

## Significance of Early Carboniferous Radiolaria from Langkap, Negeri Sembilan, Malaysia

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**Abstract:** A thinly bedded mudstone in the Langkap chert yielded a high diversity of radiolarian faunas. A total of 34 radiolarian taxa were identified. The presence of *Albaillella cornuta*, *Albaillella deflandrei* and *Albaillella undulata* indicates the *Albaillella deflandrei* Zone of late Tournaisian, Early Carboniferous. The radiolarian assemblage is very similar to those of Tournaisian of Germany and France. The similarity suggests that the radiolarian faunas occupied a similar biogeographic province in the equatorial regions of the Tethys.

### INTRODUCTION

The radiolarian chert at Langkap has been studied by Spiller and Metcalfe (1995a, 1995b). They have identified several radiolarian faunas indicating an age of Famennian, Late Devonian and Tournaisian, Early Carboniferous. Recently, we made a detailed observation of the outcrop of the chert sequence and we collected 25 samples. Only one sample (sample 22) yielded a very high specific diversity of well-preserved radiolarian faunas. The other samples are crystallised and yielded very poorly-preserved radiolarian specimens. This assemblage is slightly different in composition from those described by Spiller and Metcalfe (1995a, 1995b). The aim of the paper is to discuss the significance of younger radiolarian assemblage which represents the *Albaillella deflandrei* Zone.

### GEOLOGICAL SETTING

The study area is composed mainly of Paleozoic rocks. The metamorphic rocks belong to the Bentong Group (Khoo, 1975). The oldest rock unit is the Pilah Schist which is older than Early Silurian, probably Ordovician (Foo, 1983). The Pilah Schist consists mainly of quartz mica schist, graphitic schist, metaquartzite and phyllite with minor serpentinite and chert bodies. The serpentinite bodies are found as isolated outcrops and they are not associated with the chert bodies (Fig. 1). The serpentinite has been considered as an ophiolite (Hutchison, 1989; Tjia, 1989) represents an extension the Bentong-Raub suture zone. The schist

is unconformably overlain by the Lower Permian Kepis Formation (Khoo, 1975). The bedded chert sequence near Langkap was previously included in the Pilah Schist. Discovery of Late Devonian to Early Carboniferous radiolarian proved that the chert is a different formation. In this paper, the chert is informally called the Langkap chert. The rocks in the area were intruded by granite during the Late Triassic.

The Langkap chert consists of thinly bedded chert interbeds with mudstone. The chert forms a NE-SW trending strike-ridge and the total thickness is estimated about 105 m. It is underlain by the Pilah Schist. The contact between the two formations is not exposed. The chert is overlain by the Kepis Formation.

### DESCRIPTION OF THE OUTCROP

The Langkap chert is well-exposed at a roadcut near Kampung Langkap (02°38'N, 102°21'E). A total of 105 m thick chert sequence was measured. The chert strikes 60° and dips 50°. The chert is faulted and sheared. There are five shear-zones observed at the outcrop. The colour of the chert varies from black to dark grey. The bottom part of the section comprises the chert interbeds with thinly bedded siltstone which has thickness ranges from 4–10 cm. The beds are folded due to slumping. The upper part exhibits 1–2 cm thick parallel bedding with slightly variation in grain size from silt to clay (Fig. 2).

Most of the chert are crystallised and the Radiolaria are damaged. At the top of the sequence, approximately 2 cm thick thinly black laminated

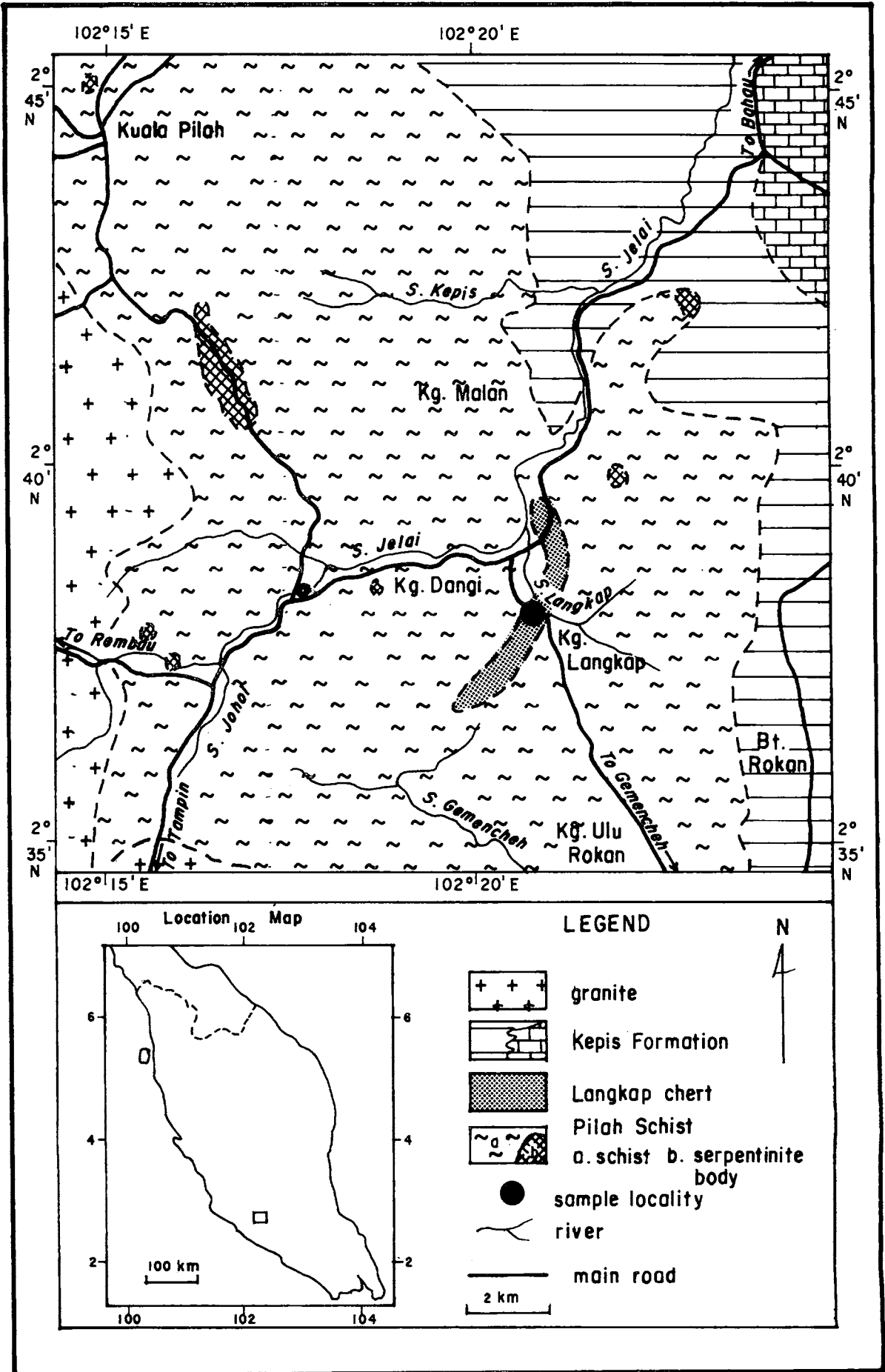
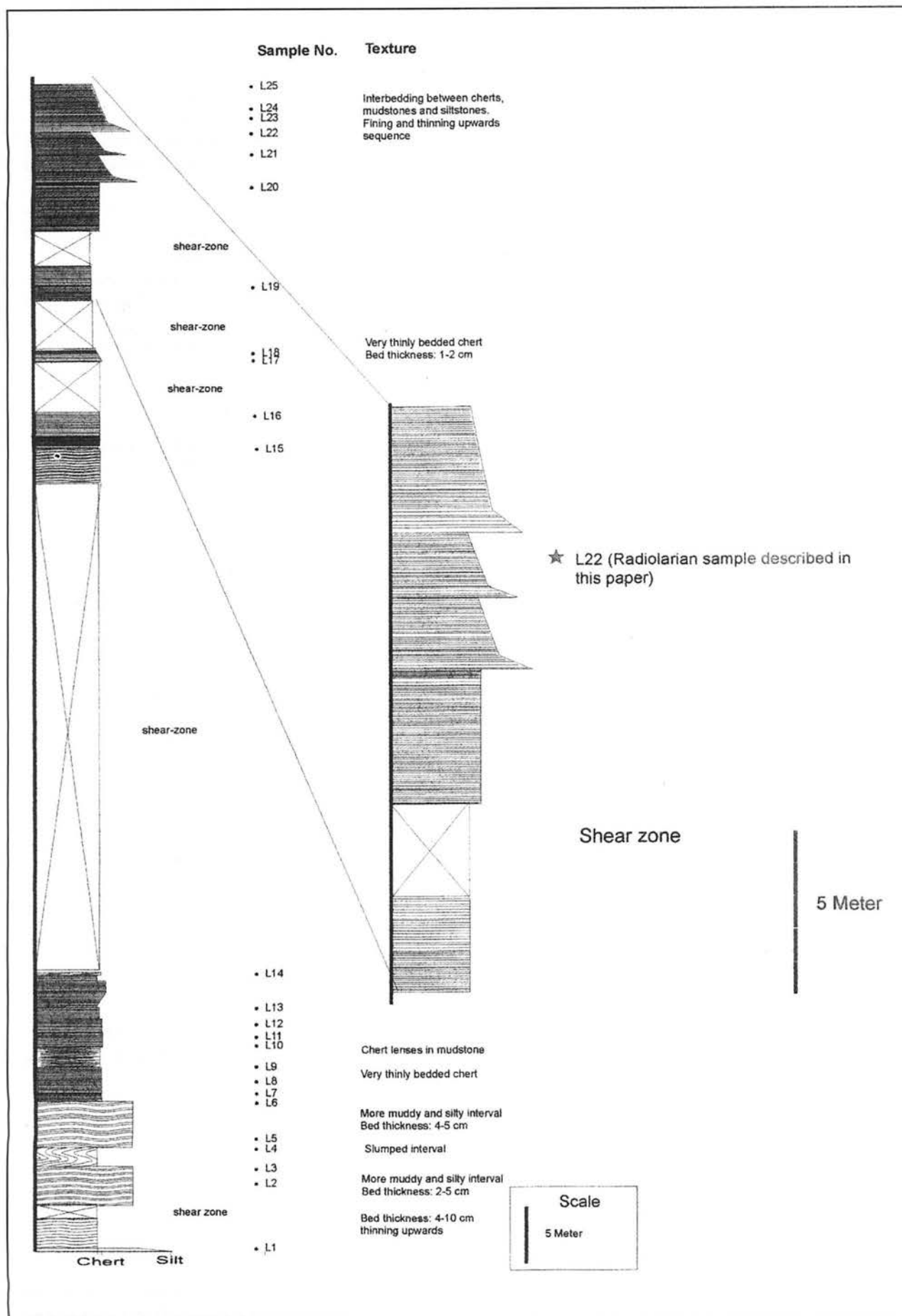


