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UPPERMOST JURASSIC? - NEOCOMIAN SHALLOW-WATER CARBONATES OF THE BLAKE NOSE, USA: DSDP SITE 392A REVISITED

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Abstract Upper Jurassic (?) to Valanginian shallow-water limestones were recovered at DSDP Sites 390 and 392, on the Blake Nose at the seaward edge of the Blake Plateau in 1975. Re-examination of the microfacies and the benthic foraminiferal and calcareous algal biota suggests a possible Late Jurassic age for the oldest limestones. The widely recognized intra-Valanginian unconformity extends to the northeastern margin of the Late Jurassic-Early Cretaceous carbonate megaplatform in the western Atlantic.

Keywords Microfacies, calcaraeous algae, Dasycladales, foraminifera, stratigraphy, USA

INTRODUCTION

The Blake Nose (Blake Spur) is a promontory on the Blake-Bahama escarpment, jutting into the North Atlantic Ocean basin at the east edge of the Blake Plateau (Fig. 1). The Blake Plateau, which forms the southeast continental margin of the US, was the site of shallow-water carbonate deposition through much of the Late Jurassic and Early Cretaceous, as part of the foundered carbonate megaplatform that underlies the modern Bahama, Florida, and, perhaps, Yucatan plateaus (Meyerhoff & Hatten, 1974). Drilling in 1975 on Leg 44 of DSDP penetrated shallow-water carbonates at Sites 390 and 392 on the outer edge of the Blake Nose (Benson & Sheridan, 1978; Enos & Freeman, 1978, 1979). A broad shallowing-upward trend in the shallow-water carbonates was apparent, followed by abrupt drowning in the Barremian (Gradstein, 1978; Fourcade & Granier, 1989). Poor recovery (<10%) constrained the age interpretations of the shallow-water section to "Neocomian or older" (Benson & Sheriden, 1978) and inhibited the identification of finer-scale cycles. These samples remain the northernmost and most oceanward samples of the carbonate megaplatform. Deposits seaward of the Blake-Bahama Escarpment are pelagic (Site 391, Benson & Sheridan, 1978; Site 534, Sheridan & Gradstein, 1983; see Fig. 1) Re-examination of the cored material allows a more precise age determination of these deposits as Berriasian-Lower Valanginian? to most likely Upper Jurassic at the base.

GEOLOGICAL SETTING

The extremely steep, erosional Blake-Bahama Escarpment (Land et al., 1999) at the eastern edge of the Blake Plateau, locus of Sites 390 and 392, generally corresponds to the transition from oceanic crust to rift-stage or continental crust as the Moho deepens gradually from oceanic values of ~15 km to 35 km beneath the North American continent (Klitgord et al., 1988). The western edge of the plateau is overstepped by Cenozoic rocks of the modern Florida-Hatteras (continental) shelf, which at this latitude roughly coincides with the 'basement hinge zone,' separating rift-stage crust from normal continental crust (Klitgord et al., 1988; Dillon & Popenoe, 1988). Some authors would extend the "Blake Plateau region" westward to the pinchout of Mesozoic rocks against the crystalline basement of the Piedmont Plateau (Fig. 1; Poag & Valentine, 1988, p. 75). The Blake Plateau narrows and disappears northward beneath the continental shelf at about the latitude of Cape Fear, North Carolina (34° north). To the south it extends to the Bahama Banks, where shallow-water carbonate deposition has continued to the present.

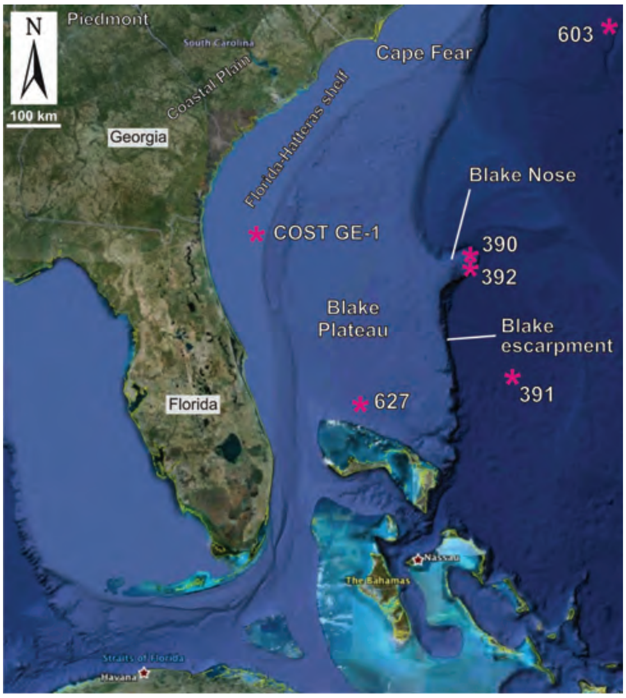

Fig. 1 – Location map of Sites 390 and 392 on the Blake Nose at the edge of the Blake Plateau (based on Google maps), and other locations mentioned in the text. Site 534 location is identical to 391.

The central Blake Plateau is underlain by the Blake Plateau basin (BPb), which was initiated by thermal subsidence following the rifting of North America from Africa in the Middle Jurassic (Klitgord et al., 1988). The roughly circular BPb is about 300 km in diameter and contains up to 13 km of strata above the rift-stage basement (Poag & Valentine, 1988). These rocks have not been sampled

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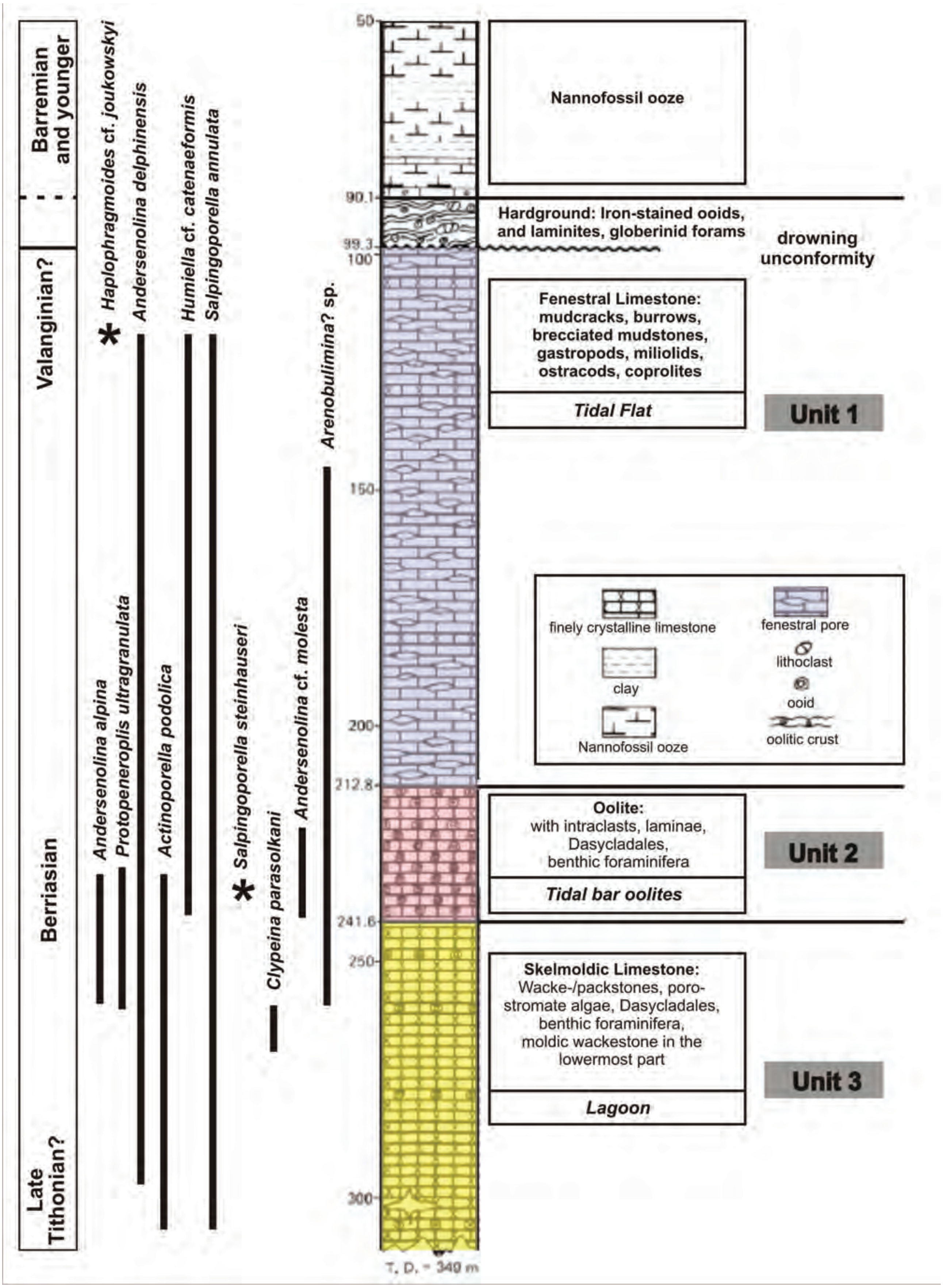

Fig. 2 – Lithostratigraphic log at Site 392A (modified from Enos & Freeman, 1978: Fig. 2) with selected microfossils (benthic foraminifera, dasycladalean algae). Stars = single occurrences.

between continental shelf test wells (e.g., COST-GE 1; Fig. 1) at the western edge of the basin and the Blake-Bahama escarpment. Recovery at Site 392 (Benson & Sheridan, 1978), dredge hauls (Sheridan et al., 1971) and submersible observations from the escarpment (Dillon et al., 1985), and seismic correlations (Dillon & Popenoe, 1988) led to the interpretation that they are largely Middle and Upper Jurassic and Lower Cretaceous (Pinet & Popenoe, 1985; Dillon & Popenoe, 1988; Poag & Valentine, 1988). The BPb shallows northward to a structural sill with 6 km of basement relief, which separates it from the narrow Carolina trough further north (Dillon & Popenoe, 1988). The sill coincides with the Blake Spur fracture zone where rift-stage crust narrows abruptly (Dillon & Popenoe, 1988). The BPb shallows gradually southward to about 6 km at the north edge of the Bahama Banks, where thick limestones extending to near the sea surface obscure basement reflections (Dillon & Popenoe, 1988; Sheridan et al., 1988). It extends east to the Blake-Bahama escarpment and shallows westward to roughly the edge of the Florida-Hatteras shelf, whence a gentler slope brings the basement to the surface at the edge of the Piedmont Plateau.

