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Palynological study of the Early Cretaceous Kurnub Sandstone Formation, Mahis area, Central Jordan

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ABSTRACT. Early Cretaceous Kurnub Sandstone Formation, cropped out in central Jordan from which we obtained 41 genera and 62 species of spores and pollen. The palynofloral assemblage includes miospore species reported here for the first time including: *Concavisporites punctatus*, *Gemmatriletes clavatus*, *Clavifera rudis*, *Balmeiopsis limbata*, *Classopollis torosa*, and *Microfoveolatosporites skottsbergii*. The presence of the former taxa together with previously described tricolpate pollen of Jarash indicates a late Aptian to early Albian age.

Pollen and spores from the lower part of the Kurnub Sandstone Formation indicate humid climatic conditions while those from its upper part reflect arid to semi-arid conditions. The palynofloral assemblage is dominated by pteridophytes with subordinate amounts of angiosperms and gymnosperms in the lower part of the formation.

KEYWORDS: pteridophytes; angiosperms; gymnosperms, Early Cretaceous, Jordan

INTRODUCTION

Palynological investigations of the Jordanian sedimentary rocks are rare. Al-Said and Mustafa (1994) investigated the palynological content of the Kurnub Sandstone Formation in north Jordan, who subdivided the whole assemblage into two assemblage zones, the first one dominated by *Matonisporites*, *Deltoidospora*, *Dictyophyllidites*, *Densoisporites*, *Inaperturopollenites*, *Lycopodiumsporites*, *Undulatisporites*, indicating Late Jurassic to Early Cretaceous age. The second zone, characterized by the presence of *Inaperturopollenites*, *Monosulcites*, *Cycadopites*, *Deltoidospora*, *Matonisporites*, *Araucariacites*, *Todisporites*, *Eucommiidites*, *Schizosporis*, *Ephedripites*, *Clavatipollenites*, and *Classopollis* assigned Albian by the first appearance of pollen. Mustafa and Al-Said (2001) confirmed a late Aptian to early Albian age of the lower part of the Upper Kurnub Sandstone Formation, by the reporting the presence of *Retimonocolpites* sp., *Tricolpites* sp., *Rousea geogensis*, *Phimopollenites pseudocheros*, and *Punctatriocolpites brevis*.

Early Cretaceous deposits in Jordan mostly consist of sandstones with intercalations of claystones deposited mainly in deltaic and fluvial environments. Locally there are marine carbonate interbeds deposited during brief marine transgressions.

GEOLOGICAL SETTING

Russegger (1837) introduced the name Nubian Sandstone to describe the clastic rocks of the Cretaceous age in Egypt and correlate it with sandy rocks in Sinai and south Jordan. Blanckenhorn (1914) subdivided the Nubian Sandstone into the lower part dated as the Cambrian and the upper part assigned to the

Early Cretaceous age. The Lower Cretaceous sandstone exposed in Palestine (Negev), WSW of the southern edge of the Dead Sea is named as Wadi Hathira (Shaw 1947), which is equivalent to the Kurnub Sandstone Formation of northern Jordan (Quennell 1956).

The Kurnub Sandstone Formation (Early Cretaceous) comprises a thick deposit of predominantly fluvial medium- to coarse-grained sandstone (quartz-arenite) in south and central Jordan with marine intercalations in north-central and northern Jordan (Bender 1974).

Palynological analysis of the lower part of the Kurnub Sandstone Formation showed a humid climate and a more semi-arid to arid climate towards its upper part (Al-Said & Mustafa 1994). This finding was confirmed by Scotese (2001) who considered the climate to be mild wet, tropical at the beginning of the Cretaceous in this area, but by the beginning of the Late Cretaceous, the northward movement of the African plate had moved the area into a more arid zone.