Figure 1. Geological map of the area showing sample locality.



**Figure 2.** Measured section of the outcrop showing sampling horizons.

mudstone yielded some quite well-preserved radiolarian faunas.

## RESULT AND DISCUSSION

Only one sample yielded a very high diversity and quite well-preserved radiolarian faunas. A total of 34 radiolarian taxa were identified as follows:-

*Albaillella cornuta* Deflandre  
*Albaillella deflandrei* Gourmelon  
*Albaillella paradoxa* Deflandre  
*Albaillella undulata* Deflandre  
*Archocyrtium clinoceros* Deflandre  
*Archocyrtium ludicrum* Deflandre  
*Archocyrtium lagabriellei* Gourmelon  
*Archocyrtium pulchrum* Braun  
*Archocyrtium strictum* Deflandre  
*Archocyrtium cf ferrum* Braun  
*Archocyrtium* sp. A  
*Archocyrtium* sp. B  
*Astroentactinia multispinosa* Won  
*Astroentactinia biaciculata* Nazarov  
*Belowea* sp.  
*Callella cf conispinosa* Won  
*Callella* sp.  
*Callella parvispinosa* Won  
*Ceratoikiscum avimexpectans* Deflandre  
*Ceratoikiscum berggredi* Gourmelon  
*Ceratoiciskum umbraculum* Won  
*Ceratoiciskum* sp.  
*Cerarchocyrtium singulum* Cheng  
*Cystisphaeractinium mendax* Deflandre  
*Cystisphaeractinium* sp. A  
*Cystisphaeractinium* sp. B  
*Entactinia digitosa* Braun  
*Entactinia vulgaris* Won  
*Entactinosphaera palimbola* Foreman  
*Huasha* sp.  
*Polyentactinia polygonia* Foreman  
*Pylentonema* sp.  
*Robotium* sp.

*Triaenosphaera sicarius* Deflandre

The present of short ranging species *Albaillella deflandrei*, *Albaillella cornuta*, *Albaillella undulata* indicates that the assemblage represents the *Albaillella deflandrei* Zone of Braun and Schmidt-Effing (1993).

Some of the taxa in the Langkap chert have been noted by Spiller and Metcalfe (1995a, 1995b). They have recorded some Late Devonian and Early Carboniferous radiolarian faunas from the same locality. The Late Devonian fauna consists of *Holoeciscus* sp. and *Archocyrtium* sp. They also reported the occurrence of *Archocyrtium eupectum* Braun, *Archocyrtium callimorphum* Braun, *Albaillella paradoxa* Deflandre, *Albaillella*

*undulata* Deflandre, *Polyentactinia polygonia* Foreman, *Ceratoikiscum berggredi* Gourmelon, *Pylentonema antiqua* Deflandre, *Pylentonema mendax* (Deflandre), *Astroentactinia biaciculata* Nazarov, *Astroentactinia spatiosa* Braun, and *Astroentactinia mirousi* Gourmelon. This assemblage was assigned to *Albaillella paradoxa* Zone of Braun (1990).

In the present material, the Late Devonian Radiolaria were not recognised despite detailed sampling. The Early Carboniferous radiolarian assemblage described by Spiller and Metcalfe (1995b) is slightly older than the present

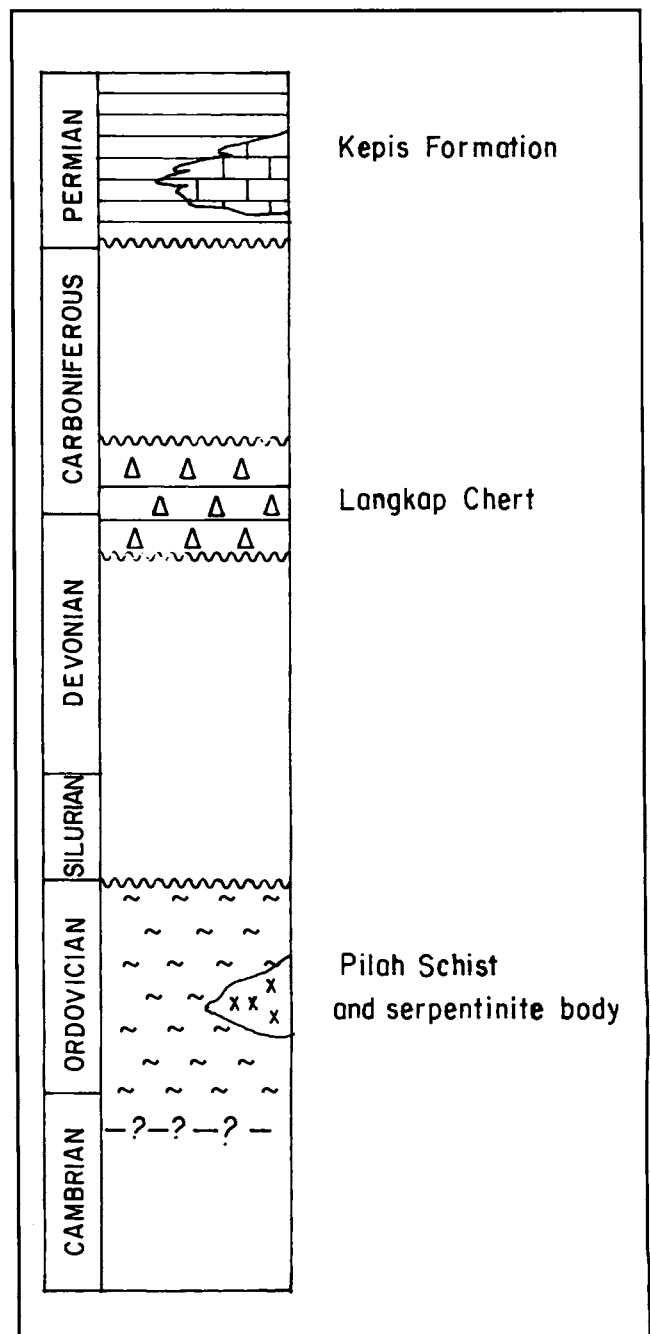


Figure 3. Lithostratigraphy of the Langkap area.

assemblage. It is assumed that their samples were probably collected from the lower part of the section. It is evident, that the age of the Langkap chert ranges from Late Devonian to the *Albaillella deflandrei* Zone of late Tournaisian, Early Carboniferous.

