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20. CRETACEOUS CALCAREOUS NANNOFOSSIL BIOSTRATIGRAPHY OF SEDIMENTS RECOVERED FROM THE GALICIA MARGIN, ODP LEG 103[1]

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ABSTRACT

Ocean Drilling Program Leg 103 recovered Lower Cretaceous sediments from the Galicia margin off the coast of Iberia. The high diversity and abundance of assemblages makes this excellent material for the study of Early Cretaceous calcareous nannofossils.

With the exception of a hiatus between the upper Hauterivian and lower Barremian, nannofossil distributions form a continuous composite section from the lower Valanginian to lower Cenomanian sediments recovered at the four sites. The sedimentation history of this rifted continental margin is complex, and careful examination of the nannofossil content and lithology is necessary in order to obtain optimum biostratigraphic resolution.

The Lower Cretaceous sequence consists of a lower Valanginian calpionellid marlstone overlain by terrigenous sandstone turbidites deposited in the Valanginian and Hauterivian during initial rifting of this part of the margin. Interbedded calcareous marl and claystone microturbidites overlie the sandstone turbidites. Rifting processes culminated in the late Aptian–early Albian, resulting in the deposition of a calcareous, clastic turbidite sequence. The subsequent deposition of dark carbonaceous claystones (black shales) represents the beginning of seafloor spreading, as the margin continued to subside to depths near or below the CCD. The diversity, abundance, and preservation of nannofossils within these varied lithologies differ, and an attempt to distinguish between nearshore and open-marine assemblages is made. Genera used for this purpose include *Nannoconus, Micrantholithus, Pickelhaube*, and *Lithraphidites.*

In this study, six new species and one new subspecies are described and documented. Ranges of other species are extended, and an attempt is made to clarify existing, yet poorly understood, taxonomic concepts. A technique in which a single specimen is viewed with both light and scanning electron microscopes was used extensively to aid in this task. In addition, further subdivisions of the Sissingh (1977) zonation are suggested in order to increase biostratigraphic resolution.

INTRODUCTION

Leg 103 of the Ocean Drilling Program (ODP) drilled a total of 15 holes at five sites on the Galicia margin (Fig. 1). From four of the sites drilled, a nearly continuous, composite section ranging in age from early Valanginian to early Cenomanian is recognized based on the recovered nannofossil assemblages. The main goals of the cruise were to record and document the timing of rifting, subsidence, and sedimentation on the Galicia margin and to determine when rifting processes ceased and seafloor spreading began between Iberia and its conjugate margin, Newfoundland.

Sites 638, 639, and 641 were drilled on a tilted fault block in an attempt to recover pre-rift, syn-rift, and post-rift sediments (Fig. 2). These sites yielded a continuous, lithologically complex, composite section with abundant and well-preserved Lower Cretaceous nannofossils. The pre-rift sediments, which overlie continental basement, consist of crystalline limestones and dolomites, essentially devoid of nannofossils, that were deposited in shallow water in the Late Jurassic and earliest Cretaceous. As rifting began, terrigenous material was shed onto the rapidly subsiding margin in the form of turbidites. Episodic rifting continued up to the late Aptian/early Albian, when rifting ceased and seafloor spreading began. The corresponding change in sedimentation has been termed the break-up unconformity (Deep Sea Drilling Project (DSDP) Leg 47B; Sibuet, Ryan, et al., 1979) and is denoted by a change from shallow-water, clastic calcareous turbidites to deep-water dark claystones deposited near or below the carbonate compensation depth (CCD).

This study documents the occurrence, abundance, and preservation of Lower Cretaceous nannofossils recovered during ODP Leg 103. In addition, the relationship between lithology and nannofossil assemblages is discussed, and new taxa are described and documented. Six new species and one new subspecies are described from the Galicia margin Lower Cretaceous sequence. The ranges of numerous species, which are restricted in other studies because of ecologic, geographic, and/or preservational effects, have been extended. Several subdivisions of the Sissingh (1977) zonation are suggested and formally presented in this report.

Species considered in this report (Appendix A) are listed alphabetically by generic and specific epithets in Appendices B and C, respectively. Most of the bibliographic references for these taxa are given by Loeblich and Tappen (1966, 1968, 1969, 1970a, 1970b, 1971, 1973), Van Heck (1979a, 1979b, 1980a, 1980b, 1981a, 1981b, 1982a, 1982b, 1983), and Steinmetz (1984a, 1984b, 1985, 1986). Entries not found therein are given in the references.

PREVIOUS LOWER CRETACEOUS NANNOFOSSIL STUDIES IN THE NORTH ATLANTIC BASIN

Lower Cretaceous nannofossils were reported by Wind and Cepek from DSDP Site 397 (Sibuet, Ryan, et al., 1979) off the northwest coast of Africa. Moderately well-preserved Hauterivian(?) nannofossils were recovered and many new taxa were described from the site. However, problems with taxonomic concepts, preservation, and the limited section containing nannofossils made precise dating of the sediment recovered difficult.

Site 398 (Sibuet, Ryan, et al., 1979), south of Galicia Bank on the Vigo Seamount, recovered upper Hauterivian to Cenomanian sediments containing poorly preserved nannofossils (Blechschmidt, 1979), making this site a poor section for the study of Lower Cretaceous calcareous nannofossils.

Roth (1978, 1983) studied calcareous nannofossils from Lower Cretaceous sediment recovered at Sites 391 (DSDP Leg 44) and

[1] Boillot, G., Winterer, E. L., et al., 1988. *Proc. ODP, Sci. Results*, 103: College Station, TX (Ocean Drilling Program).

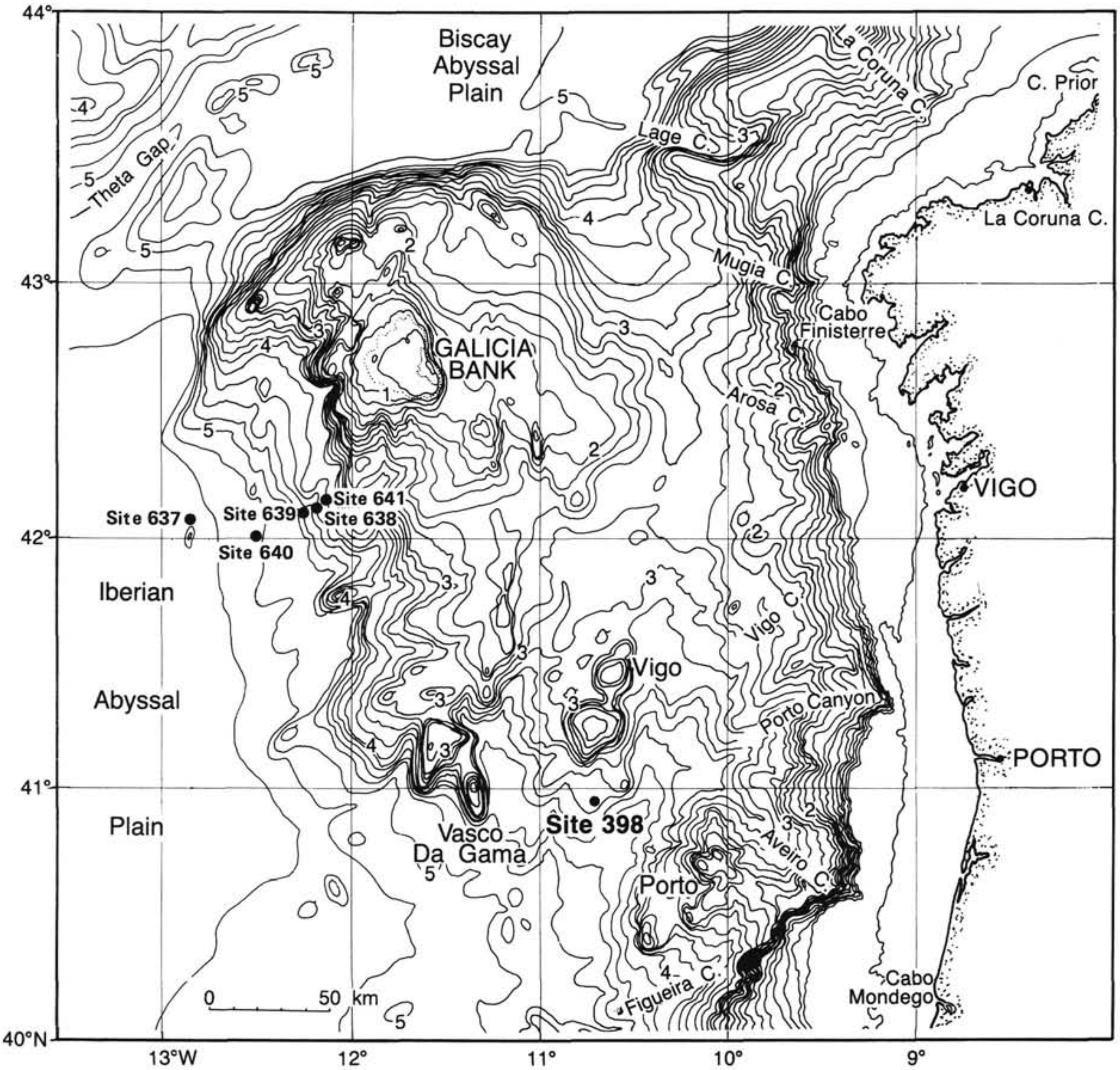

Figure 1. ODP Leg 103 site location map of the Galica margin. Bathymetry in kilometers.

534 (DSDP Leg 76) in the Blake-Bahama Basin, which provided him with the foundation for his coded number zonations.

Covington and Wise (1987) reported the nannofossil biostratigraphy of a Neocomian deep-sea fan complex at Site 603 off the eastern continental margin of North America. They noted variations in the composition of nannofossil assemblages with lithology at this site, where reworking by turbidites complicated the biostratigraphy. They attributed the nearshore nannofossil species present in the deep-sea environment to a process in which sediment is shed from within the oxygen-minimum zone along the upper slope to the outer shelf by turbidity currents. This phenomenon was widespread during the Neocomian in the North Atlantic–Tethyan realm.

METHODS

For the construction of range charts, standard smear slides were prepared from raw sediment using a method described by Hay (1970). Smear slides were then analyzed using a Zeiss Photomicroscope III under 1560× magnification. Abundances for each sample for both the total number of nannofossils and for individual species were estimated. Letters used on the range charts are keyed to the $^{10}\log$ of the number of specimens likely to be observed in any one field of view. These and the corresponding logarithms are as follows:

V = very abundant, + 1 (more than 20 specimens per field of view)
A = abundant, 0 (1 to 10 specimens per field of view)
C = common, − 1 (1 specimen per 11 to 100 fields of view)
F = few, − 2, (1 specimen per 11 to 100 fields of view)
R = rare, − 3, (1 specimen per 101 to 1000 fields of view)

Reworked taxa are indicated on range charts by lowercase letters.

Nannofossil preservation in each sample is denoted as follows:

G = good (specimens show little or no dissolution and/or overgrowth)
M = moderate (specimens show some dissolution and/or overgrowth; identification of species not impaired)
P = poor (specimens show significant dissolution and/or overgrowth; identification of species is impaired, but some still possible)

Selected samples containing well-preserved nannofossils were studied using a method devised by F. Wind (pers. comm., 1985) in which a single specimen is photographed with both light and scanning electron (SEM) microscopes. Wind used the method in several publications (Wise and Wind, 1977; Cepek and Wind, 1979) but never described the procedure. The method involves using a rubber stamp and rapidograph ink to

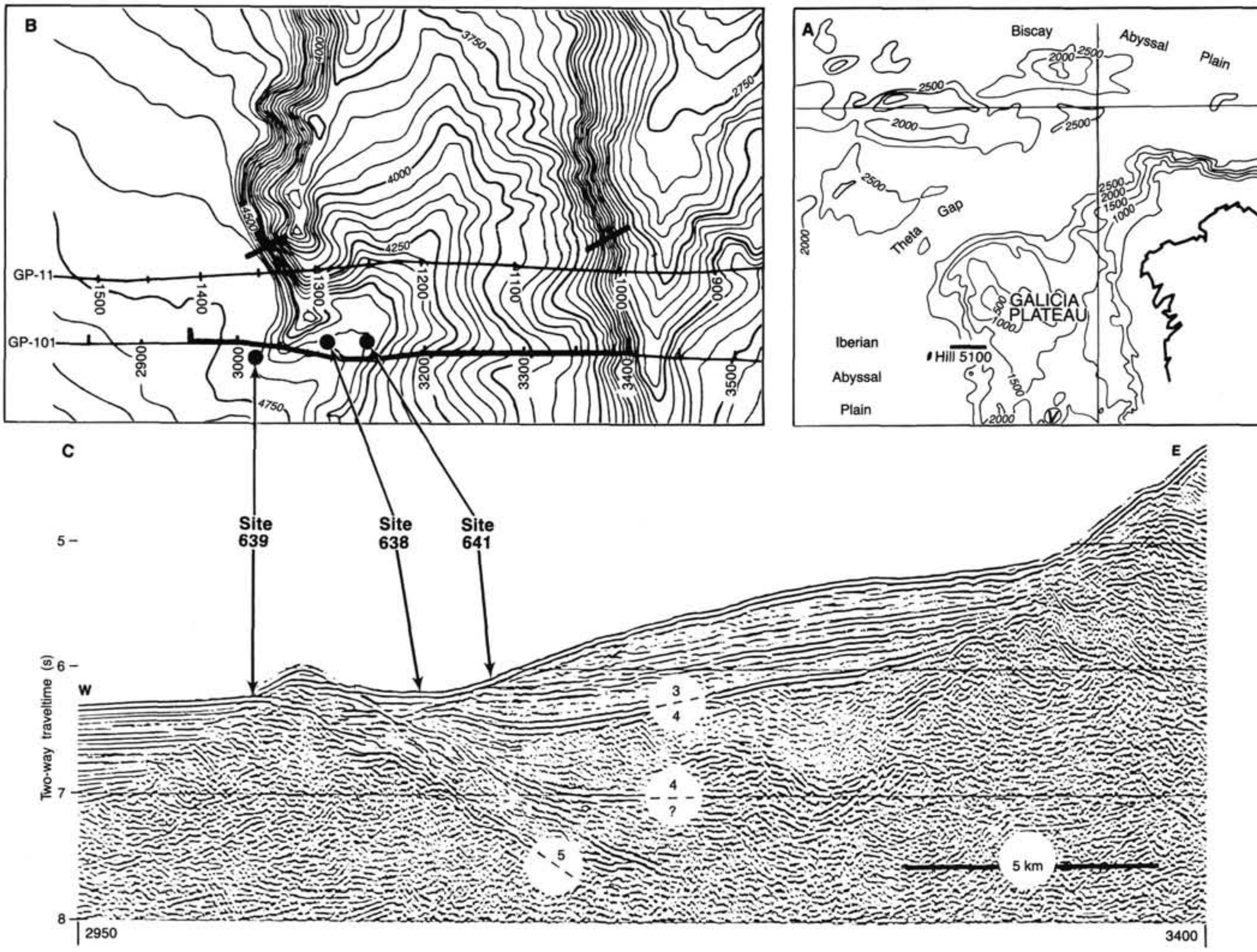

Figure 2. **A.** Galicia margin. **B.** Sea Beam map of the area near Sites 638, 639, and 641. **C.** Multichannel seismic profile GP-101, showing the location of Sites 638, 639, and 641. 3 = post-rift strata; 4 and 5 = syn-rift strata. Bathymetry in meters. Courtesy of L. Montadert.

make a grid on a round SEM coverslip. A drop of solution containing concentrated nannofossils is placed on the coverslip and allowed to dry. The coverslip is then attached to a glass slide with the concentrate facing up, and immersion oil is placed directly onto the concentrate. Specimens are photographed under the light microscope, and their location with respect to letters and other objects on the grid is recorded. The coverslip is submerged in a xylene bath three times and washed in isopropyl alcohol until all oil is removed and the sample on the coverslip appears dry, which only takes a few minutes. The coverslip is glued to an SEM stub and coated with a gold palladium alloy. The sample is then viewed under the SEM, and the specimens are relocated and photographed. This technique was used extensively in this study to document new species and to add more information for resolving existing taxonomic problems of several Lower Cretaceous nannofossils.

ZONATION AND SPECIES CONSIDERED

Past studies of Lower to middle Cretaceous nannofossils have produced many zonations. Different biogeographic settings, poor preservation of assemblages, and a general lack of studied Lower Cretaceous sections are several reasons why there is no widely accepted zonation. The majority of Lower Cretaceous zonations are based on Thierstein (1971, 1973, 1976), who studied stratotype and paratype sections in Europe and correlated the nannofossil biostratigraphy to ammonite, calpionellid, and foraminiferal biostratigraphy in the framework of the Lower Cretaceous Stages. Sissingh (1977) first applied a coded numbering system to the Cretaceous, modifying many of the existing Lower to middle Cretaceous zonations of Thierstein (1971, 1973) and Manivit et al. (1977). Perch-Nielsen (1979, 1985) further refined the zonation of Sissingh (1977) by correlating a significant number of nannofossil events to his number-coded (CC) zones. This zonation is closely followed in this report. It is also compared with the number-coded (NC) zonation of Roth (1978, 1983), based on the Lower Cretaceous of the western North Atlantic. A summary chart of both zonations along with modifications is shown in Figure 3. The following is a summary of the zonation scheme used in this report.

Retecapsa angustiforata Zone (CC2)

Definition. Interval from the first occurrence of *Retecapsa angustiforata* to the first occurrence of *Calcicalathina oblongata.*

Authors. Thierstein, 1971.

Age. Late Berriasian to early Valanginian.

Tubodiscus verenae Subzone (CC3a) of the *Calcicalathina oblongata* Zone (CC3)

Definition. Interval from the first occurrence of *C. oblongata* to the first occurrence of *Eiffellithus windii.*

Authors. CC3: Thierstein (1971), modified by Sissingh (1977) and Perch-Nielsen (1979). CC3a: this paper.

Age. Early Valanginian.

Remarks. The subdivision of CC3 is suggested here based on the first occurrence of *E. windii* n. sp. Although described here as new, it is illustrated as *Eiffellithus* sp. in earlier reports (see Appendix A). Al-

Stage	Age (m.y.) Van Hinte (1976)	Zone: Roth (1978, 1983)	Zone: Sissingh (1977), modified	Subzone		Datum level
early Cenomanian		NC11	CC10 *Microrhabdulus decoratus*	CC10b	*Gartnerago obliquum*	FAD *Quadrum gartneri*
				CC10a	*Microstaurus chiastius*	LAD *Microstaurus chiastius*
Albian	100	NC10	CC9 *Eiffellithus turriseiffeli*	CC9b	*Prediscophaera spinosa*	FAD *Lithraphidites acutus*
				CC9a	*Hayesites albiensis*	LAD *Hayesites albiensis*
		NC9	CC8 *Prediscosphaera columnata*	CC8b	*Tranolithus phacelosus*	FAD *Eiffellithus turriseiffeli*
		NC8		CC8a	*Braarudosphaera africana*	FAD *Tranolithus phacelosus*
Aptian	108	NC7	CC7 *Chiastozygus litterarius*	CC7b	*Rhagodiscus angustus*	FAD *Prediscosphaera columnata*
		NC6		CC7a	*Hayesites irregularis*	FAD *Eprolithus floralis*
Barremian	115	NC5b	CC6 *Micrantholithus hoschulzii*			FAD *Hayesites irregularis*
	121	NC5a	CC5 *Lithraphidites bollii*			LAD *Calcicalathina oblongata*
Hauterivian		NC4b	CC4 *Cretarhabdus loriei*	CC4b	*Speetonia colligata*	LAD *Speetonia colligata*
		NC4a		CC4a	*Eiffellithus striatus*	FAD *Lithraphidites bollii*
Valanginian	126	NC3	CC3 *Calcicalathina oblongata*	CC3b	*Eiffellithus windii*	FAD *Eiffellithus striatus*
				CC3a	*Tubodiscus verenae*	FAD *Eiffellithus windii*
Berriasian	131	NC2	CC2 *Retacapsa angustiforata*			FAD *Calcicalathina oblongata*
		NC1	CC1 *Nannoconus steinmannii*			FAD *Retacapsa angustiforata*

Figure 3. Summary figure of zonations considered and used in this study.

though rare to few in abundance in the study material, *E. windii* is taxonomically distinct and stratigraphically consistent in the early part of its range, making it a useful datum.

Eiffellithus windii Subzone (CC3b) of the *Calcicalathina oblongata* Zone (CC3)

Definition. Interval from the first occurrence of *E. windii* to the first occurrence of *Eiffellithus striatus.*

Authors. CC3: Thierstein (1971), modified by Sissingh (1977) and Perch-Nielsen (1979). CC3b: this paper.

Age. CC3b: late Valanginian.

Remarks. The *C. oblongata* Zone was originally defined by Thierstein (1971) and extended from the first occurrence of *C. oblongata* to the first occurrence of *Lithraphidites bollii*. Sissingh (1977) later modified the top of the zone to coincide with the first occurrence of *Cretarhabdus loriei*. Perch-Nielsen (1979) suggested the substitution of the first occurrence of *E. striatus* for the first occurrence of *C. loriei* in the Boreal region, a datum followed in this study.

As previously mentioned, Sissingh (1977) used the first occurrence of *C. loriei* (Gartner) to mark the top of this zone. However, some workers restrict this species concept to forms that occur only in Aptian and younger strata and, thus, do not recognize this species in older sediments. The top of Roth's (1978) NC3 Zone at the Valanginian/Hauterivian boundary is defined by the last occurrence of *T. verenae* and *Diadorhombus rectus*. In the study material, *T. verenae* ranges well up into the Hauterivian above the first occurrence of *L. bollii*, whereas *D. rectus* ranges into the upper Barremian above the last occurrence of *C. oblongata, L. bollii,* and *Speetonia colligata*. Therefore, the last occurrence of *T. verenae* and *D. rectus* appear diachronous and cannot be used to define the Valanginian/Hauterivian boundary. The last occurrence of an additional form used by Roth (1983), *Cyclagelosphaera deflandrei*, seems to be controlled by preservation and is not considered trustworthy (Covington and Wise, 1987). The rare but consistent occurrence of the distinctive form *E. striatus* makes it a useful datum for the top of CC3 in this study.

Eiffellithus striatus Subzone (CC4a) of the *Cretarhabdus loriei* Zone (CC4)

Definition. CC4a: interval from the first occurrence of *E. striatus* to the first occurrence of *L. bollii*.

Authors. CC4: Sissingh (1977), modified by Perch-Nielsen (1979). CC4a: this paper.

Age. CC4a: early Hauterivian.

Remarks. In this region, the occurrence of certain nannofossil species such as *L. bollii* and *C. oblongata* suggest a Tethyan or tropical environment. However, other forms previously reported only from Boreal regions, such as *Nannoconus abundans* and *E. striatus*, are also present, suggesting that the Galicia margin occupied a region intermediate between the two realms.

Speetonia colligata (CC4b) Subzone of the *Cretarhabdus loriei* Zone (CC4)

Definition. Interval from the first occurrence of *L. bollii* to the last occurrence of *S. colligata*.

Authors. CC4: Sissingh (1977) and Perch-Nielsen (1979). CC4b: this paper.

Age. CC4b: late early Hauterivian to late Hauterivian.

Lithraphidites bollii Zone (CC5)

Definition. Interval from the last occurrence of *S. colligata* to the last occurrence of *C. oblongata*.

Authors. Thierstein (1971), emended by Sissingh (1977).

Age. Latest Hauterivian to early Barremian.

Micrantholithus hoschulzii Zone (CC6)

Definition. Interval from the last occurrence of *C. oblongata* to the first occurrence of *Hayesites irregularis.*

Authors. Thierstein (1971), emended by Thierstein (1973) and Sissingh (1977).

Age. Late Barremian.

Remarks. Thierstein (1976) noted that the first occurrence of *H. irregularis* is right before the first occurrence of *Chiastozygus litterarius* (or *Chiastozygus platyrhethus* in Perch-Nielsen, 1979). However, the first occurrence of *C. literarius* has been clearly shown in this study and by other authors to extend into the Hauterivian, rendering its first occurrence useless as a Barremian-Aptian datum. The last occurrence of *Nannoconus steinmannii/colomii*, which Thierstein (1971, 1973) placed at the top of CC6, extends into the lower Aptian and cannot be used to recognize the Barremian/Aptian boundary. Therefore, the first occurrence of the distinctive form *H. irregularis* (see Appendix A) is used in this study to mark the nannofossil Barremian/Aptian boundary.

Hayesites irregularis Subzone (CC7a) of the
Chiastozygus litterarius Zone (CC7)

Definition. Interval from the first occurrence of *H. irregularis* to the first occurrence of *Eprolithus floralis*.

Authors. CC7a: Thierstein (1971), emended by Manivit et al. (1977).

Age. CC7a: early Aptian.

Remarks. Thierstein (1971) suggested that the first occurrence of *Rhagodiscus angustus* coincides with that of *E. floralis*, but it is likely that *R. angustus* has its first occurrence higher than *E. floralis*. The last occurrences of *Micrantholithus hoschulzii/obtusus, N. steinmannii*, and *Conusphaera mexicana* all occur near the top of CC7a but are difficult to use where reworking exists.

Rhagodiscus angustus Subzone (CC7b) of the
Chiastozygus litterarius Zone (CC7)

Definition. First occurrence of *E. floralis* to the first occurrence of *Prediscosphaera columnata*.

Authors. CC7b: Thierstein (1971), emended by Manivit et al. (1977).

Age. Late Aptian to earliest Albian.

Remarks. This subzone corresponds to Thierstein's (1971) *Parhabdolithus angustus* Zone.

Braarudosphaera africana Subzone (CC8a) of the
Prediscosphaera columnata Zone (CC8)

Definition. Interval from the first occurrence of *P. columnata* to the first occurrence of *Tranolithus phacelosus* (= *Tranolithus exiguus* = *Tranolithus orionatus*).

Authors. CC8: Thierstein (1971), emended by Manivit et al. (1977). CC8a: suggested by Perch-Nielsen (1979), formally presented in this paper.

Age. CC8a: early Albian.

Remarks. Perch-Nielsen (1979) first suggested the subdivision of CC8 into two subzones by using the first occurrences of the co-markers *T. phacelosus* and *Corollithion signum*, and the genus *Cribrosphaerella*. The subdivision is formally presented here.

Tranolithus phacelosus Subzone (CC8b) of the
Prediscosphaera columnata Zone (CC8)

Definition. Interval from the first occurrence of *T. phacelosus* to the first occurrence of *Eiffellithus turriseiffeli*.

Authors. CC8: Thierstein (1971), emended by Manivit et al. (1977). CC8b: suggested by Perch-Nielsen (1979), formally presented in this paper.

Age. Late Albian.

Hayesites albiensis Subzone (CC9a) and *Prediscosphaera spinosa*
Subzone (CC9b) of the
Eiffellithus turriseiffeli Zone (CC9)

Definition. CC9a: the interval from the first occurrence of *E. turriseiffeli* to the last occurrence of *Hayesites albiensis*. CC9b: the interval from the last occurrence of *H. albiensis* to the first occurrence of *Lithraphidites acutus*.

Age: CC9a: late Albian. CC9b: latest Albian to early Cenomanian.

Remarks. The subzones of CC9 are basically those of Manivit et al. (1977), which have been correlated to the number-coded scheme of Sissingh (1977).

Microstaurus chiastius (CC10a) of the
Microrhabdulus decoratus Zone (CC10)

Definition: Interval from the first occurrence of *L. acutus* to the last occurrence of *Microstaurus chiastius*.

Age. Late early Cenomanian.

Gartherago obliquum Subzone (CC10b) of the
Microrhabdulus decoratus Zone (CC10)

Definition. Interval from the last occurrence of *M. chiastus* to the lowest occurrence of *Quadrum gartneri*.

Age. Late Cenomanian.

Remarks. Subzones CC10a and CC10b are based on those of Manivit et al. (1977), which are assigned to Sissingh's (1977) number-coded scheme. Perch-Nielsen (1979) shows the first occurrence of *Microrhabdulus decoratus* and *L. acutus* at the base of CC10. However, Verbeek (1977) and others show the first occurrence of *M. decoratus* in the upper middle Cenomanian to upper Cenomanian, above the first occurrence of *L. acutus*.

LITHOSTRATIGRAPHY

Because of drilling difficulties during Leg 103, a series of holes were drilled rather than the initially planned single reentry hole. As a result, we recovered sections that combine to form a complete, composite section with a complex history of sedimentation. As pointed out by Covington and Wise (1987), it has become increasingly important to pay close attention to lithologies and sedimentary environments in working with Lower Cretaceous nannofossils of the North Atlantic and Tethyan regions. Ranges of many species are not well known because of preservation, ecologic restriction, and/or a general lack of Lower Cretaceous sequences that contain diverse, well-preserved nannofossil assemblages. In addition, many of the sites drilled on the North Atlantic–Tethyan continental margins have recovered Neocomian, Wealden-type sequences characterized by deep-sea fan complexes consisting of nearshore sediments redeposited as turbidites. Reworking is common in these varied lithologies, and careful interpretations of the nannofossil biostratigraphy must be made. For this reason, the use of highest occurrences as datums, which are difficult to determine and apply, has been avoided as much as possible.

Figure 4 is a compilation of the composite sections from Sites 638 through 641. Lithology, age, and depth are shown, along with general correlations among the local lithologic units and the oceanic formations proposed by Jansa et al. (1979) for the North Atlantic, where possible. A detailed description of the nannofossil assemblages is given in the next section of this paper (see "Biostratigraphy"), but a few general comments on the occurrence of key taxa in relation with lithology are included here.

Lithologic Unit III (Holes 641A and 641C): 149 m of middle Cretaceous (Aptian to lower Cenomanian) greenish gray and black claystone and calcareous clay and marl (53.9–202.6 m below seafloor (mbsf): Samples 103-641A-6X, CC (20 cm) to 103-641C-6R-3, 58 cm [Hatteras Formation]).

The upper part of this unit, consisting of greenish calcareous clay and marl, contains a highly diverse and moderately well-preserved nannofossil assemblage (latest Albian to early Cenomanian in age). The lower part of the unit, composed of dark, greenish gray and black claystones, contains assemblages in which diversity is greatly reduced and preservation is poorer. This indicates deposition either near or below the CCD, because the black claystones are generally barren whereas the lighter greenish claystones contain variable abundances of nannofossils.

Lithologic Unit IV (Hole 641C): 16 m of upper Aptian greenish gray marlstone and limestone conglomerate (calcareous turbidite) (202.6–218.3 mbsf: Samples 103-641C-6R-3, 58 cm, to 103-641C-7R, CC [11 cm]).

The marlstone and limestone conglomerate contain well-preserved, diverse nannofossil assemblages that were redeposited as turbidites, as shown by the presence of early Barremian species in samples of late Aptian age from Section 103-641C-6R-3. One sample taken from inside a shell in a shell lag layer contains common *Pickelhaube furtiva*, a shallow-water form that is usually rare in other samples. It should be noted that the excellent preservation of the nannofossils in this redeposited material clearly demonstrates the minimal damage that nannofossils experience during transportation by turbidites. Therefore, nanno-

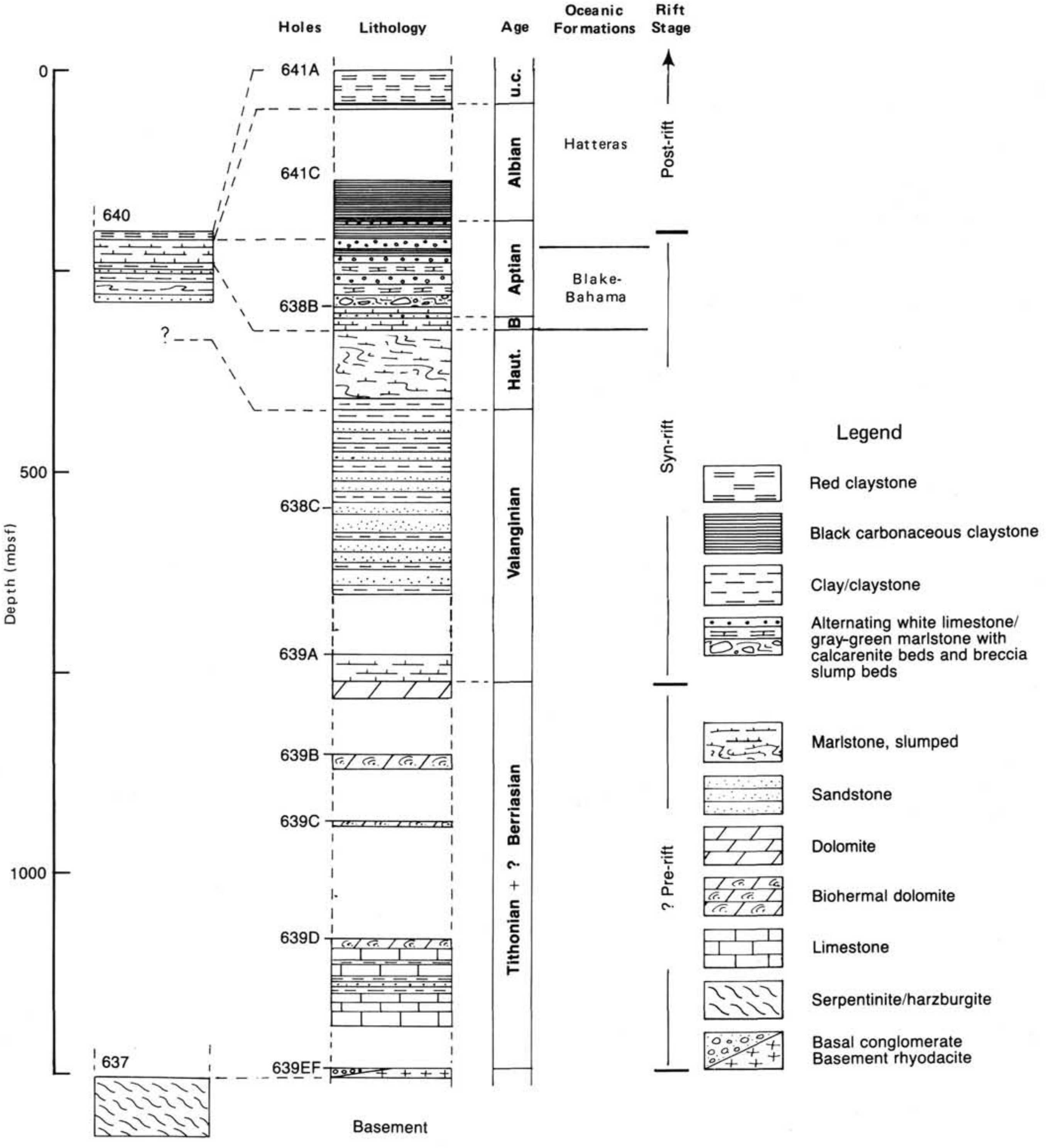

Figure 4. Compilation of composite sections including lithology, age, depth, and general correlations of lithologic units to oceanic formations.

fossil preservation generally should not be used as a factor in considering whether sediment has been redeposited.

Lithologic Unit V (Hole 641C): 32 m of lower Aptian, greenish gray calcareous microturbidites and marlstone (similar to part of the Hatteras Formation) (218.4–250.6 mbsf: Samples 103-641C-8R-1, 0 cm, to 103-641C-11R-3, 36 cm).

Unit V consists of alternations of highly varied lithologies on a scale of 10 to 50 cm. The upper part is less calcareous and contains more black carbonaceous claystone. Minor interbedded lithologies include calcarenite turbidites and debris flows containing limestone and marlstone clasts. At the top of this unit, the genera *Micrantholithus, Nannoconus*, and *Lithraphidites* dominate the nannofossil assemblages, in another demonstration of the introduction of neritic forms into the deep-sea environment. These shallow-water forms are found in high abundance in the lighter, more calcareous laminae of marl and limestone, where preservation is poor to moderate. The claystone and calcareous claystones contain better preserved nannofossils and fewer neritic forms, reflecting deposition in a more pelagic, open-ocean setting.

Lithologic Units VI (Hole 641C) and IIA (Hole 638B): Up to 50 m of upper Barremian to lower Aptian alternating light gray bioturbated limestone and clayey limestone, laminated marlstone, and calcareous microturbidites (upper part similar to the Blake-Bahama Formation, overall intermediate between Hatteras and Blake-Bahama lithologies) (250.6–305.2 mbsf: Samples 103-641C-11R-3, 26 cm, to 103-641C-16R, CC [22 cm]; 183.6–212.6 mbsf: Section 103-638B-20R, CC, to Sample 103-638B-23R-3, 3 cm).

These units are interpreted as distal turbidite deposits interbedded with extremely bioturbated limestones and marlstones (see "Sedimentology" section of "Site 641C" chapter; Boillot, Winterer, et al., 1987). The nannofossil preservation within the bioturbated limestones is very poor owing to an extensive dissolution and reprecipitation process whereby nannofossil-bearing sediment is converted to limestone (Schlanger and Douglas, 1974; Wise, 1977). This process is even more accelerated within bioturbated sediment. The nannofossil assemblage is similar to the overlying unit.

Lithologic Subunit IIB (Hole 638B): 86 m of lower Hauterivian to lower Barremian alternations of light bioturbated nannofossil marlstone and darker gray, more calcareous-rich nannofossil marlstone, deformed in places by slumping (212.6–298.4 mbsf: Samples 103-638B-23R-3, 27 cm, to 103-638B-32R-2, 95 cm).

This subunit was deposited predominantly in a pelagic setting and contains a highly diverse, moderately well-preserved nannofossil assemblage. At the top of the unit the assemblage is dominated by the genera *Nannoconus* and *Micrantholithus* and *L. bollii* (thought to be shallow-water forms; Thierstein, 1976). The abundance of these genera increase upward from the bottom of Subunit IIB, which indicates either a decrease in water depth or an increase in the amount of shallow-water material shed into deep water.

Lithologic Unit III (Site 638)

Up to 140 m of lower Valanginian to lower Hauterivian alternations of thin-bedded calcareous claystone and nannofossil marlstone laminae interbedded with terrigenous sandstone (298.4–547.2 mbsf: Samples 103-638B-32R-2, 9 cm, to 103-638C-14R, CC [30 cm]).

The lower Subunit IIIB is distinguished from the overlying Subunit IIIA by numerous, thick beds of terrigenous sandstone. The top of the highest thick sandstone bed is at 55 cm in Section 103-638B-35R-4. The nannofossil marlstone directly above Subunit IIIB contains the most diverse and well-preserved nannofossil assemblage in the Neocomian section. The diversity and overall species composition of the nannofossil assemblages change drastically in the lower sandstone turbidite subunit, where the nannoconids and micrantholiths are greatly reduced in numbers. The sandstone and claystone in Subunit IIIB are interpreted as turbidites, whereas the laminae of nannofossil marlstone are interpreted as representing background pelagic sedimentation (see "Sedimentology" section of "Site 638" chapter; Boillot, Winterer, et al., 1987). The marked decrease of nannofossils in the sandstone turbidites can be attributed to a high sedimentation rate for terrigenous material and a relatively small amount of pelagic deposition.

Lithologic Unit III (Hole 639A)

49 m of lower Valanginian pale yellow nannofossil marl/marlstone (21.6–70.3 mbsf: Samples 103-639A-4R-1, 10 cm, to 103-639A-8R, CC [7 cm]).

Nannoconids dominate assemblages in the nannofossil marl/marlstone. Change in the degree of lithification, and thus preservation, is observed downhole. A transition from soft marl to dominantly hard marlstone in Core 103-639A-7R is accompanied by a change in nannofossil preservation from poor to very poor. The triad of early Valanginian markers *C. oblongata, D. rectus*, and *T. verenae* is absent below this horizon, probably as a result of the changes in lithification and preservation.

A direct relationship between nannofossil content and lithology is observed in the varied and complex Lower Cretaceous sequence. Besides preservational changes, which are related to the higher calcite content and lithification, increased numbers of shallow-water forms redeposited from the upper slope–outer shelf to deeper water by way of turbidity flows, creeps, and slumps are observed. Despite the large amount of redeposited material, a nearly continuous stratigraphic section can be pieced together. The only significant hiatus detected in this sequence is where the upper Hauterivian–lower Barremian is missing at Holes 638B and 640A. These holes are approximately 31 km apart, demonstrating that this event may have occurred on a regional scale.

A close analogy to this sequence is that of Hole 637A (Wei et al., this volume), which contains redeposited material but is stratigraphically continuous. In Hole 637A, although upper Miocene to Recent siltstones, claystones, and nannofossil marls and oozes were redeposited into very deep water (~5000 m) by turbidity flows, a stratigraphically intact and nearly complete sequence is present with only one well-documented hiatus. Much of the material in these sections was redeposited, but the redeposition appears consistent and continuous, making use of the nannofossil biostratigraphy possible.

BIOSTRATIGRAPHY

As stated previously, a composite Lower Cretaceous sequence can be constructed from Holes 639A, 638B, 638C, 640A, 641A, and 641C. The range charts for each of these holes are in Tables 1–5 and include the total and individual species abundances, as well as the zonal assignments and ages for all samples examined. In the following biostratigraphic discussion, the five holes that make up this composite section are treated as one continuous section. Figure 5 shows the ranges of index nannofossils and other important species.

The oldest Early Cretaceous nannofossils recovered on ODP Leg 103 were from the calpionellid, nannofossil marlstone of Hole 639A. The occurrence of *C. oblongata, T. verenae*, and *D. rectus* in Sample 103-639A-7R-3, 101–102 cm, indicates an age no older than early Valanginian. *Cyclagelosphaera brezae* n. sp. and *Eiffellithus primus* n. sp. are present in many of the marlstone samples. Below Core 103-639A-7R, preservation worsens and assemblages are dominated by nannoconids and *Watznaueria barnesae*. The early Valanginian age determined from the nannofossils in this section is in good agreement with that given by the calpionellid and foraminiferal data (see "Biostratigraphy" section of "Site 639" chapter; Boillot, Winterer, et al., 1987).

Above the calpionellid-nannofossil marlstone of Hole 639A lies the sand turbidite sequence recovered in Holes 638B and 638C. The contact between the strikingly different lithologies was not recovered (the hole caved in and was abandoned just above this contact in Hole 638C). The diversity of nannofossils decreases and preservation worsens from the bottom of Hole

Table 1. Relative abundance of nannofossils, Hole 639A.