The shallow-water limestones recovered at Sites 390 and 392 underlie a surprisingly complete veneer of pelagic calcareous sediments spanning Barremian through Eocene time (Benson & Sheridan, 1978; Enos & Freeman, 1978). The contact with the underlying platform carbonates is an iron-stained hardground. Beneath is a shoaling-up carbonate sequence at least 250 m thick.

These cores of shallow-water limestone are an isolated sample of the postulated early Mesozoic megaplatform, from near its seaward margin. The only other core recovery from outer margin of the megaplatform, also from the Blake Plateau, was of upper Albian shallow-water dolomite, limestone, and gypsum from ODP Site 627 (Fig. 1; Austin et al., 1988, p. 111 ff.). By Aptian time the Blake Nose was submerged and draped by pelagic sediments (Benson & Sheridan, 1978), while platform carbonate deposition had stepped back tens of kilometers toward the interior of the Blake Plateau (Dillon & Popenoe, 1988). The only other samples of the megaplatform in this region come from much more proximal locations on the present continental shelf (e.g. the COST GE-1 well; Fig. 1; Scholle, 1979) and from the Bahamas (Great Isaac well, north of Bimini, 1971; Long Island well, 1970; Cay Sal IV, 1959, and Andros 1, 1947; Meyerhoff & Hatten, 1974). Under the continental shelf, the proximity to the Appalachians is evident in the predominance of terrestrial and paralic siliciclastics over marine carbonates and evaporites (Scholle, 1979; Poag & Valentine, 1988). Platform-interior carbonates of Early Cretaceous and possible Late Jurassic age are reported throughout the Bahamas, but little lithologic information is available (Meyerhoff & Hatten, 1974; Tator & Hatfield, 1975; Jacobs, 1977).

MICROFACIES

Enos and Freeman (1978) distinguished three lithologic units that form a general shoaling-upward sequence of shallow-water carbonates (at least 250 m thick) obtained at Site 392, in ascending order: skelmoldic limestone (unit 3), oolitic limestone (unit 2), and fenestral limestone (unit 1) (Fig. 2). The upper unit is bounded at the top by a hardground consisting of iron-stained oolites and microbial laminated crusts. As the lithologies and microfacies were described in detail by Enos & Freeman (1978), a summary is presented, updated with reference to microfossil content, an aspect that has not attracted much attention.

Skelmoldic limestone

The basal shallow-water limestone unit is finely crystalline skeletal lime wackestone and muddy packstone, >-107 m thick, with peloids, benthic foraminifers, gastropods, and green algae, both udoteaceans and dasyclads. Most of the fossils are represented by molds, giving the unit its characterizing name, skelmoldic limestone (Enos & Freeman, 1978). Dissolution features are “so pervasive that it serves to characterize the unit more than any specific depositional texture” (Enos & Freeman, 1978, p. 414). Extensive dissolution is recorded by the abundant molds and vugs and by caverns, indicated by abrupt increases in drilling rates and by drops of the drill bit of up to 10 m.

A typical microfacies type is represented by wackestones with scattered debris of Dasycladales such as *Actinoporella podolica* (Alth) or *Salpingoporella annulata* Carozzi (see Fig. 5 in Enos & Freeman, 1978) (Fig. 3a). The thalli are completely leached and replaced by homogeneous translucent calcite without any visible details of the former algae (e.g. pores). The thalli of *Actinoporella* are locally preserved with intact consecutive whorls (Fig. 6i) contrasting with the isolated broken whorls found in the overlying oolitic unit. Dissolution affected only the primary aragonitic thalli of Dasycladales, whereas skeletons of the sclerosponge *Cladocoropsis mirabilis* Felix are preserved in the original slightly yellowish calcite (detail in Fig. 3a). A similar microfacies type is wackestone with abundant finer debris of dasycladaleans including *Salpingoporella annulata* Carozzi, *Clypeina parasolkani* Farinacci & Radoičić and debris of other unidentified taxa (Fig. 3b).

The skelmoldic unit has a thickness of > -107 meters to the termination of drilling at Site 392A at a sub-bottom depth of 349 m. The biota of the wackestone microfacies e.g., *Cladocoropsis mirabilis*, indicates a sheltered lagoonal palaeoenvironment for the carbonates of unit 3 (Flügel, 1974; Turnsek et al., 1981; Leinfelder et al., 2005; Hughes, 2008), consistent with the lithofacies interpretation as deposits of a shallow subtidal platform, comparable to the interior of the modern Bahama Banks (Enos & Freeman, 1978). Notably, Late Jurassic deposits containing *C. mirabilis* were drilled on the opposite side of the Atlantic Ocean, the passive Galicia margin off the Iberian Peninsula (Dupeuble, 1979). The influence of nearby well-agitated settings towards the top of the skelmoldic limestone unit is deduced from the presence of *Protopeneroplis ultragranulata* (Gorbatchik), and supported by the intercalation of several samples of oolitic limestone. Indication of finer scale cyclicity is provided by interbedding of six intervals of oolite and five of fenestral limestone within the skelmoldic limestone. However, with recovery limited to <3% and some samples ground so small that establishing the proper sequence within the core barrel was problematic, any attempt at finer scale reconstruction would be highly speculative. The strong overprint of meteoric diagenesis, largely dissolution, likely occurred before the deposition of the subsequent units. However, the upper contact, recovered in core, gave no hints of soil or karst development.

