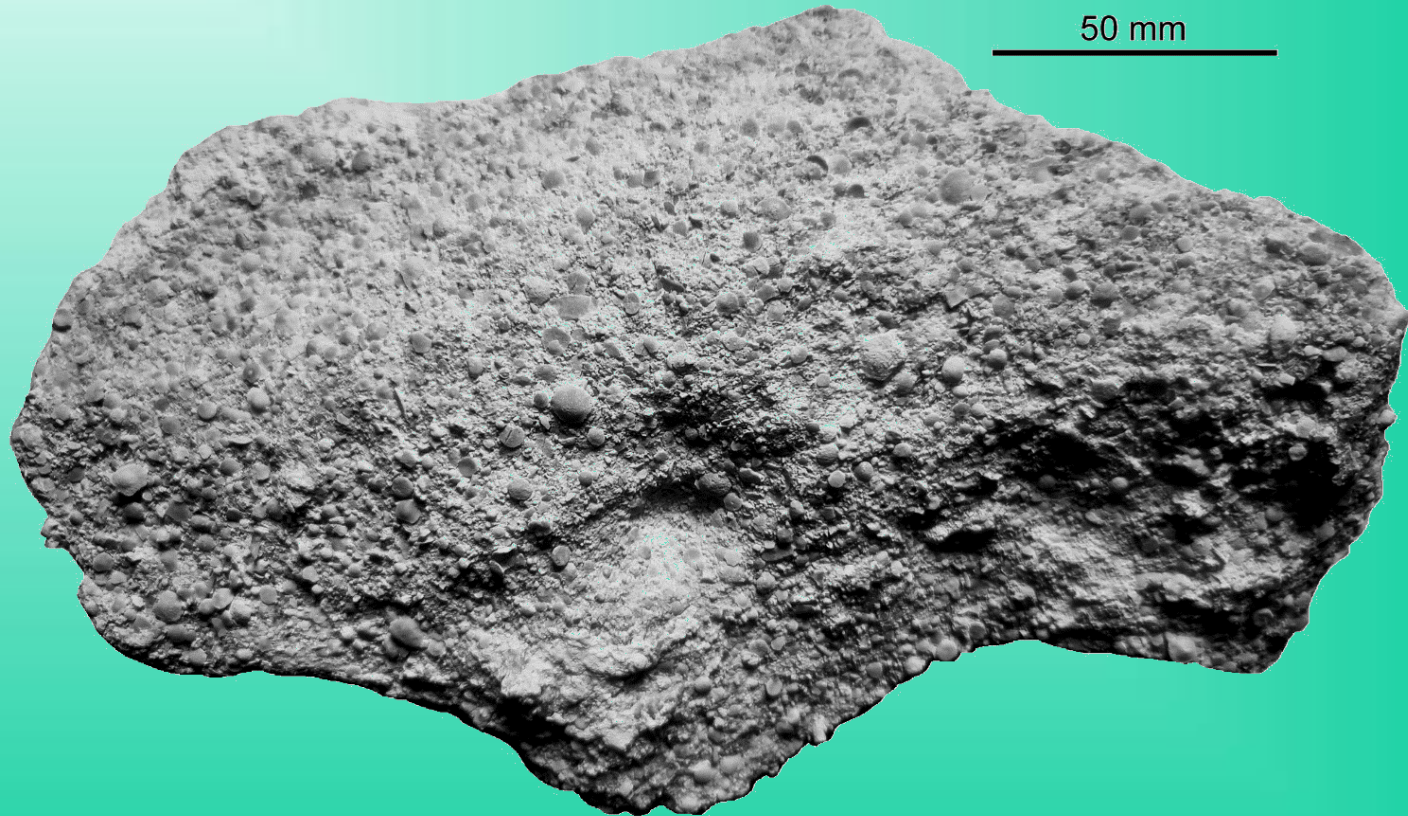


# **Basis for a LBF zonation for the American Paleogene**

**Micropalaeontological Society / Cushman Foundation**

**13<sup>th</sup> June 2022**



**Simon F. Mitchell**

**The University of the West Indies, Mona Kingston, Jamaica**

## Introduction

Some groups of LBF evolved in the American region, whereas other groups migrated into the region at different times.

This has been difficult to sort out because of a lack of an independent calibration method, with the LBF themselves being used to infer ages.

For the last 10 years we have been examining the LBF successions in the America LBF Biogeographical Province (largely in Jamaica, which was at the heart of the province). We have calibrated the occurrences of LBF using calcareous nanofossils and used this to understand the stratigraphic distribution of species and to establish a high-resolution zonal scheme (American Benthic Zones or ABZs).

Our results differ notably from those of previous studies.

To begin with, I have to acknowledge my colleagues who have worked with me on these studies:-

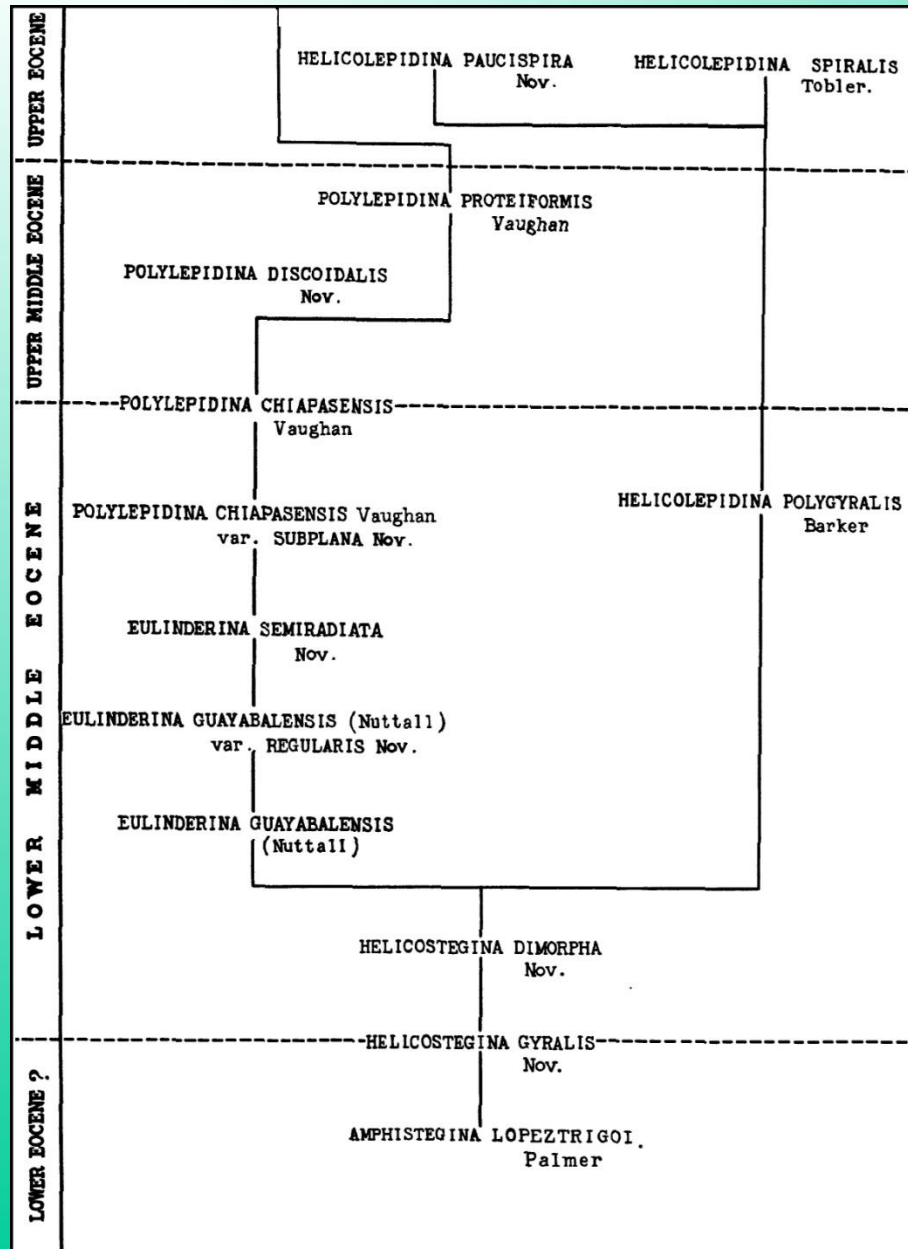
**Mark M. Jiang** - Ellington Geological Services, Texas -  
Calcareous Nannofossils.

**Ercan Özcan** – İstanbul Technical University, Turkey – LBF.

**Edward (Ted) Robinson** – UWI, Jamaica – LBF.

**Natalie Robinson** – UWI, Jamaica – LBF.

# The Barker & Grimsdale (1936) phylogenetic model



Barker & Grimsdale (1936) suggested a simple model for evolution of Asterigerinoidea in the Americas.

Their model had *Amphistegina* giving rise to *Lepidocyclina* through *Heterostegina*, *Eulinderina*, and *Polylepidina* (*Helicolepidina* also evolves from *Helicostegina*). Subsequently, **ALL** authors have followed this model.

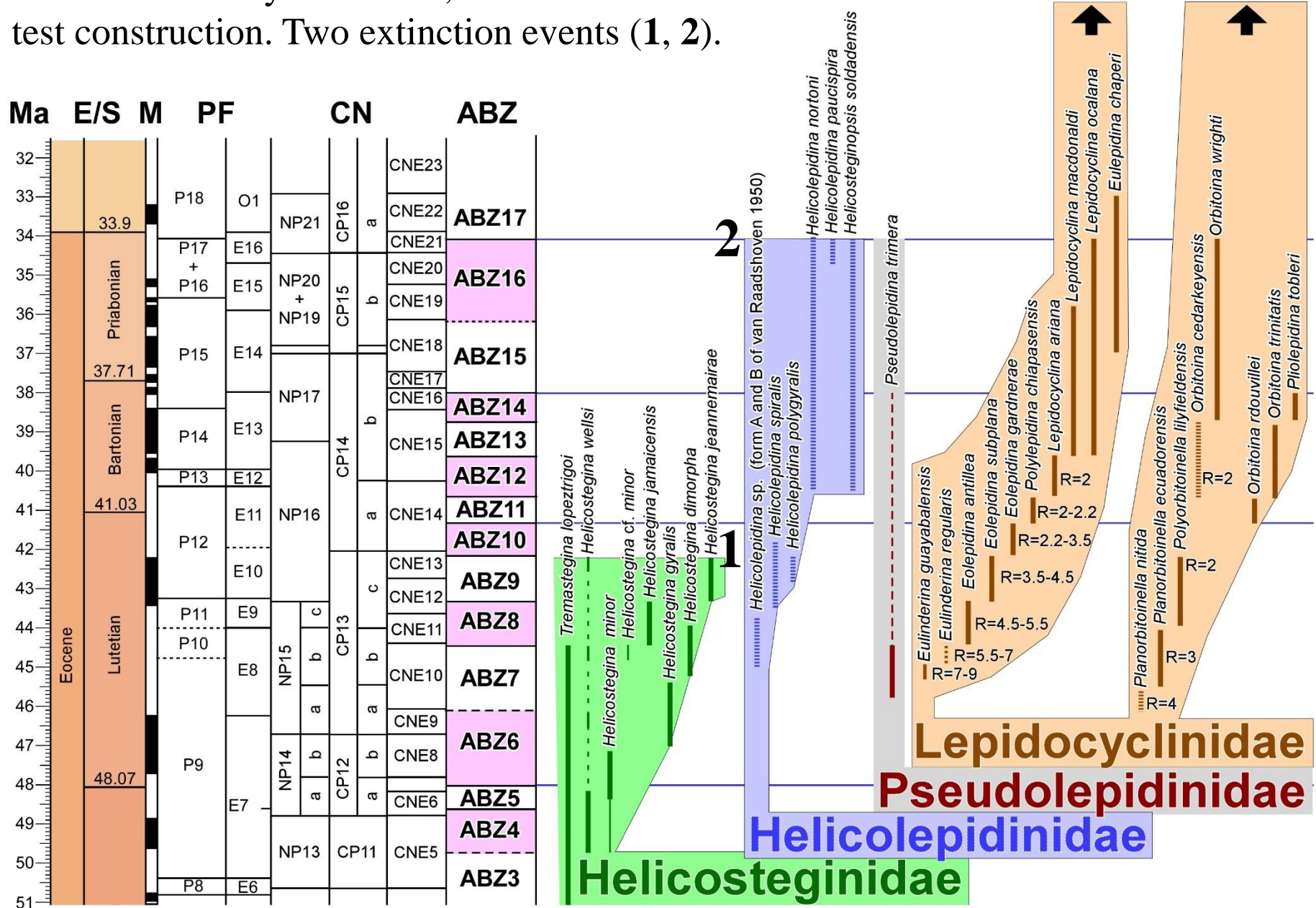
But this model is **NOT** in accordance with their stratigraphic distributions and their diverse test constructions. Consequently, such a simple phylogeny cannot be right.

A sound phylogeny needs to take into account test construction and stratigraphic distribution.

# Stratigraphic ranges of selected forams calibrated against nannos

Five evolutionary radiations, but two have the same test construction. Two extinction events (1, 2).

To L. Oligocene/M. Miocene



# **Some basics – random thin sections vs. orientated sections**

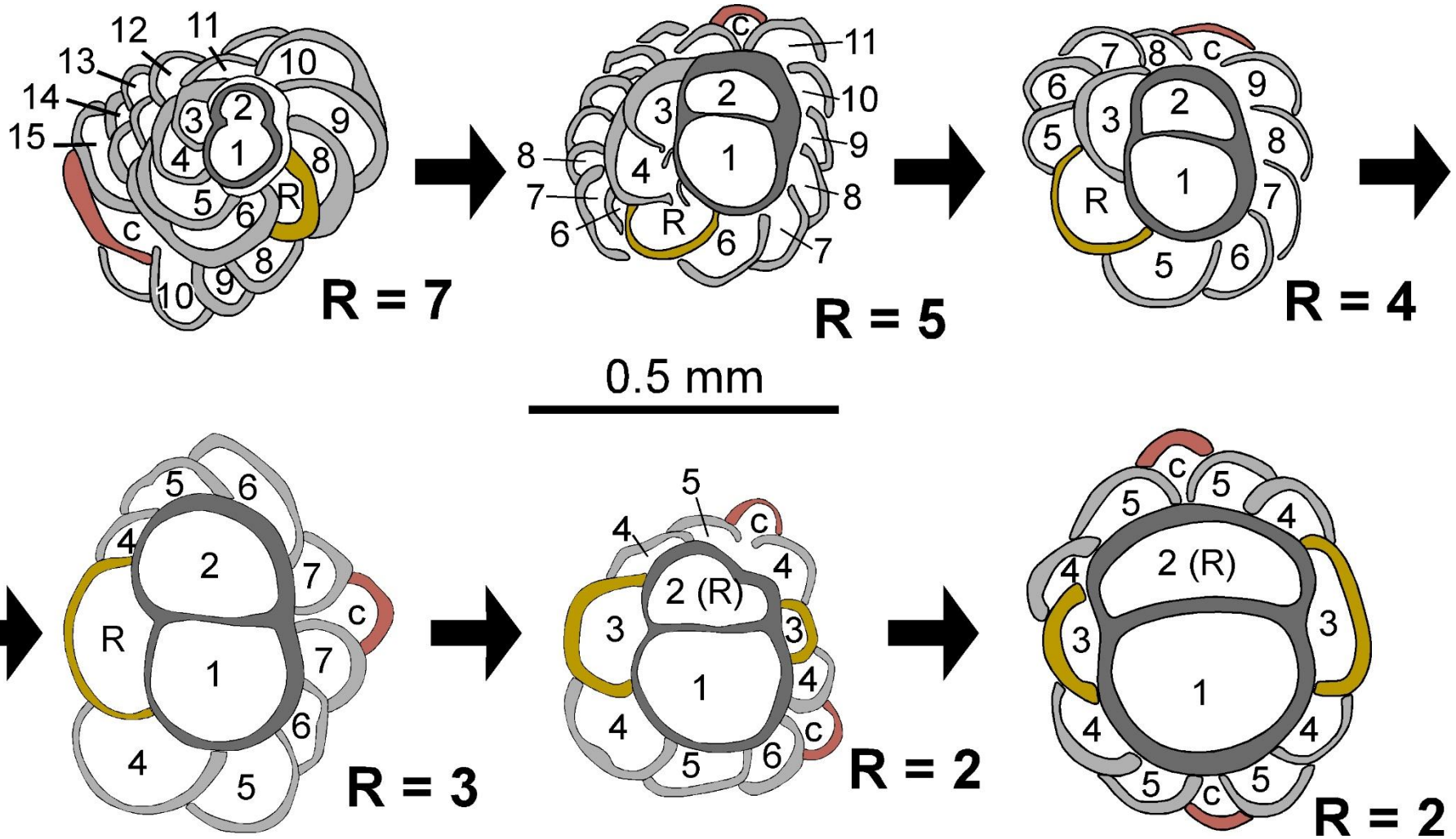
Larger benthic foraminifers (LBF) can be studied in two ways: **(1). random sections in thin-sections of rocks;** and **(2). orientated sections cut from free specimens.**

**LBF in random sections in thin sections:**– cuts invariably show off-axis or off-equatorial plane sections which are difficult to interpret and from which statistical treatments are impossible. Some species can be identified, but others are not possible to determine with any degree of certainty.

**Orientated sections of free individuals:**– multiple specimens can be cut in desired orientations (often equatorial and axial) and multiple measurements can be made allowing statistical comparison between different, or multiple, samples.

**For high-resolution biostratigraphy, the study of free specimens is absolutely preferable (assuming material is available) over random sections seen in thin sections of rock samples.**

# Nepionic acceleration in orbitoidiform foraminifera

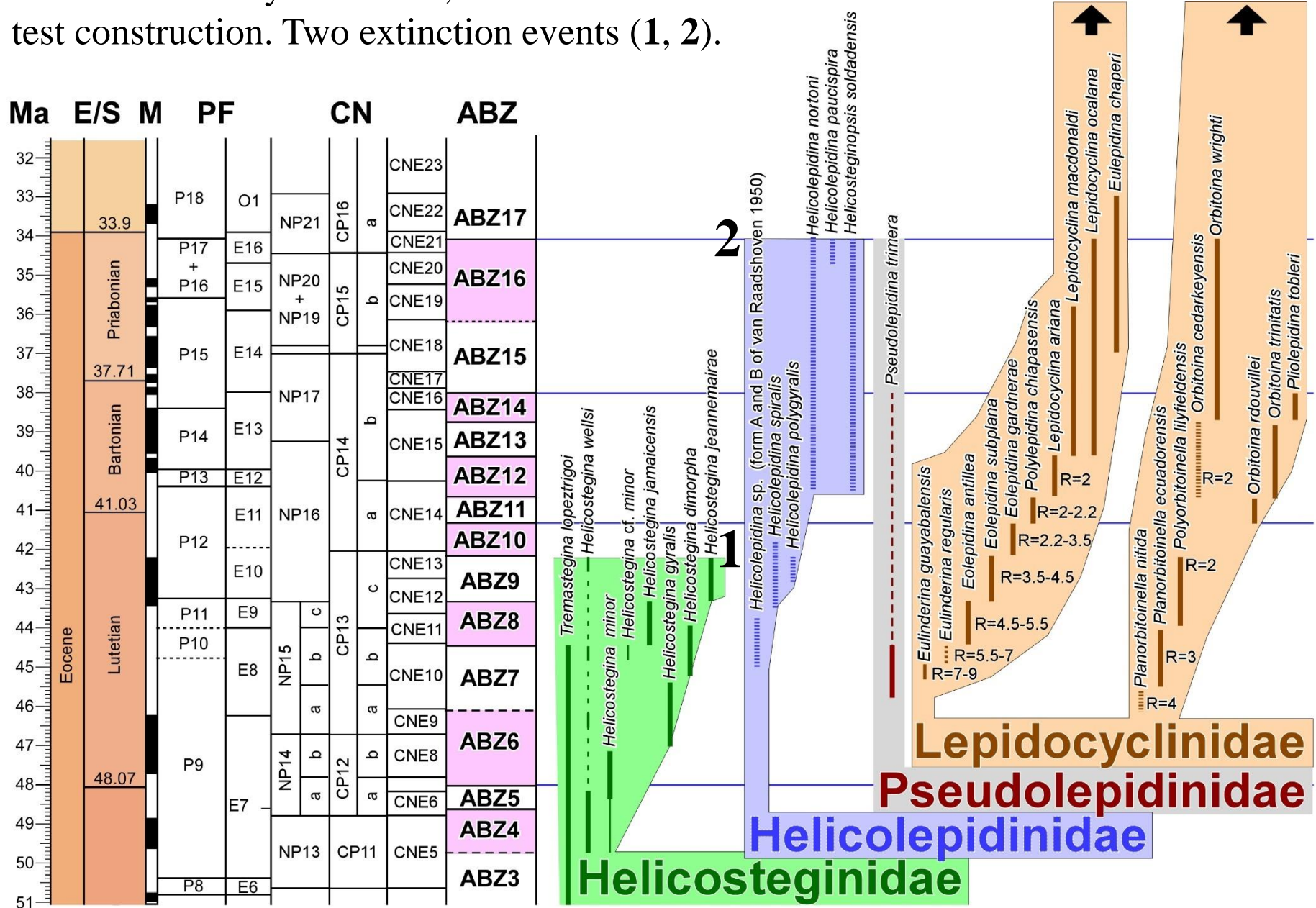


For any sample we work out the mean value of R for each species and use this to determine which species is present.

# Stratigraphic ranges of selected forams calibrated against nannos

Five evolutionary radiations, but two have the same test construction. Two extinction events (1, 2).

To L. Oligocene/M. Miocene





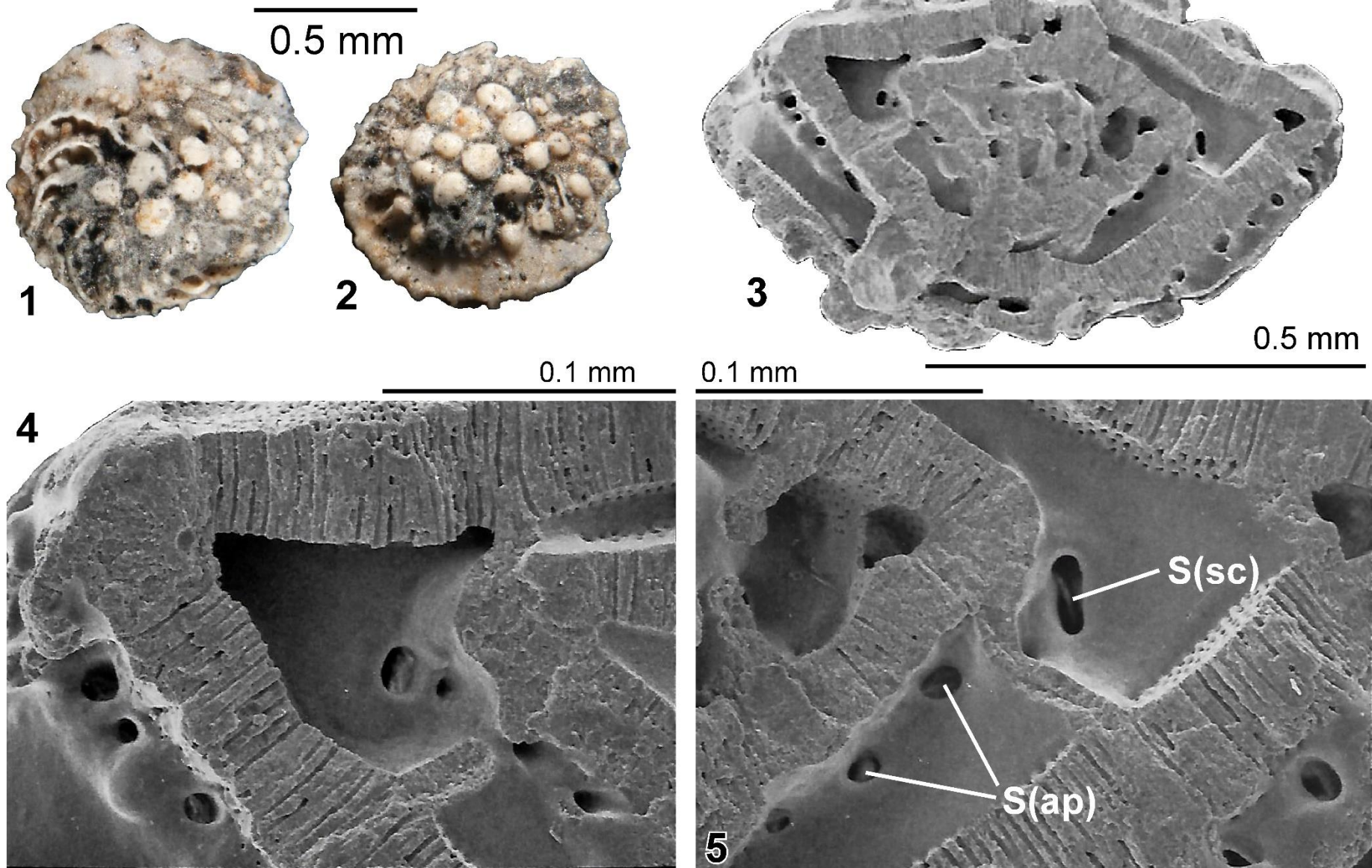
# Helicosteginidae Mitchell, Robinson & Özcan 2022

Primary spiral extends to the margin of the test (early forms) or terminates in a chamber (R) with two apertures with one forward- and one backward-facing (later forms). If an R-chamber is present, two secondary spirals coil around the perimeter of the primary spiral and terminate in a closing chamber. Equatorial chamberlets are developed from the secondary spires (which are present only if there is an R-chamber) and form an equatorial layer of chamberlets.