Age	Sissingh zonation (1977)	Lithologic unit	Abundance	Preservation	Sample	*Axopodorhabdus dietzmannii*	*Biscutum constans*	*Calcicalathina oblongata*	*Conusphaera mexicana*	*Cretarhabdus conicus*	*Cretarhabdus delicatus*	*Cretarhabdus surirellus*	*Cruciellipsis cuvillieri*	*Cyclagelosphaera brezae*	*Cyclagelosphaera deflandrei*	*Cyclagelosphaera margerelii*	*Diadorhombus rectus*	*Diazomatolithus lehmanii*	*Discorhabdus ignotus*	*Eiffellithus primus*	*Ellipsagelosphaera ovata*	*Ethmorhabdus hauterivianus*	*Grantarhabdus meddii*	*Haqius circumradiatus*	*Lithraphidites carniolensis*	*Micrantholithus hoschulzii*	*Micrantholithus obtusus*	*Microstaurus chiastius*	*Microstaurus conus*	*Nannoconus bermudezii*	*Nannoconus globulus*	*Nannoconus kampineri*	*Nannoconus steinmannii*	*Percivalia fenestrata*	*Retecapsa angustiforata*	*Retecapsa neocomiana*	*Rhagodiscus asper/splendens*	*Rhagodiscus infinitus*	*Rhagodiscus swinnertonii*	*Speetonia colligata*	*Stephanolithion laffittei*	*Tetrapodorhabdus coptensis*	*Tubodiscus verenae*	*Tubodiscus jurapelagicus*	*Vekshinella mitcheneri*	*Vekshinella stradneri*	*Watznaueria barnesae*	*Watznaueria biporta*	*Watznaueria britannica*	*Zeugrhabdotus embergeri*	*Zeugrhabdotus* ssp. (small)
early Valanginian	*Tubodiscus verenae* Subzone CC3a	III	A	P	5R-1, 84–85 cm	.	C	R	R	.	R	R	C	C	F	A	.	C	.	F	R	R	C	R	R	R	R	C	R	.	F	.	F	R	C	C	F	R	.	R	.	R	R	C	.	F	A	F	F	F	F
			F	P	5R-2, 15–16 cm	.	R	R	.	.	.	.	R	R	R	F	.	R	.	.	R	.	R	.	R	.	.	F	.	.	.	.	.	.	R	F	F	.	.	R	.	.	.	R	.	.	F	R	R	F	R
			F	P	5R-2, 29–30 cm	R	.	R	.	.	.	.	.	R	.	F	.	F	.	.	.	.	R	.	R	.	.	R	.	.	.	.	F	.	R	R	F	.	.	.	.	.	.	R	.	R	F	R	R	F	R
			VA	G	5R, CC	.	.	R	.	R	.	.	C	F	.	C	.	C	C	.	F	.	F	.	F	.	.	C	.	.	F	.	C	.	C	C	C	.	.	R	.	R	.	F	.	F	V	F	C	C	F
			C	M	6R-1, 5–6 cm	F	F	R	R	.	.	.	F	.	R	C	.	F	C	R	R	.	F	.	F	.	.	F	F	.	R	R	R	F	F	F	C	R	R	R	R	R	.	.	.	F	C	R	R	F	.
			A	P	6R-2, 20–22 cm	F	C	.	.	R	.	.	R	R	R	C	.	C	R	.	R	.	F	.	F	.	.	.	.	.	F	C	C	F	C	C	C	.	.	.	.	.	.	.	.	C	A	F	F	C	.
			C	P	6, CC	R	R	R	.	R	.	.	R	R	.	C	.	F	.	.	R	.	R	.	R	.	.	R	R	.	F	.	F	R	F	C	F	.	.	R	.	.	.	R	.	F	C	R	.	F	R
			C	P	7R-1, 16–17 cm	R	.	R	.	.	.	R	R	R	.	F	.	F	R	.	R	.	R	.	R	.	.	R	.	.	F	.	F	.	F	C	F	.	.	.	.	.	.	R	R	R	C	R	F	C	R
			A	P	7R-2, 99–100 cm	F	C	.	R	R	.	R	R	.	F	C	.	F	.	R	R	.	R	.	F	.	.	R	R	.	F	R	C	F	R	C	F	.	.	R	R	R	.	F	F	F	C	.	R	C	F
			A	P	7R-3, 82–83 cm	R	C	R	R	R	.	R	R	F	R	C	.	R	.	.	R	.	.	.	F	.	.	.	.	R	F	R	C	F	R	F	F	.	.	R	R	.	R	R	R	F	C	.	R	C	R
			A	P	7R-3, 101–102 cm	F	C	R	.	.	.	.	R	R	F	C	R	R	.	.	R	.	.	.	F	.	.	R	.	R	F	R	C	F	R	F	F	.	.	.	R	R	R	R	R	F	C	.	.	C	F
			A	P	7R, CC	R	F	.	.	.	.	R	R	R	R	F	.	.	.	.	R	.	R	.	F	.	.	.	.	R	C	.	C	R	F	F	F	.	.	.	.	.	.	R	R	R	C	.	F	C	F
			C	P	8R-1, 129–130 cm	.	R	.	.	.	.	.	.	R	R	F	.	.	.	.	R	.	.	.	R	.	.	.	.	.	F	.	C	R	R	R	R	.	.	R	.	.	.	.	.	R	A	.	R	C	R
			A	P	8R-2, 21–22 cm	R	R	.	.	.	.	.	R	R	R	F	.	F	.	R	R	.	.	.	R	.	.	.	.	R	C	.	C	R	R	R	R	.	.	R	.	.	.	.	.	R	A	.	R	C	R
			F	P	8R, CC	.	.	.	.	.	.	R	R	.	R	F	.	.	.	.	.	.	.	.	R	.	.	.	.	F	F	.	F	R	R	R	R	.	.	R	.	.	.	R	.	R	F	.	R	F	R

R = Rare; F = Few; C = Common; A = Abundant; VA = Very abundant; ? = Questionably present; . = Not present.

638C to the top of Hole 639A. The vertical distance between the two holes, calculated aboard ship from seismic sections, could be as little as 10 m. No missing section is evident from the distribution of the marker nannofossil species, although many other species first appear at the bottom of Hole 638C, including: *Nodosella silvaradion, Discorhabdus biradiatus, Glaukolithus diplogrammus, Retecapsa radiata, Octopodorhabdus plethotretus, P. furtiva, Vekshinella parallela*, and *Zeugrhabdotus pseudoangustus*. The first appearance of these taxa could be due to a small hiatus or a change in preservation.

Thierstein (1976) illustrated the first occurrences of *R. radiata* and *G. diplogrammus* near the middle of the Valanginian. *Rucinolithus wisei*, a species that has its last occurrence in the middle Valanginian, is present at the bottom of Hole 638B but is not a useful datum here because of its rare occurrence within the turbidite sequence. Roth (1983) placed the first occurrence of *Rhagodiscus infinitus* above the last occurrence of *R. wisei*; however, in this section the two species clearly overlap in occurrence as they also do at DSDP Site 603 (Covington and Wise, 1987). Bralower (1986) observed *R. infinitus* below the Valanginian, which makes its first occurrence a doubtful upper Valanginian marker.

A mid-Valanginian marker proposed here is the first occurrence of *E. windii* n. sp. This small distinctive *Eiffellithus* was first illustrated by Wind and Cepek (1979) for the Hauterivian at Site 397 and later by Covington and Wise (1987) from the Hauterivian at Site 603. Although it is rare to few in abundance in our material, *E. windii* n. sp. has a consistent occurrence and is a highly distinct form that birefringes strongly (bright white) in polarized light.

The first occurrence of *Tegumentum stradneri* in Zone CC3b extends the lower range of this species into the upper Valanginian. The last occurrence of *C. brezae* n. sp. in Sample 103-638B-33R-1, 75–76 cm, corresponds with the lowest occurrence of *E. striatus*, the datum used here to mark the Valanginian/Hauterivian boundary. *C. brezae* has its highest occurrence three cores above that of *C. deflandrei*.

In previous studies of Lower Cretaceous nannofossils many different datums were used to delineate the Valanginian/Hauterivian boundary. The last occurrences of *T. verenae* and *D. rectus* in Roth's (1978) zonal scheme cannot be used because of their occurrence in the upper Hauterivian and Barremian elsewhere. It is interesting to note that the highest common occurrence of *T. verenae* in this section (Sample 103-638B-32R-2, 8–9 cm) is roughly coincident with the lowest occurrence of *E. striatus*. Last-appearance datums must be used with caution in areas where the possibility of reworking is great. It is for this reason that the lowest occurrence of *E. striatus* is used to approximate the Valanginian/Hauterivian boundary.

The first occurrence of *C. loriei* was used by Sissingh (1977) for the Valanginian/Hauterivian boundary. A form that resembles *C. loriei* was observed in Hauterivian material from this study (*Cretarhabdus* cf. *loriei*); however, the central area and overall size of this form are not as large as those of the holotype, and the parallel laths in each of the four quadrants are not nearly as well defined as in *C. loriei*. Forms closely resembling *C. loriei* have been observed by one of the authors from the Upper Jurassic of Portugal. Unfortunately, Sissingh (1977) did not illustrate the form he identified as *C. loriei*. Thus, until further taxonomic clarification is made, this is considered an unreliable datum for the CC3/CC4 boundary.

The first occurrence of *L. bollii* marks the base of CC4b in Sample 103-638B-29-4, 18–19 cm. Our specimens are clearly synonymous with the species described by Thierstein (1971) and not the form discussed as *L. bollii*? by Wind and Cepek (1979). The upper limit of CC4b, based on the last occurrence of *S. colligata*, extends up to Sample 103-638B-23R-4, 55–56 cm. An unconformity is recognized between lithologic Subunits IIA and IIB at 278 mbsf in Section 103-638B-23R-3, where part of the upper Hauterivian and most of the lower Barremian are not detected. *L. bollii* and *C. oblongata* both appear to have their highest occurrences truncated in this section and occur in Sample 103-638B-23R-3, 16–17 cm, one core section above the highest occurrence of *S. colligata*. Species that have their lowest occurrence in CC4b include *Flabellites oblongus* and *Nannoconus liqius* n. sp. *Cruciellipsis cuvillieri* has its highest occurrence approximately 10 m below the highest occurrence of *S. colligata* in Sample 103-638B-25R-1, 86–87 cm.

Nannofossil assemblages in CC4b are dominated by the genera *Nannoconus, Micrantholithus, Lithraphidites*, and *Watznaueria*. Preservation is good, except in the bioturbated intervals, and many samples contain a background carbonate hash composed of broken micrantholith elements. Although generally good, preservation is often variable within each sample, a phenomenon also noted by Wind and Cepek (1979). Above the unconformity between lithologic Subunits IIA and IIB, upper Barremian nannofossil assemblages are present to the top of the Lower Cretaceous sequence of Hole 638B. The lower part of Hole 641C (Sample 103-641C-11R-2, 108 cm, to Section 103-641C-16R, CC) contains very similar assemblages in a lithology resembling that of the upper Barremian in Hole 638B. In the absence of both *C. oblongata* and *H. irregularis*, these intervals are assigned to the *M. hoschulzii* Zone (CC6). Species present in this interval include *Tubodiscus jurapelagicus, C. litterarius*, rare *D. rectus, N. abundans*, and *R. radiata. Rucinolithus terebrodentarius*, a form that could be confused under the light microscope with *H. irregularis*, has its lowest occurrence within this zone.

Recognition of the Barremian/Aptian boundary has long been a problem for nannofossil biostratigraphers. Thierstein (1971) first used the first occurrence of *C. litterarius*, a form described from the Maestrichtian by Gorka (1957). Forms observed in the Hauterivian and Barremian of the Leg 103 material easily fit within Thierstein's (1971) species concept of *C. litterarius*. The last occurrence of *Nannoconus steinmannii/colomii*, also proposed by Thierstein (1971) to mark the boundary, ranges up to the middle Aptian in this section.

The first occurrence of *H. irregularis* is used in this study to define the Barremian/Aptian boundary. Roth (1983) extended the range of this species down into the upper Barremian. However, under the light microscope, it can be confused with *R. terebrodentarius*, which can resemble an overgrown *H. irregularis* (see taxonomic notes). Therefore, we do not agree that *H. irregularis* occurs below the CC6/CC7 boundary. The *H. irregularis* Subzone (CC7a), is assigned to the interval from Samples 103-641C-11R-2, 108 cm, to 103-641C-8R-4, 76–77 cm. *Flabellites biforaminis*, a form previously restricted to the Aptian, has its first occurrence one sample below this interval in Sample 103-641C-12R-3, 107 cm. Many taxa disappear near the top of CC7a, including *M. hoschulzii, M. obtusus, N. steinmannii, Nannoconus globulus*, and *C. mexicana*. Some of these are found reworked with Barremian forms in a few samples zoned within CC7b.

The interval from Samples 103-641C-8R-4, 76–77 cm, to 103-641C-6R-3, 77 cm, is assigned to the *R. angustus* Subzone (CC7b). Layers of coarse shell debris in a carbonate turbidite sequence are found at the top of this interval. The common occurrence of *P. furtiva* within a shell lag layer indicates that this species is a nearshore form. The presence of definitive lower Barremian nannofossils in this lag layer indicate that *P. furtiva* is also reworked, as it is otherwise restricted to Barremian age or older sediment.

Table 2. Relative abundance of nannofossils, Site 638.

Age	Sissingh zonation (1977)	Lithologic unit	Abundance	Preservation	Sample	*Assipetra infracretacea*	*Axopodorhabdus dietzmannii*	*Biscutum constans*	*Braarudosphaera discula*	*Bukrylithus ambiguus*	*Calcicalathina oblongata*	*Chiastozygus litterarius*	*Chiastozygus platyrethus*	*Chiastozygus tenuis*	*Conusphaera mexicana*	*Corollithion acutum*	*Corollithion ellipticum*	*Cretarhabdus* cf. *loriei*	*Cretarhabdus conicus*	*Cretarhabdus delicatus*	*Cretarhabdus surirellus*	*Cruciellipsis cuvillieri* ssp. *cuvillieri*	*Cruciellipsis cuvillieri* ssp. *grandis*	*Cyclagelosphaera brezae*	*Cyclagelosphaera deflandrei*	*Cyclagelosphaera margerelii*	*Diadorhombus rectus*	*Diazomatolithus lehmanii*	*Diloma placinum*	*Diloma primitiva*
late Barremian	*Micrantholithus hoschulzii* Zone CC6	IIA	A	M	20R-3, 32-33	R	F	C	F	.	.	.	.	R	F	.	F	.	F	R	F	.	.	.	.	F	.	F	F	.
			A	G	20R, CC	.	C	C	.	R	.	R	.	.	F	.	.	.	F	R	F	.	.	.	.	F	.	R	.	.
			A	M	21R-2, 47-48	F	F	C	.	.	.	.	R	.	F	.	C	R	F	.	F	.	.	.	.	C	R	F	.	.
			A	G	21R-3, 60-62	F	C	C	.	R	.	.	R	.	F	.	C	R	F	R	F	R	.	.	.	F	.	C	.	.
			F	P	21R-4, 54-55	.	.	R	.	.	.	.	.	.	.	.	.	.	R	.	F	.	.	.	.	.	.	.	.	.
			A	G	21R-5, 93-94	F	F	F	.	.	.	.	.	.	F	R	F	.	F	.	F	.	.	.	.	R	.	F	.	R
			A	G	22R-1, 41-42	F	F	C	.	R	.	.	R	.	C	R	F	.	F	F	F	R	.	.	.	F	.	F	.	F
			VA	M	22R-2, 22-23	R	F	C	.	.	.	.	.	.	F	.	R	.	C	R	F	.	.	.	.	F	R	F	.	.
			A	P	22R-3, 55-56	.	C	C	R	.	.	.	.	.	C	.	R	R	F	.	R	.	.	.	.	F	.	F	.	.
			A	M	22R-4, 49-50	R	F	C	R	.	.	.	.	.	F	.	F	R	F	.	F	.	.	.	.	.	.	.	.	.
			A	G	22R-5, 110-111	.	C	C	F	.	.	.	.	.	R	.	F	.	R	.	F	.	.	.	.	F	R	C	.	.
			A	G	23R-1, 61-62	F	C	C	.	.	.	.	.	.	F	.	C	F	.	.	.	.	.	.	.	C	.	F	.	.
			VA	G	23R-2, 111	.	F	C	.	.	.	.	.	.	C	.	R	.	C	R	F	.	.	.	.	F	.	C	.	.
	CC5		VA	G	23R-3, 16-17	F	R	C	.	.	R	R	R	.	F	.	.	R	R	R	F	.	.	.	.	R	.	C	.	.
late Hauterivian	*Speetonia colligata* Subzone CC4b	IIB	VA	G	23R-4, 55-56	.	C	C	.	R	C	R	.	F	C	.	F	R	C	R	C	.	.	.	.	.	.	C	.	R
			VA	G	23R-5, 89-90	.	C	C	C	R	F	R	.	.	R	R	F	.	F	R	C	.	.	.	.	.	R	C	.	.
			A	M	23R-6, 58-59	F	F	C	F	R	C	R	R	R	R	.	C	.	F	.	F	.	.	.	.	F	R	C	.	R
			VA	M	24R-1, 104-105	.	C	C	.	R	C	R	.	.	F	.	F	.	F	.	C	.	.	.	.	C	.	C	.	.
			A	P	24R-2, 64-65	.	C	C	.	.	C	.	.	.	F	.	F	.	F	R	F	.	.	.	.	C	.	C	.	.
			A	G	24R-3, 11-12	.	C	C	F	R	C	.	.	.	C	R	C	.	C	R	C	.	.	.	.	F	.	C	.	.
			VA	M	24R-4, 55	.	F	C	.	R	C	.	.	.	F	.	C	.	C	.	C	.	.	.	.	C	R	C	.	.
			VA	M	24R-5, 95-96	.	C	A	F	.	C	.	.	.	R	.	F	.	F	.	C	.	.	.	.	C	R	C	.	R
			A	M	24R-6, 17-18	.	C	A	F	.	C	.	.	.	R	.	F	.	F	R	C	.	.	.	.	C	R	C	.	.
			A	M	25R-1, 86-87	F	C	A	F	.	C	.	.	.	R	.	C	.	F	.	F	R	.	.	.	C	.	C	.	.
			A	M	25R-2, 80-81	C	C	A	F	.	F	.	.	.	R	.	C	.	F	.	C	C	.	.	.	C	.	C	.	.
			VA	G	25R-3, 8-9	C	C	.	.	.	C	.	.	.	F	.	C	.	.	.	.	C	.	.	.	C	.	C	.	.
			A	M	25R-4, 48-49	F	F	C	.	.	C	.	.	.	C	R	C	.	C	.	C	C	.	.	.	C	R	C	.	R
			A	M	25R-5, 19-20	F	C	C	.	.	C	.	.	.	C	.	C	.	F	.	C	C	.	.	.	C	.	C	.	.
			VA	M	25R-6, 45-46	F	C	C	.	.	C	.	.	.	F	.	C	.	C	.	C	C	.	.	.	F	.	F	.	.
			A	P	26R-1, 9-10	R	F	C	.	.	C	.	.	.	R	.	C	.	F	.	C	C	.	.	.	F	.	C	.	.
			VA	M	26R-1, 59-60	R	F	C	.	.	F	.	.	.	F	.	F	.	F	.	C	F	.	.	.	F	.	C	.	.
			C	M	26R-2, 11-12	.	F	C	.	.	C	.	.	.	F	.	C	.	F	.	F	C	.	.	.	F	R	F	.	.
			VA	G	26R-3, 108-109	R	C	A	.	.	C	.	.	R	F	R	C	.	C	.	C	C	.	.	.	C	R	C	.	.
			A	M	26R-4, 71-72	.	C	A	R	.	C	.	.	.	F	R	C	.	C	.	F	F	.	.	.	F	.	C	.	.
			A	G	26R-5, 18-19	.	C	C	R	.	C	.	.	.	C	R	C	.	C	.	C	C	.	.	.	C	R	C	.	.
			A	G	27R-1, 68-69	F	C	C	R	R	C	.	.	F	R	F	C	F	F	.	C	F	.	.	.	F	R	F	.	R
			A	M	27R-2, 70-71	R	F	A	.	.	C	.	.	.	R	R	C	.	F	.	C	C	.	.	.	F	.	C	.	.
			A	G	27R-3, 54-55	R	C	C	F	.	C	.	.	.	R	R	C	.	F	.	F	C	.	.	.	F	R	C	.	.
			A	G	27R-4, 20-21	R	C	C	F	.	F	.	.	.	F	.	C	.	F	.	C	C	.	.	.	F	R	C	.	.
			A	G	27R-5, 54-55	F	C	C	R	R	C	R	.	.	F	.	F	.	F	R	C	C	.	.	.	C	.	C	R	.
			A	P	27R-6, 57-58	R	F	C	R	R	F	.	.	.	R	R	R	.	R	.	F	F	.	.	.	F	R	C	.	.
			A	G	28R-3, 23	.	C	A	R	.	C	.	.	.	F	.	C	R	F	.	C	C	.	.	.	C	R	C	.	.
			C	G	28R-4, 58-59	.	F	F	R	R	F	.	.	.	.	.	R	.	F	.	F	F	.	.	.	F	.	F	.	.
			VA	M	28R-5, 116-117	R	C	C	.	.	C	.	.	.	F	R	C	.	F	.	C	C	.	.	.	C	.	C	.	.
			C	P	28R-6, 31-32	.	R	F	.	.	C	.	.	.	.	.	.	.	R	.	F	R	.	.	.	F	.	F	.	.
			VA	G	28R-6, 89-90	.	C	C	.	.	C	.	.	.	F	R	C	.	F	.	C	C	.	.	.	C	R	A	.	.
			A	G	29R-1, 23	.	C	A	.	R	C	.	.	.	F	.	C	.	F	.	C	C	.	.	.	C	.	C	.	.
			A	G	29R-2, 23	.	C	A	.	F	C	.	.	.	F	.	C	.	F	.	C	C	.	.	.	C	.	A	.	R
			VA	G	29R-3, 23	.	C	C	.	.	C	.	.	.	F	R	F	.	F	R	C	C	.	.	.	C	.	A	.	.
			A	M	29R-4, 18-19	R	C	A	.	.	C	.	.	.	R	R	C	.	R	.	C	F	.	.	.	C	.	C	.	.

Sample	*Discorhabdus biradiatus*	*Discorhabdus ignotus*	*Eiffellithus primus*	*Eiffellithus striatus*	*Eiffellithus windii*	*Ellipsagelosphaera ovata*	*Ethmorhabdus hauterivianus*	*Flabellites oblonga*	*Glaukolithus diplogrammus*	*Grantarhabdus meddii*	*Haqius circumradiatus*	*Lapideacassis* sp.	*Lithraphidites bollii*	*Lithraphidites carniolensis*	*Manivitella* sp., cf. *pecten*	*Manivitella pemmatoidea*	*Micrantholithus hoschulzii*	*Micrantholithus obtusus*	*Microstaurus chiastius*	*Microstaurus conus*	*Nannoconus abundans*	*Nannoconus bermudezii*	*Nannoconus bucheri*	*Nannoconus elongatus*	*Nannoconus globulus*
20R-3, 32-33	R	C	.	.	.	R	.	.	C	.	R	R	.	A	F	C	C	C	C	.	.	.	.	.	.
20R, CC	.	C	.	.	.	R	.	.	C	R	F	.	.	C	.	C	C	C	C	.	F	.	R	.	F
21R-2, 47-48	.	C	.	.	.	F	.	.	C	.	.	.	.	A	F	C	A	C	C	.	F	R	F	.	C
21R-3, 60-62	.	C	.	.	.	F	.	.	C	R	R	.	.	C	F	C	C	C	C	F	.	.	.	.	F
21R-4, 54-55	.	.	.	.	.	.	.	.	R	.	.	.	.	F	.	.	R	.	.	.	.	.	R	.	.
21R-5, 93-94	R	F	.	.	.	.	.	.	F	.	R	.	.	C	.	F	C	F	F	R	R	.	R	.	F
22R-1, 41-42	.	C	.	.	.	F	.	C	C	.	R	R	.	A	F	C	R	F	C	F	.	.	.	.	.
22R-2, 22-23	F	F	.	.	.	F	.	.	C	R	.	.	.	C	.	C	C	F	C	R	.	.	F	.	C
22R-3, 55-56	F	C	.	.	.	F	.	.	C	.	R	.	.	A	.	C	C	A	C	.	.	.	.	.	R
22R-4, 49-50	F	F	.	.	.	F	.	.	C	.	.	.	.	A	.	C	C	C	A	.	F	.	C	.	C
22R-5, 110-111	.	C	.	.	.	F	.	.	C	R	.	.	.	A	.	F	C	F	C	.	.	.	.	.	F
23R-1, 61-62	.	C	.	.	.	F	.	.	C	.	.	.	.	A	.	C	F	R	C	.	.	.	.	.	R
23R-2, 111	.	C	.	.	.	F	.	.	C	.	.	.	.	A	.	F	F	R	C	.	.	.	R	.	C
23R-3, 16-17	R	C	.	.	.	F	.	.	C	.	R	R	.	A	C	C	F	F	C	F	.	.	R	.	R
23R-4, 55-56	.	.	.	.	.	C	.	.	.	R	R	.	F	A	.	C	F	A	C	.	R	.	R	.	C
23R-5, 89-90	F	C	.	.	.	F	.	.	C	R	R	.	C	C	.	F•	C	C	C	.	R	F	F	F	C
23R-6, 58-59	F	F	.	R	.	R	R	.	C	R	F	.	F	F	F	C	C	F	C	R	.	.	.	.	.
24R-1, 104-105	.	C	.	R	.	F	.	.	C	F	R	.	F	A	C	C	A	A	C	.	.	F	R	F	C
24R-2, 64-65	.	C	.	.	.	C	.	F	C	R	.	.	F	A	C	C	C	A	C	.	.	.	.	.	F
24R-3, 11-12	.	C	.	.	.	F	.	C	C	F	R	.	R	C	C	C	C	C	C	.	.	.	.	F	F
24R-4, 55	.	C	.	.	.	F	.	.	.	.	R	.	R	C	F	C	C	A	C	.	.	R	F	.	C
24R-5, 95-96	R	C	.	.	R	C	.	.	C	R	.	.	F	C	F	C	C	A	C	.	.	R	.	.	F
24R-6, 17-18	.	C	.	.	.	F	.	.	C	R	R	.	F	A	F	C	C	A	C	.	.	.	R	.	R
25R-1, 86-87	F	A	.	.	R	F	.	.	F	.	.	.	F	A	F	C	C	C	C	.	.	.	.	.	C
25R-2, 80-81	F	C	.	.	R	F	.	.	F	.	.	.	R	A	F	C	C	C	C	.	.	.	.	.	C
25R-3, 8-9	.	A	.	.	.	F	.	.	.	.	.	.	F	A	C	C	C	C	C	.	.	.	.	.	F
25R-4, 48-49	F	F	.	.	R	F	.	.	.	F	R	.	F	C	F	C	A	C	C	.	.	.	.	.	.
25R-5, 19-20	F	F	.	.	.	F	.	.	C	F	.	.	F	A	.	C	C	C	.	R	.	.	.	.	.
25R-6, 45-46	F	F	.	.	.	F	.	.	C	R	R	.	C	A	.	C	F	C	C	R	.	.	.	.	.
26R-1, 9-10	R	C	.	.	.	R	.	.	F	F	R	.	F	A	.	C	F	C	F	.	.	.	.	.	.
26R-1, 59-60	F	C	.	.	.	F	.	.	C	R	R	.	R	C	R	C	C	C	F	R	.	.	.	.	F
26R-2, 11-12	R	F	.	.	.	F	.	.	F	.	.	.	F	C	R	C	F	C	C	.	.	.	.	R	F
26R-3, 108-109	F	C	.	.	.	F	.	.	C	.	R	.	F	C	C	C	C	C	C	.	.	.	.	.	F
26R-4, 71-72	F	F	.	.	.	F	.	.	C	.	.	.	F	C	C	C	F	C	C	.	.	.	.	.	F
26R-5, 18-19	R	R	.	.	.	F	.	.	C	.	R	.	R	C	F	C	F	F	R	.	.	.	.	.	.
27R-1, 68-69	.	C	.	R	R	F	.	.	C	.	F	.	F	C	.	F	C	C	C	R	.	.	.	.	.
27R-2, 70-71	F	C	.	.	.	R	.	.	F	.	R	.	F	C	F	C	F	F	C	.	.	.	.	.	.
27R-3, 54-55	F	F	.	.	.	F	.	.	C	.	R	.	F	C	F	C	F	C	C	.	.	.	.	.	F
27R-4, 20-21	R	C	.	.	.	F	.	.	C	R	F	.	F	A	F	C	F	C	C	R	.	.	.	.	.
27R-5, 54-55	F	F	.	R	.	R	.	.	C	.	R	.	F	C	F	F	C	F	C	.	.	.	.	.	F
27R-6, 57-58	R	C	.	F	.	R	.	.	F	.	.	.	.	C	R	F	R	F	C	.	.	.	.	.	.
28R-3, 23	F	C	.	F	.	F	.	.	C	F	F	.	F	A	F	C	C	C	C	R	.	.	.	.	.
28R-4, 58-59	.	F	.	R	.	F	.	.	F	.	.	.	R	C	R	F	F	F	F	.	.	.	.	.	.
28R-5, 116-117	.	C	.	F	.	F	.	.	C	.	R	.	F	A	C	C	R	F	C	R	.	F	.	.	.
28R-6, 31-32	.	F	.	.	.	R	.	.	F	.	.	.	R	F	C	F	F	F	F	.	.	R	.	.	R
28R-6, 89-90	.	C	.	R	.	F	.	.	C	.	.	.	.	A	.	C	R	F	.	.	.	.	.	.	.
29R-1, 23	F	C	.	R	.	R	.	.	C	.	R	.	F	C	R	C	F	F	C	.	.	.	.	.	R
29R-2, 23	F	C	.	R	.	F	.	.	C	.	.	.	.	A	R	C	.	R	C	.	.	R	.	.	F
29R-3, 23	.	C	.	F	.	F	.	.	C	.	R	.	F	A	R	C	R	R	C	R	.	.	.	.	.
29R-4, 18-19	F	C	.	R	.	F	.	.	C	.	F	.	R	A	F	C	R	F	C	R	.	.	.	.	.

Table 2 (continued).

early Hauterivian	*Chiastozygus striatus* Subzone CC4a		A	M	30R-1, 65–66	R	C	C	.	R	C	.	.	.	R	.	R	.	F	.	C	F	.	.	.	C	R	C	.	.	R	F	.	.	.	F	R	.	.	.	R	.	.	A	F	C	R	R	C	R	.	.	.	.	.
			A	M	30R-2, 58–59	.	C	C	.	.	F	.	.	.	R	.	C	.	F	.	F	F	.	.	.	C	.	C	.	.	F	F	.	.	.	F	.	.	C	.	R	.	.	C	F	C	R	R	C	R	.	.	R	.	.
			A	G	30R-3, 50–51	F	C	R	F	.	C	?	.	.	R	.	R	.	F	R	F	F	.	.	.	F	.	C	.	.	F	F	.	R	.	F	.	.	C	.	R	.	.	C	.	C	F	F	C	.	.	R	R	.	F
			A	M	30R-4, 27–28	R	C	A	.	.	C	.	.	.	F	.	C	.	F	R	C	C	.	.	.	C	R	A	.	R	F	C	.	R	.	F	.	.	C	.	F	.	.	C	R	C	R	F	C	.	.	.	.	.	.
			A	G	30R-5, 5–6	.	C	C	.	.	C	.	.	R	F	.	C	.	F	.	C	F	.	.	.	F	.	C	.	.	.	C	.	R	.	F	.	.	C	R	F	.	.	C	.	C	R	R	C	.	.	R	.	.	R
			A	M	30R, CC	.	C	C	.	.	C	.	.	.	R	.	C	.	F	.	C	F	.	.	.	F	.	A	.	.	.	C	.	R	.	R	.	.	C	.	R	.	.	C	.	C	F	F	C	R	.	.	R	.	F
			A	M	31R-1, 125–126	.	C	C	.	R	C	.	.	.	F	.	F	.	F	.	C	C	.	.	.	C	R	C	.	R	.	F	.	F	.	R	R	.	C	R	R	.	.	C	.	C	R	R	C	F	.	.	.	.	.
			VA	M	31R-2, 83–84	R	C	C	.	R	C	.	.	.	F	.	F	R	F	.	C	F	.	.	.	C	.	C	.	.	.	F	.	.	.	F	.	.	C	.	.	.	.	C	.	C	R	F	C	F	.	.	.	.	R
			A	G	31R-3, 123–124	.	C	C	.	R	F	.	.	.	F	.	F	.	F	.	C	F	.	.	.	F	.	C	.	.	.	F	.	R	.	F	.	.	C	.	F	.	.	C	.	C	C	C	C	F	.	.	.	.	.
			VA	M	31R-4, 103–104	.	C	C	.	.	C	.	.	.	F	.	C	.	F	.	C	C	.	.	.	C	.	A	.	.	F	C	.	R	.	F	.	.	C	.	R	.	.	A	.	C	F	C	C	F	.	.	R	.	.
			C	P	31R, CC	.	R	F	.	.	F	.	.	.	R	.	.	.	R	.	F	R	.	.	.	R	.	F	.	.	R	F	.	.	.	R	.	.	F	.	R	.	.	R	.	F	R	R	C	.	.	R	R	.	R
			C	P	32R-1, 43–44	.	R	F	.	.	R	.	.	.	R	.	R	.	F	.	F	R	.	.	.	R	.	C	.	.	R	F	.	.	.	R	.	.	F	.	.	.	.	F	.	F	.	R	F	.	.	.	R	.	R
			A	M	32R-2, 8–9	R	C	C	.	.	C	.	.	.	R	.	F	.	R	R	F	R	.	.	.	C	R	A	.	.	R	C	.	.	.	F	.	.	C	.	R	.	.	C	F	C	F	F	C	F	.	.	.	.	.
			A	G	32R-2, 126–127	R	C	C	.	R	C	.	.	.	R	.	F	F	F	F	C	C	.	.	.	F	R	A	.	R	R	F	.	R	R	C	R	.	C	.	.	.	.	C	F	C	R	.	C	.	.	.	.	.	.
			C	P	32R, CC	.	C	C	.	.	F	.	.	.	R	R	F	.	R	F	F	C	.	.	.	C	.	C	.	.	R	F	.	.	R	F	.	.	C	.	.	.	.	C	.	F	C	F	C	.	.	.	.	R	F
			VA	G	33R-1, 75–76	F	C	C	R	R	C	R	.	.	C	R	F	F	C	R	C	F	.	R	.	C	F	A	.	.	C	C	R	.	R	F	F	.	C	F	R	.	.	C	.	C	F	R	C	R	.	R	F	F	C
late Valanginian	*Eiffellithus windii* Subzone CC3b		VA	G	33R-2, 97–98	R	C	C	.	.	C	.	.	.	F	.	C	F	C	R	C	C	.	.	.	C	F	C	.	.	F	C	.	.	R	F	R	.	C	.	R	.	.	C	.	C	C	F	C	R	.	.	R	.	C
			A	G	33R-3, 97–98	R	C	C	.	.	F	.	.	.	F	.	R	R	F	R	C	C	.	.	.	F	F	C	.	.	F	C	.	.	R	F	R	.	C	.	R	.	.	C	.	C	F	C	C	F	.	.	.	.	.
			A	G	33R-4, 97–98	.	C	C	.	.	C	.	.	.	C	.	.	R	F	R	C	C	.	.	.	C	R	C	.	.	R	C	.	.	.	F	R	.	C	.	R	.	.	C	.	C	F	F	C	R	.	.	.	.	.
			C	P	34R-1, 113–114	R	C	F	R	.	R	.	.	.	F	.	R	.	R	.	R	F	.	.	.	F	R	F	.	.	.	F	.	.	.	R	R	.	F	.	R	.	.	C	.	F	F	F	F	.	.	.	.	.	.
			C	G	34R-2, 88–89	R	C	C	.	R	F	.	.	.	C	.	C	.	.	.	F	C	.	.	.	F	R	C	.	.	.	F	.	.	R	R	R	.	C	.	R	.	.	C	.	C	F	R	C	.	.	.	.	.	.
			A	M	34R-4, 100–101	R	C	C	.	R	F	.	.	.	F	.	F	.	.	.	C	C	.	.	.	C	F	C	.	.	.	F	.	.	.	F	.	.	F	.	R	.	.	C	F	C	R	R	C	R	.	.	.	.	.
			VA	G	34R, CC	R	C	C	R	.	C	.	.	.	C	.	C	.	F	R	C	C	.	.	.	C	R	C	.	R	R	C	.	.	R	F	R	.	C	R	.	.	.	A	R	C	C	C	C	.	.	F	.	F	C
			A	M	35R-1, 144–145	C	C	C	.	.	C	.	.	.	C	R	F	.	F	R	F	C	.	.	.	C	R	C	.	.	.	C	.	.	.	R	R	.	C	.	.	.	.	C	.	C	R	F	C	R	.	.	.	.	.
			A	M	35R-1, 150	F	C	C	.	R	C	.	.	.	F	.	C	R	F	.	C	C	.	.	.	C	R	C	.	.	.	F	.	.	.	F	R	.	F	.	.	.	.	C	.	C	R	F	C	.	.	.	.	.	F
			A	G	35R-2, 37–38	F	C	C	.	.	F	.	.	.	C	.	C	.	R	.	F	C	.	.	.	F	R	C	.	.	R	C	.	.	R	F	R	.	C	.	.	.	.	A	F	C	F	R	C	.	.	F	.	.	F
			VA	G	35R-3, 111–112	R	C	C	R	R	F	.	.	.	F	F	A	.	F	.	C	C	.	.	R	C	F	C	R	R	C	C	.	.	F	F	R	.	C	R	R	.	.	A	C	F	C	R	C	R	.	F	R	R	F
			VA	G	35R-4, 34–35	.	C	A	R	R	C	.	.	.	F	F	A	.	F	.	F	C	.	R	F	C	C	A	R	R	C	C	.	.	R	F	R	.	C	F	R	.	.	C	.	C	C	F	C	.	.	F	F	F	F
			C	P	36R-1, 47–48	.	F	F	.	.	R	.	.	.	R	.	R	.	.	.	R	R	.	.	R	R	R	F	.	.	R	F	.	.	R	.	.	.	R	.	.	.	.	F	.	R	.	.	R	.	.	.	.	.	.
			C	P	36R-1, 47–48	.	F	F	.	R	.	.	.	.	R	.	.	.	R	.	R	R	.	.	R	F	R	F	.	.	.	R	.	.	F	.	R	.	R	.	R	.	.	R	.	F	.	R	R	.	.	.	.	.	.
			A	M	36R-1, 153	.	F	C	.	R	.	.	.	.	F	.	R	.	F	.	F	F	.	.	.	C	R	C	.	.	.	C	.	.	F	R	R	.	C	R	.	.	.	C	.	C	.	.	.	.	.	.	.	.	.
			A	M	36R-2, 57–58	R	C	C	.	R	R	.	.	.	F	.	F	.	R	.	F	C	.	.	R	C	.	C	R	.	.	C	.	.	R	.	.	.	F	R	.	.	.	C	R	F	.	.	.	.	.	.	.	.	.
			A	M	36R, CC	R	C	C	.	R	R	.	.	.	R	.	R	.	R	.	F	C	.	.	R	C	.	C	.	.	R	F	.	.	R	R	R	.	F	R	F	.	.	.	C	R	.	.	C	.	.	.	.	.	.
			A	M	37R-1, 49–50	C	C	C	.	.	C	.	.	.	F	R	F	.	F	.	C	C	.	.	R	C	R	C	.	R	R	F	.	.	F	R	R	.	F	F	.	.	.	C	R	C	.	.	C	R	.	.	.	.	.
			A	M	37R, CC	F	C	A	.	R	F	.	.	.	R	.	.	.	R	.	F	F	.	.	.	F	R	C	.	.	F	C	.	.	F	R	.	.	F	R	R	.	.	F	.	.	.	.	F	R	.	.	.	.	.
			R	P	38R-1, 16–17	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
			A	M	38R-1, 75–76	F	R	F	.	.	F	.	.	.	R	.	.	.	F	.	F	C	.	.	.	C	.	F	.	.	F	F	.	.	R	F	.	.	F	F	.	.	.	F	.	C	.	.	C	R	.	.	.	.	.
			C	M	38R, CC	F	R	F	.	.	.	.	.	.	.	.	.	.	.	.	F	F	.	F	.	F	.	F	.	.	.	R	.	.	.	R	.	.	.	.	R	.	.	R	.	R	.	.	R	.	.	.	.	.	.
			F	M	39R-1, 10–11	R	R	R	.	.	.	.	.	.	R	.	.	.	.	.	F	F	.	.	.	F	.	F	.	.	.	R	.	.	R	R	.	.	.	R	R	.	.	R	.	R	.	.	R	.	.	.	.	.	.
			A	M	39R, CC	F	F	C	.	.	F	.	.	.	.	.	.	.	.	.	C	C	.	.	.	F	R	.	.	.	R	F	.	.	R	R	R	.	F	R	.	.	.	C	.	R	.	.	F	R	.	.	.	.	.
			R	P	40R-1, 44–45	.	.	R	.	.	.	.	.	.	.	.	.	.	R	.	R	R	.	.	.	R	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
			C	G	40R, CC	R	F	C	.	.	R	.	.	.	.	.	.	.	.	.	F	F	.	.	.	F	R	C	.	R	R	F	.	.	R	R	.	.	F	.	.	.	.	F	R	F	.	.	.	.	.	.	.	.	.
		III	A	G	41R-1, 135–136	.	F	C	.	.	F	.	.	.	.	R	.	.	R	.	F	C	.	.	.	C	.	C	.	R	.	F	.	.	R	.	.	.	F	R	R	.	.	C	.	F	.	.	R	F	.	.	.	.	.
			VA	G	41R-1, 150	.	C	C	.	.	F	.	.	.	.	.	R	.	R	.	F	C	.	.	.	C	F	A	F	R	F	F	.	.	R	F	R	.	F	R	R	.	.	C	R	C	.	.	C	F	.	.	.	.	.
			A	G	41R-2, 7–8	F	F	C	.	.	R	.	.	.	R	.	.	.	F	.	F	F	.	.	.	R	R	C	.	.	F	F	.	.	R	F	R	.	F	F	R	.	.	C	.	F	.	.	C	F	.	.	.	.	.
			C	G	42R-1, 30–31	R	F	F	.	.	R	.	.	.	.	.	.	.	R	.	F	F	.	.	.	F	R	C	F	.	R	R	.	.	R	R	.	.	R	F	.	.	.	F	.	F	.	.	F	R	.	.	.	.	.
			VA	G	42R-1, 134–135	F	C	C	.	R	F	.	.	.	.	.	C	.	R	.	F	C	.	.	.	C	C	A	.	R	F	C	.	.	R	F	.	.	C	R	R	.	.	A	.	F	.	.	C	R	.	.	.	.	.
			A	G	42R-2, 12–13	F	C	C	.	.	F	.	.	.	R	.	R	.	R	.	R	C	.	.	R	F	R	C	.	R	R	F	.	.	R	R	.	.	F	R	R	.	.	C	.	F	.	.	F	C	.	.	.	.	.
			A	G	42R, CC	F	C	C	.	.	F	.	.	.	F	.	F	.	F	.	C	C	.	.	R	C	F	C	.	R	R	C	.	.	F	R	R	.	F	R	R	.	.	C	.	F	.	.	F	F	.	.	.	.	.
			A	G	43R-1, 41–42	F	C	C	.	.	F	.	.	.	F	.	F	.	F	.	C	C	.	.	R	C	F	C	.	R	R	C	.	.	F	R	R	.	F	R	R	.	.	C	.	F	.	.	F	F	.	.	.	.	.
			A	M	43R-2, 55–56	F	F	C	.	R	R	.	.	.	R	.	R	.	C	.	F	F	.	.	.	F	R	C	.	.	.	F	.	.	R	R	.	.	F	R	.	.	.	C	.	F	.	.	C	C	.	.	.	.	.
			F	M	43R, CC	.	.	R	.	.	R	.	.	.	.	.	.	.	R	.	R	F	.	.	.	R	.	F	.	.	.	R	.	.	R	R	.	.	R	.	.	.	.	R	.	R	.	.	R	R	.	.	.	.	.
			A	G	44R-1, 38–39	F	C	C	.	.	F	.	.	.	R	.	.	.	C	R	C	C	.	.	R	C	.	C	.	R	R	F	.	.	R	F	R	.	F	R	R	.	.	C	.	F	.	.	C	R	.	.	.	.	.
early Valanginian	*Tubodiscus verenae* Subzone CC3a		C	M	44R-2, 31–32	.	R	F	.	.	R	.	.	.	.	.	.	.	F	.	R	R	.	.	R	F	.	F	.	.	.	R	.	.	.	F	.	.	R	R	R	.	.	R	.	R	.	.	F	R	.	.	.	.	.
			A	M	44R-2, 115	F	C	C	.	.	F	.	.	.	R	.	R	.	C	.	C	C	.	.	.	F	R	C	.	.	.	F	F	.	.	F	.	.	F	R	R	.	.	C	.	F	.	.	F	F	.	.	.	.	.
			A	M	44R-3, 115	.	F	C	.	.	F	.	.	.	R	.	R	.	C	.	F	C	.	.	.	C	R	A	.	.	.	C	.	.	.	F	.	.	F	R	.	.	.	C	.	F	.	.	C	.	.	.	.	.	.
			C	M	45R-1, 62–64	.	R	F	.	.	F	.	.	.	R	.	.	.	F	.	R	C	.	.	R	C	.	C	.	.	.	F	.	.	.	F	.	.	R	.	.	.	.	R	.	R	.	.	.	R	.	.	.	.	.
			A	G	45R-2, 79–80	R	C	C	.	R	C	.	.	.	R	.	F	.	.	.	F	C	.	.	.	C	R	A	.	.	R	F	.	.	.	F	.	.	C	.	R	.	.	C	.	F	.	.	C	R	.	.	.	.	R
			A	G	45R-3, 28–29	.	F	C	.	.	F	.	.	.	.	.	.	.	F	.	C	C	.	.	.	C	.	A	.	.	.	C	.	.	.	F	.	.	C	.	.	.	.	A	.	F	.	.	C	F	.	.	.	.	.
			A	M	45R, CC	R	F	C	.	.	F	.	.	.	R	.	R	.	R	.	F	C	.	F	.	C	.	C	.	.	.	C	.	.	.	R	.	.	C	.	.	.	.	C	.	F	.	.	C	R	.	.	.	.	.
			C	M	1R-1, 77–78	.	F	F	.	.	R	.	.	.	.	.	.	.	R	.	R	F	.	.	F	F	R	F	.	.	.	.	.	.	.	R	.	.	R	.	.	.	.	R	.	R	.	.	F	R	.	.	.	.	.
			A	G	1R-1, 102	R	C	C	.	.	F	.	.	.	.	.	.	.	F	.	F	C	.	.	R	C	R	C	.	.	.	C	R	.	.	R	.	.	F	F	R	.	.	C	.	R	.	.	C	R	.	.	.	.	.
			VA	G	1R-2, 17–18	.	C	C	.	R	F	.	.	.	.	.	F	.	F	.	F	F	.	.	R	C	R	A	.	.	.	C	.	.	.	R	.	.	.	.	.	.	.	C	.	F	.	.	C	F	.	.	.	.	.
			A	G	1R-3, 8–7	.	C	C	.	.	F	.	.	.	.	R	F	.	F	.	F	F	.	.	.	C	F	C	.	R	R	C	F	.	.	R	R	.	C	R	.	.	.	C	.	C	.	.	C	F	.	.	.	.	.
			VA	G	3R-2, 141–142	R	C	C	.	.	C	.	.	.	C	.	R	.	C	R	C	C	.	.	F	C	R	A	.	.	R	C	.	.	.	F	R	.	C	F	.	.	.	A	.	C	F	R	C	C	.	.	.	.	.
			VA	G	4R-4, 28–29	.	C	A	.	.	.	.	.	.	F	.	C	.	C	R	C	C	.	R	.	C	F	A	.	R	F	C	R	.	.	C	R	.	C	R	R	.	.	A	.	C	F	R	C	F	.	R	.	.	F
			VA	G	6R-1, 17–18	R	C	C	.	.	C	.	.	.	F	.	F	.	C	F	C	C	C	C	.	C	F	A	.	.	F	C	.	.	.	C	R	.	C	.	.	.	.	C	.	C	F	R	C	C	.	R	.	.	.
			VA	G	6R-3, 13–14	R	F	C	.	.	R	.	.	.	F	.	.	.	R	.	R	C	C	R	.	C	R	C	.	.	.	C	R	.	.	C	R	.	R	.	.	.	.	F	.	F	.	.	F	.	.	.	.	.	.
			A	M	7R-3, 31–32	.	C	C	.	.	R	.	.	.	R	.	F	.	F	F	F	C	C	F	.	C	F	C	.	.	R	C	R	.	.	F	R	.	C	R	R	.	.	C	.	F	.	.	C	R	.	.	.	.	.
			A	G	9R-1, 90–91	.	C	A	.	R	?	.	.	.	C	.	C	.	C	F	C	C	.	F	.	C	C	A	R	R	F	C	R	.	.	F	R	.	C	F	R	.	.	A	.	C	.	.	C	R	.	R	.	.	R
			VA	G	10R-1, 35–36	.	C	A	.	R	?	.	.	.	F	.	C	.	C	F	C	C	.	C	F	C	F	A	F	.	F	C	R	.	.	C	R	.	C	R	R	.	.	C	C	C	F	F	C	F	.	R	.	.	F

R = Rare; F = Few; C = Common; A = Abundant; VA = Very abundant; ? = Questionably present; . = Not present.

