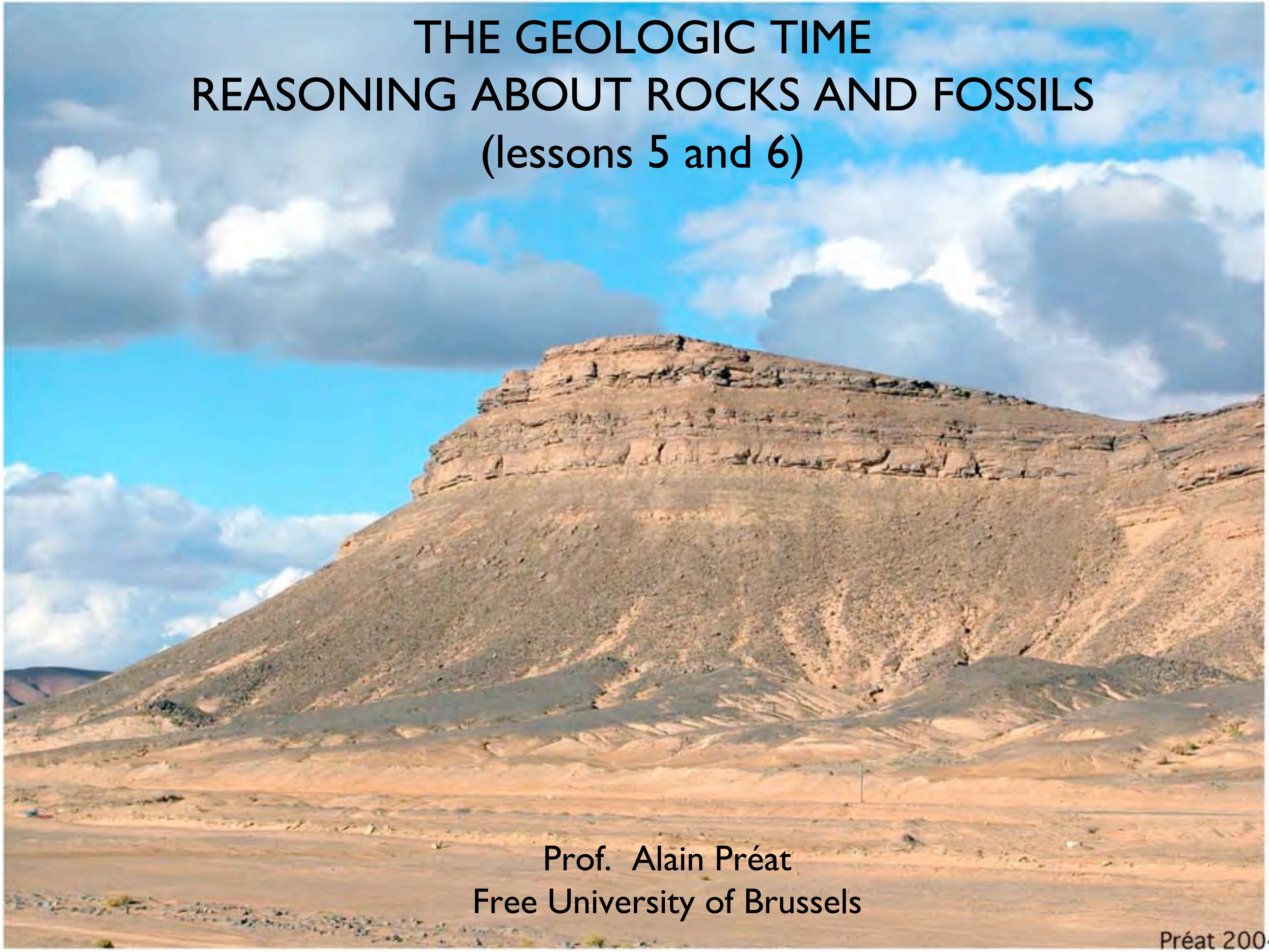
THE GEOLOGIC TIME
REASONING ABOUT ROCKS AND FOSSILS
(lessons 5 and 6)

GEOL.F.104



Prof. Alain Préat
Free University of Brussels

RELATIVE CHRONOLOGY

apparent simplicity ...

1. Principle of superposition

2. Principle of continuity

3. Principle of palaeontological identity

1. PRINCIPLE OF SUPERPOSITION

(17th century by Nicolaus Steno)

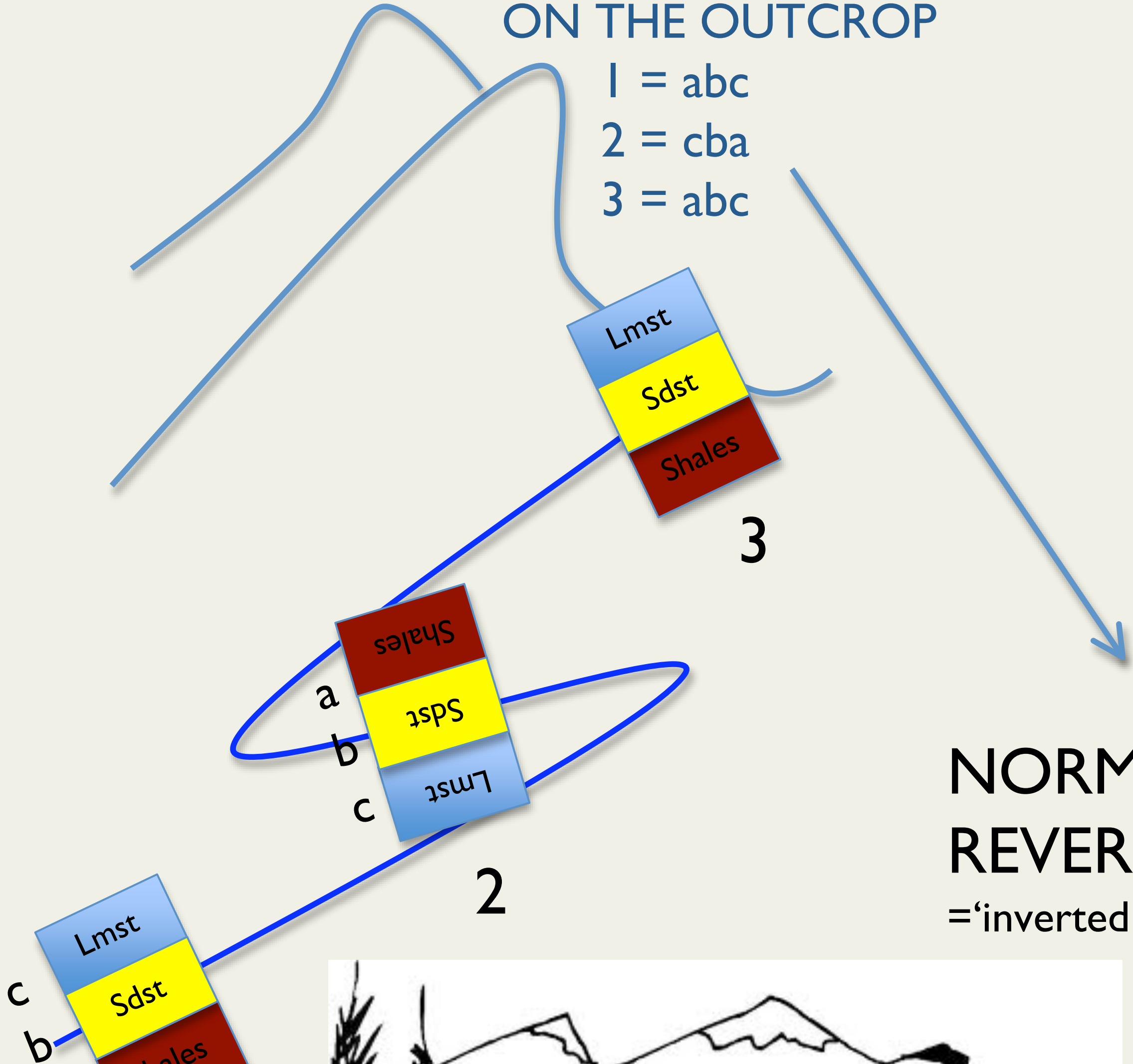
‘STRATA BECOME YOUNGER UPWARDS’

This implies

1. Strata were initially deposited flat (=‘principle of initial horizontality’)
2. The entire section has not been overturned during deformation (tectonic or other)

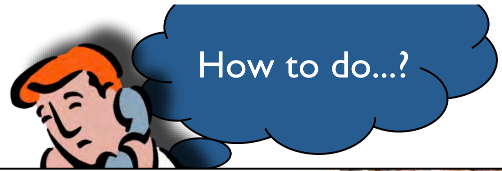
EXAMPLE OF A HECTOMETRIC FOLD ON THE OUTCROP

1 = abc
2 = cba
3 = abc



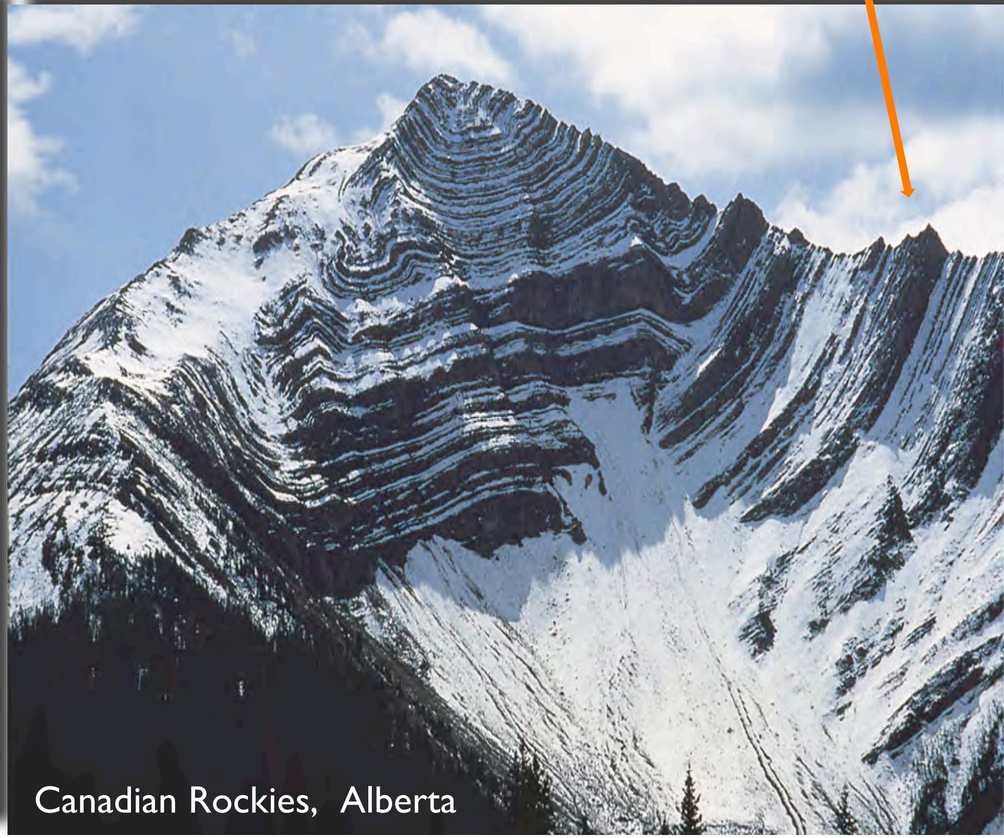
NORMAL STRATA (abc)
REVERSE STRATA (cba)
=‘inverted beds or section’

‘local’ 2D (disconnected)



Principle of superposition (horizontality at the origin)

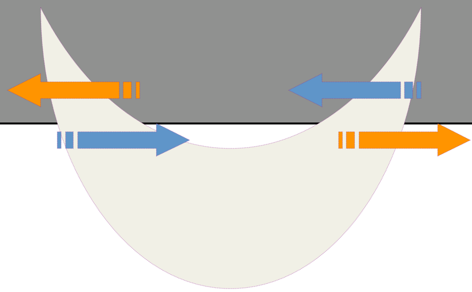
… the layers settle horizontally …. almost true at a large scale => a layer is more recent than those it covers



Application on the field…. not so easy ….

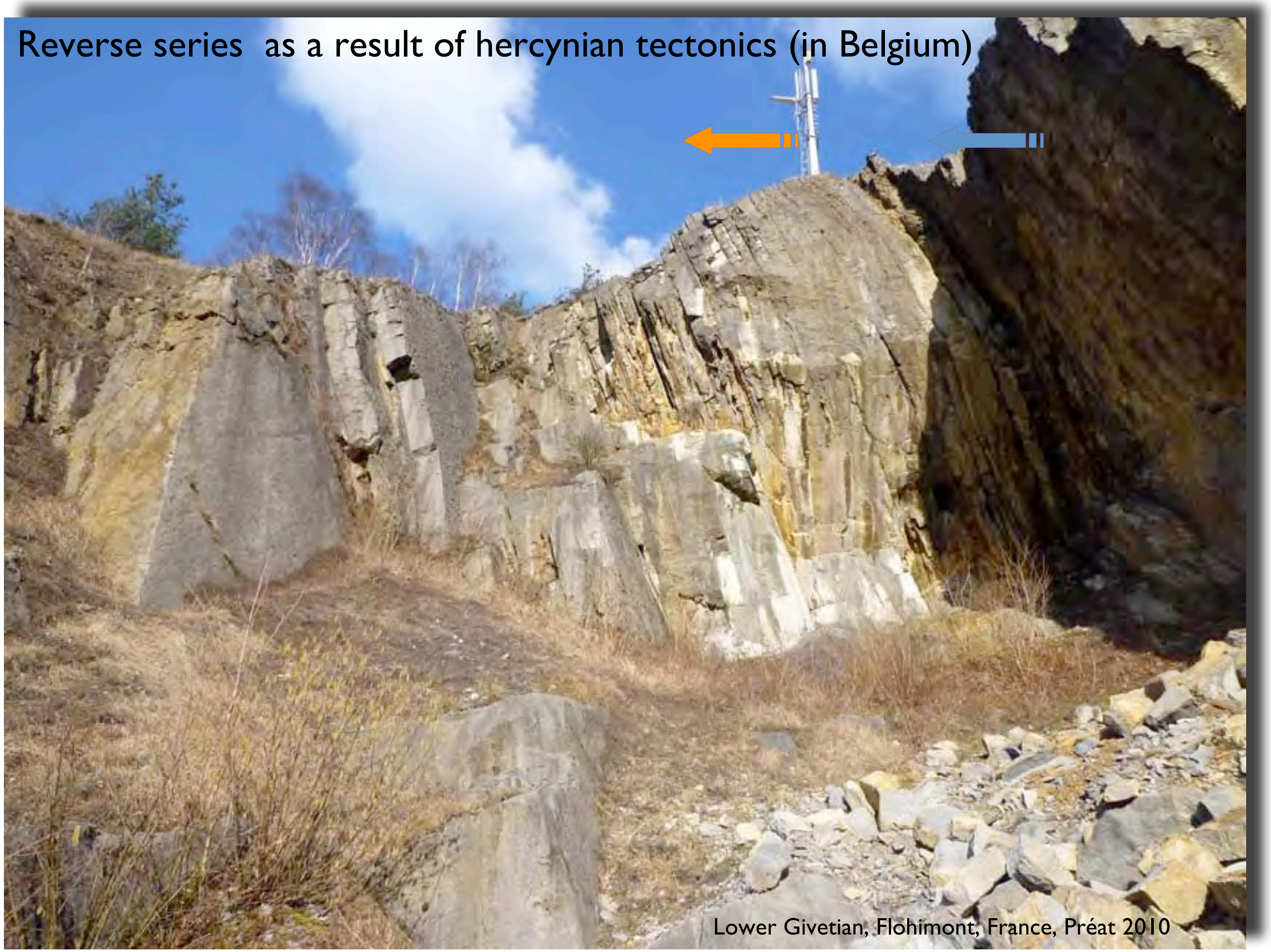
younger older

Principle of superposition (horizontality at the origin)



Application on the field…. not so easy ….

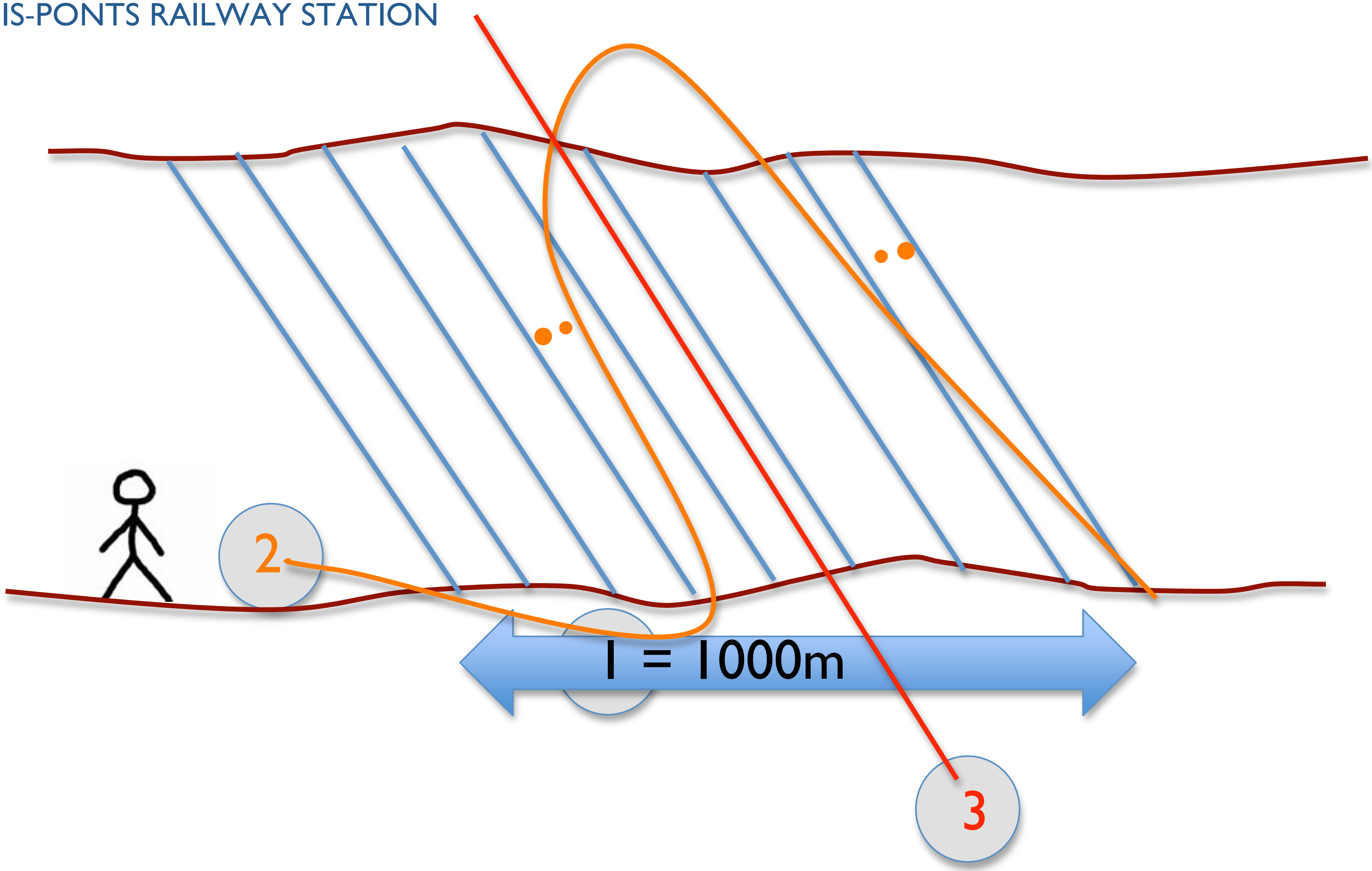
Principle of superposition (horizontality at the origin)



MAIN CONSEQUENCE = TRUE SERIES THICKNESSES

Example of the turbidites of the Stavelot Massif, Belgium (Rv4-Cm)

TROIS-PONTS RAILWAY STATION



⇒ NEEDS CRITERIA OF POLARITY

(now in Belgium, acritarch biozones…)

SANDSTONES or CLASTICS

- graded beddding
- cross-bedding : a layer is younger than any layers it cuts across
- ….

= ‘hydrodynamism’ or energy parameters

LIMESTONES

- geopetal cavities (= diagenesis with internal sediment…)
- organisms in life position (= paleoecology)
- burrows (= paleoichnology)
- vadose cementation (= early diagenesis)
- pisoids-calcretes (pedogenesis with inverse grading!)

….

= more complex than for sandstones

POLARITY CRITERIA ARE NUMEROUS
Useful in a small outcrop or section
Useful in thin section

TWO EXCEPTIONS

1. ALLUVIAL TERRACES : the youngest are below the oldest
$\Rightarrow$important for the study of Quaternary series
but inside the terrace the principle is applicable
2. VOLCANIC FLOWS : the oldest on the plateau, the youngest in the valleys

4’ Iron bacteria (Jurassic, Italy)

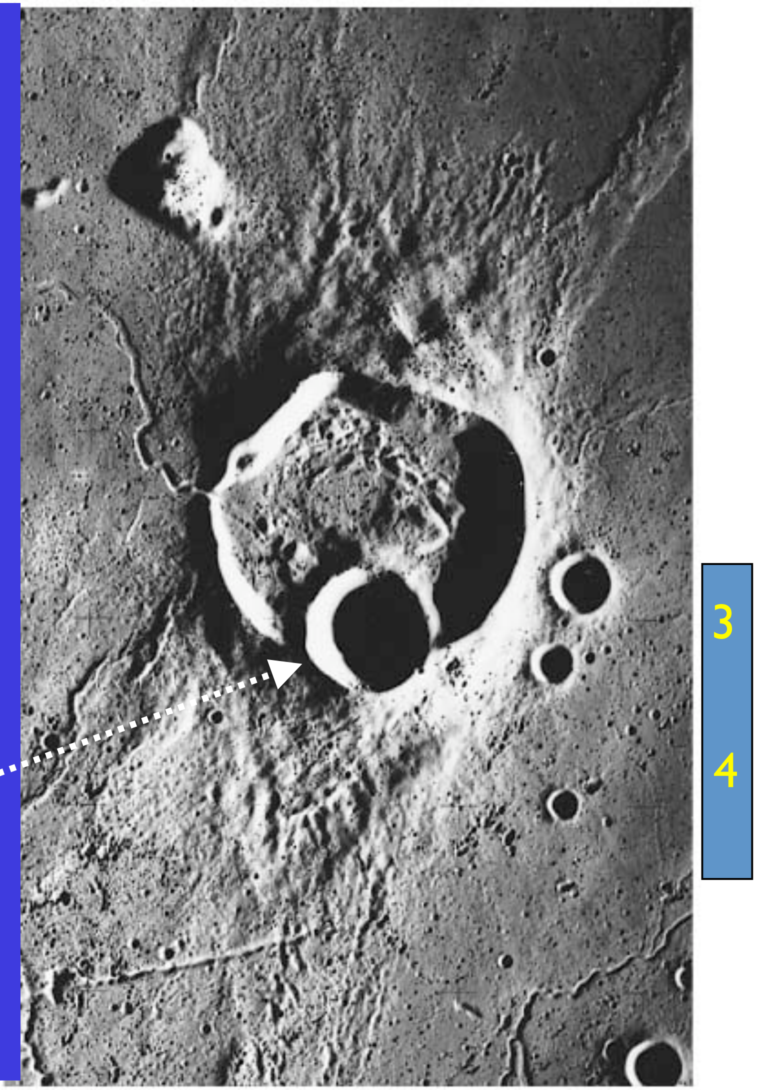
Principle of superposition valid at all scales …

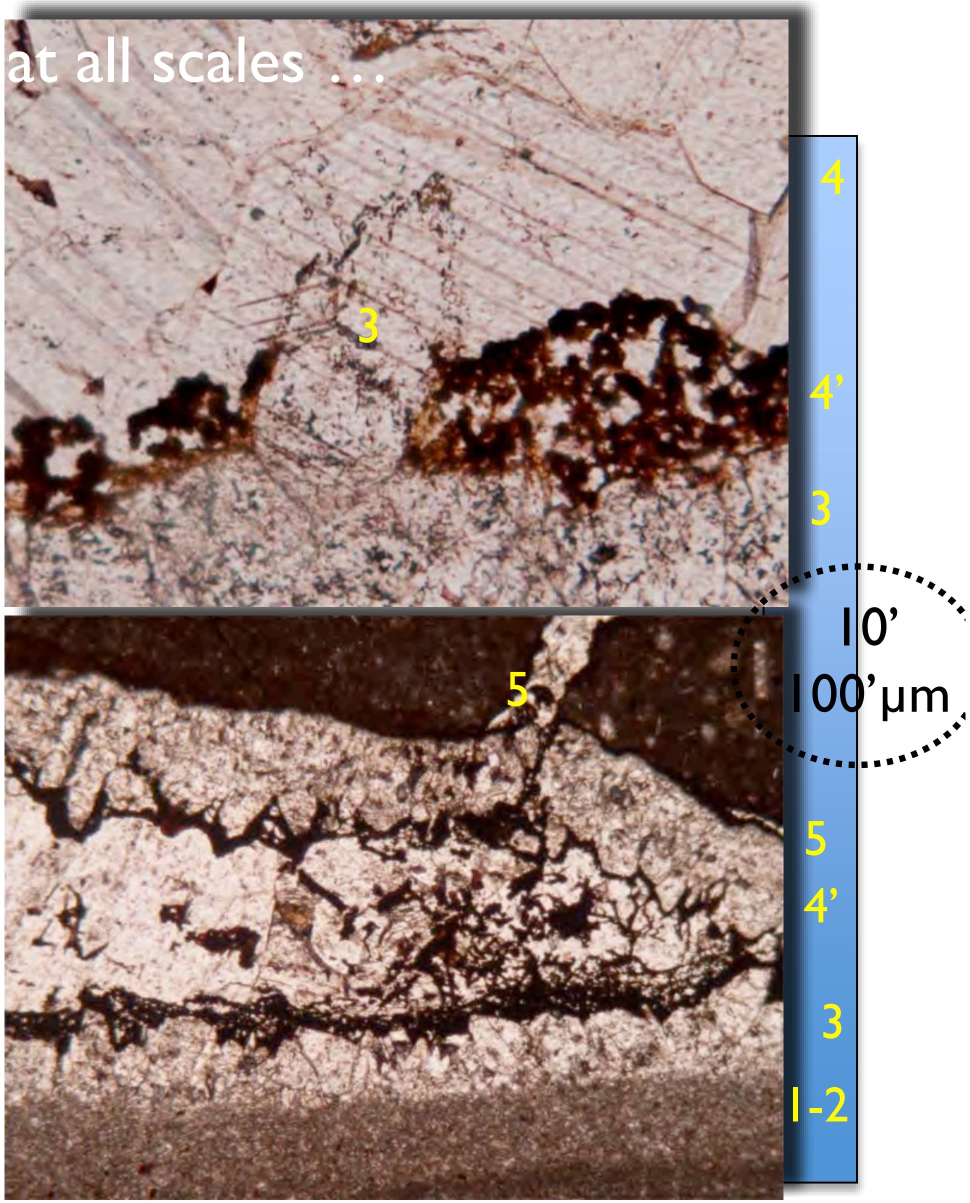
10’
100’km

Easy

All the others

are difficult





… and also for magmatic and metamorphic rocks (geometric relations)

2. PRINCIPLE OF CONTINUITY

= base for geologic correlations

A sedimentary layer bounded by a 'roof' and a 'wall' and defined by a given facies has the same age in all its points => this implies that a layer is of the same age in all its points

=> At the origin of a layer, the same phenomena affected in the same time the area where the layer has been formed

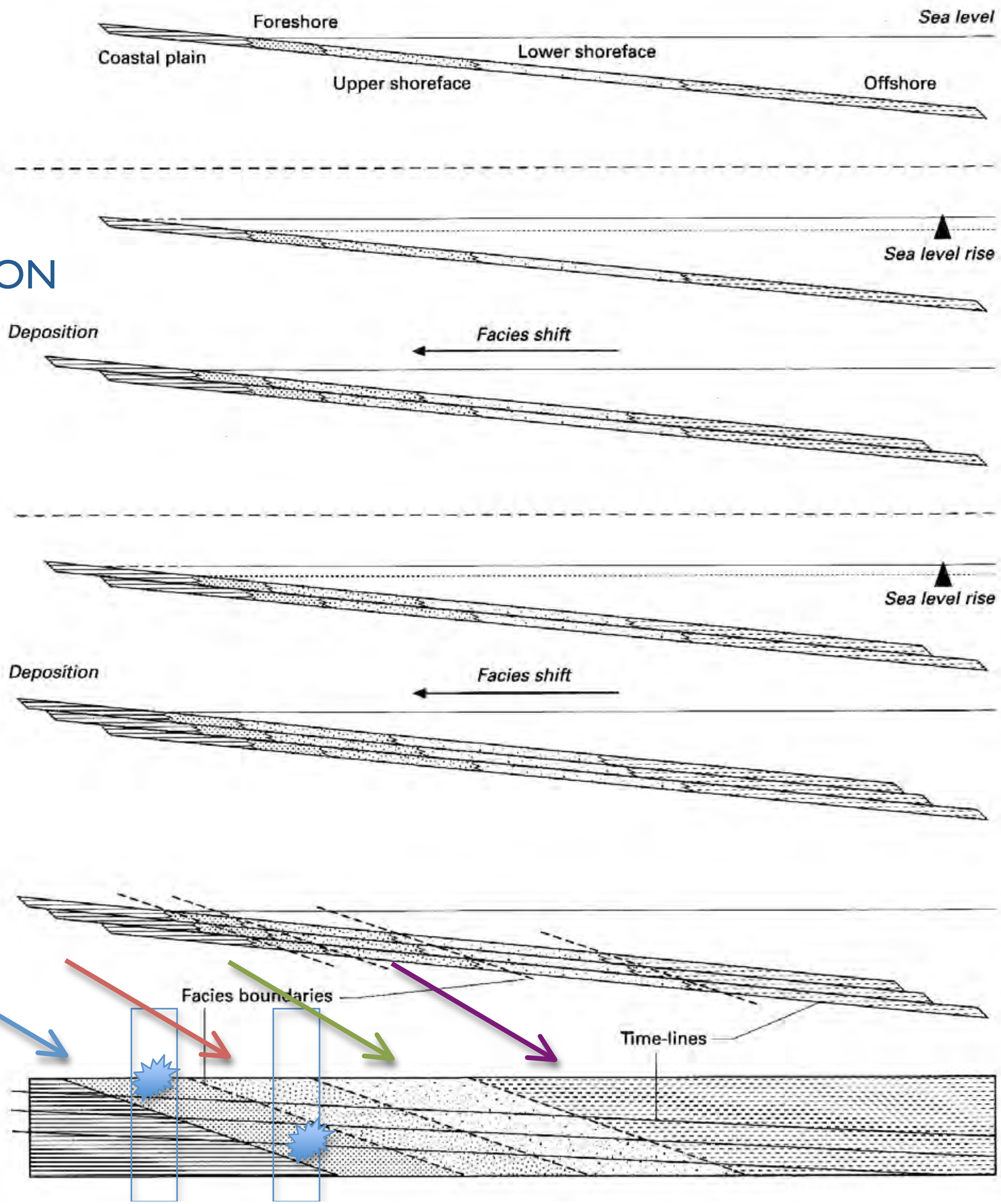
DESPITE THIS IS MORE OR LESS THE CASE, IT IS HOWEVER NOT ALWAYS TRUE…

- a 'transgressive' layer is more and more recent during the transgression (and it is always the same facies (i.e. the same layer)
- idem during a 'regression'
- bear in mind : absolute *vs* relative sea level variation(s)

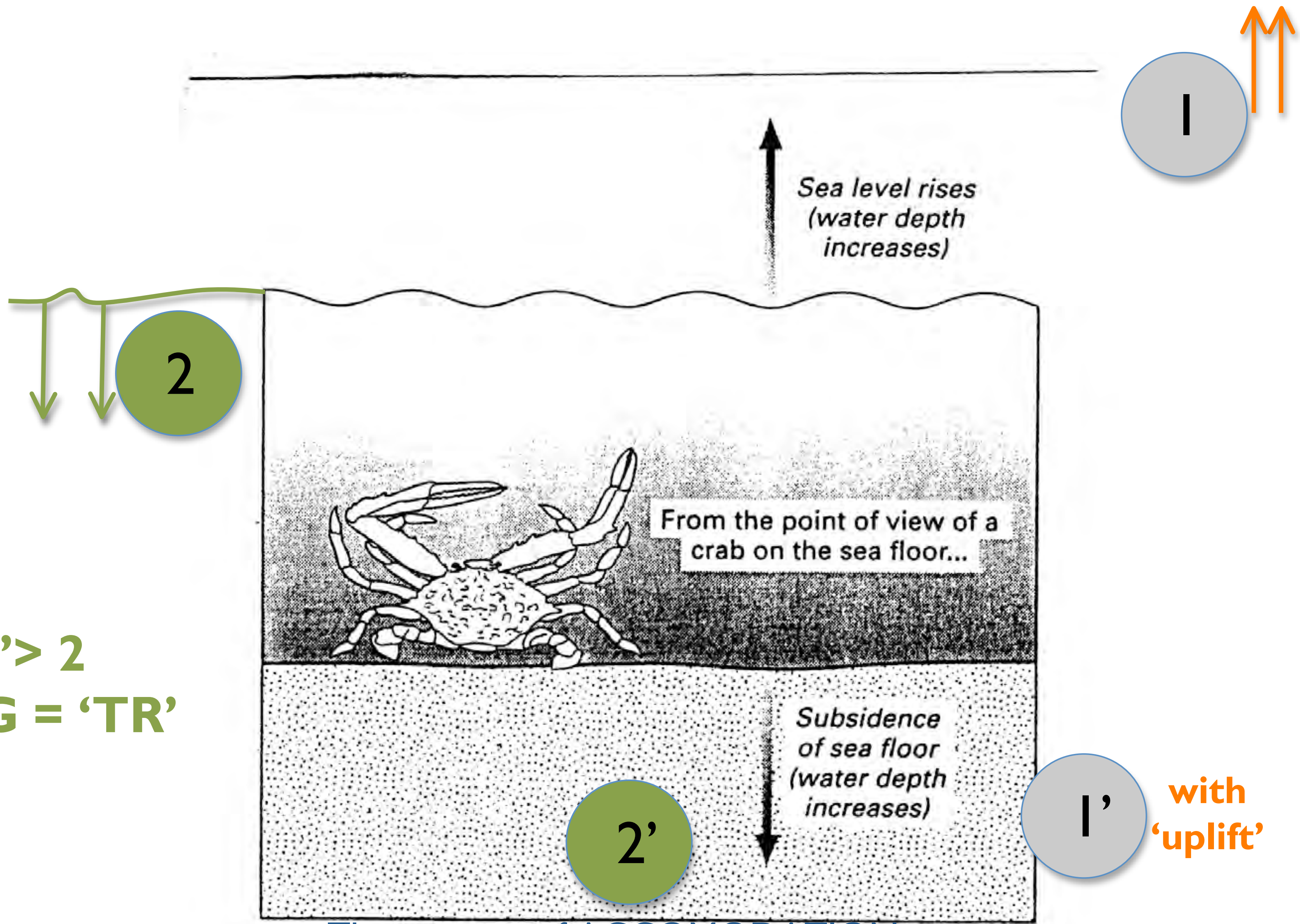
GRADUAL
SEA LEVEL RISE

LATERAL FACIES VARIATION
'DIACHRONISM'

'seismic reflectors'
KISS 'principle'



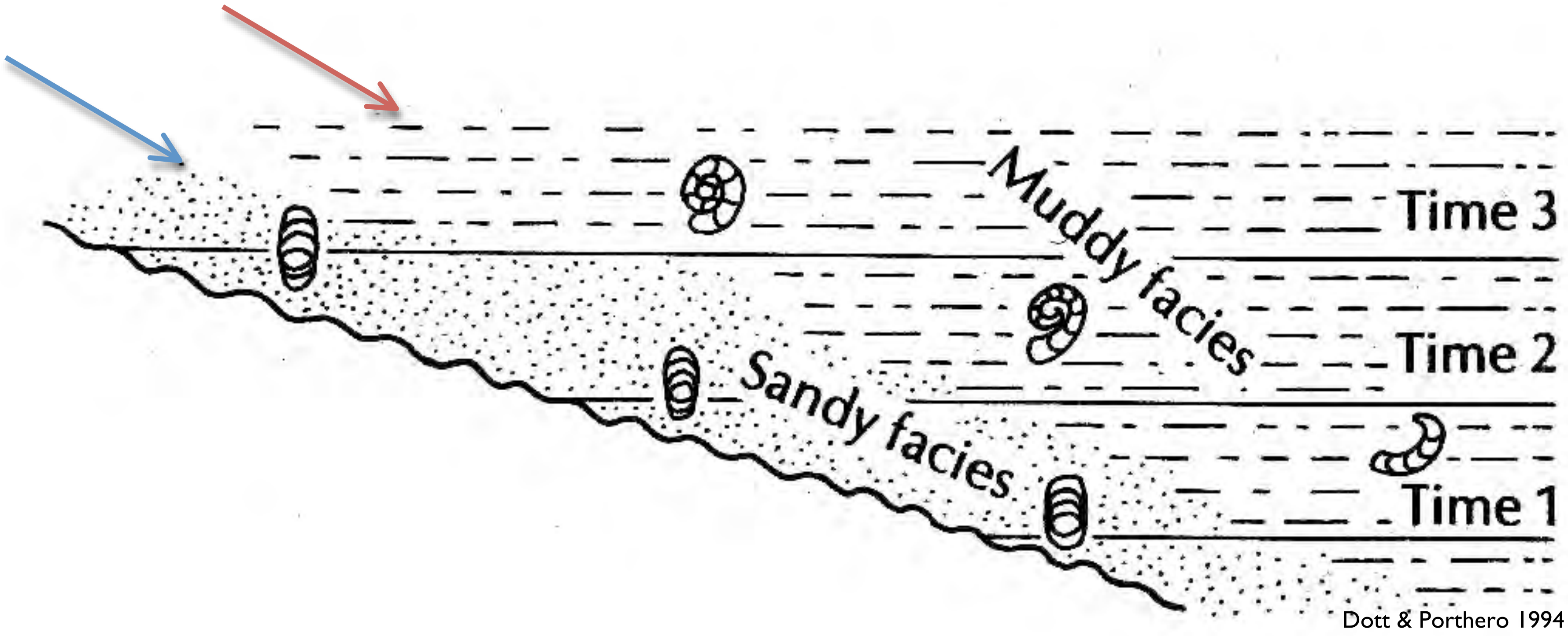
Nichols 1999



The concept of ACCOMODATION space

If 2 '> 2
REG = 'TR'

‘seismic reflectors’
KISS ‘principle’



Contrasting rates of evolution and **shifting** environments. The **brachiopod** *Lingula* lives in the sandy nearshore facies and evolves extremely slowly => it is a poor biostratigraphic indicator. **Ammonoids** that swam in the open ocean, however, are excellent for biostratigraphy : they evolved rapidly and were not tied to any particular facies (as they are free-swimming).

With this principle the true stratigraphic difficulties start!
BECAUSE IT IS DIFFICULT TO FOLLOW A SAME LAYER
OVER GREAT DISTANCES (outcrop conditions, erosive hiatuses …)

mainly in the PALEOZOIC

⇒ USA-UK geologists are mainly SEDIMENTOLOGISTS (1) (not all is folded)

⇒ European geologists are mainly STRATIGRAPHERS (2) (at least at the beginning) the facies varying laterally and the series being strongly folded (Caled.-Hercyn.-Alps)

(1) directly useful…. (2) is more complex for direct application

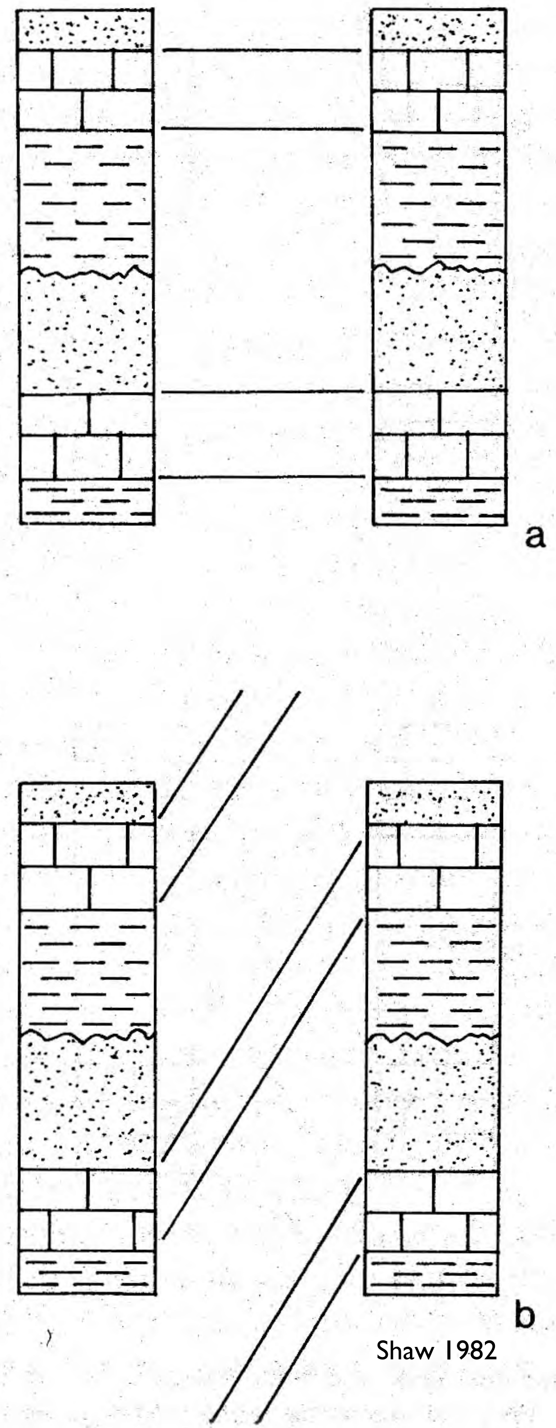
So, how has this principle been applied?

• at the origin (at the 'birth' of modern geology)

⇒the key factor was the LITHOLOGICAL CHARACTERISTICS (cf. geologic maps = rocks)

==> LITHOSTRATIGRAPHY and notion of FORMATION

Lithic continuity can be proved **ONLY** by lateral tracing of the rock bodies



Shaw 1982

For a long time the **FORMATIONS** were considered as having the same age for a particular lithology => chalks = Cretaceous, coal = Carboniferous… and today they are still associated with an age!

