Reconstructing palaeoenvironments using molluscs

Frank P. Wesselingh

Jon Todd

NCB Naturalis
Nederlands Centrum voor Biodiversiteit

NATURAL HISTORY MUSEUM

Molluscan Palaeoecology

- Introduction
- I Form and function
- II Environmental indicator taxa
- III Communities and community palaeoecology
- IV Taphonomy & environmental successions
- V Shells as archives of environmental change
- VI

Molluscs live almost anywhere

Molluscs live almost anywhere

Molluscs live almost anywhere

Molluscs live almost anywhere

Extant molluscan classes

Bivalvia

www.brotherspets.com

Gastropoda

Cephalopoda

Polyplacophora

Scaphopoda

(Monoplacophora + “Aplacophora”)

www.linternaute.com

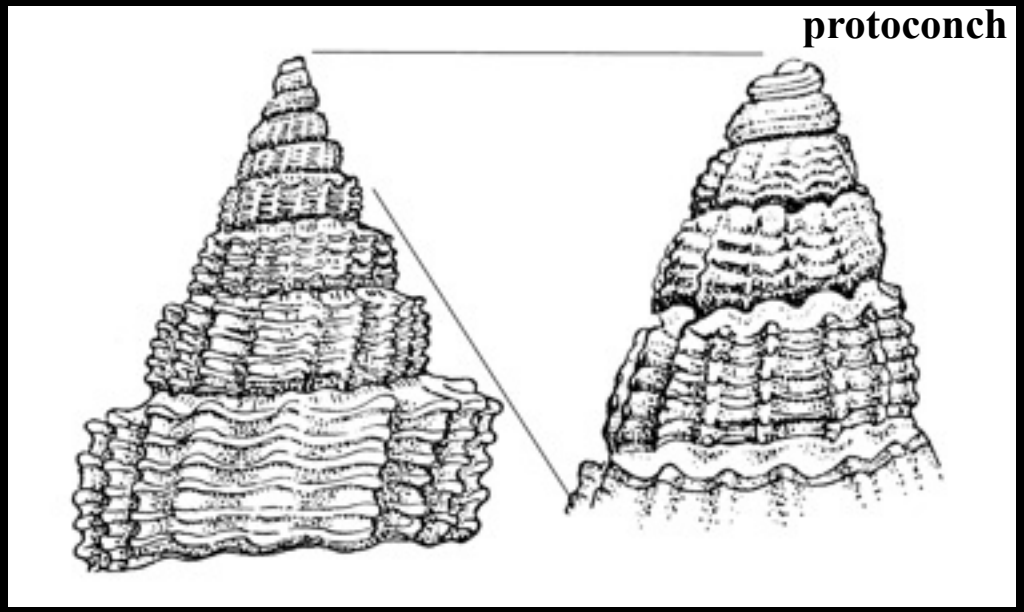
What makes a mollusc ?

Body plan (= *bauplan*) with 4 major regions

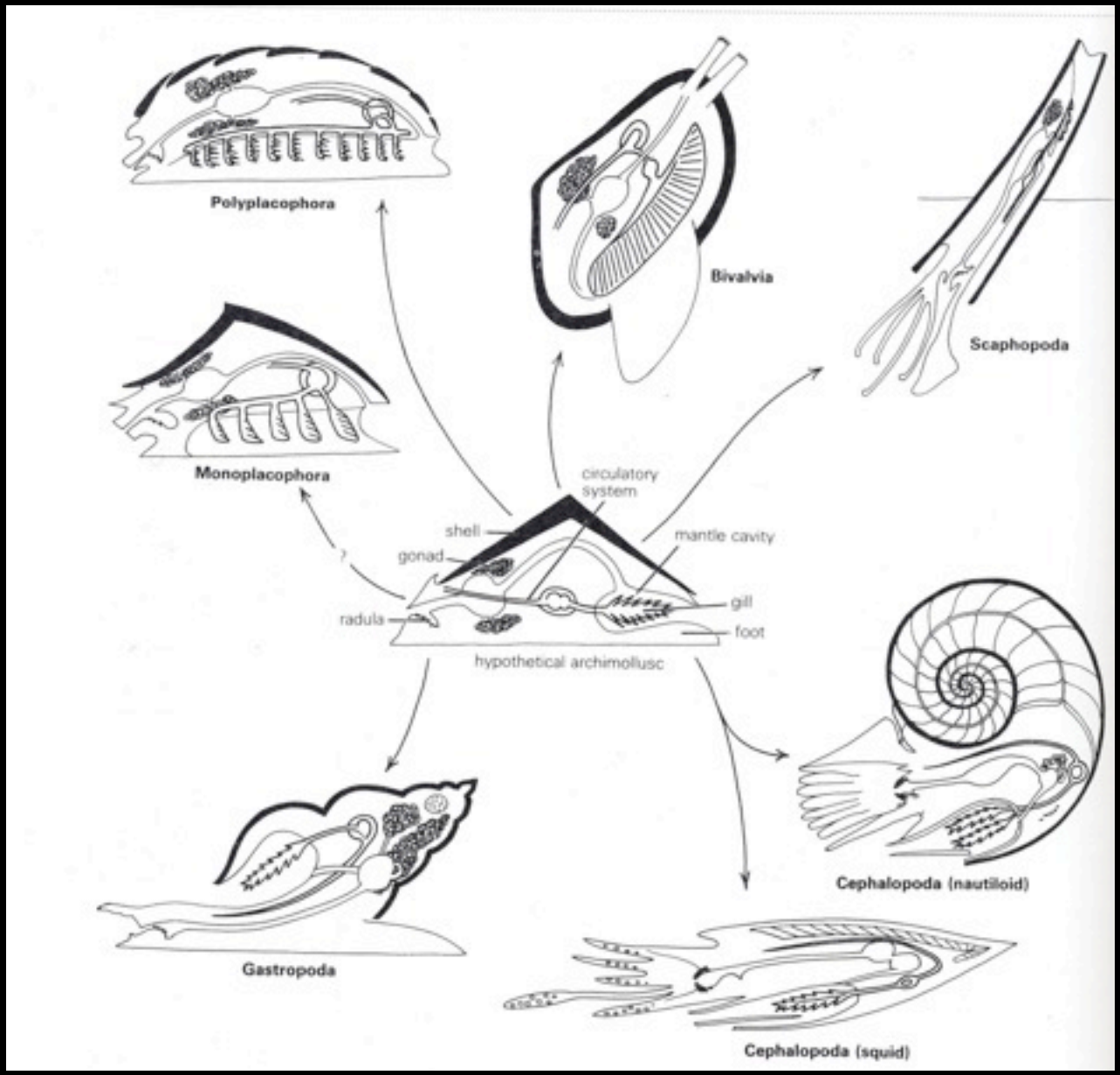
- Mantle - dorsal epithelium with thick cuticle, secretes spicules or accretionary shell
- Head - characteristic circum-oesophageal nerve ring (=brain)
- Foot – ciliated ventral expansion, usually for creeping or modified for other locomotion
- Visceral mass – hump with guts and gonads

Orange = Unique to molluscs

Accretionary Growth



Hypothetical derivation of body plans



Modifications of:

- Head
- Foot
- Gills

Molluscs: what are they good for ?

- Evolutionary Biology
  - excellent fossil record – taphonomically durable
  - character-rich, accretionary shells : whole of ontogeny preserved
- Palaeoecology and palaeoenvironments
  - abundant in most aquatic facies
  - relationship of: shell morphology to environment
  - shell geochemistry to environment
  - accretionary growth: sclerochronology to reconstruct palaeoenvironments
- Stratigraphic utility: biozonation

Extant molluscan classes: diversity

Bivalvia	10,000 species	mostly infaunal (burrowers)
Gastropoda	90,000	mostly epibenthic (crawlers)
Cephalopoda	700	mostly pelagic (swimmers)
Polyplacophora	600	epibenthic (crawlers)
Scaphopoda	550	infaunal (burrowers)
(Monoplacophora +	30	epifaunal
"Aplacophora")	320	mostly epifaunal (crawlers)

Molluscan classes

Bivalvia

Two valves

Hinge

Foot

Marine

Freshwater

Includes scallops, oysters, clams

www.brotherspets.com

www.linternaute.com

Growth: open cone

Umbo and hinge

Epifaunal v infaunal

Inequivalve, equilateral

Equivalve, inequilateral

Molluscan classes

Bivalvia

Gastropoda

Cephalopoda

Polyplacophora

Scaphopoda

(Monoplacophora + “Aplacophora”)

www.ladiving.smugsmug.com

Molluscan classes

Gastropoda

Single shell

Snails and slugs

Eyes

Foot

Marine, Freshwater and Land

Pliocene, Philippines

Molluscan classes

Bivalvia

Gastropoda

Cephalopoda

Polyplacophora

Scaphopoda

(Monoplacophora + “Aplacophora”)

Molluscan classes

Cephalopoda

Nautilus, squid, Octopus

Tentacles

Eyes

Swimming

Marine

Molluscan classes

Bivalvia

Gastropoda

Cephalopoda

Polyplacophora

Scaphopoda

(Monoplacophora + "Aplacophora")

Chitons

8 shell plates and girdle

Marine

Rocky shores

www.mogaauto.com

Molluscan classes

Bivalvia

Gastropoda

Cephalopoda

Polyplacophora

Scaphopoda

(Monoplacophora + “Aplacophora”)

Tusk shells

Tube like

Marine

Soft bottoms

www.eol.org

Major factors controlling gross shell morphology

Feeding

Movement/Relationship to sediment

Protection

Trophic modes

Carnivore
Scavenger
Parasitic
Deposit-feeder
Suspension-feeder
Grazer
Photosymbiont
Chemosymbiont

Paul J. Morris/ www.flickr.com

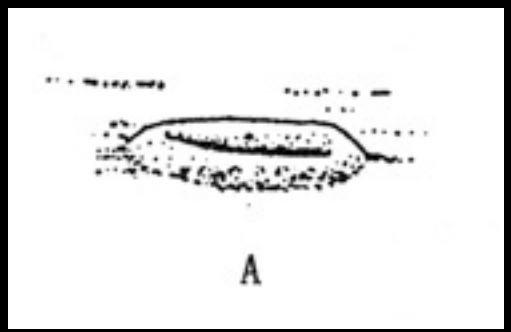
www.brotherspets.com

Parasite (=browsing carnivore?)

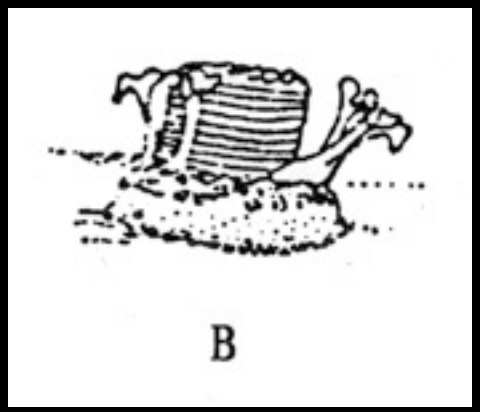
source unspecified

source unspecified

Eulimidae



(Reid & Reid, 1974)



(Reid & Reid, 1974)

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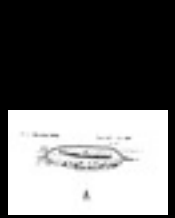
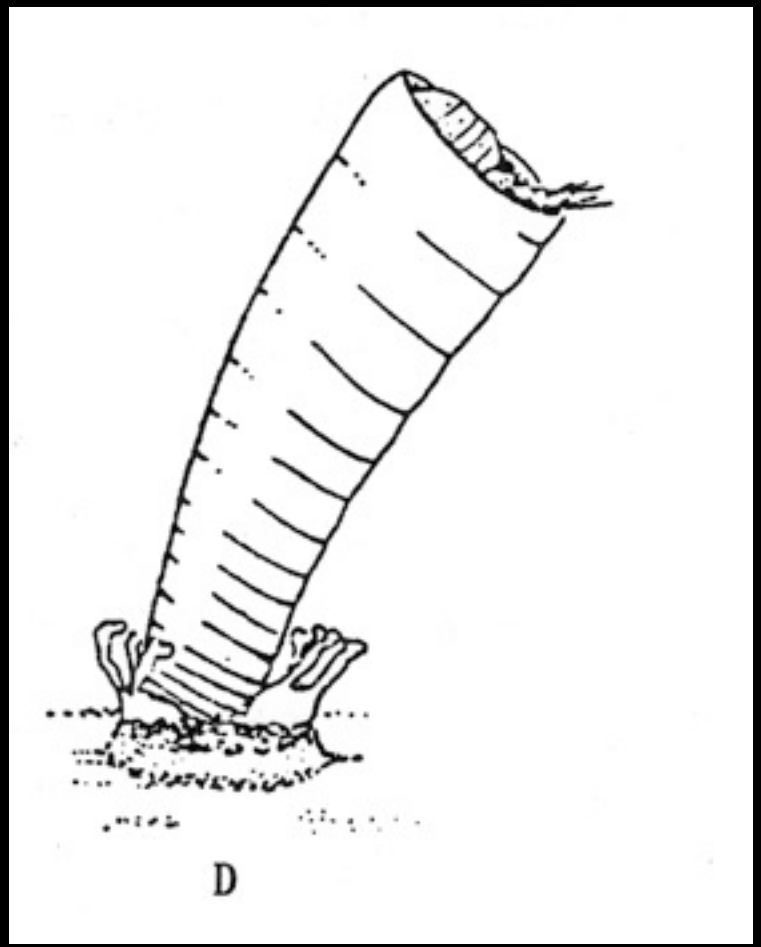
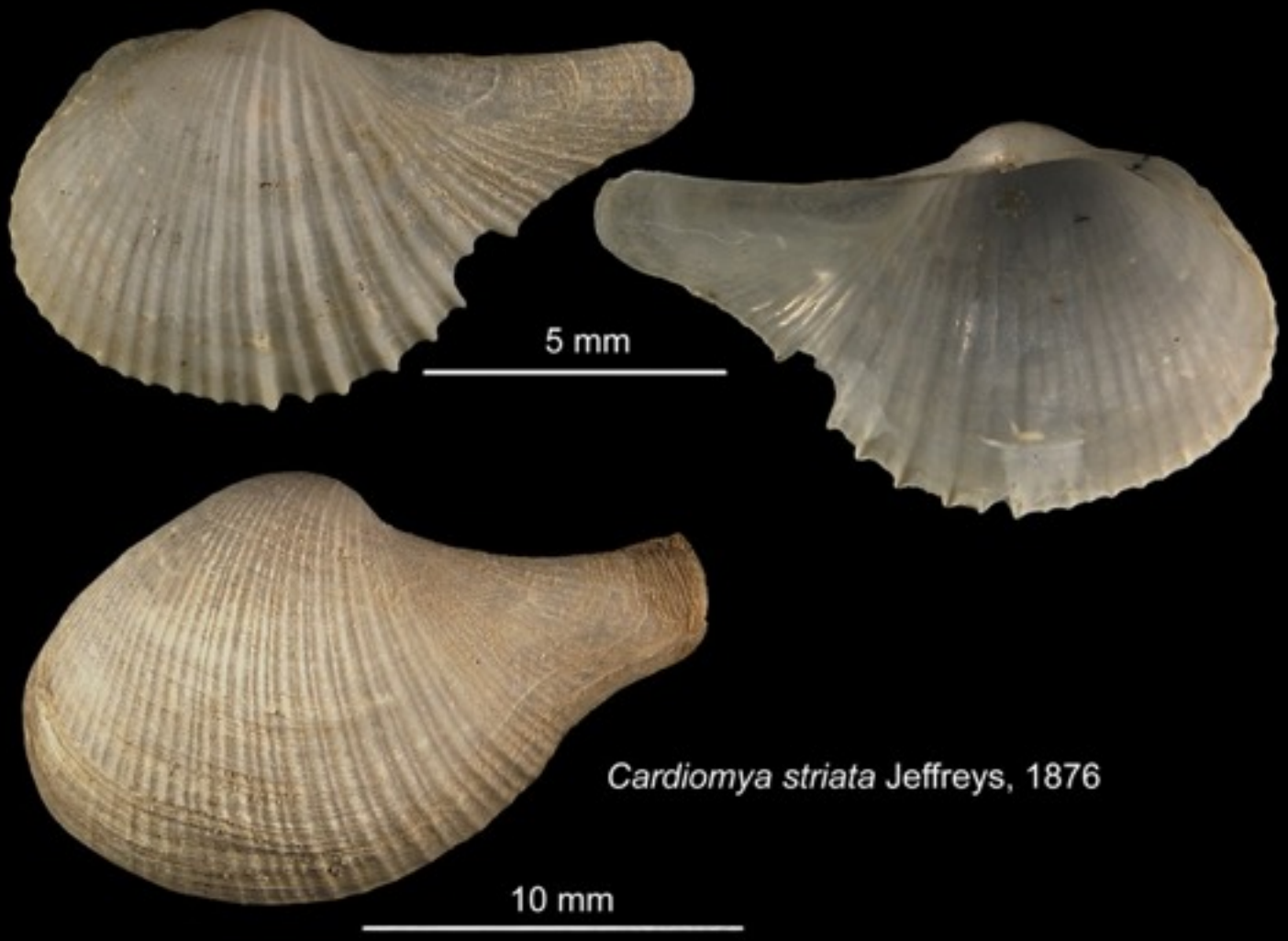




