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NEW CALCAREOUS NANNOFOSSIL SPECIES FROM THE EARLY JURASSIC OF TETHYS

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Key-words: Calcareous nannofossils, Early Jurassic, new species, evolution.

Riassunto. Un numero significativo di nannofossili calcarei appartenenti ai generi *Lotharingius*, *Watznaueria* e *Carinolithus*, sono stati rinvenuti in sezioni tetidee di età Giurassico inferiore e medio. Nel presente lavoro sono state riconosciute e descritte quattro nuove specie di nannofossili calcarei. Tali specie sono ritenute importanti da un punto di vista biostratigrafico, compaiono in un intervallo di tempo che va dal Domeriano superiore al Toarciano inferiore e costituiscono delle forme chiave per ricostruire le relazioni filetiche attraverso i generi *Lotharingius* - *Watznaueria* e *Calyculus* - *Carinolithus*. Le nuove specie introdotte nel presente lavoro sono rinvenute comunemente, anche se non abbondanti, nel Toarciano ed Aaleniano di numerose successioni dei dominii Tetideo e Boreale.

Abstract. Significant numbers of calcareous nannofossils belonging to the genera *Lotharingius*, *Watznaueria* and *Carinolithus* have been recorded from the Lower and Middle Jurassic of Tethys. Four new species of calcareous nannofossils are described in the present work. These species are age-diagnostic for the interval spanning the Late Domerian-Middle Toarcian, and help reconstructions of the phyletic relationships between the genera *Lotharingius* - *Watznaueria* and *Calyculus* - *Carinolithus*. Although never abundant, these new species are commonly found in the Toarcian and Aalenian of several Tethyan and some Boreal sections.

Introduction.

The Early Jurassic represents a very important period for calcareous nannofossils, because of their rapid evolution and diversification, diffusion throughout the Tethys ocean and North Europe shelves. During the Early Jurassic nannoplankton becomes one of the most important components of preservable marine phytoplankton.

After the pioneristic taxonomic studies of the 1950's, the nannofossil taxonomy and biostratigraphy received a great input in the last decade (Noël, 1965, 1973; Medd, 1971, 1979; Rood et al., 1971, 1973; Grün et al., 1974; Goy, 1981; Bown, 1987a, 1987b, Bown & Cooper, 1989; Cobianchi, 1990; De Kaenel & Berger, 1993). Some of these papers are based on the use of electron microscope. The present work is concerned with observations made mainly with the light microscope, the basic instrument for routine biostratigraphy.

Several ammonite-dated successions have been studied in Central Italy and compared to other Tethyan and North European areas (Tab. 1). Some time intervals, such as the Toarcian and Aalenian, contain rich and diverse nannofossil assemblages, in which some genera attain a particular importance in terms of both abundance and number of species. The genus *Lotharingius*, for example, becomes well diversified and very common in the Toarcian, being represented by several species. Among these, *Lotharingius hauffii*, is present with a great morphological variability. Morphometric studies and detailed observations of the central area structures allow to distinguish two new species closely related to *L. hauffii*, representing key forms to understand the Lower Jurassic evolutive lineage of the genus *Lotharingius*. Similarly, a great morphological variability exists both in the genera *Calyculus* and *Carinolithus*, with transitional characters from one genus to the other. A new species of *Carinolithus* is here described, and the links with the genus *Calyculus* are discussed.

Materials and methods.

Fourty sections of age from Sinemurian to Kimmeridgian were investigated. Most of them are well dated on the basis of ammonite and/or dinoflagellate and radiolarian biostratigraphies. In some cases magnetostratigraphy has also been performed. Table 1 shows the locations, main characteristics, reference papers and the number of samples studied for each section. The investigation of more than 2000 samples representing different lithologies includes both quantitative and semiquantitative analyses. Smear slide preparation was as simple as possible to retain the original nannofossil assemblage