In northern and central Jordan the Kurnub Sandstone Formation, dated as Neocomian-early Barremian to Albian, has been divided into three formations: Ramel, Jarash and Bir Fa'as by Amireh (1997, 2000). The Neocomian early Barremian age of the Kurnub Sandstone Formation is constrained by its position above the Middle to Late Jurassic carbonates (Basha 1983, Amireh & Abed 1999). The Neocomian age is based on megafloral evidence (Edwards 1926), and palynology (Al-Said & Mustafa 1994, Mustafa & Al-Said 2001).

Palynomorphs data presented here where obtained from samples collected from Kurnub Sandstone Formation cropped out at Mahis locality in north-central Jordan (Figs 1, 2) at N 31°59′43.7″, E 035°45′29.2″.

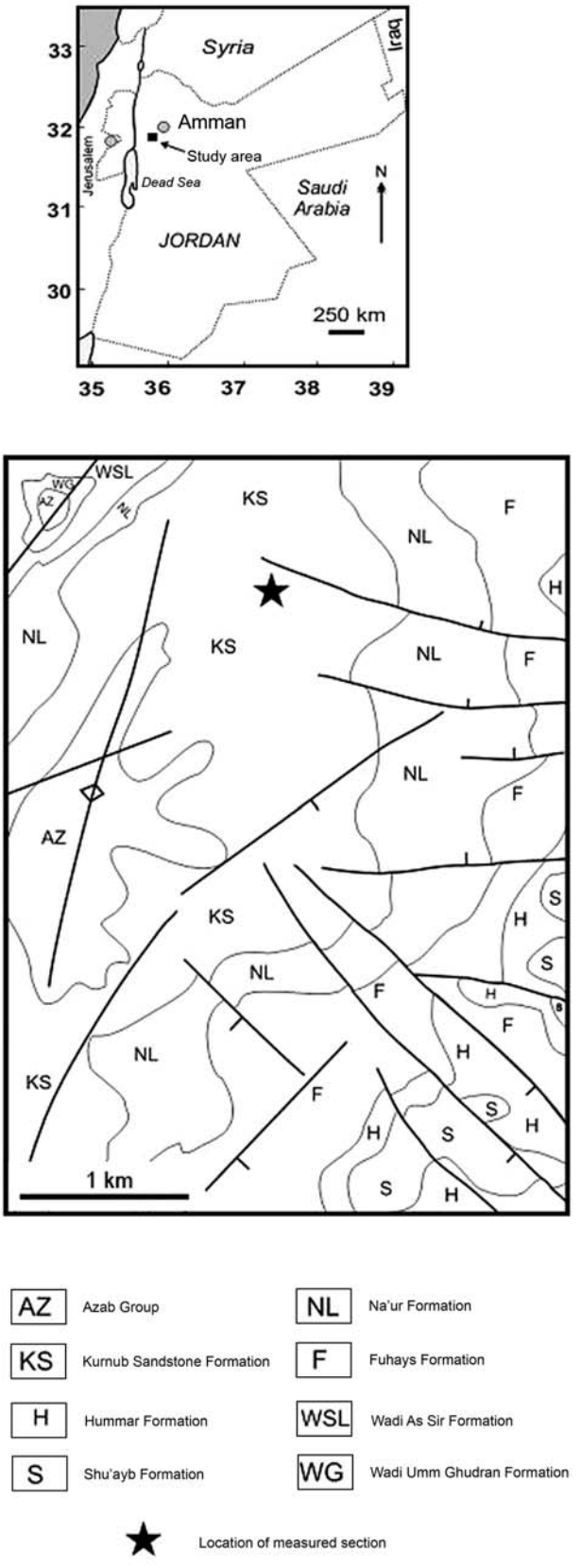

Fig. 1. Location and geology of the study area

MATERIAL AND METHODS

Ten clay samples were palynologicaly processed in order to extract their fossil palynomorphs content. Preparation was carried out by mechanical and chemical methods. Each sample was tested for the presence of carbonate by the addition of few drops of dilute hydrochloric acid, if present, the carbonates removed by the adding of hydrochloric acid to the crushed sample for about 24 hour, then washed three times by water, the residual covered by 70% hydrofluoric acid for 72 hours. The insoluble fluorides are eliminated by boiling the residue in 10% hydrochloric acid and then washed three times with distilled water. The organic residue is poured into a test tube with 10% nitric acid for oxidation, heated in a double boiler for 1–2 minutes, then washed and centrifuged. The organic residue is sieved through a mesh sieve to remove the

