# New observations on Mesozoic miospores and acritarchs, and the implications for existing taxonomy, classification and phylogeny.

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## Thanks to

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# Jurassic non-marine assemblages

**Traditional view**

Low diversity microfloras with **few** reliable stratigraphic markers.

Relatively simple, well established ecological model, e.g. Abbink et al 2004.

**However, not all in the garden is rosy.....**

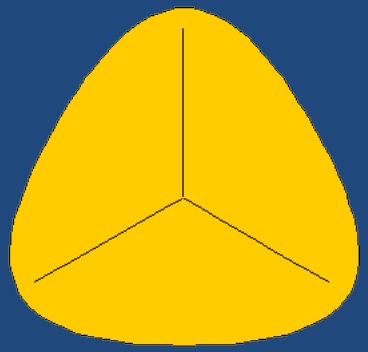
Miospore systematics and taxonomy are over-simplified.

Our current models do not reflect the numerous and varied life-cycles of lower plants.

Neither do they consider, or reflect morphological changes due to growth or sexual maturity.

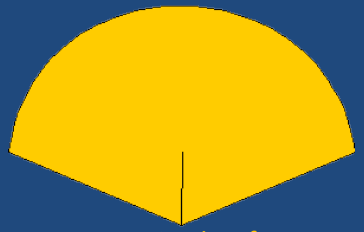
**Applications.....**

# Trilete spores



Proximal Polar view

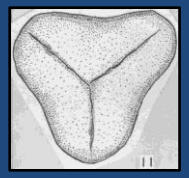
Distal surface



lateral view

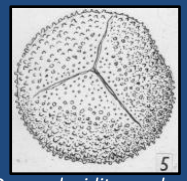
Proximal surface

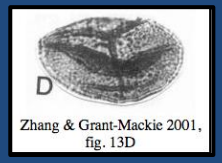
*Cyathidites/Deltoidospora*



*Cyathidites australis*
Couper Drawing of holotype

*Osmundacidites/Baculatisporites*

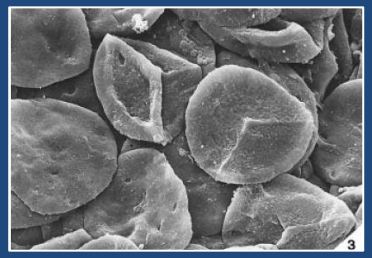




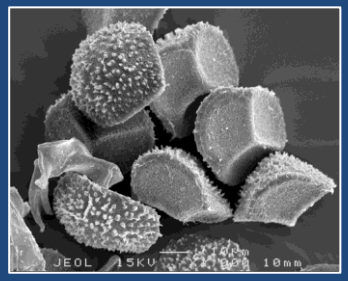

*Osmundacidites welmanii*
Couper Drawing of holotype

The general assumption has been **trilete mark on proximal surface, reflecting contact with other members the tetrad.** (Playford & Dettman 1996).

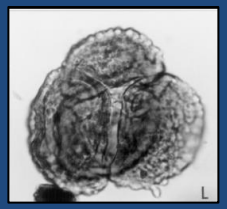
# Trilete mark does not always reflect tetrad



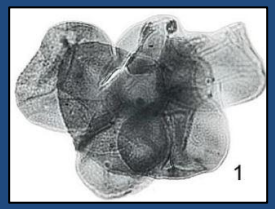
Spores of *Scylaspora*. Early Devonian. From Wellman 1999, pl.1, fig.3.



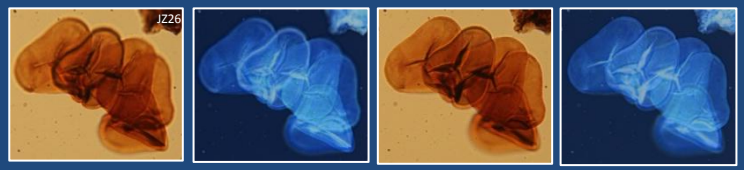
*Phaeoceros carolinianus*, an extant hornwort. Fig. 12 *in* Glime 2013



Tetrad of *Uvaesporites verrucosus*. From de Jersey & Raine 1990, pl.3, fig. L. *in* Raine *et al.* 2011. Triassic



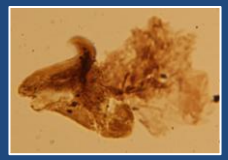
*Granulatisporites infirmus* Plate 2, fig. 1 *in* Cornet & Traverse 1975. Hettangian

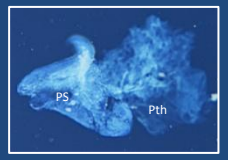


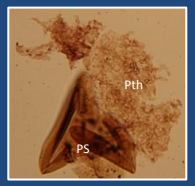
?*Cyathidites* sp. Hugin Formation Late Callovian NNS

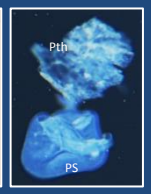
All are dispersed reproductive cells and produced within a sporangium.

# Evidence of germination in fossil spores

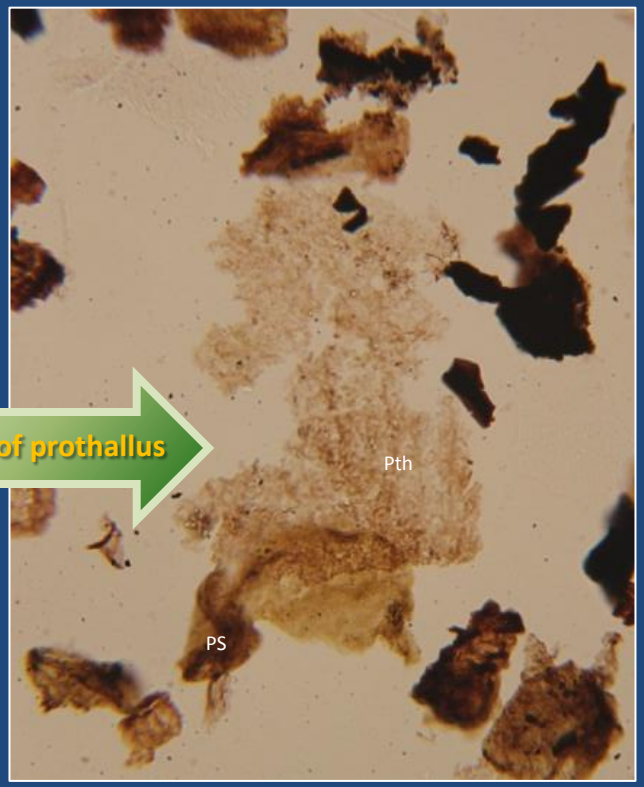


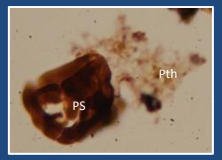


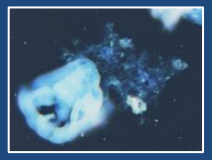



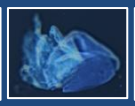



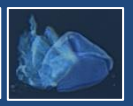

growth of prothallus

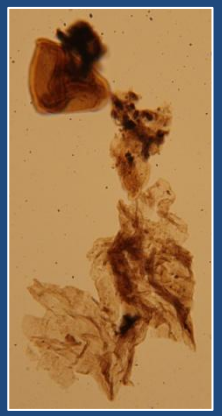




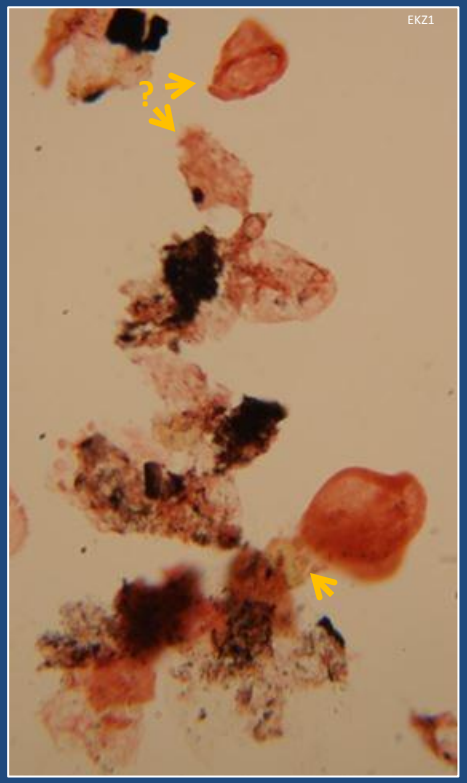





**Early and Middle Jurassic , NNS**

PS Primary spore
Pth Prothallus (gametophyte)

# Attached sporomorphs

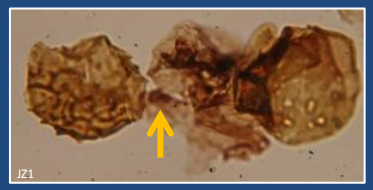



Upper Draupne Formation (Berriasian), SVG

immature?
sterile?

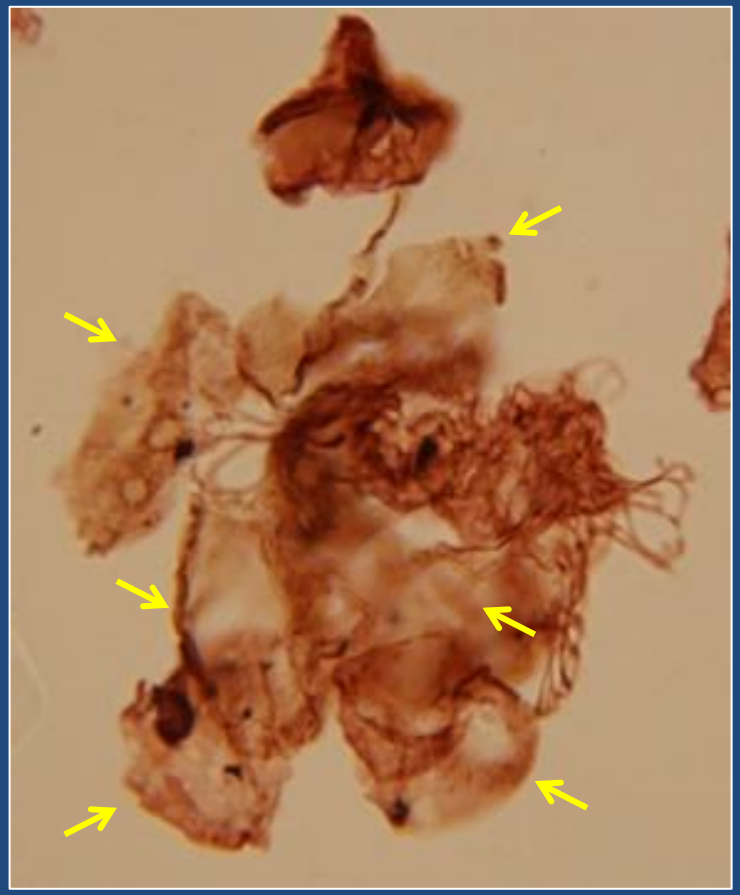

***Cyathidites*-like cell. Hugin Formation (Callovian), South Viking Graben**

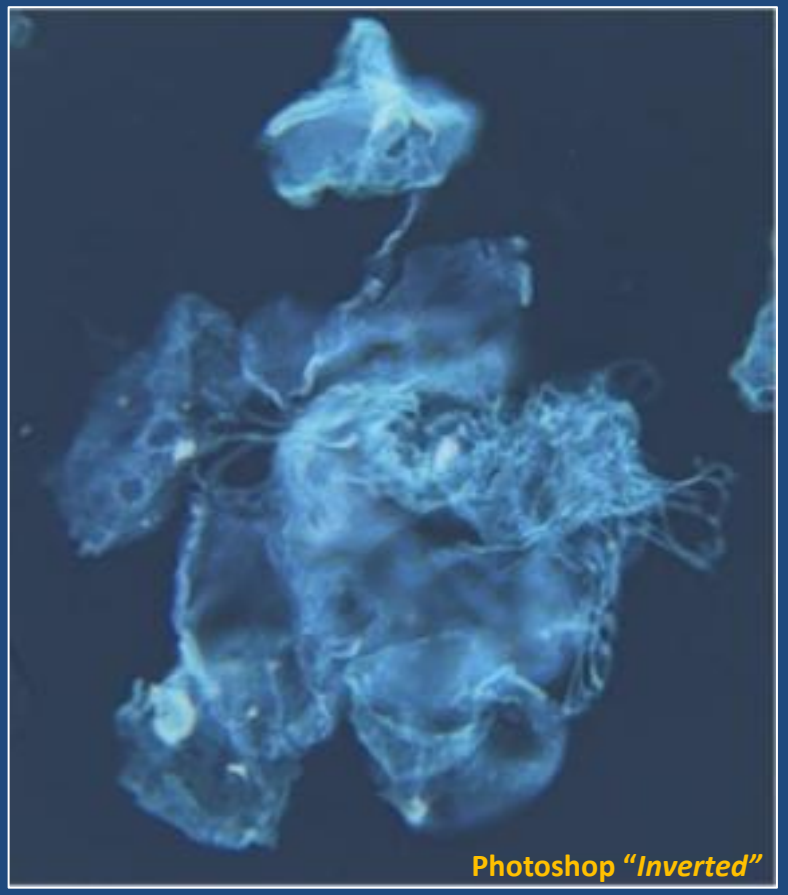
250µ




***Retitriletes*-like cell. Åre Formation (Early Hettangian), Norwegian Sea.**

## *Cyathidites*-like cell attached to a twin skolochorate cell.

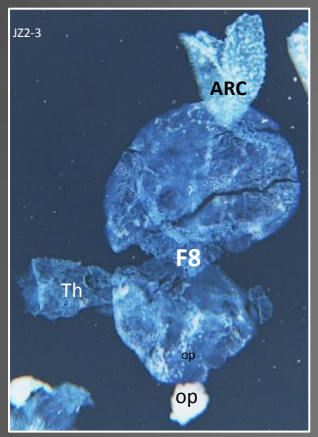


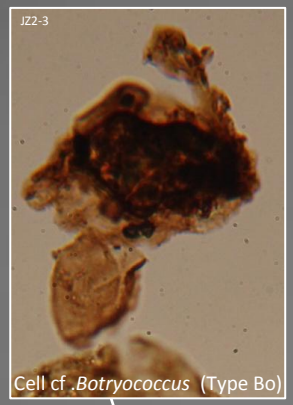



Heather Formation (Callovian), SVG

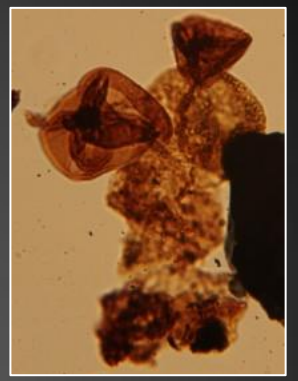
# Attached reproductive cells, NOT dispersed spores.