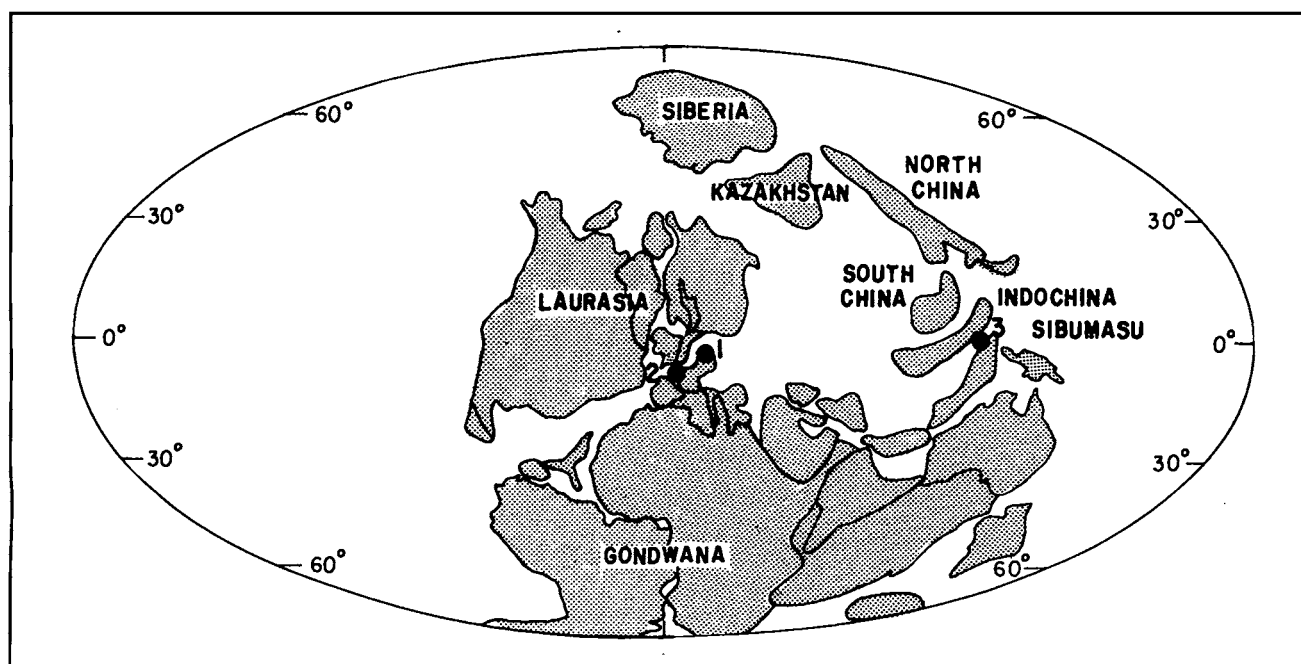
Discovery of Late Devonian and Early Carboniferous radiolarian faunas in the chert sequence indicates the existing of sedimentary sequence during the Late Devonian and Early Carboniferous which was previously unknown in the area. Three lithostratigraphic units are now recognised namely, the Pilah Schist, Langkap chert, and Kepis Formation (Fig. 3). The stratigraphy of the area needs to be revised and a proper lithostratigraphic unit for the chert sequence should be established.

Comparison between some selected taxa found in the present material and other published radiolarian occurrence worldwide provides some clues to the possibility of locating the paleobiogeographic province (Table 1). The present assemblage shows a very close affinity to those recorded from Germany and France. But only four, five and seven taxa of the same age were reported from Australia, Turkey and North America respectively. Early Carboniferous Radiolaria from China are represented only by very few species namely, *Albaillella cf cartalla*, *Albaillella cf paradoxa*, *Belowea variabilis*, and *Entactinia tortispina* (Wu *et al.*, 1994), thus they cannot

properly be compared. Aitchison (1990) indicated that most of the Carboniferous radiolarian localities worldwide are located at low latitude. The variation in the specific diversity of the taxa may be due to the state of preservation of the Radiolaria. The similarity in radiolarian composition between the present sample and those of western Europe suggests that the radiolarian assemblage was probably occupying the similar paleobiogeographic province during the Early Carboniferous. They represent a low latitude equatorial assemblage during the Tournaisian (Fig. 4).

Spiller and Metcalfe (1995b) indicated that the bedded chert was deposited in an ocean which separated the Sibumasu and Indochina/East Malaya terranes from at least Late Devonian to late Early Permian. It is difficult to estimate how wide the ocean was. Metcalfe (1996) indicated that both the Sibumasu and the Indochina blocks were located very close to the Palaeoequator during Early Carboniferous. The Early Carboniferous paleogeographic map constructed by Scotese and Mckerrow (1990) shows that the Sibumasu, the Indochina and the South China blocks are very close to each other. This suggests that the Sibumasu and East Malaya Blocks was probably separated by only a narrow sea.

Spiller and Metcalfe (1995a) suggested that the chert sequence was deposited on the ocean basin floor near the mid-ocean ridge and continental margin based on the cerium anomaly (Ce/Ce\*).



**Figure 4.** Palaeogeographic map (modified after Scotese and McKerrrow, 1990) showing the three localities of a similar radiolarian assemblage. 1. Germany (Braun, 1989, 1990; Braun & Schmidt-Effing, 1993; Giese & Schmidt-Effing, 1989), 2. France (Deflandre, 1952, 1953, 1963, 1972a, 1972b, 1973; Gourmelon, 1985, 1986, 1987a, 1987b, 1987c.), 3. Langkap (present study).

**Table 1.** Comparison between some selected Early Carboniferous taxa in the present study to those of published data worldwide.

	FRANCE	GERMANY	AUSTRALIA	TURKEY	NORTH AMERICA
<i>Albaillella cornuta</i> Deflandre	★	★		★	★
<i>Albaillella deflandrei</i> Gourmelon	★	★			
<i>Albaillella paradoxa</i> Deflandre	★	★	★	★	★
<i>Albaillella undulata</i> Deflandre	★		★	★	
<i>Archocyrtium clinoceros</i> Deflandre	★	★			
<i>Archocyrtium ludicrum</i> Deflandre	★		★		
<i>Archocyrtium lagabriellei</i> Gourmelon	★	★			
<i>Archocyrtium pulchrum</i> Braun		★			
<i>Archocyrtium strictum</i> Deflandre	★				
<i>Astroentactinia multispinosa</i> Won	★	★			
<i>Astroentactinia biaciculata</i> Nazarov	★	★			
<i>Callella parvispinosa</i> Won		★			
<i>Ceratoikiscum avimexpectans</i> Deflandre	★	★	★	★	★
<i>Ceratoikiscum berggredi</i> Gourmelon	★	★			
<i>Ceratoikiscum umbraculum</i> Won	★	★			
<i>Cerarchocyrtium singulum</i> Cheng					★
<i>Cystiphaeractinium mendax</i> Deflandre	★			★	★
<i>Entactinia digitosa</i> Braun		★			
<i>Entactinia vulgaris</i> Won	★	★			
<i>Entactinosphaera palimbola</i> Foreman	★	★			★
<i>Polyentactinia polygonia</i> Foreman	★	★			★
<i>Triaenosphaera sicarius</i> Deflandre	★	★			

France: Data obtained from: Deflandre, 1952, 1953, 1963, 1972a, 1972b, 1973, Gourmelon, 1985, 1986, 1987a, 1987b, 1987c.