Table 2 (continued).

Age	Sissingh zonation (1977)	Lithologic unit	Abundance	Preservation	Sample	*Nannoconus grandis*	*Nannoconus kampineri*	*Nannoconus ligius*	*Nannoconus steinmannii*	*Nannoconus truittii*	*Nannoconus wassallii*	*Nodosella silvaradion*	*Octopodorhabdus plethotretus*	*Parhabdolithus judithae*	*Percivalia fenestrata*	*Perissocyclus noeliae*	*Pickelhaube furtiva*	*Pickelhaube* sp. 1	*Retecapsa angustiforata*	*Retecapsa neocomiana*	*Retecapsa radiata*	*Rhagodiscus asper/splendens*	*Rhagodiscus infinitus*	*Rhagodiscus swinnertonii*	*Rhombolithion rhombicum*	*Rucinolithus terebrodentarius*	*Rucinolithus wisei*	*Sollasites hayi*	*Sollasites horticus*	*Sollasites lowei*	*Speetonia colligata*	*Stephanolithion laffittei*	*Tegumentum stradneri*	*Tetrapodorhabdus coptensis*	*Tetrapodorhabdus decorus*	*Thurmannolithion clatratum*	*Tranolithus gabalus*	*Tubodiscus verenae*	*Tubodiscus jurapelagicus*	*Vekshinella mitcheneri*	*Vekshinella angusta*	*Vekshinella parallela*	*Vekshinella pseudocarinolithus*	*Vekshinella stradneri*	*Watznaueria barnesae*	*Watznaueria biporta*	*Watznaueria britannica*	*Zeugrhabdotus embergeri*	*Zeugrhabdotus pseudoangustus*	*Zeugrhabdotus* ssp. (small)	*Zeugrhabdotus xenotus*	cf. *Dictyolithus quadratus*
late Barremian	*Micrantholithus hoschulzii* Zone CC6	IIA	A	M	20R-3, 32–33	.	.	.	C	F	.	.	.	.	F	.	.	R	C	.	R	C	C	.	.	.	.	.	R	.	.	C	F	F	.	.	R	.	C	.	.	.	.	.	C	F	.	C	.	C	.	F
			A	G	20R, CC	.	.	.	F	.	.	.	.	.	R	.	.	.	C	.	R	C	C	.	.	F	.	.	.	.	.	C	C	.	.	.	.	.	R	.	.	.	.	C	A	R	.	C	.	C	F	.
			A	M	21R-2, 47–48	.	.	.	C	.	F	.	.	.	F	.	.	R	F	.	R	C	F	.	.	.	.	R	R	.	.	C	F	R	.	.	F	.	F	.	.	.	.	A	C	R	.	C	R	F	.	.
			A	G	21R-3, 60–62	.	.	.	F	.	.	.	R	.	F	.	.	F	F	.	F	A	R	F	.	.	.	.	.	.	.	C	F	F	.	.	F	.	.	R	.	.	.	C	A	F	.	C	R	A	.	.
			F	P	21R-4, 54–55	.	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	F	R	.	R	.	R	.	.
			A	G	21R-5, 93–94	.	.	.	C	R	.	F	.	.	F	.	.	.	F	.	R	F	F	R	.	F	.	.	R	.	.	F	F	R	.	.	F	.	.	.	.	.	.	C	C	.	.	C	R	F	.	R
			A	G	22R-1, 41–42	.	R	.	R	.	.	.	.	.	C	.	.	.	C	F	F	A	F	F	.	F	.	.	.	.	.	C	C	F	.	.	F	.	.	.	.	.	.	A	A	F	.	C	.	C	.	F
			VA	M	22R-2, 22–23	.	.	.	C	.	.	.	.	.	F	.	.	F	C	F	F	A	C	R	.	.	.	.	.	.	.	C	.	R	.	.	R	.	.	.	.	.	.	A	V	F	.	C	.	C	.	.
			A	P	22R-3, 55–56	.	.	.	F	.	.	.	.	.	C	.	.	.	C	.	.	A	C	F	.	.	.	.	R	.	.	C	.	F	.	.	R	.	.	F	R	.	.	C	A	C	.	C	.	C	.	R
			A	M	22R-4, 49–50	.	.	.	F	.	.	.	.	.	C	.	.	.	C	.	.	A	C	.	.	.	.	.	.	.	.	C	.	.	.	.	.	.	.	F	C	.	.	A	A	F	.	C	.	A	.	.
			A	G	22R-5, 110–111	.	.	.	C	.	R	.	.	.	F	.	.	.	C	F	R	C	F	.	.	.	.	.	.	.	.	C	R	.	.	.	R	.	.	.	F	.	.	C	A	F	.	C	.	C	.	.
			A	G	23R-1, 61–62	.	.	.	F	.	.	F	R	.	F	.	.	F	.	C	R	C	F	R	.	.	.	.	.	.	.	C	F	R	.	.	R	.	.	.	R	.	.	C	A	.	.	C	.	C	.	.
			VA	G	23R-2, 111	R	R	.	C	.	R	.	R	.	F	.	R	C	.	.	R	C	F	.	.	.	.	.	.	.	.	C	.	F	.	.	R	.	.	.	R	R	.	C	A	.	.	C	.	C	.	.
late Hauterivian	CC5	IIB	VA	G	23R-3, 16–17	.	R	.	F	R	.	.	.	.	C	.	.	F	C	.	R	A	F	F	.	.	.	.	.	.	.	C	.	.	.	.	.	.	.	R	.	.	.	C	A	F	.	C	.	C	.	C
	Speetonia colligata Subzone CC4b		VA	G	23R-4, 55–56	.	F	R	A	R	.	F	R	.	C	.	.	.	C	.	F	A	C	F	.	.	.	.	.	R	R	C	F	.	.	.	F	.	.	.	R	R	.	C	A	F	.	C	R	A	.	.
			VA	G	23R-5, 89–90	.	C	F	A	R	.	F	.	.	F	.	.	.	C	.	.	C	C	F	.	.	.	.	.	.	R	C	F	F	.	.	C	.	.	.	R	.	.	C	A	F	.	C	F	C	.	.
			A	M	23R-6, 58–59	.	.	F	R	R	.	F	R	.	C	R	.	.	C	.	R	A	F	F	.	.	.	.	.	R	R	A	R	R	.	.	R	.	.	F	.	R	.	A	A	F	.	C	F	F	.	F
			VA	M	24R-1, 104–105	.	.	.	A	.	.	.	R	.	F	.	.	R	C	.	R	C	F	.	.	.	.	.	.	.	R	C	F	F	.	.	.	.	.	.	F	.	.	A	A	F	.	C	.	C	.	.
			A	P	24R-2, 64–65	.	.	.	C	.	.	.	.	.	R	.	.	.	C	C	.	C	F	.	.	.	.	.	.	.	F	C	F	F	.	.	R	R	.	.	F	.	.	C	A	F	.	C	R	A	.	.
			A	G	24R-3, 11–12	.	.	.	F	.	.	.	R	.	F	.	.	.	C	C	.	C	F	.	.	.	.	.	.	.	F	C	C	F	.	.	R	R	.	.	.	.	.	C	A	F	.	C	.	A	.	.
			VA	M	24R-4, 55	.	.	.	C	F	.	R	R	.	F	.	.	.	C	C	.	C	F	.	.	.	.	.	R	.	F	C	F	F	.	.	.	.	.	R	R	.	.	C	A	.	.	C	.	C	.	.
			VA	M	24R-5, 95–96	.	.	.	C	.	.	F	R	.	R	.	.	.	C	C	R	C	F	.	.	.	.	.	.	.	F	C	F	F	.	R	R	.	.	.	F	R	.	C	V	F	.	C	R	.	.	.
			A	M	24R-6, 17–18	.	.	.	F	.	.	F	.	.	R	.	.	.	C	C	.	C	R	.	.	.	.	.	.	.	F	C	F	F	.	.	F	R	.	.	F	.	.	C	A	F	.	C	R	A	.	.
			A	M	25R-1, 86–87	.	R	.	C	.	.	F	.	.	F	.	.	.	F	C	.	C	R	.	.	.	.	.	.	.	C	C	F	F	.	.	R	.	.	.	R	.	.	C	A	F	R	C	R	A	.	.
			A	M	25R-2, 80–81	.	.	.	C	.	.	F	.	.	R	.	.	.	C	C	.	C	R	.	.	.	.	.	R	.	C	C	F	C	.	.	.	R	.	.	R	F	.	C	A	F	.	C	R	A	.	.
			VA	G	25R-3, 8–9	.	.	.	C	.	.	F	.	.	F	.	.	.	.	F	.	.	R	R	.	.	.	.	.	.	C	C	.	F	.	.	.	.	.	.	.	F	.	C	V	F	.	C	R	C	.	.
			A	M	25R-4, 48–49	.	.	F	C	R	.	R	.	.	C	.	.	F	C	R	R	C	C	.	.	.	.	.	.	.	R	C	F	F	.	.	R	R	.	R	.	.	.	C	C	F	.	C	F	C	R	F
			A	M	25R-5, 19–20	.	.	.	F	.	.	F	R	.	F	R	.	R	C	F	.	C	F	.	.	.	.	.	R	R	C	C	F	F	.	.	.	R	.	.	.	C	.	C	A	F	.	C	F	C	R	.
			VA	M	25R-6, 45–46	.	.	.	F	.	.	F	R	.	F	.	.	.	C	F	.	C	F	.	.	.	.	.	R	.	C	C	F	C	.	.	.	.	.	.	.	C	.	.	A	F	.	C	F	.	.	.
			A	P	26R-1, 9–10	.	.	.	F	.	.	R	R	.	R	.	.	.	C	F	.	C	F	.	.	.	.	.	.	.	F	C	F	R	.	.	F	R	.	.	F	F	.	C	A	F	.	C	F	A	F	.
			VA	M	26R-1, 59–60	.	.	.	F	.	.	F	.	.	R	.	.	.	C	F	.	C	F	.	.	.	.	.	.	.	F	C	R	R	.	.	R	.	.	.	F	R	.	C	A	R	.	C	R	A	R	.
			C	M	26R-2, 11–12	.	.	R	F	.	.	C	R	.	F	.	.	.	C	F	.	A	F	.	.	.	.	.	.	.	F	C	.	F	.	.	.	.	.	R	C	F	R	C	A	F	.	C	.	A	F	.
			VA	G	26R-3, 108–109	.	.	R	C	.	.	C	R	.	F	R	.	.	C	F	.	A	R	.	.	.	.	.	R	.	C	C	R	F	.	.	.	.	.	R	R	F	.	C	V	F	.	C	F	A	R	.
			A	M	26R-4, 71–72	.	.	.	F	.	.	C	R	.	F	.	.	.	C	C	.	C	R	.	.	.	.	.	R	.	C	C	R	F	.	.	.	.	.	.	R	F	.	C	A	F	.	C	R	C	R	.
			A	G	26R-5, 18–19	.	.	.	.	.	.	C	.	.	F	.	.	.	C	C	R	C	F	.	.	.	.	.	.	.	F	C	R	F	.	.	R	.	.	.	R	R	.	C	A	R	R	C	F	C	R	.
			A	G	27R-1, 68–69	.	.	.	R	.	.	C	R	.	F	R	R	R	C	C	R	C	C	F	.	.	.	F	.	.	F	C	F	F	.	.	F	.	.	.	.	R	.	C	A	F	.	C	C	C	R	C
			A	M	27R-2, 70–71	.	.	.	.	.	.	C	R	.	F	R	.	.	C	F	R	C	R	.	.	.	.	.	.	.	F	C	.	R	.	.	.	R	.	.	.	R	.	C	A	F	R	C	F	C	F	.
			A	G	27R-3, 54–55	.	.	.	C	.	.	C	R	.	F	R	R	.	C	F	.	C	F	.	.	.	.	.	.	.	R	C	.	F	.	.	R	.	.	.	.	C	.	C	A	R	R	C	R	C	R	.
			A	G	27R-4, 20–21	.	.	.	F	.	.	F	R	.	F	.	.	.	F	F	.	A	C	.	.	.	.	.	.	.	F	C	R	R	.	.	R	.	.	R	R	.	.	C	A	F	.	C	.	C	F	F
			A	G	27R-5, 54–55	.	.	.	C	.	.	F	.	.	C	R	.	.	F	.	.	C	C	.	R	.	.	F	R	.	F	C	C	R	.	R	R	.	.	F	R	F	.	C	C	F	.	C	F	C	.	R
			A	P	27R-6, 57–58	.	.	.	.	.	.	.	.	.	F	.	.	.	F	F	.	C	F	.	.	.	.	.	.	.	F	C	.	F	.	.	.	.	.	.	F	R	.	C	A	R	.	C	R	C	F	.
			A	G	28R-3, 23	.	.	.	F	.	.	C	.	.	R	.	.	.	C	F	.	C	F	.	.	.	.	.	R	.	F	C	R	F	.	R	.	.	.	.	.	.	.	C	A	C	F	C	R	C	C	.
			C	G	28R-4, 58–59	.	.	.	F	.	.	R	.	.	.	.	.	.	F	F	.	C	R	.	.	.	.	.	.	.	R	F	.	R	.	.	.	R	.	.	.	.	.	C	C	R	.	C	.	C	F	.
			VA	M	28R-5, 116–117	.	.	.	F	.	.	C	R	.	C	.	R	.	C	F	.	C	C	.	.	.	.	.	.	.	R	C	.	F	.	.	.	.	.	.	.	C	.	C	A	F	.	C	R	A	R	.
			C	P	28R-6, 31–32	.	.	.	C	F	.	.	.	.	R	.	.	.	F	.	.	F	.	.	.	.	.	.	.	.	R	F	.	.	.	.	.	.	.	.	.	C	.	C	C	R	.	F	.	C	R	.
			VA	G	28R-6, 89–90	.	.	.	R	.	.	F	R	.	C	.	.	.	C	.	.	A	F	.	.	.	.	.	.	.	C	A	.	R	.	.	R	.	.	.	F	.	.	C	A	R	.	C	C	C	F	.
			A	G	29R-1, 23	.	.	.	F	.	.	F	R	.	C	R	.	.	C	F	.	C	F	.	.	.	.	.	.	.	C	C	.	F	.	R	F	.	.	.	C	C	.	C	A	F	R	C	F	C	F	.
			A	G	29R-2, 23	.	.	.	F	.	.	C	R	.	C	.	.	.	C	.	.	C	F	.	.	.	.	.	F	.	F	C	R	F	.	R	F	.	.	.	F	C	.	C	A	F	.	C	F	C	F	.
			VA	G	29R-3, 23	.	.	.	R	.	.	A	R	.	C	.	.	.	C	C	.	C	C	.	.	.	.	.	R	R	F	C	R	F	.	.	F	R	.	.	F	C	.	C	V	F	.	C	F	C	F	.
			A	M	29R-4, 18–19	.	.	.	.	.	.	R	.	.	R	.	.	.	C	.	.	C	F	.	.	.	.	.	.	.	R	C	R	F	.	.	R	R	.	.	.	C	.	C	A	R	.	C	R	C	C	.

Table 2 (continued).

early Hauterivian	*Chiastozygus striatus* Subzone CC4a		A	M	30R-1, 65-66	.	.	.	R	.	.	F	.	.	C	.	.	.	C	.	.	A	F	.	.	.	.	.	.	.	R	C	R	F	.	.	.	.	.	R	R	C	.	C	A	R	.	C	F	C	C	.
			A	M	30R-2, 58-59	.	.	.	R	.	.	F	.	.	F	.	.	.	C	R	.	C	F	.	.	.	.	.	.	.	F	C	.	F	.	.	.	.	.	R	R	F	.	C	C	R	.	C	R	F	F	.
			A	G	30R-3, 50-51	.	.	.	C	R	.	F	R	.	F	.	.	F	F	.	.	C	C	.	.	.	.	.	.	.	F	C	C	F	.	.	F	.	.	F	R	C	.	C	A	F	.	C	.	C	F	.
			A	M	30R-4, 27-28	.	.	.	F	.	.	F	R	.	F	.	.	R	C	.	R	A	F	R	.	.	.	.	.	.	F	C	F	F	.	.	R	R	.	F	R	C	.	C	A	R	.	C	F	C	F	.
			A	G	30R-5, 5-6	.	.	.	F	.	.	F	R	.	F	.	.	.	C	R	.	C	F	.	.	.	.	.	.	.	F	.	F	R	.	.	R	.	.	R	.	F	.	C	A	R	.	C	R	C	C	.
			A	M	30R, CC	.	.	.	F	.	.	F	R	.	F	.	.	.	F	R	.	C	R	.	.	.	.	.	.	.	C	C	R	R	.	.	.	.	.	F	.	R	.	C	A	F	.	C	.	C	F	.
			A	M	31R-1, 125-126	.	.	.	R	.	.	R	R	.	F	.	.	.	C	R	.	C	F	.	.	.	.	.	.	.	C	C	R	R	.	.	.	F	.	.	.	R	.	C	A	R	.	C	.	F	F	.
			VA	M	31R-2, 83-84	.	.	.	.	.	.	F	.	.	F	.	.	.	C	.	.	C	F	.	.	.	.	.	.	.	C	C	F	F	.	.	.	.	.	F	R	.	R	C	A	F	.	C	.	F	.	.
			A	G	31R-3, 123-124	.	.	.	R	.	.	F	.	.	F	.	.	.	F	.	.	C	C	.	.	.	.	.	.	.	C	C	R	R	.	.	.	R	.	F	.	R	.	C	V	F	.	C	.	F	C	.
			VA	M	31R-4, 103-104	.	.	.	R	.	.	F	.	.	F	.	.	.	C	.	R	C	C	.	.	.	.	.	.	.	C	A	F	F	.	.	.	.	.	F	.	F	R	C	V	F	.	C	.	C	C	.
			C	P	31R, CC	.	.	.	F	.	.	.	.	.	R	.	.	.	F	.	.	F	R	.	.	.	.	.	.	.	R	F	.	.	.	.	.	.	.	.	.	.	.	F	C	R	.	C	.	F	.	.
			C	P	32R-1, 43-44	.	.	.	F	.	.	.	.	.	R	.	.	.	F	.	.	F	R	.	.	.	.	.	.	.	R	F	.	R	.	.	.	.	.	.	.	R	.	F	C	R	.	C	R	F	.	.
			A	M	32R-2, 8-9	.	.	.	R	.	.	R	.	.	F	.	.	.	F	.	.	C	R	F	.	.	.	.	.	.	C	C	.	F	.	.	.	C	.	.	.	F	.	C	A	R	.	C	.	F	.	.
			A	G	32R-2, 126-127	.	.	.	R	R	.	R	.	.	F	.	R	R	C	C	.	C	R	C	.	.	.	.	.	.	C	C	R	F	.	.	.	R	.	F	.	C	.	C	A	F	.	C	F	C	.	.
			C	P	32R, CC	.	.	.	C	.	.	R	.	.	R	.	.	R	F	.	.	C	R	F	.	.	.	.	R	.	R	C	F	.	.	.	.	F	.	F	.	F	.	C	C	F	.	C	.	C	.	.
			VA	G	33R-1, 75-76	.	F	.	C	F	R	F	R	.	F	R	.	.	C	.	.	C	C	F	.	.	.	.	R	.	C	C	F	R	R	.	.	F	C	.	R	R	.	C	A	C	.	C	R	C	.	.
late Valanginian	*Eiffellithus windii* Subzone CC3b		VA	G	33R-2, 97-98	.	.	.	.	F	.	C	R	.	F	R	.	.	C	.	.	C	R	F	.	.	.	.	F	.	C	C	.	F	.	.	F	F	.	.	.	C	.	C	A	F	.	C	.	C	R	.
			A	G	33R-3, 97-98	.	.	.	.	.	.	R	R	.	F	.	.	.	C	.	.	C	C	F	.	.	.	.	.	.	R	C	F	F	.	.	R	F	.	.	.	F	.	C	C	R	.	C	R	C	R	.
			A	G	33R-4, 97-98	.	.	.	.	.	.	.	.	.	F	.	R	.	C	.	.	C	F	F	.	.	.	.	.	.	C	C	F	F	.	.	.	C	.	.	.	R	.	C	C	F	.	C	.	F	F	.
			C	P	34R-1, 113-114	.	.	.	C	.	.	F	.	.	F	.	.	.	F	.	.	C	R	C	.	.	.	.	R	.	F	C	.	.	.	.	.	.	.	.	.	R	.	C	C	R	C	C	F	F	R	.
			C	G	34R-2, 88-89	.	.	.	.	.	.	C	.	.	C	.	.	.	F	.	.	C	R	F	.	.	.	.	.	.	F	C	F	.	.	.	.	F	.	.	.	R	.	C	C	R	F	C	.	C	R	.
			A	M	34R-4, 100-101	.	.	.	.	.	.	F	.	.	F	.	.	.	C	.	.	C	F	F	.	.	.	.	R	.	C	C	R	R	.	.	.	.	.	.	.	F	.	C	C	F	F	C	R	C	R	.
			VA	G	34R, CC	.	.	.	C	.	.	C	R	.	C	R	.	.	C	.	R	C	C	F	.	.	.	.	R	.	C	A	.	F	.	.	.	F	.	.	.	C	R	C	A	F	F	C	F	C	R	.
			A	M	35R-1, 144-145	.	.	.	.	.	.	.	.	.	C	.	.	.	C	F	.	C	C	R	.	.	.	.	R	.	C	C	.	F	.	.	.	C	.	.	.	.	.	C	A	R	F	C	.	C	.	.
			A	M	35R-1, 150	.	.	.	F	.	.	C	.	.	F	.	.	.	C	F	.	C	F	F	.	.	.	.	R	.	C	C	.	R	.	.	F	F	.	.	.	.	.	C	A	R	F	C	.	C	.	.
			A	G	35R-2, 37-38	.	.	.	F	F	.	C	R	.	R	R	.	.	C	F	.	C	F	R	.	.	.	.	R	.	F	C	.	F	.	.	R	.	.	R	.	F	.	C	A	.	C	C	.	C	R	.
			VA	G	35R-3, 111-112	.	.	.	C	R	.	C	R	.	F	R	R	.	C	.	.	C	F	R	.	.	.	.	R	.	C	A	.	.	.	.	F	R	.	.	.	C	R	C	A	R	C	C	C	C	R	.
			VA	G	35R-4, 34-35	.	F	.	C	R	.	C	R	F	C	R	R	.	C	.	R	C	C	F	.	.	.	.	F	.	C	A	R	F	.	.	C	F	.	R	.	F	.	C	C	F	R	C	C	A	.	.
			C	P	36R-1, 47-48	.	.	.	.	.	.	F	R	.	F	R	.	.	F	.	.	F	R	R	.	.	.	.	R	.	F	F	.	R	.	.	.	R	.	R	.	.	.	F	C	R	F	F	R	F	R	.
			C	P	36R-1, 47-48	.	.	.	.	.	.	R	.	.	R	R	.	.	F	.	.	F	R	F	.	.	.	.	R	.	F	F	.	.	.	.	.	.	.	.	R	F	.	C	C	R	R	F	.	F	.	.
			A	M	36R-1, 153	.	.	.	R	.	.	F	.	.	R	R	.	.	C	.	.	R	R	F	.	.	.	.	R	R	F	C	.	F	.	.	F	F	.	R	.	.	.	C	A	F	R	C	.	C	.	.
			A	M	36R-2, 57-58	.	.	.	.	.	.	C	.	.	R	R	.	.	C	.	.	C	R	F	.	.	.	.	F	.	F	C	.	F	.	.	R	.	.	.	.	.	.	C	A	F	R	C	R	F	.	.
			A	M	36R, CC	.	.	.	.	.	.	F	.	.	F	.	R	.	C	.	.	C	F	F	.	.	.	.	R	.	F	C	R	R	.	.	R	R	.	.	.	.	.	C	A	C	F	C	.	C	.	.
			A	M	37R-1, 49-50	.	.	.	R	.	.	F	R	.	F	F	.	.	F	.	R	C	F	F	.	.	.	.	F	.	R	C	R	.	.	.	R	R	F	.	.	.	.	C	A	C	C	C	F	C	.	.
			A	M	37R, CC	.	.	.	.	.	.	R	.	.	R	R	.	.	F	.	.	C	F	R	.	.	.	.	R	.	F	C	.	R	R	.	R	R	.	.	.	.	.	C	A	R	F	C	.	F	R	.
			R	P	38R-1, 16-17	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	R	.	.	.	.
			A	M	38R-1, 75-76	.	.	.	.	.	.	.	.	.	R	.	.	.	F	.	.	C	R	F	.	.	.	.	R	.	F	C	.	.	.	.	.	R	.	R	.	.	.	A	A	C	F	C	.	C	.	.
			C	M	38R, CC	.	.	.	.	.	.	.	.	.	F	.	.	.	F	.	.	.	R	R	.	.	.	.	R	.	R	F	.	.	.	.	.	R	.	.	.	.	.	C	C	F	R	F	.	F	.	.
			F	M	39R-1, 10-11	.	.	.	.	.	.	.	.	.	R	.	.	.	R	.	.	F	R	F	.	.	.	.	R	.	R	F	.	.	.	.	.	.	.	.	.	.	.	F	F	.	R	F	.	F	.	.
			A	M	39R, CC	.	.	.	.	.	.	.	R	.	R	.	.	R	F	.	R	C	R	F	.	.	.	.	R	.	F	C	.	R	.	.	.	.	.	.	.	.	.	C	C	F	R	C	R	R	.	.
			R	P	40R-1, 44-45	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	R	R	.	R	.	.	.	.
			C	G	40R, CC	.	.	.	.	.	.	.	.	.	F	.	.	R	F	.	R	F	F	F	.	.	.	.	R	.	R	C	.	R	.	.	.	R	.	.	.	.	.	C	C	R	F	C	.	F	.	.
		III	A	G	41R-1, 135-136	.	.	.	.	.	.	R	.	.	F	.	.	.	C	.	.	F	R	F	.	.	.	.	R	.	R	F	.	.	.	.	.	R	.	.	.	.	.	C	C	R	F	C	.	F	.	.
			VA	G	41R-1, 150	.	.	.	R	.	.	F	R	.	R	R	R	.	C	.	R	C	R	F	.	.	.	.	R	.	C	A	.	F	.	.	R	.	.	.	.	.	.	C	A	F	F	.	.	.	.	.
			A	G	41R-2, 7-8	.	.	.	.	.	.	.	.	.	F	.	.	.	F	.	R	C	F	F	.	.	F	.	R	.	.	.	.	.	.	.	.	F	.	.	.	.	.	C	C	F	F	C	R	C	.	.
			C	G	42R-1, 30-31	.	.	.	.	.	.	.	.	.	R	.	.	.	F	.	.	C	R	R	.	.	.	.	.	.	R	F	.	R	.	.	.	R	.	.	.	.	.	C	C	F	R	F	.	F	.	.
			VA	G	42R-1, 134-135	.	.	.	.	.	.	.	.	.	R	.	R	R	C	.	.	.	R	F	.	.	.	.	R	.	C	A	.	R	R	.	.	R	.	R	.	.	.	A	A	F	F	.	C	C	.	.
			A	G	42R-2, 12-13	.	.	.	.	.	.	R	R	.	R	R	R	.	F	.	.	F	R	F	.	.	.	.	.	.	C	F	.	R	.	.	.	F	.	.	.	.	.	C	C	F	C	C	F	F	.	.
			A	G	42R, CC	.	.	.	.	.	.	F	.	.	F	.	.	.	C	.	.	F	R	F	.	.	.	.	R	.	C	A	.	R	.	.	.	F	.	R	.	.	.	C	A	F	C	C	R	C	.	.
			A	G	43R-1, 41-42	.	.	.	.	.	.	F	.	.	C	.	.	.	C	.	.	F	R	F	.	.	.	.	R	.	C	A	.	R	.	.	.	F	.	R	.	.	.	C	A	F	C	C	R	C	.	.
			A	M	43R-2, 55-56	.	.	.	R	.	.	F	.	.	F	R	.	.	C	.	.	F	R	R	.	.	.	.	R	.	R	C	.	.	.	.	.	R	.	.	.	.	.	C	A	R	F	C	R	F	.	.
			F	M	43R, CC	.	.	.	.	.	.	.	.	.	R	.	.	.	R	.	.	R	.	R	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	F	F	R	F	F	.	R	.	.
			A	G	44R-1, 38-39	.	.	.	.	.	.	R	R	.	F	.	.	.	F	.	.	C	R	R	.	.	.	.	R	.	F	C	.	F	.	.	.	F	R	.	.	.	.	C	A	C	C	C	.	C	.	.
early Valanginian	*Tubodiscus verenae* Subzone CC3a		C	M	44R-2, 31-32	.	.	.	.	.	.	.	.	.	R	.	.	R	R	.	.	F	R	R	.	.	R	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	F	C	R	F	F	.	F	.	.
			A	M	44R-2, 115	.	.	.	R	.	.	F	.	.	F	.	.	.	C	R	.	C	R	R	.	.	.	.	R	.	F	C	.	R	.	.	F	R	.	R	.	.	.	A	A	F	C	C	.	C	.	.
			A	M	44R-3, 115	.	.	.	.	.	.	F	.	.	R	.	.	.	F	R	.	F	R	.	.	.	R	.	R	.	R	C	.	.	.	.	C	R	.	R	.	.	.	C	A	F	F	C	R	F	.	.
			C	M	45R-1, 62-64	.	.	.	R	.	.	.	.	.	R	.	.	.	F	R	.	F	.	.	.	.	.	.	.	.	R	F	.	R	.	.	R	R	.	.	.	.	.	F	C	F	F	.	.	F	.	.
			A	G	45R-2, 79-80	.	.	.	R	.	.	F	.	.	R	R	.	.	.	R	.	C	.	.	.	.	F	.	.	.	F	A	.	F	.	.	C	.	.	R	.	.	.	C	A	C	F	C	.	C	.	.
			A	G	45R-3, 28-29	.	.	.	.	.	.	.	R	.	R	.	.	.	C	R	.	C	R	.	.	.	F	.	R	.	F	C	.	F	.	.	C	.	.	.	.	.	R	C	A	C	C	C	R	C	.	.
			A	M	45R, CC	.	.	.	.	.	.	F	.	.	F	R	.	.	F	R	.	C	R	.	.	.	.	.	R	.	R	A	.	F	.	.	C	.	.	.	.	.	.	C	C	F	R	C	.	F	.	.
			C	M	1R-1, 77-78	.	.	.	.	.	.	.	.	.	R	.	.	.	C	R	.	F	.	.	.	.	.	.	R	.	.	F	.	.	.	.	R	.	.	.	.	.	.	C	C	R	F	F	.	F	.	.
			A	G	1R-1, 102	.	.	.	.	.	.	F	.	.	R	R	.	.	C	F	.	F	.	.	.	.	.	.	F	.	R	C	.	R	.	.	F	.	.	R	.	.	.	C	A	R	F	C	.	F	.	.
			VA	G	1R-2, 17-18	.	.	.	.	.	.	F	.	.	F	R	.	.	C	F	.	C	R	.	.	.	.	.	R	.	F	C	.	R	.	.	R	.	.	R	.	.	.	C	C	R	F	C	R	F	.	.
			A	G	1R-3, 8-7	.	.	.	.	.	.	F	R	R	F	R	.	.	C	R	R	C	R	.	.	.	.	.	R	.	F	C	.	F	.	.	F	.	.	R	.	.	.	C	C	R	F	C	F	C	.	.
			VA	G	3R-2, 141-142	.	.	.	F	.	.	R	R	R	C	R	.	.	C	R	R	C	R	.	.	.	.	.	R	.	C	C	.	F	.	.	C	.	.	.	R	.	.	C	A	F	C	C	.	C	.	.
			VA	G	4R-4, 28-29	.	.	.	C	.	.	C	R	.	C	.	R	R	C	F	.	C	C	R	.	.	.	.	R	.	C	A	.	F	.	.	F	R	.	R	.	.	R	A	A	C	C	C	F	C	.	.
			VA	G	6R-1, 17-18	.	.	.	C	.	.	F	R	R	F	.	R	.	C	C	.	C	C	F	.	.	.	.	R	.	C	A	.	R	.	.	R	.	.	R	.	.	F	C	V	C	C	C	R	C	.	.
			VA	G	6R-3, 13-14	.	.	.	.	.	.	.	.	.	R	.	R	.	R	.	.	F	C	F	.	.	.	.	.	.	R	C	.	.	.	.	.	R	.	.	.	.	.	C	A	F	C	C	.	F	.	.
			A	M	7R-3, 31-32	.	.	.	.	.	.	F	.	.	F	R	R	R	C	R	.	C	C	.	.	.	.	.	R	.	F	C	.	F	R	.	.	.	R	.	.	.	F	A	A	F	C	C	.	C	.	.
			A	G	9R-1, 90-91	.	.	.	R	.	.	F	R	R	F	.	.	R	C	R	R	C	C	.	.	.	.	.	R	.	C	C	.	F	.	.	R	.	.	.	.	.	F	C	V	C	C	C	F	C	.	.
			VA	G	10R-1, 35-36	.	.	.	F	.	.	R	R	.	C	R	R	.	C	R	R	C	C	.	.	.	.	.	R	.	C	C	.	F	F	.	C	R	R	R	.	.	.	A	V	C	C	C	C	C	.	.

R = Rare; F = Few; C = Common; A = Abundant; VA = Very abundant; ? = Questionably present; . = Not present.

Table 3. Relative abundance of nannofossils, Site 640A.

Age	Sissingh zonation (1977)	Lithologic unit	Abundance	Preservation	Sample	*Assipetra infracretacea*	*Axopodorhabdus dietzmannii*	*Biscutum constans*	*Braarudosphaera discula*	*Bukrylithus ambiguus*	*Calcicalathina oblongata*	*Chiastozygus tenuis*	*Conusphaera mexicana*	*Corollithion acutum*	*Corollithion ellipticum*	*Cretarhabdus conicus*	*Cretarhabdus delicatus*	*Cretarhabdus surirellus*	*Cruciellipsis cuvillieri*	*Cyclagelosphaera margerelii*	*Diadorhombus rectus*	*Diazomatolithus lehmanii*	*Diloma primitiva*	*Discorhabdus biradiatus*	*Discorhabdus ignotus*	*Eiffellithus windii*	*Ellipsagelosphaera ovata*	*Ethmorhabdus hauterivianus*	*Flabellites oblonga*	*Glaukolithus diplogrammus*	*Grantarhabdus meddii*	*Haqius circumradiatus*	*Lapideacassis* sp.	*Lithraphidites bollii*	*Lithraphidites carniolensis*	*Manivitella pemmatoidea*	*Micrantholithus hoschulzii*	*Micrantholithus obtusus*	*Microstaurus chiastius*	*Microstaurus* sp. 1
late Barremian	*Micrantholithus hoschulzii* Zone CC6	II	A	P	2R-2, 60 cm	R	R	.	.	.	.	.	.	.	.	F	.	.	.	F	.	F	.	.	F	.	.	.	.	.	.	.	.	.	C	C	F	F	R	.
			A	M	2R, CC	.	R	F	.	R	.	R	.	.	.	F	R	.	.	C	.	C	.	.	C	.	.	.	.	R	R	.	.	.	C	C	.	R	F	.
			A	M	2R, CC (29 cm)	F	C	C	.	.	.	R	.	.	.	C	.	.	.	F	.	C	.	.	C	.	.	.	R	R	R	R	.	.	C	C	F	C	C	.
			A	G	3R-2, 68 cm	.	F	C	.	R	.	.	C	.	F	F	.	.	.	C	.	F	.	.	C	.	.	.	.	C	R	R	.	.	C	C	C	C	C	.
			A	G	3R-3, 56–57 cm	.	C	C	.	R	.	R	F	.	F	F	.	.	.	C	.	F	R	F	C	.	.	.	.	C	.	R	.	.	C	C	C	C	C	.
			A	G	3R, CC	.	C	C	.	.	.	.	F	.	R	C	.	F	.	C	.	C	.	F	C	.	R	.	.	C	.	.	.	.	C	C	C	C	C	.
	Lithraphidites bollii Zone CC5		VA	G	4R-1, 104–105 cm	.	C	C	R	R	F	.	R	.	.	C	.	C	.	C	.	C	.	F	C	.	.	.	.	C	R	.	.	.	C	C	A	C	C	.
			A	M	4R-2, 9–10 cm	R	F	C	.	.	R	.	R	.	C	C	.	F	.	C	R	C	R	F	C	.	.	.	.	C	R	R	.	.	C	C	F	R	C	.
			VA	G	4R, CC	.	F	C	.	.	F	R	F	.	F	F	R	F	.	C	R	C	R	F	C	.	.	.	.	C	F	R	.	.	C	C	F	F	C	.
			VA	G	5R-1, 3 cm	.	C	C	R	R	R	R	R	.	F	C	R	R	.	C	.	C	.	F	C	R	.	.	.	C	R	F	.	?	C	C	R	.	C	.
late Hauterivian			A	G	5R-1, 7 cm	.	F	C	.	R	C	R	F	R	A	F	F	C	R	C	F	A	R	C	C	R	.	R	.	C	F	R	R	.	C	C	F	C	F	.
	Speetonia colligata Subzone CC4b		A	G	5R-1, 22 cm	.	C	C	R	R	F	R	R	.	C	C	R	C	R	F	F	C	.	F	C	.	R	.	.	C	F	F	.	R	C	C	R	R	C	.
			A	G	5R, CC	.	C	C	.	R	R	R	F	.	C	C	F	F	.	F	R	C	R	F	C	.	.	.	C	F	F	F	.	.	C	C	.	.	C	R
			A	G	6R-1, 50 cm	.	C	A		R	F	R	F	.	C	C	F	F	R	C	R	C	R	R	C	.	.	.	C	C	R	R	R	R	C	C	R	R	C	.
			A	G	6R-1, 120 cm	.	F	C	.	R	C	F	C	R	C	C	R	F	R	C	C	C	.	F	C	.	.	.	C	C	R	R	.	F	C	C	C	C	C	R
			A	M	6R, CC	.	F	C	.	F	F	.	R	.	F	F	.	F	F	C	F	C	.	R	C	.	.	.	C	C	R	R	.	.	C	C	R	R	C	R
			A	M	7R-1, 115–116 cm	.	F	C	.	R	F	.	F	.	C	C	R	F	F	C	F	C	.	F	C	.	.	.	R	C	.	R	.	.	C	C	R	R	F	.
			A	P	7R-2, 10–11 cm	.	R	C	.	.	C	.	F	.	R	F	.	R	R	C	R	C	.	.	C	.	.	.	.	C	R	.	.	F	C	F	C	C	C	.
			A	G	7R, CC	.	F	C	.	R	C	.	R		F	C	R	F	F	C	R	C	.	R	C	.	.	.	.	F	R	R	.	.	C	C	R	.	C	.
			A	M	7R, CC	.	F	C	R	.	C	.	F	.	R	F	R	F	R	C	R	C	.	R	F	.	.	.	.	C	R	R	.	F	C	C	C	C	C	.
			A	M	8R-1, 8–9 cm	.	C	C	R	R	C	.	R	.	C	C	.	F	R	C	R	C	.	R	C	.	R	.	.	C	R	R	R	F	C	C	R	F	C	.
			VA	G	9R-1, 1 cm	R	R	F	.	.	F	.	R	.	R	F	.	F	R	F	R	C	.	R	F	.	R	.	.	C	.	R	.	R	F	F	R	F	F	.
			C	P	8R, CC (5–6 cm)	R	C	C	F	R	C	.	R	.	C	C	R	F	F	C	F	C	.	F	C	.	R	.	.	C	R	R	.	F	C	C	C	C	C	R

R = Rare; F = Few; C = Common; A = Abundant; VA = Very abundant; ? = Questionably present; . = Not present.

Table 3 (continued).