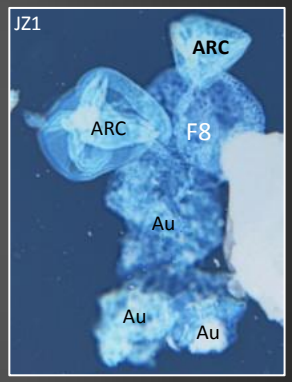
ARC Attached reproductive cell
F8 F8 cell
Th Thalloid cell
GM Gamete mass?
Op opaque cell

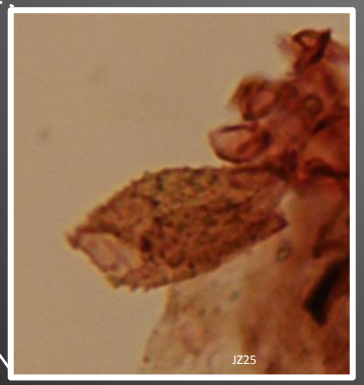



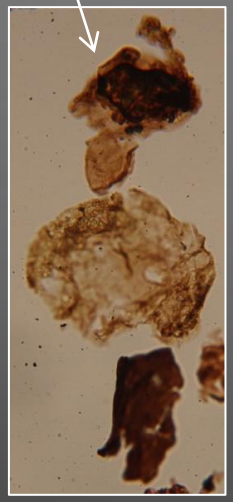


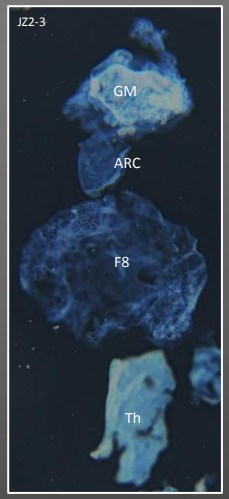




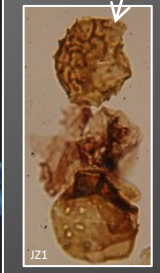

500µ

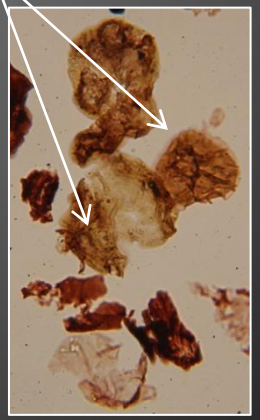



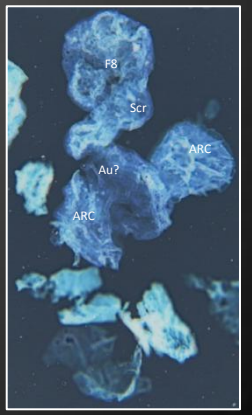





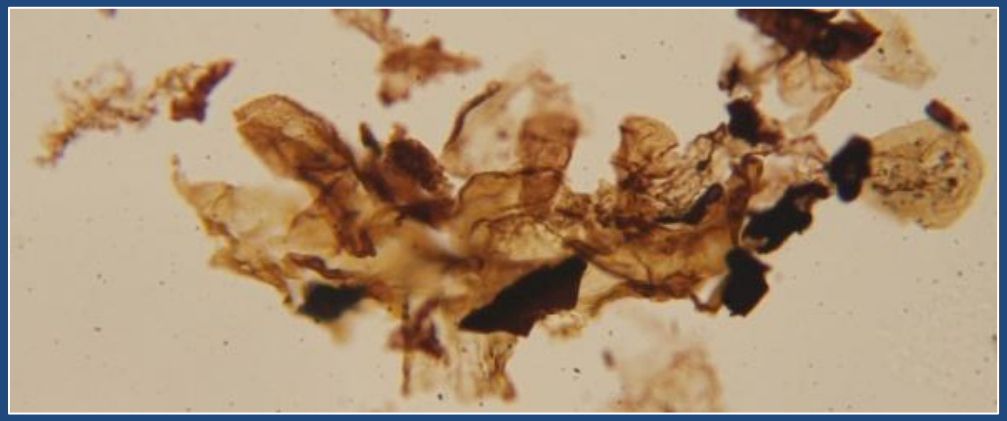

cf. *Retitriletes* (Type Ra)





# Fruiting structure with numerous attached reproductive cells in various stages of maturity.



Åre Formation (Hettangian), Mid Norway


ARC Attached reproductive cells
op Opaque cells

500µ

For the present, use the loose term; “attached reproductive cells” (ARC)

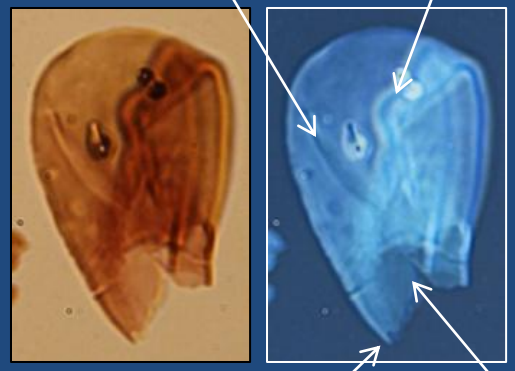
# Morphology of attached reproductive cells.

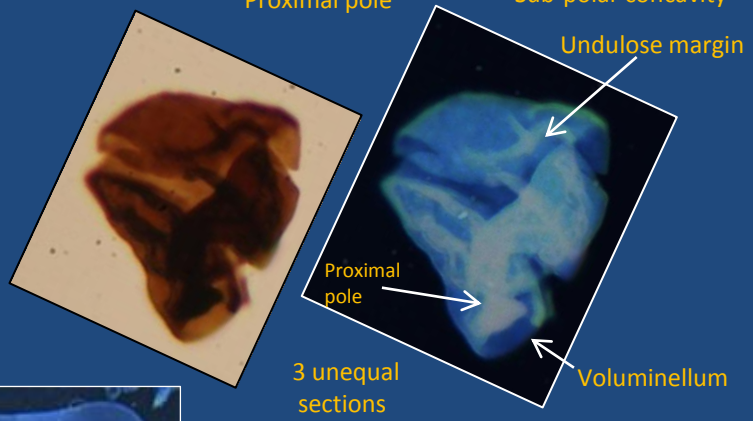
**PRIMARY FEATURES:**

- Attachment structure.
- Attachment to host cell at proximal pole.
- Exhibits growth.
- Trilete mark (if present) on distal or lateral surface.

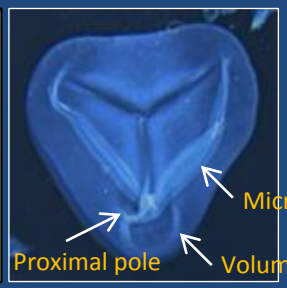
**SECONDARY (variable) FEATURES:**

- Voluminellum (scroll) developed at proximal pole.
- Splits into 3 unequal sections.
- One section commonly with an undulose margin.
- Other modes of rupturing.
- Microfolium.
- Sub-polar concavity.
- Generally does not exhibit radial symmetry.





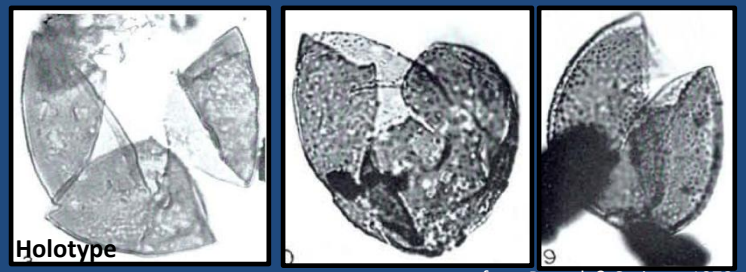



# *Teichertodinium* Pocock & Sarjeant 1972

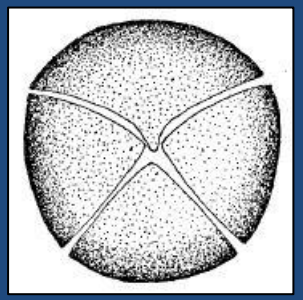
**Original diagnosis is rather vague and not substantiated by illustrated specimens**

Diagnosis (from Pocock & Sarjeant 1972): “Vesicle spheroidal to broadly ovoidal; wall two-layered. The vesicle divides into four sections. The main body divides into three sections of closely similar size and shape (though the antapical section may differ slightly from the two lateral sections). The apical cap is of comparable size, but differs in its possession of two "tongues" fitting into the space at the point of junction of the three main-body sections (see text-fig. 3). The surface may be psilate or faintly punctate or may be covered with closely spaced, low granules or more widely spaced, enlarged granules or short baculae (see plate 3). In psilate forms, the wall is relatively thin: the forms with more marked ornamentation are also thicker-walled”.

## *Teichertodinium triassicum* Triassic Type material

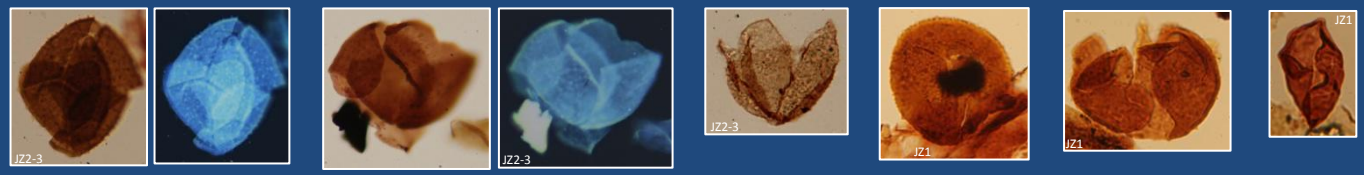



from Pocock & Sarjeant 1972



Text-fig. 3 in Pocock & Sarjeant 1972

## *Teichertodinium triassicum* from Late Triassic and Jurassic, NNS



# *Rugidinium* Pocock & Sarjeant 1972

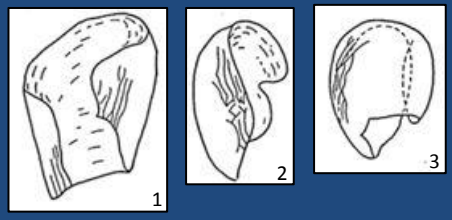
**Original diagnosis insufficient and not substantiated by illustrated specimens**

*Rugidinium undulatum*
Holotype (reoriented)

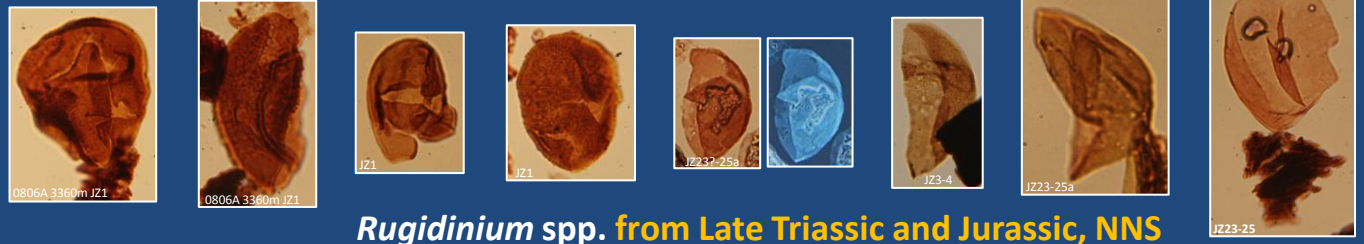
*Rugidinium ornatum*
(reoriented)

Diagnosis (from Pocock & Sarjeant 1972) "Vesicle ovoid to subespherical, dividing into three dissimilar sections. Two of these sections represent the main part of the vesicle, the third (and the smallest) forming the apical cap. Wall two-layered, the outer layer rugulose, giving the surface an overall undulose appearance. Other ornament, when present, comprises narrow anastomosing ridges, more or less paralleling the margins of the two portions forming the main part of the vesicle".

**No trilete**

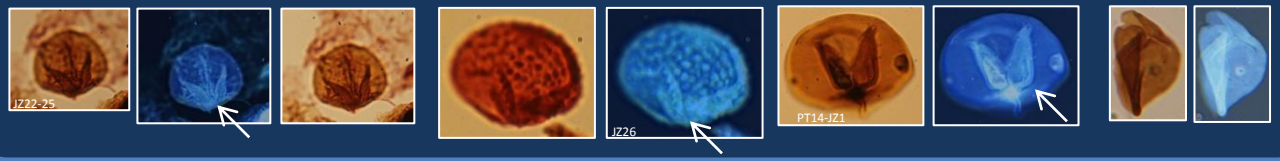


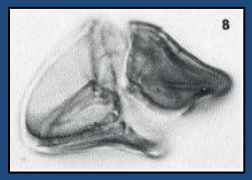

*Rugidinium ornatum*, from Fig.1 in Pocock & Sarjeant 1971. The drawings are rotated 180 degrees. Original caption reads; "*a* and *b*; larger (left) and smaller (right) sections of the main body of the vesicle". The third specimen, *c*, is captioned; "Complete main body, lacking only the apical cap".
Sub polar concavity visible in 3, undulose margin in 2.
**Note**. In the original publication the diagrams are labelled 1-3, but the caption is *a-c*.




