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Late Ordovician Palynomorphs

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ACRITARCHS

Ordovician acritarchs have been recorded in five core samples collected between 2520 ft. and 3000 ft. in Well E1-81, and ten cutting samples taken between 12150 ft. and 13240 ft. in Well J1-81A. All the assemblages recovered are of Late Ordovician age; no Early Ordovician or Middle Ordovician assemblages have been identified.

Investigations have so far concentrated on the acritarch assemblages from Well E1-81. The highest three Ordovician samples from depths of 2520 to 2550 ft., 2552 to 2557 ft., and 2562 to 2567 ft., yielded similar assemblages which include *Veryhachium irroratum*, *V.* cf. *lairdii*, *V. oklahomense?*, *V. subglobosum*, *V. trispinosum*, *Villosacapsula setosapellicula* and a new species, *Striatotheca* sp. A. *Navifusa similis?* is represented by one specimen in the sample from 2552 to 2557 ft. Another specimen from the same sample is tentatively referred to *Aremoricanium syringosagis*. Specimens of *Baltisphaeridium*, *Peteinosphaeridium*, *Leiofusa* and *Eupoikilofusa* occur throughout the interval 2520 to 2567 ft. but are rare. Commonly occurring species include *V. irroratum* and *V. setosapellicula*. *V. irroratum* has been recorded from the Middle Ordovician of North America (Loeblich & Tappan, 1969) and the Caradoc of England (Turner, 1984) but Cramer & Diez (1979) maintain that it has its acme in the Ashgill. *V. setosapellicula* is common in the Sylvan Shale of Oklahoma (Loeblich, 1970) which is generally understood to be of Ashgill age, but is rare in the Eden Shale (Caradoc) of Indiana (Colbath, 1979) and in the type section of the Caradoc Series in Shropshire, England (Turner, 1984). The common occurence of these two species could be taken to indicate an Ashgill age for the interval between 2520 and 2567 ft., an age which is consistent with the chitinozoan evidence for the age of samples from 2572 ft., and 2558 to 2574 ft. (see below).

A major change in the composition of the acritarch assemblages takes place between 2567 ft. and 2790 ft. in Well E1-81. A number of the species that are recorded above this interval also occur in samples from 2790 to 2840 ft. and 2970 to 3000 ft. These include *V. irroratum*, *V.* cf. *lairdii*, *V. oklahomense?*, *V. subglobosum*, *V. trispinosum* and *V. setosapellicula*. *Striatotheca* sp. A, however, is absent below 2790 ft., *V. irroratum* and *V. setosapellicula* are less common, and *Veryhachium* cf. *reductum* is present. Other species present below 2790 ft., include *Actinotodissus* cf. *crassus*, *Baltisphaeridium longispinosum delicatum*, *?Baltisphaerosum bystrentos*, *B. christoferii*, *Dactylofusa spinata?*, *Goniosphaeridium* cf. *conjunctum*, *Ordovicidium heteromorphicum?*, *Orthosphaeridium* cf. *chondrododora* and *Peteinosphaeridium nudum*. Several of these species occur in the type Caradoc Series in England (Turner, 1984), in the Eden Shale (Caradoc) of North America (Loeblich & Tappan, 1978; Colbath, 1979) and in the Viruan (Middle Ordovician) of Sweden (Kjellstrom, 1971). They suggest a Caradoc, possibly late Caradoc, age for the sediments between 2790 ft. and 3000 ft.

CHITINOZOANS

Recent work on Late Ordovician chitinozoan assemblages from Anticosti Island (Canada), the Baltoscandian area and the Anti-Atlas region of Morocco has added substantially to the body of available data on the distribution of Ordovician chitinozoans, enabling relatively precise age determinations to be proposed for the assemblages recovered in the present study.

Neither Early Ordovician nor Middle Ordovician assemblages have been identified in the material so far investigated. Two wells, E1-81 (core samples from depths 2558 to 2574 ft. and 2572 ft.) and J1-81A (eleven cutting samples ranging from depth 12150 to 13337 ft., the deepest of which from 13240 to 13337 ft., being barren) have yielded Ashgill assemblages. The main species recorded are: *C. (Calpichitina) lenticularis*, *Armoricochitina nigerica*, *Plectochitina sylvanica*, *Tanuchitina bergstroemi* and *Ancyrochitina merga* (or closely related forms). *Armoricochitina nigerica* is the most abundant species in the assemblages from Well E1-81, which are less diverse in composition than the assemblages from Well J1-81A. In the latter well, the above mentioned taxa are accompanied by numerous other species including *Belonechitina micracantha typica*, *Cyathochitina latipatagium*, *D. (Pseudodesmochitina) minor* f. *typica*, *Spinachitina bulmani*, *Conochitina elegans*, *Belonechitina capitata* and a new species called here *Spinachitina* sp. A. In addition, two other taxa that are present, *Acanthochitina barbata* and *Lagenochitina baltica* have wide geographical distri-

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butions but ranges which are restricted to the Onnian-Pusgillian-Early Cautleyan (Jenkins, 1967; Laufeld, 1967; Achab, 1977 a, b, 1978 a, b; Nolvak, 1980; Grahn, 1982). The Late Ordovician Chitinozoan assemblages from Well J1-81A display strong affinities with those described in the Upper Ktaoua Formation (Morocco) which is referred to the Pusgillian-Cautleyan (Elaouad-Debbaj, 1984), and with those from the middle part of the Vauréal Formation referred to the Pusgillian (Achab, 1977a). However, the apparent absence of the genus *Hercochitina* from the Libyan material should be noted. The samples from Well J1-81A, especially the youngest, are of Early Ashgill age.

The Ordovician Chitinozoan assemblages from Well E1-81 are very close to those described by Bouché (1965) from the Kourneida Well (Djado, Niger) which also appear to be of Ashgill age. A more precise stratigraphical assignment is difficult because of the lack of good stratigraphical control on the Djado material.

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Explanation of Plate 1

Fig. 1. *Actinotodissus* cf. *crassus* Loeblich & Tappan, 1978. E1-81, 2790–2840 ft., Slide 1, E40/3, × 400, AGC 1.

