shape. The medulla is very weakly calcified. The subcortical zone has relatively smaller pilules. The cortical zone is the most calcified part, but it is relatively thin and can be easily broken.
Dimensions (in mm): Length of thallus (L) = 10+; Width of thallus (D) = 1.08-2; Width of medulla (d) = 0.35; Thickness of cortex and subcortex (c) = 0.07-0.43; Diameter of medullar filaments (dtm) = 0.03; Diameter of cortical filaments (dtc1) = 0.01; Dimensions of pilules (dtc2) = 0.25-0.4
Occurrence: *Succodium* sp. occurs at the base of the Midhnab member (sample Pkm 46): It is found with *Mizzia velebitana*, *Gymnocodium bellerophontis*, benthonic foraminifera such as *Globivalvulina* sp. and bryozoans.

Order Dasycladales PASCHER 1931
Family Dasycladaceae KUTZING 1843
Tribe Coniporelleae BASSOULLET et al. 1979
Subtribe Mizziinae BASSOULLET et al 1979
Genus *Mizzia* (SCHUBERT 1907) REZAK 1959

Mizzia velebitana SCHUBERT 1908 (Pl. 45/7-10)

Description: Hollow, bead-like segments, spherical, oval or elongated oval, pear-shaped or pyrifom, composed of a

Plate 46 Permian algae and algal microfacies from Unayzah, Quassim district, Saudi Arabia

Fig. 1. *Permocalculus plumosus* ELLIOTT 1955: Longitudinal section showing an elongated, finger-like segment with pores. Sample Pkm 108e. x 30

Fig. 2. *Permocalculus plumosus* ELLIOTT 1955: Longitudinal section showing pinching and swelling units. Sample Pkm 117. x 30

Fig. 3. *Gymnocodium bellerophontis* (ROTHPLETZ) ACCORDI 1956: Oblique-longitudinal section showing a hollow segment. Sample Pkm 109. x 30

Fig. 4. *Gymnocodium bellerophontis* (ROTHPLETZ) ACCORDI 1956: Longitudinal section showing radiating pores and sporangia. Sample Pkm 108d. x 30

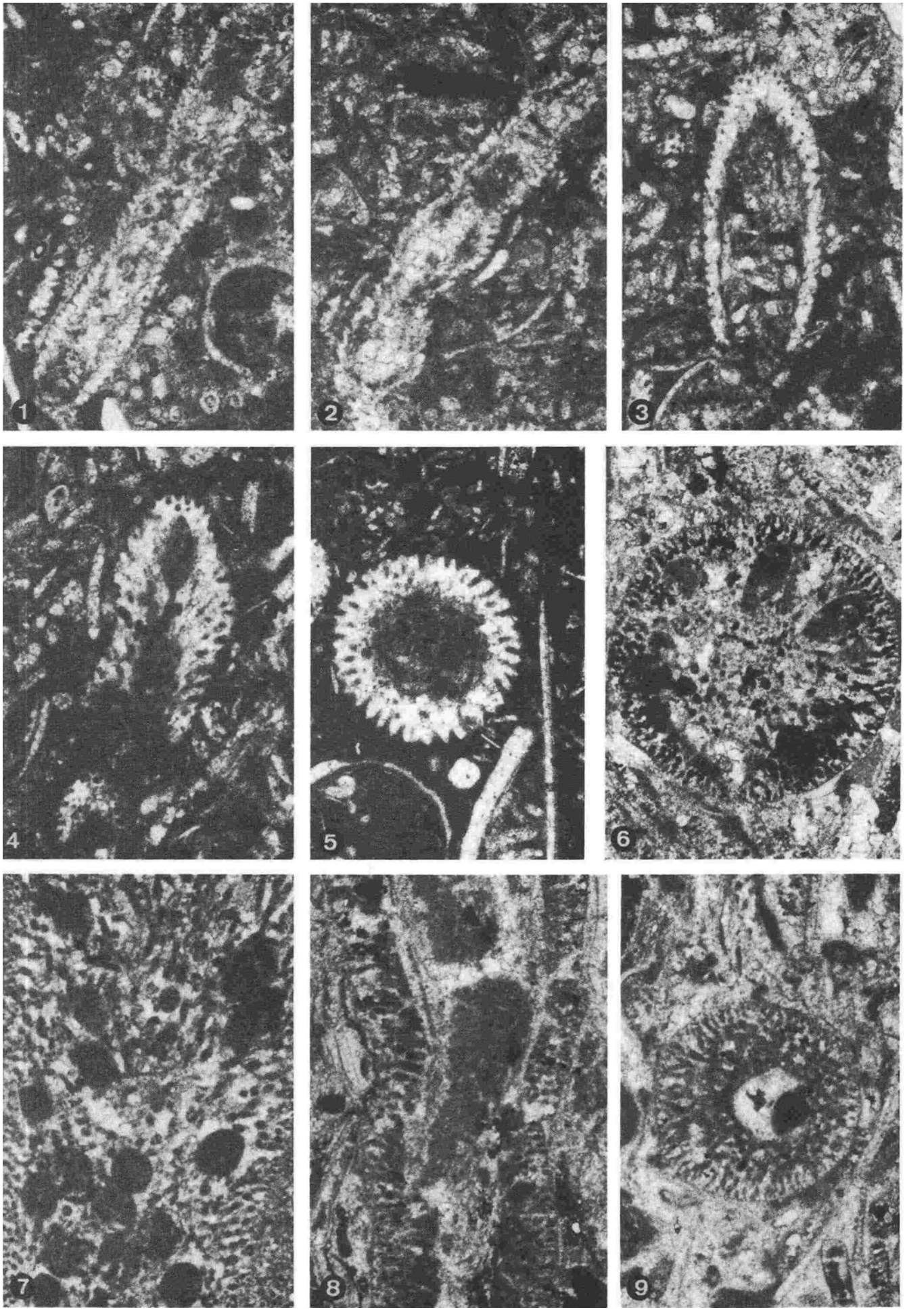
Fig. 5. *Gymnocodium bellerophontis* (ROTHPLETZ) ACCORDI 1956. Oblique-transverse section with coarse radiating pores. Sample Pkd 68. x 30