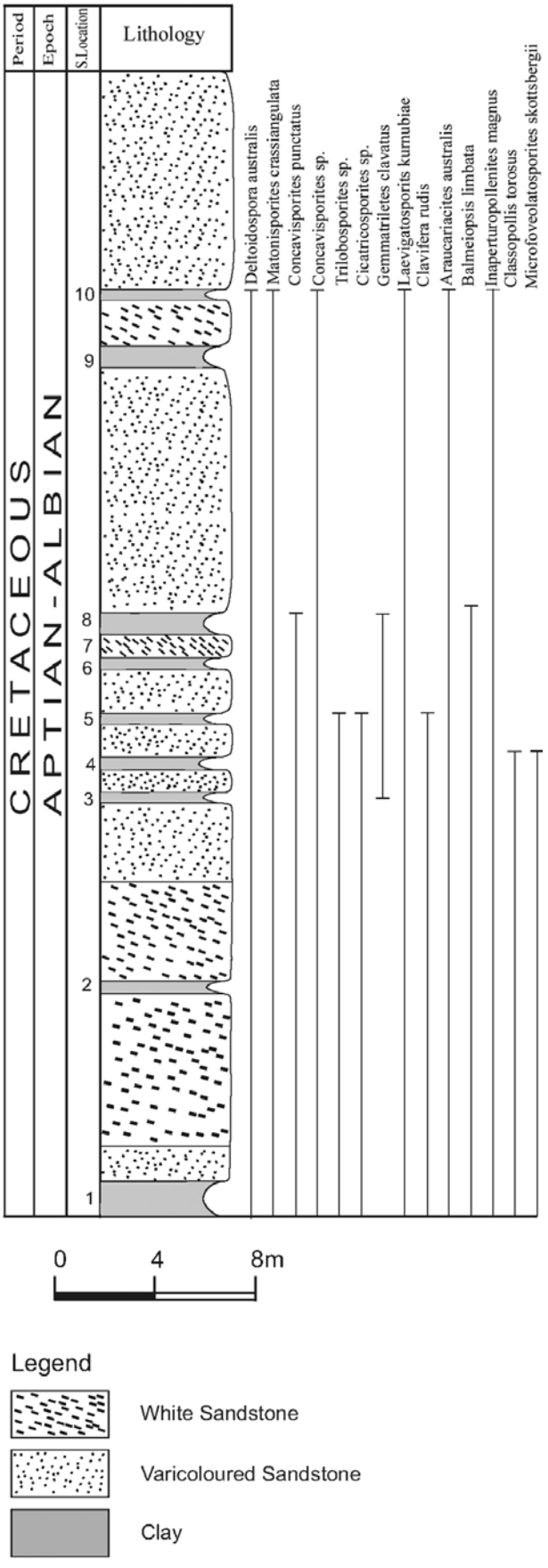

Fig. 2. Lithology, position of samples, and distribution of palynological taxa recorded in the present study

debris (larger than 100 µm) and small debris (less than 5 µm), then the 5–100 µm fraction was washed with distilled water, and concentrated by centrifuging. The final residue mixed with cellusize (hydroxyl ethyl cellulose) is strewn on a cover-slip, dried and mounted by overturning the cover slip on a couple of drops of Canada Balsam on a microscope slide.

The slides are stored at the Department of Earth Sciences, The Hashemite University, Jordan.