Fig. 2. *A.* cf. *crassus* Loeblich & Tappan, 1978. E1-81, 2790–2840 ft., Slide 1, V38/2, × 400, AGC 2.

Fig. 3. *Goniosphaeridium* cf. *conjunctum* Kjellstrom, 1971. E1-81, 2790–2840 ft., Slide 1, P42/0, × 400, AGC 3.

Fig. 4. *G.* cf. *conjunctum* Kjellstrom, 1971. E1-81, 2790–2840, Slide 1, S33/2, × 400, AGC 4.

Fig. 5. *Leiofusa* sp. E1-81, 2562–2567 ft., Slide 1, R45/0, × 160, AGC 5.

Fig. 6. *Dactylofusa spinata*? (Staplin, Jansonius & Pocock) Combaz, Lange & Pansart, 1967. E1-81, 2790–2840 ft., Slide 1, C41/4, × 400, AGC 6.

Fig. 7. *Eupoikilofusa striata*? (Staplin, Jansonius & Pocock) Eisenack, Cramer & Diez, 1976. E1-81, 2562–2567 ft., Slide 1, Q44/3, × 400, AGC 7.

Fig. 8. *Peteinosphaeridium nudum* (Eisenack) Eisenack, 1969. E1-81, 2790–2840 ft., Slide 1, R32/0, × 400, AGC 8.

Fig. 9. *D. spinata*? (Staplin, Jansonius & Pocock) Combaz, Lange & Pansart, 1967. E1-81, 2790–2840 ft., Slide 1, V37/0, × 400, AGC 9.

Fig. 10. *P. nudum* (Eisenack) Eisenack, 1969. E1-81, 2790–2840 ft., Slide 1, C33/1, × 400, AGC 10.

Fig. 11. *Ordovicidium heteromorphicum*? (Kjellstrom) Turner, 1984. E1-81, 2790–2840 ft., Slide 1, K37/0, × 400, AGC 11.

Fig. 12. *D. spinata*? (Staplin, Jansonius & Pocock) Combaz, Lange & Pansart, 1967. E1-81, 2790–2840 ft., Slide 1, V37/0, × 1000, AGC 9.

Fig. 13. *O. heteromorphicum*? (Kjellstrom) Turner, 1984. E1-81, 2790–2840 ft., Slide 1, F44/1, × 400, AGC 12.

Fig. 14. *Baltisphaerosum christoferii* (Kjellstrom) Turner, 1984. E1-81, 2790–2840 ft., Slide 1, P46/0, × 400, AGC 13.

Fig. 15. *A.* cf. *crassus* Loeblich & Tappan, 1978. E1-81, 2790–2840 ft., Slide 1, E40/3, × 1000, AGC 1.

Fig. 16. *B. christoferii* (Kjellstrom) Turner, 1984. E1-81, 2790–2840 ft., Slide 1, N37/0, × 400, AGC 14.

Fig. 17. *B. christoferii* (Kjellstrom) Turner, 1984. E1-81, 2790–2840 ft., Slide 1, U37/3, × 400, AGC 15.

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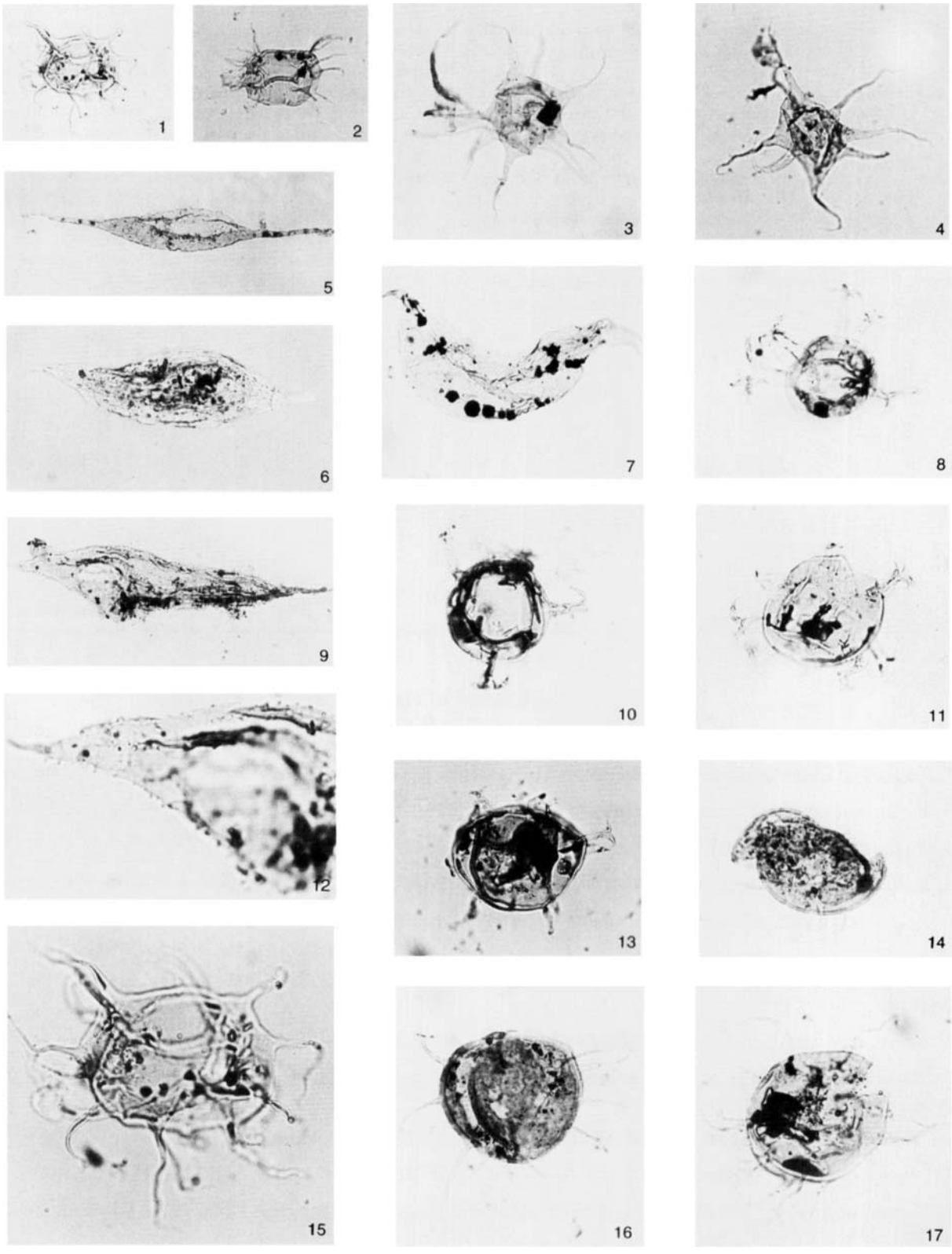
Late Ordovician Acritarchs