***Rugidinium* spp. from Late Triassic and Jurassic, NNS**

## Immature ARCs in the early stages of growth. "Butterfly"

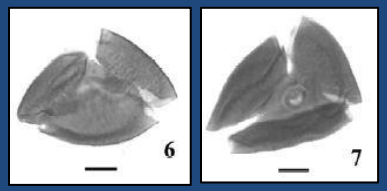


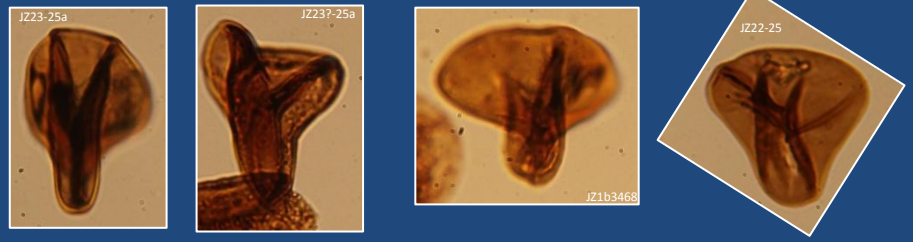
"Loose tetrad". Illustrated specimen of Richardson 1988, Pl.19, fig. 8. Late Ordovician-Early Silurian.

*Sangarella lenaensis*
Early Cretaceous

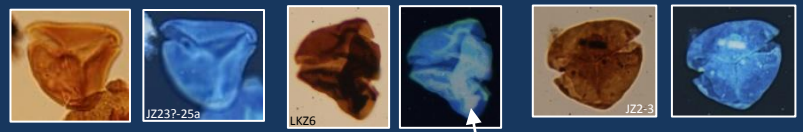
from Pestchevitskaya & Fradkina 2001



Spore Type 1 *in* Shushang Hu 2006, Pl. 22, figs 6 & 7; "spores tetrahedral trilete(?), laesurae not clear because of splitting, hilate in distal view". Cenomanian.




500µ





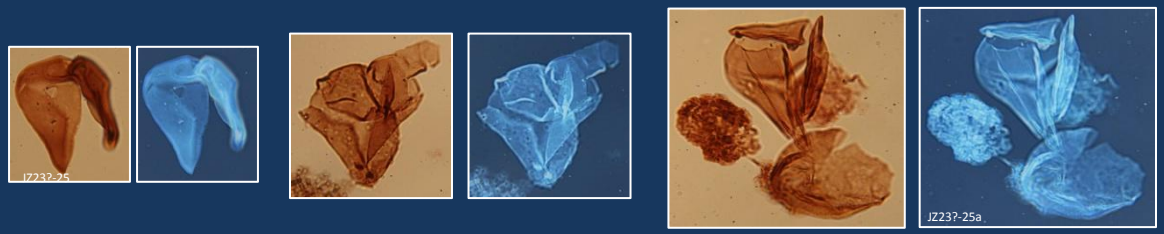
3 sections, approximately equal in size

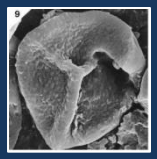
= triple junction

Isolated sections of *Teichertodinium*

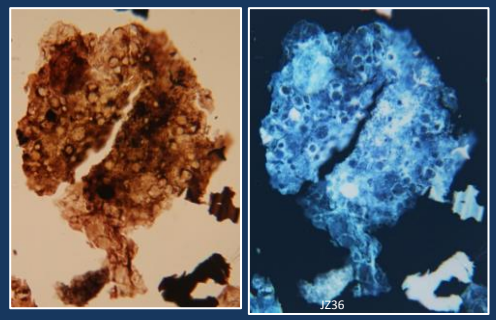
# Other varieties of spore-like attached reproductive cells


*cf. Teichertodinium*: splits but remains intact. Trilete mark present on lateral surface.

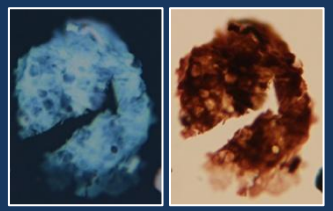


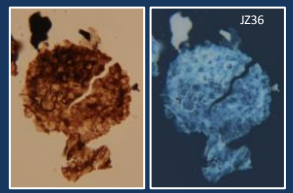



Spore of *Scylaspora*. Early Devonian. From Wellman 1999, pl.2, fig.6.

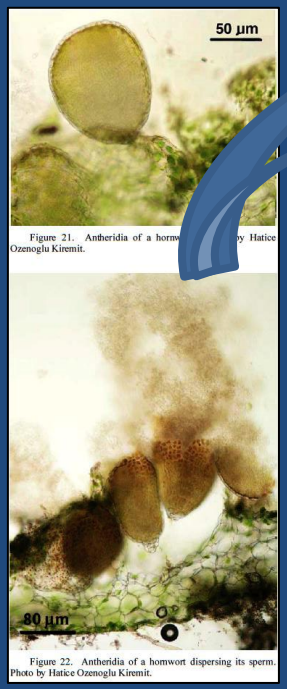



*"Schizosangarella"*

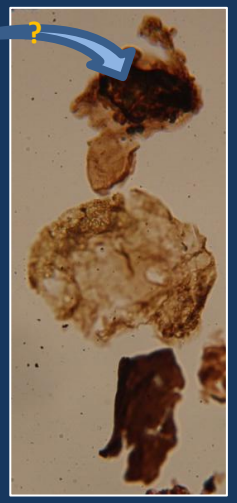


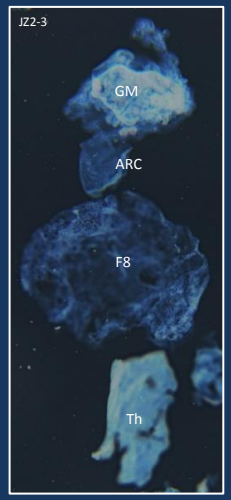


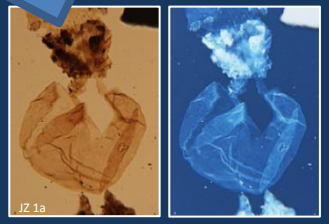
# Attached reproductive cells may be gamete-producing antheridia




From Glime et al. 2013



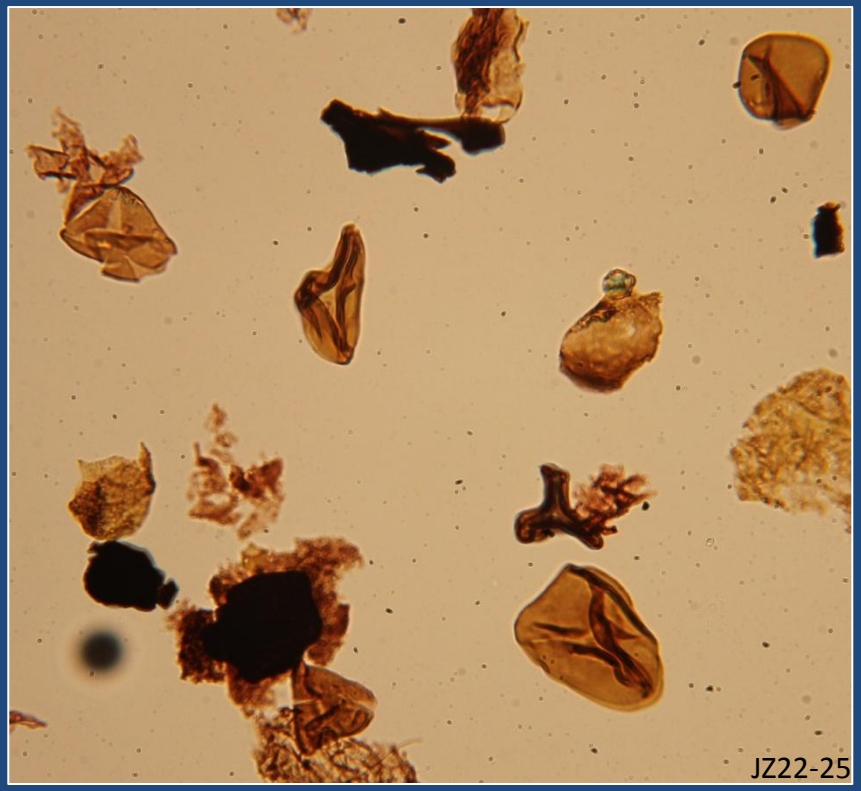



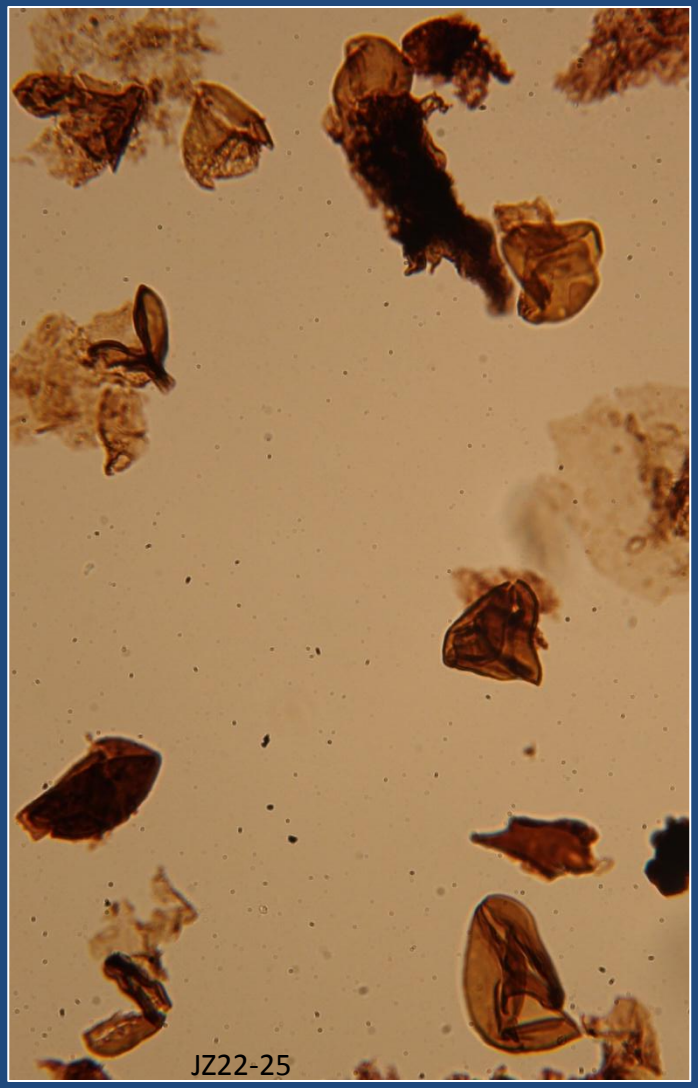

| | |
|---|---|
| ARC | Attached reproductive cell |
| F8 | F8 cell |
| Th | Thalloid cell |
| GM | Gamete mass? |

500 µ

Attached reproductive cells are abundant, diverse and widespread. With a very few exceptions, they have been completely overlooked.

Emendation of term “miospore”?
ARCs already published as spores.



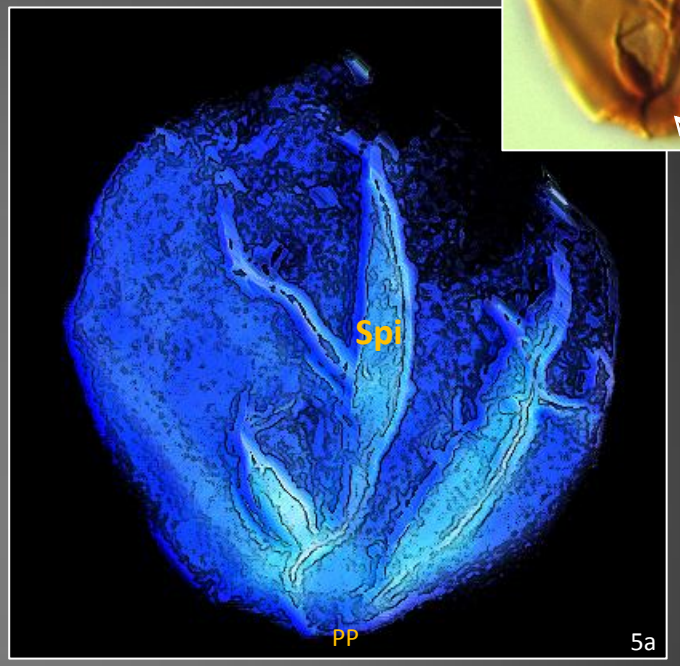

500µ

B

# “Microfolium”

Microfolium: - A “protophyte” within some miospores and acritarchs, arising from the proximal pole as branch-like elements. The microfolium exhibits growth within the expanding host cell, initially as a minute butterfly shaped structure centred on the proximal pole (1 & 2). Growth habit varies, but a common pattern is with two larger (lateral), and one smaller (central) branchlet (3). Branchlets may develop a blade-like feature similar to a spear tip (spiculum) distally (5). Some microfolia appear to “outgrow” the cell and bend sharply inwards across the distal portion of the cell (4). In most cases, the branchlets appear to be fused into the cell wall. Smaller side branches may be observed arising from primary branches (5).

**Many miospores and leiosphaerid acritarchs are microfoliate, but this feature has been overlooked, or misinterpreted as folds, kyrtomes, margos and Interadial crassitudes in spores, and as folds in leiospheres.**





*Leiosphaeridia* sp., Late Cambrian. Note the secondary branching of the microfolium and **distolateral** rupturing of the cell.