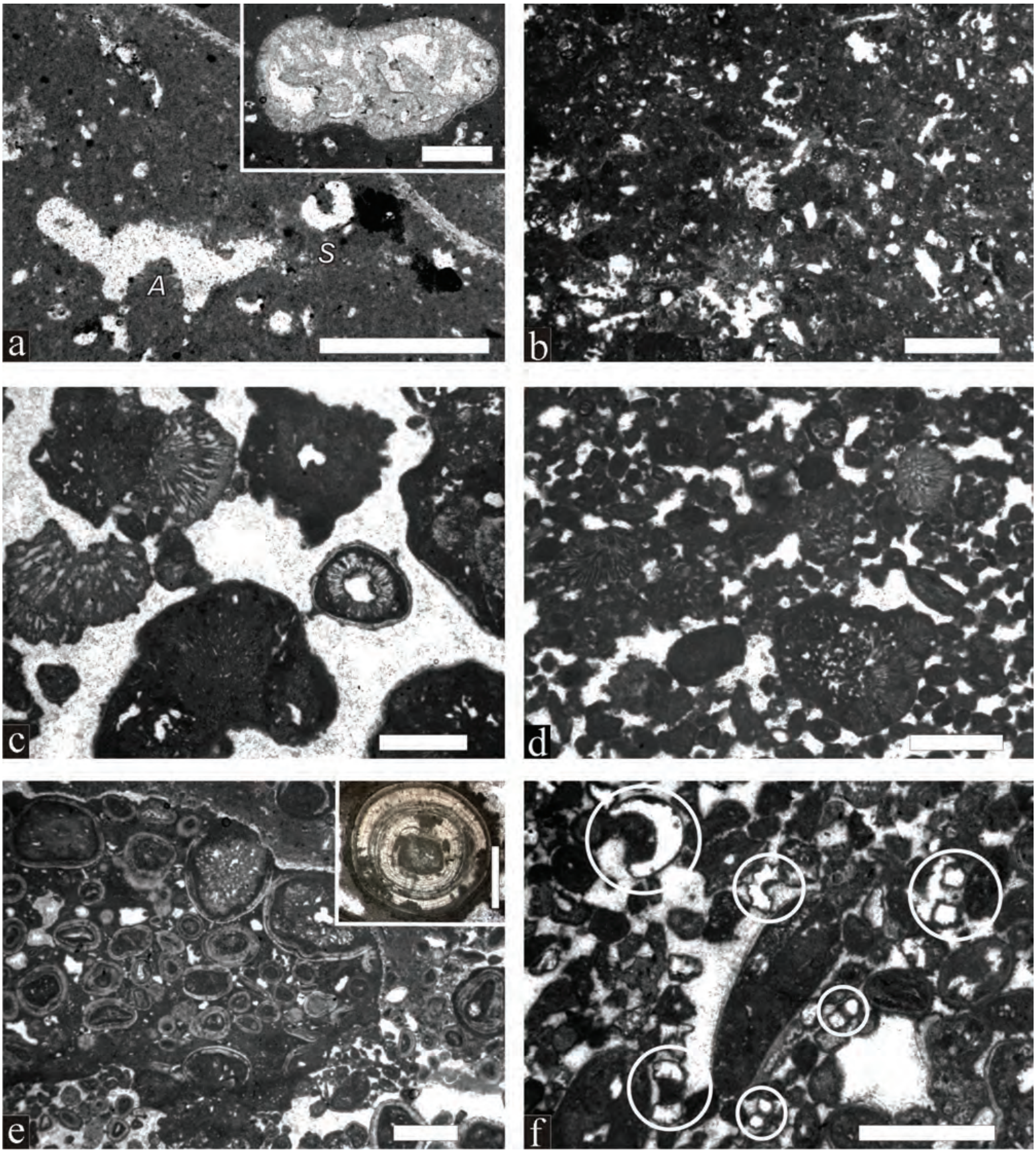

Fig. 3 – Microfacies of Uppermost Jurassic? – Neocomian shallow-water carbonates: skelmoldic (a-b) and oolitic limestone units (c-f). Depths at Site 392; shown in Fig. 2. **a** Wackestone with cement-filled molds of dasycladalean algae, *Actinoporella podolica* (Alth) (*A*) and *Salpingoporella annulata* Carozzi (*S*). Detail shows skeleton of sclerosponge *Cladocoropsis mirabilis* Felix. Thin-section 392A-28 CC, sub-bottom depth 307 m. **b** Wackestone with debris of Dasycladales (*Salpingoporella*? sp., *Clypeina*? sp.) ("algal-debris facies"). Thin-section 392A-23-1-148, sub-bottom depth 259.5 m. **c-d** Grainstone/packstone with Rivulariacean-type algae ("Porostromata") and *Salpinoporella* cf. *pygmaea* (Gümbel). Thin-sections 392A-21-1-137, sub-bottom depth 240.5m, and 392A-19-1-141, sub-bottom depth 221.5 m. **e** Intraclastic ooidal packstone. Thin-section 392A-21-1-137, sub-bottom depth 240.5 m. The detail shows a radial-fibrous ooid exhibiting micrite-filled microborings. Thin-section 392A-22-1-95, sub-bottom depth 249.5 m. **f** Packstone with debis of *Salpingoporella annulata* Carozzi (circles). Thin-section 392A-20-1-112, sub-bottom depth 231 m.
Scale bars 1 mm. Detail in e: 0.5 mm

Oolitic limestone

Ooid, peloidal and algal lime grainstone and packstone, 29 m thick, overlie the muddier skelmoldic limestones. Specific microfacies include intraclastic oolitic grain- to packstones and dasycladalean-rivularicean grain- to packstones (Enos & Freeman, 1978, figs. 22-23). The algal thalli display thin oolitic envelopes. Typical microfossils of this unit include *Protopeneroplis ultragranulata* (Gorbatchik), *Arenobulimina*? sp, *Humiella* cf. *catenaeformis* (Radoičić), and *Actinoporella podolica* (Alth).

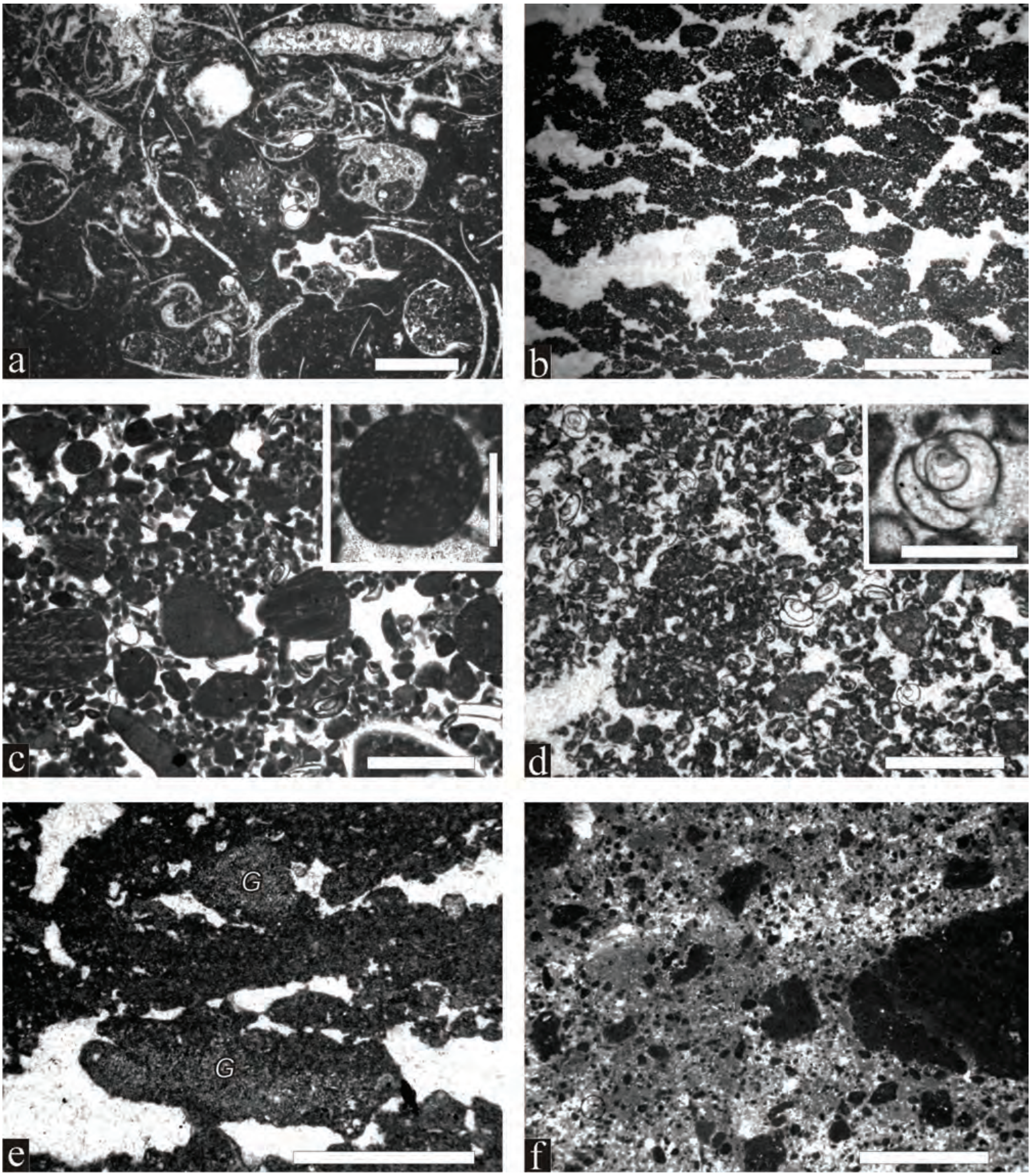

Fig. 4 – Microfacies of Neocomian shallow-water carbonates: fenestral limestone unit. Depths at Site 392; shown in Fig. 2. **a** Gastropod rudstone. Thin-section 392A-9-1-146, sub-bottom depth 138.96 m. **b** Laminoid fenestral fabric with laterally connected voids within a peloidal grainstone. Thin-section 392-2-2-135, sub-bottom depth 60 m. **c** Grainstone with coprolites of the morphogenus *Favreina* (see detail). Thin-section 392A-9-1-102, sub-bottom depth 138.52 m. **d** Ostracode-miliolid-peloidal grainstone. Detail shows the test of *Pseudotriloculina* sp. Thin-section 392A-6-1-91, sub-bottom depth 116 m. **e** Fenestral limestone with reworked fragments of *Girvanella*-type microbial mats (*G*). Thin-section 392-2-2-66, sub-bottom depth 59 m. **f** Black-pebble breccia. Thin-section 392A-5-70, sub-bottom depth 106.8 m. Scale bars 2 mm for a, f; 1 mm for b-e; 0.5 mm detail in c; 0.2 mm detail in d.

The occurrence of the oolitic unit between lagoonal wackestones (below) and typical peritidal carbonates (above) gives evidence that these high-energy deposits represent tidal bar sands rather than ooidal shoals near a platform margin. Within the latter we would also expect debris of corals and other organisms. At least 20 intervals of micritized limestone, small sheet cracks, pendant cements, and internal sediment within this unit probably represent hard grounds and/or short-term subaerial exposure surfaces (Enos & Freeman, 1978).

Fenestral limestone

The uppermost unit of shallow-water limestone, 114 m thick, includes a variety of depositional textures and constituents characterized by fenestral porosity, small-scale synsedimentary brecciation, desiccation cracks, and local cyanobacterial lamination. This assemblage indicates tidal deposition, perhaps in the shelter of marginal ooid shoals (Enos & Freeman, 1978) or reefs. It contains five intervals of muddy skelmoldic limestone, a further hint of finer scale cyclicity.

Microfacies include various types that can be referred to tidal-flat depositional settings (Fig. 4): peloidal fenestral packstones (Fig. 4b), mudstones exhibiting desiccation cracks (Enos and Freeman, 1978, Fig. 41), black pebble breccias (Fig. 4f), gastropod wackestones (Fig. 4a), coprolithic (genus *Favreina*) (Fig. 4c) and miliolid packstones (Fig. 4d) dominated by *Istriloculina* sp. (see Neagu, 1984; Arnaud-Vanneau & Premoli-Silva, 1995). *Istriloculina* was formerly ascribed to *Pseudotriloculina* sp. in the Lower Cretaceous and referred to restricted lagoonal environments (Arnaud-Vanneau, 1980, 2005). Some fenestral limestone contains abundant fragments of microbial crusts (e.g., *Girvanella* sp., Fig. 4e) that derive from the erosion/reworking of microbial crusts/mats. Sample 392A-6-1-91 (16.7 m below the top of the unit) is an algal-foraminiferal packstone with miliolids, *Haplophragmoides* cf. *joukowskyi* Charollais, Brönnimann & Zaninetti, *Andersenolina delphinensis* (Arnaud-Vanneau, Boisseau & Darsac), *Vercorsella* sp., some specimens of *Thaumatoporella,* and *Salpingoporella annulata* Carozzi.

