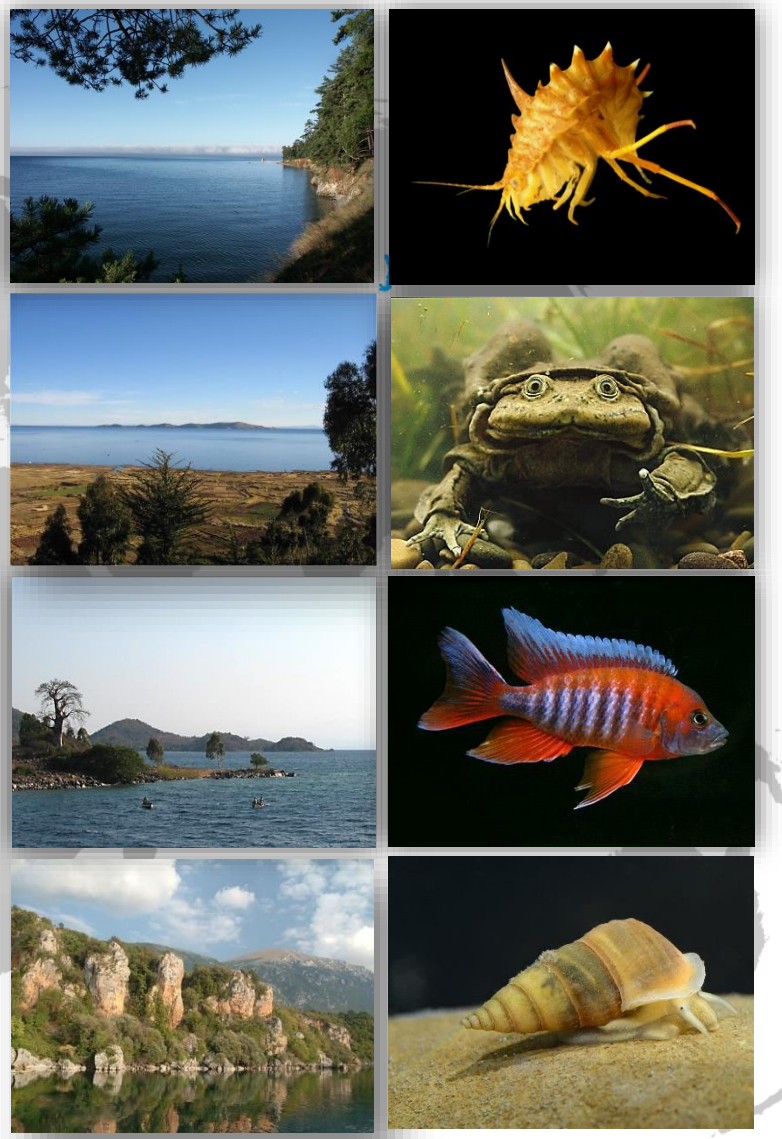
Worldwide ancient lakes

Worldwide ancient lakes: Geological evolution

Worldwide ancient lakes: Biological evolution

Lake	Total # endemic species
Baikal	> 1200
Malawi	> 1000
Tanganyika	> 800
Ohrid	> 300
Titicaca	64
Biwa	59



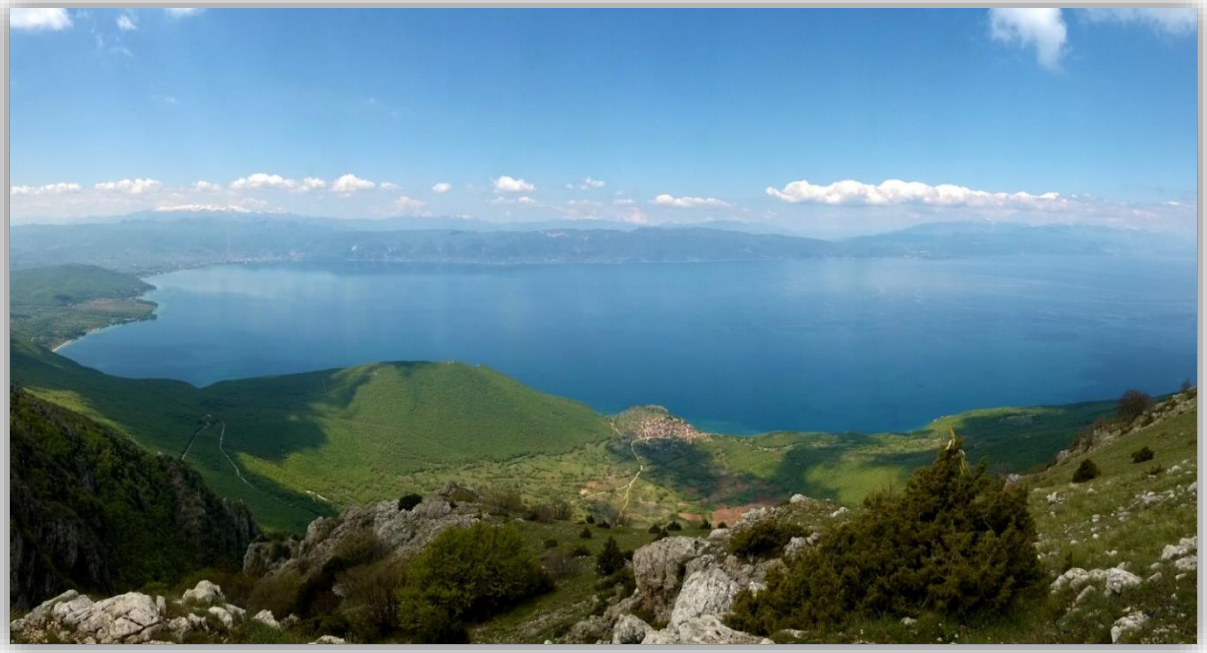
Lake Ohrid endemic biodiversity

Lake	Total # endemic species	Lake size in km²	Endemic biodiversity index (log N x log A^{-1})
Baikal	> 1200	31.494	0.68
Malawi	> 1000	29.600	0.67
Tanganyika	> 800	32.900	0.64
Ohrid	> 300	360	0.97
Titicaca	64	8.372	0.46
Biwa	59	670	0.62