Age	Sissingh zonation (1977)	Lithologic unit	*Nannoconus abundans*	*Nannoconus bucheri*	*Nannoconus elongatus*	*Nannoconus globulus*	*Nannoconus ligius*	*Nannoconus steinmannii*	*Nodosella silvaradion*	*Octopodorhabdus plethotretus*	*Percivalia fenestrata*	*Pickelhaube furtiva*	*Pickelhaube* sp. 1	*Retecapsa angustiforata*	*Retecapsa neocomiana*	*Retecapsa radiata*	*Rhagodiscus asper/splendens*	*Rhagodiscus infinitus*	*Rhagodiscus swinnertonii*	*Rucinolithus terebrodentarius*	*Sollasites hayi*	*Sollasites horticus*	*Sollasites lowei*	*Speetonia colligata*	*Stephanolithion laffittei*	*Tegumentum stradneri*	*Tetrapodorhabdus coptensis*	*Tetrapodorhabdus decorus*	*Tranolithus gabulus*	*Trapezopentus sarmatus*	*Tubodiscus verenae*	*Tubodiscus jurapelagicus*	*Vekshinella mitcheneri*	*Vekshinella angusta*	*Vekshinella parallela*	*Vekshinella stradneri*	*Watznaueria barnesae*	*Watznaueria biporta*	*Watznaueria britannica*	*Zeugrhabdotus embergeri*	*Zeugrhabdotus pseudoangustus*	*Zeugrhabdotus* ssp. (small)	*Zeugrhabdotus xenotus*	cf. *Dictyolithus quadratus*
late Barremian	*Micrantho-lithus hoschulzii* Zone CC6		F	F	F	C	.	A	.	.	.	.	.	F	.	R	C	R	.	.	.	.	.	.	F	.	.	.	R	.	.	.	.	.	.	F	A	.	.	F	.	.	.	.
			.	.	.	.	.	.	.	.	R	F	F	C	.	F	C	R	.	R	.	.	.	.	C	.	.	.	.	.	.	R	.	.	.	C	A	.	.	F	.	F	.	.
			.	.	.	R	.	F	.	.	R	R	.	C	.	F	C	F	.	F	.	.	.	.	C	R	.	.	.	.	.	R	.	.	.	C	A	.	.	C	R	F	.	.
			R	R	.	C	.	C	.	.	R	.	.	C	.	R	C	C	.	R	.	.	.	.	C	F	.	F	.	.	.	C	.	.	.	C	A	.	.	C	.	F	.	R
			R	F	.	C	.	C	.	R	F	R	F	C	.	C	C	C	R	.	.	.	.	.	C	R	C	F	.	.	.	C	.	R	.	C	A	.	.	C	.	C	.	.
			R	F	.	C	.	C	.	R	R	R	R	C	.	F	C	C	R	F	.	.	.	.	C	R	C	F	.	.	.	F	C	.	.	C	A	.	.	C	R	C	.	.
	Lithraphidites bollii Zone CC5		.	C	.	C	.	A	.	R	F	.	R	C	.	R	C	C	R	R	.	.	.	.	C	R	C	R	R	R	.	F	F	R	.	C	A	.	.	C	.	C	.	.
			.	.	.	F	.	F	.	.	F	R	.	C	.	.	C	C	.	R	.	.	F	.	C	R	F	R	.	.	.	.	R	R	.	C	A	.	R	C	.	C	.	.
			.	.	.	F	.	C	.	.	F	.	.	C	.	.	F	F	.	.	.	.	R	.	C	R	F	.	.	.	.	R	R	F	C	C	A	.	.	C	R	C	.	.
			.	.	.	F	.	F	.	.	C	F	.	C	R	.	C	C	R	.	.	.	.	.	C	R	F	R	R	.	.	.	.	F	C	C	A	.	.	C	.	C	.	.
			F	R	.	F	F	F	.	R	C	.	.	C	C	R	C	C	F	.	.	.	.	F	C	F	C	F	R	.	R	F	R	F	F	C	A	.	.	C	C	A	.	.
late Hauterivian	*Speetonia colligata* Subzone CC4b	II	R	.	.	R	R	R	.	R	C	R	.	C	F	R	C	C	F	.	.	R	.	C	C	C	C	F	.	.	.	F	R	F	F	C	A	.	.	C	C	A	.	.
			.	.	.	.	R	R	.	R	F	R	.	C	F	R	C	F	R	.	.	.	.	C	C	F	F	F	.	R	.	R	.	R	F	C	A	.	.	C	C	C	R	.
			F	.	.	R	.	F	R	.	F	R	.	C	R	R	C	F	.	.	.	.	.	C	F	R	C	F	.	.	.	R	R	F	F	C	A	.	.	C	C	C	F	.
			F	R	R	F	.	C	F	.	C	R	.	C	R	F	C	F	.	.	R	.	.	F	C	F	C	F	R	.	.	.	.	F	F	C	A	.	.	C	F	C	.	.
			R	R	.	R	.	F	F	R	F	.	.	C	F	R	C	F	.	.	R	.	.	F	C	F	F	R	.	.	R	R	.	R	F	C	A	.	.	C	R	C	R	.
			.	.	.	R	.	F	R	R	F	.	.	C	F	.	C	F	R	.	.	.	.	F	C	R	F	.	.	.	R	R	.	R	R	C	A	R	.	C	R	C	.	.
			F	R	.	R	.	C	.	.	.	.	.	F	R	.	C	F	F	.	.	.	.	R	C	.	R	.	.	.	.	.	.	.	R	C	A	.	.	C	R	F	.	.
			R	.	.	F	.	F	F	R	R	R	.	C	.	R	C	F	R	.	.	.	.	R	C	R	R	.	.	.	.	.	.	.	F	C	A	.	.	C	F	C	.	.
			F	F	.	F	.	C	R	R	F	.	.	C	.	.	C	F	F	.	.	.	.	R	C	.	.	R	.	.	.	.	.	R	F	C	A	.	.	C	R	C	.	.
			R	.	.	R	.	F	F	.	R	R	.	C	F	.	C	F	R	.	.	.	.	F	C	R	F	R	R	.	R	.	R	R	C	C	A	R	.	C	R	C	R	.
			.	R	.	F	R	C	R	.	R	.	.	C	F	.	C	R	R	R	.	.	.	R	C	.	R	.	.	.	R	R	.	.	R	C	C	.	.	C	R	F	.	.
			R	F	.	C	.	C	F	R	F	R	.	C	F	.	C	C	F	.	.	.	.	F	C	F	F	F	R	.	R	R	.	R	C	C	A	R	.	C	F	C	R	.

Table 4. Relative abundance of nannofossils, Hole 641C.

Age	Sissingh zonation (1977)	Lithologic unit	Abundance	Preservation	Sample	*Amphizygus brooksi*	*Axopodorhabdus albianus*	*Axopodorhabdus dietzmannii*	*Biscutum constans*	*Braarudosphaera africana*	*Braarudosphaera discula*	*Bukrylithus ambiguus*	*Chiastozygus litterarius*	*Chiastozygus platyrhethus*	*Chiastozygus tenuis*	*Conusphaera mexicana*	*Corollithion achylosum*	*Corollithion acutum*	*Corollithion ellipticum*	*Cretarhabdus conicus*	*Cretarhabdus delicatus*	*Cretarhabdus loriei*	*Cretarhabdus surirellus*	*Cyclagelosphaera margerelii*	*Cylindralithus nudus*	*Diadorhombus rectus*	*Diazomatolithus lehmanii*
early Albian	*Braarudosphaera Subzone* CC8a	III	A	G	1R-1, 52–53 cm	R	R	.	C	R	.	F	R	.	.	.	R	.	.	R	.	R	F	.	R	.	.
			A	G	1R-1, 120–121 cm	R	.	R	C	.	.	R	.	.	.	.	R	.	.	R	.	.	F	.	R	.	.
			C	G	1R-2, 85–86 cm	R	.	R	C	.	.	R	R	.	.	.	R	.	.	R	.	R	F	.	R	.	.
			C	G	1R-3, 81–82 cm	R	.	R	C	.	.	R	R	.	.	.	R	.	.	R	.	R	F	.	.	.	.
			VA	G	1R-4, 17–18 cm	R	.	R	C	.	.	R	F	R	.	.	F	.	.	F	.	R	F	.	.	.	.
			F	P	1R-6, 39–40 cm	.	.	.	R	.	.	R	.	.	.	.	R	.	.	.	.	.	R	.	.	.	.
			F	M	1R, CC	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
			C	M	2R-1, 25–26 cm	.	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	R	.	.
			C	P	2R-1, 118–119 cm	.	.	.	F	.	.	R	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.
			A	M	3R-2, 138 cm	R	.	.	F	.	.	.	.	.	.	.	R	.	.	R	.	.	F	.	R	.	.
			C	M	3R-3, 110 cm	.	.	.	F	.	.	.	.	.	.	.	R	.	.	R	.	.	F	.	R	.	.
			F	P	6R-2, 67 cm	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
			A	G	6R-3, 43 cm	.	.	R	C	.	.	.	.	R	.	.	.	.	.	F	.	.	F	.	.	.	.
			A	G	6R-3, 51 cm	R	.	R	C	.	.	R	R	.	.	.	R	.	.	R	.	.	C	.	.	.	.
			A	G	6R-3, 55 cm	.	.	R	C	.	.	R	.	.	.	.	R	.	.	R	.	.	C	.	.	.	.
early Albian to late Aptian	*Rhagodiscus angustus* Subzone CC7b	IV	B		6R-3, 77 cm	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
			C	M	6R-3, 78 cm	.	.	.	C	.	.	.	.	.	.	.	.	.	.	R	.	.	F	.	.	.	.
			A	G	6R-3, 91 cm	.	.	R	C	.	.	.	.	.	.	.	.	.	.	F	.	.	F	.	.	.	.
			A	G	6R-3, 123 cm	R	.	C	C	.	.	R	C	F	.	.	F	.	.	C	.	F	C	.	.	.	.
			A	G	6R-4, 8–9 cm	.	.	.	C	.	.	R	.	.	.	.	.	.	.	F	.	.	F	.	.	.	.
			VA	G	6R, CC	R	.	.	C	.	.	F	R	.	.	.	.	.	.	F	.	.	F	.	.	.	.
			VA	G	7R-1, 115–116 cm	.	.	.	C	.	.	R	R	.	.	.	.	.	.	F	.	R	F	R	.	.	.
			VA	G	7R-2, 114–115 cm	R	.	.	C	.	.	F	F	.	.	.	.	.	.	C	.	.	F	R	.	.	.
		V	A	G	8R-1, 59–60 cm	R	.	F	A	.	.	R	F	.	.	.	.	.	.	C	.	.	F	R	.	.	.
			A	G	8R-2, 13–14 cm	R	.	R	C	.	.	.	R	.	.	.	.	.	.	C	.	.	F	R	.	.	.
			C	M	8R-3, 90–91 cm	R	.	.	C	.	.	R	R	.	.	.	R	.	.	R	.	.	R	R	.	.	.
			A	M	8R-4, 76–77 cm	R	.	.	F	.	.	F	R	.	.	.	.	.	.	.	.	.	R	R	.	.	.
early Aptian	*Hayesites irregularis* Subzone CC7a		C	M	8R-4, 121–122 cm	R	.	F	.	.	.	.	.	.	.	C	.	.	.	F	.	.	C	C	.	.	.
			VA	G	9R-1, 57–58 cm	.	.	.	C	.	.	.	.	.	.	.	.	.	.	.	.	R	F	R	.	.	.
			VA	G	9R-3, 139 cm	.	.	.	C	.	.	.	.	.	.	.	.	.	.	F	.	.	F	C	.	R	.
			A	M	9R-4, 37–38 cm	F	.	C	C	.	R	R	R	.	.	R	F	C	R	F	.	R	F	C	.	.	.
			A	M	9R, CC	F	.	F	C	.	R	R	F	.	.	.	R	F	F	F	R	.	F	C	.	.	.
			A	M	10R-2, 56 cm	R	.	C	C	.	.	R	F	.	.	R	R	R	F	F	R	.	F	C	.	.	.
			A	G	10R-3, 133 cm	R	.	R	C	.	.	.	R	.	.	.	.	.	.	.	.	.	R	C	.	.	.
			A	M	10R-4, 15–16 cm	.	.	R	C	.	.	.	R	.	.	R	R	R	.	.	.	.	R	F	.	.	.
			A	P	10R-4, 46 cm	R	.	R	C	.	.	.	R	.	.	.	.	.	.	C	R	R	F	C	.	.	.
			A	G	10R, CC	.	.	R	F	.	.	.	.	.	.	.	R	.	.	F	R	.	F	F	.	.	.
			A	G	11R-2, 55–56 cm	R	.	F	C	.	.	.	R	.	.	R	R	R	.	.	F	.	F	C	.	.	.
			A	G	11R-2, 60 cm	R	.	.	C	.	R	.	F	.	.	C	R	R	.	.	R	.	F	C	.	.	.
			A	M	11R-2, 108 cm	F	.	C	C	.	.	R	F	.	.	R	R	R	.	F	R	R	F	C	.	.	.
			A	P	11R-3, 76 cm	.	.	R	C	.	R	.	.	.	.	C	.	.	.	F	R	.	R	F	.	.	.
late Barremian	*Micrantholithus hoschulzii* Zone CC6	VI	A	M	12R-1, 27–28 cm	.	.	R	F	.	.	.	.	.	.	F	.	.	.	F	R	.	F	.	.	.	.
			A	G	12R-2, 44 cm	.	.	R	F	.	.	.	.	.	.	R	.	.	.	F	.	.	R	R	.	.	.
			VA	G	12R-3, 103 cm	.	.	R	C	.	.	.	.	R	.	R	.	.	.	F	R	R	F	R	.	.	.
			A	G	12R-3, 107 cm	.	.	F	C	.	F	.	R	.	.	C	.	.	.	C	.	.	F	C	.	.	.
			A	G	12R-4, 91 cm	.	.	F	C	.	.	.	R	.	.	F	.	.	.	F	.	.	F	C	.	.	.
			A	G	12R-5, 96 cm	.	.	F	C	.	.	R	R	.	.	C	.	.	.	C	R	.	C	C	.	.	F
			A	G	12R-6, 4–5 cm	.	.	F	C	.	.	.	R	.	.	.	.	.	.	F	R	.	F	C	.	.	F
			C	M	13R-1, 45–46 cm	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
			A	G	13R-2, 36 cm	.	.	F	C	.	.	.	.	.	R	C	.	.	.	F	.	.	F	C	.	R	.
			C	P	13R-4, 119 cm	.	.	.	C	.	.	.	.	.	.	F	.	.	.	F	R	.	R	C	.	.	.
			VA	G	13R-5, 27 cm	.	.	F	C	.	.	.	.	.	.	F	.	.	.	C	.	.	F	C	.	.	.
			A	M	14R-3, 46 cm	.	.	R	C	.	.	.	.	.	.	C	.	.	.	C	.	.	F	C	.	.	.
			A	M	14R-4, 31 cm	.	.	R	C	.	.	.	.	.	.	C	.	.	.	F	.	.	R	C	.	.	.
			A	M	15R-2, 40 cm	.	.	R	C	.	.	.	.	.	.	C	.	.	.	F	R	.	F	C	.	.	R
			A	M	15R-3, 27 cm	.	.	R	C	.	.	.	.	.	.	C	.	.	.	F	.	.	R	F	.	.	.
			A	G	15R-5, 40 cm	.	.	R	F	.	.	.	.	.	.	C	.	.	.	C	R	.	.	R	.	.	.
			A	G	16R-2, 35 cm	.	.	.	C	.	.	.	.	.	R	F	.	.	.	C	R	.	F	C	.	.	.
			A	M	16R-4, 61 cm	.	.	R	F	.	.	.	.	.	.	C	.	.	.	C	.	.	F	F	.	.	.
			A	P	16R-5, 36 cm	.	.	.	F	.	.	.	.	.	.	F	.	.	.	F	.	.	R	C	.	.	.
			A	M	16R-8, 28 cm	.	.	R	C	.	.	.	.	.	.	C	.	.	.	C	R	.	F	C	.	.	.

R = Rare; F = Few; C = Common; A = Abundant; VA = Very abundant; ? = Questionably present; . = Not present.

Table 4 (continued).

Diloma primitiva	*Discorhabdus ignotus*	*Discorhabdus rotaterius*	*Ellipsagelosphaera ovata*	*Eprolithus floralis*	*Flabellites biforaminis*	*Flabellites oblonga*	*Glaukolithus diplogrammus*	*Grantarhabdus meddii*	*Haqius circumradiatus*	*Hayesites albiensis*	*Hayesites irregularis*	*Lapideacassis* sp.	*Lithraphidites carniolensis*	*Manivitella pemmatoidea*	*Micrantholithus hoschulzii*	*Micrantholithus obtusus*	*Microstaurus chiastius*	*Microstaurus conus*	*Nannoconus abundans*	*Nannoconus bermudezii*	*Nannoconus bucheri*	*Nannoconus elongatus*	*Nannoconus globulus*	*Nannoconus kamptneri*	*Nannoconus steinmannii*	*Nannoconus truittii*	*Nannoconus wassallii*	*Nodosella silvaradion*	*Octopodorhabdus plethotretus*	*Percivalia fenestrata*	*Pickelhaube furtiva*	*Pickelhaube* sp. 1	*Prediscosphaera columnata*	*Prediscosphaera spinosa*	*Radiolithus planus*	*Retecapsa angustiforata*	*Retecapsa radiata*	*Rhagodiscus angustus*	*Rhagodiscus asper/splendens*	*Rhagodiscus infinitus*	*Rhagodiscus swinnertonii*	*Rucinolithus terebrodentarius*
.	C	F	F	F	R	.	F	.	.	F	R	.	A	F	.	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	R	.	C	.	F	C	F	C	.
.	C	F	F	R	R	.	C	R	.	F	.	.	C	C	.	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	C	.	F	C	F	C	.
.	C	R	R	R	R	.	F	.	.	F	.	.	F	F	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	R	.	F	.	R	F	R	R	.
.	F	R	R	R	R	.	C	.	.	R	.	.	C	F	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	F	.	R	F	.	F	.
.	C	F	R	R	.	.	C	R	.	C	.	.	A	C	.	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	F	.	C	.	F	C	R	C	.
.	R	R	.	R	.	.	R	.	.	F	.	.	R	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	R	.	R	R	R	C	.
.	R	R	R	.	.	.	F	.	.	R	.	.	R	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	R	.	R	.	.	.	.
.	F	R	R	R	R	.	F	.	.	R	.	.	R	R	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	R	F	R	.
.	F	R	F	R	.	.	F	.	.	R	.	.	F	F	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	R	R	R	.
.	F	C	F	F	F	.	F	R	R	R	R	.	C	F	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	R	R	C	.	R	C	R	R	.
.	F	F	F	F	F	.	F	R	.	F	R	.	C	F	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	F	.	.	C	R	R	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	R	.	.	.
.	C	.	R	F	F	.	C	F	.	R	R	.	C	C	.	.	F	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	R	C	.	.	C	R	.	R
.	C	R	F	R	F	.	F	F	.	.	.	.	C	F	.	.	C	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	R	.	R	C	.	F	C	F	.	.
.	C	R	R	C	F	.	F	R	.	.	C	R	C	F	.	.	C	.	.	.	.	F	.	.	.	F	.	.	.	.	.	.	R	.	R	C	.	R	C	F	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	C	F	F	F	R	.	C	F	R	R	R	.	C	C	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	F	.	R	F	R	.	.
.	.	F	.	R	.	.	C	.	R	.	R	.	C	C	.	.	F	.	R	.	.	R	.	.	.	F	.	.	.	R	.	.	.	.	R	F	.	.	C	R	.	.
.	C	F	R	C	F	.	C	C	F	.	R	.	V	C	.	.	C	.	.	.	.	.	.	.	.	.	.	.	.	R	C	R	.	.	F	C	.	.	C	C	.	.
.	C	.	R	F	R	.	C	R	.	.	R	.	C	F	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	F	F	.	.
.	C	R	F	C	R	.	C	F	.	.	R	R	A	F	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	C	F	.	.
.	C	.	R	C	R	.	C	R	.	.	.	.	C	C	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	C	F	.	.	F	F	.	.
.	C	R	F	F	F	.	C	F	R	.	.	.	C	F	.	.	C	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.	F	F	.	.	C	C	.	.
.	A	.	F	C	R	.	C	F	R	.	.	.	C	F	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	F	C	.	.	A	C	.	R
.	C	R	R	F	.	.	C	R	R	.	.	.	C	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	F	.	.	C	F	.	.
.	F	C	R	R	.	.	F	.	R	.	.	.	A	C	R	R	C	.	.	.	.	.	R	.	.	.	.	.	.	R	.	.	.	.	.	R	.	.	C	F	.	.
.	R	F	F	R	R	.	F	.	R	.	R	.	C	F	R	R	C	.	.	.	R	.	F	R	F	.	.	.	.	.	.	.	.	.	.	R	.	.	C	F	.	.
.	.	.	F	.	.	.	F	.	.	.	.	.	C	C	A	C	C	.	.	.	.	.	C	.	C	.	.	.	.	.	.	.	.	.	.	C	.	.	C	C	.	.
.	F	F	R	.	R	.	F	.	R	.	.	.	R	F	.	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	C	F	.	.
R	F	F	F	.	R	.	R	.	F	.	R	.	R	C	.	.	C	.	.	.	R	.	F	R	.	.	.	.	.	.	.	.	.	.	.	C	.	.	F	C	F	.
.	C	R	F	.	R	.	F	R	R	.	.	.	A	C	R	R	C	.	.	.	.	.	F	.	F	.	.	R	.	F	.	.	.	.	.	C	.	.	C	C	.	.
.	C	R	F	.	R	.	C	.	R	.	R	.	C	C	R	R	C	.	.	.	.	.	R	.	F	.	.	.	.	F	.	.	.	.	.	C	.	.	C	C	.	.
.	C	C	R	.	R	.	C	.	R	.	F	.	C	C	R	R	F	.	.	.	.	.	R	.	R	.	.	.	R	.	.	.	.	.	.	C	.	.	C	C	.	.
.	F	.	F	.	F	.	C	.	R	.	C	.	C	R	.	.	F	.	.	.	.	.	.	.	R	.	.	.	.	F	.	.	.	.	.	F	.	.	C	R	.	.
.	F	.	.	.	.	.	C	.	.	.	C	.	F	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	F	F	.	.
.	C	.	F	.	.	.	C	.	R	.	F	.	C	C	.	.	F	.	.	.	.	.	.	.	.	.	.	.	R	.	.	R	.	.	.	C	.	.	C	C	.	.
.	C	.	F	.	.	.	C	.	R	.	R	.	F	C	.	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	F	F	.	.
.	C	.	R	.	R	.	C	.	F	.	R	.	C	F	.	.	C	.	.	.	.	.	.	.	R	.	.	.	.	R	R	.	.	.	.	C	.	.	C	F	.	R
.	C	.	R	.	R	.	C	R	C	.	R	.	C	.	C	F	C	C	C	.	.	.	C	.	C	.	.	.	.	.	.	.	.	.	.	C	.	.	C	F	.	.
.	A	.	R	.	R	.	F	.	F	.	R	.	C	R	.	.	F	.	.	.	.	.	.	.	R	.	.	.	.	F	.	.	.	.	.	C	.	.	F	C	.	.
.	C	.	R	.	R	.	C	.	R	.	.	.	C	F	C	.	F	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	F	.	.	C	R	.	.
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.	F	.	.	.	R	.	F	.	.	.	.	.	C	F	.	.	F	.	.	.	.	.	.	.	R	.	.	.	.	F	.	.	.	.	.	R	.	.	C	F	.	.
R	F	.	R	.	F	C	F	F	F	.	.	.	C	F	.	.	C	.	.	.	.	.	C	.	R	.	.	.	.	F	R	.	.	.	.	C	.	.	C	F	.	.
.	C	.	F	.	R	F	C	R	.	.	.	.	C	C	C	C	C	.	.	.	F	.	C	F	C	.	.	.	.	F	.	.	.	.	.	C	.	.	C	C	.	.
.	C	.	F	.	.	C	C	.	F	.	.	.	C	F	C	C	F	.	.	.	F	.	F	F	C	.	.	.	.	R	.	.	.	.	.	C	.	.	C	F	.	.
.	C	.	C	.	.	C	C	R	.	.	.	.	C	F	F	R	C	.	.	.	.	.	.	.	F	.	.	.	.	F	.	.	.	.	.	C	.	.	C	C	.	.
.	F	.	F	.	.	F	C	.	R	.	.	.	C	R	R	R	C	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	C	.	.	C	C	.	.
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.	F	.	F	.	.	.	C	.	.	.	.	.	C	C	F	C	C	.	R	F	.	R	C	.	C	.	.	.	.	F	R	.	.	.	.	C	R	.	C	C	.	.
.	C	.	.	.	.	.	F	.	.	.	.	.	F	F	C	C	F	.	F	.	.	.	C	.	C	.	.	.	.	R	.	.	.	.	.	F	.	.	C	F	.	.
.	C	.	.	.	.	.	C	R	R	.	.	.	C	C	R	F	F	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	C	.	.	C	F	.	.
.	C	.	.	.	.	.	C	.	.	.	.	R	C	F	F	C	F	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	F	.	.	C	R	.	R
.	C	.	R	.	.	.	F	.	.	.	.	.	C	F	.	R	F	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	F	.	.	C	F	.	R
.	C	.	R	.	.	.	F	.	R	.	.	.	C	C	.	F	F	.	R	.	.	.	F	.	C	.	.	.	.	F	.	.	.	.	.	F	.	.	C	F	.	.
.	F	.	R	.	.	.	F	.	R	.	.	.	C	C	C	C	C	.	F	.	.	.	F	.	F	.	.	.	.	R	.	.	.	.	.	C	.	.	C	F	.	.
.	F	.	R	.	.	.	C	.	R	.	.	.	C	C	F	C	C	.	F	.	.	.	F	.	F	.	.	.	.	R	.	.	.	.	.	C	.	.	C	R	.	.
.	F	.	R	.	.	.	C	.	.	.	.	.	C	F	F	F	C	.	F	.	.	.	R	.	F	.	.	.	.	F	.	.	.	.	.	C	.	.	C	F	F	F
.	C	.	R	.	.	.	C	.	F	.	.	.	C	C	F	A	C	.	R	.	.	.	F	F	C	.	.	.	.	F	.	.	.	.	.	C	.	.	C	F	F	F
.	F	.	.	.	.	.	C	.	.	.	.	.	F	F	F	A	C	.	R	.	.	.	.	.	F	.	.	.	.	R	.	.	.	.	.	F	.	.	C	F	.	R
.	C	.	R	.	.	.	C	.	R	.	.	R	C	C	C	C	C	.	F	.	.	.	F	.	F	.	.	.	.	R	.	.	.	.	.	C	.	.	C	F	C	F

Table 4 (continued).

Age	Sissingh zonation (1977)	Lithologic unit	Abundance	Preservation	Sample	*Stephanolithion laffittei*	*Tegumentum stradneri*	*Tetrapodorhabdus coptensis*	*Tetrapodorhabdus decorus*	*Tranolithus gabalus*	*Tubodiscus jurapelagicus*	*Vagalapilla matalosa*	*Vekshinella angusta*	*Vekshinella parallela*	*Vekshinella stradneri*	*Watznaueria barnesae*	*Watznaueria biporta*	*Watznaueria britannica*	*Zeugrhabdotus embergeri*	*Zeugrhabdotus pseudoangustus*	*Zeugrhabdotus* sp. (small)	*Zeugrhabdotus xenotus*
early Albian	*Braarudosphaera* Subzone CC8a	III	A	G	1R-1, 52–53 cm	.	F	.	.	.	.	R	.	.	F	A	F	R	C	.	F	F
			A	G	1R-1, 120–121 cm	F	F	.	R	.	.	.	.	.	F	A	F	R	C	.	F	F
			C	G	1R-2, 85–86 cm	R	F	.	.	.	.	.	.	.	R	C	R	R	F	.	R	.
			C	G	1R-3, 81–82 cm	F	R	.	.	.	.	.	.	.	R	C	R	F	F	.	.	.
			VA	G	1R-4, 17–18 cm	C	C	.	.	.	.	R	R	.	.	A	R	R	C	.	.	.
			F	P	1R-6, 39–40 cm	.	R	.	.	.	.	.	.	.	R	F	R	R	F	.	F	.
			F	M	1R, CC	.	R	.	.	.	.	.	.	.	R	F	.	R	R	.	F	.
			C	M	2R-1, 25–26 cm	R	F	.	.	.	.	.	.	.	R	C	F	R	R	.	.	.
			C	P	2R-1, 118–119 cm	R	R	.	.	.	.	.	.	.	R	C	F	R	F	.	.	.
			A	M	3R-2, 138 cm	R	F	.	.	.	.	.	.	.	F	A	F	F	C	.	F	.
			C	M	3R-3, 110 cm	F	F	.	.	.	.	R	.	.	F	A	F	F	C	.	R	.
			F	P	6R-2, 67 cm	.	.	.	.	.	.	.	.	.	.	F	R	F	R	.	.	.
			A	G	6R-3, 43 cm	F	C	.	.	.	.	.	.	.	C	A	F	C	C	.	C	.
			A	G	6R-3, 51 cm	C	C	.	R	.	.	R	.	.	C	C	F	R	C	.	R	.
			A	G	6R-3, 55 cm	F	F	.	R	.	.	.	R	.	C	A	F	R	C	.	F	.
early Albian to late Aptian	*Rhagodiscus angustus* Subzone CC7b	IV	B		6R-3, 77 cm	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
			C	M	6R-3, 78 cm	C	C	.	.	.	.	.	.	.	C	A	F	R	C	.	C	R
			A	G	6R-3, 91 cm	C	F	.	.	.	.	.	R	.	C	C	F	F	C	.	F	.
			A	G	6R-3, 123 cm	C	C	F	C	.	.	.	R	.	C	A	F	.	C	.	C	R
			A	G	6R-4, 8–9 cm	F	F	.	.	.	.	.	R	.	C	C	R	R	C	.	F	.
			VA	G	6R, CC	C	F	.	.	.	.	.	.	.	C	A	F	.	F	.	F	R
			VA	G	7R-1, 115–116 cm	C	F	.	.	.	.	.	.	.	C	C	F	R	C	.	C	.
			VA	G	7R-2, 114–115 cm	C	C	.	.	.	.	.	.	.	C	A	F	F	C	.	C	R
		V	A	G	8R-1, 59–60 cm	C	C	.	.	.	.	.	R	.	A	A	F	C	C	.	C	.
			A	G	8R-2, 13–14 cm	C	C	.	.	.	.	.	.	.	C	C	R	F	C	.	F	.
			C	M	8R-3, 90–91 cm	C	F	.	.	.	.	.	.	.	C	C	F	R	C	.	R	.
			A	M	8R-4, 76–77 cm	C	F	.	R	.	.	.	.	.	C	C	R	.	C	.	F	.
early Aptian	*Hayesites irregularis* Subzone CC7a		C	M	8R-4, 121–122 cm	C	R	.	.	.	.	.	.	.	C	A	F	.	C	.	C	.
			VA	G	9R-1, 57–58 cm	C	.	.	.	.	.	.	.	.	F	C	R	.	C	.	F	.
			VA	G	9R-3, 139 cm	F	.	.	.	.	.	.	.	.	C	V	F	F	F	.	C	.
			A	M	9R-4, 37–38 cm	C	C	F	.	R	.	.	.	.	C	A	F	.	C	.	F	.
			A	M	9R, CC	C	C	F	R	R	.	.	.	.	C	A	C	.	C	.	C	.
			A	M	10R-2, 56 cm	C	C	F	.	R	.	.	R	.	.	.	F	.	C	.	C	.
			A	G	10R-3, 133 cm	F	F	F	.	.	.	R	R	.	C	A	F	.	C	.	C	.
			A	M	10R-4, 15–16 cm	F	F	.	.	.	.	.	.	.	C	A	.	.	R	.	F	.
			A	P	10R-4, 46 cm	C	F	F	.	.	.	.	R	.	C	A	F	F	R	.	C	.
			A	G	10R, CC	C	F	.	.	.	.	.	.	.	C	A	F	.	R	.	F	.
			A	G	11R-2, 55–56 cm	C	F	R	.	.	.	R	.	.	C	A	.	.	C	.	C	F
			A	G	11R-2, 60 cm	C	F	R	.	.	.	.	R	.	C	A	R	.	C	.	C	F
			A	M	11R-2, 108 cm	C	F	F	.	.	.	F	.	.	C	A	.	.	C	.	C	C
			A	P	11R-3, 76 cm	C	R	R	.	.	.	.	.	.	.	A	F	R	C	.	C	.
late Barremian	*Micrantholithus hoschulzii* Zone CC6	VI	A	M	12R-1, 27–28 cm	F	R	R	.	.	.	.	.	.	C	A	R	F	C	.	C	.
			A	G	12R-2, 44 cm	C	R	.	.	.	.	.	.	.	C	A	R	R	F	.	F	.
			VA	G	12R-3, 103 cm	C	F	R	R	.	.	.	.	.	C	C	.	.	C	.	F	F
			A	G	12R-3, 107 cm	C	F	F	F	.	.	.	.	.	C	A	F	R	C	.	F	C
			A	G	12R-4, 91 cm	C	F	R	F	.	.	.	.	.	C	A	F	R	C	.	C	C
			A	G	12R-5, 96 cm	C	F	F	R	.	.	R	R	.	C	A	F	F	C	.	C	C
			A	G	12R-6, 4–5 cm	C	F	R	.	.	.	.	.	.	C	A	F	F	C	.	C	C
			C	M	13R-1, 45–46 cm	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
			A	G	13R-2, 36 cm	C	F	.	.	.	.	.	R	.	C	A	F	R	C	.	C	F
			C	P	13R-4, 119 cm	C	.	.	.	.	.	.	.	R	C	C	.	R	F	.	F	.
			VA	G	13R-5, 27 cm	C	.	R	.	.	.	.	.	.	C	A	.	R	F	.	F	.
			A	M	14R-3, 46 cm	F	R	.	R	.	.	.	.	.	C	A	R	.	R	F	C	.
			A	M	14R-4, 31 cm	C	.	.	F	.	.	.	.	.	C	A	R	.	C	.	F	.
			A	M	15R-2, 40 cm	C	.	.	F	.	.	.	.	.	C	A	R	.	C	.	C	.
			A	M	15R-3, 27 cm	F	.	.	.	.	.	.	.	.	C	A	.	.	C	.	C	.
			A	G	15R-5, 40 cm	F	.	.	.	.	.	.	.	.	C	A	R	R	C	.	F	.
			A	G	16R-2, 35 cm	C	.	.	.	.	R	.	.	.	C	A	R	F	C	.	C	.
			A	M	16R-4, 61 cm	C	.	R	.	.	R	.	.	.	C	A	R	R	C	.	F	.
			A	P	16R-5, 36 cm	C	.	R	.	.	.	.	.	.	C	A	F	R	C	.	R	.
			A	M	16R-8, 28 cm	F	.	.	.	.	.	.	.	.	C	A	F	R	C	.	F	.

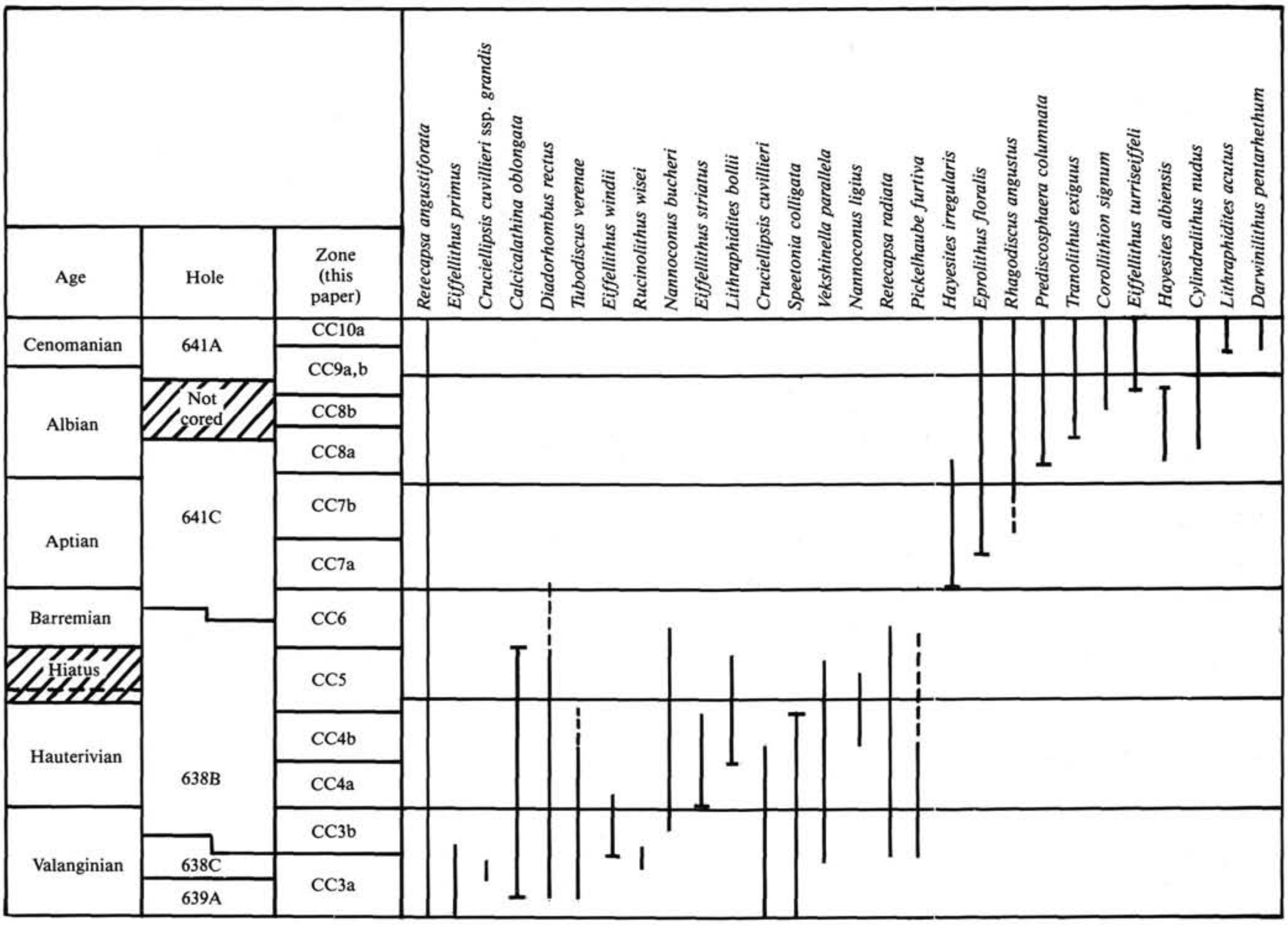

Figure 5. Ranges of index nannofossils and other important species considered.

Radiolithus planus appears near the middle of CC7b, whereas *H. albiensis* and *R. angustus* appear near the very top of CC7b. *Percivalia fenestrata* disappears near the top of this interval.

The first occurrence of *P. columnata*, defining the base of CC8, occurs at the contact between the clastic carbonate turbidites and dark green and black claystones. This change in sedimentation style and correlation to the seismic stratigraphy suggests an unconformity. Species that have their first occurrence in the lower Albian of Site 641 include *P. columnata, Prediscosphaera spinosa*, and *Cylindralithus nudus*. The earliest cylindraliths previously reported were from the uppermost Albian–lower Cenomanian of Leg 77 (Watkins and Bowdler, 1984). *C. nudus* is most likely the earliest representative of the genus. *Axopodorhabdus albianus*, a species Thierstein (1976) uses as a zonal marker in the mid-Albian, is present in the uppermost sample of Hole 641C. The first occurrences of *T. phacelosus, Cribrosphaerella ehrenbergi*, and *Corollithion signum*, which are used to divide the lower and upper Albian (CC8a/CC8b), were not observed because 50 m of the lower to middle Albian section in Hole 641C was washed in response to time constraints. The lowermost samples in Hole 641A contain the taxa *T. exiguus, Cruciribrum striatum striatum, C. ehrenbergi, E. turriseiffeli, Lithraphidites alatus*, and *Prediscosphaera cretacea*. These species were not present in the upper part of Hole 641C; therefore, their first occurrences must be within the 50-m washed interval in the hole.

The Albian/Cenomanian boundary cannot be accurately resolved using nannofossils. Thierstein (1976) used the first occurrence of *L. alatus* to define this boundary; however, both Verbeek (1977) and Watkins and Bowdler (1984) extended its range into the upper Albian. The Albian/Cenomanian boundary is placed within Core 103-641A-7X using foraminifer biostratigraphy. The interval from Sample 103-641A-7X-1, 3–4 cm, to Section 103-641A-7X, CC, is placed in the *P. spinosa* Subzone (CC9b) of late Albian to early Cenomanian age. The first occurrences of *Lithraphidites acutus* ssp. *eccentricus, Lithraphidites acutus* ssp. *acutus*, and *Darwinilithus pentarhethum* are in Sample 103-641A-6X, CC (40 cm). Only the core catcher of Core 103-641A-6X contained nannofossils (below a black barren zeolitic claystone), which indicate an early to mid-Cenomanian age, and this short interval is assigned to the *L. acutus* Zone (CC10). Watkins and Bowdler (1984) described *L. acutus* spp. *eccentricus* and *D. petarhethum* from the Cenomanian recovered on DSDP Leg 77. He explained that *L. acutus* ssp. *acutus*, a marker for the middle Cenomanian, was not present and that *L. acutus* spp. *eccentricus* was probably an "ecologic variant" of *L. acutus* spp. *acutus*. The co-occurrence of these subspecies in samples from Section 103-641A-6X, CC, confirms that they are indeed subspecific variants.

SUMMARY, CONCLUSIONS, AND DEPOSITIONAL HISTORY

The composite sequence for the Lower to middle Cretaceous of ODP Leg 103 is nearly continuous from the lower Valanginian to middle Cenomanian. This makes it an excellent section for the study and documentation of calcareous nannofossils. Most of the highly varied lithologies within the column contain

Table 5. Relative abundance of nannofossils, Hole 641A.

Age	Sissingh zonation (1977)	Lithologic unit	Abundance	Preservation	Sample	*Amphizygus brooksii*	*Axopodorhabdus albianus*	*Axopodorhabdus dietzmannii*	*Biscutum constans*	*Bukrylithus ambiguus*	*Chiastozygus litterarius*	*Chiastozygus platyrhethus*	*Corollithion achylosum*	*Corollithion signum*	*Cretarhabdus conicus*	*Cretarhabdus loriei*	*Cretarhabdus surirellus*	*Cribrosphaerella ehrenbergii*	*Crucicribrum striatum* ssp. *striatum*	*Cylindralithus nudus*	*Darwinilithus pentarhethum*	*Discorhabdus ignotus*	*Discorhabdus* sp. 1	*Eiffellithus* sp. 1	*Eiffellithus* sp. 2	*Eiffellithus* sp. 3	*Eiffellithus turriseiffeli*	*Ellipsagelosphaera ovata*
early to middle Cenomanian	CC10a	III	C	P	6X, CC (21–24 cm)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	R	.	.	.	.	.	R	
			VA	G	6X, CC (27 cm)	.	R	.	A	.	.	F	.	R	.	.	C	.	F	.	F	C	.	F	F	R	C	
			VA	G	6X, CC (29 cm)	C	F	.	A	.	F	F	.	R	F	.	C	F	C	.	.	.	.	.	.	.	C	
			A	G	6X, CC (40 cm)	C	R	R	A	.	R	R	.	.	R	.	F	R	C	R	R	F	C	.	.	.	C	
early Cenomanian to late Albian	CC9b		A	G	7X-1, 3–4 cm	C	F	R	A	R	R	R	.	.	.	R	F	R	C	R	.	R	F	.	.	R	C	
			A	G	7X-1, 20–21 cm	F	R	R	A	.	R	R	.	.	F	R	.	.	C	.	.	F	R	F	F	F	C	
			A	M	7X-1, 91–92 cm	F	F	R	A	R	F	R	R	R	R	R	R	F	C	R	.	F	R	R	R	R	C	
			A	G	7X-3, 48–49 cm	F	F	.	A	R	F	.	.	.	.	R	F	F	C	R	.	C	R	R	R	R	C	
			A	M	7X-4, 50–51 cm	R	R	.	A	.	R	.	.	.	.	R	F	.	F	R	.	F	.	R	F	R	C	
			VA	G	7X-5, 30–31 cm	C	C	.	A	.	R	.	.	.	F	.	R	F	C	.	.	C	R	R	R	F	C	
			C	P	7X-5, 102–103 cm	F	R	.	C	.	R	.	.	.	.	.	F	.	R	R	.	R	.	.	F	.	F	
			A	G	7X-6, 14–15 cm	F	F	.	A	.	.	.	.	.	.	.	C	.	F	R	.	F	R	R	R	R	C	
			A	G	7X, CC	C	F	.	A	.	R	R	.	.	R	R	C	R	F	F	.	F	R	R	.	R	C	

R = Rare; F = Few; C = Common; A = Abundant; VA = Very abundant; ? = Questionably present; . = Not present.

nannofossils, with the exception of the lower Valanginian sandstones and a few cores of Albian black shale. Abundance and diversity vary greatly but are generally much higher than reported from most other Lower Cretaceous sequences. Preservation is highly variable within the different lithologies and is often variable within an individual sample. However, overall preservation throughout the column is moderate to good.

The nannofossil biostratigraphy reveals a nearly complete record of sedimentation from the lower Valanginian to middle Cenomanian, although parts of the uppermost Hauterivian–lower Barremian are missing. The nannofossil assemblages evidence a complex evolution for the Galicia margin. The sequence of events is as follows:

1. In the early Valanginian, a 40-m-thick calpionellid-nannofossil marlstone was deposited on a shallow-water carbonate platform. Nannoconids dominate the assemblage.

2. During initial rifting and subsidence, terrigenous sands and clays were deposited by turbidites and interbedded with nannofossil marlstone of early to late Valanginian age. Shallow-water forms such as the nannoconids no longer dominate the assemblage; diversity and preservation increase considerably.

