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BioStrat
Stratigraphic Consultancy

Recognising the full range of morphological variation in microspores produced by a single fossil plant species in dispersed assemblages; new observations from the Sleipner Formation (Middle Jurassic) of the North Sea.

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Palaeo7

Morphological variability of reproductive cells produced by a single plant species.

- Numerous palaeobotanical studies have highlighted the wide morphological variation in microspores produced by a single parent species
- Not fully addressed by the palynological community

Main causes of morphological variation

- Late ontogenetic development prior to dispersal (e.g. fern spores)
- Other types of cell growth/development in spore-*like* cells with uncertain affinities
- Rupture of cell wall during germination/dehiscence

Ontogenetic **D**evelopment **S**tages

Diez *et al* 2005 Examined spores from variably mature fern sporangia (Albian).

Each contained a population of equally mature microspores, corresponding to the maturity of the sporangium.

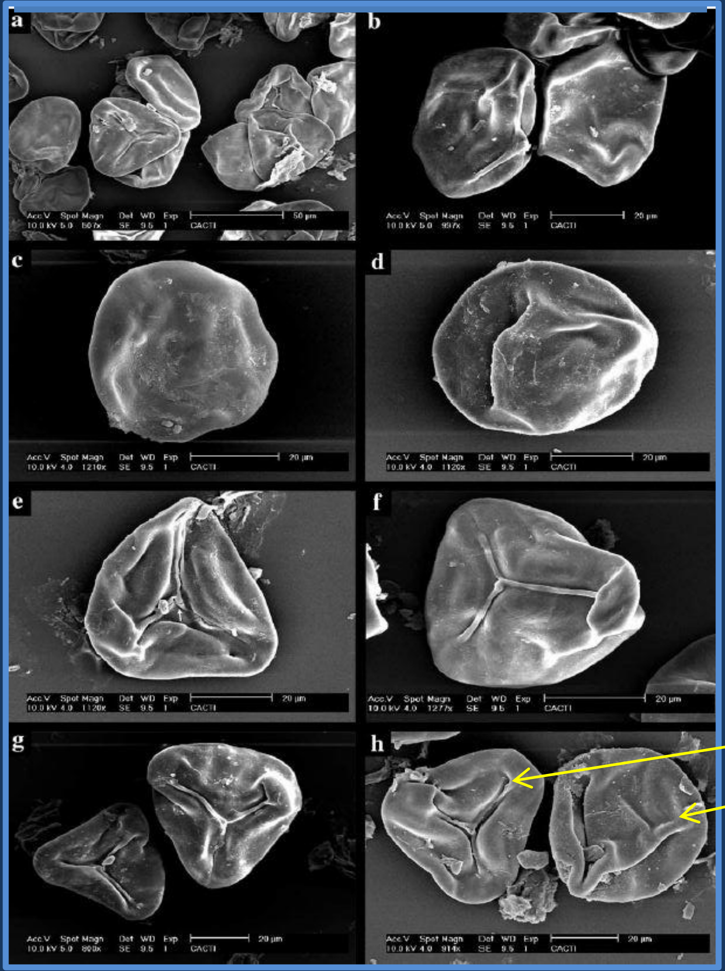
ODS1 = immature
ODS2 = maturing
ODS3 = mature = dispersal

Diez *et al* 2005 Plate III

ODS1

ODS3

ODS3



ODS1 = discoid, alete

ODS2

ODS2 –ODS3

ODS3 = triangular, trilete

ODS2

Applied here, but only loose equivalents

Maturity of reproductive cells in dispersed assemblages

Generally assumed to be fully mature prior to dispersal.

In some terrestrial environments, large quantities of immature and maturing forms may be released by weathering and erosion processes.

If transportation from source is minimal, then microfloras recovered from these sediments can include substantial amounts of immature forms.

In addition, many cells are preserved still linked in life position to other reproductive cells or plant cell structures

Small numbers of immature & maturing microspores likely to occur in most assemblages. Proportional to distance offshore?

= immature spores

Identifying the range of variability in reproductive cells from a single plant in dispersed assemblages

Evidence from

- ❑ Cells linked in life position
- ❑ Life cycle
- ❑ Internal structure

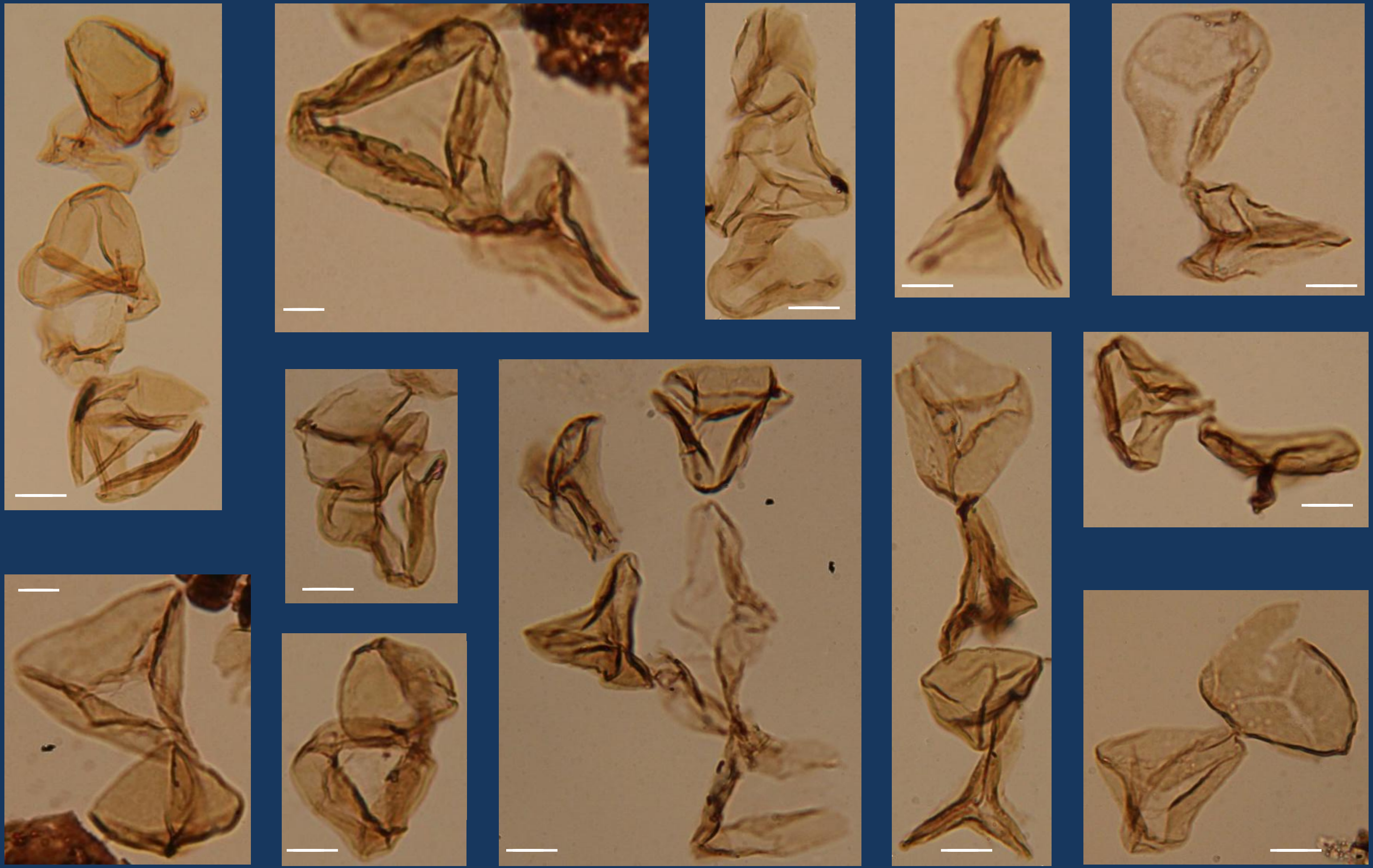
Cells linked in life position: - to other reproductive cells

linked to dissimilar cells - maturity?

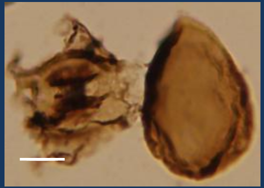
variety of linkage types

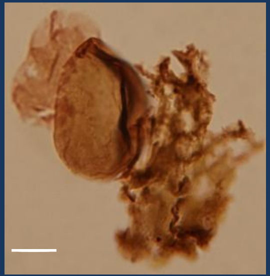
life cycles?

scale bars all 20µ

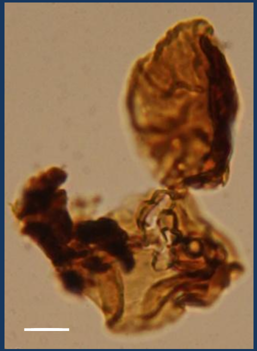


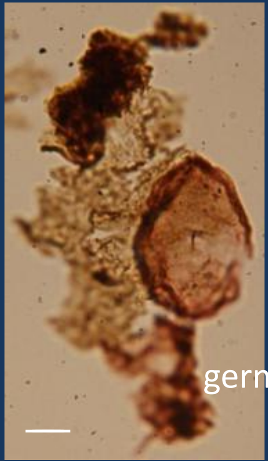
- cells linked to thalloid cell structures – diversity of life cycles





Todisporites

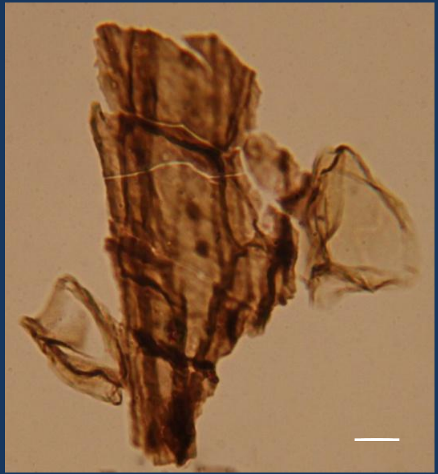




germinated?

single cell

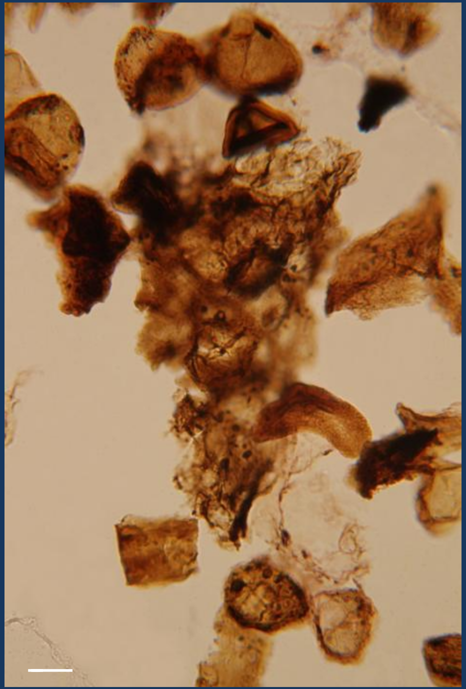
bar = 20µ

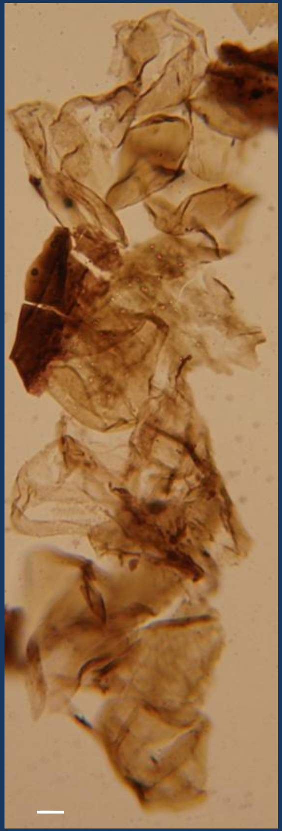


multiple cells - ?gemmae

Remnant plant reproductive structures

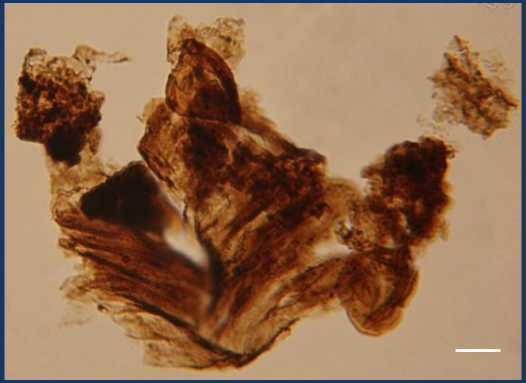
- Fern sporangia with attached spores

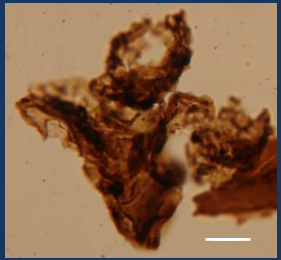




bar = 20µ

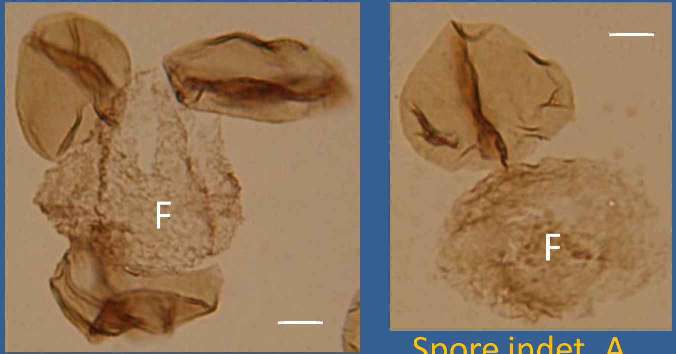
- Unknown fruiting structures; possible liverwort with gemmae?