Germany: Data obtained from: Braun, 1989, 1990; Braun & Schmidt-Effing, 1993; Giese & Schmidt-Effing, 1989.

Australia: Data obtained from: Aitchison, 1988; Aitchison & Flood, 1990.

Turkey: Data obtained from: Holdsworth, 1973.

North America: Data obtained from: Cheng, 1986; Sandberg & Gutschick, 1984; Foreman, 1983. Schwartzapfel & Holdsworth, 1996.

However, in this area, the chert is underlain by the Pilah Schist and no ophiolitic chert association was observed. The presence of mudstone in the chert sequence indicates that the depositional environment was very close to a continental margin. The chert-mudstone association is considered as a continental margin chert association (Jones and Murchey, 1986).

## CONCLUSIONS

The chert sequence which was previously included in the Pilah Schist must be separated and should be defined as a new lithostratigraphic unit. The age of the Langkap chert now ranges from Famennian (Late Devonian) to the *Albaillella deflandrei* Zone, late Tournaisian. The similarity in composition of the radiolarian faunas in the present material to those of Germany and France suggests that they were occupying the similar paleobiogeographic province in the equatorial region during Early Carboniferous.

## TAXONOMIC NOTES

Subclass Radiolaria Müller, 1958  
 Order Polycystida Ehrenberg, 1838  
 Suborder Albaillellaria Deflandre, 1952, emend. Holdsworth, 1969  
 Superfamily Albaillellacea Cheng, 1986  
 Family Albaillellidae Deflandre, 1952, emend. Holdsworth, 1977  
 Genus *Albaillella* Deflandre, 1952, emend. Holdsworth, 1966

### *Albaillella cornuta* Deflandre, 1952 (Pl. 1, figs. 1, 2)

*Albaillella cornuta* Deflandre 1952, p. 873, figs. 6,7; Holdsworth 1973, p. 127, pl. 1, fig. 16; Sandberg and Gutschick 1984, p. 168, pl. 5, figs. U, V; Gourmelon 1985, p. 1263, pl. 2, fig. 22; Giese and Schmidt-Effing 1989, p. 72, pl. 1, fig. 5.

#### Remarks

Six quite well-preserved specimens were retrieved. The specimens have very delicate crenulated lamellar shell with an apical spine and single wing. Specimens possess features characteristic of *Albaillella cornuta* illustrated by Deflandre (1952). The holotype of the species was not formally described.

#### Stratigraphic range

*Albaillella cornuta* has been recorded from the Early Carboniferous (Tournaisian) of France (Deflandre, 1952; Gourmelon, 1985), Germany

(Giese and Schmidt-Effing, 1989), Turkey (Holdsworth, 1973), and North America (Sandberg and Gutschick, 1984).

### *Albaillella deflandrei* Gourmelon, 1987 (Pl. 1, figs. 3, 4)

*Albaillella deflandrei* Gourmelon 1987a, p. 85–86, pl. 11, figs 6–8; Braun 1990, p. 85, pl. 4, figs. 15–16.

#### Remarks

Ten moderately well-preserved specimens of the species were retrieved. Specimens are unwinged and have slightly crenulated lamellar conical shells tapering towards apical spine. The H frame are well preserved. These specimens exhibit morphology similar to the specimen described by Gourmelon (1987a).

#### Stratigraphic range

The species was recorded from the Tournaisian of France (Gourmelon, 1987a). It has been used by Braun (1990) as a zonal marker in the late Tournaisian of Germany.

### *Albaillella paradoxa* Deflandre, 1952 (Pl. 1, figs. 5, 6)

*Albaillella paradoxa* Deflandre, 1952, p. 872–874, figs. 1–3; Holdsworth, 1973, p. 127, pl. 1, figs. 12,15; Gourmelon, 1985, p. 1263, pl. 2, fig. 20; Gourmelon, 1986, p. 191, pl. 3, fig. 5; pl. 4, fig. 4; Gourmelon, 1987a, p. 84, pl. 11, figs. 1–5; Aitchison and Flood, 1990, p. 15, figs. 4R, S,T; Braun, 1990, p. 90–91, pl. 2, fig. 9–13; pl. 4, figs. 13,14.

#### Remarks

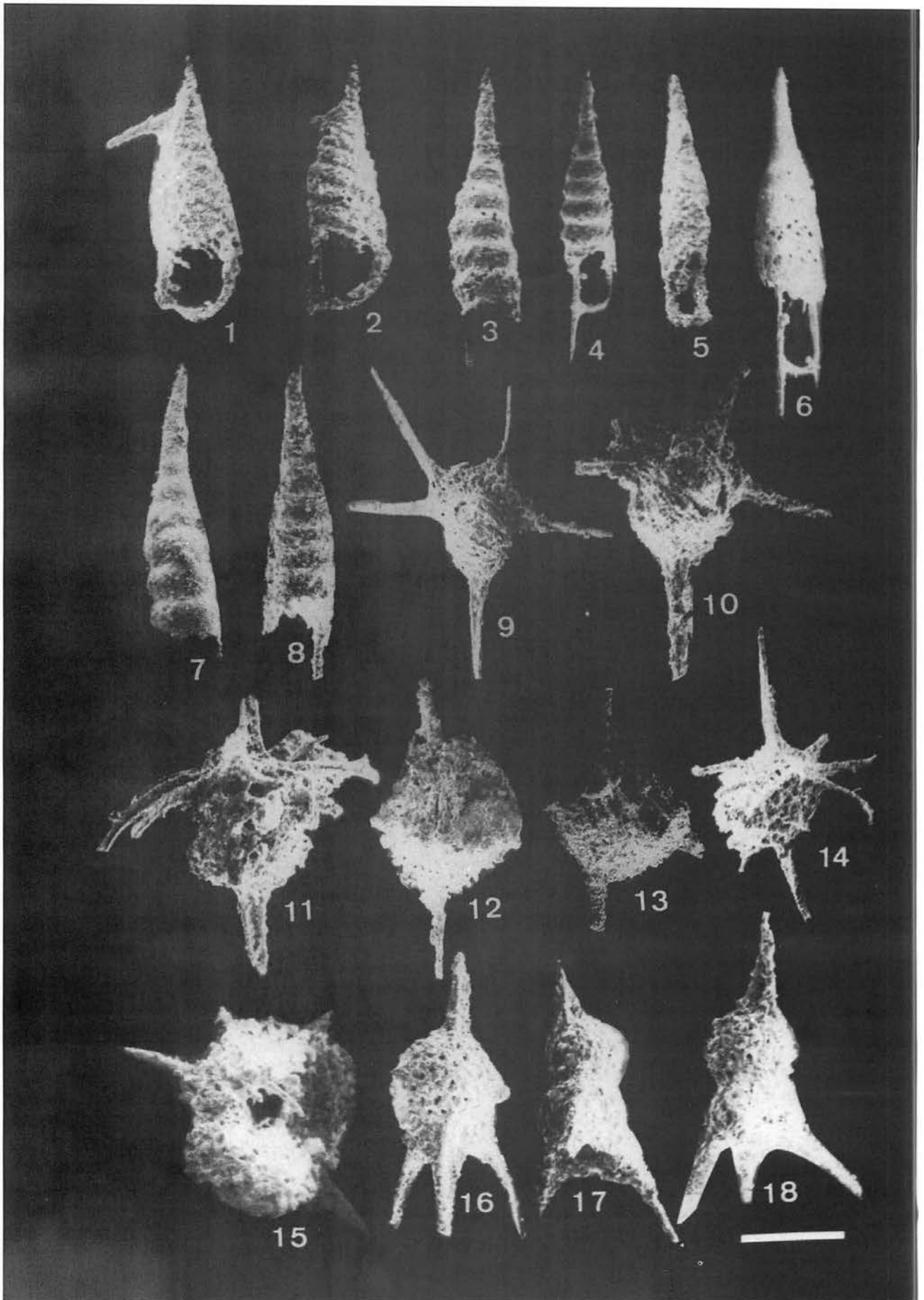
Seven moderately well-preserved specimens were retrieved. Specimens have smooth conical lamellar shells without wing which cover two-thirds of the apical part of columella. They have narrow H frame. A well-preserved specimen have features very similar to those specimens illustrated by Deflandre (1952).