(Reid & Reid, 1974)

A bivalve and yet a ferocious predator: *Cardiomya*



Motility: moving around or staying put

Vagile epifaunal
Sessile epifaunal
Vagile infaunal
Sessile infaunal
Borer
Attached
Cemented
Planktonic
Nektonic

Pholas

www.bumblebee.org

Cavolinia

source unknown

vagile mud/sand inhabitants

I. Introduction

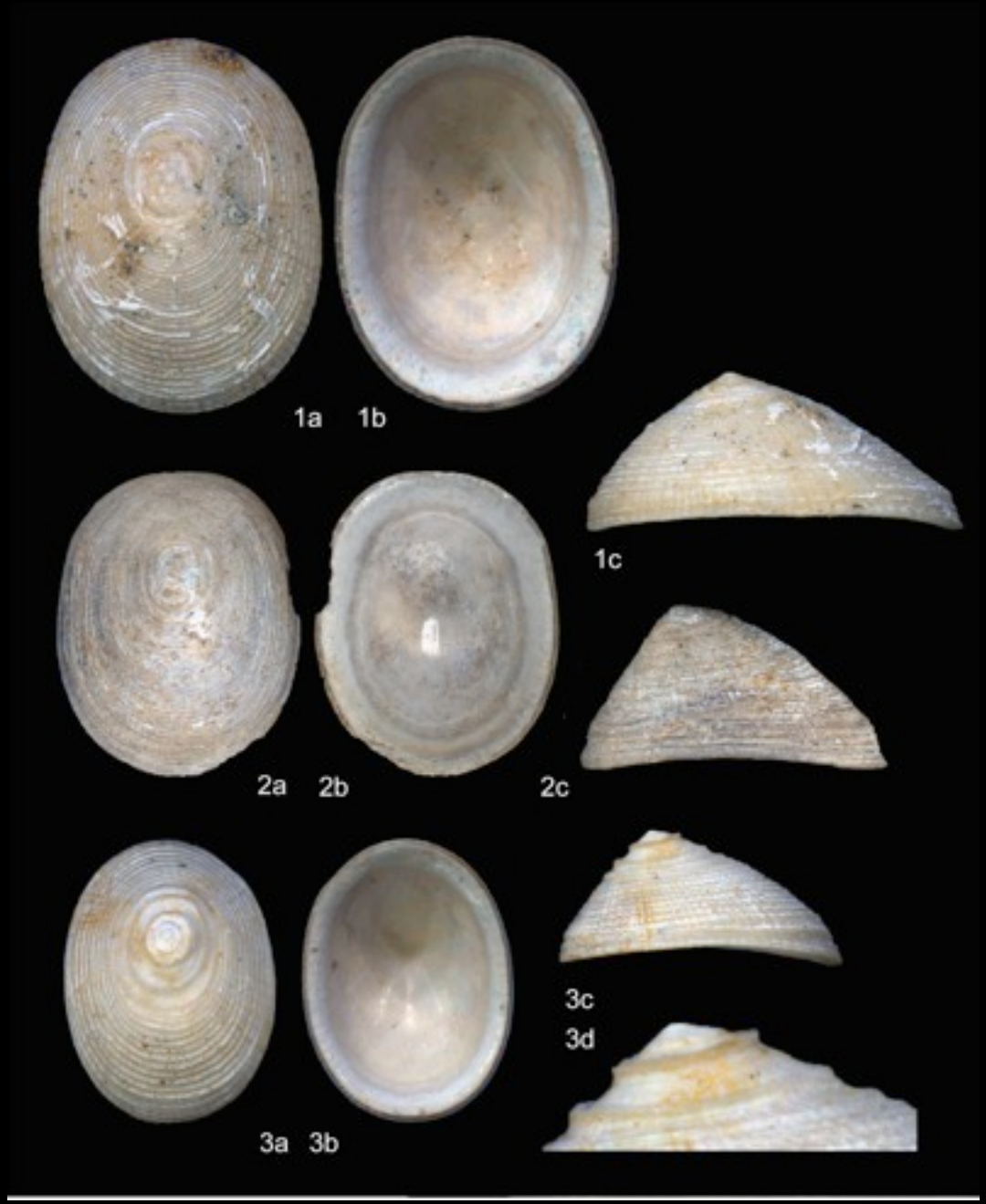
source unspecified

source unspecified

Living in Wood

I. Introduction

Living in Wood … caused Dutch dykes to burst!



Grazing on wood in the deep sea

Deepwater limpets from the Philippine Pliocene

I. Introduction

Molluscan Palaeoecology

Introduction

I Form and function

II Environmental indicator taxa

III

Communities and community palaeoecology

IV Taphonomy & Environmental successions

V Molluscs as history books

V!

Eating, moving and surviving

- Much shell morphology interpretable:
- Feeding mode
- Moving/relationship to substrate
- Defence

Thorny issue: adaptation

Defence

- Prevent ‘handling’
- Increase in size
- Cheap increase in thickness
- Camouflage

Spondylus

Defence

Scars of decapod attacks on whelk (*Buccinum undatum*, North Sea)

VI. Molluscs as history books

Direct biotic interactions can drive morphology

Evolutionary arms-race
Escalation between
armament and defences

predator vs prey

West et al., 1991

feeding

Batissa

a suspension feeding burrower

Pallial sinus

Batissa

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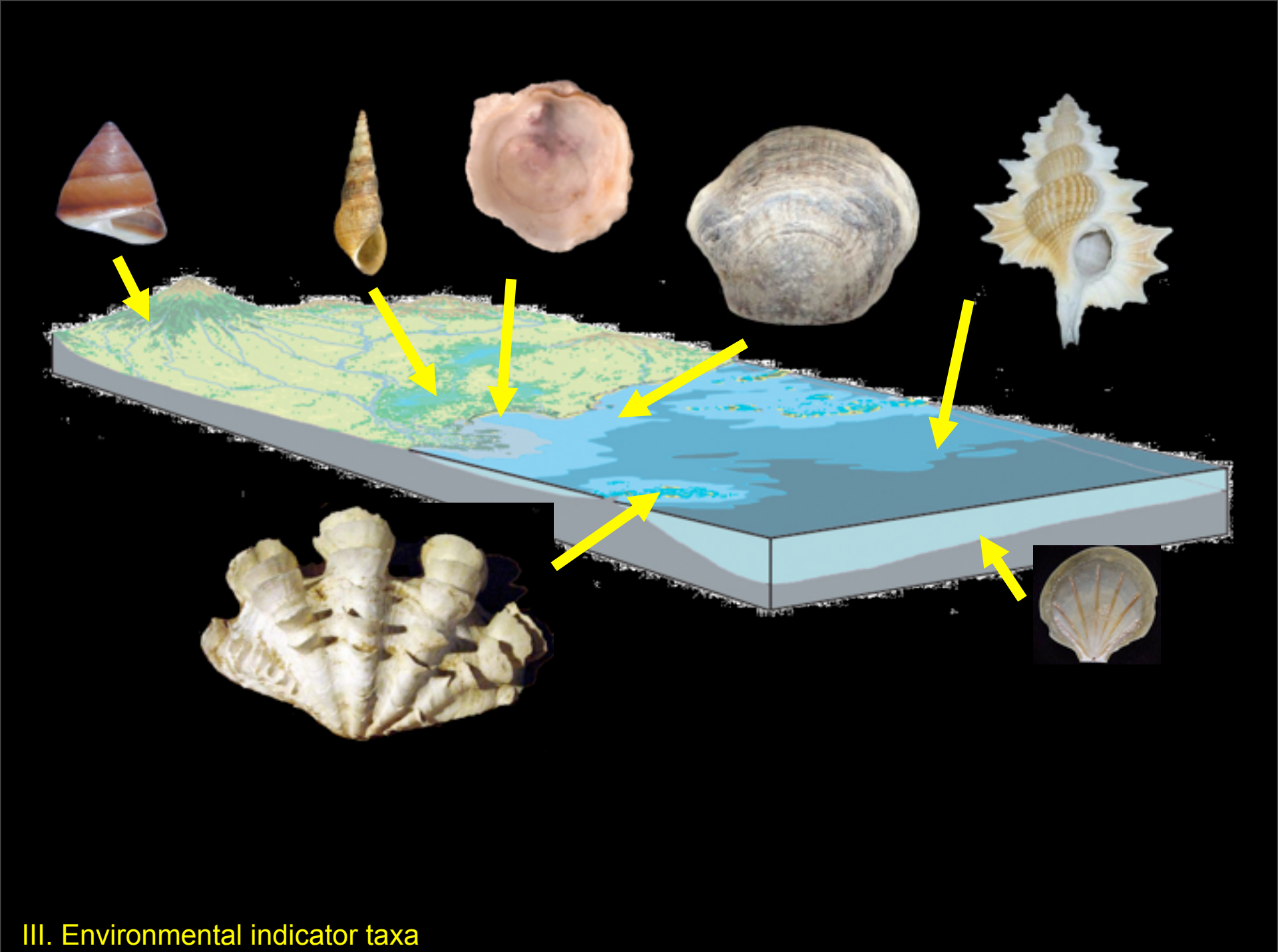

III. Environmental indicator taxa

Stylammatophore pulmonate snails are terrestrial indicators

Pearly freshwater mussels (unionoid) and *Corbicula* clams are freshwater indicators

Corbicula

Pearly fresh water mussels
(Unio/Anodonta/Psilunio)

Some SE Asian freshwater snail taxa

Melanoides *Tarebia* *Brotia* *'Planorbis'* *Bellamya*

III. Environmental indicator taxa

Freshwater indicators

Still / stagnant (ponds, swamps, shallow lakes)

Agitated (streams, rivers)

Mangrove/Estuarine indicators

Batissa

Parahyotissa

Mangrove indicators

Nerita

Cerithidea

Terebralia

Telescopium

Mangrove indicators

Terebralia

Mangrove indicators

Oysters and mussels: substrate

Reef indicators

Reef flat

Reef slope

Reef flat indicators

Tridacna

III. Environmental indicator taxa

Reef flat indicators

Tridacna

Clypeomorus

Plesiotrochus

Soft bottom coastal-offshore indicators

Placuna

Natica

Turritella

Paphia

Sea grass meadow indicators

Smaragdia

Timoclea

Turritella

Biplex

Marine soft bottom indicators

III. Environmental indicator taxa

Deep water indicators

Cardiomya

Yoldiella

Propeamussium

Oceanic indicators: pteropods

Cavolinia/Diacria

Pitfalls of taxonomic uniformitarianism:

Throughout Mesozoic common soft substrate dwellers in shallow shelf to deeper water

Now live at 100m+ on steep fore-reef slopes and rock faces

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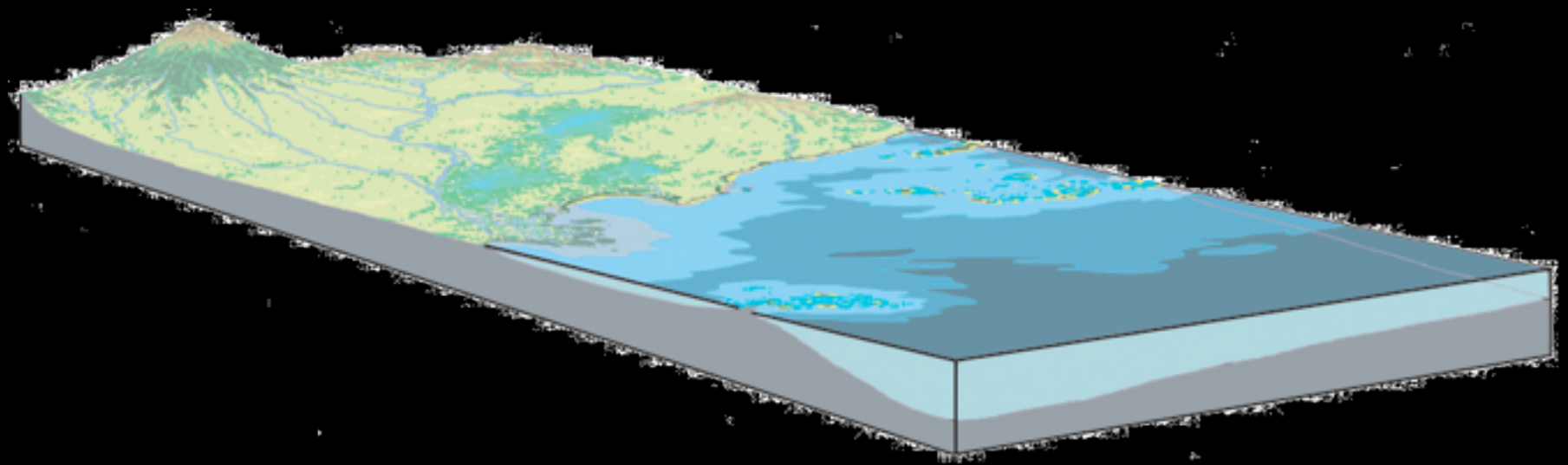
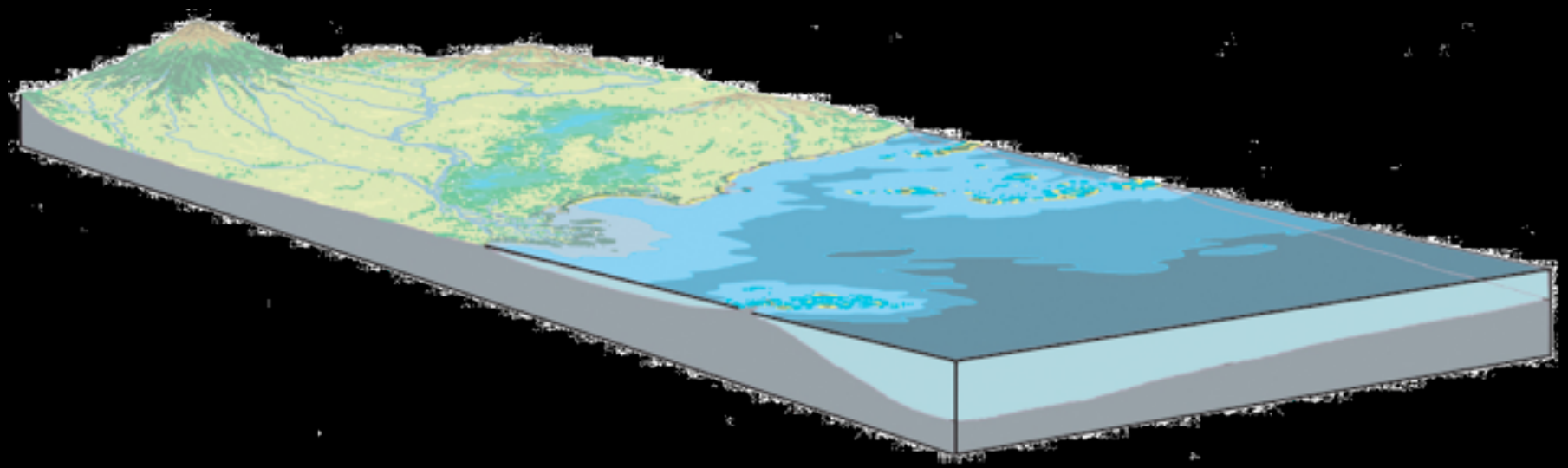
Species richness across environmental gradients