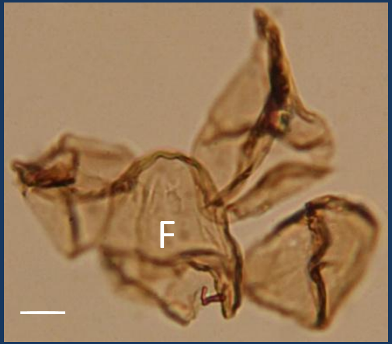
Different life-cycles

- Spore-like cells linked to “fruiting” cells



Spore indet. A

equally mature



equally mature

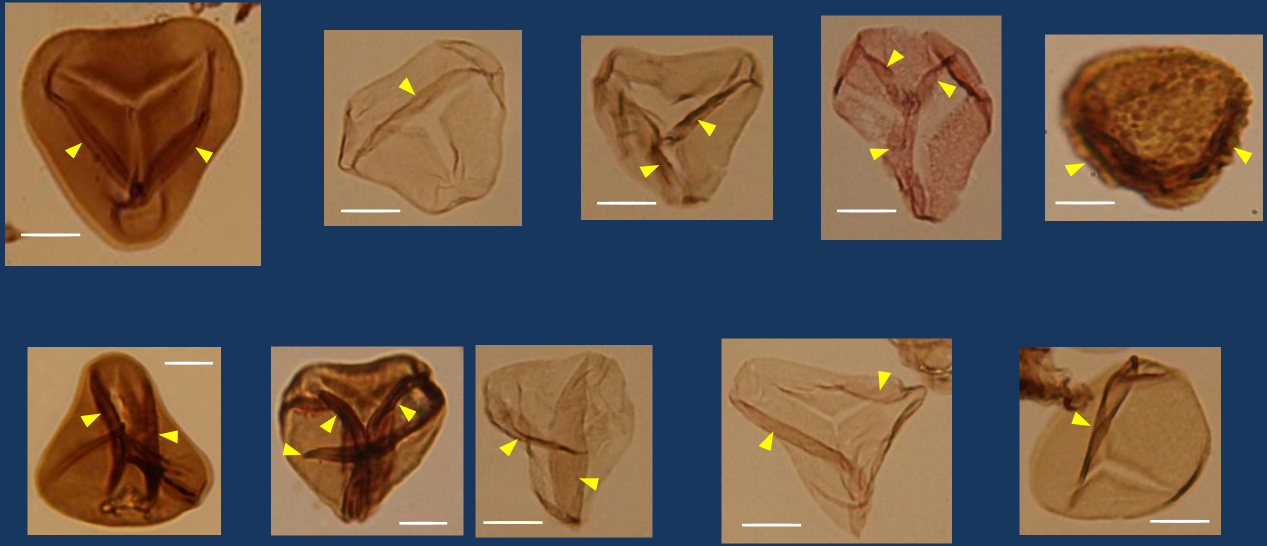
bar = 20µ

variably mature

- ❖ Linked cells give a direct match, but relatively rare to get such excellent preservation
- ❖ Interpretation of varied life-cycles requires botanical expertise

More widely applicable evidence

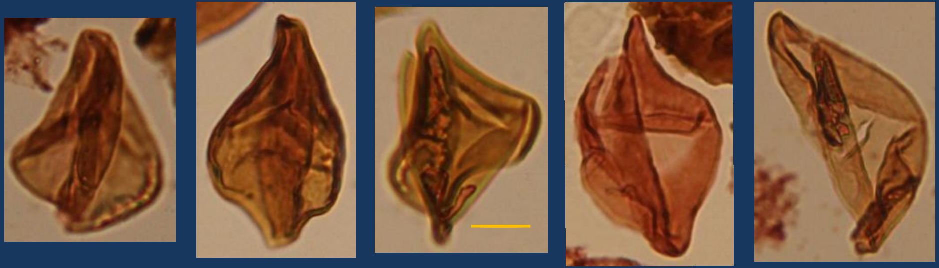
Evidence from internal structure



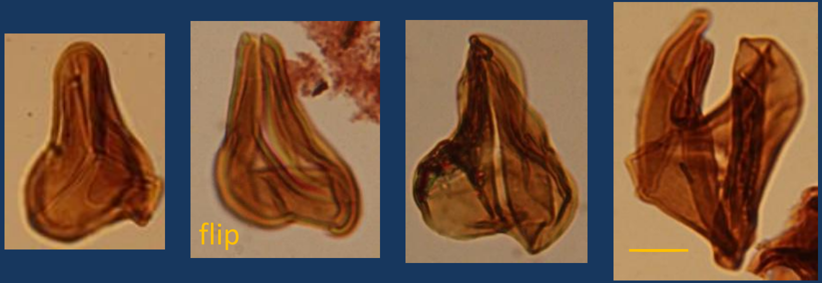
Normally treated as compressional folds

bar = 20µ

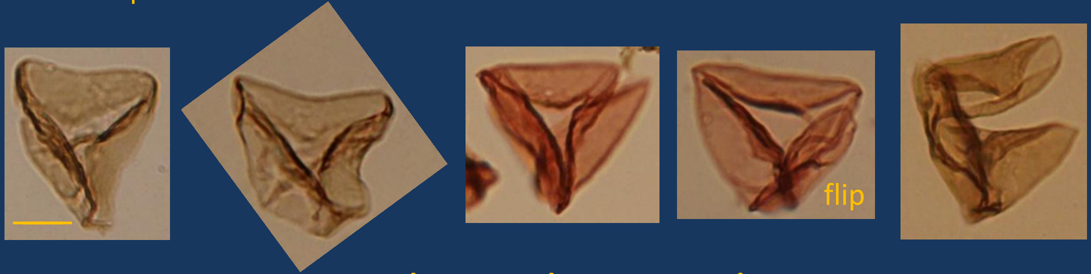
NOT
compression folds



Features are related to internal structure and development/ growth of the ?spore (-like cell)



bar = 20µ



increasing maturity →

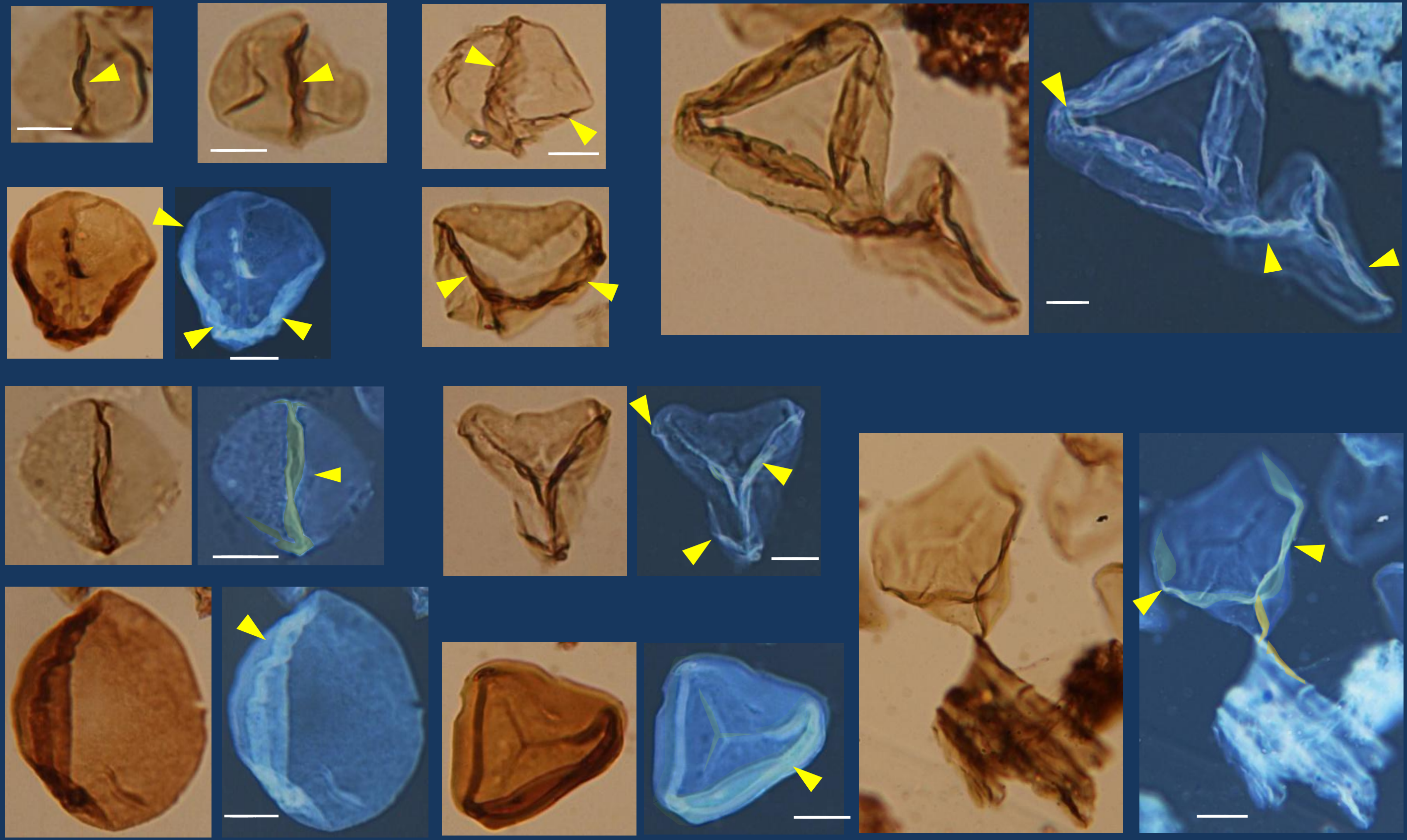
Also related to germination/dehiscence.

More evidence:-

The case against compressional folding

- Twisting axial growth
- Scrolling
- Continuous with external connective elements
- Complexity of form
- Consistency of form

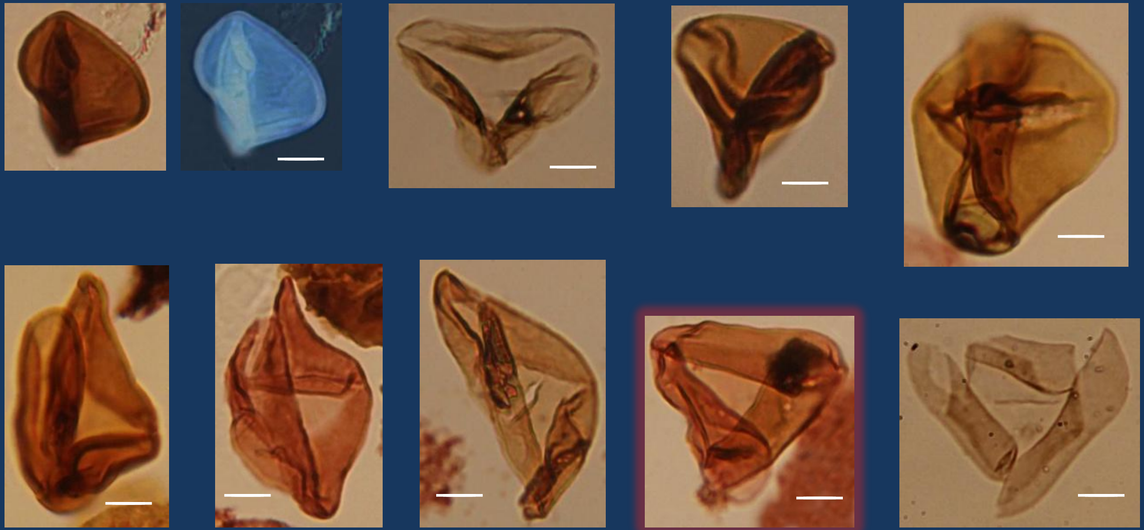
Twisting axial growth



bar = 20µ

Individual elements twisted along direction of growth, or two elements around a common axis

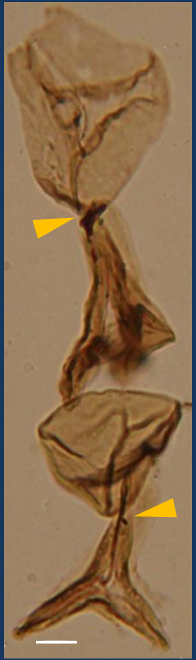
- Scrolling



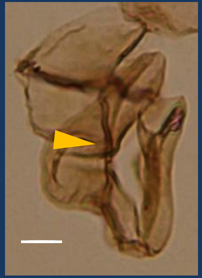
bar = 20μ

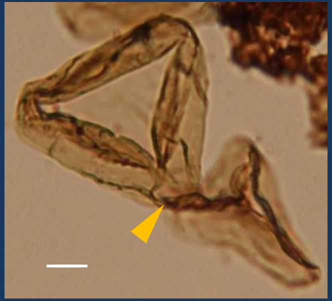
▪ Continuous with external connective elements -

- which extend through the cell wall, connecting with similar features in adjacent reproductive cells.