3. A siltstone-claystone-marlstone sequence deposited in fairly deep water during the late Valanginian and Hauterivian shows evidence of redeposition (creep and slump features; "Sedimentology" section; "Site 638" chapter; Boillot, Winterer, et al., 1987). Shallow-water forms become abundant as time passes, again dominating nannofossil assemblages; diversity of nannofossils is extremely high in the late early to late Hauterivian.

4. The latest stages of rifting occurred in the late Barremian and Aptian and resulted in deposition of a clastic calcareous turbidite sequence containing coarse shell lags, which include reworked, lower Barremian neritic nannofossils.

5. Further subsidence occurred as seafloor spreading began in the late Aptian–early Albian. Dark green to black carbonaceous claystones were deposited in deep water near or close to the CCD; nannofossil preservation, abundance, and diversity diminish.

6. In the latest Albian, a light green to gray nannofossil marlstone was deposited in deep water. The deposition of the nannofossil marlstone continued into the early to mid-Cenomanian.

7. Black carbonaceous claystone and brownish claystones devoid of calcareous nannofossils were deposited in deep water below the CCD in the Upper Cretaceous and possibly up into the Paleogene.

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Table 5 (continued).

Eprolithus floralis	*Flabellites biforaminis*	*Glaukolithus diplogrammus*	*Grantarhabdus coronaduentis*	*Haqius circumradiatus*	*Helicolithus trabeculatus*	*Lithraphidites acutus* ssp. *acutus*	*Lithraphidites acutus* ssp. *eccentricus*	*Lithraphidites alatus*	*Lithraphidites carniolensis*	*Manivitella pemmatoidea*	*Microstaurus chiastius*	*Prediscosphaera columnata*	*Prediscosphaera cretacea*	*Prediscosphaera spinosa*	*Radiolithus planus*	*Rhagodiscus angustus*	*Rhagodiscus asper/splendens*	*Rhagodiscus infinitus*	*Stephanolithion laffittei*	*Tegumentum stradneri*	*Tetrapodorhabdus decorus*	*Tranolithus phacelosus*	*Vagalapilla matalosa*	*Vekshinella stradneri*	*Watznaueria barnesae*	*Watznaueria biporta*	*Watznaueria britannica*	*Zeugrhabdotus embergeri*	*Zeugrhabdotus* ssp. (small)	*Zeugrhabdotus theta*
R	.	.	.	.	.	.	.	.	R	C	R	.	.	.	.	R	R	.	.	R	.	.	.	R	C	.	C	R	.	.
R	.	F	F	.	.	R	F	F	C	C	F	C	R	F	.	C	F	C	F	F	.	C	.	F	C	F	C	C	.	.
F	.	C	F	.	.	.	F	C	C	C	C	C	C	C	F	C	C	R	C	C	.	A	C	F	C	C	.	C	.	.
R	.	C	R	.	R	R	R	F	C	C	F	C	C	C	.	C	F	C	F	C	R	C	C	F	C	F	.	C	R	C
R	.	C	R	.	.	.	.	.	F	C	C	C	F	F	.	C	F	.	C	C	R	C	F	F	A	C	.	C	F	C
R	.	C	F	.	.	.	.	R	C	C	.	C	C	.	.	C	C	R	R	C	.	F	R	F	C	C	.	C	F	.
R	.	C	.	.	.	.	.	R	F	C	F	C	F	R	.	C	F	R	C	C	.	F	F	F	C	C	.	C	R	.
R	R	C	R	.	.	.	.	R	C	C	.	C	F	R	.	C	F	.	F	C	.	F	R	F	C	C	.	C	R	.
F	R	C	R	.	.	.	.	.	C	C	R	F	F	R	.	C	C	.	F	C	.	R	R	R	C	F	.	C	.	R
F	.	C	R	.	.	.	.	R	C	C	R	C	F	.	.	A	C	R	C	C	.	C	R	F	C	R	.	C	F	.
.	.	C	R	R	.	.	.	R	F	F	F	F	F	.	.	F	F	.	R	R	.	.	.	R	C	F	.	C	.	.
.	.	C	R	R	.	.	.	R	C	C	F	C	F	.	.	C	C	.	C	C	.	R	.	C	A	R	.	C	F	F
R	.	C	R	.	.	.	.	R	C	C	C	F	F	R	.	C	C	R	F	C	.	F	.	F	C	F	.	C	F	F

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APPENDIX A
Systematic Paleontology

Genus *COROLLITHION* Stradner, 1961

Corollithion acutum, Thierstein, 1972
(Pl. 17, Figs. 4-6)

Ellipsochiastus quadriserratus Worsley, 1971, p. 1308, pl. 1, figs. 36-38 (invalid).
Corollithion acutum Thierstein, 1972, p. 438, pl. 2, figs. 1-9.
Corollithion acutum Thierstein, Covington and Wise, 1987, pl. 20, fig. 4.

Remarks. This small elliptical species of *Corollithion* is described by Thierstein (1972) as having "40 to 50 non imbricate elements surmounted by a narrow rim." However, he illustrated a paratype (pl. 2, fig. 3) that has approximately 30 elements and in which the angle between the crossbars approaches 90°. Smaller specimens of this species were observed in this study and are constructed of 20 to 30 elements (Pl. 17, Figs. 5 and 6) whereas the larger, more rarer forms possess 40-50 elements (Pl. 17, Fig. 4). This smaller form is believed to be the same as Worsley's (1971) *Ellipsochiastus quadriserratus* and is considered here synonymous with *Corollithion acutum.* The angle between the crossbars in the larger forms is clearly less than 90°. In the smaller forms this angle approaches and sometimes reaches 90°.

Occurrences. Rare to few in the Valanginian through Aptian in ODP Holes 638B, 638C, and 641C. Worsley (1971) used the first occurrence of this species as a datum for the Berriasian/Valanginian boundary; however, we could not use it because of its rare and sporadic occurrence downhole.

Genus *CRUCIELLIPSIS* Thierstein, 1971

Cruciellipsis cuvillieri cuvillieri Thierstein, 1971
Cruciellipsis cuvillieri Thierstein, 1971, p. 477, pl. 5, figs. 4-8
Cruciellipsis cuvillieri ssp. *grandis* Applegate and Bergen, n. ssp.
(Pl. 29, Figs. 9 and 10)

Diagnosis. A subspecies of *Cruciellipsis cuvillieri* distinguished by its small central area and robust size.

Description. The holotype is 12.5 μm in length and the width of the central area is one-quarter or less the total width of the coccolith. Many specimens were observed that measure 15-16 μm in length.

Differentiation. *Cruciellipsis cuvillieri* ssp. *cuvillieri* is usually less than 10 μm and has a larger central area.

Remarks. *Cruciellipsis cuvillieri* ssp. *grandis* is common through 30 m of sediment in the lower part of Hole 638C and is found in layers of light greenish gray nannofossil marlstone containing moderately well-preserved nannofossils that are not overgrown with calcite. Hence, the robust size and small central area are not a result of overgrowth.

Occurrences. Common in the lower Valanginian of ODP Hole 638C, Galicia margin.

Size. 11 to 16 μm; holotype 12.5 μm in length. Central area, 3.5 × 2.5 μm.

Holotype. Plate 29, Figures 9 and 10.

Type locality. ODP Sample 103-638C-6R-1, 17-18 cm.

Genus *CYCLAGELOSPHAERA* Noel, 1965

Cyclagelosphaera brezae Applegate and Bergen, n. sp.
(Pl. 20, Figs. 1-3)

Diagnosis. A large delicate *Cyclagelosphaera* with a small proximal shield.

Description. A species of *Cyclagelosphaera* in which the diameter of the inner cycle is about one-third the total diameter of the coccolith. Both the proximal and distal shields contain approximately 30 flat, radial elements, and because of its large size, one can easily count the number of elements on the distal shield under the light microscope. In cross-polarized light, *Cyclagelosphaera brezae* exhibits a first-order gray to bright white birefringence. In sediments that contain overgrown nannofossils and are rich in calcite, *C. brezae* does not exhibit first-order colors in polarized light, as does *Cyclagelosphaera deflandrei.*

Remarks. Named in honor of marine sedimentologist James R. Breza, Florida State University. The large size and bright, but low-order, birefringence distinguish this taxon from other species of *Cyclagelospaera.*

Differentiation. This form differs from *Cyclagelospaera margerelii* by its larger size and less imbricate elements. Because of this difference in rim structure, *C. margerelii* appears brighter in polarized light.

Occurrences. Rare to common in the lower to upper Valanginian of ODP Holes 638B and 638C, Galicia margin.

Size. Holotype, 9.0 μm.

Holotype. Plate 20, Figures 1-3.

Type locality. ODP Sample 103-638B-44R, CC.

Genus *EIFFELLITHUS* Reinhardt, 1965

Eiffellithus primus Applegate and Bergen, n. sp.
(Pl. 11, Figs. 1-12 and 14)

Diagnosis. A small species of *Eiffellithus* that has crossbars in the major and minor axes.

Description. Under the light microscope in cross-polarized light, this species exhibits split crossbars that are aligned with the major and minor axes when viewed rotated 45° to the crossed nicols. When viewed at 0°, the crossbars appear to be solid and appear to be at an angle from 10° to 20° from the major and minor axes. In phase contrast or transmitted light, the crossbars are observed in the major and minor axes.

Differentiation. *Eiffellithus primus* differs from *Eiffellithus eximius* by its smaller size and unique behavior under crossed polars (as previously described). *Eiffellithus* sp. 1 has its central cross 10°-15° from the major and minor axes and does not exhibit a split in the central cross in polarized light. It is distinguished from *Eiffellithus windii* n. sp. by havings its crossbars in the major and minor axes.

Remarks. This species is the oldest known form of the genus *Eiffellithus*, and hence the name "primus". This form has its last occurrence near the first occurrence of *E. windii*, suggesting an evolutionary step in which the central cross rotates 45° to the major and minor axes.

Occurrences. Rare to few in the lower to upper Valanginian of ODP Holes 638B, 638C, and 639A.

Size. Holotype, 6.5 µm in length.

Holotype. Plate 11, Figures 1-5.

Type locality. ODP Sample 103-638C-10R-1, 35-36 cm.

Eiffellithus windii, Applegate and Bergen, n. sp.
(Pl. 10, Figs. 1-6 and 8)

Eiffellithus? sp. Wind and Cepek, 1979, pl. 10, figs. 5-13.
Eiffellithus sp. 1. Covington and Wise, 1987, p. 34.

Diagnosis. A small species of *Eiffellithus* that has a small central area and short crossbars, intermediate to the major and minor axes. A stem may or may not be present.

Description. This small *Eiffellithus* has rather stubby crossbars that occupy most of the narrow, open central area, which is about one-half the total width of the coccolith. Under the SEM, the crossbars appear fibrous because of their construction of small parallel laths.

Differentiation. This form closely resembles *Eiffellithus striatus* (Black) and differs from the latter by its smaller size, narrower central opening, shorter crossbars, and the lack of split crossbars when observed in polarized light parallel to the crossed nicols. Transitional forms between these two species are observed, for which a size break of 6.4 µm is used as the cutoff between them.

Remarks. Named in honor of Frank H. Wind, who, along with Pavel Cepek, first illustrated this species from the Hauterivian of Site 397, DSDP Leg 44. Their forms are smaller than the holotype, and in this section, a general decrease in size is seen downsection.

Occurrences. Rare to few in the mid-Valanginian to upper Hauterivian of ODP Holes 638B and 638C.

Size. Holotype, 5.8 × 4.4 µm.

Holotype. Plate 10, Figures 1, 3, and 4.

Type locality. ODP Sample 103-638B-35R-3, 111-112 cm.

Eiffellithus striatus (Black) Applegate and Bergen, n. comb.

Chiastozygus striatus Black, 1971, pl. 34, Fig. 7.
Chiastozygus tripes Kothe, 1981, pl. 3, Figs. 4, 5.

Remarks. After examination of many specimens with both the light microscope SEM and existing illustrations in the literature, we conclude that this species belongs to the genus *Eiffellithus*. The rim structure differs from *Chiastozygus* and *Tegumentum* in having an inner cycle of plate-formed elements with a thin outer rim of highly inclined elements. *Chiastozygus* is constructed of a single cycle of elements with crossbars intermediate to the major and minor axis. The distinct elements of the inner cycle of *Tegumentum* are slightly inclined and imbricate, whereas the inner cycle of *E. striatus* resembles *Eiffellithus*; in most specimens this inner cycle appears granular (proximal view) or amorphous (distal view). It is difficult to discern any elements of the inner cycle from past illustrations, including those of the holotype (Black, 1971).

Genus *HAYESITES* Manivit, 1971, emend. Applegate, Covington, and Wise *in* Covington and Wise, 1987

Hayesites irregularis Thierstein, 1972, Applegate, Covington, and Wise *in* Covington and Wise, 1987
(Pl. 5, Figs. 1-12)

Rucinolithus irregularis Thierstein *in* Roth and Thierstein, 1972, p. 438, pl. 2, figs. 10-19.
Rucinolithus irregularis Thierstein, 1973, p. 45, pl. 3, figs. 1-14.
Hayesites irregularis (Thierstein) Applegate et al., 1986, p. 36.

Description. The observation of many specimens of this species allows a more complete description of *Hayesites irregularis*. The dextrally imbricate elements, seen clearly in distal view, form a low cone and emanate from a small inner ring of flat, slightly imbricate elements of the proximal side (Pl. 5, Figs. 2 and 12).

The inner ring of elements on the proximal side consists of about 24-28 flat, slightly dextral, imbricate elements that are indiscernable under the light microscope. Thierstein (1972) first described this species from specimens viewed from the distal side and later illustrated a proximal view (1973, pl. 3, fig. 11) in which this inner ring is faintly visible. The living form of this species probably attached the inner ring of the nannolith to the cell wall. This implies that the nannoliths would be concave outward, which is unlike the more common concave-inward structure of placoliths on coccospheres. However, the distal side of *H. irregularis* often exhibits a stem or central process, which one would expect to occur on the distal side of the nannolith.

Remarks. This species always exhibits a first-order white or gray birefringence, even in samples that are rich in carbonate and contain other nannofossils that are overgrown. Previous workers have extended the range of this species into the upper Barremian. The lowest occurrence of this species was observed only 2 cores below the magnetic event M0 (see "Magnetostratigraphy," "Site 641" chapter; Boillot, Winterer, et al., 1987), and the first-appearance datum of *H. irregularis* is accepted here as a valid datum for the Barremian/Aptian boundary.

Hayesites albiensis Manivit, 1971
(Pl. 4, Figs. 1-8)

Hayesites albiensis Manivit, 1971, p. 138, pl. 14, figs. 1-7.
Hayesites albiensis Manivit, 1971, Thierstein, 1973, p. 45, pl. 6, figs. 1-5.

Remarks. *Hayesites albiensis* is rare to common in the lower Albian of ODP Hole 641C. The last-appearance datum of this species was not observed because that part of the section was not recovered. An SEM micrograph (Pl. 4, Figs. 1-8) shows ornamentation on the distal side with radially extending pointed elements that bisect each of the larger proximal elements.

Genus *LITHRAPHIDITES* Deflandre, 1963

Lithraphidites bollii (Thierstein, 1971) Thierstein, 1973
(Pl. 14, Figs. 1-12)

Microrhabdulus bollii Thierstein, 1971, p. 481, pl. 3, figs. 6-10.
Lithraphidites bollii (Thierstein) Thierstein, 1973, p. 45.
Lithraphidites bollii (Thierstein) Thierstein, 1976, p. 350, pl. 3, figs. 24-26.

Remarks. Forms of *Lithraphidites bollii*, as illustrated in Thierstein (1971, 1976), are observed in ODP Holes 638B and 640A. This species seems to be restricted to the Tethyan region and is common in many samples of Hauterivian to early Barremian age. Forms questionably identified as *Lithraphidites*? *bollii* in Wind and Cepek (1979) are observed in samples from Hole 638C (Pl. 15, Figs. 4-6) and are early Valanginian in age. This form, as shown by an SEM micrograph, is clearly an overgrown *Vekshinella parallela* n. comb., which has calcite crystals randomly oriented on the rhabdolith, unlike the orderly structure of *L. bollii*. Furthermore, if dissolution of a rhabdolith base and consequent overgrowth of the rhabdolith were the process necessary to "form" a *L. bollii* sensu stricto (Wind and Cepek, 1979), then one would expect to see intermediate forms in samples where both species are found. In samples from Hole 638B, with moderate to good preservation, both species are few to common and intermediate forms are not observed. It is concluded here that these are two separate and distinct species and that the first occurrence of *L. bollii* in the upper lower Hauterivian is a valid biostratigraphic datum.

Genus *NANNOCONUS* Kamptner, 1931

Nannoconus ligius Applegate and Bergen, n. sp.
(Pl. 13, Figs. 1-10 and 15)

Diagnosis. A small delicate *Nannoconus* that has eight distinct petaloid elements and a narrow canal.

Description. This species is constructed of flat cycles with eight distinct petals emanating from the center, stacked upon one another to form eight columns parallel to the axis.

Remarks. *Nannoconus ligius* is easily distinguished from other taxa of the genus on end view by its eight distinct petals. The species was not observed in side view under the light microscope because it tends to orient its axis perpendicular to the field of view as a result of its short length. The canal, as observed with the SEM, is usually very narrow.

Differentiation. This species differs from *Nannoconus cornuta* in having straight parallel sides rather than a highly irregular shape. *Nannoconus abundans* has a flaring base and lacks the eight distinct elements of *N. ligius*.

Occurrences. Rare to few in the upper Hauterivian to lower Barremian in ODP Holes 638B and 640A.

Size. Holotype, 6 μm in diameter.

Holotype. Plate 13, Figures 1 and 2.

Type locality. ODP Sample 103-638B-23R-5, 89–90 cm.

Genus *PICKELHAUBE* Applegate et al., 1987

Pickelhaube furtiva (Roth) Applegate et al., 1987
(Pl. 21, Figs. 1–12, and Pl. 22, Figs. 1, 3, and 9)

Cruciplacolithus furtivus Roth, 1983, p. 609, pl. 6, figs. 1–4.
Pickelhaube furtiva Applegate et al., 1987, p. 42, pl. 16, figs. 1 and 2, and pl. 23, figs. 1 and 2.

Remarks. The genus *Pickelhaube*, as described by Applegate et al. (1987), is a helmet-shaped nannofossil, consisting of a wide, flaring, nonimbricate proximal rim and a more distinct distal rim that yields an extinction figure reminiscent of that of the genus *Reticulofenestra.* The genus may or may not support a central multilath cross surmounted by a spine.

When viewed under the light microscope, this species exhibits a very high relief, as shown in Plate 21, Figures 2–5. Forms with a small central area are observed in younger sediments of Barremian and Aptian age. The species is rare in the lower Valanginian to the Barremian of ODP Holes 638B and 638C, with the exception of one sample. In Sample 103-641C-6R-3, 123 cm, taken within a coarse shell lag of broken shallow-water macrofossils, *Pickelhaube furtiva* was common and probably reworked from older sediments based on the presence of *Calcicalathina oblongata* in this sample. The nearshore provincalism of this species is indicated by the common occurrence of this species with the shallow-water nannofossil flora (as noted by Covington and Wise, 1987).

Pickelhaube sp. 1
(Pl. 22, Figs. 2, 4, and 7)

Remarks. This is a form of *Pickelhaube* that has an open central area. Many observed specimens of *Pickelhaube* lacked any central cross and process. In some of these specimens (Pl. 21, Figs. 7–12) the central process is lacking, probably because of preservation. However, it is clear that *Pickelhaube* sp. 1 in Plate 22, Figure 7, lacks a crossbar in structure, and the separation of this form is warranted. *Pickelhaube* sp. 1 closely resembles the Tertiary genus *Reticulofenestra* and can be differentiated from that genus by the former having much higher relief and a distinct distal ring of elements. The shape of *Pickelhaube* sp. 1 is variable; subrounded to elliptical forms are observed.

Occurrences. Rare to common in the lower Valanginian to lower Aptian of ODP Holes 638B, 638C, and 641C.

Genus *RETECAPSA* Black, 1971

Retecapsa angustiforata Black, 1971
(Pl. 12, Figs. 3–6)

Retecapsa angustiforata Black, 1971, p. 409, pl. 33, fig. 4.

Retecapsa radiata (Worsley) Applegate and Bergen, n. comb.
(Pl. 12, Figs. 5 and 6)

Rucinolithus radiatus Worsley, 1971, pl. 1, figs. 51–52.
Hayesites bulbus Thierstein, 1972, p. 438, pl. 2, figs. 20–23.
Discoaster? *atlanticus* Wilcoxen, 1972, p. 431, pl. 6, figs. 5–6.

Remarks. This species was first described by Worsley (1971) who misreferenced it on p. 311 as plate 1, figures 53 and 54, whereas the figure captions were actually figures 51 and 52. The name is therefore invalid, yet Thierstein (1976) validated it by using a new combination of *Hayesites radiatus.* In this study, it is shown that this species is clearly an ornament of *Retecapsa angustiforata.* However, *Retecapsa radiata* is not observed in sediment younger than Barremian and therefore, we choose to keep it a separate species because it has a useful stratigraphic range.

Genus *RUCINOLITHUS* Stover, 1971

Rucinolithus terebrodentarius Applegate et al., 1987
(Pl. 6, Figs. 1–8)

Rucinolithus terebrodentarius Applegate, Covington, and Wise, *in* Covington and Wise, 1987, p. 48, pl. 17, figs. 7–8, pl. 18, figs. 5–7, and pl. 19, figs. 1–5.

Remarks. This globular form of *Rucinolithus* resembles, under the light microscope, what could appear to be an overgrown *H. irregularis.* When viewed at different angles under the SEM, *Rucinolithus terebrodentarius* is globular and may revolve around an axis, whereas *H. irregularis* forms a low cone and always exhibits a low-order birefringence in polarized light, even in samples with abundant calcite and overgrown nannofossils. *R. terebrodentarius* has rare to few occurrences in the upper Barremian and is rare in the Aptian–lower Albian of ODP Holes 638B and 641C.

Genus *TUBODISCUS* Thierstein, 1973

Tubodiscus verenae, Thierstein, 1973
(Pl. 18, Fig. 9, Pl. 24, Figs. 3 and 6–9, Pl. 25, Figs. 1–10, and Pl. 26, Figs. 6–9)

Tubodiscus verenae Thierstein, 1973, pl. 2, figs. 1–7.

Remarks. *Tubodiscus* is described by Thierstein (1973) as having a central tube rising distally, producing a distinct collar. We found through the examination of many specimens under both the light microscope and SEM that this species exhibits at least a first-order yellow-orange birefringence under cross-polarized light, when viewed on end. There is an evolutionary change in this species from the lower Valanginian to the upper Hauterivian. In the lower Valanginian the collar is fully extended and is approximately 1.5× the total height of the coccolith (measured from the outer cycle of elements). When viewed in the light microscope under crossed nicols, on end view, the collar exhibits a first-order orange birefringence. The height of the collar decreases in younger forms and ultimately shortens to a height where it exhibits a first-order white under crossed nicols (see *Tubodiscus jurapelagicus*). Near the Valanginian/Hauterivian boundary, the height of the collar is approximately one-half the total height of the coccolith. At this height, a first-order yellow-orange birefringence is still observed under polarized light. Previous workers have restricted this form to the Valanginian. However, this species occurs consistently up into the uppermost Hauterivian in Hole 638B, and therefore, its last occurrence is difficult to use as a datum for the Valanginian/Hauterivian boundary.

Occurrences. Lower Valanginian to upper Hauterivian of ODP Holes 638B and 638C.

Tubodiscus jurapelagicus (Worsley) Roth, 1973
(Pl. 24, Figs. 1 and 2)

Watznaueria jurapelagicus Worsley, 1971, p. 1315, pl. 2, figs. 29–31.
Tubodiscus jurapelagicus Roth, 1973, p. 724, pl. 26, fig. 6.
Tubodiscus sp. cf. *T. verenae* Wise and Wind, 1977, pl. 67, fig. 6.

Remarks. This form of *Tubodiscus* has a short distinct central collar and exhibits a first-order gray to white birefringence observed on end view under polarized light. This species is thought to have evolved from its close relative *T. verenae* as it is observed in younger sediment than the latter. However, the lowest occurrence of *T. jurapelagicus* below that of *T. verenae* would imply the opposite. Wise and Wind (1977) documented this species as *T. verenae* from Albian sediment from the Faukland Plateau. However, the central collar of the species they illustrated is not extended as in *T. verenae.* This species occurs from the lower Valanginian to upper Barremian in ODP Holes 638B, 638C, and 641C.

Genus *VEKSHINELLA* Loeblich and Tappan, 1963

Vekshinella parallela (Wind and Cepek) Applegate and Bergen, n. comb.
(Pl. 15, Figs. 1–9)

Eurhabdus luciformus Wilcoxon, 1972, pl. 10, fig. 4.

Rhabdolekiskus parallelus Wind and Cepek, 1979, p. 232, pl. 3, figs. 3–6.
"Rhabdolekiskus" parallelus Covington and Wise, in press, pl. 23, figs. 3–5.

Remarks. This species is transferred to the genus *Vekshinella* based on the construction of the base of the rhabdolith as observed in SEM micrographs (Pl. 15, Figs. 8 and 9). The small base is constructed of a simple eiffellithid rim with a central cross aligned with the major and minor axes. When the species becomes overgrown, it vaguely resembles *L. bollii*; however, this was only observed in a few samples from the lower Valanginian. The length of *V. parallela* varies from 6–11 μm and the base is 2–3 μm. Roth (1983) used the first-appearance datum of this species as a datum in the lower Hauterivian. The occurrence of this species in the bottom of Hole 638C extends the range of *V. parallela* down into the lower Valanginian.

Vekshinella pseudocarinolithus Applegate and Bergen n. sp.
(Pl. 16, Figs. 1–9)

Rhabdolith with possible affinity to *Diadorhombus rectus* Worsley, Wind and Cepek, 1979, explanation for pl. 3, figs. 7 and 8.
Genus *et* species *indet.* 2, Covington and Wise, 1987, p. 56, pl. 23, figs. 7 and 8.

Diagnosis. Straight-sided rhabdolith with a small *Vekshinella* base at the proximal end and a large "flowery" ornament on the distal end.

Description. The base of this rhabdolith is constructed of a simple eiffellithal rim with a central cross aligned in the major and minor axes. The distal end is constructed of about six large "misshapened" elements.

Differentiation. In side view, this species closely resembles those assigned to the genus *Carinolithus* from the Jurassic. Carinoliths have bases with lamellar radial elements at a low angle, whereas this species has a *Vekshinella* base. The distal ornament of this species resembles the species *Hexalithus hexalithus*, which measures about 4 μm and was described from the Upper Jurassic (Covington and Wise, 1987). Wiegand (1984, pl. 1, figs. 1–4) illustrated another form *Hexalithus magharensis*, which possesses a stem. W. A. Bergen (unpubl. data) has observed that *H. magharensis* is actually distal parts on *Carinolithus*; thus, it appears that *Hexalithus* may represent a form genus.

Remarks. This species is named for its close resemblance to the genus *Carinolithus.*

Occurrences. Rare to few in the lower Valanginian to Hauterivian of ODP Holes 638C and 638B.

Size. Holotype, base 2.2 μm, length 9.5 μm.

Holotype. Plate 16, Figures 8 and 9.

Type locality. ODP Sample 103-638B-45R-3, 28–29 cm.

Vekshinella mitcheneri Applegate and Bergen n. sp.
(Pl. 23, Figs. 7–9)

Eiffellithus? sp. 2 Covington and Wise, 1987, p. 34, pl. 22, figs. 7–9.

Diagnosis. A form of *Vekshinella* that has a small central area that exhibits a bright birefringence under crossed polars.

Description. The distal rim of this species is constructed of highly inclined, imbricate elements that give this species a bright birefringence under crossed polars. The ends of the central cross flare at the rim, resulting in a small central openings. The crossbars exhibit a bright, white birefringence.

Remarks. This species resembles the genus *Eiffellithus*. However, in comparison to that species (Pl. 11), one can clearly observe the difference in the rim structure. *Eiffellithus* has a wider inner cycle and a thinner outer rim structure. The central cross of *E. primus* exhibits different optical characteristics in polarized light than does *Vekshinella mitcheneri.* It differs from *Vekshinella stradneri* in having a much brighter birefringence in polarized light and crossbars with flared distal extremities.

Remarks. Although many of the observed forms are small (~4–5 μm), their size increases in the upper Hauterivian–lower Barremian. Covington and Wise (1987) described this species as *Eiffellithus*? sp. 2 from the Barremian and illustrated a form that is larger than the holotype.

Occurrences. Rare to few in the lower Valanginian to upper Barremian of ODP Holes 638B, 638C, and 639A.

Size. Holotype, 4.1 μm in length.

Holotype. Plate 23, Figures 7–9.

Type locality. ODP Sample 103-638B-30R-5, 5–6 cm.

Genus *ZEUGRHABDOTUS* Reinhardt, 1965

Zeugrhabdotus pseudoangustus Bralower, Applegate, Covington, and Wise, *in* Wise and Covington, 1987
(Pl. 7, Figs. 11 and 12)

Rhagodiscus cf. *R. angustus* Perch-Nielsen, 1979, p. 229, fig. 3.
Zeugrhabdotus? *pseudoangustus* Bralower, Applegate, Covington, and Wise, *in* Covington and Wise, 1987, p. 53, pl. 8, figs. 2–4.

Remarks. This species, which closely resembles *Rhagodiscus angustus*, is rare to common in many samples from ODP Holes 638B and 638C. A proximal or basal granular cover has not been observed across the rim as in *R. angustus. Zeugrhabdotus pseudoangustus* can be distinguished from *R. angustus* by the former's lack of a basal cover, a smaller length to width ratio, and a subrectangular outline with somewhat squared ends. The bridge that spans the minor axis is delicate, and in most specimens, not observed. *Z. pseudoangustus* is rare to common in the lower Valanginian to upper Barremian to ODP Holes 638B and 638C.

APPENDIX B
Calcareous Nannofossils Considered in This Chapter (in alphabetical order of generic epithets)

Amphizygus brooksii Bukry, 1969
Assipetra infracretacea (Thierstein) Roth, 1973
Axopodorhabdus albianus (Black) Wind and Wise *in* Wise and Wind, 1977
Axopodorhabdus dietzmannii (Reinhardt) Wind and Wise, 1983
Biscutum constans (Gorka) Black *in* Black and Barns, 1959
Braarudosphaera africana Stradner, 1961
Braarudosphaera discula Bramlette and Riedel, 1954
Bukrylithus ambiguus Black, 1971a
Calcicalathina oblongata (Worsley) Thierstein, 1971
Chiastozygus litterarius (Gorka) Manivit, 1971
Chiastozygus platyrhethus Hill, 1976
Chiastozygus tenuis Black, 1971
Conusphaera mexicana Trejo, 1969
Corollithion achylosum (Stover) Thierstein, 1971
Corollithion acutum Thierstein *in* Roth and Thierstein, 1972
Corollithion ellipticum Bukry, 1969
Cretarhabdus conicus Bramlette and Martini, 1964
Cretarhabdus delicatus Applegate, Covington, and Wise *in* Covington and Wise, 1987
Cretarhabdus cf. *loriei* Gartner, 1969
Cretarhabdus loriei Gartner, 1969
Cretarhabdus surirellus (Deflandre *in* Deflandre and Fert) Reinhardt emend. Thierstein, 1971
Cribrosphaerella ehrenbergii (Arkhangelsky) Deflandre *in* Piveteau, 1952
Crucicribrum striatum striatum (Stradner) Wise, 1983
Cruciellipsis cuvillieri cuvillieri (Manivit) Thierstein, 1971
Cruciellipsis cuvillieri ssp. *grandis* Applegate and Bergen, n. ssp.
Cyclagelosphaera brezae Applegate and Bergen, n. sp.
Cyclagelosphaera deflandrei (Manivit) Roth, 1973
Cyclagelosphaera margerelii Noel, 1965
Cylindralithus nudus Bukry, 1969
Darwinilithus pentarhethum Watkins *in* Watkins and Bowdler, 1984
Diadorhombus rectus Worsley, 1971
Diazomatolithus lehmanii Noel, 1965
Diloma placinum Wind and Cepek, 1979
Diloma primitiva (Worsley) Wind and Cepek, 1979
Discorhabdus biradiatus (Worsely) Thierstein, 1973
Discorhabdus ignotus (Gorka) Perch-Nielsen, 1968
Discorhabdus sp. 1
Eiffellithus primus Applegate and Bergen, n. sp.
Eiffellithus striatus (Black) Applegate and Bergen, n. comb.
Eiffellithus turriseiffeli (Deflandre in Deflandre and Fert) Reinhardt, 1965
Eiffellithus windii Applegate and Bergen, n. sp.
Eiffellithus sp. 1 Perch-Nielsen, 1979
Eiffellithus sp. 2 Perch-Nielsen, 1979
Eiffellithus sp. 3 Perch-Nielsen, 1979
Ellipsagelosphaera ovata (Bukry) Black, 1973
Eprolithus floralis (Stradner) Stover, 1966
Ethmorhabdus hauterivianus (Black) Applegate, Covington, and Wise *in* Covington and Wise, 1987

Flabellites biforaminis Thierstein, 1973
Flabellites oblongus (Bukry) Crux *in* Crux et al., 1982
Glaukolithus diplogrammus (Deflandre *in* Deflandre and Fert) Reinhardt, 1964
Grantarhabdus coronadventis (Reinhardt) Grun *in* Grun and Allemann, 1975
Grantarhabdus meddii Black, 1971
Haqius circumradiatus (Stover) Roth, 1978
Hayesites albiensis Manivit, 1971
Hayesites irregularis (Thierstein) Applegate, Covington, and Wise *in* Covington and Wise, 1987
Helicolithus trabeculatus (Gorka) Verbeek, 1977b
Lapideacassis sp.
Lithraphidites acutus acutus Verbeek and Manivit *in* Manivit et al., 1977
Lithraphidites acutus eccentricus Watkins *in* Watkins and Bowdler, 1984
Lithraphidites alatus Thierstein *in* Roth and Thierstein, 1972
Lithraphidites bollii (Thierstein) Thierstein, 1973
Lithraphidites carniolensis Deflandre, 1963
Manivitella cf. *pecten* Black, 1973
Manivitella pemmatoidea (Deflandre *in* Manivit) Thierstein, 1971
Micrantholithus hoschulzii (Reinhardt) Thierstein, 1971
Micrantholithus obtusus Stradner, 1963
Microstaurus chiastius (Worsley) Grun *in* Grun and Allemann, 1975
Microstaurus conus (Worsley) Wind and Cepek, 1979
Nannoconus abundans Stradner and Grun, 1973
Nannoconus bermudezii Bronnimann, 1955
Nannoconus bucheri Bronnimann, 1955
Nannoconus elongatus Bronnimann, 1955
Nannoconus globulus Bronnimann, 1955
Nannoconus grandis Deres and Acheriteguy, 1980
Nannoconus ligius Applegate and Bergen, n. sp.
Nannoconus kamptneri Bronnimann, 1955
Nannoconus steinmannii Kamptner, 1931
Nannoconus truitti Deres and Acheriteguy, 1980
Nannoconus wassallii Bronnimann, 1955
Nodosella silvaradion (Filewicz et al. *in* Wise and Wind) Perch-Nielsen, 1984
Octopodorhabdus plethotretus Wind and Cepek *ex* Applegate, Covington, and Wise *in* Covington and Wise, 1987
Parhabdolithus judithae Black, 1972
Percivalia fenestrata (Worsley) Wise, 1983
Perissocyclus noeliae Black, 1971, emend. Wind and Cepek, 1979
Pickelhaube furtiva (Roth) Applegate, Covington, and Wise *in* Covington and Wise, 1987
Pickelhaube sp. 1
Prediscosphaera columnata (Stover) Perch-Nielsen, 1984
Prediscosphaera cretacea (Arkangelsky) Gartner, 1968
Prediscosphaera spinosa (Bramlette and Martini) Gartner, 1968
Radiolithus planus Stover, 1966
Retecapsa angustiforata Black, 1971a
Retecapsa neocomiana Black, 1971a
Retecapsa radiata (Worsley) Applegate and Bergen, n. comb
Rhagodiscus angustus (Stradner) Reinhardt, 1971
Rhagodiscus asper (Stradner) Reinhardt, 1967
Rhagodiscus infinitus (Worsley) Applegate, Covington, and Wise *in* Covington and Wise, 1987
Rhagodiscus splendens (Deflandre) Verbeek, 1977
Rhagodiscus swinnertonii (Black) Applegate, Covington, and Wise, *in* Covington and Wise, 1987
Rhombolithion rhombicum (Stradner and Adamiker) Black, 1973
Rucinolithus terebrodentarius Covington and Wise, 1987
Rucinolithus wisei Thierstein, 1971
Sollasites hayi (Black) Perch-Nielsen, 1984
Sollasites horticus (Stradner et al. *in* Stradner and Adamiker) Cepek and Hay, 1969
Sollasites lowei (Bukry) Roth, 1970
Speetonia colligata Black, 1971
Stephanolithion laffittei Noel, 1956
Tegumentum stadneri Thierstein *in* Roth and Thierstein, 1972
Tetrapodorhabdus coptensis Black, 1971
Tetrapodorhabdus decorus (Deflandre *in* Deflandre and Fert) Wind and Wise *in* Wise and Wind, 1977
Thurmannolithion clatratum Grun and Zweili, 1980
Tranolithus exiguus Stover, 1977
Tranolithus gabalus Stover, 1966
Tubodiscus verenae Thierstein, 1973
Tubodiscus jurapelagicus (Worsley) Roth, 1973
Vagalapilla matalosa (Stover) Thierstein, 1973
Vekshinella angusta (Stover) Verbeek, 1977b
Vekshinella mitcheneri Applegate and Bergen, n. sp.
Vekshinella parallela (Wind and Cepek) Applegate and Bergen, n. comb.
Vekshinella pseudocarinolithus Applegate and Bergen, n. sp.
Vekshinella stradneri Rood, Hay, and Barnard, 1971
Watznaueria barnesae (Black *in* Black and Barnes) Perch-Nielsen, 1968
Watznaueria biporta Bukry, 1969
Watznaueria britannica (Stradner) Reinhardt, 1964
Zeugrhabdotus embergeri (Noel) Perch-Nielsen, 1984
Zeugrhabdotus pseudoangustus bralower, Applegate, Covington, and Wise *in* Covington and Wise, 1987
Zeugrhabdotus sp. (small)
Zeugrhabdotus theta (Black *in* Black and Barnes) Black, 1973

APPENDIX C
Calcareous Nannofossils Considered in This Chapter (in alphabetical order of specific epithets)

Nannoconus abundans Stradner and Grun, 1973
Corollithion achylosum (Stover) Thierstein, 1971
Corollithion acutum Thierstein *in* Roth and Thierstein, 1972
Lithraphidites acutus acutus Verbeek and Manivit *in* Manivit et al., 1977
Lithraphidites acutus eccentricus Watkins *in* Watkins and Bowdler, 1984
Braarudosphaera africana Stradner, 1961
Lithraphidites alatus alatus Thierstein *in* Roth and Thierstein, 1972
Axopodorhabdus albianus (Black) Wind and Wise *in* Wise and Wind, 1977
Hayesites albiensis Manivit, 1971
Bukrylithus ambiguus Black, 1971a
Vekshinella angusta (Stover) Verbeek, 1977b
Retecapsa angustiforata Black, 1971a
Rhagodiscus angustus (Stradner) Reinhardt, 1971
Rhagodiscus asper (Stradner) Reinhardt, 1967
Watznaueria barnesae (Black *in* Black and Barnes) Perch-Nielsen, 1968
Nannoconus bermudezii Bronnimann, 1955
Flabellites biforaminis Thierstein, 1973
Watznaueria biporta Bukry, 1969
Discorhabdus biradiatus (Worsley) Thierstein, 1973
Lithraphidites bollii (Thierstein) Thierstein, 1973
Cyclagelosphaera brezae Applegate and Bergen, n. sp.
Watznaueria britannica (Stradner) Reinhardt, 1964
Nannoconus bucheri Bronnimann, 1955
Lithraphidites carniolensis Deflandre, 1963
Microstaurus chiastius (Worsley) Grun *in* Grun and Allemann, 1975
Haqius circumradiatus (Stover) Roth, 1978
Thurmannolithion clatratum Grun and Zweili, 1980
Speetonia colligata Black, 1971
Prediscosphaera columnata (Stover) Perch-Nielsen, 1984
Cretarhabdus conicus Bramlete and Martini, 1964
Biscutum constans (Gorka) Black *in* Black and Barns, 1959
Microstaurus conus (Worsley) Wind and Cepek, 1979
Tetrapodorhabdus coptensis Black, 1971
Grantarhabdus coronadventis (Reinhardt) Grun *in* Grun and Allemann, 1975
Prediscosphaera cretacea (Arkangelsky) Gartner, 1968
Cruciellipsis cuvillieri cuvillieri (Manivit) Thierstein, 1971
Cruciellipsis cuvillieri ssp. *grandis* Applegate and Bergen, n. ssp.
Tetrapodorhabdus decorus (Deflandre *in* Deflandre and Fert) Wind and Wise *in* Wise and Wind, 1977
Cyclagelosphaera deflandrei (Manivit) Roth, 1973
Cretarhabdus delicatus Applegate, Covington, and Wise *in* Covington and Wise, 1987
Axopodorhabdus dietzmannii (Reinhardt) Wind and Wise, 1983
Glaukolithus diplogrammus (Deflandre *in* Deflandre and Fert) Reinhardt, 1964
Braarudosphaera discula Bramlette and Riedel, 1954

Cribrosphaerella ehrenbergii (Arkangelsky) Deflandre *in* Piveteau, 1952
Corollithion ellipticum Bukry, 1969
Nannoconus elongatus Bronnimann, 1955
Zeugrhabdotus embergeri (Noel) Perch-Nielsen, 1984
Tranolithus exiguus Stover, 1977
Percivalia fenestrata (Worsley) Wise, 1983
Eprolithus floralis (Stradner) Stover, 1966
Pickelhaube furtiva (Roth) Applegate, Covington, and Wise, *in* Covington and Wise, 1987
Tranolithus gabalus Stover, 1966
Nannoconus globulus Bronnimann, 1955
Nannoconus grandis Deres and Acheriteguy, 1980
Ethmorhabdus hauterivianus (Black) Applegate, Covington, and Wise *in* Covington and Wise, 1987
Sollasites hayi (Black) Perch-Nielsen, 1984a
Sollasites horticus (Stradner et al. *in* Stadner and Adamiker) Cepek and Hay, 1969
Micrantholithus hoschulzii (Reinhardt) Thierstein, 1971
Discorhabdus ignotus (Gorka) Perch-Nielsen, 1968
Rhagodiscus infinitus (Worsley) Applegate, Covington, and Wise *in* Covington and Wise, 1987
Assipetra infracretacea (Thierstein) Roth, 1973
Hayesites irregularis (Thierstein) Applegate, Covington, and Wise *in* Covington and Wise, 1987
Parhabdolithus judithae Black, 1972
Tubodiscus jurapelagicus (Worsley) Roth, 1973
Nannoconus kamptneri Bronnimann, 1955
Stephanolithion laffittei Noel, 1956
Diazomatolithus lehmanii Noel, 1965
Nannoconus ligius Applegate and Bergen, n. sp.
Chiastozygus litterarius (Gorka) Manivit, 1971
Cretarhabdus loriei Gartner, 1969
Cretarhabdus sp. cf. *C. loriei* Gartner, 1969
Sollasites lowei (Bukry) Roth, 1970
Cyclagelosphaera margerelii Noel, 1965
Vagalapilla matalosa (Stover) Thierstein, 1973
Grantarhabdus meddii Black, 1971
Conusphaera mexicana Trejo, 1969
Vekshinella mitcheneri Applegate and Bergen, n. sp.
Retecapsa neocomiana Black, 1971a
Perissocyclus noeliae Black, 1971, emend. Wind and Cepek, 1979
Cylindralithus nudus Bukry, 1969
Calcicalathina oblongata (Worsley) Thierstien, 1971
Flabellites oblongus (Bukry) Crux *in* Crux et al., 1982
Micrantholithus obtusus Stradner, 1963
Ellipsagelosphaera ovata (Bukry) Black, 1973
Vekshinella parallela (Wind and Cepek) Applegate and Bergen, n. comb.
Manivitella sp. cf. *M. pecten* Black, 1973
Manivitella pemmatoidea (Deflandre *in* Manivit) Thierstein, 1971
Darwinilithus pentarhethum Watkins *in* Watkins and Bowdler, 1984
Diloma placinum Wind and Cepek, 1979
Radiolithus planus Stover, 1966
Chiastozygus platyrhethus Hill, 1976
Octopodorhabdus plethotretus (Wind and Cepek) Applegate, Covington, and Wise, *in* Covington and Wise, 1987
Diloma primitiva (Worsley) Wind and Cepek, 1979
Eiffellithus primus Applegate and Bergen, n. sp.
Zeugrhabdotus pseudoangustus Bralower, Applegate, Covington, and Wise *in* Covington and Wise, 1987
Vekshinella pseudocarinolithus Applegate and Bergen, n. sp.
Retecapsa radiata (Worsley) Applegate and Bergen, n. comb
Diadorhombus rectus Worsley, 1971
Rhombolithion rhombicum (Stradner and Adamiker) Black, 1973
Nodosella silvaradion (Filewicz et al. *in* Wise and Wind) Perch-Nielsen, 1984
Discorhabdus sp. 1
Eiffellithus sp. 1 Perch-Nielsen, 1979
Eiffellithus sp. 2 Perch-Nielsen, 1979
Eiffellithus sp. 3 Perch-Nielsen, 1979
Lapideacassis sp.
Pickelhaube sp. 1 Applegate and Bergen
Prediscosphaera spinosa (Bramlette and Martini) Gartner, 1968
Rhagodiscus splendens (Deflandre) Verbeek, 1977
Nannoconus steinmannii Kamptner, 1931
Tegumentum stradneri Thierstein *in* Roth and Thierstein, 1972
Vekshinella stradneri Rood, Hay, and Barnard, 1971
Crucicribrum striatum striatum (Stradner) Wise, 1983
Eiffellithus striatus (Black) Applegate and Bergen, n. comb.
Creatarhabdus surirellus (Deflandre *in* Deflandre and Fert) Reinhardt emend. Thierstein, 1971
Rhagodiscus swinnertonii (Black) Applegate, Covington, and Wise *in* Covington and Wise, 1987
Chiastozygus tenuis Black, 1971
Rucinolithus terebreodentarius Covington and Wise, 1987
Zeugrhabdotus theta (Black *in* Black and Barns) Black, 1973
Helicolithus trabeculatus (Gorka) Verbeek, 1977b
Nannoconus truitti Deres and Acheriteguy, 1980
Eiffellithus turriseiffeli (Deflandre *in* Deflandre and Fert) Reinhardt, 1965
Tubodiscus vereane Thierstein, 1973
Nannoconus wassallii Bronnimann, 1955
Eiffellithus windii Applegate and Bergen, n. sp.
Rucinotithus wisei Thierstein, 1971

NOTE ON PLATES

The illustrations on the following plates are scanning electron and light micrographs. The abbreviations P, D, and L denote proximal, distal, and lateral views, respectively. The abbreviations Pol, Ph, and Tr denote light micrographs that were taken in cross-polarized, phase contrast, and transmitted light, respectively. CN is an abbreviation for crossed nicols. A photomicrograph of a specimen that is also illustrated by a SEM micrograph is denoted in the plate captions as a superscript on the photomicrograph illustration number. For example, on Plate 1, (2 and 3)^{s1} denotes that the specimen shown in light micrographs 2 and 3 is the same specimen illustrated in the SEM micrograph figure 1.