Alar prolongations on dorsal side undivided in early forms and may be lost in later forms where they are replaced by a laminated test lacking chamberlets.

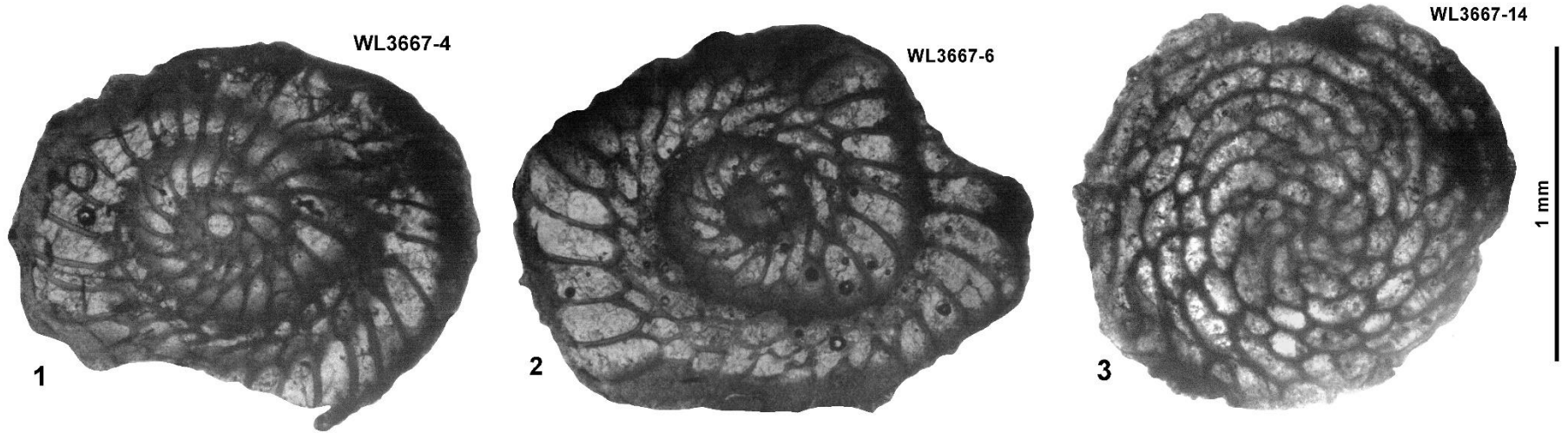
Ventral side of test with either: alternations of alar prolongations and stellar chambers combined with a series of ventral solons; or, with a spiral layer of subsidiary chamberlets. In later forms subsidiary chamberlets form an orbitoidal-like layer on the ventral side, which, with the chamberlets of the equatorial layer, extend peripherally to form a double flange.

# *Tremastegina senni* (CUSHMAN in VAUGHAN 1945)

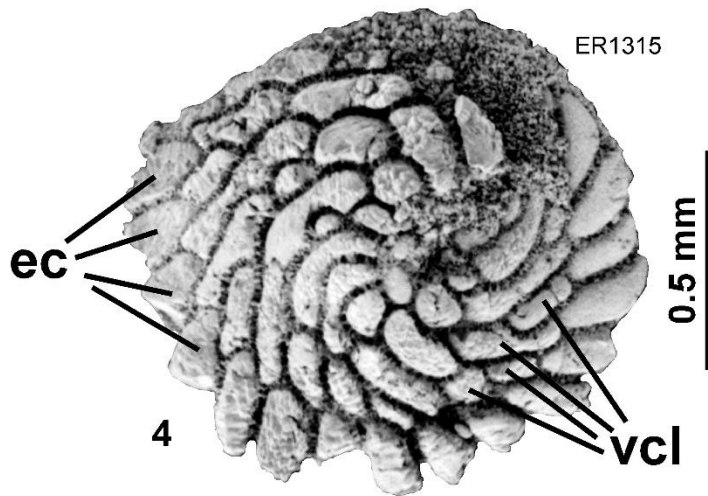


Showing stolons connecting alar prologations and stellar chambers on ventral side

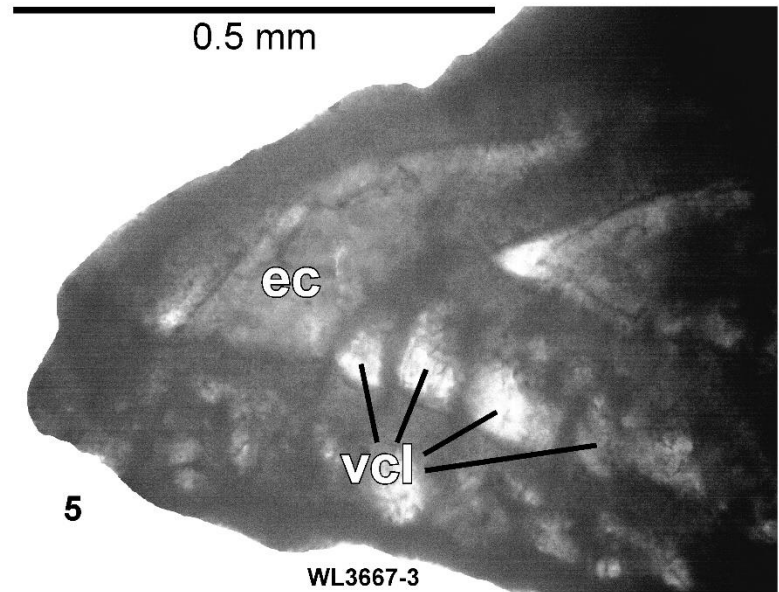
# *Helicostegina minor* Mitchell, E. Robinson & Özcan



1-3: equatorial sections cut at different levels to show ventral chamberlets

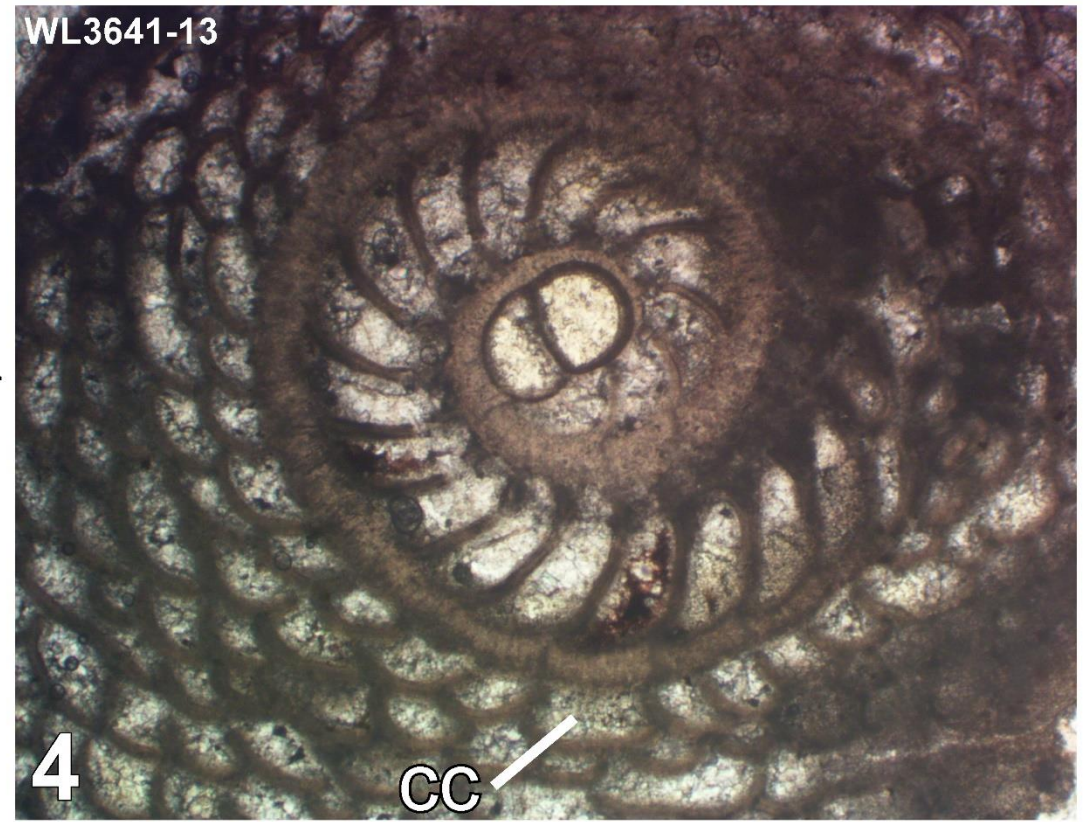
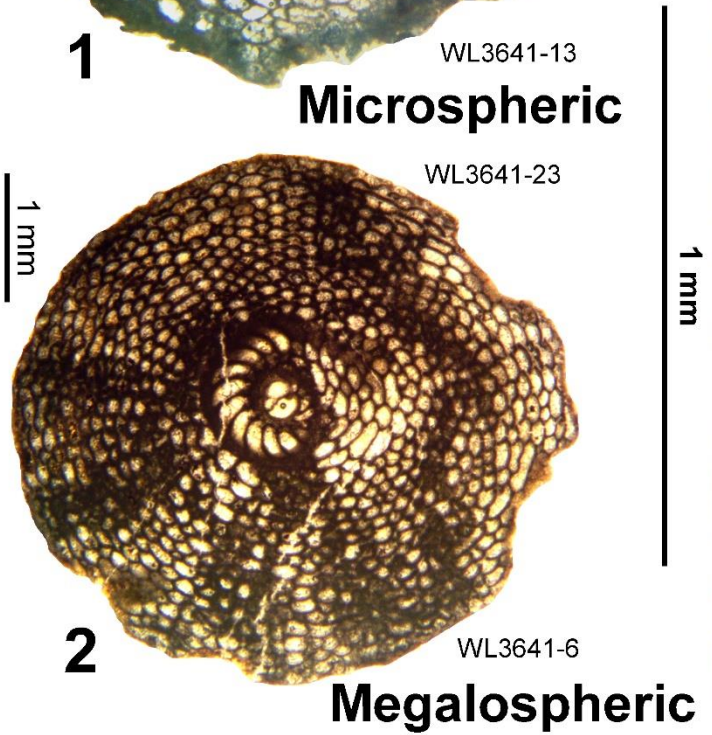
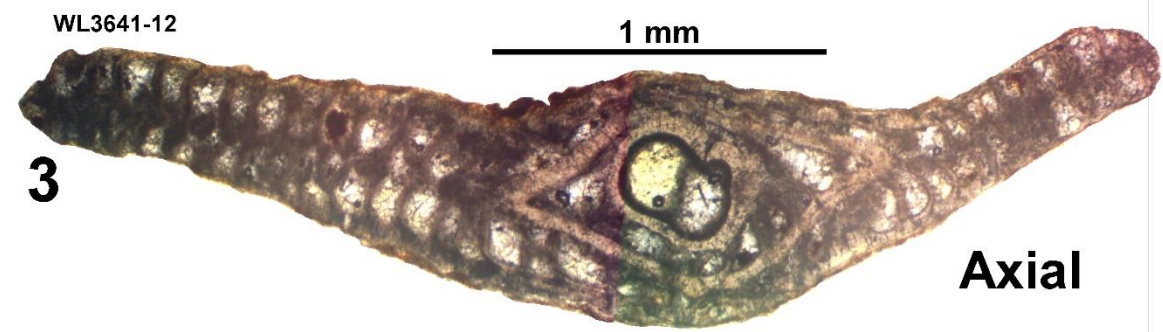
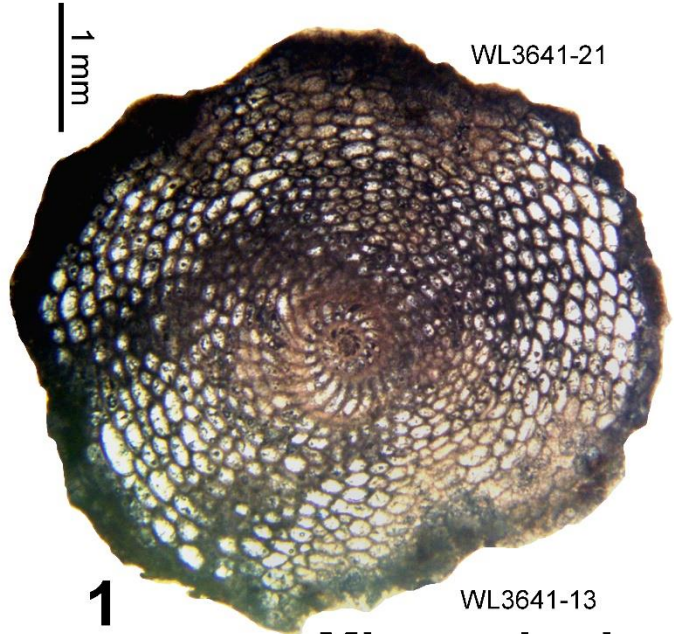


4: Specimen with test dissolved away - ventral view



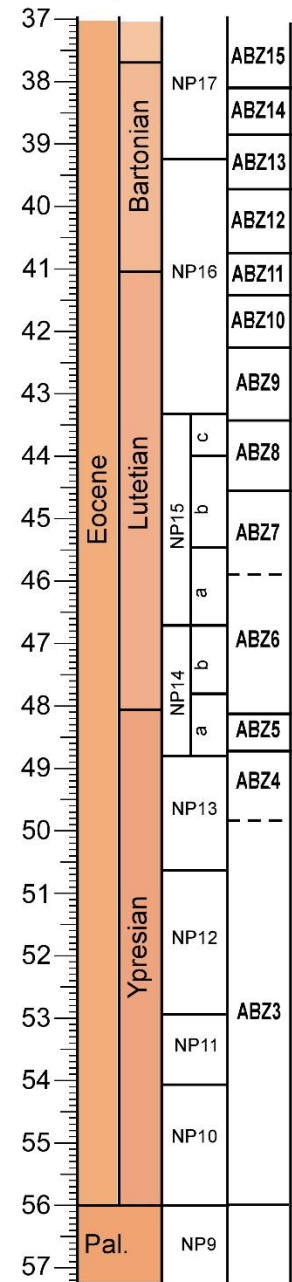
5: Axial view showing equatorial chambers (ec) and ventral chamberlets (vcl)

# *Helicostegina jeannemairae* E. Robinson, Mitchell & Özcan



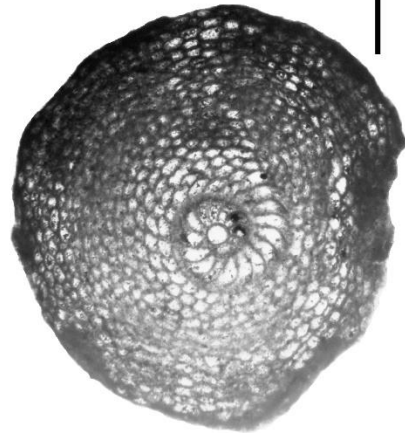
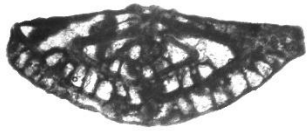
# Evolution of the Helicosteginidae

Ma Stage NP AE



*Tremastegina semni/lopeztrigoi*

*Helicostegina wellsii*  
*Helicostegina minor*  
*Helicostegina cf. minor*  
*Helicostegina jamaicensis*  
*Helicostegina gyralis*  
*Helicostegina dimorpha*  
*Helicostegina jeannemairae*

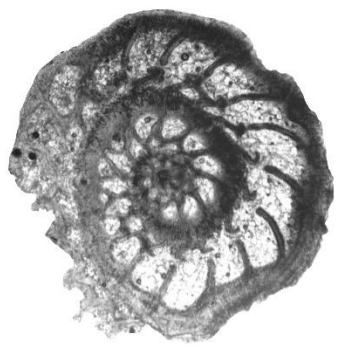


*H. gyralis*

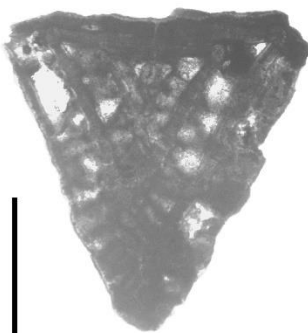
*H. dimorpha*

*H. jeannemairae*

All scale bars = 1 mm



*T. lopeztrigoi*



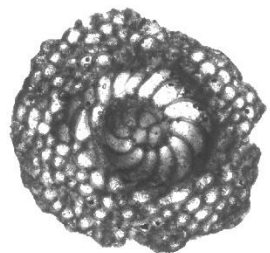
*H. wellsii*



*H. minor*



*H. jamaicensis*



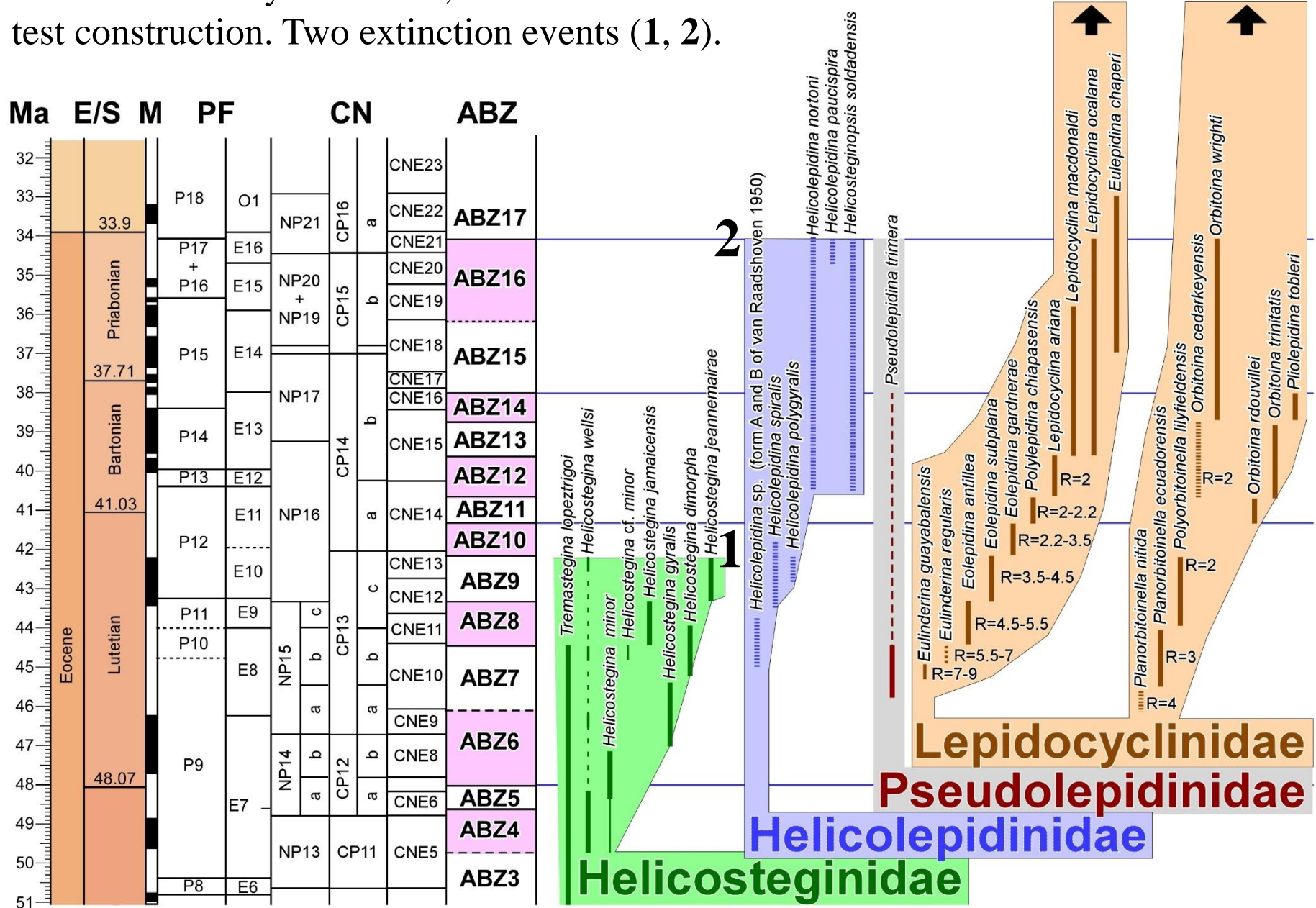
*H. cf. minor*



# Stratigraphic ranges of selected forams calibrated against nannos

Five evolutionary radiations, but two have the same test construction. Two extinction events (1, 2).

To L. Oligocene/M. Miocene



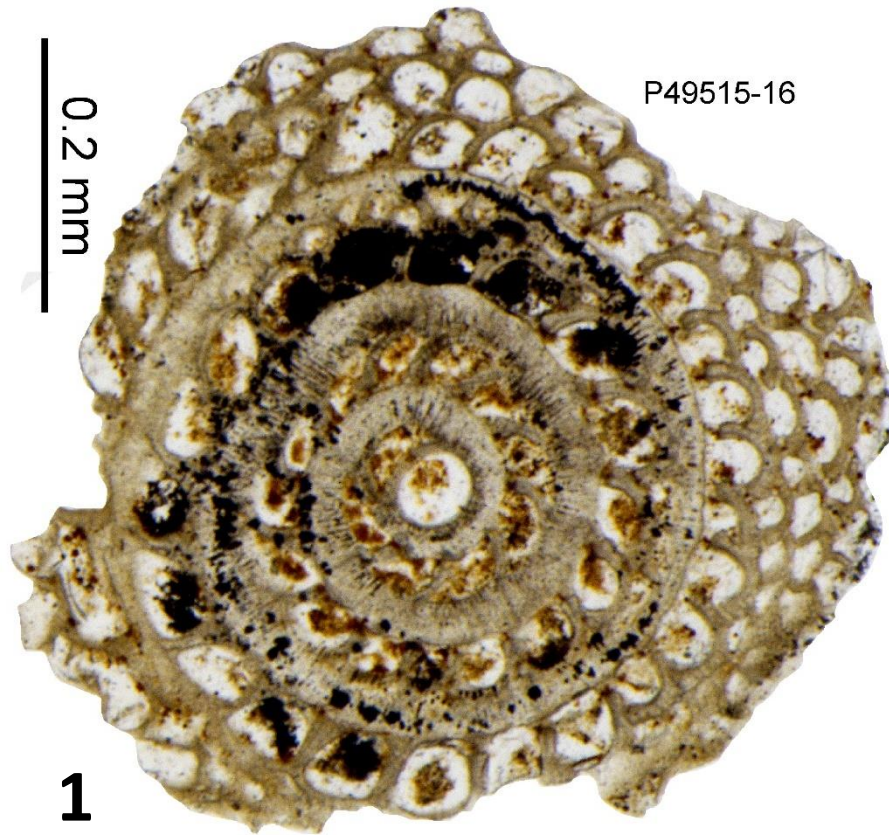
## **Helicolepidinidae Tan 1936**

Primary spiral of equatorial chambers extends to the margin of the test or terminates within the test. Equatorial chamberlets developed on the outside of the primary spire from the equatorial chambers.

Orbitoidiform growth occurs if the primary spire terminates.

Lateral sides of the test symmetrical with lateral chamberlets developed on each side. This contrasts markedly with the *Helicosteginidae* which has a ventral layer of subsidiary chamberlets.