#### Stratigraphic range

*Albaillella paradoxa* has been reported from the Tournaisian, Early Carboniferous of France (Deflandre, 1952; Gourmelon, 1985;1986;1987), Germany (Braun, 1990), Turkey (Holdsworth, 1973), and Australia (Aitchison and Flood, 1990).

### *Albaillella undulata* Deflandre, 1952 (Pl. 1, figs. 7, 8)

*Albaillella undulata* Deflandre, 1952, p. 872–874, figs. 8,9; Holdsworth, 1973, pl. 1, fig. 13; Gourmelon (1985), pl. 2, fig. 21; Aitchison and Flood, 1990, p. 15, figs. 5A, B, C, D, E, F, G; Braun, 1990 p. 93, pl. 4, figs. 9, 10.





**Remarks**

Five specimens were retrieved from the present material. Most of the specimens have broken H-frame. This species possesses undulose elongate conical lamellar shell without wing. The specimens possess morphological features very similar to *Albaillella undulata* (Deflandre, 1952).

**Stratigraphic range**

The species has been recorded from the Tournaisian of France (Deflandre, 1952), Germany (Braun, 1990), Turkey (Holdsworth, 1973), and Australia (Aitchison and Flood, 1990).

Family Ceratoikiscidae Holdsworth, 1969  
Genus *Ceratoikiscum* Deflandre, 1953

***Ceratoikiscum avimexpectans* s.l. Deflandre, 1953 (Pl. 1, figs. 9, 10)**

*Ceratoikiscum avimexpectans* Deflandre, 1953, p. 409, figs. 309a, b; Holdsworth, 1973, p. 126, pl. 1, figs. 10–11; Cheng, 1986, p. 77–78, pl. 1, fig. 2; pl. 7, figs. 5, 7; Gourmelon, 1987c, p. 71–75, pl. 1, figs. 1–7; Aitchison, 1988, pl. 2, figs. 7, 11; Braun, 1990, p. 94, pl. 5, fig. 6; pl. 6, fig. 12; Schwartzapfel and Holdsworth, 1996, p. 101–104, pl. 11, figs. 4, 5, 9, 15, 16, 19; pl. 16, figs. 4, 5, 10, 19, 20, 21; pl. 8, figs. 4–7, 14, 18–20.

**Remarks**

*Ceratoikiscum avimexpectans* was first illustrated by Deflandre (1953). The holotype was later described by Gourmelon (1987c). The species exhibits some variations. Schwartzapfel and Holdsworth (1996) distinguished four morphotypes of the species. In this paper all the closely related forms are group together as *C. avimexpectans* s.l. The species are very common in the present material. Specimens possess features characteristic of *C. avimexpectans* as described by Gourmelon (1987).

**Stratigraphic range**

The species was recorded from the Late Famennian and Tournaisian of North America (Cheng, 1986; Schwartzapfel and Holdsworth, 1996), Tournaisian of France (Deflandre, 1953; Gourmelon, 1985; 1986; 1987c), Germany (Braun, 1990), Turkey (Holdsworth, 1973), and Australia (Aitchison, 1988).

***Ceratoikiscum berggredi* Gourmelon, 1987 (Pl. 1, fig. 11)**

*Ceratoikiscum berggredi* Gourmelon, 1987a, p. 96–98, pl. 13, figs. 7–8; Braun, 1990, p. 95, pl. 5, figs. 4, 5; pl. 6, figs. 8, 9

**Remarks**

Three fairly well-preserved specimens were retrieved. Specimens possess morphological features very similar to *Ceratoikiscum berggredi* illustrated and described by Gourmelon (1987a).

**Stratigraphic range**

*Ceratoikiscum berggredi* was reported from the Tournaisian of France (Gourmelon, 1987a) and Germany (Braun, 1990).

***Ceratoikiscum umbraculum* Won, 1983 (Pl. 1, figs. 12, 13)**

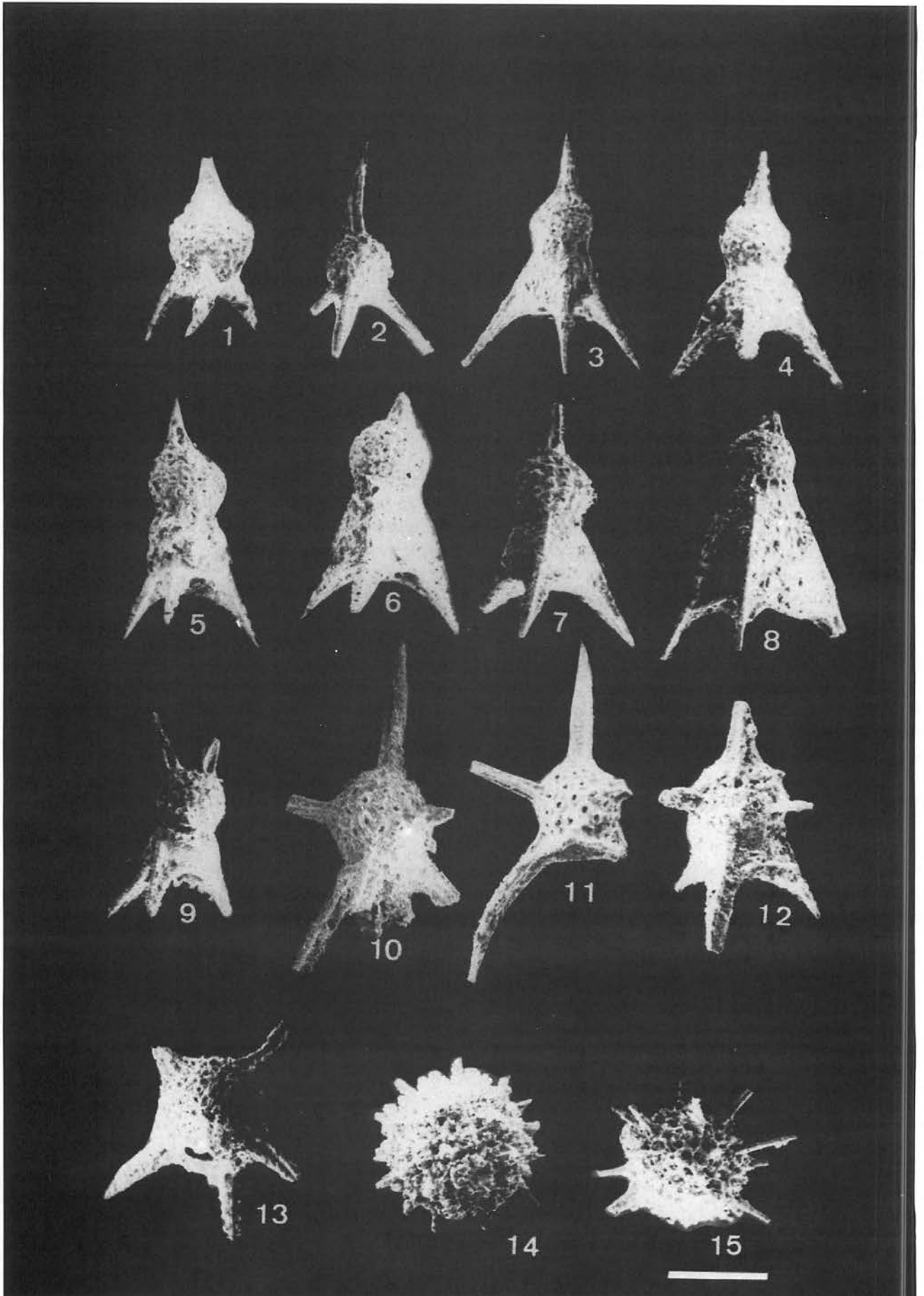
*Ceratoikiscum umbraculum* Won, 1983, p. 139, pl. 2, figs. 7, 8; text-fig. 4d; Gourmelon, 1986, p. 194, pl. 1, fig. 9; Gourmelon, 1987a, p. 99–100, pl. 14, figs. 3–9; Braun and Schmidt-Effing, 1993, pl. 2, fig. 8.