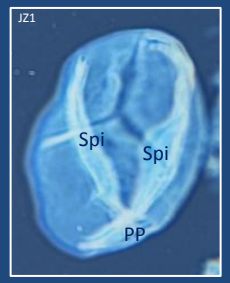




**1-4, Attached reproductive cells, illustrating cell growth and stages in the growth of the microfolium (Triassic-Jurassic, NNS).**

all x2 regular scale, except 6a at 3x

# Microfoliate miospores


*Todisporites* sp. Are Formation, Hettangian, Mid Norway. Two longer and one short branchlets. Trilete on lateral surface?



*Calamospora impexa.* Triassic. From Vigran *et al*. 2014, Fig. 26.B (reoriented) Specimen illustrates secondary branching of the microfolium.

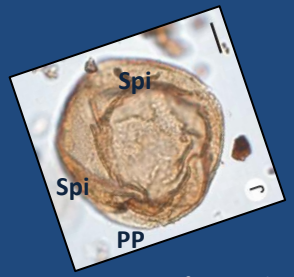

*Aratrisporites cf. minimus.* Are Formation, Hettangian, Mid Norway. Growth of the microfolium primarily axial.



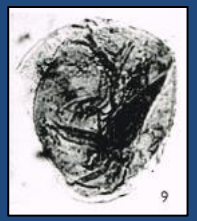
*Classopollis* chateunovi Reyre 1970. Illustrated specimen of Mildenhall 1994 (reoriented). From Raine et al.2011.

*Dictyophyllidites harrisii.* Illustrated specimen from the Type Material of Couper, 1958, pl.21, fig.5. Middle Jurassic.


*Geminospora* sp. A *sensu* Wicander & Playford 2013, Plate 5, fig. 20 (reoriented). Late Devonian, Illinois.



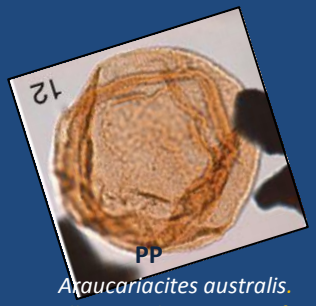

*Araucariacites cf. australis.* Illustrated specimen of Cantrill & Raine 2006 (reoriented). Taken from Raine et al. 2011. E. Jurassic.



*Perinopollenites elatoides* Holotype from Couper 1958 pl. 27, fig.9. Mid Jurassic.

*Laricoidites subcarpaticus,* polar view. Late Triassic of the Barents Sea


*Inaperturopollenites readi.* From Zhang & Grant-Mackie 2001, Fig. 24.K (reoriented)




*Araucariacites australis.* Illustrated specimen of Bonis 1983 Pl. 1, Fig. 12 (reoriented). Triassic-Jurassic transition.


*Inaperturopollenites dubius.* Illustrated specimen of Norris 1969, Pl. 110, fig 9 (reoriented).

growth


*Araucariacites australis.* Illustrated specimen of Norris 1969 Pl. 110, fig. 17 (reoriented).

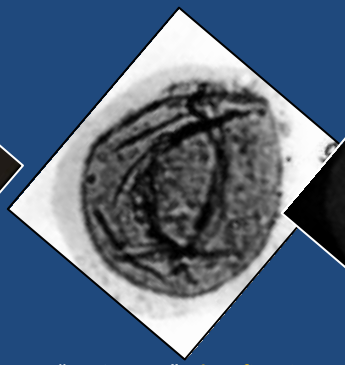
**scales vary**

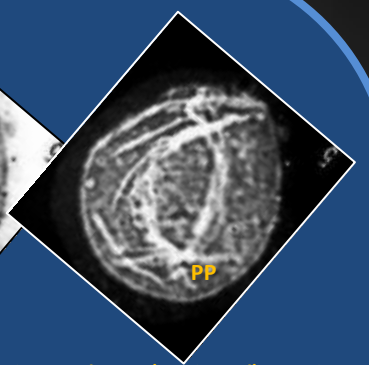
# Microfoliate acritarchs

## Attached reproductive cells?



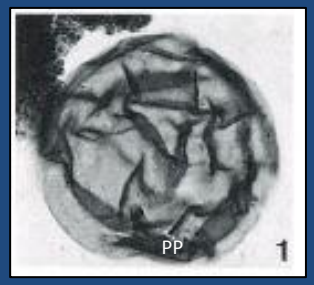
*Leiosphaeridia* sp. Mid Cambrian. Illustrated specimen of Traverse 2007, pl 6.1 fig. S (reoriented).



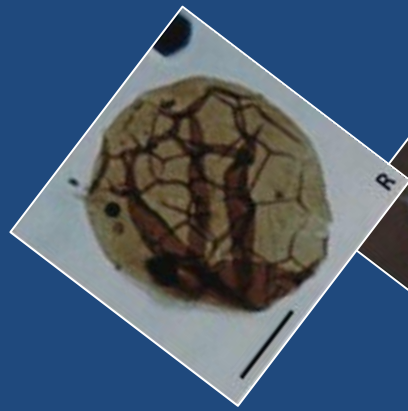


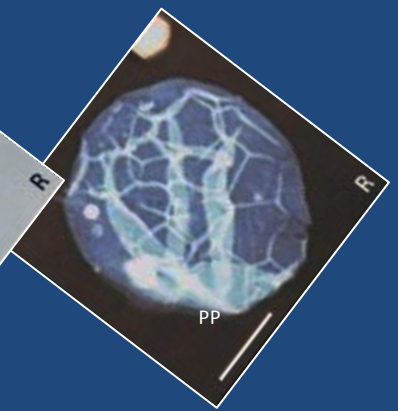

"Marine cyst". Pl 27, fig. 5 in Pocock 1970 (reoriented) Jurassic.


*Comasphaeridium molliculum* From Moczydlowska and Vidal 1988. (1521-22) at www.fossilid.info University of Talin (reoriented).



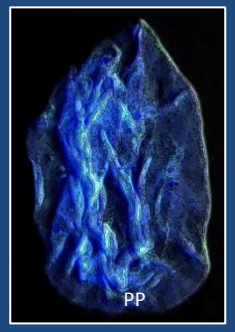

*Leiosphaeridia asperata* From Baudet 1988, Pl.2, fig.1. Precambrian, Libya.



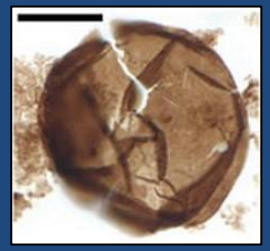



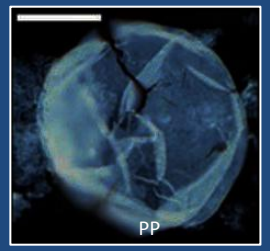

*Retisphaeridium dichamerum* Staplin et al. Middle Cambrian. Illustrated specimen of Traverse 2007, pl. 6.1 fig. R (reoriented). Three primary branchlets.

## scales vary




*Leiosphaeridia gregalis* Hagenfeldt 1989. Middle Cambrian. Illustrated specimen (1521-12) from www.fossilid.info. University of Talin (reoriented).





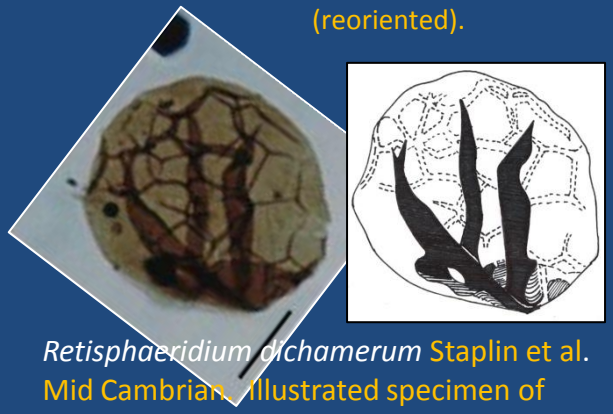

*Valeria lophostriata.* Illustrated specimen of Nagy *et al.* 2009, Figure 1.a

# Folding vs. microfolium

*Inaperturopollenites dubius*. Illustrated specimen of Norris 1969, Pl. 110, fig 9 (reoriented).

*Pareodinia ceratophora,* Jurassic dinocyst. Thin-walled, compressed specimen with numerous folds.

- No "plant-like" appearance.
- No point of convergence (PP).
- More or less uniform distribution.
- Widest in middle, pointed both ends.
- Often crossing.
- "Boomerangs" – darker mid section.

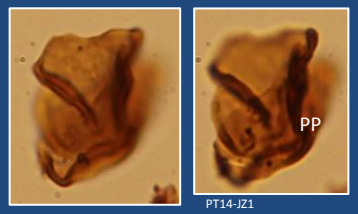


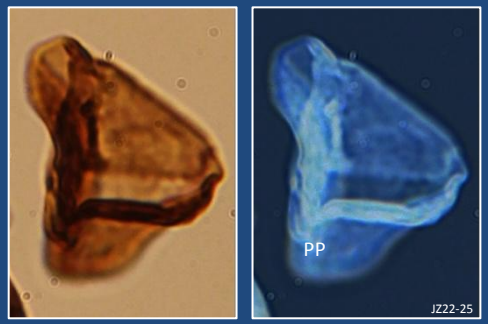
*Retisphaeridium dichamerum* Staplin et al. Mid Cambrian. Illustrated specimen of Traverse 2007, pl. 6.1 fig. R (reoriented). Three primary branchlets.

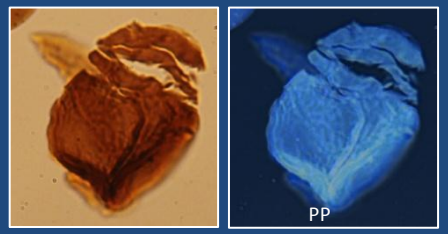
Still at an early stage, but already clear that microfolia exhibit numerous and different growth habits. These are likely to be high level criteria for systematics & taxonomy.


*Leiosphaeridia sp.* Late Cambrian, Ulgase Formation, Estonia. Illustrated specimen (1520-19) from www.fossilid.info University of Talin (reoriented).

# Microfolium: dehiscence mechanism?

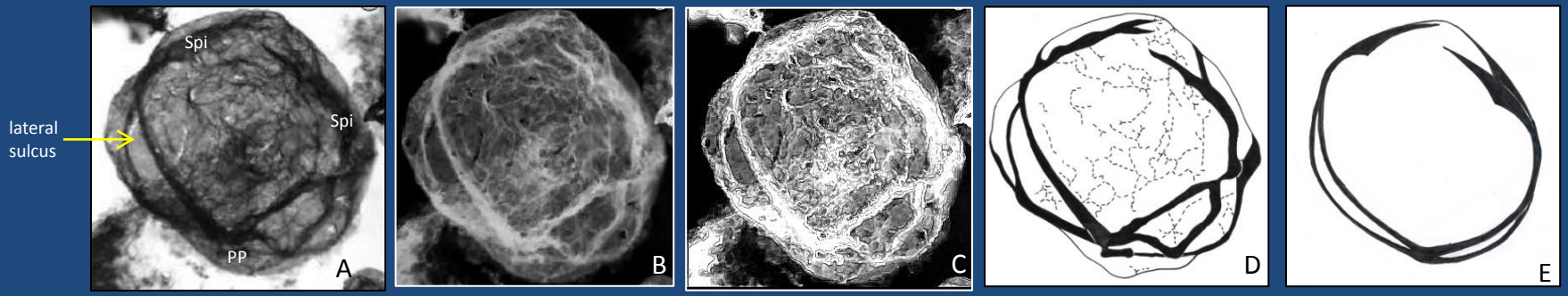




?*Teichertodinium* spp. Note how branchlets of the microfolium are fused into the cell wall

**Dehiscence** is the splitting of the cell wall at maturity along built-in line of weakness, usually facilitated by drying.

Stress might be produced by differing desiccation rates of the cell wall and the thicker branchlets. There may also be elastic energy stored in the curved branchlets.

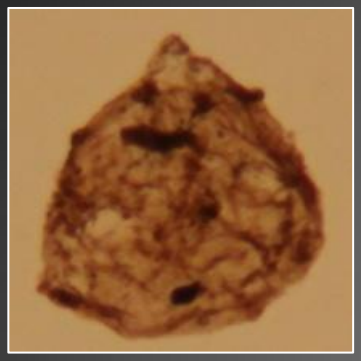


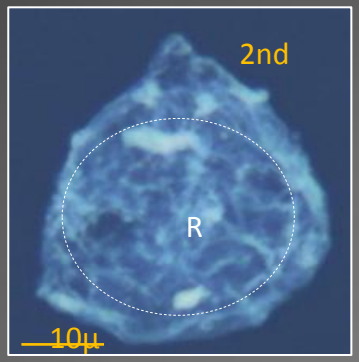

*Leiosphaeridia* sp. Cuneiform (wedge-shaped) acritarch from the Australian Mesoproterozoic. Figure 2g *in*: Knoll *et al.* 2006 (reoriented). The microfolium comprises four branchlets, two on each side. The depression between each pair forms a lateral sulcus, which is wider proximally, becoming narrower distally. **A**, original image. **B** & **C**, inverted images with different contrast. D, line drawing with interpretation of microfolium E, schematic interpretation PP = proximal pole. Spi = spiculum.