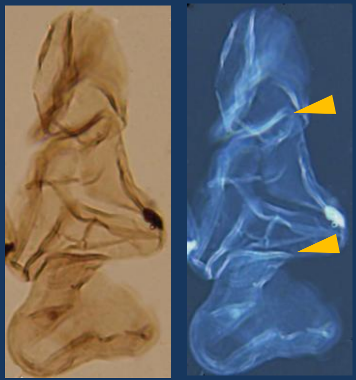


bar = 20µ

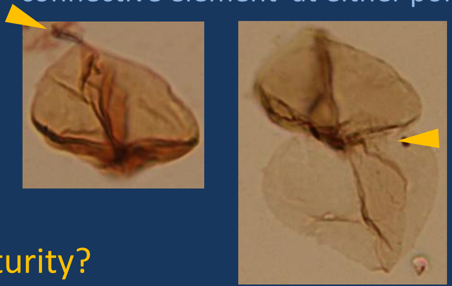




shared between 2 cells



Axial structure extends into connective element at either pole

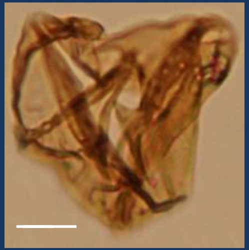


Adjacent cells often very dissimilar, - different maturity?

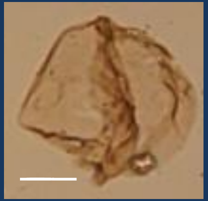
Complexity of form

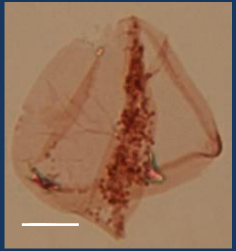
overall structure

axial twisting



individual elements



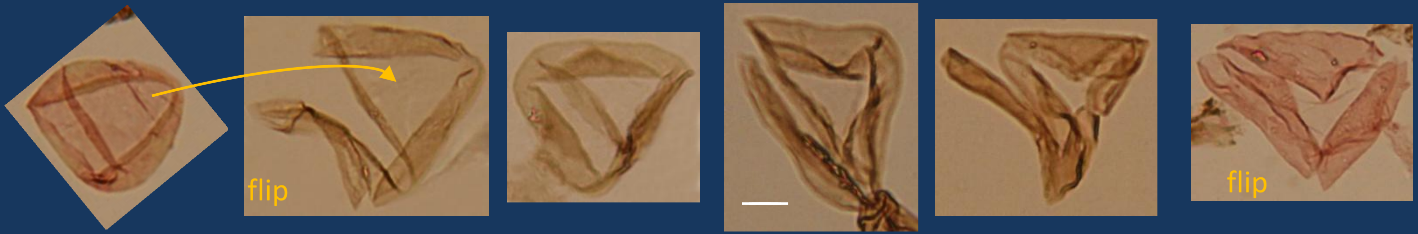


Surface features of elements differ from cell wall

bar = 20µ

Consistency of form

Consistency in position, orientation and arrangement of elements



Primary morphological features, fundamental to cell development

bar = 20μ

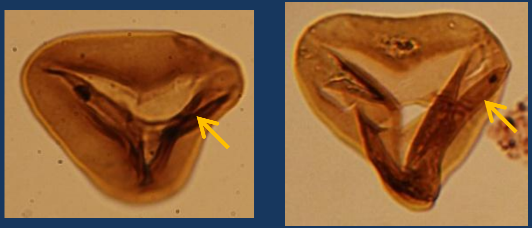
Interpreted as a single structure

▪ Consistency of form

Other morphological features only form as the reproductive cell approaches maturity.

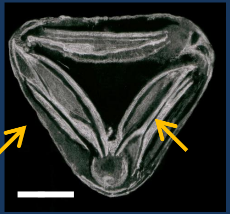
Parallel secondary elements

ODS 3



?*Cyathidites* sp. A

ODS 3



Cyathidites minor sensu Tahoun and Mohamed, (2014, Figure 3.11 (300º)). Scale bar 10µ, Jurassic.

ODS 3

Cyathidites mesozoicus sensu Na *et al.* 2014 .

Distal secondary elements

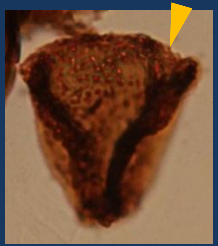
bar = 20µ

ODS 3

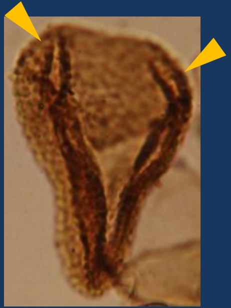
Biretisporites sp. A

ODS 2

ODS 2



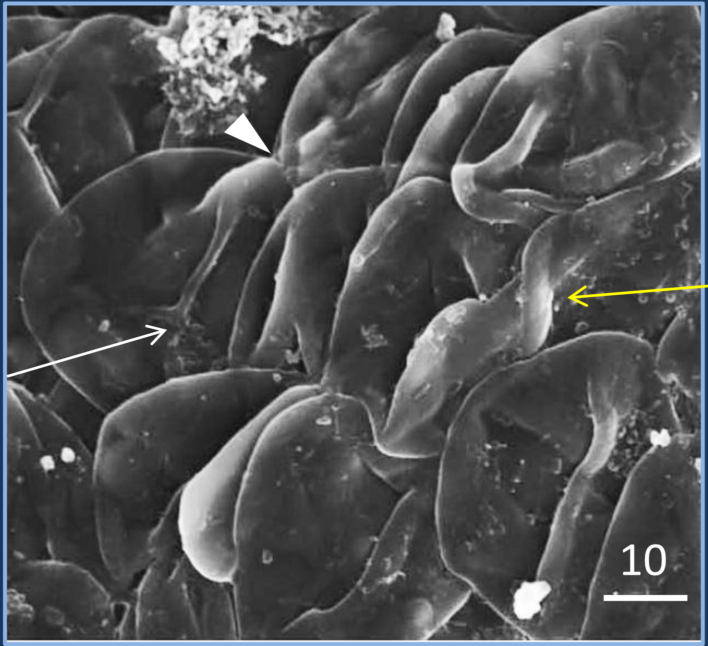
ODS 3



Verrucosisporites cf. cheneyi

Elements appear as positive features under SEM

Aligned into continuous features



Trilete mark

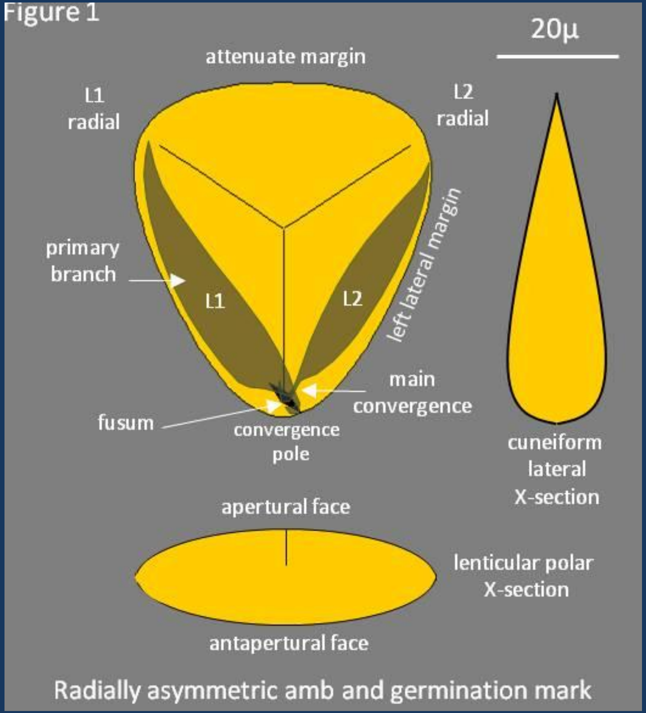
axial twisting of external element

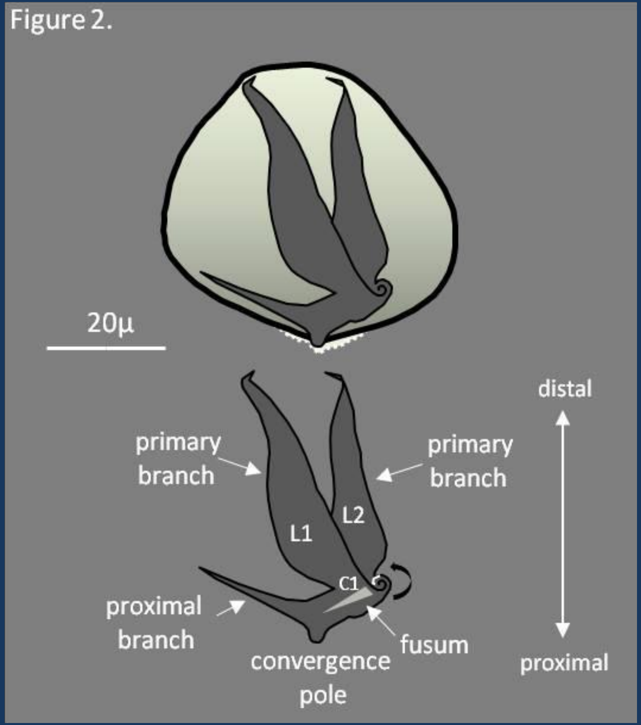
Kvaček, J. and Dašková, J., 2010 Pl. 3, fig. 3

Microfolium

Enables orientation

Unique morphological characteristics = “habit”





Similar habit in variably mature spores from the same parent plant = “growth sequences”