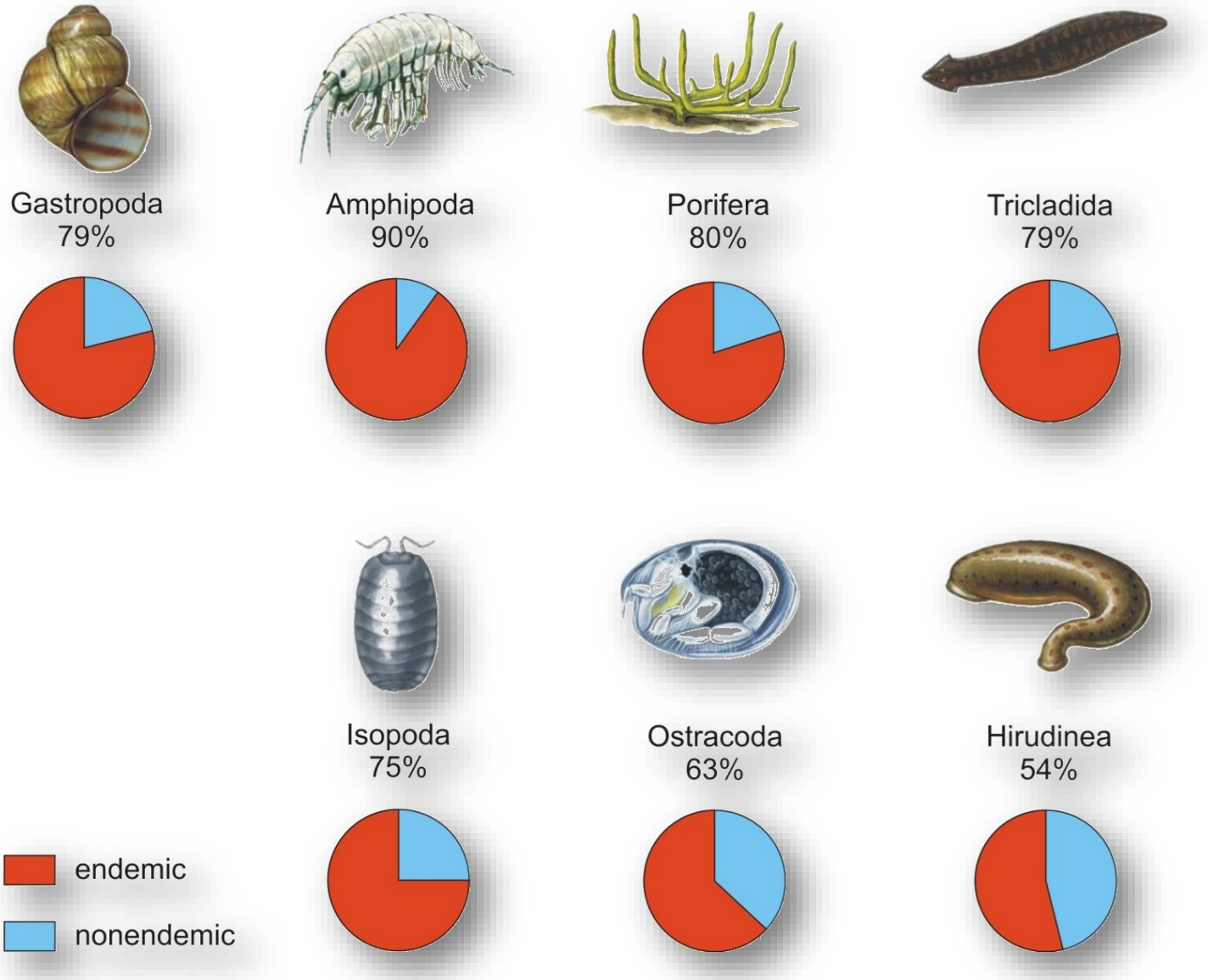
The oldest lake in Europe: Lake Ohrid

- Length: 30.3 km
- Width: 15.6 km
- Max. depth: 293 m
- Water balance: ~50% sublacustrine springs; ~50% precipitation
- Age: ?

Photo: Wilke (2014)



Lake Ohrid endemic biodiversity



Dolapia ornata

Gocea ohridana

Macedopyrgula wagneri

The unique biosphere of Lake Ohrid: Linking geological and biological evolution

Tom Wilke

Foto: Leicher (2013)

The SCOPSCO ICDP campaign

- Interdisciplinary research project linking the geological and biological histories of Lake Ohrid

- Major goals are to obtain information about:

  1) age and origin of Lake Ohrid,

  2) the seismotectonic history of the lake area,

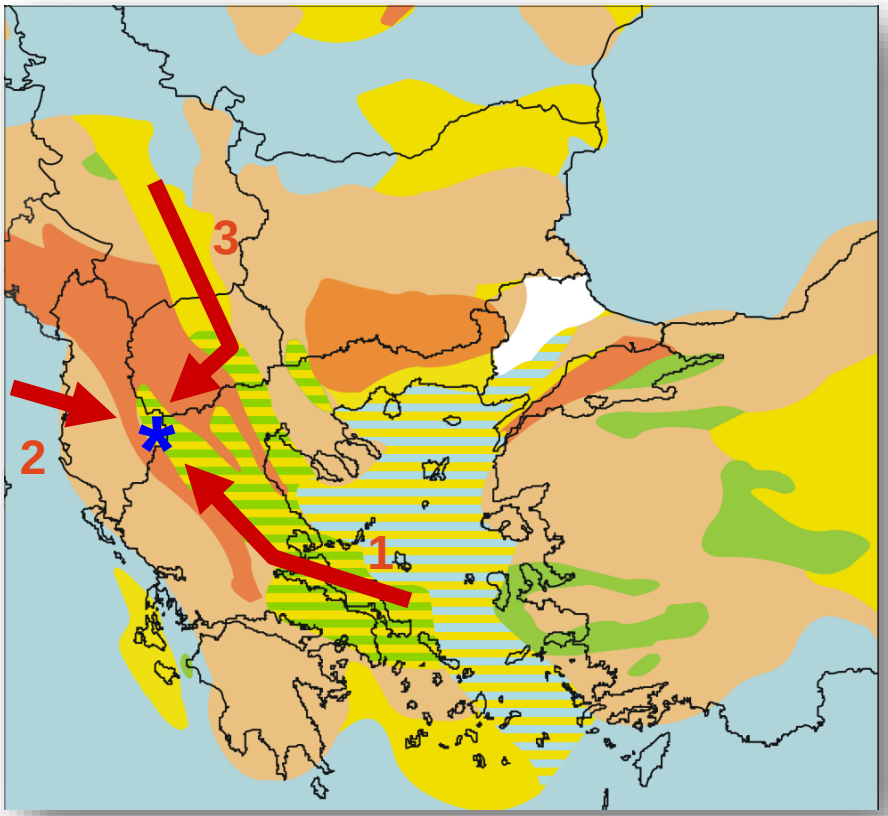
  3) volcanic activities and climatic changes during the Quaternary, and

  4) the driving forces for biotic evolution.

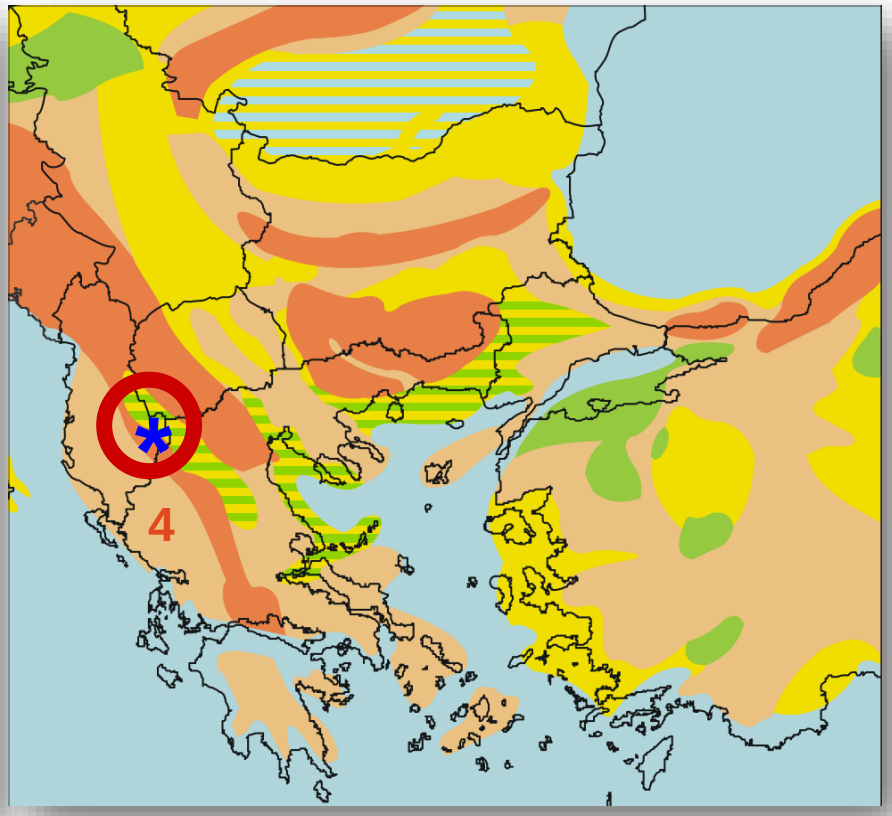
Multidisciplinary questions ⇨ interdisciplinary questions

Goal 1: Age and origin of Lake Ohrid

- Hypothesis 1: Mesohellenic Trough derivate hypothesis
- Hypothesis 2: Tethys derivate hypothesis
- Hypothesis 3: Lake Pannon derivate hypothesis
- Hypothesis 4: *de novo* hypothesis