Plate 1



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Explanation of Plate 2

Fig. 1. *Leiofusa* sp. E1-81, 2520–2550 ft., Slide 1, M30/1, × 400, AGC 16.

Fig. 2. *Baltisphaeridium longispinosum delicatum* Turner, 1984. E1-81, 2562–2567 ft., Slide 1, N44/3, × 400, AGC 17.

Fig. 3. *B. longispinosum delicatum* Turner, 1984. E1-81, 2790–2840 ft., Slide 1, H50/1, × 400, AGC 18.

Fig. 4. *Baltisphaeridium* sp. E1-81, 2562–2567 ft., Slide 1, D40/0, × 400, AGC 19.

Fig. 5. *B. longispinosum delicatum* Turner, 1984. E1-81, 2562–2567 ft., Slide 1, G34/3, × 400, AGC 20.

Fig. 6. *Aremoricanium syringosagis*? Loeblich & MacAdam, 1971. E1-81, 2552–2557 ft., Slide 1, J46/4, × 400, AGC 21.

Fig. 7. *Orthosphaeridium* cf. *chondrododora* Loeblich & Tappan, 1971. E1-81, 2790–2840 ft., Slide 1, T42/2, × 400, AGC 22.

Fig. 8. *Baltisphaerosum*? sp. E1-81, 2790–2840 ft., Slide 1, M31/4, × 400, AGC 23.

Fig. 9. ?*Baltisphaerosum bystrentos* (Loeblich & Tappan) Turner, 1984. E1-81, 2790–2840 ft., Slide 1, Q44/0, × 400, AGC 24.

Fig. 10. *Baltisphaerosum*? sp. E1-81, 2790–2840 ft., Slide 1, M31/4, × 1000, AGC 23.

Fig. 11. *Navifusa similis*? (Eisenack) Turner, 1984. E1-81, 2552–2557 ft., Slide 1, B32/0, × 1000, AGC 25.

Fig. 12. *Eupoikilofusa striata* ? (Staplin, Jansonius & Pocock) Eisenack, Cramer & Diez, 1976. E1-81, 2552–2557 ft., Slide 1, D41/0, × 400, AGC 26.

Fig. 13. *Leiofusa* sp. E1-81, 2552–2557 ft., Slide 1, C30/0, × 160, AGC 27.

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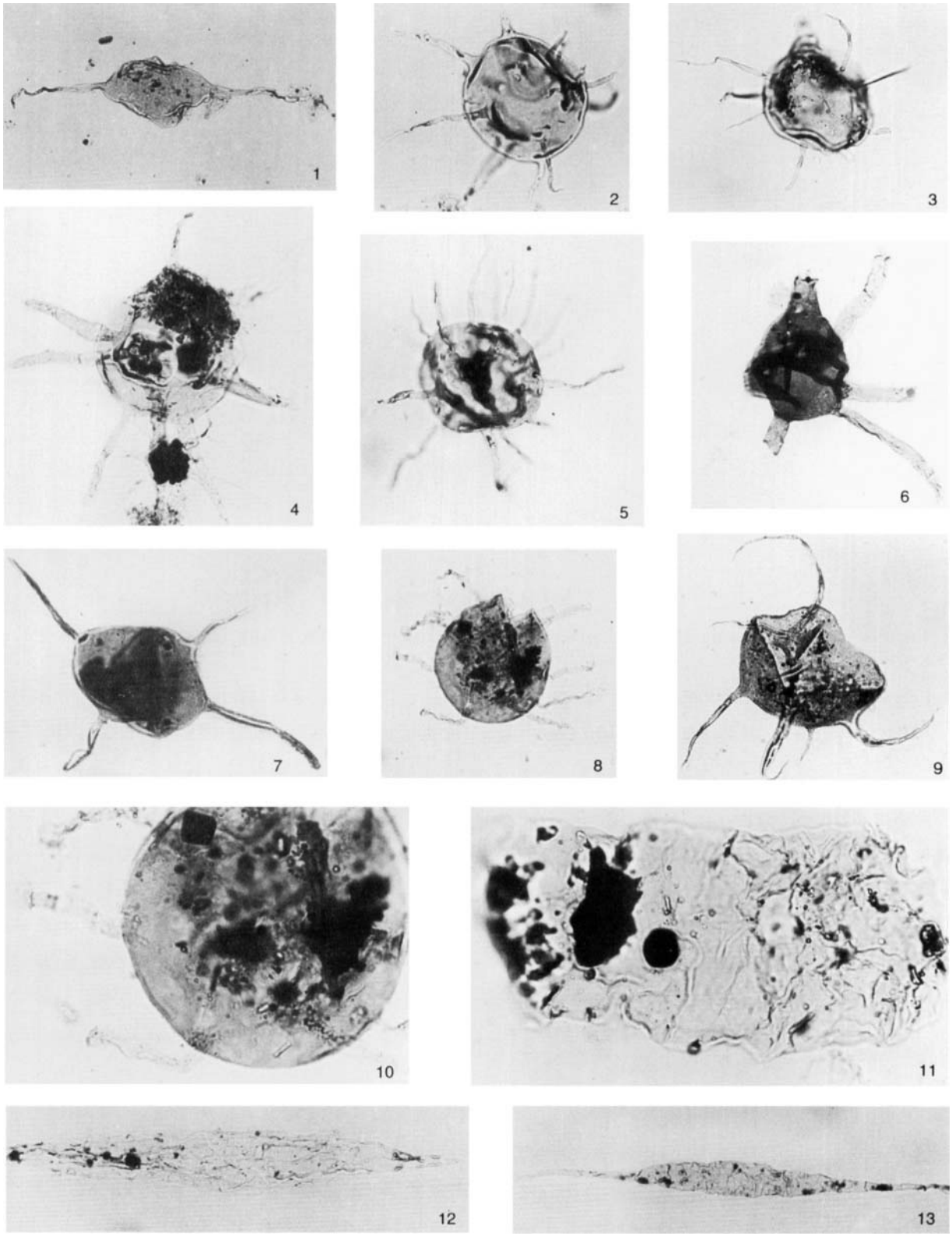
Plate 2