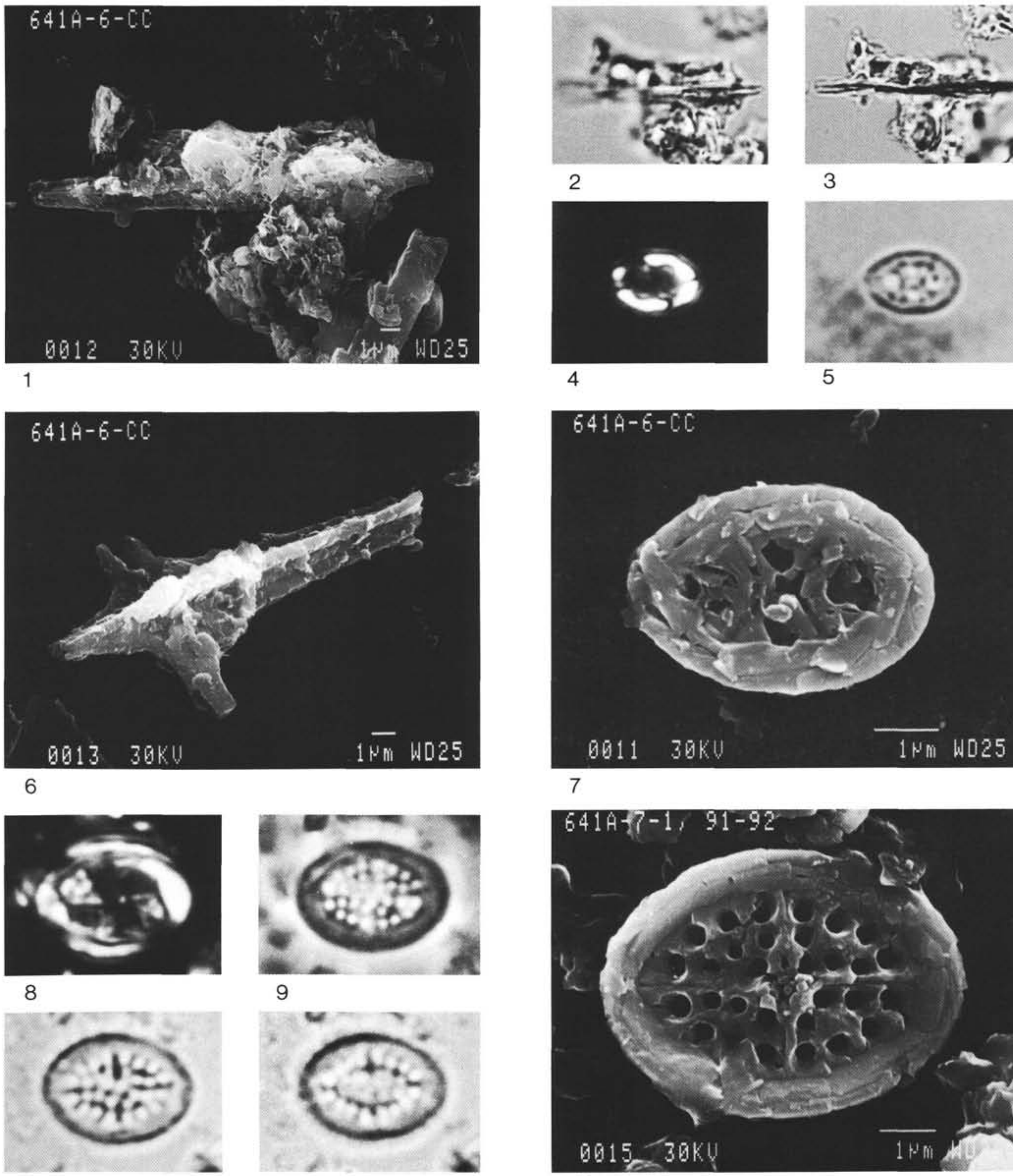

Plate 1. **1-3 and 6.** *Lithraphidites acutus* ssp. *eccentricus* Watkins, Sample 103-641A-6X, CC, (1 cm), L, 3400×, (2 and 3)[s1] 1600× (2, Tr, high focus; 3, Tr, low focus). **4, 5 and 7.** *Helicolithus trabeculatus* (Gorka), Sample 103-641A-6X, CC, (4 and 5)[s7] 3500× (4, Pol; 5, Ph), (7) D, 11,000×. **8-12.** *Crucicribrum striatum* ssp. *striatum* Stradner, Sample 641A-7X-1, 91-92 cm (8-11)[s12] 4000×, (8, Pol; 9, Ph; 10, Tr, low focus; 11, Tr, high focus), (12), D, 9000×.

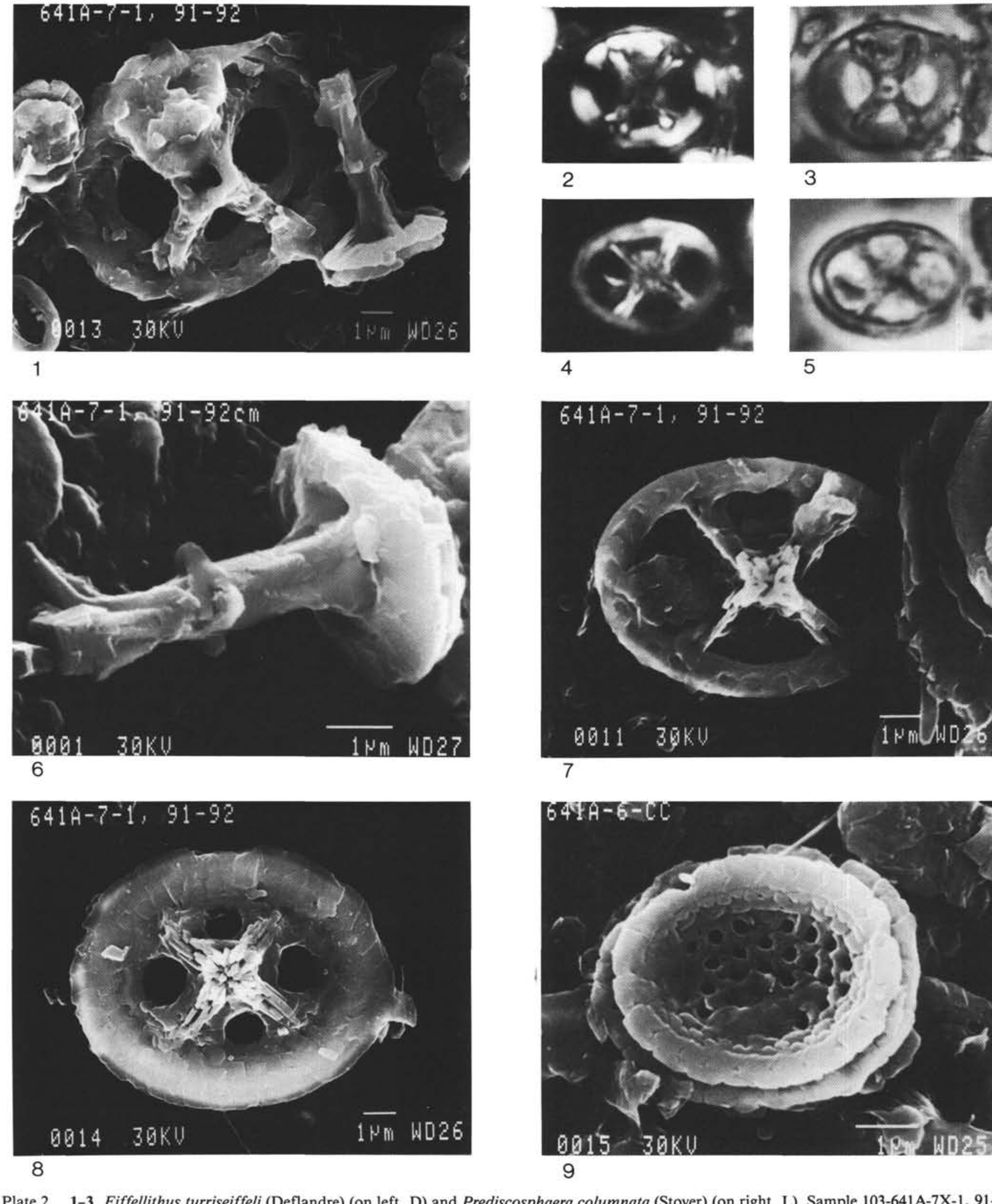

Plate 2. **1–3.** *Eiffellithus turriseiffeli* (Deflandre) (on left, D) and *Prediscosphaera columnata* (Stover) (on right, L), Sample 103-641A-7X-1, 91–92 cm, (1) 5500×, (2 and 3)[s1] 3400×, (2, Pol: 3, Ph). **4, 5 and 7.** *Chiastozygus platyrhethum* Hill, Sample 103-641A-7X-1, 91–92 cm, (4 and 5)[s7] 3400×, (4, Pol; 5, Ph), (7) D, 7100×. **6.** *Prediscosphaera spinosa* (Bramlette and Martini), Sample 103-641A-7X-1, 91–92 cm, L, 12,000×. **8.** *Grantarhabdus coronadventis* (Reinhardt), Sample 103-641A-7X-1, 91–92 cm, D, 5800×. **9.** *Cribrosphaerella ehrenbergii* (Arkangelsky), Sample 103-641-6X, CC, P, 11,200×.

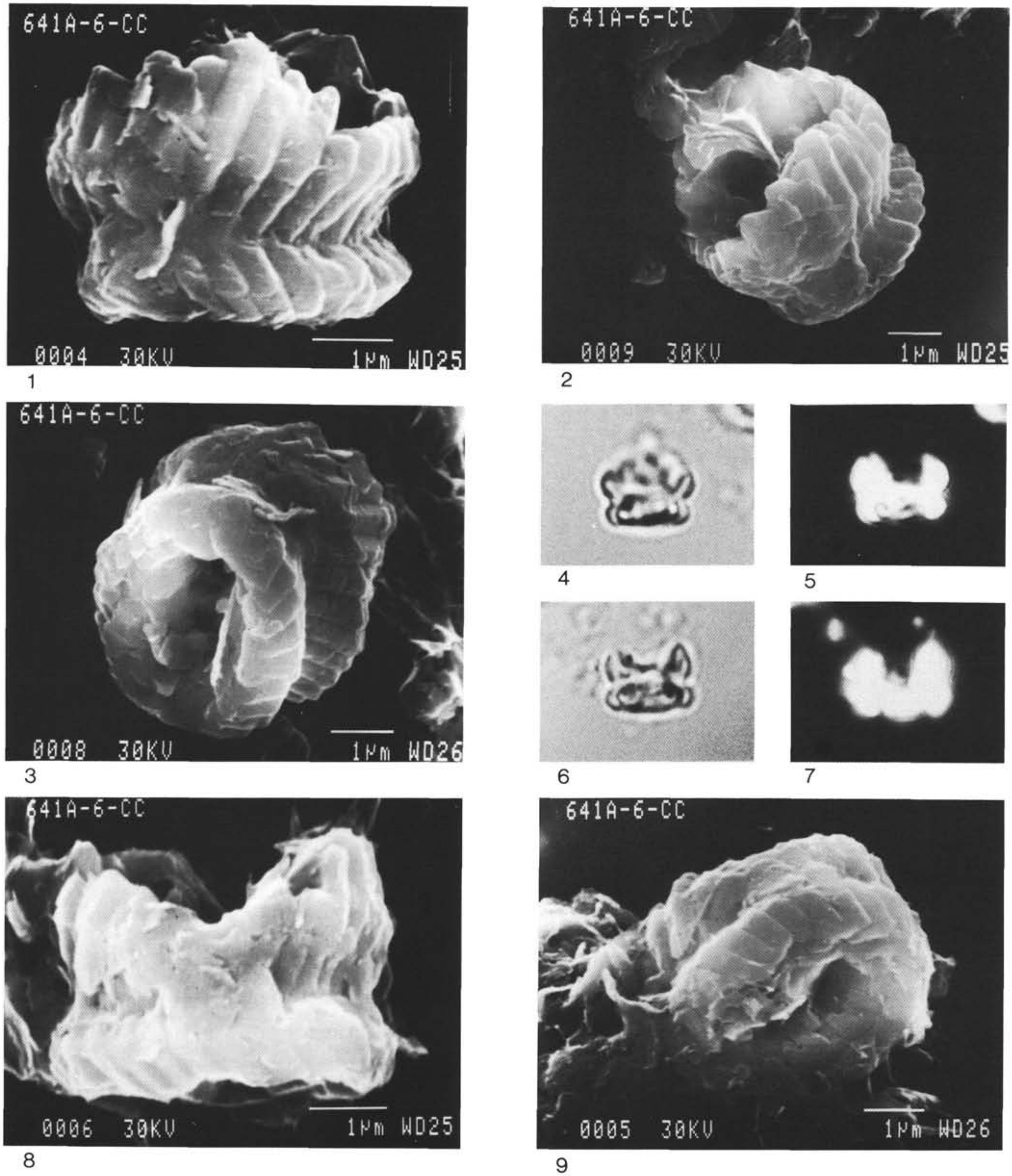

Plate 3. All specimens from Sample 103-641A-6X, CC, *Cylindralithus nudus* Bukry. **1.** L, 14,200×. **2^{s1}.** Oblique and view, 9500×. **3^{s1}.** P, 11,000×. **4 and 5^{s1}.** 3300×, (4, Tr; 5, Pol). **6 and 7^{s8}.** 3000×, (6, Tr; 7, Pol). **8.** L, 13,800×. **9^{s8}.** 10,700×.

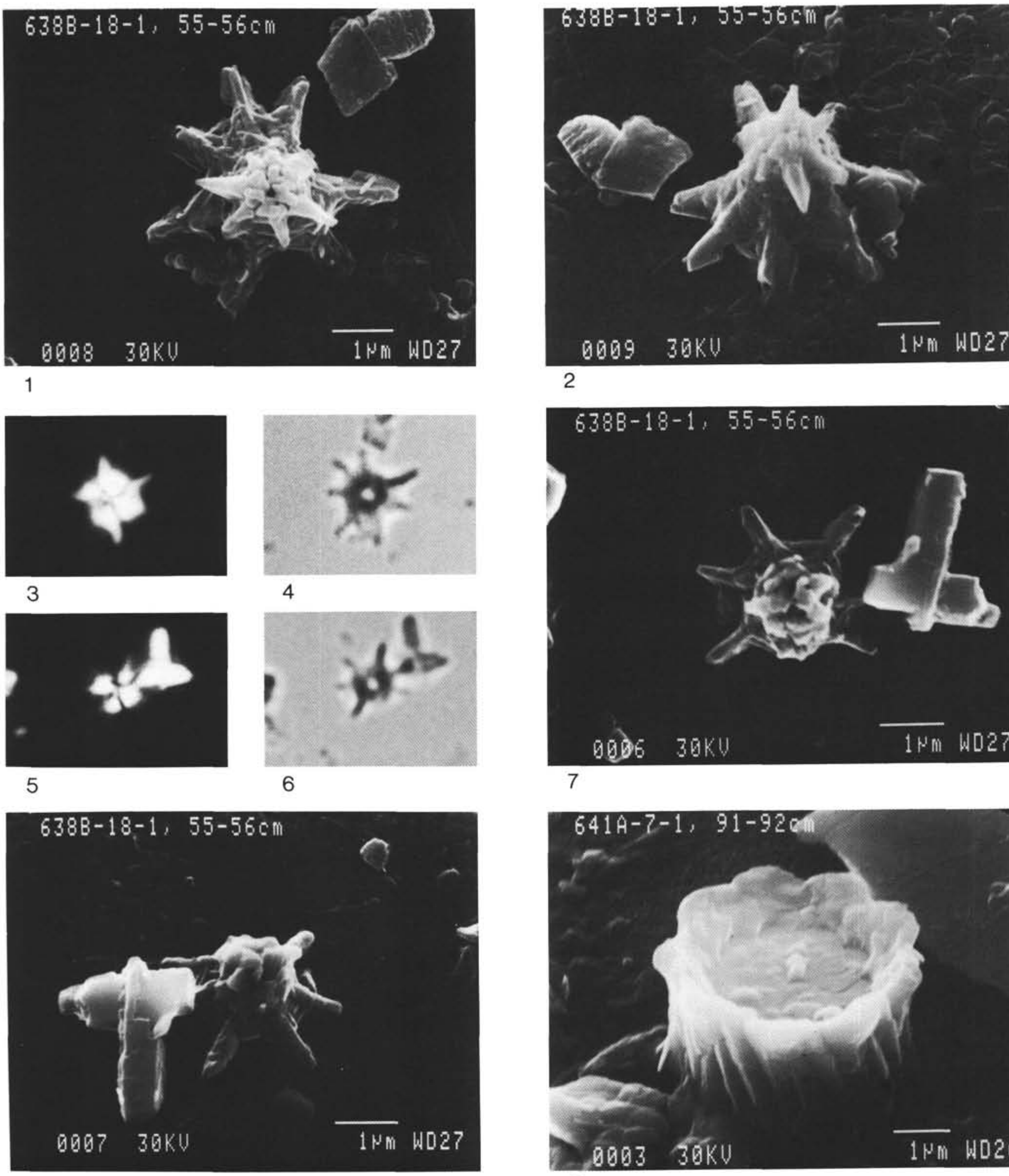

Plate 4. **1–8.** *Hayesites albiensis* Manivit, Sample 103-638B-18R-1, 55–56 cm, (1, D, 10,500×) (2–4)[s1], (2, oblique L, 11,000×; 3, Pol, 4300×; tr, 4300×). (5–8)[s7], (5, Pol, 3900×; 6, Tr, 3900×; 7, D, 11,000×; 8, oblique L, 11,000×). **9.** *Eprolithus floralis* (Stradner) Sample 103-641A-7X-1, 91–92 cm, oblique L, 10,000×.

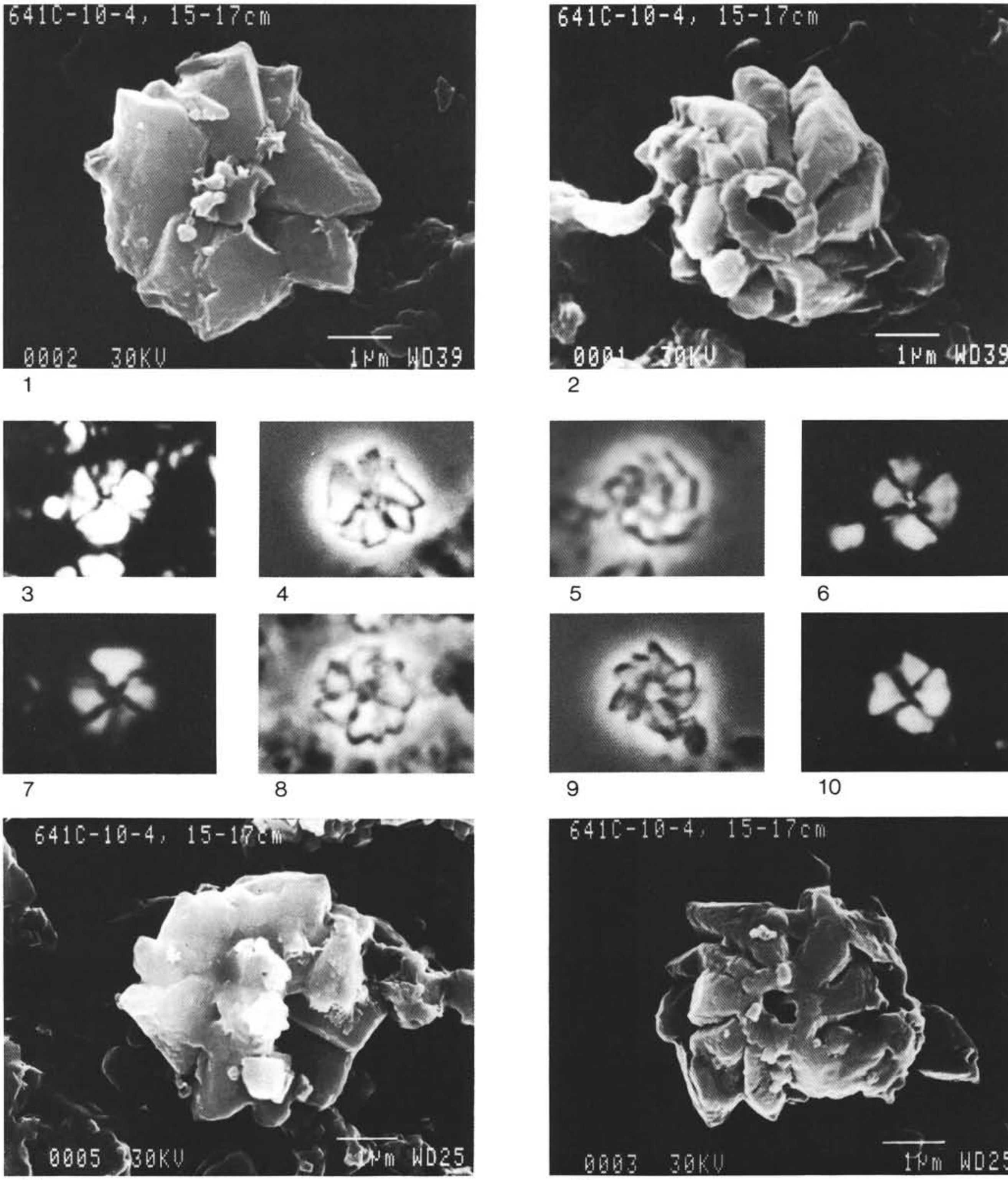

Plate 5. All specimens from Sample 103-641C-10R-4, 15–17 cm, *Hayesites irregularis* (Thierstein). **1.** D, 11,000×. **2.** P, 11,000×. **3 and 4[s1].** 3900×, (3, Pol; 4, Ph). **5 and 6[s2].** 3500×, (5, Pol; 6, Ph). **7 and 8[s11].** 3800×, (7, Pol; 8, Ph). **9 and 10[s12].** 3500×, (9, Pol; 10, Ph). **11.** D, 10,500×. **12.** P, 10,800×.

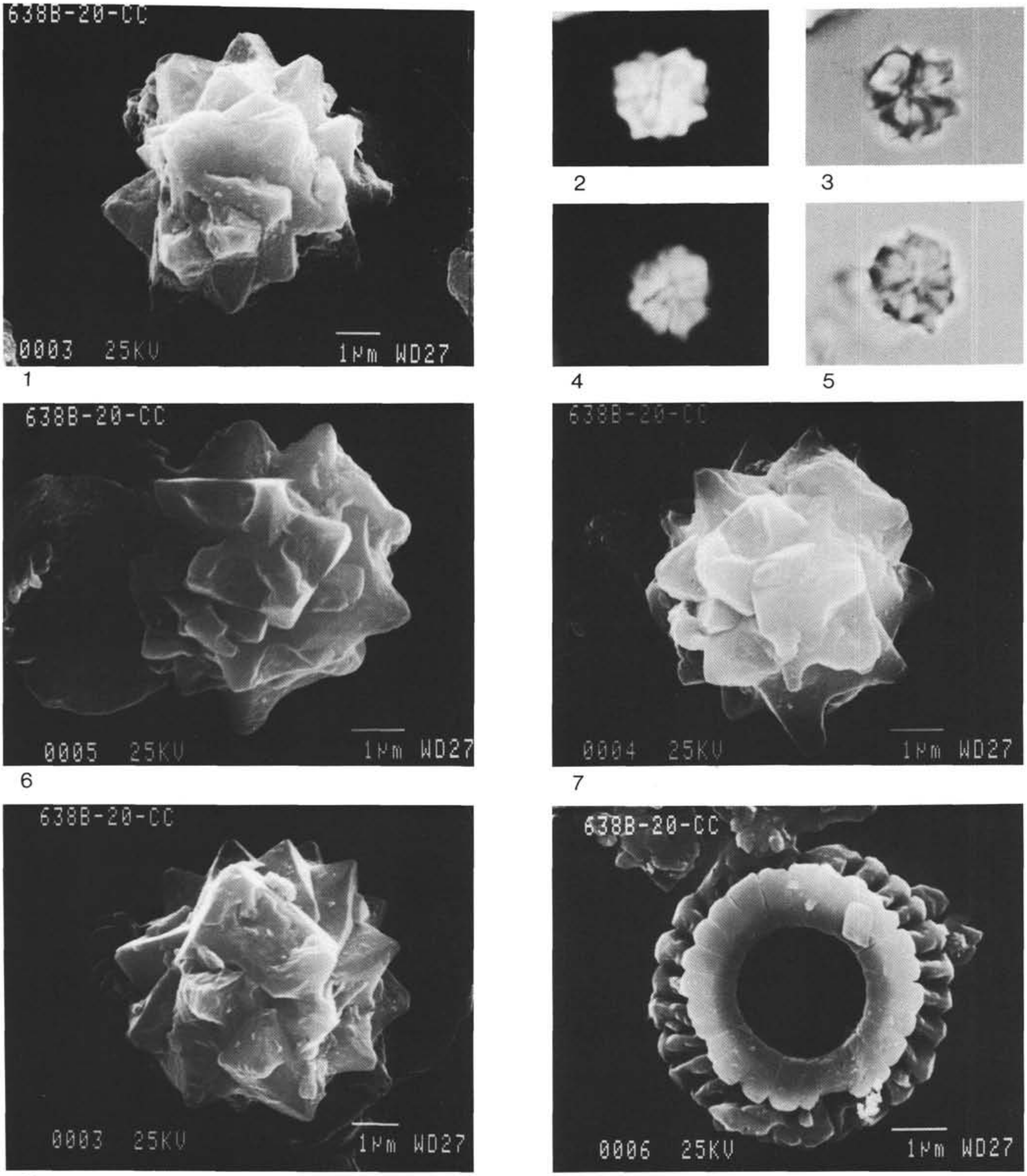

Plate 6. All specimens from Sample 103-638B-20R, CC. **1-8.** *Rucinolithus terebrodentarius* Applegate, Covington, and Wise, (1, 7500×; 2^{s1}, Pol, 3100×; 3^{s1}, Tr), (4^{s7}, Pol, 2900×; 5^{s7}, Tr; 6^{s7}, 0° from"polar axis," 9400×; 7^{s6}, 65° from polar axis, 9300×), (8, 8000×. **9.** *Diazomatolithus lehmanii* Noel, D, 9500×.

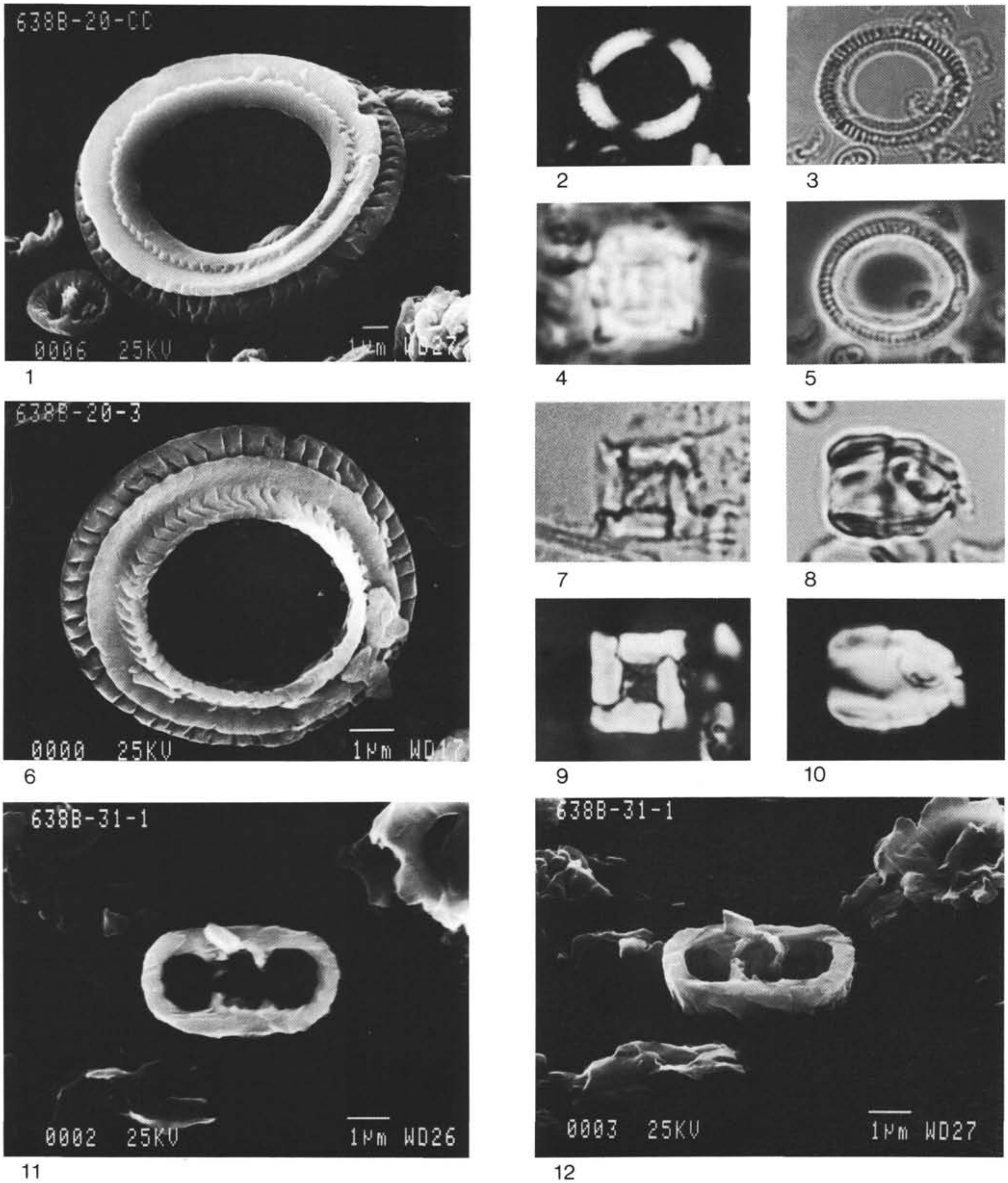

Plate 7. **1–3, 5, and 6.** *Manivitella pemmatoidea* (Deflandre), Sample 103-638B-20R, CC, (1, D, 4700×; 2^{sl}, pol, 1760×; 3^{sl}, Tr; 5^{sl}, Ph), (6), Sample 103-638B-20R-3, 32–33 cm, D, 8000×. **4, 7, and 8.** cf. *Dictyolithus quadratus* (Gorka), Sample 103-638B-22R-3, 55–56 cm, 2900×, (4, Ph: 7, Tr; 8, Pol). **10.** *Lapodeacassis* sp. Sample 103-638B-20R, CC, 2300× (9, Tr; 10, Pol). **11 and 12.** *Zeugrhabdotus pseudoangustus* Bralower, Applegate, Covington, and Wise, Sample 103-638B-31R-1, 125–126 cm, 7800× (11, D; 12, oblique D).

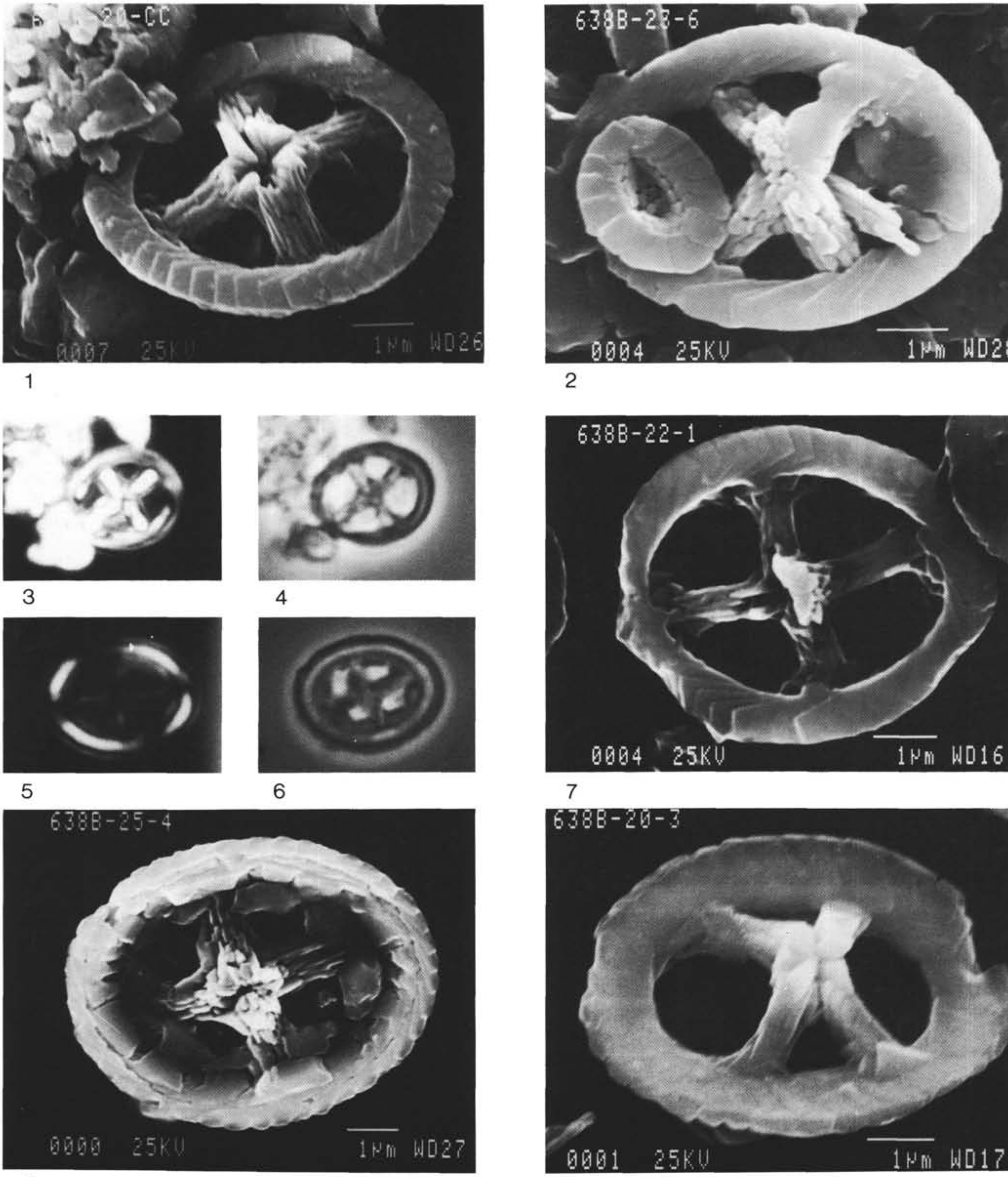

Plate 8. **1–4.** *Chiastozygus litterarius* (Gorka). (1) Sample 103-638B-20R, CC, D, 11,000×, (2) Sample 103-638B-23R-6, 58–59 cm, D, 12,400×, (3 and 4)[s1], 3700× (3, Pol; 4, Ph). **5, 6, and 8.** *Vekshinella angusta* (Stover), Sample 103-638B-25R-4, 48–49 cm, (5 and 6)[s8], 3600× (5, Pol; 6, Ph), (8) D, 9000×. **7.** *Chiastozygus* sp., Sample 103-638B-22R-1, 41–42 cm, D, 11,100×. **9.** *Tegumentum stradneri* Thierstein, Sample 103-638B-20R-3, 32–33 cm, D, 12,100×.

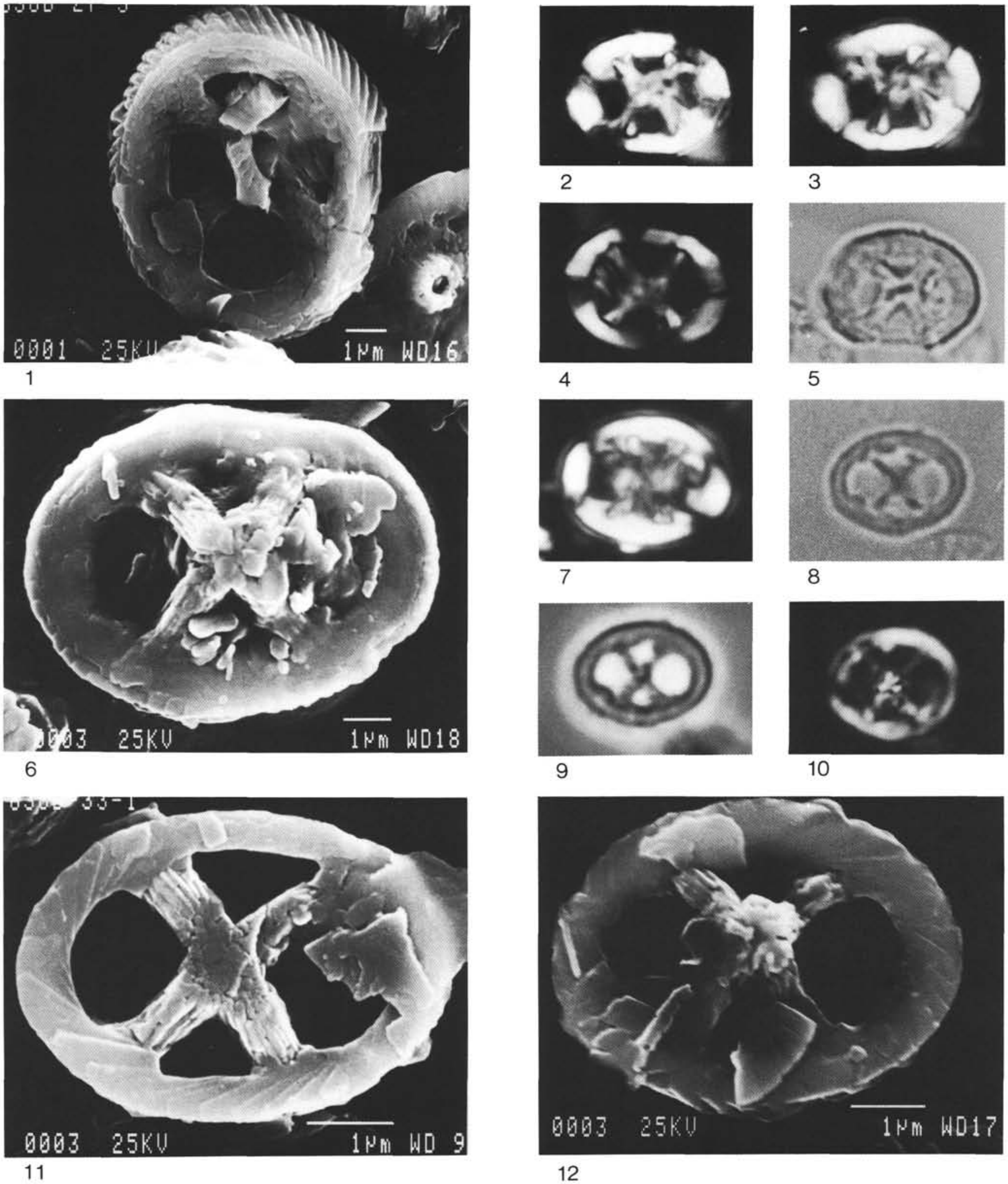

Plate 9. **1–7.** *Eiffellithus striatus* (Black), (1–5) Sample 103-638B-27R-5, 54–55 cm, (1) P, 7200×, (2–5)[s1] 3300×, (2, Pol, 0° to CN; 3, Pol, 10° to CN; 4, Pol, 45° to CN; 5, Tr), (6) D, Sample 103-638B-30R-5, 5–6 cm, 8500×, (7)[s6], Pol, 10° to CN. **8–10 and 12.** *Chiastozygus tenuis* Black, Sample 103-638B-27R-5, 54–55 cm, (8–10)[s12] (8, Tr; 9, Ph, 10, Pol) (12) D, 13,000×. **11.** *Chiastozygus litterarius* (Gorka), Sample 103-638B-33R-1, 75–76 cm, 15,300×.