LIST OF TAXA

Following data are recorded here from Jordan for the first time (Tab. 1):

Table 1. List of the palynomorph taxa and their botanical affinities

Division	Family	Taxa of pollen and spores
Pteridophyta	Cyatheaceae, Dicksoniaceae?	*Deltoidospora australis*
		Trilobosporites
	Matoniaceae	*Matonisporites crassiangulata*
		Concavisporites punctatus
		Concavisporites sp.
	Schizaeaceae	*Cicatricosisporites* sp.
		Microfoveolatosporites skottsbergii
	Gleicheniaceae	*Clavifera rudis*
	Polypodiaceae	*Laevigatosporites kurnubiae*
		Germmatriletes clavatus
Coniferophyta	Cheirolepidiaceae	*Classopollis torosus*
	Araucariaceae	*Araucariacites australis*
		Balmeiopsis limbata
	Taxodiaceae	*Inaperturopollenites magnus*

TAXONOMY

Anteturma Proximegerminantes Potonié 1970

Turma Triletes-Azonales Reinsch emend. Dettmann 1963

Suprasubturma *Acavatitriletes* Dettmann 1963

Subturma *Azonotriletes* Luber emend. Dettmann 1963

Infraturma *Laevigati* Bennie & Kidston emend. R. Potonié 1956

Genus ***Deltoidospora*** (Miner 1935) Potonié 1956

Deltoidospora australis (Couper) S.K. Srivastava 1975

Pl. 1, fig. 1

1953 *Cyathidites australis* Couper, p. 27, pl. 2, fig. 11.

Description. Trilete spore. Triangular to fusiform amb, trilete mark reaching more than 2/3 radius of the spore, concave sides, with rounded apices. Exine two layered, the inner one, smooth, about 2 µm thick, the outer layer about 1 µm thick, psilate.

Grain size. 52–63 µm.

Age. Late Aptian to early Albian.

Previous records. Saad and Ghazaly (1976), recorded it from the Kimmeridgian-Santonain-Campanian from Egypt, and Al-Said and Mustafa (1994) reported it from the Kimmeridgian-Necomian age from North Jordan.

Matonisporites crassiangulatus (Balme, 1957) Dettmann, 1963

Matonisporites crassiangulata (Balme, 1957)

Pl. 1, figs 2–3

1957 *Cyathidites crassiangulatus* Balme, p. 22, Pl. 3, figs 39–41.

Description**.** Trilete spore, triangular amb, trilete mark reaching more than 2/3 radius of the spore. Straight to concave sides, apices broadly rounded. Exine 2–3 µm, thicker at the apices, where it reaches 7 µm, psilate.

Spore size. 43–59 µm.

Age. Late Aptian to early Albian.

Previous record. Horowitz (1970) described the species from the Jurassic of Northern Negev and Al-Said and Mustafa (1994) reported it from the Kimmeridgian-Necomian age from North Jordan.

Genus ***Concavisporites*** Pflug in Thomson & Pflug 1953

Concavisporites punctatus (Delcourt & Sprumont) Brenner 1963

Pl. 1, fig. 4

1955 *Concavisporites punctatus* (Delcourt & Sprumont) p. 25, pl. 1, fig. 8, pl. 2, fig. 2.

Description. Trilete with simple long laesurae reaching the equator. Amb triangular, sides concave. Exine smooth, about 1–3 µm thick.

Spore size. 42–56 µm.

Age. Late Aptian to early Albian.

Concavisporites sp.

Pl. 1, Fig. 5

Remarks. This genus includes smooth to slightly ornamented trilete spores with kyrtomes and concave sides. The kyrtomes are formed by an abruptly convex exine area surrounding the laesurae which is reduced to three arcuate folds in the proximal interradial regions on compressed spores (Singh 1971).

Age. Late Aptian to early Albian.

Infraturma Murornati Potonie & Kremp 1954

Genus ***Cicatricosisporites*** (Potonié & Gelletich 1933), Dettmann & Clifford 1992

***Cicatricosisporites* sp.**

Pl. 1, figs 7–8

Description. Trilete spore, subcircular amb, laesurae with raised lips reaching or almost reaching the equator. Amb rounded to triangular. Proximal and distal exine with beaded cicatricose-reticulate sculpture. Ribs 0.5–1.0 µm wide. Exine 1–3 µm thick.

Spore size. 35–52 µm.