• Of course, this is wrong: example of the O.R.S. = Old Red Sandstones, they are very thick (km') and post-orogenic, i.e. Devonian (in Europe) and 'post-Caledonian' >< N.R.S. = NEW RED SANDSTONES (Permian and 'post-Hercynian'

Nb: O.R.S. = N-Europe (Ireland- Russian Platform) + E-Canada
Also present below the Carboniferous (Kashmir, India where the folding occured later)

• Idem for coal, for phosphorites, for Tertiary sands (of Paris basin)…
⇒ for the sands : superposition + continuity ==> geometry
===> 'lower', 'middle' and 'upper' sands
• Idem for geological mapping

ALL THIS IS NOT ENOUGH TO CANCEL THE UNCERTAINTIES

IT NEEDS THEREFORE THE PALEONTOLOGICAL ARGUMENT
=> since the beginning of the 19th : BIOSTRATIGRAPHY

- 1800-1850 deduce if horizontal strata (in Belgium for example) are youngest than folded strata!...
- 1850-1900 : LITHOSTRATIGRAPHY
- > 1950 : Exploration of sea floors (after WWII…)
  => SEDIMENTOLOGY and PLATE TECTONICS (1968)

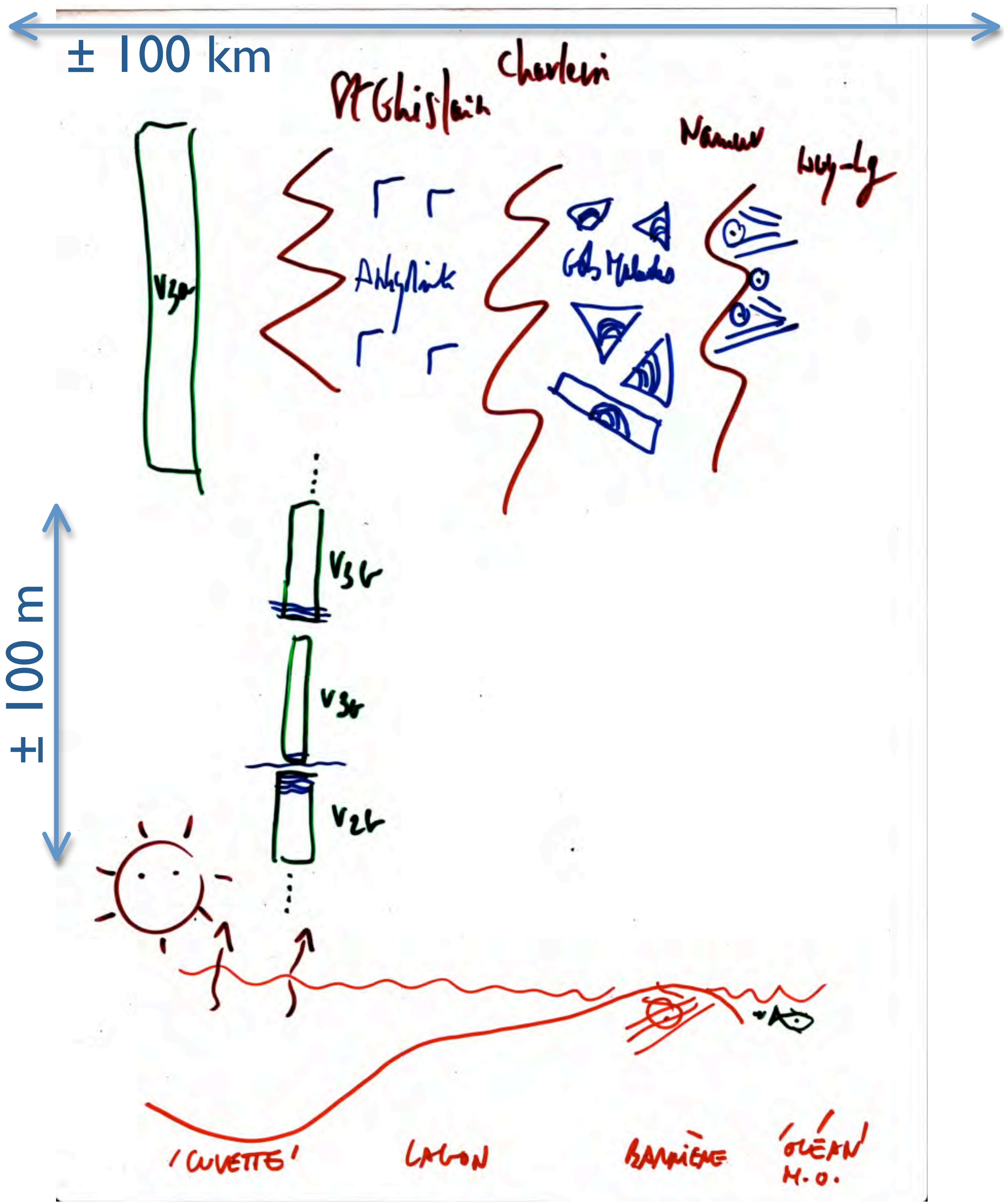
…

- 1990s : despite these advancements, numerous problems still exist (mainly due to the lateral facies variations)

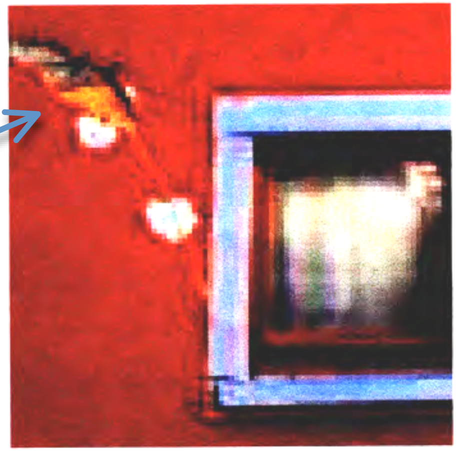
⇒Two examples in Belgium (but they exist everywhere)

1. 'GRANDE BRECHE' V3a (= Viséan)
2. MUD MOUNDS or biohermal lenses F2ij (= Frasnian)

Collapse breccia
vs
Mudflow
or
Tectonic breccia

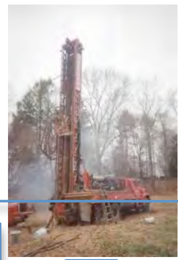


STAUFEN-EN-BRISGAU (GERMANY): GEOTHERMAL DRILLINGS (2008)



THE UNDERGROUND MOVES AT 1CM/MONTH => FUTURE CAVITIES

129 houses have been broken
7 drillcores (2007)



H_2O

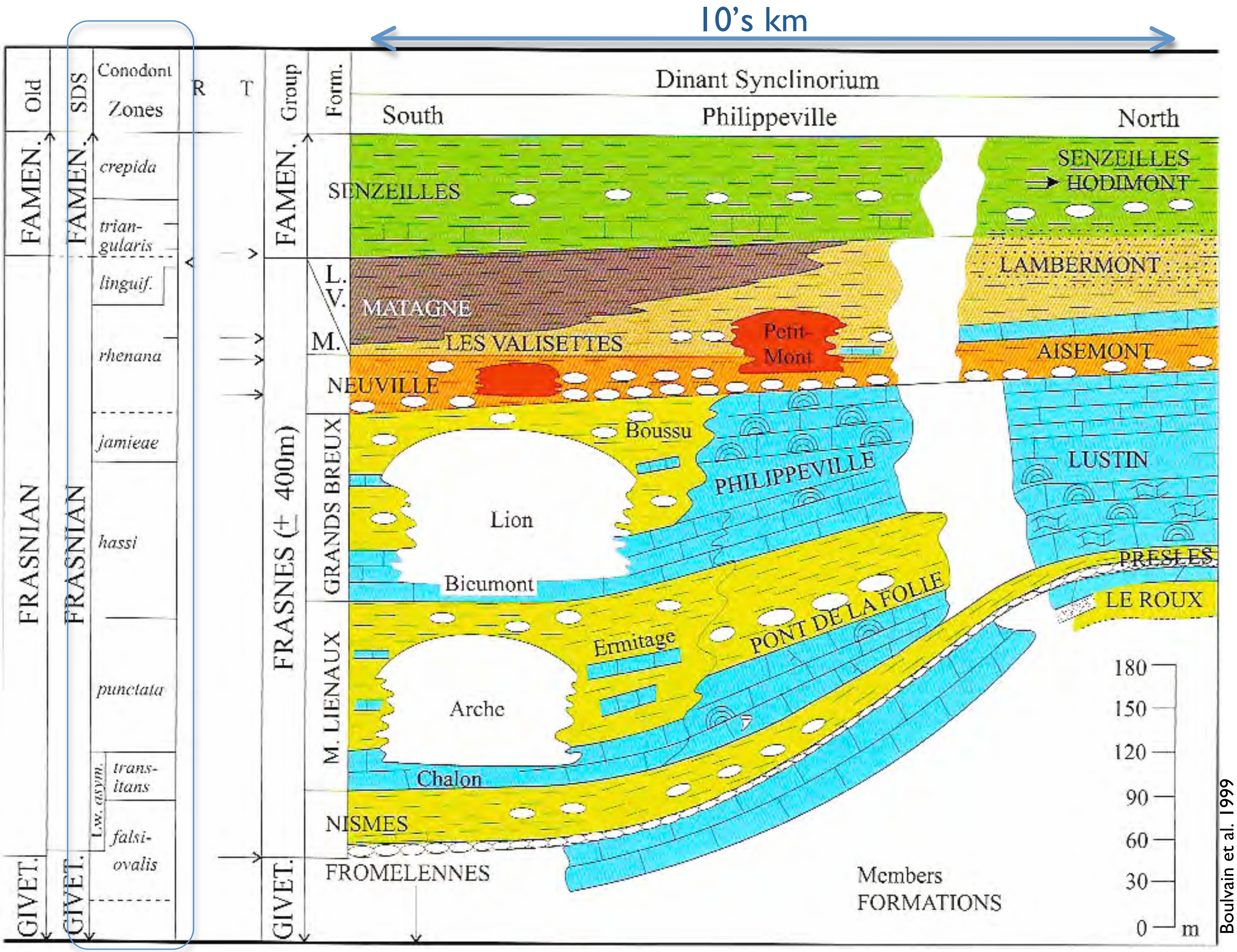
H_2O

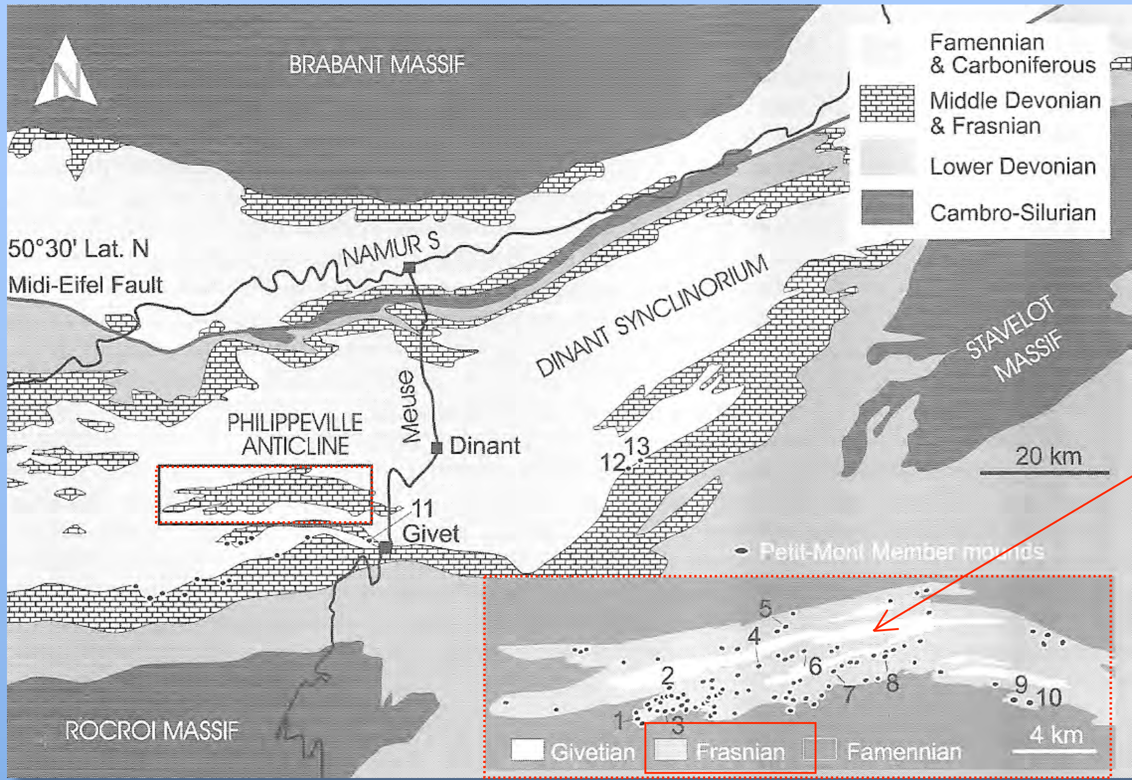
GYPSUM (ΔVOL = 60%)

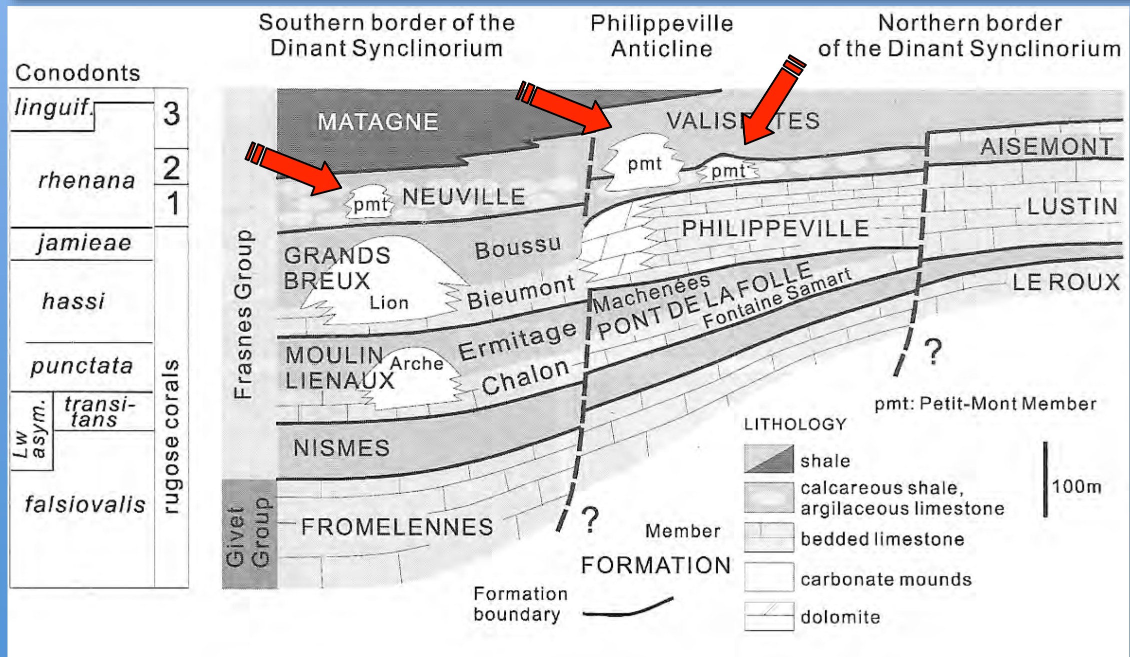
140m (depth)

ANHYDRITE

UPPER DEVONIAN STRATIGRAPHY, SOUTH BELGIUM







Boulvain et al 2001

MUD MOUNDS
BIOHERMS
BIOHERMAL LENSES

69 reported 'red' mud mounds

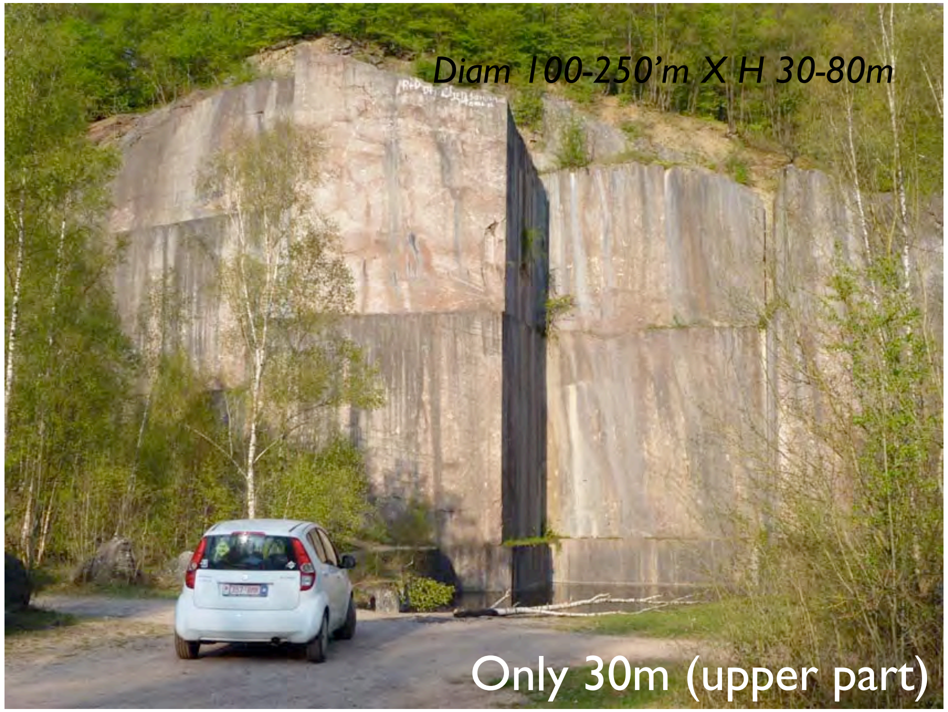
Severe eustatic sea level rises

High vertical facies differenciation

High content in microaerophilitic iron bacteria (in *stromatactis* cavities)

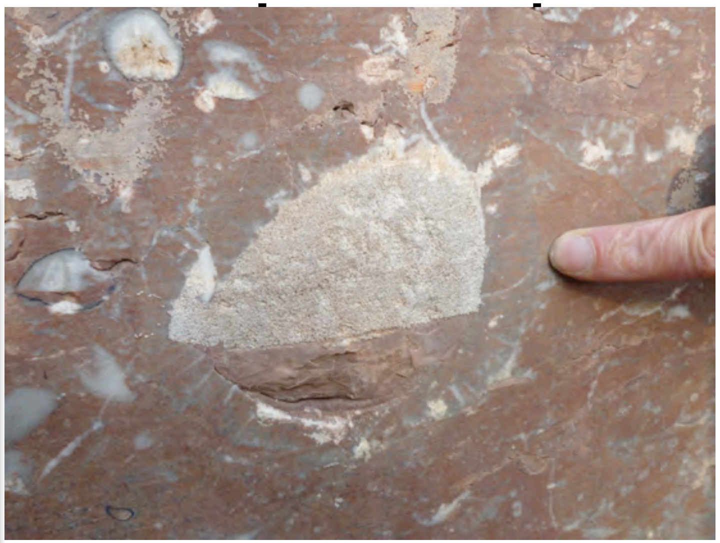
Submicronic hematite hexagonal plates dispersed in the matrix

Fe_2O_3 : average 2% (max 5%)



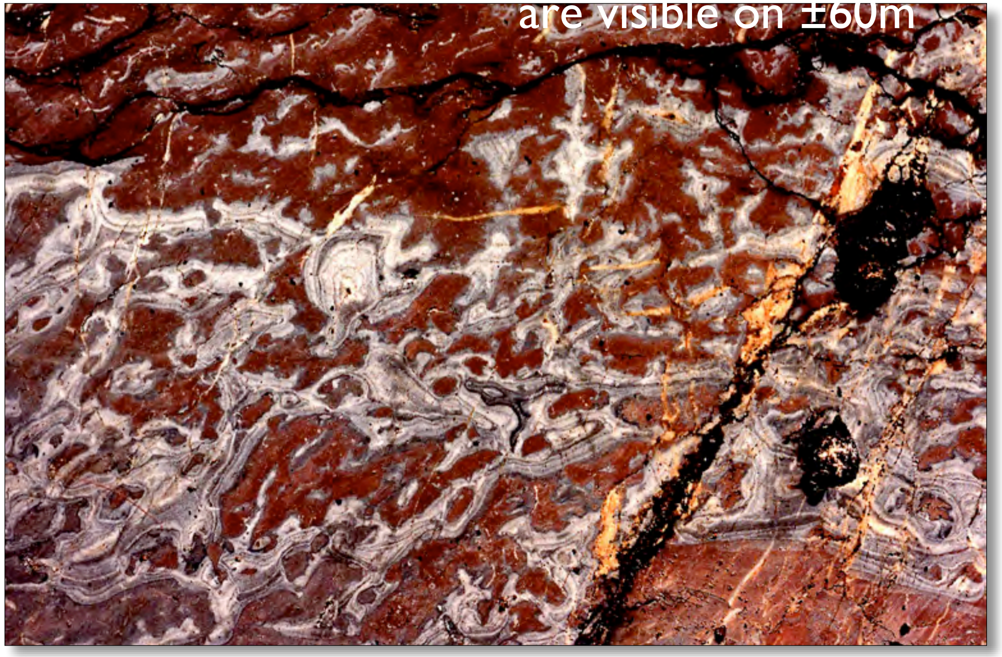
BEAUCHATEAU QUARRY
near Senzeilles
Philippeville Massif
BELGIUM

Frasnian 'F2j'



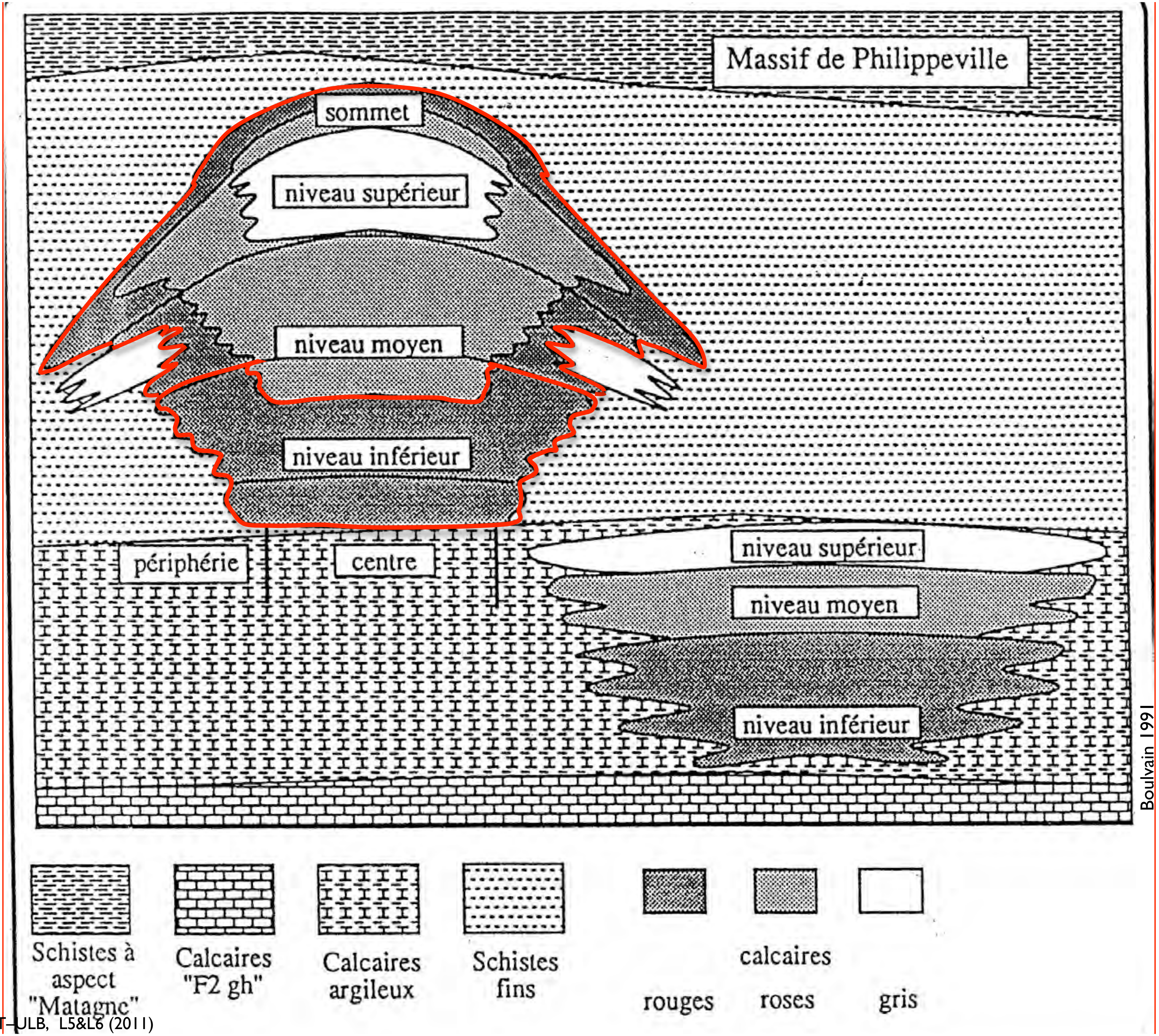
griottes
+'stromatactis'
(1880)

10cm



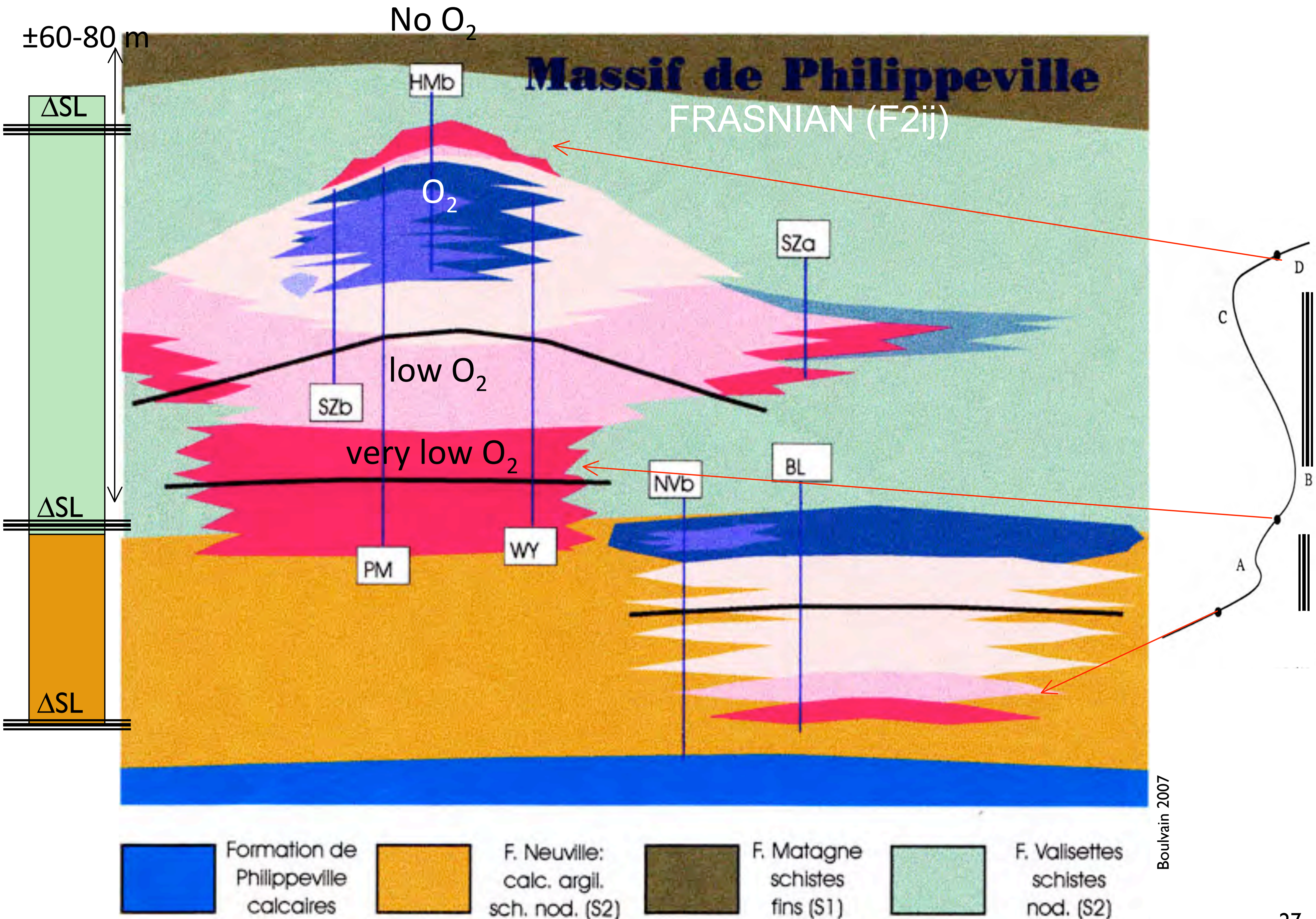
Fe_2O_3 : average 1.8% (XRD)
// Mg, Si, Al i.e. // clay content

as already mentioned by Delhaye, 1908



Frasnian
'F2ij'

The red-pink-grey color (succession) is 'ECOLOGICAL'



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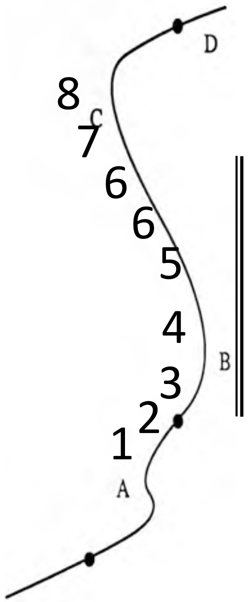
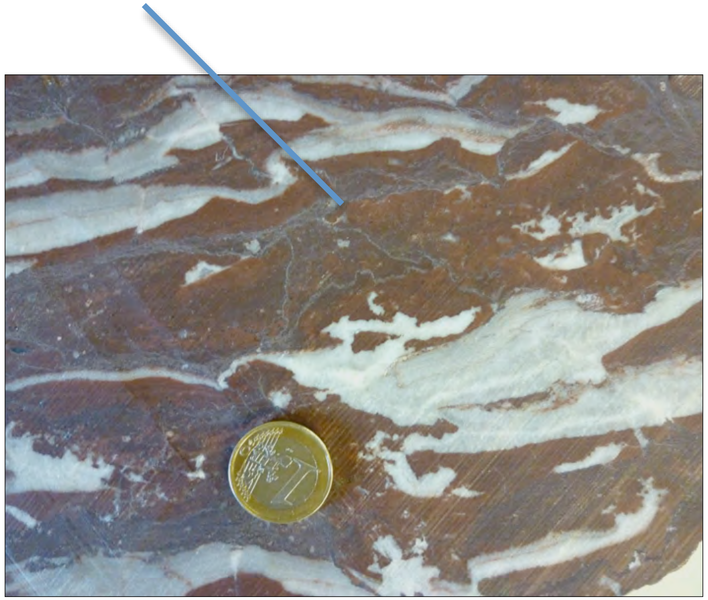
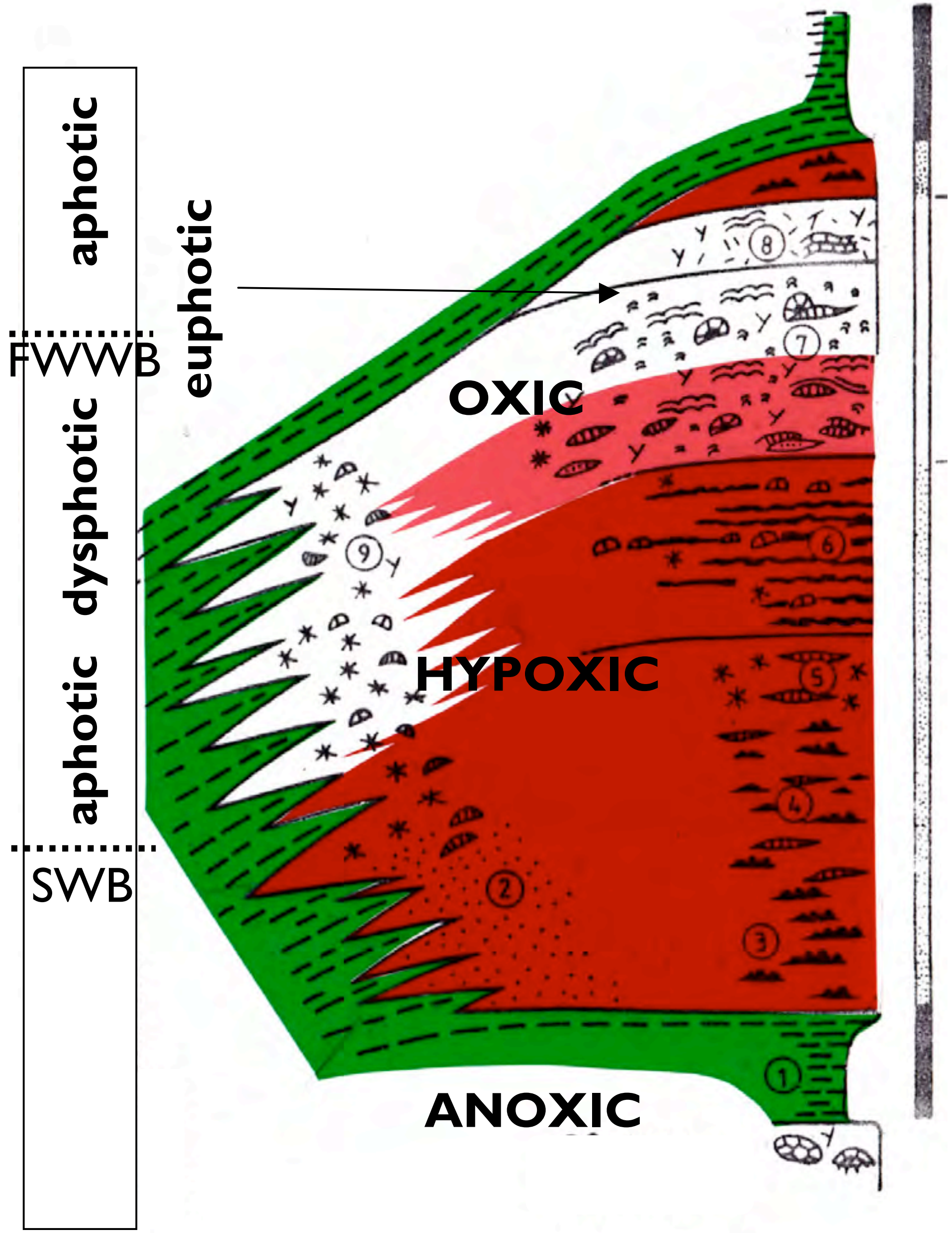


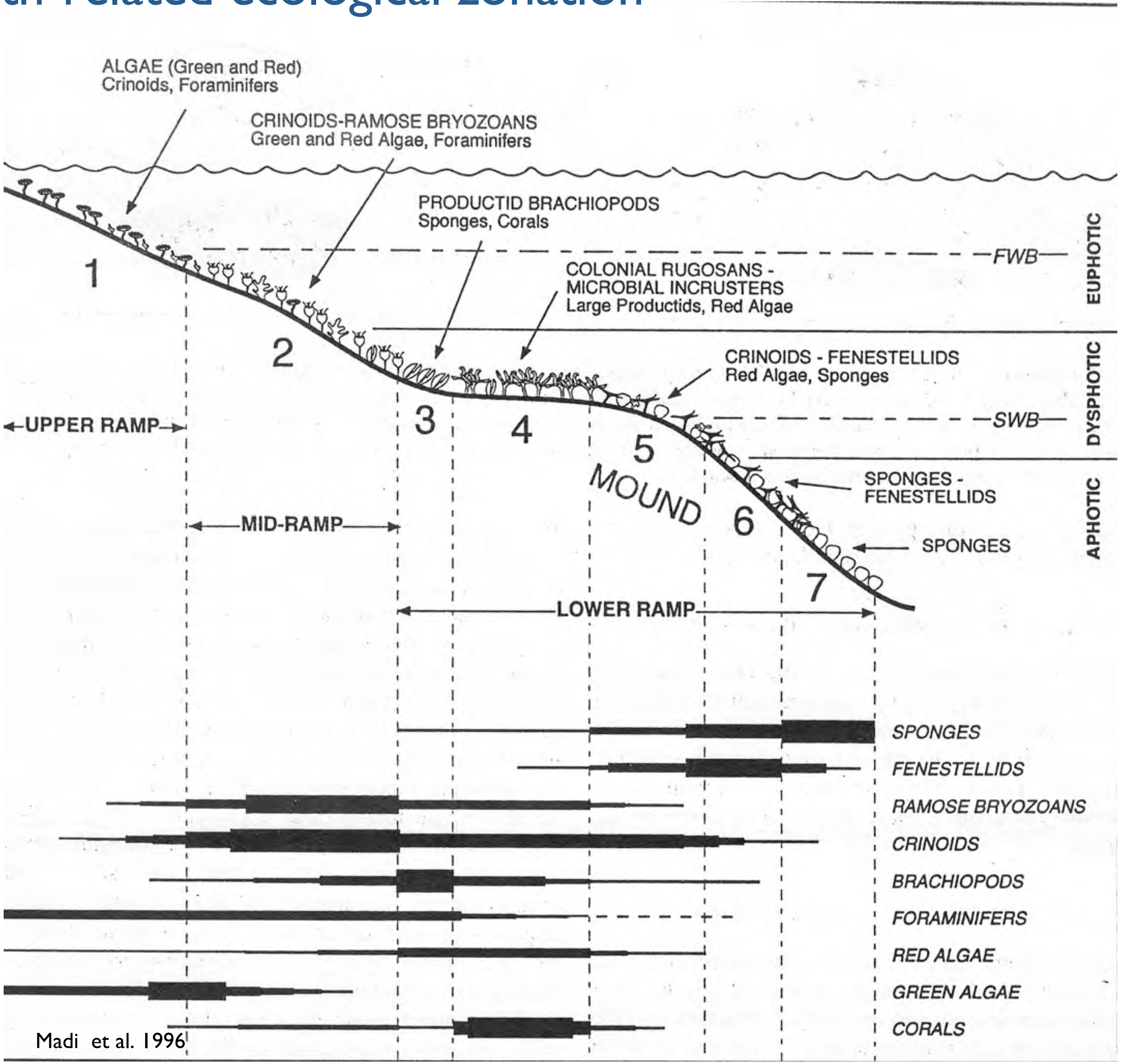




I : recurrence
7-8-9 : FWWB, cyanobacteria, algal (green algae)-coral-peloid wackestones-packstones
5-6 : progressive biotic enrichment (stromatoporoids, corals...)
4 : SWB, oligophotic environment (corals, crinoids, *stromatactis*)
3 : iron bacteria-sponge in a quiet aphotic/hypoxic environment, *stromatactis*
2: shale and carbonates with brachiopods, corals, crinoids _sponges
I : shale with poor fauna, mainly sponges (substrate)

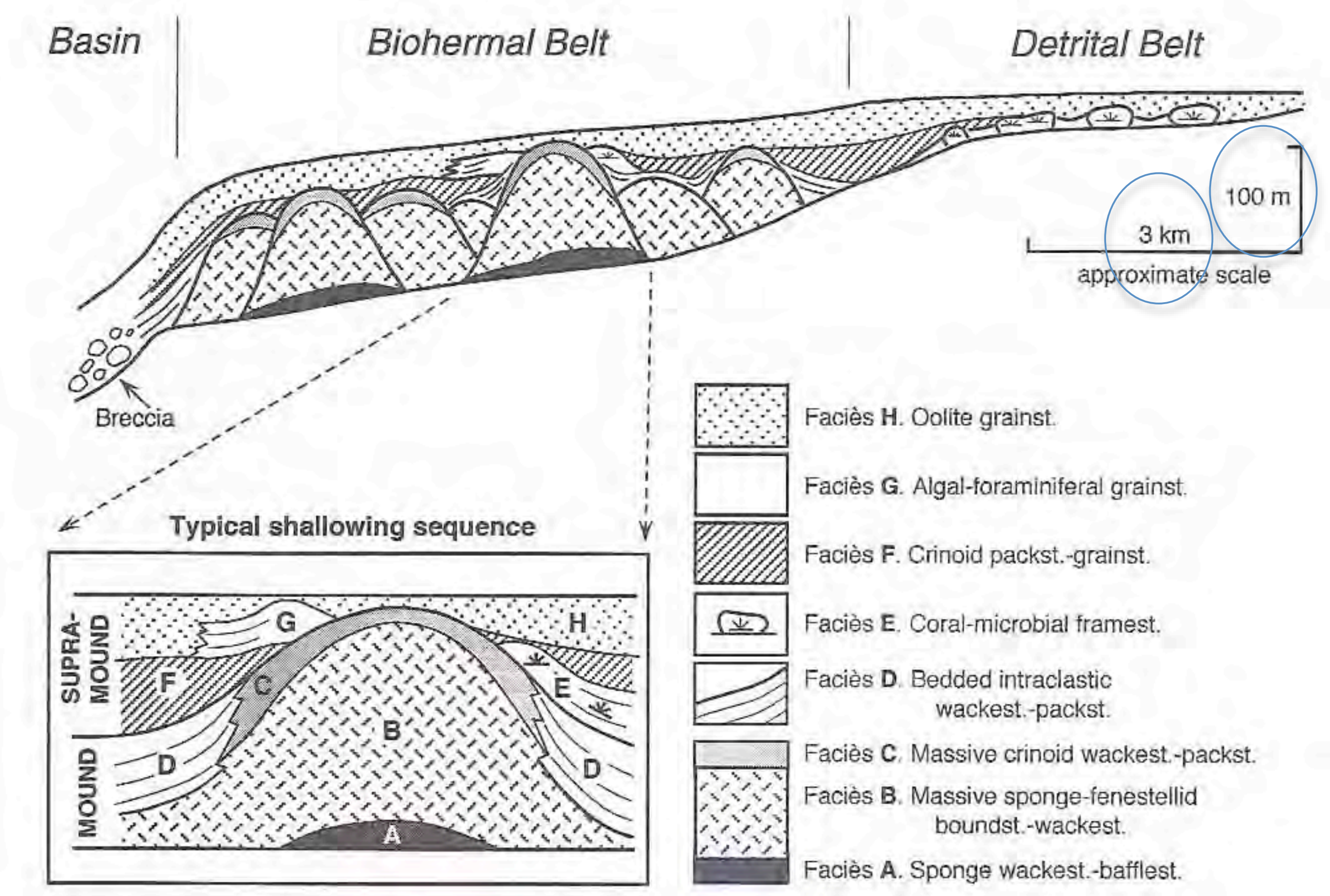
MICROFACIES SHALLOWING-UPWARD SEQUENCE

UPPER VISEAN, BECHAR BASIN, WESTERN ALGERIA
Depth-related ecological zonation



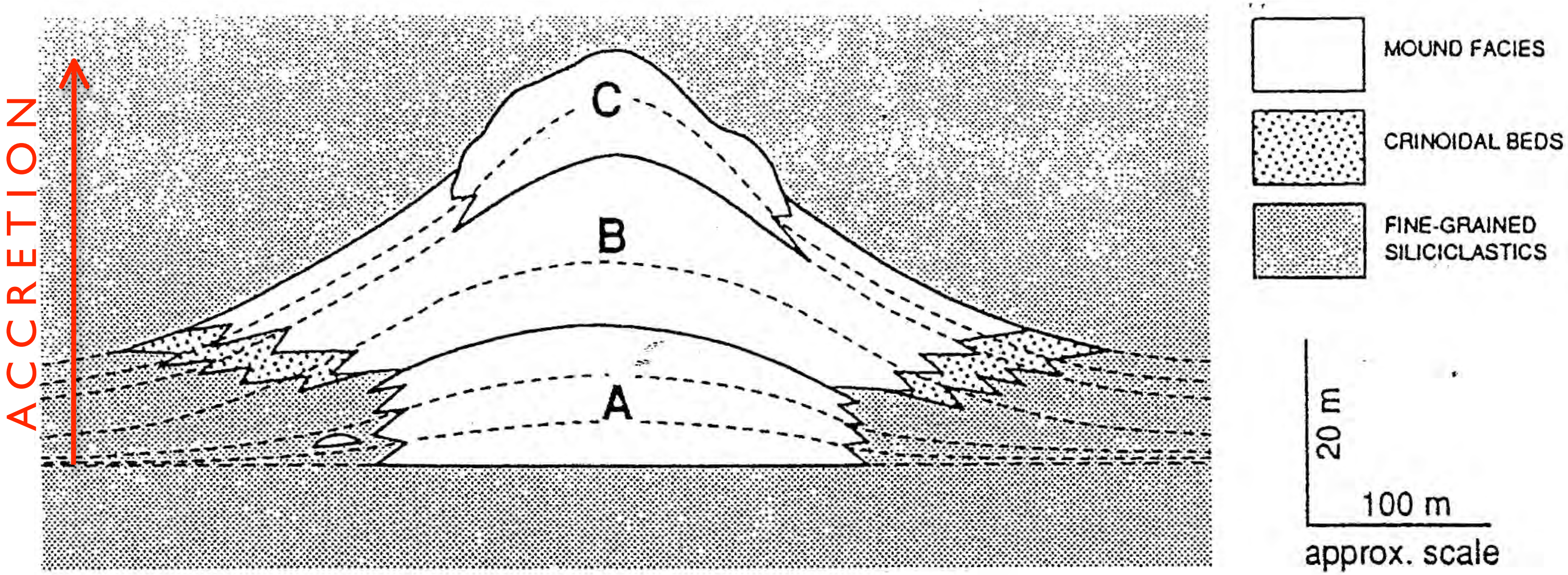
Madi et al. 1996

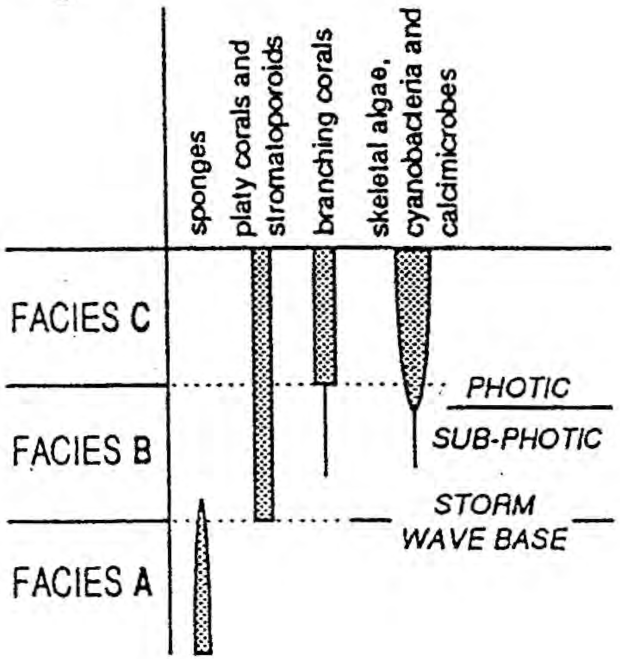
UPPER VISEAN, BECHAR BASIN, WESTERN ALGERIA
Vertical and lateral facies distribution

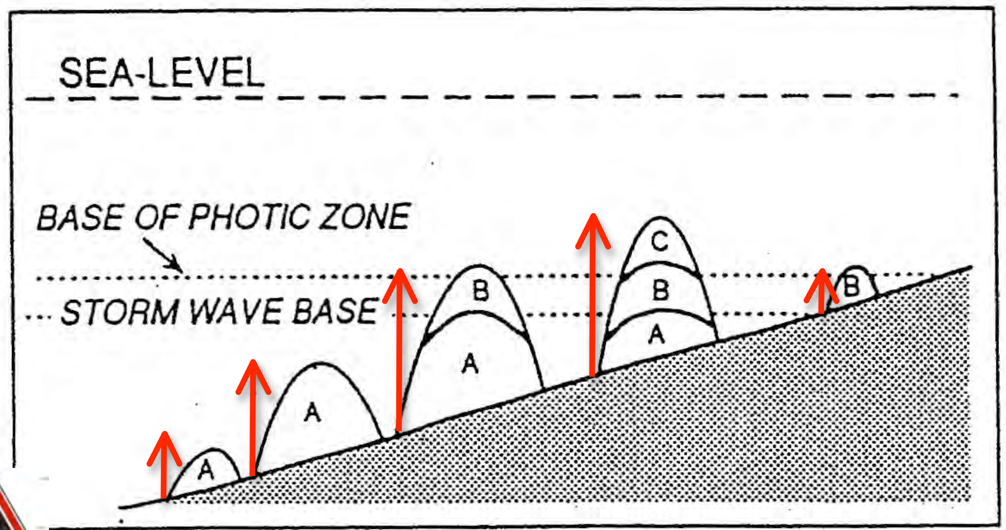


Madi et al. 1996

CARBONIFEROUS of ALGERIA







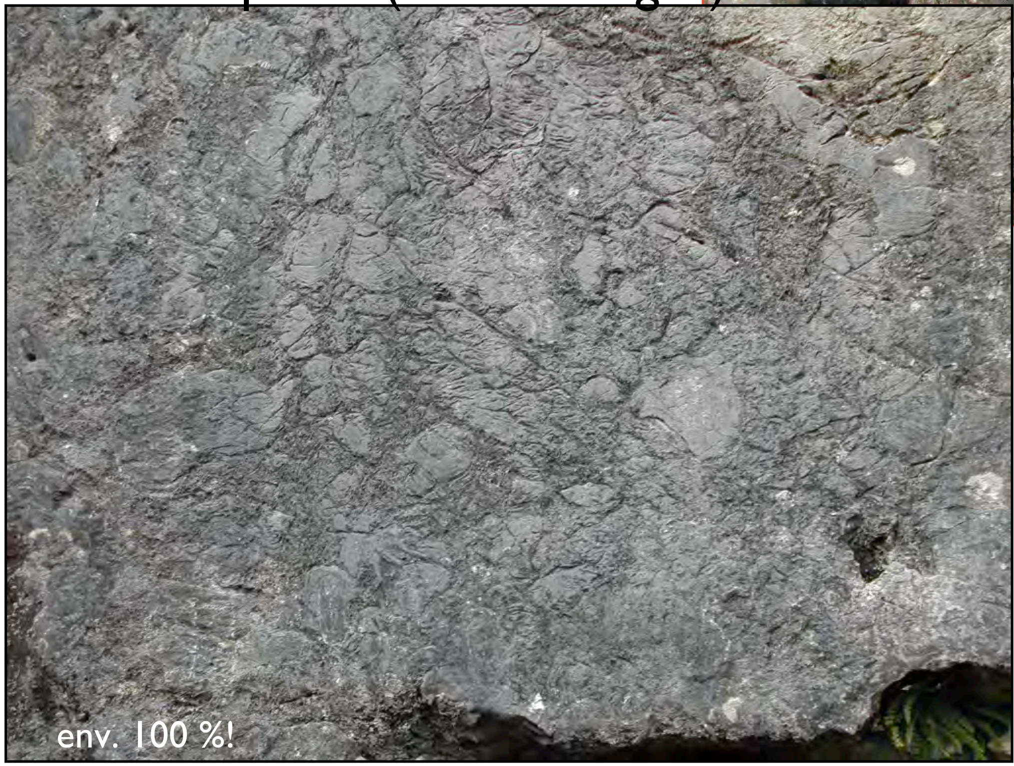
Finally…. What happens if folding => outcrops, profiles ….?

E/G transition

BARRIER?