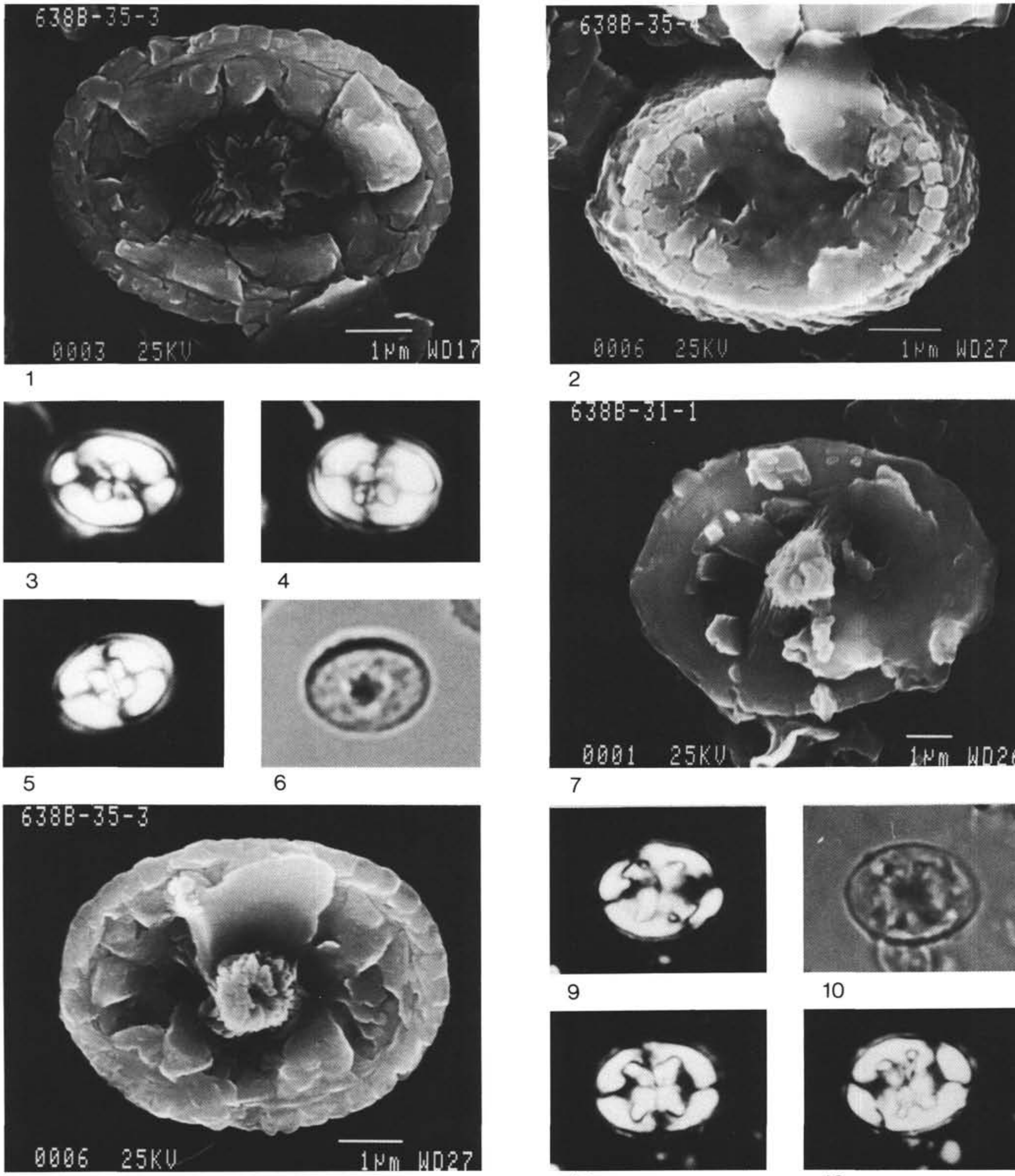

Plate 10. **1–6 and 8.** *Eiffellithus windii* Applegate and Bergen n. sp. (1) Sample 103-638B-35R-3, 111–112 cm, D, 11,400×, holotype. (2) Sample 103-638B-35R-4, 34–35 cm, P, 12,600×. (3 and 4)[s1], 4900×, (3, pol, 0° to CN; 4, pol, 10° to CN). (5 and 6)[s8], 3500×, (5, pol; 6, Tr), (8, D, 11,500×). **7 and 9–12.** *Eiffellithus striatus* (Black), Sample 103-638B-31R-1, 125–126 cm, (7) D, 7800×, (9–12)[s7], 2700×. (9, pol, 0° to CN; 10, Tr; 11, pol, 45° to CN; 12, pol, 10° to CN).

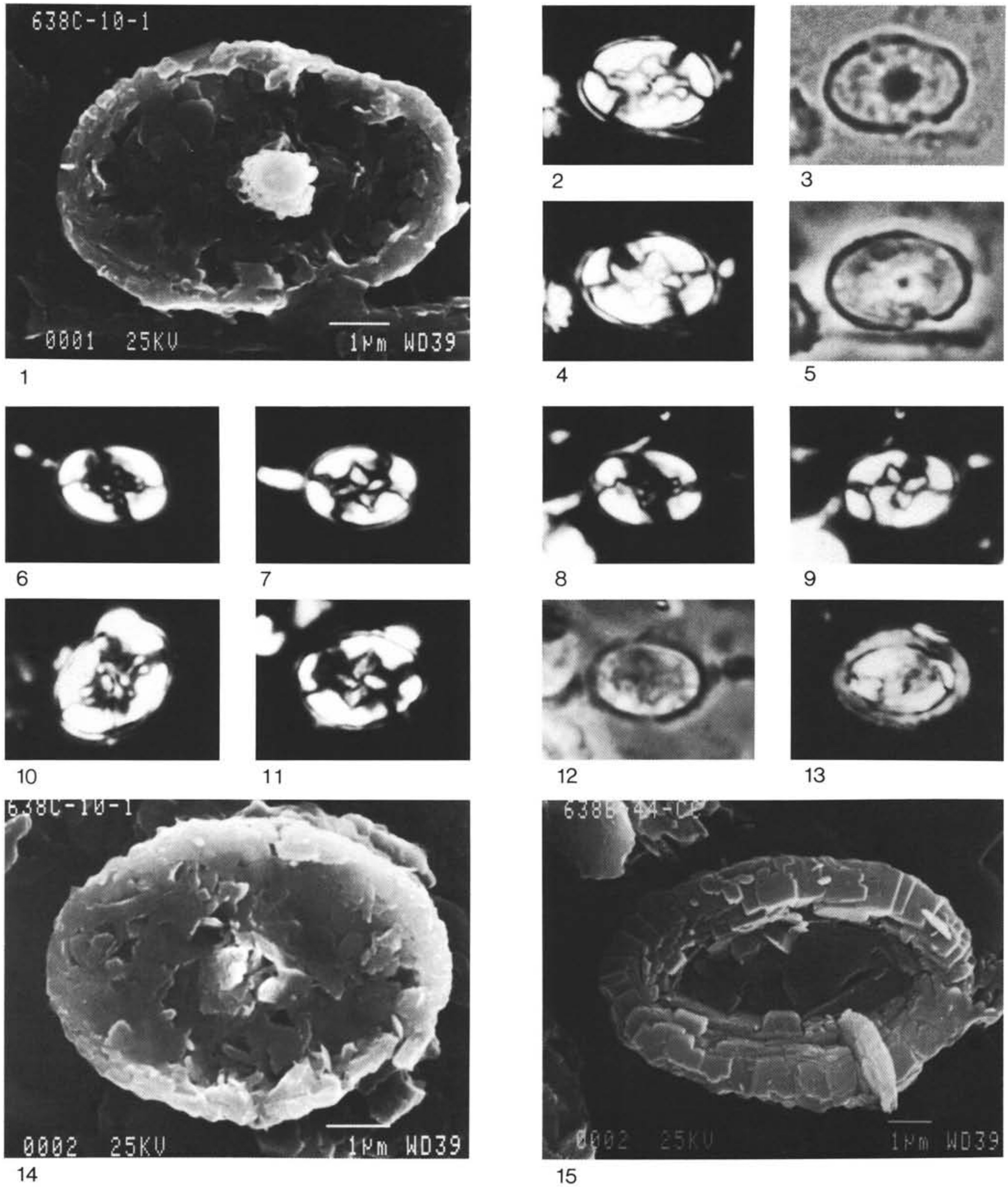

Plate 11. **1–12 and 14.** *Eiffellithus primus* Applegate and Bergen n. sp., Sample 103-638C-10R-1, 35–36 cm, (1) D, 10,500×, holotype, (2–5)^{s1} 3700×, (2, pol, 45° to CN; 3, Tr; 4, pol, 0° to CN; 5, Ph). (6, pol, 45° to CN; 7, pol, 0° to CN, 3700×). (8, 9, 12) 3700×, (8, pol, 45° to CN; 9^{s8}, pol, 0° to CN, 12, Ph). (10 and 11)^{s14} 3700×, (10, pol, 45° to CN; 11, pol, 0° to CN). (14, D, 11,600×). **13 and 15.** *Percivalia* cf. *P. fenestrata* (Worsley) (13)^{s15} pol, 2900×, (15) D, 7600×.

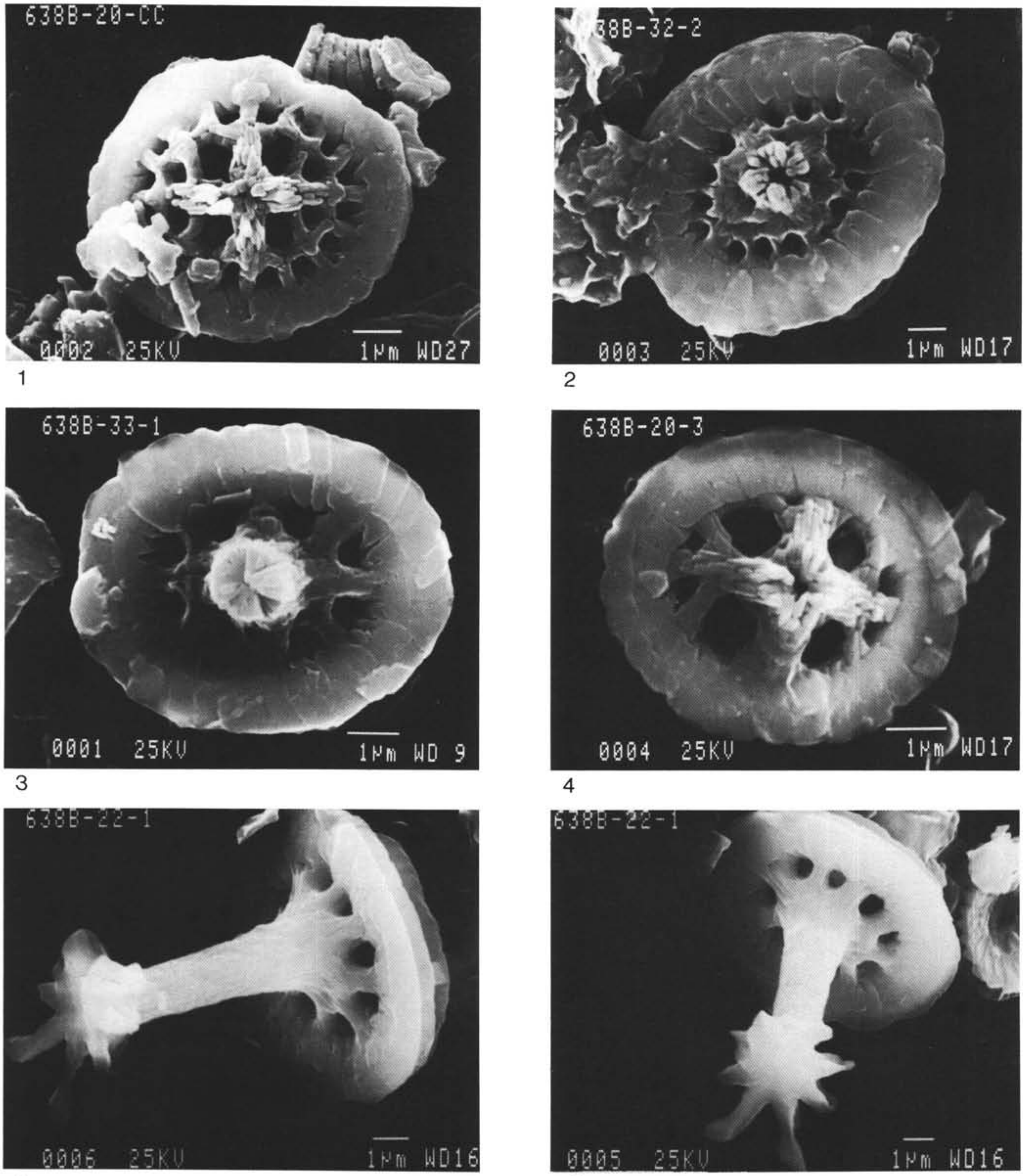

Plate 12. **1.** *Cretarhabdus conicus* Bramlette and Martini, Sample 103-638B-20R, CC, D, 8400×. **2.** *Cretarhabdus surirellus* Thierstein, Sample 103-638B-32R-2, 126–127 cm, D, 6700×. **3 and 4.** *Retecapsa angustiforata* Black (3) Sample 103-638B-33R-1, 75–76 cm, D, 9000×, (4) Sample 103-638B-20R, CC, D, 10,600×. **5 and 6.** *Retecapsa angustiforata* Black and *Retecapsa radiata* (Worsley), Sample 103-638B-22R-1, 41–42 cm, (5) D, 6100× (6) D, 5200×.

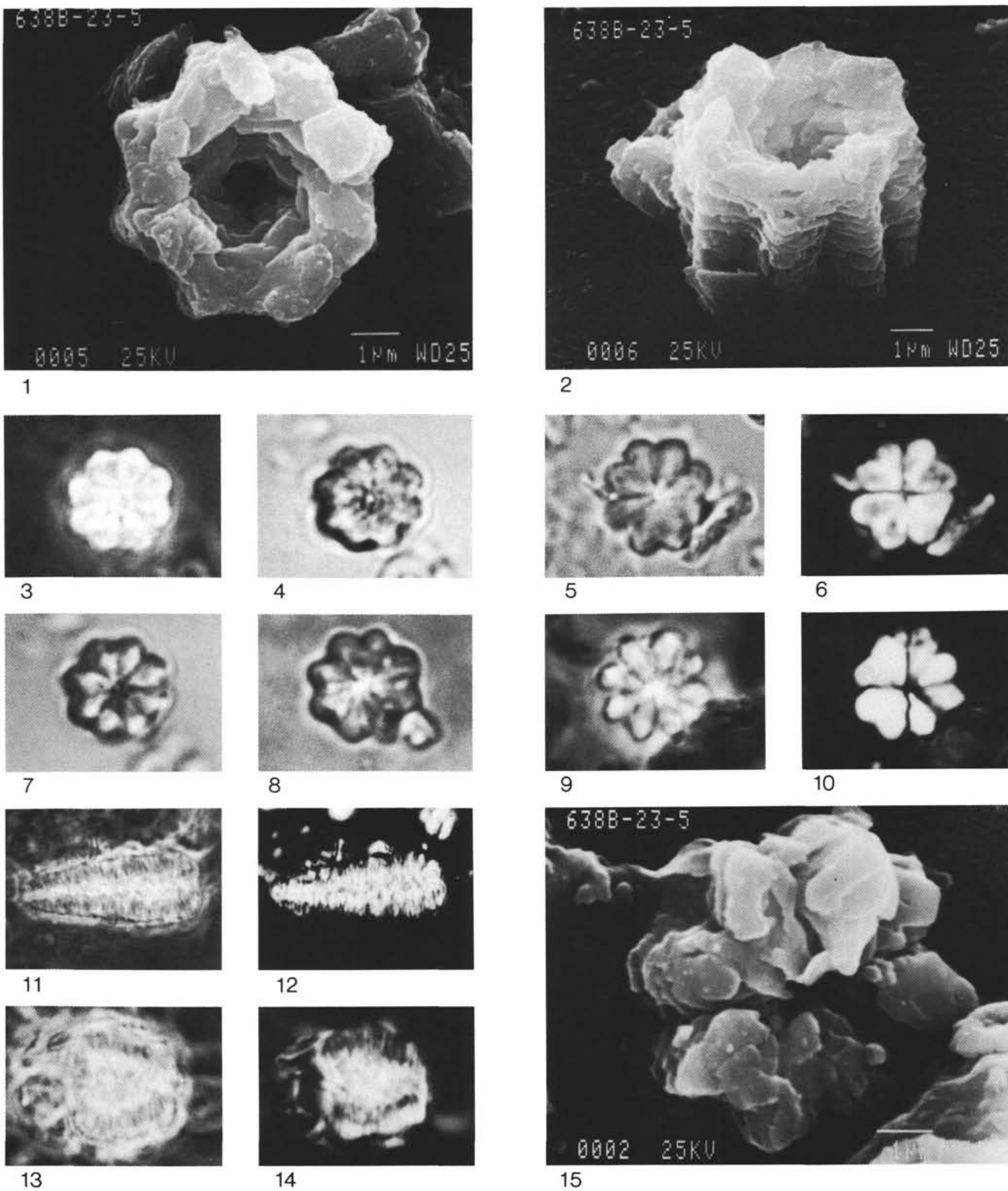

Plate 13. **1–10 and 15.** *Nannoconus ligius* Applegate and Bergen n. sp., Sample 103-638B-23R-5, 89–90 cm. (1) 8400×, holotype, (2)[s1] 7500×. (3–8) 3300×, (3, pol; 4, Tr; 5, Tr; 6, Pol; 7, Tr; 8, Tr). (9 and 10)[s15] 3300×, (9, Ph; Pol), (15) 10,000×. **11 and 12.** *Nannoconus bermudezi* Bronniman, Sample 103-638B-35R-3, 111–112 cm, 1600×, (11, Ph; 12, Pol). **13 and 14.** *Nannoconus bucheri* Bronnimann, Sample 103-638B-32R-1, 43–44 cm, 2200×, (13, Ph; 14, Pol).

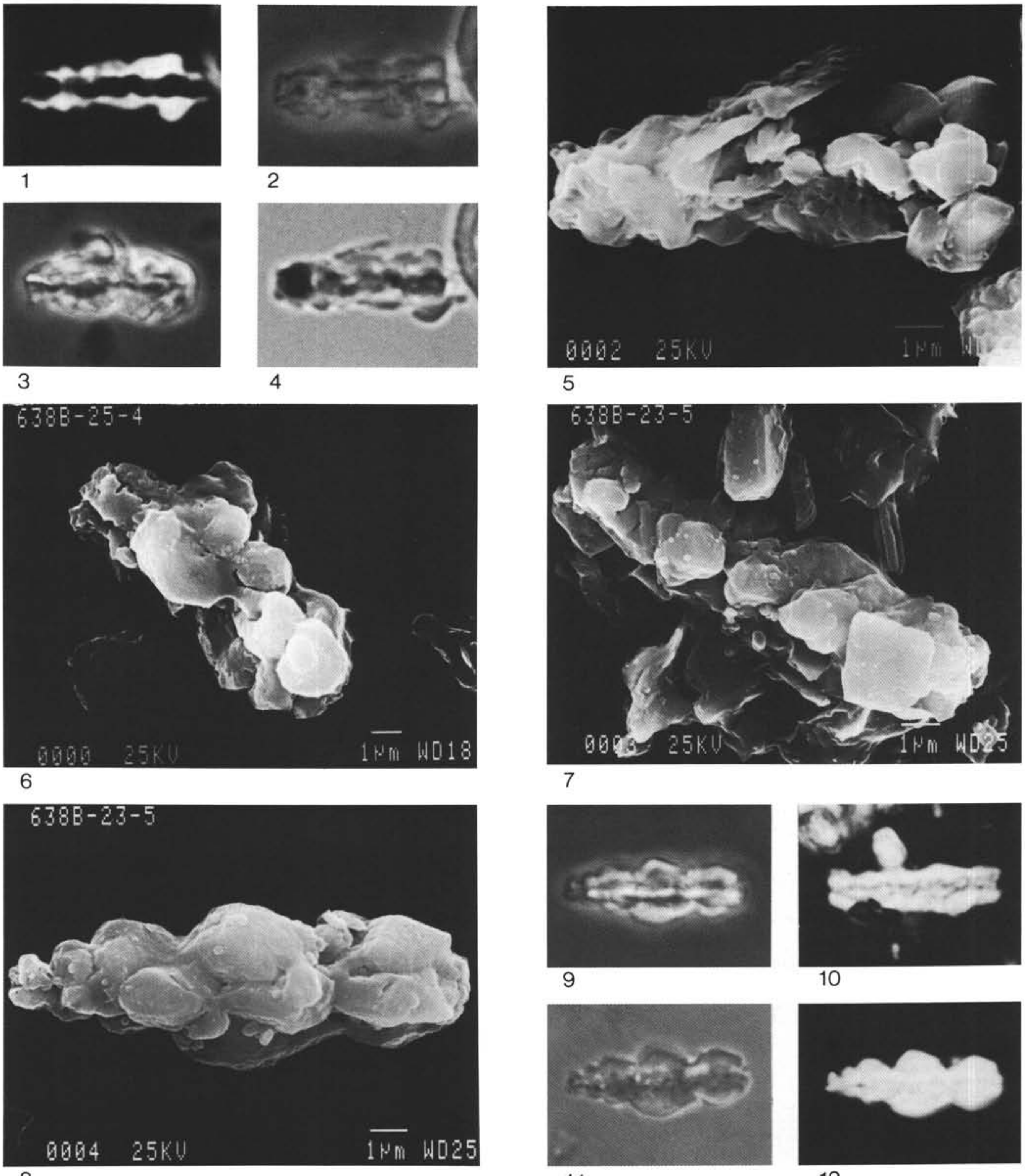

Plate 14. **1-12.** *Lithraphidites bollii* (Thierstein), (1, 2, and 4)[s5] Sample 103-638B-27R-5, 54–55 cm, (1, Pol; 2, Ph; 4, Tr), (5) 8500×. (3[s6], 6) Sample 103-638B-25R-4, 48–49 cm, (3, Ph, 2700×; 6, 5200×), (7, 10[s7]) Sample 103-638B-23R-5, 89–90 cm, (7, 6800×; 10, Pol, 2400×). (8) Sample 103-638B-23R-5, 89–90 cm, 6500×. (9, 11, and 12)[s8], 5200×, (9, Ph; 11, Tr; 12, Pol).

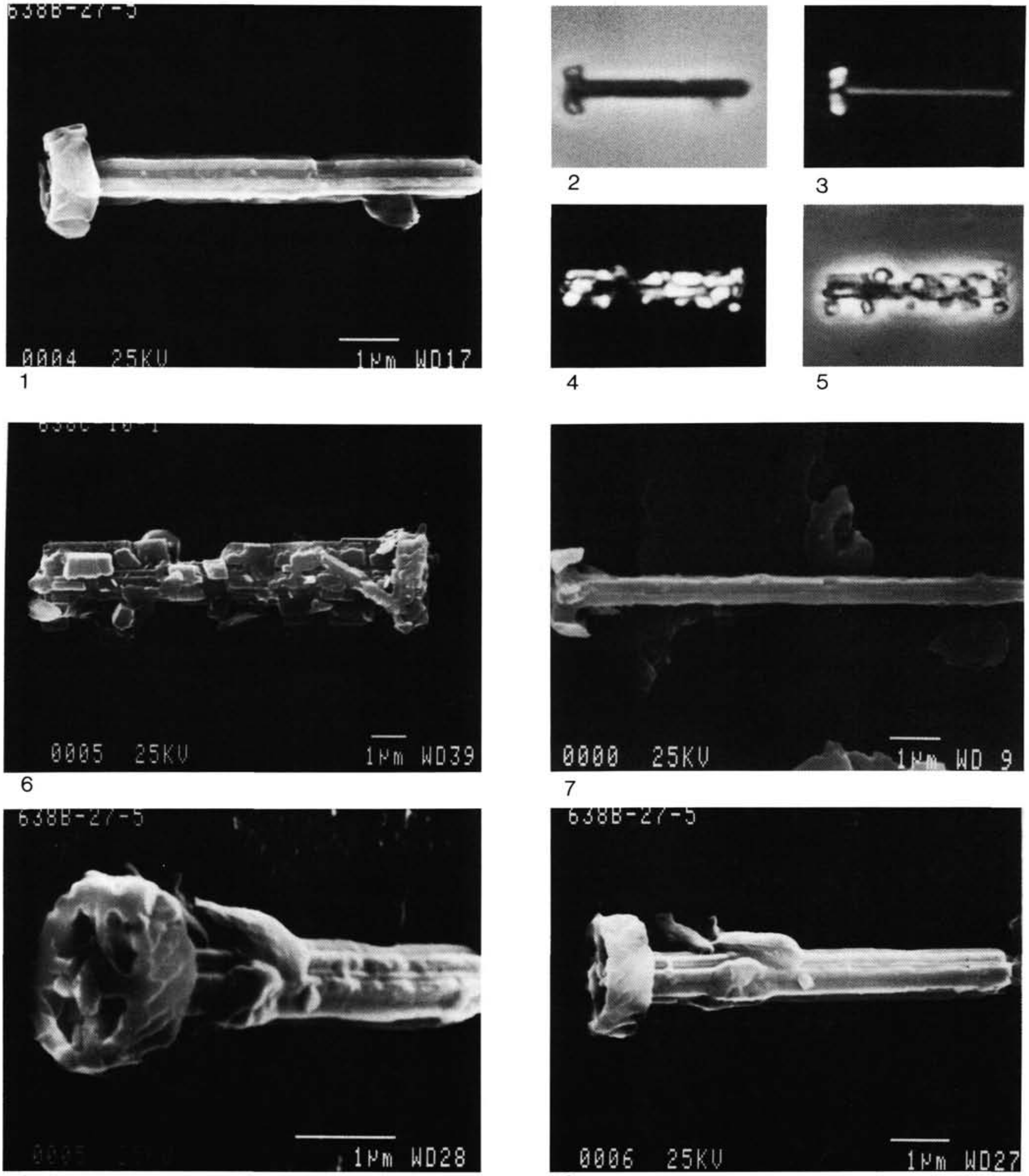

Plate 15. **1-9.** *Vekshinella parallela* (Wind and Cepek) (1) Sample 103-638B-27R-5, 54–55 cm, L, 10,200× (2 and 3)[s1] 400×, (2, Tr; 3, Pol). (4 and 5)[s6], Sample 103-638C-10R-1, 35–36 cm, 4000×, (4, Tr; 5, Pol), (6) L, 6000×. (7) Sample 103-638B-27R-5, 54–55 cm, L 8800×, (8–9) Sample 103-638B-27R-5, 54–55 cm, (8, oblique P, 17,200×; 9, L, 10,000×).

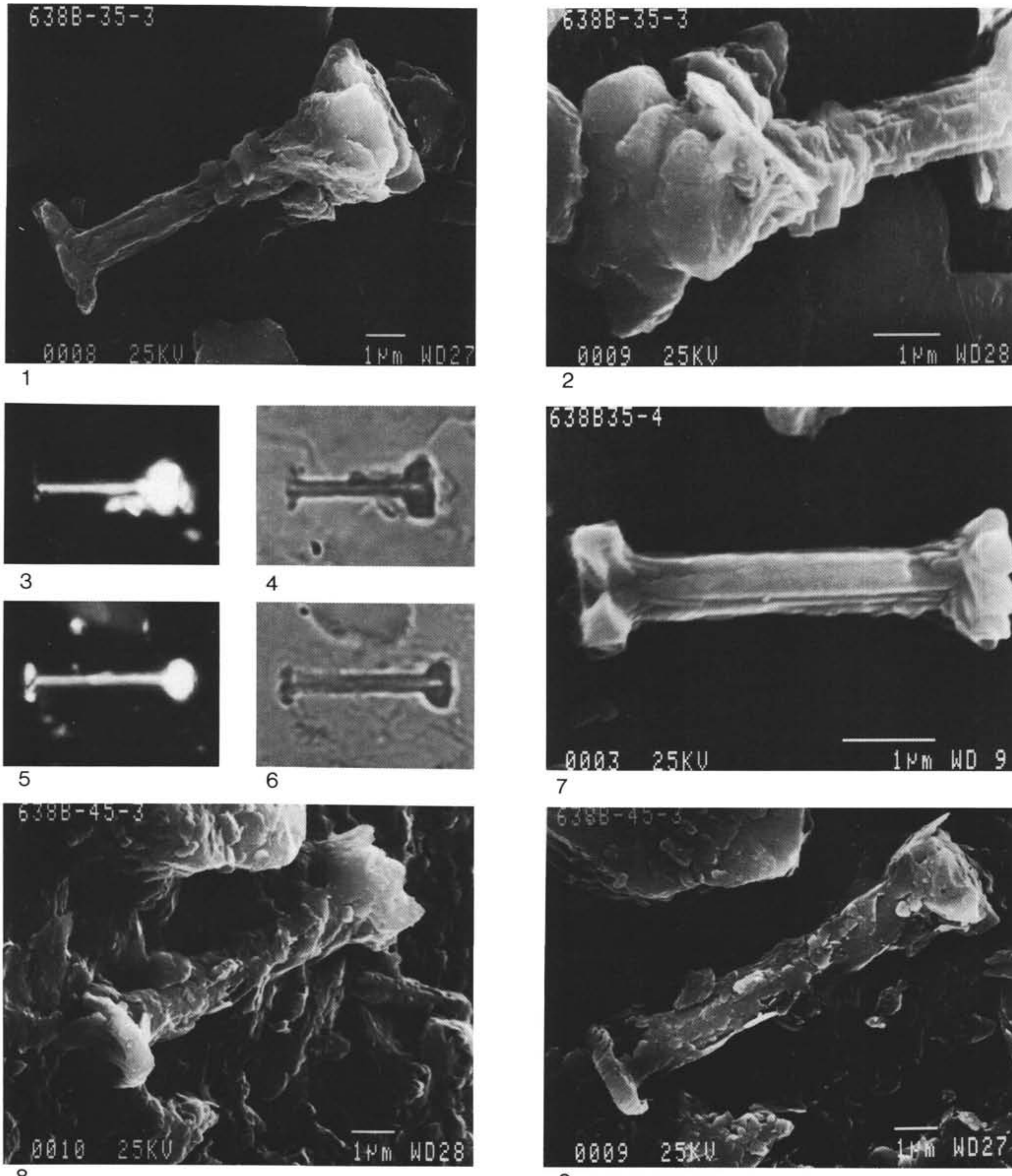

Plate 16. **1–9.** *Vekshinella pseudocarinolithus* Applegate and Bergen n. sp. (1–4) Sample 103-638B-35R-3, 111–112 cm, (1, L, 6800×; 2, oblique D, 11,400×, (4)[s1], 2600×, (3, Pol; 4, Tr), 5, 6, 8, and 9) Sample 103-638B-45R-3, 28–29 cm, (5 and 6)[s8] holotype, 2800×, (5, Pol; 6, Tr), (8) oblique P, 7500×, (9) L, 7500×.

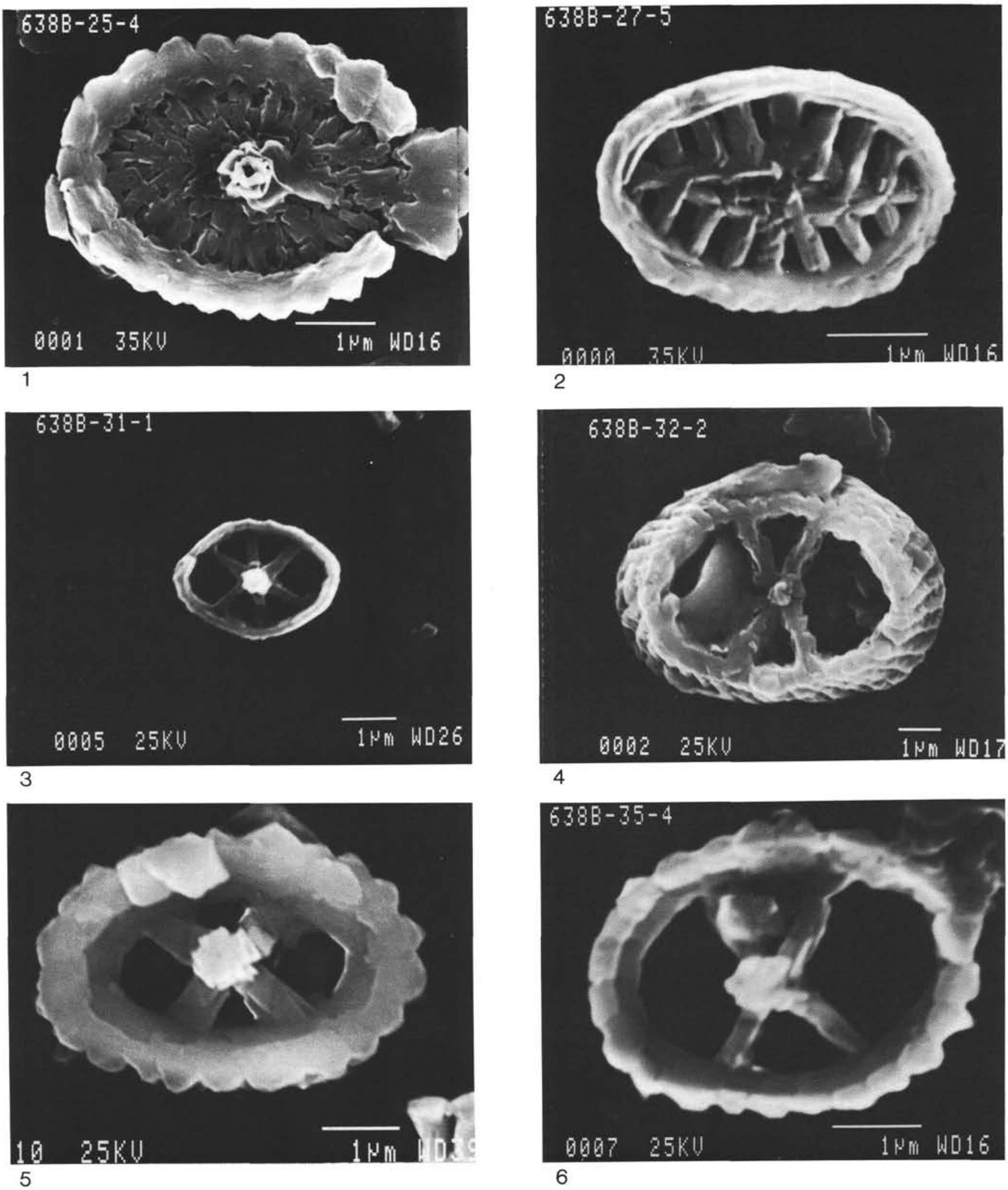

Plate 17. **1.** *Nodosella silvaradion* (Filewicz), Sample 103-638B-25R-4, 48–49 cm, D, 14,200×. **2.** *Thurmannolithion clatratum* Grun and Zweili, Sample 103-638B-27R-5, 54–55 cm, D, 17,900×. **3.** *Corollithion ellipticum* Bukry, Sample 103-638B-31R-1, 125–126 cm, 9700×. **4–6.** *Corollithion acutum* Thierstein, (4) Sample 103-638B-32R-2, 125–126 cm, P, 7500×, (5 and 6) Sample 103-638B-35R-4, 34–35 cm, (5) D, 13,800×, (6) D, 15,800×.

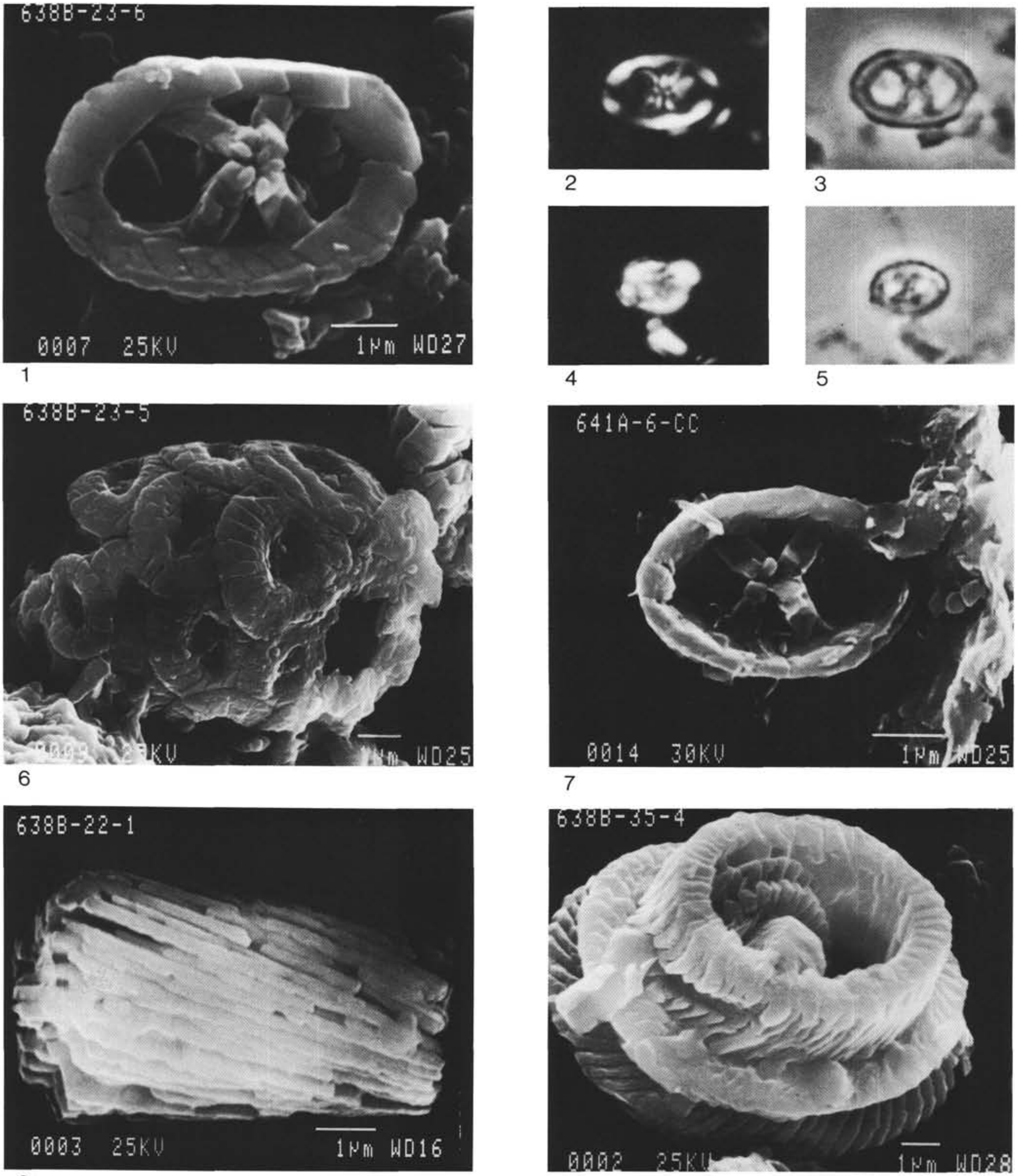

Plate 18. **1–3.** *Tegumentum stradneri* Thierstein, Sample 103-638B-23R-6, 58–59 cm, (1) D, 11,500×, (2 and 3)[s1] 3900×, (2, Pol; 3, Ph). **4, 5, and 7.** *Corollithion acutum* Thierstein, Sample 103-641A-6X, CC, (4 and 5)[s7] 3600×, (4, Pol; 5, Ph), (7) D, 12,500×. **6.** Coccosphere, *Biscutum constans* (Gorka), Sample 103-638B-23R-5, 88–89 cm, 7800×. **8.** *Conusphaera mexicana* Trejo, Sample 103-638B-22R-1, 41–42 cm. L, 10,500×. **9.** *Tubodiscus verenae* Thierstein, Sample 103-638B-35-4, 34–35 cm, D, 7000×.

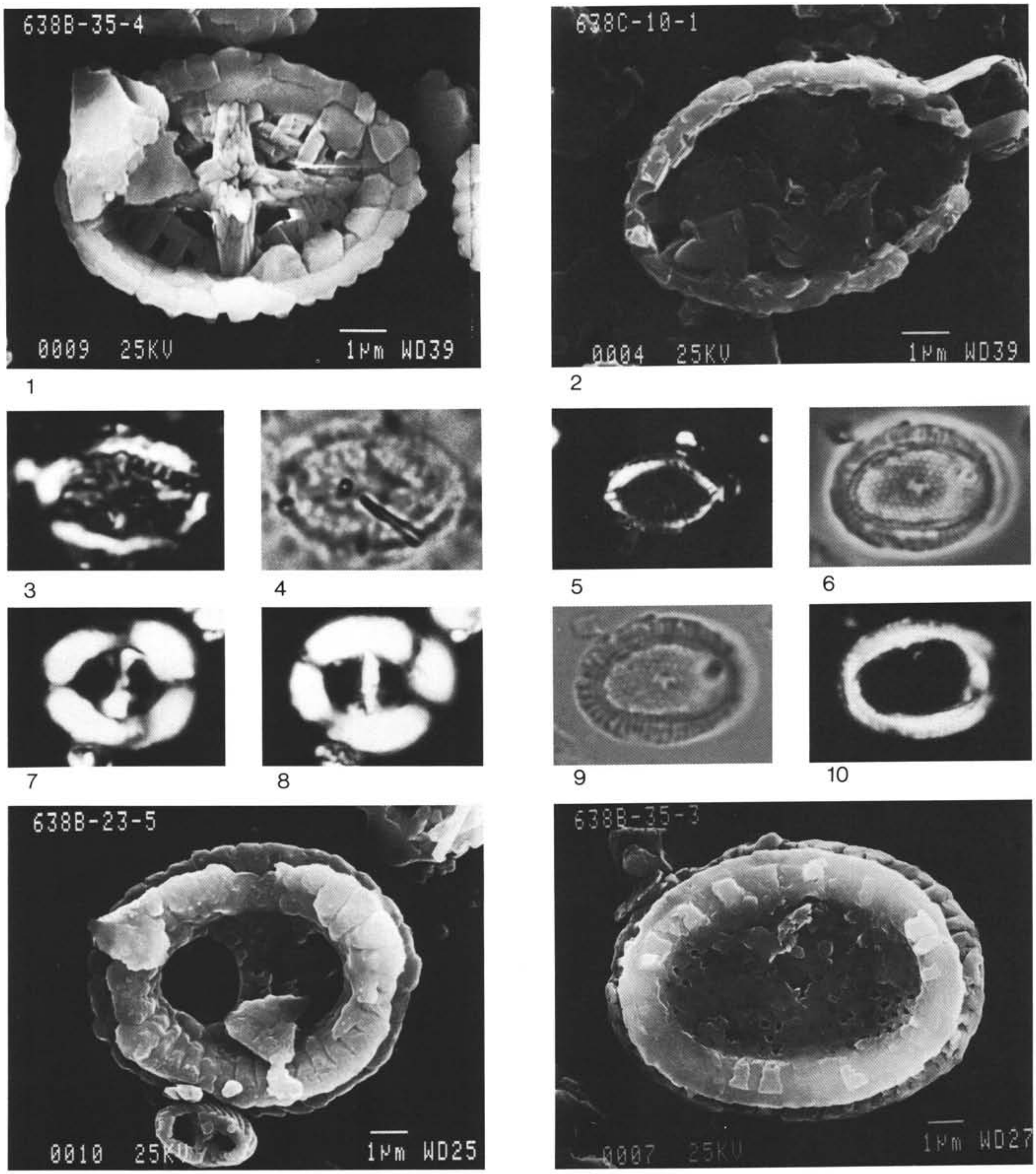

Plate 19. **1, 3, and 4.** *Diloma primitiva* (Worsley), (1) Sample 103-638B-35R-4, 34–35 cm, D, 8000×. (3 and 4) Sample 103-638B-44R-1, 38–29 cm, 4100×, (3, Pol; 4, Tr). **2 and 5.** *Diloma* sp. Wind and Cepek, Sample 103-638C-10R-1, 35–36 cm, (2) D, 8200×. (5^{s2}, Pol, 2700×). **6, 9, 10, and 12.** *Ethmorhabdus hauterivianus* (Black), Sample 103-638B-35R-3, 111–112 cm, $(6, 9, \text{and } 10)^{s12}$ 2300×, (6, Ph; 9, Tr; 10, Pol) (12) P, 6000×. **7, 8, and 11.** *Speetonia colligata* Black, Sample 103-638B-23R-5, 89–90 cm, $(7 \text{ and } 8)^{s11}$ 3000×, Pol, (11) P, 6300×.