**Remarks**

The specimen exhibits four rod-like extensions surrounding the central frame with six pairs of caveal ribs and strongly developed patagium. Some parts of the specimens are covered by siliceous matrix. The specimens resemble *Ceratoikiscum umbraculum* described and illustrated by Won (1983).

**Plate 1.** Scale bar in  $\mu\text{m}$  is indicated in the parentheses.

- 1, 2. *Albaillella cornuta* Deflandre (100  $\mu\text{m}$ )
- 3, 4. *Albaillella deflandrei* Gourmelon (100  $\mu\text{m}$  and 200  $\mu\text{m}$  respectively)
- 5, 6. *Albaillella paradoxa* Deflandre (200  $\mu\text{m}$  and 133  $\mu\text{m}$  respectively)
- 7, 8. *Albaillella undulata* Deflandre (133  $\mu\text{m}$ )
- 9, 10. *Ceratoikiscum avimexpectans* Deflandre (133  $\mu\text{m}$  and 100  $\mu\text{m}$  respectively)
11. *Ceratoikiscum berggredi* Gourmelon (100  $\mu\text{m}$ )
- 12, 13. *Ceratoikiscum umbraculum* Won (100  $\mu\text{m}$  and 133  $\mu\text{m}$  respectively)
14. *Ceratoikiscum* sp. (133  $\mu\text{m}$ )
15. *Huasha* sp. (66  $\mu\text{m}$ )
16. *Pylentonema* sp. (133  $\mu\text{m}$ )
- 17, 18. *Archocyrtium clinoceros* Deflandre (80  $\mu\text{m}$  and 100  $\mu\text{m}$  respectively)



**Stratigraphic range**

The species has been reported from Tournaisian of Germany (Won, 1983; Braun and Schmidt-Effing, 1993) and France (Gourmelon, 1986, 1987a)

***Ceratoikiscum* sp. (Pl. 1, fig. 14)****Remarks**

Specimen is very similar to *Ceratoikiscum berggredi* except it has three pairs of smooth caveal ribs. This is probably a new taxon.

Genus *Huasha* Cheng, 1983

***Huasha* sp. (Pl. 1, fig. 15)****Remarks**

Specimen is not well preserved. Only three extra rods and three short caveal ribs are preserved. Patagium is strongly developed at the ventral side of the skeletal frame.

Suborder Nassellariina Ehrenberg, 1875

Superfamily Cyrtioidea Haeckel, 1862

Family Pylentonemidae, Deflandre 1963, emend. Holdsworth, 1977, emend. Cheng, 1986

Genus *Pylentonema* Deflandre, 1963, emend. Cheng, 1986

***Pylentonema* sp. (Pl. 1, fig. 16)****Remarks**

Specimen possesses a subspherical lattice shell with a prominent apical spine, three very short lateral spines and three feet. The specimen is poorly preserved and not sufficient for species identification.

Family Archocyrtiidae Kozur and Mostler, 1981, emend. Cheng, 1986

Genus *Archocyrtium* Deflandre, 1972, emend. Cheng, 1986

***Archocyrtium clinoceros* Deflandre, 1973 (Pl. 1, figs. 17, 18)**

*Archocyrtium clinoceros* Deflandre, 1973, p. 151, pl. 1, figs. 7, 8; pl. 3, figs. 3, 4; Giese and Schmidt-Effing 1989, p. 72, pl. 1, fig. 2.

**Remarks**

Seven moderately well-preserved specimens were retrieved. This species is distinguished from other species of *Archocyrtium* in having a tilted apical spine. The present specimens possess the characteristic features of *Archocyrtium clinoceros* Deflandre.

**Stratigraphic range**

It was originally described from the Visean of France (Deflandre, 1973). Giese and Schmidt-Effing (1989) subsequently reported it from the Early Carboniferous of Germany.

***Archocyrtium ludicrum* Deflandre, 1972 (Pl. 2, fig. 1)**

*Archocyrtium ludicrum* Deflandre, 1972b, p. 150, pl. 1, fig. 5; pl. 2, fig. 5; Gourmelon, 1985, pl. 2, fig. 14; Aitchison and Flood, 1990, p. 11, fig. 4E.

**Remarks**

Five moderately well-preserved specimens were recovered. The species is characterised by having a spherical lattice shell, a short tapering apical spine and a narrow pylome rim with three short slightly curved feet. The pores are covered by matrix.

**Stratigraphic range**

*Archocyrtium ludicrum* was recorded from the Tournaisian of France (Deflandre, 1972; Gourmelon, 1985) and Early Carboniferous of eastern Australia (Aitchison and Flood, 1990).

**Plate 2.** Scale bar in  $\mu\text{m}$  is indicated in the parentheses.

1. *Archocyrtium ludicrum* Deflandre (80  $\mu\text{m}$ )
2. *Archocyrtium lagabriellei* Gourmelon (133  $\mu\text{m}$ )
- 3, 4. *Archocyrtium pulchrum* Braun (100  $\mu\text{m}$ )
5. *Archocyrtium strictum* Deflandre (80  $\mu\text{m}$ )
6. *Archocyrtium cf ferrum* Braun (80  $\mu\text{m}$ )
7. *Archocyrtium* sp. A (100  $\mu\text{m}$ )
8. *Archocyrtium* sp. B (133  $\mu\text{m}$ )
9. *Cerarchocyrtium singularium* Cheng (100  $\mu\text{m}$ )
10. *Cystisphaeractinium mendax* Deflandre (80  $\mu\text{m}$ )
11. *Cystisphaeractinium* sp. A (100  $\mu\text{m}$ )
12. *Cystisphaeractinium* sp. B (133  $\mu\text{m}$ )
13. *Robotium* sp. (100  $\mu\text{m}$ )
14. *Astroentactinia biaciculata* Nazarov (100  $\mu\text{m}$ )
15. *Entactinia digitosa* Braun (133  $\mu\text{m}$ )

***Archocyrtium lagabrieliei* Gourmelon, 1987  
(Pl. 2, fig. 2)**

*Archocyrtium lagabrieliei* Gourmelon, 1987a, p. 115–116, pl. 19, figs. 1–4; Braun, 1990, p. 126, pl. 17, figs. 7, 8.

**Remarks**

Only three well-preserved specimens were recovered. The species possesses a spherical lattice shell with a relatively long apical spine and three feet which are triradiate in axial section. The specimens closely resemble *Archocyrtium lagabrieliei* Gourmelon (1987a)

**Stratigraphic range**

*Archocyrtium lagabrieliei* has been recorded from the Tournaisian and Viséan of France (Gourmelon, 1987) and Tournaisian of Germany (Braun, 1990)

***Archocyrtium pulchrum* Braun, 1990 (Pl. 2, figs. 3, 4)**

*Archocyrtium pulchrum* Braun 1990, p. 126–127, pl. 1, figs. 1, 2; pl. 17, fig. 5.

**Remarks**

Five specimens were retrieved. The species possesses characteristic features of *Archocyrtium pulchrum* Braun.

**Stratigraphic range**

It was first recorded from the Tournaisian of Germany (Braun, 1990)

***Archocyrtium strictum* Deflandre, 1973 (Pl. 2, fig. 5)**

*Archocyrtium strictum* Deflandre, 1973, p. 151, pl. 1, fig. 6; pl. 3, figs. 1, 2. Gourmelon 1985, pl. 2, fig. 15.

**Remarks**

Specimen possesses a subspherical perforate cephalis with a single triradiate apical horn and three feet. Pylome margin has extended skirt. These morphological features closely resemble *Archocyrtium strictum* as described and illustrated by Deflandre (1973).