Late Miocene



Late Pliocene/Early Pleistocene

Map modified from Popov et al. 2004

Age and origin of Lake Ohrid: Biology

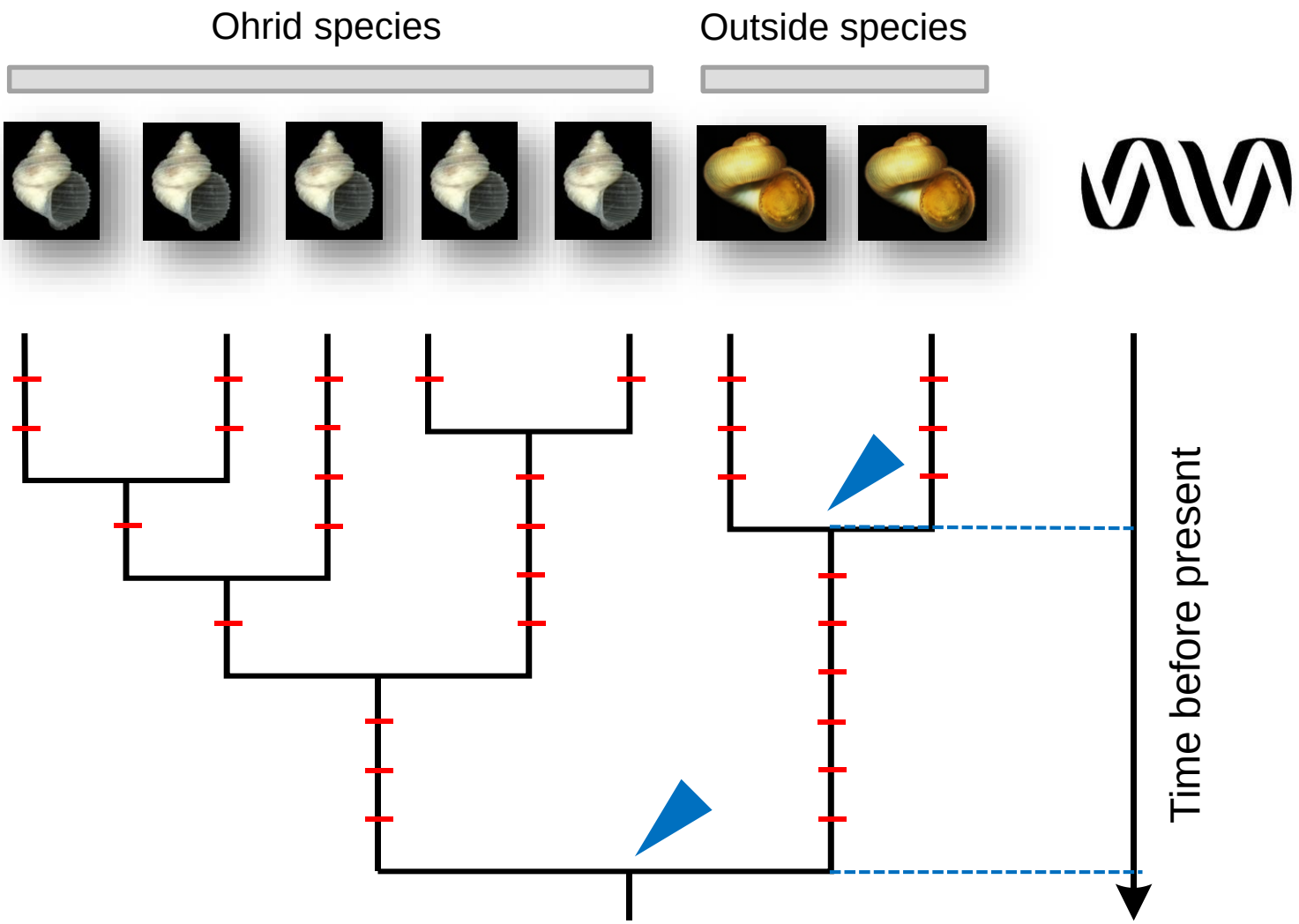
- Operational criteria for testing the paleolimnological history of Lake Ohrid

	'Mesohellenic Trough hypothesis'	'Tethys derivate hypothesis'	'Lake Pannon hypothesis'	'*de novo* hypothesis'
Timeframe of evolution	> 8-10 My	> 5-7 My	> 5-7 My	< 5 My
Ancestral area	Aegean Basin	Adriatic Region	Paratethys	central Balkan
Paleohabitat	brackish or marine	brackish or marine	brackish	freshwater

- Age: *Molecular clock coalescent approach*
- Ancestral area: *Ancestral state reconstruction*
- Paleohabitat: *Ancestral state reconstruction & paleohabitat modeling*

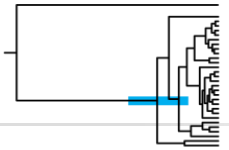
Age and origin of Lake Ohrid: Biology

- The molecular clock:

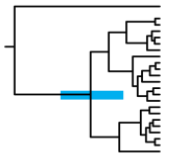


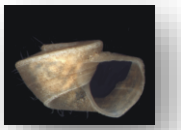
The molecular clock

- Onset of endemic radiations: 1.5–1.9 (2.6) My ago
- Split to outside sister groups: 2.2–5.0 My ago