Age. Late Aptian to early Albian.

Infraturma *Apiculati* Bennie & Kidston emend. R. Potonié 1956

Genus ***Gemmatriletes*** Pierce 1961

Gemmatriletes clavatus Brenner 1968

Pl. 1, fig. 9

1968 *Gemmatriletes clavatus* Brenner, p. 353, pl. 1, fig. 7.

Description. Trilete spore with circular outline. Lasurae obscured by sculptural elements in most specimens. Both proximal and distal surfaces densely covered by pila, consisting of

rods up to 5 µm high with pronounced swollen distal ends.

Age. Late Aptian to early Albian.

Previous records. Albian-? Cenomanian of Peru (Brenner 1968); Hauterivian – Cenomanian of Israel (Brenner 1974); middle Cenomanian of Alberta (Singh 1983).

Turma *Monoletes* Ibrahim, 1933

Suprasubturma *Acavatomonoletes* Dettmann, 1963

Subturma *Azonomonoletes* Luber, 1935

Infraturma *Laevigatomonoleti* Dybová & Jachowicz, 1957

Genus ***Laevigatosporites*** Ibrahim, 1933

Laevigatosporites kurnubiae (Al-Said & Mustafa 1994)

Pl. 1, fig. 10

1994 *Laevigatosporites kurnubiae* Al-Said & Mustafa, p. 145, pl. 4, figs 1, 9.

Description. Monolete spore, bean shaped, monolete mark extending along the whole length of the spore, 2–4 µm thick, intrapunctate, punctae closely spaced. Spores range in length 80–90 µm, and 40–45 µm in width. The species differ from other *Laevigatosporites* in its large size and in having punctae spreading all over the spore.

Age. Late Aptian to early Albian.

Infraturma Laevigati Bennie & Kidston 1886 emend. R. Potonié 1956

Genus ***Clavifera*** Bolkhovitina 1966

Clavifera rudis Bolkhovitina 1968

Pl. 2, fig. 1

1968 *Clavifera rudis* Bolkhovitina, p. 48; pl. 13, figs 9–18; pl. 14, figs 1–15; pl. 15, figs. 1–12.
1971 *Clavifera rudis* Bolkhovitina, Playford, p. 544; pl. 104, figs 18–-19.

Description. Microspores radial, trilete; distal surface arched. Amb subtriangular with almost straight sides and relatively short appendices. Laesurae long, extending near to equator. Equatorial thickenings consisting of three, smooth, interradial crassitudes, with maximum width (6–12 µm) at centers of interradial amb, and gently undulating margins. Proximal surface laevigate. Distal surface conspicuously regulate and /or verrucate, elevations typically confined to triangular region.

Age. Late Aptian to early Albian.

Previous records. Bolkhovitina (1968) recorded *Clavifera rudis* from Russian Aptian to Cenomanian strata.

Turma *Aletes* Ibrahim 1933

Subturma *Azonaletes* Luber emend. R. Potonié & Kremp 1954

Genus ***Araucariacites*** Cookson ex Couper 1953

Araucariacites australis Cookson ex Couper 1953

Pl. 2, fig. 2

1970 *Araucariacites australis* Cookson, Horowitz, p. 173, pl. 3, fig. 18.

Description. Outline circular or sub-circular, frequently distorted by folding. No germinal mechanism or tetrad markings visible. Exine thin, granulate, with granulations of varying size (up to 1 µm), closely spaced to distinctly separated.

Grain size. Maximum diameter 56–86 µm.

Age. Late Aptian to early Albian.

Previous records. Saad & Ghazaly (1976), recorded it from the Kimmeridgian-Santonain/ Campanian from Egypt, and Al-Said and Mustafa (1994) reported it from the Kimmeridgian-Necomian age from North Jordan, and Upper Aptian – Lower Albian herein.