***Helicosteginopsis soldadensis***  
**Grimsdale in Vaughan & Cole**  
**1941**



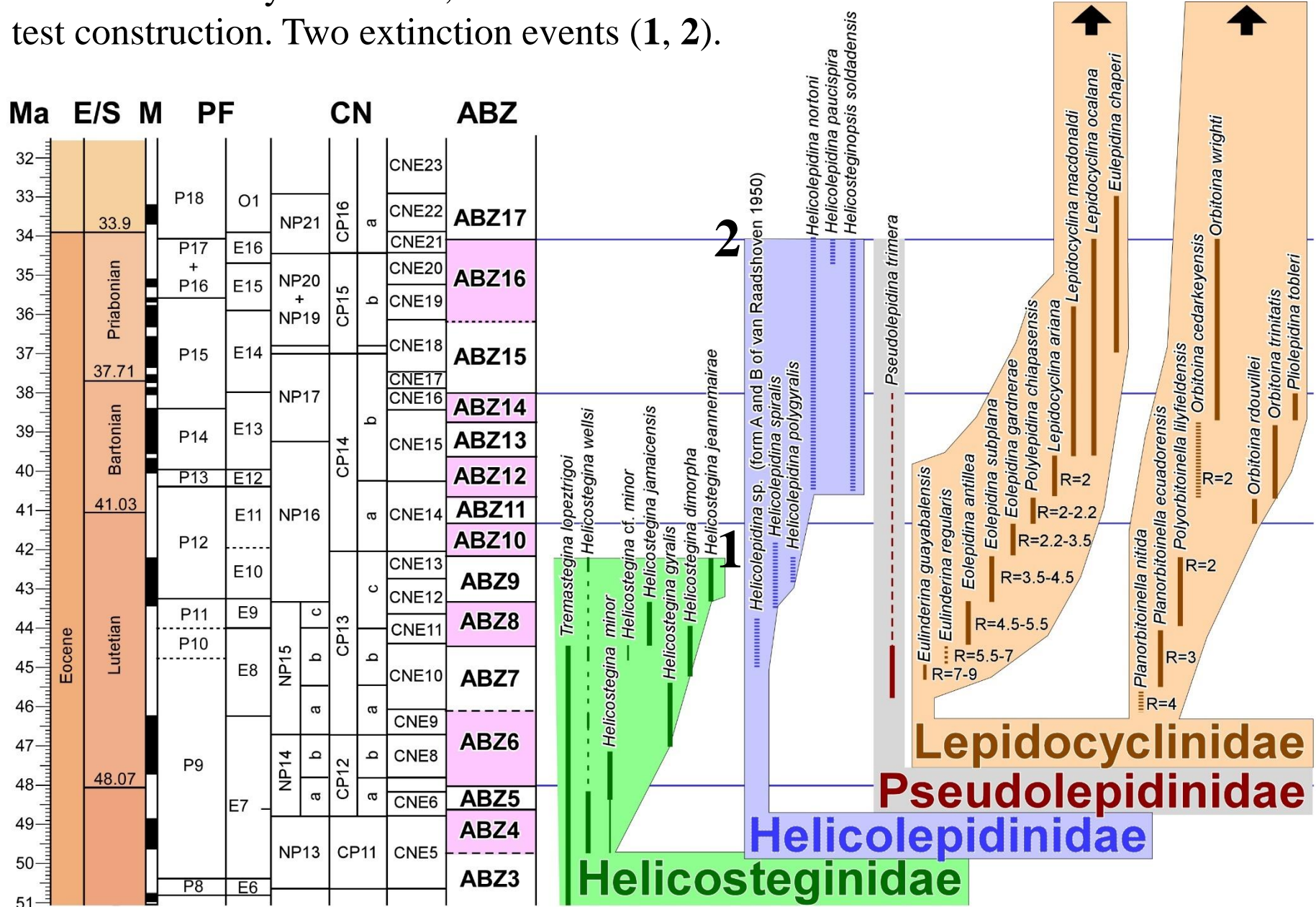
**Note single equatorial layer and symmetrical lateral chamberlets**



# Stratigraphic ranges of selected forams calibrated against nannos

Five evolutionary radiations, but two have the same test construction. Two extinction events (1, 2).

To L. Oligocene/M. Miocene



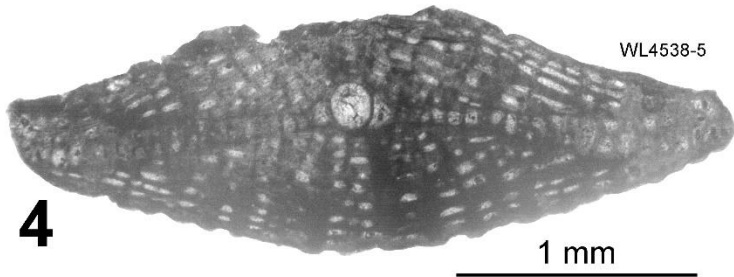
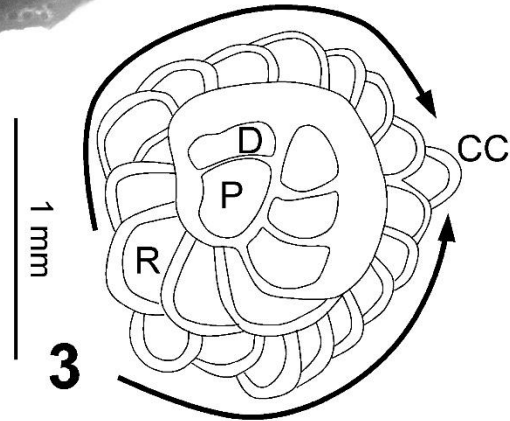
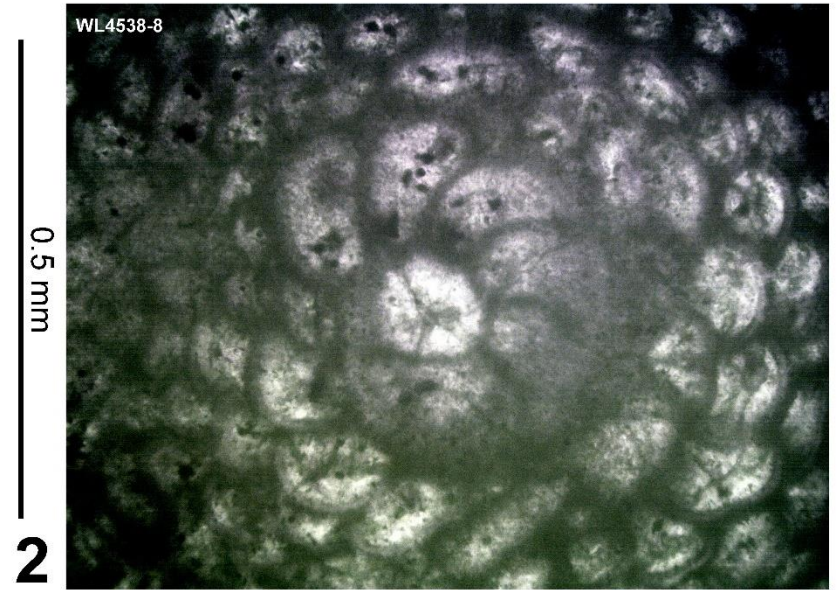
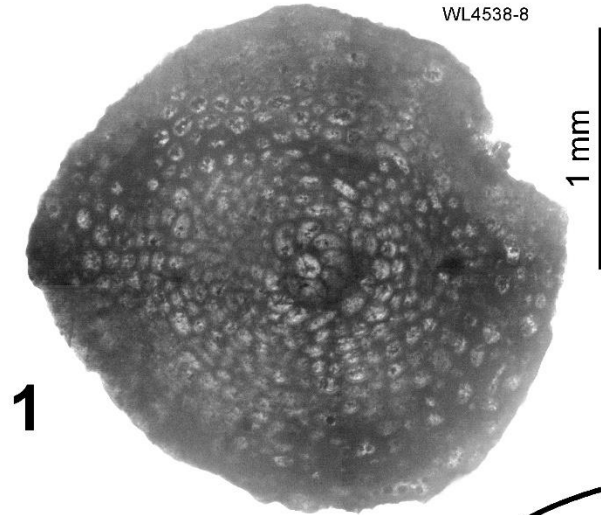
# **Pseudolepidinidae Mitchell, Robinson & Özcan 2022**

Primary spiral extends to the margin of the test margin but develops into a true double layer close to the embryo. The embryo consists of two chambers, proloculus or protoconch and deuterolocus or deuterococonch. A short primary spire of equatorial chambers may be present, or one or two Principal Auxiliary Chambers (PCA). In some forms a 'third' PCA may be developed, which could be considered as part of the embryo. Orbitoidiform growth is developed in the two double layers of equatorial chamberlets. In later forms a calcite lamina may separate the layers in two double equatorial layers.

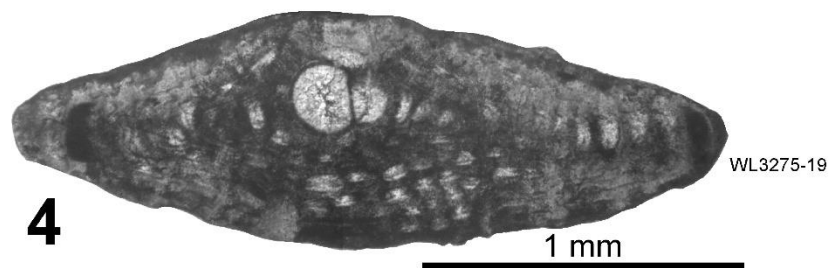
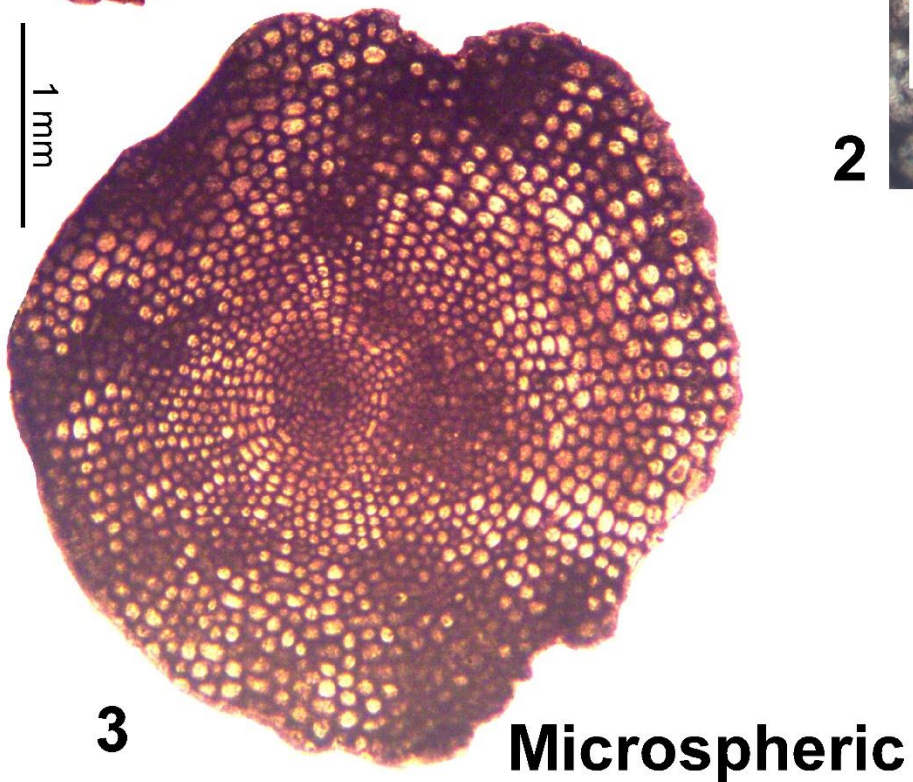
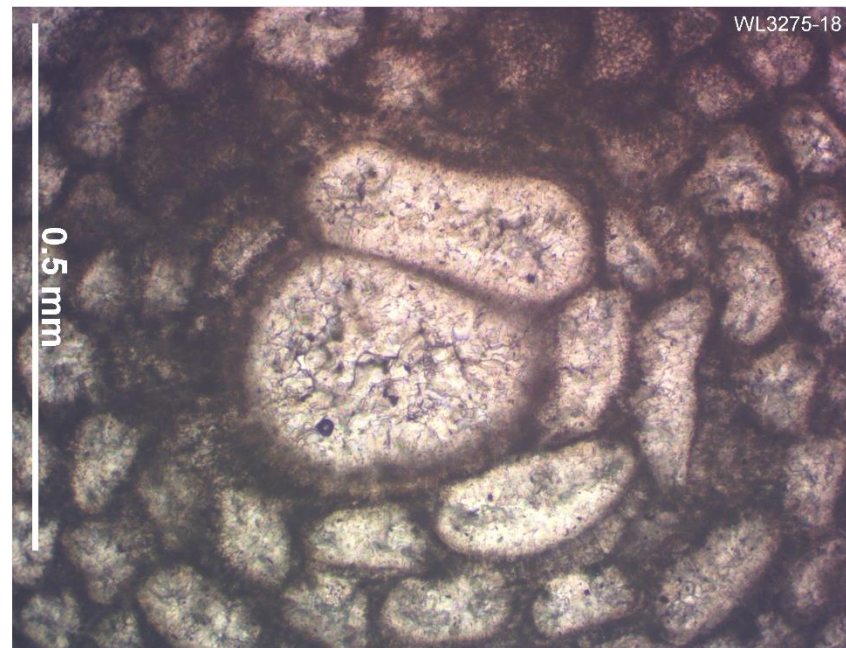
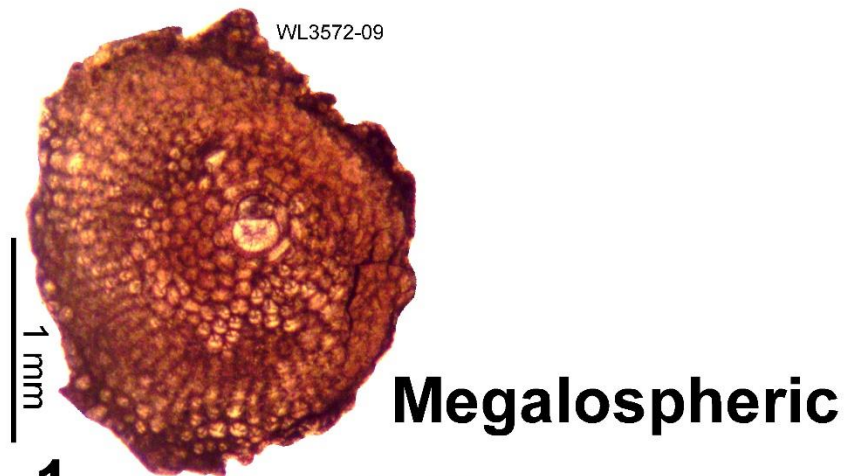
Lateral sides of the test symmetrical with multiple layers of lateral chamberlets (with clearly open chambers) developed on each side as in the Helicosteginidae.

Three genera, but not used in the zonation.

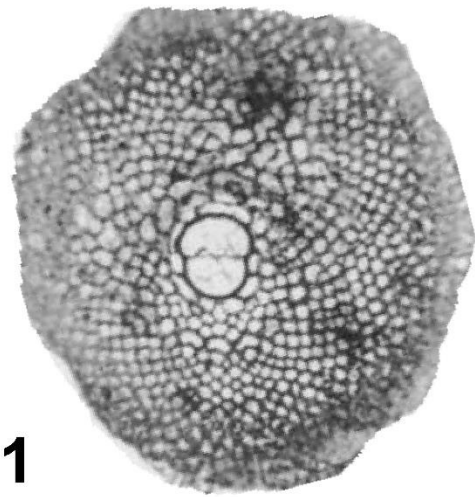
# *Hanovolepidina primalis* sp. nov.



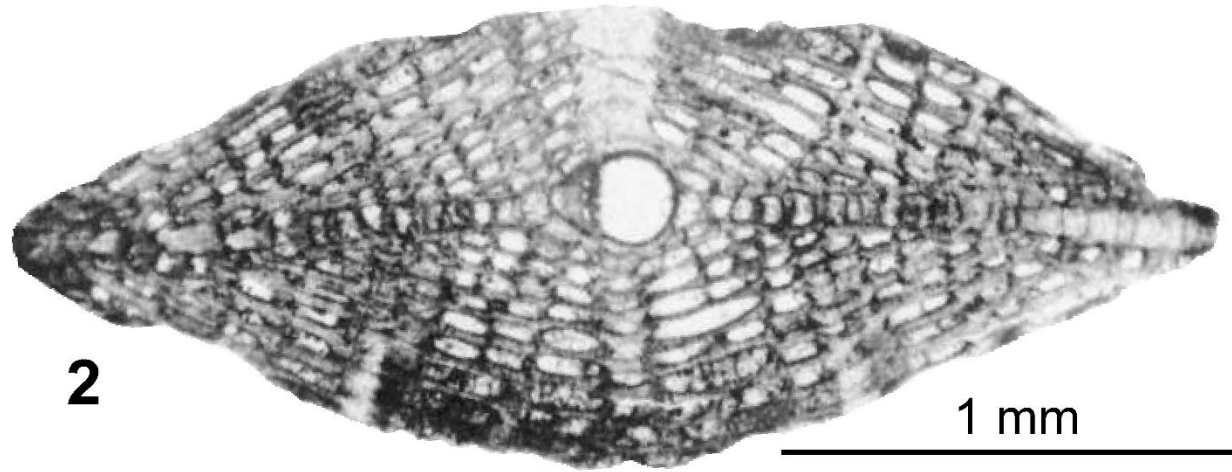
# *Pseudolepidina trimera* (Barker & Grimsdale 1937)



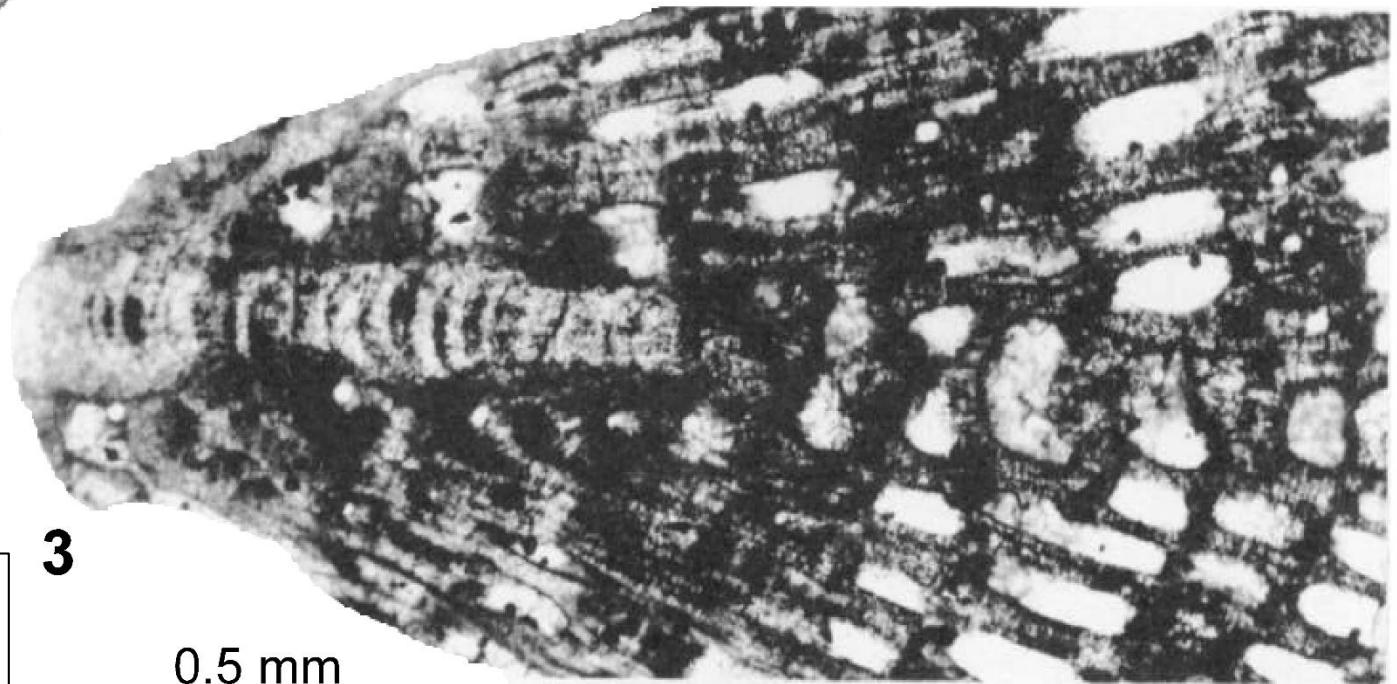
# *Triplalepidina veracruzensis* Vaughan & Cole 19



1 mm



1 mm



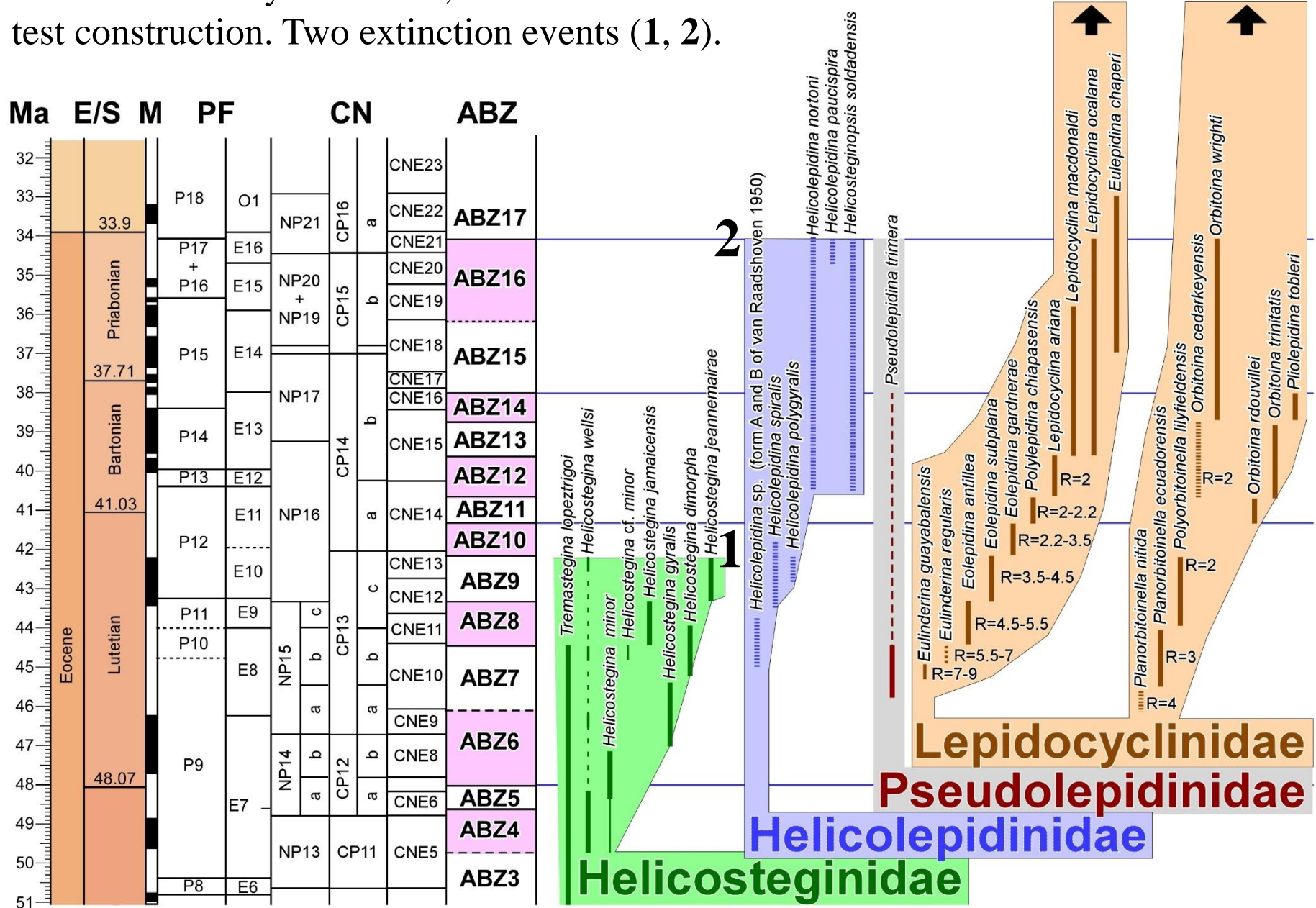
0.5 mm

**Not yet seen in  
Jamaica**

# Stratigraphic ranges of selected forams calibrated against nannos

Five evolutionary radiations, but two have the same test construction. Two extinction events (1, 2).

To L. Oligocene/M. Miocene



# Lepidocyclinidae Scheffen 1932

Embryo formed of an embryo consisting of a proloculus or protoconch and a deuteroloculus or deuteuroconch. In early forms a primary spire of equatorial chambers is developed from the embryo and terminates in a retrovert chamber (R). From R two spirals develop and terminate in a closing chamber. Over time the primary spire of equatorial chambers becomes progressively short (nepionic acceleration), eventually leading to one PAC and finally two PACs. Once two PACs are developed three or four spires develop from them with two closing chambers and eventually these spires become four symmetrical spires about the protoconch-deuteuroconch axis. Subsequent development sees the development of auxiliary chambers from the deuteuroconch and protoconch and the increase in width of the deuteuroconch that envelops the protoconch.

Lateral chamberlets absent in earliest forms and symmetrically developed around the equatorial layer in later forms.

# Lepidocyclinidae Scheffen 1932

Two separate, out-of-step, radiations developed from the early Lutetian (Middle Eocene) onwards.