60 m

stromatopores (+ corals-algae)



'FONDRY DES CHIENS'
Dinant Basin, Belgium

lenses

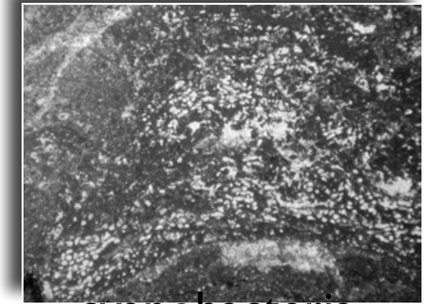
100'-1km

X

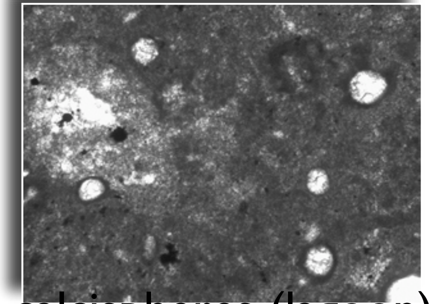
10'm

vadose (intertidal)

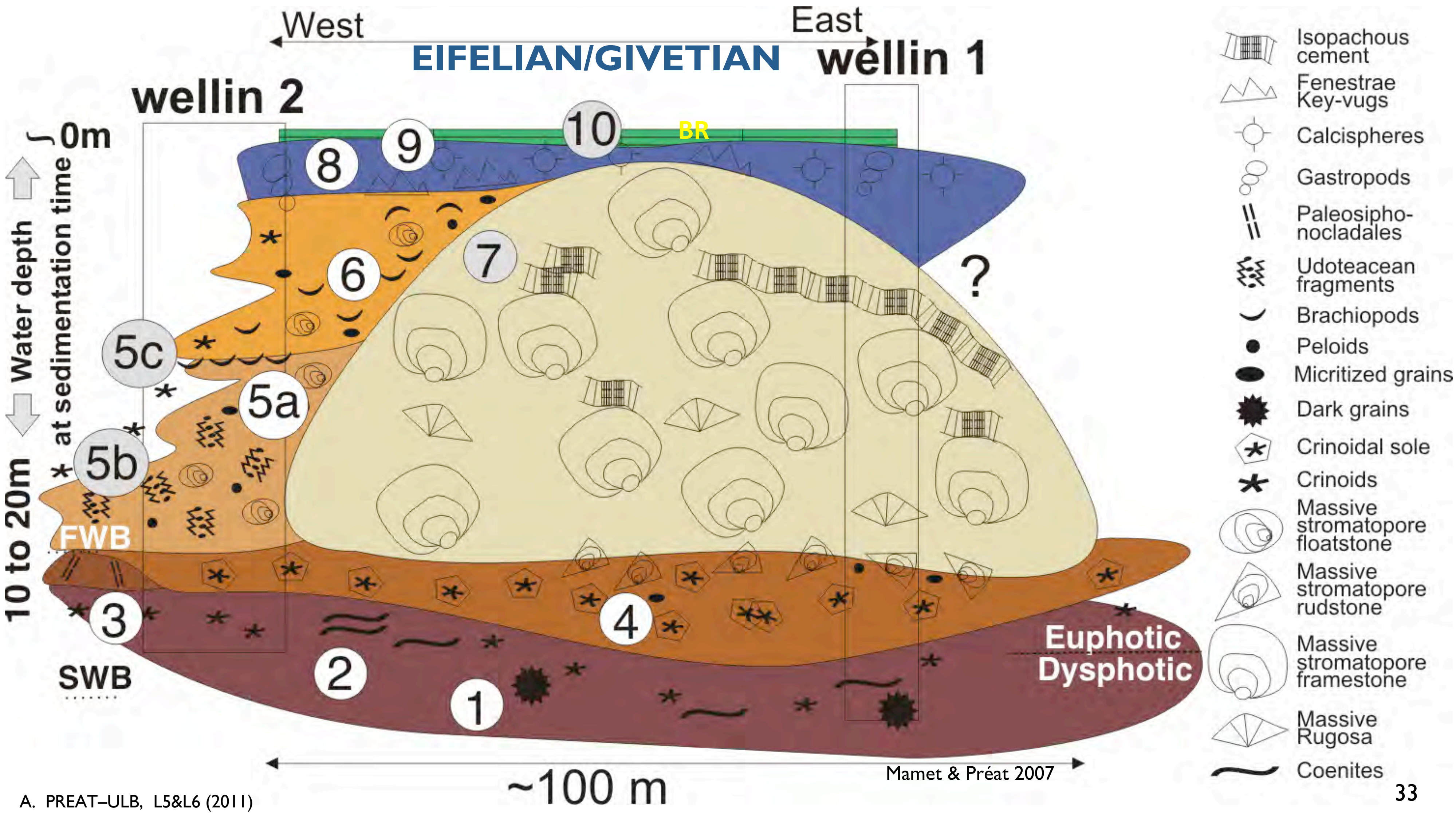
algae (subtidal flanks)



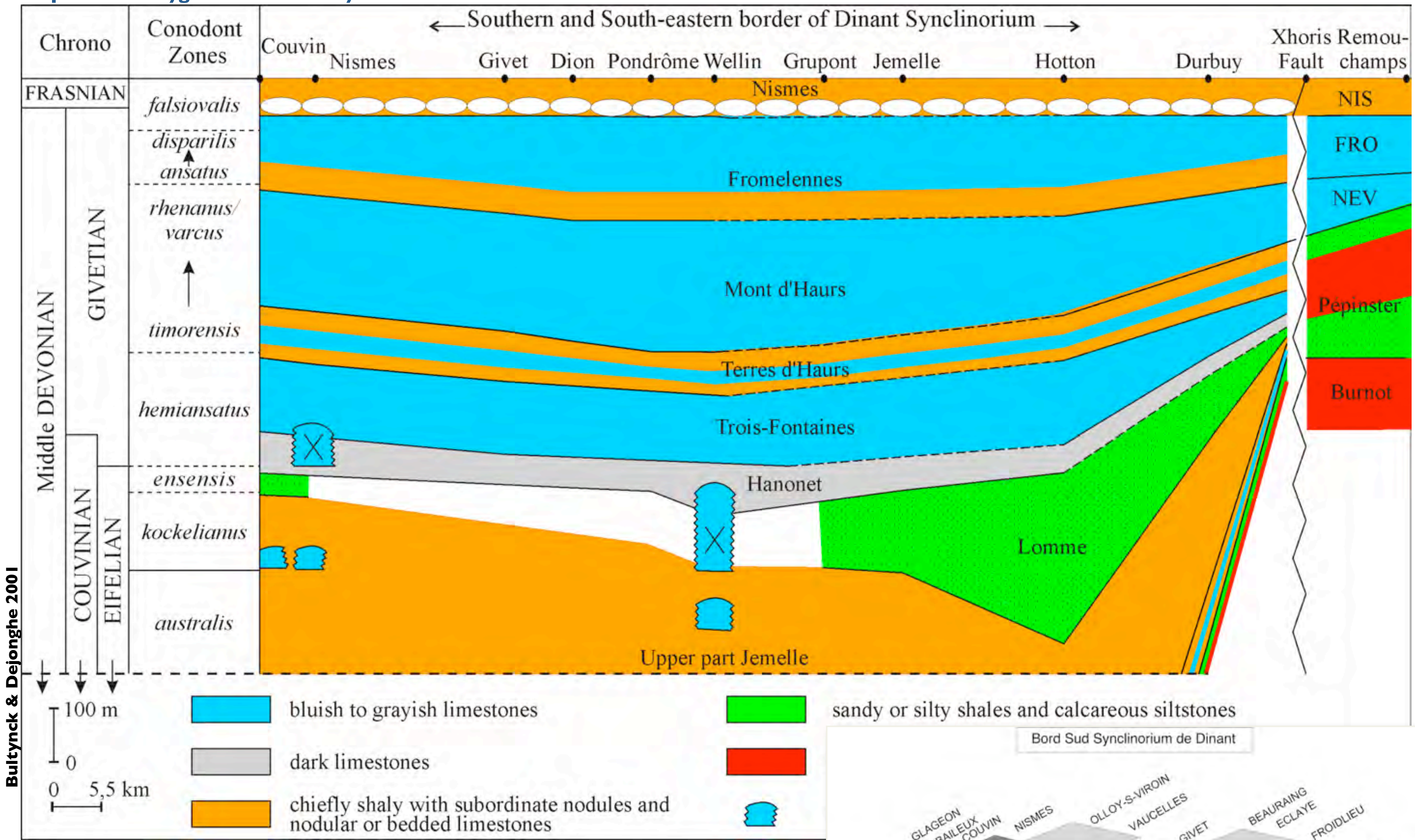
cyanobacteria

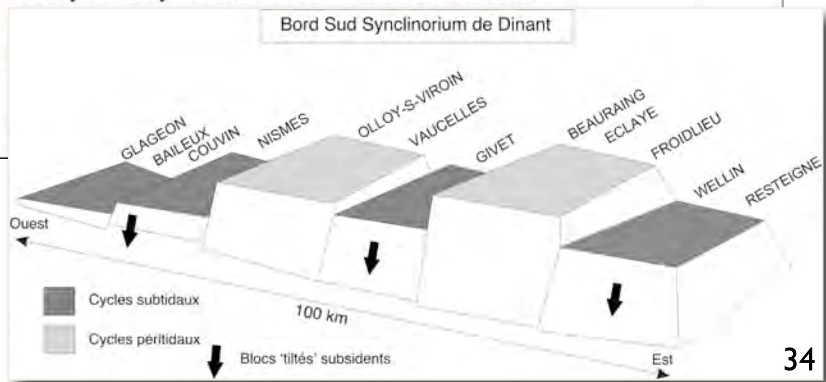


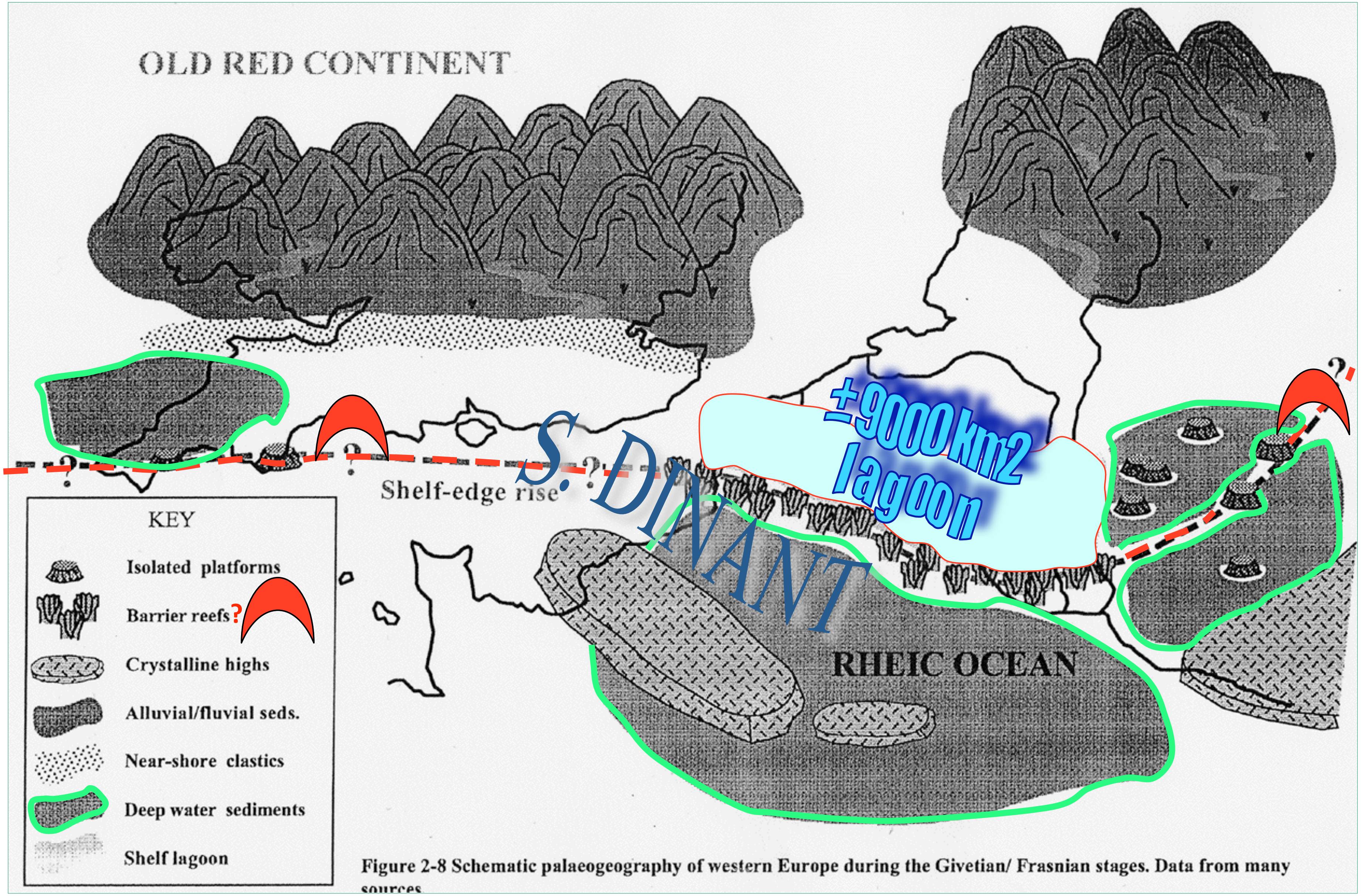
calcispheres (lagoon)



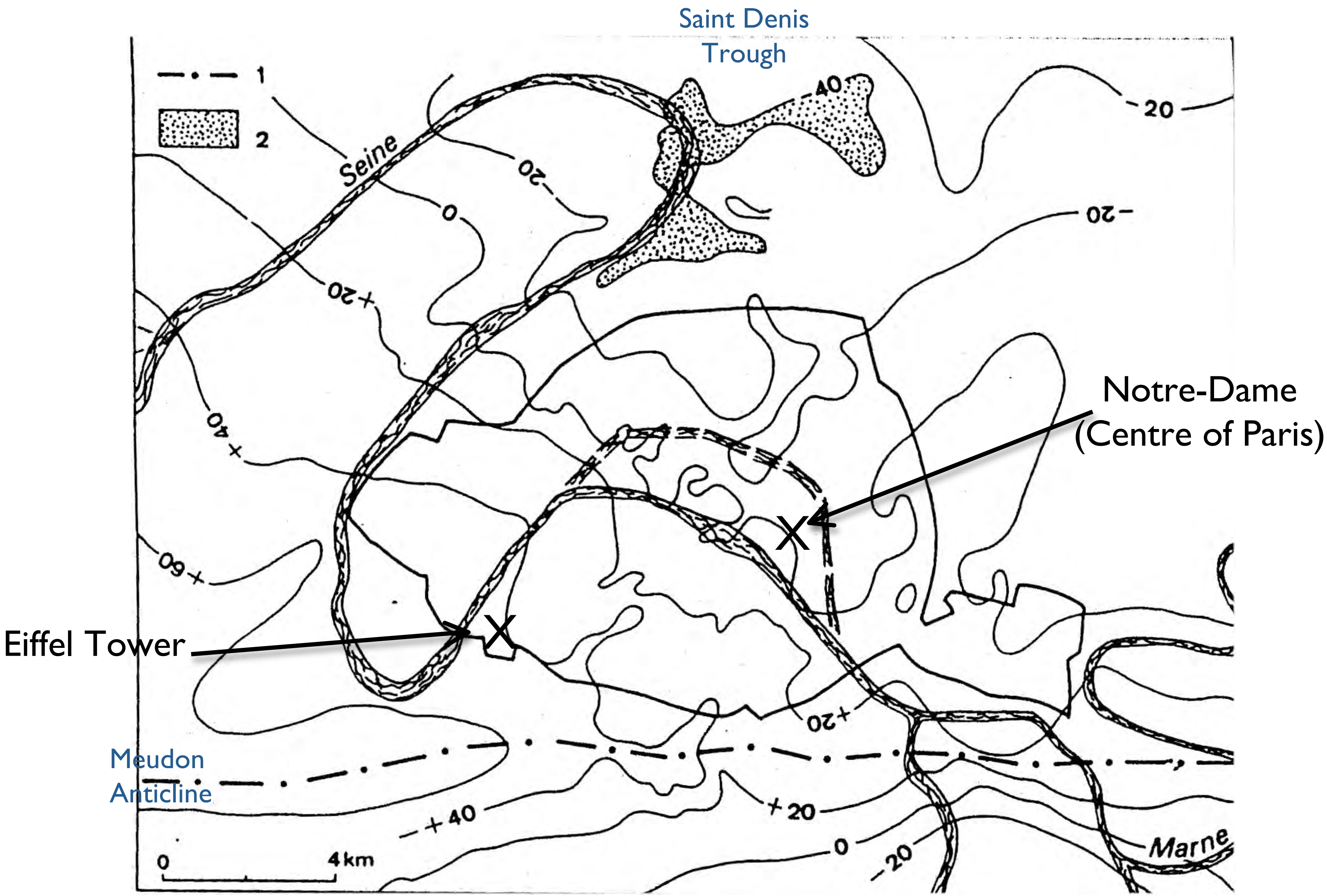
Std Zonation
AND
parallel *Polygnathus* and *Ancyrodella* zonation







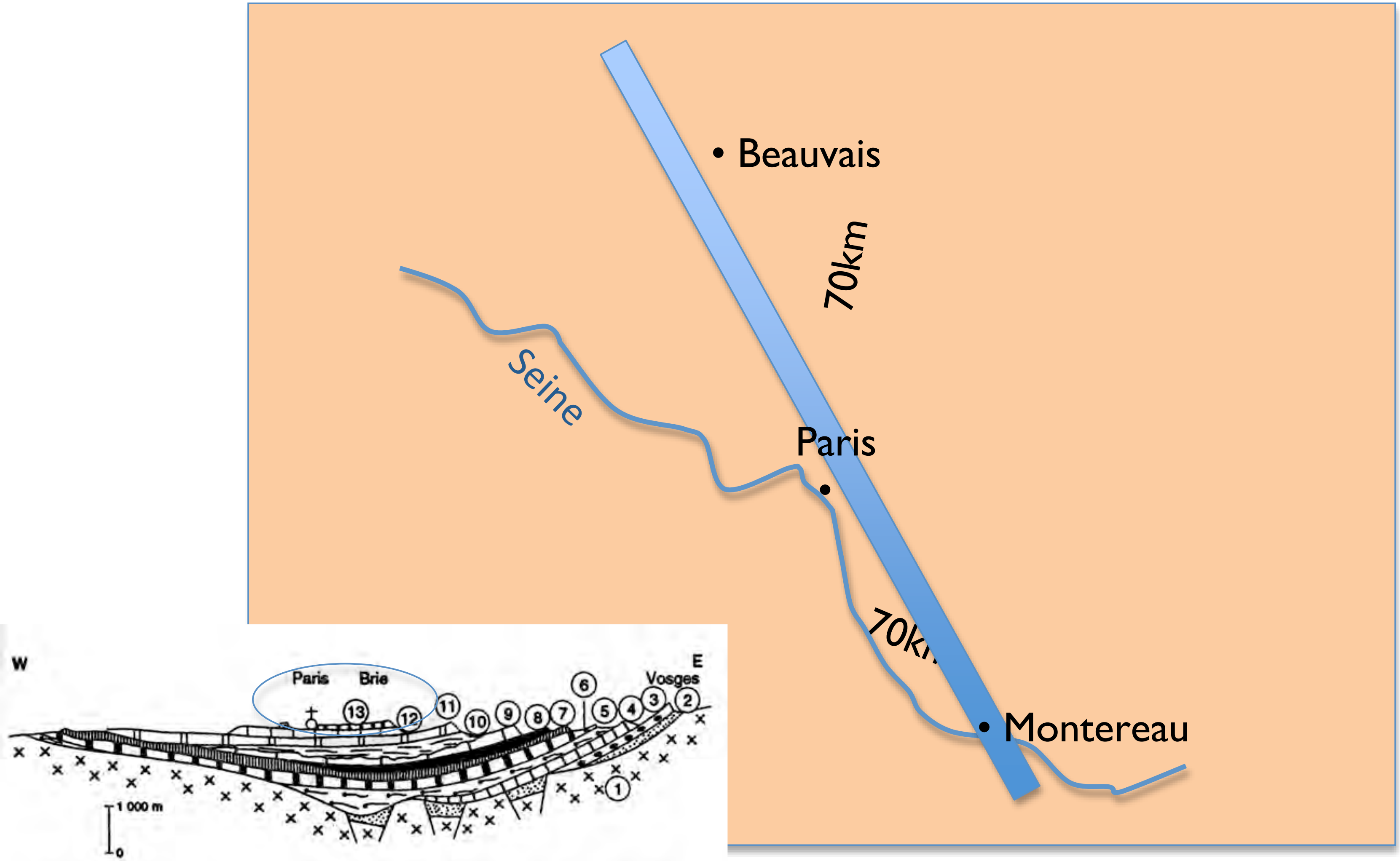
Before the folding… (shortening of 33% in Burchette, 1981)



Structural map of Paris area (base of Lutetian, middle Eocene)

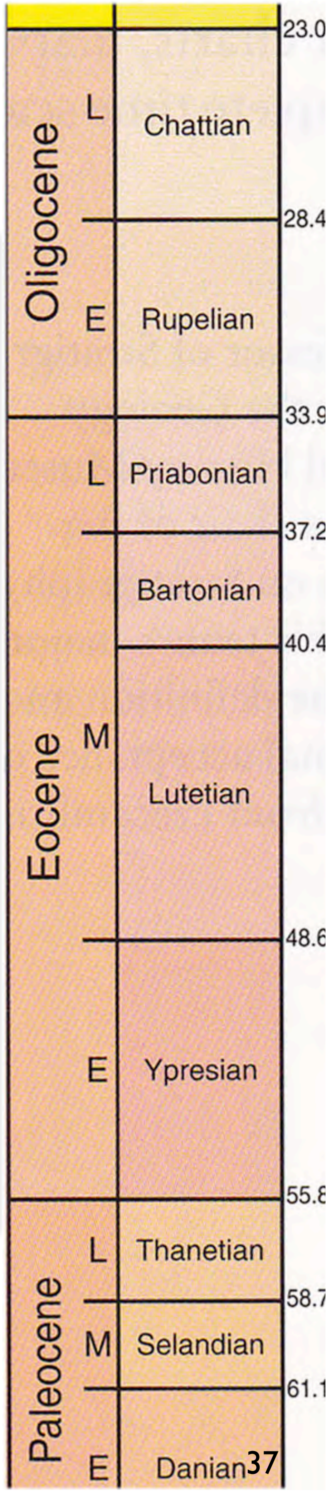
Slight N-dip 1/3° i.e. 100m/15km from Meudon Anticline to Saint Denis Trough

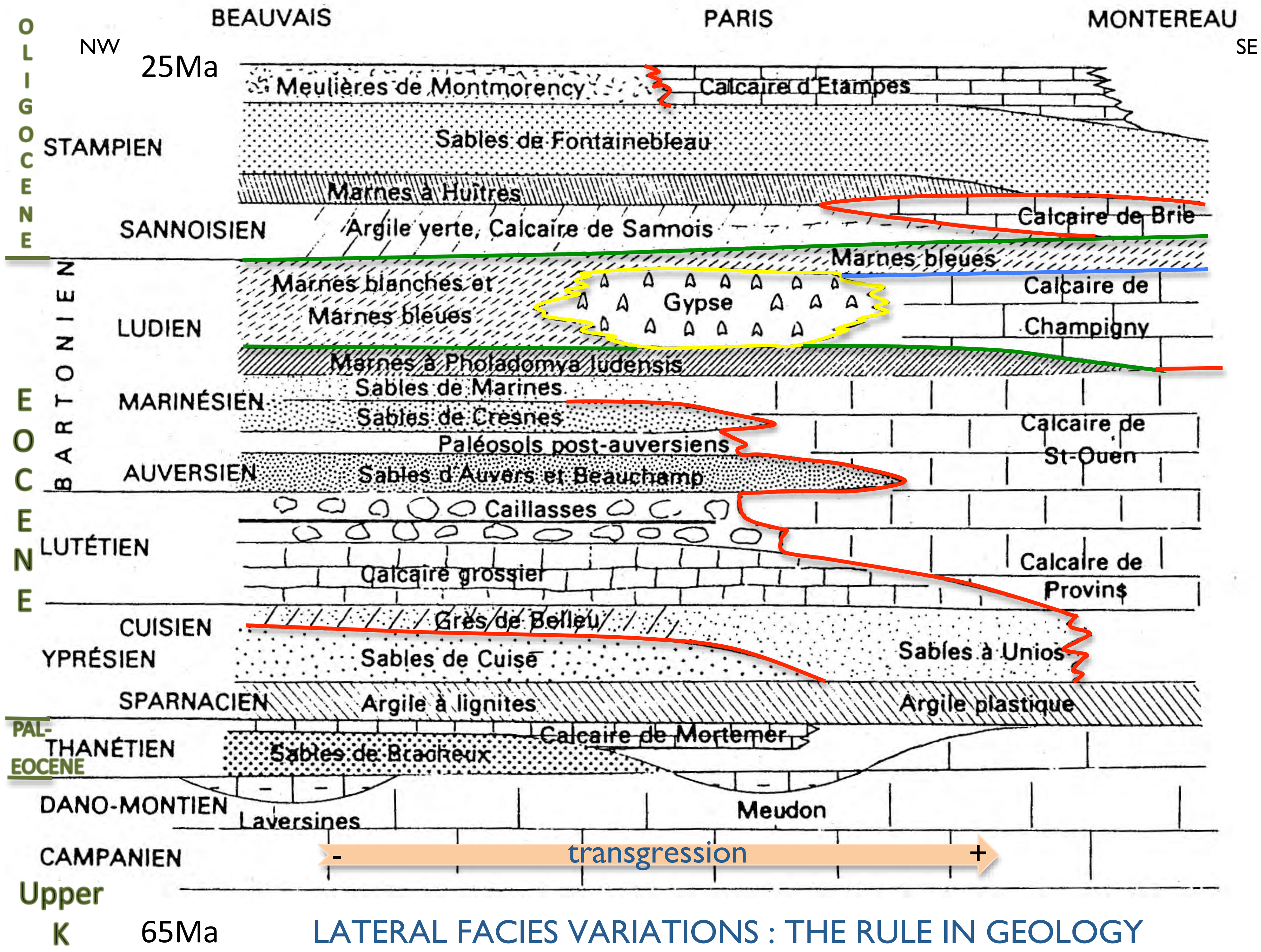
'SMALL AREA' in PARIS BASIN



1. Socle antépermien
2. Permien
3. Grès bigarré (Trias)
4. Muschelkalk
5. Trias supérieur
6. Jurassique inférieur
7. Aalénien-Bathonien (côte de Moselle)
8. Callovien-Oxfordien (côte de Meuse)
9. Kimméridgien-Portlandien (côte des Bars)
10. Crétacé inférieur
11. Crétacé supérieur (côte de Champagne)
12. Éocène (côte de l'Ile-de-France)
13. Oligocène

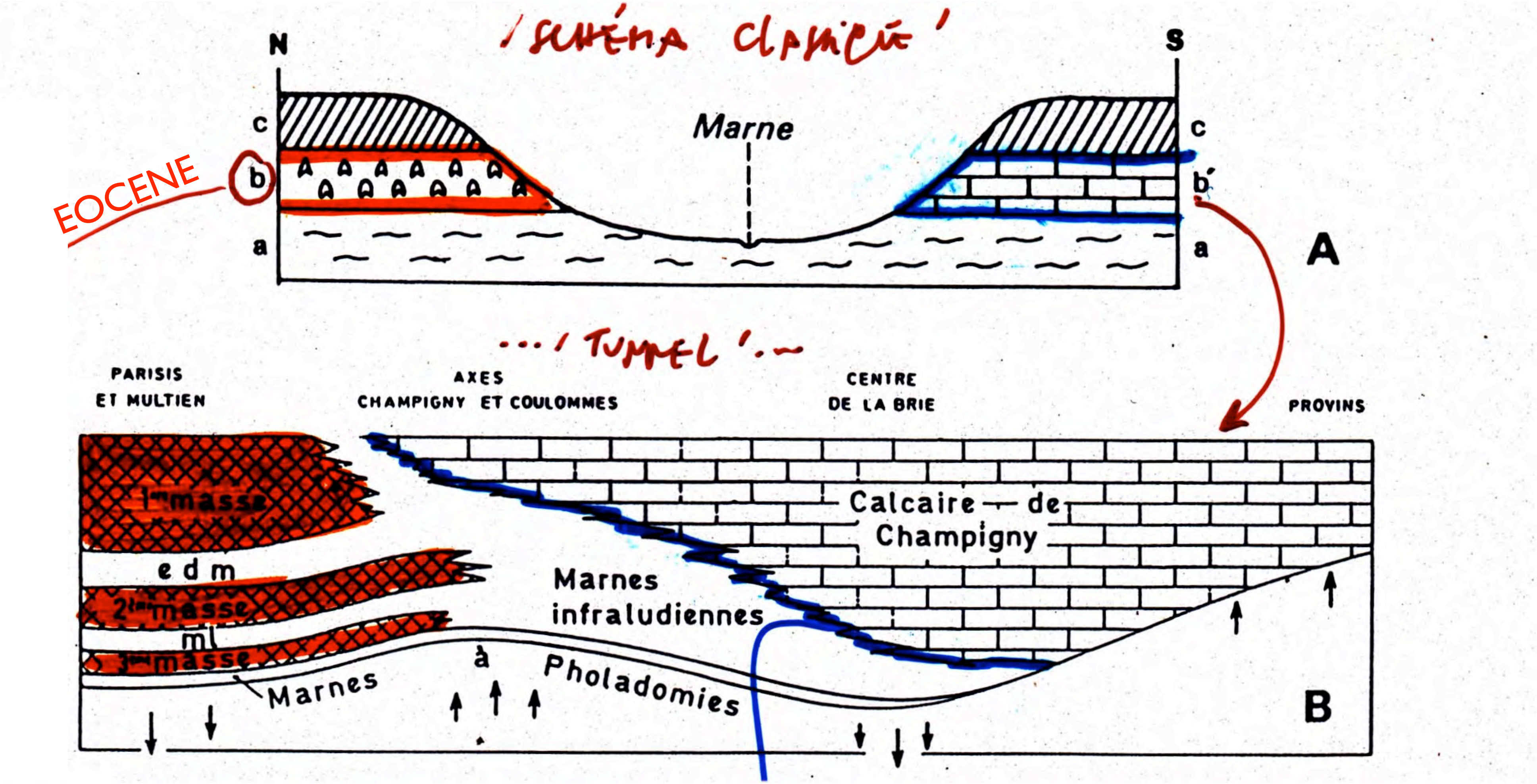
Elmi & Babin 2006





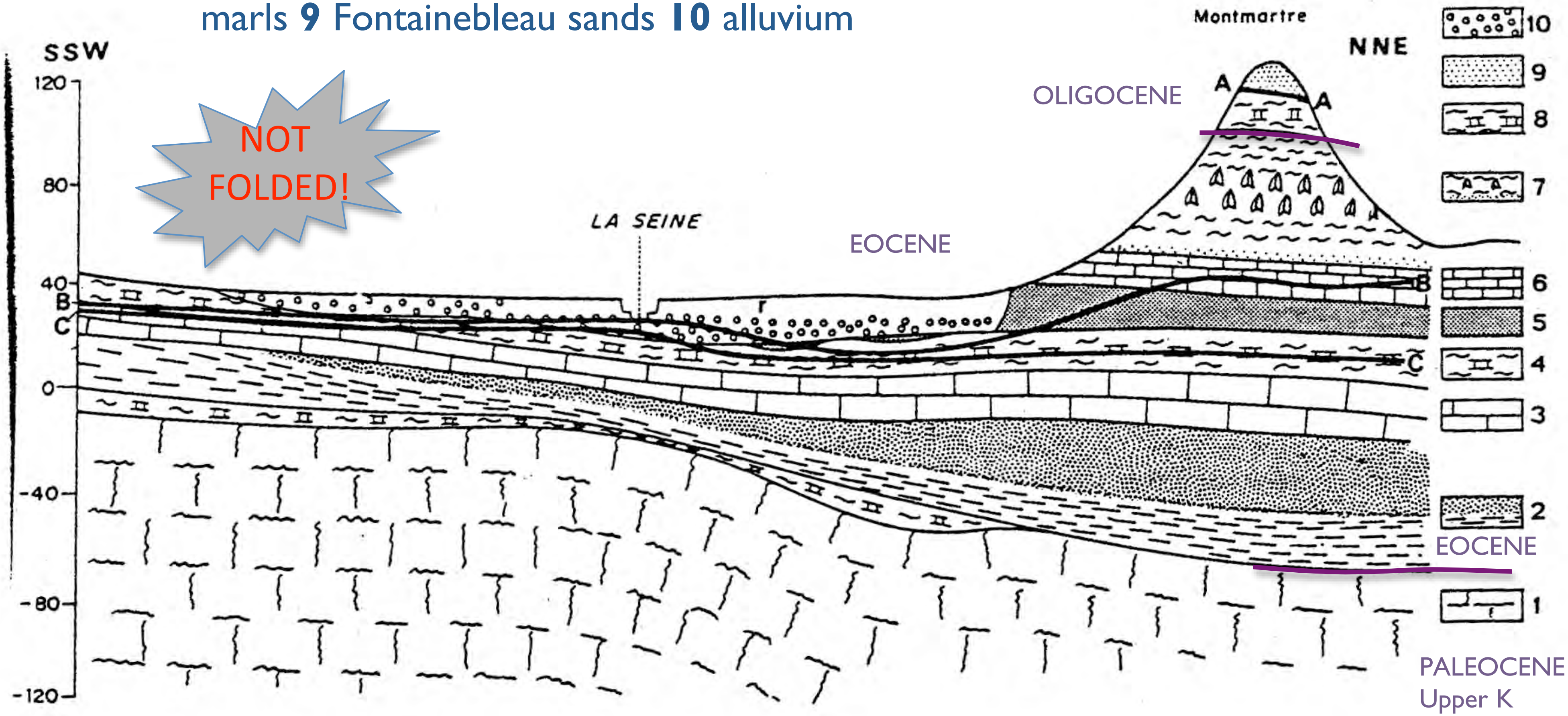
LATERAL FACIES VARIATIONS : THE RULE IN GEOLOGY

CORRELATION BY CONTINUITY



Validated by later true facies interpenetration observation (Chalifert tunnel, 1974)

1 Meudon chalks-marls **2** Ypresian clays-sands **3** coarse limestone **4** marls and 'caillasses' **5** Beauchamp sands **6** St-Ouen limestone **7** Monceau sands with marls and gypsum **8** green clays and osyter marls **9** Fontainebleau sands **10** alluvium



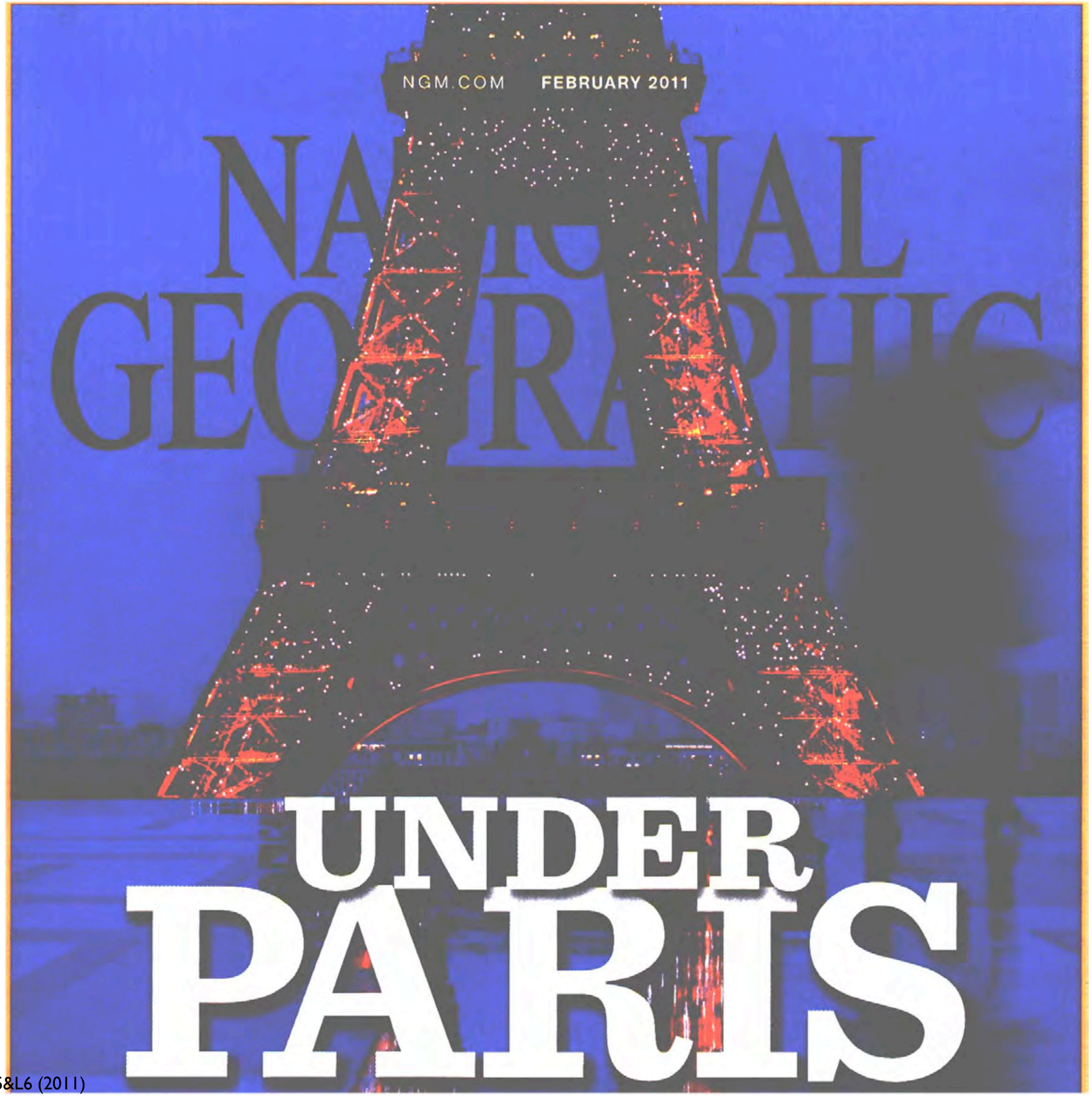
Position of the different phreatic water tables at Paris

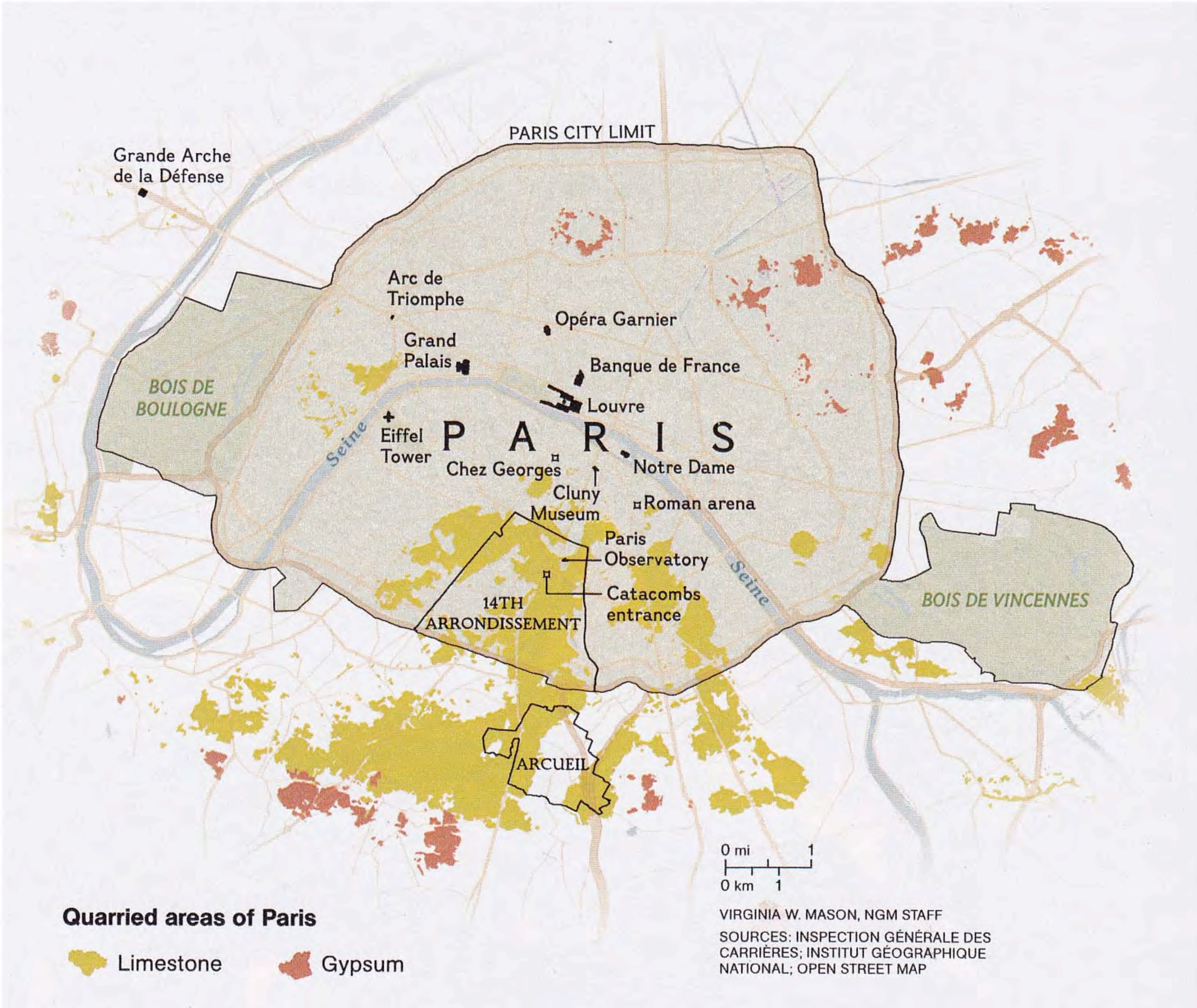
AA perched water table (base of Fontainebleau sands)

BB general water table

CC water table in the Ypresian sands

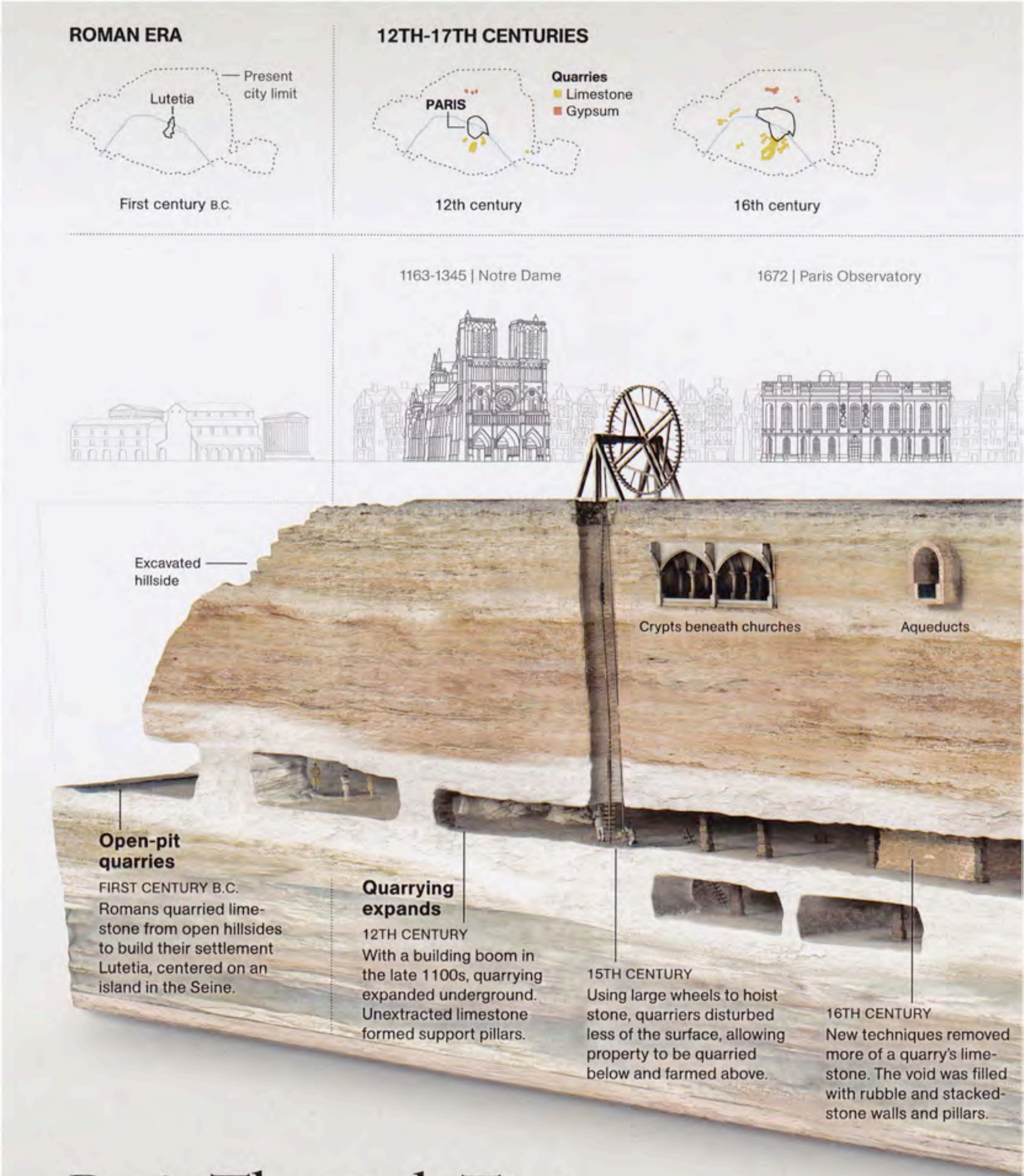
GYPSUM QUARRY AT ROMAINVILLE, Paris (1906)


NGM.COM FEBRUARY 2011
NATIONAL GEOGRAPHIC
UNDER PARIS



City With a Subconscious As Paris grew from its ancient heart near Notre Dame, limestone quarries that had once been outside the city—and had provided stone for the cathedral and other structures—were built over. Trespassing *cataphiles*, like the student at right, venture into this buried past for the thrill of it; some draw their own elaborate maps of its intricacies.

2011



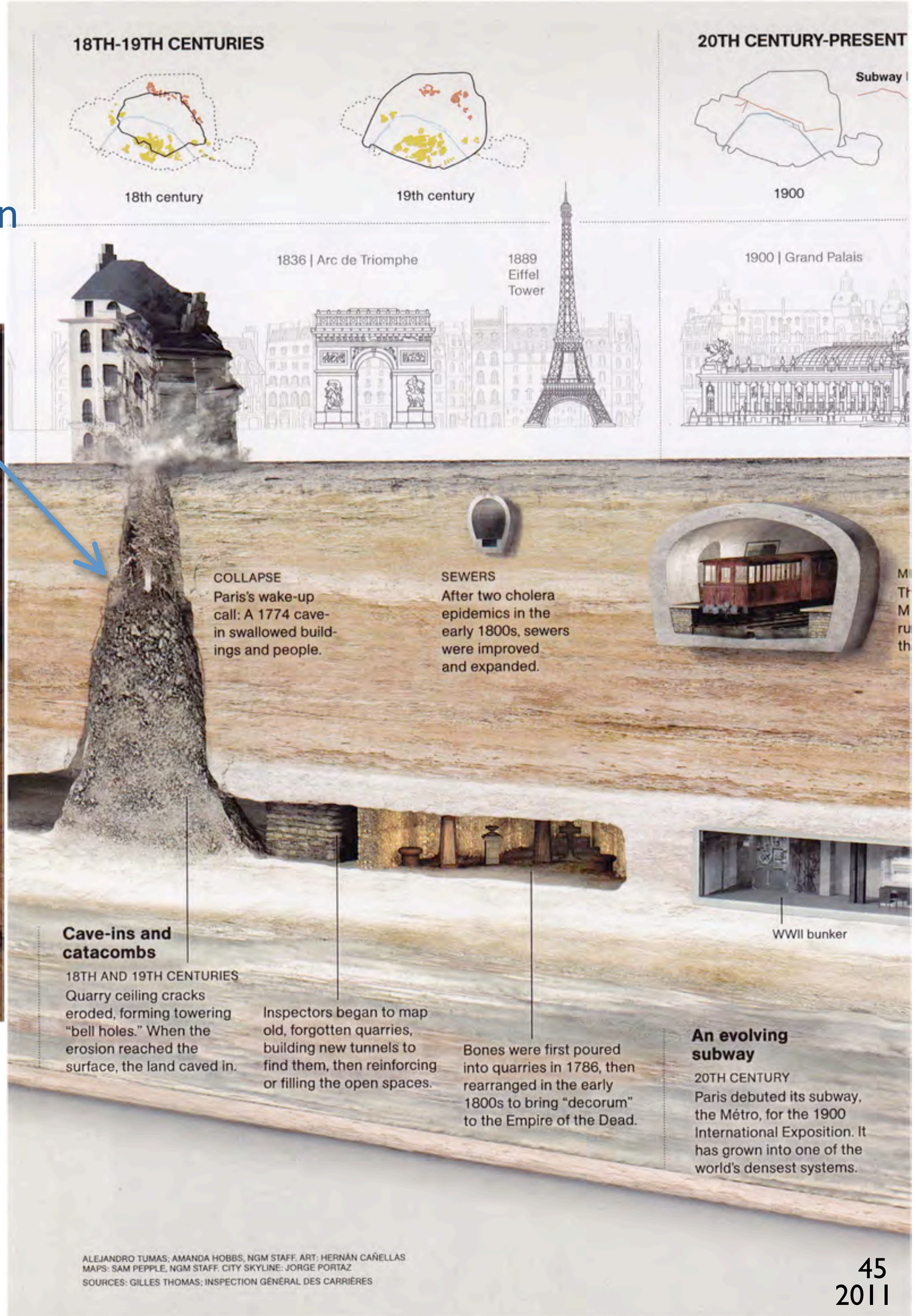
Paris Through Time

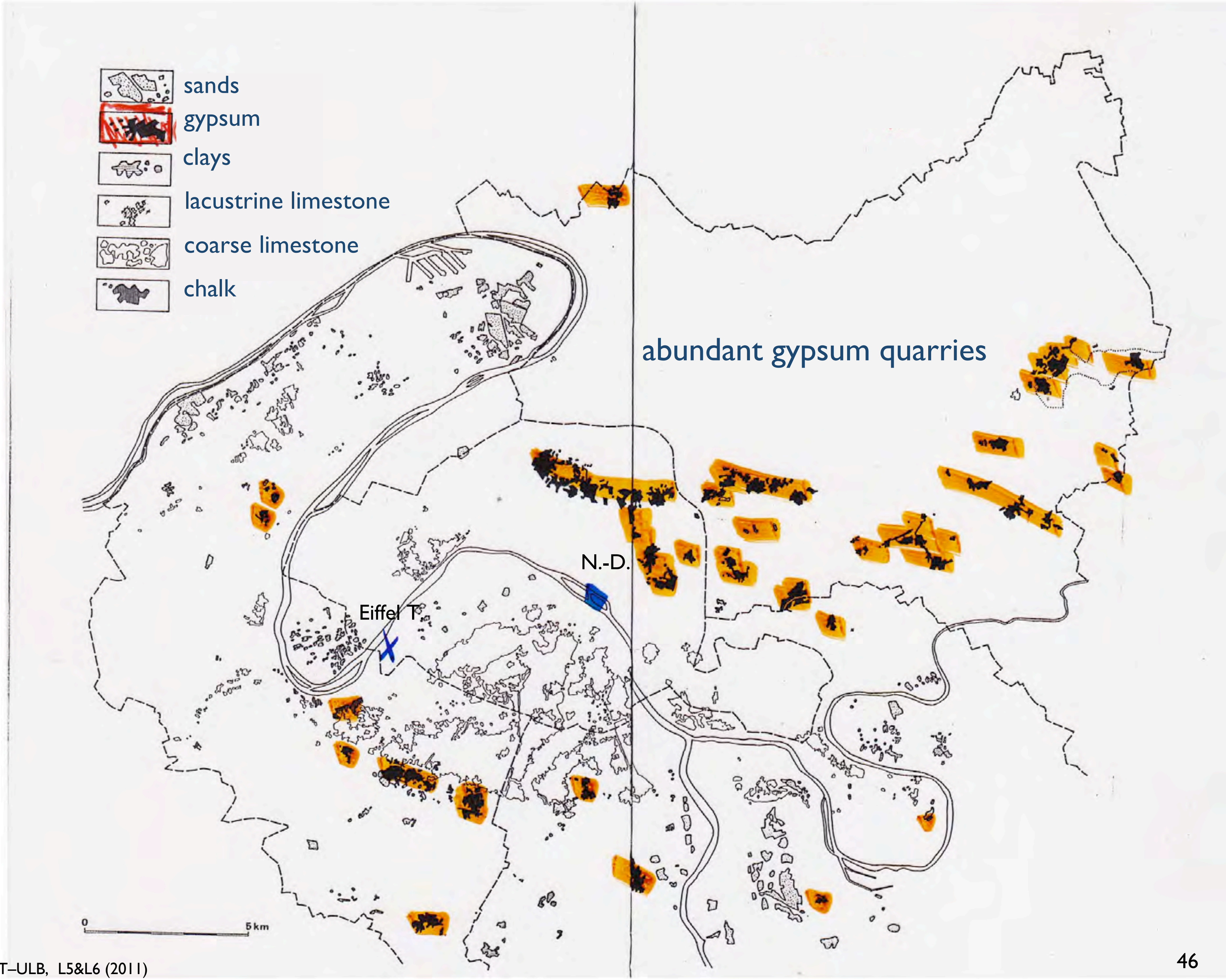
Century by century, the city's underbelly took on a geography all its own. The extent of the limestone quarries, or *carrières*, beneath Paris was unknown until a deadly collapse in 1774 prompted Louis XVI to create a department to map them. The Inspection Général des Carrières (IGC) is still at work today, monitoring the maze of tunnels it created to find and reinforce the quarries. By 1860 the last limestone quarries had closed; gypsum was quarried, for plaster of paris, until 1873 (maps at top).