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SECTIONS	LOCATION	Thick.	Sampl.	AGE	Reference	Ammonites	Radiol.	Dinoc.	Magnet.
A	M. Cetona-S Tuscany, central Italy	20	20	Toarcian	Bucefalo Palliani et al., 1996	.	.	X	.
Belvedere	M. Cetona-S Tuscany, central Italy	80	42	Lotharingian-Toarcian	Bucefalo Palliani et al., 1996	partim	.	X	.
Infernaccio	M.Nerone-Marche, central Italy	15	19+26	Carixian-Early Bajocian	Baldanza et al., 1990	X	.	.	.
Presale	M.Nerone-Marche, central Italy	25	27+30	Late Domerian-Early Bajocian	Baldanza et al., 1990	X	.	.	.
Ranchi	M.Nerone-Marche, central Italy	9	9+25	Late Aalenian-Early Bajocian	Baldanza et al., 1990	X	.	.	.
Fonte Avellana	M.Nerone-Marche, central Italy	55	56	Pliensbachian-Bathonian	Reale et al., 1992	partim	.	.	X
Bosso	Cagli-Marche, central Italy	250	76	Sinemurian-Pliensbachian	Cresta et al., 1988	X	.	.	.
Colle d'Orlando	M.Cucco-NE Umbria, central Italy	113	163	Pliensbachian-Early Bajocian	Bucefalo Palliani & Mattioli, 1994	X	.	.	X
Colle d'Orlando	M.Cucco-NE Umbria, central Italy	23	87	Early Toarcian	Bucefalo Palliani & Mattioli, 1994	X	.	X	X
Burano	M.Burano-NE Umbria, central Italy	30	52	Sinemurian-Pliensbachian	Cresta et al., 1988	.	.	.	X
Fonte Cocce	M. Vermenone-Mid-E Umbria, central Italy	41	43	Late Domerian-Middle Toarcian	Morettini et al., 1996	partim	.	.	.
Colle Corno	M. Vermenone-Mid-E Umbria, central Italy	49	48	Late Domerian-Late Toarcian	Morettini et al., 1996	.	.	.	.
Fiuminata	M. Vermenone-Mid-E Umbria, central Italy	30	136	Mid Toarcian-Aalenian	Mattioli, 1994	partim	.	.	X
Pale Vallone A	M.Pale-Central Umbria, central Italy	27	75	Late Carixian-Kimmeridgian	Reale et al., 1992	partim	X	.	.
M. Serrone	M.Serrone-Central Umbria, central Italy	64	36	Late Domerian-Middle Toarcian	Reale et al., 1992	X	.	.	.
M. Serrone 1	M.Serrone-Central Umbria, central Italy	82	229	Late Domerian-Middle Toarcian	Reale et al., 1992	X	.	X	.
M. Civitella	M.Civitella-Central Umbria, central Italy	21	35	Late Domerian-Late Toarcian	Reale et al., 1992	X	.	.	.
Pozzale	M.Martani-S Umbria, central Italy	40	68	Late Domerian-Middle Aalenian	Reale et al., 1992	X	.	.	.
Pozzale 1	M.Martani-S Umbria, central Italy	12	84	Late Domerian-Early Toarcian	Reale et al., 1992	X	.	X	.
Cima Panco	M.Martani-S Umbria, central Italy	20	61	Late Domerian-Toarcian	Reale et al., 1992	X	.	.	.
Somma	M. della Somma-S Umbria, central Italy	5	40	Early Toarcian	Nini et al., 1995	.	.	X	.
Torrecola	M. della Somma-S Umbria, central Italy	10	35	Late Domerian-Early Toarcian	Nini et al., 1995	.	.	.	.
Colle Bertone	M.la Pelosa-S Umbria, central Italy	69	70	Late Toarcian-Early Bajocian(?)	Bartolini et al., 1995	partim	X	.	X
Fonte Cerro	M.Sabini-N Latium, central Italy	10	87	Early Toarcian	Bucefalo Palliani & Mattioli, 1994	X	.	X	.
Terminilletto	M.Terminillo-N Latium, central Italy	70	50	Early Aalenian-Kimmeridgian	Bartolini et al., 1995	partim	X	.	X
Sella dei due	Gran Sasso-N Abruzzo, central Italy	111	65	Domerian-Aalenian	Bigozzi, 1994	partim	.	.	.
Filettino	M.Simbruini-Latium, central Italy	53	47	Late Domerian-Early Toarcian	Bartolini et al., 1992	partim	.	.	.
Marettimo	Sicily, southern Italy	20	12	Sinemurian-Pliensbachian		partim	.	X	.
Peniche	W Portugal	15	2	Lower-Mid Carixian	Baldanza & Mattioli, 1992	.	.	.	.
Rabaçal	W Portugal	52	11	Upper Domerian-Upper Toarcian	Baldanza & Mattioli, 1992	.	.	X	.
Cap Mondego	W Portugal	80	4	Lower Bajocian-Callovian	Baldanza & Mattioli, 1992	.	.	.	.
Kaballos	W Greece	51	34	Upper Domerian-Upper Toarcian	Pettinelli et al., 1995	.	.	.	.
Kalamitsi	W Greece	10	11	Lower Toarcian	Pettinelli et al., 1995	.	.	X	.
Kalvaria	Central Hungary	40	6	Sinemurian-Toarcian	Baldanza & Mattioli, 1992	.	.	X	.
Kozoskut	Central Hungary	2.5	6	Pliensbachian-Bajocian	Baldanza & Mattioli, 1992	partim	.	.	.
Reka	Central Hungary	15	5	Domerian-Lower Toarcian	Baldanza & Mattioli, 1992	X	.	X	.
Csengohegy	Central Hungary	30	5	Lower Bajocian-Callovian	Baldanza & Mattioli, 1992	partim	.	.	.
Lokut	Central Hungary	100	14	Carixian-Kimmeridgian	Baldanza & Mattioli, 1992	partim	.	.	.
Dotternhausen	Swabia, SW Germany	13	8	Lower Toarcian	Jäger et al., 1995	X	.	X	.
Opalinum Clay	Swabia, SW Germany	20	4	Aalenian	Jäger et al., 1995	X	.	X	.
Wittnau	Germany	110	110	Toarcian-Aalenian	Ohmert & Rolf, 1994	X	.	X	X

Tab. 1 - Age, location, biostratigraphical control and reference where a reader can find further informations about the examined sections.

composition. Slides were examined mainly under light microscope (at 1000X magnification). Scanning electron microscope investigations were carried out only in a few samples with good preservation.

Preservation of nannofossils is generally moderate to poor, depending mainly on the different lithologies. In some time intervals (i.e. the Toarcian-Aalenian), concomitant with marly lithotypes, a better preservation of coccoliths has been observed. Abundance is in general medium to high in the Toarcian-Aalenian, while in the other intervals, it is rare to medium.

Morphometric studies have comprised the measure of the rim/central area and long/short axis ratios in some twenty specimens of all the considered species.

Systematic Palaeontology

Division **Prymnesiophyta** Hibberd, 1976

Class Prymnesiophyceae Hibberd, 1976

Order Watznaueriales Bown, 1987b

Family *Watznaueriaceae* Rood, Hay & Barnard, 1971 emend. Bown, 1987b

Genus *Lotharingius* Noël, 1973 emend. Goy, 1979

Lotharingius frodoi sp. nov.

Pl. 1, fig. 1-5; Pl. 3, fig. 1, 2; Text-fig. 1

Holotype. Plate 1, fig. 1.

Repository. Dipartimento di Scienze della Terra, University of Perugia.

Type locality. Dotternhausen (Rohrbach quarry), SW Germany (Toarcian Posidonia Shales, Lias ε), sample Dott. 3.

Type stratum. Lower Toarcian, *exaratum* Subzone, sample Dott. 3.

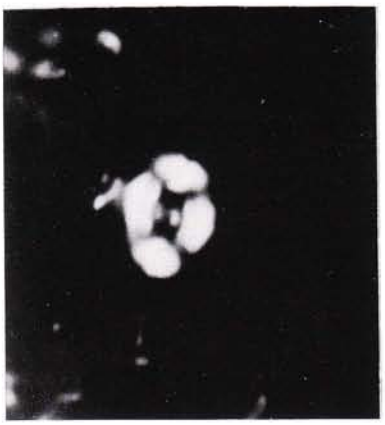
Etymology. Named after "Frodo", the fantasy character of Tolkien's book "The lord of the rings".

Diagnosis. An elliptical species of the genus *Lotharingius* with a small, narrowly elliptical central area, bearing two buttresses aligned with the minor axis of the ellipse.

Description. A relatively small coccolith with a typical lotharingiacean rim. The general shape is narrowly elliptical. In distal view the inner and the outer cycles show comparable width. The outer cycle of the distal shield is formed by 20-25 counter-clockwise imbricating elements, displaying inclined sutures. The inner cycle is composed of 20-25 subsquare elements which display near radial sutures. The proximal shield, gently sloping inward, is slightly smaller than the distal