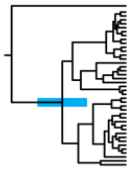


Ancylus

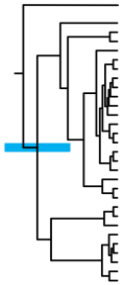




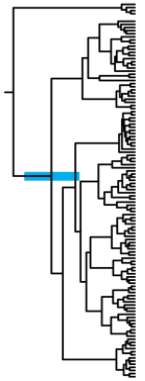
Gyraulus



Dina

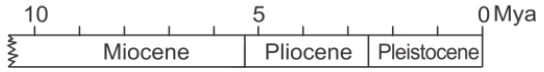


Pyrgulinae



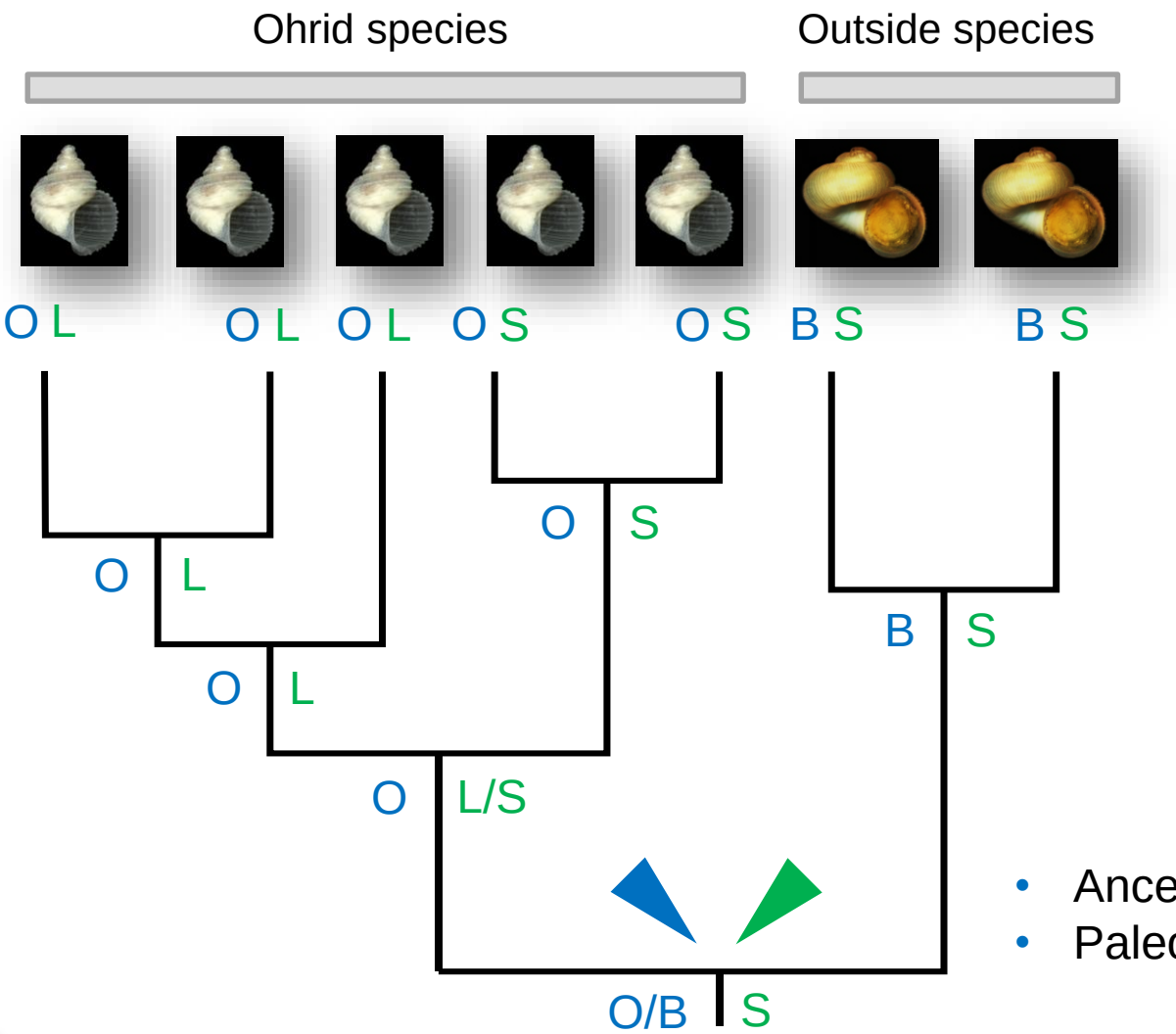
Horatiinae

Molecular clock estimates



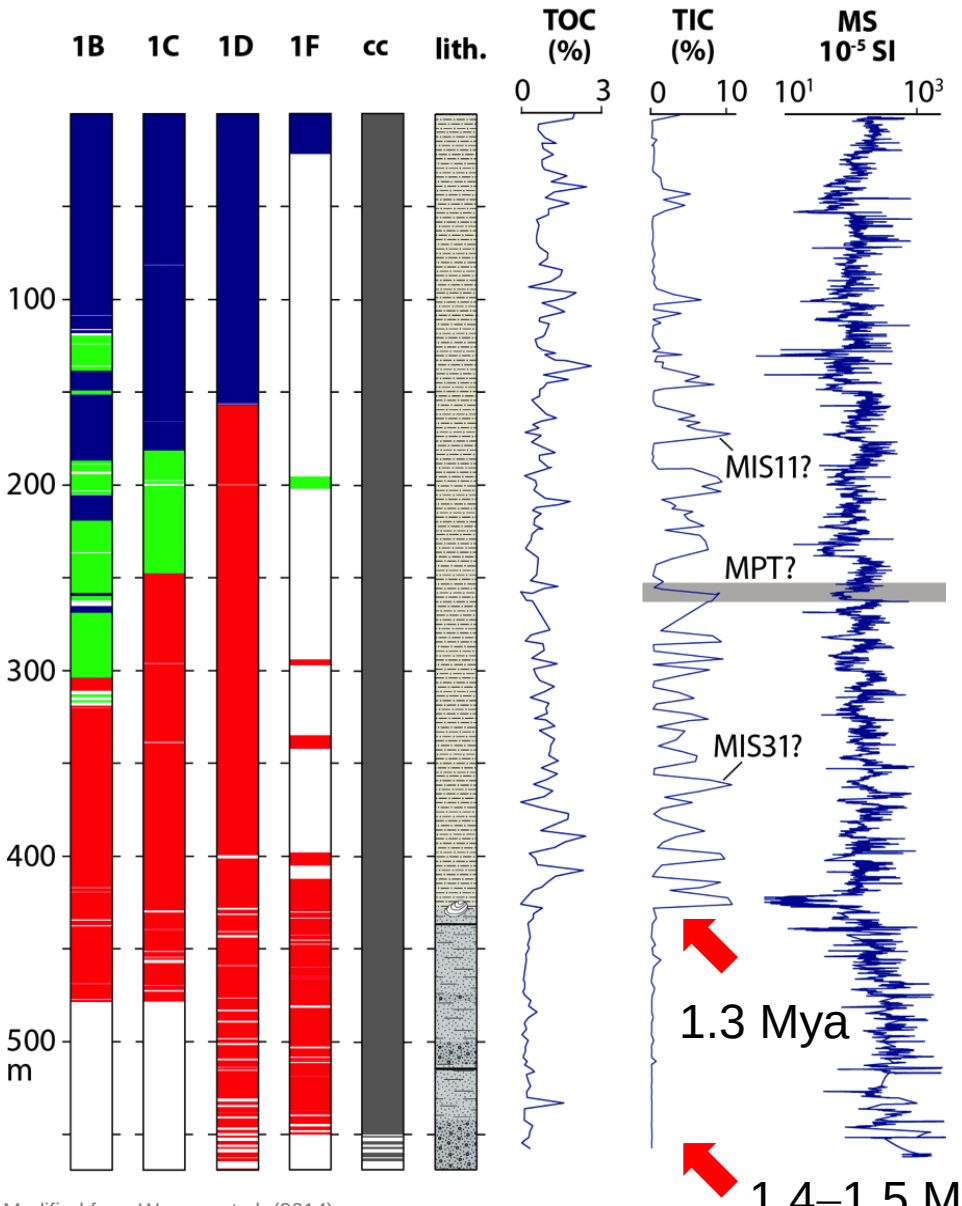
Age and origin of Lake Ohrid: Biology

- Ancestral state reconstruction: area and habitat



- Ancestral area: central Balkan
- Paleohabitat: freshwater (river and springs)

Age and origin of Lake Ohrid: Sedimentology

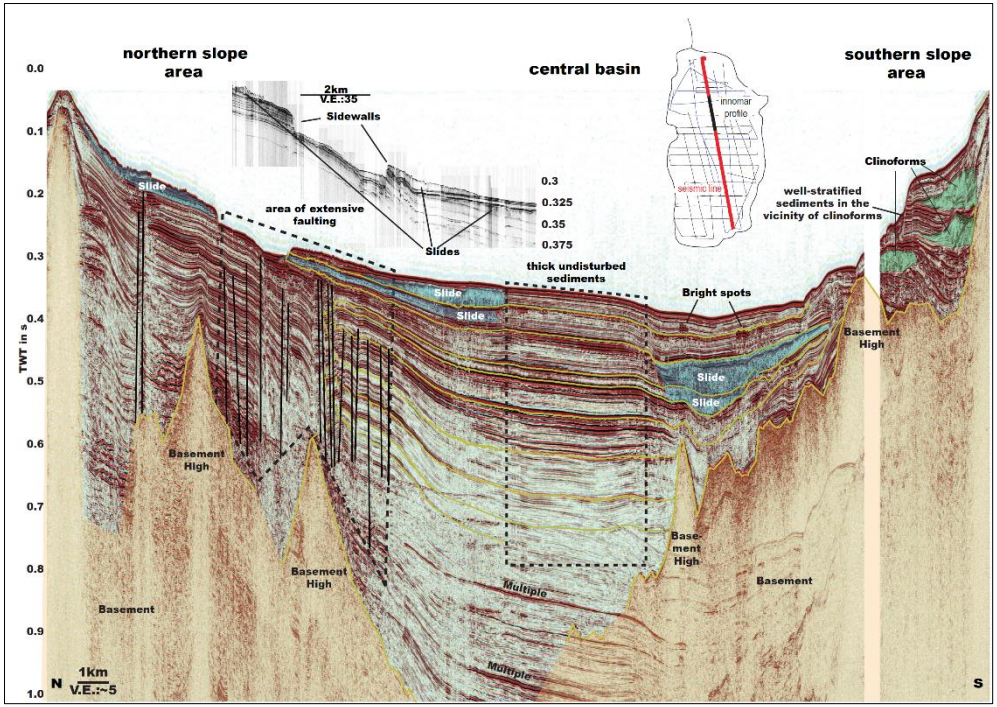


Modified from Wagner et al. (2014)

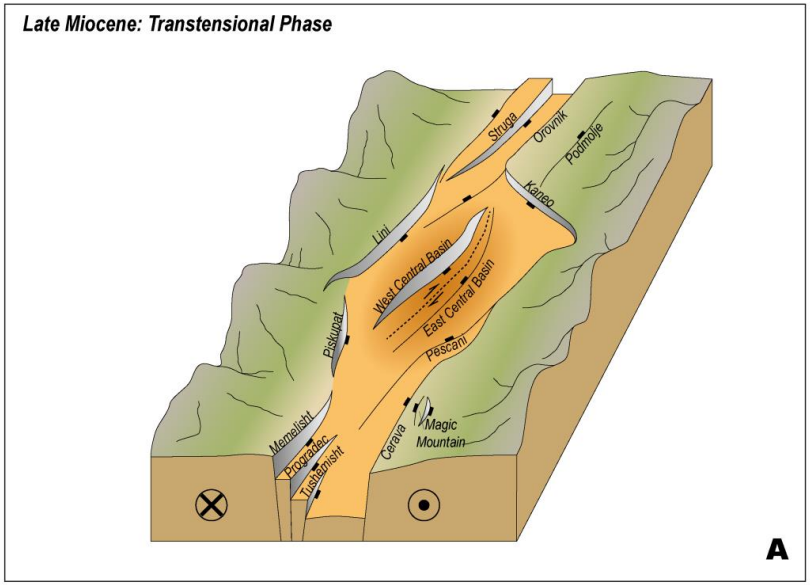
Core catcher material at 569 m blf

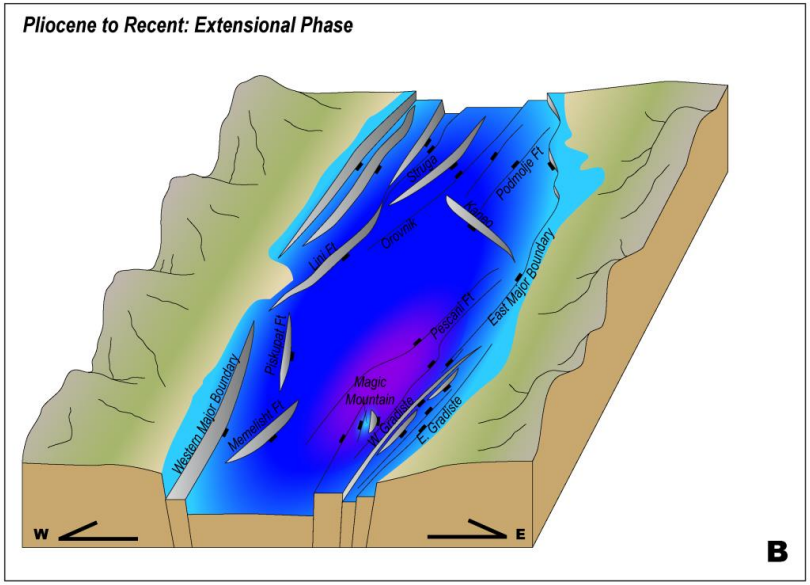
(from Wagner et al. 2014)