Hardground

The contact between the platform carbonates and overlying pelagic oozes is marked by a lithified interval, at least 13 cm thick, stained by iron oxides, mostly goethite, in the form of coatings on lithoclasts and skeletal debris, ooids, laminated crusts, and stained matrix. Coccoliths abound along with fragments of corals, sponges, belemnites, and other skeletal debris. Although the underlying limestones were deposited at sea level, there is no evidence of prolonged subaerial exposure at this point. Rather the extensive alteration apparently marks a submarine omission surface. This drowning horizon represents an appreciable interval of time, possibly from early Valanginian (Fourcade & Granier, 1989) until onset of pelagic ooze deposition in the Barremian (Gradstein, 1978), more than 4 Ma (Ogg et al., 2008).

MICROPALEONTOLOGY

In the micropalaeontological section, exclusive reference is made to dasycladalean green algae (Figs. 6-7) and benthonic foraminifera (Fig. 8), treated in alphabetical order.

Dasycladalean algae

Order Dasycladales Pascher, 1931
Family Dasycladaceae Kützing, 1843
Genus ***Actinoporella*** (Gümbel in Alth, 1881)
Actinoporella podolica (Alth, 1878) Conrad, Praturlon & Radoičić, 1974
Figs. 3a, 6a-n
Selected synonymy
1974 *Actinoporella podolica* (Alth) emend. - Conrad et al., p. 1-15, figs. 1-12.
1989 *Actinoporella podolica* (Alth) - Fourcade & Granier, pl. 1, figs. 4-5.
1991 *Actinoporella podolica* (Alth) - Farinacci & Radoičić, p.137, pl. 1, figs. 7-11.
1992 *Actinoporella lucasi* (Emberger) nov. comb. - Granier, p. 242, pl. 1, figs. 5-6.
1994 *Actinoporella podolica* (Alth) - Granier, pl. 1, figs. 1, 4, 8-10, pl. 3, figs. 5-8.
1996 *Actinoporella podolica* (Alth) - Sokač, p. 27-28, pl. 20, figs. 1-3, 5-13.
2011 *Actinoporella podolica* (Alth) - Bucur, p. 621-623, pl. 1, figs. 1-5, pl. 3, figs. 1-3, pl. 4, figs. 1-6, pl. 6, figs. 6-7, 11, pl. 7, figs. 1-6.

Remarks: For description of *Actinoporella podolica* and general information regarding the genus see Conrad et al. (1974), Granier (1994), Sokač (1996) and Bucur (2011). In the material from Site 392, *Actinoporella podolica* is only preserved with successive verticils in the

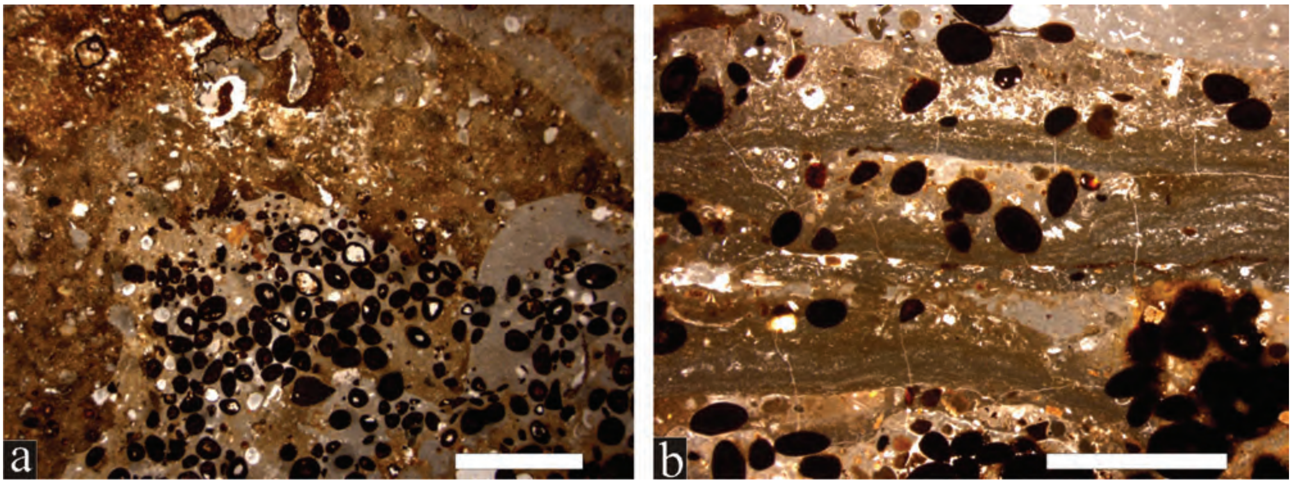

Fig. 5 – **a** Hardground with reworked, bored, iron-stained lithoclasts with larger pockets filled with iron-stained ooids within a mudstone matrix. Thin-section 392A-4CC-9-14, sub-bottom depth 98 m. **b** Hardground with layers of microbial crusts and iron-stained ooids. Thin-section 392-1-1-139, sub-bottom depth 57 m. Depths at Site 392; shown in Fig. 2. Scale bars 2 mm.

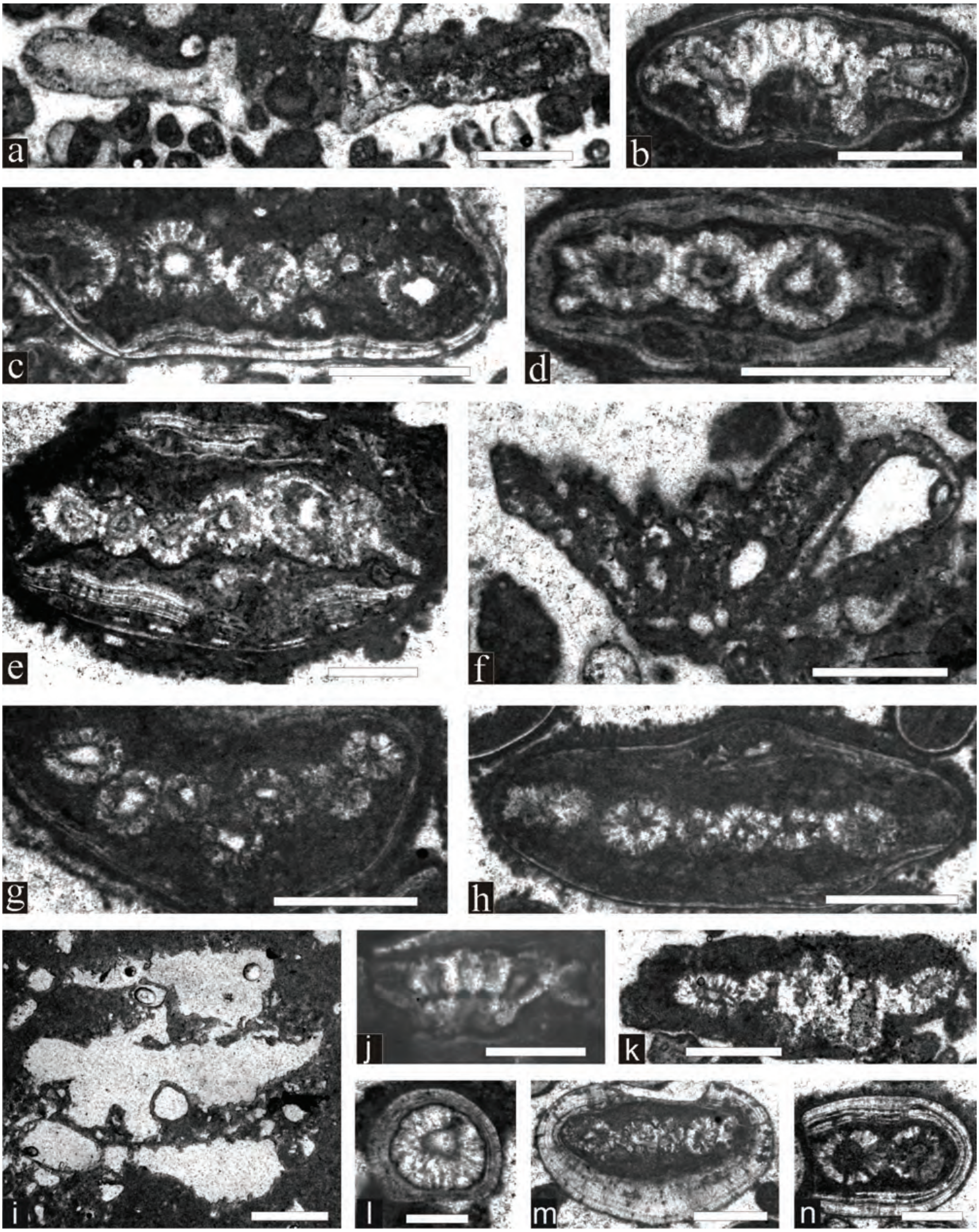

Fig. 6 – Dasycladalean algae from Uppermost Jurassic? – Neocomian shallow-water carbonates at Site 392. Depths at Site 392A; shown in Fig. 2. **a-n** *Actinoporella podolica* (Alth). Thin-section 392A-20-1-137, sub-bottom depth 231.5 m. (**a, f,** aff.), Thin-section 392A-22-1-109, sub-bottom depth 249.6 m. (**b, g-h**), Thin-section 392A-21-1-137 sub-bottom depth 240.5 m. (**c, m**), Thin-section 392A-22-1-95, sub-bottom depth 249.5 m. (**d, n**), Thin-section 392A-22-1-95, sub-bottom depth 249.5 m (**e, l**), Thin-section 392A-28CC, sub-bottom depth 307 m. (**i**), Thin-section 392A-22-1-89, sub-bottom depth 249.4 m. (**j**), Thin-section 392A-20-1-90, sub-bottom depth 230.8 m (**k**). Scale bars 0.5 mm for a-k, m; 0.2 mm for l, n.