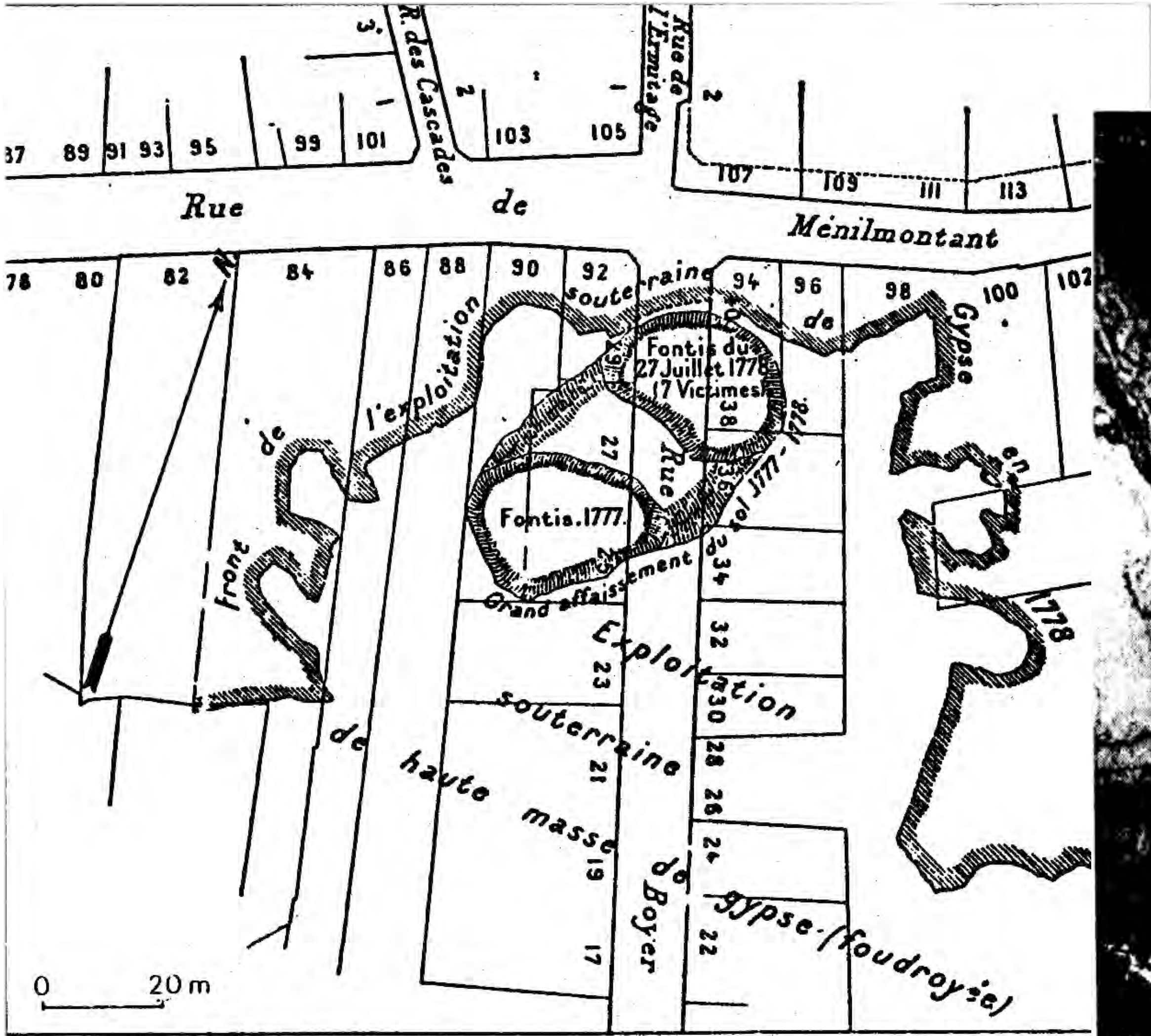
2011

It can explain other geologic settings
Exemple: Cretaceous in Belgium
(Mons basin)
⇒ Iguanodons (crocodiles, turtles) Wealdian
(Bernissart)

=> Underlying Carboniferous
+ geothermal energy




sands
gypsum
clays
lacustrine limestone
coarse limestone
chalk
abundant gypsum quarries
N.-D.
Eiffel T.
0
5km



‘FONTIS’ = collapse

1777 and 1778 on the map

EOCENE

(Bartonian)

Height 15m
Diameter 15m
Volume 1500 m^3

(Lutetian)

(ancient ages, ancient nomenclature)

TYPE LOCALITIES — MAIN FACIES — LATERAL FACIES

Période	Étage et sous-étage		Localités types	Faciès principaux	Faciès latéraux
25 Ma		Aquitanien		Calcaire de Beauce	Calcaire de l'Orléanais
OLIGOCÈNE	STAMPIEN s.l.	Stampien s.s.	Étampes (Essonne)	Calcaire d'Étampes Sables et grès de Fontainebleau Marnes à Huîtres	Meulière de Montmorency
37 Ma		Sannoisien	Sannois (Val-d'Oise)	Calcaire de Sannois Argile verte Glaises à Cyrènes	Calcaire de Brie
	BARTONIEN	Ludien	Ludes (Marne)	Marnes blanches de Pantin Marnes bleues d'Argenteuil Gypse et marnes intercalées Marnes à *Pholadomya ludensis*	Calcaire de Champigny et de Château-Landon
		Marinésien	Marines (Val-d'Oise)	Sables de Marines Sables de Cresnes	Calcaire de Saint-Ouen
		Auversien	Auvers (Val-d'Oise)	Sables et grès de Beauchamp Sables d'Auvers	Calcaire de Nogent-l'Artaud Argile de Saint-Gobain
ÉOCÈNE	LUTÉTIEN	supérieur	Lutèce (Paris)	Caillasses et biozone à *Discorinopsis kerfornei*	
		moyen		Calcaire à Milioles, *Orbitolites complanatus et Num. variolarius*	Calcaire de Provins et de Morancez
		inférieur		Calcaire grossier à *Num. laevigatus*	
	YPRÉSIEN	Cuisien	Cuise (Oise)	Grès de Belleu Sables de Pierrefonds — *Num. planulatus* Sables de Cuise	Argile de Laon Sables à Unios et Térédines
		Sparnacien	Ypres (Belgique) Épernay (Marne)	Argile à lignites du Soissonnais Argile plastique	Falun de Pourcy
55 Ma PALÉOCÈNE	THANÉTIEN		Isle of Thanet (Kent)	Sables de Bracheux Tuffeau de La Fère	Calcaire et Sable de Rilly Conglomérat de Cernay Travertin de Sézanne
	DANO-MONTIEN		Mons (Belgique)	Marnes de Meudon Calcaire « pisolitique »	
65 Ma CRÉTACÉ sup.	CAMPANIEN		Champagne de Saintonge	Craie blanche à Bélemnitelles	

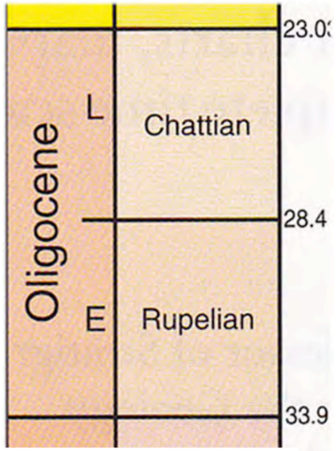
(ancient ages,
***ancient nomenclature*)**

SYNTHESIS FOR AN AREA

'Bruxellian' ← LUTETIEN

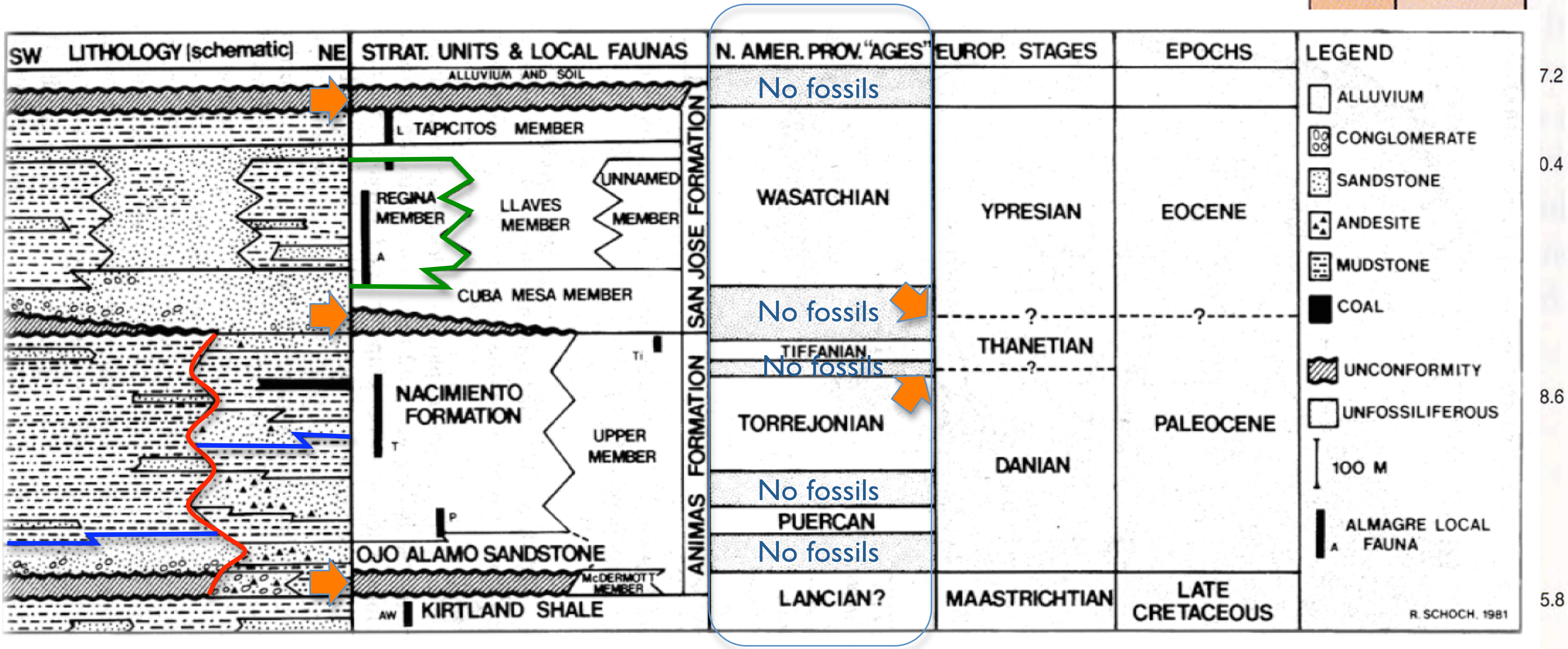
PÉRIODES		ÉPOQUES	ÉTAGE OU SOUS-ÉTAGE		FORMATIONS
QUATERNAIRE		HOLOCÈNE			Alluvions modernes
	10 000 ans	PLÉISTOCÈNE		Würm	Alluvions anciennes
				Riss	Limons des plateaux, loess
				Mindel	Cailloutis de Sénart
TERTIAIRE	2 Ma – NÉOGÈNE	PLIOCÈNE			Sables de Lozère
	5 Ma	MIOCÈNE			
	22 Ma – PALÉOGÈNE	OLIGOCÈNE (1)	STAMPIEN s.l.	Stampien s.s.	Meulière de Montmorency Sables de Fontainebleau Marnes à Huîtres
	35 Ma			Sannoisien	Calcaires de Brie et de Sannois Argile verte de Romainville
		ÉOCÈNE	BARTONIEN s.l.	Ludien	Marnes blanches Marnes bleues Masses et marnes du Gypse Marnes à Pholadomies
				Marinésien	4° masse de gypse et calcaire de Noisy-le-Sec Sables de Monceau Calcaire de Saint-Ouen Horizon de Mortefontaine Calcaire de Ducy
				Auversien	Sables de Beauchamp
			LUTETIEN		Marnes et caillasses Calcaire grossier
			YPRESIEN	Cuisien	
				Sparnacien	Sables supérieurs Fausses glaises Sables d'Auteuil Argile plastique Conglomérat de Meudon
	55 Ma	PALÉOCÈNE		Montien	Calcaires et marnes de Meudon
MESOZOIQUE	65 Ma	CRÉTACÉ SUP		Campanien	Craie blanche à silex

Epoch		Stage	Age
			23.0
Oligocene	L	Chattian	28.4
	E	Rupelian	33.9
Eocene	L	Priabonian	37.2
		Bartonian	40.4
	M	Lutetian	48.6
	E	Ypresian	55.8
Paleocene	L	Thanetian	58.7
	M	Selandian	61.1
	E	Danian	

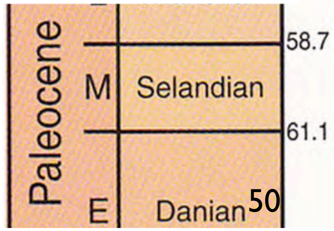


COMPOSITE STRATIGRAPHIC SECTION FOR A **LOCAL** SEDIMENTARY BASIN

Diagrammatic summary of the latest Cretaceous, Paleocene, and Eocene strata of the San Juan Basin, New Mexico

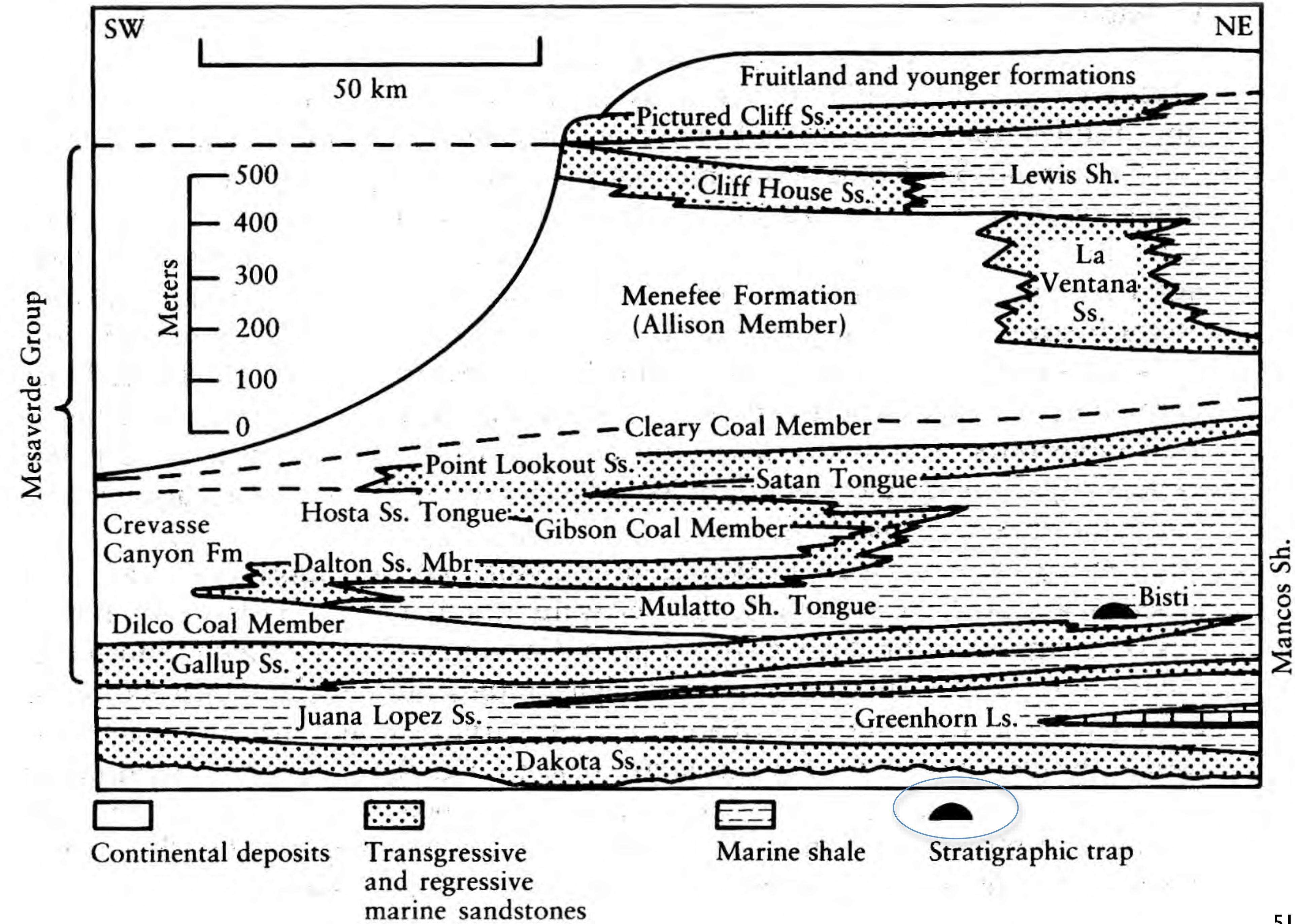


Same stratigraphic interval of Paris Basin!



Upper Cretaceous stratigraphic cross-section of the San Juan Basin, New Mexico

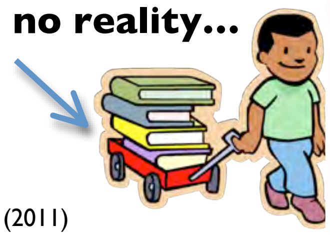
Dean & Sears 1956



Seismic record and interpretative cross-section through the Hohne oil field, Gifhorn Basin West Germany.

Oil is produced from the **Dogger** beds immediately below the Cretaceous unconformity .

The 'layer-cake' filling of the basins is too simple and has no reality…



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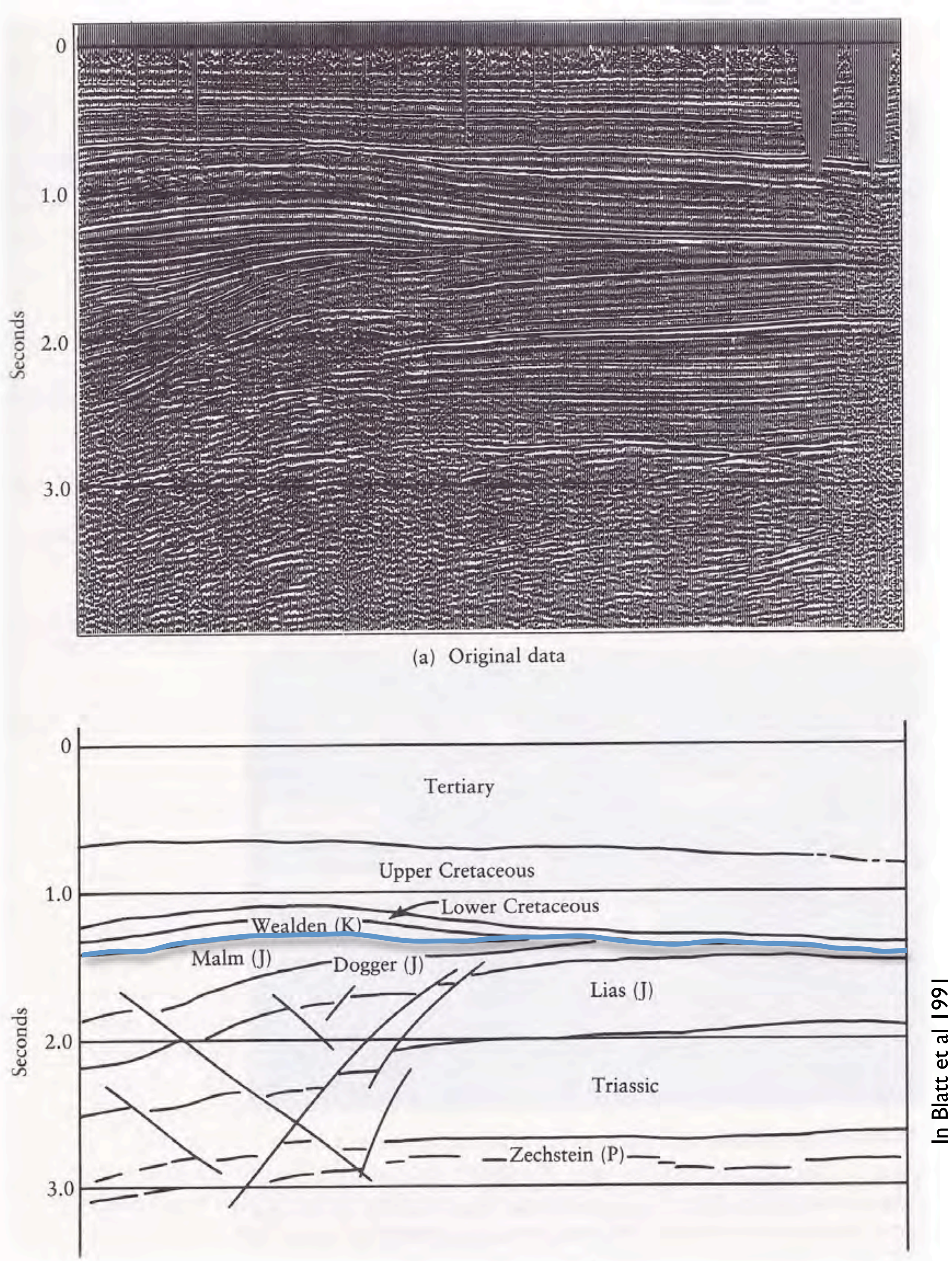
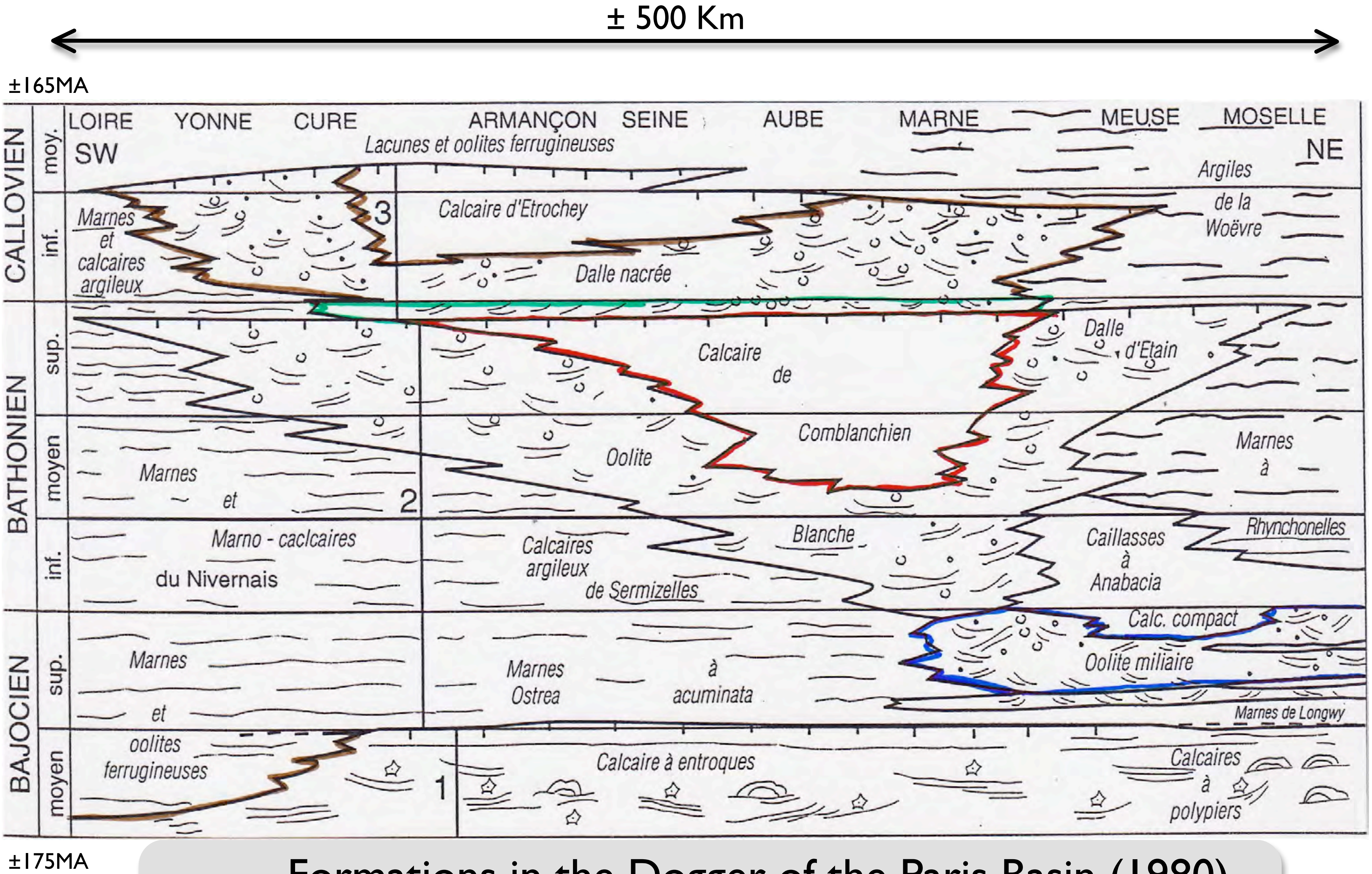


In Blatt et al 1991



Formations in the Dogger of the Paris Basin (1980)

Rock Reservoir: porosity, permeability *vs* lateral variations

3D-geometry + HR Seismic and ?outcrops

layer-cake organization is wrong

IN MOST OF THE CASES

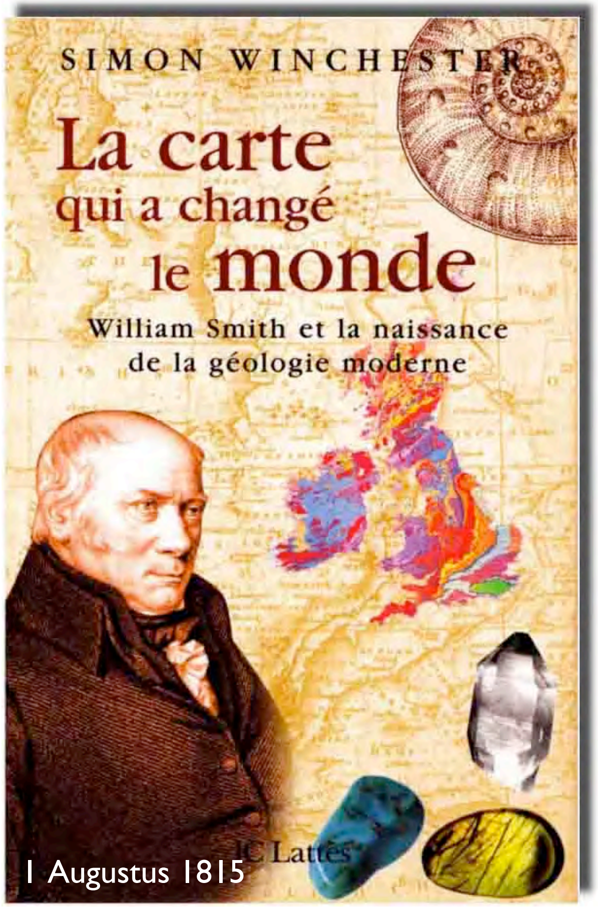
1900 Biostratigraphy based on

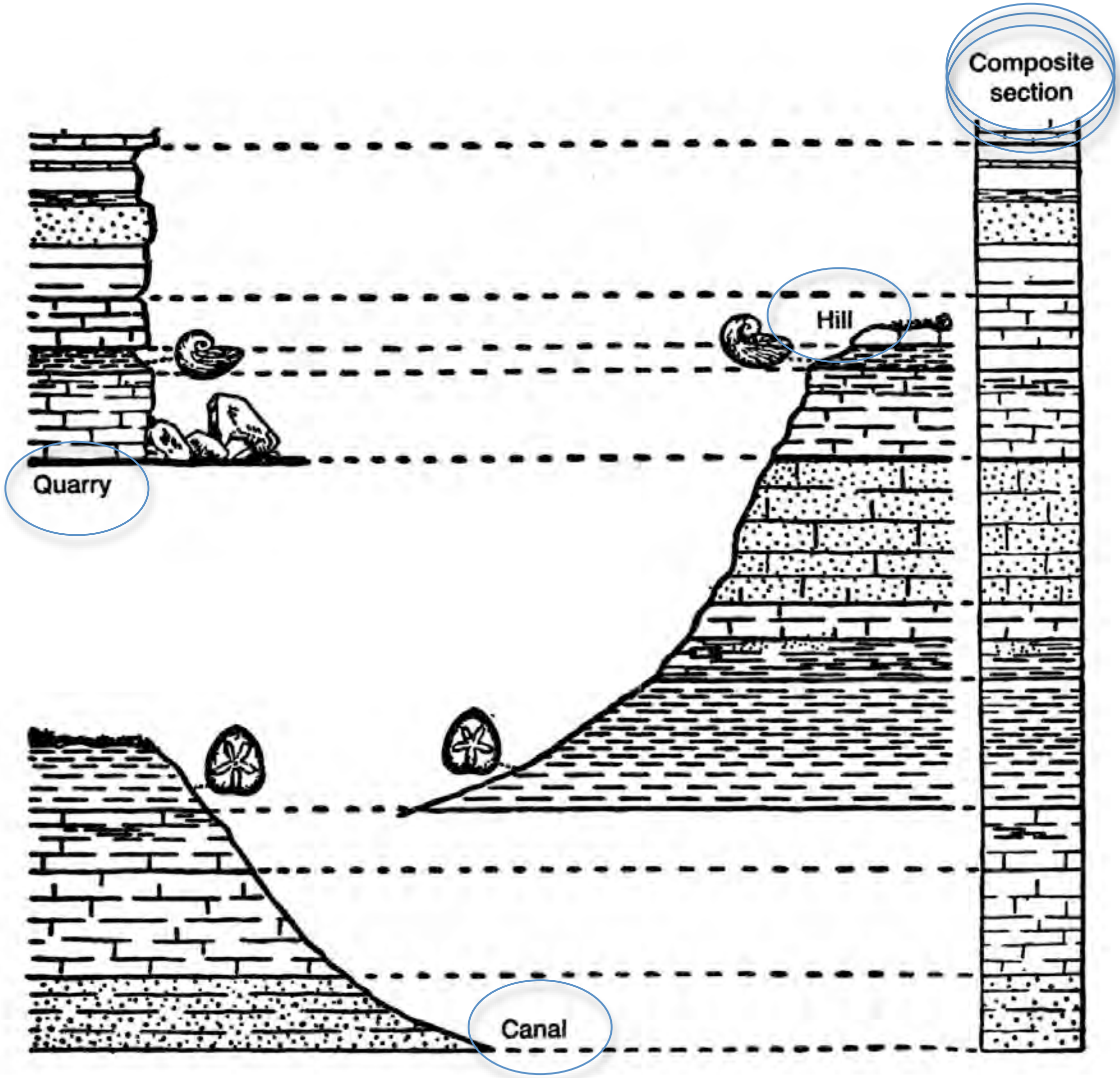
C. PRINCIPLE OF PALEONTOLOGICAL IDENTITY

• which consists to assume that each rock unit containing the same paleontological assemblage (= '**STRATIGRAPHIC FOSSILS**') has the same age
⇒ using these fossils, rock units could be placed in their correct stratigraphic position in scattered outcrops

• biostratigraphy is therefore the establishement of fossil-based successions and their use in stratigraphical correlations

• the recognition and use of '**zone**' fossils is fundamental to biostratigraphical correlation => they are several types of fossil zones (….). The base of each zone is defined by the appearance of certain new species, and its top by the by the appearance of certain new species that defines the base of the succeeding zone (…)





William Smith's (1769-1839) use of 'guide' fossils and faunal succession to match beds, hill and canal sections, combine to give the **COMPOSITE** SECTION (in Brookfield, 2004)

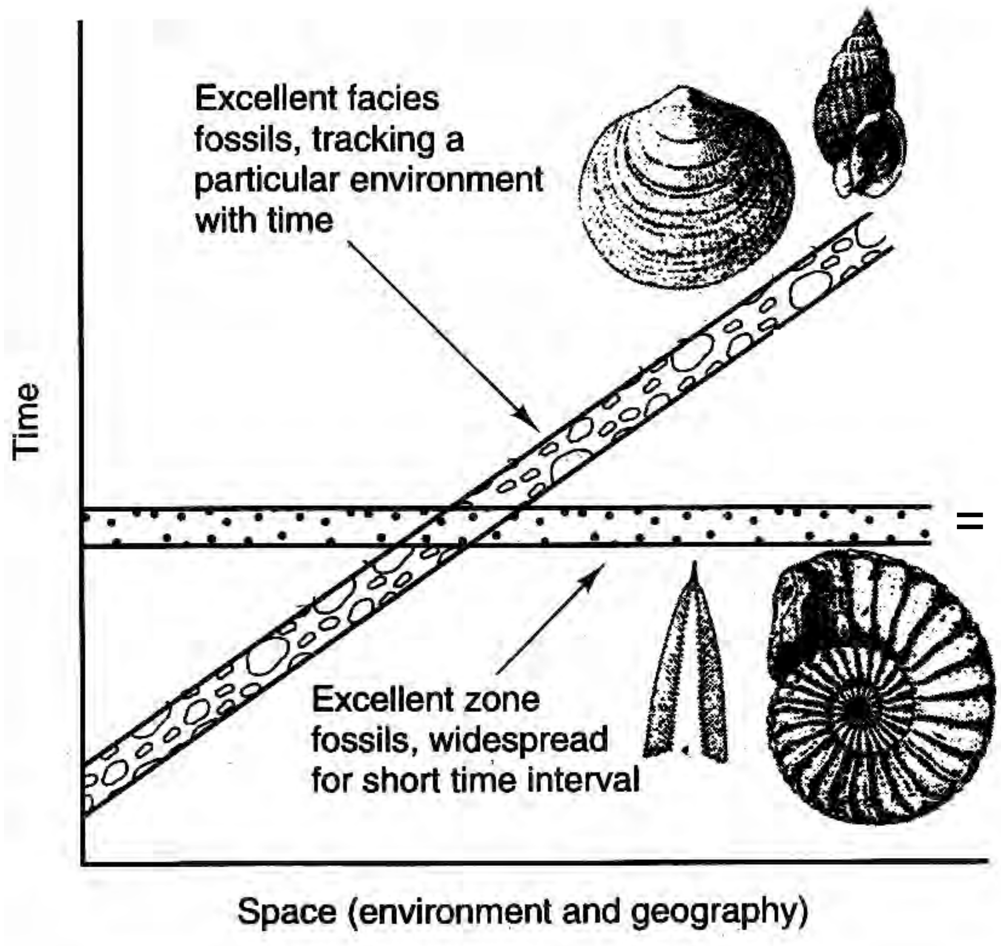
WE MUST THEREFORE DISTINGUISH BETWEEN

⇒ STRATIGRAPHIC or ZONE FOSSILS

(± independent of the environment)

⇒ FACIES FOSSILS

(dependent of the environment 'O.R.S-N.R.S'



= 'guide' or 'marker' fossils

STRATIGRAPHICAL (MICRO)FOSSILS
= 'GUIDE or MARKER' or ZONE FOSSILS

What are the characteristics of good zone fossils? They should ideally highlight the smallest time intervals over the widest area

• wide paleogeographic range allowing long distance correlations
=> only **PELAGIC** or **PLANKTONIC** organisms fit this requisite, the others (benthonic) are associated with too local environments

• limited vertical time range of species
⇒ rapidly evolving lineages

• relatively common, capable of being preserved

• easily to identify

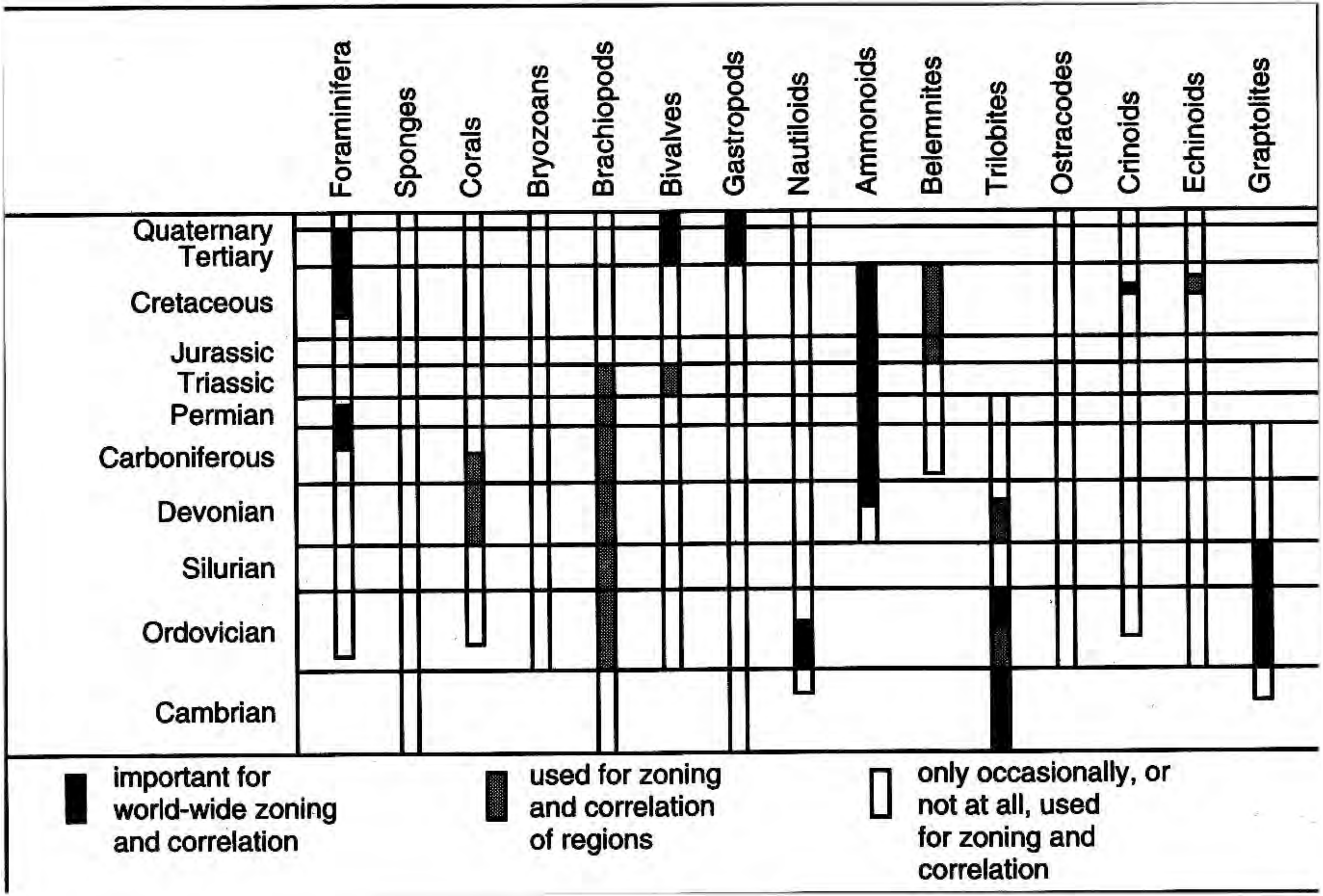
STRATIGRAPHICAL (MICRO)FOSSILS

= 'GUIDE, MARKER' or ZONE FOSSILS

PELAGIC or PLANKTONIC are the best

⇒ floating, swimming (or flying) forms are less likely to be controlled by specific bottom or surface conditions, and are more likely to be carried by waves, currents, or winds into graves in a variety of different environments.

However, their distribution may be controlled by environmental differences in water masses and by where they get their food.

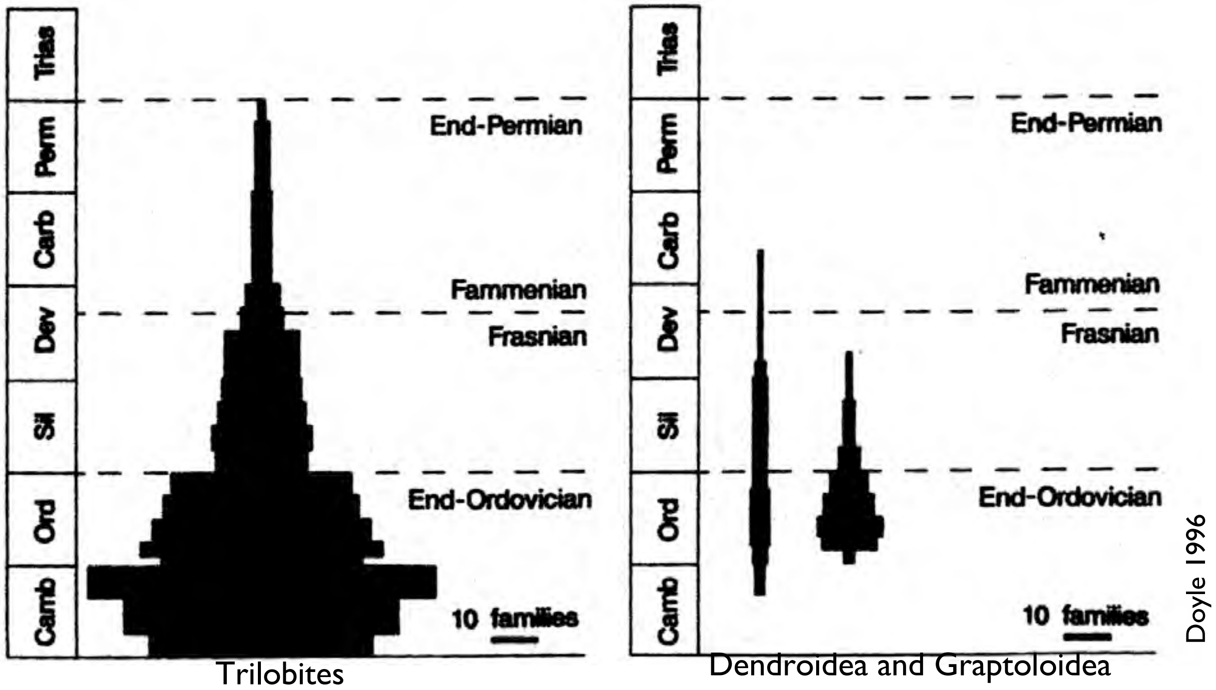


MAIN BIOSTRATIGRAPHICALLY USEFUL INVERTEBRATE FOSSIL GROUPS

MACROFAUNA

PALEOZOIC

=> Trilobites (Cambrian…), Graptolites (Ord-Sil), Goniatites (Dev) …



MESOZOIC

⇒ Ammonites (Cephalopods) : 10,000 fossil species >< 400 present day

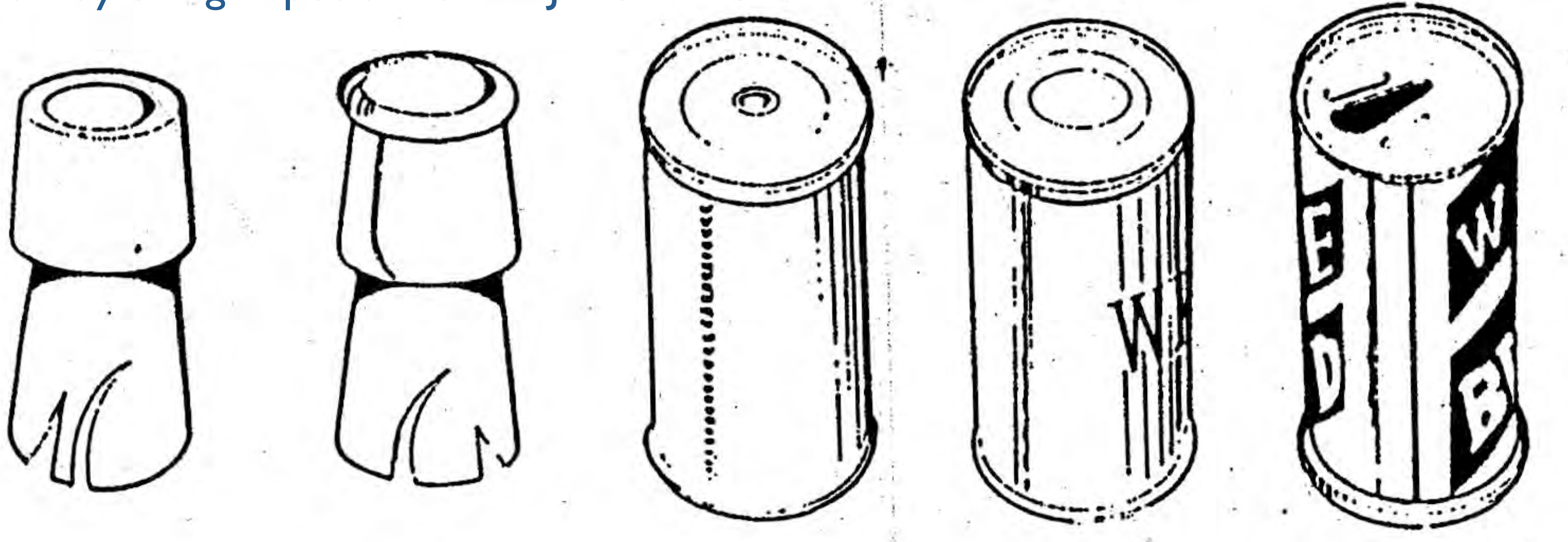
CENOZOIC

=> rare

Q? What could be today the best (object) stratigraphic fossil?? = CC!!!

INDEX FOSSIL?

Beer cans of these various kinds have actually been used to date sediments presently being deposited off BAJA CALIFORNIA



(a) (b) (c) (d) (e)

< 1900 — 1900 — ~1920 — ~1930 — 1967 ---

Figure 7.3 Beer bottles and beer cans considered as stratigraphical palaeontology: (a) hand-made bottle for cork; (b) machine-made bottle for metal cap; (c) early tin can with soldered joints and unpreserved paper label; (d) can sealed by crimping with label printed on metal; (e) with tear-off metal flap ((a) to (d) after Hunt, 1959)

INDEX FOSSIL?

= FACIES FOSSILS ?

- very abundant on the desert surfaces of the American south-west
- presumably rare in deep-sea deposits

= ECOLOGICAL FOSSILS?

- less common in wine-drinking regions
- virtually unknown in strictly Islamic countries

= 'DIACHRONIC' FOSSILS ? (stratigraphical drawbacks of migration and diachronism)

- the beer can evolved in N-America in the 1920s and 1930s and did not reach Europe after WWII except as erratic specimens

= EVOLUTIVE FOSSILS ?