Fig. 6. *Succodium difficile* KORDE 1965: Transverse section showing medulla, cortex and the large tapering utricles. Sample Pkm 101a. x 30

Fig. 7. *Succodium difficile* KORDE 1965: Longitudinal section with a number of the large utricles. Sample Pkm 102b. x 30

Fig. 8. *Succodium* sp.. Longitudinal section showing the relatively heavily calcified cortex. Sample Pkm 46a. x 30

Fig. 9. *Succodium* sp.: Transverse section showing the cortex and subcortical zone with relatively small utricles. Sample Pkm 46b. x 30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central cavity from which simple expanding unbranched rays radiate in regular, alternating, horizontal whorls around the stem. The expanded ends of the branches are in mutual contact at the outer periphery of each segment giving rise to a honeycomb pattern on the surface. The measured dimensions (in mm) are;
External diameter (D) = 0.8-1.0; Diameter of central canal (d) = 0.54-0.69; Length of branches (l) = 0.15 - 0.16. Number of branches (w) =11-16; Ø of branches (p) = 0.07-0.15
Occurrence: *Mizza velebitana* is found in the basal limestone of the Duhaysan member (Sample Pkd 66) and through the basal calcarenitic beds of the Midhnab member (Samples Pkm 46, Pkm 104 and Pkm 108). It occurs together with *Succodium* sp., *Gymnocodium bellerophontis*, *Permocalculus plumosus*, benthonic foraminifera, particularly, *Globivalvulina* sp., *Langella* sp. and bryozoans.

Division Rhodophyta WETTERSTEIN 1901
Class Rhodophyceae RUPRECHT 1851
Order Nemaliales SCHMITZ 1892, orth. mut. CHRISTENSEN
Family Gymnocodiaceae ELLIOTT 1955
Genus *Gymnocodium* (PIA 1920) ELLIOTT 1955,

Gymnocodium bellerophontis (ROTHPLETZ) ACCORDI 1956 (Pl. 46/3-5)

Gymnocodium bellerophontis (ROTHPLETZ) ACCORDI 1956 – ELLIOTT 1955, plate 1, figs. 3-7, page 85

Description; Hollow calcareous segments which are cylindrical, oval or cone-shaped, and circular or oval in cross section. Rarely bifurcating. The walls are perforated by pores which radiate oblique-distally and widen markedly outward. The sporangia are ovoid in terminal segments
Measured dimensions (in mm): Length of thallus (L) = 3.4+; Diameter of thallus (D) = 0.54-1.48; Wall thickness (e) =0.1-0.36; Diameter of pores (p) = 0.04-0.05; Diameter of sporangia (ds) =0.18-0.25
Occurrence: *Gymnocodium bellerophontis* is found in many places throughout the Duhaysan member (Samples Pkd 65, Pkd 66, Pkd 67, Pkd 68, Pkd 69 and Pkd 71). It is also found in the basal calcarenites of the Midhnab member (Samples Pkm 46, Pkm 108, Pkm 109, Pkm 177 and Pkm 119). It occurs mostly with *Mizzia velebitana* and *Permocalculus plumosus*. It is also found with benthonic foraminifera (*Pachyphloia* sp., *Globivalvulina* sp.).

Genus *Permocalculus* ELLIOTT 1955
Permocalculus plumosus ELLIOTT 1955 (Pl. 46/1-2)

Permocalculus plumosus ELLIOTT 1955 plate 3 figs. 2-5, page 87.