wackestones of unit 1 (skelmoldic limestone) (Fig. 6a). In the other units, the species is recorded by isolated verticils only, usually exhibiting ooid coatings (e.g., Fig. 6m). Mostly the verticils are perpendicular to the main axis or slightly inclined upwards (Fig. 6a), in one case a distinct inclination is observed (oblique section in Fig. 6f). The laterals may be arranged directly in the vertical plane (Fig. 6d) or slightly undulating with individual laterals that do

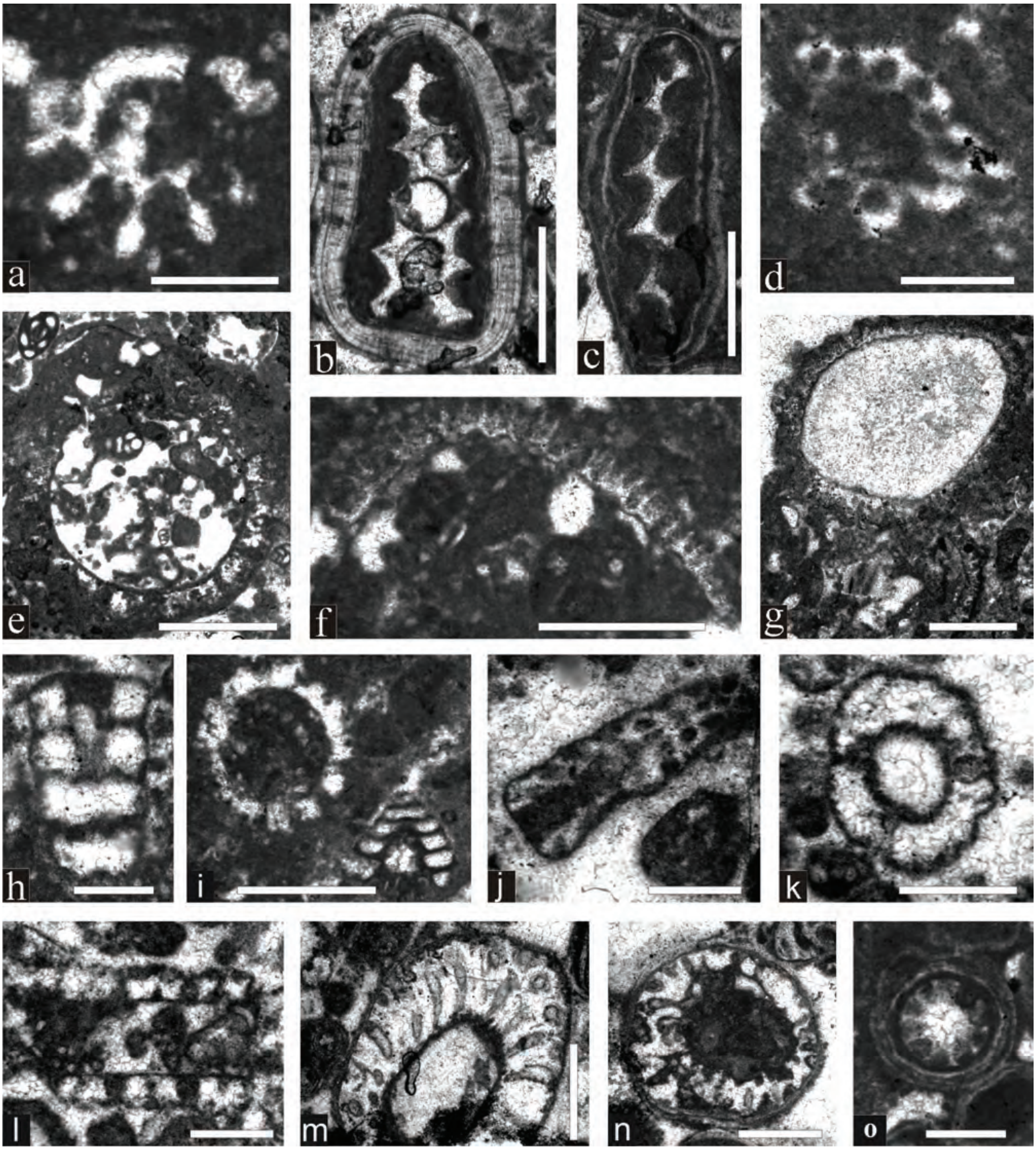

Fig. 7 – Dasycladalean algae from Uppermost Jurassic? – Neocomian shallow-water carbonates at Site 392A. Depths in Fig. 2. **a** *Clypeina parasolkani* Farinacci & Radoičić. Thin-section 392A-23-1-148, sub-bottom depth 259.5 m. **b-c** Gen. et sp. indet. 1. Thin-sections 392A-21-1-137, 392-21-1-75, sub-bottom depths 240.5 m and 239.8 m. **d** ?*Holosporella somalica* (Conrad, Peybernès & Masse). Thin-section 392A-24-CC, sub-bottom depth 269 m. **e** Gen. et sp. indet. 2. Possible transverse section of the main axis of *Humiella* cf. *catenaeformis* (Radoičić). Thin-section 392A-23-1-148, sub-bottom depth 259.5 m. **f-g** *Humiella* cf. *catenaeformis* (Radoičić). Thin-sections 392A-10-2-83, 392A-20-1-112, sub-bottom depths 144.83 and 231 m. **h**, **k**?, **l**? *Salpingoporella annulata* Carozzi. Thin-section 392A-23-1-95-98, 392A-6-1-91 (**k-l**), sub-bottom depths 259 m and 116 m. **i** *Salpingoporella* sp. (left) and *Andersenolina* cf. *delphinensis* (Arnaud-Vanneau, Boisseau & Darsac) (right). Thin-section 392A-23-1-148, sub-bottom depth 259.5 m. **j** *Salpingoporella steinhauseri* Conrad, Praturlon & Radoičić. Thin-section 392A-21-1-137, sub-bottom depth 240.5 m. **m-n** *Suppiluliumaella*? sp. Thin-section 392A-20-1-112, sub-bottom depth 231 m. **o** *Terquemella* sp. Thin-section 392A-21-1-75, sub-bottom depth 239.8 m. Scale bars 0.2 mm for a, d, h, j-l, o; 0.5 mm for b-c, e-g, i, m-n.

not accommodate in it (Figs. 6e, g).

In all cases (except the molds of unit 1), we observed tiny pores transjecting the calcareous wall enveloping the laterals. This feature has according to our knowledge only been mentioned by Granier (1988) and interpreted as microbial microborings. The overall good preservation in the material from Site 392 might possibly be due to the occurrence of the algal fragments, mostly individual verticils, as nuclei of ooids (e.g., Figs. 6b-g). Comparable pores were reported from *Clypeina jurassica* by Radoičić