Explanation of Plate 3

Fig. 1. *Veryhachium trispinosum* (Eisenack) Deunff 1954 ex Downie, 1959. E1-81, 2520–2550 ft., Slide 1, U35/0, × 400, AGC 28.

Fig. 2. *Veryhachium irroratum* Loeblich & Tappan, 1969. E1-81, 2552–2557 ft., Slide 1, P31/2, × 400, AGC 29.

Fig. 3. *Villosacapsula setosapellicula* (Loeblich) Leoblich & Tappan, 1976. E1-81, 2520–2550 ft., Slide 1, U38/0, × 400, AGC 30.

Fig. 4. *Veryhachium subglobosum* Jardiné, Combaz, Peniguel & Vachey, 1974. E1-81, 2790–2840 ft., Slide 1, U33/2, × 400 AGC 31.

Fig. 5. *V. subglobosum* Jardiné *et al.*, 1974. E1-81, 2790–2840 ft., Slide 1, D33/0, × 400, AGC 32.

Fig. 6. *V. subglobosum* Jardiné *et al.*, 1974. E1-81, 2790–2840 ft., Slide 1, M39/2, × 400, AGC 33.

Fig. 7. *Veryhachium* cf. *reductum* (Deunff) Jekhowsky, 1961. E1-81, 2790–2840 ft., Slide 1, V43/3, × 400, AGC 34.

Fig. 8. *V.* cf. *reductum* (Deunff) Jekhowsky, 1961. E1-81, 2790–2840 ft., Slide 1, V43/3, × 1000, AGC 34.

Fig. 9. *V.* cf. *reductum* (Deunff) Jekhowsky, 1961. E1-81, 2790–2840 ft., Slide 1, H42/0, × 1000, AGC 35.

Fig. 10. *V.* cf. *reductum* (Deunff) Jekhowsky, 1961. E1-81, 2790–2840 ft., Slide 1, H42/0, × 1000, phase contrast, AGC 35.

Fig. 11. *V. setosapellicula* (Loeblich) Loeblich & Tappan, 1976. E1-81, 2552–2557 ft., Slide 1, F40/4, × 1000, AGC 36.

Fig. 12. *V. irroratum* Loeblich & Tappan, 1969. E1-81, 2552–2557 ft., Slide 1, P31/2, × 1000, AGC 29.

Fig. 13. *V. irroratum* Loeblich & Tappan, 1969. E1-81, 2552–2557 ft., Slide 1, T46/4, × 1000, AGC 37.

Fig. 14. *V. setosapellicula* (Loeblich) Loeblich & Tappan, 1976. E1-81, 2552–2557 ft., Slide 1, F40/4, × 1000, phase contrast, AGC 36.

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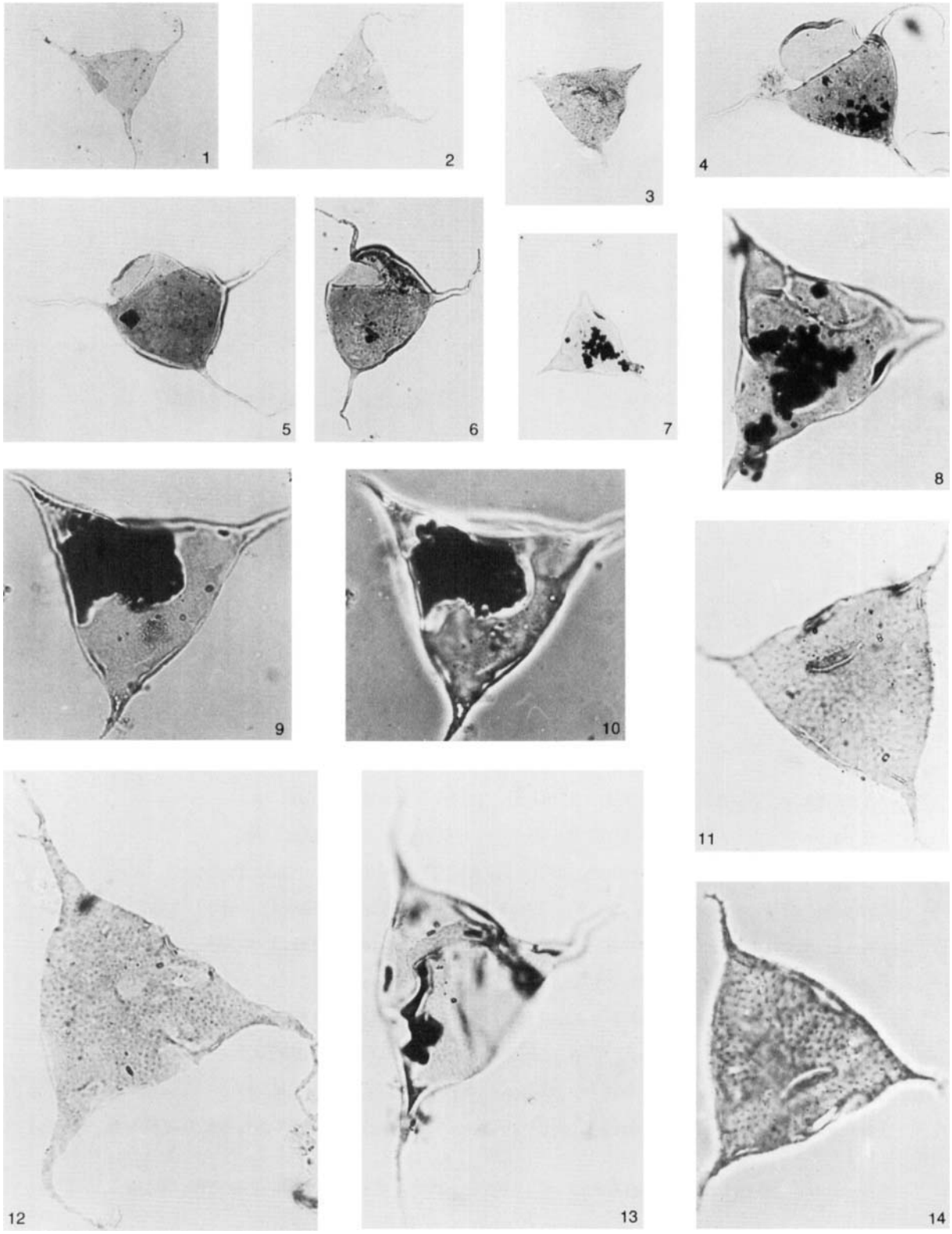
Plate 3