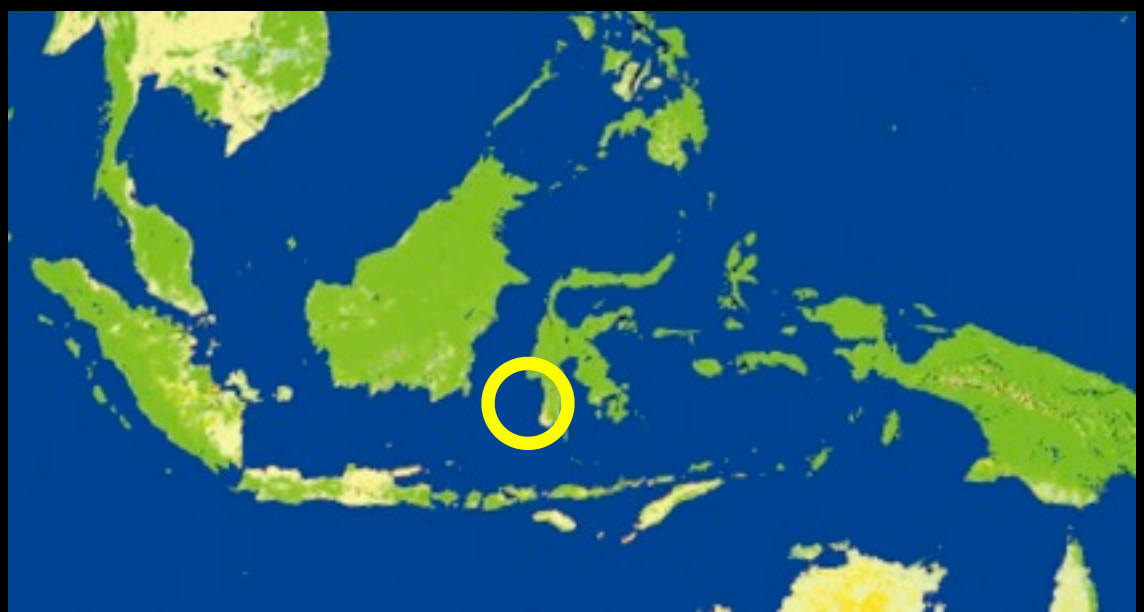


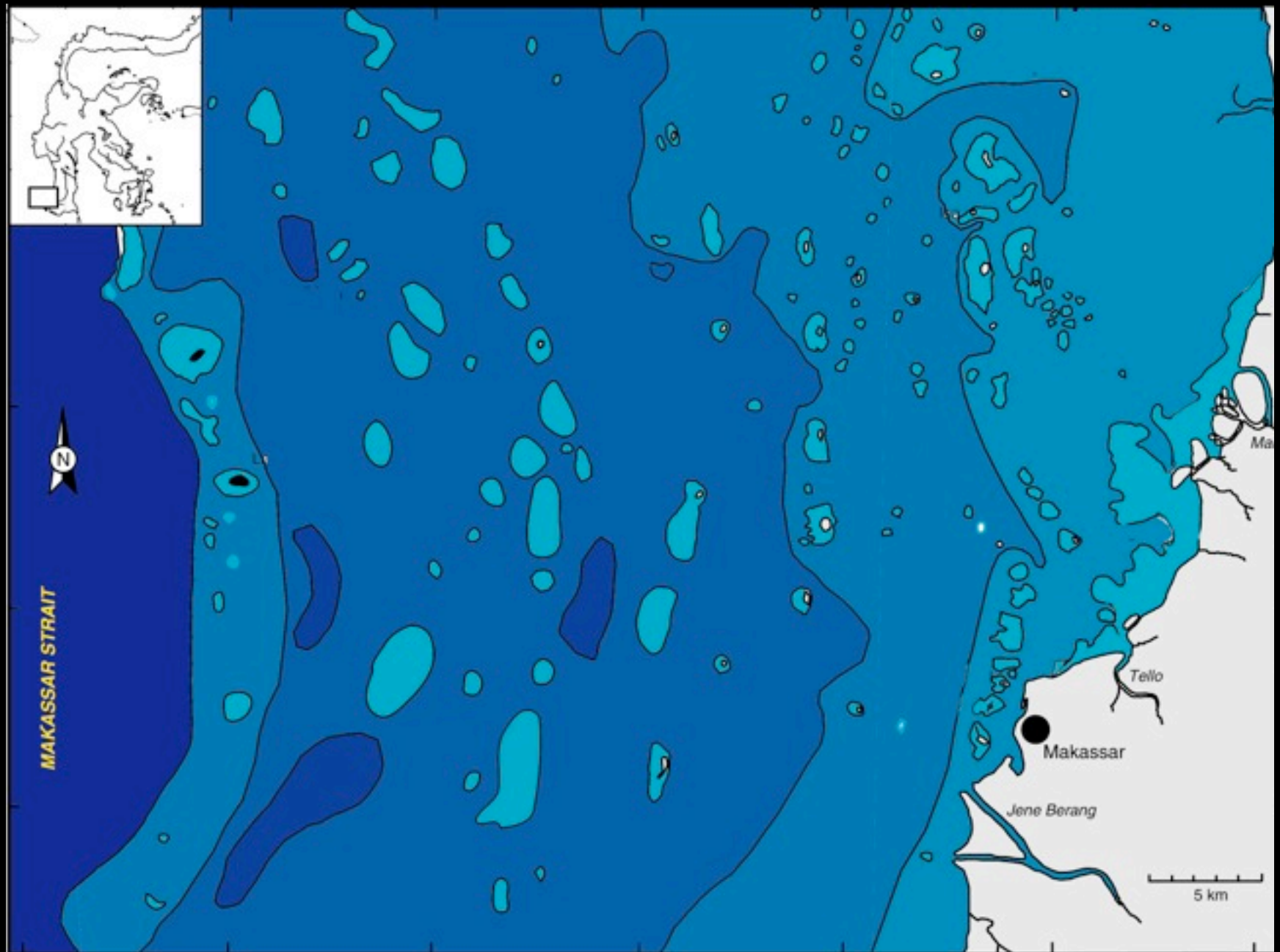
Species richness across environmental gradients

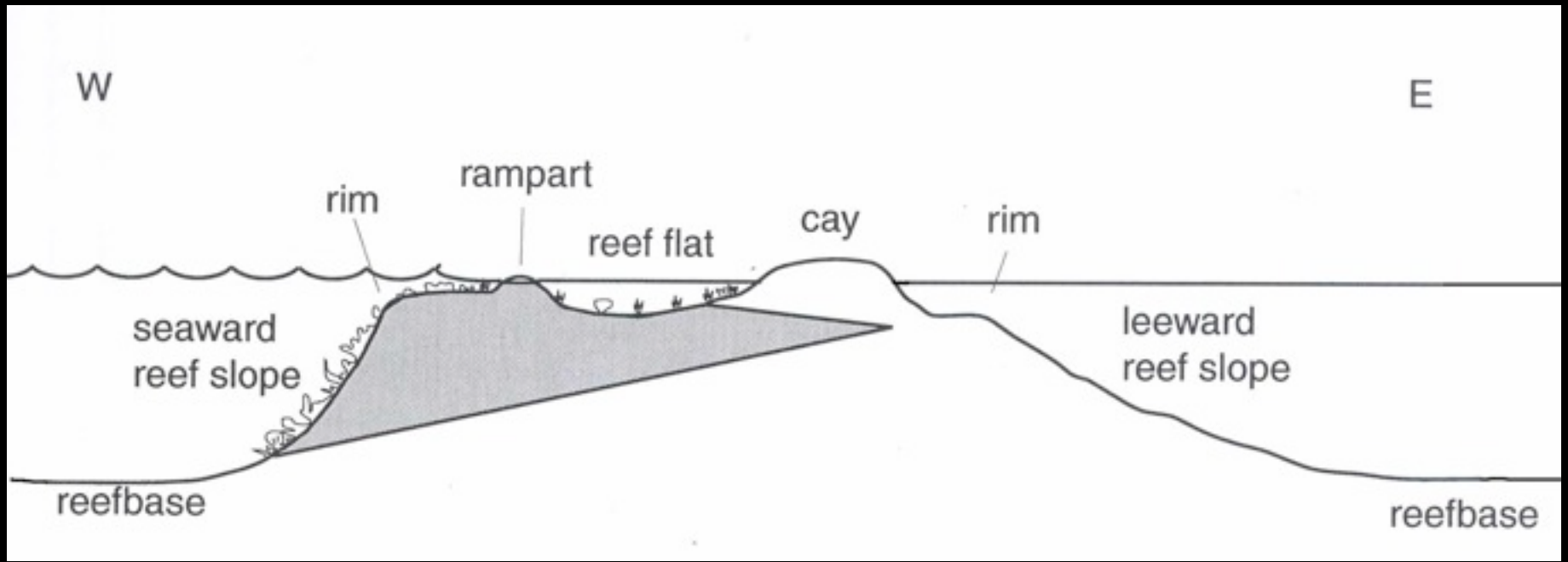


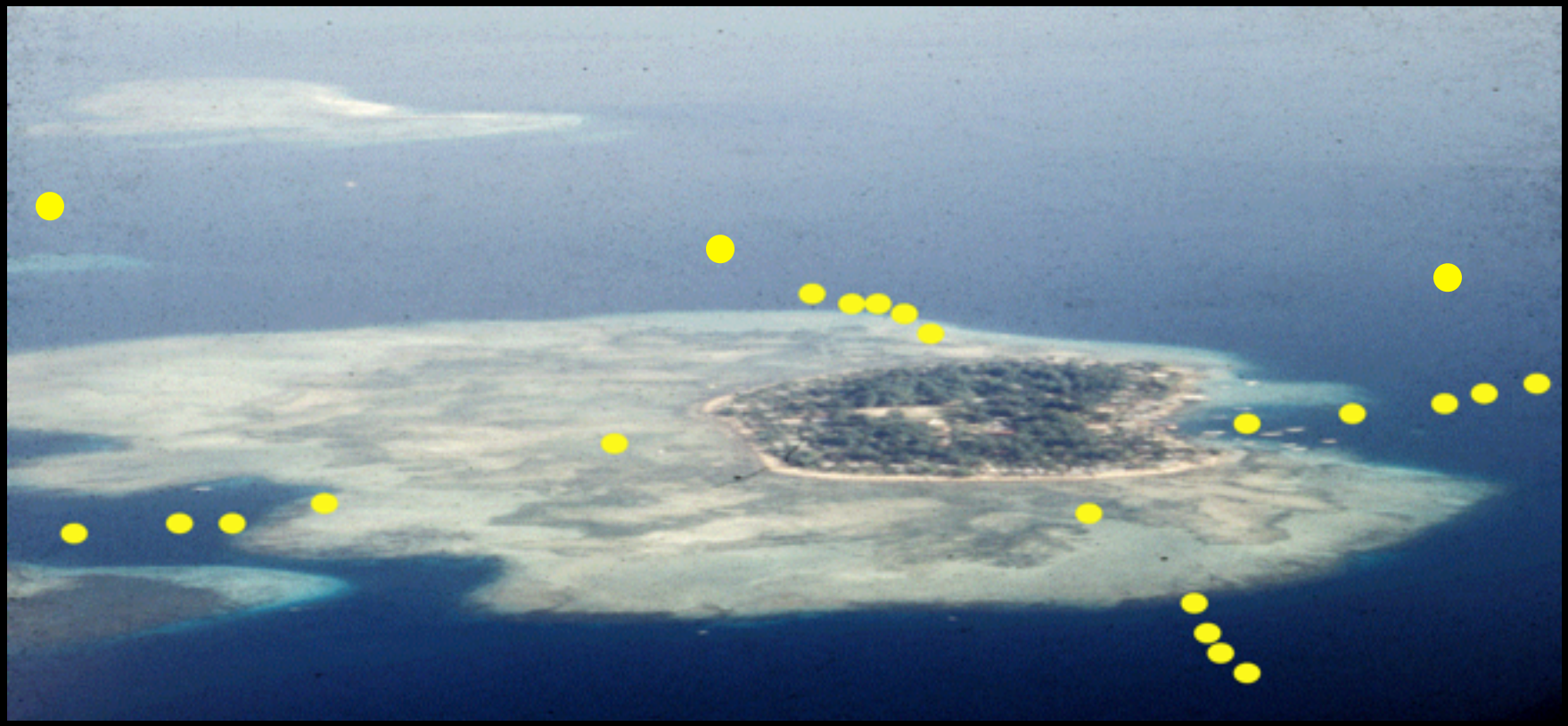
3-D topography in habitat add niches and feeding tiers
Reefs, algal and seagrass meadows

Spermonde/ Sulawesi
(data from van Det, 2002)




MAKASSAR STRAIT
N
Tello
Makassar
Jene Berang
5 km


W
E
rim
rampart
reef flat
cay
rim
seaward
reef slope
leeward
reef slope
reefbase
reefbase