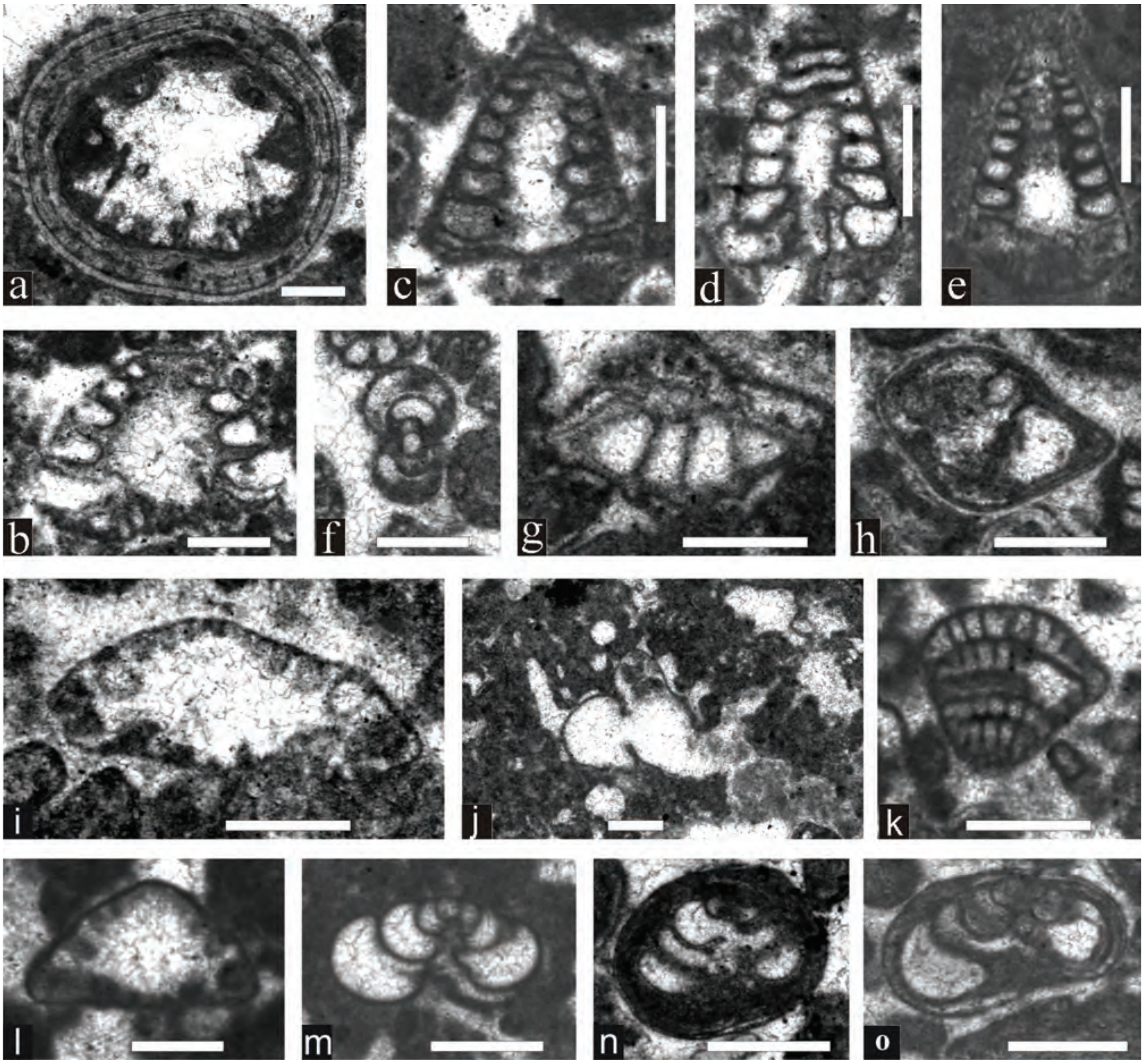

Fig. 8 – Benthic foraminifera from Uppermost Jurassic? – Neocomian shallow-water carbonates at Site 392A. Depths in Fig. 2. **a-b** *Andersenolina alpina* (Leupold). Thin-sections 392A-21-1-75, 392A-23-1-95, sub-bottom depths 239.8 and 259 m. **c-e** *Andersenolina delphinensis* (Arnaud-Vanneau, Boisseau & Darsac). Thin-sections 392A-23-1-95, 392A-23-1-148-150, 392A-23-1-148, sub-bottom depths 249.5, 259.5, & 259.5 m. **f** *Haplophragmoides joukowskyi* Charollais, Brönnimann & Zaninetti. Thin-section 392A-6-1-91, sub-bottom depth 116 m. **g-h** *Protopeneroplis ultragranulata* (Gorbatchik). Thin-sections 392A-20-1-112, 392A-21-1-75, sub-bottom depths 231 and 239.8 m. **i, l** *Andersenolina*? cf. *molesta* (Gorbatchik). Thin-sections 392A-21-1-137, 392A-19-1-141, sub-bottom depths 240.5 and 221.5 m. **j** *Troglotella incrustans* Wernli & Fookes. Thin-section 392A-20-1-137, sub-bottom depth 231.5 m. **k** *Vercorsella* sp. Thin-section 392A-1-91, sub-bottom depth 116 m. **m-o** *Arenobulimina*? sp. cf. Thin-sections 392A-10-2-83, 392A-20-1-90, sub-bottom depths 114.83 and 230.8 m. Scale bars 0.2 mm.

(1969) and De Castro (1997, pl. 20) and interpreted as a “calix” of sterile branches or hairs. Radoičić assumed that these were also arranged in verticils. Other studies of this species have demonstrated that their preservation seems to be an exceptional case (Remane, 1969). Such tiny pores (“corresponding to secondary ramifications on the sporangia and sterile ramifications on the main stem) are regarded the “key for the definition of the genus” *Humiella* Sokač & Velić, according to Sokač (1987, p. 17). Consequently, the Berriasian species *Clypeina delmaturum* Sokač & Velić was transferred to the genus *Humiella* by Sokač (1987). Narrow pores at the distal periphery of the calcareous envelope and interpreted as sterile hairs were also reported by Bucur (2002) from *Kopetdagaria sphaerica* Maslov. Concerning *Actinoporella podolica*, we only can confirm such pores in the calcareous envelope of the laterals: their existence on the main stem is not known. These pores are visible in all specimens, except those recovered from the skelmoldic limestone unit. Most are slightly widening distally and completely transect the wall; they are not confined to the external surface, thus blind pores. The perforated character might be specific to *A. podolica*, as with the branching thalli in some species of *Salpingoporella* (Sokač, 1996; Sokač & Grgasović, 2008). It has so far not been reported from any other *Actinoporella* species (e.g. Granier, 1994).

The stratigraphic range of *Actinoporella podolica* is Tithonian to Barremian (Granier & Deloffre, 1993;

Bucur, 2011).

The two specimens from Site 392A assigned by Fourcade & Granier (1989, pl. 1, figs. 4-5) to *Actinoporella podolica* were later included in the new combination *Actinoporella lucasi* (Emberger), which "species is much larger than the type-species" (Granier et al., 1991, p. 182), i.e., "three times larger" (Granier, 1992, p. 242, translated). However, the range of 2.5 to 3.0 mm for the external diameter of *A. lucasi*, the dimensions indicated by Emberger (1955), seems unusually narrow for a large dasycladale. This data range was apparently obtained from only a few specimens. Taking into account the size ranges indicated in the literature (Tab.1), a clear-cut separation of two taxa solely by their dimensions is highly problematic (see new data of Bucur, 2011, in Tab. 1). Therefore we follow Conrad et al. (1974) who treated *Clypeina lucasi* Emberger a synonym of *Actinoporella podolica* (Alth).

Genus ***Clypeina*** (Michelin, 1845) Bassoullet et al., 1978
Clypeina parasolkani Farinacci & Radoičić, 1991
Fig. 7a
Selected synonymy
1991 *Clypeina parasolkani* n. sp. - Farinacci & Radoičić, p. 137, pl. 2, figs. 1-18.
2000 *Clypeina parasolkani* Farinacci & Radoičić - Bucur et al., p. 442-443, pl.4, figs. 1-12.
2005 *Clypeina parasolkani* Farinacci & Radoičić - Schlagintweit et al., p. 49-51, fig. 33a-b, ?c, d.

Remarks: Some sections of *C. parasolkani* were observed in algal wackestones of the upper part of the skelmoldic limestone unit (samples 392A-23-1 148 and 392A-10-2-83). *C. parasolkani* is similar to the larger *Clypeina*? *solkani* Conrad & Radoičić. Concerning the dimensions indicated by Farinacci & Radoičić (1991, tab. 1), the most distinctive parameter should be the vertical spacing (h): other parameters are less significant. The stratigraphic range of *C. parasolkani* is (Latest Kimmeridgian) Tithonian-Hauterivian (e.g., Schlagintweit et al., 2005; Bucur et al., 2000).

Gen. et sp. indet. 1
Figs. 7b-c

Remarks: These remains of an unknown, most likely larger form, were observed as rare fragments in the oolitic unit.

Gen. et sp. indet. 2
Fig. 7e

Remarks: The transverse section of an unknown dasycladale from the upper part of the skelmoldic limestone unit is characterized by a wide main axis (D: 1.44 mm, d: 1.11 mm) and an indefinite pore pattern.

Genus ***Holosporella*** Pia, 1930
Holosporella? sp.
Fig. 7d

Remarks: The single oblique section was observed in the upper part of the skelmoldic limestone unit. We note similarities to sections of *Clypeina somalica* Conrad, Peybernès & Masse, 1983, for example Masse & Arnaud-Vanneau (1995, pl. 1, fig. 11). The taxonomy of this form is disputed: *Holosporella somalica* (acc. to Granier, 1992), *Piriferella somalica* (acc. to Sokač, 1996) or *Similiclypeina somalica* (acc to Bucur, 1993a, followed by Masse & Arnaud-Vanneau, 1995).

Genus ***Humiella*** (Sokač & Velić, 1981) Masse, Acquaviva & Luperto Sinni, 1984
Humiella cf. *catenaeformis* (Radoičić, 1967)
Figs. 7f-g
Selected synonymy
1967 *Lacrymorphus catenaeformis* n. sp. - Radoičić, p. 274-275, pls. 1-2, pl. 3, figs. 1-3.
1984 *Humiella catenaeformis* (Radoičić) - Masse et al., pl. 1, figs. 1-7.
1987 *Humiella catenaeformis* (Radoičić) - Sokač, p. 22-24, pl. 4, fig. 7, pls. 7-10.
2006 *Humiella catenaeformis* (Radoičić) - Husinec & Sokač, fig. 4c.
2011 *Humiella catenaeformis* (Radoičić) - Schlagintweit, p. 195, pl. 2, fig. i.

Remarks: According to Granier & Deloffre (1993), *Humiella catenaeformis* represents a nomen nudem without designated holotype. *Humiella* might be a synonym of *Neogyroporella* Yabe & Toyama (pers. comm. M. Conrad), therefore the names used have only a provisional character needing taxonomic revision.

After *Actinoporella podolica* (Alth) and *Salpingoporella annulata* Carozzi, *Humiella* cf. *catenaeformis* (Radoičić) is the most frequent dasycladalean alga in the thin-sections studied. This species, which occurs from the lowermost part of the oolitic limestone unit into the upper part of the fenestral limestone unit, is represented only by broken, isolated fertile laterals or fragments there-of. The laterals are rather large, and ovoid to drop-shaped in longitudinal section. The thin calcareous envelope displays external indentations or pores. Many of the latter do not transect the wall completely, but end blindly (Fig. 7f).

Note that in the Dinarids, Husinec & Sokač (2006) established a *Clypeina parasolkani-Humiella catenaeformis* interval zone (Berriasian-earliest Valanginian). The stratigraphic relevance was previously discussed by Sokač (1987). The first appearance of *Humiella catenaeformis* has now been established as Late Tithonian (*intermedia* subzone) (Schlagintweit, 2011).

Genus ***Salpingoporella*** Pia in Trauth, 1918, emend. Carras et al., 2006
Salpingoporella annulata Carozzi, 1953
Fig. 7h, k?-l?
Selected synonymy
1953 *Salpingoporella annulata* n.sp. - Carozzi, p. 382, figs. 1-24, 27-29, 31-46.
1968 *Salpingoporella oceania* n. sp. - Johnson, pl. 1, fig. 1.
1978 dasyclad green algae (?) - Enos & Freeman, figure 5.
1989 *Salpingoporella annulata* - Fourcade & Granier, pl. 1, fig. 7.
2006 *Salpingoporella annulata* Carozzi - Carras et al., p. 464-468, pl. 1, figs. 1-5 (with synonymy).

Remarks: This well-known taxon spans a wide stratigraphic interval (Early Bathonian to Early Barremian, according to Carras et al., 2006). It is common in the thin-sections studied, occurring in all three units.

