

The stratigraphic positions of the Wadi Dukhan and Al Uwayliah formations, northeast Libya – a review

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The stratigraphic positions of the Wadi Dukhan and Al Uwayliah formations are reviewed. Diagnostic Maastrichtian larger foraminiferal species from the Wadi Dukhan Formation in well B7 – 41 (Cyrenaica) and in well U2 – 6 (northeastern Sirt Basin) are illustrated for the first time. These species are *Omphalocyclus macroporus* (Lamarck), *Siderolites* cf. *calcitrapoides* Lamarck and *Orbitoides* cf. *media* (d'Archiac).

Following the rules of nomenclature, the type section of the Al Uwayliah Formation should be considered a composite stratotype. The section east of al Uwayliah village is the holostatotype (upper part of the formation) and the Jardas al Jarrari section is the parastratotype (lower part of the formation). The combined thickness of the two component stratotypes seems to be too thin to represent the whole Paleocene Series. Palaeontologic evidence also suggests that parts of the Paleocene standard foraminiferal zones are not represented in either of the two component stratotypes. Most probably, a middle part of the Al Uwayliah Formation, below the holostatotype and above the parastratotype (late Danian to Selandian), has not yet been recognised.

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Introduction

More than 70 names of different and synonymous rock units are mentioned in the geologic literature of the last century for the Cretaceous-Tertiary sedimentary rocks of northeastern Libya (Fig. 1), many of which are in need of revision. This has created controversies on rock unit names, ages and boundaries amongst workers in the area (e.g., Pietersz, 1968; Kleinsmiede & van den Berg, 1968; Barr, 1968; Barr & Weegar, 1972; Rölich, 1974; Klen, 1974; Zert, 1974; El Deftar & Issawi, 1977; Francis & Issawi, 1977; Mazhar & Issawi, 1977; Eliagoubi, 1980; Megerisi & Mangain, 1980a, b; Tawadros, 2001; Muftah *et al.*, 2002; El Mehaghag & Ashahomi, 2005).

The Wadi Dukhan and Al Uwayliah formations are reviewed stratigraphically and palaeontologically. Further palaeontologic evidence, from subsurface Cyrenaica and northeastern Sirt Basin, is illustrated for the Wadi Dukhan Formation (Pls. 1, 2) to confirm its Maastrichtian age.