Explanation of Plate 4

Fig. 1. *Striatotheca* sp. A. E1-81, 2562–2567 ft., Slide 1, 035/3, × 400, AGC 38.

Fig. 2. *Striatotheca* sp. A. E1-81, 2552–2557 ft., Slide 1, U33/0, × 400, AGC 39.

Fig. 3. *Veryhachium oklahomense* ? Loeblich, 1970. E1-81, 2790–2840 ft., Slide 1, R45/3, × 400, AGC 40.

Fig. 4. *V. oklahomense*? Loeblich, 1970. E1-81, 2790–2840 ft., Slide 1, H39/4, × 400, AGC 41.

Fig. 5. *V. oklahomense*? Loeblich, 1970. E1-81, 2552–2557 ft., Slide 1, U38/3, × 400, AGC 42.

Fig. 6. *V. oklahomense*? Loeblich, 1970. E1-81, 2552–2557 ft., Slide 1, U38/3, × 1000, AGC 42.

Fig. 7. *V. oklahomense*? Loeblich, 1970. E1-81, 2790–2840 ft., Slide 1, H39/4, × 1000, AGC 41.

Fig. 8. *Striatotheca* sp. A. E1-81, 2552–2557 ft., Slide 1, T39/4, × 1000, AGC 43.

Fig. 9. *Striatotheca* sp. A. E1-81, 2552–2557 ft., Slide 1, U33/0, × 1000, AGC 39.

Fig. 10. *Veryhachium* cf. *lairdii* (Deflandre) Deunff 1959 ex Downie, 1959. E1-81, 2520–2550 ft., Slide 1, U35/0, × 1000, AGC 44.

Fig. 11. *V.* cf. *lairdii* (Deflandre) Deunff 1959 ex Downie, 1959. E1-81, 2790–2840 ft., Slide 1, V37/4, × 1000, AGC 45.

Fig. 12. *Striatotheca* sp. A. E1-81, 2562–2567 ft., Slide 1, 035/3, × 1000, AGC 38.

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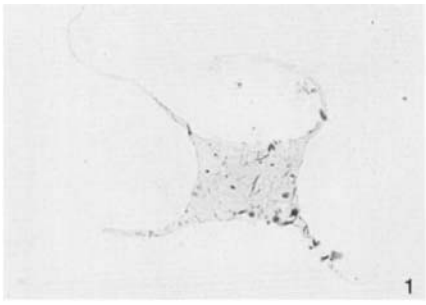
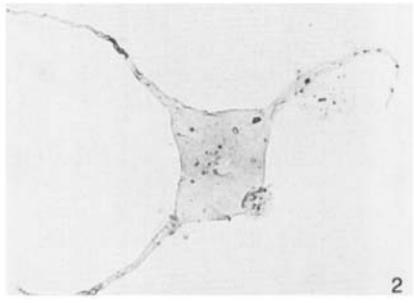
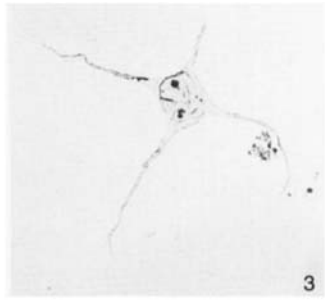
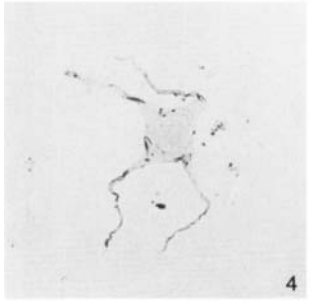
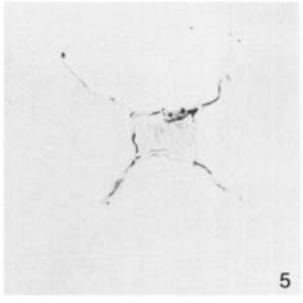
Plate 4