- severe competition as index fossils from the plastic bottle, which is more easily preserved

⇒ humorous French classification of the topmost stratigraphical stage into:

Poubellien supérieur (à plastique)
Poubellien inférieur (sans plastique)

or in other words : *Upper dustbinian/trashcanian (with plastic)*
Lower dustbinian/trashcanian (without plastic)

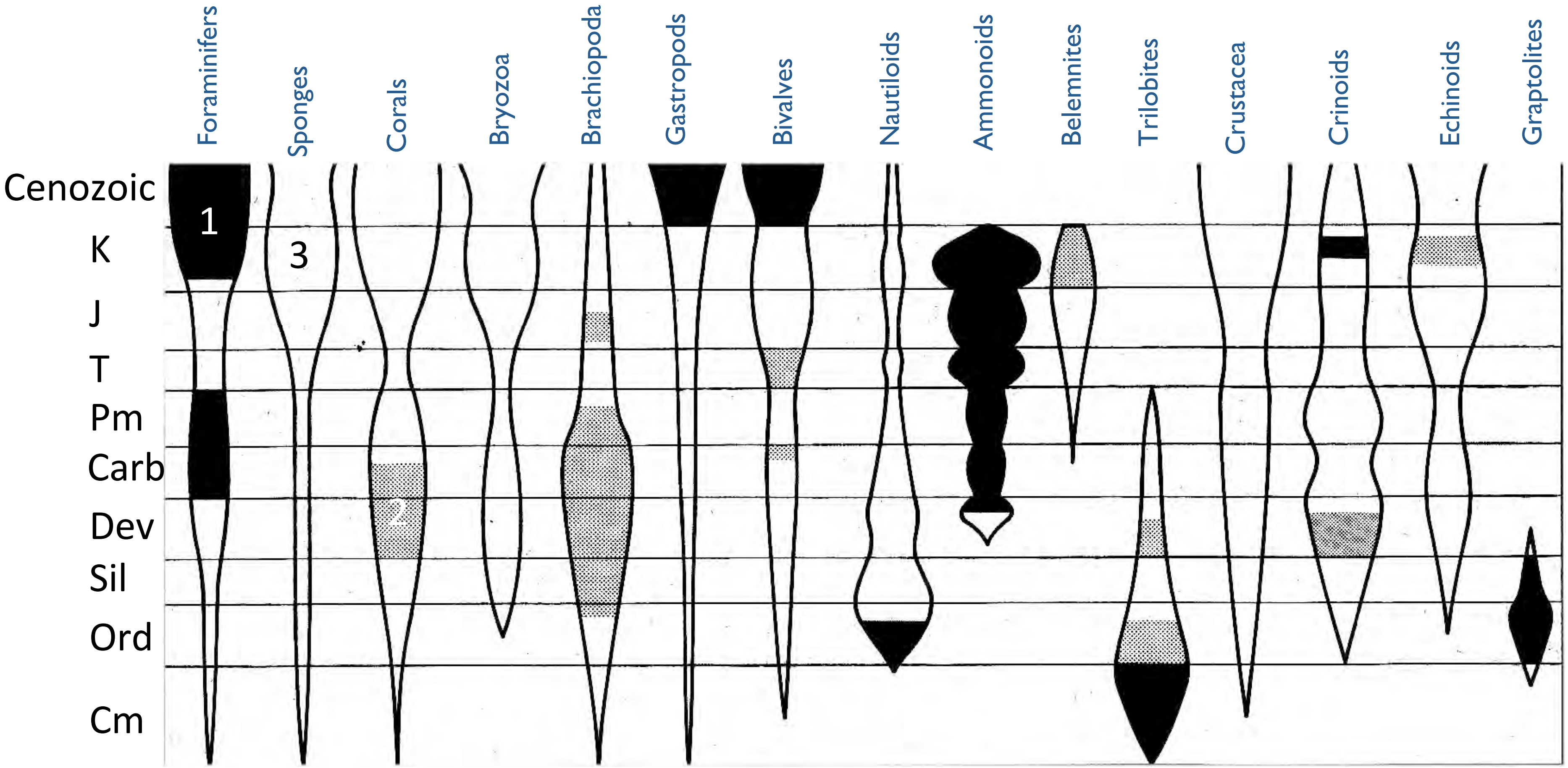
= 'TECHNICAL' FOSSILS ?

- see 'D-shaped' piece

conclusion

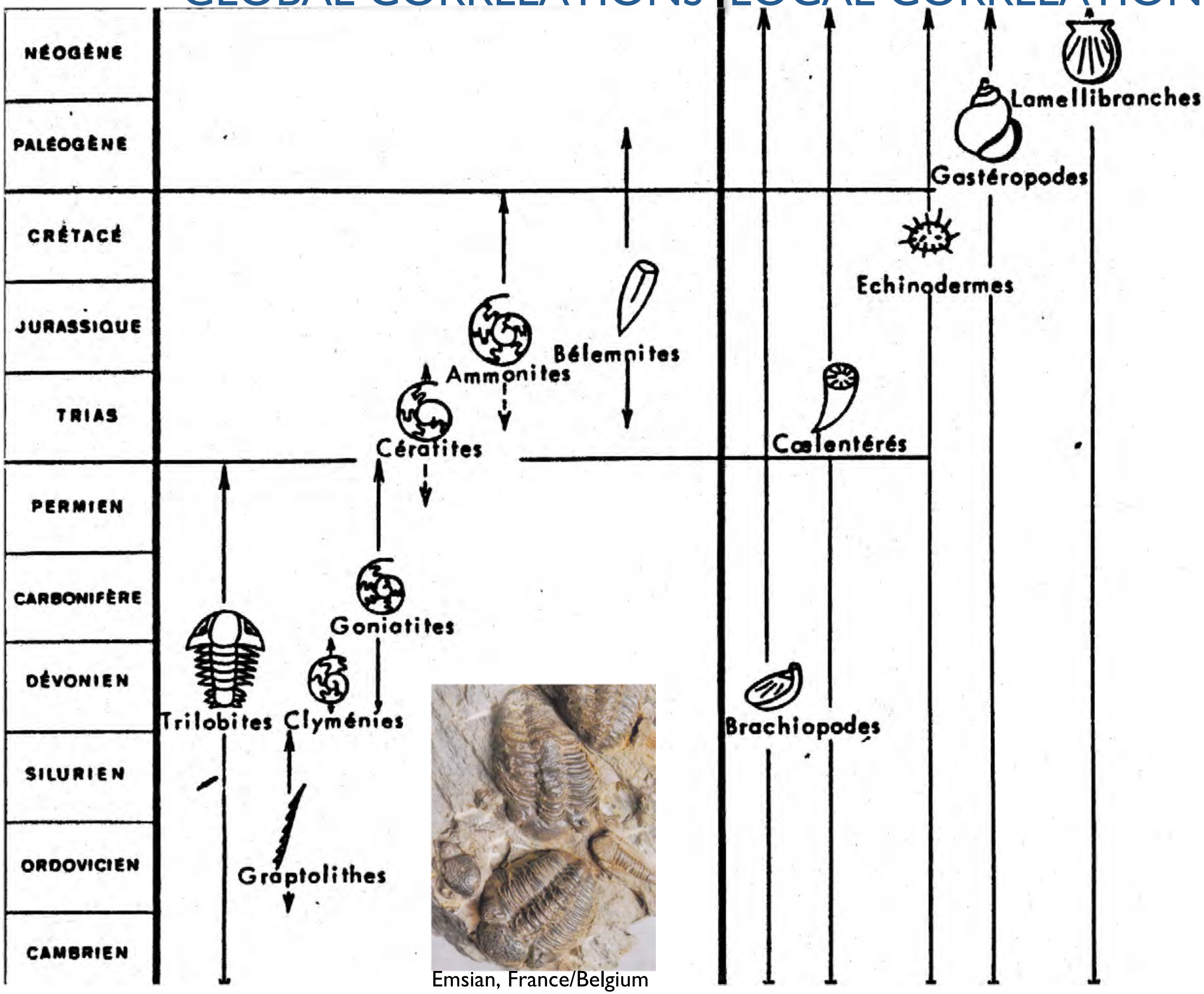
STRATIGRAPHIC FOSSILS <?> FACIES FOSSILS

RELATIVE BIOSTRATIGRAPHIC IMPORTANCE OF MAIN INVERTEBRATE GROUPS



1 important for long distance correlation
2 useful for regional correlations
3 not useful

GLOBAL CORRELATIONS | LOCAL CORRELATIONS



Emsian, France/Belgium

STRATIGRAPHIC MICROFOSSILS
= 'GUIDE or MARKER' or ZONE FOSSILS

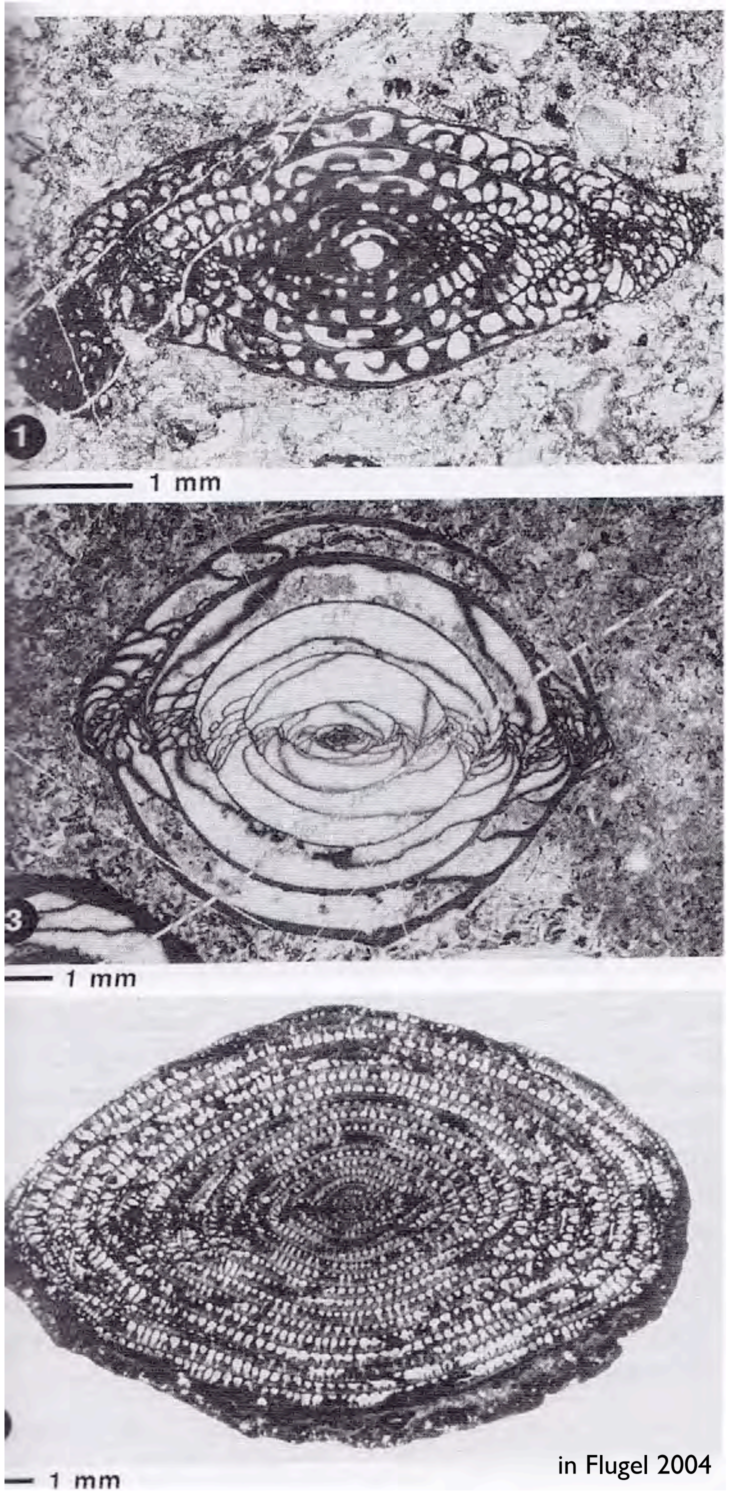
PALEOZOIC (some examples)

⇒ **FUSULINIDA** (Foraminifera, Carboniferous : evolved at the beginning of the Carboniferous, diversified rapidly and became extinct at the end of the Permian)
= considerable use in the stratigraphic division of the Carb-Pm platform carbonates of the Tethyan Realm, including West-Texas, Spitzbergen, U.K., Belgium, North Africa, Russian Platfom, India and the Far East

⇒ **CONODONTS** = phosphatic tooth-like microfossils ranging in age from Cambrian to Triassic.The function of the conodont elements as teeth or possibly lophophore supports, within an eel-like fish, has been established only recently 1990s
= 1500 sp. …worldwide Devonian
• useful for biozones and 'cyclostratigraphy'
• useful for diagenetic and burial studies

=> + ostracods, acritarchs, charophytes, chitinozoans, pollens, spores…

LATE PALEOZOIC LARGER FORAMINIFERS = FUSULINIDS



Beedina sp.
Middle Carboniferous (Moscovian), Donetz basin, Ukraine

Sphaeroschwagerina carniolica
Early Permian (Asselian)
Carnic Alps, Austria

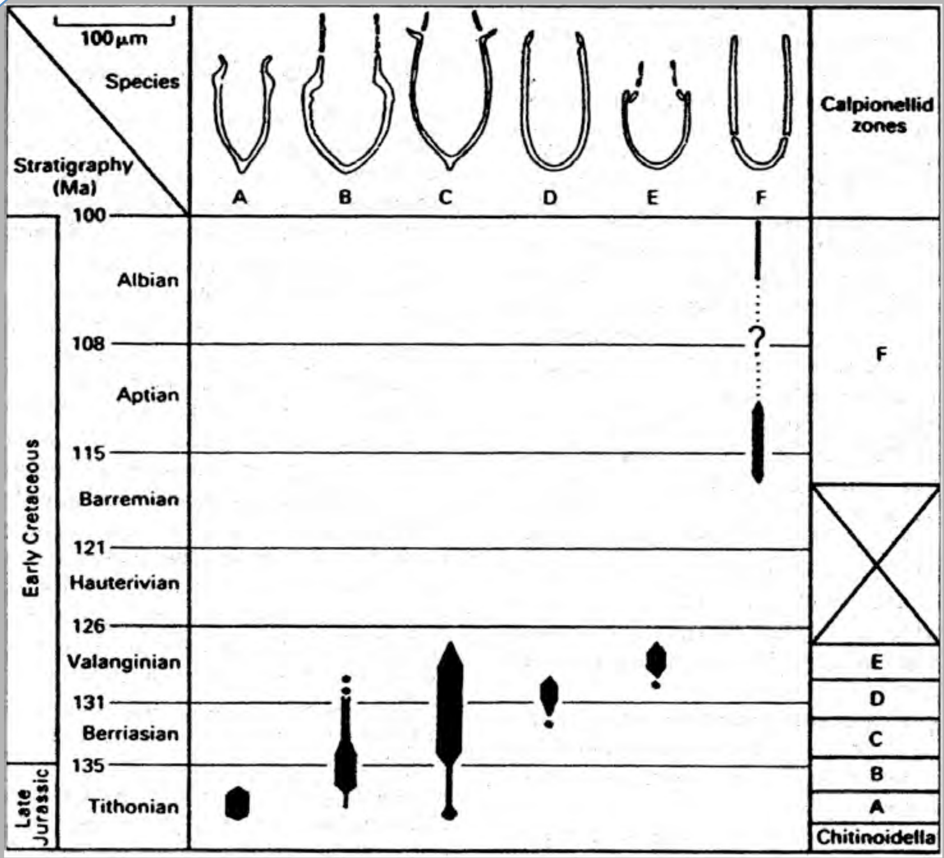
Yabeina syrtalis
Middle Permia)
Southern Tunisia

in Flugel 2004

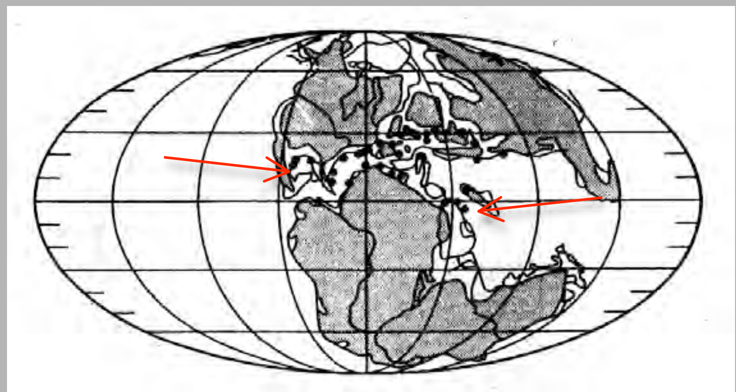
STRATIGRAPHIC MICROFOSSILS
= 'GUIDE or MARKER' or ZONE FOSSILS

MESOZOIC (some examples)

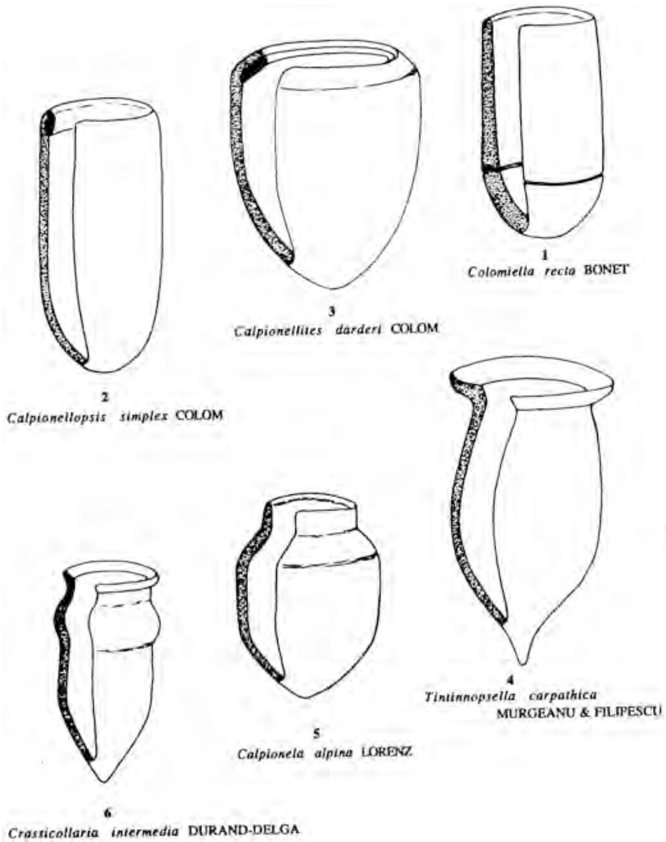
⇒ **CALPIONELLIDS** : Late Jurassic- Early Cretaceous
• easy to use! despite uncertain taxonomic affinity = tintinnids?
• application: thrust nappes in Algeria, in the Alps…



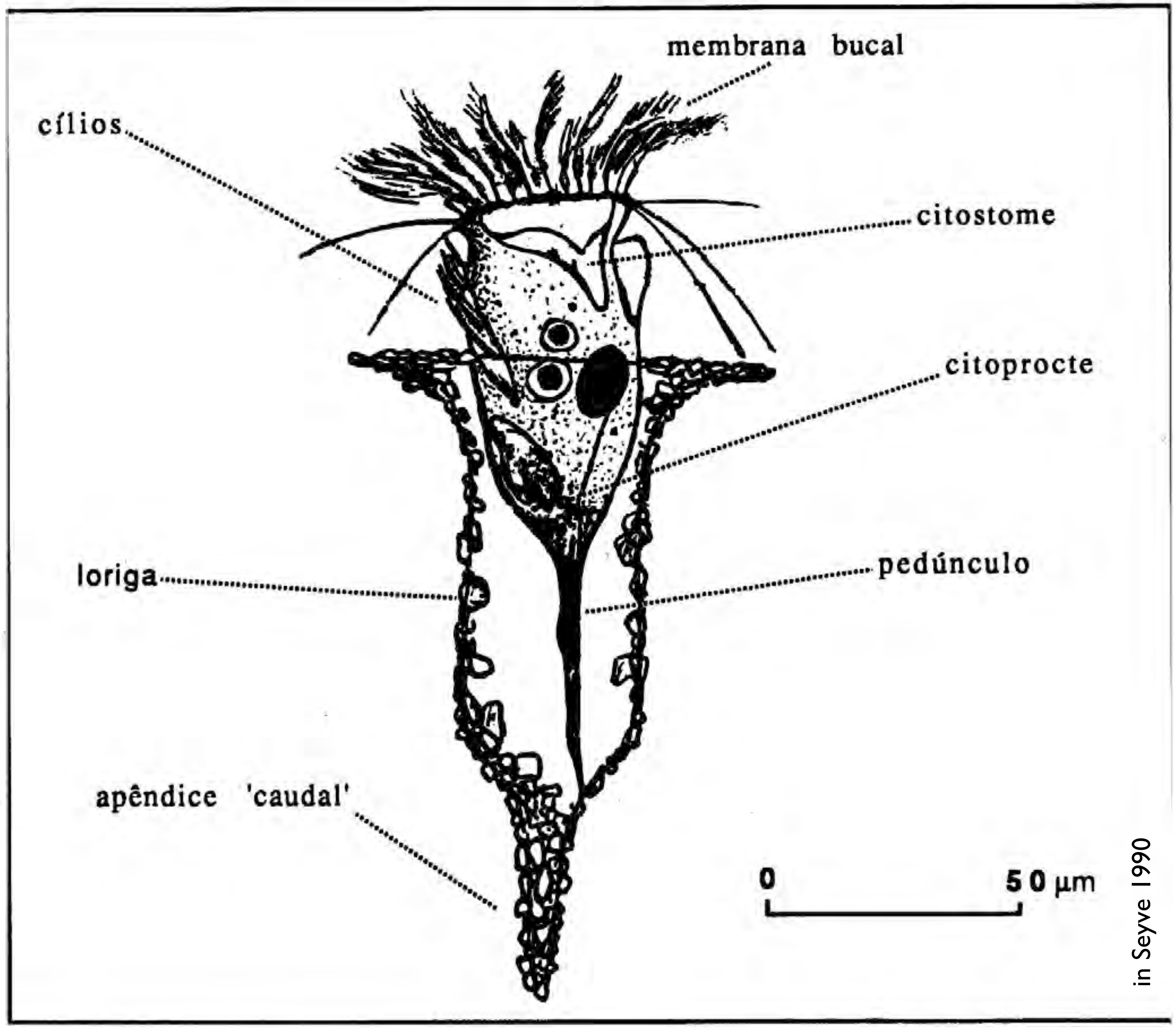
Exclusively marine and planktonic in habit, with a wide geographic distribution in low to mid Tethyan latitudes (= 'oceanic environments')



RECENT TINTINNID (microzooplankton)
ciliate protozoan

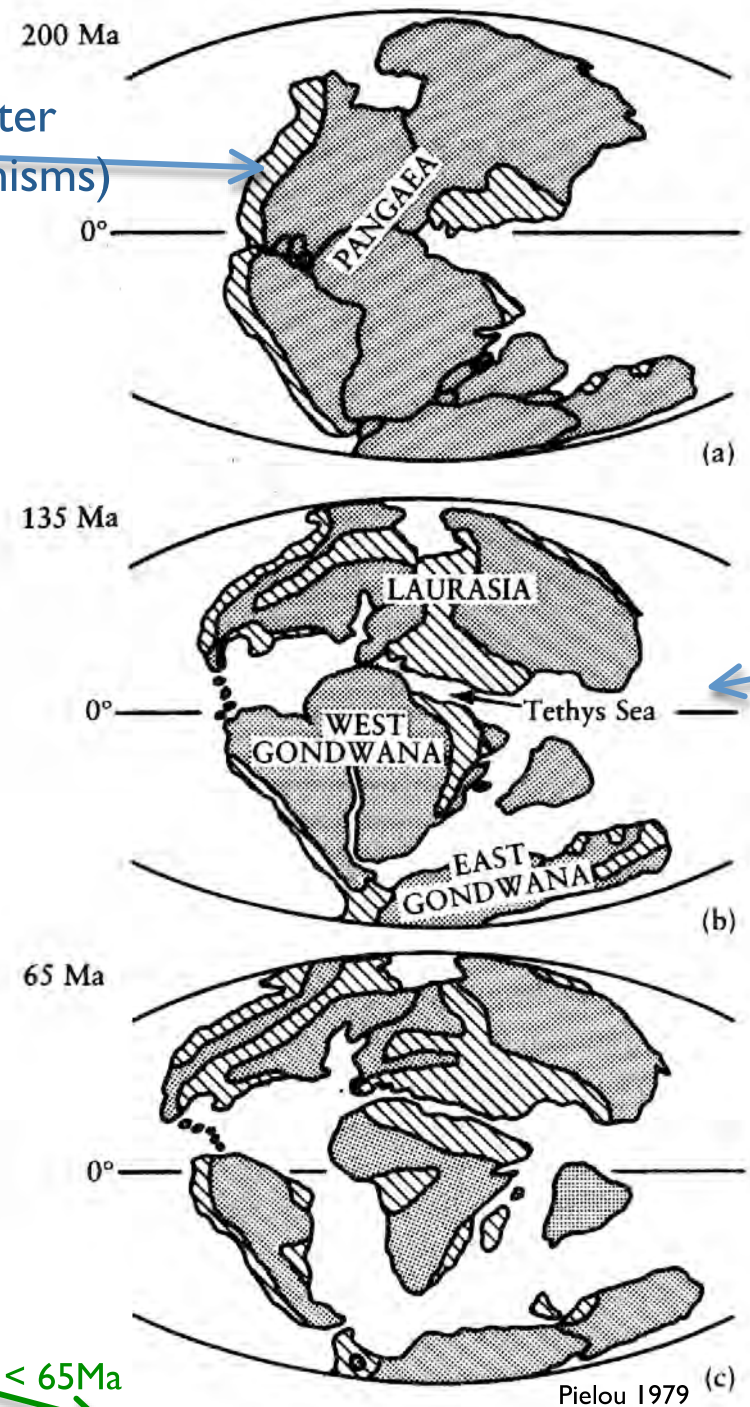


Most common Calpionellids
Used in **worldwide** correlations
Late Jurassic-Cretaceous
(Rename 1971)



in Seyve 1990

shallow-water
(benthic organisms)



Pielou 1979

Gross (simplified) paleogeography showing the breakup of Pangea and the position of epicontinental seas.

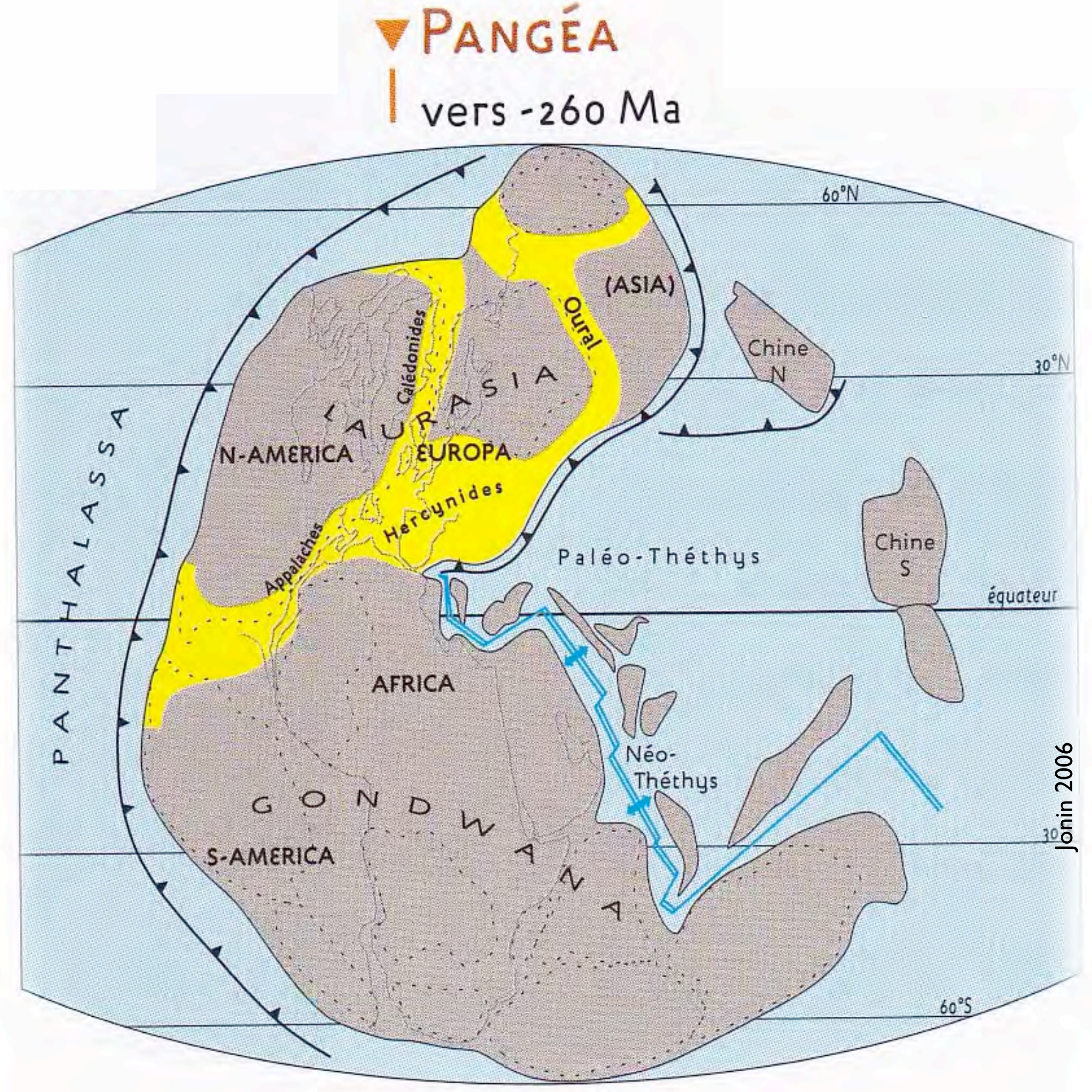
seaway
(planktonic organisms)

\+

oil

During Tertiary = 'orogens'
⇒ stratigraphic organisms
⇒ indispensable…

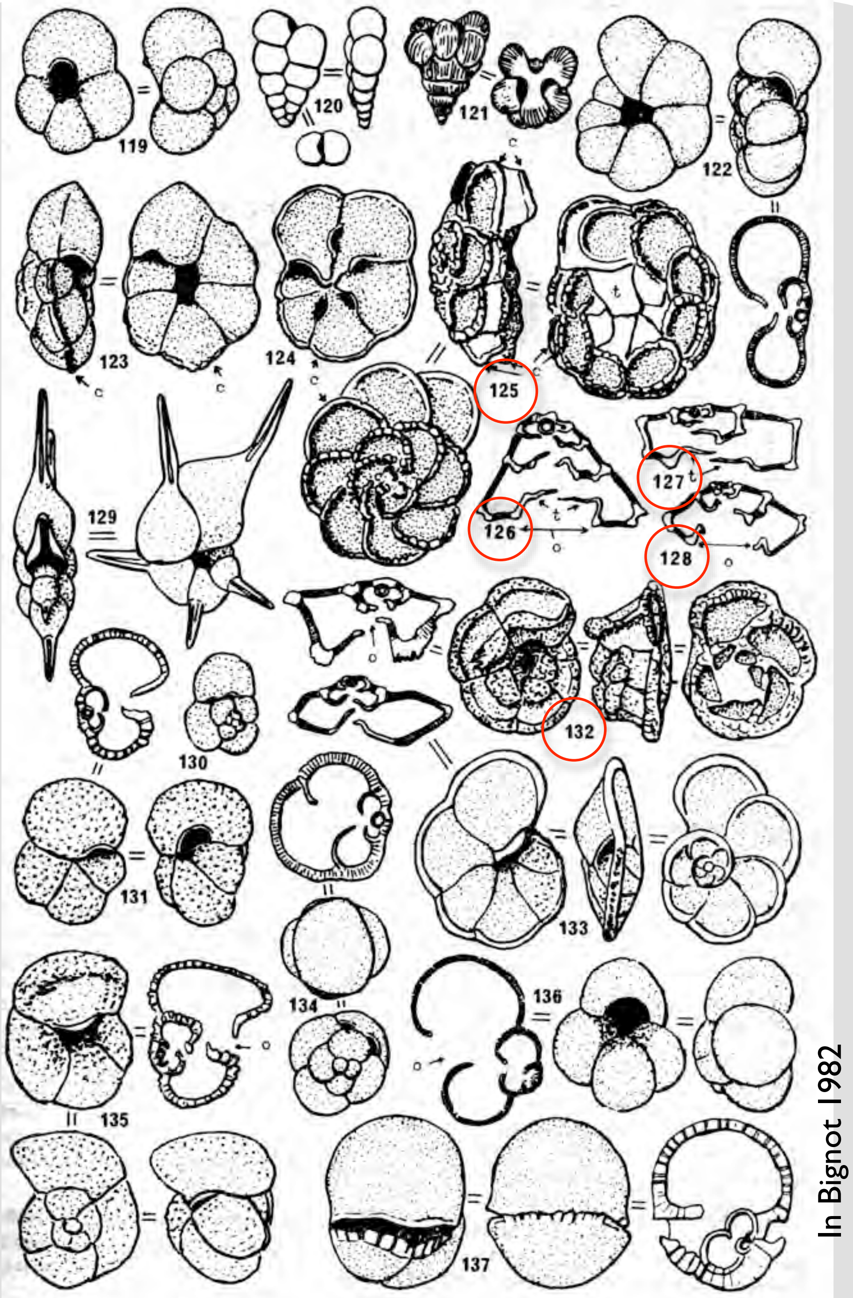
< 65Ma



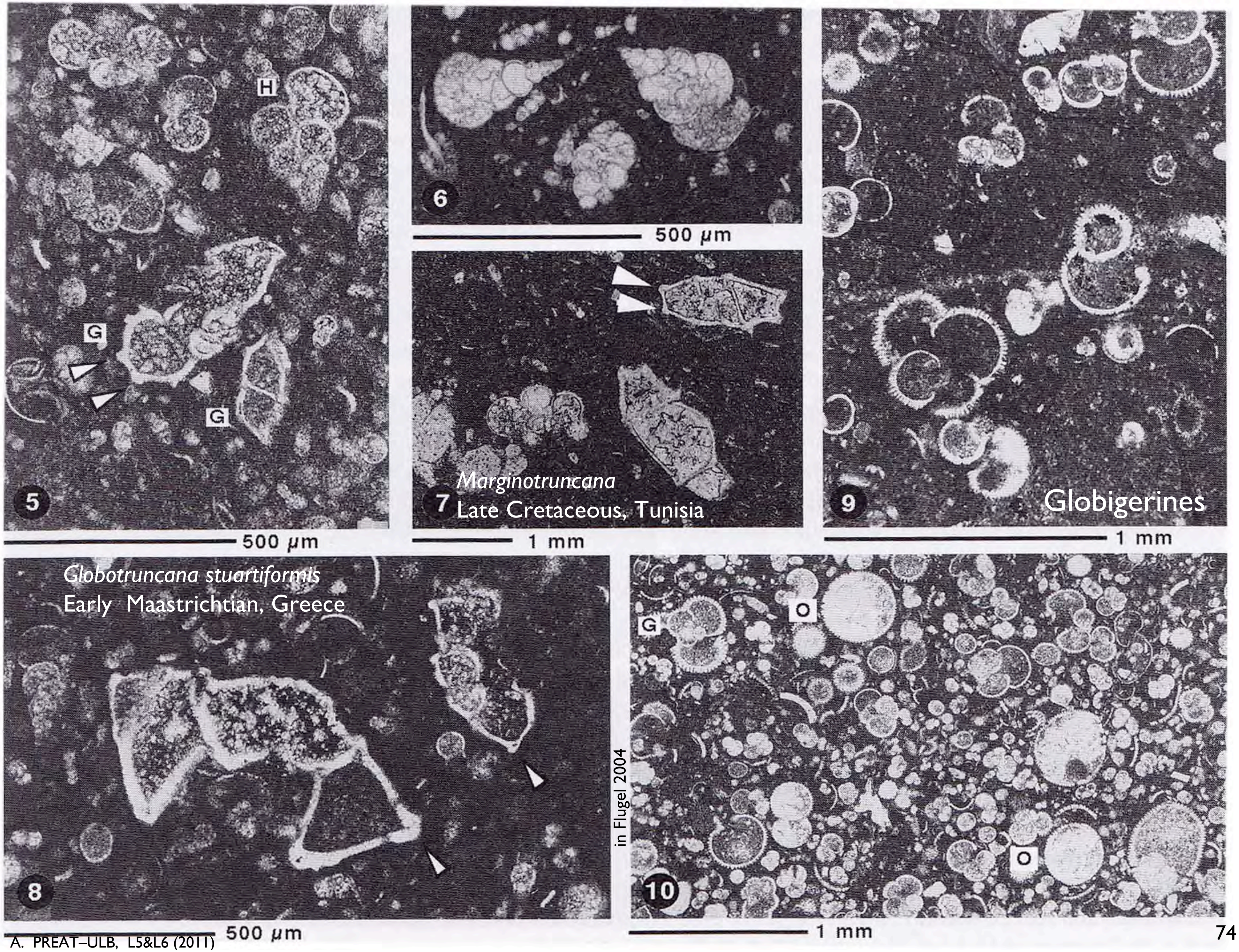
End of Fusulinids …

=> **GLOBOTRUNCANIDS**: Late Cretaceous –Recent

= plurilocular foraminifers (125-128, 132)



In Bignot 1982

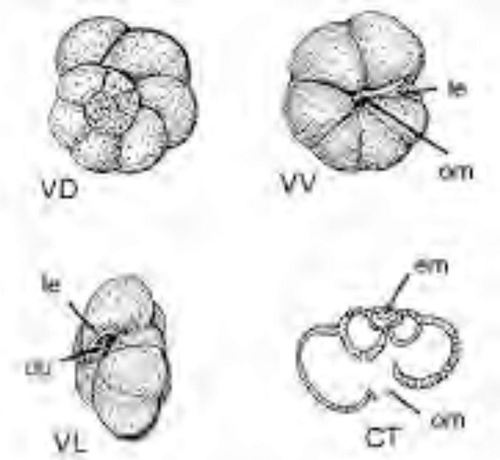

H
G
G
5
500 µm
6
500 µm
Marginotruncana
7 Late Cretaceous, Tunisia
1 mm
9
Globigerines
1 mm
Globotruncana stuartiformis
Early Maastrichtian, Greece
8
500 µm
G
O
O
10
in Flugel 2004
1 mm

STRATIGRAPHIC MICROFOSSILS
= 'GUIDE or MARKER' or ZONE FOSSILS

CENOZOIC (some examples)

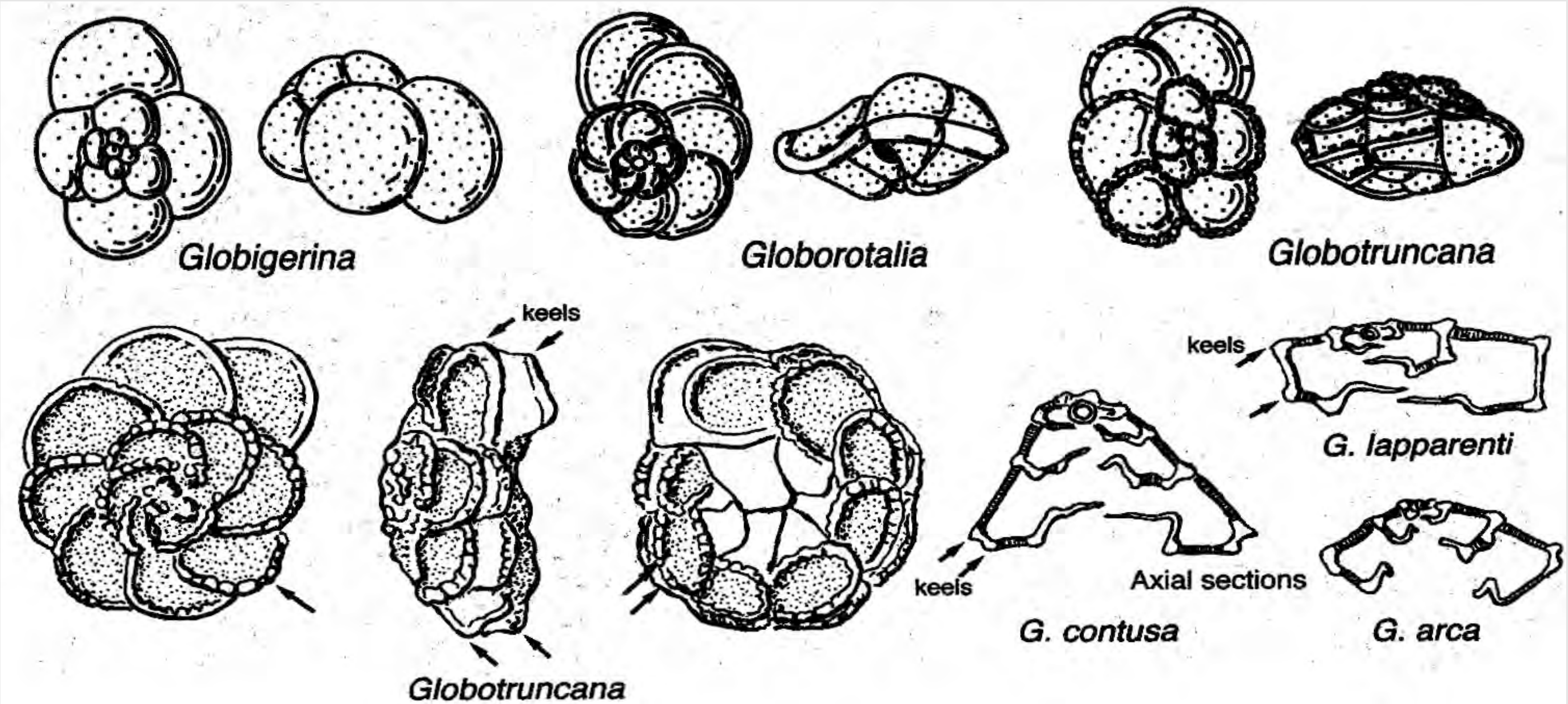
=> **GLOBOROTALIDS** : Paleocene to Recent (foraminifers)

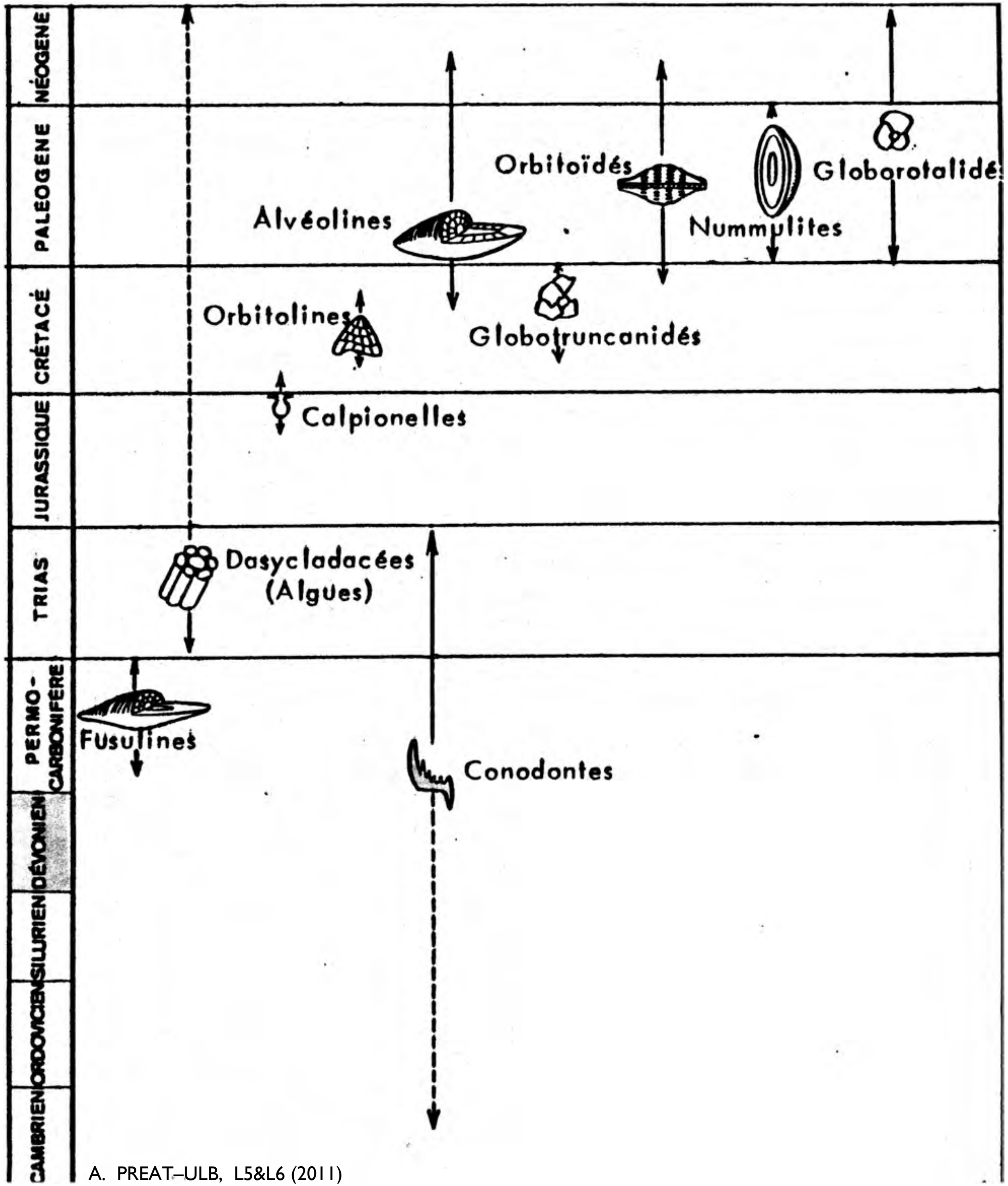
Globorotalia (d'après W.H. Blow 1969)

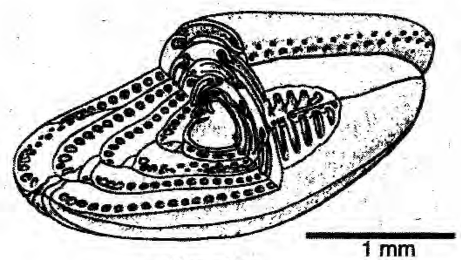


Globorotalia

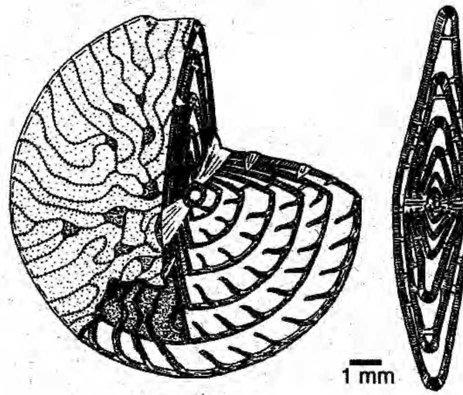
TYPICAL PLANKTONIC FORAMINIFERA







Alveolina



Nummulites

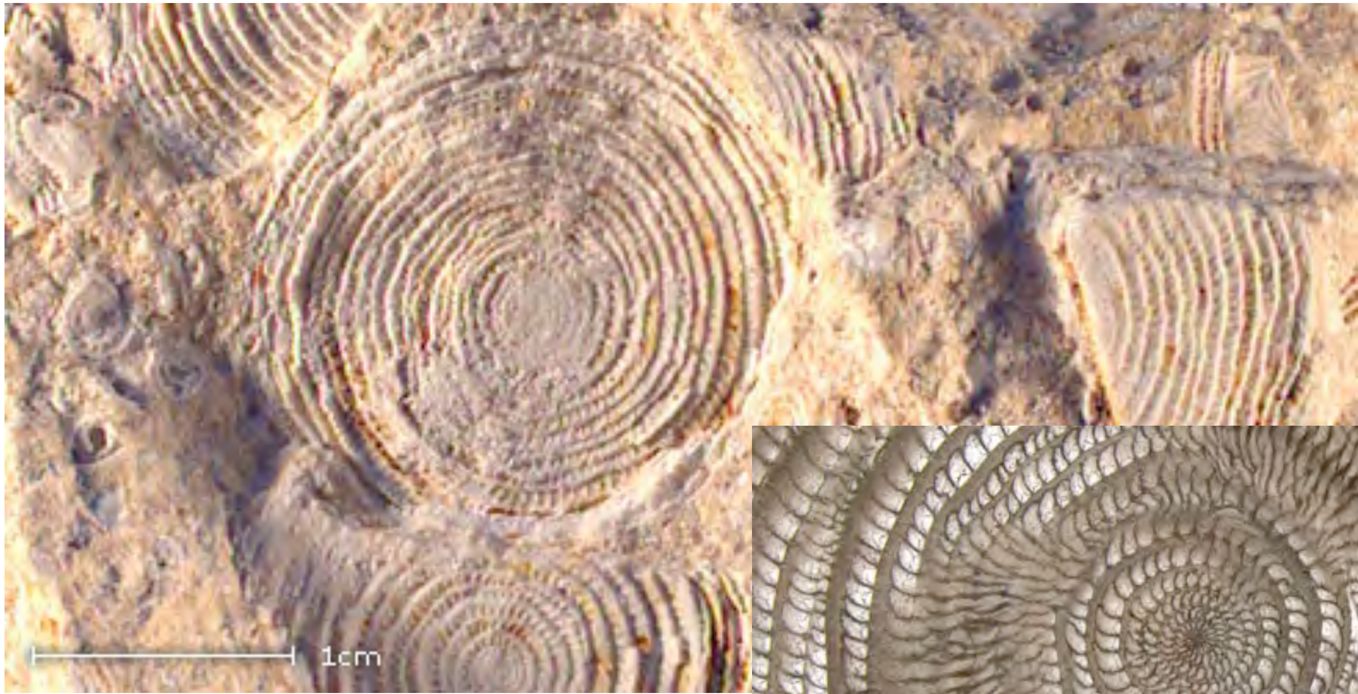
MICROFAUNAS

⇒ **ORBITOLINIDS** : ‘middle’ Cretaceous

⇒ **ORBITOIDS** : Upper Cretaceous – Miocene

=>**NUMMULITIDS** : Paleogene **(Brussels …)**

etc..