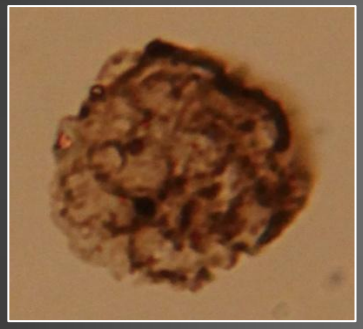
**There are even more types of reproductive cell...**

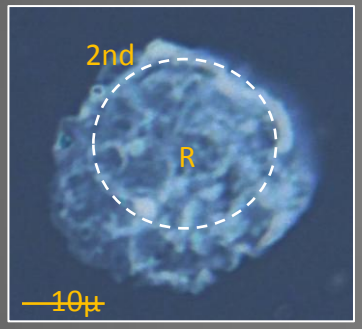
*“Sangarelladinium”*

# *"Sangarelladinium"*

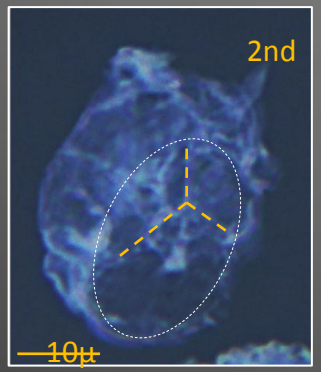











- Sub triangular to sub pentagonal, often lacrimate (teardrop) in outline. Lenticular or flattened in cross-section.
- Normally alete, sometimes indistinctly trilete.
- Curvatural thickening, with or without "rosette".
- Primary horn (polar) & secondary horn (sub polar).
- Clusters/polyads, ?diads, isolated or in short chains.
- Linkage of cells may be polar, sub-polar or lateral.
- Lateral sulcus (variable).
- Microfoliate

**These features are variable from obvious to absent!**

2nd - secondary horn; incipient to prominent

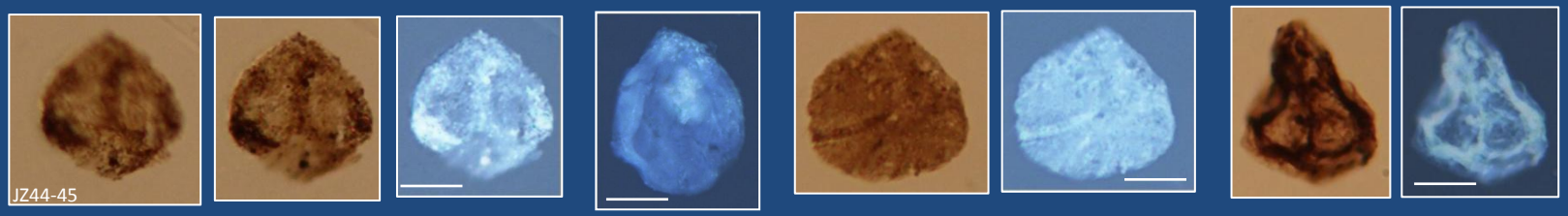
- curvatural thickening

R -"rosette"

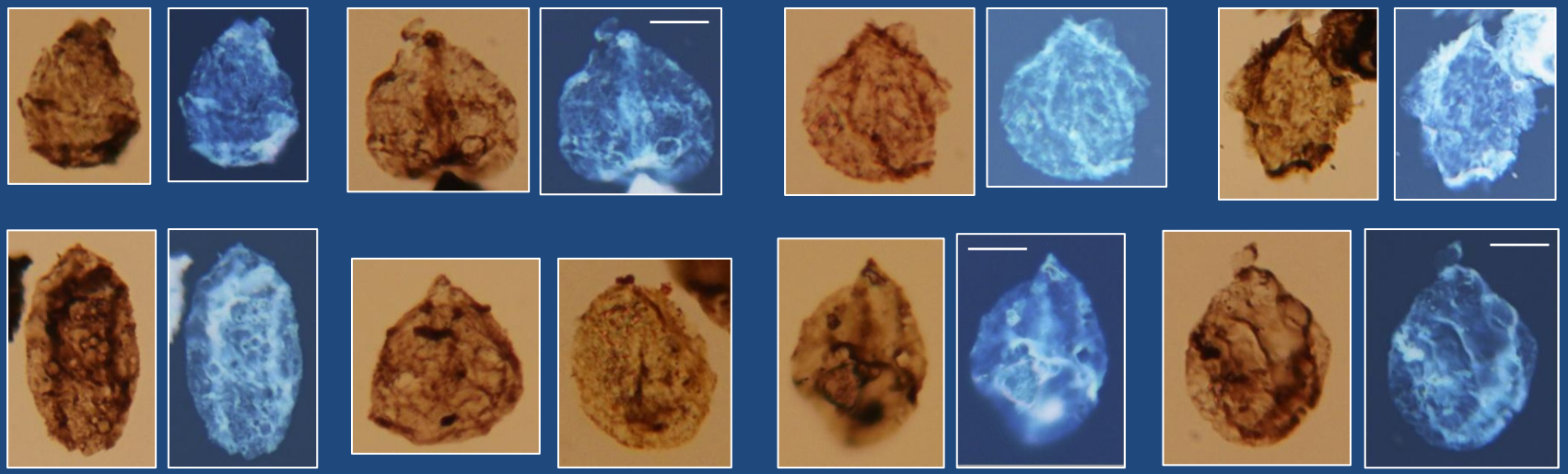
- trilete mark

# Affinity of *"Sangarelladinium"*?

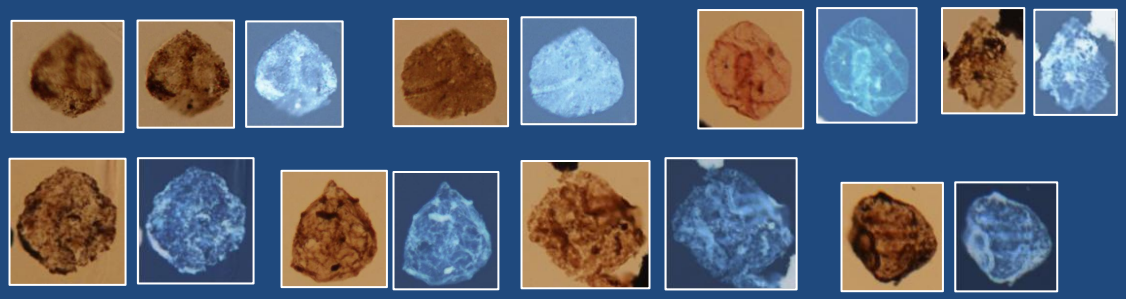
## Spore-like



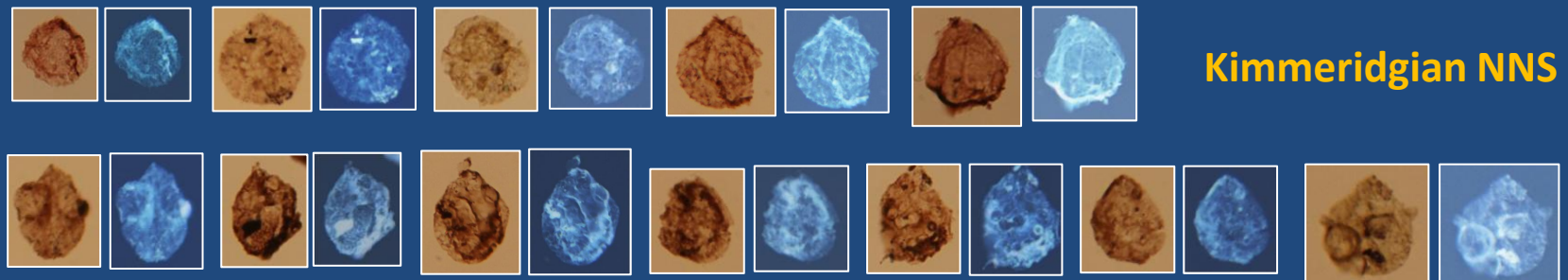

## Dinocyst-like



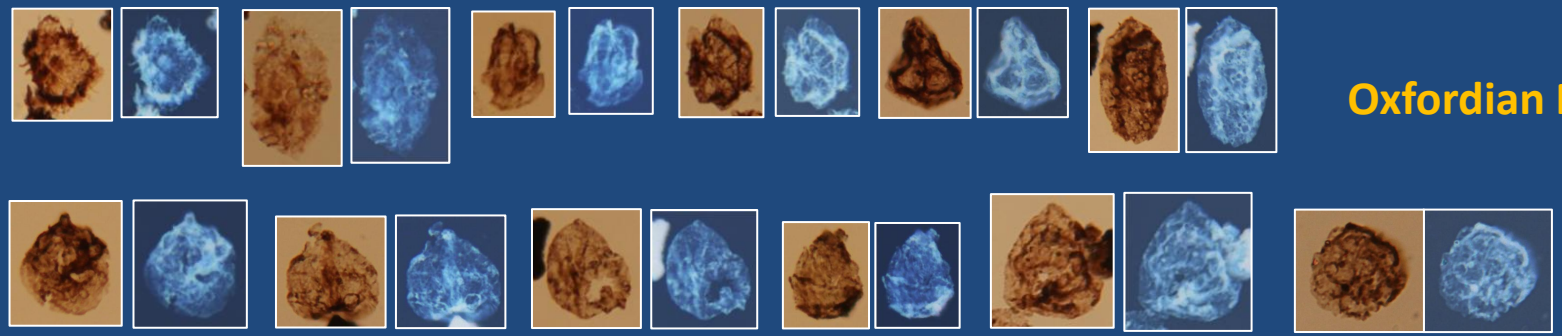
# *"Sangarelladinium"* is abundant and ?ubiquitous



Tithonian NNS



Kimmeridgian NNS

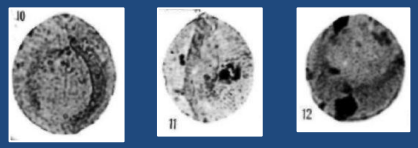


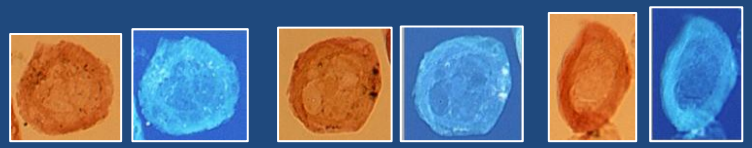
Oxfordian NNS

Also abundant, locally dominant throughout the Late Triassic to Jurassic (at least)

*"Sangarelladinium"* **has probably already been published from the Jurassic of northern Canada**

## *Leiosphaeridia granulosa* Pocock 1972

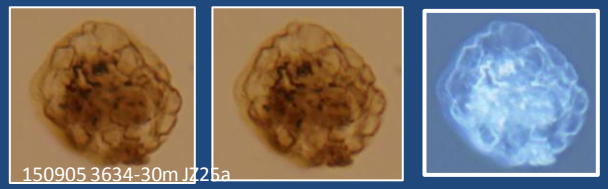




Originally logged as *Lecaniella* sp. 6. NNS JZ42-43 Early Tithonian

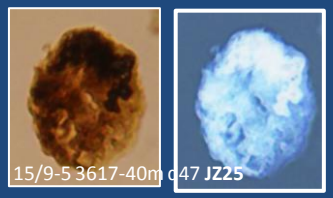
# *Pterospermopsis bulbosum* Pocock 1972

Holotype, Pocock 1972
(reoriented)

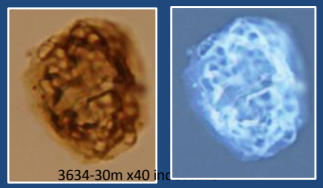


150905 3634-30m JZ25a

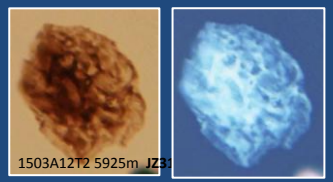
150905 3634-30m **JZ25a**



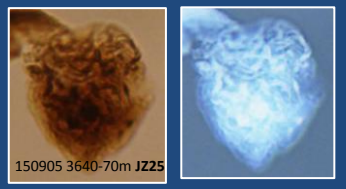
15/9-5 3617-40m c47 **JZ25**



3634-30m x40 jn



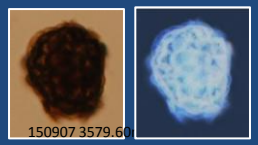
1503A12T2 5925m **JZ3**



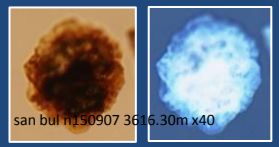
150905 3640-70m **JZ25**

san bul n150910 3098.55m JZ25

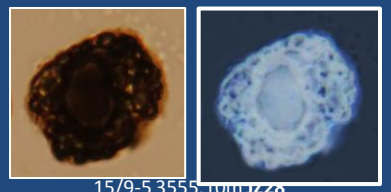
1509B04T2 6198.90m JZ25b



150907 3579.60



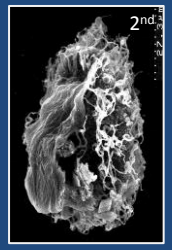
san bul n150907 3616.30m x40



15/9-5 3555.10m **JZ28**

*"Sangarelladinium bulbosum"* Middle Jurassic

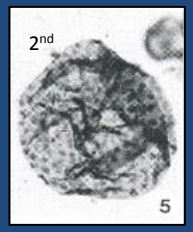
# Palaeozoic & Precambrian Acritarchs with "*Sangarelladinium*" – like features

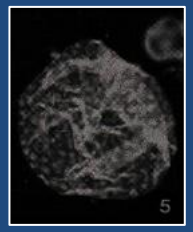




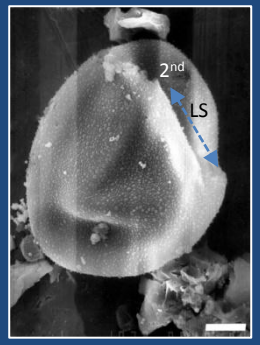
*Aryballomorpha* sp. Leetse Formation,?Tremadocian of Estonia .Note flattened ?proximal surfaces with reduced ornament and sub polar secondary horns.


*Aryballomorpha* grootaertii Martin & Leiming 1988, ?Tremadocian of Estonia

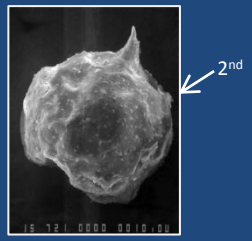



*Kildinosphaera verrucata*. Illustrated specimen of Knoll, 1996, pl.4, fig.5. Pre-Cambrian.