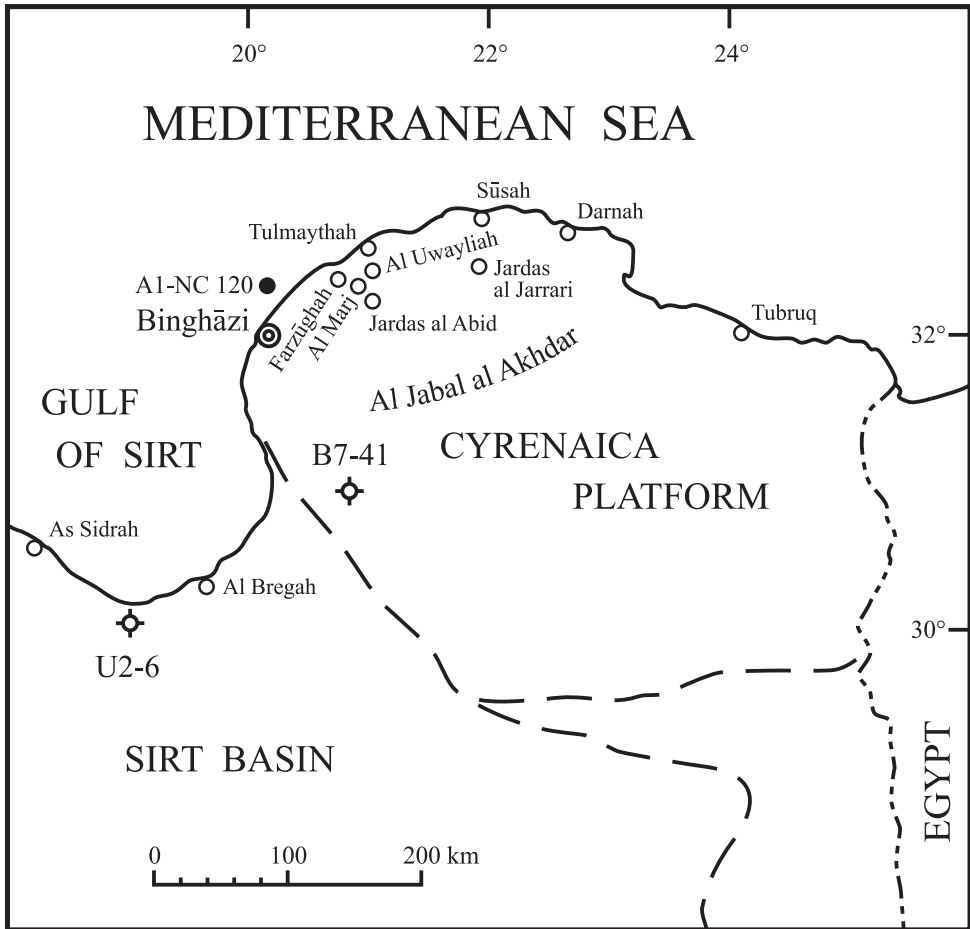


Fig. 1. Location map of northeastern Libya.

Wadi Dukhan Formation

Kleinsmiede & van den Berg (1968, p. 118), following the stratigraphic subdivision adopted by Libya Shell N.V., and Pietersz (1968, pp. 126, 127) introduced this formation (in the same publication) from al Jabal al Akhdar as the "Wadi Ducchan" Formation. The latter author designated the area between Got Sas (= Ghawat Sas) and Wadi Dukhan, approximately 10 km east of Jardas al Abid, as the type locality.

Pietersz (1968) estimated that about 2000 ft (610 m) of section of the Wadi Dukhan Formation was exposed in the Jardas al Abid area. Although he reported no diagnostic fossils, he tentatively assigned the formation to the uppermost Cretaceous to lowermost Tertiary. According to Pietersz, the Wadi Dukhan Formation consists of hard, grey to brown, micro-crystalline dolomite and calcitic dolomite to dolomitic limestone, which is very irregularly weathered (vugular) and shows a fairly homogeneous composition.

Kleinsmiede & van den Berg (1968, p. 118) stated that the Wadi Dukhan Formation,

which is mainly dolomite, is generally barren of fauna, but occasional concentrations of "leached fossil molds" were found. They reported poorly preserved rudists in the lower part and poorly preserved "nummulite-casts" in the upper part of the formation. Based on its stratigraphic position and poor faunal content, Kleinsmiede & van den Berg considered the Wadi Dukhan Formation to be of Paleocene(?) - Maastrichtian age.

Both Pietersz (1968) and Kleinsmiede & van den Berg (1968) reported that the Wadi Dukhan Formation conformably overlies the Jardas Formation (Cenomanian to Campanian) and is unconformably overlain by the Apollonia Limestone, Derna Formation or Cyrene Formation in the Jardas al Abid and al Marj areas. Klen (1974) stated that the thickness of the Wadi Dukhan Formation ranges from 50 to 150 m. He reported that the lower contact of the Wadi Dukhan Formation is conformable with the Al Majahir Formation (= upper part of Jardas Formation of Kleinsmiede & van den Berg, 1968), whereas the upper boundary is erosional and unconformably overlain by younger stratigraphic units.

Klen (1974, pp. 19, 20) reported "echinoderm spicules and sections of highly conical species of the genus *Globotruncana*" in a thin section from a highly dolomitized and recrystallized sample from the lower part of Wadi Dukhan Formation. This is the only report of planktonic foraminifera in this formation, but no illustrations were given.

Rölich (1974) reported other exposures of the Wadi Dukhan Formation in the proximity of Jardas al Jarrari, where he estimated its thickness to be about 40 to 100 m (131 to 328 ft). He stated that, in all the exposures, the Wadi Dukhan Formation rests conformably on the underlying Al Majahir Formation. The contact of the Wadi Dukhan Formation with Al Uwayliah Formation (Paleocene) can only be seen in the area surrounding Jardas al Jarrari, where it is "sharp but it seems to be conformable" (Rölich, 1974, p. 25). Rölich recovered no fossils from the Wadi Dukhan Formation.