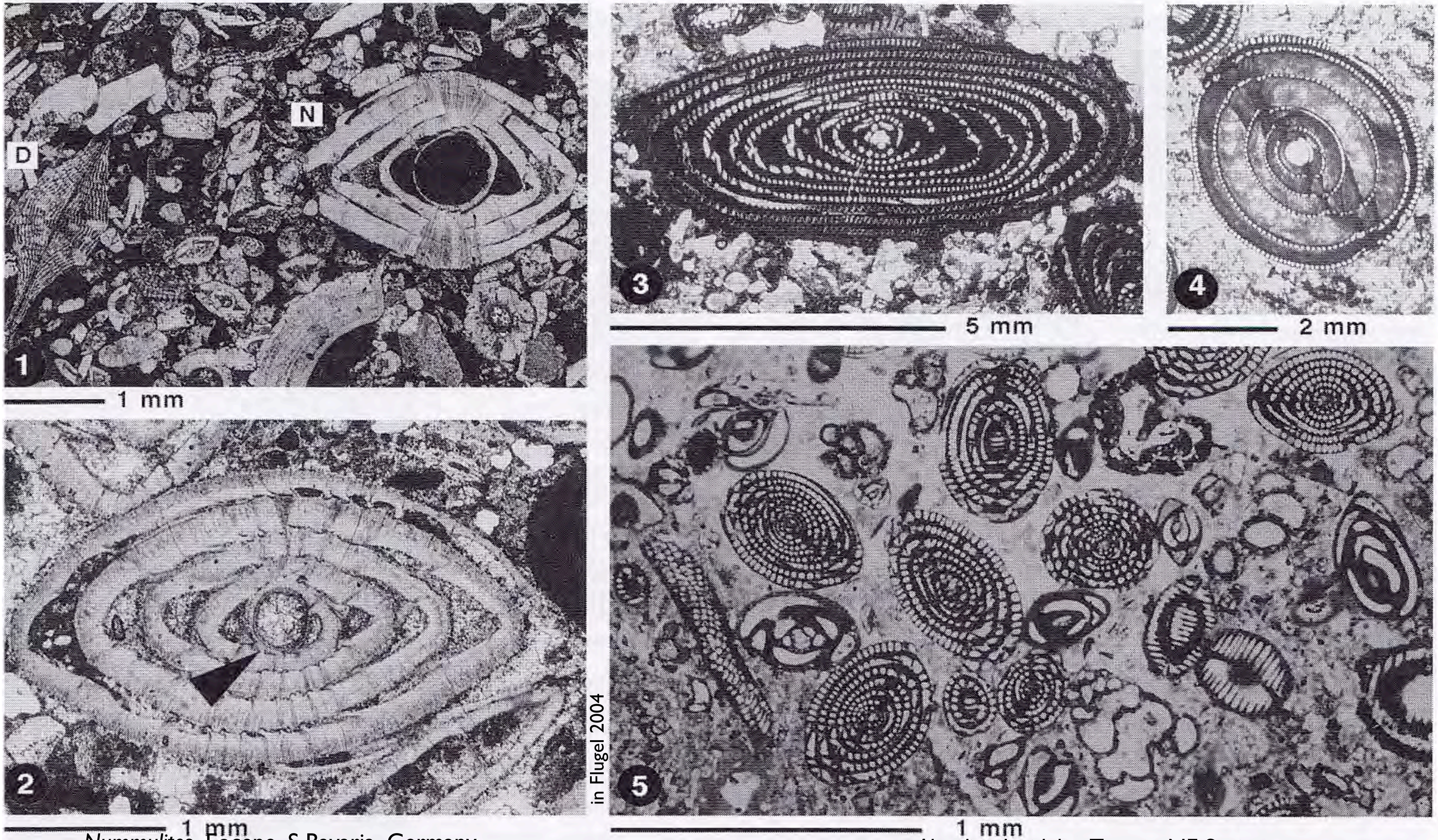
Nummulites gizehensis

NUMMULITID and ALVEOLINID LIMESTONES

Nummulites, Eocene, S Bavaria, Germany

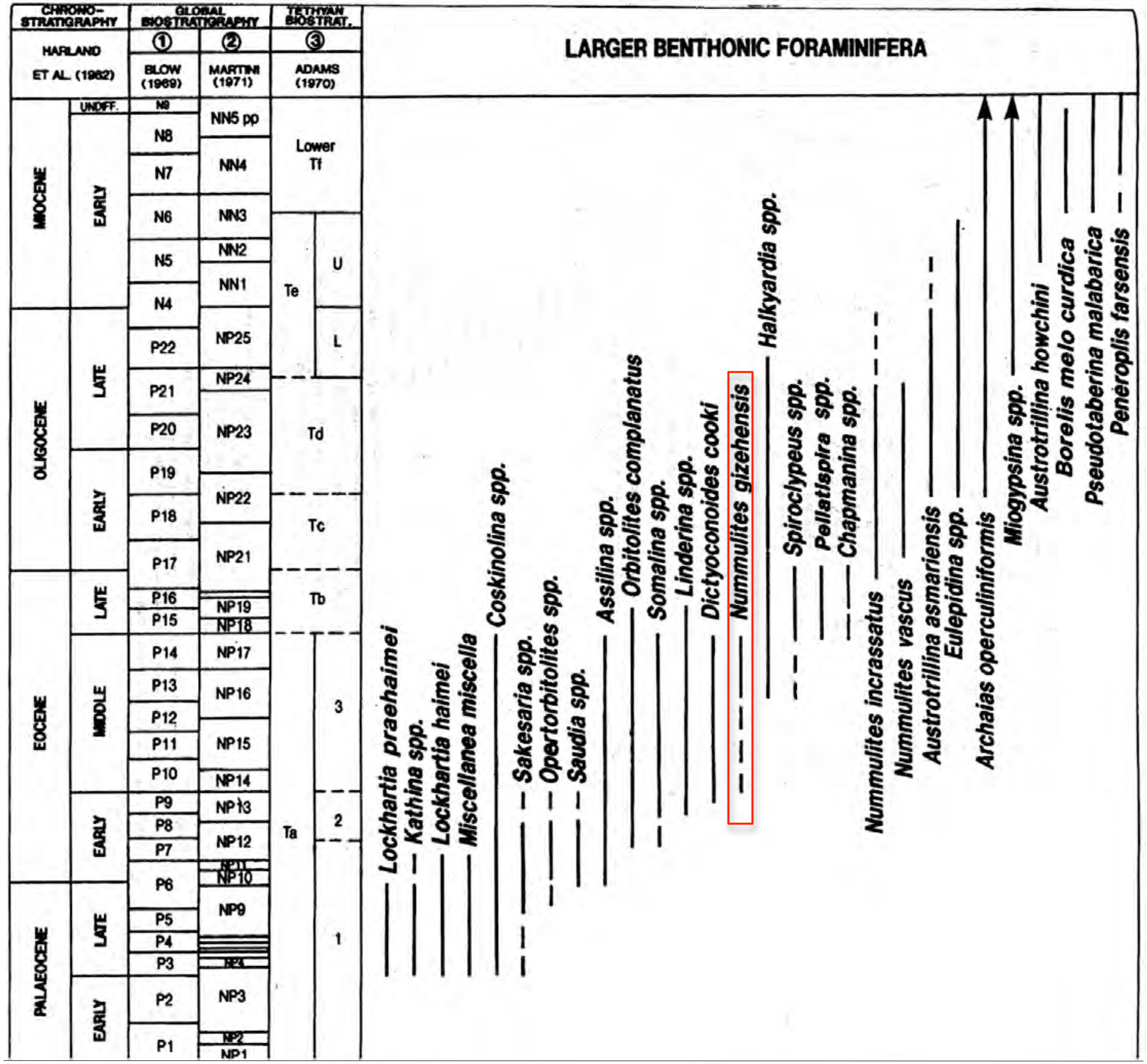
Alveolina, Early tertiary,, Slovenia

Alveolina, id. equatorial section



Nummulites, Eocene, S Bavaria, Germany

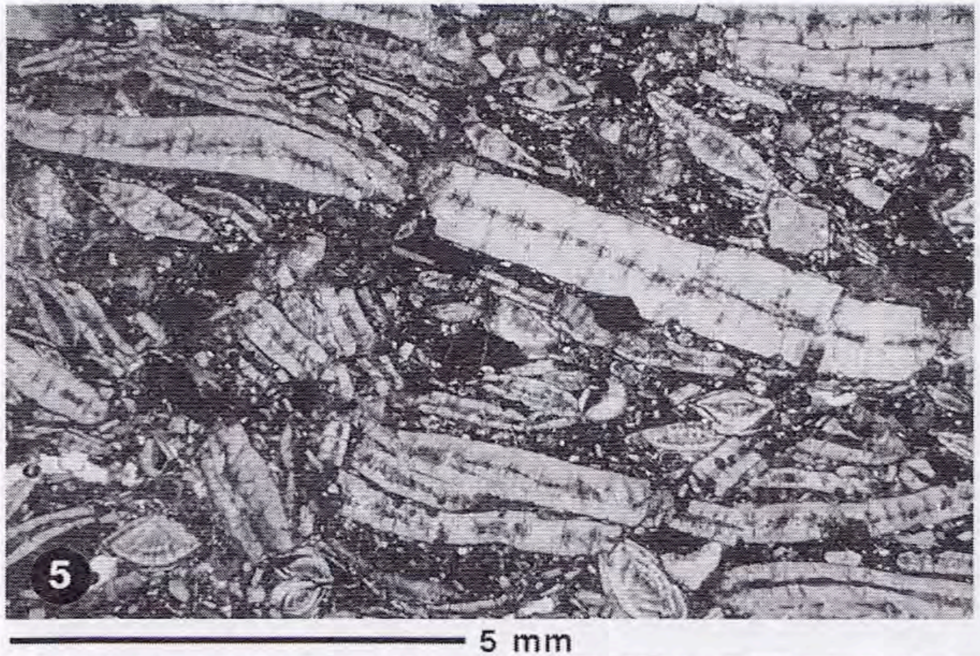
Alveolina lepidula, Tremp, NE Spain



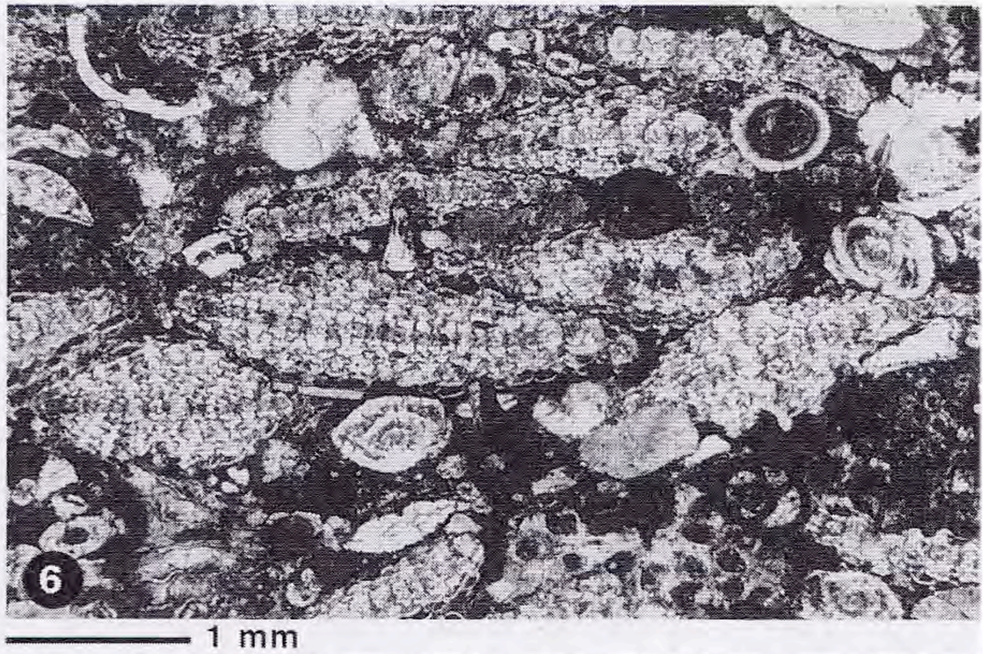
Cenozoic, Middle East, Jones & Racey 1994

OPERCULINID and LEPIDOCYCLINID LIMESTONES

Operculina, Miocene, S Turkey

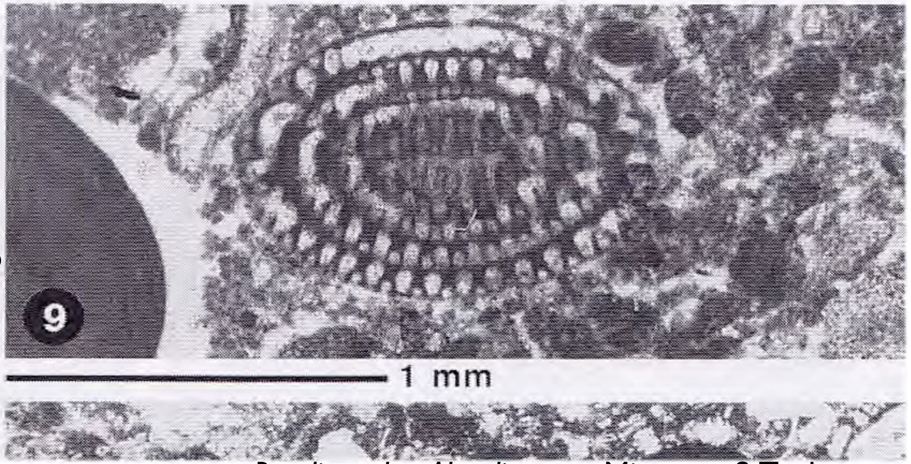


Miogypsina, Oligocene, S Turkey



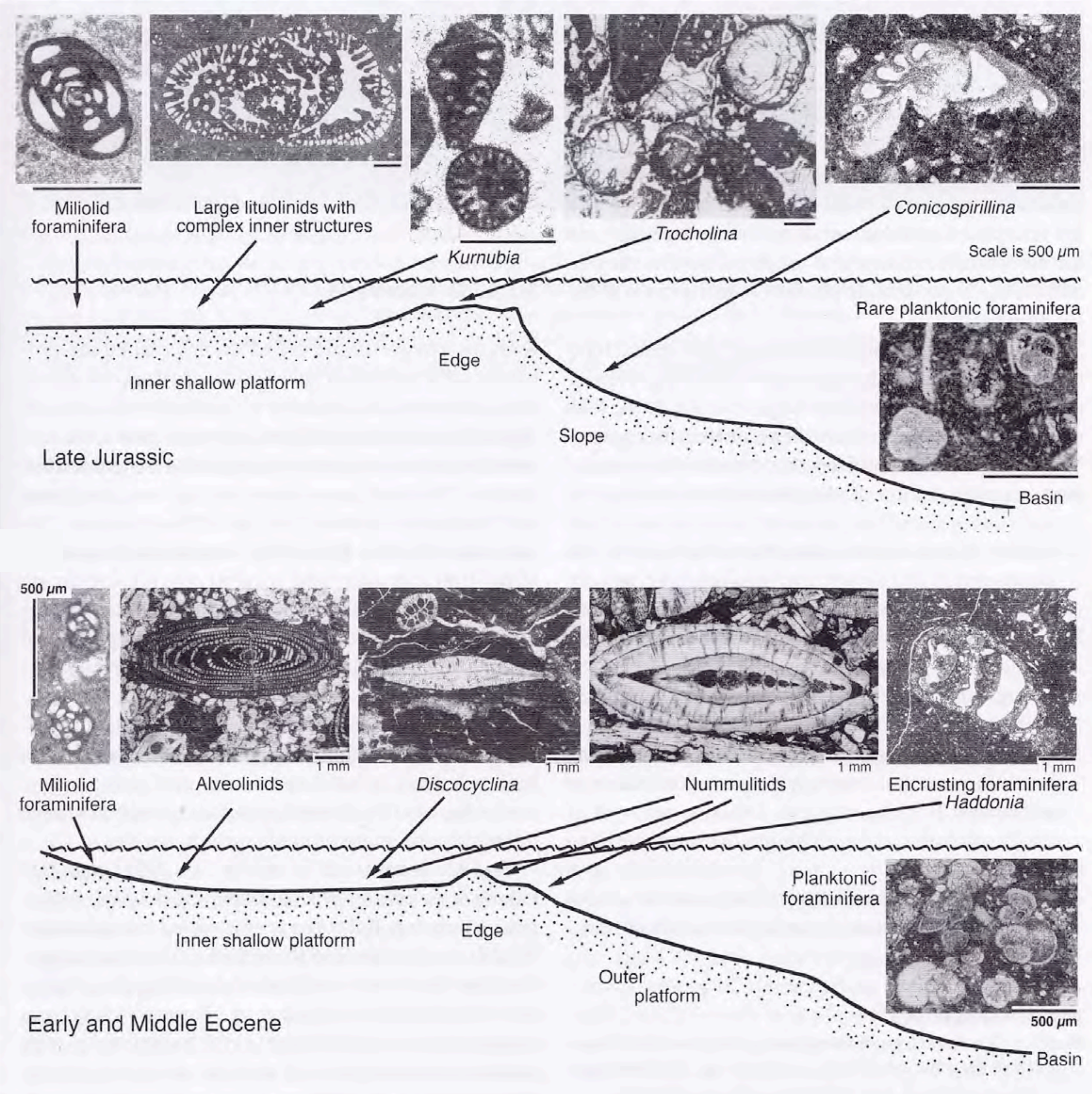
Lepidocyclina, Oligocene, W Greece

in Flugel 2004



Borelis melo, *Alveolinacea*,, Miocene, S Turkey

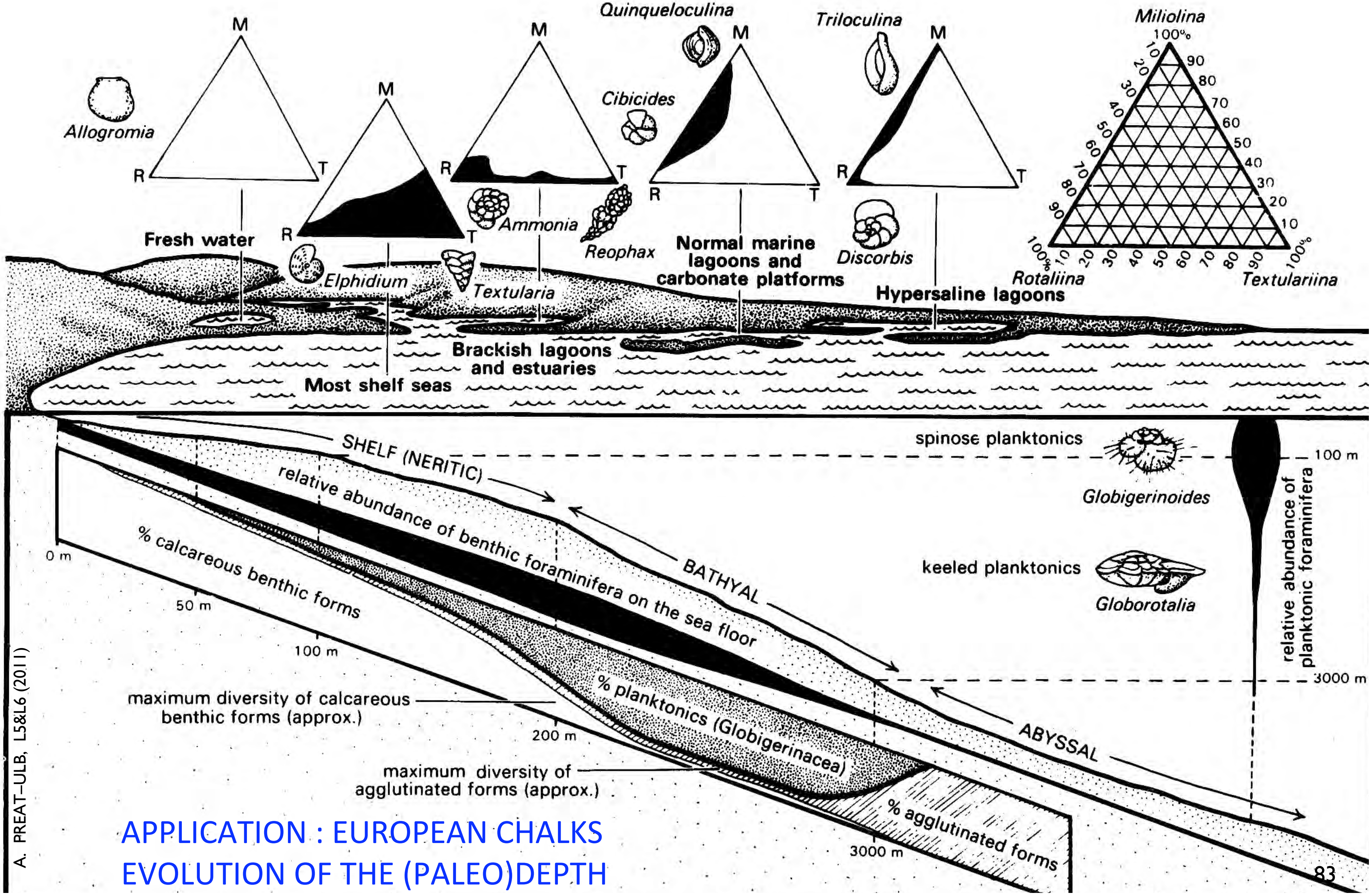
Generalized patterns of the distribution of common foraminifera in different sedimentary environments



in Flugel 2004

BENTHIC AND PLANKTONIC FORAMINIFERID ABUNDANCE AND GENERAL CHANGE WITH DEPTH AND SALINITY (in Brasier, 1980).

Some typical genera are shown.



APPLICATION : EUROPEAN CHALKS

EVOLUTION OF THE (PALEO)DEPTH

MICROFLORAS

⇒ **DASYCLADACEAN ALGAE** : Triassic – Recent

⇒ ….

MACROFLORAS

⇒ **PTERIDOPHYTA** : Carboniferous (Gondwana)

ACRITARCHS : ('acros' = uncertain, taxon) = Organic-walled microfossils of uncertain and probably disparate taxonomic affinity (some forms being at least arguably ancestral to dinoflagellates). Little is known of the biology, the basic morphology is of a hollow spherical or subspherical body or vesicle with or without 'spines'. **Sizes : 20-50 µm**.

=> phytoplankton?

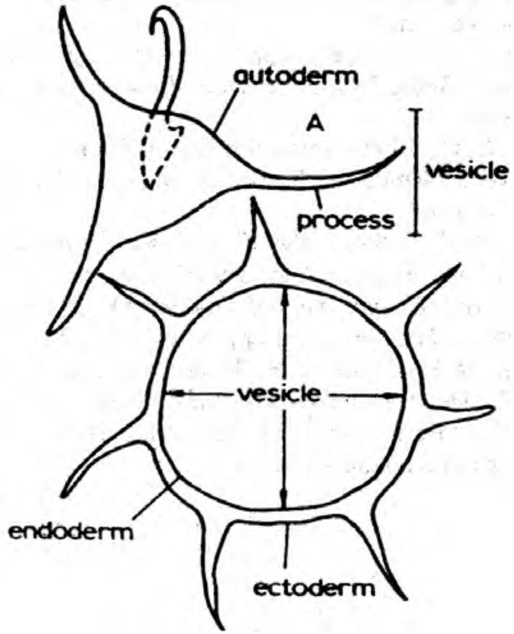
⇒ 'recent invention' USA-Europe …. = 'palynomorphs'

⇒ Late PCm (acme), Cm-Sil-Dev-Pm (=diversification), Mesoz-Cenozoic (=decline)

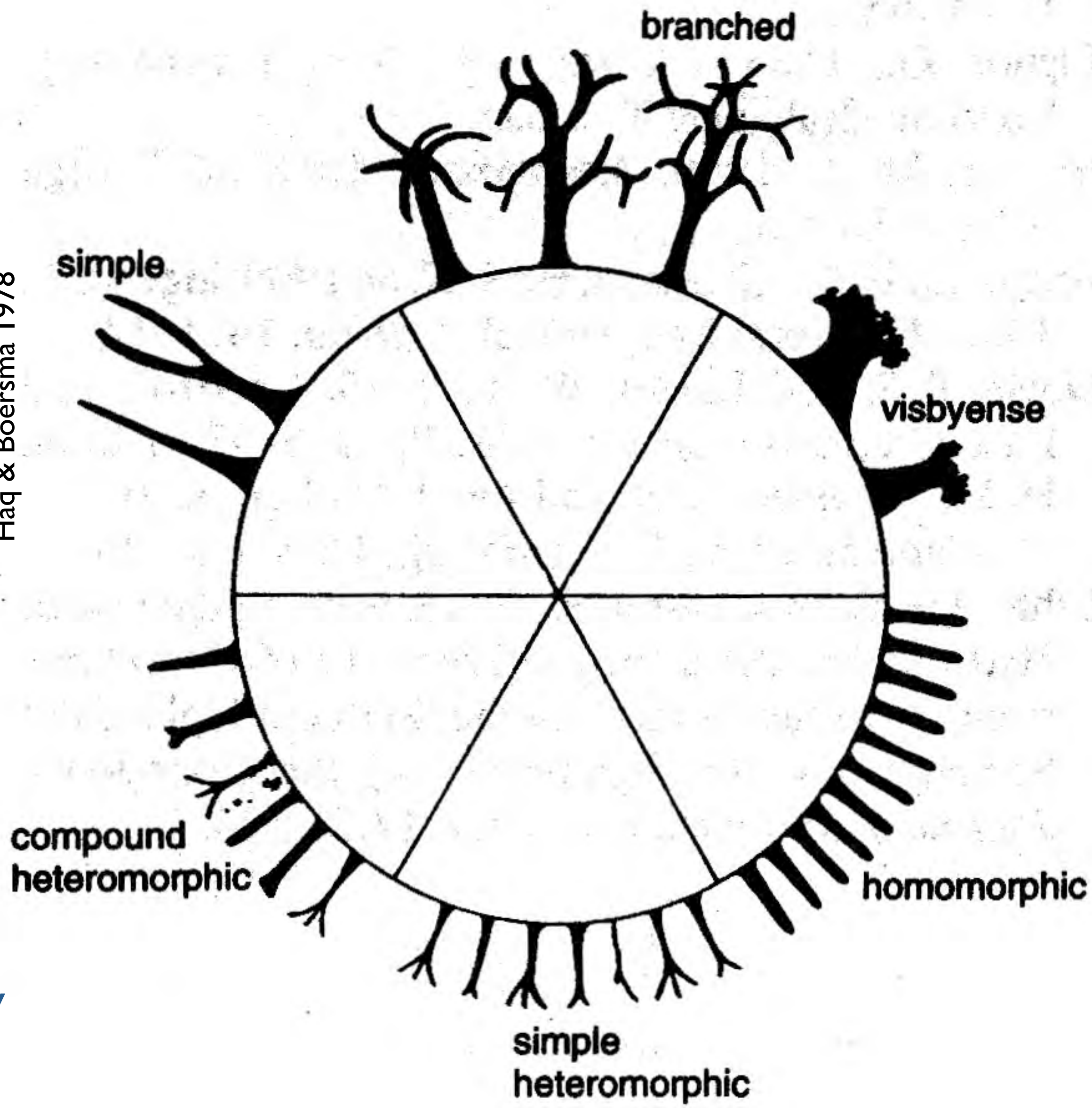
⇒ Stavelot/Brabant massifs (Belgium) : Lessines cores = folded monotonous series (siliceous)

⇒ UNPUBLISHED stratigraphic scales (oil companies…)

=> the rocks are dissolved (strong acids) to get the microfossils

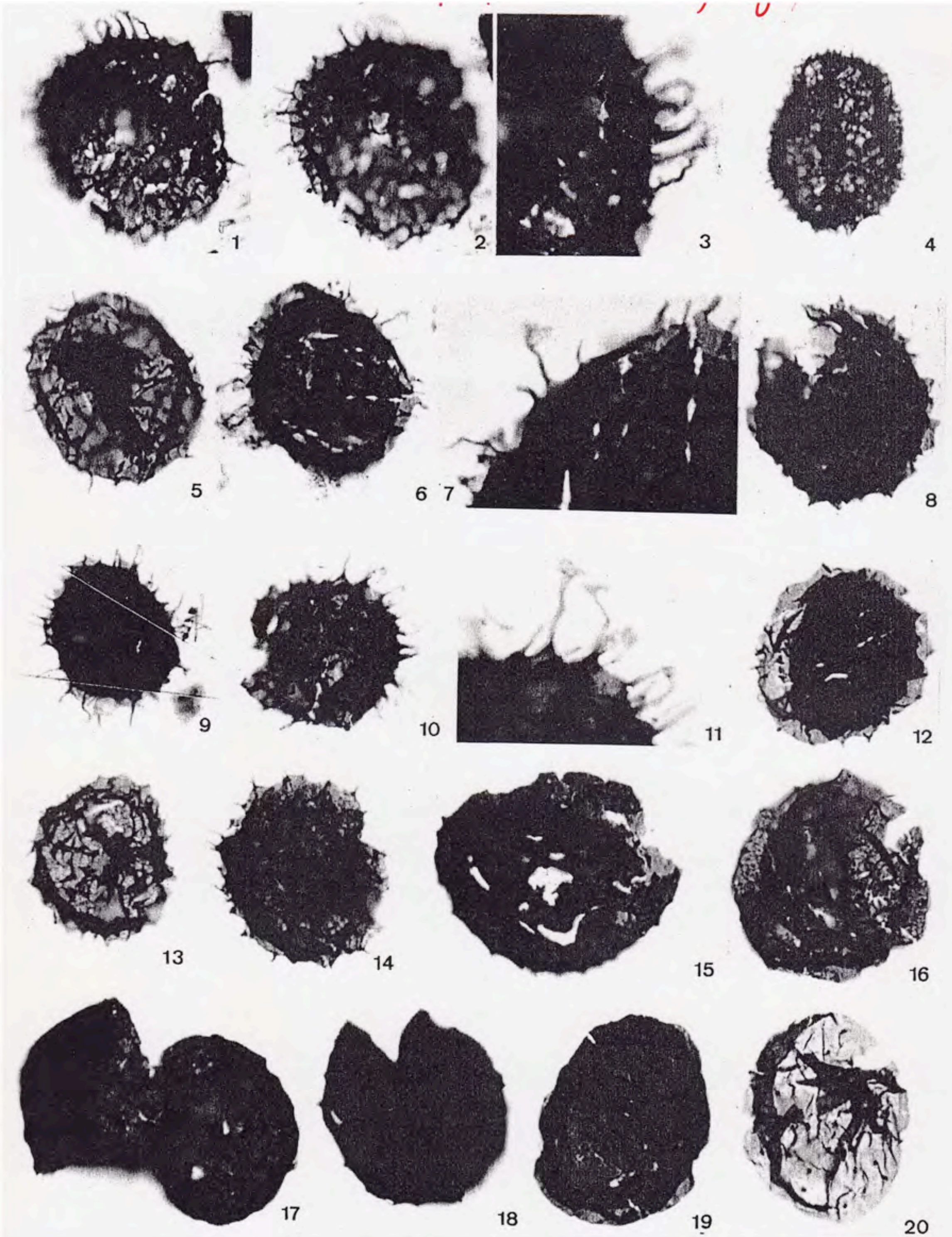


Haq & Boersma 1978

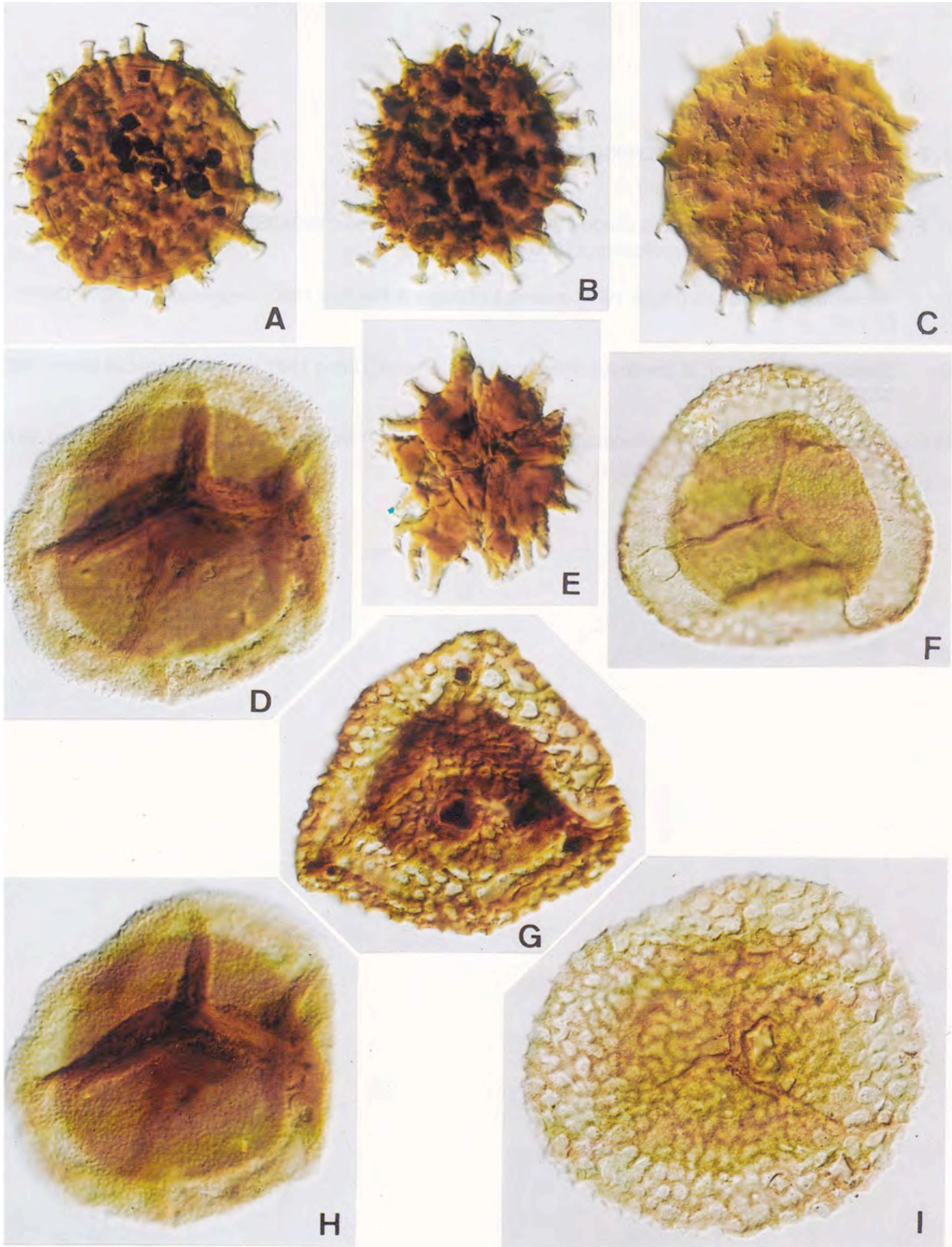


Descriptive terminology
Diameters : 20-50 µm

Diameters 20-50 µm
Cambrian
Brabant massif
Lessines, drilling

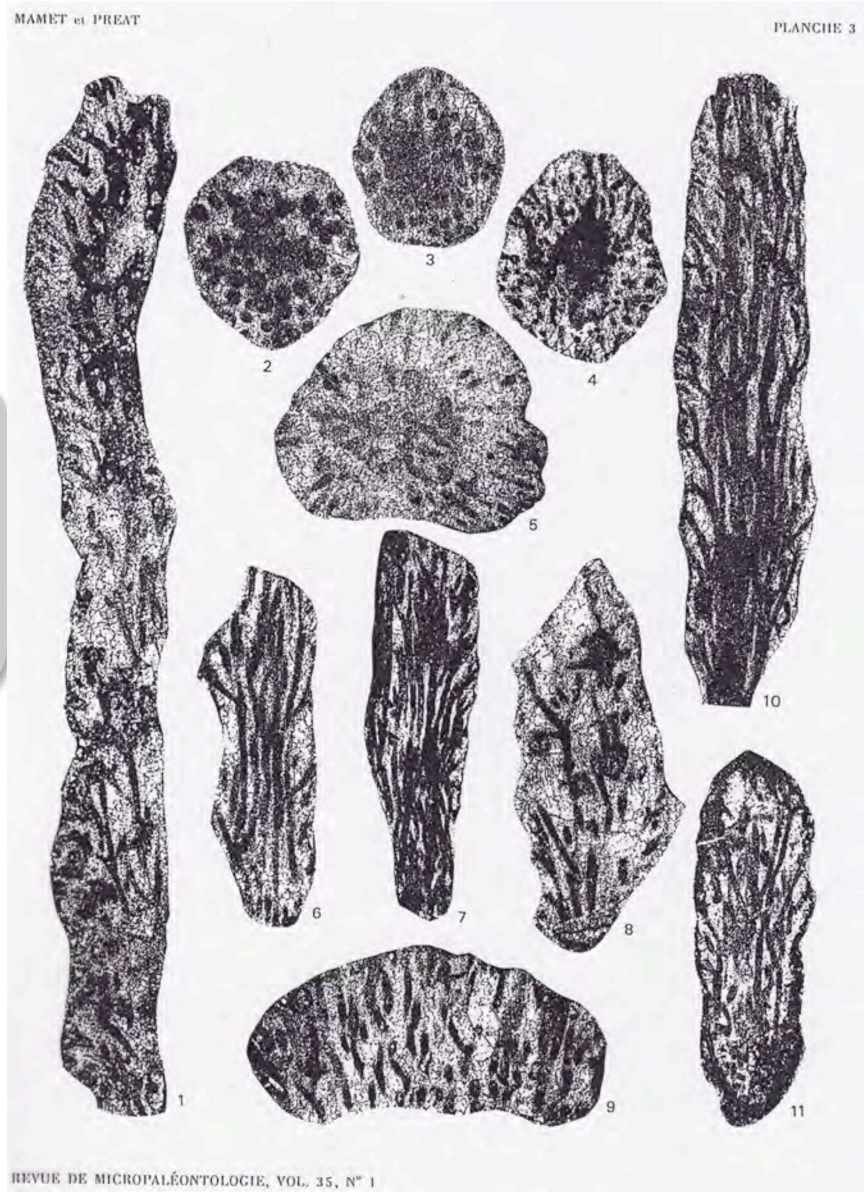


Acritarchs
Other sp.
…



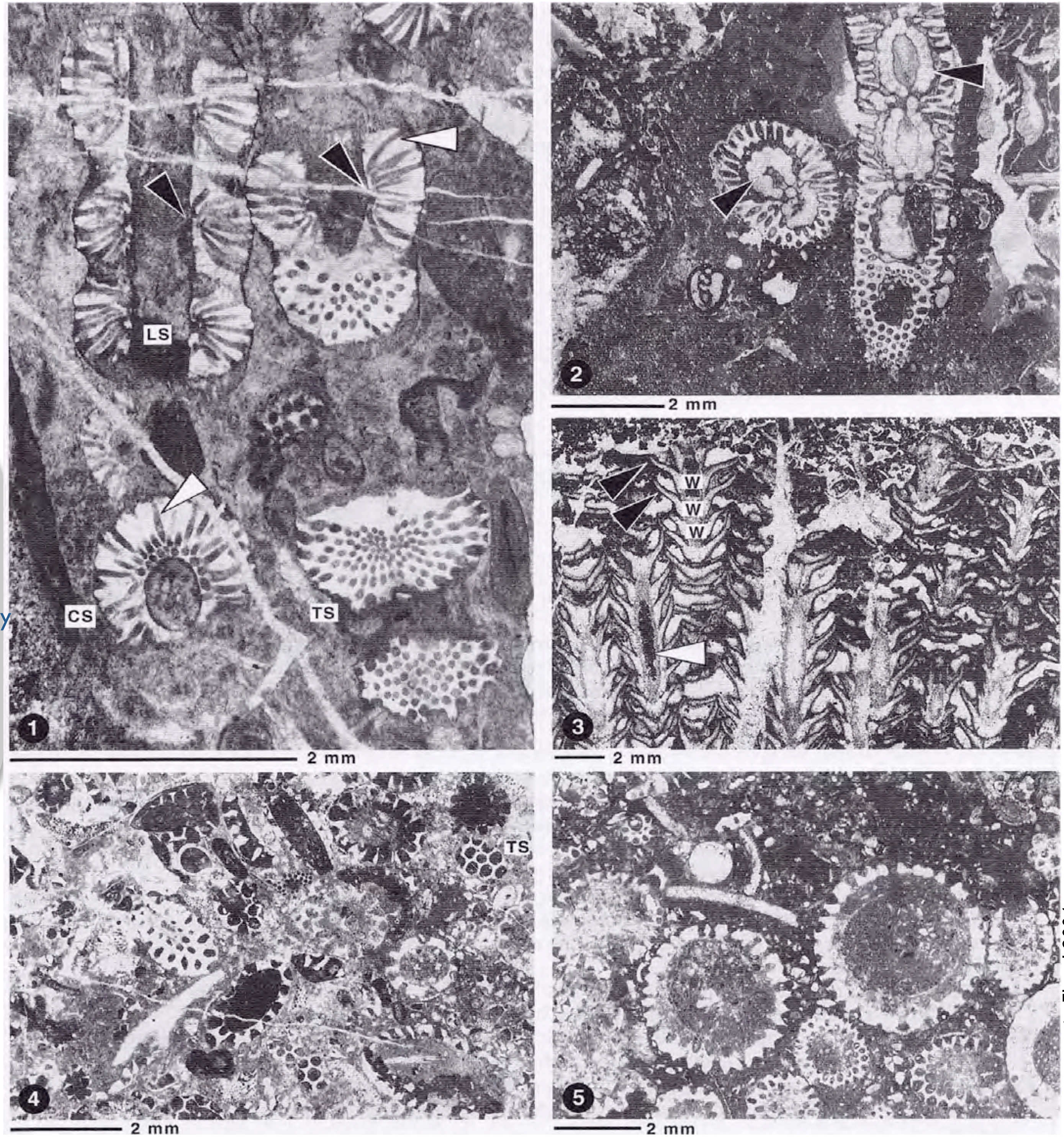
CORALS : local stratigraphic scale (but microstructures…)
ALGAE : Belgian-French Devonian = facies-controlled

Udoteacean green algae 100'µm-mm Eifelian, Belgium



Dasycladad green algae

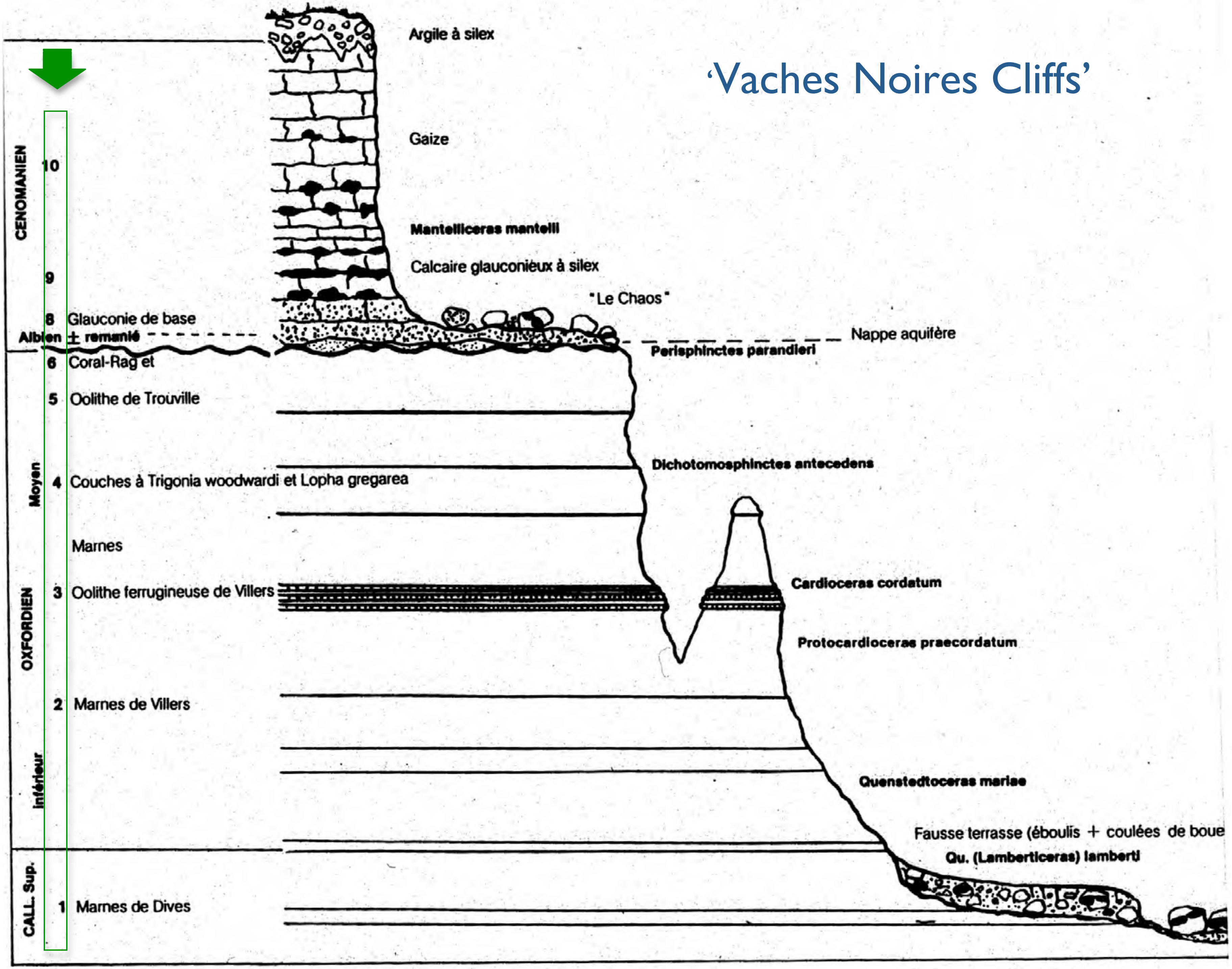
1 *Eovelebitella*, Viséan, Spain
2 *Diplopora*, Late Triassic, Germany
3 *Neoteutloporella*, Late Jurassic, Italy
4 *Mizzia*, Late Permian, W Turkey
5 *Mizzia*, id.



in Flugel 2004

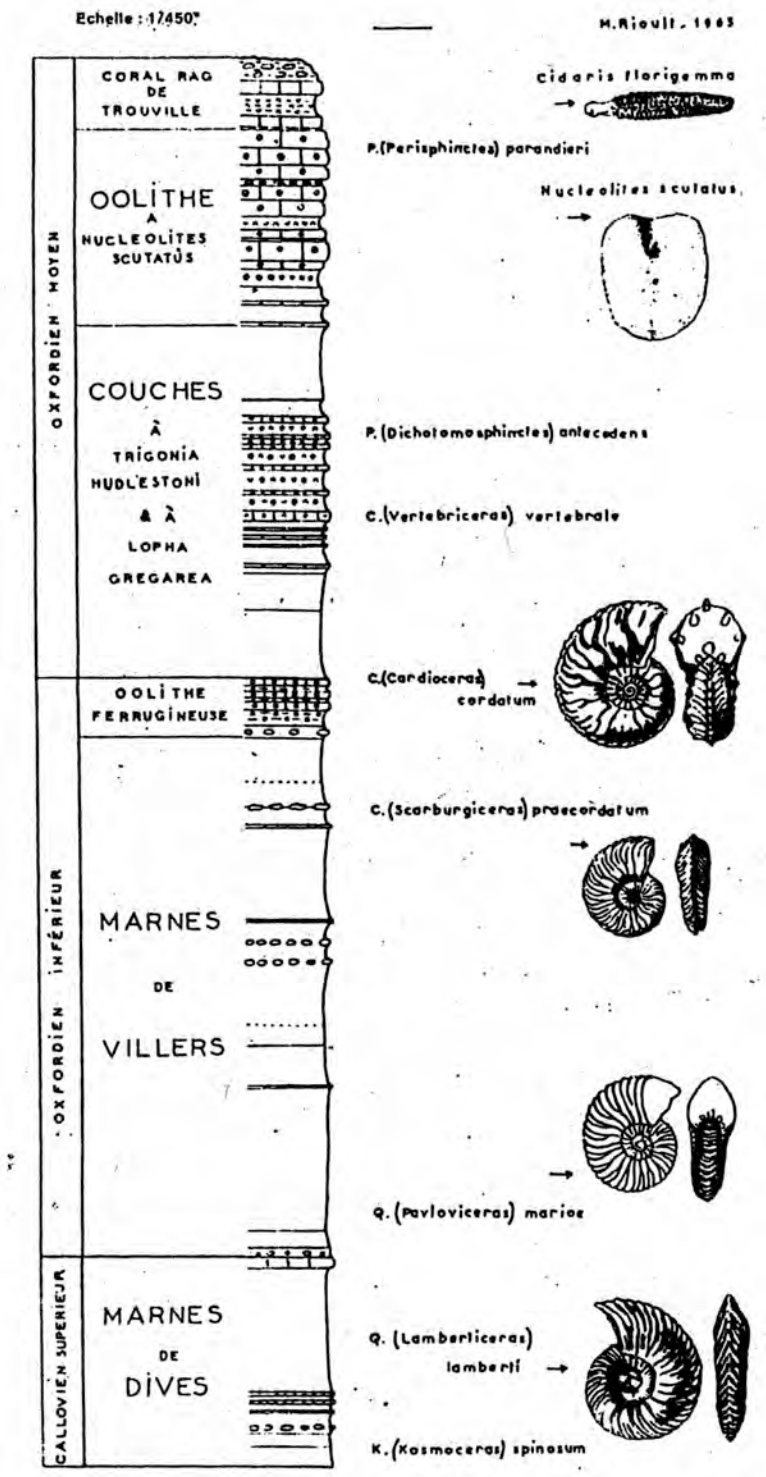
JURASSIC- NORMANDY
‘Vaches Noires Cliffs’

‘Vaches Noires Cliffs’



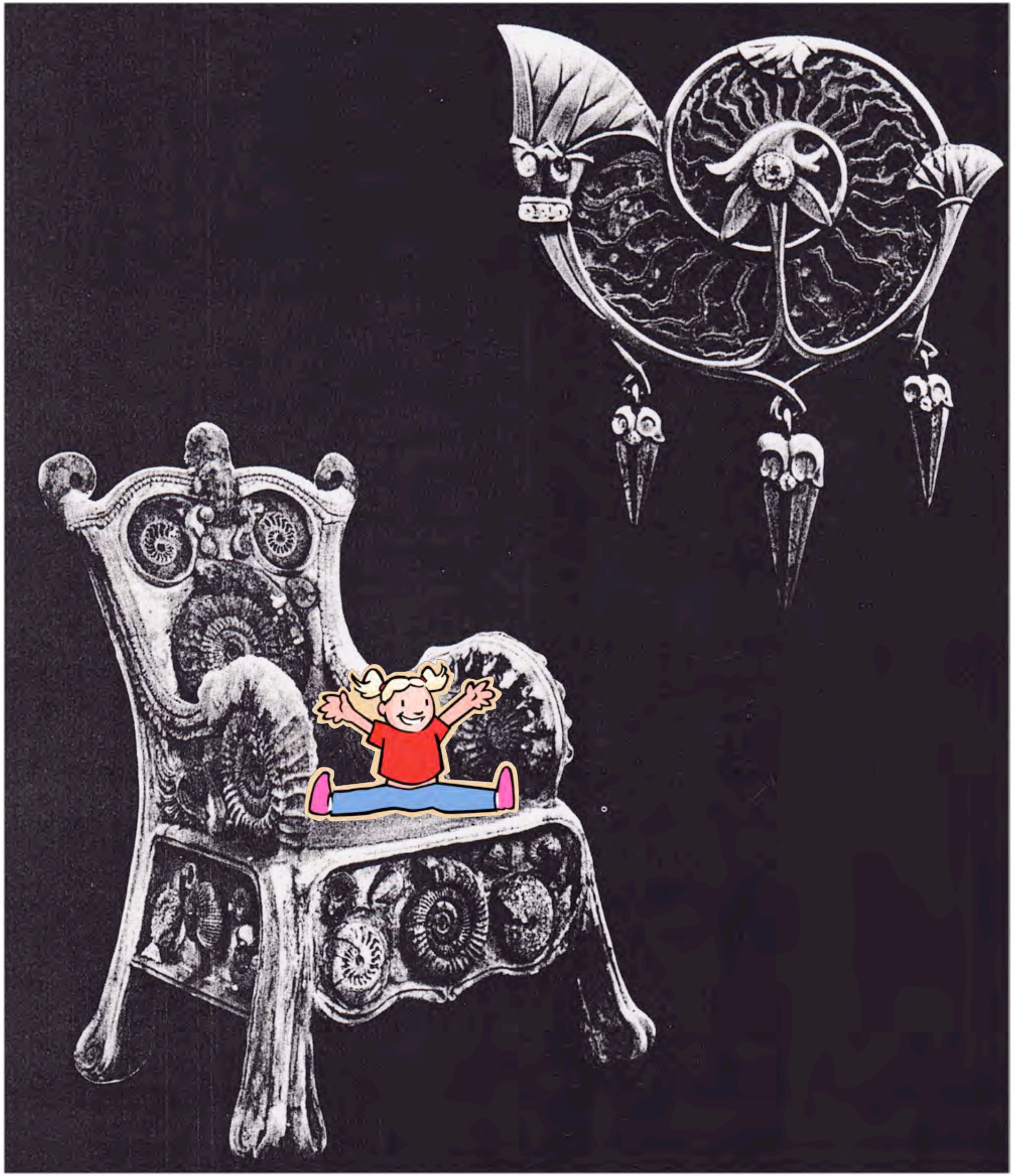
‘Vaches Noires Cliffs’

Callovian-Oxfordian



Sea urchins

Ammonites



TODAY : GREAT IMPORTANCE OF PELAGIC MICROFAUNAS

⇒ ACCURATE AGE => DSDP (Deep Sea Drilling Project)

Example: superimposed thrust sheets in Algeria ('nappes') from a hand lens!