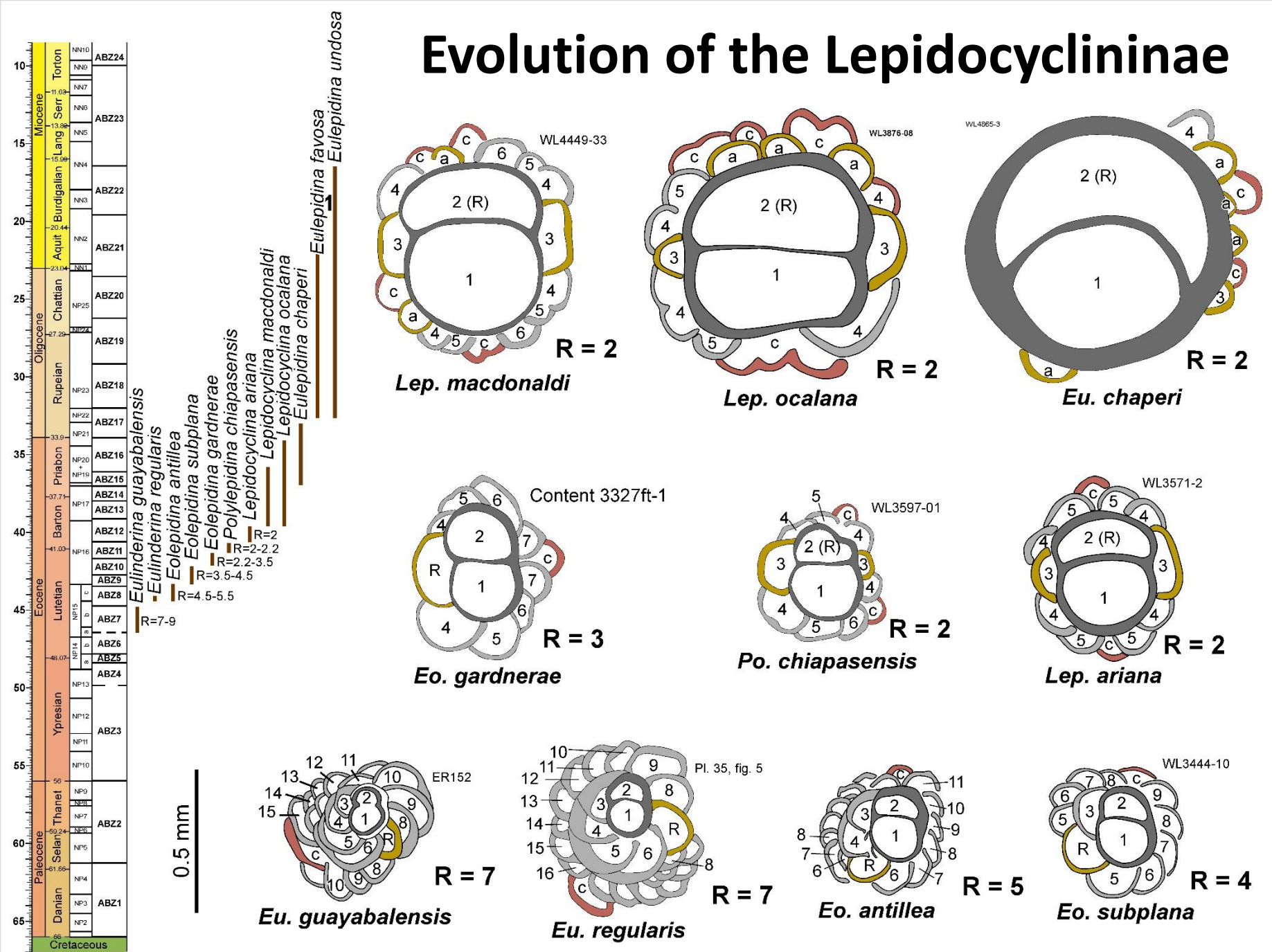
**Lepidocyclininae Scheffen 1932** – less advanced (in terms of nepionic acceleration), larger proloculus/embryo, small number of layers of lateral chamberlets.

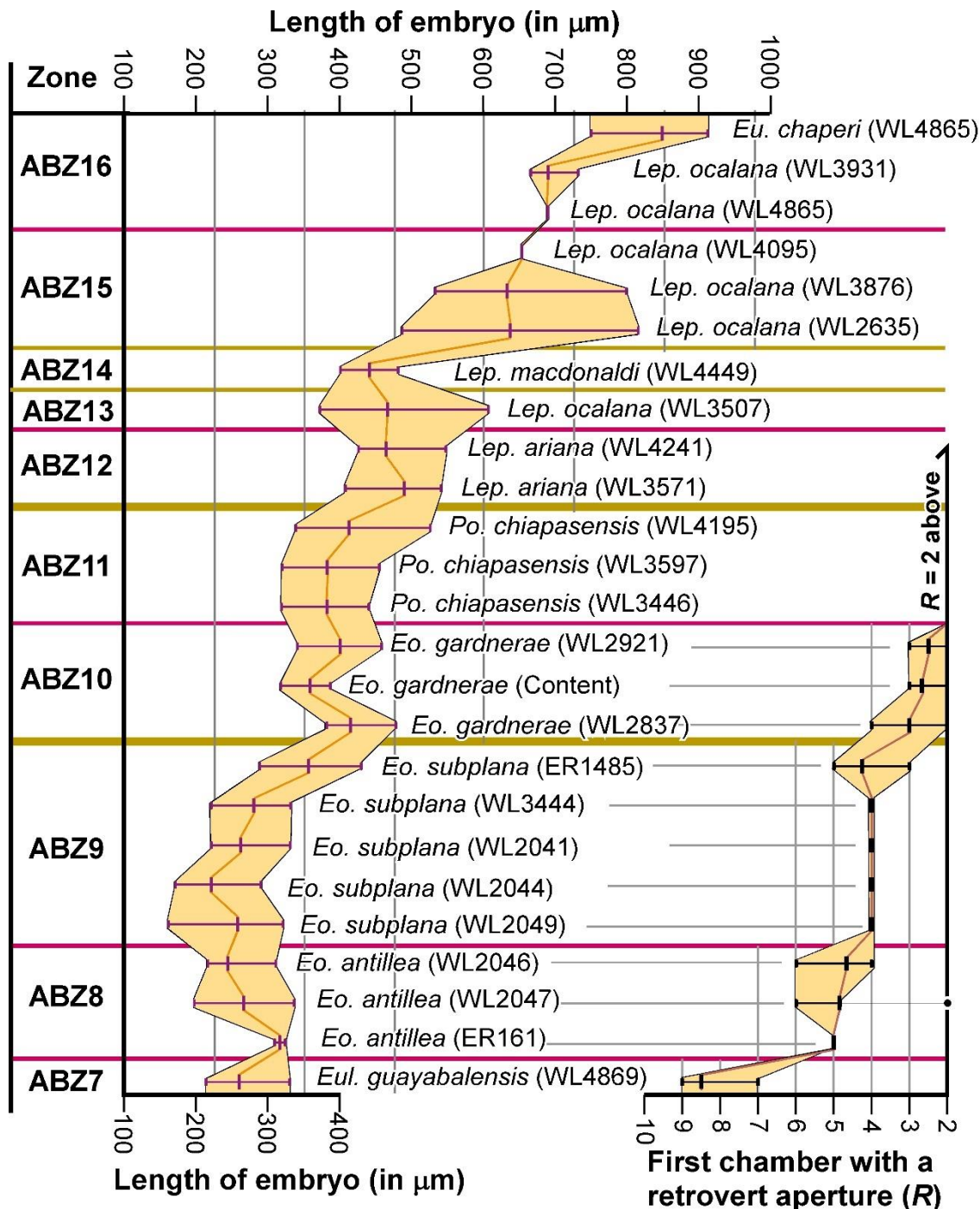
**Orbitoniinae Mitchell, Robinson & Özcan 2022** – more advanced (in terms of nepionic acceleration), smaller proloculus/embryo, larger number of layers of lateral chamberlets.

These two subfamilies run parallel through the Eocene and, therefore, in the Eocene each step in each lineage needs to be given a different generic name. Separate names are already in use for the Oligocene to Miocene forms (e.g., *Nephrolepidina* and *Eulepidina*).

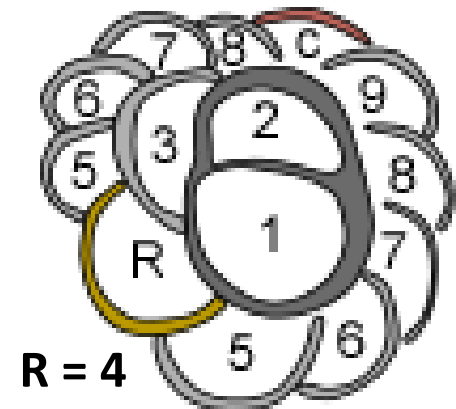
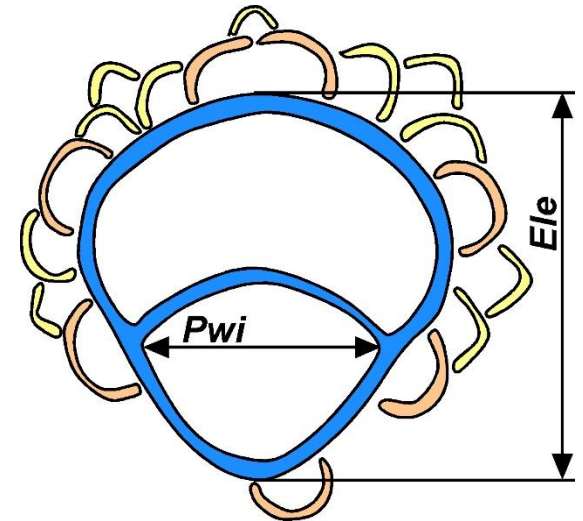


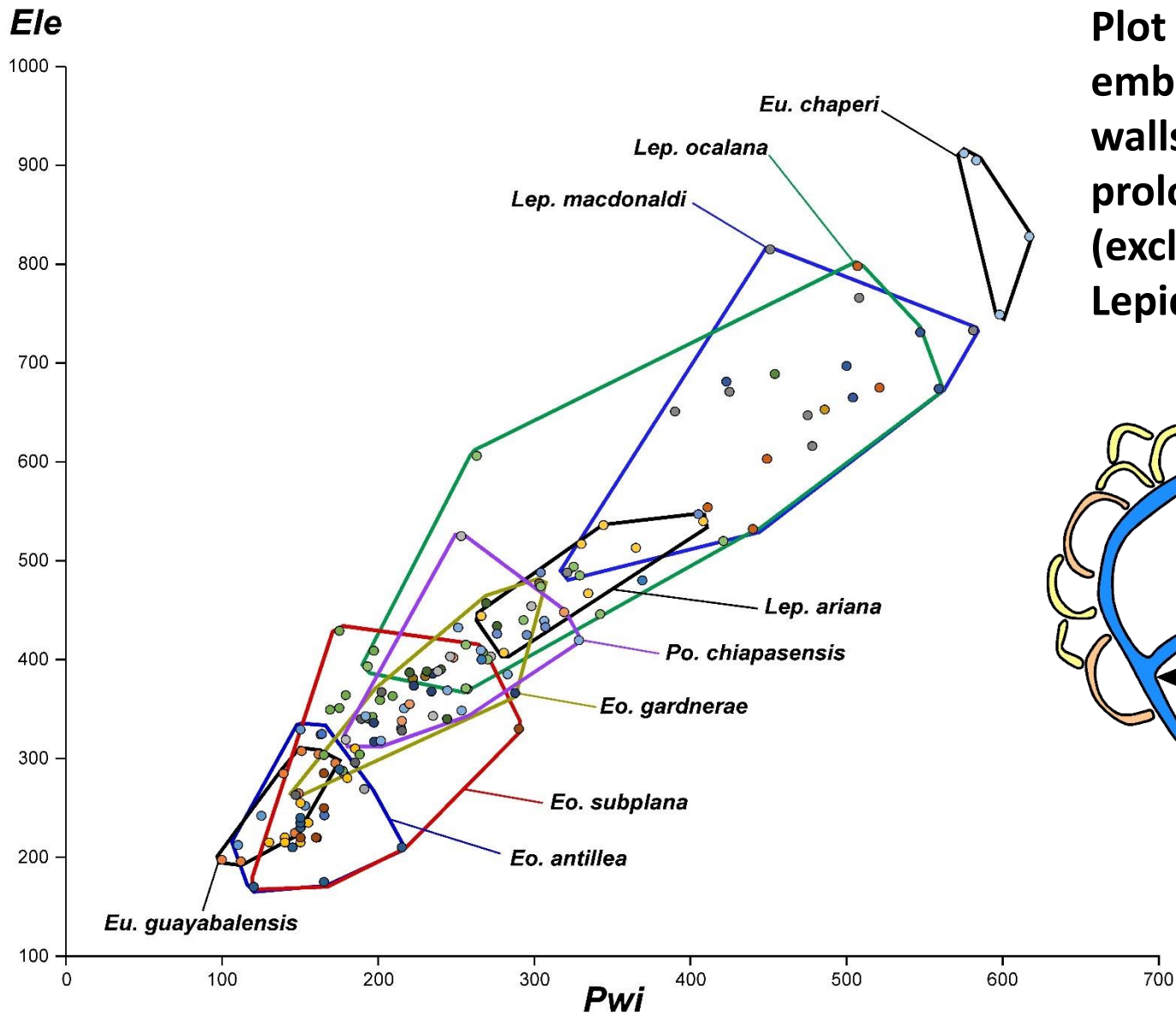
# Evolution of the Lepidocyclininae



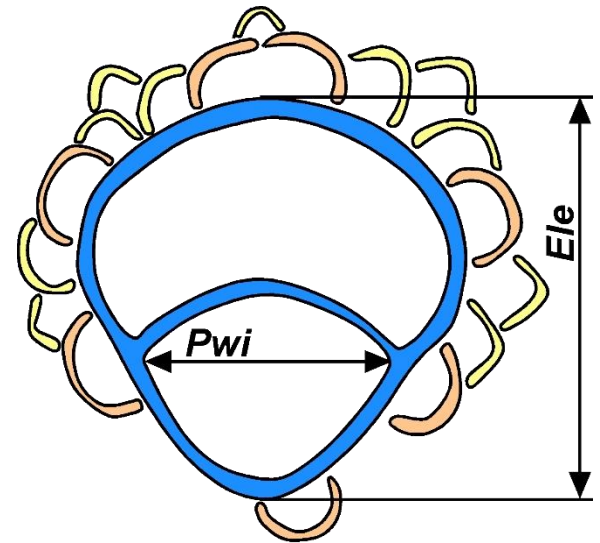


**Changes in the length (including walls) of the embryo (*Ele*) and in position of R in Lepidocycliniinae**





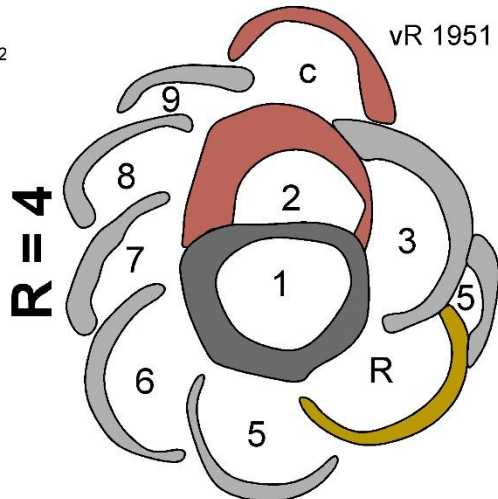
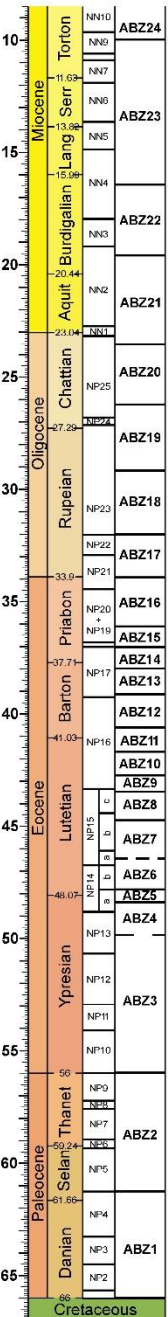
Plot of length of embryo (including walls) vs. width of proloculus/ protoconch (excluding walls) in Lepidocyclinae



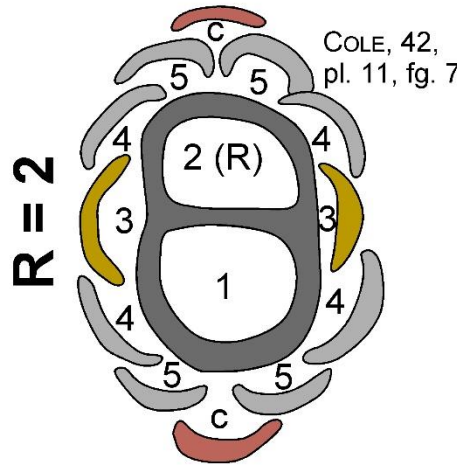
- *Eu. guayabalensis* ER152
- *Eo. antillea* WL2047
- *Eo. antillea* WR161
- *Eo. antillea* WL2046
- *Eo. subplana* WL3444
- *Eo. subplana* ER1485
- *Eo. subplana* WL2044
- *Eo. subplana* WL2041
- *Eo. gardnerae* W4449
- *Eo. gardnerae* WL2921
- *Eo. gardnerae* Content Well
- *Eo. gardnerae* WL2837
- *Po. chiapasensis* WL3446
- *Po. chiapasensis* WL4195
- *Po. chiapasensis* WL3597
- *Lep. ariana* WL3591
- *Lep. ariana* WI4241
- *Lep. ocalana* WL3507
- *Lep. ocalana* WL2635
- *Lep. ocalana* WL3876
- *Lep. ocalana* WL4095
- *Lep. ocalana* WL3931
- *Lep. ocalana* WL4865
- *Lep. macdonaldi* WL4449

This kind of plot was first used by Cole (1963: *American Bulletins of Paleontology*)

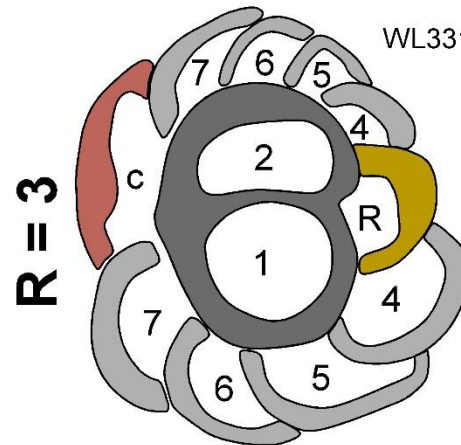
# Evolution of the Orbitoininae



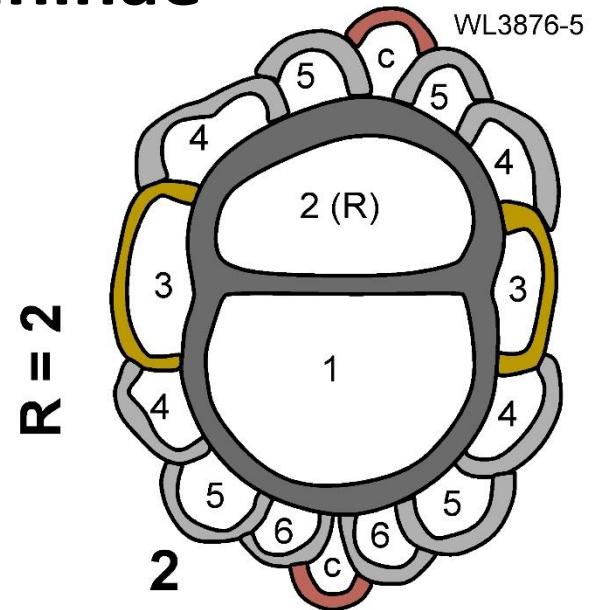
*Pl. nitida*



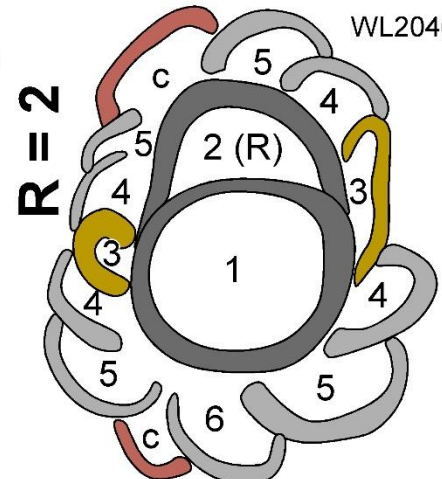
*Or. cedarkeysensis*



*Pl. ecuadorensis*

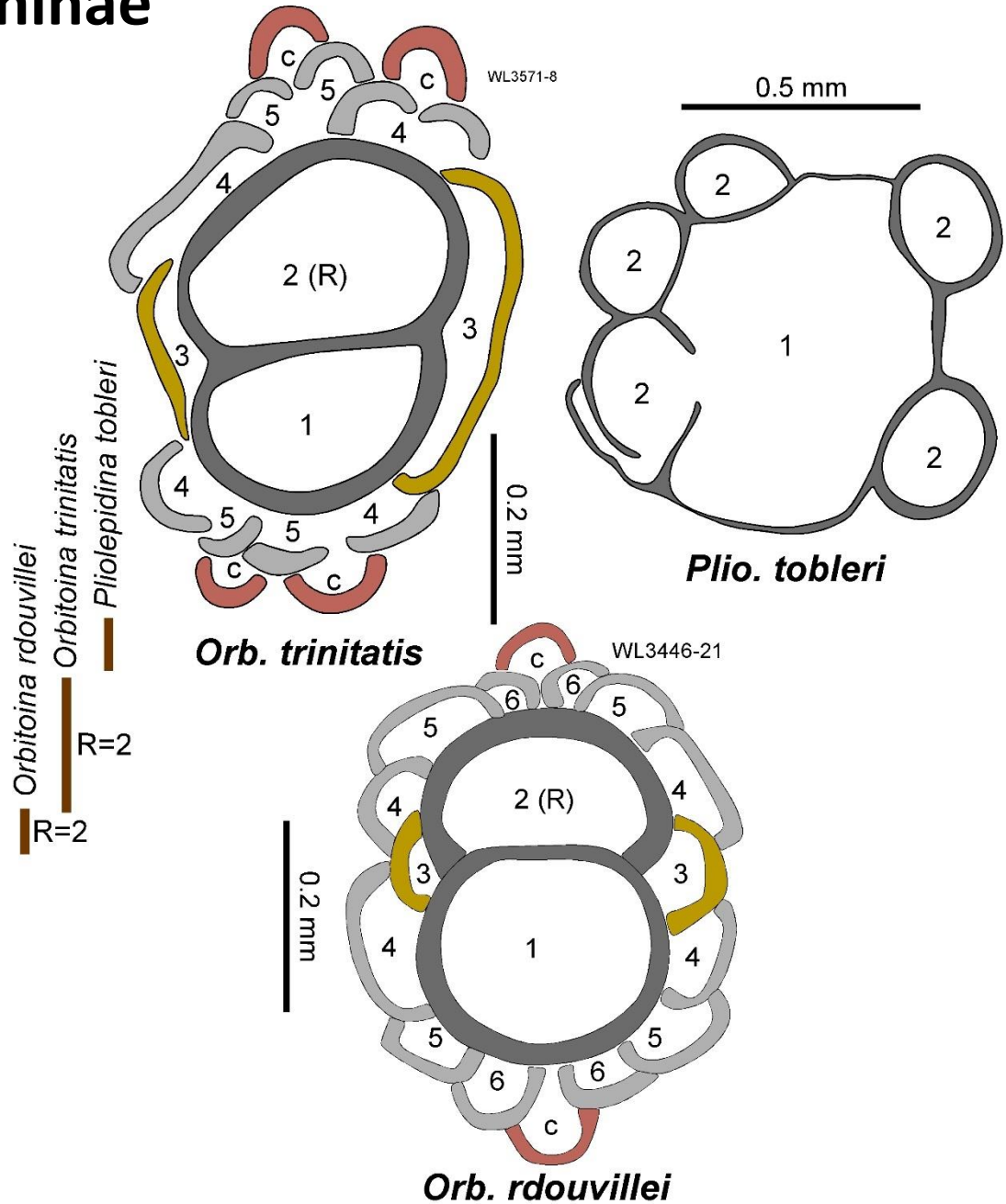
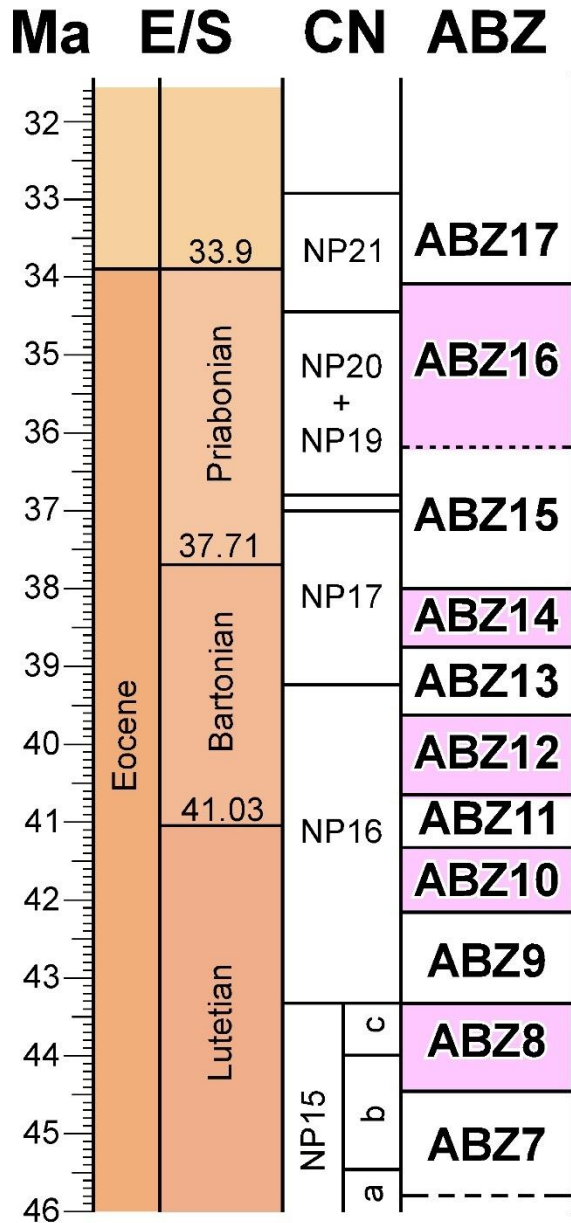