The Wadi Dukhan Formation has also been reported from the subsurface in Cyrenaica and the northeastern part of the Sirt Basin. In well B7 - 41, about 130 km southeast of Benghazi (31°04'39"N 20°46'20"E), the Wadi Dukhan Formation was encountered between sample depths 6950 and 9950 ft (2118 and 3033 m) (Tmalla, 1984). The 3000 ft (914 m) thick section of this formation consists mainly of a dolomite sequence with two relatively thin, partly dolomitic lime packstone to wackestone interbeds in the middle part. The dolomite is brown to grey with different degrees of darkness, hard, generally finely crystalline and very rarely medium to very coarsely crystalline. Sporadic traces of anhydrite, organic matter and bitumen have been observed, especially in the lower part. Where dolomitization was selective, ghosts of miliolids can still be recognized. Porosity is generally poor to fair, with some thin intervals of good biomoldic porosity.

The lower, partly dolomitic, lime packstone to wackestone interbed (8370 to 8600 ft = 2551 to 2621 m) yielded common to abundant Maastrichtian fauna, which is entirely fragmentary due to the hard sedimentary rock. The following species of larger foraminifera (Pls. 1, 2), which have never hitherto been reported from the Wadi Dukhan Formation, are recognized in this dolomitic interbed: *Omphalocyclus macroporus* (Lamarck, 1816); *Siderolites* cf. *calcitrapoides* Lamarck, 1801, including abundant loose spines; and *Orbitoides* cf. *media* (d'Archiac, 1837).

The upper, partly dolomitic lime packstone to wackestone interbed (7870 to 8060 ft = 2399 to 2457 m) contained abundant, poorly preserved and highly recrystallized miliolids. No planktonic foraminifera have been recognized in the entire formation.

The larger foraminiferal species encountered in the lower, partly dolomitic interbed and the miliolids recognized in several levels of this formation in well B7 – 41 together suggest deposition in a shallow water, probably mostly restricted, marine environment. This interpretation is in agreement with Kleinsmiede & van den Berg (1968). However, the single thin section from the lower part of Wadi Dukhan Formation, with “sections of highly conical species of the genus *Globotruncana*” (Klen, 1974, p. 19), is not considered in this environmental interpretation.

The Wadi Dukhan Formation in the B7 - 41 well rests conformably on the Santonian to Campanian Al Majahir Formation and unconformably underlies the Apollonia Limestone with its abundant planktonic foraminifers, including *Morozovella aequa* (Cushman & Renz, 1942) and *Morozovella subbotinae* (Morozova, 1939), representing the lowermost part of the Early Eocene. Common limestone pebbles with specimens of *Glomalveolina primaeva* (Reichel, 1936) have been observed in the basal part of the Apollonia Formation, indicating Late Paleocene reworking (Tmalla, 1984). Lehmann *et al.* (1967, pl. 29, fig. 2) illustrated such shallow marine reworked pebbles, containing miliolids and *Glomalveolina primaeva* of Late Paleocene age in Early Eocene sedimentary rocks with deeper marine planktonic and smaller benthic foraminifera, from the northeastern Sirt Basin.

The same assemblage of Maastrichtian larger foraminifers encountered in the Wadi Dukhan Formation in well B7 - 41 (see above) was also observed in the same formation in well U2 - 6, northeastern Sirt Basin (30°11'27.54" N 19°02'49.3"E). The lithology is thin dolomitic limestone interbeds within the interval 7950 to 8100 ft (2423 to 2469 m) (Tmalla, 1966).

Dolomites of the Wadi Dukhan Formation are not present in the offshore area north of Benghazi as seen in well A1-NC 120 (32°20'23"N 20°05'52"E). Here, Maastrichtian sedimentary rocks are interbeds of mudstone – wackestone and marl with globotruncanids (Duronio *et al.*, 1991).