Genus ***Balmeiopsis*** Archangelsky 1979

Balmeiopsis limbata (Balme) Archangelsky 1977

Pl. 2, fig. 3

1957 *Inaperturopollenites limbatus* Balme, p. 31, pl. 7, figs 83, 84.
1977 *Balmeiopsis limbata* (Balme) Archangelsky, p. 123, pl. 1, figs 1–5.
1986 *Araucariacites australis* auct. non Cookson 1947; Lawal & Moullade, pl. 1, figs 23, 24.
2006 *Balmeiopsis limbata* (Balme) Archangelsky, 1977; Zobba, pl. 3, figs 13, 14

Description. Pollen grains with sub-circular outline. Exine about 3 µm thick, rarely folded, smooth to very finely granulate, frequently ruptured irregularly.

Grain size. Maximum diameter about 60 µm.

Age. Late Aptian to early Albian.

Genus ***Inaperturopollenites*** Pflug, 1952 ex Thomson & Pflug, 1953 emend. Potonié, 1958

Inaperturopollenites magnus Potonié, 1953

Pl. 2, fig. 4

1953 *Inaperturopollenites magnus* (Potonié), Thomson & Pflug, p. 64, pl. 4, figs 83–88.

1994 *Inaperturopollenites magnus* (Potonié), Mustafa & Al-Said p. 150, pl. 7, fig. 12, pl. 8, fig. 7 and pl. 9, fig. 5.

Description. Inaperturate pollen, with oval to spherical outline. Two or more folds with maximum width of 12 µm scattered all over the grain, pointing where the folds start. Exine 1–2 µm thick, ornamentation psilate to minutely granulate in some grains.

Grain size. 47–65 µm.

Age. Late Aptian to early Albian.

Turma *Poroses* Naumova emend. R. Potonié 1960

Subturma *Monoporines* Naumova 1939

Genus ***Classopollis*** Pflug 1953

Classopollis torosus (Reissinger 1950) Couper emend. Burger 1965

Pl. 2, fig. 5

Description. Pollen grains, ovoid to spherical, isolated or occurring as tetrads, distally pseudoporate. Exine two layered, smooth, scabrate or striate. Ectexine thickened in the equatorial region forming a band or belt which may be smooth or ornamented by striations. Endexine variably distinct to indistinct. Sometimes there is a proximal trilete mark.

Grain size. 22–42 µm.

Age. Late Aptian to early Albian.

DISCUSSIONS

The presence of a high diversity of sculptured trilete spores *Cicatricosisporites*, *Concavisporites*, and *Trilobosporites* and the abundance of gymnosperm pollen grains (*Inaperturopollenites*, *Classopollis*) indicate some resemblance with the palynologic data obtained from North American-Eurasian Subprovince defined by Herngreen et al. (1996).

The genus *Trilobosporites*, obtained here from the Aptian, is generally abundant in the Berriasian and Valanginian sections described from several locations; Delcourt and Sprumont (1955) from Belgium; Burger (1966) from Netherlands; Taugourdeau-Lantz & Donze (1971) from Portugal; Dorhöfer & Norris (1975) from north-western Europe; Dorhöfer (1977) from North-West Germany, and (Dorhöfer 1979) from Europe and North America. The Occurrence of *Ephedripites multicostatus* Brenner 1963 recorded by Al-Said and Mustafa (1994) from the Jordanian Kurnub Sandstone is from Hauterivian to Cenomanian in north and south hemispheres. North hemisphere: Maryland (Brenner 1963) and Oklahoma (Wingate 1980), USA; Hungary (Juhász 1983); Great Britain as *Ephedripites* sp. (Hughes & McDougall 1994); France (Azéma et al. 1990); Portugal (Hasenboehler 1981); Spain (Doubinger & Mas 1981; Villanueva-Amadoz et al. 2011). South hemisphere: Hauterivian-Cenomanian. Morocco (Bettar & Meón 2006); Nigeria (Ola-buraimo & Boboye 2011).