*Lophosphaeridium disparpelliculum* Playford & Martin 1984. Ordovician, Rapla Borehole, Estonia. Note lateral sulcus and secondary horn.

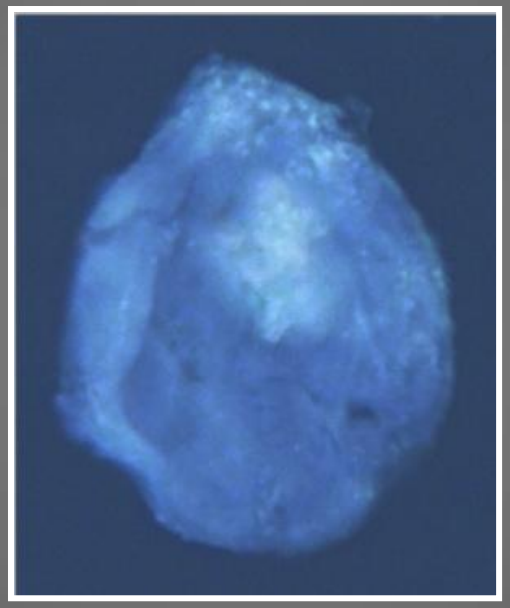



*Bacisphaeridium granulatum* Uutela & Tynni 1991. Late Ordovician, Estonia. Clearly defined secondary horn


*Leiosphaeridia*? *voigtii* Eisenack 1958 Tremadocian, Estonia. Discoidal, with "rosette" visible on facing surface.

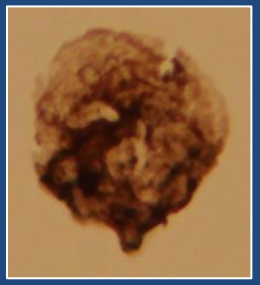
Unless indicated, all from www.fossilid.info

## So what is "*Sangarelladinium*"?



## Gemma of extant liverwort *Marchantia*


50µ approx



*"Sangarelladinium confusum"* from the Mid-Late Jurassic

**Gemmae: asexual propagules of bryophytes.**

**Minute clones propagate by vegetative growth.**

**Primitive kind of dispersed spore**

# Gemmae cups and gemmae of extant liverwort *Marchantia.*




1mm approx for gemmae cups

**Gemmae cups, - a primitive type of "open sporangium"**

## Gemmae cups of the liverwort *Marchantia polymorpha*



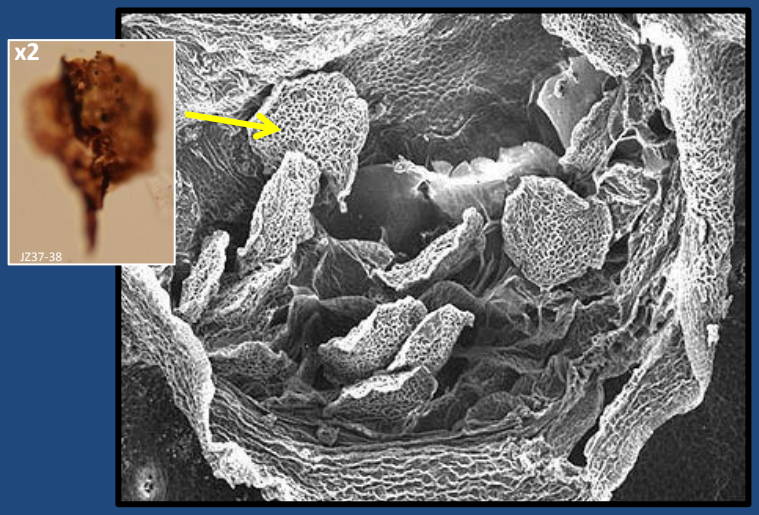


Lens-shaped

Dispersal by raindrops

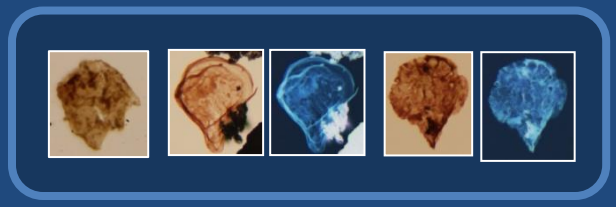
# Gemmae cups and gemmae

Gemmae cup of *Lunularia cruciata*, an extant liverwort. www.botany.ubc.ca

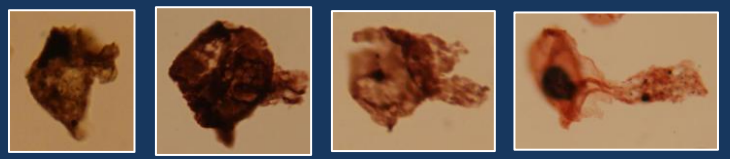



Liverwort gemmae in gemmae cup. www.ou.edu


500µ approx



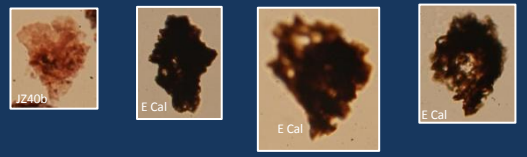
Early Jurassic, Mid Norway



Early vegetative growth of Jurassic gemmae

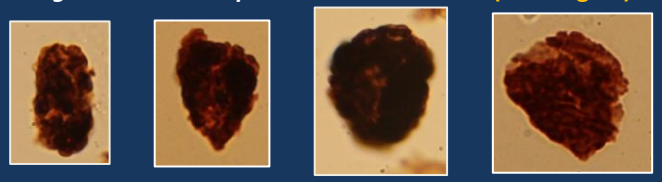
# Modern and fossil gemmae

*"Sangarelladinium"* sp. D
Heather Fm. (Late Oxfordian)





*"Sangarelladinium asperum"* Åre Formation (Hettangian)

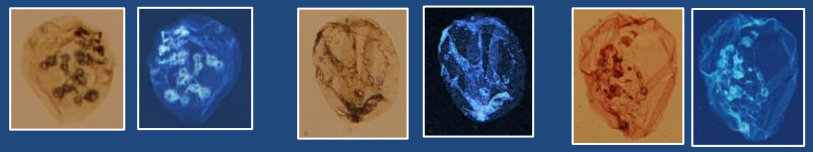


Gemmae of extant liverwort *Radula*
www.una.edu

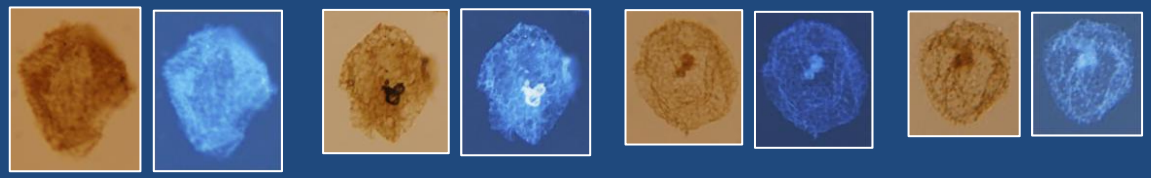
*"Sangarelladinium asperum"* Hugin & Sleipner Fm, Callovian

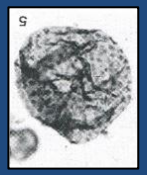
500µ

*"Sangarelladinium ignotum "* very abundant in Hugin



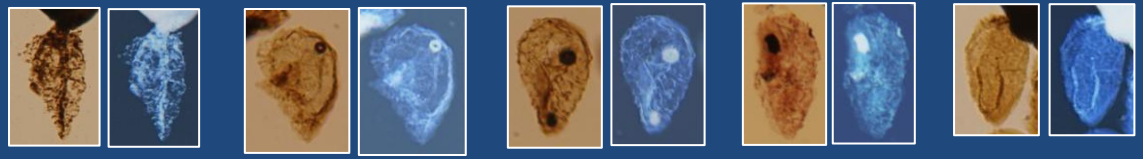
*"Sangarelladinium reticulata"* common in Callovian



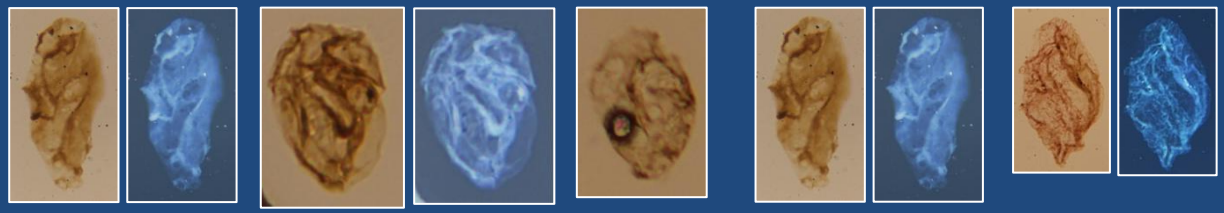


*Kildinosphaera verrucata*. Illustrated specimen of Knoll, 1996, pl.4, fig.5. Precambrian (reoriented).

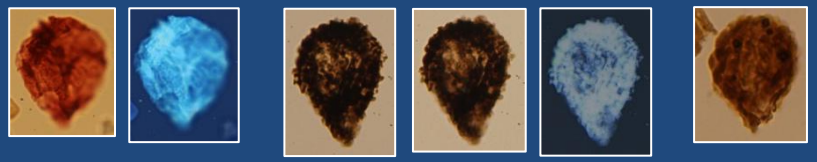
*"Sangarelladinium reticulata"* ssp. Callovian



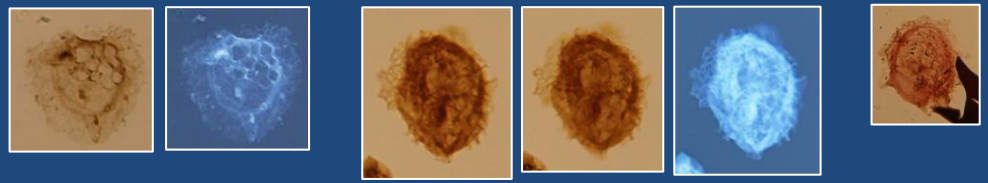
*"Sangarelladinium elongatum"* Early-Middle Jurassic



*"Sangarelladinium asperum"* Triassic-Jurassic?

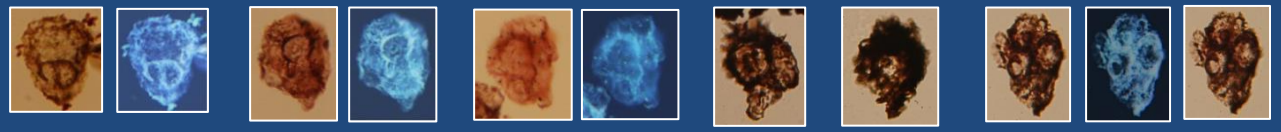


*"Sangarelladinium magnificum"* Callovian



"*Sangarelladinium*" sp. M Early Callovian

"*Sangarelladinium*" sp. K Callovian-Kimmeridgian



**Gemmae and other vegetative propagules of hepatic plants are abundant in the fossil record and probably ubiquitous in palynological samples from sediments of Mid Ordovician age and younger .**

**Many have already been published as spores, cryptospores, pollen, dinocysts and acritarchs.**

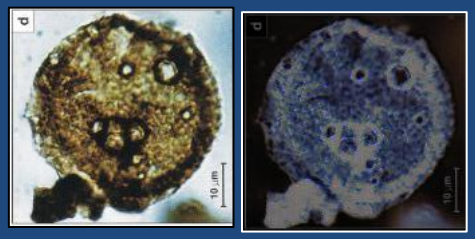
## Small selection of species and illustrated specimens

List of references available at BioStrat.org.uk/taxonomy

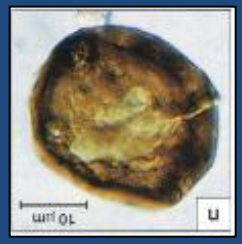
# Gemmae published as spores, cryptospores or pollen
## (all reoriented)

*Lundbladispora brevicula sensu* Awatar *et al.* 2014 (Figure 4a). Permian.

*Cyclogranisporites distinctus sensu* Awatar *et al.* 2014 , (Figure 4d) Permian

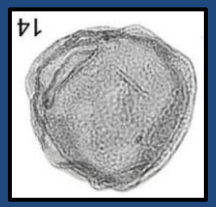


*Hispanaediscus* sp.B. Illustrated specimen of Steemans et al., 2000, pl.2, fig.d. Llandovery.



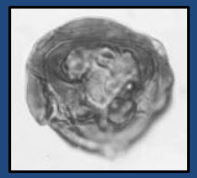
*Laevolancis chibrikovae* Illustrated specimen of Steemans et al., 2000, pl.2, fig.n. Llandovery.

?*Retialetes* sp. Illustrated specimen of Le Hérissé *et al.* 2001, Plate 2, fig. 8.



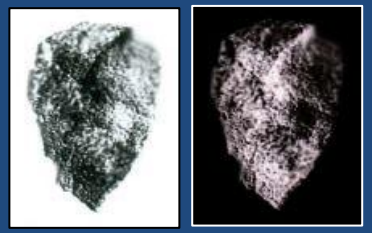
*Araucariacites punctus.* Pl. 6, fig 14, in Cornet & Traverse 1975

*Pilasporites allenii.* Illustrated specimen of Cornet & Traverse 1975 , pl. 4, fig 11.