Makassar
Jene Berang

Analytical design

depends on the question to resolve

Analytical design

depends on the question to resolve

R-mode sample clustering

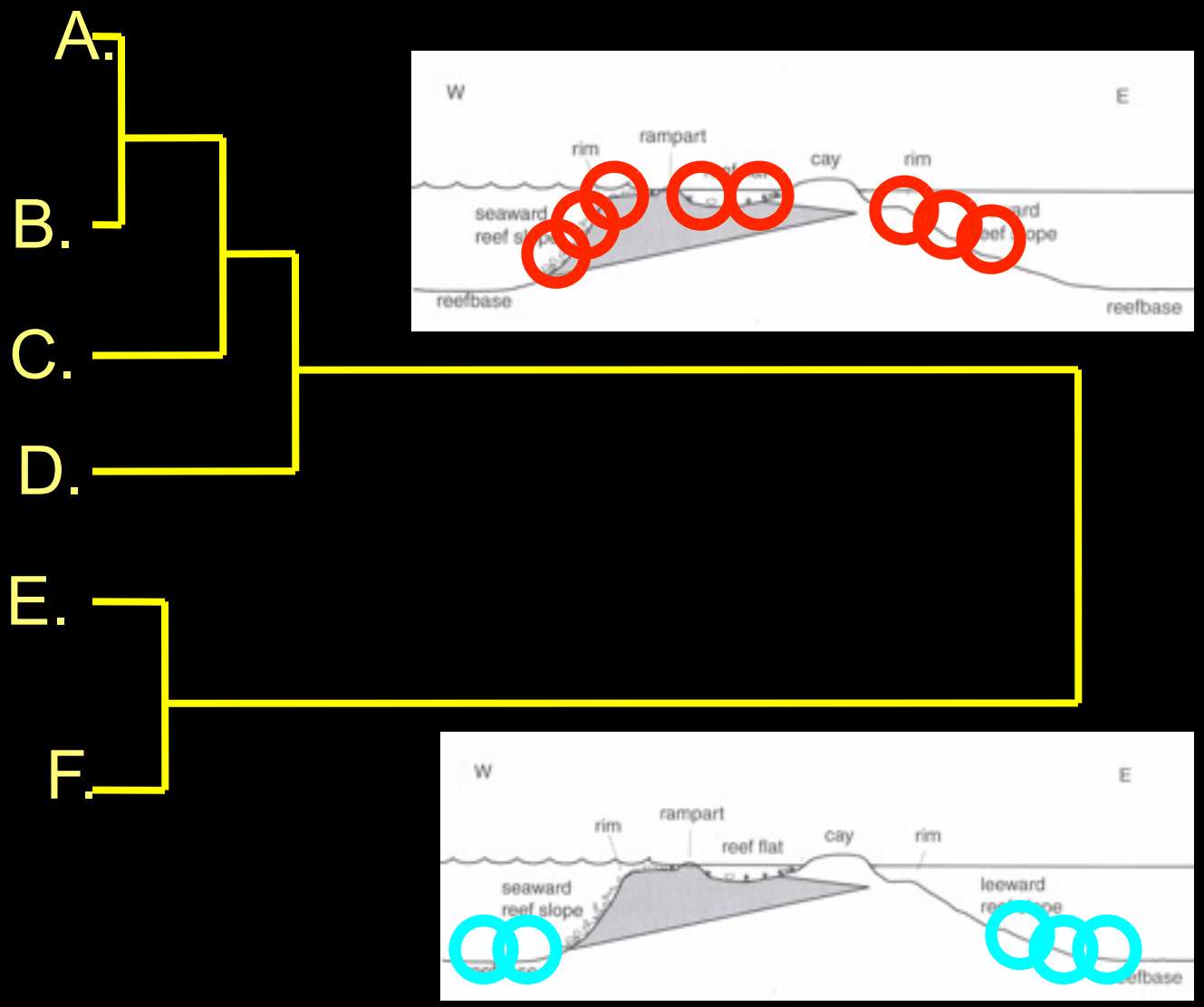


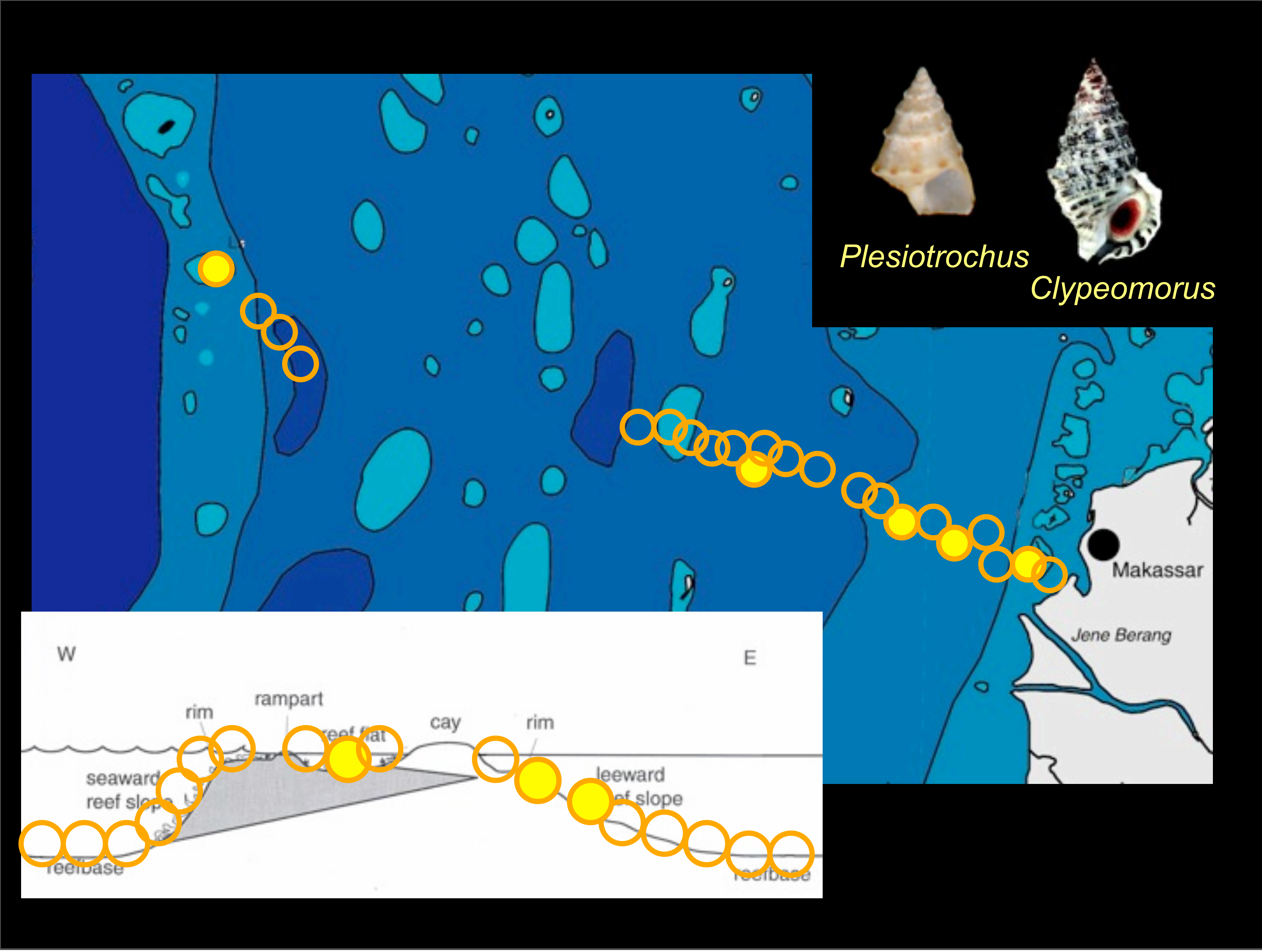





I.
II.
III.
IV.
V.
VI.
VII.
VIII.

Q-mode sample clustering



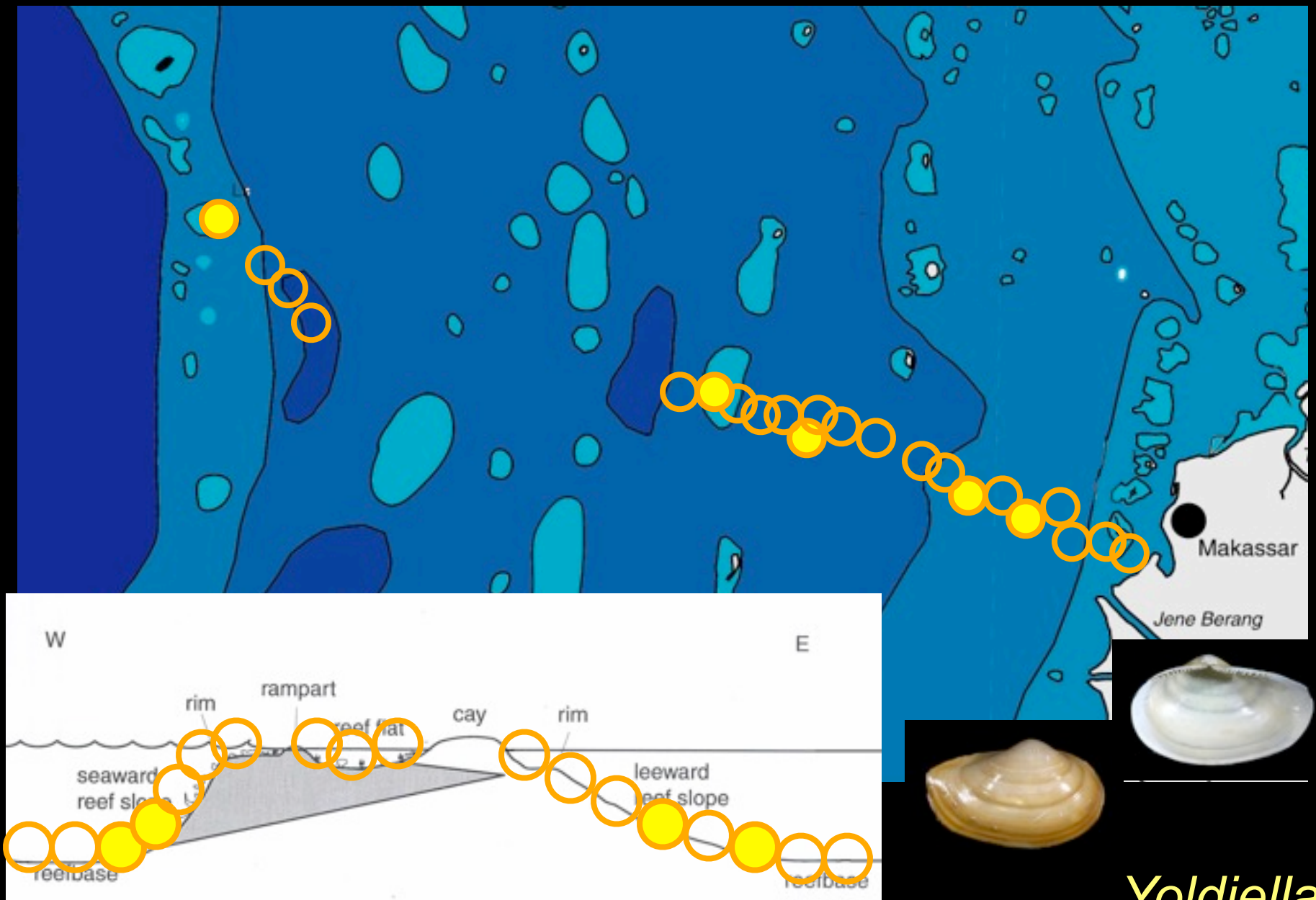


Friday, 7 October 2011

Assemblage 1 (*Clypeomorus-Plesiotrochus*)

Plesiotrochus

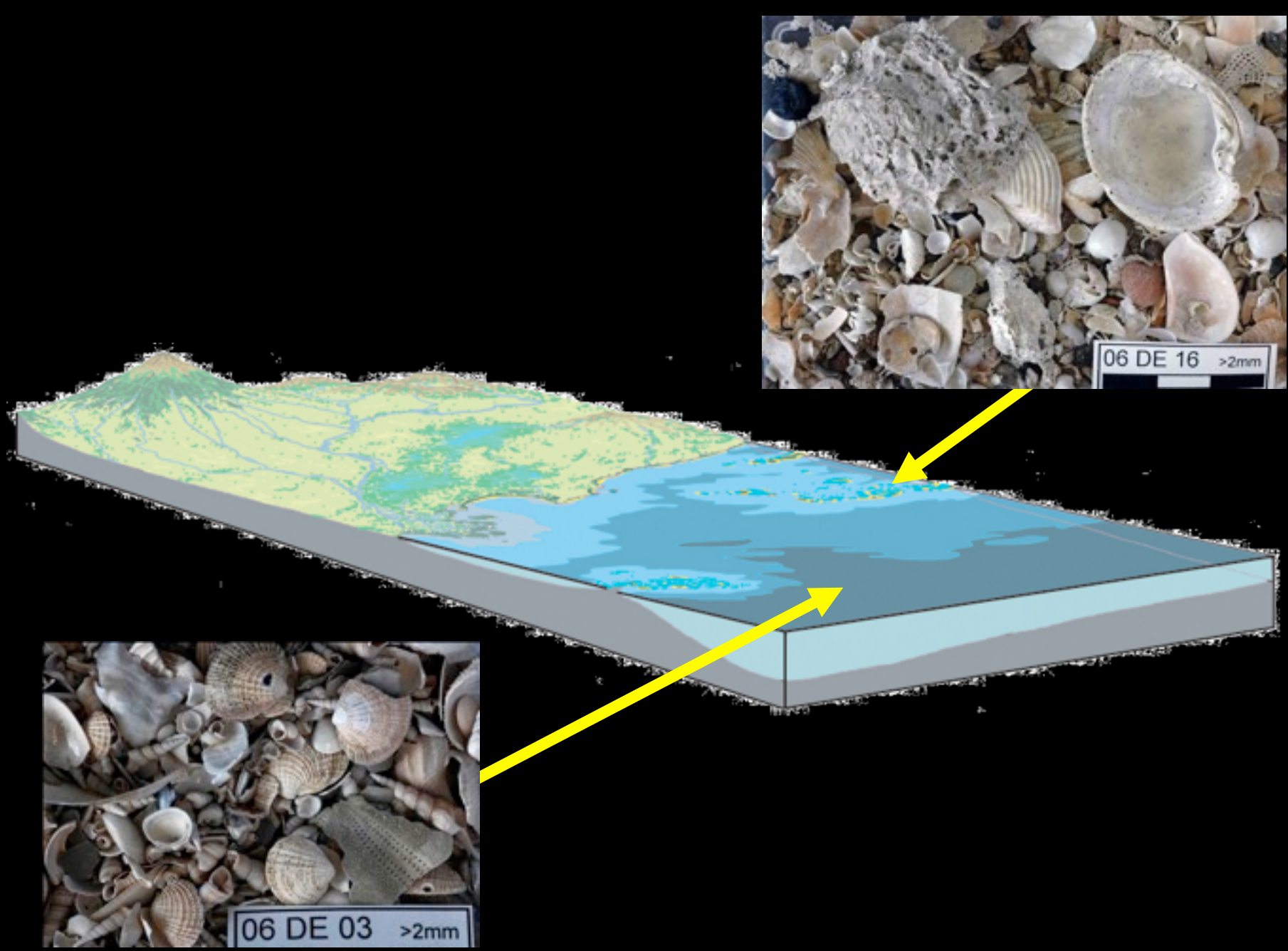
Clypeomorus


Makassar
Jene Berang
W
E
rim
rampart
cay
rim
seaward
leeward
reef slope
reefbase
reefbase

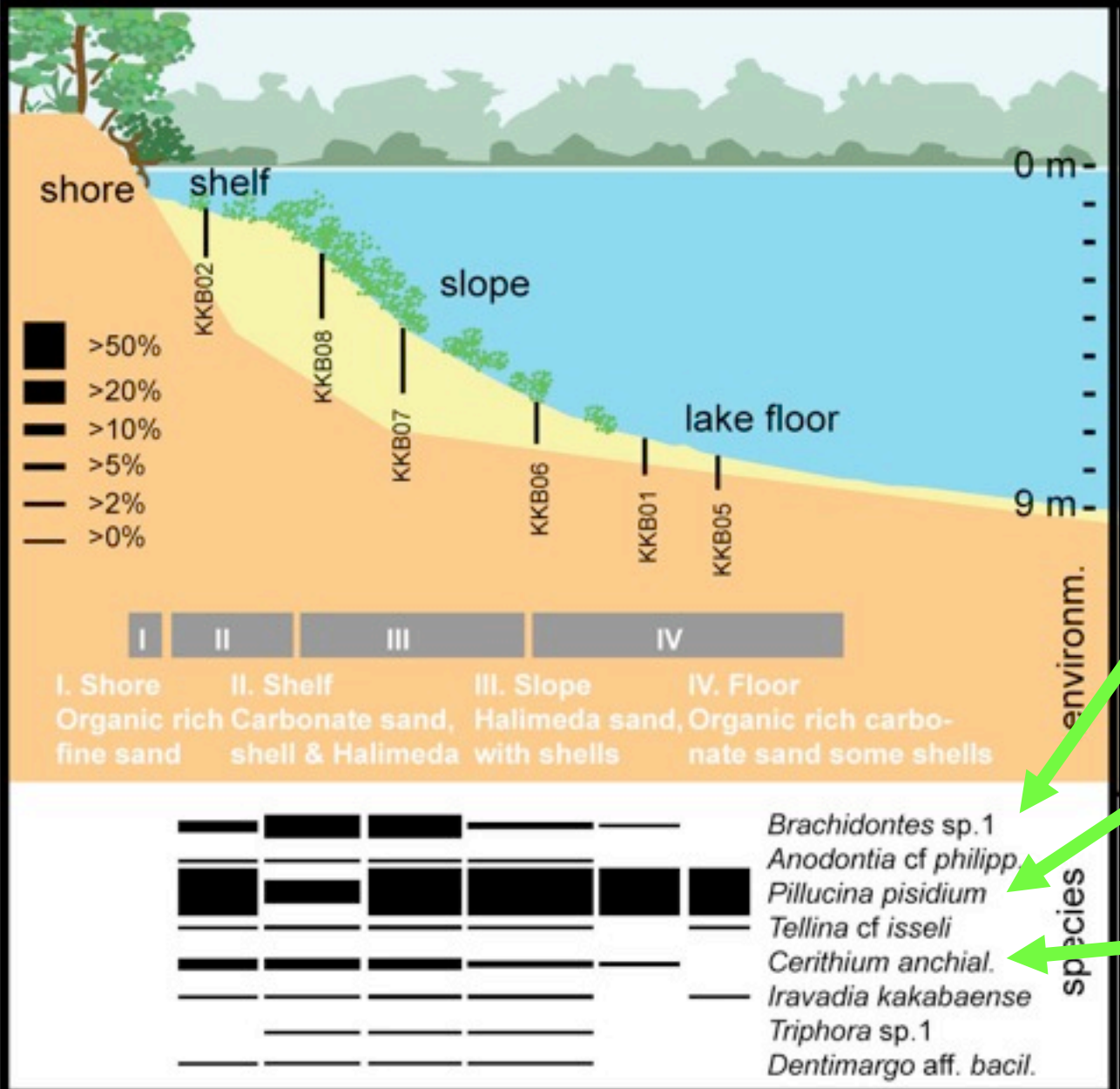
Yoldiella

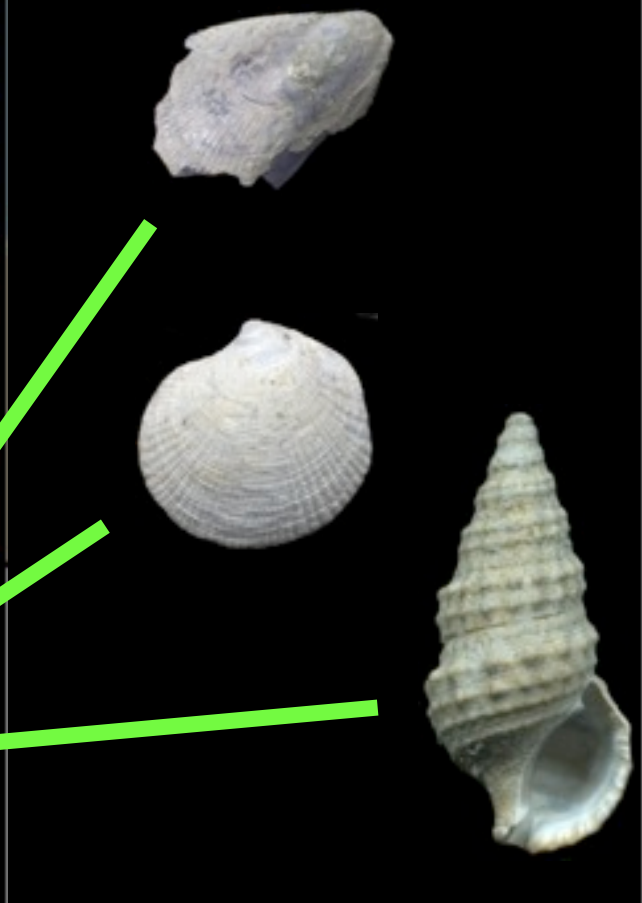
Assemblage 7 (*Yoldiella*)