Description: relatively large, elongated segments. Irregularly finger-like, with pinching and swelling units. Calcification is thin and with radial-oblique pores.
Measured dimensions (in mm): Length of thallus (L) = 6+; Diameter of thallus (D) = 0.68-1.4; Wall thickness (e) = 0.18-0.22; Diameter of pores (p) = 0.03-0.04
Occurrence: *Permocalculus plumosus* occurs particularly in the basal calcarenites of the Midhnab member (Samples Pkm 108, Pkm 117 and Pkm 119). Found with *Mizzia velebitana*, *Gymnocodium bellerophontis*, *Pachyphloia* sp. and *Langella* sp.

Algal Microfacies

The term algal microfacies is used to designate rocks consisting completely of the remains of alga. The term includes also algal oncoids and stromatolites. These algal microfacies are found at the base of the Midhnab member below the claystones and the shales of the same member (Samples Pkm 49, Pkm 89, Pkm 90, Pkm 105 and Pkm 106).

Phylloid Microfacies
These algae are found as undulating blades differentiated into cortex with inner and outer layers and a medulla. The inner cortex (subcortex) is composed of utricles parallel to the surface. The reproductive organs lie within the subcortex. Unidentifiable phylloid algae make up whole layers near the top of the measured section in the upper limestones of the Midhnab member (Samples Pkm 90, Pkm 105 and Pkm 106). They are not well-preserved. Measured fragments are up to 6 mm in length and 0.07 to 0.25 mm in width (Pl. 45/5-6). The thickness of the cortex is 0.02 to 0.07 mm.

Oncoid Microfacies
These are small nonskeletal single and compound grains made up of dark material typical of the blue-green algae or cyanophytes. The single grains are 0.25 to 0.7 mm long and 0.1 to 0.4 mmwide (Pl. 45/3-4). The compound grains range in size from 0.55 to 1.2 mm in length and 0.52 to 0.75 mm in width. These oncoid microfacies are found near the top of the measured section in the calcarenites of the Midhnab member (Sample Pkm 89).

Stromatolite Microfacies
These algal stromatolites form thin laminated layers that can be recognized even in the field. In thin sections these algal stromatolites form distinctive laminations containing various trapped skeletal and non-skeletal grains. The thickness of these laminae range from 0.4mm to 3.2 mm (Pl. 45/1-2). These algal stromatolites are particularly frequent near the base of the bioclastic carbonates of the Midhnab member (Sample Pkm 49).

DEPOSITIONAL ENVIRONMENT

A thick sequence of Ordovician to Permian sandstones and shales was deposited to form the Middle East (Arabian) Platform, a broad shelf bordering the positive Afro-Arabian Massif to the northeast and east (POWERS et al., 1966, MURRIS, 1980, Sharief, 1982, 1983 AL-LABOUN, 1986, 1987). In central Arabia, these sediments extended north of Quassim district, curved around Hail Arch and passed into the Tabouk and Widyan Basins to the north. The Late Permian was marked by a change in sedimentation from dominant clastics to mostly carbonates which began with a widespread transgression extending to the edge of the Arabian Shield. The first major carbonate sediment series that blanketed the entire central Arabian Platform, was the Khuff Formation: It marked the beginning of what is called the 'layer-cake' sedimentation of the Arabian Platform (AL LABOUN, 1986).

The algal flora of the carbonates studied indicates deposition in very shallow marine environments. WILSON (1975) mentions the presence of algae in shoal environments,

in agitated water, in restricted marine shoals, in restriced marine shelf lagoons and in protected environments. Recent benthonic calcareous algae develop in greatest abundance in shallow water near the crest (WRAY 1977, FLÜGEL, 1982). Blue-green algae prefer tidal zones, green algae are frequently found in depths down to about 20-30 m and some red and codiacean algae may occur in water as deep as 50 m. Udoteacean, dasycladacean and gymnocodiacean algae in the studied section most frequnetly occur in the bioclastic and calcarenitic beds of Midhnab member. The algae were somewhat transported. The sediments reveal a low diversity ofdasycladacean algae and foraminfera. BASYONI (1984) interpreted an equivalent part of the studied section as a back barrier beach lagoon in an open shoreline. The phylloid algae were possibly deposited as a small near-shore algal mound. A similar position had been suggested for Permian phylloid algae in the Southern Alps (FLÜGEL, 1977). The occurrence of small blue-green algae oncolites is also an indicator of a shallow water environment. The size of the oncolites is often regarded as an indication of turbulence.

The presence of stromatolites can also be an indicator of shallow warm, marine waters. BASYONI (1984) suggested an origin of stromatolites in the lower Khuff Formation in shallow pools of the intertidal zone.

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