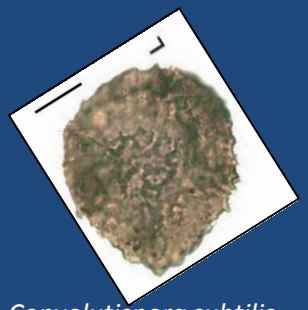


*Discisporites psilatus* Plate 12, figure A, in de Jersey & Raine 1990

*Thymospora ipsviciensis* Figure 22Q in Zhang and Grant Mackie 2001

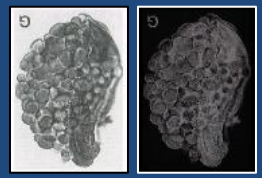


*Microfoveolatispora* sp. *sensu* Abu Hamad 2004, Pl.32, Fig 1

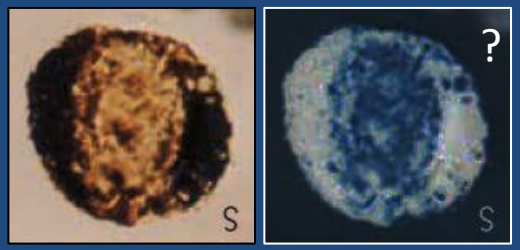


*Convolutispora subtilis*. Illustrated specimen of Noetinger & Di Pasquo, 2011, fig II L. Devonian, Argentina.

*Discisporites verrucosus* From de Jersey & Raine 1990, pl. 3, fig. J. Triassic (possible).

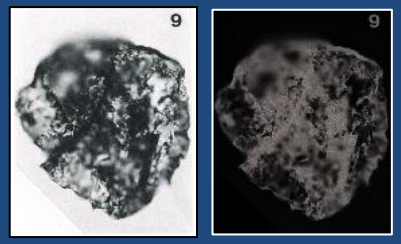


*Secarisporites lacunatus.* Illustrated specimen of Backhouse 1988, fig.16 G. Permian.



*Triadispora obscura.* Illustrated specimen of Vigren et al. 2014, Pl.10, S. Middle Triassic, Svalbard (possible).

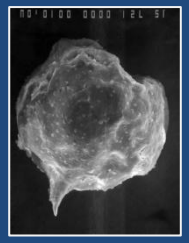
# Published as acritarchs, including pre-embryophytic. All reoriented



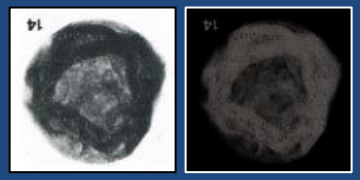
Sphaeromorph sp. Illustrated specimen of Baudet 1988, Pl.3, fig.6. Precambrian, Libya.

*Kildinosphaera verrucata*. Illustrated specimen of Baudet 1988, Pl.4, fig.5. Precambrian, NE Libya.

*Kildinosphaera verrucata*. Illustrated specimen of Knoll, 1996, pl.4, fig.5. Pre-Cambrian.



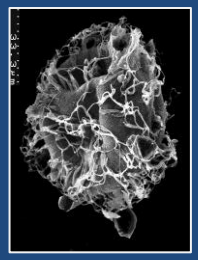
*Bacisphaeridium granulatum* Uutela & Tynni 1991. Late Ordovician, Estonia. www.fossilid.info



*Kildinosphaera chagrinata* Illustrated specimen of Baudet 1988, Pl.1, fig.14. Precambrian, NE Libya.

*Archaeodiscina* sp. Illustrated specimen of Baudet 1988, Pl.3, fig.5. Precambrian, Libya

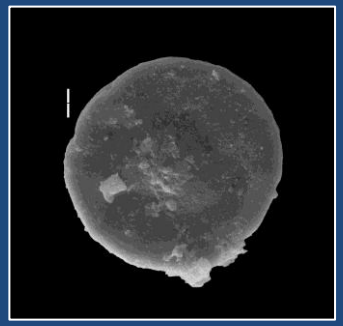
*Leiosphaeridia voigtii* Eis.1958 Tremadocian, Estonia. www.fossilid.info



*Aryballomorpha* grootaertii Martin & Leiming 1988, ?Tremadocian of Estonia www.fossilid.info

*Lophosphaeridium disparpelliculum* Playford & Martin 1984. Ordovician of Estonia. Note lateral sulcus and secondary horn. www.fossilid.info

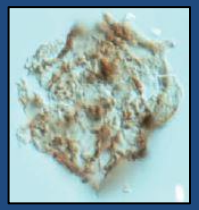
*Aryballomorpha* sp. Leetse Formation,?Tremadocian of Estonia .Note flattened ?proximal surfaces with reduced ornament and sub polar secondary horns. www.fossilid.info



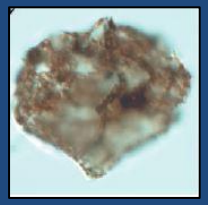
*Leiosphaeridia*? *voigtii* Eisenack 1958 Tremadocian, Estonia. Discoidal, with "rosette" visible on facing surface. www.fossilid.info

see also Strother *et al.* 2011

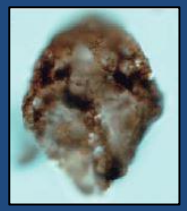
# Published as Dinocysts



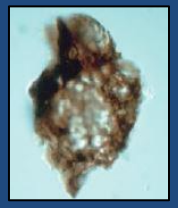
*Heibergella cf. salebrosacea sensu* Ghasemi-Nejad *et al.* 2008, Pl. 3, fig. 1 (reoriented). Late Triassic.



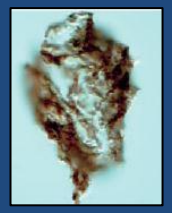
*Heibergella cf. salebrosacea sensu* Ghasemi-Nejad *et al.* 2008, Pl. 3, fig. 3 (reoriented). Late Triassic.



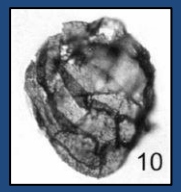
*Heibergella* sp. *sensu* Ghasemi -Nejad *et al.* 2008, Pl. 3, fig. 1 (reoriented). Late Triassic.



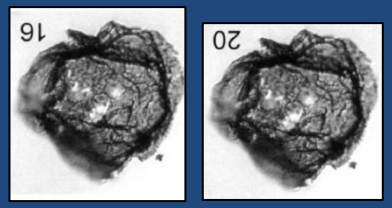
*Svedrupiana cf. septentrionalis sensu* Ghasemi-Nejad *et al.* 2008, Plate 2, fig. 7 (reoriented). Triassic.



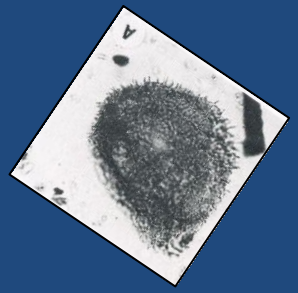
Genus indet. A morphotype 1 *sensu* Ghasemi-Nejad *et al.* 2008, Pl. 3, fig. 1 (reoriented). Late Triassic.




*cf. Noricysta pannucea sensu* Honchuli & Frank 2000, Plate 2, figs 16 & 20. Triassic



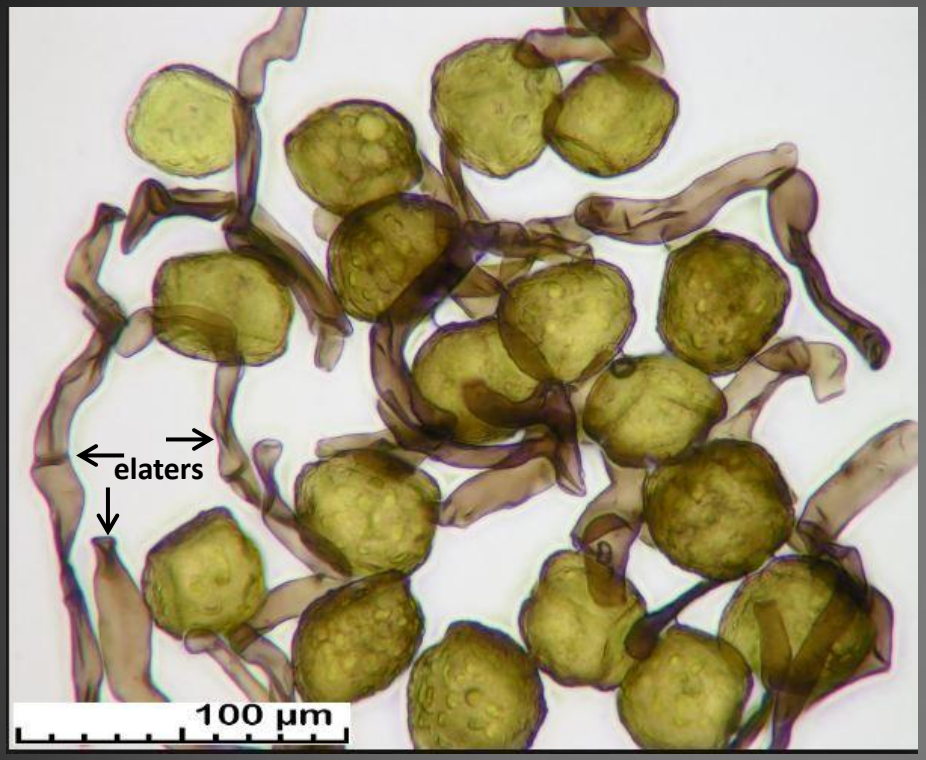

Indeterminate palynomorph , ?dinoflagellate cysts (37 microns). Illustrated specimen of Honchuli & Frank 2000, Plate 2, figs 16 & 20

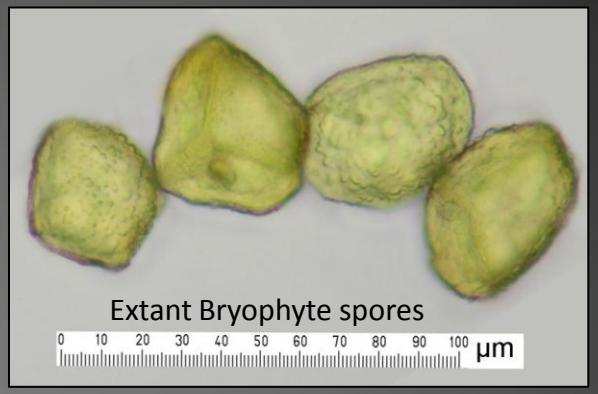



*Serjeantia triassica.* Illustrated specimen of Conway & Cousminer 1983, figs.1A&B . Triassic, Israel.

# Hepatic plants may produce gemmae AND dispersed spores

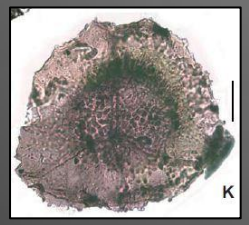
**Bryophytic dispersed trilete spores have similar shape to gemmae; lenticular x-section, radial asymmetry & sub polar horn**






*Samarisporites triangulatus*. Illustrated specimen of Noetinger & Di Pasquo, 2011, fig IV C. Devonian, Argentina.




*Grandispora protea*. From Noetinger & Di Pasquo, 2011, fig III K. Devonian, Argentina.

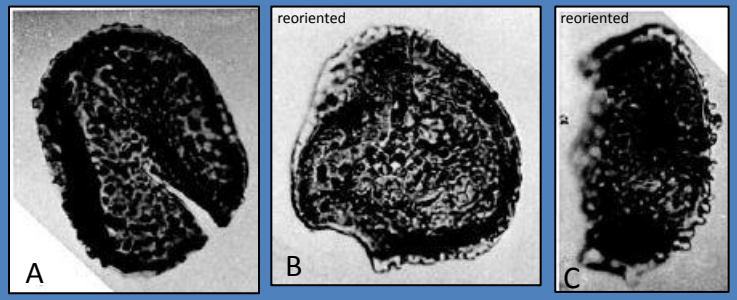

*Uvaesporites sp.* Illustrated specimen of Vigren et al. 2014, Pl.4, L. Middle Triassic, Svalbard.


*Thomsonisporites undulatus.* Illustrated specimen of Vigren et al. 2014, Pl.10, I. Middle Triassic, Svalbard.

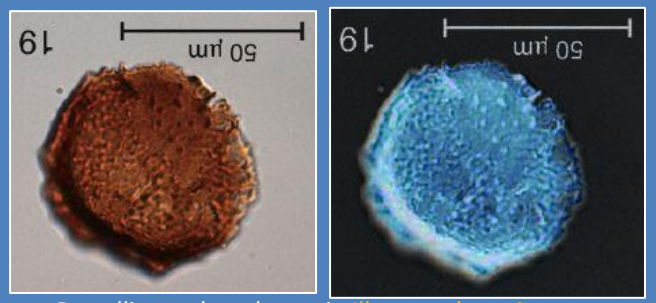
*Discisporites verrucosus* From de Jersey & Raine 1990, pl. 3, fig. J. Triassic

# Gemma or spore? Does it matter?

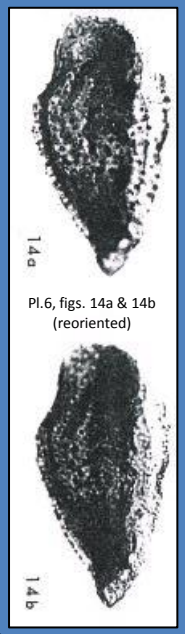
## *Porcellispora longdonensis* (Clark 1965) Scheuring 1970 emend. Moreby 1975



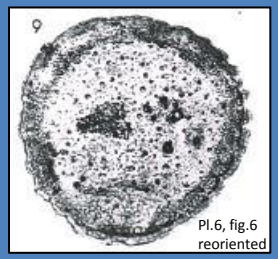

Figured specimens from the type material, including holotype (A). Lateral view (C). From Clark 1965, pl. 36, figs. 1, 3 & 4 respectively.



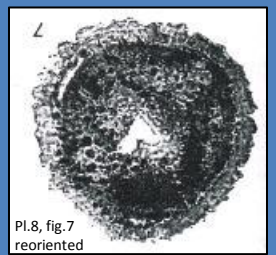

*Porcellispora longdonensis*. Illustrated specimen of Bonis 1983, pl. II, fig.19 (reoriented). Rhaetian.