Yoldiella


06 DE 16 >2mm
06 DE 03 >2mm

Lateral distribution on small scale: marine lake Kakaban





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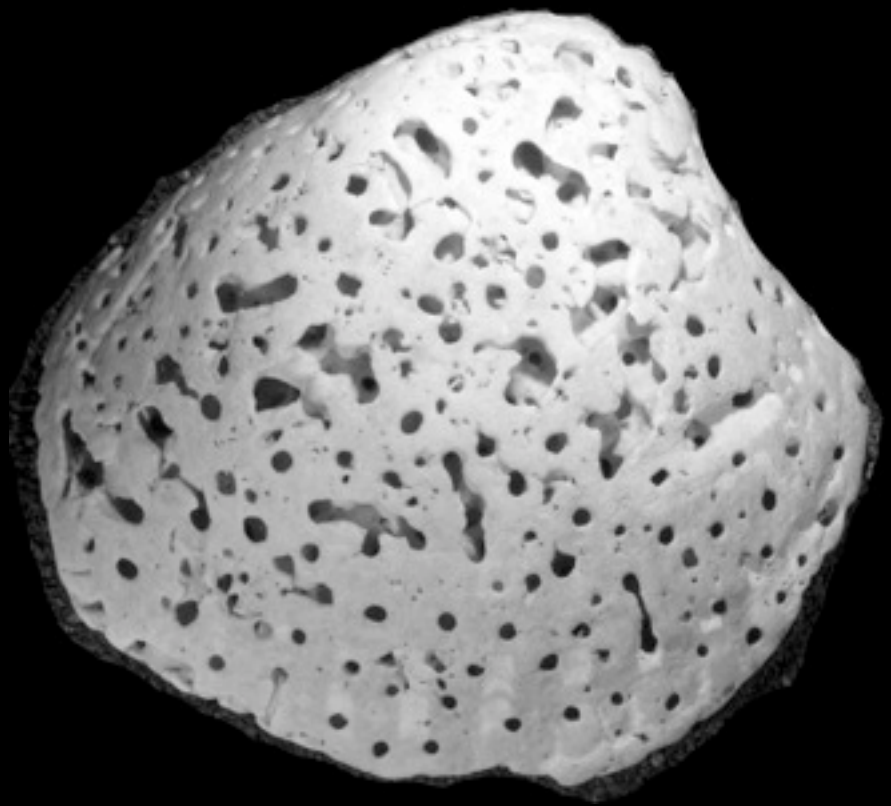
Taphonomy = the study of fossilization processes
(after death but before diagenesis)

V. Taphonomy & environmental successions

Hardship during life: well-preserved sharp edged fragments indicate cracking type of predation (birds, fish)

V. Taphonomy & environmental successions



Hardship after life: Bioerosion by clionid sponge on Eocene bivalve (*Venericor planicosta,* North Sea)

V. Taphonomy & environmental successions

After life: reworking causes abrasion (*Venerupis*, Quaternary, North Sea)

shiny (polished)
rounded edges
preferential areas (umbo)

Worn on the beach (Ijsselmeer, Netherlands)

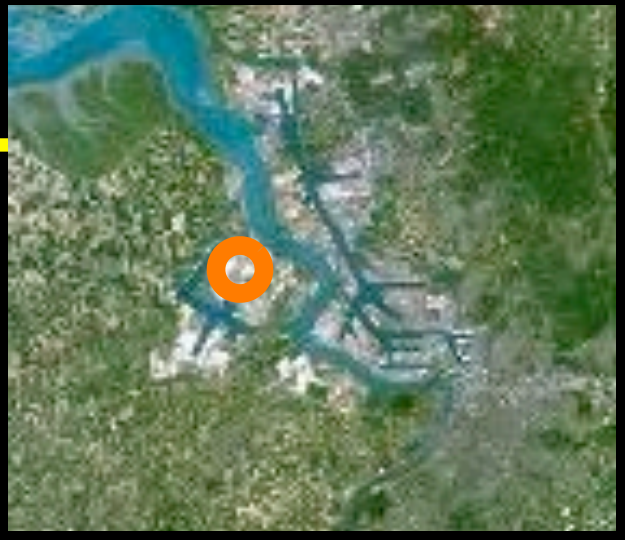
Paired bivalves: died where they lived

V. Taphonomy & environmental successions

Using taphonomy in reconstruction of sedimentary successions

V. Taphonomy & environmental successions

Antwerp



V. Taphonomy & environmental successions

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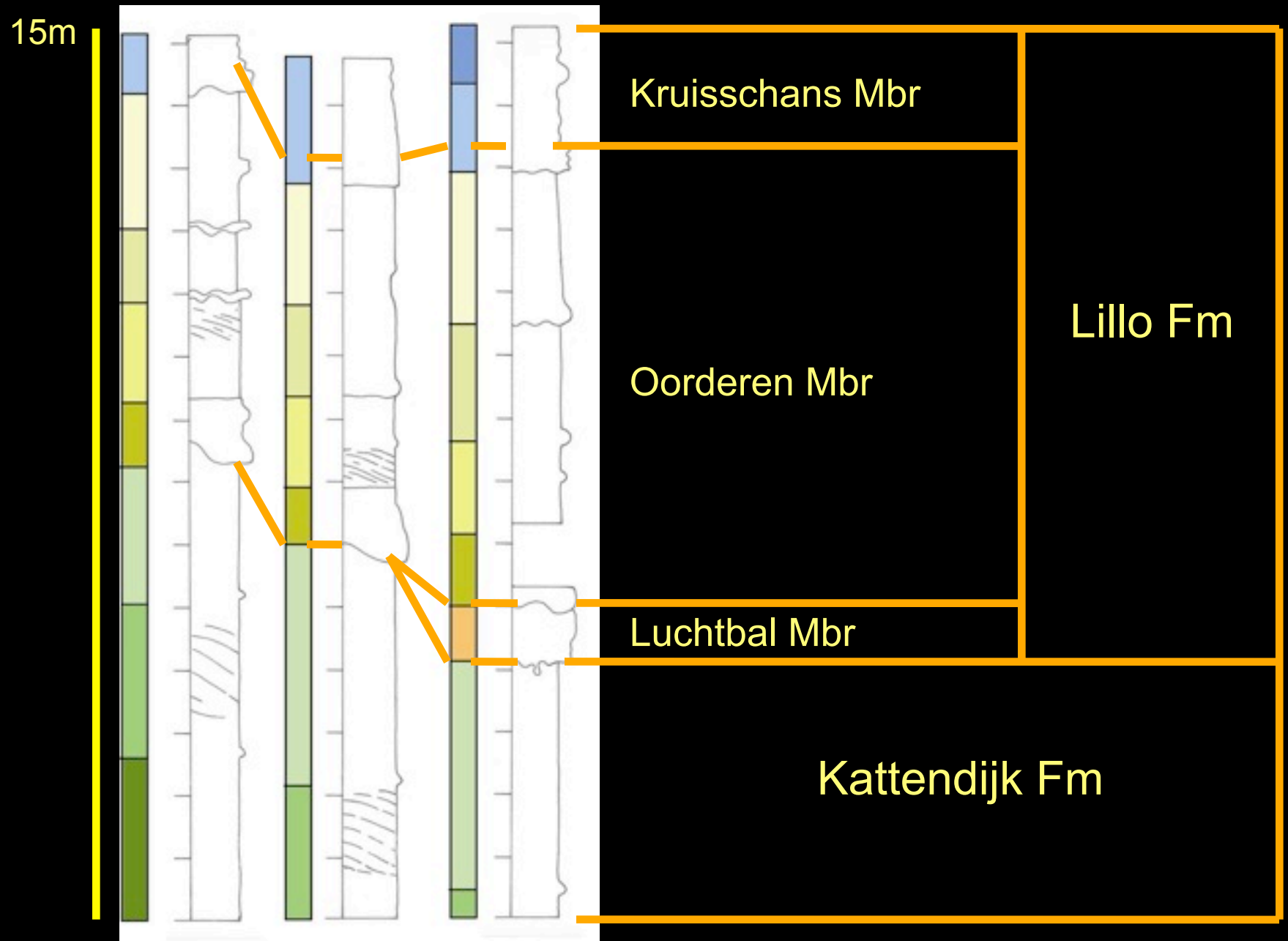
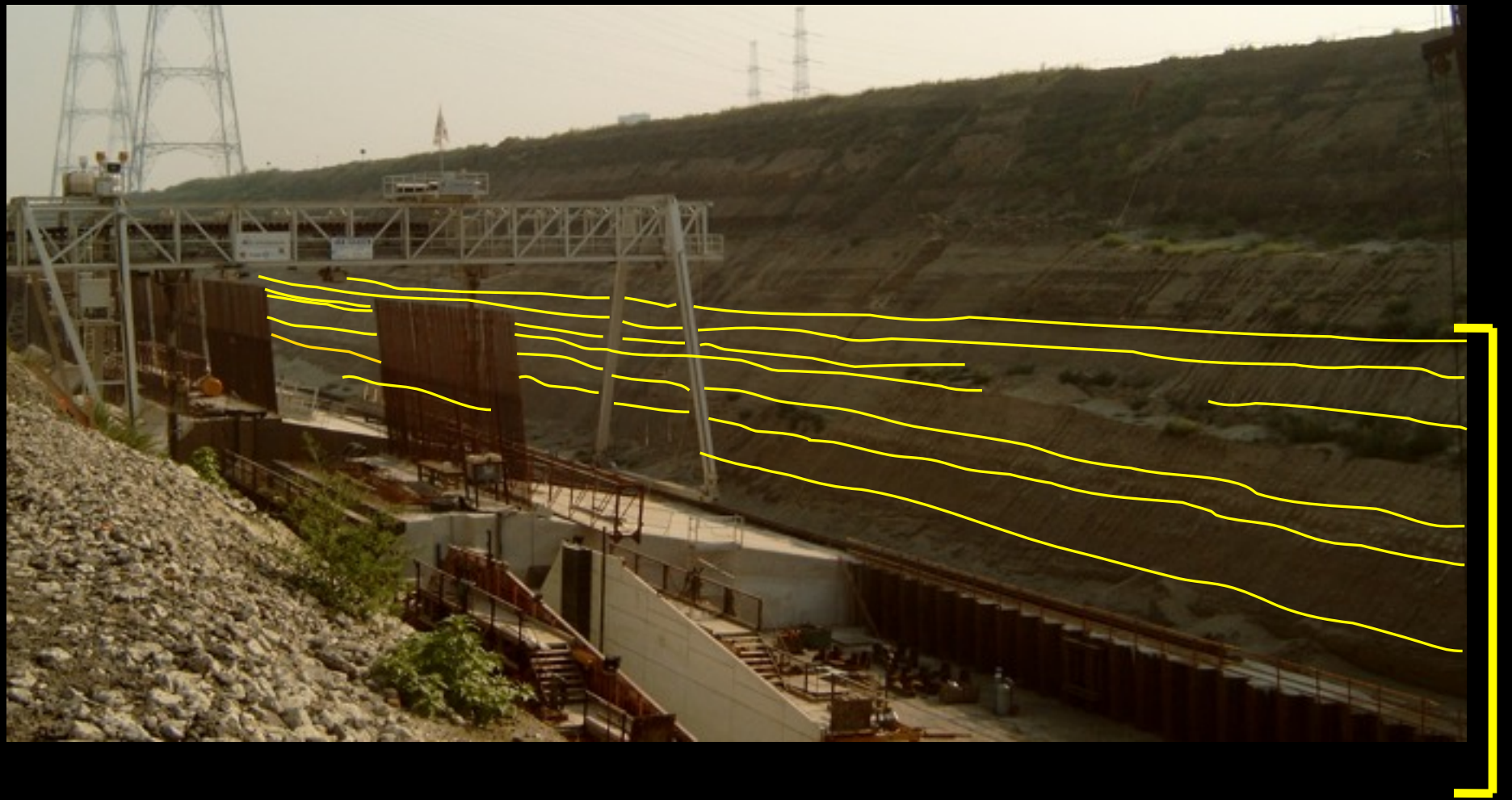