Age and origin of Lake Ohrid: Geophysics



Lindhorst et al. 2010



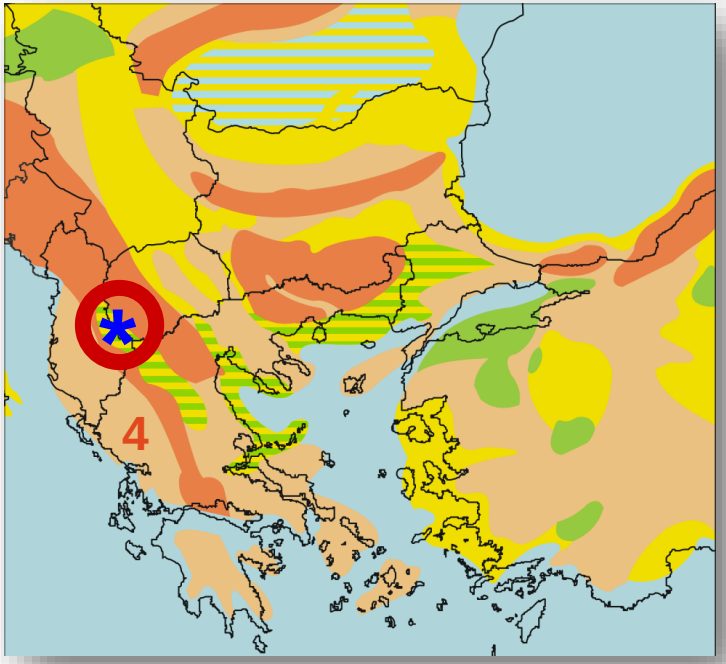


- Max age: 2.0 My
- Paleohabitat: River?

Lindhorst et al. 2015

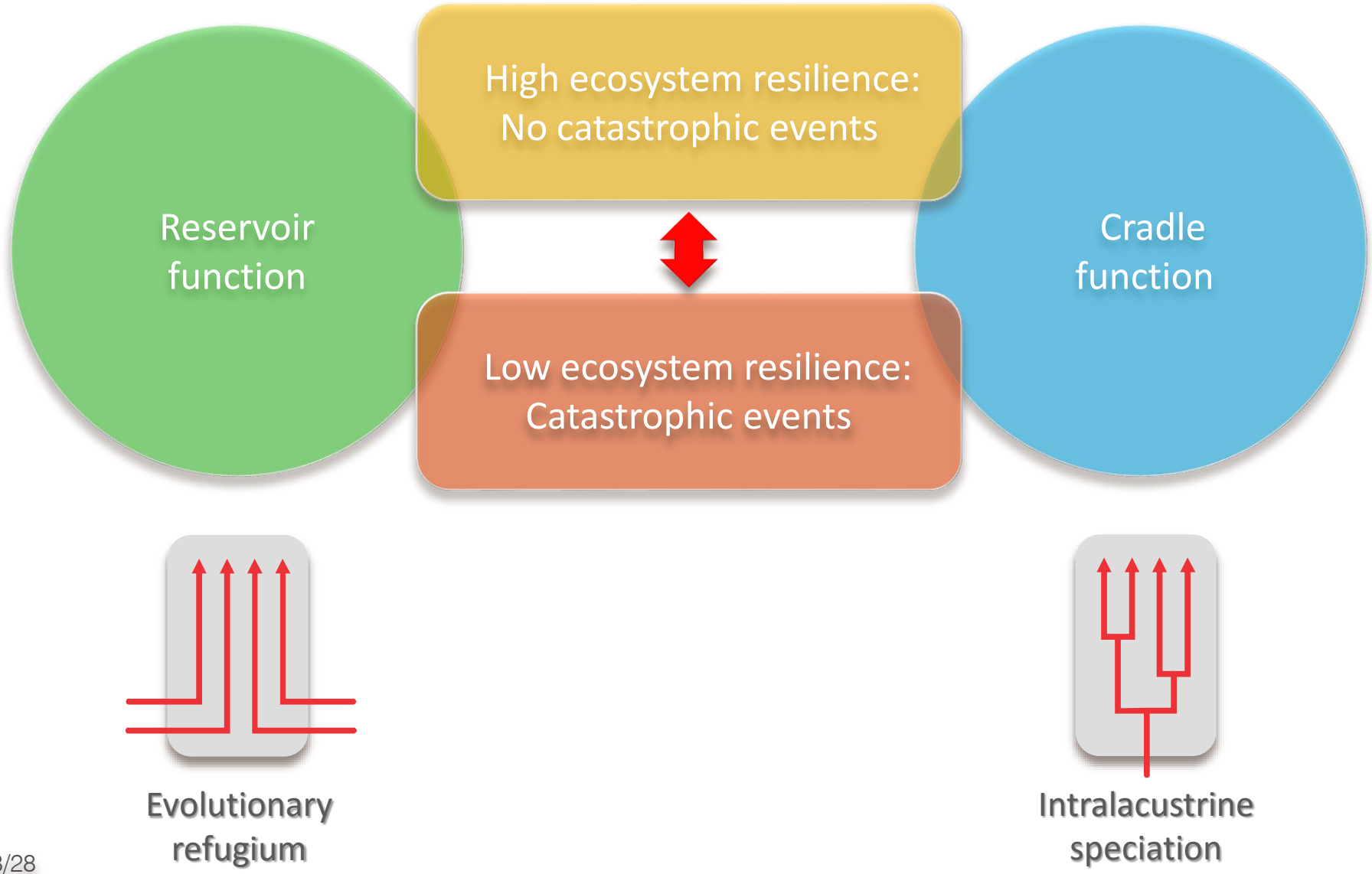
Age and origin of Lake Ohrid: Linking geology and biology

	Biology	Geophysics	Sedimentology	**Synthesis**
Age	Min./max. 1.5–2.2 My	Max. 2.0 My	Min. 1.4 My	**1.5–2.0 My**
Origin	spring/river	riverine?	riverine	**non-lacustrine freshwater**