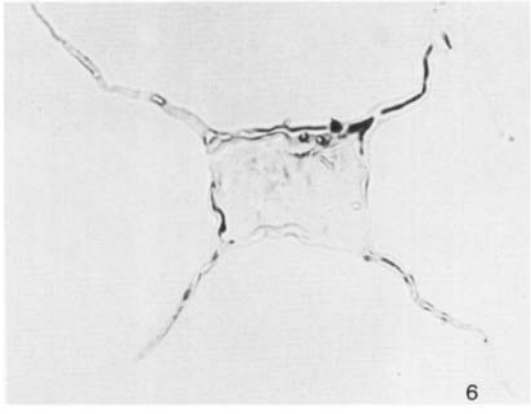


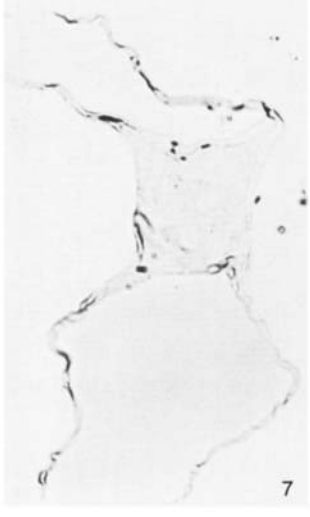


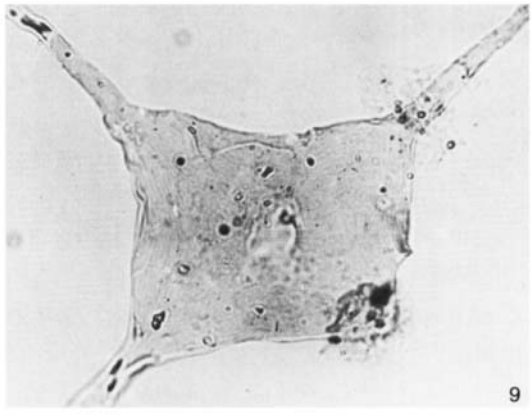


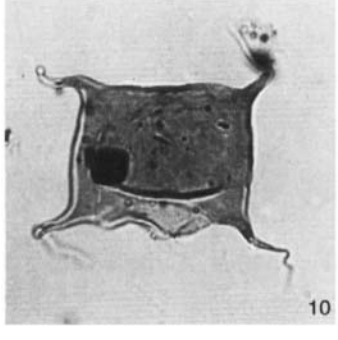


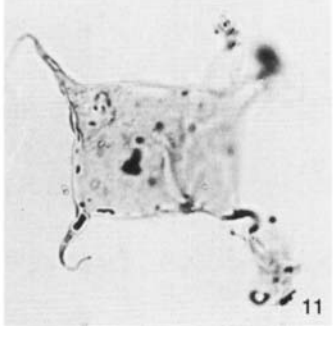


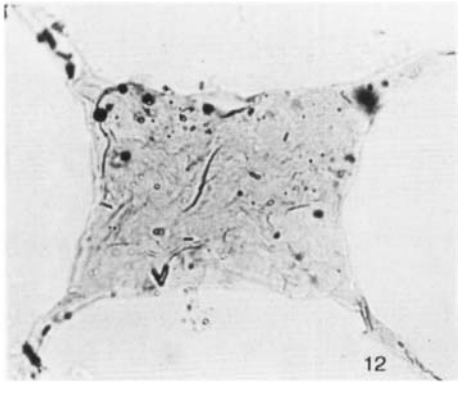












Explanation of Plate 5

Fig. 1 a–b. *Spinachitina bulmani* (Jansonius, 1964). J1-81 A, 12800–12850 ft., Slide 2, 035, 1a : × 250 ; 1b : × 1250, AGC 46 (Caradoc–Ashgill).

Fig. 2. *Plectochitina sylvanica* (Jenkins, 1970). J1-81 A, 12950–13000 ft., Slide 1, 035/4, × 400, AGC 47. (Early Ashgill).

Fig. 3. *Ancyrochitina* cf. *merga* Jenkins, 1970. J1-81A, 12950–13000 ft., Slide 1, P38/4, × 300, AGC 48. (Early Ashgill for *A. merga*).

Fig. 4. *Plectochitina sylvanica* (Jenkins, 1970). J1-81 A, 12800–12850 ft., Slide 2, M35, × 300, AGC 49. (Early Ashgill).

Fig. 5. *Plectochitina sylvanica* ? (Jenkins, 1970). J1-81 A, 12800–12850 ft., Slide 2, P35, × 300, AGC 50. (Early Ashgill).

Fig. 6. *Plectochitina sylvanica* (Jenkins, 1970). J1-81 A, 12950–13000 ft., Slide 1, N38, × 400, AGC 51. (Early Ashgill).

Fig. 7. *Tanuchitina bergstroemi* Laufeld, 1967. J1-81 A, 12950–13000 ft., Slide 1, 039/4, × 150, AGC 52. (Latest Caradoc–Ashgill).

Fig. 8. *Plectochitina spongiosa* (Achab, 1977b). J1-81 A, 12950–13000 ft., Slide 1, 036/3, × 300, AGC 53. (Ashgill Early Llandovery ?).

Fig. 9. *Plectochitina spongiosa* (Achab, 1977b). J1-81 A, 12950–13000 ft., Slide 1, P41/2, × 300, AGC 54. (Ashgill – Early Llandovery ?).

Fig. 10. *Belonechitina micracantha typica* (Eisenack, 1965). J1-81 A, 12950–13000 ft., Slide 1, N37, × 300, AGC 55. (Late Arenig – Ashgill).

Fig. 11 a–b. *Belonechitina micracantha typica* (Eisenack, 1965). J1-81 A, 12950–13000 ft., Slide 1, P37/2, 11a : × 200 ; 11b : × 1000, AGC 56. (Late Arenig–Ashgill).

Fig. 12 a–b. *Spinachitina* sp. A. J1-81 A, 12950–13000 ft., Slide 1, P41/3, 12 a : × 300 ; 12 b : × 1000, AGC 57.