Biretisporites sp. A - growth sequence

ODS 1

ODS 1-2

ODS 2

ODS 3

bar = 20µ

more growth sequences

ODS 1-2

ODS3

Attenuate re-entrant angle

?*Leiotriletes* sp. K

► = Transverse element

bar = 20µ

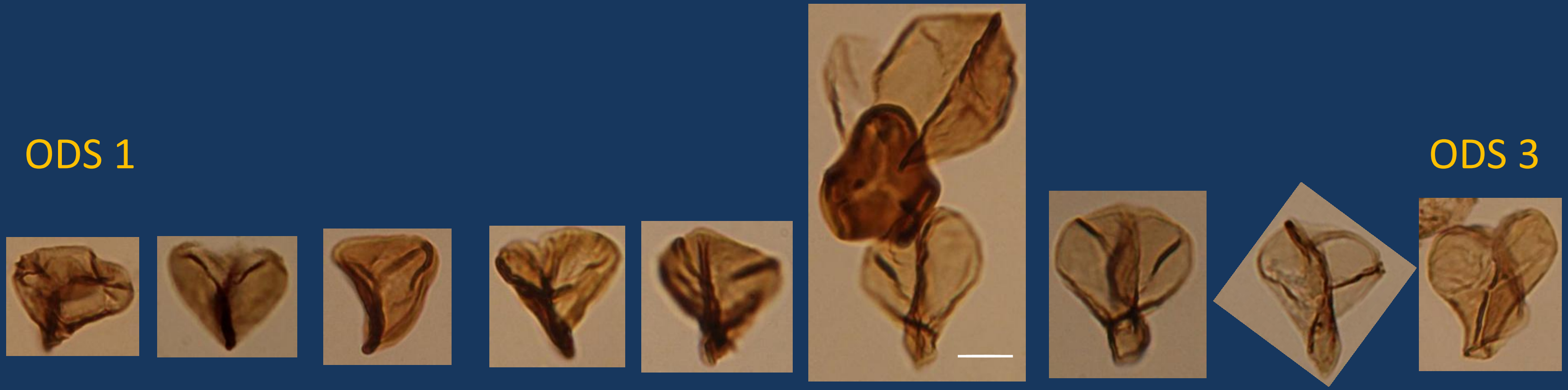
?*Leiotriletes* sp. L

ODS 1

ODS 2-3

ODS 1

ODS 3

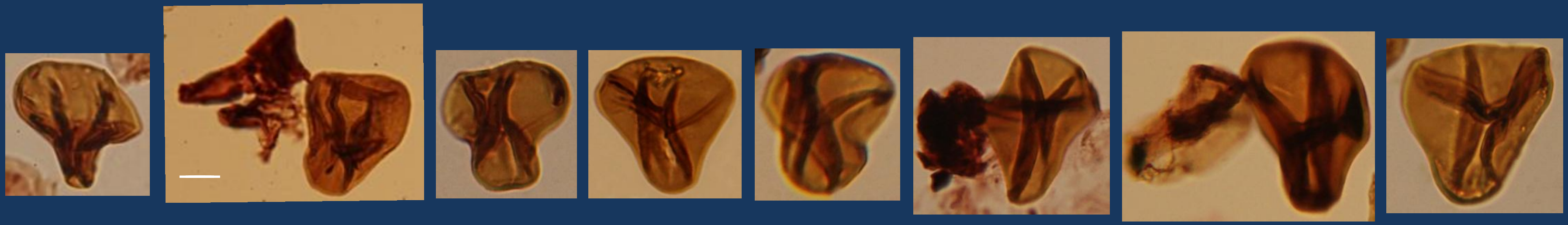


Spore indet B

bar = 20µ

ODS 1-2

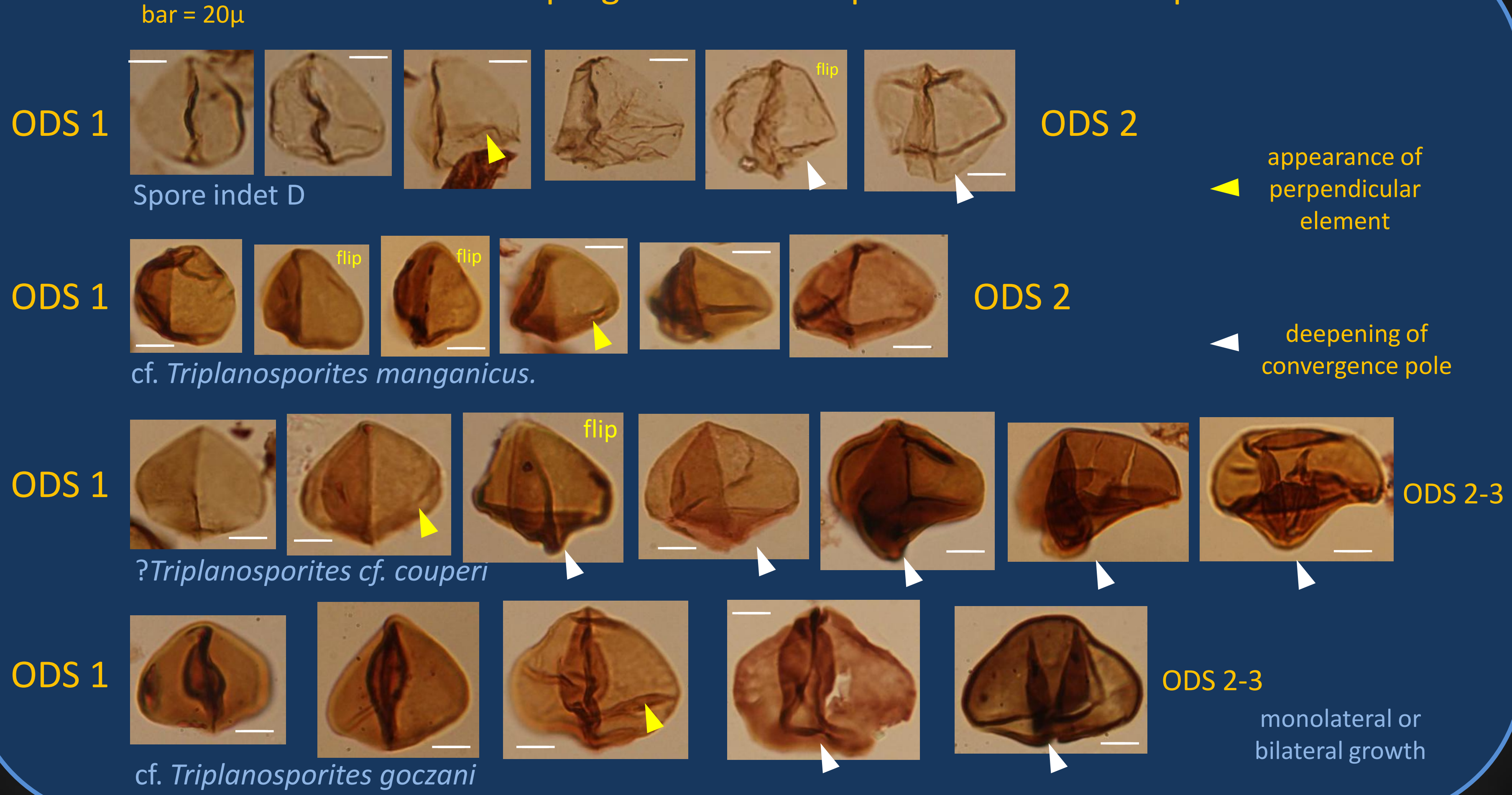
ODS 3



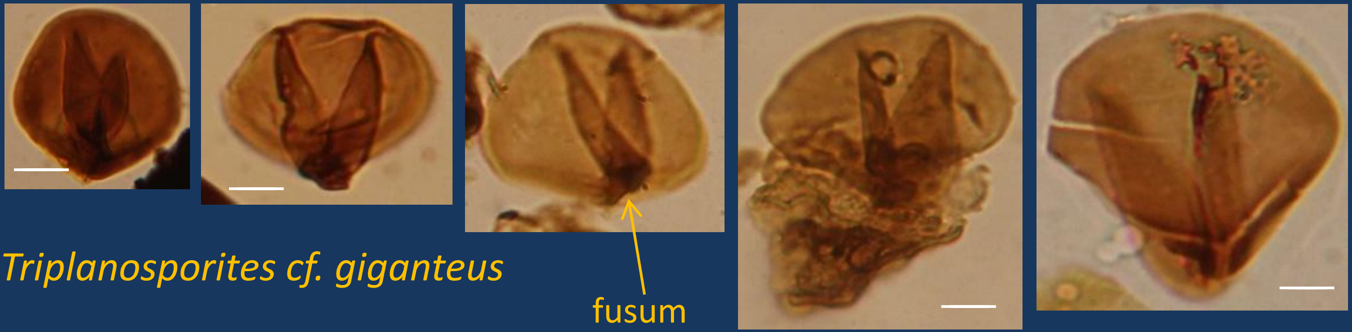
Spore E

bar = 20µ

Similarities in progressive development in different spores

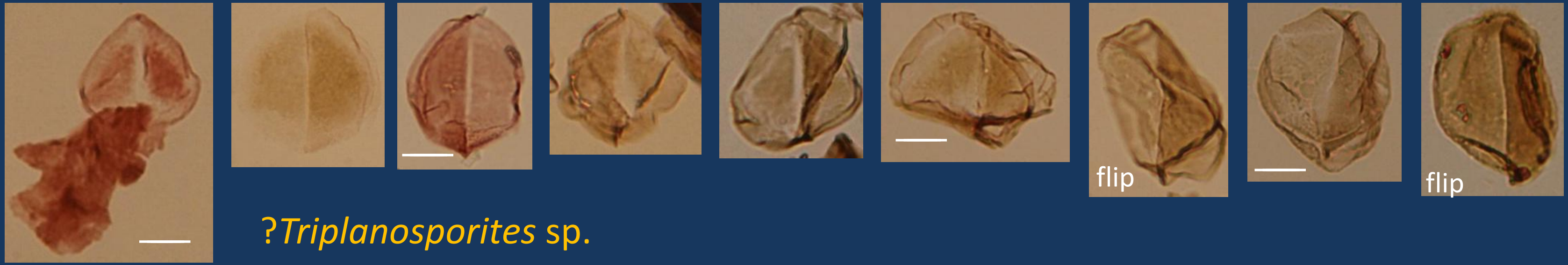


ODS 1 ODS 3



Triplanosporites cf. giganteus

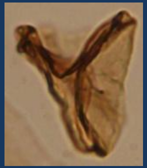
ODS 1 ODS 2-3

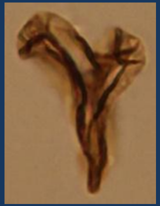


?*Triplanosporites* sp.

bar = 20µ

ODS 1





Spore indet 5

bar = 20µ —— all

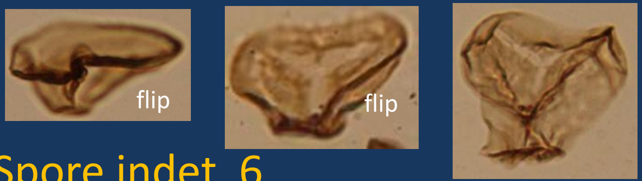
ODS 2-3

ODS 1 ODS3

?*Leiotriletes* sp. Y

bar = 20µ —— all

ODS 1 ODS3



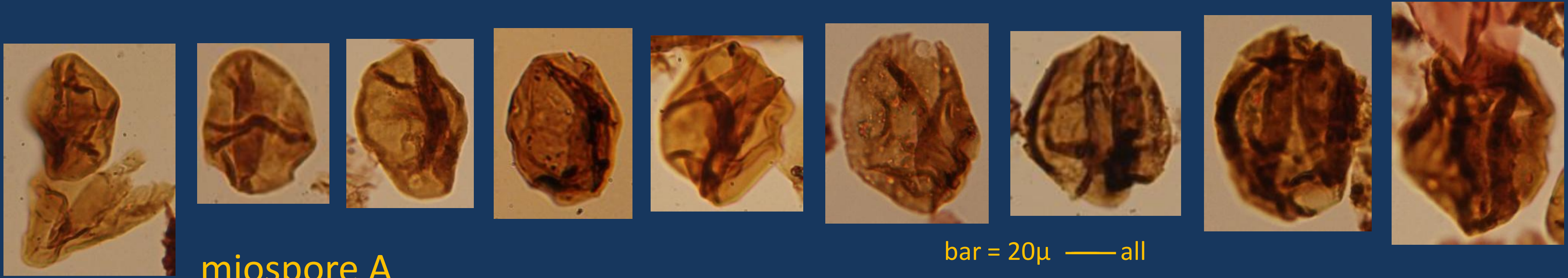
Spore indet 6

ODS 1 ODS3

Spore indet 8

ODS 1

ODS3



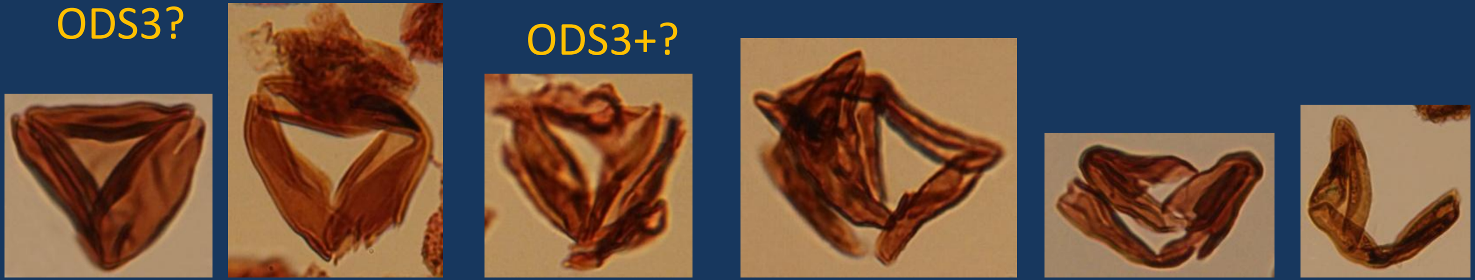
miospore A

bar = 20µ —— all

ODS3?

ODS3?

ODS3+?



miospore B

No growth sequence yet, though clear similarities in the microfolium

?*Leiotriletes* sp B.

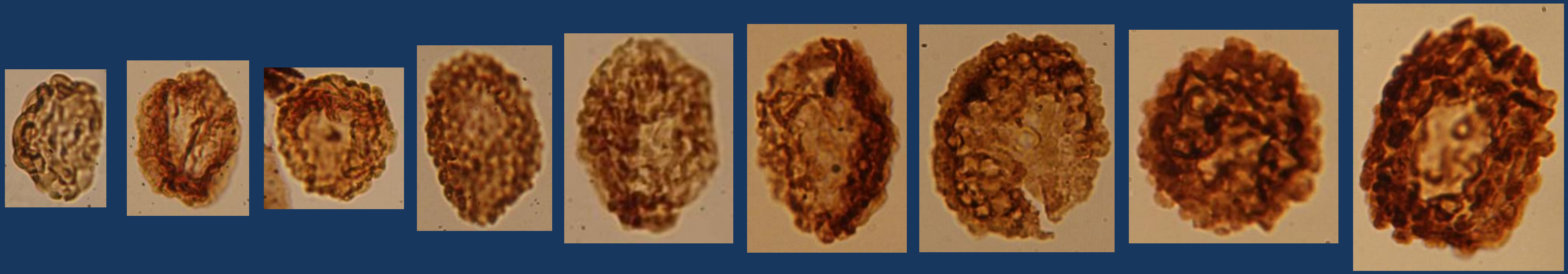
well-developed parallel secondary elements