**Stratigraphic range**

The species was recorded from the Viséan (Deflandre, 1973) and Tournaisian (Gourmelon, 1985) of France.

***Archocyrtium cf ferreum* Braun, 1989 (Pl. 2, fig. 6)**

**Remarks**

It has subspherical lattice shell with short apical horn. Pylome rim expands and covers two thirds of the three feet. This form is similar to *Archocyrtium ferreum* Braun (1989). The specimen is not well preserved and the species cannot properly be identified.

***Archocyrtium* sp. A (Pl. 2, fig. 7)**

**Remarks**

Seven specimens were recovered. The species possesses a subspherical lattice shell with relatively widely spaced pore frames. Pores inset in pore cones. It has a straight apical spine and three feet which are triradiate in cross section. Pylome has expanded pylome rim. It is very similar to *Archocyrtium coronaesimile* Won except it has more expanded pylome rim.

***Archocyrtium* sp. B (Pl. 2, fig. 8)**

**Remarks**

Specimen possesses a relatively small perforated cephalis with a short triradiate apical spine and three feet with long extended skirt. This is probably a new taxon.

Genus *Cerarchocyrtium* Deflandre, 1973

***Cerarchocyrtium singularium* Cheng, 1986  
(Pl. 2, fig. 9)**

*Cerarchocyrtium singularium* Cheng, 1986, p. 130, pl. 7, fig. 2

**Remarks**

It has a subspherical lattice shell with sparsely distributed pore frames. Pores are surrounded by slightly elevated rims. There are five unequal triradiate spines; two subapical spines of unequal lengths and three feet which merge with pylome rim at the base. The specimen closely resemble *Archocyrtium singularium* described and illustrated by Cheng (1986).

**Stratigraphic range**

The species was first described from the late Famennian of Oklahoma, United States of America (Cheng, 1986).

Genus *Cystisphaeractenium* Deflandre, 1972

***Cystisphaeractinium mendax* Deflandre, 1972 (Pl. 2, fig. 10)**

*Cystisphaeractinium mendax* Deflandre, 1972a, p. 3535, pl. 1, figs. 5–11; pl. 2, figs. 4–5; Deflandre, 1972b, p. 14–15; Sandberg and Gutschick, 1984, pl. 5, fig. Y.

*Cyrtentactinia* sp. Holdsworth, 1973, p. 123–124, pl. 1 fig. 9.

*Pylentonema mendax* (Deflandre) Gourmelon, 1987b, p. 286–287, pl. 1, figs 8–10.

**Remarks**

*Cystisphaeractinium mendax* was first illustrated by Deflandre (1972a) without a proper description. Subsequently, a brief description was made (Deflandre, 1972b) with reference to the first illustration.

Specimen is characterised by having a perforate cephalis with a long apical spine, three triradiate lateral spines, three feet and thick rim bearing comb-like structures. The specimen closely resemble *Cystisphaeractinium mendax* (Deflandre, 1972a, 1972b).

**Stratigraphic range**

*Cystisphaeractinium mendax* has been reported from middle and upper Tournaisian of France (Deflandre, 1972a, 1972b; Gourmelon, 1987b), Turkey (Holdsworth, 1973) and North America (Sandberg and Gutschick, 1984).

***Cystisphaeractenium* sp. A (Pl. 2, fig. 11)**

**Remarks**

Specimen possess a straight triradiate apical spine, three lateral spines and three feet. Two of the three feet are broken. The species cannot properly be identified.

***Cystisphaeractinium* sp. B (Pl. 2, fig. 12)**

**Remarks**

Specimen has a lattice shell with one apical spine, three short lateral spines and three short feet. Specimen is poorly preserved.  
Genus *Robotium* Cheng, 1986

***Robotium* sp. (Pl. 2, fig. 13)**

**Remarks**

Specimen possesses subspherical lattice shell with six spines; two subapical spines and four feet. One of the four feet is broken. The specimen is not well preserved and the species cannot be identified.  
Suborder Spumellaria Ehrenberg, 1875

Family Entactiniidae Riedel, 1967  
Genus *Astroentactinia* Nazarov, 1975

***Astroentactinia biaciculata* Nazarov, 1975 (Pl. 2, fig. 14)**

*Astroentactinia biaciculata* Nazarov, 1975, p. 84–85, pl. 8, fig. 8; pl. 10, figs. 6–7; Gourmelon, 1987a, p. 69–70, pl. 8, figs. 1–5; Braun, 1990, p. 100–101, pl. 8, figs. 8, 9; pl. 12, fig. 3.

**Remarks**

Seven moderately well-preserved specimens were retrieved. The species is characterised by having many relatively long spines. The specimens have shorter spines compared to the holotype described by Nazarov (1975).

**Stratigraphic range**

*A. biaciculata* has been reported from Late Devonian of Southern Urals (Nazarov, 1975), middle to late Tournaisian of France (Gourmelon, 1987a) and in the *Albaillella deflandrei* Zone of Germany (Braun, 1990).

***Astroentactinia digitosa* Braun, 1990 (Pl. 2, fig. 15; Pl. 3, fig. 1)**

*Astroentactinia digitosa* Braun 1990, p. 101–102, pl. 8, figs. 10–12

**Remarks**

Six specimens were retrieved from the sample. The specimens exhibit features that resemble *Astroentactinia digitosa* Braun (1990) except some pores are covered by matrix.

**Stratigraphic range**

Braun (1990) reported it from the *Albaillella indensis* Zone, Tournaisian of Germany.

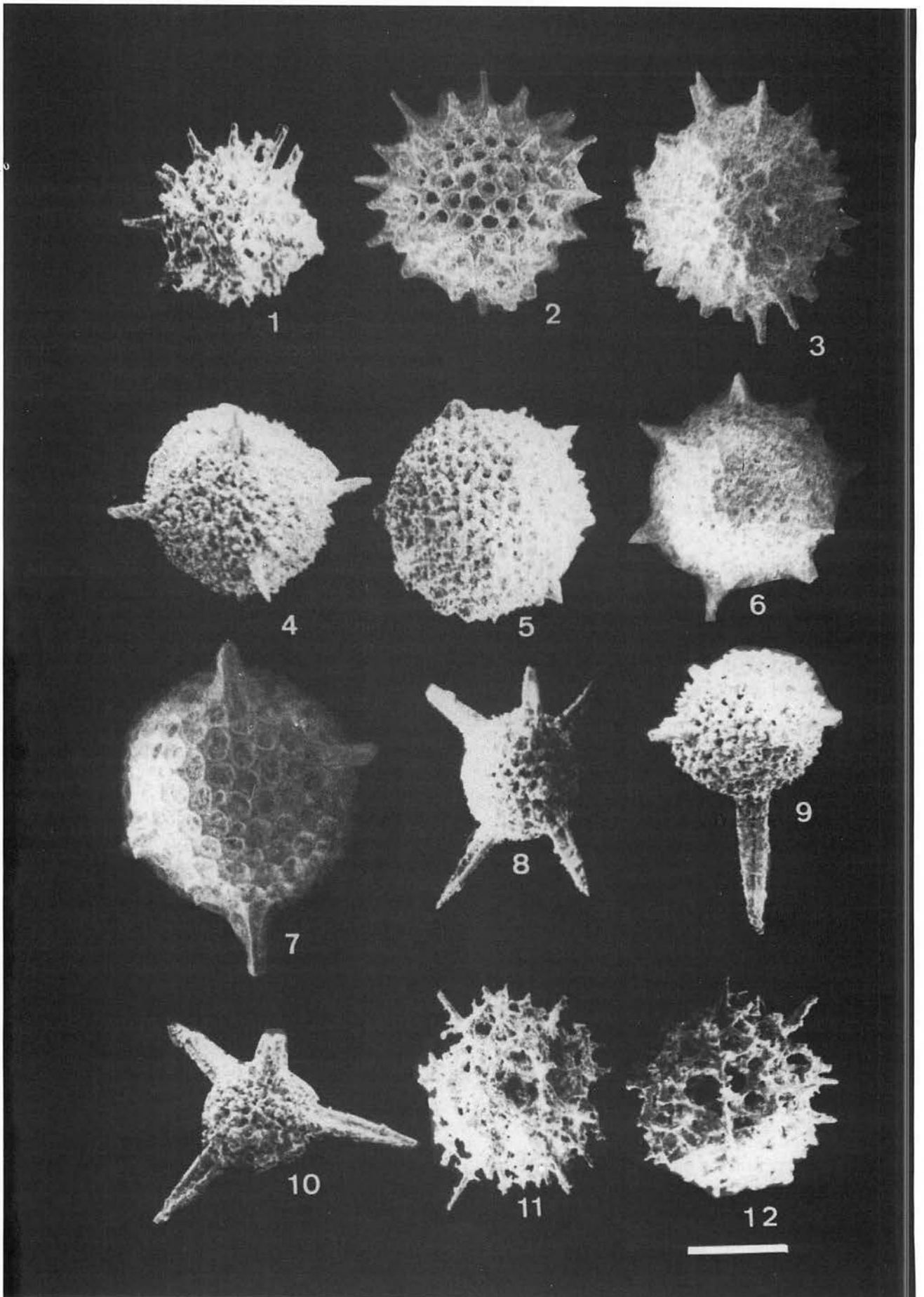
***Astroentactinia multispinosa* Won, 1983 (Pl. 3, figs. 2, 3)**