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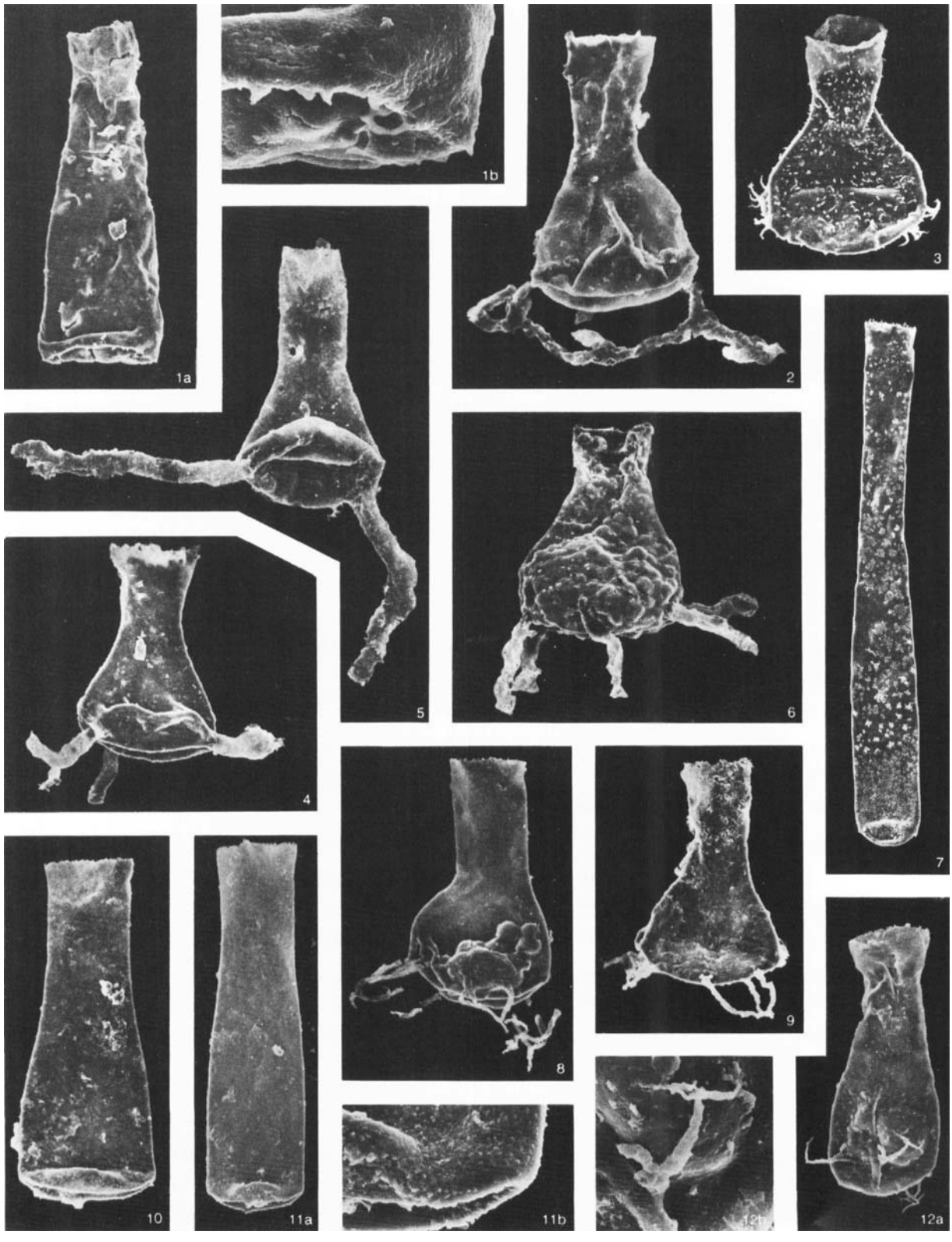
Plate 5



Explanation of Plate 6

Fig. 1 a,b. *Acanthochitina barbata* Eisenack, 1931. J1-81 A, 12150–12360 ft., Slide 3, R46/1, 1a : × 150 ; 1b : × 500, AGC 58. (Latest Caradoc – Early Ashgill).

Fig. 2. *Spinachitina* sp. A. J1-81 A, 12150–12360 ft., Slide 3, U44/1, × 300, AGC 59.

Fig. 3. *Belonechitina capitata* (Eisenack, 1962). J1-81 A, 12150–12360 ft., Slide 3, W43, × 150, AGC 60. (Late Llanvirn – Early Ashgill).

Fig. 4. *Belonechitina* sp. aff. *schopfi* (Taugourdeau, 1965). J1-81 A, 12150–12360 ft., Slide 3, V45/4, × 250, AGC 61.

Fig. 5. ? *Plectochitina* sp. J1-81 A, 12150–12360 ft. Slide 3, U45/1, × 300, AGC 62.

Fig. 6 a,b. *Calpichitina (Calpichitina) lenticularis* (Bouché, 1965). J1-81 A, 12150–12360 ft., Slide 3, T46/1, 6a : × 300 ; 6b : × 1250, AGC 63. ("Middle" Caradoc – Ashgill).

Fig. 7. *Tanuchitina anticostiensis* (Achab, 1977a). E1-81, 2572 ft., Slide 5, P36, × 400, AGC 64. (Ashgill).

Fig. 8. *Desmochitina (Pseudodesmochitina) minor* forma *typica* Eisenack, 1958. J1-81 A, 12150–12360 ft., Slide 3, R45/4, × 300, AGC 65. (Llanvirn – Ashgill).

Fig. 9 *Armoricochitina nigerica* (Bouché, 1965). E1-81, 2572 ft., Slide 5, 036, × 200, AGC 66. (Late Caradoc – Ashgill).

Fig. 10. Enlargement of the granulose ornamentation of *Armoricochitina nigerica* (Bouché, 1965) represented pl. 7, fig. 1. E1-81, 2252– 2574 ft., Slide 4, J/39, × 1000, AGC 69.

Fig. 11. *C. (Calpichitina) lenticularis* (Bouché, 1965). Aboral view, J1-81 A, 12150–12360 ft., Slide 3, S46/2, × 300, AGC 67. ("Middle" Caradoc – Ashgill).

Fig. 12. *Ancyrochitina* cf. *merga* Jenkins, 1970. J1-81 A, 12800–12850 ft., Slide 2, 039/2, × 300, AGC 68. (*A. merga* is reported in the Ashgill).