*Or. wrighti*

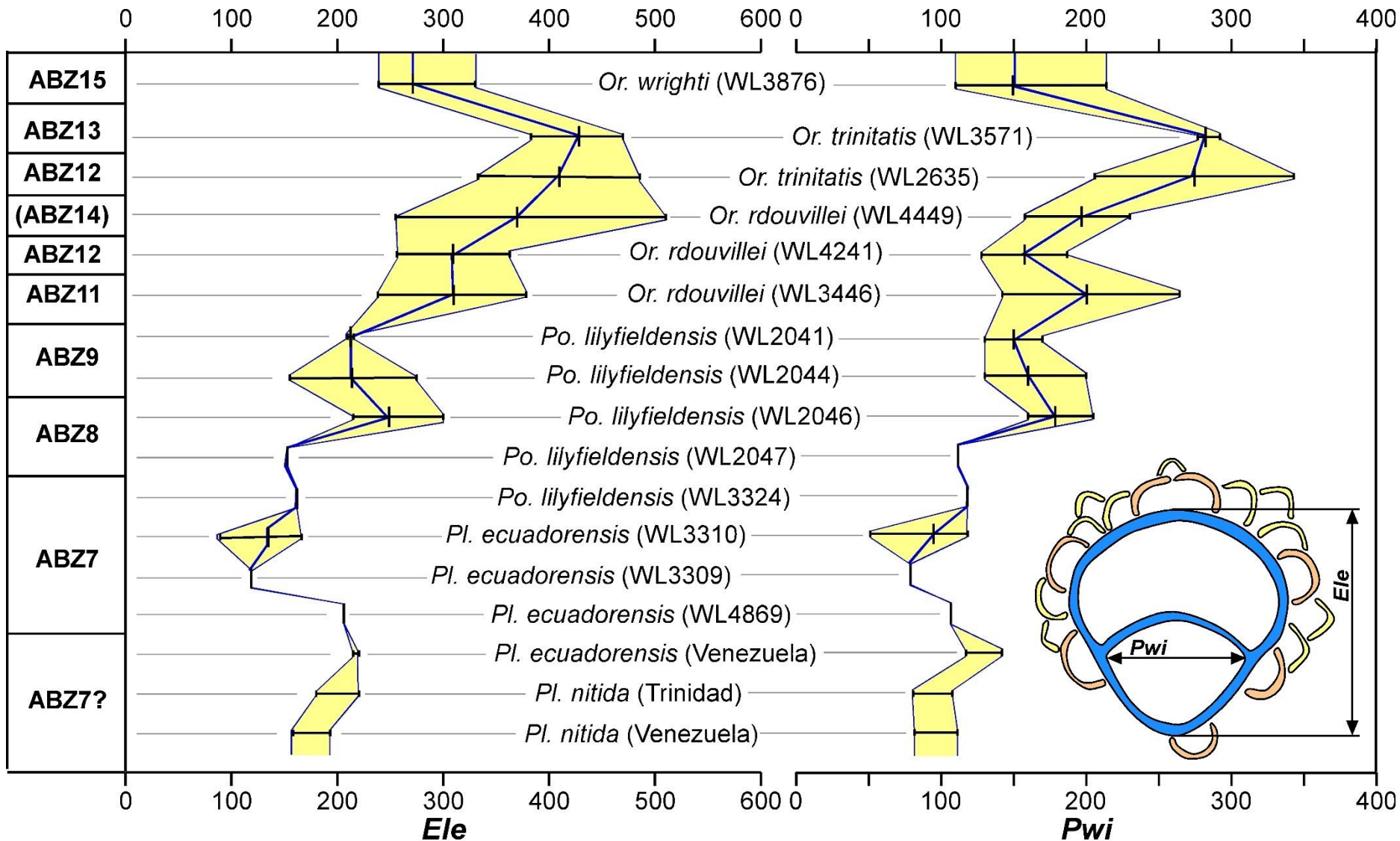


*Po. lilyfieldensis*

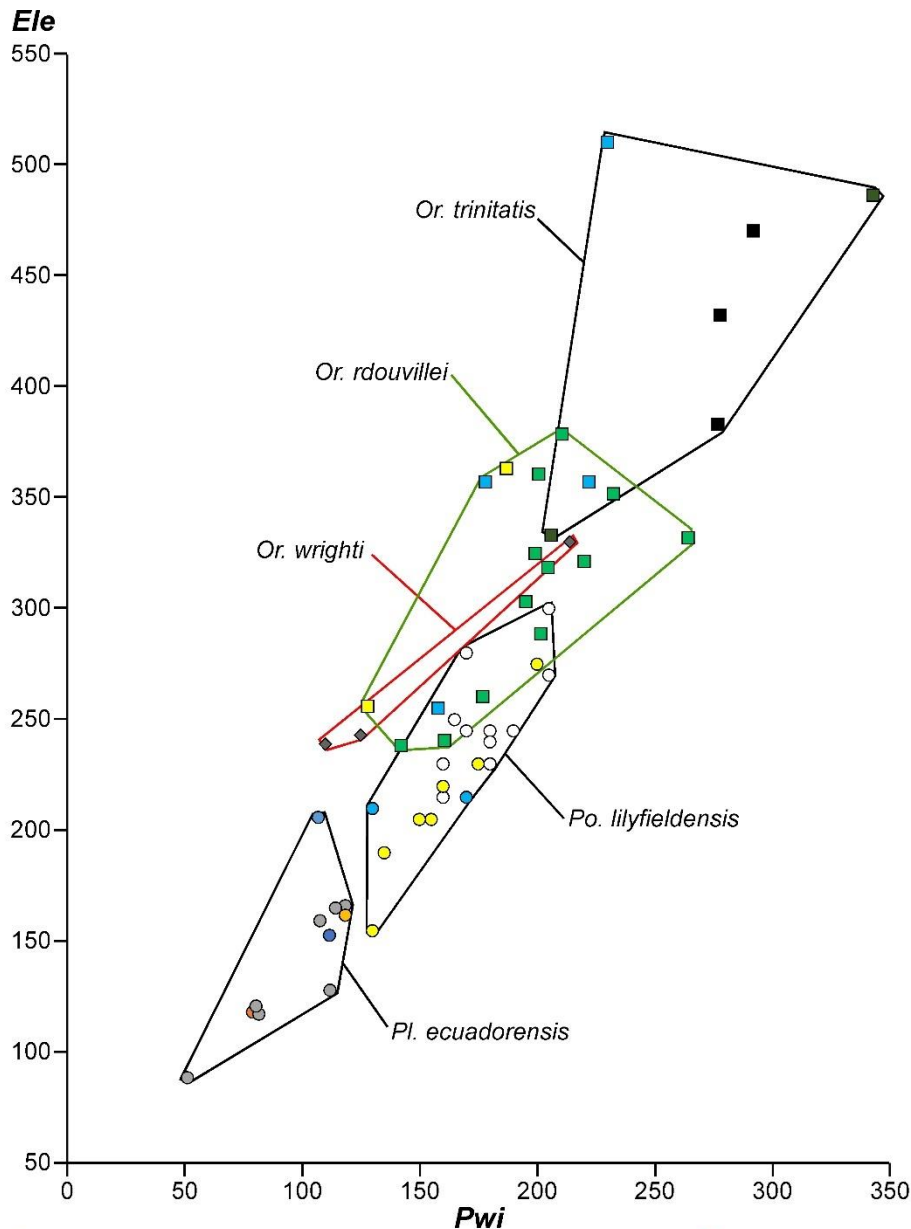
# Evolution, Lepidocyclininae



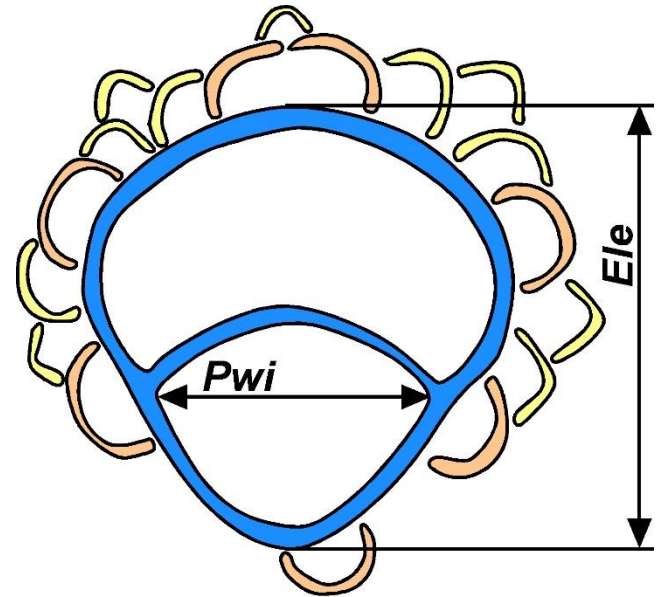
# Changes in length of embryo (including walls) and width of proloculus (excluding walls) in Orbitoininae



# Plot of length of embryo (including walls) vs. width of proloculus/protoconch (excluding walls) in Orbitoïninae



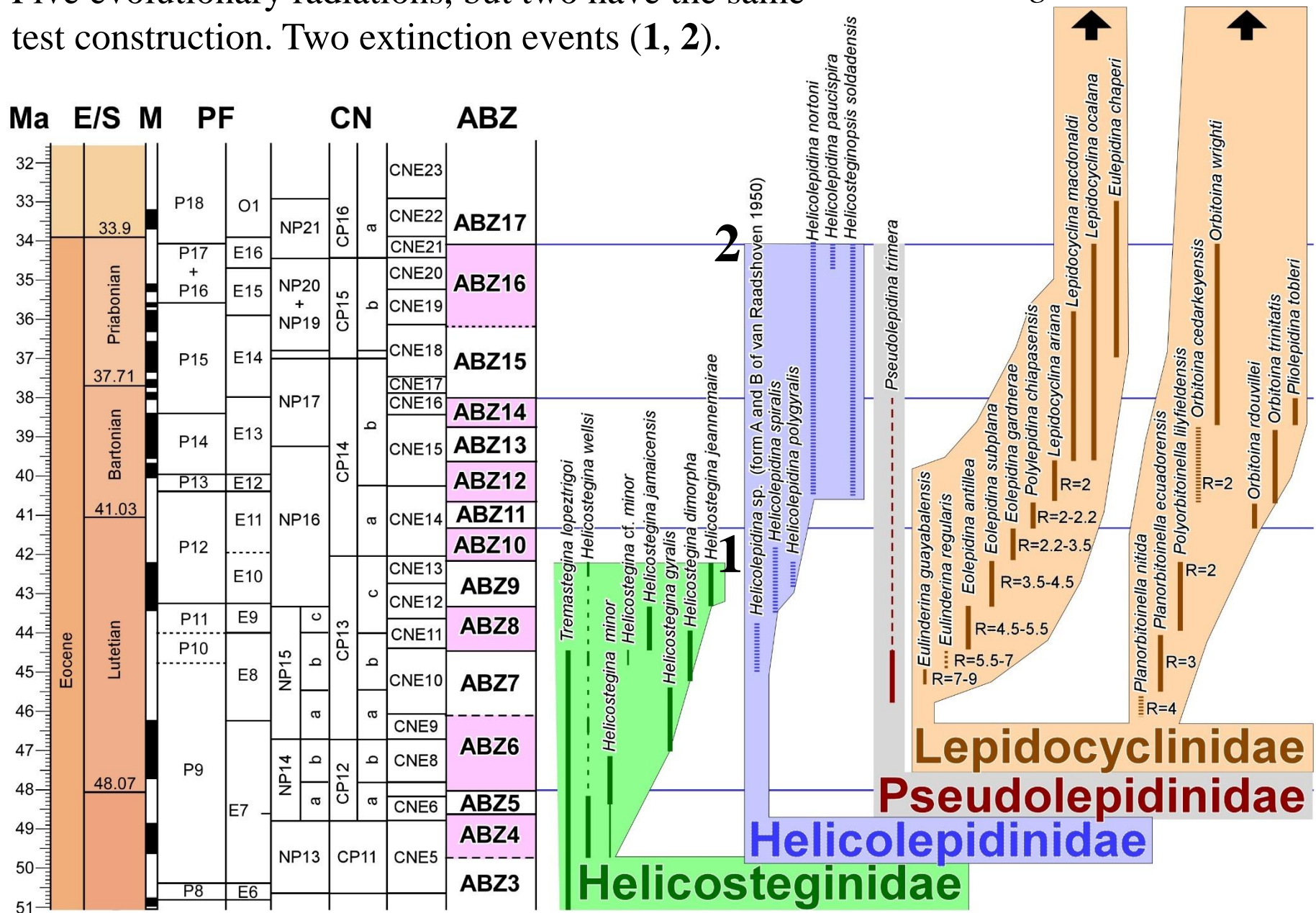
- |                                    |                                      |                                   |
|------------------------------------|--------------------------------------|-----------------------------------|
| ● <i>Pl. ecuadorensis</i> (WL4869) | ○ <i>Po. lilyfieldensis</i> (WL2046) | ■ <i>Or. rdouvillei</i> (WL3446)  |
| ● <i>Pl. ecuadorensis</i> (WL3309) | ● <i>Po. lilyfieldensis</i> (WL2044) | ■ <i>Or. rdouvillei</i> (WL4241)  |
| ● <i>Pl. ecuadorensis</i> (WL3310) | ● <i>Po. lilyfieldensis</i> (LW2041) | ■ <i>Or. rdouvillei</i> (WL4449*) |
| ● <i>Pl. ecuadorensis</i> (WL3324) | ◆ <i>Po. wrighti</i> (WL3876)        | ■ <i>Or. trinitatis</i> (WL3571)  |
| ● <i>Pl. ecuadorensis</i> (WL2047) |                                      | ■ <i>Or. trinitatis</i> (WL3635)  |



# Stratigraphic ranges of selected forams calibrated against nannos

Five evolutionary radiations, but two have the same test construction. Two extinction events (1, 2).

To *L. Oligocene*/*M. Miocene*





# Nummulitidae Blainville 1827

In contrast to the Asterigerinoidea, the Nummulitidae do not have continuously evolving records in the Cenozoic of the Americas (other than for some smaller taxa). Many tend to appear for short stratigraphic intervals and then disappear. The following events can be recognized:

**5. Short-lived influx of *Heterostegina antillea* (late Oligocene to early Miocene)**

**4. Short-lived influx of *H. ocalana* (late Eocene)**

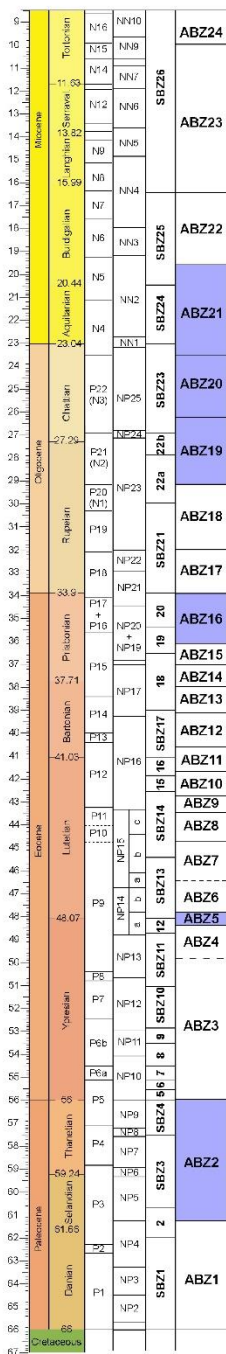
**3. Appearance of small nummulitids (*Operculinoides* and *Nummulites*) (early Lutetian up to mid Miocene).**

**2. Short-lived appearance of *Nephronummulites macgillavryi* (latest Ypresian).**

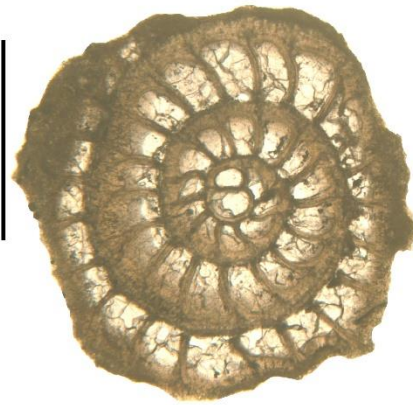
**1. Short-lived appearance of *Ranikothalia* (mid-late Paleocene).**

Useful, but could be diachronous.

Chrono P N Zones



*Operculinoides* spp.  
*Heterostegina ocalana*  
*Heterostegina antillea*  
*Nummulites* spp.  
*Ranikothalia catenula* | *Nephronummulites macgillivryi*



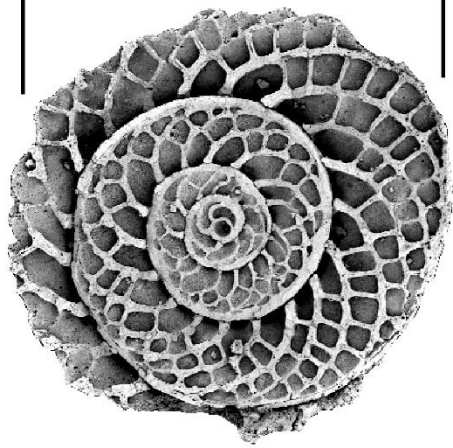
*Ranikothalia* sp.



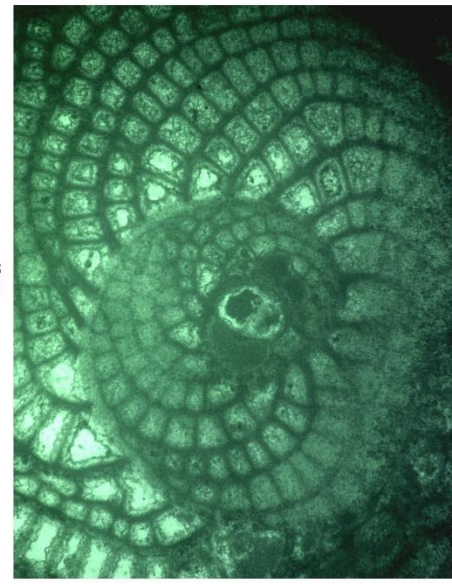
*Nephronummulites macgillavryi*



*Operculinoides* sp.

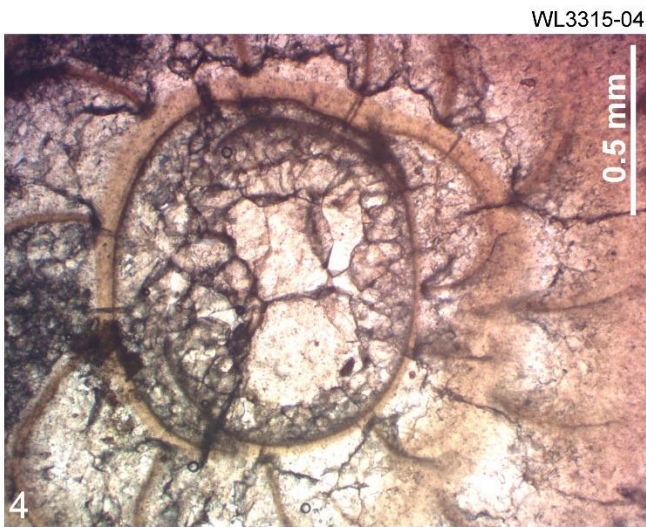
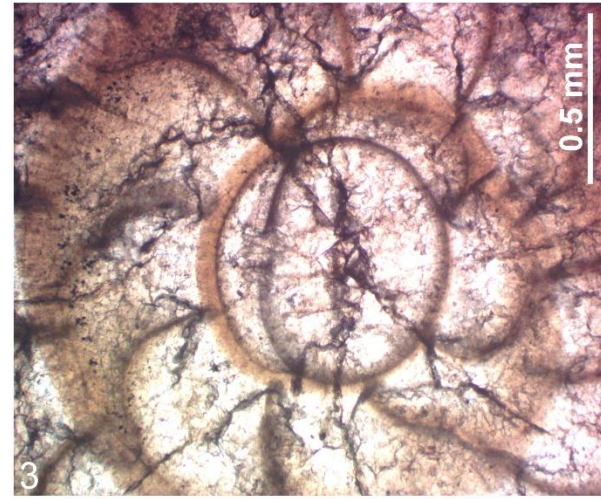
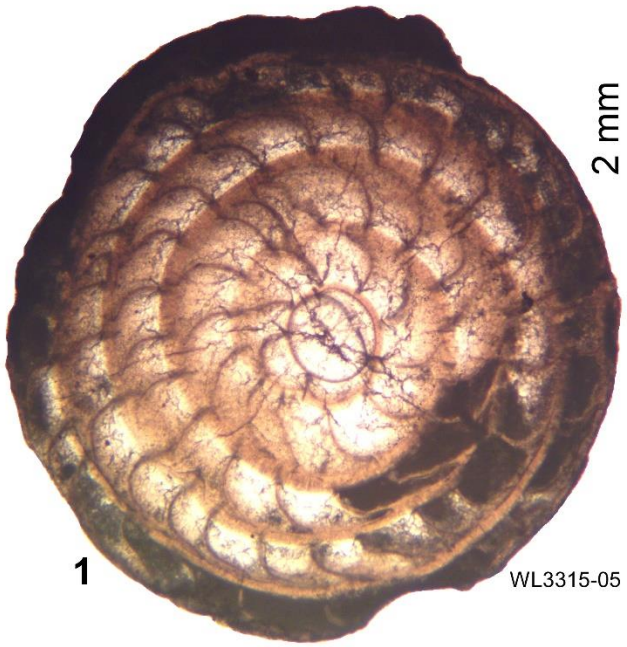