bar = 20µ

ODS 1

Cerebropollenites macroverrucosus

ODS 3

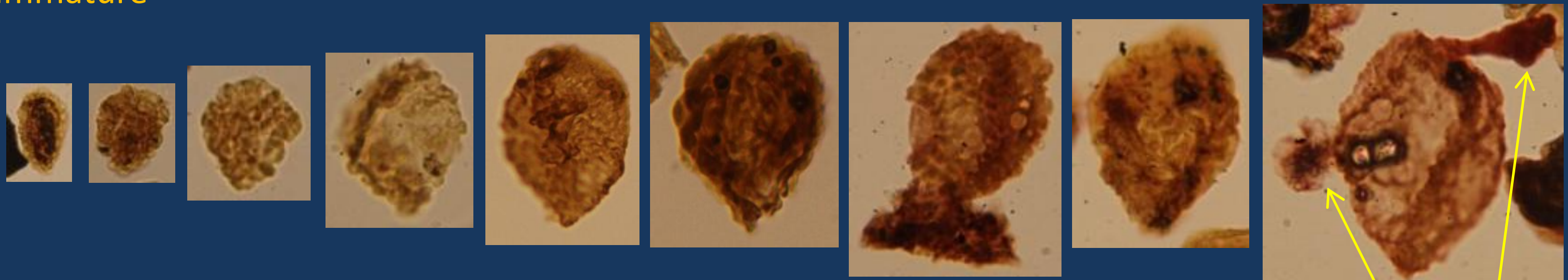


bar = 20µ —— all

immature

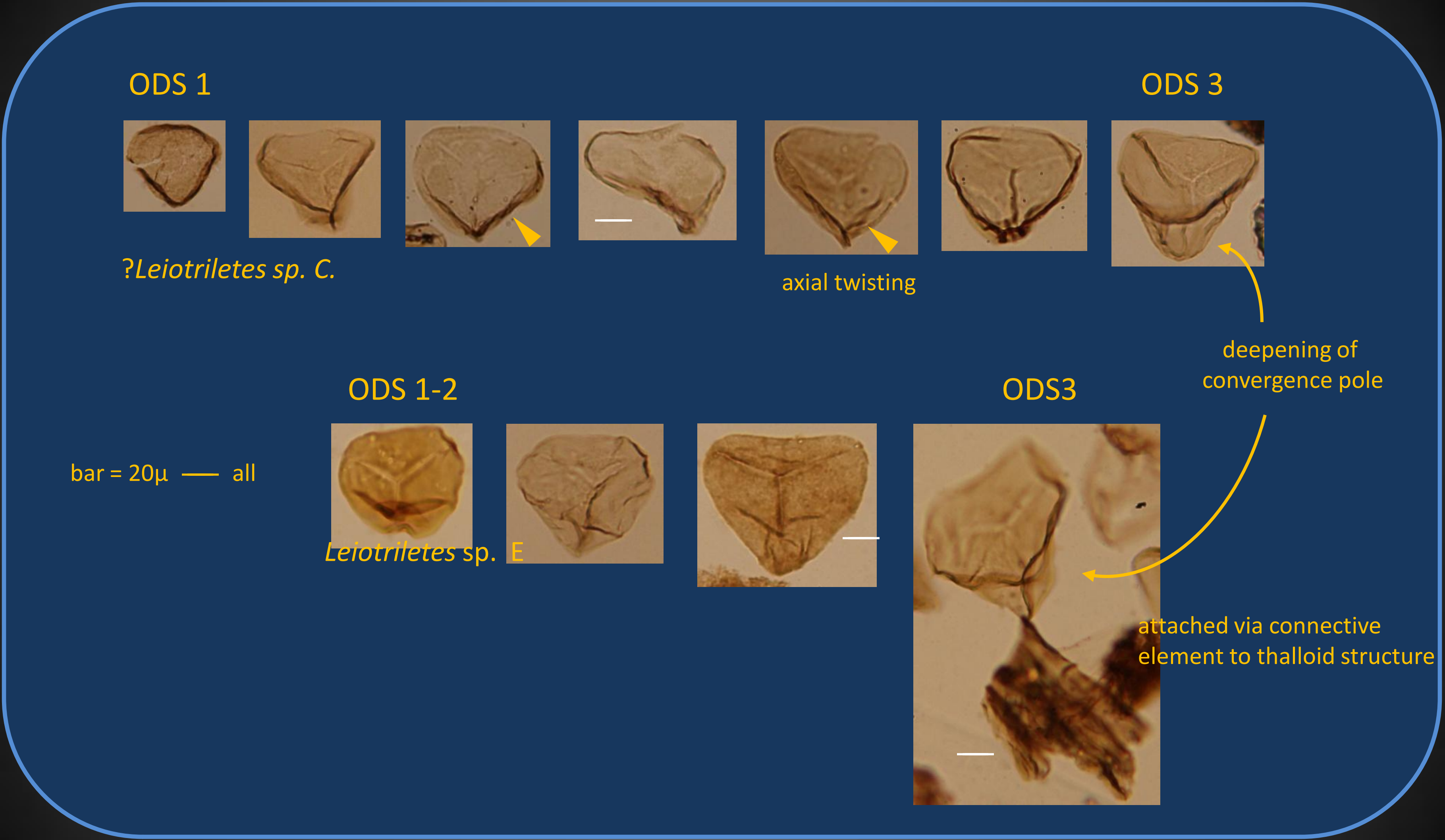
Gemmae?

mature

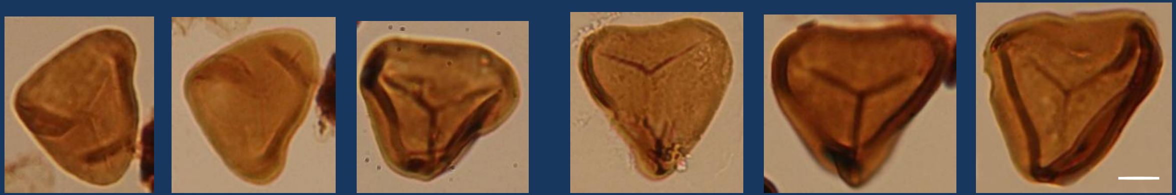


propagules

"S. asperum" sensu BioStrat ; similar to C .*macroverrucosus* and often more common.


ODS 1
ODS 3
?Leiotriletes sp. C.
axial twisting
deepening of convergence pole
ODS 1-2
ODS3
bar = 20µ —— all
Leiotriletes sp. E
attached via connective element to thalloid structure

ODS 1-2 ODS3



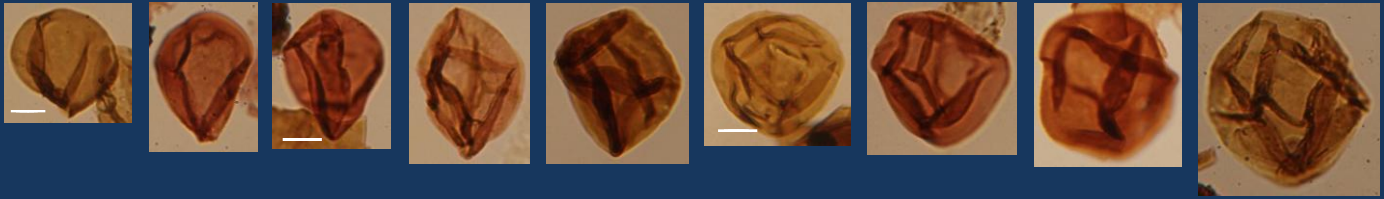
?*Trilobosporites* sp.

bar = 20μ —— all

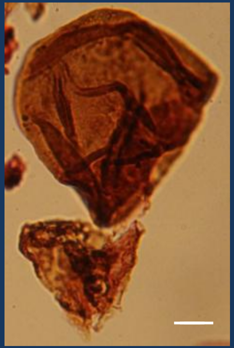
ODS 1-2 ODS3

Spore indet. 2

ODS 1



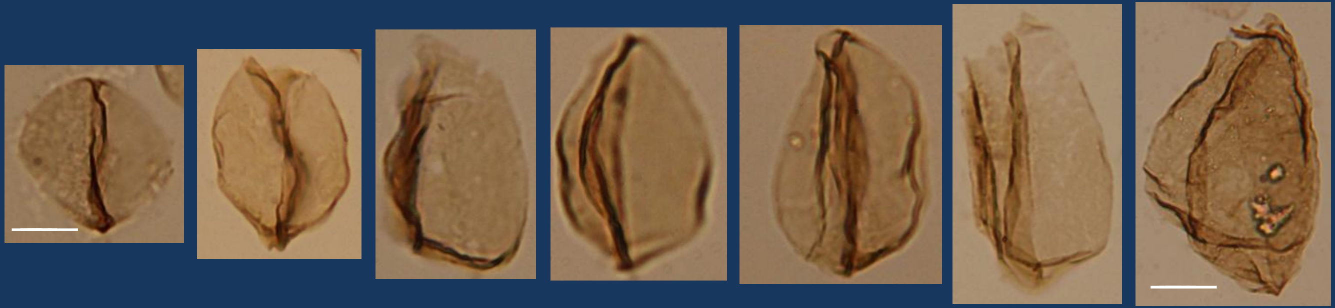
ODS 3



Inaperturopollenites cf. giganteus

bar = 20µ —— all

ODS 1 ODS 3 ODS 3+

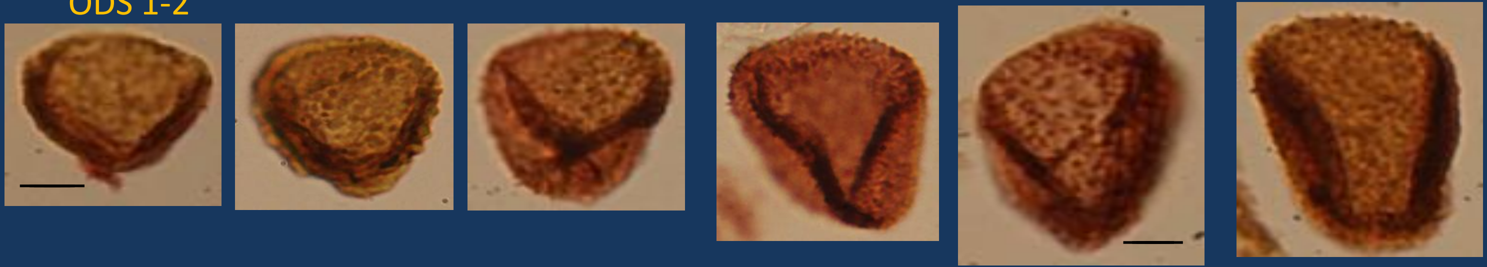


cf. *Laevigatosporites* sp.

bar = 20μ —— all

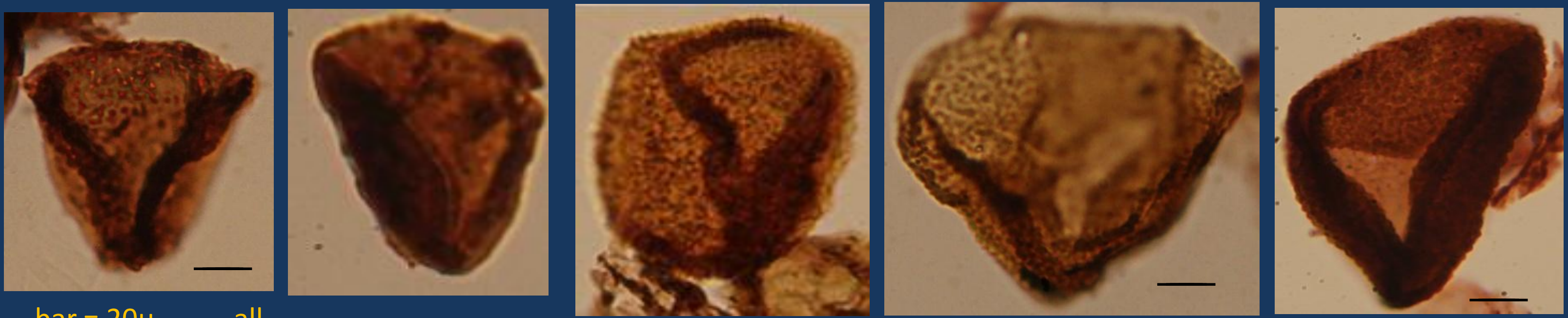
Verrucosisporites cf. cheneyi

ODS 1-2



ODS 3

ODS 3+

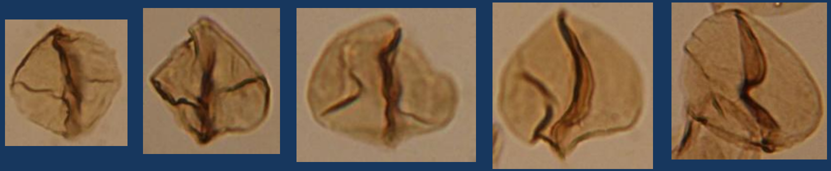


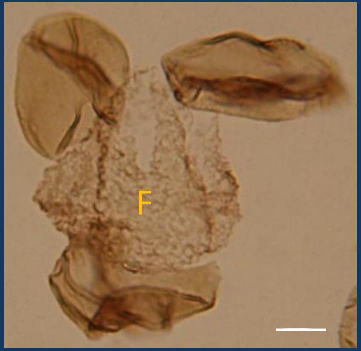
bar = 20µ —— all

Other life cycles; Attached reproductive cells - ARCs

ODS 1 (equivalent)

ODS 3





Spore indet. A

bar = 20μ —— all

- ❖ attached to “fruiting cell”
- ❖ clues to life cycle?

Other life cycles; Attached reproductive cells - ARCs

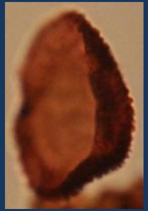
?*Conaletes* sp.

ODS 1

ODS 3

ODS 3+

alete



affinities?

bar = 20µ —— all

attached to branching thalloid structure

Attached reproductive cells - ARCs

ODS 1 ODS 3

cf. *Matonisporites* sp.
or spp. ?