Al Uwayliah Formation

In contrast to the well-exposed Early Eocene to Middle Miocene sedimentary rocks, exposures of Paleocene sedimentary rocks are very rare in northeastern Libya. Barr (1968, p. 137) recorded, for the first time, Paleocene foraminifera from the al Jabal al Akhdar area. He described a chalky limestone section, about 6 m thick, exposed along the al Marj - al Bayda road, about 6 km east of the village al Uwayliah (32°33'N 20°59'E). Rölich (1974) designated this as the type section of the Al Uwayliah Formation. Barr (1968) illustrated the following Paleocene planktonic foraminiferal species from Al Uwayliah type section, where neither the lower nor the upper contact of the formation with other rock units were visible; *Morozovella angulata* (White), *Globanomalina chapmani* (Parr) and *Subbotina trilocolinoides* (Plummer). He assigned this assemblage to the Late Paleocene *Globanomalina pseudomenardii* Zone (Landenian = late Selandian to Thanetian).

Rölich (1974) reported the following species of foraminifera from Al Uwayliah Formation at its type section, near al Uwayliah village; *Morozovella velascoensis* (Cushman), *Globanomalina pseudomenardii* (Bolli), *Morozovella angulata* (White), *Subbotina trilocolinoides* (Plummer), *Praemurica* ex gr. *uncinata* (Bolli), *Globigerina* ex gr. *inaequispira* Subbotina, *Anomalinoidea danica* (Brotzen), *Lenticulina* ex gr. *navarroensis* (Plummer), *Lenticulina pseudosecans* Cushman, *Dentalina* ex gr. *delicatula* Cushman and *Rotalia* ex gr. *fim-*

briatula Cushman & Hedberg. He noted that neither the lower nor the upper boundaries of this formation were exposed at the type locality.

In his study of Al Uwayliah Formation at its type locality, Eliagoubi (1980) described and illustrated eleven species of planktonic foraminifera; *Subbotina velascoensis* (Cushman), *Morozovella acuta* (Toulmin), *Morozovella aequa* (Cushman & Renz), *Globanomalina chapmani* (Parr), *Morozovella apantesma* (Loeblich & Tappan), *Morozovella velascoensis* (Cushman), *Acarinina mckannai* (White), *Morozovella occlusa* (Loeblich & Tappan), *Globorotalia perclara* Loeblich & Tappan, *Subbotina triloculinoides* (Plummer) and *Morozovella angulata* (White). Eliagoubi (1980) assigned the Al Uwayliah Formation at its type locality to the *Morozovella angulata* and *Globanomalina pseudomenardii* Zones of Postuma (1971), which indicate a Late Paleocene age (= late Selandian to Thanetian).

Muftah *et al.* (2002) revised the biozonation of Al Uwayliah type section, east of Al Uwayliah village, by studying its foraminifera and calcareous nannoplankton. They illustrated 18 calcareous nannofossil species including *Discoaster multiradiatus* Bramlette & Riedel, *Fasciculithus alanii* Perch-Nielsen, *F. involutus* Bramlette & Sullivan and *F. tympaniformis* Hay & Mohler. They also illustrated 13 planktonic foraminiferal species including *Globanomalina pseudomenardii*, *Morozovella occlusa*, *M. velascoensis*, *M. cf. angulata* (White), *Acarinina mckannai* and *Subbotina triloculinoides* (Plummer). These authors concluded that the type section of the Al Uwayliah Formation represents the lower part of the nannofossil *D. multiradiatus* Zone (NP9) of Martini (1971), which is equivalent to the uppermost part of the foraminifer *G. pseudomenardii* Zone (late Thanetian). This conclusion is unlike that of Eliagoubi (1980), who assigned the Al Uwayliah type section to both the *M. angulata* and the *G. pseudomenardii* Zones (late Selandian to Thanetian). It must be noted here that *Subbotia triloculinoides*, which is recorded by Barr (1968), Rölich (1974), Eliagoubi (1980) and Muftah *et al.* (2002) in the Al Uwayliah type section, is not younger than the lower part of the *G. pseudomenardii* Zone and certainly older than the *D. multiradiatus* Zone (NP9). The distinction level (LAD) of *S. triloculinoides* is within the lowermost part of *G. pseudomenardii* Zone = upper Selandian (Toumarkine & Luterbacher, 1985; Tmalla, 1996; Berggren & Norris, 1997; Olsson *et al.*, 1999).