*Heterostegina ocalana*

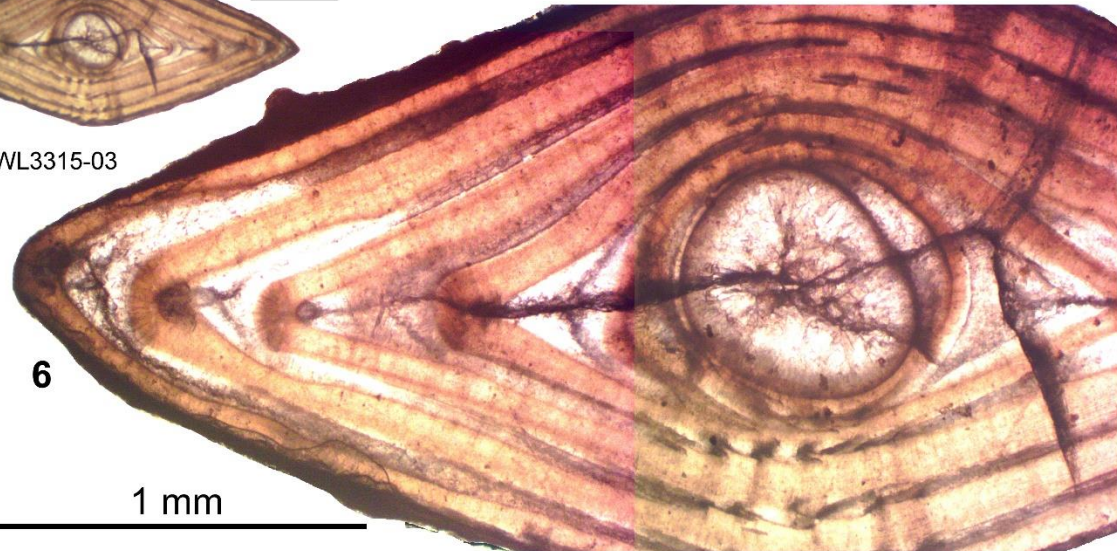


*Heterostegina antillea*

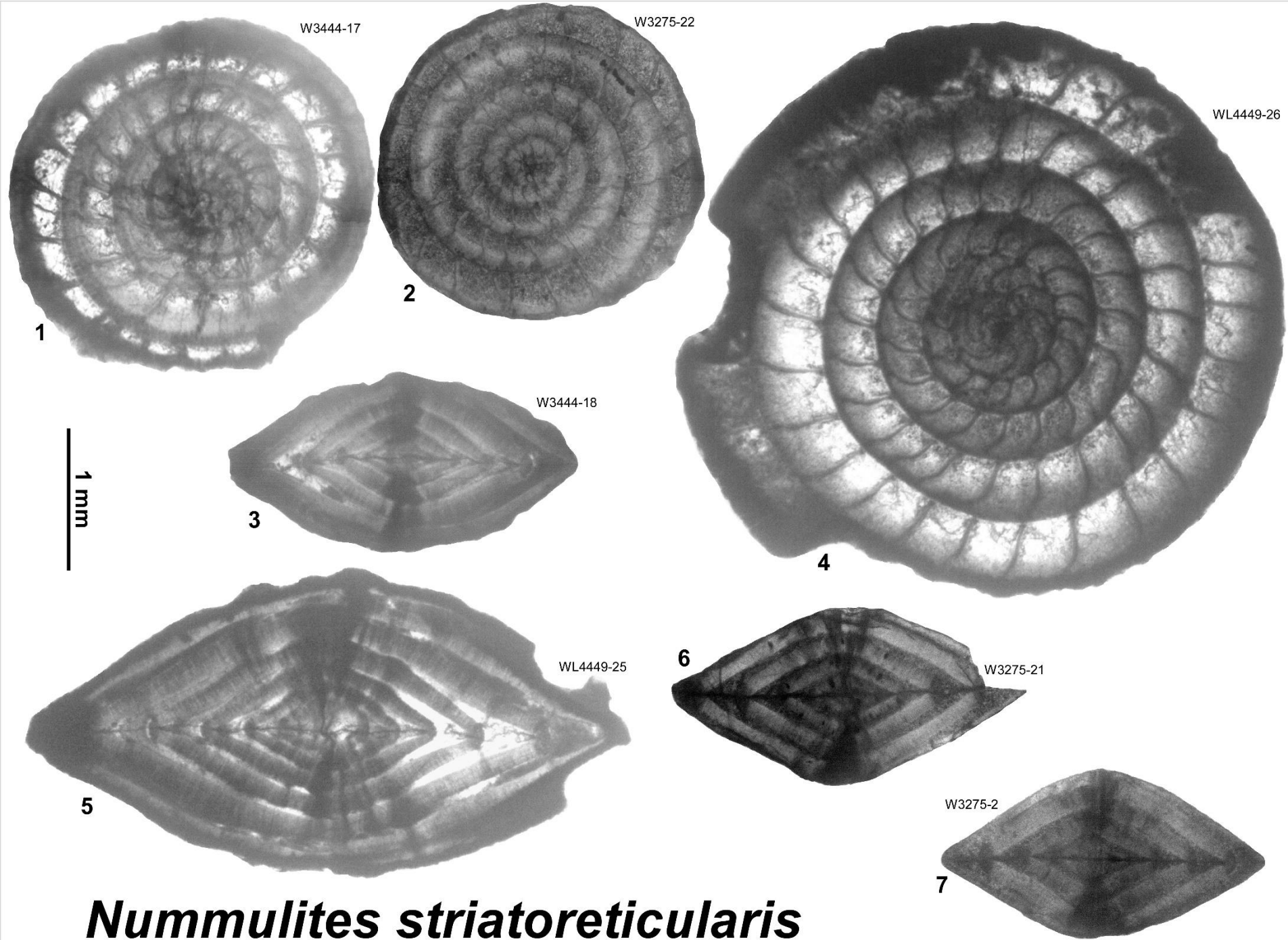
WL3315-05

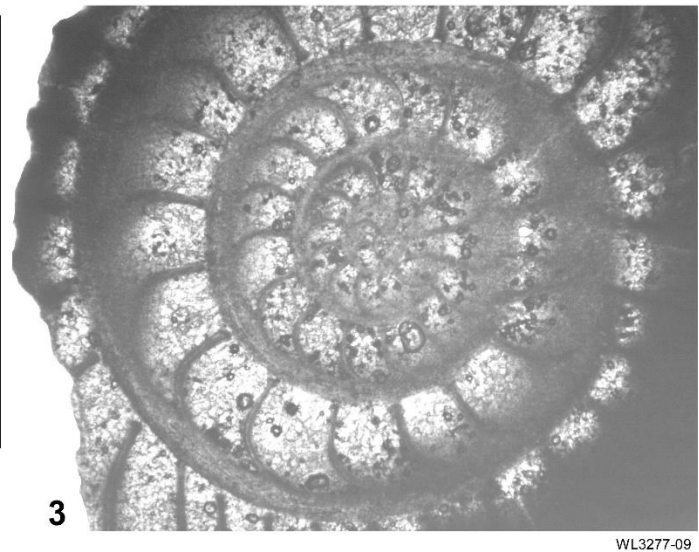
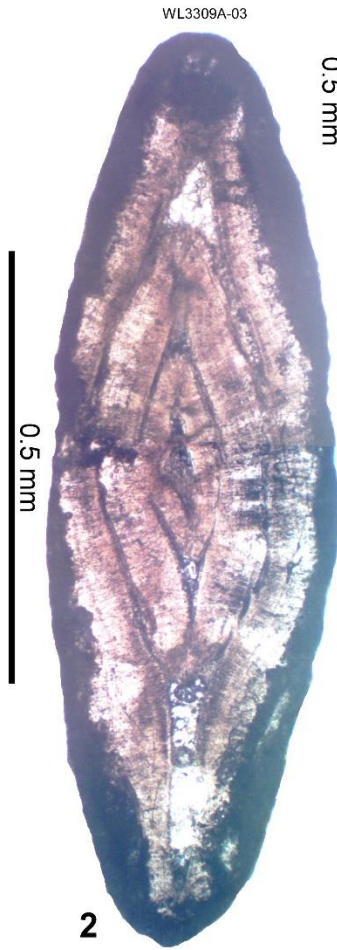
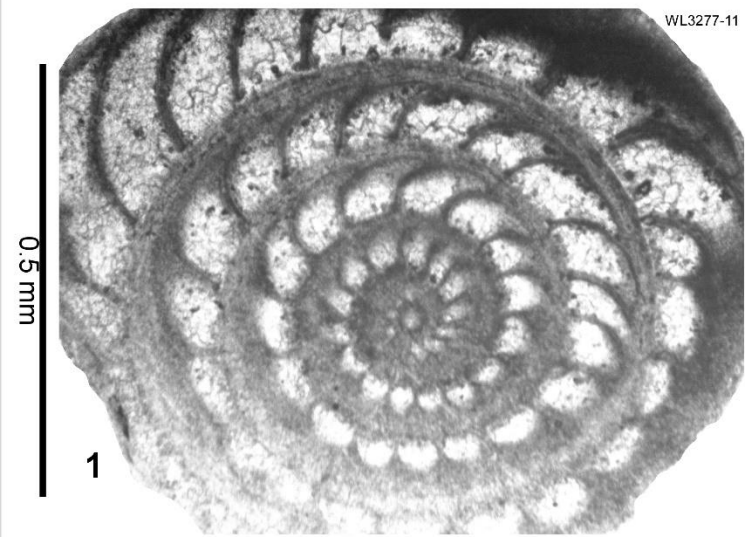


WL3315-03

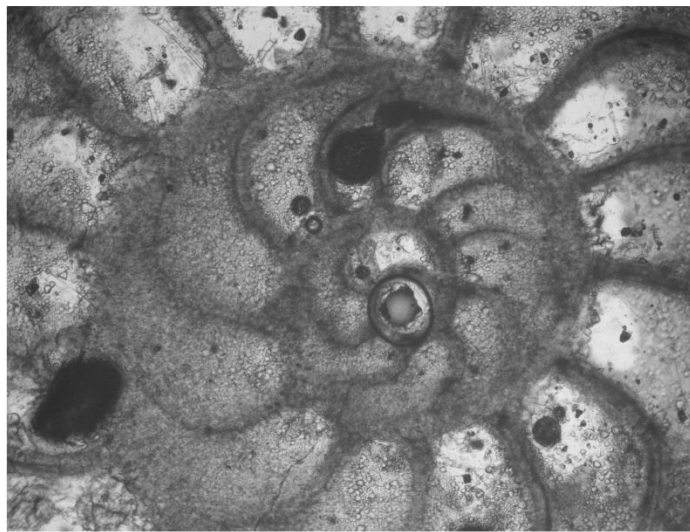


***Nephronummulites macgillavryi***



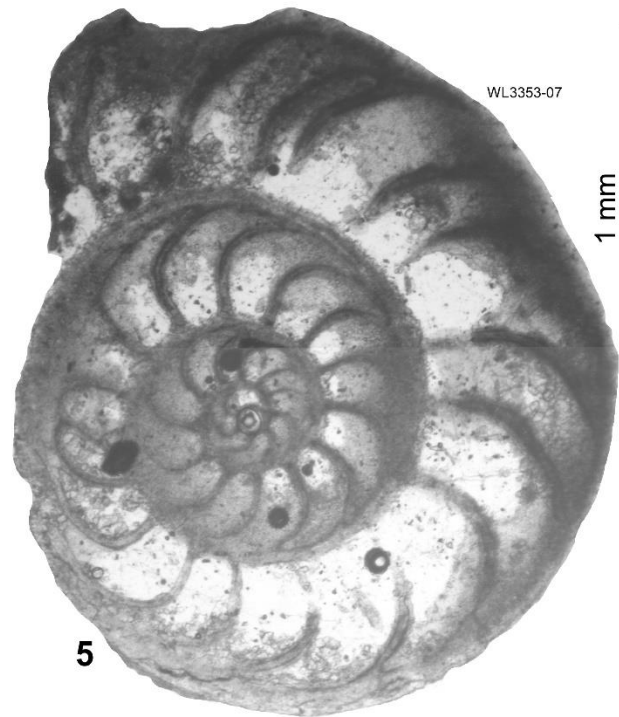


WL3277-09

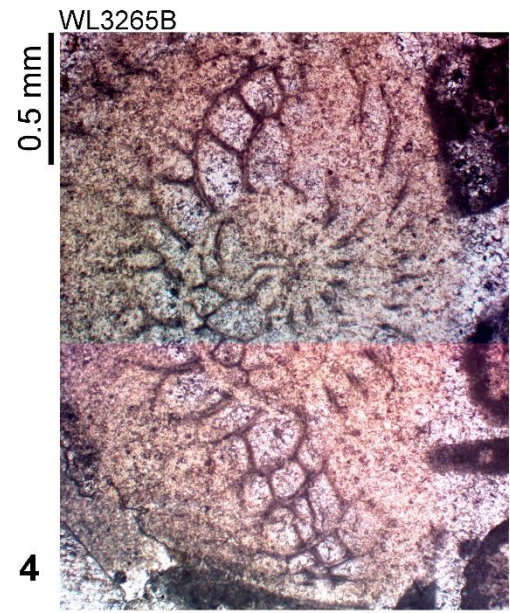
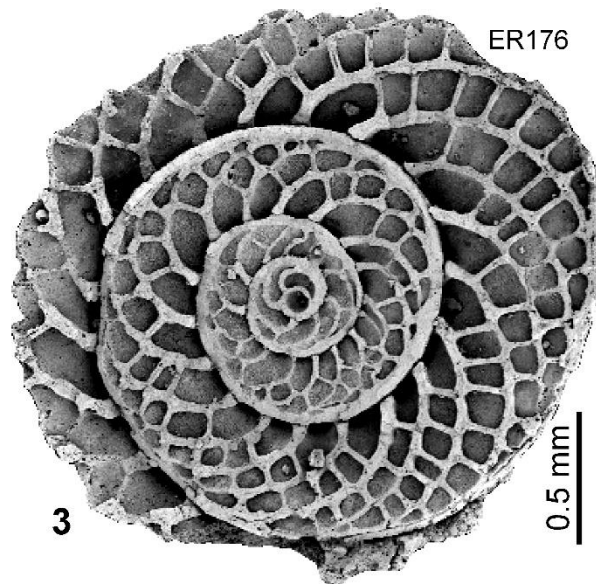
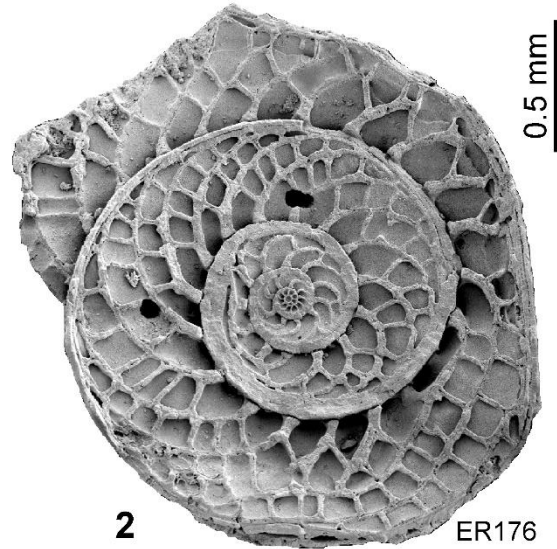
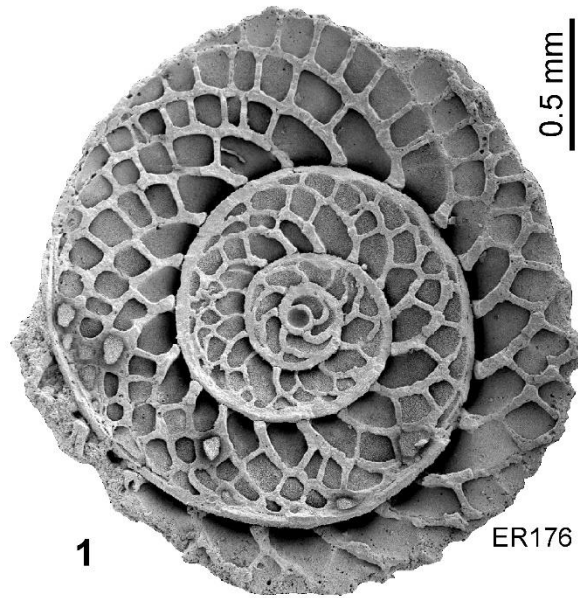


WL3353-07

0.5 mm



***Opperculinooides* spp.**

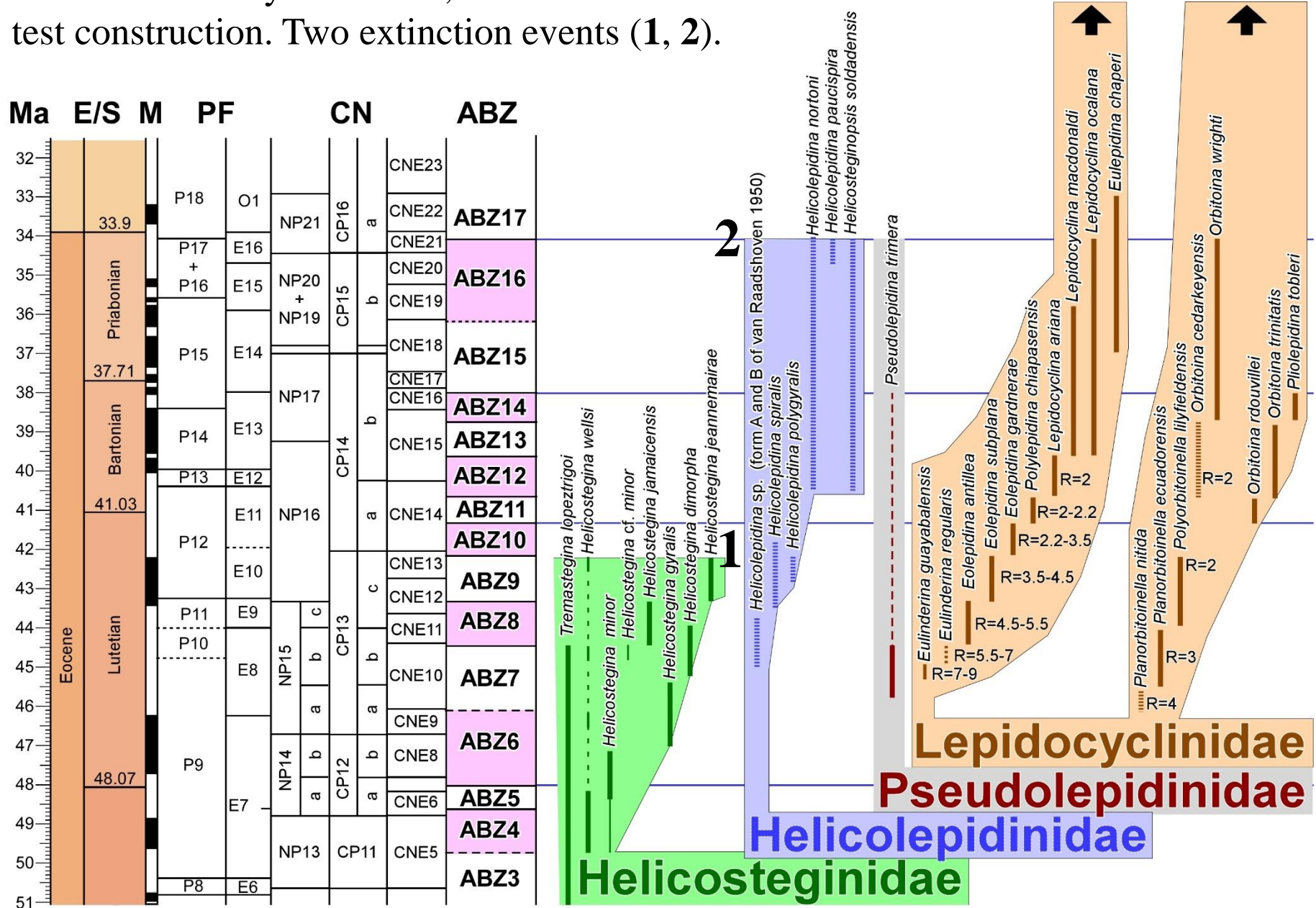


***Heterostegina ocalana***

# Stratigraphic ranges of selected forams calibrated against nannos

Five evolutionary radiations, but two have the same test construction. Two extinction events (1, 2).

To L. Oligocene/M. Miocene



# Palaeoecological ranges of forams in Jamaica

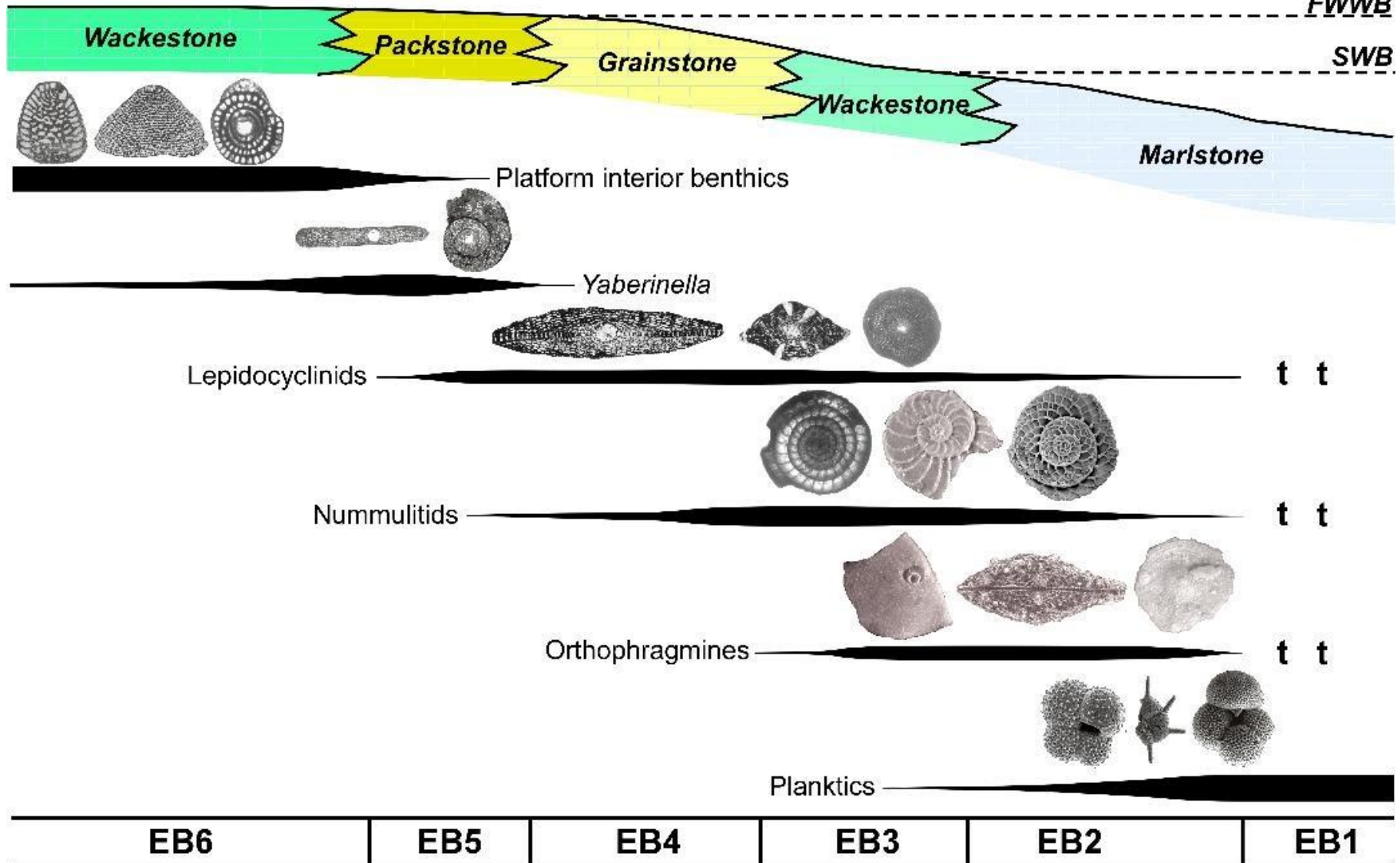
Clarendon Block

North Coast Belt

Sea level

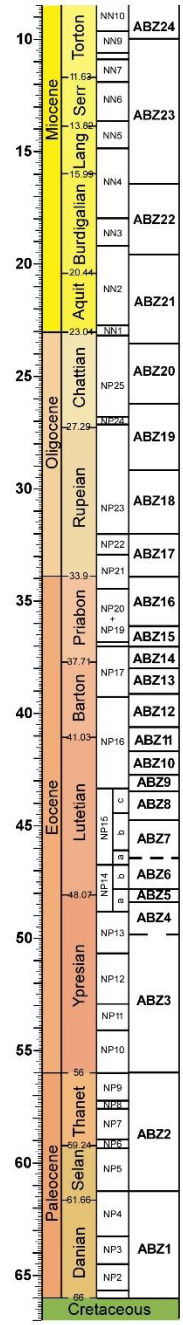
FWWB

SWB

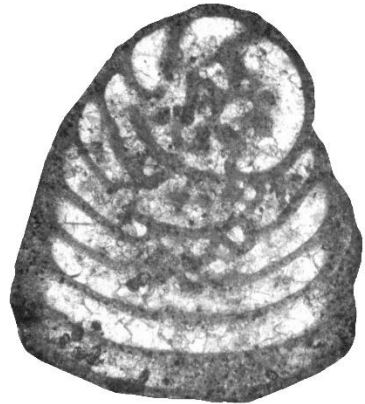




# Selected agglutinated Larger Benthic Foraminifera



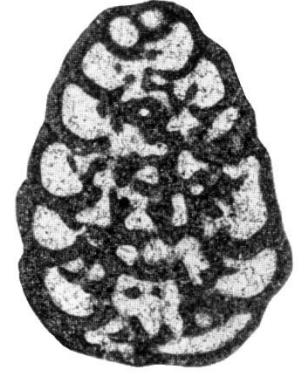
- *Fallotella cookei*
- *Cushmania* sp. 1
- *Cushmania americana*
- *Cushmania fontabellensis*
- *Coleiconus zanshi*
- *Coleiconus christianiensis*
- *Verseyella jamaicensis*
- *Coskinolina* sp. 2
- *Coskinolina* sp. 1
- *Robinsoniella jamaicensis*
- *Pseudochrysalidina floridana*