species of the Watznaueriaceae	morphology								stratigraphical distribution
	coccolith shape	central area	dimensions	outer/inner cycle ratio	rim/central area ratio	A.M./a.m. ratio	extintion cross arms	central area structures	
 *L. hauffii*	subcircular to elliptical	small, subcircular to elliptical	AM:3.5-4μm am:3.2-3.5μm	1:1 to 2:1	1 to 1.2 mean 1.1	1 to 1.2 mean 1.19	slightly arcuated	circular, probably bearing a spine	Late Domerian *E.emaciatum* Zone to Kimmeridgian
 *L. frodoi* sp.nov.	elliptical	small, elliptical	AM:4-4.8μm (4.75μm) am:3.8-4.5μm (3.65μm)	1:1	1 to 1.3 mean 1.15	1.25 to 1.3 mean 1.27	slightly arcuated	two little buttresses aligned with the minor axis of the ellipse	Late Domerian *E.emaciatum* Zone to Kimmeridgian
 *L. umbriensis* sp.nov.	subcircular, to broadly elliptical	very small subcircular	AM:3.5-5μm (3.6μm) am:3.3-4.5μm (3.35μm)	2:1	1.25 to 1.7 mean 1.42	1.05 to 1.1 mean 1.08	markly arcuated	small cross made by equidimensional elements	Late Domerian *E.emaciatum* Zone to Aalenian
 *L. barozii*	elliptical	wide, elliptical	AM:4.5-5.5μm am:4-5μm	1:1	0.7 to 0.75 mean 0.72	1.17 to 1.25 mean 1.22	slightly arcuated	cross	Late Domerian *E.emaciatum* Zone to Aalenian
 *L. sigillatus*	elliptical	quite wide, elliptical	AM:5-6.5μm am:4.5-6μm	1:1 to 2:1	1	1.17 to 1.25 mean 1.22	arcuated	buttress aligned with the major axis of the ellipse and a system of granular, radially disposed elements	Early Toarcian *D.tenuicostatum* Zone to Callovian
 *L. crucicentralis*	elliptical	quite wide, elliptical	AM:5-7μm am:4.5-6μm	1:1 to 2:1	0.8 to 1.1 mean 0.93	1.07 to 1.4 mean 1.2	arcuated	a cross and a system of radially arranged granulations	Early Toarcian *D.tenuicostatum* Zone to Kimmeridgian
 *L. velatus*	elliptical	wide, elliptical	AM:6-8.5μm am:5.5-7.5μm	2:1	0.7 to 1 mean 0.9	1.1 to1.2 mean 1.16	arcuated	a system of granulations arranged partly parallelly to the major axis, partly radially	Early Toarcian *D.tenuicostatum* Zone to Callovian
 *W. colacicchii* sp. nov.	broadly elliptical	quite small, subcircular to subelliptical	AM:5.2-7μm (6μm) am:4.5-6μm (5μm)	2:1 to 3:1	1 to 1.4 mean 1.23	1.2 to 1.4 mean 1.23	markedly arcuated	a small cross made by equidimensional elements	Early Toarcian *H.serpentinus* Zone to Bajocian
 *Watznaueria* sp.1	narrowly elliptical	small, narrowly elliptical	AM:6μm am:5μm	2:1 to 3:1	2 to 2.3 mean 2.11	1.25 to 1.3 mean 1.28	markedly arcuated	no structures	Early Toarcian *H.serpentinus* Zone to Middle Jurassic

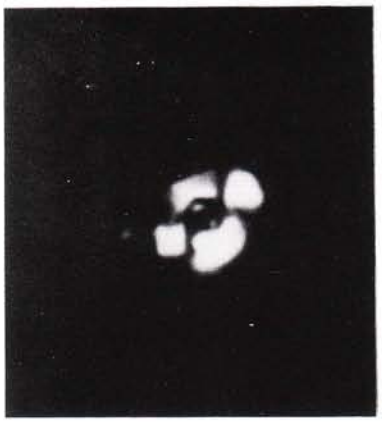
Fig. 1 - Comparison of morphological characters and stratigraphical distribution of the Lower Toarcian species of Watznaueriaceae. The dimensions of the holotypes are in brackets. AM = major axis of the ellipse; am = minor axis of the ellipse.



1. *Lotharingius frodoi*

2. *Lotharingius frodoi*

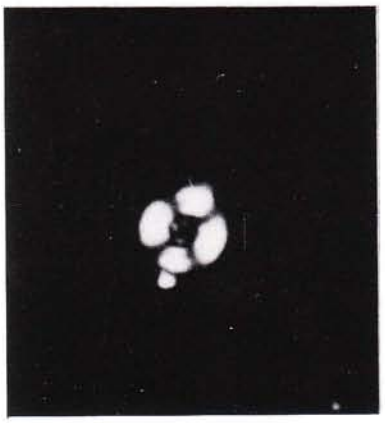
3. *Lotharingius frodoi*



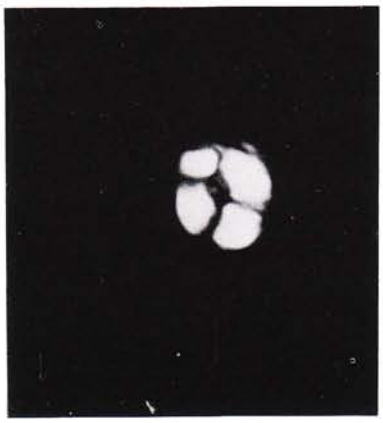
4. *Lotharingius frodoi*

5. *Lotharingius frodoi*

6. *Lotharingius umbriensis*

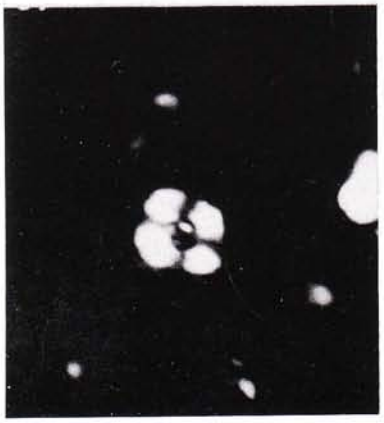


7. *Lotharingius umbriensis*



8. *Lotharingius umbriensis*

9. *Lotharingius umbriensis*



10. *Lotharingius umbriensis*

11. *Lotharingius umbriensis*

12. *Lotharingius umbriensis*

Occurrence. Central Italy - M. Cetona, Lower Toarcian; Colle d'Orlando, *tenuicostatum* Zone to Aalenian; Fiuminata, Middle Toarcian to Aalenian; Monte Serrone, Toarcian; Pozzale, *tenuicostatum* Zone to *serpentinus* Zone; Cima Panco, Early Toarcian; Terminilletto, Aalenian; Fonte Cerro, *emaciatum* Zone to *serpentinus* Zone; Filettino, Upper Domerian to Lower Toarcian; Sella dei due Corni, Upper Domerian to Middle-Upper Toarcian. Portugal - Rabaçal, Lower Toarcian to Upper Toarcian. Greece - Lower Toarcian to Middle Toarcian. Hungary - Reka, *serpentinus* Zone (Lower Toarcian). Germany - Dotternhausen, *semicelatum* Zone to *falciferum* Zone (Toarcian); Weilen unter den Rinnen, *opalinum* Zone (Aalenian); Wittnau, *insigne* Subzone (Upper Toarcian).