Salpingoporella cf. *pygmaea* (Gümbel, 1891), emend. Carras et al., 2006
Fig. 3c
Selected synonymy
1891 *Gyroporella pygmaea* n. sp. - Gümbel, figs. 6-7.
2006 *Salpingoporella pygmaea* (Gümbel) - Carras et al., 484-488, pl. 9, figs. 1-12 (with synonymy).

Remarks: Some specimens were observed in the oolitic limestone unit. *S. pygmaea* has a long stratigraphic record ranging from the Bathonian to the Aptian (Carras et al., 2006).

Salpingoporella sp.
Fig. 7i

Remarks: The transverse section from the upper part of the skelmoldic limestone unit is characterized by a comparatively wide main axis (D: 0.63 mm, d: 0.4 mm).

Salpingoporella steinhauseri Conrad, Praturlon and Radoičić, 1973
Fig. 7j
Selected synonymy
1973 *Salpingoporella steinhauseri* n. sp. - Conrad et al., text-fig. 1, pl. 1, figs. 1-4.
2006 *Salpingoporella steinhauseri* Conrad, Praturlon and Radoičić - Carras et al., p. 488, pl. 10, figs. 1-3 (with synonymy).

Remarks: One oblique longitudinal section was observed from the oolitic unit (sample 392A 20 1-137). According to Carras et al. (2006), *S. steinhauseri* has a Berriasian-Valanginian (p.p. Hauterivian?) stratigraphic range. The species was previously unknown from the American Early Cretaceous Atlantic margin.

Genus ***Suppiluliumaella*** Elliott, 1968
Suppiluliumaella? sp.
Figs. 7m-n
1978 *Acroporella* cf. *radoicicae* - Enos & Freeman, fig. 23.

Remarks: The clear identification of terminally swollen primaries bearing secondaries excludes a precise determination. Some sections, such as the one illustrated as *Acroporella* cf. *radoicicae* by Enos & Freeman (1978) look rather like a representative of *Salpingoporella* such as *S. pygmaea* (Gümbel). *Suppiluliumaella*? sp. is common in the oolitic limestone unit.

Form genus ***Terquemella*** Munier-Chalmas *ex* Morellet & Morellet, 1913
Terquemella sp.
Fig. 7o

Remarks: One section was observed in the oolitic unit (sample 392 21 1-75). Diameter (D): 0.27 mm, pore diameters (p): 0.03 to 0.05 mm, number of pores: 10. Forms described as *Acicularia jurassica* from the Upper Jurassic? of the subsurface of the Gulf Coast (Alabama and Texas) display identical number of pores (sporangial cavities) but smaller dimensions of D and p (Johnson, 1961).

Benthic foraminifera

Genus ***Andersenolina*** Neagu, 1994
Andersenolina alpina (Leupold, in Leupold & Bigler, 1935)
Figs. 8a-b
Selected synonymy
1935 *Coscinoconus alpina* n. sp. - Leupold in Leupold & Bigler, p. 610, pl. 18, figs. 1-8, 9?, 10-11.
1989 *Trocholina* gr. *alpina* (Leupold) - Fourcade & Granier, pl. 1, fig. 10.
1994 *Andersenolina alpina* (Leupold) nov. comb. – Neagu, p. 133, pl. 7, figs. 8-9, pl. 8, figs. 1-10, pl. 12, figs. 1-5, text-fig. 4/3-4.
1995 *Trocholina alpina* (Leupold) - Bucur et al., pl. 2, figs. 8, 10.
1999 *Trocholina alpina* (Leupold) - Mancinelli & Coccia, p. 150-151, pl. 3, figs. 1-3, 7-8.

Remarks: Some specimens of *A. alpina* were observed in the oolitic limestone unit. The species is known from Late Jurassic (Kimmeridgian) to the Early Valanginian (Arnaud-Vanneau et al., 1988; Neagu, 1994; Mancinelli & Coccia, 1999).

Andersenolina delphinensis (Arnaud-Vanneau, Boisseau & Darsac, 1988)
Figs. 8c-e
Selected synonymy
1988 *Trocholina delphinensis* n. sp. - Arnaud-Vanneau et al., p. 358, fig. 2, pl. 1, fig. 1, pl. 3, figs. 1-8.
1994 *Andersenolina delphinensis* (Arnaud-Vanneau, Boisseau & Darsac) nov. comb. - Neagu, p. 138, pl. 7, figs. 1-7, pl. 11, figs. 22, 26, pl. 13, figs. 10-12, 18, text-fig. 4/1.
1995 *Trocholina delphinensis* Arnaud-Vanneau, Boisseau & Darsac - Bucur et al., pl. 2, figs. 6, 12-13.
1996 *Trocholina delphinensis* Arnaud-Vanneau, Boisseau & Darsac - Claps et al., pl. 1, figs. 1-2, 5.
1998 *Trocholina delphinensis* Arnaud-Vanneau, Boisseau & Darsac - Ebli & Schlagintweit, p. 15, pl. 2, figs. 1-2, 9.
1999 *Trocholina delphinensis* Arnaud-Vanneau, Boisseau & Darsac - Mancinelli & Coccia, p. 154-155, pl. 3, fig. 4, pl. 4, fig. 6.

Remarks: *A. delphinensis* has a rather wide range in 392A, from the skelmoldic limestone unit to the upper part of the fenestral limestone unit. The test diameter is from 0.36 mm to 0.4 mm, the test height from 0.44 mm to 0.58 mm, exhibiting 9 to 12 whorls. Many specimens exhibit distinct micritization of the test between the lumina of the chamber.

Andersenolina? cf. *molesta* (Gorbatchik, 1959)
Fig. 8i
Selected synonymy
1959 *Trocholina molesta* n. sp. - Gorbatchik, p. 79, pl. 4, figs. 1-2.
1988 *Trocholina molesta* Gorbatchik - Arnaud-Vanneau et al., p. 359, fig. 3, pl. 6, figs. 11-21.
?1995 *Neotrocholina burgeri molesta* (Gorbatchik) nov. comb. - Neagu, p. 16-19, pl. 1, figs. 13-16, 21-22, 25-26, pl. 7, figs. 62-67, 70-71, pl. 9, figs. 1-9, pl. 13, fig. 13, 25-26.
2000 *Andersenolina molesta* (Gorbatchik) - Bernaus, p. 69, pl. 9, figs. 12-14.

Table 1 – Dimensions of *Actinoporella podolica* (Alth) Conrad, Praturlon & Radoičić. A From Conrad et al. (1974, including data from Pia, 1918); B From Granier (1992) *for Actinoporella lucasi* (Emberger); C From Bucur (2011); D Axial section shown in Fig. 6a (this work).

Reference	**D (external diameter)**	**d (internal diameter)**	**w (number of laterals per whorl)**
A: Conrad et al. (1974) for A. podolica (incl. data from Pia, 1918)	0.7-3.2 mm	0.18-1.1 mm	13-24
B: Granier (1992) for A.lucasi	2.5-3.0 mm	0.35-0.48 mm	12-18
C: Bucur (2011) for A. podolica	0.72-2.45 mm	0.3-0.82 mm	16-26
D: This work, Fig. 6a	2.95 mm	0.52	-

2001 “*Trocholina*” *molesta* Gorbatchik - Pop & Bucur, pl. 7, figs. 4-5.
2004 *Andersenolina molesta* (Gorbatchik) - Bucur et al., pl. 4, fig. 2.
2007 *Neotrocholina molesta* (Gorbatchik) - Krajewski & Olszewska, p. 303, fig. 7a.

Remarks: The selected references in the synonymy clearly demonstrate the taxonomic uncertainty concerning Gorbatchik´s species (and many other Late Jurassic-Early Cretaceous “trocholinids”), which has been assigned to three different genera. According to Arnaud-Vanneau et al. (1988, Fig. 7), *A. molesta* is known from the Berriasian to Barremian (Albian?) interval.

Genus ***Arenobulimina*** Cushman, 1927
Arenobulimina? sp.
Figs. 8m-o

Remarks: Small trochospiral (3 to 3 ½ whorls) benthic foraminifer with a test diameter ranging from 0.24 to 0.48 mm and height of 0.12 to 0.25 mm. Chamber margins rounded; umbilical depressions marked. This taxon occurs from the upper part of the skelmoldic limestone unit (depth 259 m) to the upper part of the fenestral limestone unit (depth 144.83 m), most abundantly in the oolitic unit. The generic status of the taxon in question remains open. We note morphological similarities to sections of *Arenobulimina* cf. *meltae* Kovatcheva figured by Bernaus (2000, pl. 3, figs. 15-16, Lower Cretaceous of Spain), or *Archaeosepta coratina* (Luperto Sinni & Masse, 1993, pl. 3, Lower Cretaceous of Italy). *A. coratina* exhibits a double-layered wall with a hyaline outer layer, however.

Genus ***Haplophragmoides*** Cushman, 1910
Haplophragmoides cf. *joukowskyi* Charollais, Brönnimann & Zaninetti, 1966
Fig. 8f
Selected synonymy
1966 *Haplophragmoides joukowskyi* n. sp. - Charollais et al., pl. 2, figs. 1, 5, 7.
1988 *Haplophragmoides joukowskyi* Charollais, Brönnimann & Zaninetti - Bucur, p. 383, pl. 2, figs. 4-5.
2002 *Haplophragmoides joukowskyi* Charollais, Brönnimann & Zaninetti - Ullastre et al., pl. 1, fig. 5

R**emarks:** Some specimens were observed in foraminiferan grainstones in the fenestral limestone unit.