15m
Kruisschans Mbr
Oorderen Mbr
Luchtbal Mbr
Lillo Fm
Kattendijk Fm



Lateral continuous shell beds in Pliocene strata

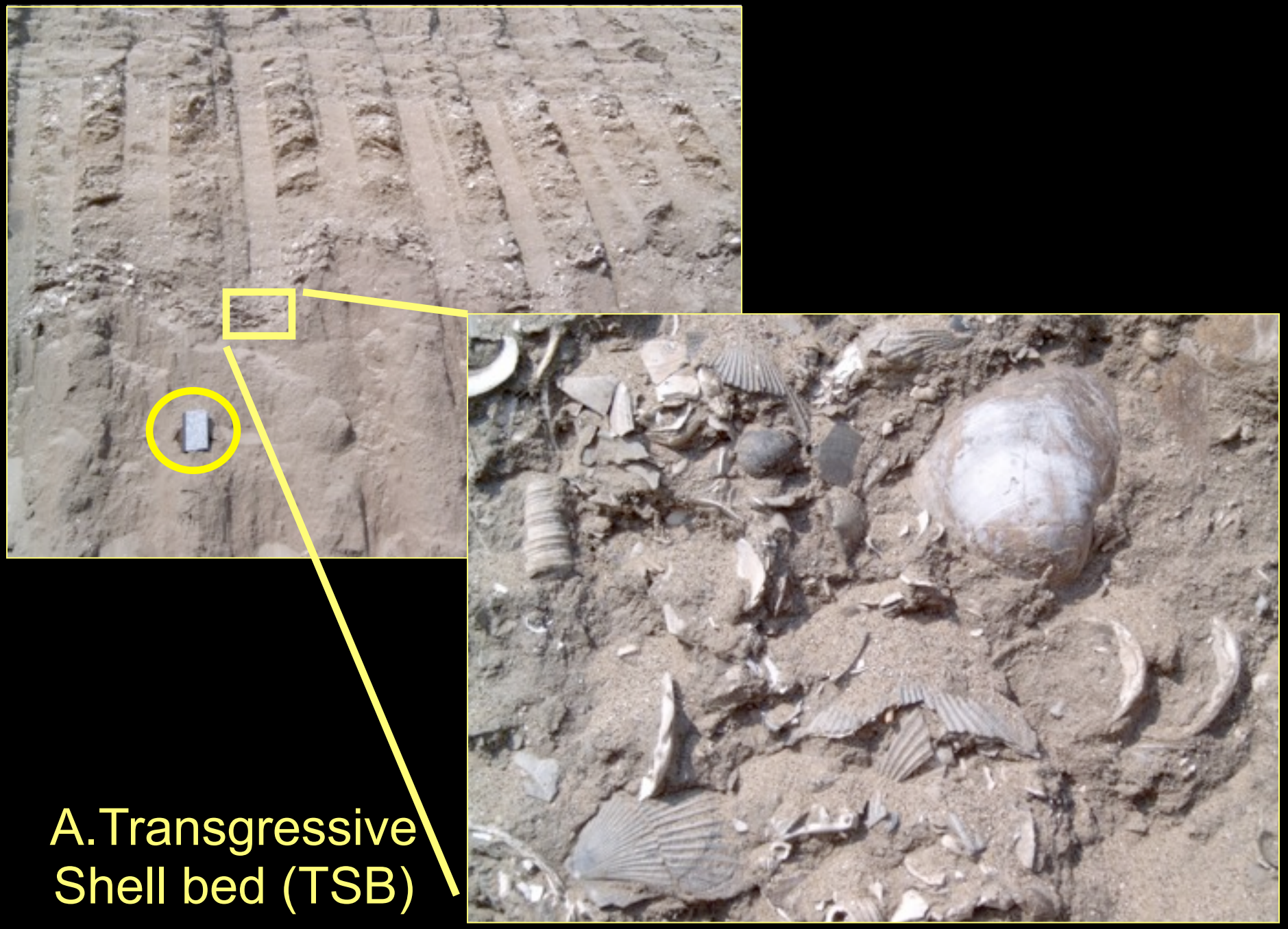
V. Taphonomy & environmental successions

Three types of Shell beds in Pliocene deposits of Antwerp (Belgium)

V. Taphonomy & environmental successions

A.Transgressive Shell bed (TSB): base Oorderen Mbr

V. Taphonomy & environmental successions



A.Transgressive
Shell bed (TSB)

Transgressive shell bed is characterized by:

1. admixture of ecological incompatible species
2. different preservation styles (colouration, bio-erosion and abrasion)
3. gravel
4. scoured base

B. Highstand (condensed) shellbed (HSSB): Kattendijk Formation

V. Taphonomy & environmental successions

B. Highstand (condensed) shellbed

Highstand shell bed
is characterized by:

1. admixture of ecological compatible species,
   often in life position
2. similar preservation styles (little abrasion,
   but variable and in general abundant bioerosion)
3. authigenetic phosphate

This concerns a temperate situation, in tropical situations reef development can be expected if water turbidity and depth are convenient.

Sediment starvation may lead to hard ground formation

C. Depositional environmentally controlled shellbeds (DSB); Oorderen Member

- storm beds (from prograding settings)
- beached associations (from wave ravinement or in prograding settings)
- in situ accumulations

Atrina fragilis

V. Taphonomy & environmental successions

Mediterranean *Atrina*

V. Taphonomy & environmental successions

V. Taphonomy & environmental successions

Three types of Shell beds in Pliocene de
Antwerp (Belgium)

Three types of Shell beds in Pliocene deposits of Antwerp (Belgium)

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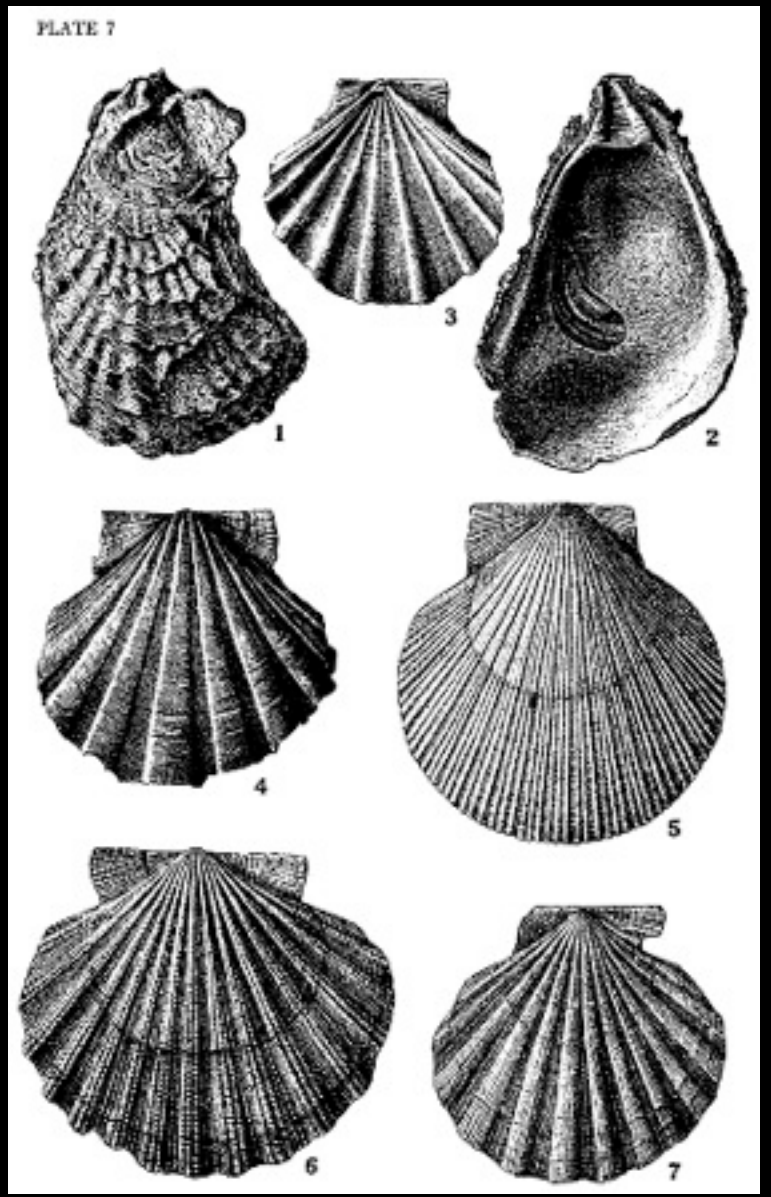

V. Taphonomy & environmental successions

Data from Kidwell (1989)

V. Taphonomy & environmental successions

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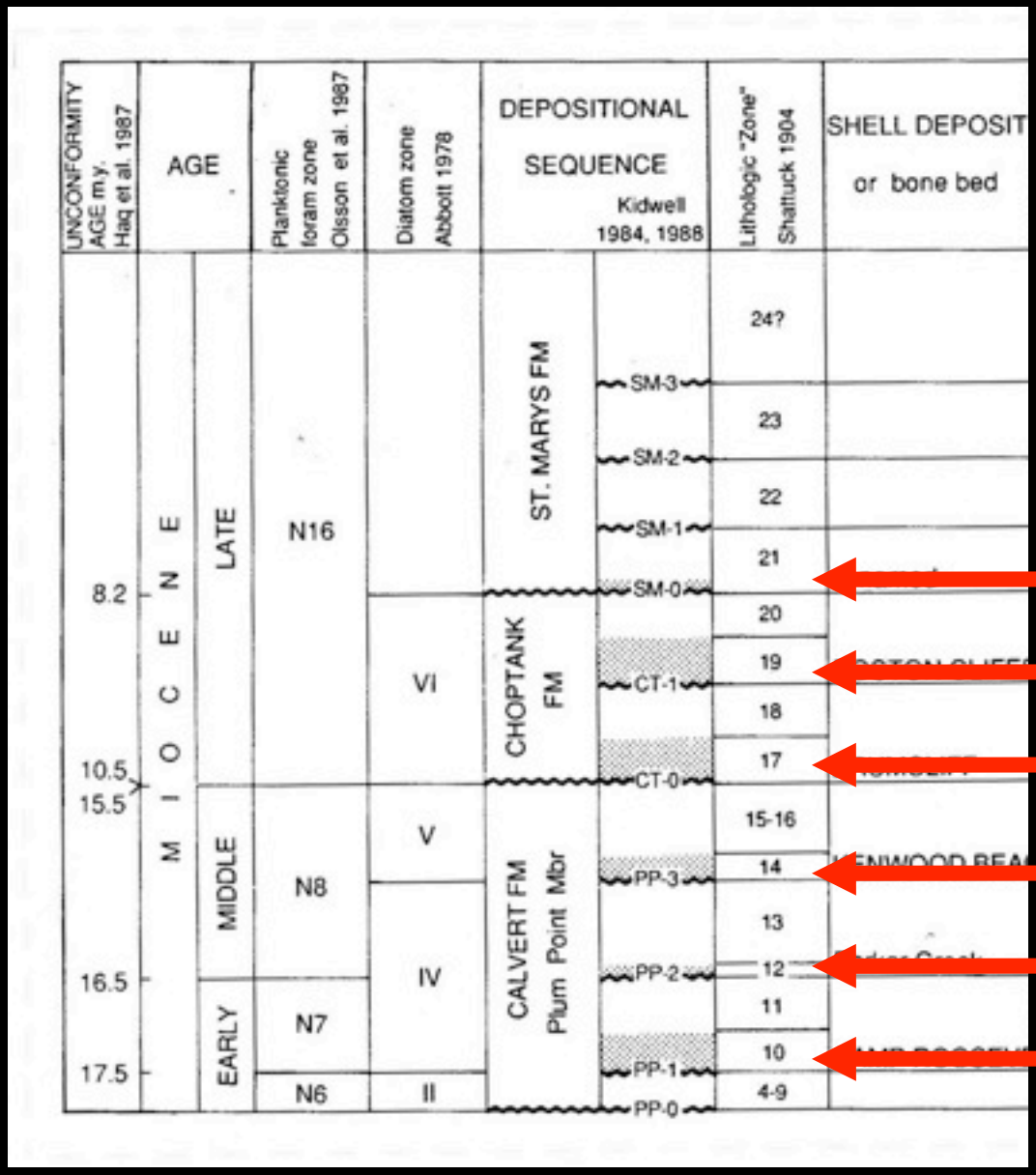
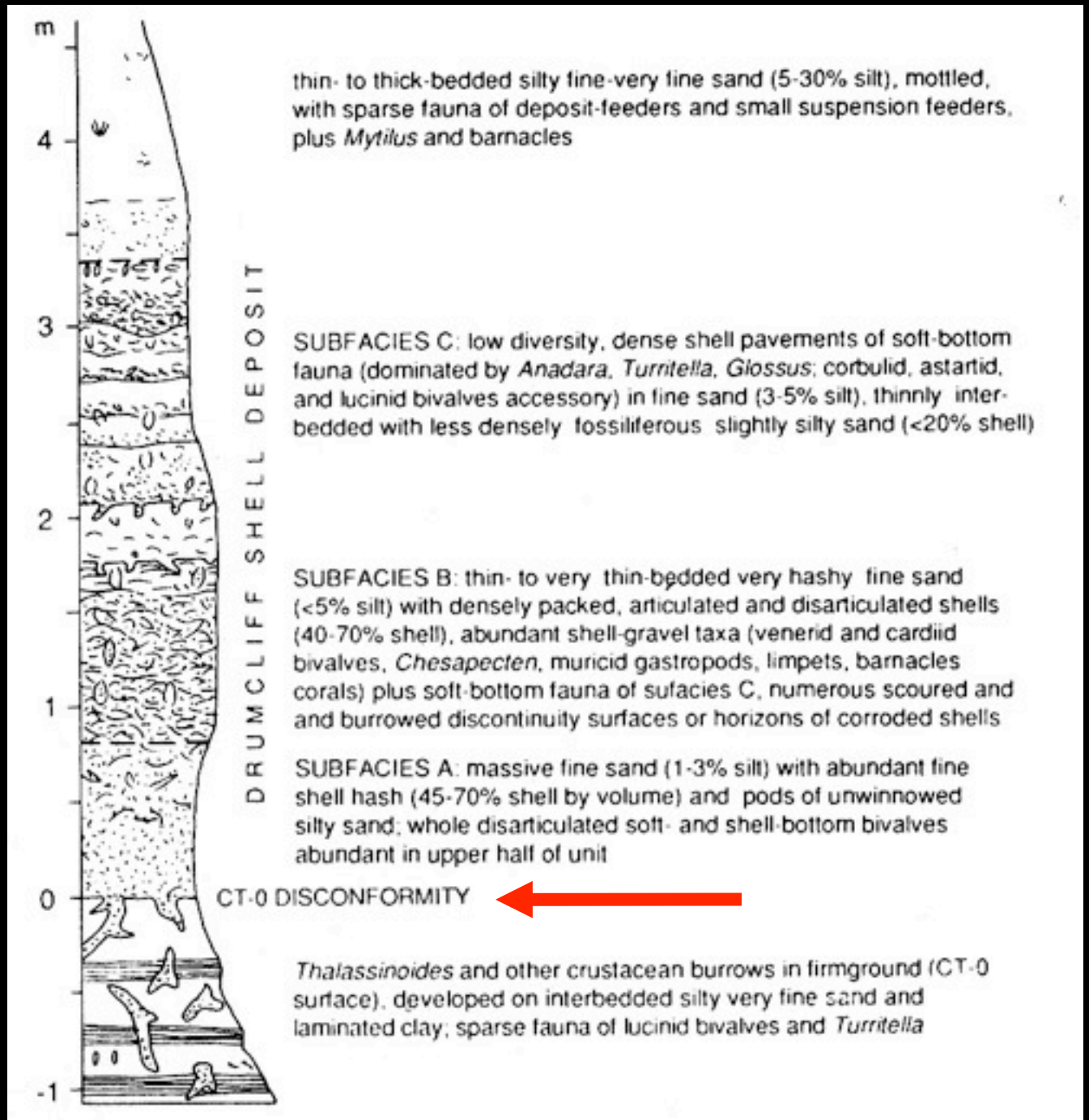
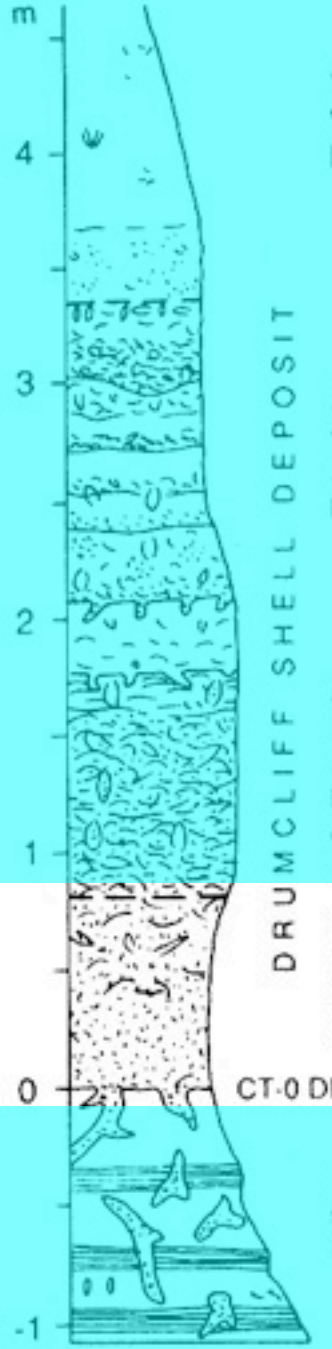


Lateral continuous shell beds

Data from Kidwell (1989)





thin- to thick-bedded silty fine-very fine sand (5-30% silt), mottled, with sparse fauna of deposit-feeders and small suspension feeders, plus *Mytilus* and barnacles