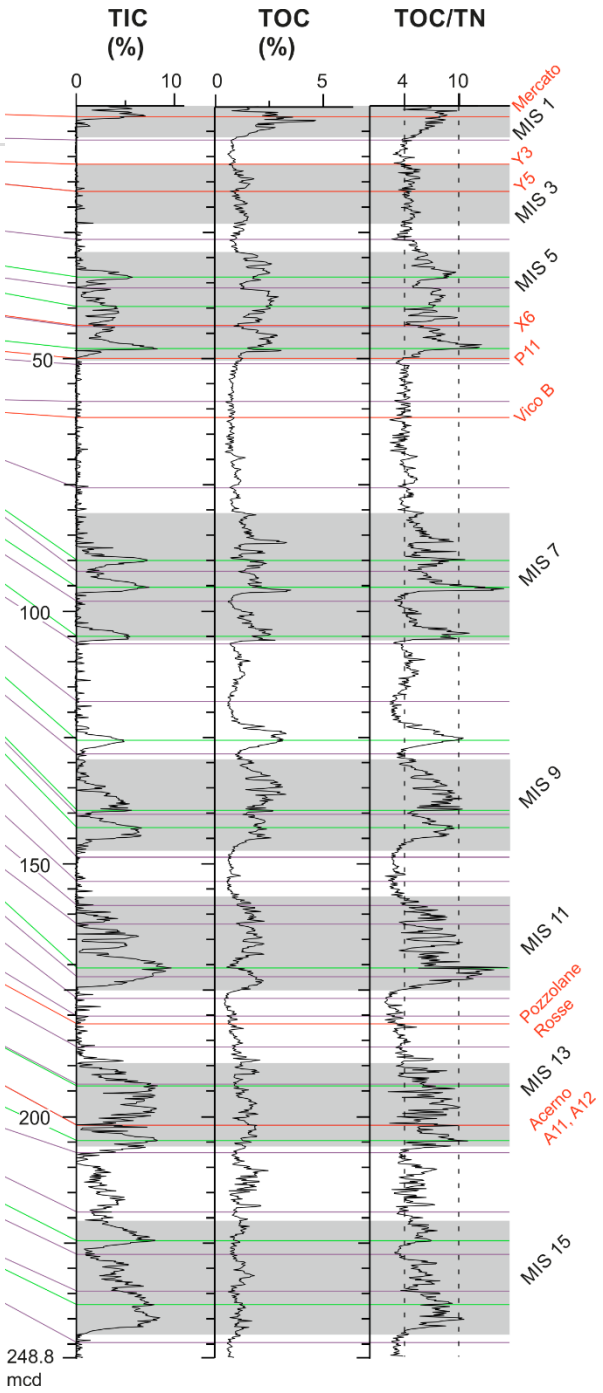
de novo hypothesis

Goal 2: Driving forces for biotic evolution



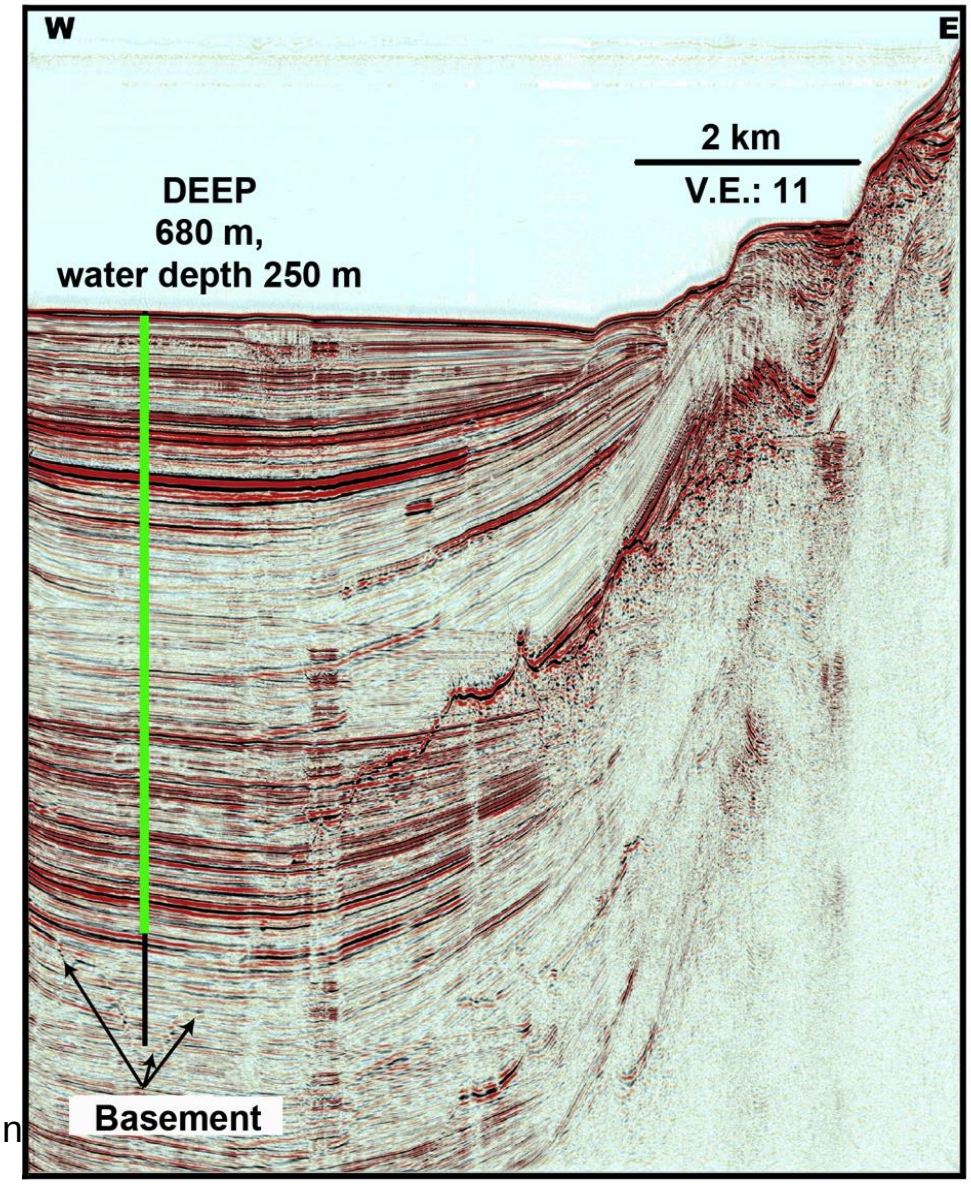
Driving forces: Sedimentology

- Past 640 ky: Major environmental changes but no evidence for salinization events etc.



Francke et al. (2015)

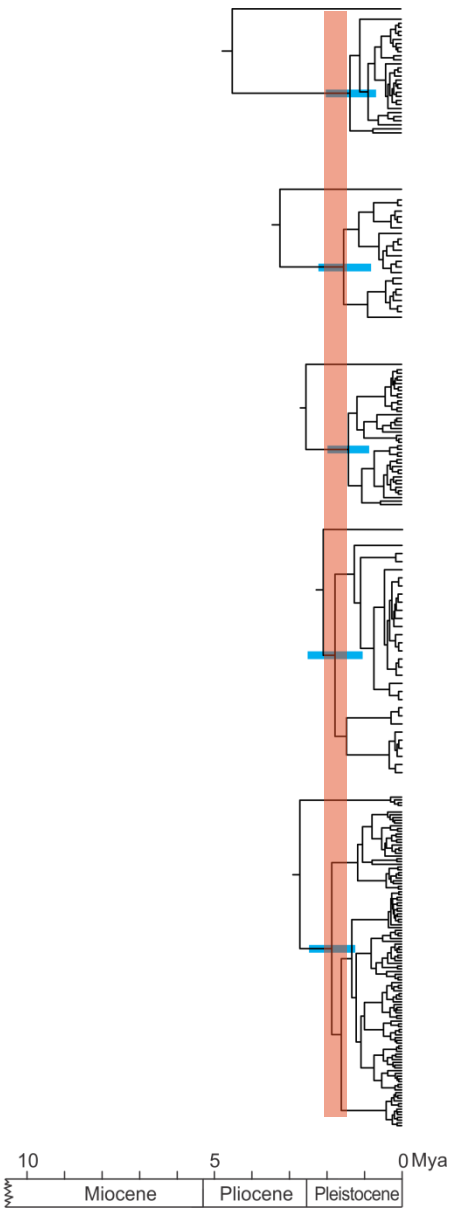
Driving forces for biotic evolution: Geophysics



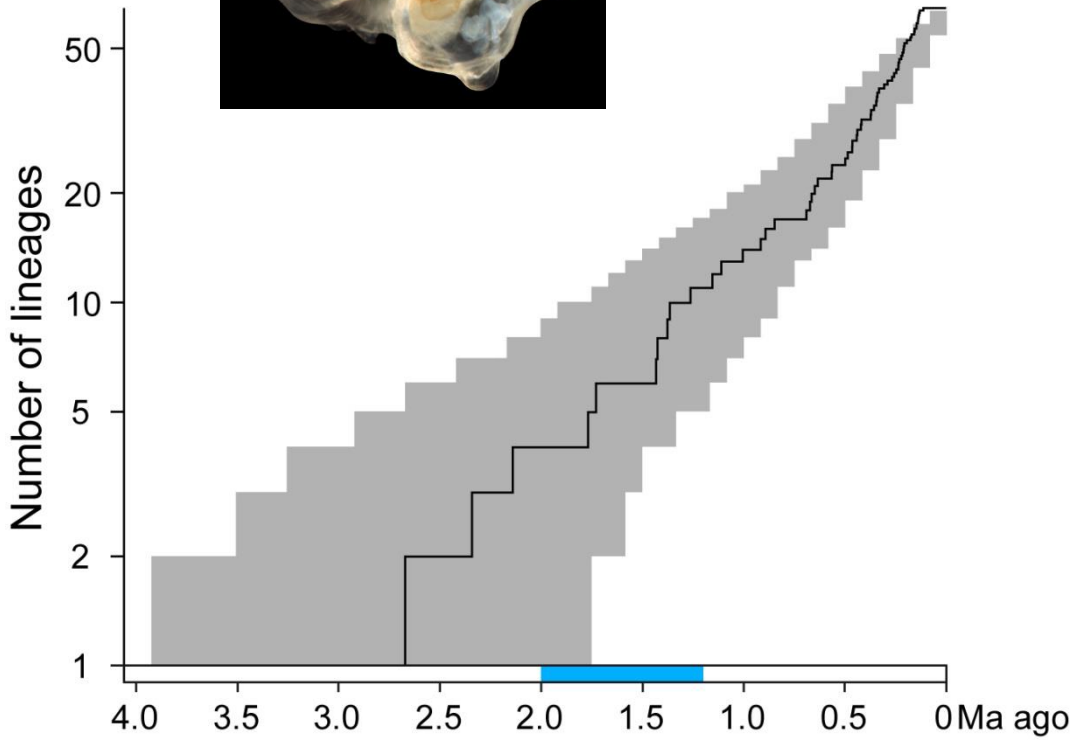
- Largely undisturbed sediments: probably no desiccation events

Wagner et al. (2014)

Driving forces for biotic evolution: mol. Biology



- Most species: intralacustrine evolution
- LTT's: no deviation from constant speciation model