Rölich (1974) reported a second Paleocene section, which represents the lower part of the Al Uwayliah Formation and rests conformably on the Wadi Dukhan Formation. It is located about 70 km to the east of al Uwayliah village, in the vicinity of the village of Jardas al Jarrari (32°32'N 21°47'E). It displays about 20 m (66 ft) of whitish chalky limestone, thin to medium bedded with subordinate white chalk and greenish marl. Rölich (1974) recorded the following foraminiferal species from an exposure at the junction of Wadi Jardas and Wadi Bu Raqibah, 1 km northeast of Jardas al Jarrari, but gave no illustrations; *Globorotalia perclara* Loeblich & Tappan, *Globoconusa cf. daubjergensis* (Brönnimann), *Eoglobigerina ex gr. spiralis* (Bolli), *Guembelitra cretacea* Cushman, *Anomalinoidea burlingtonensis* Jennings, *Cibicides* sp. and *Anomalina(?) ekblomi* Brotzen. This foraminiferal assemblage indicates that the Jardas al Jarrari section is Early Paleocene (Danian).

The association of the planktonic foraminiferal species recorded by Barr (1968), Rölich (1974) and Eliagoubi (1980) indicates that the type section of Al Uwayliah Formation, near al Uwayliah village, represents only the upper part of the formation. This part belongs to the upper part of the Selandian and part of the Thanetian Stages (Late Paleocene) (Fig. 2). Muftah *et al.* (2002) assigned the same type section east of al Uwayliah village to the nannofossil (NP9) Zone (= uppermost part of the *G. pseudomenardii* Zone), which represents a small portion of the upper part of the Thanetian Stage.

Following the rules of stratigraphic nomenclature, as recommended by Salvador (1994), the Al Uwayliah stratotype should be considered a composite stratotype, composed of two component stratotypes. The section described by Barr (1968) from the al Uwayliah locality is the holostatotype, representing the upper part of Al Uwayliah Formation, and the section in the vicinity of Jardas al Jarrari (Rölich, 1974) is the parastratotype, representing the lower part of the formation.

The total thickness of sedimentary rocks of the Al Uwayliah Formation as represented in both localities is about 26 m (about 6 m seen in the al Uwayliah section and about 20 m in the Jardas al Jarrari section). Notwithstanding the different geologic history of both the Sirt Basin and the al Jabal al Akhdar area, this thickness still seems to be too thin to represent the entire sedimentary succession of the Paleocene. The thickness of the Paleocene, mainly carbonate sedimentary rocks on platforms in the Sirt Basin (including the eastern part), is locally well in excess of 610 m and it is much greater in structurally low areas with clastic sedimentary sequences (Barr & Weegar, 1972; Berggren, 1974; Tawadros, 2001).

Epoch	Stage	Planktonic foraminiferal Zones	P Zones	NP Zones	Formations		
P A L E O C E N E	EOC.						
		Ypres.					
			<i>M. subbotinae</i> Zone	E1-3	NP 10	Apollonia Limestone (or younger units)	
	Late	Thanetian	<i>M. velascoensis</i> Zone	P5	NP 9	Al Uwayliah Formation (holostatotype)	
			<i>G. pseudomenardii</i> Zone	P4	NP 5-8		
	Selandian		<i>I. pusilla</i> and <i>M. angulata</i> Zones	P3	NP 4		?
			<i>P. uncinata</i> Zone	P2			
	Early	Danian	<i>G. trinidadensis</i> Zone	P1	NP 2-3	Al Uwayliah Formation (parastratotype)	
			<i>P. pseudobulloides</i> Zone				
			<i>P. eugubina</i> and <i>G. cretacea</i> Zones	PO + Pz			NP 1
LATE CRETACEOUS	Maastrihtian	<i>Omphalocyclus macroporus</i> , <i>Siderolites</i> cf. <i>calcitrapoides</i> and <i>Orbitoides</i> cf. <i>media</i> (in the subsurface)			Wadi Dukhan Formation		
SA-CA					Al Majahir Fm. (= u. part Jardas Fm.)		