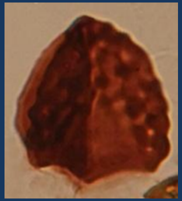
ODS 1 ODS 3

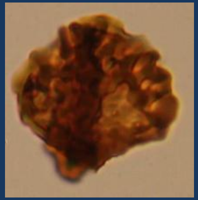
bar = 20µ —— all

Attached reproductive cells - ARCs

ODS 1

ODS3





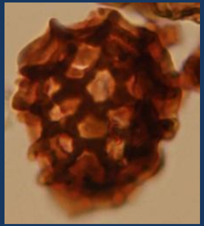
cf. *Ischyosporites marburghensis*

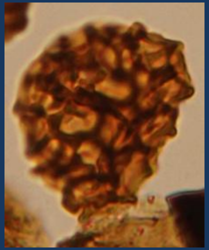
thalloid cell? or protonemal tissue?

bar = 20µ —— all

ODS 1

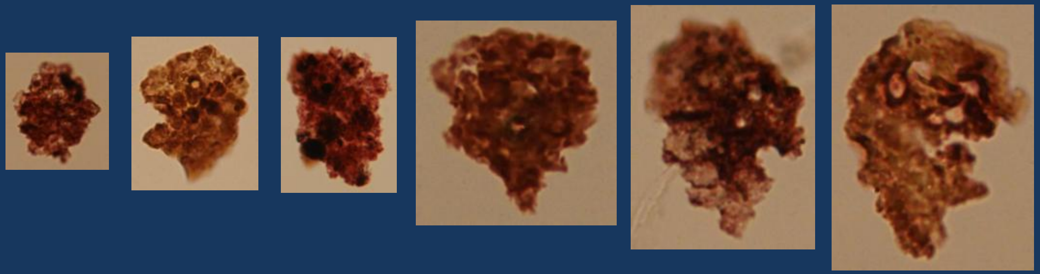
ODS3

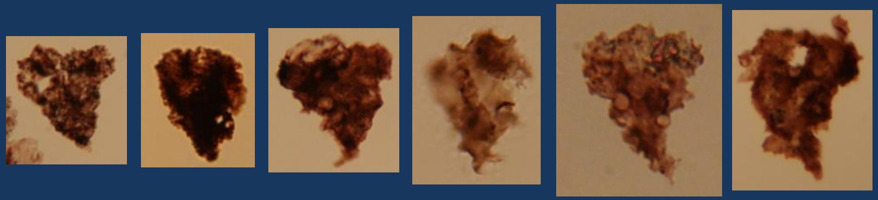




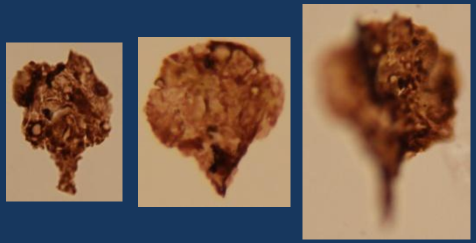
Ischyosporites "latimurus" BioStrat

Other life cycles;   gemmae of hepatic plants





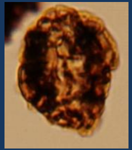
bar = 20µ —— all

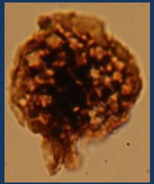


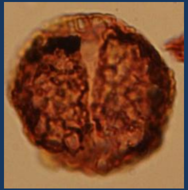
all from Jurassic-Triassic, North Sea & Norwegian Sea

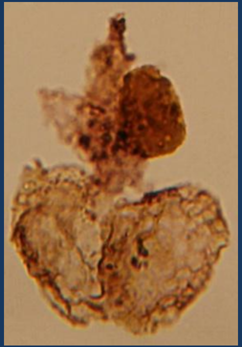
Other life cycles; Attached reproductive cells - ARCs

Bisaccate-like ARC develops longitudinal split







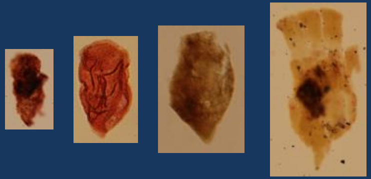



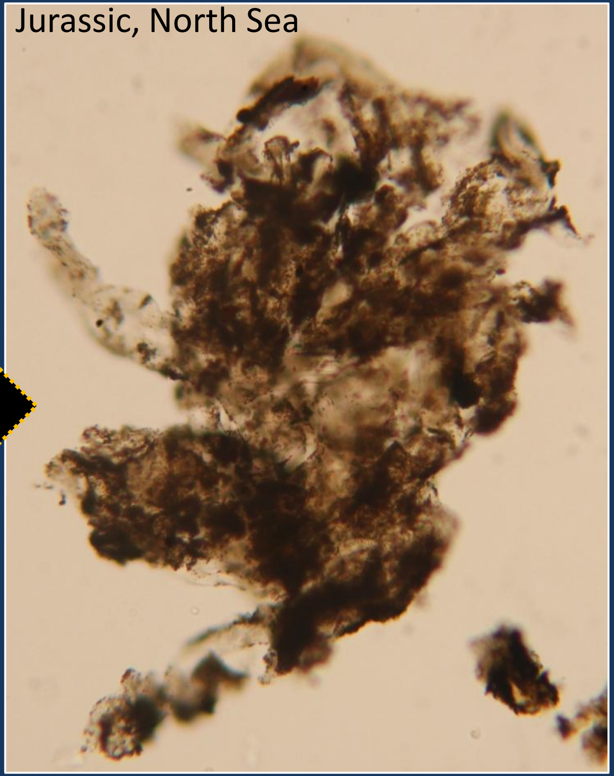
immature

mature

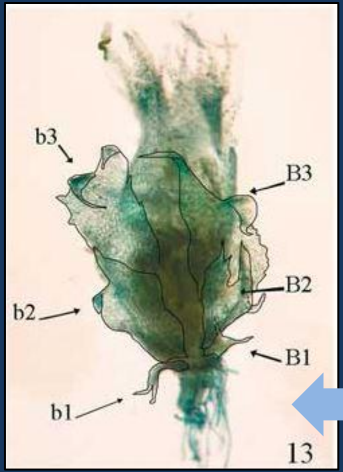
bar = 20µ —— all

Other life cycles; "fruiting growth"





500 microns

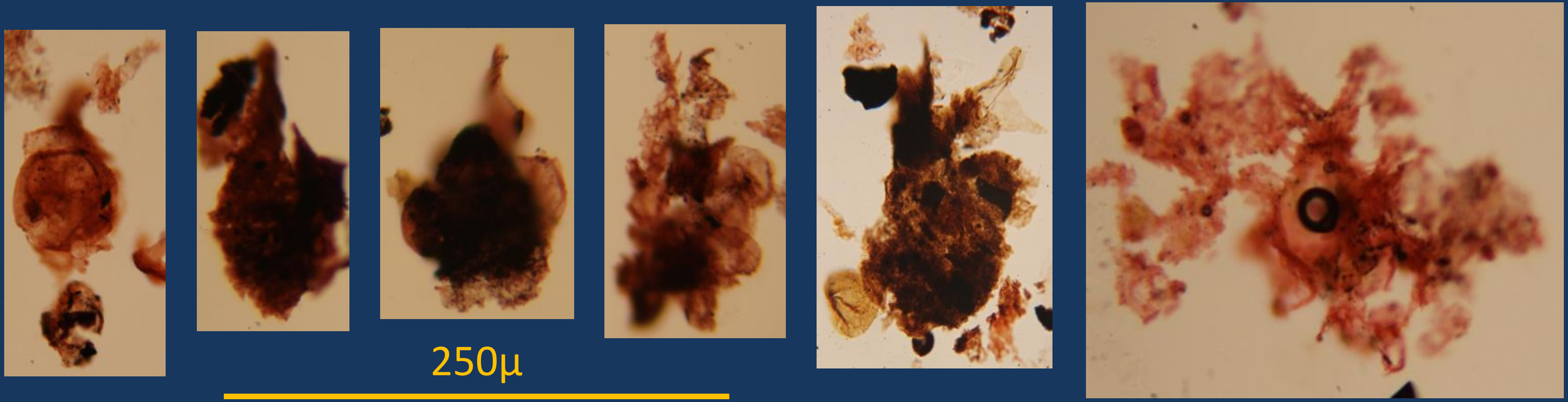


500 microns

Gynoecium of *Octoscyphus crassicaulis* (extant liverwort), with bracts and bracteoles highlighted. Figure 13 *in*: Engel *et al.* 2012.

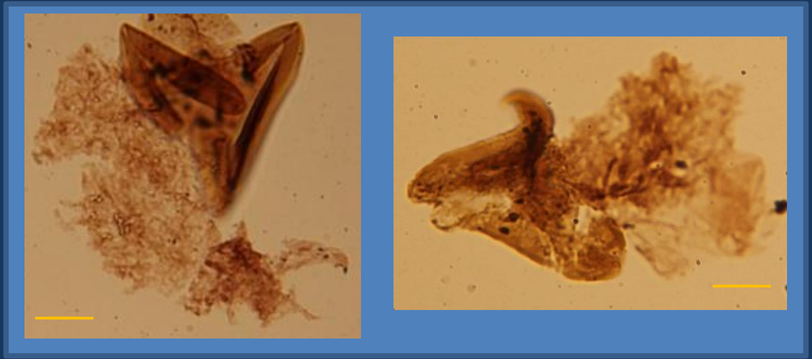
Other life cycles; "fruiting growth"

immature → mature



Possible gynoecium or perianth of a liverwort. Jurassic NNS

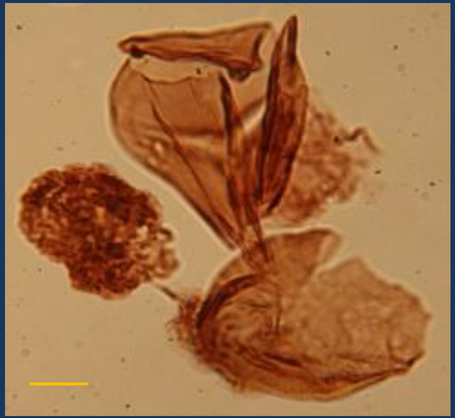
In dispersed assemblages further morphological variability is caused by rupturing of the cell wall during germination/dehiscence.

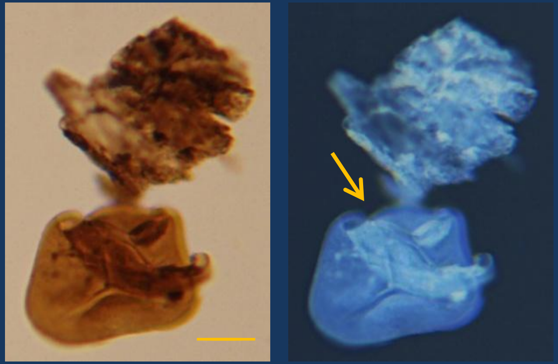


“Normal” spore germination

Other types of wall rupturing observed in many spore-like cells, - inconsistent with "normal" germination. - *dehiscent cells*

Teichertodinium triassicum
Stover & Sarjeant 1972





cell contents do not emerge through germination aperture

bar = 20µ

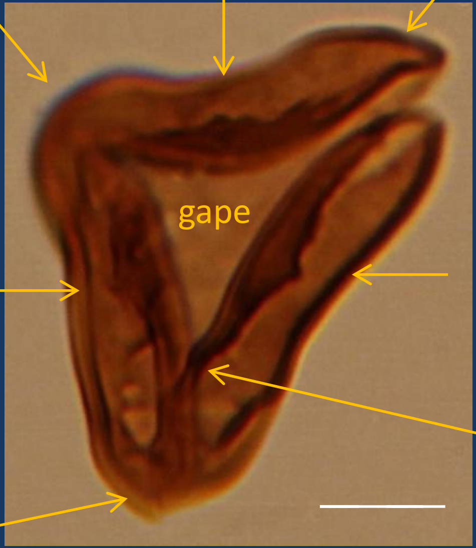
Wide variety of dehiscent spore-like cells reflect more diverse life cycles

Dehiscent spores - unknown affinities

Rupturing continues onto antapertural surface

monolateral dehiscence

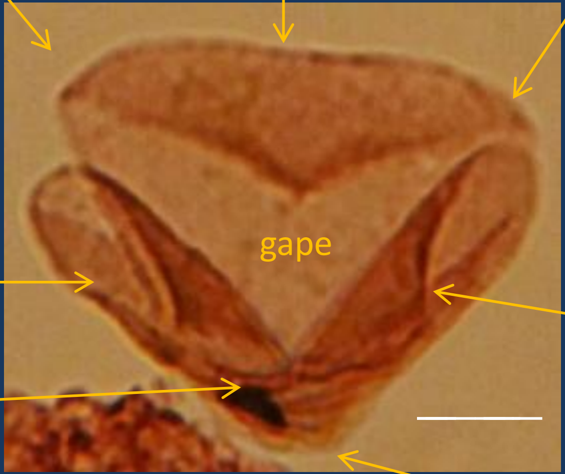
cell remains entire



cf. *Cyathidites mesozoicus sensu* Na *et al.* 2014

bilateral dehiscence

attenuate valve commonly lost



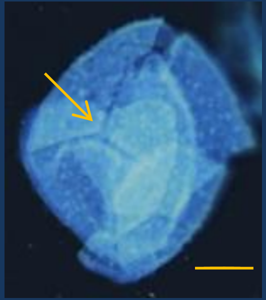
cf. *Teichertodinium* Pocock & Sarjeant 1972

bar = 20μ

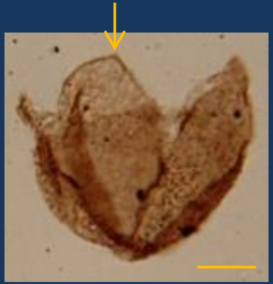
Dehiscent spores

Teichertodinium triassicum Stover & Sarjeant 1972

bar = 20µ



triple point



Published as an acritarch

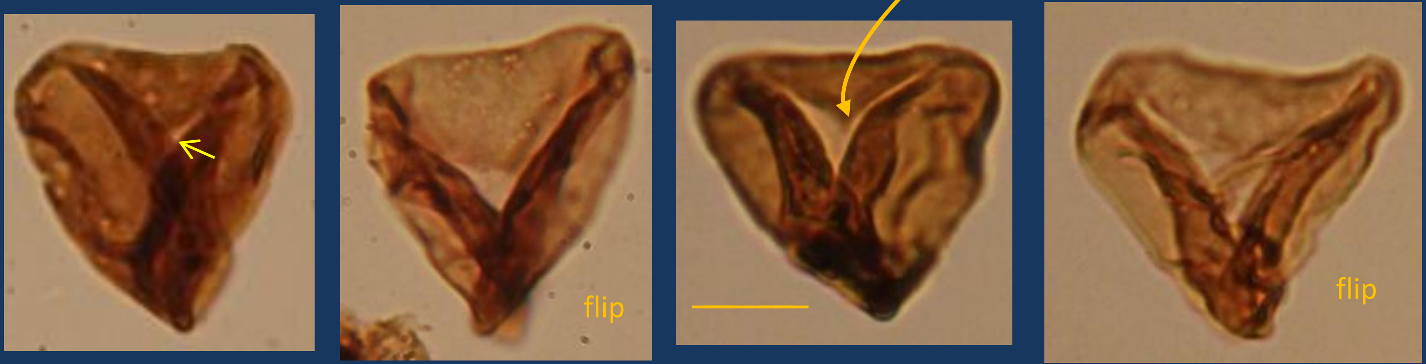
Spore-like, including trilete mark

ARC – attached reproductive cell

“Bilete” gaping aperture; - ?affinities

bar = 20µ

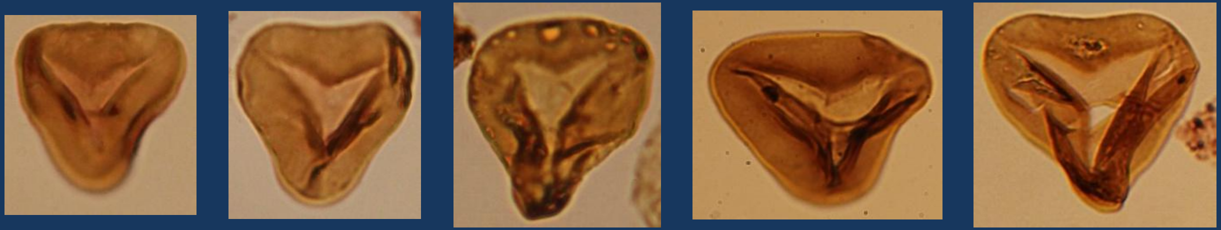
attenuate re-entrant



Splitting initiates from point inside divergence of lateral branches *(yellow arrow),* gradually extending in two directions towards attenuate radials.