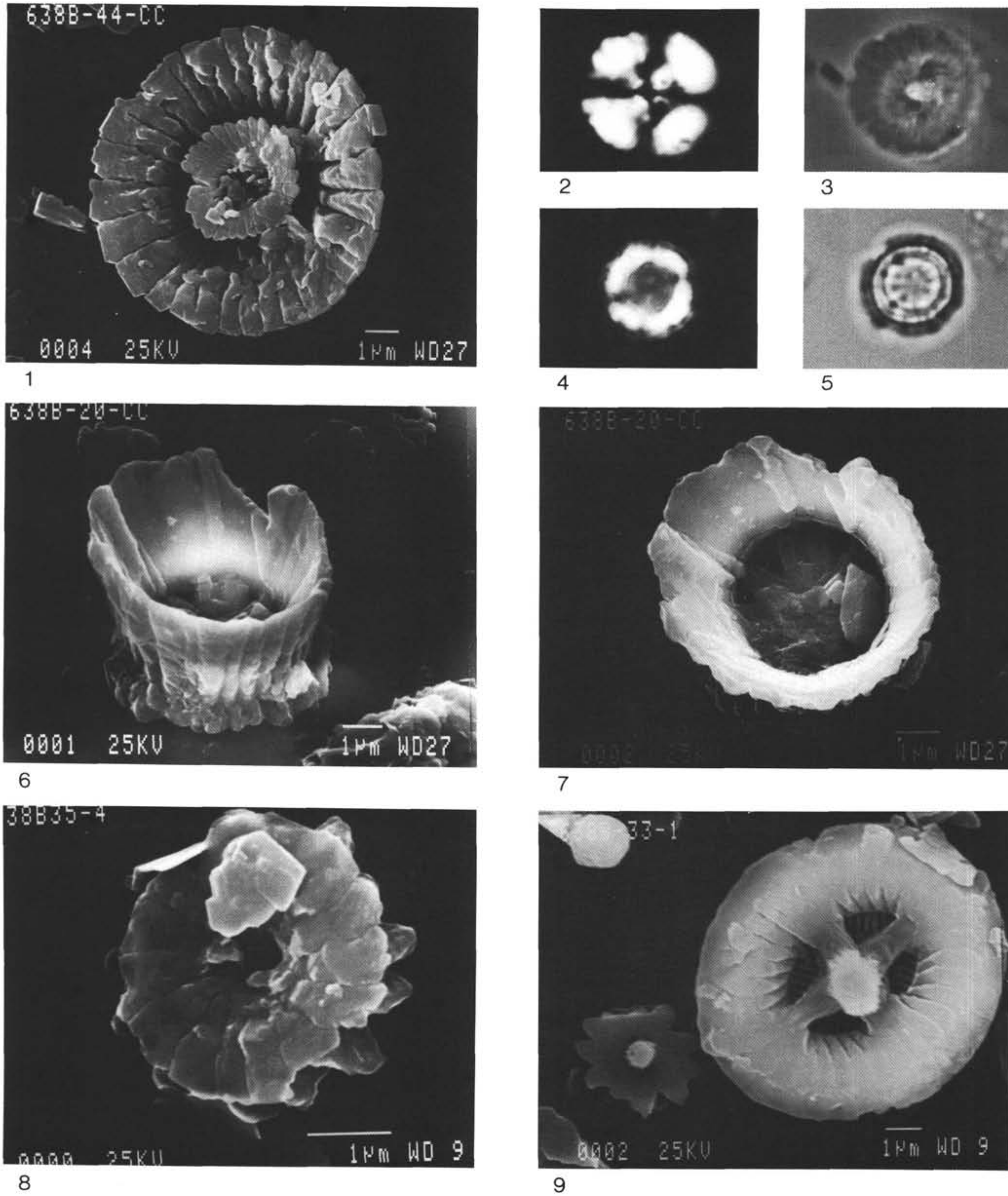

Plate 20. **1-3.** *Cyclagelosphaera brezae* Applegate and Bergen n. sp., Sample 103-638B-44R, CC, (1) P, 5900×, (2 and 3)[s1] 2800×, (2, Pol; 3, Ph). **4-7.** *Stephanolithion laffittei* Noel, Sample 103-638B-20R, CC, (4 and 5)[s7] 3100×, (4, Pol; 5, Tr), (6)[s7] oblique D, 6900×, (7) D, 7800×. **8.** *Discorhabdus biradiatus* (Worsley), Sample 103-638B-35R-4, 34-35 cm, P, 14,500×. **9.** *Cruciellipsis cuvillieri* ssp. *cuvillieri* Manivit and *Discorhabdus biradiatus* (Worsley), Sample 103-638B-33R-1, 75-76 cm, D, 6200×.

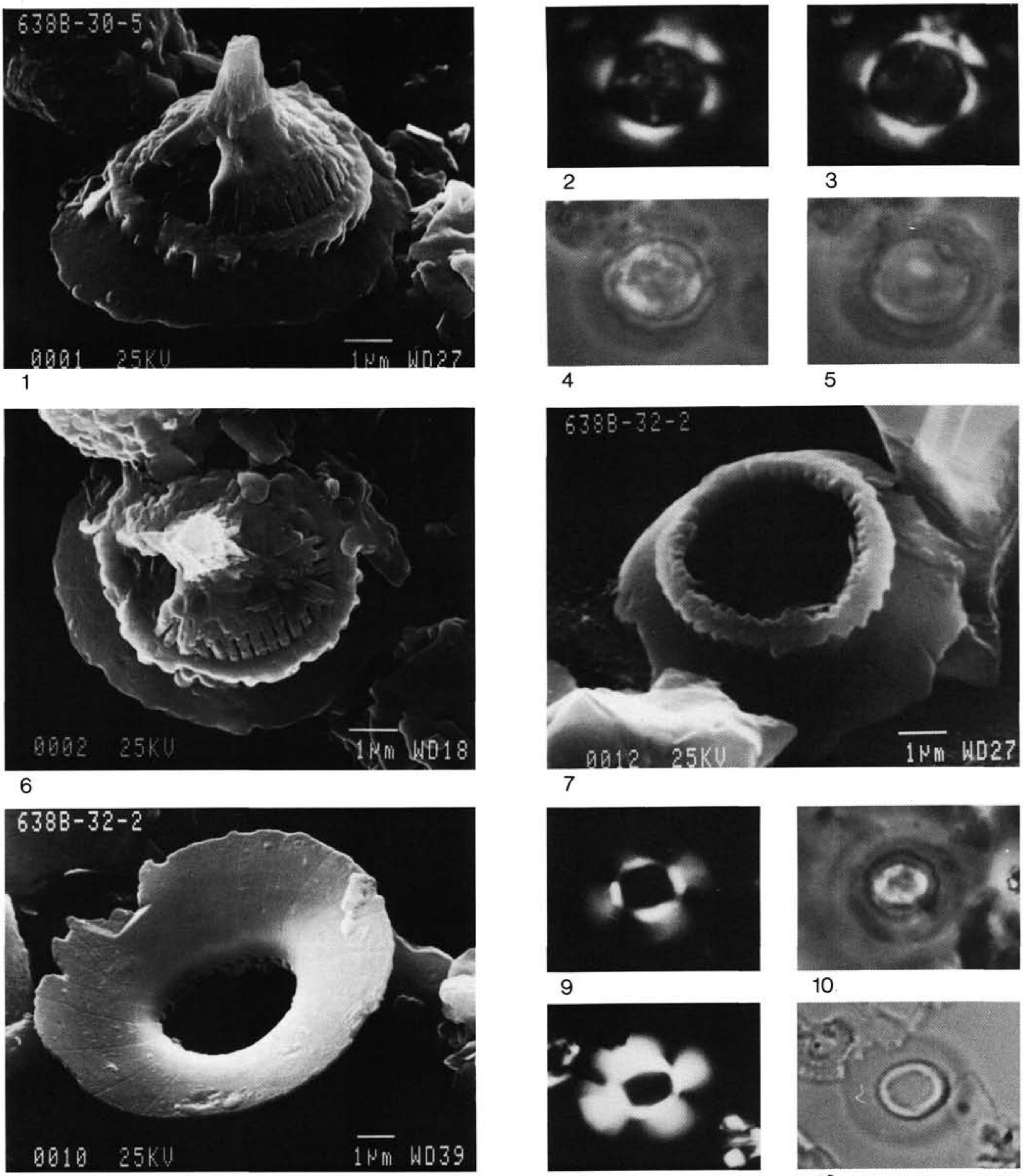

Plate 21. **1–12.** *Pickelhabube furtiva* (Roth), (1–6) Sample 103-638B-30R-5, 5–6 cm, (1)[s6] oblique D, 8300×, (2–5)[s6] 3700×, (2, Pol, high focus; 3, Pol, low focus; 4, Tr, high focus; 5, Tr, low focus), (6) D, 8500×, (7–12) Sample 103-638B-32R-2, 126–127 cm, (7) oblique D, 8500×, (8) oblique P, 6500×, (9 and 10)[s7] 2800×, (9, Pol; 10, Tr), 11 and 12)[s8] 2500×, (11, Pol; 12, Tr).

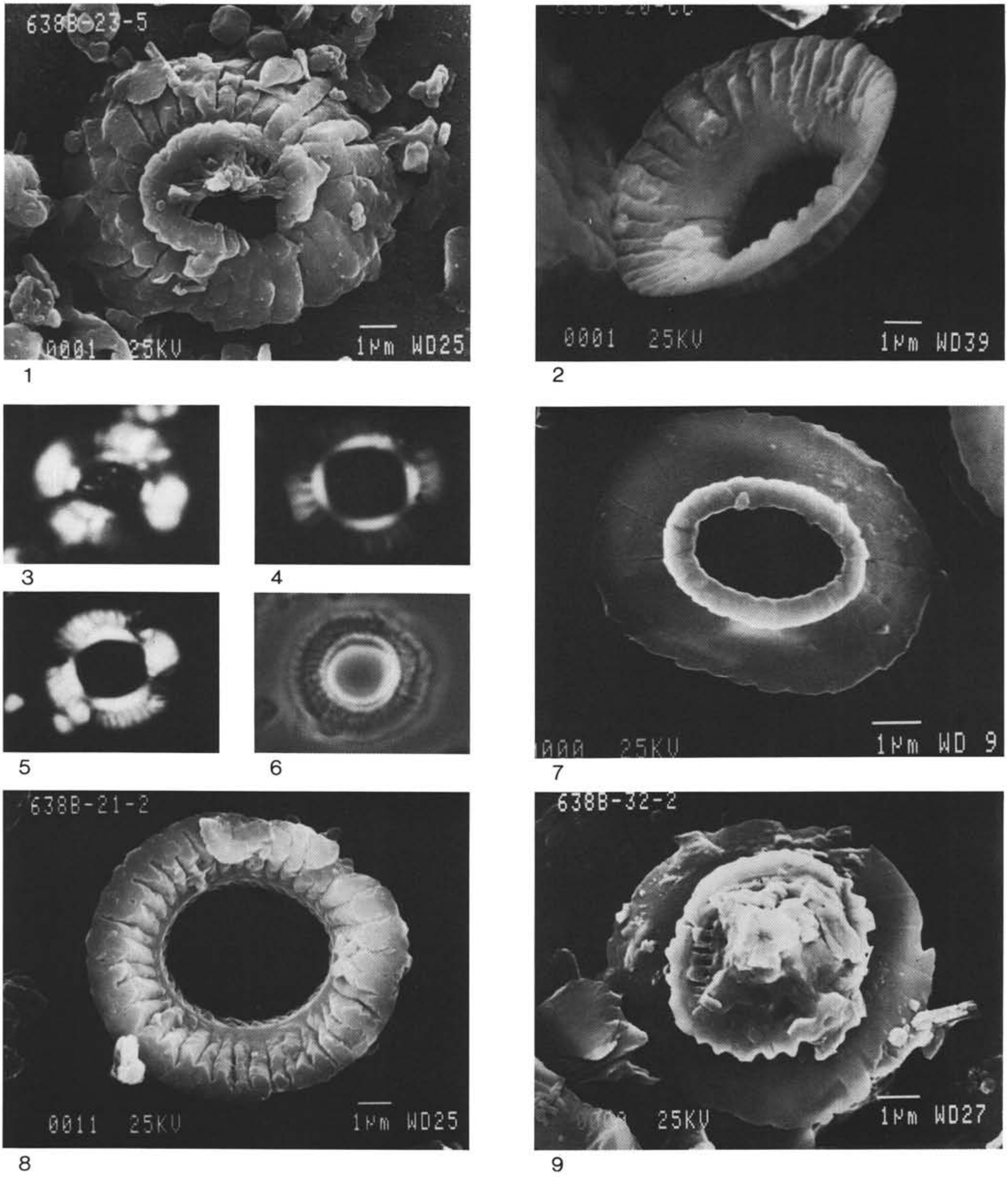

Plate 22. **1, 3, and 9** *Pickelhaube furtiva* (Roth), (1 and 3) Sample 103-638B-23R-5, 89–90 cm, (1) D, 6500×, $(3)^{s1}$ 3300×, Pol, (9) Sample 103-638B-32R-2, 126–127 cm, D, 7800×. **2, 4, and 7.** *Pickelhaube* sp. 1. (2 and 4) Sample 103-638B-20R, CC, (2) oblique P, 6600×, $(4)^{s2}$, Pol, 2800×, (7) Sample 103-638B-22R-1, 41–42 cm, D, 8600×. **5, 6, and 8.** *Manivitella* cf. *M. pemmatoidea* (Deflandre), Sample 103-638B-21R-2, 47–48 cm, (5 and $6)^{s8}$ 2400×, (5, Pol; 6, PhO, (8) P, 6000×.

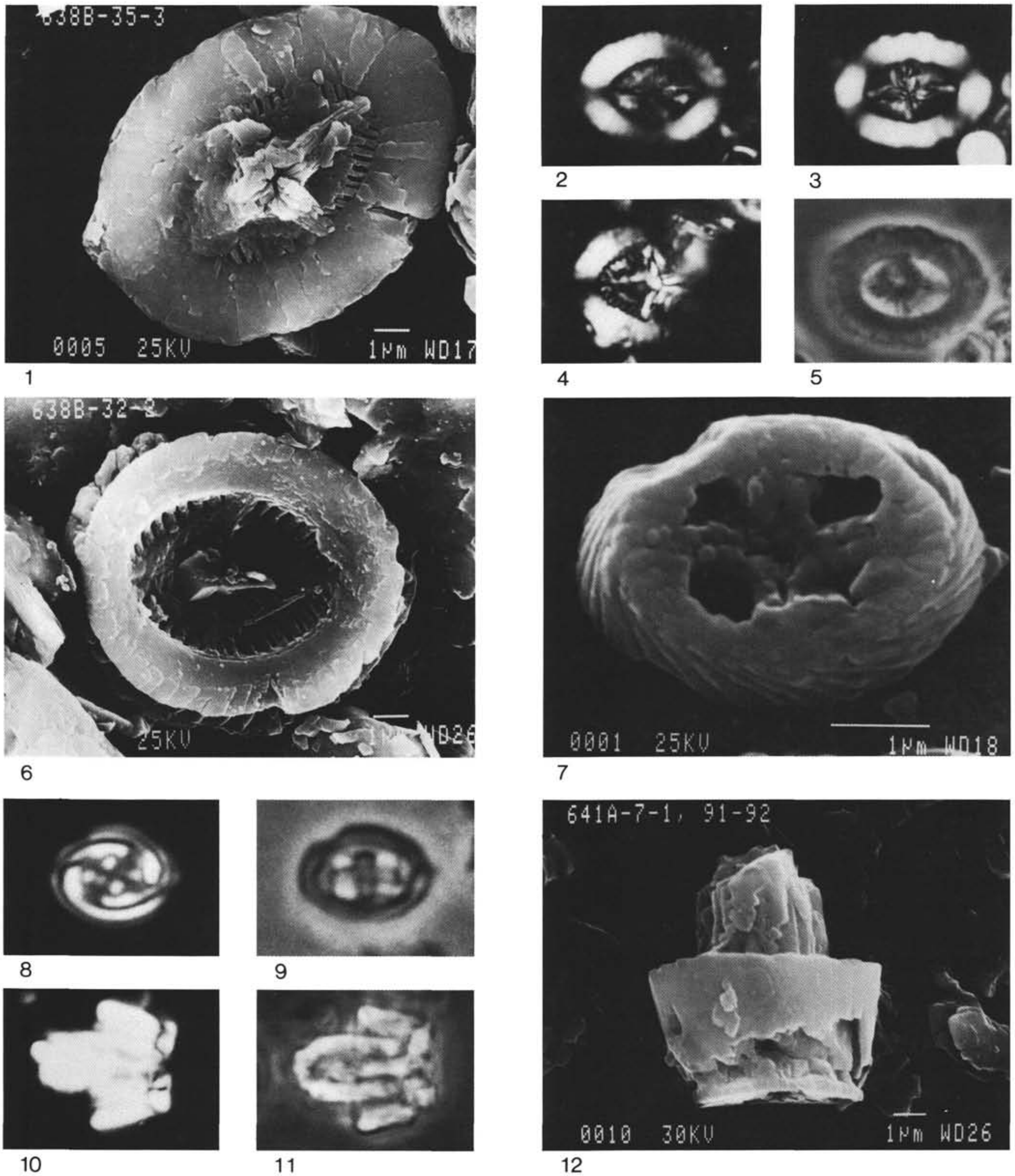

Plate 23. **1-6.** *Cretarhabdus delicatus* Applegate, Covington, and Wise, (1-3) Sample 103-638B-35R-3, 111-112 cm, (1), D, 6200×, (2 and 3)[s1] 3000×, 92, Pol, 45° to CN; 3, Pol, 0° to CN), (4-6) (Sample 103-638B-32R-2, 126-127 cm, (4) 2400×, Pol, (5) 2300×, Tr, (6) P, 6100×. **7-9.** *Vekshinella mitcheneri* Applegate and Bergen n. sp., Sample 103-638B-30R-5, 5-6 cm, (7) P, 17,400×, (8-9)[s7] 6400×, (8, Pol; 9, Tr). **10-12.** *Parhabdolithus* sp. Sample 103-641A-7X-1, 91-92 cm, (10 and 11)[s12] 2900×, (10, Pol; 11, Ph), (12) L, 5800×.

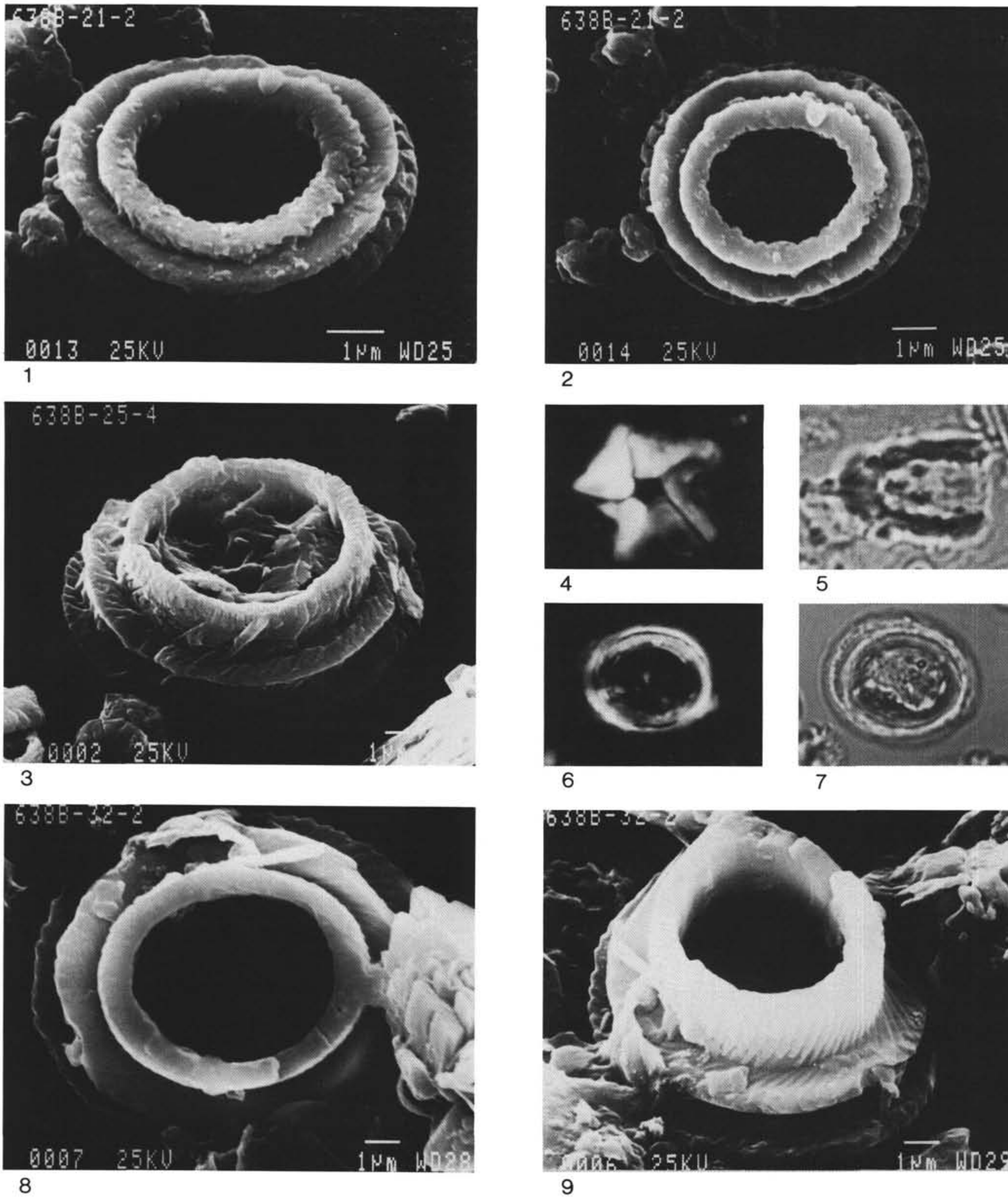

Plate 24. **1 and 2.** *Tubodiscus jurapelagicus* (Worsley), Sample 103-638B-21R-2, 47–48 cm, (1) oblique D, 10,000×, (2)[s1] P, 7800×. **3 and 6–9.** *Tubodiscus verenae* Thierstein, (3) Sample 103-638B-25R-4, 48–48 cm, oblique D, 4400×, (6 and 7)[s3] 2600×, (6, Pol; 7, Tr), (8 and 9) Sample 103-638B-32R-2, 126–127 cm, (8)[s9] D, 6200×, (9) oblique D, 6400×. **4.** *Micrantholithus* cf. *obtusus* Stradner, Sample 103-638C-10R-1, 35–36 cm, 2600×, pol. **5.** *Lapideacassis* sp. Sample 103-638B-22R-1, 41–42 cm, 2400×, Tr.

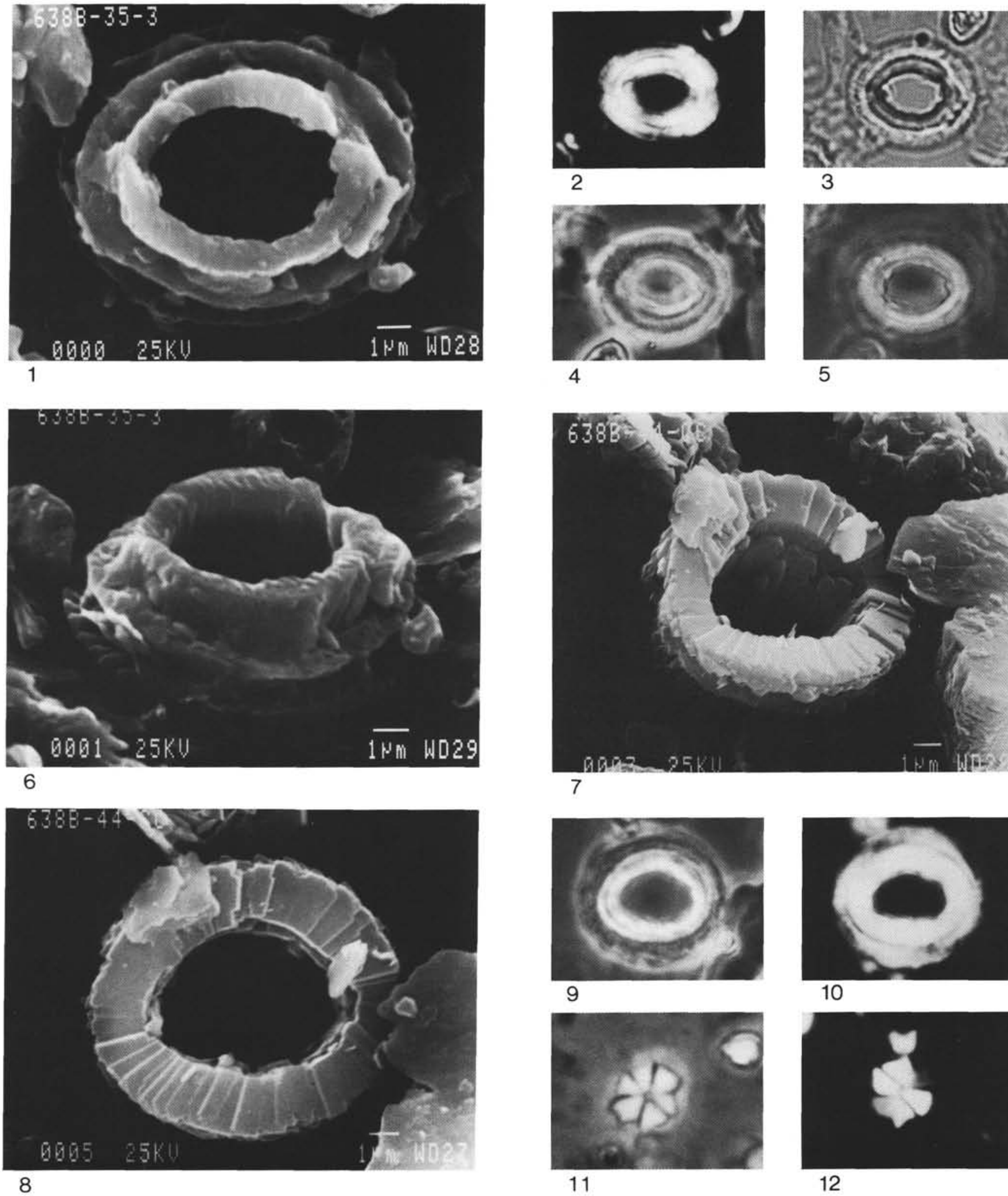

Plate 25. **1–10.** *Tubodiscus verenae* Thierstein, (1–6) Sample 103-638B-35R-3, 111–112 cm, (1) D, 5900×, (2–5)[s1] 2100×, (2, Pol; 3, Tr; 4, Ph low focus; 5, Ph, high focus), (6)[s1] oblique D, 6100× (7–10) Sample 103-638B-44R-1, 38–39 cm, (7)[s8] oblique P, 5000×, (8) P, 5100×, (9 and 10)[s8] 2300×, (9, Ph; 10, Pol). **11 and 12.** *Rucinolithus wisei* Thierstein, Sample 103-638B-45R-2, 79–80 cm, 4600×, (11, Ph: 12, Pol).

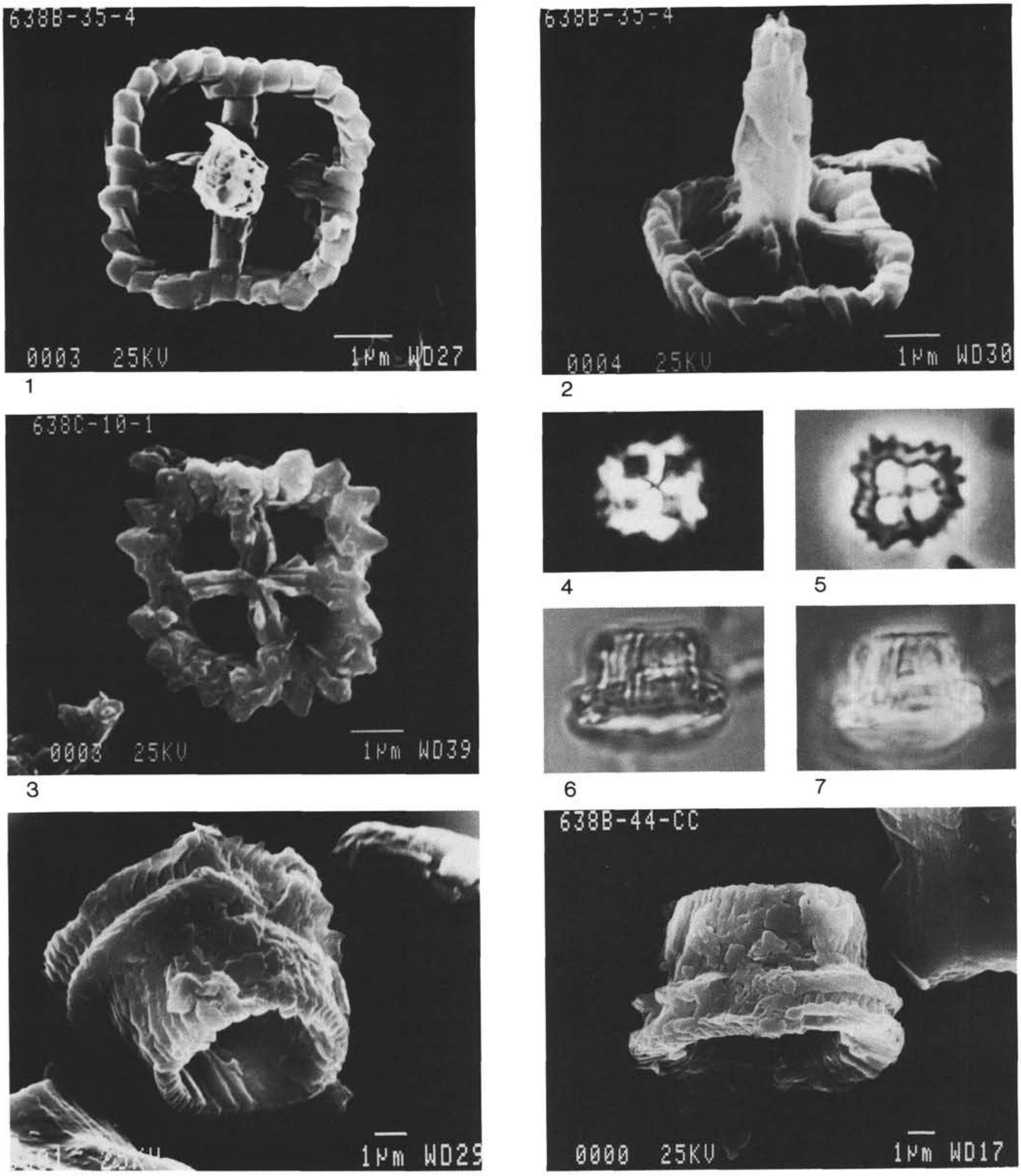

Plate 26. **1–5.** *Diadorhombus rectus* Worsley (1 and 2) Sample 103-638B-35R-4, 34–35 cm, (1) D, 10,000×, (2) oblique D, 9700×, (3–5) Sample 103-638C-10R-1, 35–36 cm, (3) D, 9000×, (4–5)[s3] 3600×, (4, Pol; 5, Ph). **6–9.** *Tubodiscus verenae* Thierstein, Sample 103-638B-44R, CC, (6 and 7)[s9] 2300×, (6, Tr; 7, Ph), (8) oblique P, 5500×, (9) L, 4800×.

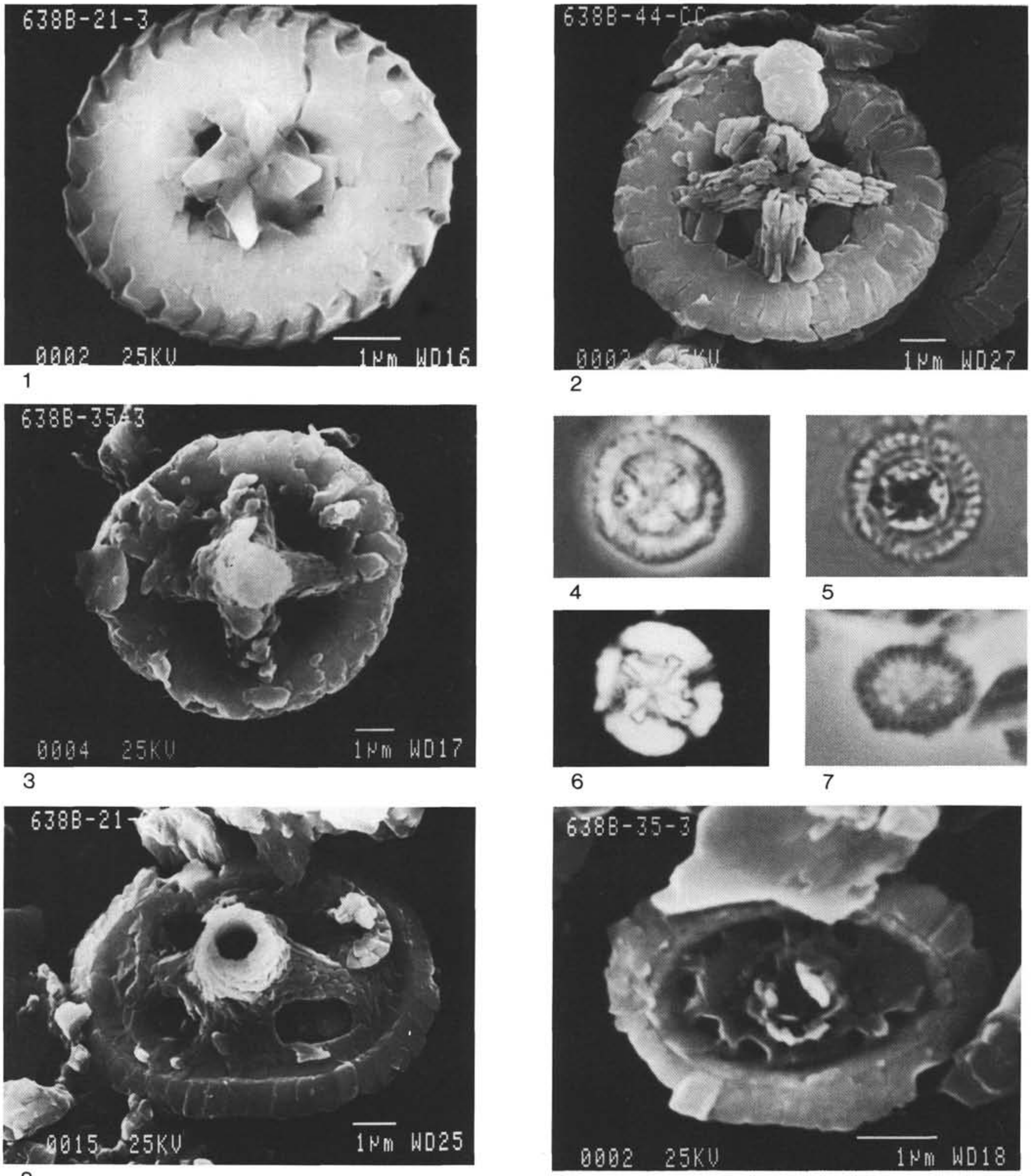

Plate 27. **1.** *Microstaurus chiastius* (Worsley, Sample 103-638B-21R-3, 60–62 cm, D, 11,800×. **2–6.** *Microstaurus conus* (Worsley), (2) Sample 103-638B-44R, CC, D, 8000×, (3–6) Sample 103-638B-35R-3, 111–112 cm (3) D, 6900×, (4–6)^{s3} 3300×, (4, Ph; 5, Tr; 6, Pol). **7 and 9.** *Perissocyclus noeliae* (Black), Sample 103-638B-35R-3, 111–112 cm, (7)^{s9} 4500×, Ph, (9) D, 14,000×. **8.** *Axopodorhabdus dietzmannii* (Reinhardt), Sample 103-638B-21R-2, 47–48 cm, D, 7300×.

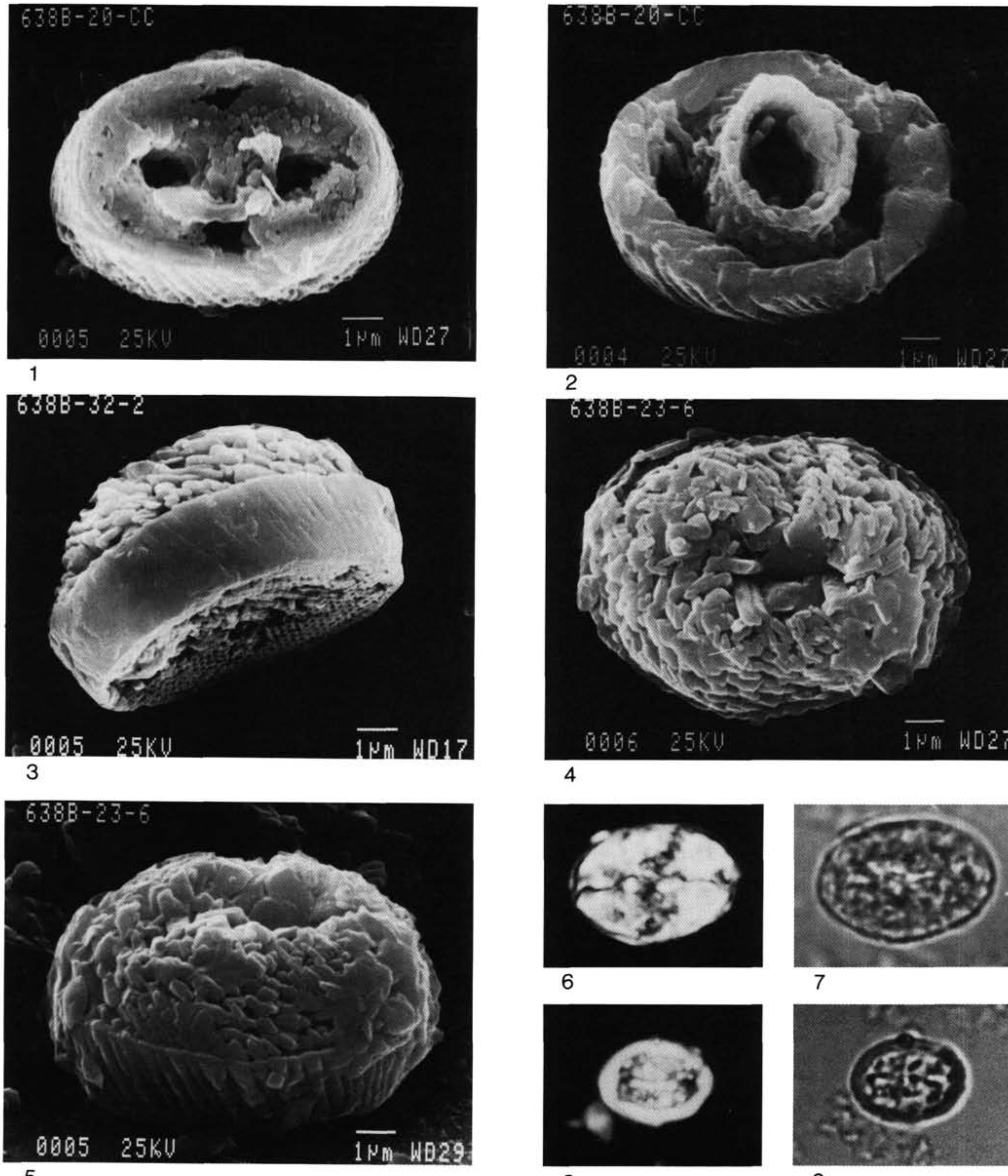

Plate 28. **1 and 2.** *Rhagodiscus infinitus* (Worsley), Sample 103-638B-20R, CC, 7000×, (1, P; 2, D). **3–7.** *Calcicalathina oblongata* (Worsley), (3) Sample 103-638B-32R-2, 8–9 cm. L, 7200×, (4–7) Sample 103-638B-23R-6, 58–59 cm, (4), D, 6900×, (5)[s4] oblique D, 7000×, (6 and 7)[s4] 3100×, (6, Pol; 7, Tr). **8 and 9.** *Rhagodiscus* cf. *infinitus* (Worsley), Sample 103-638B-10R-1, 35–36 cm, 2400×, (8, Pol; 9, Tr).

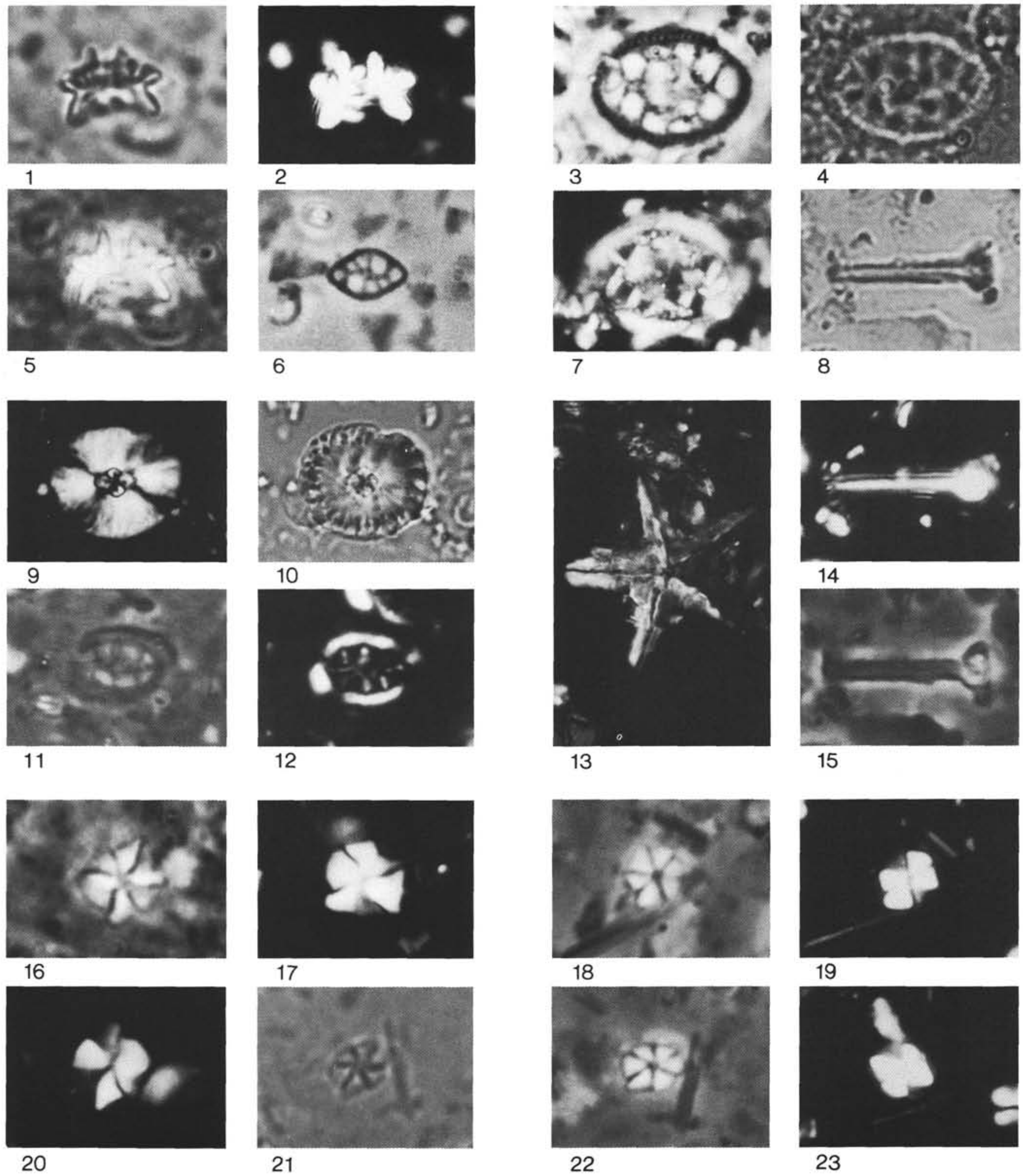

Plate 29. **1, 2, and 5.** *Darwinilithus pentarhethum* Watkins, Sample 103-641A-6, CC (29 cm), 3700×, (1, Tr; 2, Pol; 5, Ph). **3, 4, and 7.** *Octopodorhabdus plethotretus* Wind and Cepek, Sample 103-638B-24R-3, 11–12 cm, 2800×, (3, Ph; 4, Tr; 7, Pol). **6.** *Rhombolithion rhombicum* (Stradner and Adamiker), Sample 103-638B-27R-5, 54–55 cm, 3800×, Tr. **8, 14, and 15.** *Vekshinella pseudocarinolithus* Applegate and Bergen n. sp., Sample 103-638B-42R-2, 12–13 cm, 2700×, (8, Tr; 14, Pol; 15, Ph). **9 and 10.** *Cruciellipsis cuvillieri* ssp. *grandis* holotype, Applegate and Bergen n. ssp., Sample 103-638C-6R-1, 17–18 cm, 1800×, (9, Pol; 10, Tr). **11 and 12.** *Cretarhabdus* sp. Sample 103-638B-44R-2, 115–116 cm 4100×, (11, Tr; 12, Pol). **13.** *Micrantholithus* sp., Sample 103-638B-25R-4, 48–49 cm, 1400×, Pol. **16–20.** *Rucinolithus wisei* Thierstein, Sample 103-638B-44R-3, 9–10 cm, (16, 17, and 20) 4400×, (16, Ph; 19^{s18}, Pol). **21–23.** *Rucinolithus* cf. *wisei* Thierstein, Sample 103-638B-45R-3, 28–29 cm, 4500×, (21, Tr; 22, Ph; 23, Pol).