Genus *Watznaueria* Reinhardt, 1964

Remarks. The main differences between the genera *Lotharingius* and *Watznaueria* concern the general arrangement of the shield rather than the central area structures, that can be considered as a diagnostic feature for species diagnosis. In the genus *Watznaueria* the sutural lines among the elements of the distal shield outer cycle appear more inclined than in the genus *Lotharingius* and the general shape of the coccolith is marked concavo-convex. In light microscope these features produce an extinction pattern with isogyres displaying right angle bent arms, revealing also the net optical discontinuity between the outer and inner cycles of the distal shield. In the genus *Lotharingius* the optical discontinuity in distal view is less marked. The author disagrees with the Bown's statement (1987b) according to which the genus *Lotharingius* is distinguishable for possessing a distinctive central area cross and additional lateral bars. Some typical specimens of this genus have either a prominent longitudinal bar and subordinated radial elements (as in the case of *Lotharingius sigillatus*) or a series of granulations arranged longitudinally and radially (such as in *Lotharingius velatus*). Cross structures can be also present in the central area of species of the genus *Watznaueria* (see *W. contracta*).

Watznaueria colacicchii sp. nov. Mattioli & Reale

Pl. 2, fig. 1-8; Pl. 3, fig. 5, 7; Text-fig. 1

1992 *Lotharingius contractus* Reale et al., pl. 2, fig. 15, 16.
1994 *Watznaueria* aff. *W. contracta* Mattioli, fig. 5g and 5l.
1995 *Lotharingius* aff. *L. contractus* Mattioli, pl. 2, fig. 12.

Holotype. Plate 2, fig. 1.

Repository. Dipartimento di Scienze della Terra, University of Perugia.

Type locality. Wittnau, Germany (Upper Toarcian clays with *Bositra*).

Type stratum. Middle Toarcian, *variabilis* Zone, sample Witt. 100.80/100.82.

Etymology. Named in honour of the geologist Prof. Roberto Colacicchi, University of Perugia. This species was contemporaneously recognized by the author and Dr. Viviana Reale, University of Florence.

Diagnosis. A broadly elliptical to sub-circular species of the genus *Watznaueria*, with a reduced central area crossed by a system of bars forming a cross, aligned with the axes of the coccolith.

Description. This coccolith is generally broadly elliptical in shape, as well as the fairly reduced central area. The elements of the outer cycle of the distal shield (about 30) are clearly imbricated with inclined sutures. The inner cycle of the distal shield is about one third of the total width, its elements are small. The two shields have a concavo-convex shape. The reduced central area is almost completely filled with the cross aligned with the axes of the ellipse.

Dimensions: lenght 5.2-7.0 μm (6.0 μm); width 4.5-6.0 μm (5.0 μm).

Discussion. In light microscope under crossed nicols, the extinction pattern has very arcuated arms, clearly indicating the optical discontinuity between the inner and outer cycles of the distal shield. *Watznaueria colacicchii* sp. nov. is distinguished from the Mid-Jurassic *W. contracta* (Bown & Cooper, 1989) Cobianchi et al., 1992 by its smaller size and more open central area and from the other species of the genus *Watznaueria* for its central area structure. In poorly preserved material the cross is not observed; however *Watznaueria colacicchii* sp. nov. is distinguishable from *Watznaueria* sp. 1 in Cobianchi et al. (1992) by the four inserts of the cross that are always visible.

This species marks the entry of the genus *Watznaueria* and can be considered as an intermediate form between the small sub-circular *Lotharingius* (i.e. *L. umbriensis*) and the typically more elliptical and larger *Watznaueria* species.

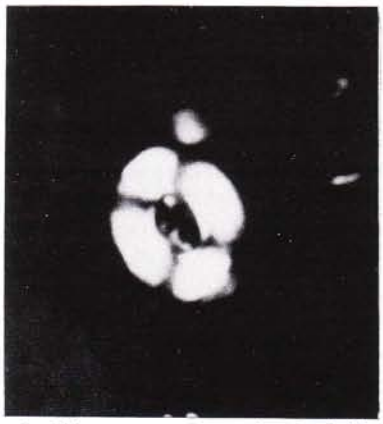
The specimens figured as *Lotharingius contractus* by Reale et al. (1992), as *Watznaueria* aff. *W. contracta*

PLATE 2

All light micrographs crossed nicols, approximately X 3600.

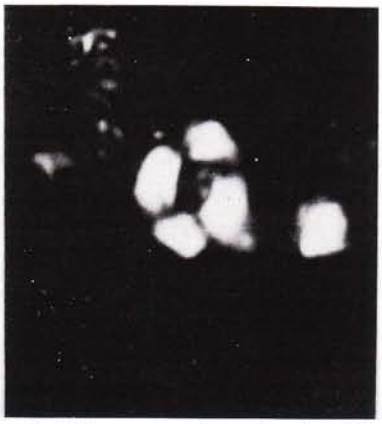
Fig. 1-8 - *Watznaueria colacicchii* sp. nov.; 1: Witt. 100.80/100.82, Wittnau, *insigne* Subzone, Late Toarcian; 2: FLE 20.20, Fiuminata, Late Toarcian; 3: FLE 19.5, Fiuminata, Late Toarcian; 4: Witt. 100.80/100.82, Wittnau, *insigne* Subzone, Late Toarcian; 5: FLE 0, Fiuminata, Middle Toarcian; 6: FLE 27.60, Fiuminata, Early Aalenian; 7: FLE 0.35, Fiuminata, Middle Toarcian; 8: FLE 27.60, Fiuminata, Early Aalenian.

Fig. 9- 12 - *Carinolithus poulnabronei* sp. nov.; 9: PO 3.6, Pozzale, *tenuicostatum* Zone, Early Toarcian; 10: Dott. 3, Dotternhausen, *exaratum* Subzone, Early Toarcian; 11: FLE 27.60, Fiuminata, Early Aalenian; 12: FLE 27.60, Fiuminata, Early Aalenian.



1. *Watznaueria colacicchii*

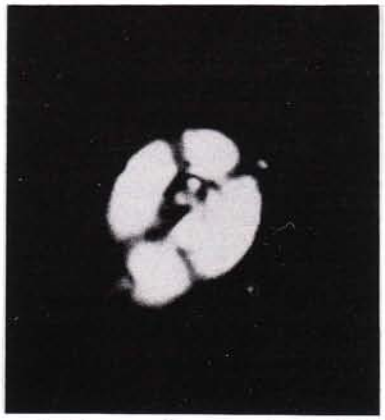
2. *Watznaueria colacicchii*



3. *Watznaueria colacicchii*

4. *Watznaueria colacicchii*

5. *Watznaueria colacicchii*



6. *Watznaueria colacicchii*

7. *Watznaueria colacicchii*

8. *Watznaueria colacicchii*

9. *Carinolithus poulnabronei*

10. *Carinolithus poulnabronei*

11. *Carinolithus poulnabronei*

12. *Carinolithus poulnabronei*

and *Lotharingius* aff. *L. contractus* by Mattioli (1994; 1995) from the Middle and Upper Toarcian of central Italy should be assigned to *W. colacicchii*. The named specimens are smaller and possess a slightly wider central area compared to the holotype of *L. contractus*. In the Umbria-Marche sections, the first occurrence of *L. contractus* was observed in the *bifrons* Zone and an increase in its size was recorded from the basal Aalenian (Reale et al., 1992; Baldanza & Mattioli, 1992). Probably, only the larger forms could be considered as unquestionable *L. contractus*.