Fig. 2. The stratigraphic positions of Wadi Dukhan and Al Uwayliah formations. Planktonic foraminiferal zonation after Luterbacher & Premoli – Silva (1964), Bolli (1966), Stainforth *et al.* (1975), Smit (1982) and Tourmakine & Luterbacher (1985). P Zones after Blow (1979) and Berggren *et al.* (1995). NP Zones after Martini (1971); their correlation with the P Zones follows Berggren & Pearson (2005).

A sequence of over 60 m of Paleocene sedimentary rocks was reported in well C1-18 located near the village of Farzūghah, west of al Marj, at a depth of 915 m (Barr & Berggren, 1980). The well is about 33 km west southwest of the al Uwayliah type locality (Fig. 1).

The foraminiferal species reported by Barr (1968) and Eliagoubi (1980), and the calcareous nannofossils and foraminifers recorded by Muftah *et al.* (2002) from the holostratotype and by Rölich (1974) from the parastratotype (the upper and lower parts of Al Uwayliah Formation, respectively), suggest that this formation does not represent the whole Paleocene Series. It seems that at least the uppermost part of the Danian Stage (foraminiferal Zone P2) and the lower part of the Selandian Stage (the lower part of the foraminiferal Zone P3) are not represented in either part of the formation (Fig. 2). Duronio *et al.* (1991) also noted that the Paleocene is only partially represented in Cyrenaica. The uppermost portion of the Thanetian Stage (i.e., the *Morozovella velascoensis* Zone) has been recognized in neither of the two component-stratotypes of this formation nor anywhere else in the Jabal al Akhdar area. More detailed geologic and palaeontologic studies of both stratotypes of Al Uwayliah Formation are needed to clarify its exact stratigraphic position.

Rölich (1974, p. 32) related the sporadic and incomplete occurrence of the Al Uwayliah Formation to uplifting above sea level and moderate folding of al Jabal al Akhdar area at the beginning of the Eocene. After emergence, the formation suffered extensive erosion.

Conclusions

The presence of typical Maastrichtian larger foraminifera (Pls. 1, 2) in the Wadi Dukhan Formation confirms its age. No other workers in the area have ever confirmed the 'nummulite-casts' reported by Kleinsmiede & van den Berg (1968) in this formation. Wadi Dukhan Formation is also present in the subsurface of northeastern Sirt Basin, but in the offshore, north of Benghazi, interbeds of deeper marine mudstone – wackestone and marl with globotruncanids represent the Maastrichtian.

The type section of the Al Uwayliah Formation is a composite stratotype. The section east of al Uwayliah village, reported by Barr (1968), is the holostratotype representing the upper part of the formation. The section described from the vicinity of Jardas al Jarari village by Rölich (1974) is the parastratotype that represents the lower part of the formation (Fig. 2).

Palaeontologic evidence suggests that parts of the Paleocene standard foraminiferal zones are not represented in either of the two component-stratotypes of the Al Uwayliah Formation (Fig. 2). The combined thickness of the two component-stratotypes of this formation seems to be too thin to represent the sedimentary succession of the entire Paleocene Series. It is concluded that a middle part of this formation, between the holostratotype and the parastratotype (late Danian to early Selandian), has never been observed.

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Plate 1*Omphalocyclus macroporus* (Lamarck, 1816)

Fig. 1. RGM 554 900, natural equatorial section, well B7-41: 8490 – 8500 ft. Scale bar represents 600 μm .

Fig. 2. RGM 554 901, equatorial section, well B7-41: 8440 – 8450 ft (scale bar represents 420 μm).