*Coskinolina*  
Undivided marginal chambers

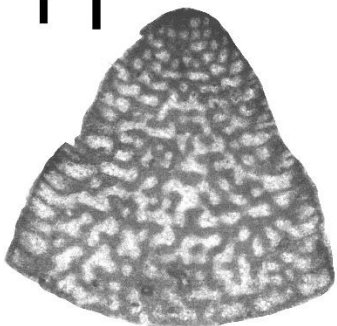


*Coleiconus*  
Divided marginal chambers

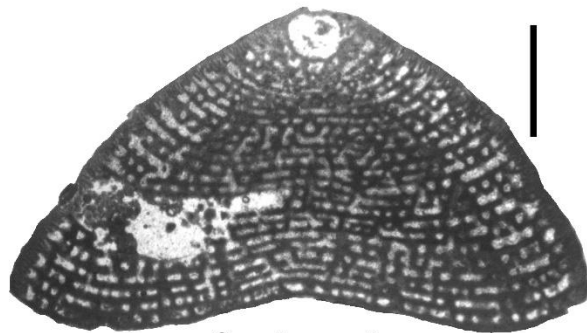


*Pseudochrysalidina*  
Triserial

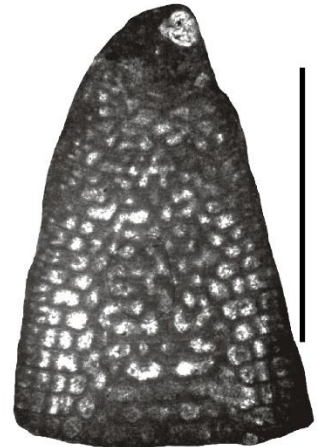
Scale bar = 1 mm



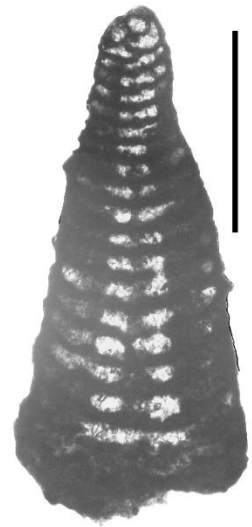
*Fallotella*  
One rafter/beam



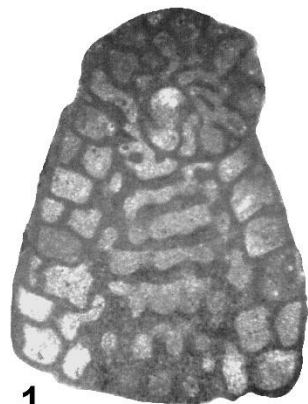
*Cushmania*  
Many rafters/beams



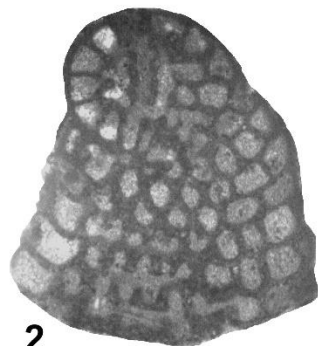
*Robinsoniella*  
One rafter/beam



*Verseyella*  
Biserial stage



1



2



3



4



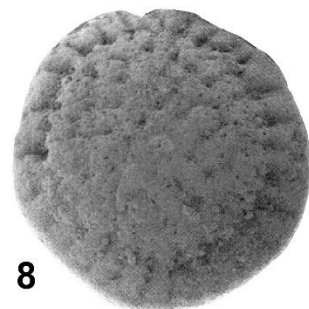
5



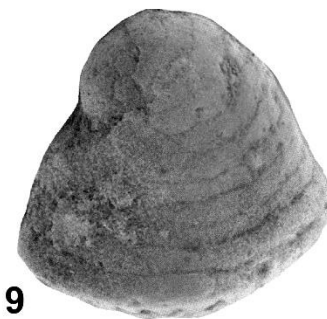
6



7



8



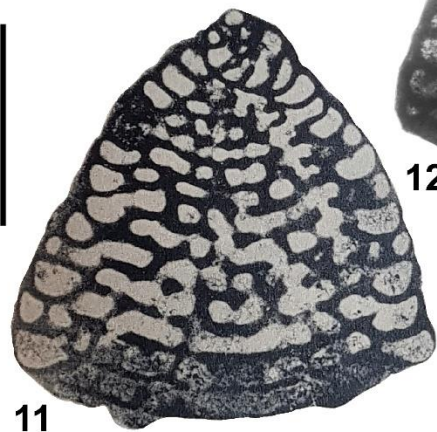
9



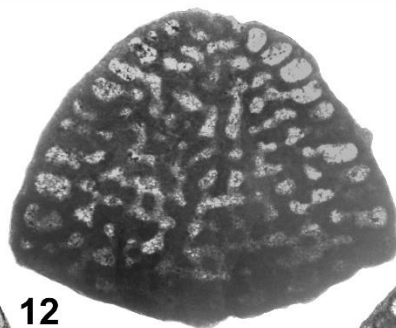
10

Scale bar = 1 mm

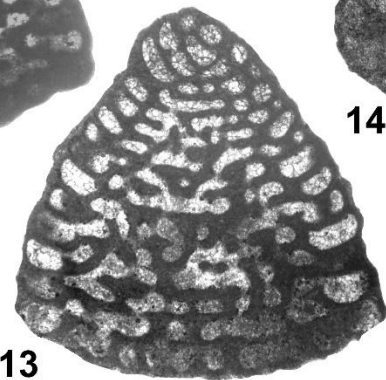
***Coleiconus christianaensis***



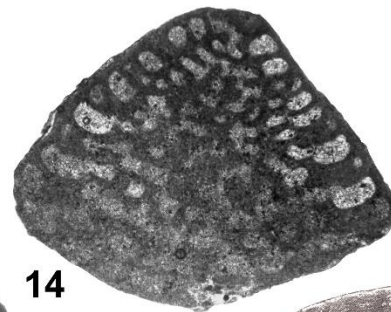
11



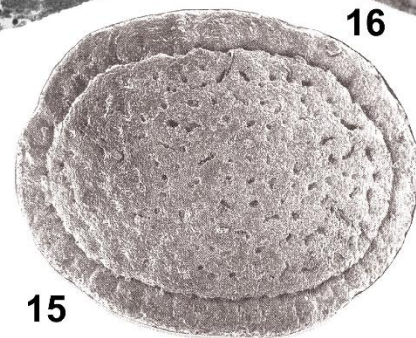
12



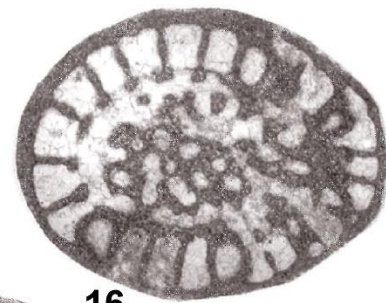
13



14

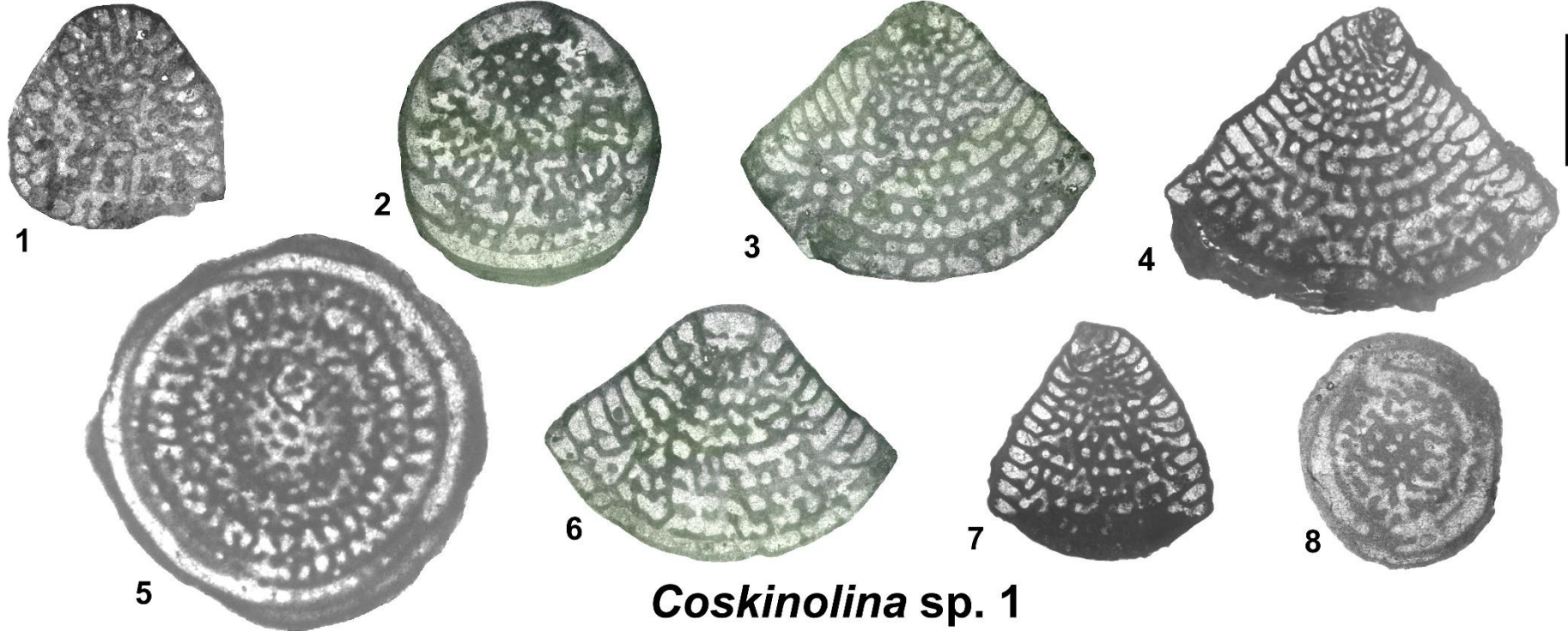


15

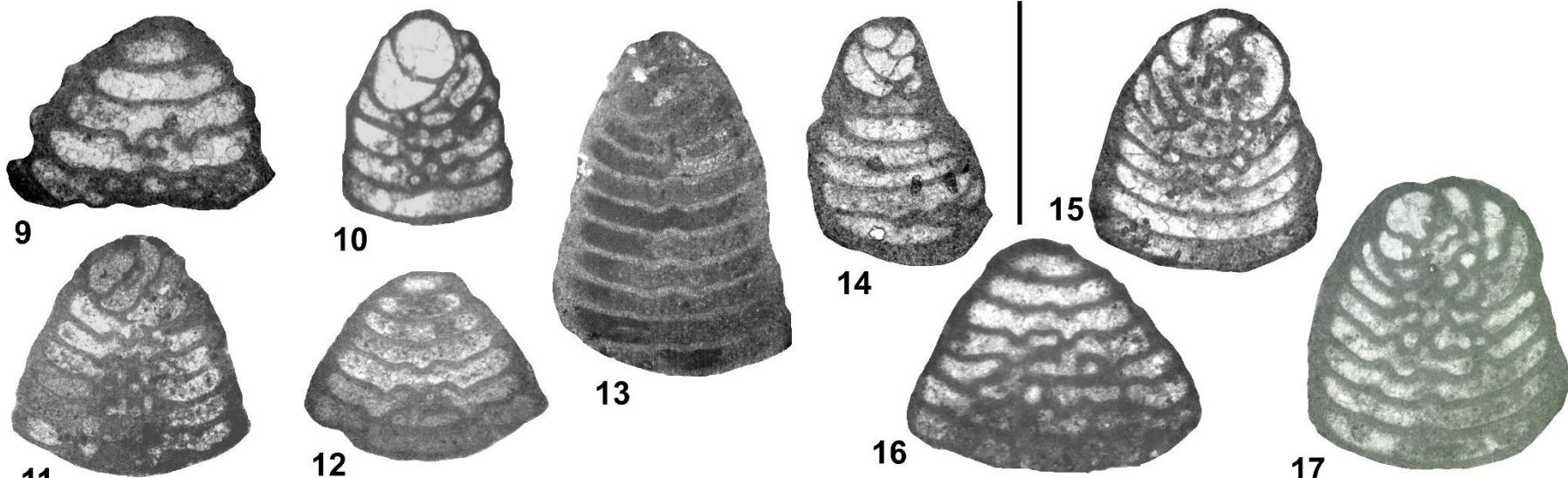


16

***Coleiconus zansi***

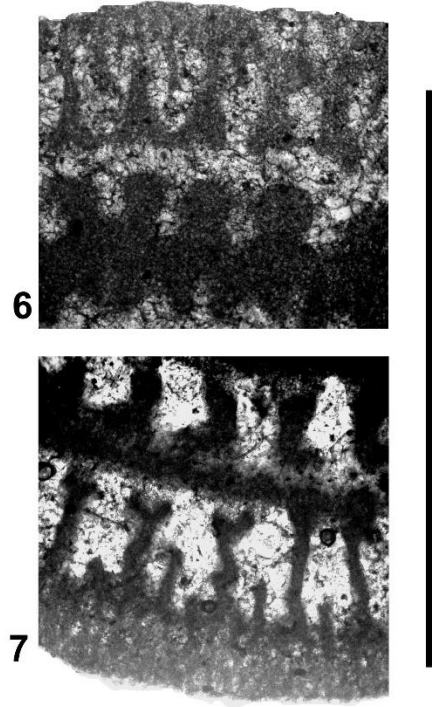
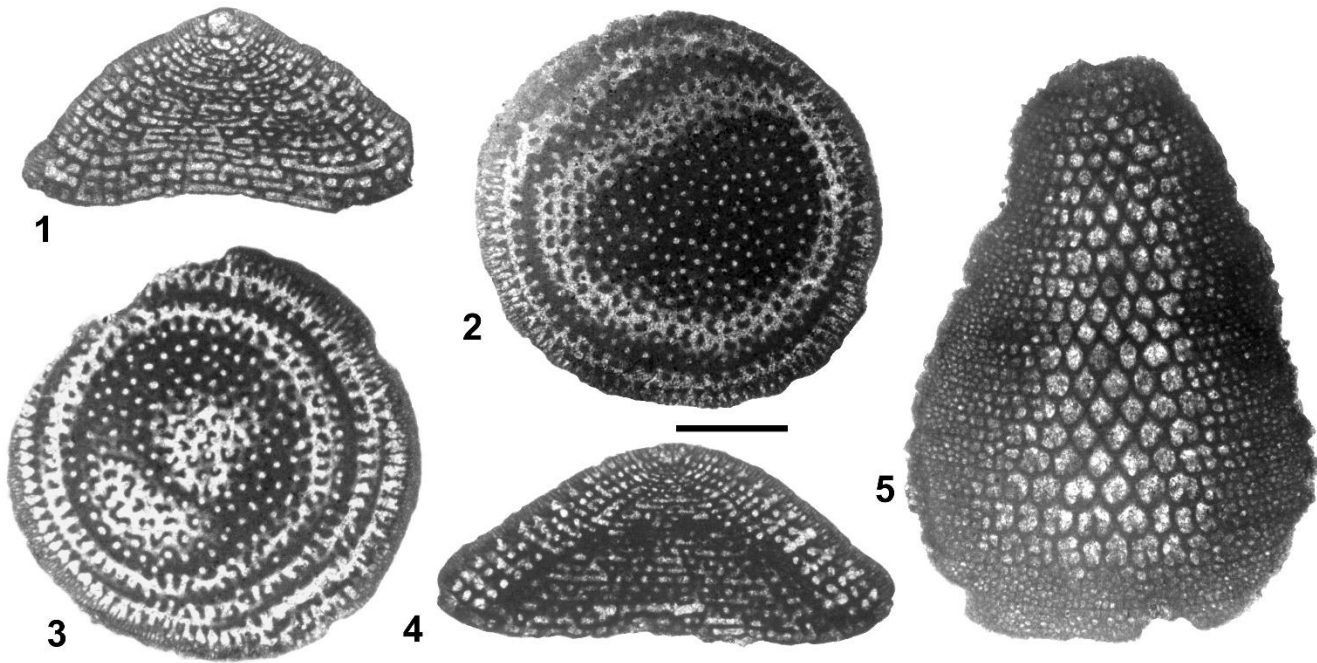


*Coskinolina* sp. 1



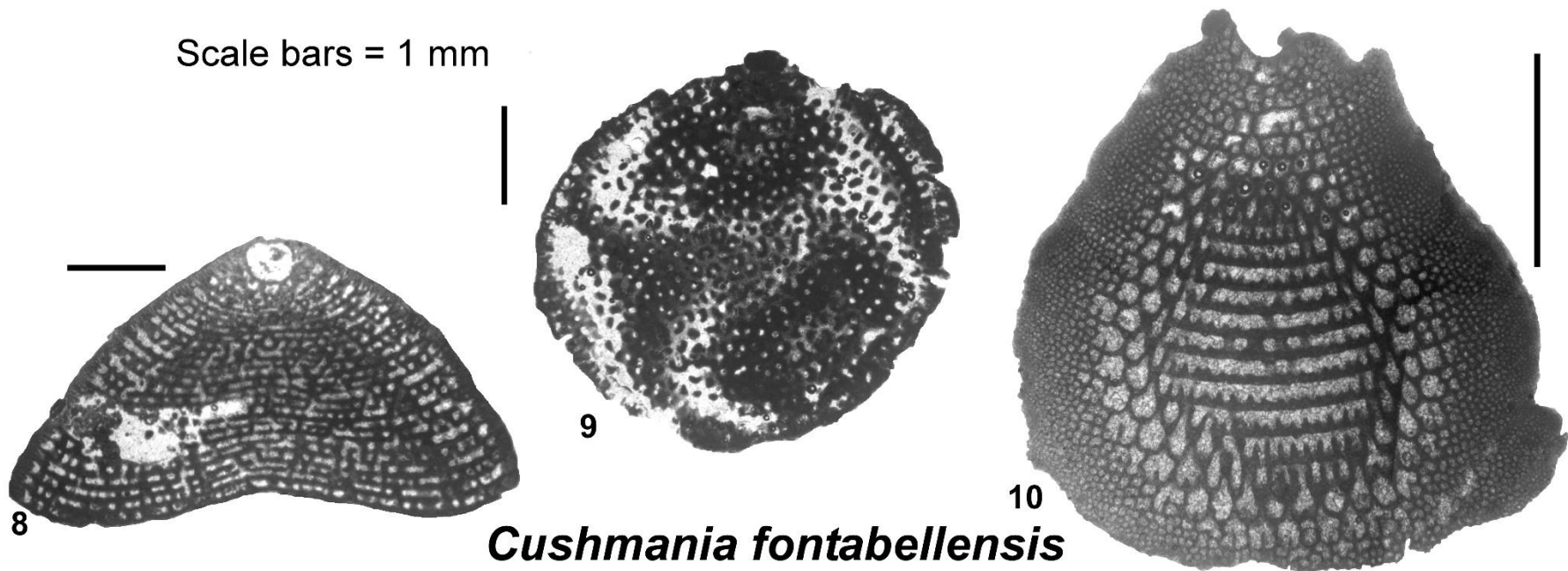
*Coskinolina* sp. 2

Scale bar = 1 mm

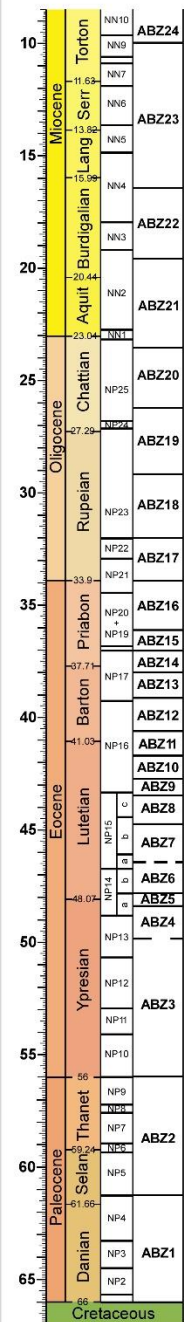


*Cushmania americana*

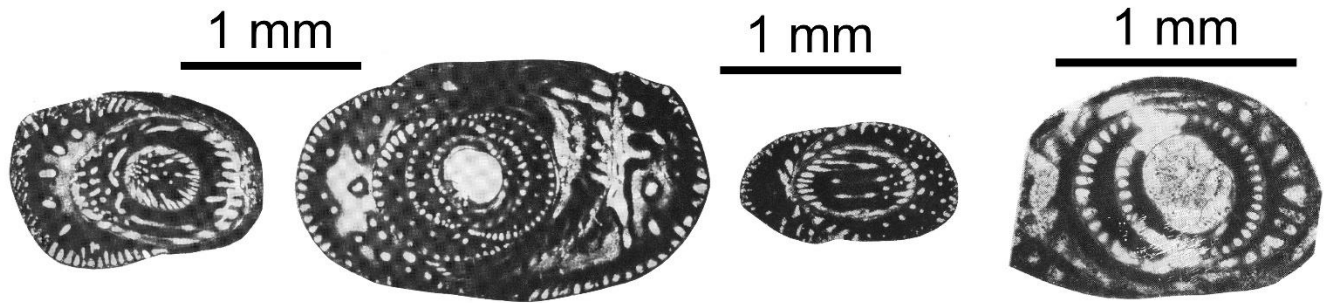
Scale bars = 1 mm



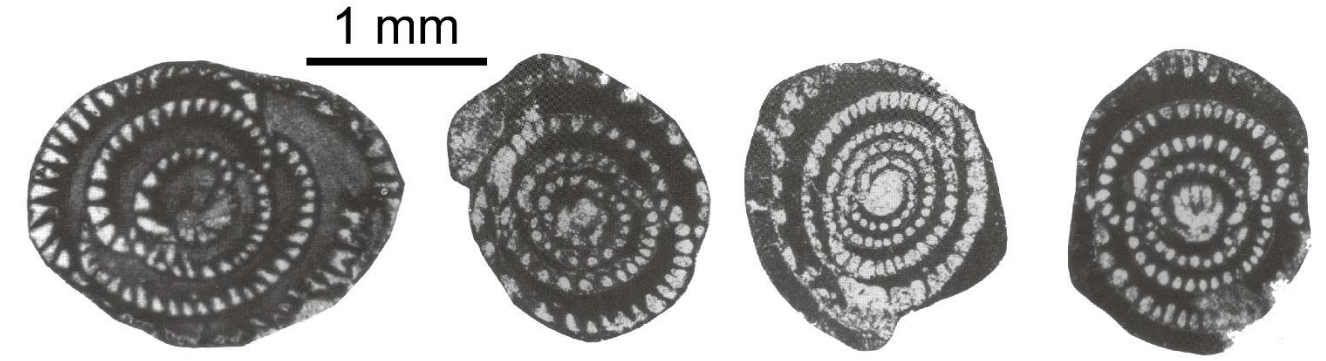
*Cushmania fontabellensis*



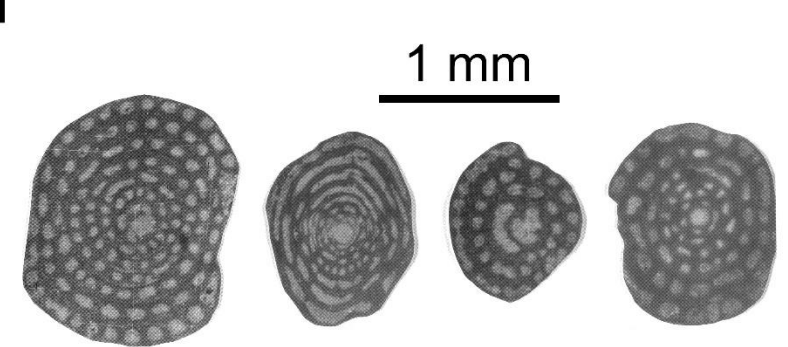
■ *F. colei*  
 ■ *F. vaughani*  
 ■ *F. hanzawai*  
 ■ *F. verseyi*