In the studied formation, the columellate-tectate monosulcate genus *Clavatipollenites* is a well-represented angiosperm group. This genus seems to have been the first widespread angiosperm taxon and is a useful biostratigraphic index species. It has been recorded from the Valanginian of Portugal (Trincão 1990), the Late Hauterivian of Israel (Brenner & Bickoff 1992, Brenner 1996) and the Early Hauterivian (possibly Late Valanginian) of Morocco (Gübeli et al. 1984), and England (Hughes & McDougall 1987, 1994. Hughes et al. 1991, Hughes1994). Peyrot et al. (2007) recorded it from the Upper Aptian age of Spain.

Tricolpites sp. is important indicator since it ranges as far back as the Late Barremian in southern Laurasia (Kemp 1970, Laing 1975 & 1976, Doyle & Robbins 1977, Hickey & Doyle 1977, Doyle et al. 1982, Penny 1989, Hughes & McDougall 1990, Doyle 1992,. Hughes 1994).

As a result, the very low representation of poorly diversified tricolpate forms compared to other palynofloras of southern Laurasia and northern Gondwana dated as Lower to Middle Albian (Médus & Berthou 1980, Bettar & Méon 2001) also support an Upper Aptian-Lower Albian.

Al-Said & Mustafa (1994), from the distribution of the spores and pollen of the Kurnub Sandstone Formation, concluded a humid climate for the lower part of the formation and an arid to semi arid in the upper part of the formation, the same conclusion reached by Taylor et al. (2008).

Late Albian age is assigned to the Bir Fa'as Formation at the top of the Kurnub Group based on an ammonite *Knemiceras* spp. and a dated glauconite marker bed (GMB) at 96.1±1.1 Ma (Amireh 1997, Amireh et al. 1998).

Palynomorph assemblages from carbonaceous layers from the Upper Jarash Formation suggest an Albian age (Brenner 1974, 1996, Taylor et al. 2008, Hu et al. 2008).

Palynological studies of the lower Kurnub Group together with the presence of the fern *Weichselia reticulata* (Edwards 1926) evidence for a Neocomian age (Al-Said & Mustafa 1994). The basal part of the Kurnub Group in Israel has also been dated by Brenner and Bickoff (1992) as late Barremian age based on angiosperm pollen.

CONCLUSIONS

The palynological succession of the Lower Cretaceous Kurnub Sandstone Formation in Mahis area, Jordan provides new biostratigraphic data. The study of miospores indicates an Upper Aptian-Lower Albian age.

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PLATES

Plate 1

Palynomorphs from the Kurnub Sandstone Formation, magnification for all figures is ×1000

1. *Deltoidospora australis* Couper 1953
2–3. *Matonisporites crassiangulata* Balme, 1957
4. *Concavisporites punctatus* (Delcourt & Sprumont) Brenner, 1963
5. *Concavisporites* sp.
6. *Trilobosporites* sp.
7–8. *Cicatricosisporites* sp.
9. *Gemmatriletes clavatus* Brenner, 1968
10. *Laevigatosporites kurnubiae* Al-Said & Mustafa, 1994