*Entactinia?* *multispinosa* Won 1983, p. 145–146, pl. 2, figs. 15–16.

*Astroentactinia multispinosa* (Won) Gourmelon 1987a p. 71–72, pl. 8, figs. 9, 10; Giese and Schmidt-Effing 1989, p. 73, pl. 2, fig. 2; Braun 1990, p. 103, pl. 9, figs. 1–3; pl. 12, fig. 1.

**Remarks**

Eight moderately well-preserved specimens were recovered from the sample. The specimens exhibit spherical lattice shells with many short spines. The pores are covered by matrix. They possess characteristic features of *Astroentactinia multispinosa* (Won).



**Stratigraphic range**

The species has been recorded from Early Carboniferous of Germany (Won, 1983; Giese and Schmidt-Effing, 1989; Braun 1990) and France (Gourmelon, 1987a).

Genus *Belowea* Won, 1983

***Belowea* sp. (Pl. 3, fig. 4)****Remarks**

The specimen possesses a spherical lattice shell with six short spines. Surface of the shell is covered by numerous small pores. This form is closely related to *Belowea variabilis*? Won (1983).

Genus *Callella* Won, 1983

***Callella parvispinosa* Won, 1983 (Pl. 3, fig. 5)**

*Callella parvispinosa* Won, 1983, p. 134, pl. 2, figs. 3, 4.

**Remarks**

Six specimens were recovered. The species possesses spherical lattice shell with many very short spines. The specimens are very similar to *Callella parvispinosa* described and illustrated by Won (1983).

**Stratigraphic range**

Won (1983) recorded it from the Early Carboniferous of Germany.

***Callella cf. conspicinosa* Won, 1983 (Pl. 3, fig. 6)****Remarks**

Specimen has a spherical lattice shell with cone-shaped short spines. The specimen is not well preserved and the species cannot properly be identified.

***Callella* sp. (Pl. 3, fig. 7)****Remarks**

The specimen possesses a spherical lattice shell with six spines. Surface of the shell is covered by relatively large circular pore frames. This is probably a new form.

Genus *Entactinia* Foreman, 1963

***Entactinia vulgaris* Won, 1983 (Pl. 3, fig. 8)**

*Entactinia vulgaris* Won, 1983, p. 144, pl. 4, figs. 1–3; Gourmelon, 1986, p. 184, pl. 2, fig. 4; Gourmelon 1987a, p. 50, pl. 4, figs. 1–6; Giese and Schmidt-Effing, 1989, p. 74, pl. 2, figs. 4, 9.

*Entactinia vulgaris vulgaris* Won, Braun 1990, p. 110–111, pl. 7, figs. 7–10.

**Remarks**

Seven specimens were retrieved. The species possesses a spherical lattice shell with six triradiate spines. This form closely resemble *Entactinia vulgaris* Won (1983). The pores of the specimens are partly covered by matrix.

**Stratigraphic range**

The species was recorded from the Early Carboniferous of Germany (Won, 1983). Braun (1990) reported it from the Tournaisian, Early Carboniferous of Germany. Gourmelon (1986, 1987a) recorded it from the Tournaisian of France. Genus *Entactinosphaera* Foreman 1963

***Entactinosphaera palimbola* Foreman, 1963 (Pl. 3, fig. 9)**

*Entactinosphaera palimbola* Foreman 1963, p. 277–278, Pl. 2, Figs. 7a–e; Pl. 3, Figs. 3a–d; Gourmelon 1985, Pl. 2, Fig. 4; Gourmelon 1987a, p. 52–53, Pl. 4, Figs. 7–10; Braun 1990, p. 112–113, Pl. 7, Figs. 11, 12.

**Plate 3.** Scale bar in  $\mu\text{m}$  is indicated in the parentheses.

1. *Astroentactinia digitosa* Braun (133  $\mu\text{m}$ )
- 2, 3. *Astroentactinia multispinosa* Won (80  $\mu\text{m}$  and 100  $\mu\text{m}$  respectively)
4. *Belowea* sp. (100  $\mu\text{m}$ )
5. *Callella parvispinosa* Won (80  $\mu\text{m}$ )
6. *Callella cf. conspicinosa* Won (80  $\mu\text{m}$ )
7. *Callella* sp. (66  $\mu\text{m}$ )
8. *Entactinia vulgaris* Won (100  $\mu\text{m}$ )
9. *Entactinosphaera palimbola* Foreman (100  $\mu\text{m}$ )
10. *Triactinosphaera sicarius* Deflandre (100  $\mu\text{m}$ )
- 11, 12. *Polyentactinia polygonia* Foreman (133  $\mu\text{m}$ ).

**Remarks**

Eight specimens were recovered. The species is distinguished from other species of *Entactinosphaera* by having spherical lattice shell with a relatively large spine. The pores are partly covered by siliceous matrix.

**Stratigraphic range**

*Entactinosphaera palimbola* was first described from the Late Devonian of Ohio, North America by Foreman (1963). Gourmelon (1987a) and Braun (1990) recorded it from the Tournaisian of France and Germany respectively.

Genus *Triaenosphaera* Deflandre, 1973

***Triaenosphaera sicarius* Deflandre, 1973 (Pl. 3, fig. 10)**

*Triaenosphaera sicarius* Deflandre 1973, p. 1150, pl. 2, figs. 2a–c; Gourmelon 1987a, p. 63–64, pl. 6, figs. 1–4; Schmidt-Effing 1988, p. 35, pl. 3, fig. 5; Braun 1990, p. 114–115, pl. 11, figs. 8, 9.

**Remarks**

Specimen possesses a spherical lattice shell with relatively four long triradiate spines. It is very similar to *Triaenosphaera sicarius* described and illustrated by Deflandre (1973).

**Stratigraphic range**

It was reported from the Late Devonian of Germany (Schmidt-Effing, 1988), Tournaisian of France (Deflandre, 1973; Gourmelon, 1987a) and of Germany (Braun, 1990).

Genus *Polyentactinia* Foreman, 1963

***Polyentactinia polygonia* Foreman, 1963 (Pl. 3, figs. 11, 12)**

*Polyentactinia polygonia* Foreman 1963, p. 281, pl. 5, figs. 1a–c; Gourmelon 1985, pl. 2, fig. 6. Gourmelon 1987a, p. 79, pl. 10, figs. 1–6; Braun 1990, p. 131, pl. 14, figs. 1–3, 9; pl. 15, figs. 10–12.

**Remarks**

Specimen is quite well-preserved and possesses morphological features that closely resembles *Polyentactinia polygonia* as described and illustrated by Foreman (1963).

**Stratigraphic range**

*Polyentactinia polygonia* was first described from Late Devonian of Ohio Shale, North America (Foreman, 1963). The species was recorded from Early Carboniferous of France (Gourmelon, 1985; 1987a) and Germany (Braun, 1990).

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