Watznaueria contracta Cobianchi, Erba & Pirini Radrizzani, 1992, is a new combination for *Lotharingius contractus* Bown & Cooper, 1989, because of the presence of a Watznaueriacean rim in this form. After a revision of the specimens of the Umbria-Marche area, the authors agree with Cobianchi et al. (1992) in this new combination. Typical specimens of *W. contracta* appear therefore in the Lower Aalenian of Umbria-Marche and Lombardy basins (Cobianchi et al., 1992; Mattioli, 1994; Mattioli et al., 1996, in progress), later than the occurrence of *W. colacicchii*.

Range. *serpentinus* Zone (Lower Toarcian) to Bajocian. Reale et al. (1992), *bifrons* Zone of central Italy. Mattioli (1994), Middle Toarcian of Fiuminata (central Italy). Mattioli (1995a), *serpentinus* Zone (Lower Toarcian) of Pozzale (central Italy).

Occurrence. Central Italy - Colle d'Orlando, Middle Toarcian (*variabilis* Subzone) to Lower Bajocian; Fiuminata, Middle Toarcian (*variabilis* Subzone) to Aalenian; Pozzale, *serpentinus* Zone (Lower Toarcian) to Aalenian; Cima Panco, Lower Toarcian to Aalenian; Colle Bertone, Upper Toarcian to Bajocian; Terminilletto, Aalenian to Bajocian; Sella dei due Corni, Lower Toarcian to Aalenian. Portugal - Rabaçal, Middle to Upper Toarcian. Greece - Kaballos, Lower to Upper Toarcian. Germany - Weilen unter den Rinnen, *opalinum* Zone (Aalenian); Wittnau, *insigne* Subzone (Upper Toarcian).

Order Podorhabdales Rood, Hay & Barnard, 1971

Family *Calyculaceae* Noël, 1973

Genus *Carinolithus* Prins in Grün et al., 1974 emended Bown, 1987b

Carinolithus poulnabronei sp. nov.

Pl. 2, fig. 9-12; Pl. 3, fig. 3; Text-fig. 2

1987 *Calyculus* sp., Crux, p. 55, pl. 1, fig. 16.
1995 *Calyculus* sp., Mattioli, pl. 2, fig. 1, 2.

Holotype. Plate 2, fig. 9.

Repository. Dipartimento di Scienze della Terra, University of Perugia.

Type locality. Pozzale section, Monti Martani, Central Italy (Lower Toarcian Marne di Monte Serrone Fm.).

Type stratum. Lower Toarcian, *tenuicostatum* Zone, sample PO 3.6.

Etymology. Named after "Poulnabrone" one of the most ancient and fascinating dolmens of Ireland.

Diagnosis. A thick species of the genus *Carinolithus* with a reduced proximal shield from which the elements of the distal shield, enlarging upward, extend to form a trumpet-like structure flaring at its distal extremity.

Description. The proximal shield is notably smaller than the distal shield and has a very reduced central area. In side view, the distal shield appears to be formed by few (10-12) wedge-shaped elements, whose extremity flares out to form a flat base displaying radial sutures. The axial canal, although reduced, tends to slightly enlarge distally to confer a lateral V-shape to the coccolith.

Dimensions: proximal shield, 3.0-4.0 µm (3.0 µm); distal shield, 6.0-7.0 µm (7.0 µm); rim height, 7.0-10.0 µm (9.0 µm).

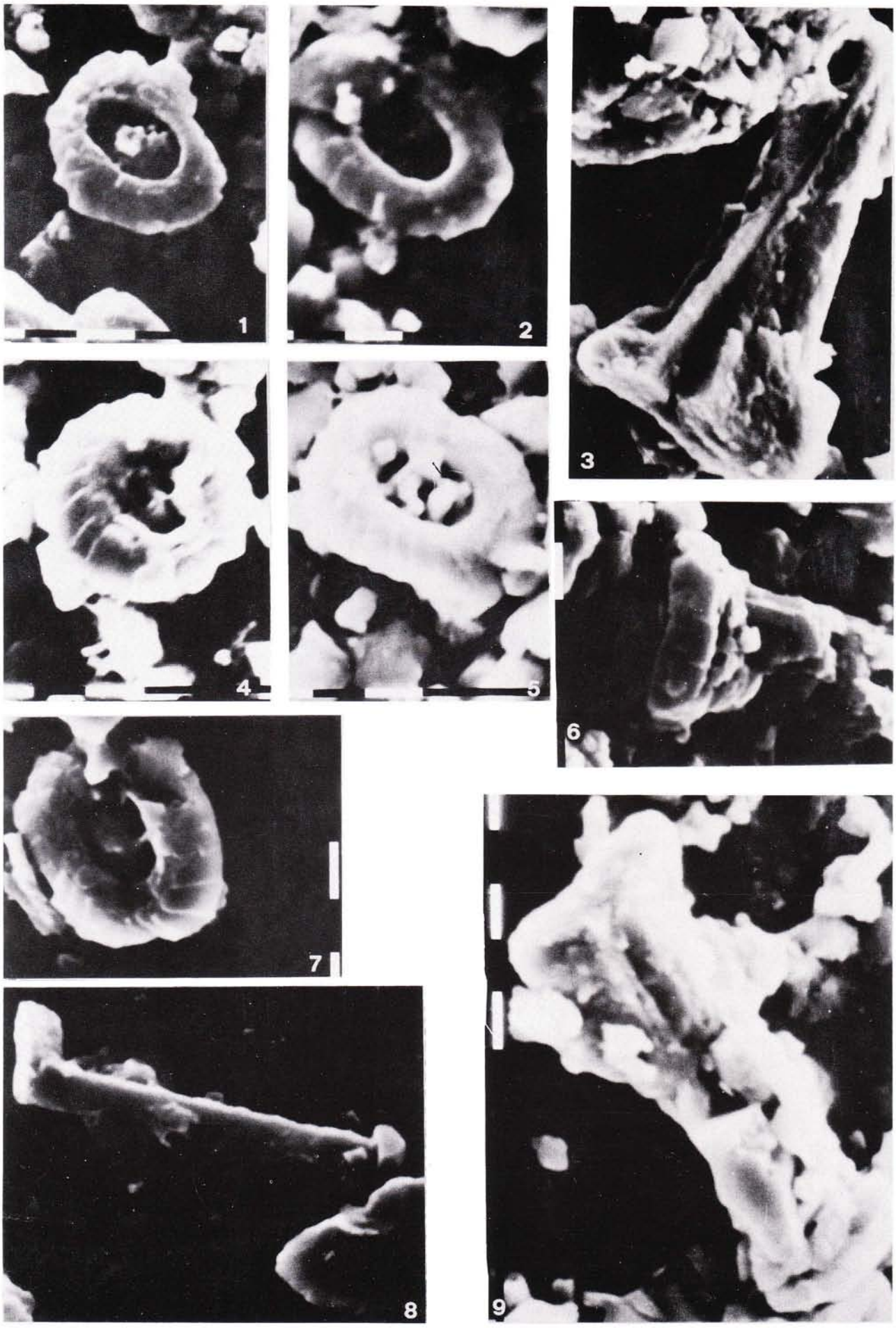
Discussion. This species is distinguished from other *Calyculus* species for its more reduced axial canal, smaller dimensions of the proximal shield and very reduced central area in proximal view; from *C. superbus* for the thicker elements of the distal shield that confer to the coccolith a less elegant general shape; from *C. cantaluppii* for the lack of the enlargement of the vertical extension of the distal shield at one fifth of the height. *Carinolithus poulnabronei* sp. nov. has been often observed overgrown.