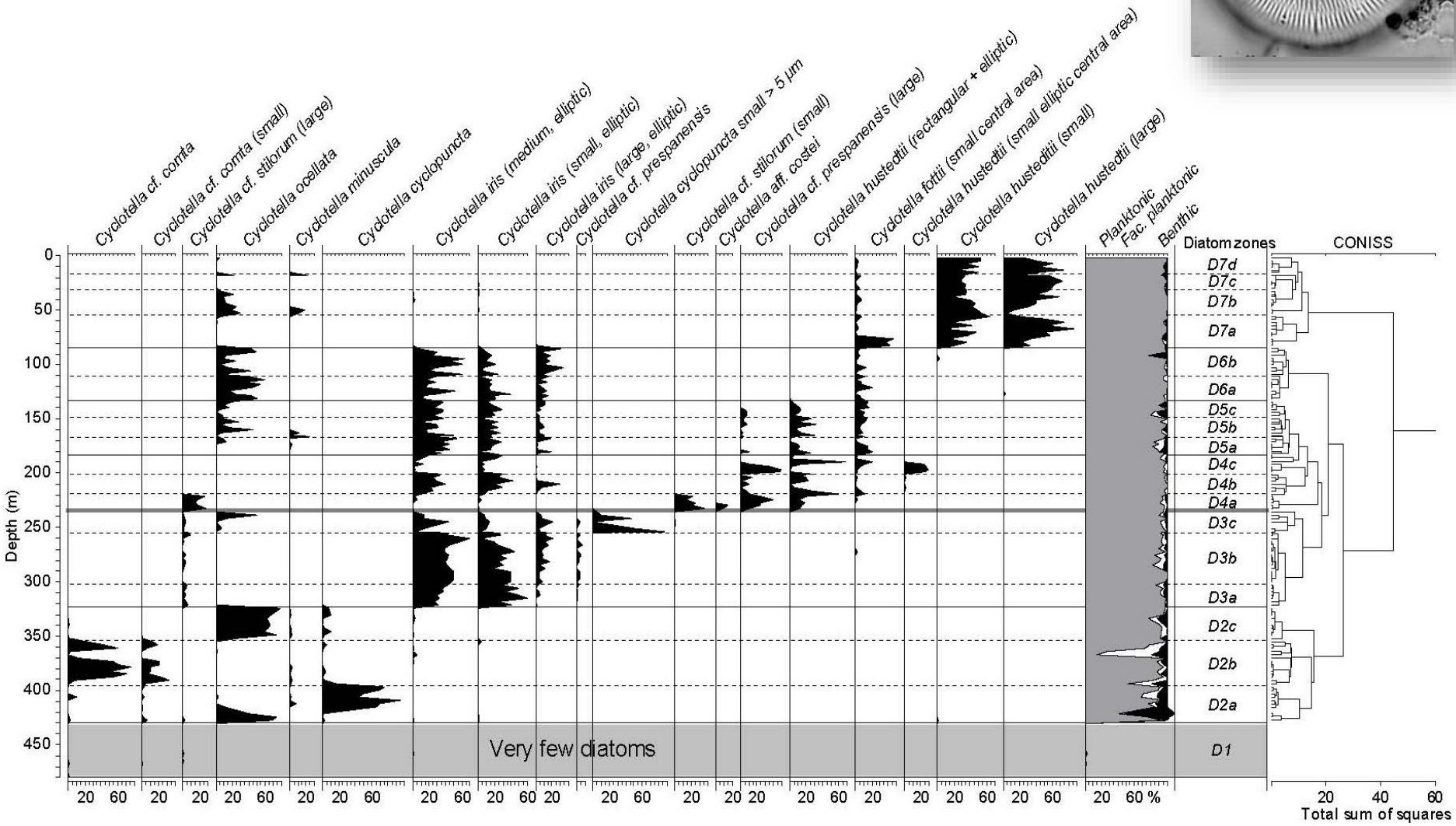
Driving forces for biotic evolution: Paleontology

- Mollusk fossil record does not indicate major extinction events

Modified from Albrecht et al. (2010)

Driving forces for biotic evolution: Paleontology

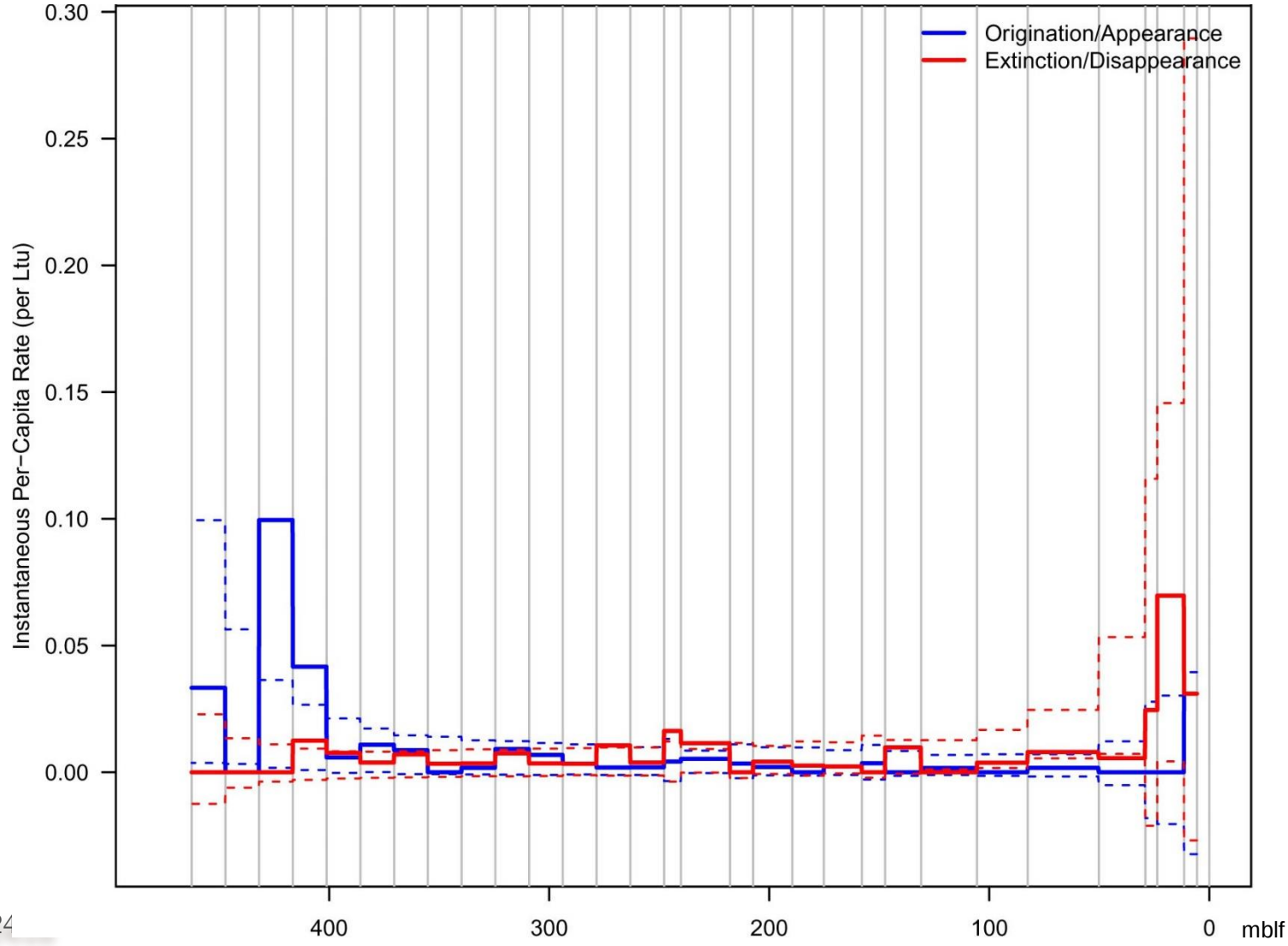
- Diatom fossil record over ca. 1 Mio. years



Modified from Wagner et al. (2014)

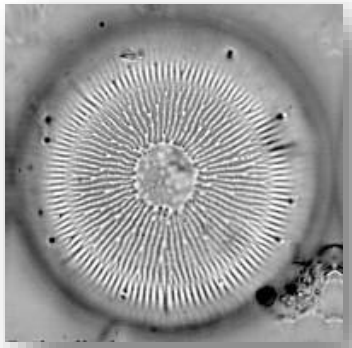
Driving forces for biotic evolution: Paleontology