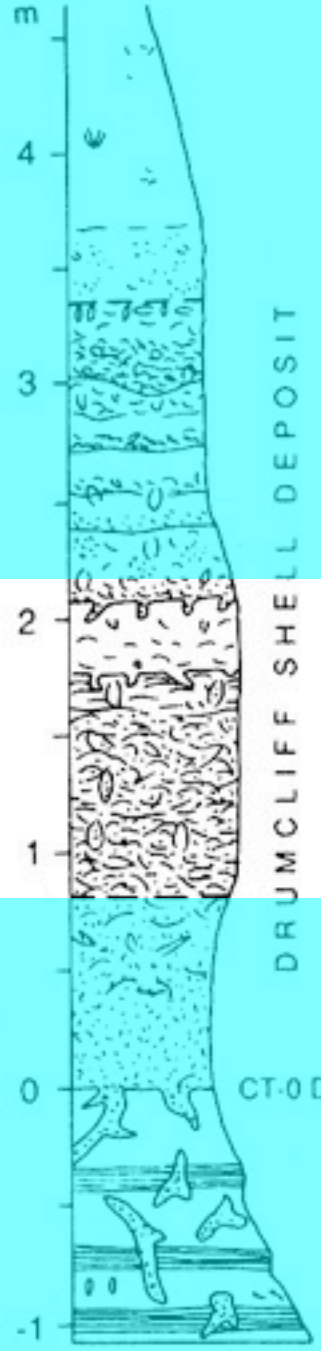
SUBFACIES C: low diversity, dense shell pavements of soft-bottom fauna (dominated by *Anadara*, *Turritella*, *Glossus*; corbulid, astartid, and lucinid bivalves accessory) in fine sand (3-5% silt), thinnly interbedded with less densely fossiliferous slightly silty sand (<20% shell)

SUBFACIES B: thin- to very thin-bedded very hashy fine sand (<5% silt) with densely packed, articulated and disarticulated shells (40-70% shell), abundant shell-gravel taxa (venerid and cardiid bivalves, *Chesapecten*, muricid gastropods, limpets, barnacles corals) plus soft-bottom fauna of sufacies C, numerous scoured and and burrowed discontinuity surfaces or horizons of corroded shells

SUBFACIES A: massive fine sand (1-3% silt) with abundant fine shell hash (45-70% shell by volume) and pods of unwinnowed silty sand; whole disarticulated soft- and shell-bottom bivalves abundant in upper half of unit

CT-0 DISCONFORMITY

Thalassinoides and other crustacean burrows in firmground (CT-0 surface), developed on interbedded silty very fine sand and laminated clay; sparse fauna of lucinid bivalves and *Turritella*



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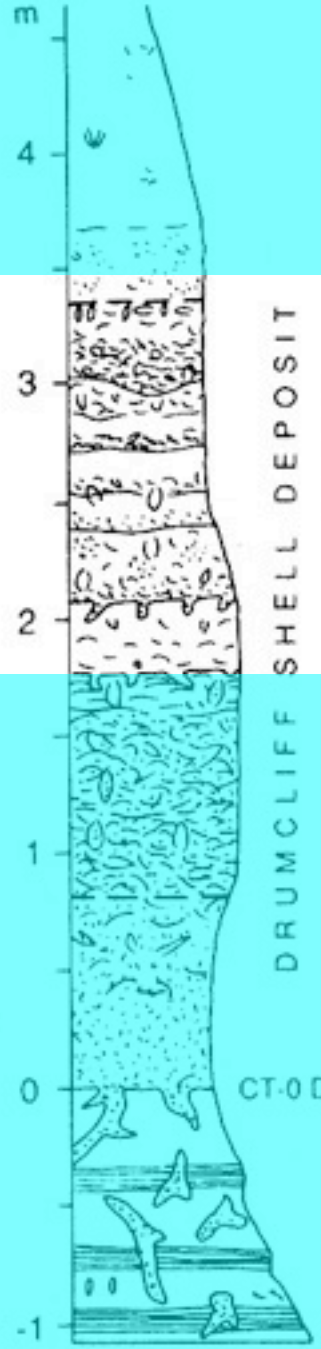
SUBFACIES A: massive fine sand (1-3% silt) with abundant fine shell hash (45-70% shell by volume) and pods of unwinnowed silty sand; whole disarticulated soft- and shell-bottom bivalves abundant in upper half of unit

CT-0 DISCONFORMITY

Thalassinoides and other crustacean burrows in firmground (CT-0 surface), developed on interbedded silty very fine sand and laminated clay; sparse fauna of lucinid bivalves and *Turritella*



thin- to thick-bedded silty fine-very fine sand (5-30% silt), mottled, with sparse fauna of deposit-feeders and small suspension feeders, plus *Mytilus* and barnacles

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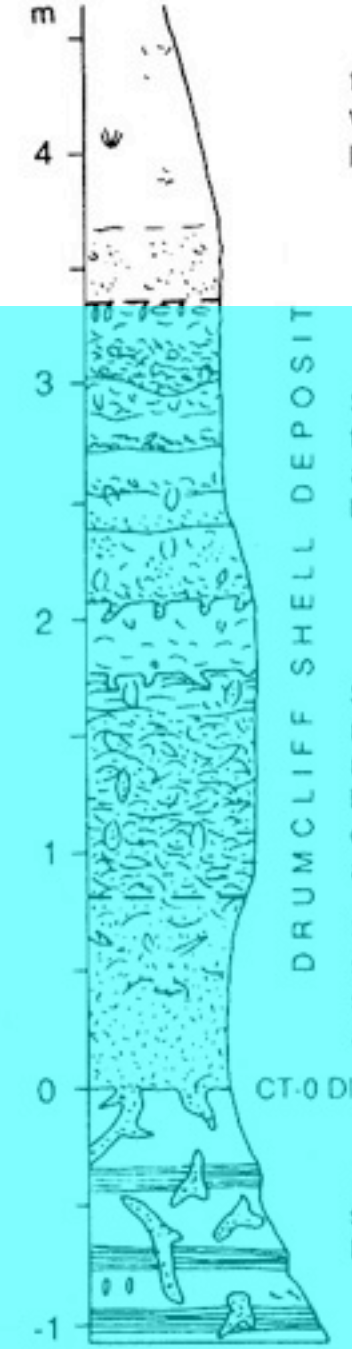

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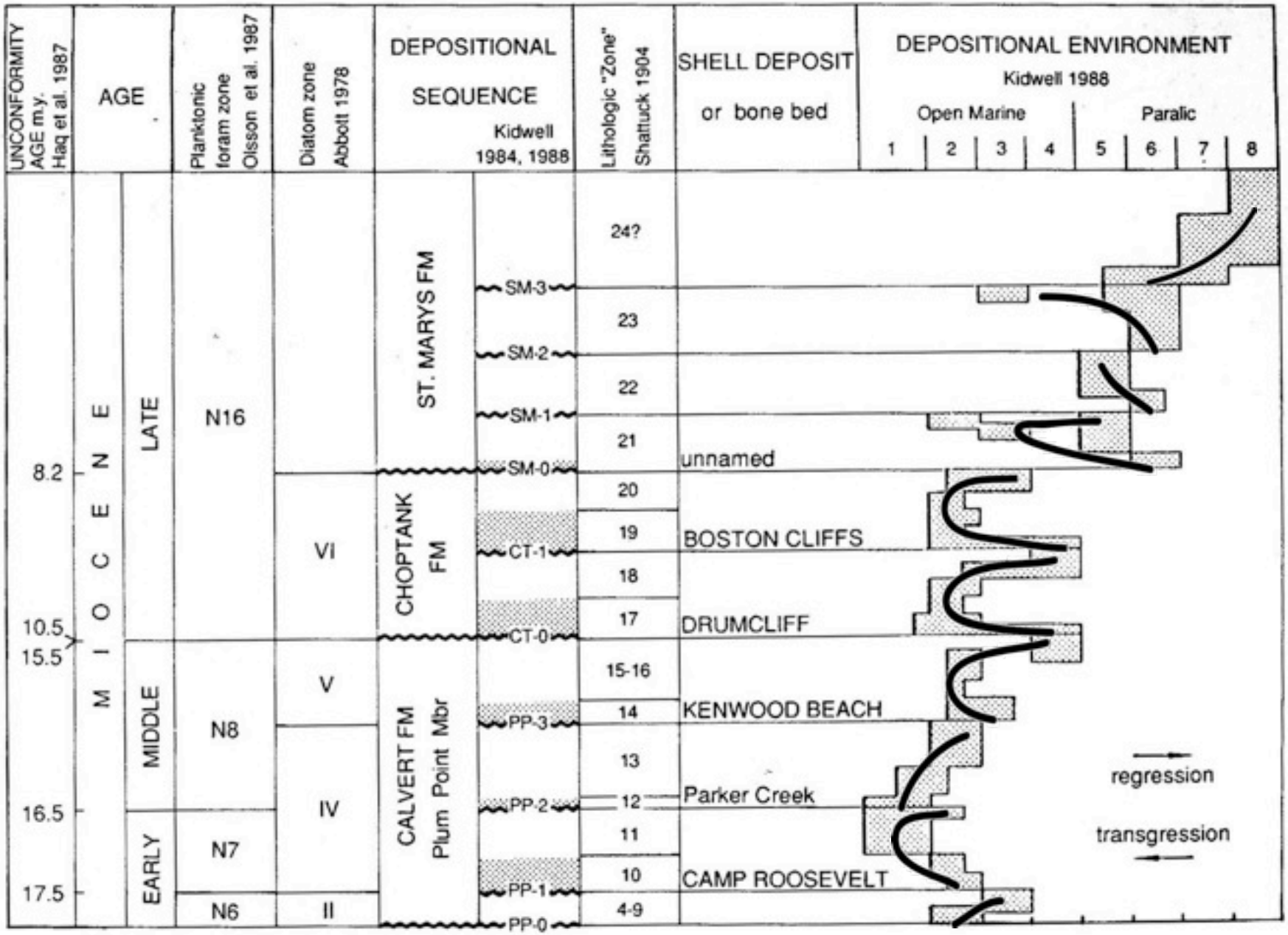

UNCONFORMITY AGE m.y. Haq et al. 1987
AGE
Planktonic foram zone Olsson et al. 1987
Diatom zone Abbott 1978
DEPOSITIONAL SEQUENCE Kidwell 1984, 1988
Lithologic "Zone" Shattuck 1904
SHELL DEPOSIT or bone bed
DEPOSITIONAL ENVIRONMENT Kidwell 1988
Open Marine
Paralic
1 2 3 4 5 6 7 8
MIOCENE
LATE
MIDDLE
EARLY
8.2
10.5
15.5
16.5
17.5
N16
N8
N7
N6
VI
V
IV
II
ST. MARYS FM
CHOPTANK FM
CALVERT FM
Plum Point Mbr
SM-3
SM-2
SM-1
SM-0
CT-1
CT-0
PP-3
PP-2
PP-1
PP-0
24?
23
22
21
20
19
18
17
15-16
14
13
12
11
10
4-9
unnamed
BOSTON CLIFFS
DRUMCLIFF
KENWOOD BEACH
Parker Creek
CAMP ROOSEVELT
regression
transgression

V. Taphonomy & environmental successions

Molluscan Palaeoecology

Introduction

I Form and function

II Environmental indicator taxa

III

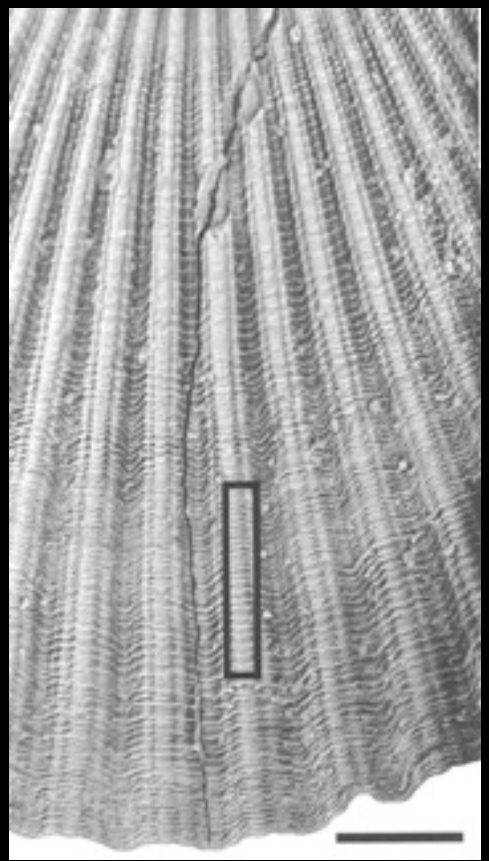
Communities and community palaeoecology

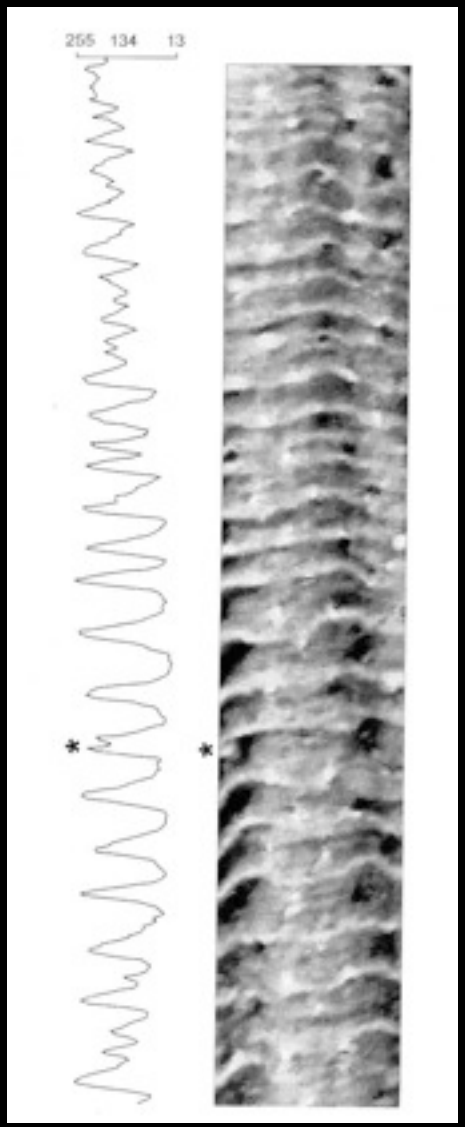
IV Taphonomy & environmental successions