Carinolithus poulnabronei sp. nov. represents a transitional form from the genus *Calyculus* to the genus *Carinolithus*. The evolutive lineage between these two genera, according also to Crux (1987) and Bown (1987b), passes through a gradual vertical development of the elements of the distal shield, with the contemporary tendency to the closing of the central area of the proximal shield, of the axial canal, and the reduction of the proximal shield width. The transition between the two genera is fairly rapid and occurs within the *tenuicostatum* Zone.

PLATE 3

SEM photographs, the bar corresponds to 1 %m.

Fig. 1, 2 - *Lotharingius frodoi* sp. nov., FLE 1.21, Fiuminata, Middle Toarcian.
Fig. 3 - *Carinolithus poulnabronei* sp. nov., FLE 1.21, Fiuminata, Middle Toarcian.
Fig. 4 - *Lotharingius umbriensis* sp. nov., FLE 1.21, Fiuminata, Middle Toarcian.
Fig. 5 - *Watznaueria colacicchii* sp. nov., FLE 1.21, Fiuminata, Middle Toarcian.
Fig. 6 - *Carinolithus superbus*, FLE 1.21, Fiuminata, Middle Toarcian.
Fig. 7 - *Watznaueria colacicchii* sp. nov., FLE 1.21, Fiuminata, Middle Toarcian.
Fig. 8, 9 - *Carinolithus superbus*, FLE 1.21, Fiuminata, Middle Toarcian.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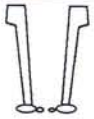
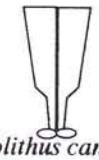
species of the Family Calyculaceae	morphology				stratigraphical distribution
	dimensions	axial canal	general shape	proximal/distal shield ratio	
 *§ Calyculus cribrum*	DS: 6-10 μm PS: 5-8 μm H: 2-3 μm	wide short	low basket	4:5	Late Domerian (*E. emaciatum* Zone) to Late Toarcian (*D. meneghinii* Zone)
 *§ Calyculus noelae depressa*	DS: 6-10 μm PS: 5-8 μm H: 4-5 μm	wide short	low basket	4:5	Late Domerian (*E. emaciatum* Zone) to Late Toarcian (*D. meneghinii* Zone)
 *§ Calyculus noelae recondita*	DS: 6-10 μm PS: 5-8 μm H: 6-8 μm	wide high	high basket	4:5	Late Domerian (*E. emaciatum* Zone) to Late Toarcian (*D. meneghinii* Zone)
 *Carinolithus poulnabronei sp. nov.*	DS:6-7μm (7) PS:3-4μm (3) H:7-10μm (10)	quite reduced high	trumpet like	1:2	*D. tenuicostatum* (Early Toarcian) to Late Toarcian(*D. meneghinii* Zone)
 *Carinolithus cantaluppii*	DS:3-4μm PS:2.3-2.8μm H:8-10μm	very thin high	funnel-shaped	1:2	*H. tenuicostatum* (Early Toarcian) to Late Toarcian (*D. meneghinii* Zone)
 *Carinolithus superbus*	DS:3.5-5.5μm (3.5) PS:2-3μm (3) H:7-10μm (10)	very thin high	trumpet like	1:2	*D. tenuicostatum* (Early Toarcian) to Early Bajocian

Fig. 2 - Summary of morphological characters and stratigraphical distribution of the Lower Toarcian components of the Family Calyculaceae. The dimensions of the holotypes are in brackets. Dimensions and stratigraphical distribution of *C. cantaluppii* are from Cobianchi (1990). The symbol § is referred to the species grouped into *Calyculus* spp. DS = distal shield width; PS = proximal shield width; H = height of the vertical extension of the distal shield.

The specimens figured by Crux (1987) and Mattioli (1995) as *Calyculus* sp. can be referred to *C. poulnabronei* sp. nov. based on the presence of a quite reduced axial canal and small central area in proximal view.

Range. *tenuicostatum* Zone to Lower Aalenian. Crux (1987), Early Jurassic of southern North Sea. Mattioli (1995a), Late Liassic of the Pozzale section (central Italy).

Occurrence. Central Italy - M. Cetona, Lower Toarcian; Colle d'Orlando, *tenuicostatum* Zone to *variabilis* Subzone; Pozzale, *tenuicostatum* Zone to *serpentinus* Zone; Fiuminata, Middle Toarcian to Aalenian; Monte Serrone, Toarcian; Cima Panco, *tenuicostatum* Zone to *serpentinus* Zone; Fonte Cerro, *tenuicostatum* Zone to *serpentinus* Zone. Portugal - Rabaçal, Lower to Middle Toarcian. Germany - Dotternhausen, *semicelatum* Zone to *falciferum* Zone (Toarcian).

Some considerations about evolutive lineages.

It is important to bear in mind that "... Evolution may be defined as the modification through time of genes and gene frequencies. In palaeontology it is seen as the modification through time of morphology, assuming that morphology is the phenotypic expression of the genotype. ..." (Bown, 1987b, p. 83). This observation lets us understand the importance of precise observations on morphometric variations, although our considerations concern parataxonomy, the objects of the study being single parts of the original organism.