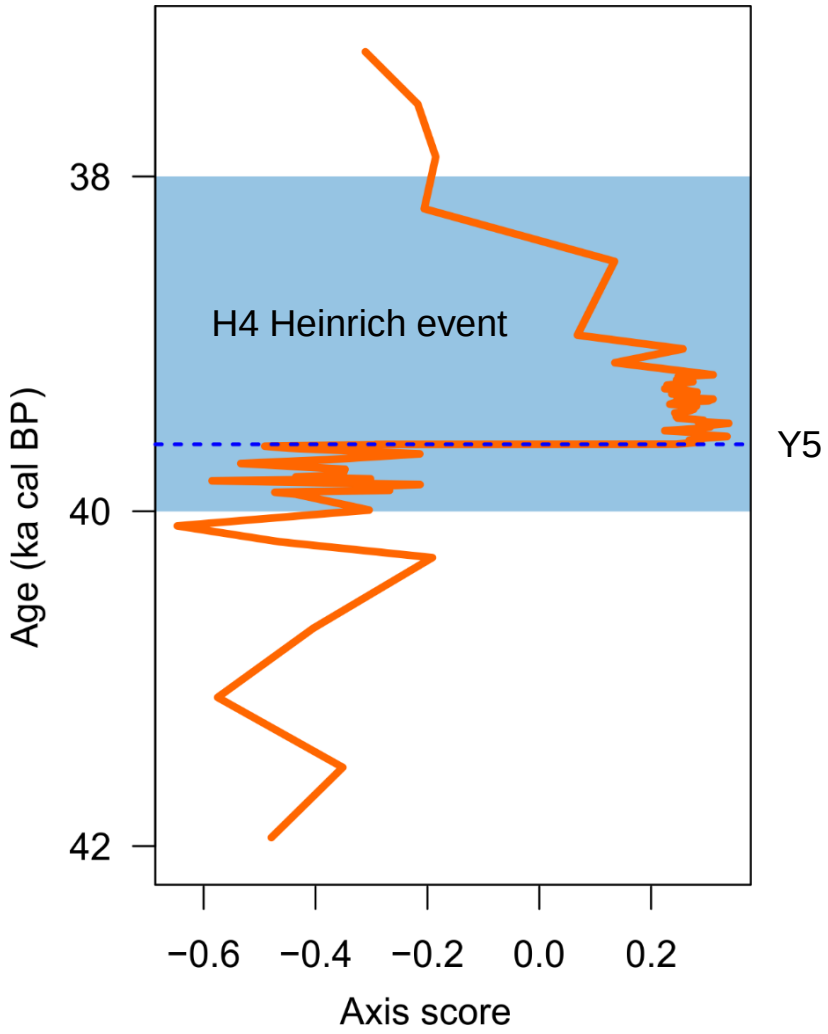
- Diatom speciation (appearance) and extinction (disappearance) rates



Driving forces for biotic evolution: Paleontology

- Response of endemic taxa to environment disturbances: High ecosystem resilience of Lake Ohrid





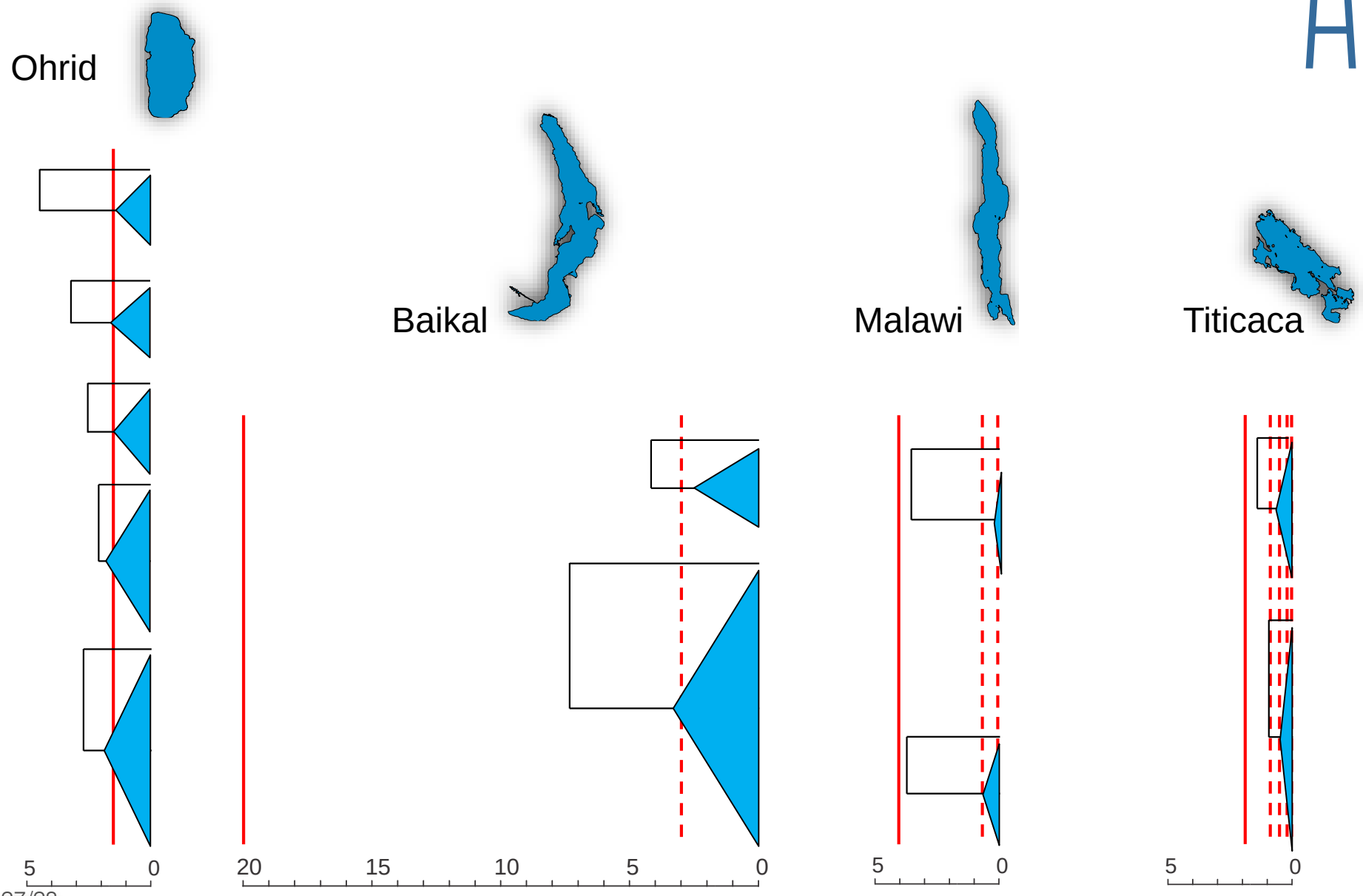
Benthic diatom community structure in Lake Ohrid (Jovanovska et al. 2015)

Driving forces for biotic evolution: Linking geology and biology

	Geophysics	Sedimen-tology	Pale-ontology	**Mol. Biology**	**Synthesis**
Reservoir vs. cradle	N/A	N/A	Mostly reservoir	Mostly reservoir	**Mostly reservoir**
Catastrophic events	No evidence	No evidence	No evidence	No evidence	**Unlikely**
Ecosystem resilience	N/A	N/A	High	High	**High**

- Main (nonexclusive) drivers of high endemic biodiversity:
  - High rate of intralustrine speciation
  - High ecosystem resilience → reduced extinction events
  - Lack of catastrophic events → no ecosystem reset

The role of catastrophic events: A comparison (mollusks)



Take home message

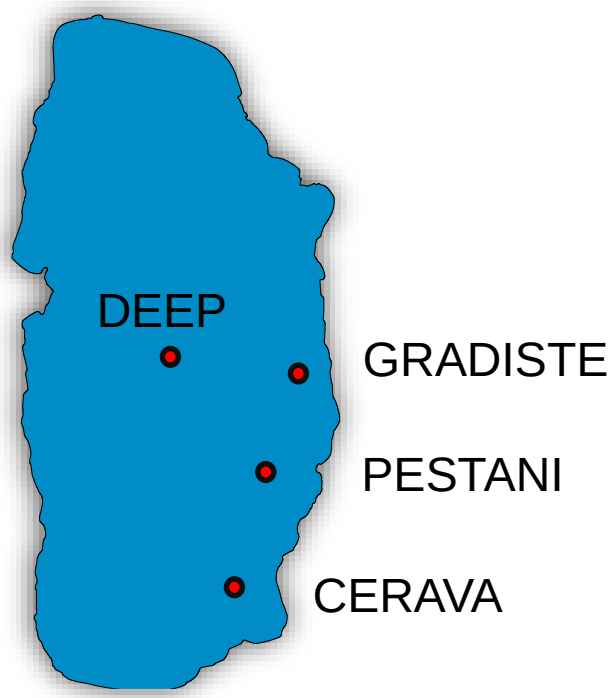
- The SCOPSCO program: linking geological and biological histories
  - Provide an ideal basis for interdisciplinary research
  - Enable testing of geological and biological hypotheses
  - Modern advances in evolutionary research allow for the generation of complementary data sets
- What next?

Site 1 (DEEP)
- 1B: 480 m
- 1C: 480 m
- 1D: 569 m
- 1F: 550 m

Site 2 (CERAVA)
- 2A: 85 m
- 2B: 90 m

Site 3 (GRADISTE)
- 3B: 82 m
- 3C: 120 m
- 3D: 116 m

Site 4 (PESTANI)
- 4A: 194 m




Thank you!