B U T …

'MAJOR PROBLEM'

Platforms *(thick series)* vs ***Basins*** *(thin series)*

'Historical stratotypes' → 'New stratotypes' and/or better = **LIMITOTYPES**

Nb: not all these pelagic (micro)biozonations still exist
(particularly in the PALEOZOIC)
⇒ Use of faunas with more limited biotopes….

MACROFAUNAS
Corals => Triassic
Gastropods and Pelecypods => Mesozoic
Brachiopods => Paleozoic
etc….

What is a **PELAGIC FACIES?**

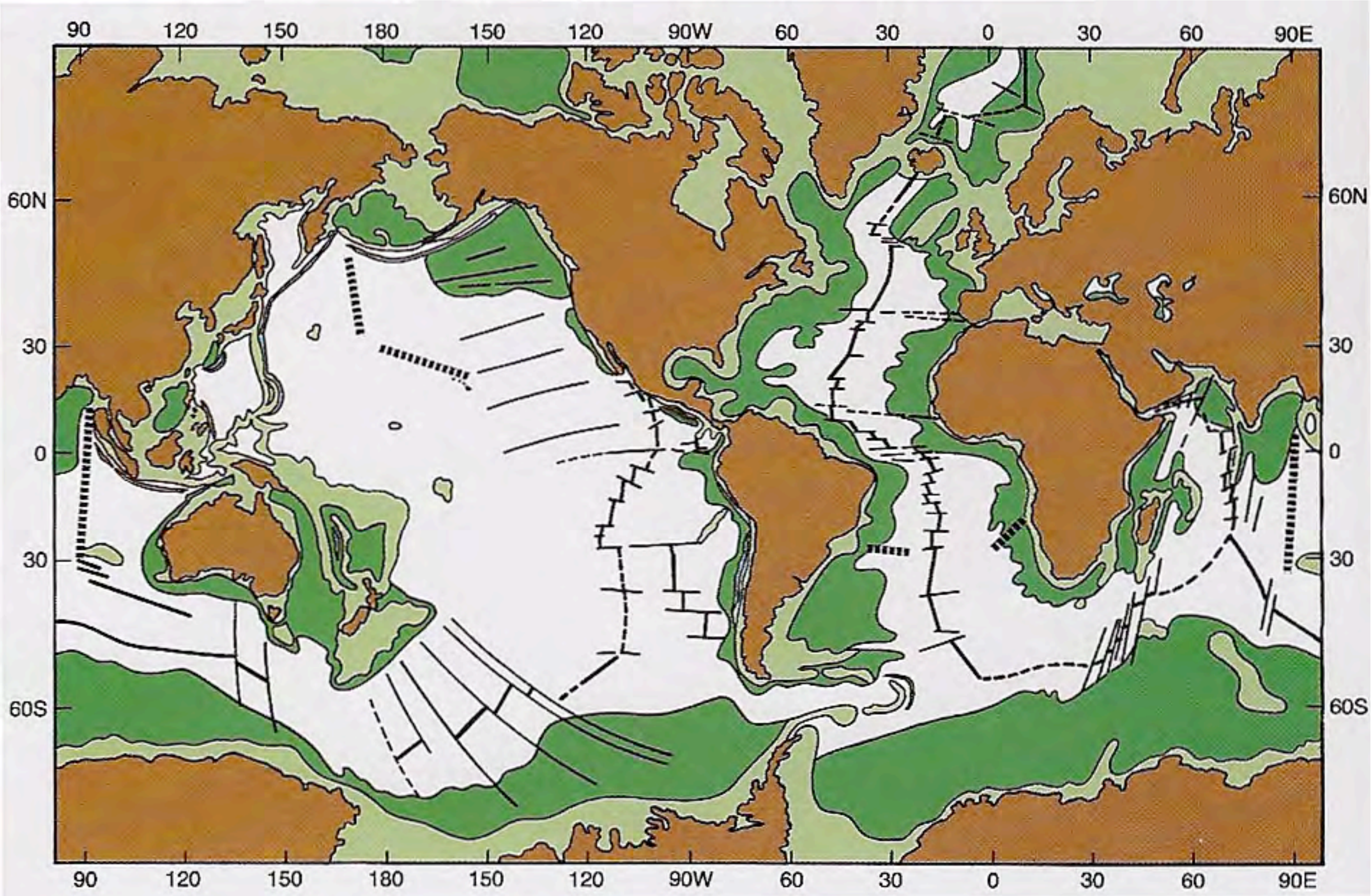
It is not a simple definition because there are a wide variety of biogenic and non-biogenic components in most 'pelagic sediments' and there can be **no specific detph connotation** to the world 'pelagic'

⇒ descriptive sense = open-marine deposits, whether in **shallow** epicontinental seas and outer shelf areas or in **deep** sea on oceanic crust in settings such as aseismic ridges, submerged plateaus, mid-ocean ridges and abyssal plains

==> the term 'pelagic' can also be applied to organisms that inhabit the open ocean and are exluded from marginal marine environments

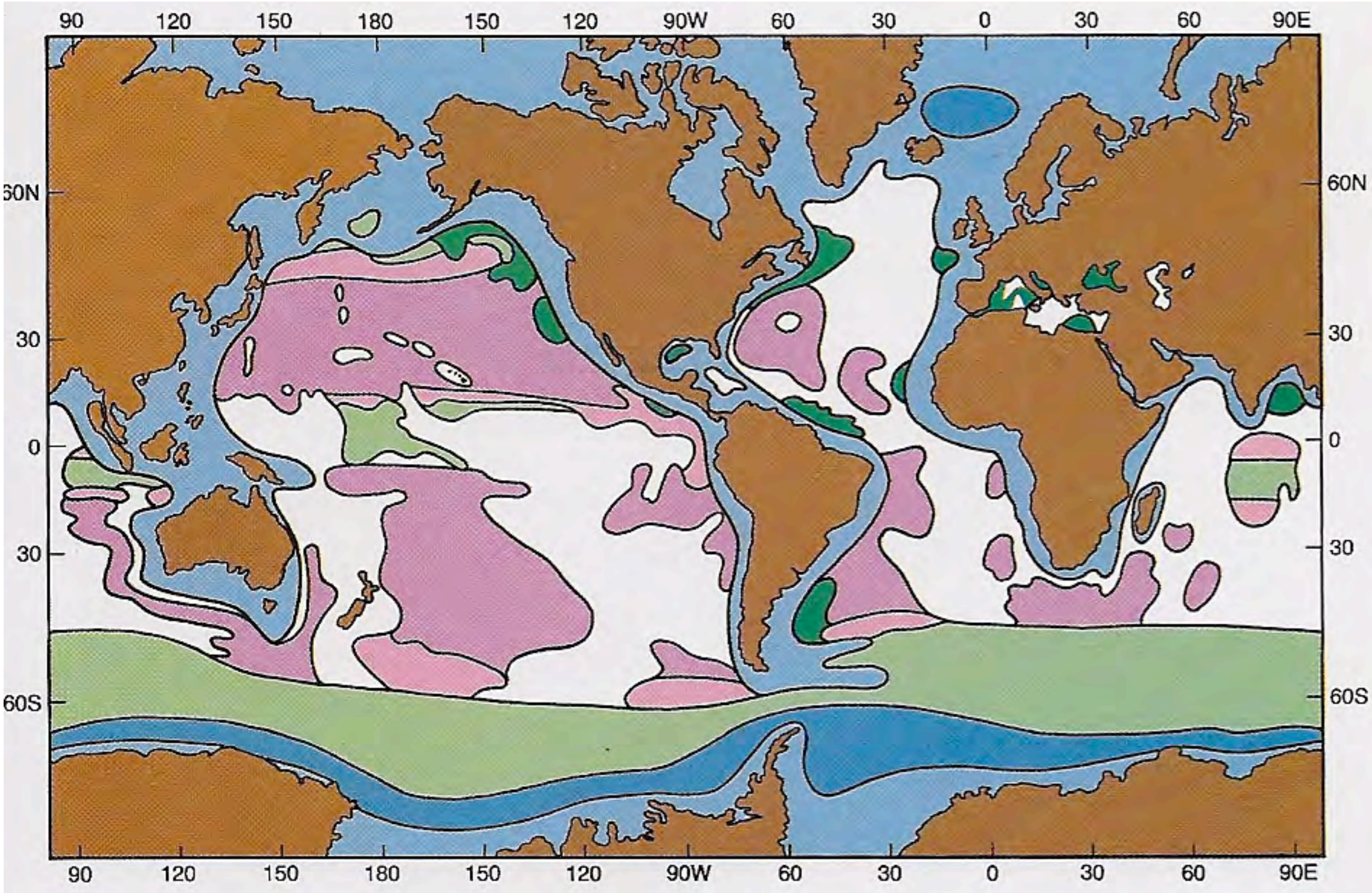
===> **in general : pelagic sedimentation implies a lack of significant influence of terrigenous sources** ('hemipelagic' for sediments containing a substantial amount of fine-grained terrigenous material).

PELAGIC FACIES = slow 'grain-by-grain' settling of material biochemically produced in surface water and **HEMIPELAGIC FACIES** = redeposition of material, either downslope as in dilute-suspension turbidity current or by settling out of bottom-currents or 'nepheloid' layers.



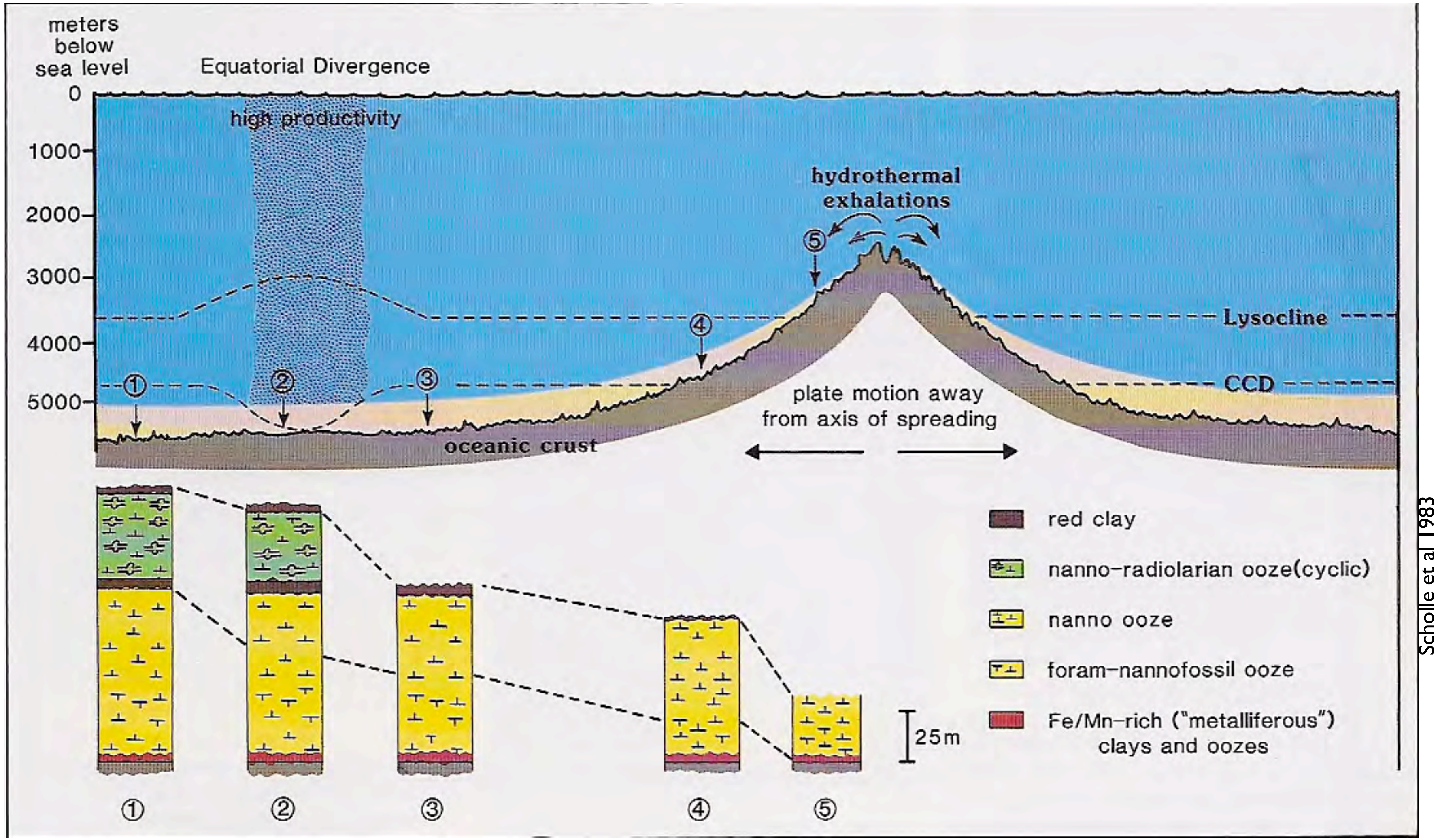
Scholle et al 1983

brown : land areas
light green : shelf areas (<200m water depth)
dark green : continental slopes, rises and abyssal plains (mainly turbidite and hemipelagic sedimentation)
white : mid-ocean and aseismic ridge flanks, seamount provinces and basins dominated by pelagic sedimentation

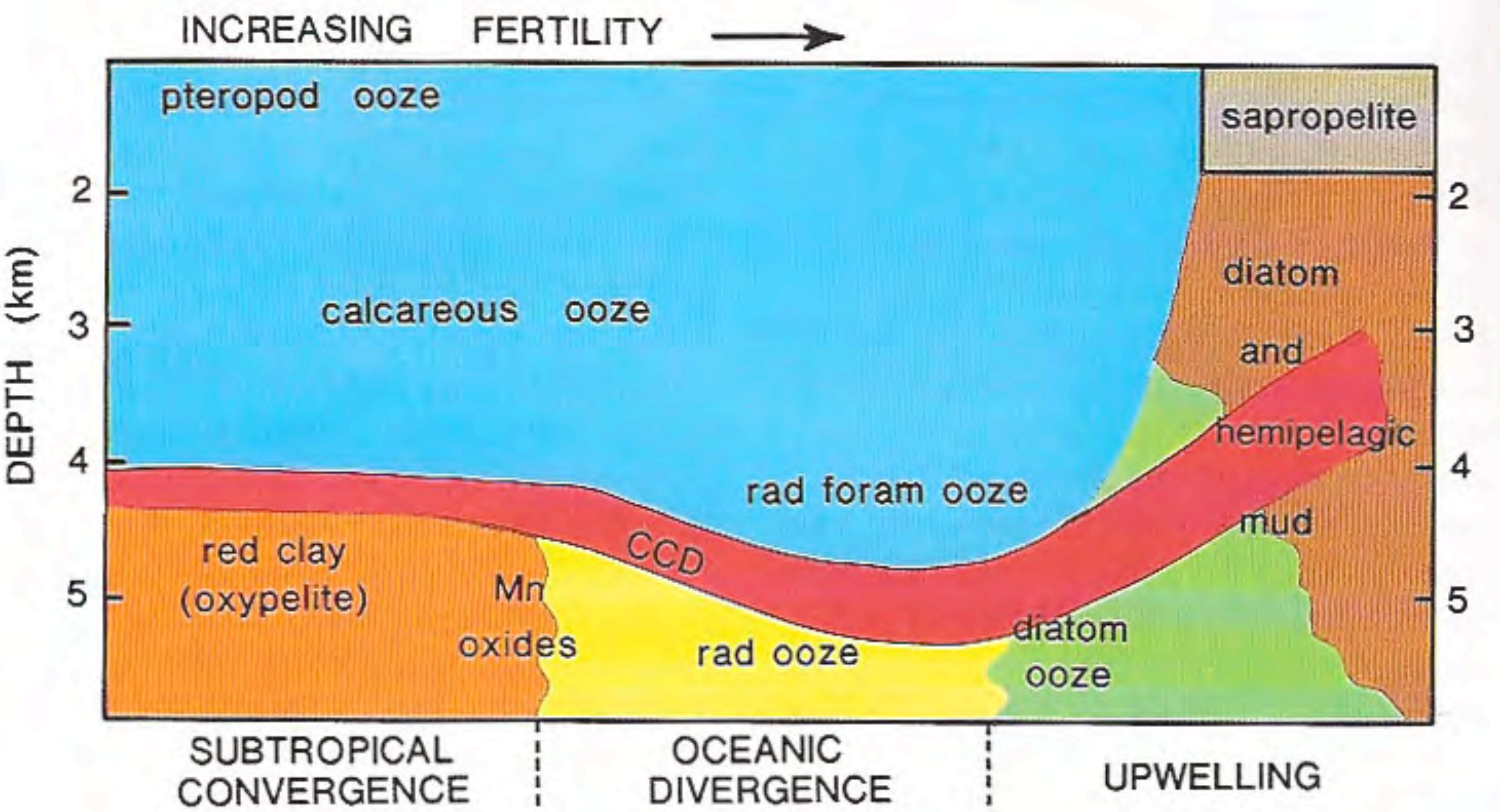


in Scholle et al 1983

brown : land areas
light blue : continental margin sediments dominated by clastic terrigenous debris or carbonate shelf debris
dark blue : sediments of glacial-marine origin
light green : siliceous biogenic pelagic deposits
lavander : pelagic red clays
pink : overlap of siliceous biogenic sediments and red clays
dark green : deep sea fans and abyssal plains dominated by clastic terrigenous turbidites
white : sea floor covered primarily by pelagic carbonate sediments



Diagrammatic representation of subsidence of oceanic crust and succession of sediment facies related to changes in water depth and productivity of surface water.



Generalized relationships of pelagic and hemipelagic facies versus depth, fertility and proximity to continental margins (after Berger, 1974).

nb: Present day (>< Past)

Atlantic CCD ±5600m, lysocline ±4800m ACD ±2100m

Pacific CCD ±4500m, lysocline ± 3600m ACD ±2000m

PALEOZOIC : THE CONODONTS

Conodonts : Pandler 1856!, Late Cambrian- Late Triassic, one dozen up to 1000s/kg of rock

- phosphatic tooth-like vertebrate remains
- nothing is known of the biology of the parent animal as it is extinct
- they are found as individual elements which can be conical, bar or blade shaped (ramiform) or platform type, < 1mm long
- classification (into form genera) is based on details of morphology
- they are EXCLUSIVELY MARINE and characteristically DEEP MARINE, **but**…
- Late Cambrian, diversification in the Ordovician and again in the Late Devonian and Carboniferous, declined in the Permian and disappeared in the Triassic
- USEFUL in the stratigraphic subdivision of Paleozoic marine sediments in a range of palaeogeographic provinces (‘worldwide zonations-and/or range charts)

= THE CONODONT ENIGMA…

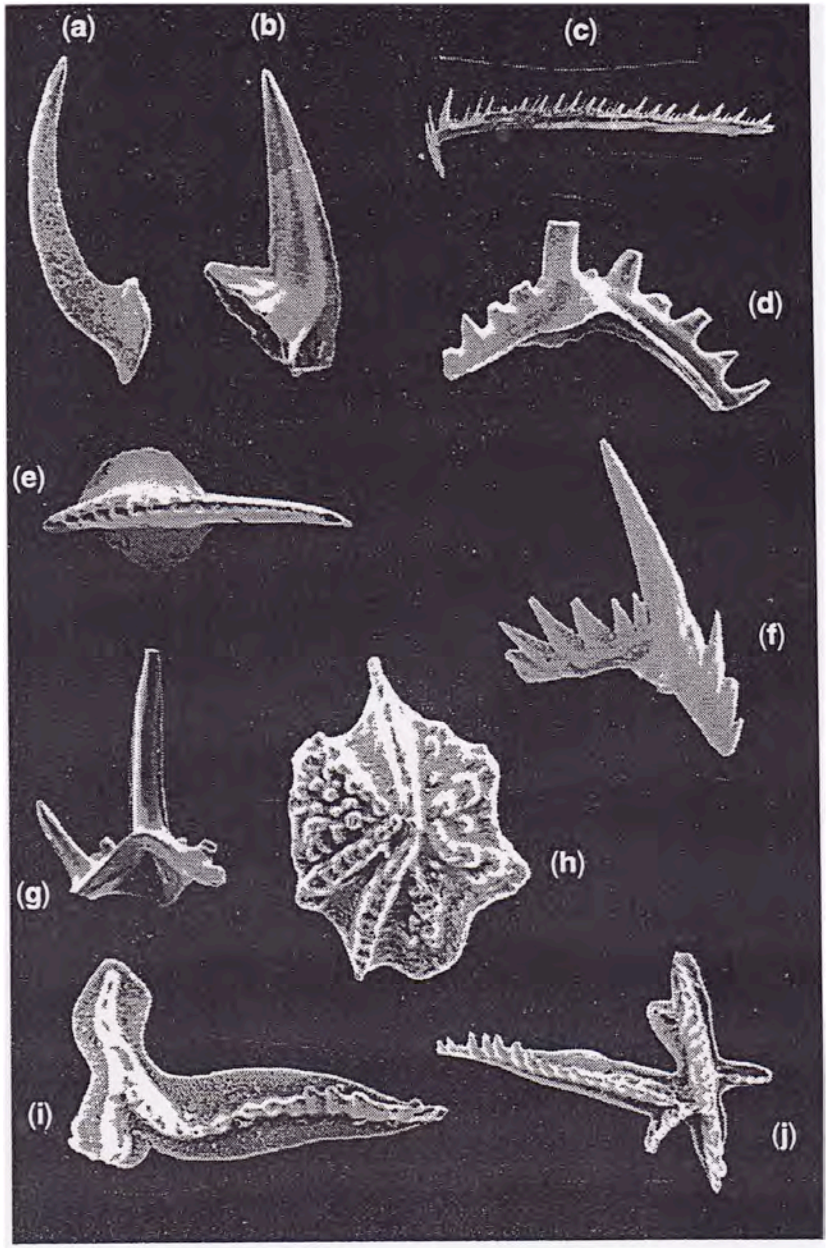
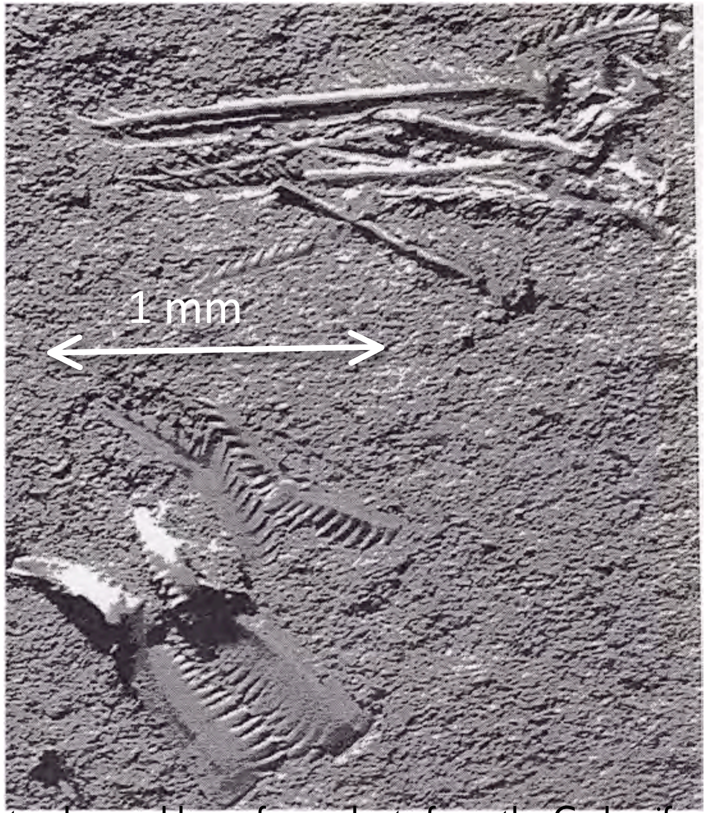
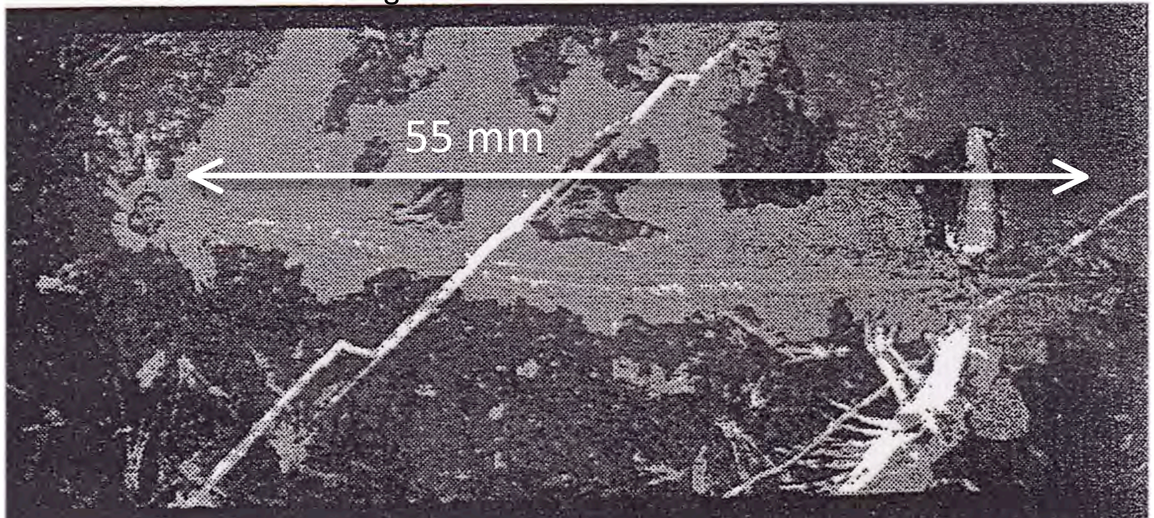


Fig 11.22 Conodont elements: (a) coniform, lateral view, (b) coniform, lateral view, (c) ramiform, lateral view, (d) ramiform, lateral view, (e). straight blade, upper view, (f) arched blade, lateral view, (g) ramiform, posterior view, (h) platform, upper view, (i) platform, upper view, (j) platform, upper view (×20–35).

A. PREAT–ULB, L5&L6 (2011)



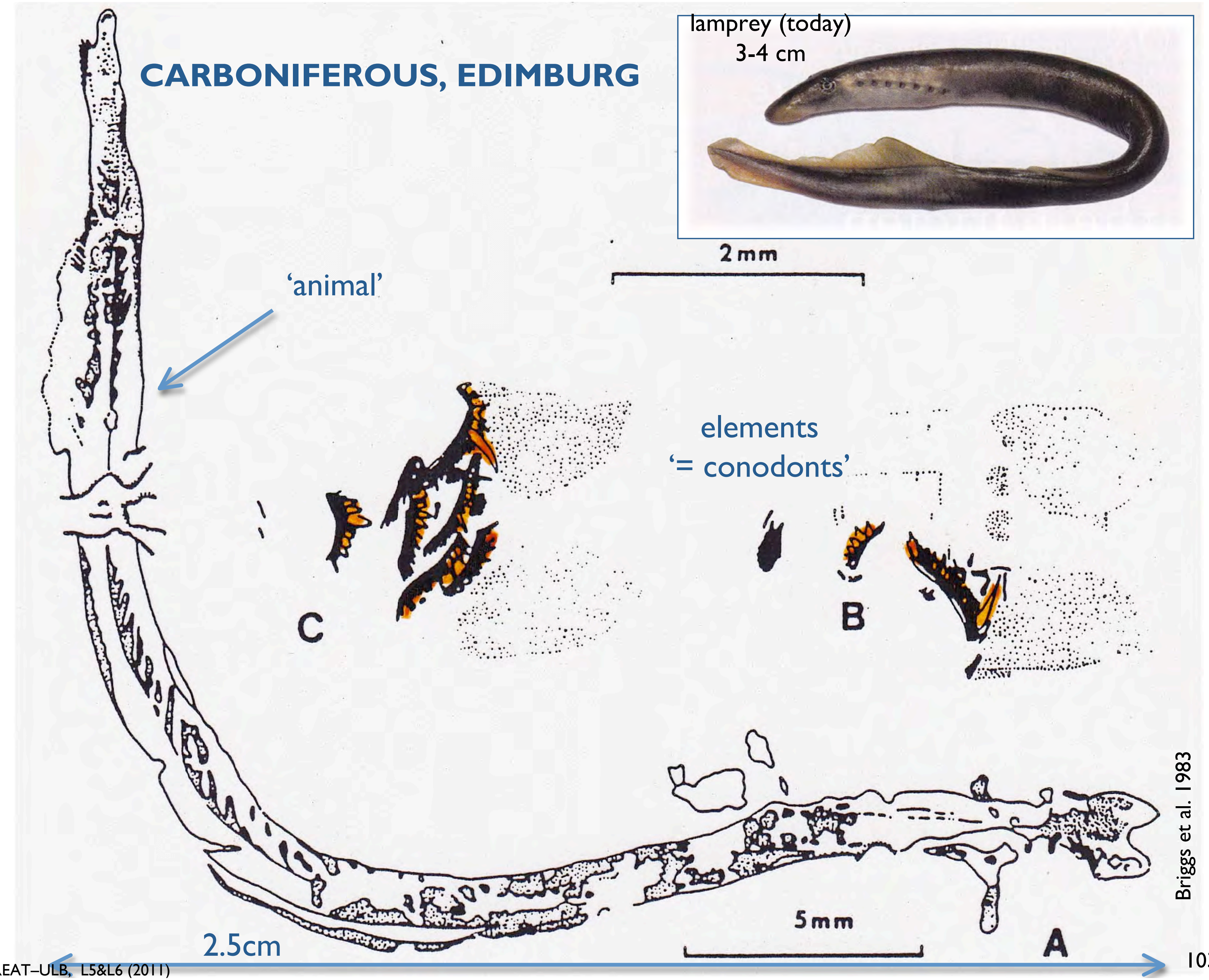
Natural assemblage of conodonts from the Carboniferous



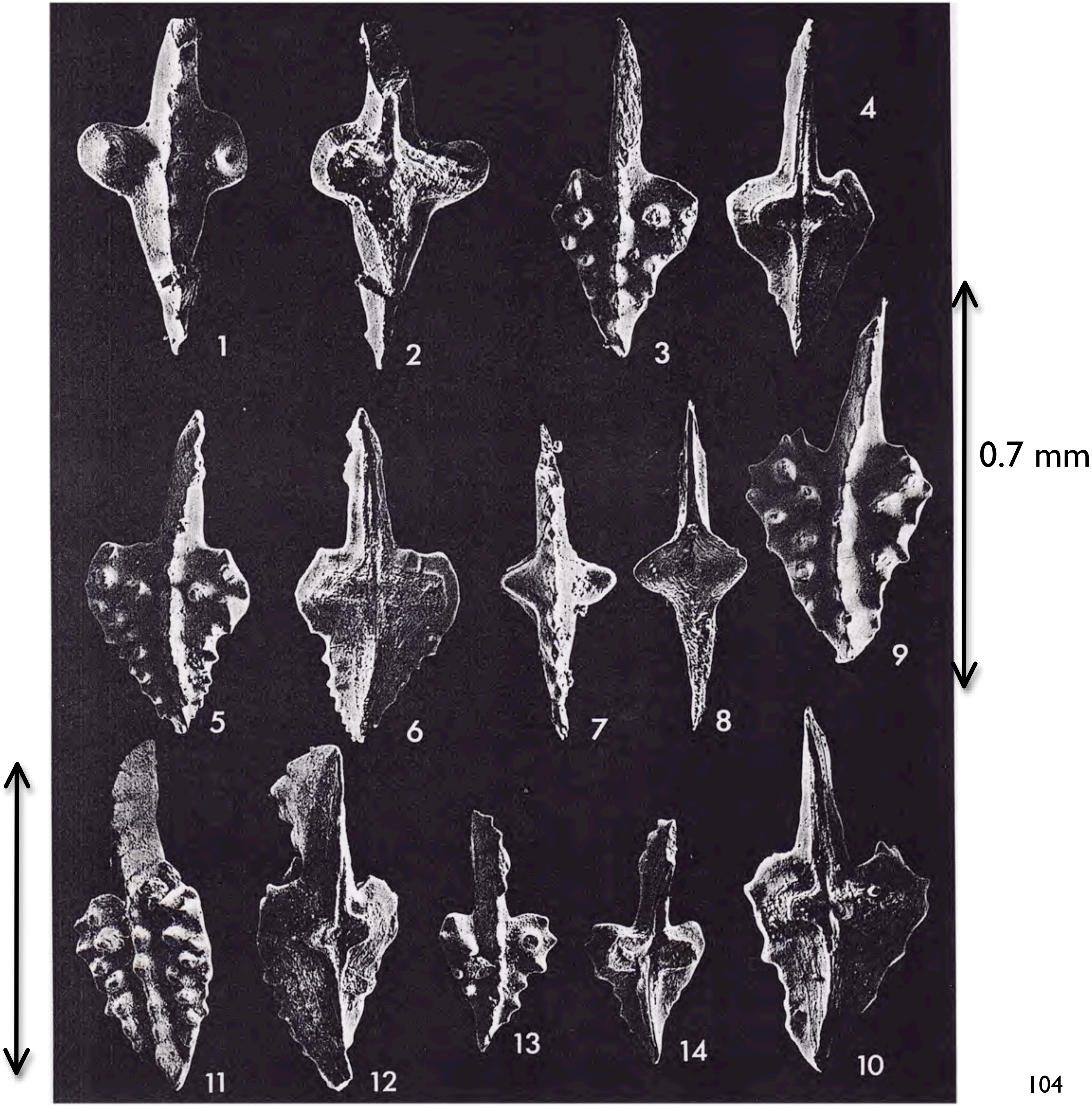
THE CONODONT ANIMAL, CARBONIFEROUS, GRANTON SHRIMP BED, EDINBURG (1980s)

in Benton & Harper 1997

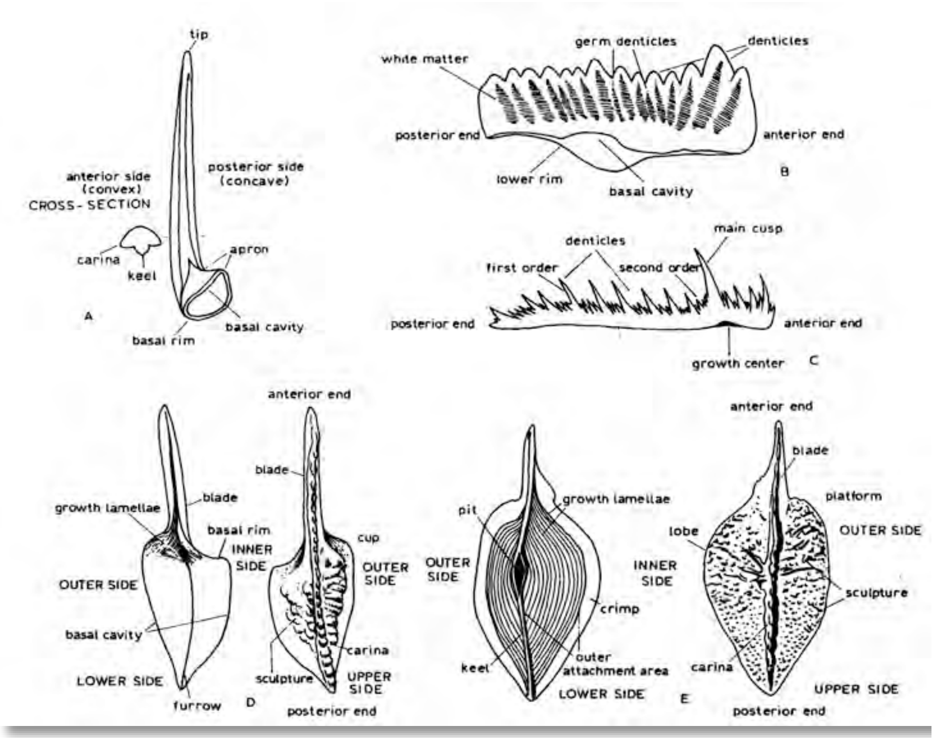
CARBONIFEROUS, EDIMBURG

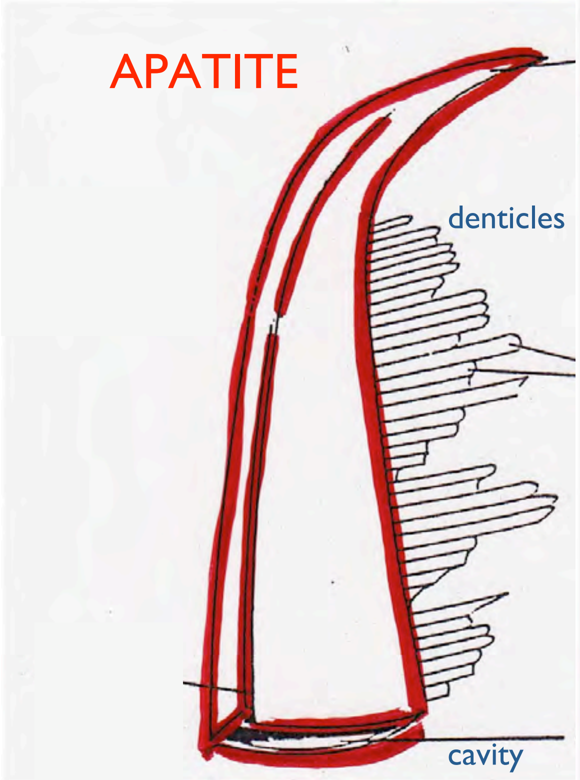


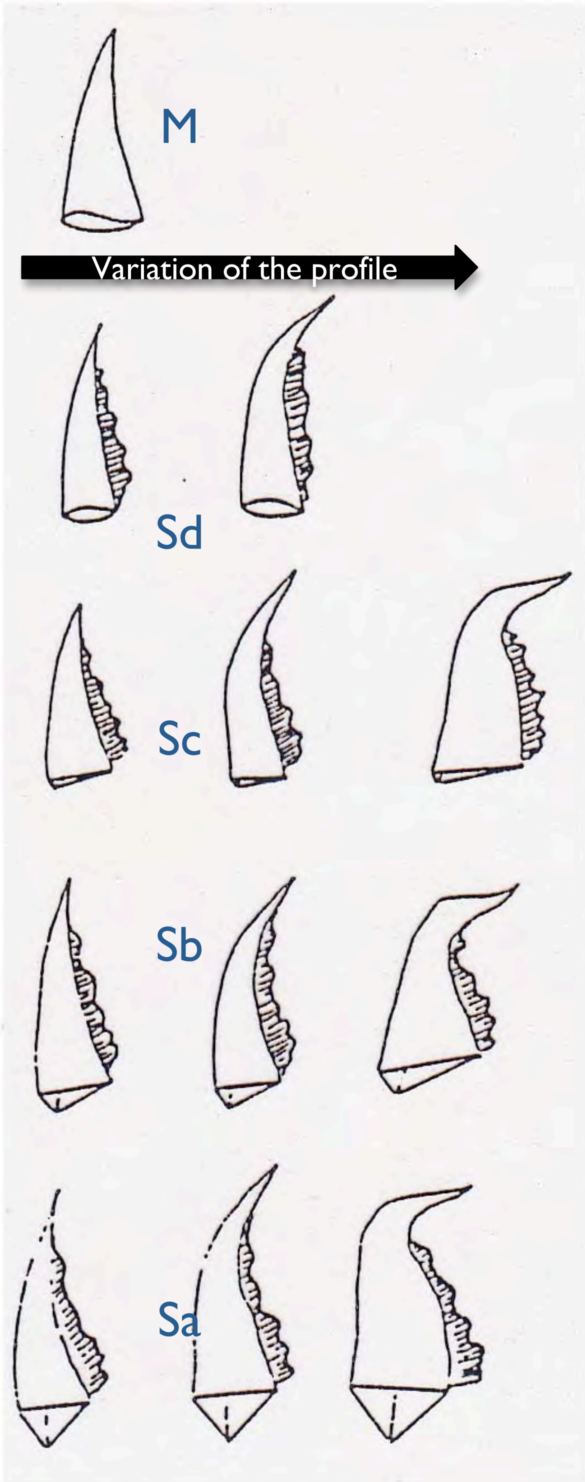
Middle-Late Devonian
Ancyrodella sp.