V Molluscs as history books

VI

Growth increments also tell a story: seasonal growth and temperatures





Aequipecten opercularis
Pliocene, Coralline Crag Formation, England

Johnson et al., 2000

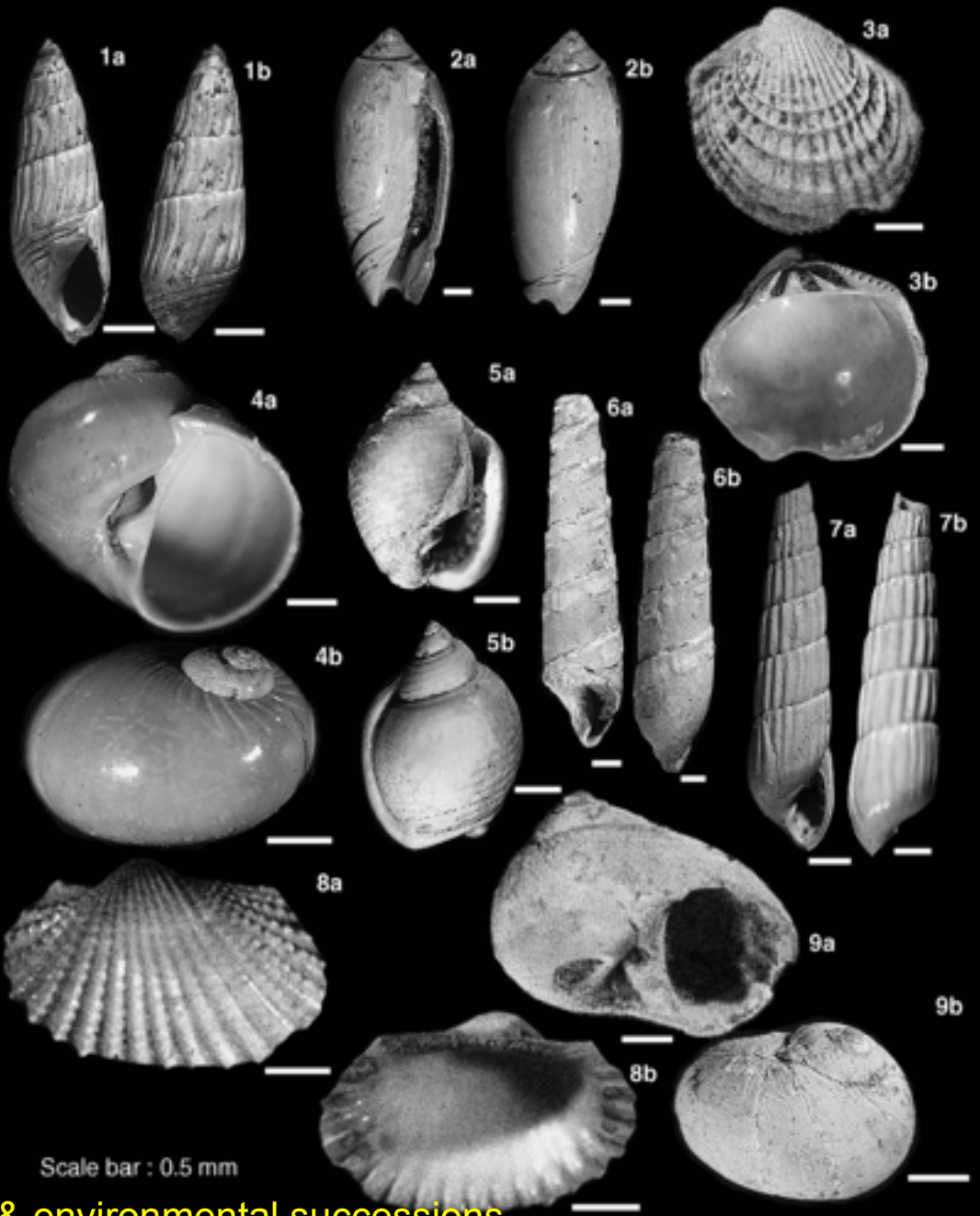
Shell occurrences

V. Taphonomy & environmental successions

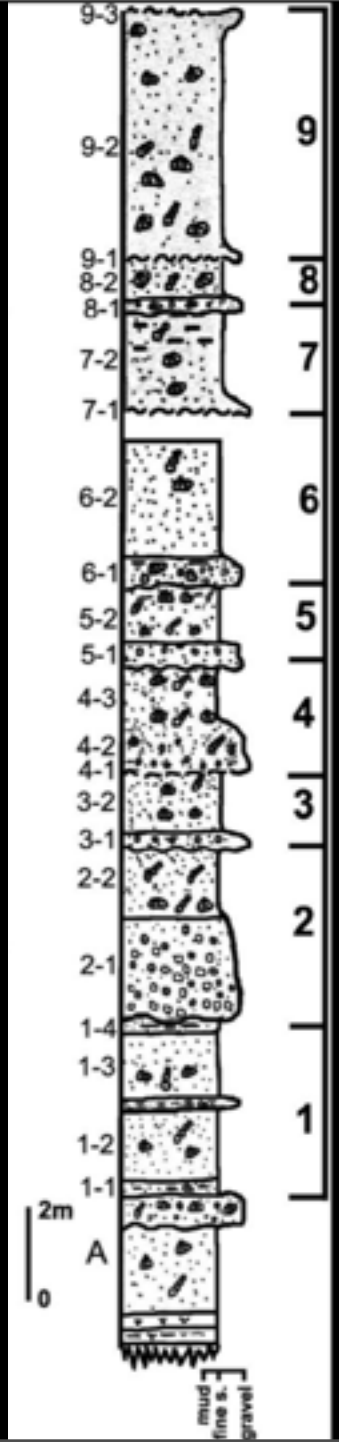
Miocene facies successions from West Java

From: Aswan & Ozama (2006)

V. Taphonomy & environmental successions



V. Taphonomy & environmental successions



1. nine depositional sequences in approximately 30 m section

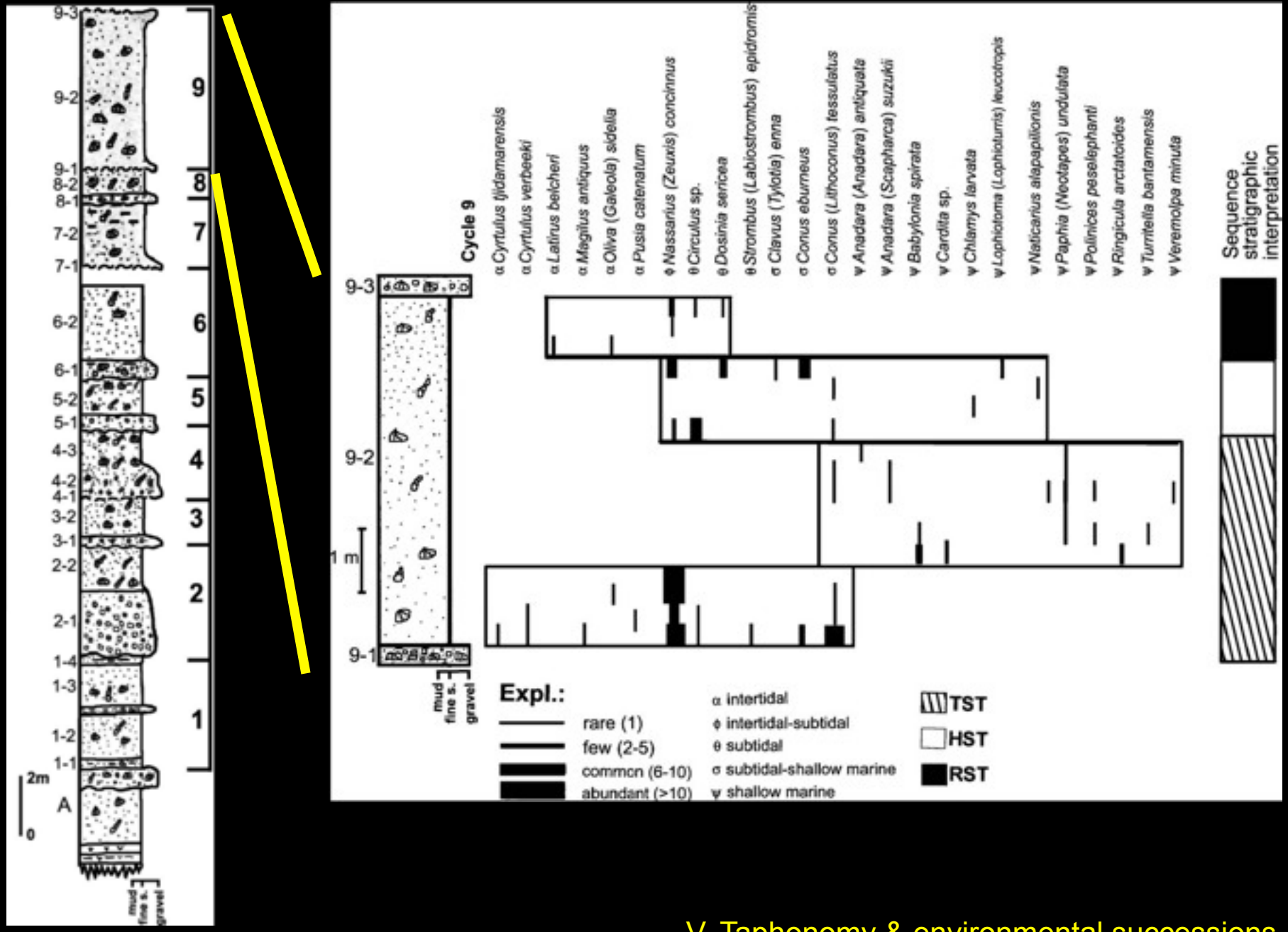
2. settings dominated by marginal marine (lower intertidal to upper subtidal conditions)

3. some supposed fluvial conglomerates

4. Fossiliferous

(nb. High angle coastal setting with strong imput of volcanoclastic deposits)

V. Taphonomy & environmental successions



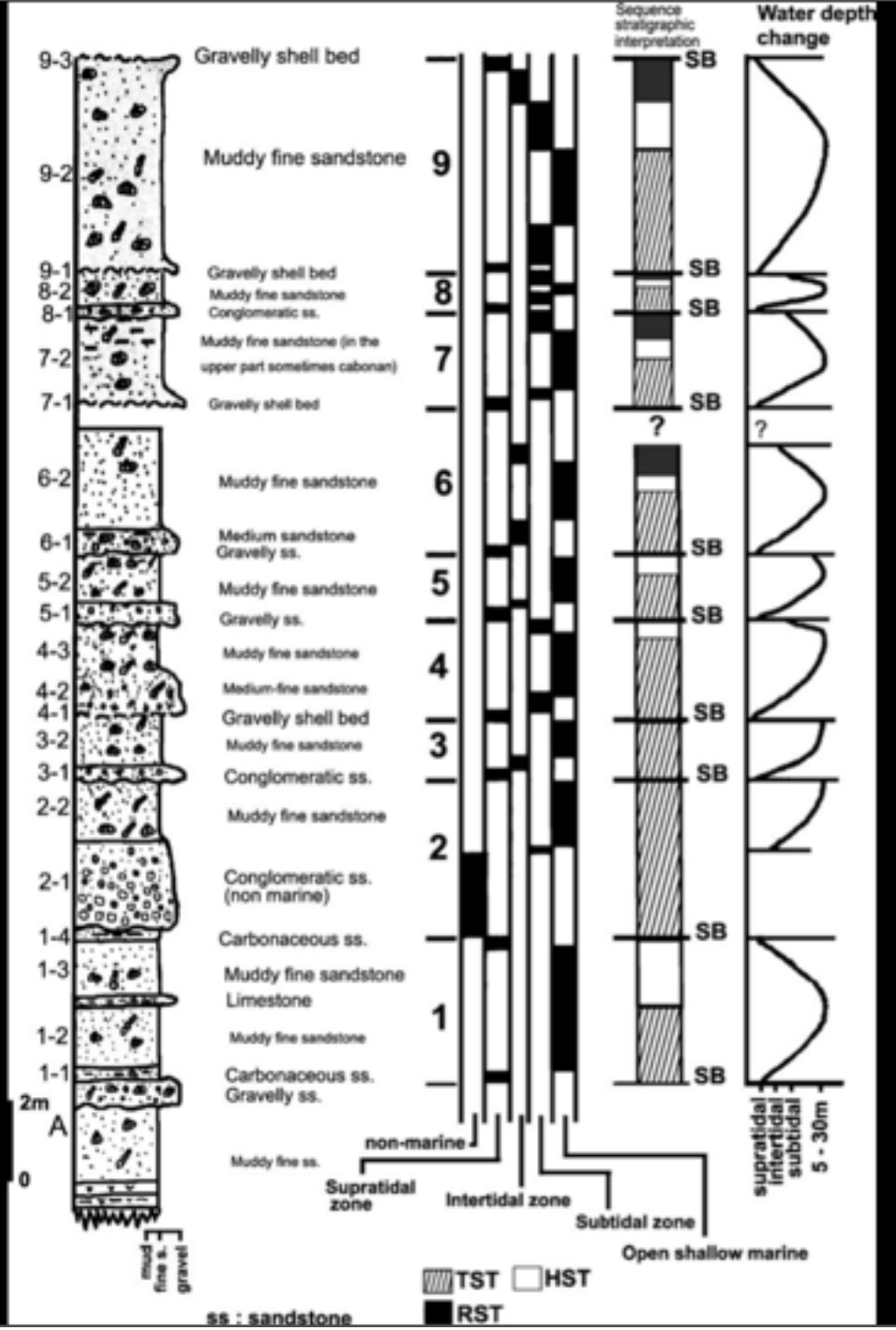
V. Taphonomy & environmental successions

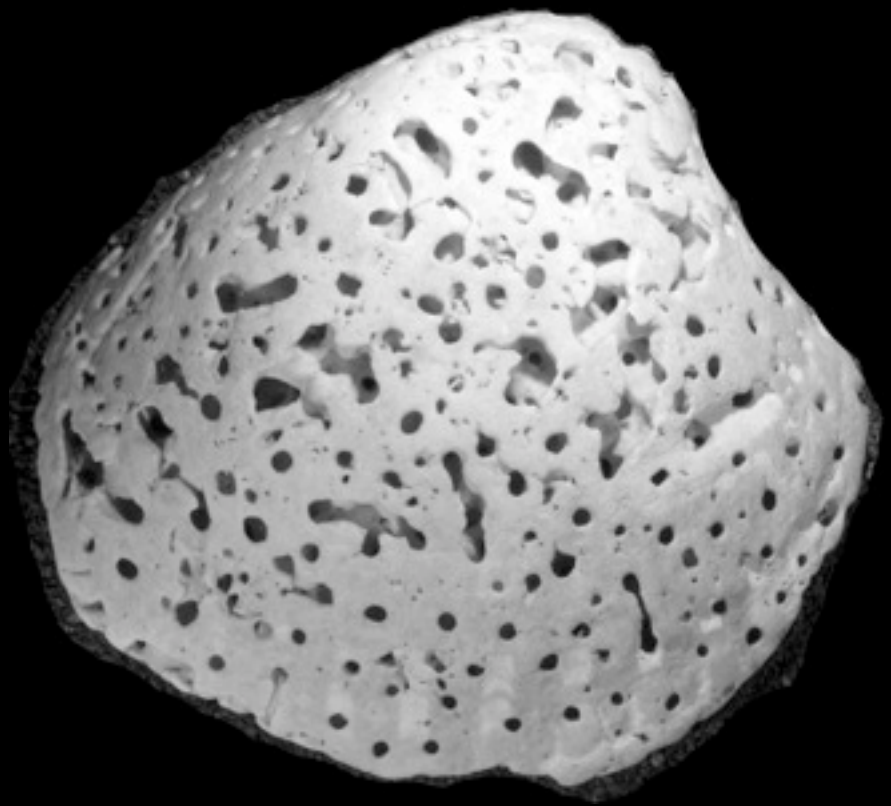
1. nine depositional sequences with recurring faunal successions

2. sequences interpreted as cycles, and proposed to represent 42 Ka duration (orbital)

3. How to dinstinguish from episodic volcanoclastic imput?

4. what to expect of the taphonomy?





Hardship after life: Bioerosion by clionid sponge on Eocene bivalve (*Venericor planicosta,* North Sea)

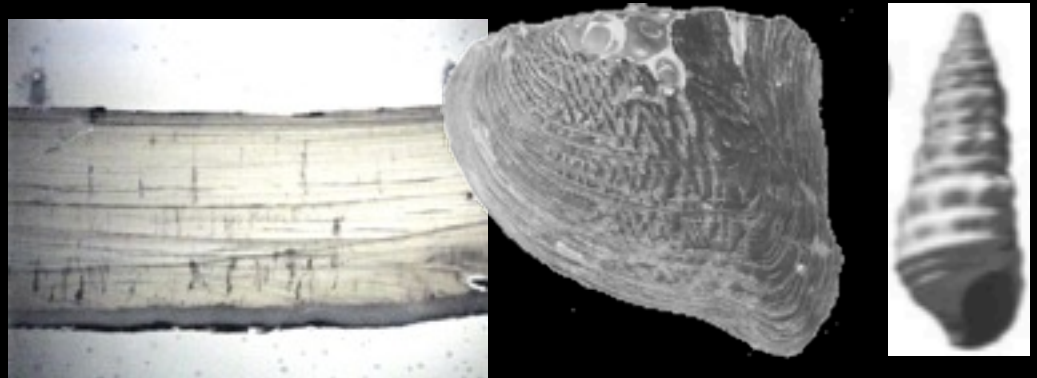
VI. Molluscs as history books

Conclusions

- stable isotopes are very useful in the reconstruction of past environments and processes on a range of temporal and lateral scales

- applications include reconstruction of aquatic chemistry (e.g., paleosalinities), processes (e.g. water mixing), habitats and palaoeclimate regimes

- diagenesis should be taken into account in such studies



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V!

Show me your shell, I will tell you where you grew up

Reconstructing palaeoenvironments using molluscs

Frank P. Wesselingh

Jon Todd

NCB Naturalis
Nederlands Centrum voor Biodiversiteit

NATURAL HISTORY MUSEUM