During the Late Domerian-Early Toarcian time interval, the nannoplankton underwent an intense phase of diversification and turnover in the assemblage com-

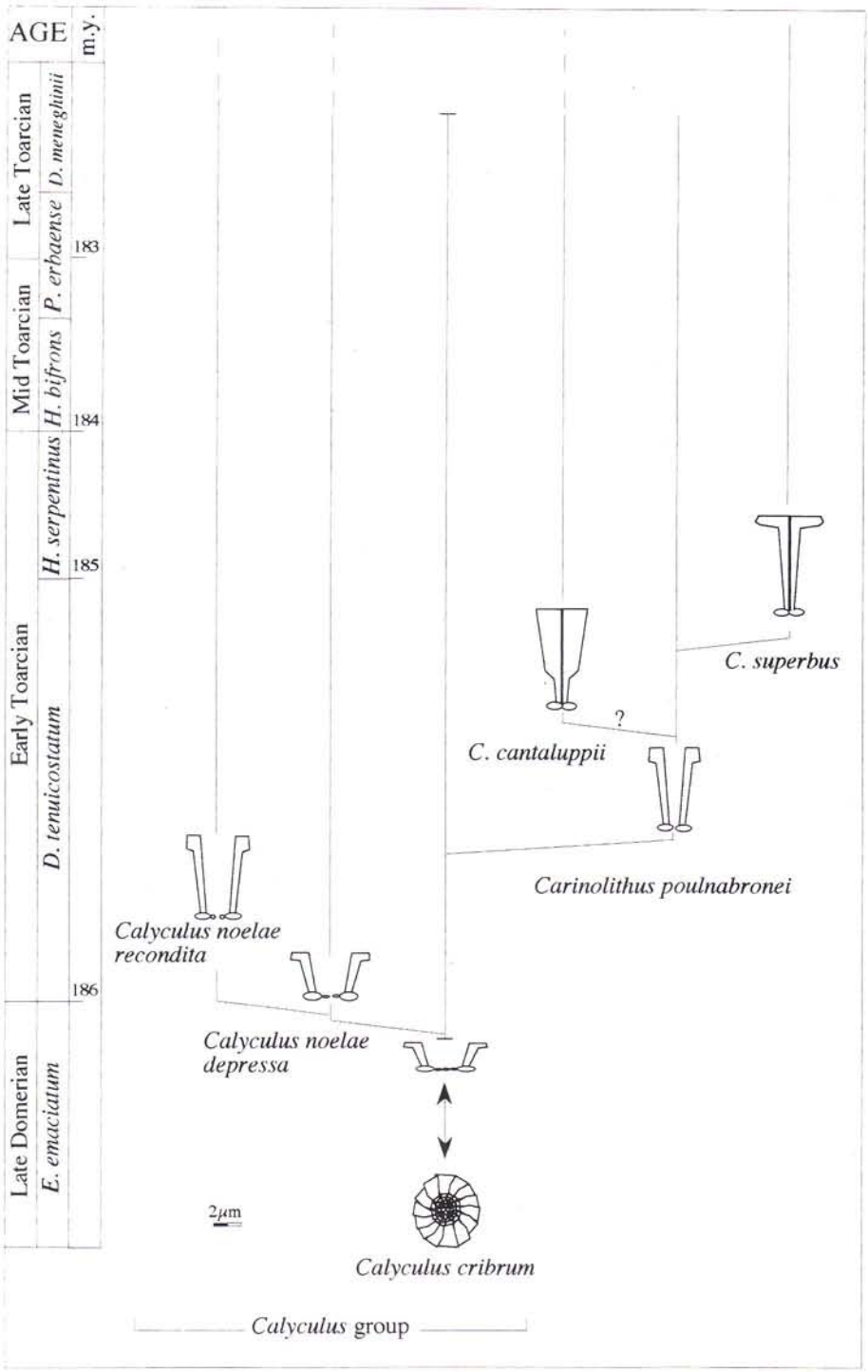


Fig. 3 - Evolutive lineage from the genus *Calyculus* Noël, 1973 to the genus *Carinolithus* (Prins in Grün et al., 1974) Bown, 1987b.

position. Accelerated biological processes occurred at that time and several species and genera first appeared. The new species discussed in the present paper all first appeared during this intense phase of diversifications that lasted about four million years.

Radiating placolith rim group: Calyculaceae lineage.

The evolutive lineage between the genera *Calyculus* and *Carinolithus*, already discussed by Bown (1987b), passes through a gradual vertical development of the elements of the distal shield with the contemporary tendency to the closing of the axial canal and reduction of the total width and central area dimensions of the proximal shield. A similar evolutionary trend was first observed by Prins (1969), who considered these forms as evolved from *Crepidolithus crassus*. Crux (1987) considered as a significant evidence of the evolution of *Calyculus* sp. into *Discorhabdus* (= *Carinolithus*) *superbus* the development of a more circular shape of the coccolith and the reduction of the central area dimensions.

Within the genus *Calyculus*, specimens with a similar coccolith arrangement but with a different thic-