Genus ***Protopeneroplis*** Weynschenk, 1950
Protopeneroplis ultragranulata (Gorbatchik, 1971)
Figs. 8g-h
Selected synonymy
1971 *Hoeglundia* (?) *ultragranulata* n. sp. - Gorbatchik, p. 135, pl. 5, figs. 2a-c.
1974 *Protopeneroplis trochangulata* n. sp. - Septfontaine, p. 608, pl. 1, figs. 1-18.
1989 *Protopeneroplis trochangulata* Septfontaine - Fourcade and Granier, pl. 1, fig. 11.
1993b *Protopeneroplis ultragranulata* (Gorbatchik) - Bucur, p. 214, pl. 2, figs. 1-2, 5, 8, 11-12 (with synonymy).
2005 *Protopeneroplis ultragranulata* (Gorbatchik) - Schlagintweit et al., p. 37-38, figs. 21a-d (with synonymy).

R**emarks:** *P. ultragranulata* is typically observed in well agitated palaeoenvironments such as ooid shoals. In core 392A it occurs in the uppermost part of the skelmoldic limestone unit and the lower part of the oolitic unit.

Genus ***Troglotella*** Wernli & Fookes, 1992
Troglotella incrustans Wernli & Fookes, 1992
Fig. 8j
Selected synonymy
1992 *Troglotella incrustans* n. gen., n. sp. - Wernli & Fookes, p. 97-100, pls. 1-2.
2011 *Troglotella incrustans* Wernli & Fookes - Bucur & Săsăran, pl. 2, fig. 5, pl. 4, figs. 12, 14 (pars), pl. 5, figs. 4-6, pl. 16, fig. 3 (pars).
2012 *Troglotella incrustans* Wernli & Fookes - Schlagintweit, 19-22, fig. 1a, b pars, figs. 3-10 (with synonymy).

Remarks: A single specimen was observed in the lower part of the oolitic unit (sample 392A-20-1-137).

Genus ***Vercorsella*** Arnaud-Vanneau, 1980 emend. Arnaud-Vanneau & Sliter, 1995
Vercorsella sp.
Fig. 8k

Remarks: A single specimen was observed in a foraminiferal-dasycladalean grainstone in the fenestral limestone unit (thin-section 392A-6-1-91).

Stratigraphy

The stratigraphy of the shallow-water limestones at site 392A was indicated by Enos and Freeman (1978, p. 413) as “probably Lower Cretaceous on the basis of a green alga (*Acroporella* cf. *radoicicae*) found in the oolitic limestone”.

This age assignment was taken as the base for a correlation with basinal sediments of the Blake-Bahama basin dated by both benthic and planktonic foraminifera (Gradstein, 1978). In the latter work, the oldest datable sediments overlying the unconformity were dated as Barremian. Later, in an overview on the sedimentary environments and stratigraphy of the western North Atlantic, the neritic limestones of Site 329A were summarized as (Tithonian?) Berriasian to Barremian (Sheridan et al., 1978). Based on dasycladalean green algae and benthic foraminifera, Fourcade and Granier (1989) gave a more precise age for the carbonates from leg 392A as Berriasian-early Valanginian.

The first appearance of the benthic foraminifer *Protopeneroplis ultragranulata* (Gorbatchik) in grainstone intercalations within the upper part of unit 3 (see Fig. 2), suggests a maximum age of Middle/Late Tithonian (Heinz & Isenschmid, 1988; Altiner & Özkan, 1991; Gawlick & Schlagintweit, 2009). Most records of *P. ultragranulata* are from the Berriasian and Valanginian; the last occurrence is recorded in the Early Barremian (Bucur, 1993b). Due to the preference of this foraminifer for highly energetic environments, we do not know if its absence in the underlying carbonates of unit 3 is facies controlled or means that these rocks are in fact Middle/Late Tithonian or older. Facies control would be a logical reason for its absence in samples of the tidal flat deposits of unit 1 on the one hand and the lagoonal wackestones of unit 3 on the other hand, but it is also absent in five ooid grainstone intercalations below its first occurrence in unit 3.

Another foraminifer observed in unit 3 is the conical *Andersenolina delphinensis* (Arnaud-Vanneau, Boisseau and Darsac, 1988). Its stratigraphic range is indicated by Arnaud-Vanneau et al. (1988, p. 358) as essentially Berriasian becoming less abundant in the Late Berriasian and disappearing during the Valanginian. These authors also indicate its possible first appearance in the Late Tithonian (op. cit., fig. 7). In Lower Cretaceous deposits of Romania, *A. delphinensis* is reported from the Upper Berriasian to Lower Valanginian (Neagu, 1994).

According to Altiner & Özkan (1991, fig. 5), *Haplophragmoides joukowskyi* has a stratigraphic range from the Late Berriasian (*oblonga* calpionellid zone) to the Early Hauterivian.

The dasycladale *Actinoporella podolica* Alth is known from the (Upper) Tithonian to Aptian (Granier, 1994; Sokač, 1996). Its occurrence in the basal samples of unit 3 indicates that these are not older than (Late) Tithonian.

Based on the distribution of the microfossils indicated in the lithological column, a tentive biostratigraphy is proposed (Fig. 2). Boundaries, like Tithonian-Berriasian or Berriasian-Valanginian cannot be defined.

DISCUSSION

In the Upper Jurassic? to Necomian interval preserved in Site 392A, a general upward shallowing trend can be observed from the base towards the top with lagoonal facies, followed by tidal-bar oolites and peritidal carbonates (tidal-flat facies). The superjacent discontinuity surface may thus represent maximum regression with subaerial exposure, although the development of the capping iron-stained hardground reflects a submarine omission surface, i.e., the subsequent transgression (Enos & Freeman, 1978, 1979). The overlying sediments with pelagic microfossils document a transgression and drowning with an upward deepening sequence. The sequence studied can be considered a further example of platform drowning preceded by emergence (Schlager, 1998; Föllmi, 2012; Rameil et al., 2012). The timing of the exposure and its duration can only be approximated from our data. It was possibly intra-Valanginian based on the biostratigraphy (see also Fourcade & Granier, 1989), but the overlying submarine hardground may have included the entire Hauterivian, as the draping pelagic oozes are Barremian (Gradstein, 1978). The Valanginian age is consistent with literature examples from adjoining as well as far-distant regions, as discussed in the following.

In the basinal facies recovered at Site 603 on the lower continental rise about 435 km east of Cape Hatteras, North Carolina (see Fig. 1), a lithologic change from a “limestone facies” to a “sand facies” is marked in the upper part of the Valanginian, evidence of the “first clear-cut indication of downslope depositional processes” (Wise & Van Hinte, 1987, p. 1367). In the US Gulf coastal plain (Louisiana, Mississippi, Alabama), a hiatus is recorded for the late Early Valanginian to latest Valanginian interval (Mancini et al., 2008, fig. 3) terminating the Gulf of Mexico T-R J3 cycle that started in the Middle Tithonian (Mancini & Puckett 2005). This stratigraphic accordance is probably not coincidental. The late Early Valanginian unconformity is not just a regional feature (Mancini et al., 2008), but seems to have a much wider chronostratigraphic context in the North Atlantic and Neotethyan depositional systems (Bosellini & Morsilli, 1997; Granier, 2007; Bonin et al., 2012). It is recorded from the Bahama Escarpment with similar microfossil associations in the pre-drowning successions (Granier, 2005). This Early Valanginian unconformity (*Calpionellites* Zone) is also reported from Spain, southern France, the Middle East (Granier, 2007), and from the Apulia platform margin exposed in the Gargano Peninsula of south Italy (Bosellini & Morsilli, 1997; Bosellini et al., 1999). Another example is recorded from the Eastern Carpathians of Romania where Berriasian-Lower Valanginian peritidal carbonates are overlain by shelf deposits separated by a hardground (Săsăran et al., 2011). The age of the shelf deposits is Late Valanginian – Early Hauterivian (Ioan Bucur, pers. comm.).

This major change is recorded not only in the platforms but also the adjacent basins. In the Vocontian Basin of southern France for example, a major lithological change is reported in the Lower Valanginian (*campylotoxus* ammonite zone) where the “deposits start to become increasingly argillaceous” (Gréselle & Pittet, 2010, p. 1661). For the carbonate platforms adjacent to the Vocontian basin, a hiatus is recorded from the latest Early Valanginian (*campylotoxus* Zone) to the earliest Hauterivian (*loryi* Zone) (Bonin et al., 2012) (= D1 phase in Föllmi et al., 1994). These lithological changes related to sea-level fluctuations, are discussed in terms of Valanginian glacio-eustasy by Gréselle & Pittet (2010) (for other possible reasons see Morales et al., 2013). Last but not least, the intra-Valanginian drowning event might be coeval with the occurrence of black shales in the basin, the so-called Weissert event (Erba et al., 2004; for further discussion see Kujau, 2012).

Recognition of a possibly intra-Valanginian unconformity at Site 392, the most northerly and most seaward outpost of the Upper Jurassic?-Lower Cretaceous carbonate megaplatform, further demonstrates its regional significance.

CONCLUSIONS

A more detailed examination of the benthic foraminifera, calcareous algae, and microfacies of the shallow-water limestones cored at ODP sites 390 and 392 provides a more definitive age of this interval as Barremian through possibly Early Valanginian at top and possibly latest Jurassic at the base. The Jurassic (Middle/Late Tithonian) age is based on the first occurrence of the benthic foraminifer *Protopeneroplis ultragranulata* in the upper part of the lowermost unit. As this appearance could also be facies controlled, this conclusion is rather tentative.

A major hiatus that separates Lower Valanginian shallow-water limestones from the overlying Barremian pelagic limestones is marked by iron-oxide laced crusts a few decimeters thick. This extends the Valanginian unconformity, which is widely recognized in the American Gulf Coast and the Neotethyan region, to the northeastern margin of the postulated Upper Jurassic-Lower Cretaceous carbonate megaplatform of the western Atlantic.

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