Gaping apertures

ODS 1-2 ODS3

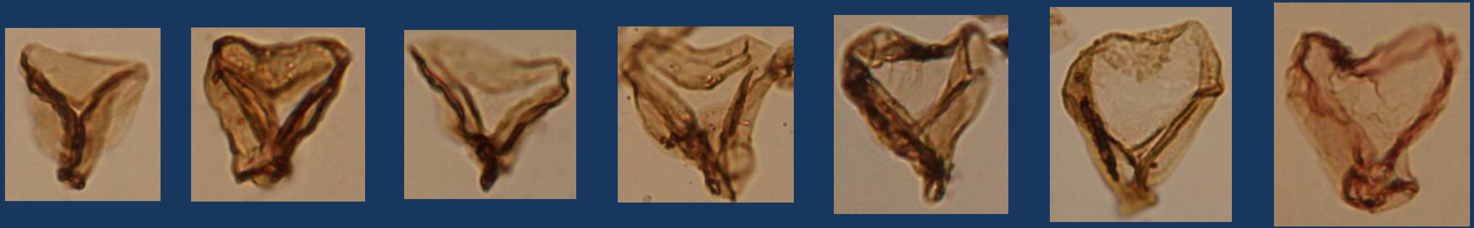


bar = 20µ —— all

?*Cyathidites* sp. A

★ Rupturing restricted to apertural face. ★

ODS 1-2 ODS3



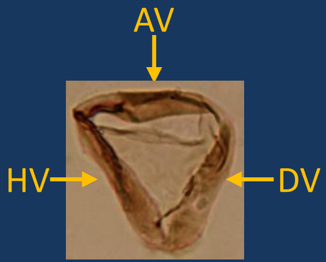
?*Leiotriletes* sp. F

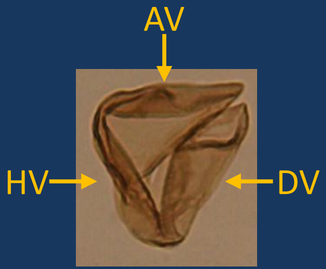
Aperture becomes larger, with relatively little associated increase in cell size

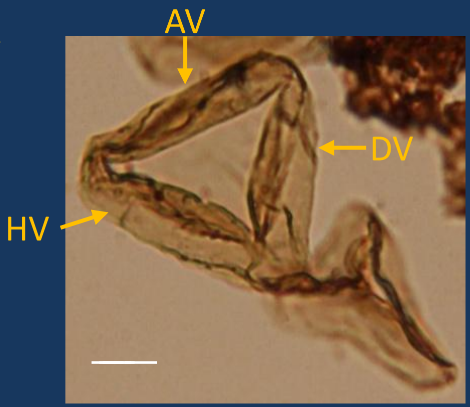
Not mature until gape fully formed

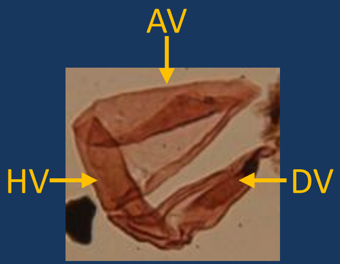
Dehiscent spores

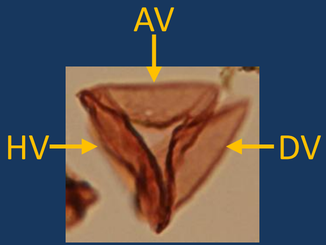
Monolateral dehiscence



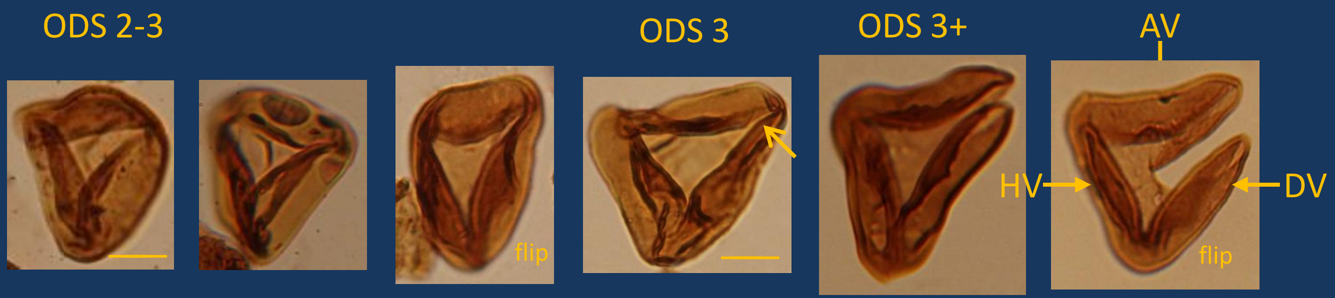






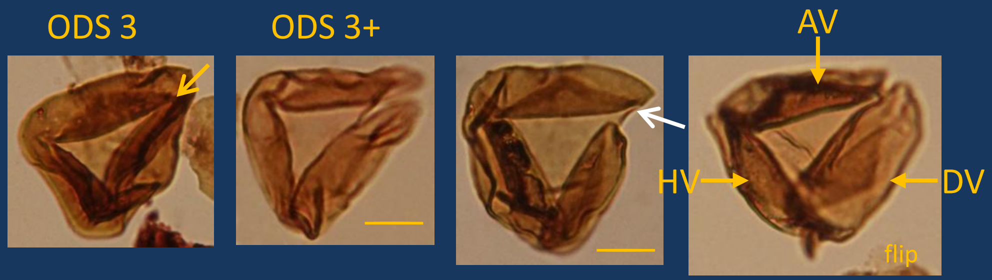


Monolateral dehiscence



Cyathidites mesozoicus sensu Na *et al.* 2014

bar = 20µ

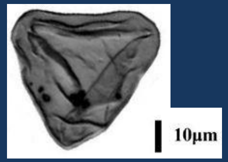


Cyathidites cf. mesozoicus sensu Na *et al.* 2014

★ rupturing extends around dehiscent radial onto the antapertural face

★ cell remains entire

ODS 3



Cyathidites mesozoicus sensu Na *et al.* 2014 (rotated) .

Monolateral dehiscence

?*Leiotriletes* sp. G

distinctive diagonal split with folded margins on antapertural surface

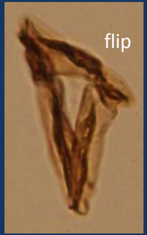
?*Leiotriletes* sp. H

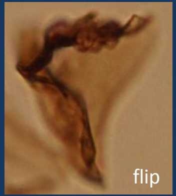
bar = 20µ —— all

Monolateral dehiscence

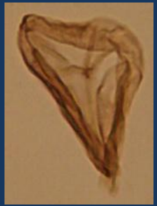
immature

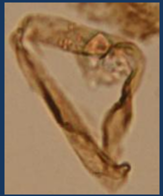
mature

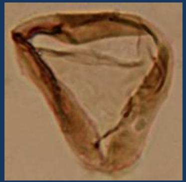




Indeterminate
spore-like cell





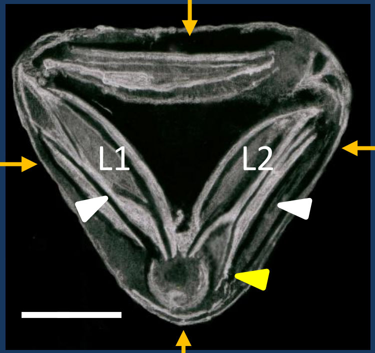


all mature?

bar = 20µ —— all

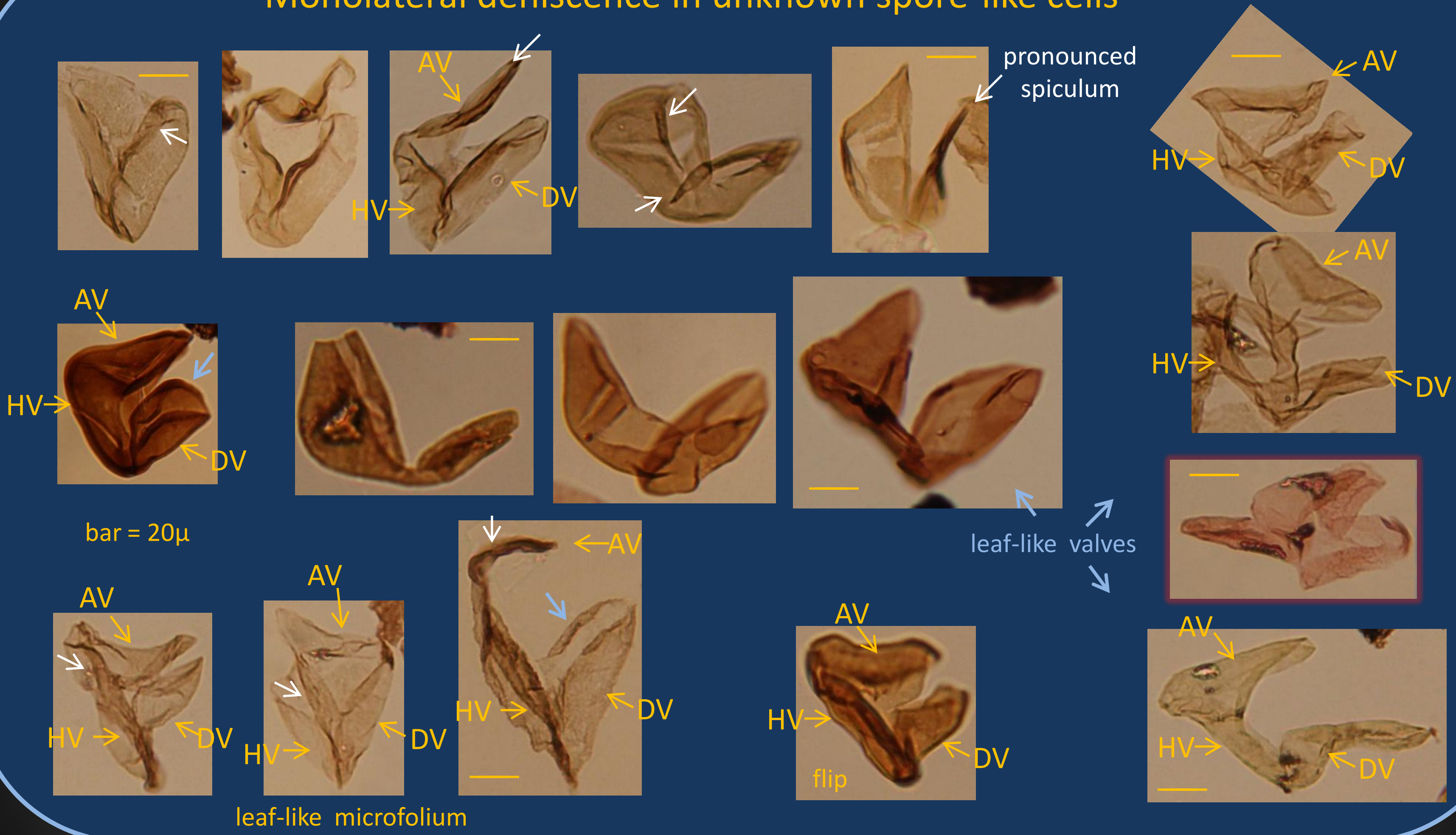
Monolateral dehiscence

Even before dehiscence occurs



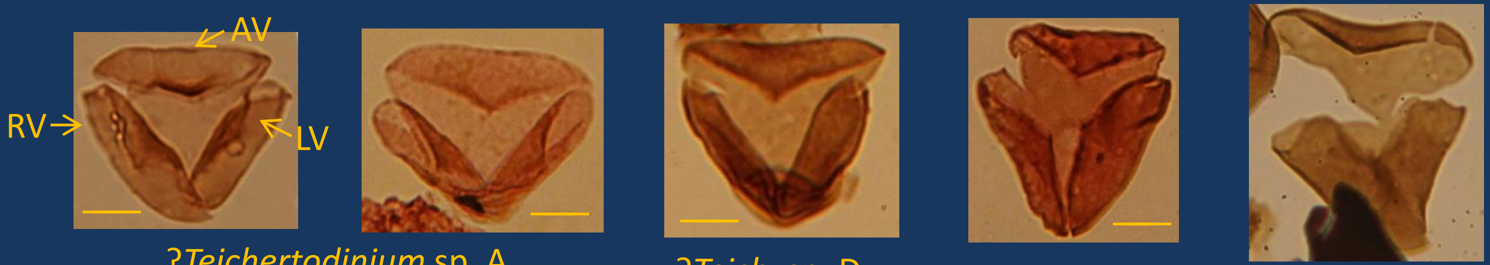
Cyathidites minor sensu Tahoun and Mohamed, (2014, Figure 3.11 (300º)). Scale bar 10µ, Jurassic.