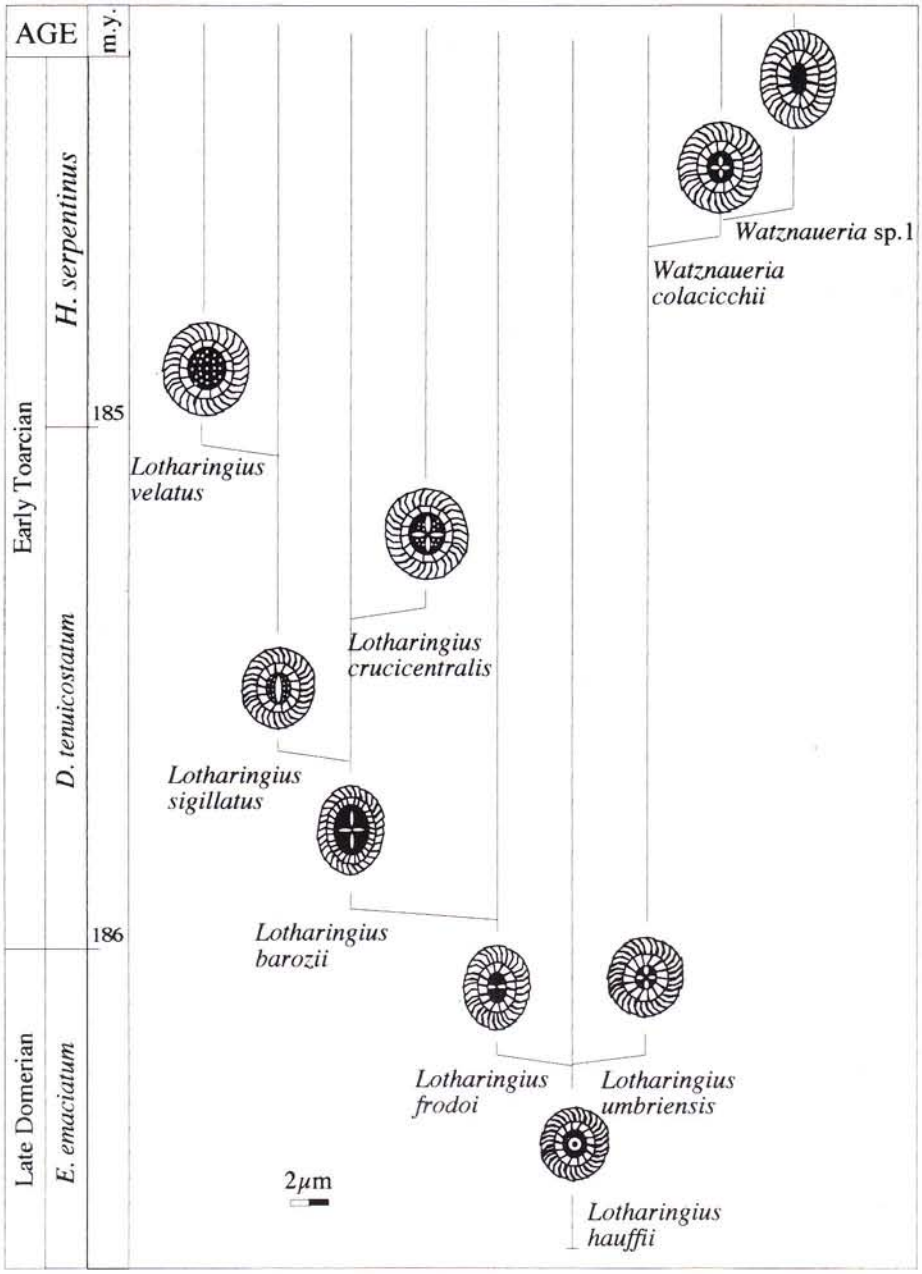


Fig. 4 - Evolutive lineage from the genus *Lotharingius* Noël, 1973 emend. Goy, 1979 to the genus *Watznaueria* Reinhardt, 1964.

kness of the distal shield have been observed in side view, namely *Calyculus cribrum*, *C. noelae depressa* and *C. noelae recondita*. These forms are here grouped into the *Calyculus* spp. group (Fig. 2 and 3), as it is difficult to observe them in side view. The new species here described has to be placed within the genus *Carinolithus*, despite its thickness, because of the presence for the first time of a quite developed vertical extension of the distal shield and an almost reduced axial canal. A similar trend toward an increase of the height of the stem and reduction of the central area is observed also in the most common representative of the genus, *C. superbus*, that in some youngest forms appears exceptionally developed distally. *Carinolithus cantaluppii* could be considered as a species derived from *C. poulnabronei* (Fig.3) by a reduction of the width of the proximal side of the stem, once demonstrated its younger occurrence with respect to *C. poulnabronei*.

The transition between the genera *Calyculus* and *Carinolithus* is observed to be fairly rapid and occurs within the *tenuicostatum* Zone (Fig. 3). The appearance of the genus *Carinolithus* in the lowermost part of the Toarcian is highly relevant for biostratigraphy.

Imbricating placolith rim group: Watznaueriaceae lineage.

The author agrees with the general tendency, already observed by Cobianchi et al. (1992), of an increase in coccolith size in successive new taxa both of *Lotharingius* and *Watznaueria*. Moreover, Cobianchi et al. (1992) evidenced some important morphological modifications in the evolution within the genus *Lotharingius*

regarding both rim and central area structures (pp. 22-23).

The main modifications within the genus *Lotharingius* observed in the present paper pass trough: 1) an increase of the dimensions of the elliptical central area, with a consequent reduction of the ratio margin/central area dimensions; 2) an increase of the outer cycle with respect to the inner cycle in distal view; 3) the development of more complex central area structure, passing from simple bars or crosses aligned with the axes of the ellipse (i.e. in *L. frodoi* and *L. barozii*) to little and numerous granular elements, disposed both longitudinally and radially (i.e. in *L. velatus*).

The existence of specimens of *Lotharingius* with a monocyclic distal shield (i.e. *L. primigenius*) is questionable. More probable is the loss of some shield structure by dissolution, as already observed by Bown (1987b, p. 63). In the present paper it is hypothesized that, beginning from the most ancestral *Lotharingius* (i.e. *L. hauffii*), two evolutive lineages occurred (Fig. 4): 1) the *Lotharingius* lineage is characterized by an enhancement of the general elliptical shape, an increase of the dimensions of both coccolith and central area. In distal view, the outer/inner cycle ratio varies from 1:1 to 2:1 in the most evolved *Lotharingius* (Fig. 1). The central area structures evolved into an increasingly complex arrangement of granular elements, such as in *L. velatus* (Fig. 4); 2) the *Watznaueria* lineage includes: a) a tendency toward a broadly elliptical to subcircular shape of the coccolith, b) reduction of the central area, c) simplifications of the central structures and d) an increase of the optical discontinuity between the inner and outer cycle of the distal shield, due both to an accentuation of the concavo-convexity and to a major inclination and imbrication of the outer cycle elements. In distal view, the outer/inner cycle ratio is 2:1 to 3:1 (Fig. 1). The outer cycle is thus always more developed than the inner cycle.

Watznaueria colacicchii sp. nov. evolving from the most ancestral species of the genus *Lotharingius* underwent considerable reduction in size of the central area which resulted in a shrinking of the central cross complex (Fig. 4). Its occurrence is almost contemporary with the appearance of *Watznaueria* sp. 1 of Cobianchi et al. (1992), characterized by a small and open central area. A common evolutive origin can be tentatively hypothesized for these two species.

Species Index.

Division Prymnesiophyta Hibberd, 1976
Class Prymnesiophyceae Hibberd, 1976
Order Eiffellithales Rood, Hay & Barnard, 1971
Family Zygodiscaceae Hay & Mohler, 1967
Genus *Crepidolithus* Noël, 1965

Crepidolithus crassus (Deflandre, 1954) Noël, 1965

Family Calyculaceae Noël, 1973
Genus *Calyculus* Noël, 1973
Calyculus cribrum Noël, 1974 emend. Goy 1979
Calyculus noelae depressa (Goy in Goy et al., 1979) Crux, 1987
Calyculus noelae recondita (Goy in Goy et al., 1979) Crux, 1987

Genus *Carinolithus* (Prins in Grün et al., 1974) Bown, 1987b
Carinolithus cantaluppii Cobianchi, 1990
Carinolithus poulnabronei sp. nov.

Order Watznauerialesales Bown, 1987b
Family Watznaueriaceae (Rood et al., 1971) Bown, 1987b
Genus *Lotharingius* Noël, 1973 emend. Goy, 1979

Lotharingius barozii Noël, 1973
Lotharingius crucicentralis (Medd, 1971) Grün & Zweili, 1980
Lotharingius frodoi sp. nov.
Lotharingius hauffii Grün & Zweili in Grün et al., 1974
Lotharingius primigenius Bown, 1987b
Lotharingius sigillatus (Stradner, 1961) Prins in Grün et al., 1974
Lotharingius umbriensis sp. nov.
Lotharingius velatus Bown & Cooper, 1989

Genus *Watznaueria* Reinhardt 1964

Watznaueria colacicchii sp. nov. Mattioli & Reale
Watznaueria contracta (Bown & Cooper, 1989) Cobianchi, Erba & Pirini Radrizzani, 1992
Watznaueria sp. 1 Cobianchi, Erba & Pirini Radrizzani, 1992

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