Pl.6, figs. 14a & 14b (reoriented)



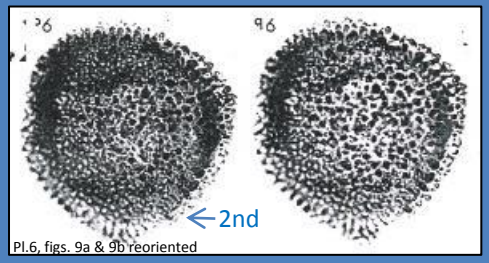

Pl.6, fig.6 reoriented



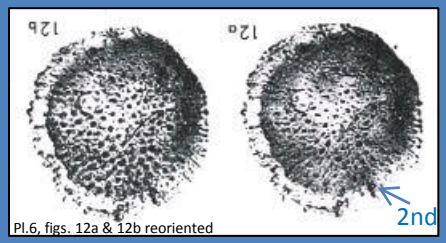

Pl.8, fig.7 reoriented


Pl.6, fig.8

*Porcellispora longdonensis*, - figured specimens of Moreby 1975 (individually labelled plate numbers). Note the sub polar secondary horn (2nd) visible in figures 9 and 12.

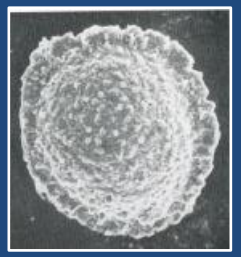



Pl.6, figs. 9a & 9b reoriented




Pl.6, figs. 12a & 12b reoriented

Emended diagnosis includes "proximally hilate, occasionally trilete", "zonate or cinguli-zonate", "amb convexly triangular to circular", and "Proximal profile flat to convex, distal profile convex" (Moreby 1975, p. 23).



"Spore of *Naiadita*", a Triassic hepatic. Abundant and well preserved macrofossils, with gemmae cups (gemmae not mentioned). Figure 5.16 in Taylor & Taylor 1993, page 141. "contain spores in tetrahedral tetrads" and "lens shaped"

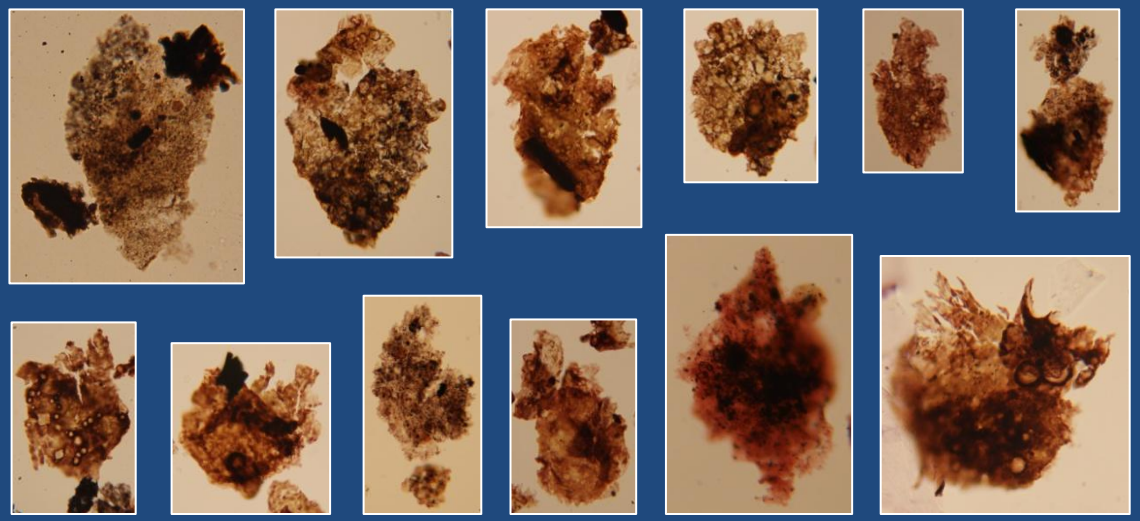
**Orientation of hepatic spores?**

# Caducous vegetative propagula of bryophytes

**Bulbils, turions, tubers, leaf buds, adventitious branches , gemmae (pars).**

**Even randomly broken non-specialised fragments may regenerate.**

**Hugin-Sleipner Formation (Callovian) SVG**



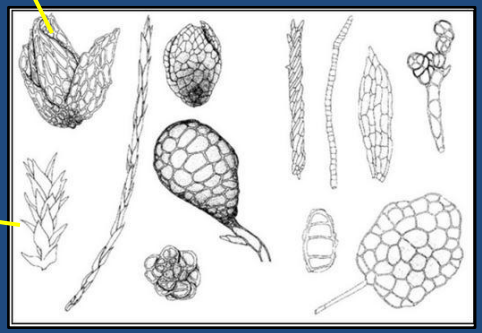
**Draupne Formation (Kimmeridgian), SVG**

## Bulbils?


***Brynum dichotomum* bulbil from leaf axil Fig 93 in Glime 2014.**

## Caducous buds?

**Late Triassic-Jurassic NNS**

**Propagula and gemmae of selected bryophytes. Figure 74 in Glime 2014 (redrawn from Imura and Iwatsuki 1990).**

**All have similar strategy and same outcome as dispersed spores.**
**Should we include all/some in miospores?**
**Some already are!**

## Should “Miospore” be replaced by “Diaspore”?

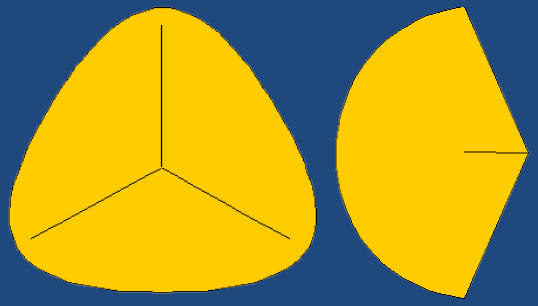
Glime 2014....“spores and other propagules that function in dispersal”

# Diaspores

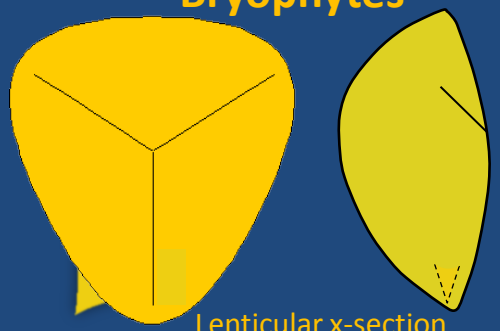
## Pteridophytes & Lycophytes

## Bryophytes

**Dispersed**



Radial symmetry, trilete



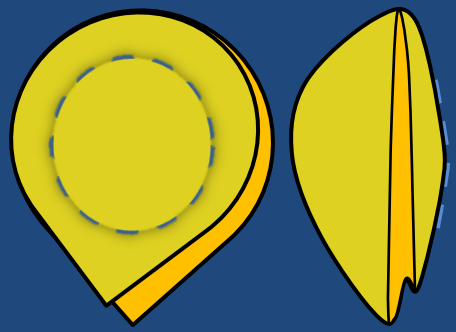
Lenticular x-section
no radial symmetry, trilete

## Bryophytes & Cryptospores?

## Gemmae

## Bulbils, tubers etc.

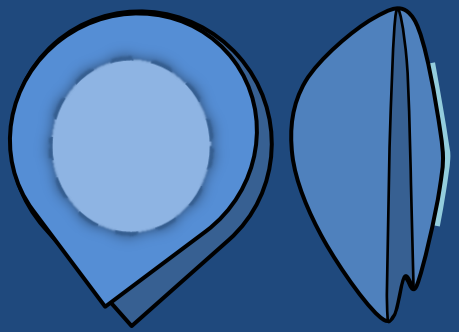
**Caducous**



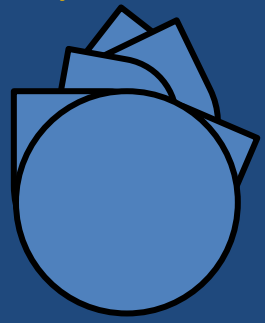
Lenticular: alete/hilate

?

=



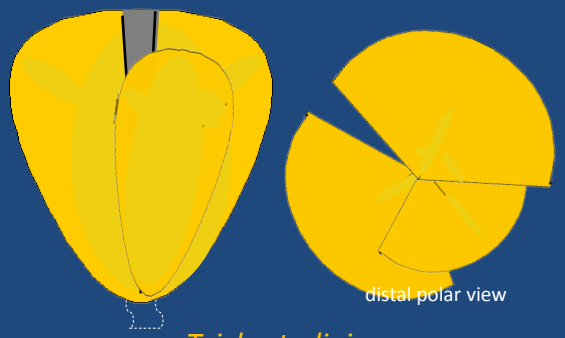
Lenticular: alete/hilate



Other vegetative propagules

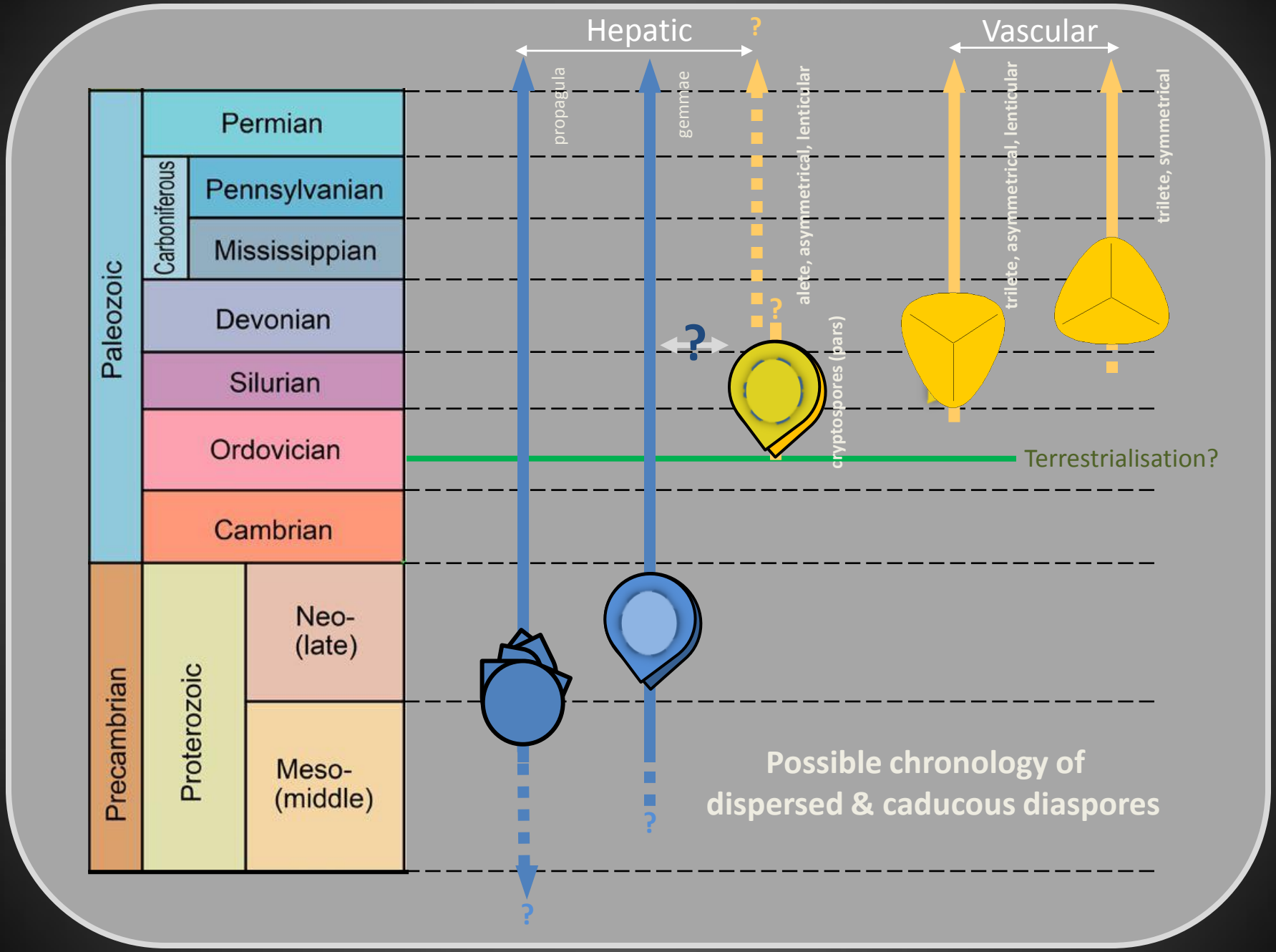
**Attached**

*"Schizosangarella"*




*Teichertodinium*


Other dehiscence?


Hepatic
?
Vascular
propagula
gemmae
alete, asymmetrical, lenticular
trilete, asymmetrical, lenticular
trilete, symmetrical
cryptospores (bars)
?
?
Terrestrialisation?
Paleozoic
Permian
Carboniferous
Pennsylvanian
Mississippian
Devonian
Silurian
Ordovician
Cambrian
Precambrian
Proterozoic
Neo-
(late)
Meso-
(middle)
?
Possible chronology of
dispersed & caducous diaspores

# Conclusions

Attached reproductive cells are common in many palynological samples, but have almost exclusively been misidentified as dispersed spores.

The Microfolium is a high level taxonomic criterion of certain diaspores that has been so far completely overlooked.

Gemmae and other vegetative propagules of hepatic plants are abundant in the fossil record and nearly ubiquitous in Mid Ordovician and younger sediments.

Many have already been published as pteridophytic and lycophytic spores, cryptospores, pollen, dinocysts and acritarchs. Need to reassess their affinities.

Macrofossils of the earliest land plants are uncommon, so fossil gemmae offer a great opportunity for further advancement in the understanding of the phylogeny of early embryophytes, together with the evolutionary steps that enabled colonisation of the terrestrial environment during the Lower Palaeozoic.

Some pre-embryophytic acritarchs have gemmae-like morphology; -ancestral algae? or earlier terrestrialisation (Strother *et al.* 2011).

Emendation/replacement of the term miospore?