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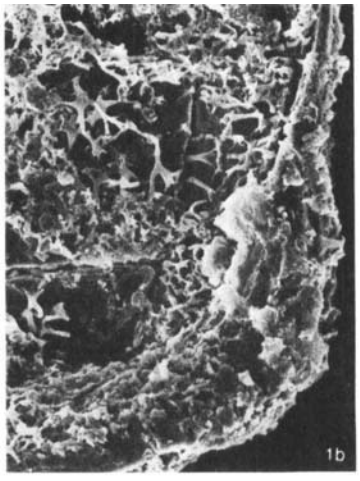
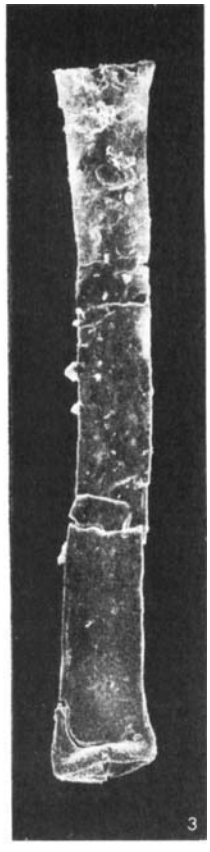
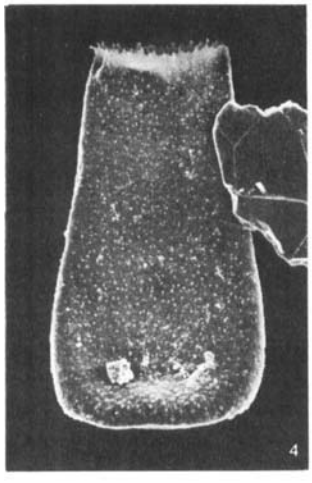
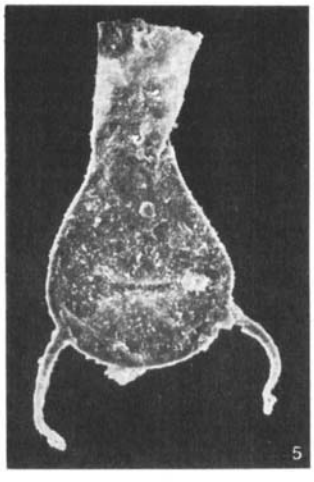
Ashgill Chitinozoans

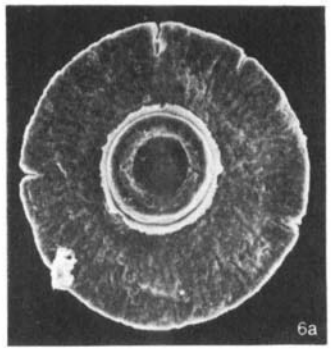
Plate 6

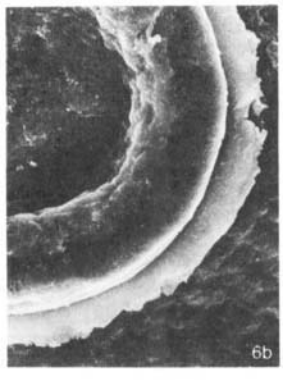


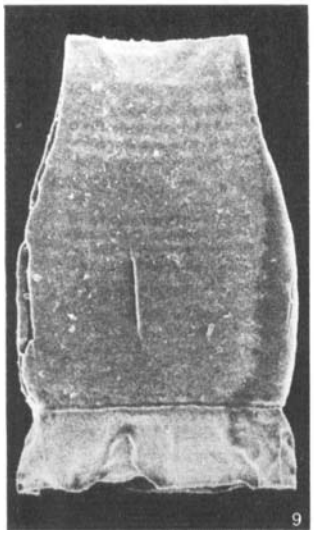


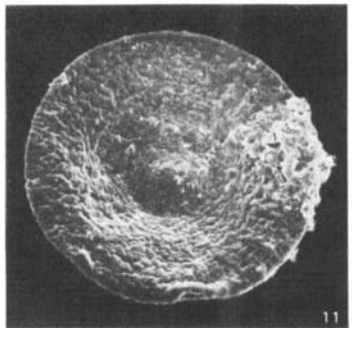


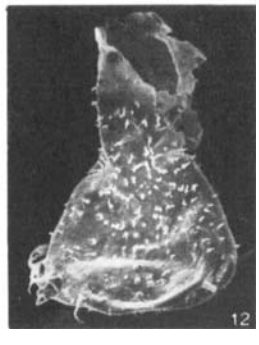












Explanation of Plate 7

Fig. 1. *Armoricochitina nigerica* (Bouché, 1965). E1-81, 2552–2574 ft., Slide 4, J39, × 250, AGC 69. (Late Caradoc – Ashgill).

Fig. 2 a,b. *Armoricochitina nigerica* (Bouché, 1965). E1-81, 2552–2574 ft., Slide 4, J37/4, 2 a : × 300; 2b : × 750, AGC 70. (Late Caradoc – Ashgill).

Fig. 3. *Armoricochitina nigerica* (Bouché, 1965). E1-81, 2252–2574 ft., Slide 4, M40, × 1250; details of the carina ; see the granulose ornamentation, AGC 71. (Late Caradoc – Ashgill).

Fig. 4. *Lagenochitina baltica* Eisenack, 1931. E1-81, 2572 ft., Slide 5, S37, × 300, AGC 72. (Late Caradoc – Early Ashgill).

Fig. 5. *Ancyrochitina onniensis* Jenkins, 1967. E1-81, 2552–2574 ft., Slide 4, P39, × 400, AGC 73. (Latest Caradoc (Onnian) – Ashgill).

Fig. 6 a,b. *Tanuchitina bergstroemi* Laufeld, 1967. E1-81, 2572 ft., Slide 5, S40/3, 6a : × 150 ; 6b : × 750, AGC 74. (Latest Caradoc – Ashgill).

Fig. 7. *Belonechitina micracantha* (Eisenack, 1931). E1-81, 2572 ft., Slide 5, 035/1, × 200, AGC 75. (Ordovician).

Fig. 8 a,b. *Belonechitina* sp. A. E1-81, 2572 ft., Slide 5, R36, 8a : × 250 ; 8b : × 1000, AGC 76.

Fig. 9. a,b. *Spinachitina suecica* (Laufeld, 1967). E1-81, 2572 ft., Slide 5, 035, 9a : × 400 ; 9b : × 1000, AGC 77. (Caradoc).

Fig. 10. *Calpichitina (Calpichitina) lenticularis* (Bouché, 1965). E1-81, 2572 ft., Slide 5, N38/1, × 300, AGC 78. ("Middle" Caradoc – Ashgill).

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Plate 7

Late Caradoc – Ashgill Chitinozoans