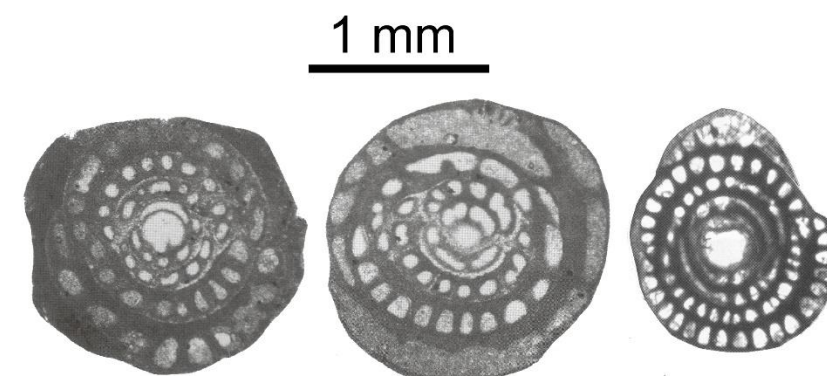
*Fabularia verseyi*



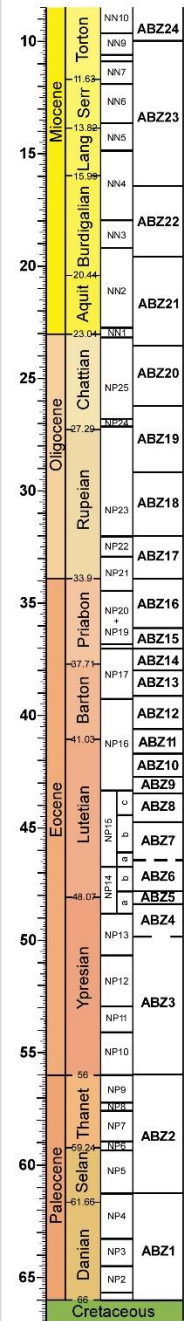
*Fabularia hanzawai*



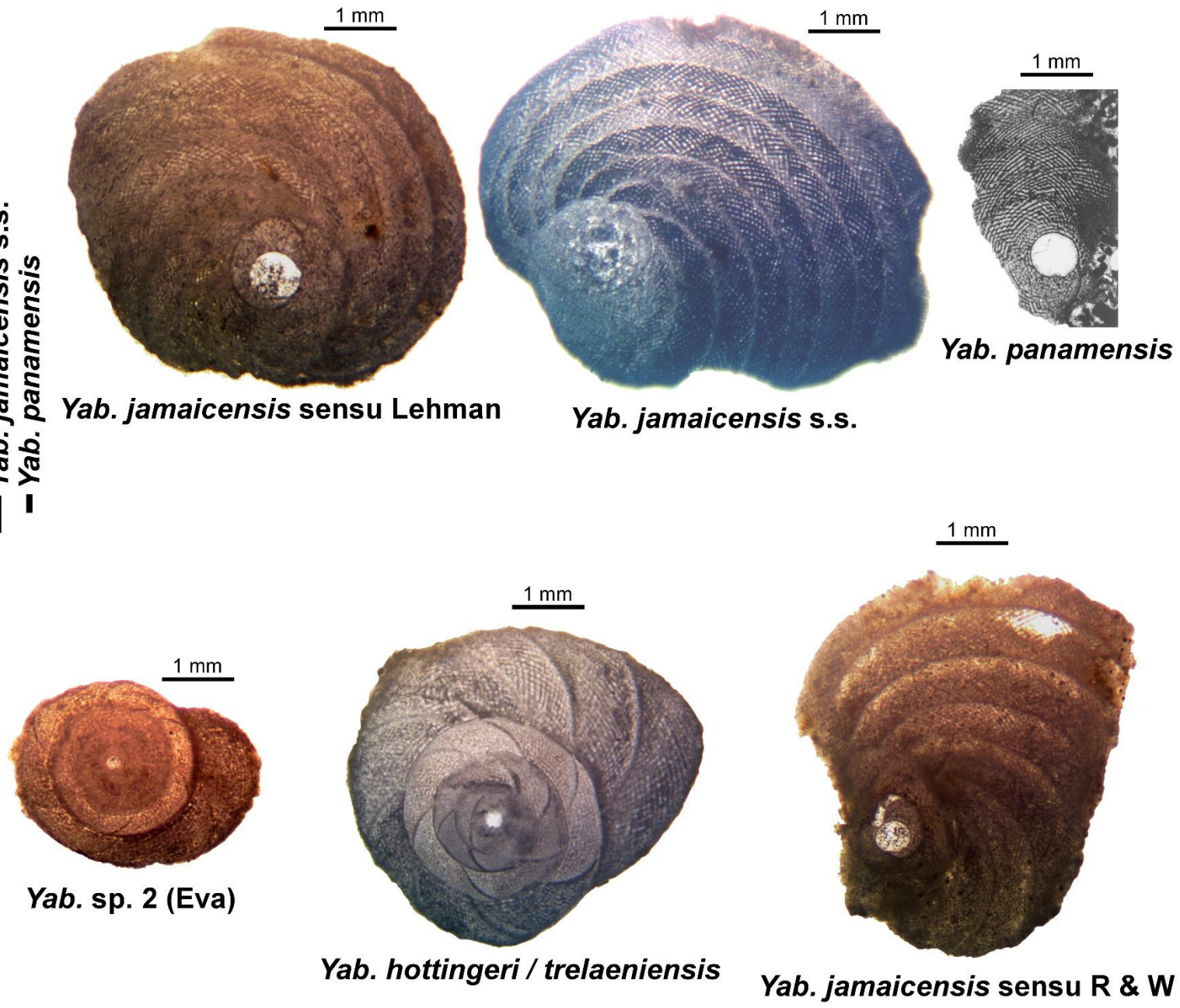
*Fabularia colei*



*Fabularia vaughani*



- ***Yab. sp. 2 (Eva)***
- ***Yab. hottingeri / trelaeniensis***
- ***Yab. jamaicensis sensu R & W***
- ***Yab. jamaicensis sensu Lehman***
- ***Yab. jamaicensis s.s.***
- ***Yab. panamensis***



***Yab. jamaicensis sensu Lehman***

***Yab. jamaicensis s.s.***

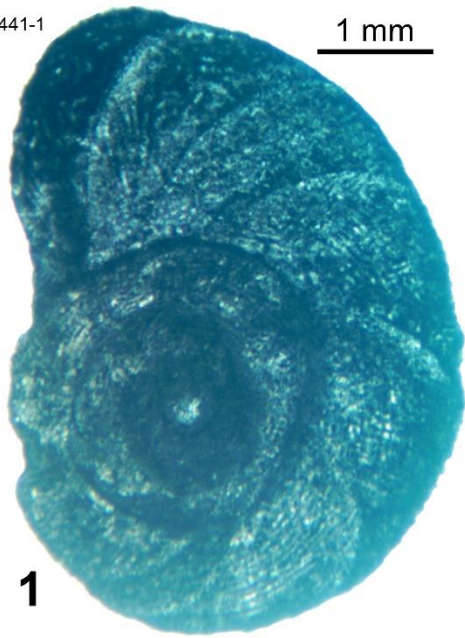
***Yab. panamensis***

***Yab. sp. 2 (Eva)***

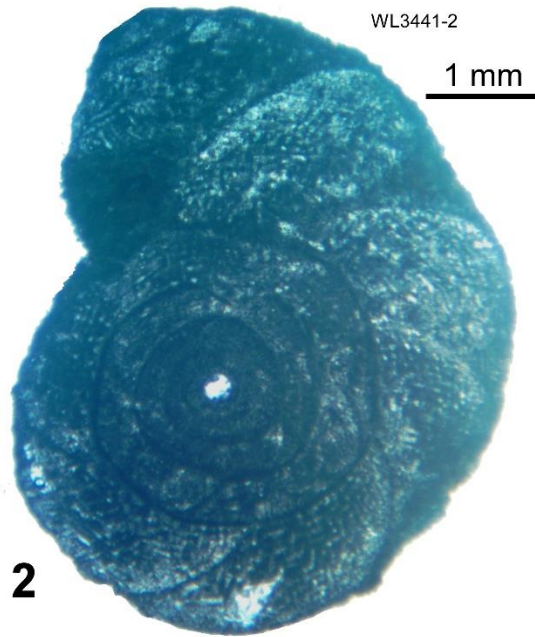
***Yab. hottingeri / trelaeniensis***

***Yab. jamaicensis sensu R & W***

WL3441-1



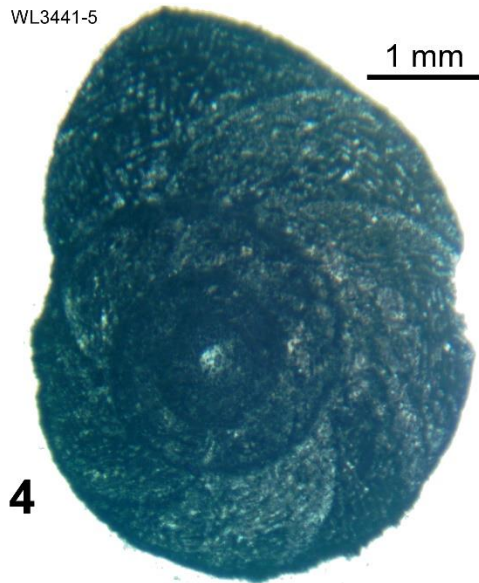
WL3441-2



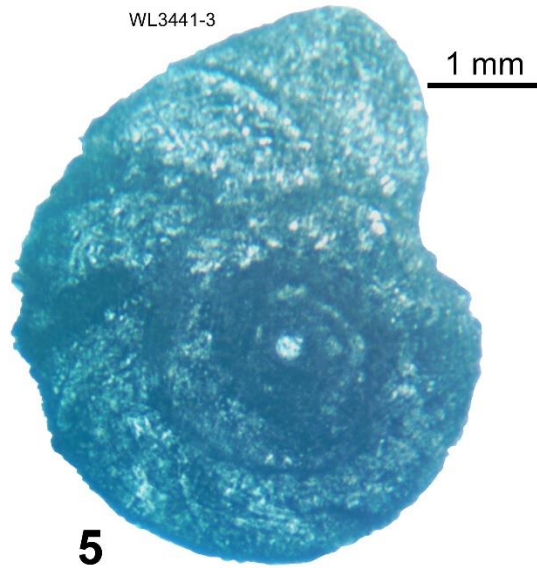
WL3441-4



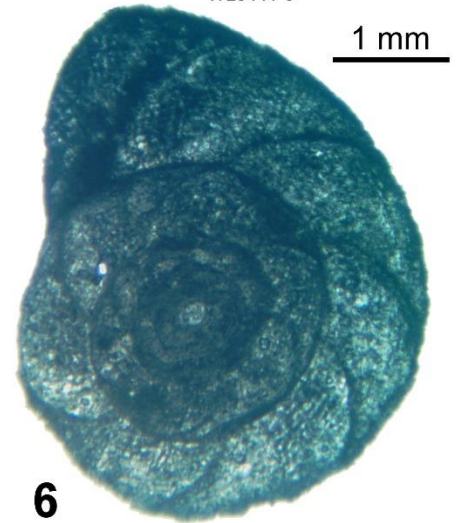
WL3441-5



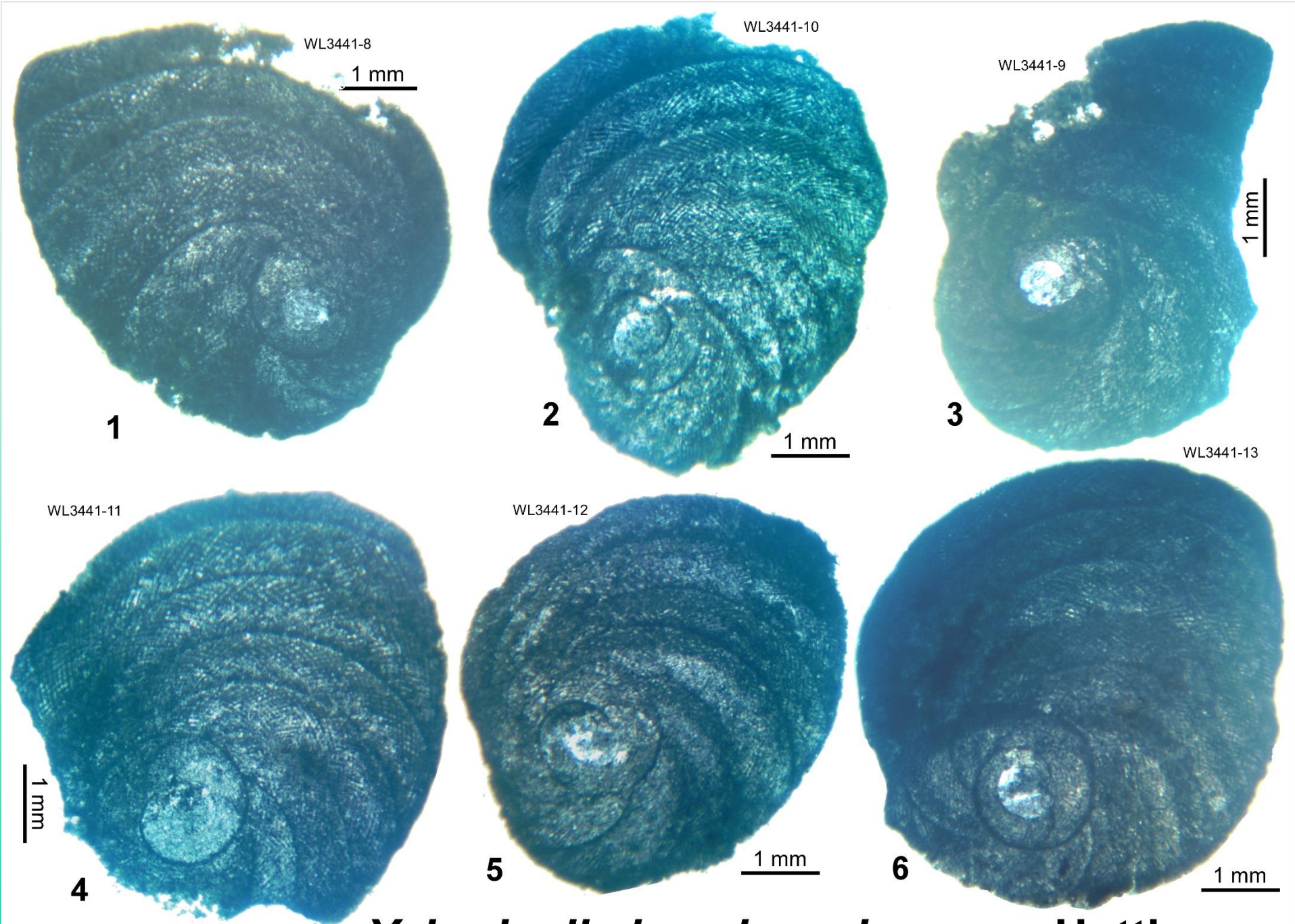
WL3441-3



WL3441-6



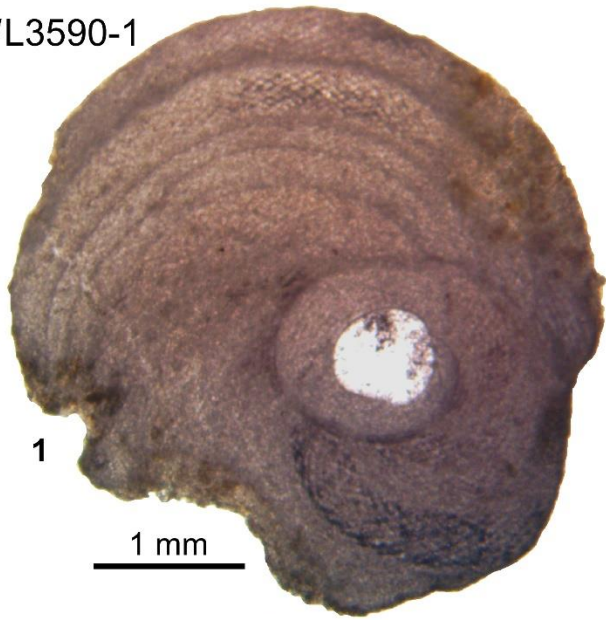
***Yaberinella trelawniensis***



***Yaberinella jamaicensis* sensu Hottinger**



WL3590-1



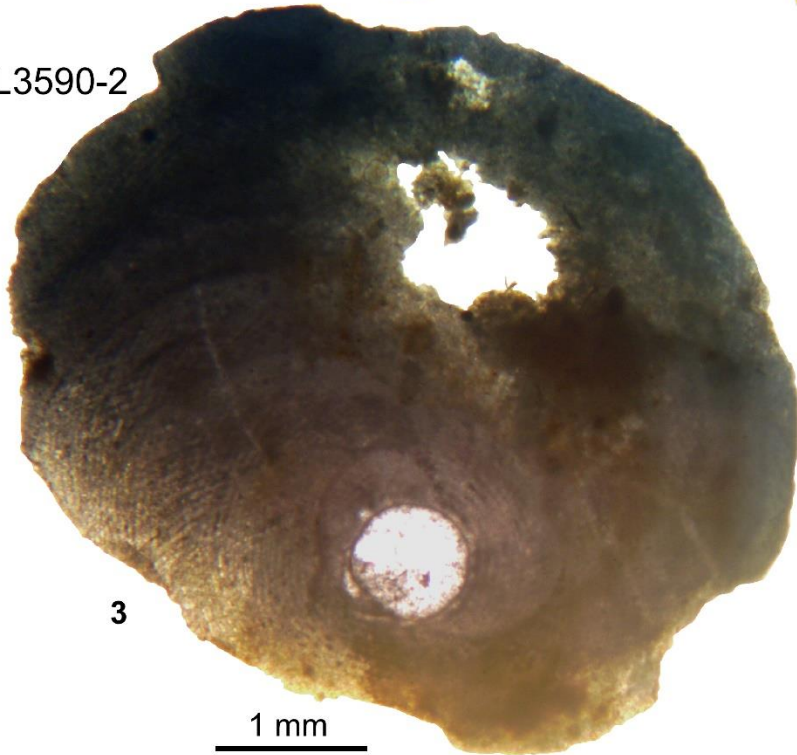
1 mm

WL3590-3



1 mm

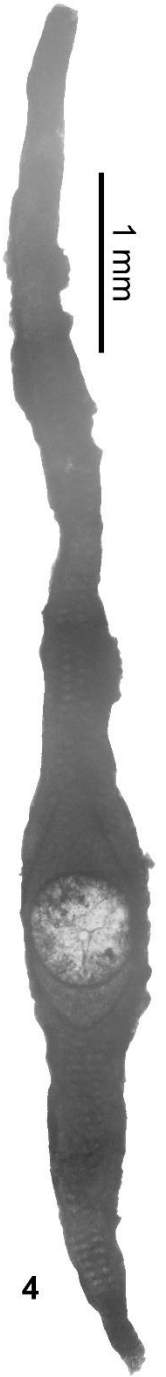
WL3590-2

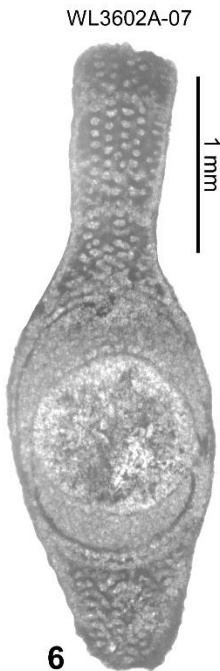
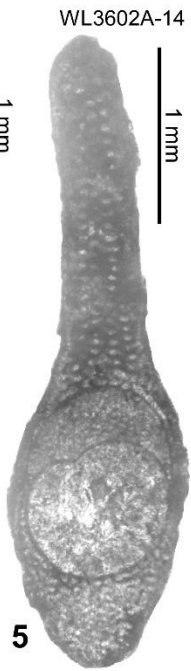
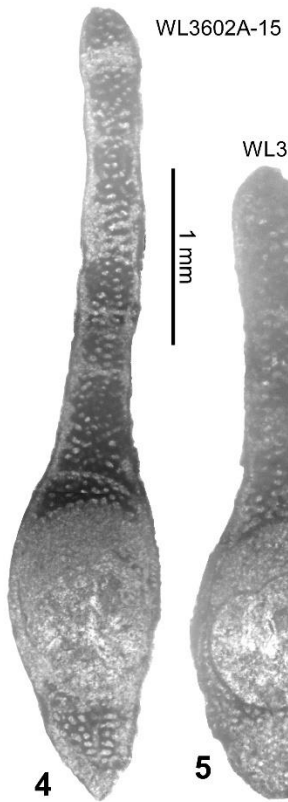
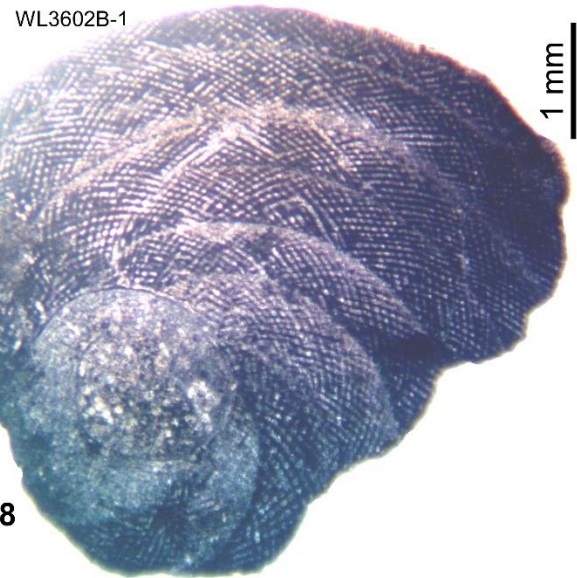
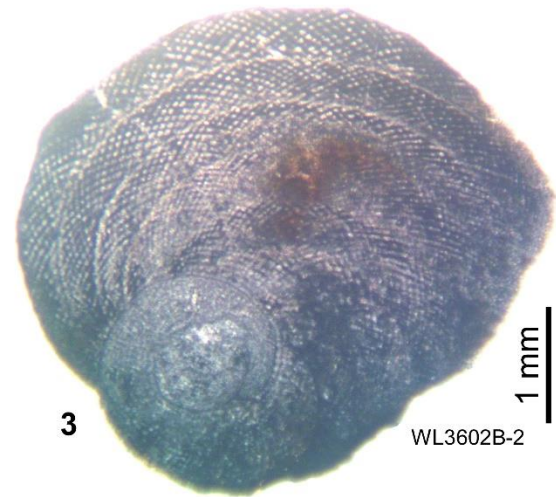
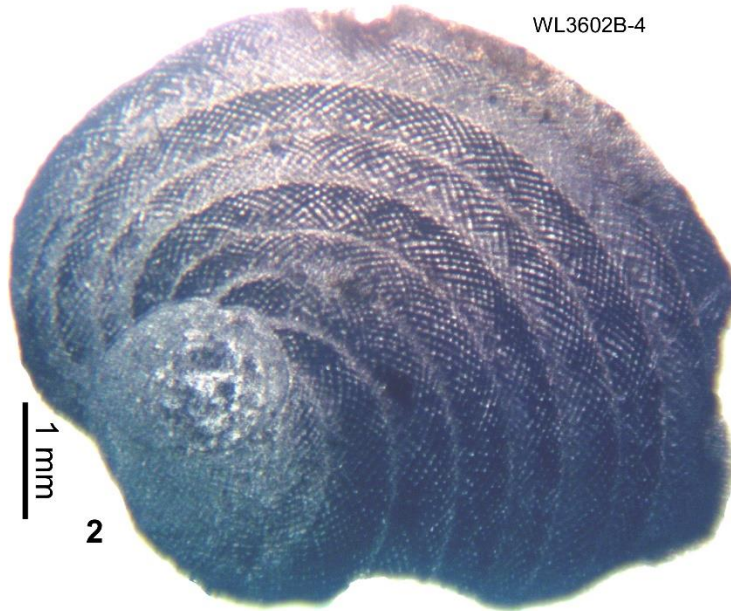
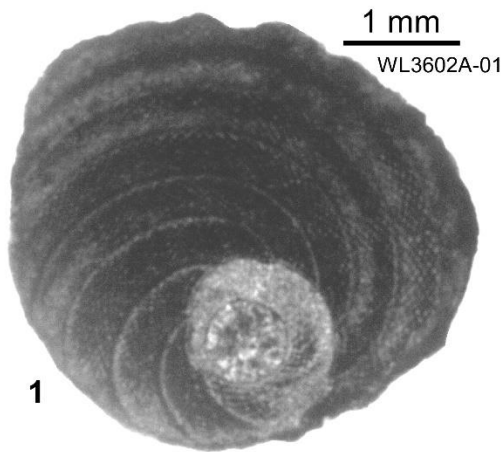


1 mm

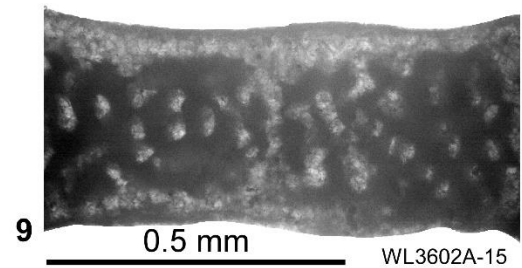
***Yaberinella*  
*jamaicensis*  
sensu Lehman**

4





***Yaberinella  
jamaicensis* s.s.**



# Conclusions

The foraminifers of the Paleogene either evolved rapidly or saw repeated short-lived migration events. This can be used to establish a high-resolution zonation applicable to platform margins.

For the Eocene 14 zones are recognized. Two zones can be recognized in the Paleocene and additional zones in the Oligocene to mid Miocene.

The zonation can be extended into platform interiors where platform interior species occur with platform edge species.

Greater resolution may become possible when detailed analyses of the evolution of other groups (e.g., orthophragmines and nummulitids) has been completed.

Full paper: *Carnets Geol.* (to be published shortly)

This presentation: *sfmgeology.com* and *ResearchGate*

**Thank You**