Monolateral dehiscence in unknown spore-like cells



Bilateral dehiscence

cf. Teichertodinium Pocock & Sarjeant 1972



?*Teichertodinium* sp. A

?*Teich.* sp. D

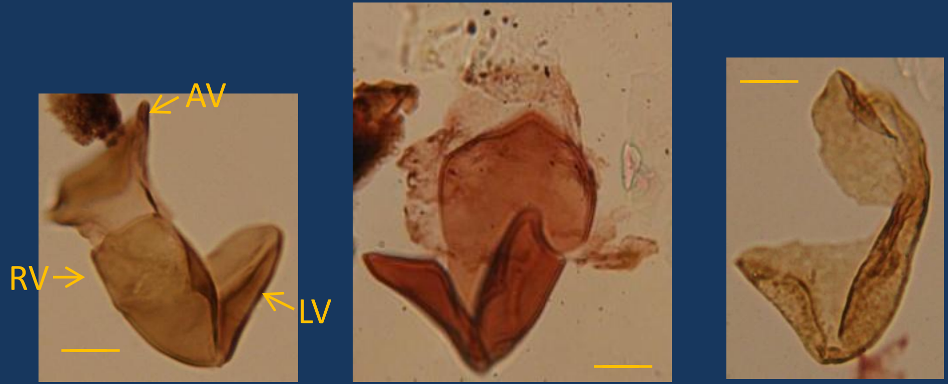
?*Teich.* sp. E

bar = 20µ

Rupturing extends around both attenuate radials onto antapertural face.

Attenuate valve may remain attached, though commonly lost

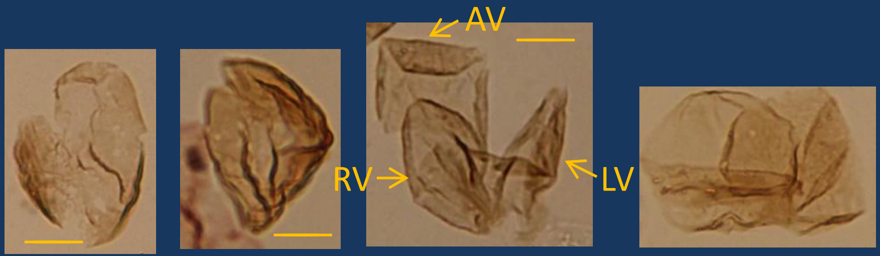
Bilateral dehiscence



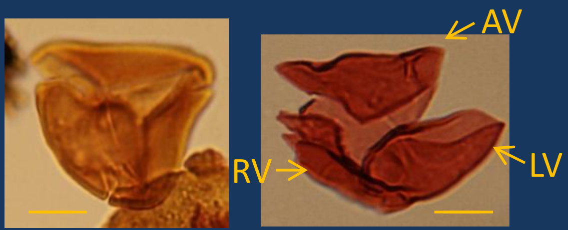
attenuate valve fully operated, still attached

bar = 20µ

?*Teichertodinium* sp. A



?*Teichertodinium* sp. B



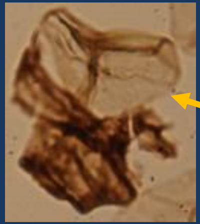
?*Teichertodinium* spp.

!!?

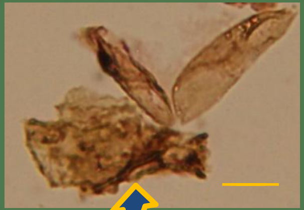
vegetative growth of new thallus

older thallus

?*Biretisporites* sp. A



?*Teichertodinium* sp. A

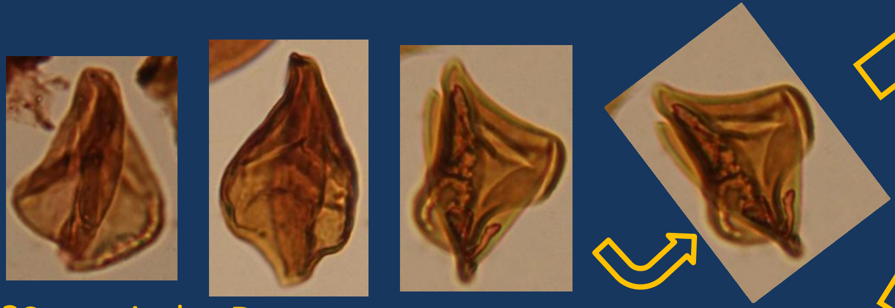


newer thallus

older thallus

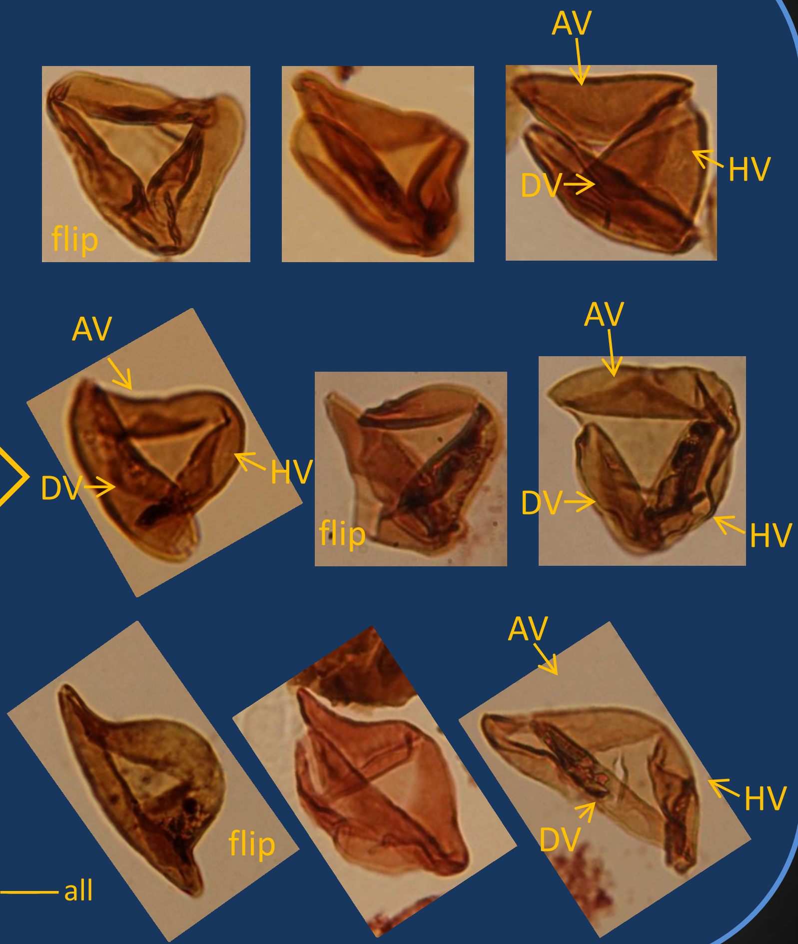
bar = 20µ

The microfolium is related to the internal structure, shape & growth of the cell



?Spore indet D

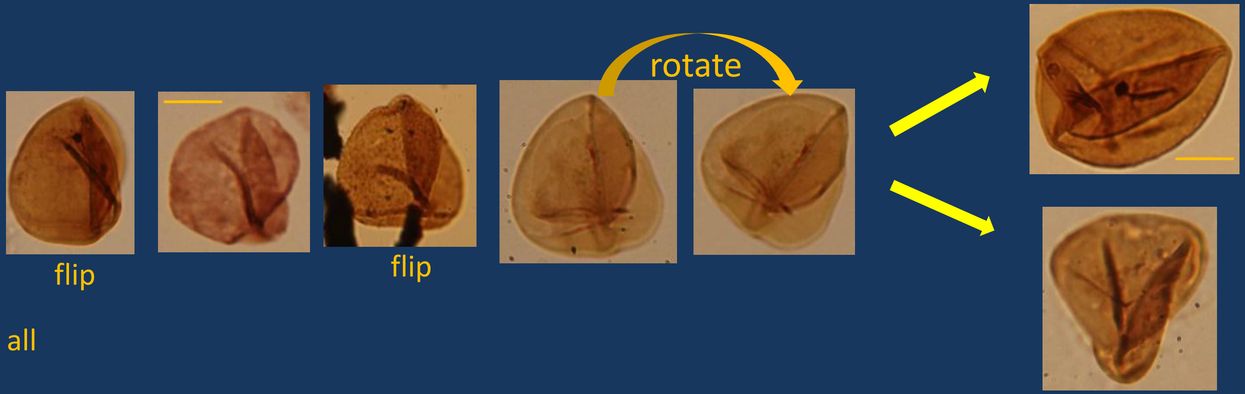
Equivalent “branches” & valves



And to rupturing of the cell wall during germination/dehiscence

bar = 20µ —— all

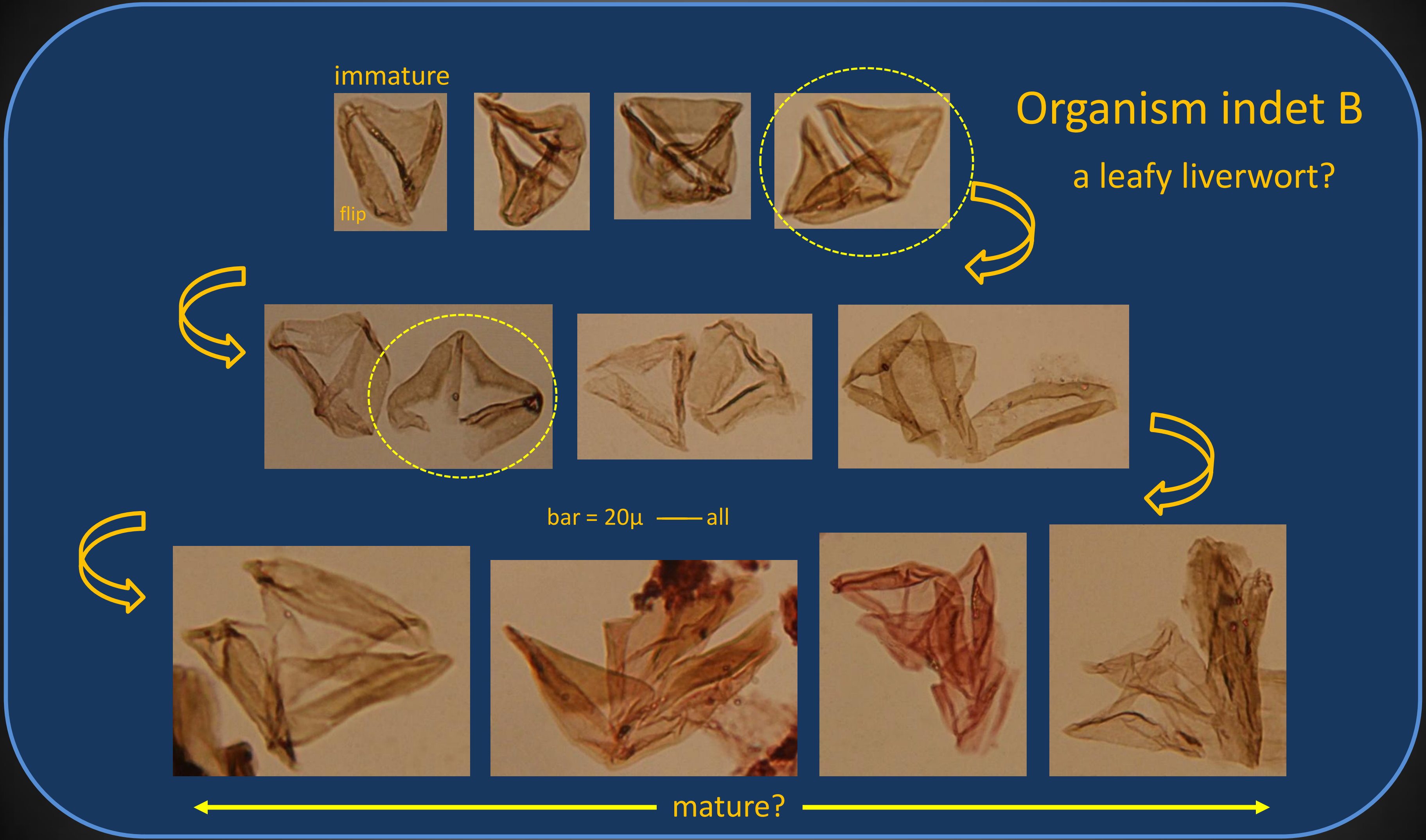
Branch equivalence *Ax & Px = L1 & L2*



bar = 20µ —— all

Organism indet A

Why have a trilete mark?


Organism indet B
a leafy liverwort?
immature
flip
bar = 20µ —— all
mature?

Conclusions

- Current models for the description of fossil miospores do not sufficiently consider or accurately reflect the variety of life cycles in ancient plant communities
- Nor the significant morphological variation in spores produced by a single plant species
- The microfolium is fundamental to the internal structure of many fossil plant/algal reproductive cells.
- Offers strong potential as a high-ranking morphological feature in taxonomy and classification.
- The microfolium has a similar “habit“ in variably mature microspores produced by a single plant.
- Input of botanical expertise required:- living representatives, life cycles