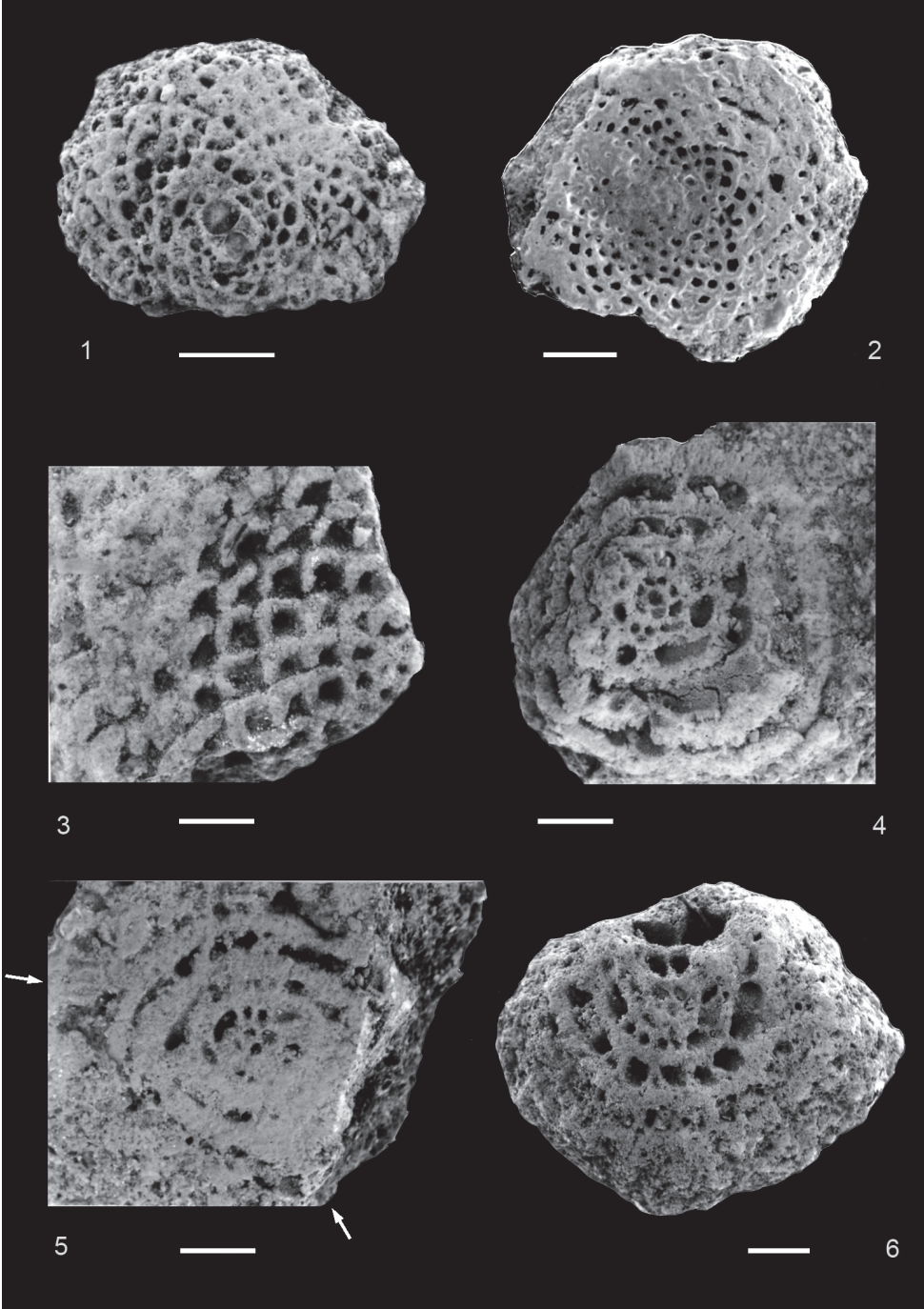
Fig. 3. RGM 554 902, fragment of a specimen, natural equatorial section, well B7-41: 8490 – 8500 ft (scale bar represents 310 μm).

Siderolites cf. calcitrapoides Lamarck, 1801

Fig. 4. RGM 554 903, broken specimen within dolomitic limestone, well B7-41: 8440 – 8450 ft (scale bar represents 260 μm).

Fig. 5. RGM 554 904, broken specimen within dolomitic limestone, showing an oblique section (note spines at arrows), well B7 – 41: 8544 – 8450 ft (scale bar represents 420 μm).

Fig. 6. RGM 554 905, broken specimen within dolomitic limestone, well U2-6: 8030 – 8040 ft (scale bar represents 200 μm).