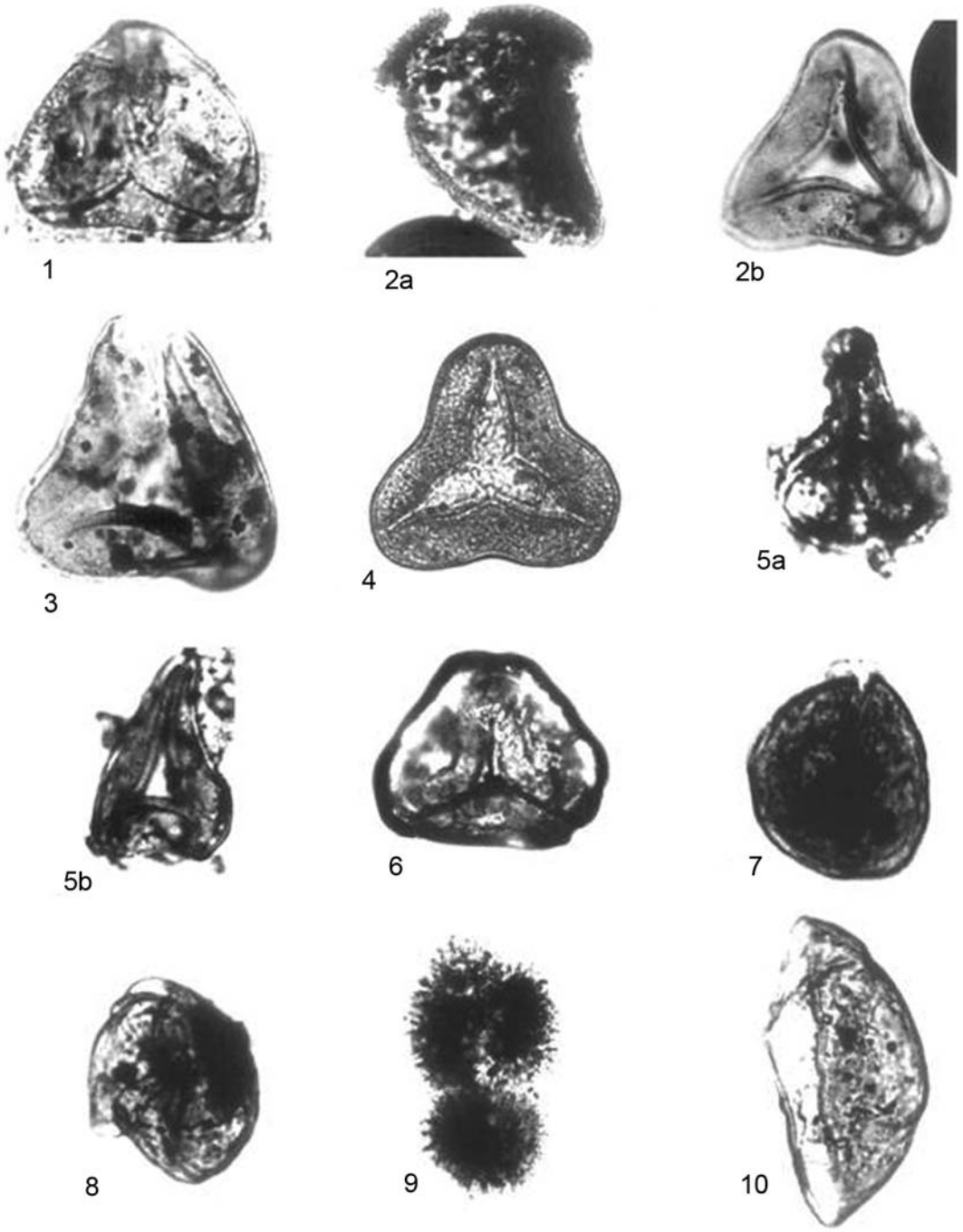

1
2a
2b
3
4
5a
5b
6
7
8
9
10

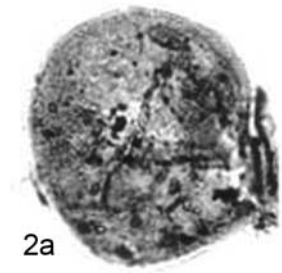
Plate 2

Palynomorphs from Kurnub Sandstone Formation, magnification for all figures is ×1000

1. *Clavifera rudis* Bolkhovitina 1968
2. *Araucariacites australis* Cookson 1947
3. *Balmeiopsis limbata* (Balme) Archangelsky 1977
4. *Inaperturopollenites magnus* Potonie, 1953
5. *Corollina torosa* Reissinger, 1950
6. *Microfoveolatosporis skottsbergii* (Selling) Srivastava, 1971

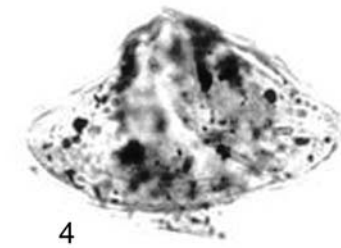

1a


1b


2a


2b


3


4


5


6a


6b