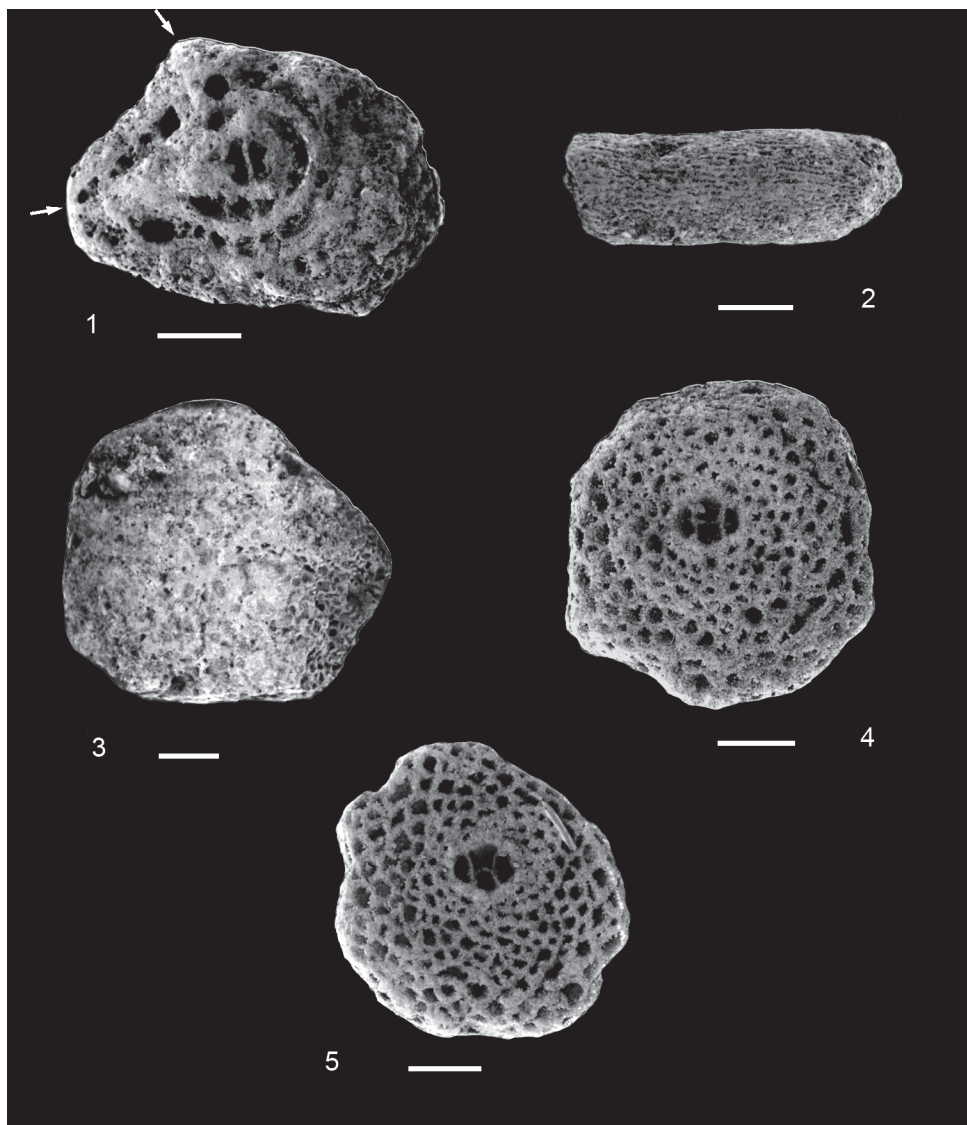


Plate 2

Siderolites cf. calcitrapoides Lamarck, 1801

Fig. 1. RGM 554 906, obliquely broken specimen (note spines at arrows), well U2-6: 8030 – 8040 ft (scale bar represents 400 μm).

Fig. 2. RGM 554 907, a loose spine, well B7-41: 8490 – 8500 ft (scale bar represents 400 μm).

Orbitoides cf. media (d'Archiac, 1837)

Fig. 3. RGM 554 908, external view, well B7-41: 8490 - 8500 ft (scale bar represents 500 μm).

Fig. 4. RGM 554 909, natural equatorial section, well U2-6: 7950 – 7960 ft (scale bar represents 300 μm).

Fig. 5. RGM 554 910, natural equatorial section, well U2-6: 7950 – 7960 ft (scale bar represents 300 μm).