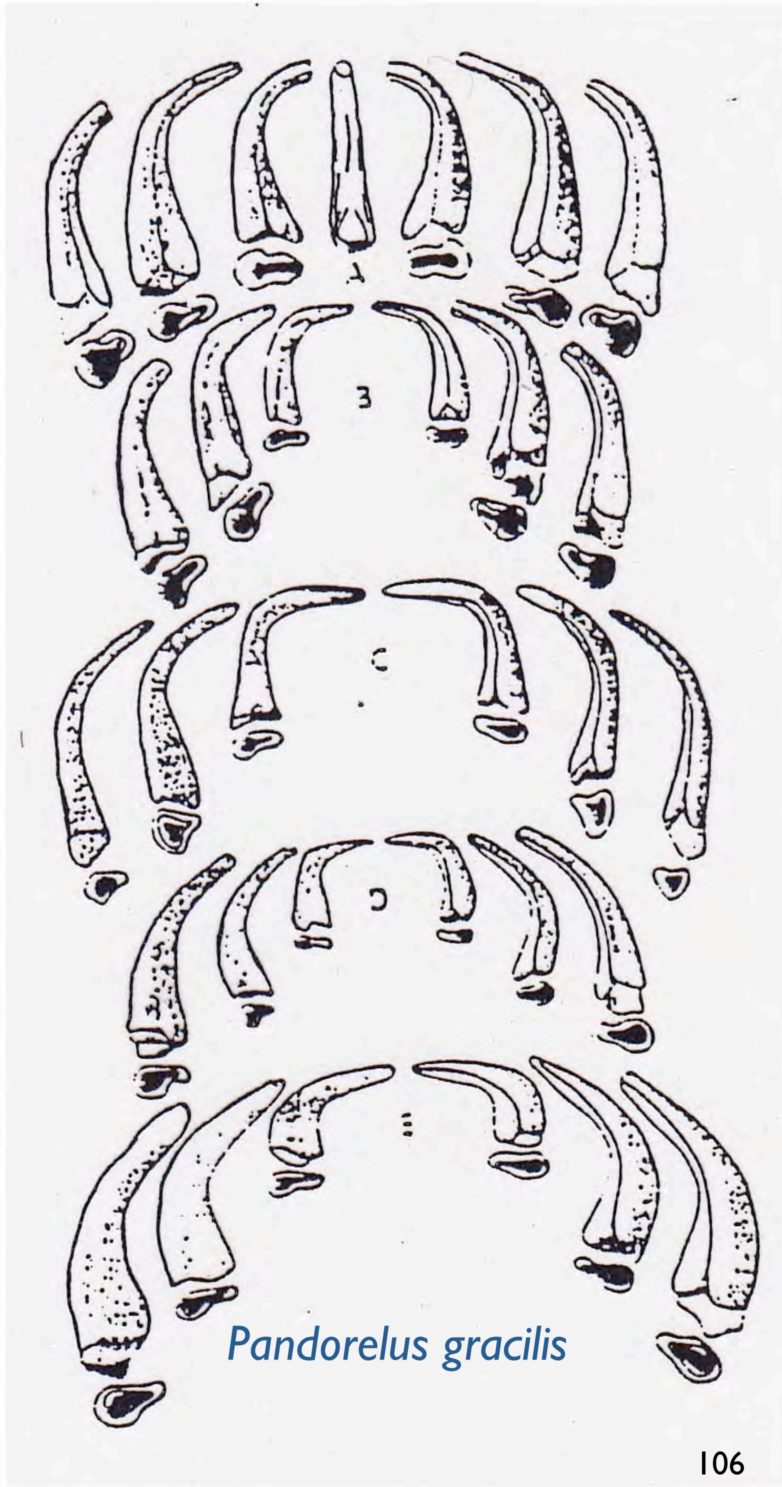


Morphology of conodont elements
from Haq & Boersma 1978.
(A)Cone type, (B) blade type, (C) bar type
(D) platform type (*Gnathodus*)
(E) platform type (*Polygnathus*)

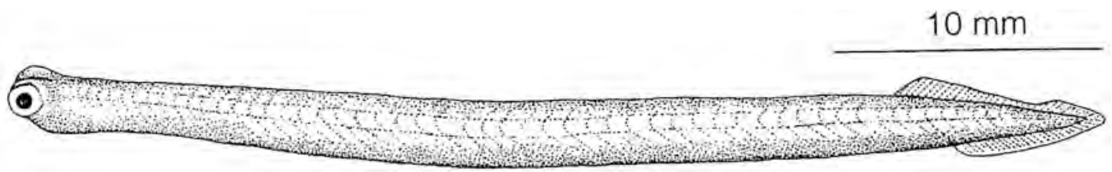




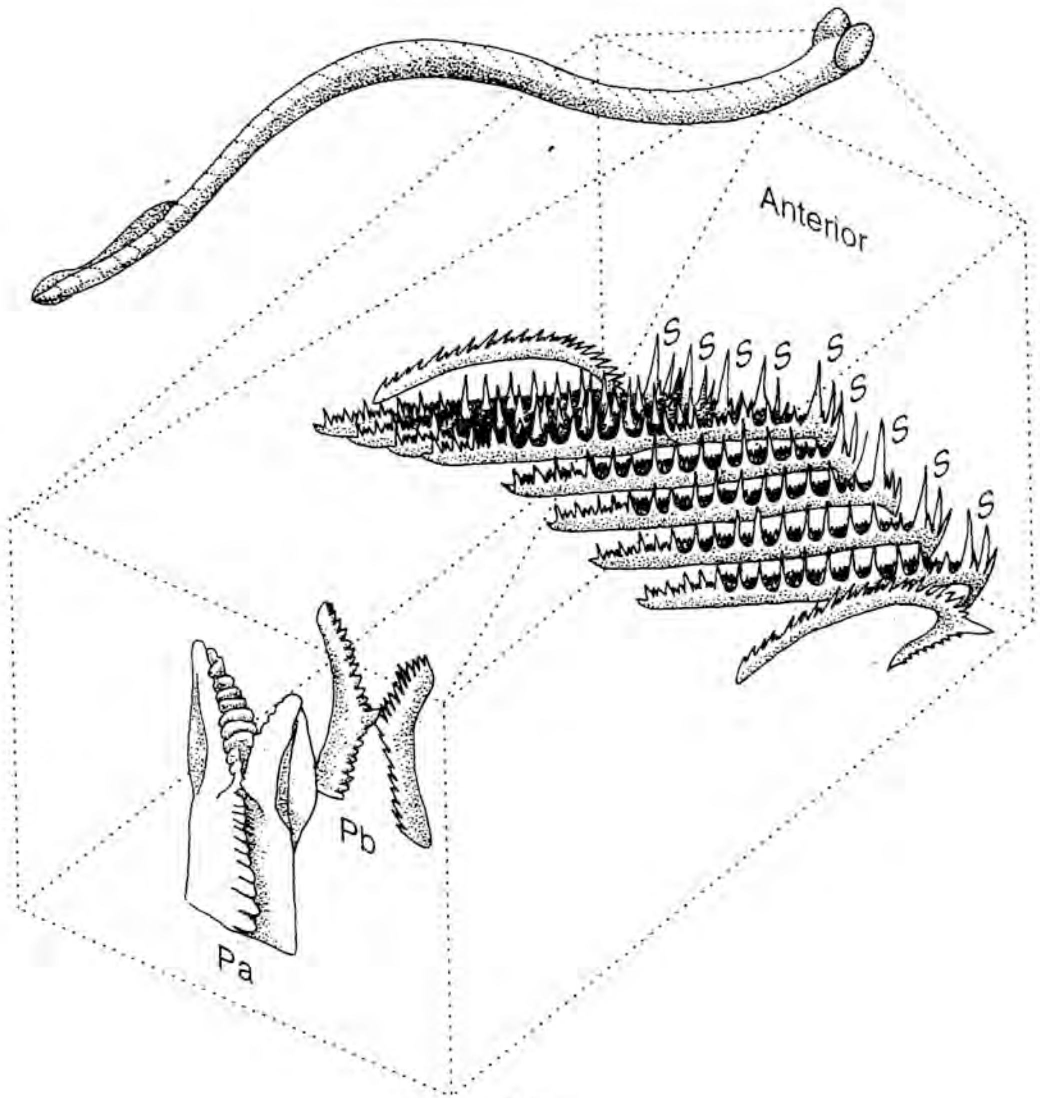




Different element types
in *Belodella devonica*



(a) *Clydagnathus* (L. Carboniferous, Edinburg)

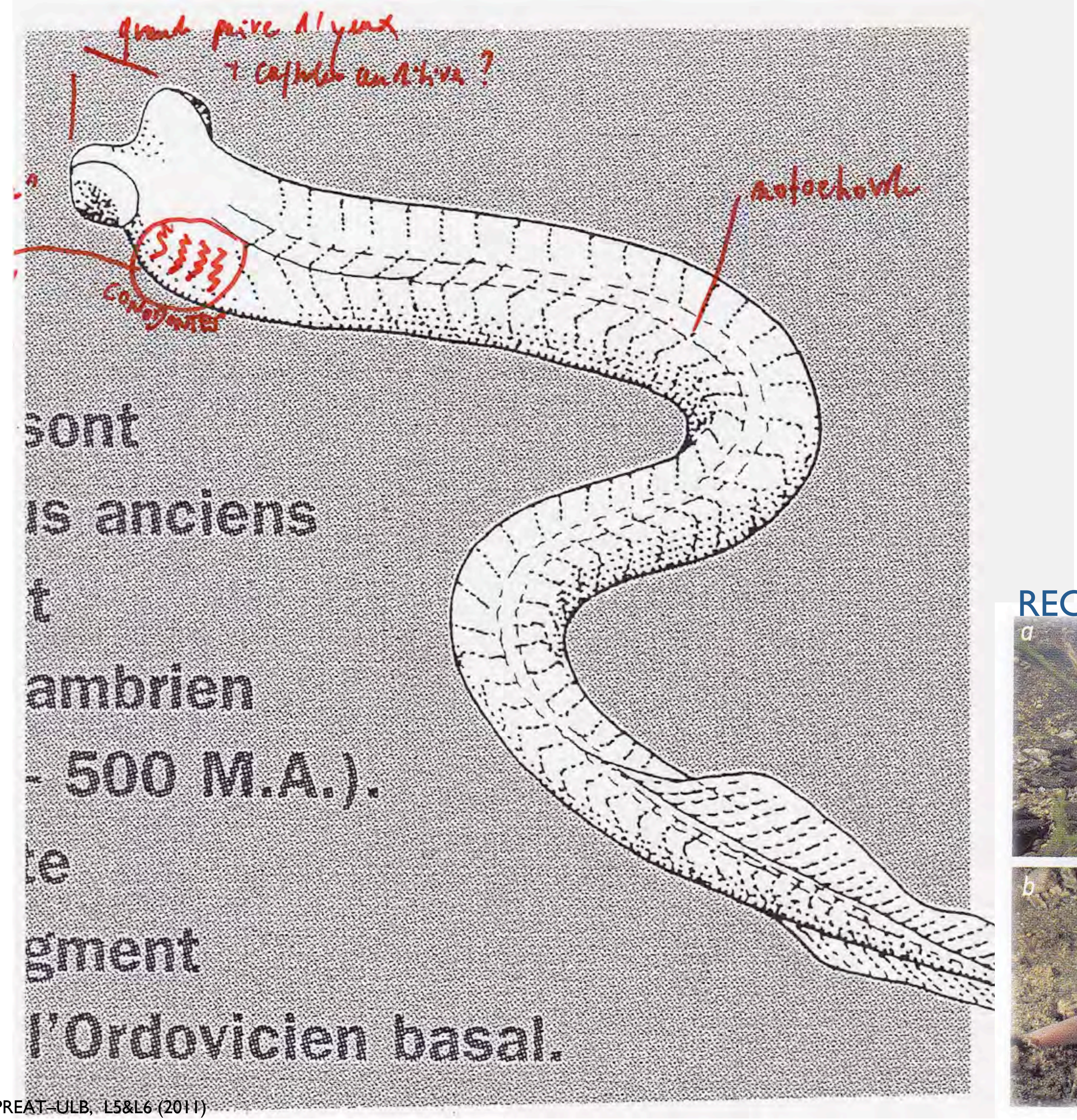


(b)

within the 'pharynx'

feeding apparatus (conodont elements) inside the head of *Idiognathus*

anterior S elements for grasping and posterior P elements for crushing

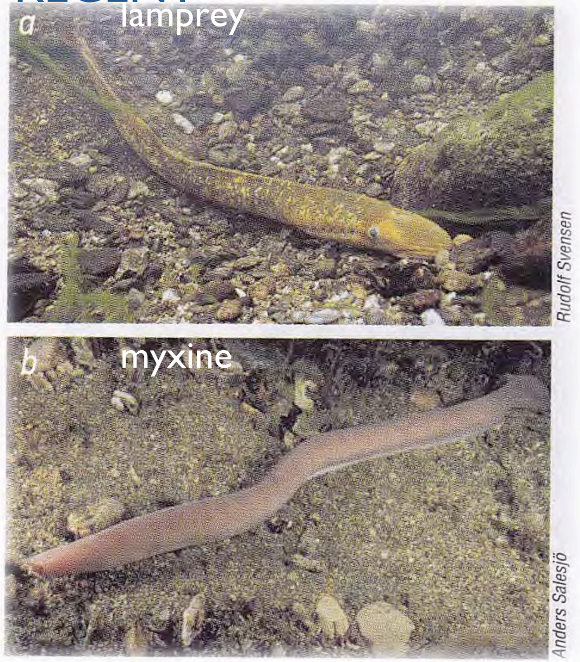


L 4 cm or <
cf
RECENT
Hagfishes-
Myxinoidea
and
Lampreys

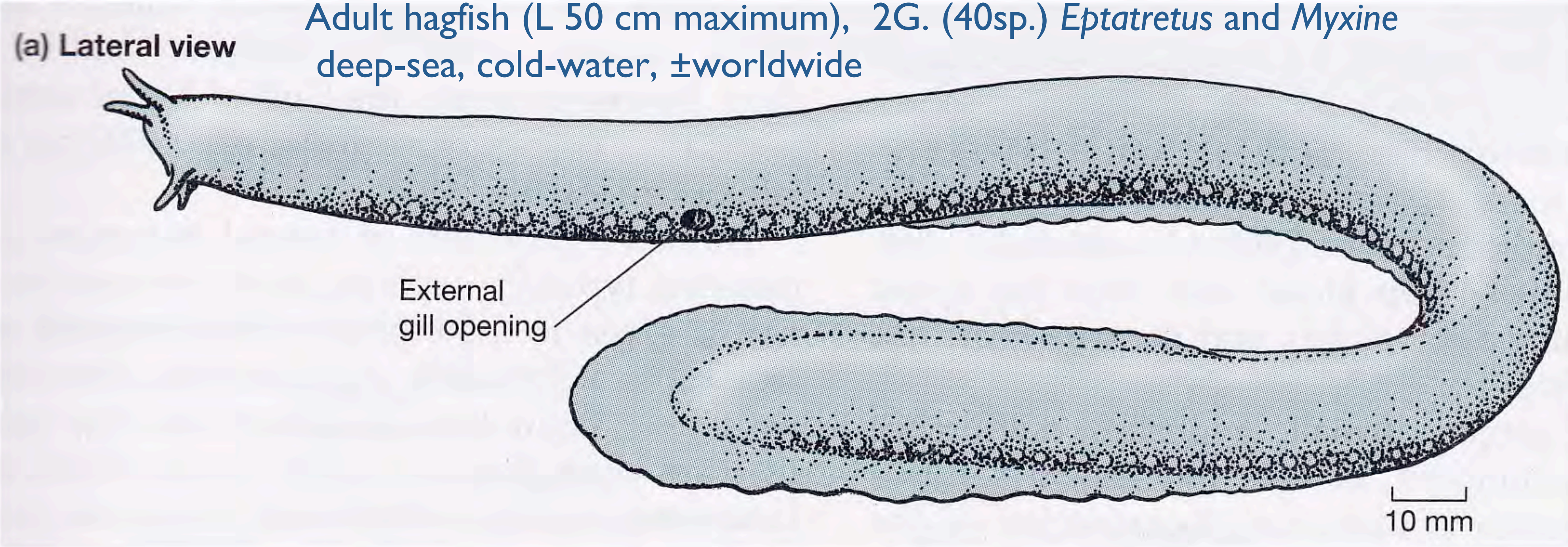
=

AGNATHA
no jaws ….

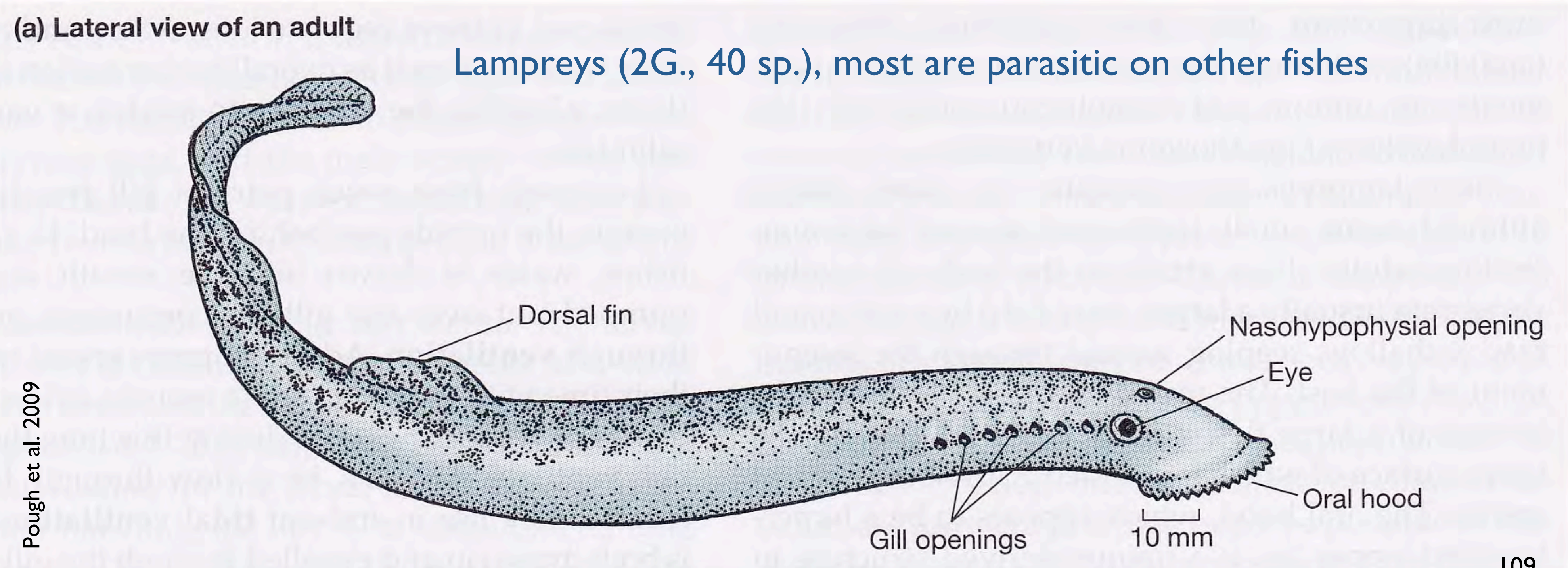
RECENT



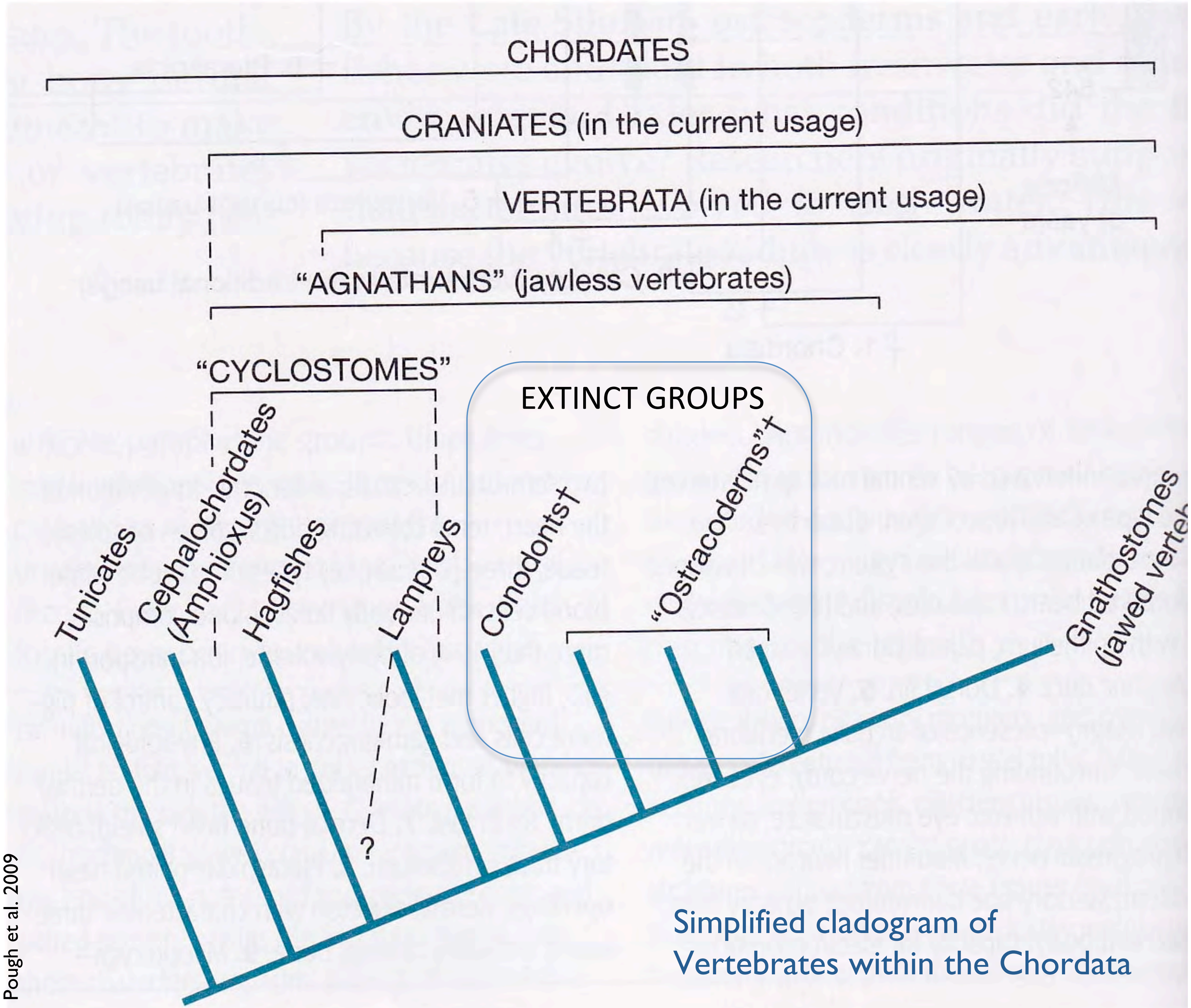
Adult hagfish (L 50 cm maximum), 2G. (40sp.) *Eptatretus* and *Myxine*
deep-sea, cold-water, ±worldwide



Lampreys (2G., 40 sp.), most are parasitic on other fishes



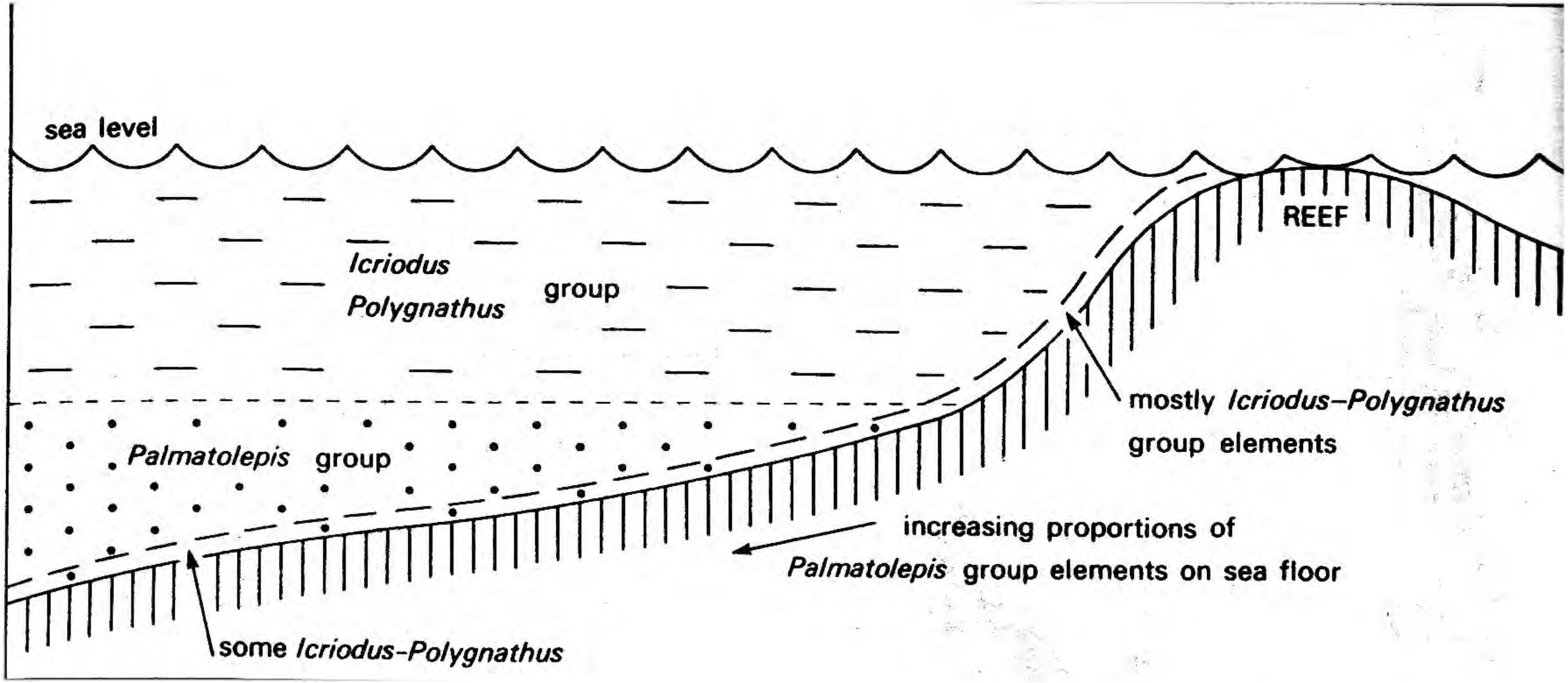
Pough et al. 2009

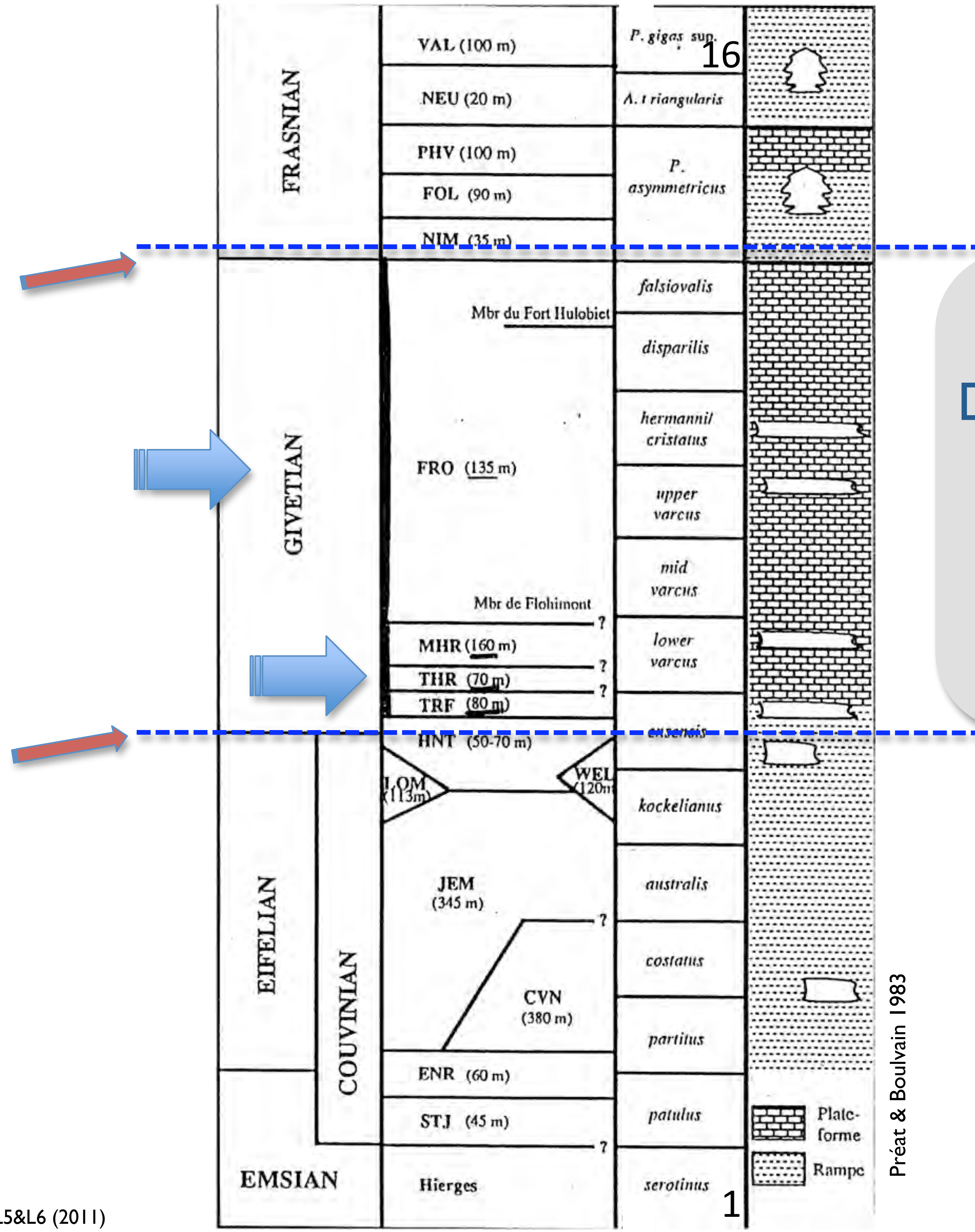


Simplified cladogram of Vertebrates within the Chordata

Pough et al. 2009

PALEOECOLOGICAL DISTRIBUTION OF CONODONTS IN RELATION TO A REEF PROFILE IN THE LATE DEVONIAN (WORLDWIDE) – FROM BRASIER 1980



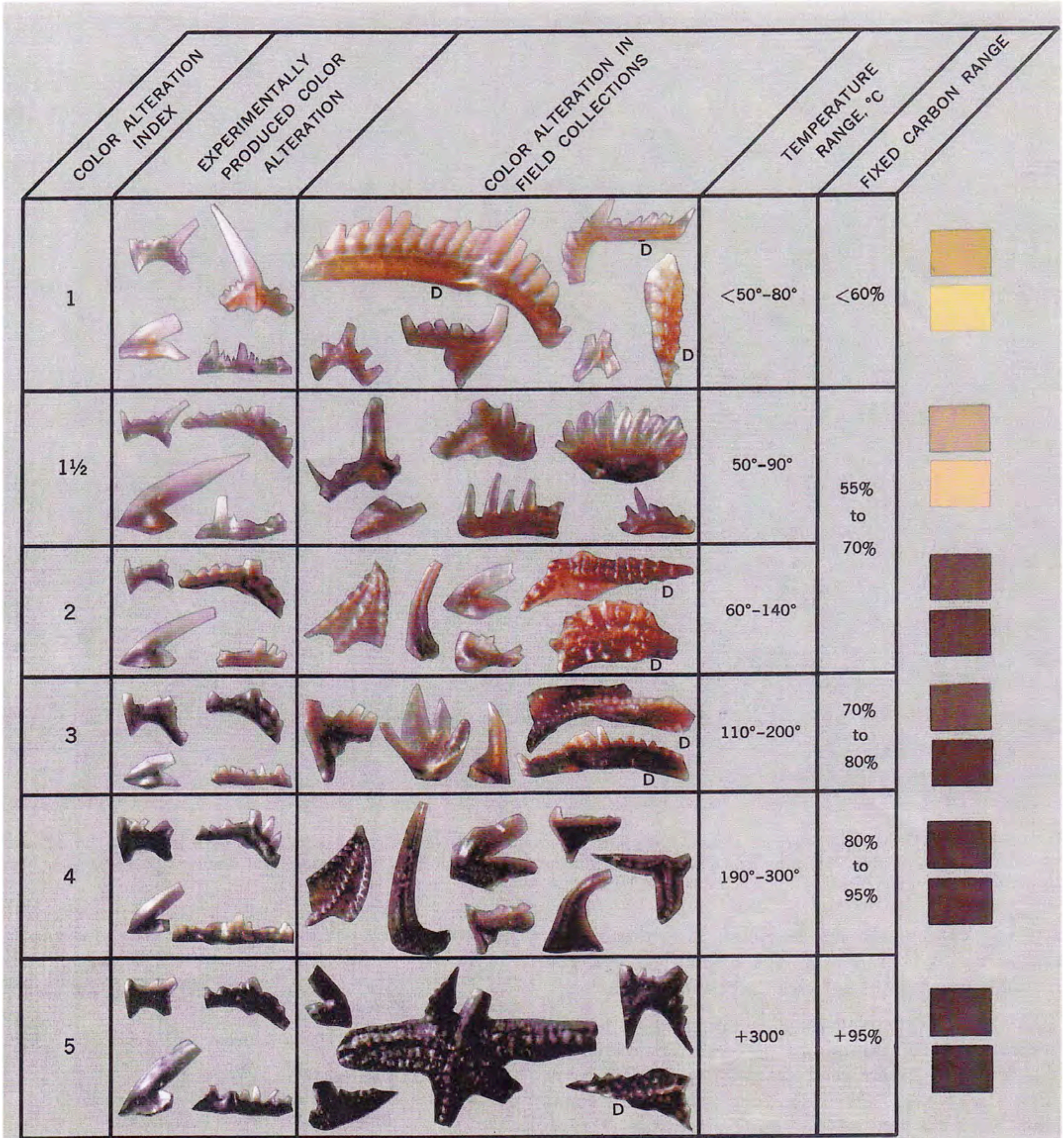


South Border
Dinant Synclinorium

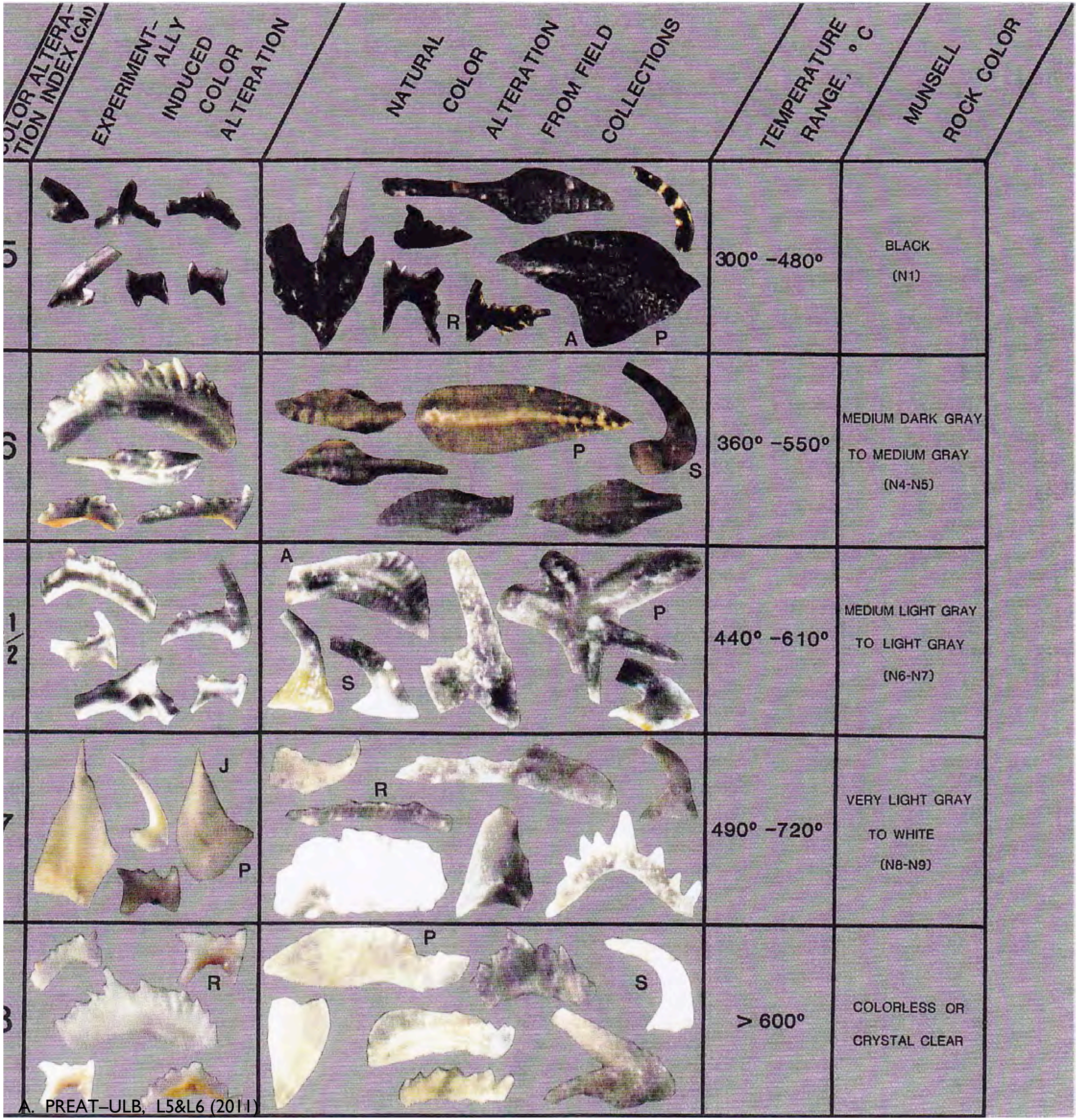
'1.5 myr/150-200m'

CAI

COLOR ALTERATION INDEX
1 to 5



A. PREAT–ULB. L5&L6 (2011)



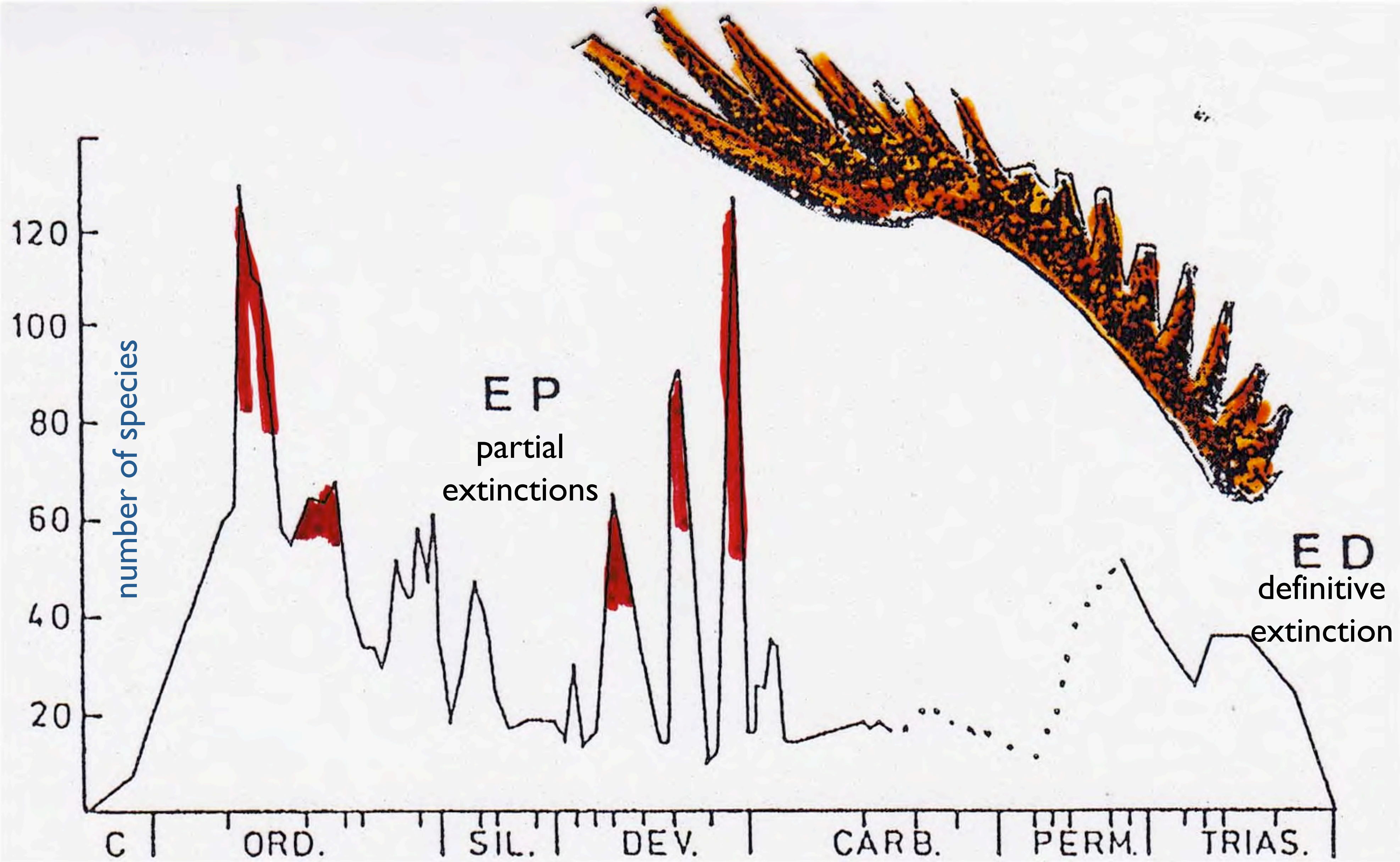
CAI

COLOR ALTERATION INDEX 5 To 8

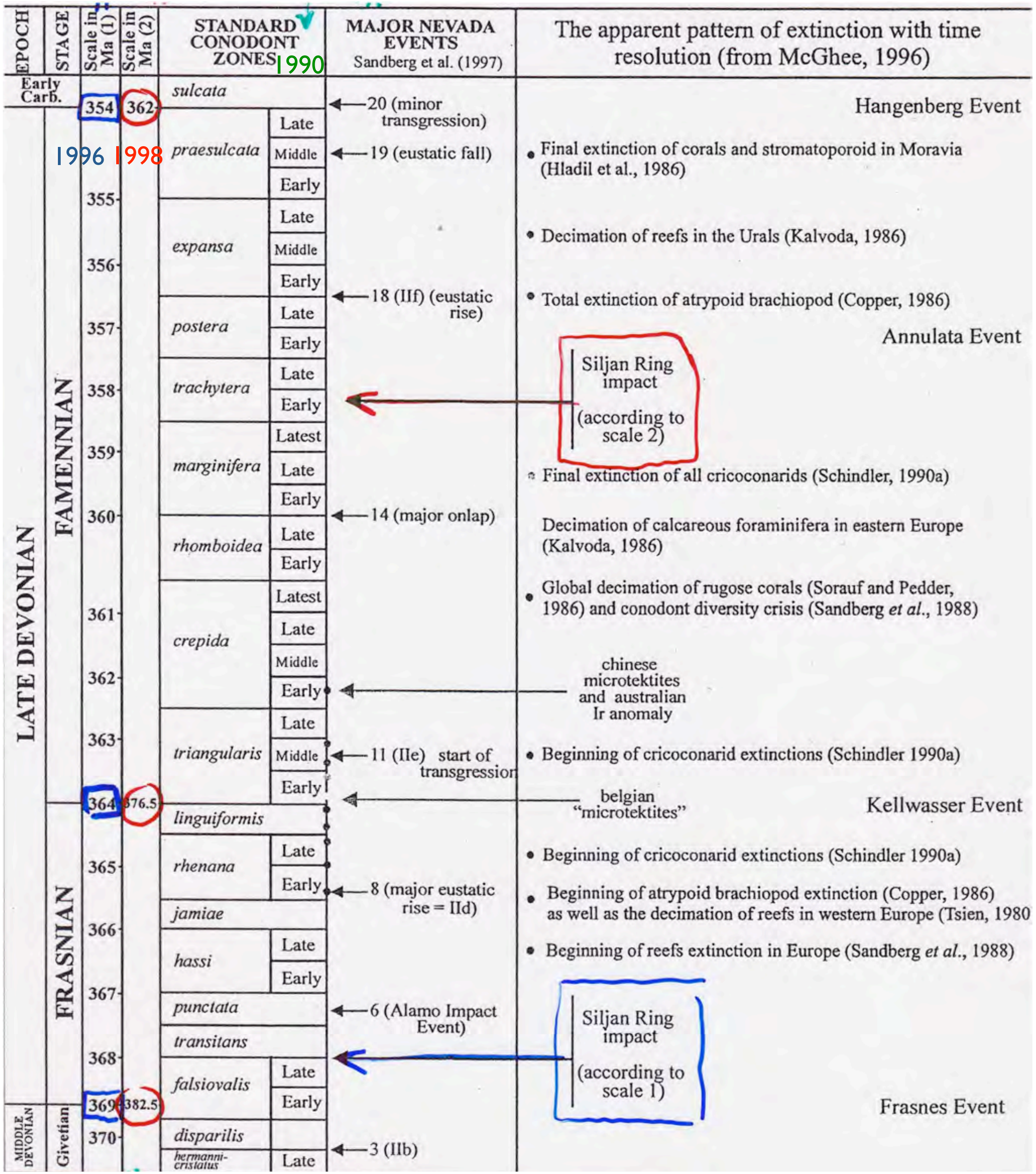
The geological T range for each CAI covers durations of 1,000 yr to 500 myr

CAI > 6 in rocks affected by a relatively high T, short term contact metamorphic event

P platform element
R ramiform element
S simple-cone element
J juvenile
A adult

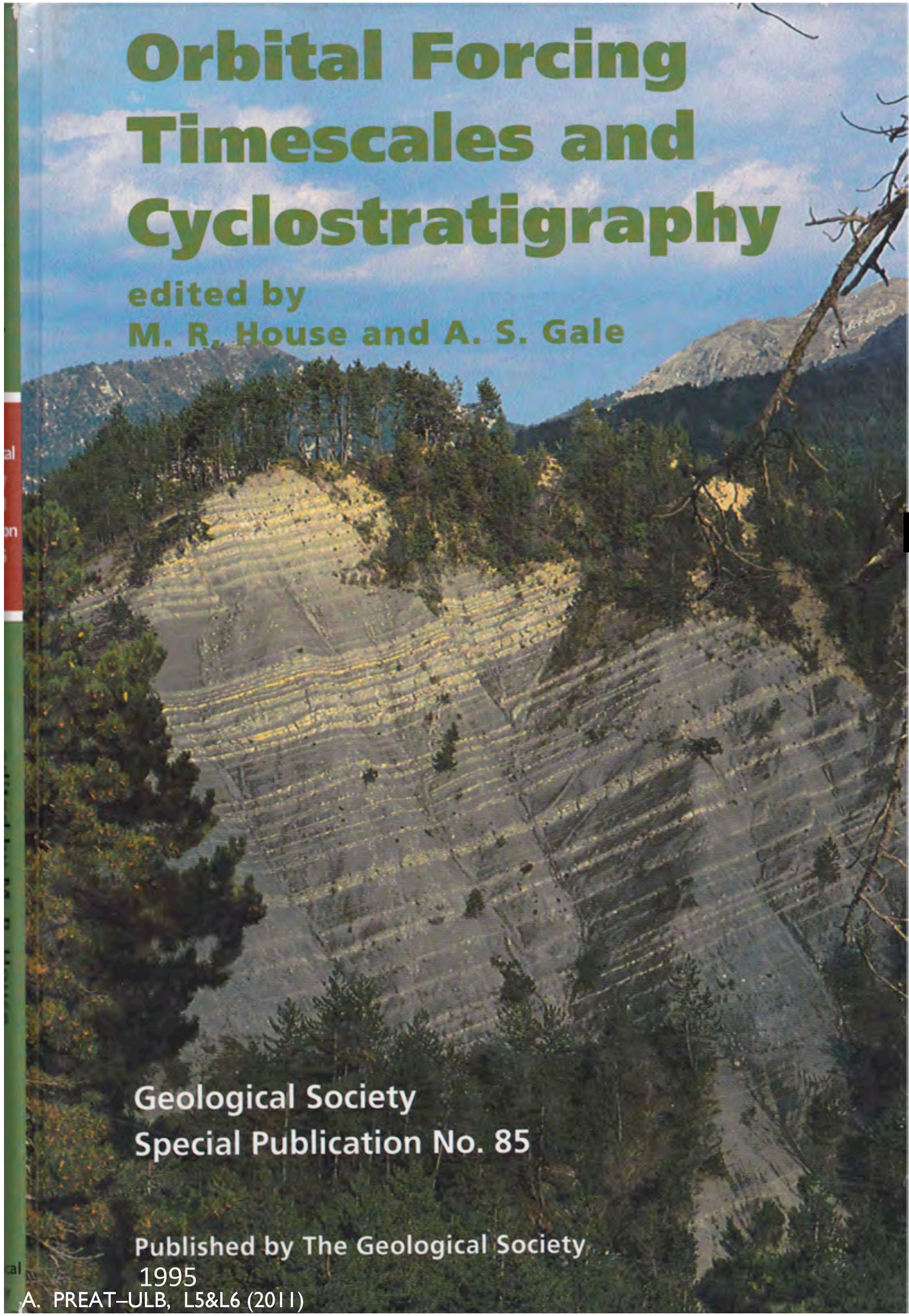


CONODONT DIVERSITY



Siljan Impact
Sweden
The largest in Europe
Diameter : 75 km
Age?
377 Ma
F/F 2008: 374.5 Ma

U-Pb
zircon



1995

ESTIMATION OF THE DURATION (OF A STAGE, OR….) INDEPENDANTLY FROM RADIOMETRIC DATES

WHY?

… because the duration of the Devonian (for example) based on radiometric data show considerable divergence

Author	Devonian duration (Ma)	Givetian duration (Ma)	Givetian as a percentage of Devonian duration
Harland *et al.* 1982	40	6	12.5
Palmer 1983	48	6	12.5
Odin 1985	40	5	12.5
McKerrow *et al.* 1985	58	11	18.96
Snelling 1985	50	(10)	(20)
Harland *et al.* 1989	46	3.4	7.39
Cowie & Bassett 1989	55	–	–
Menning 1989	46	–	–
Odin & Odin 1990	50	5	10.0
Fordham 1992	44	*c.* 8.7	19.8

EIFELIAN

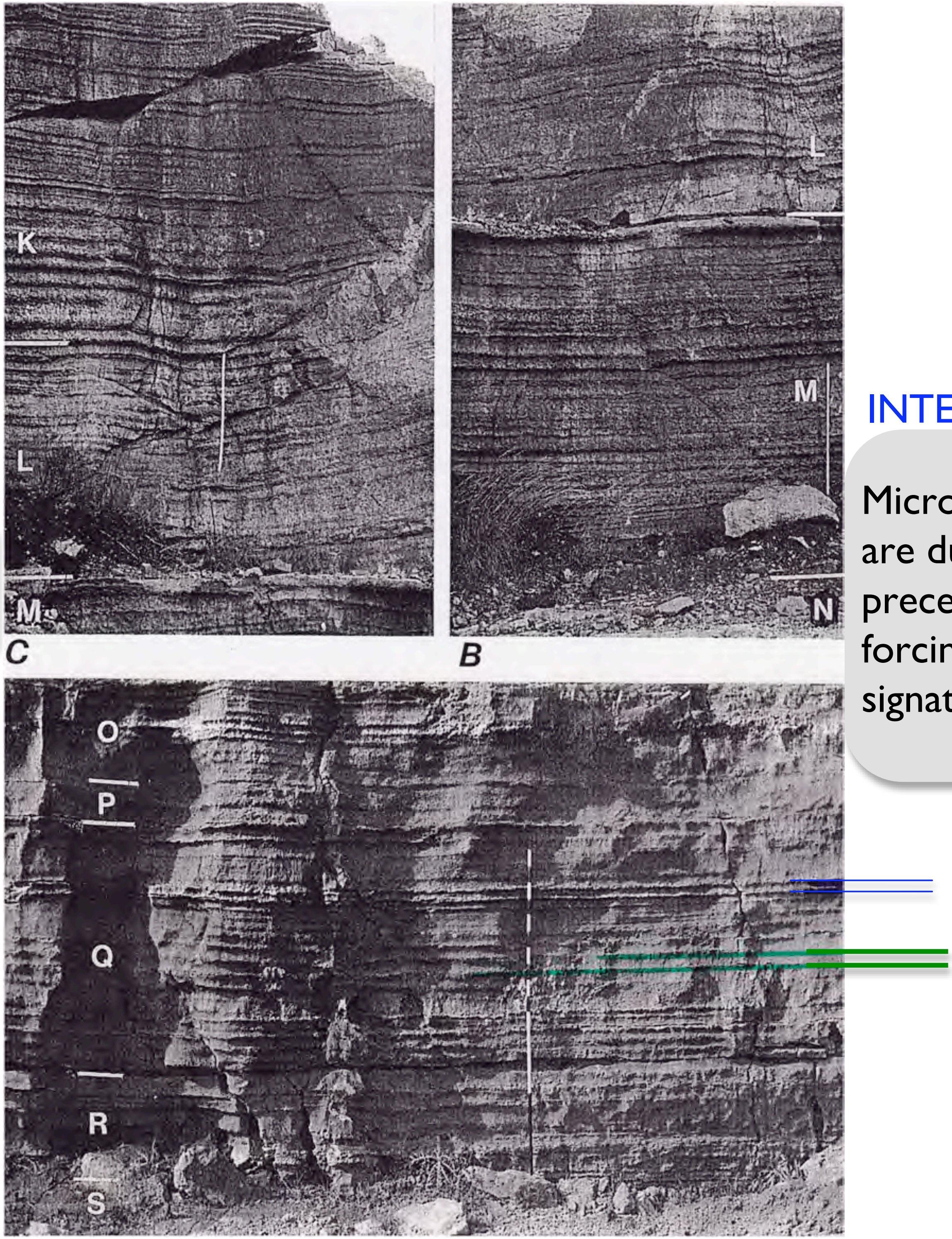
Marbrière Nord
Pic de Bissous
Montagne Noire
France

INVERTED SECTION

GIVETIAN

OBERVATION

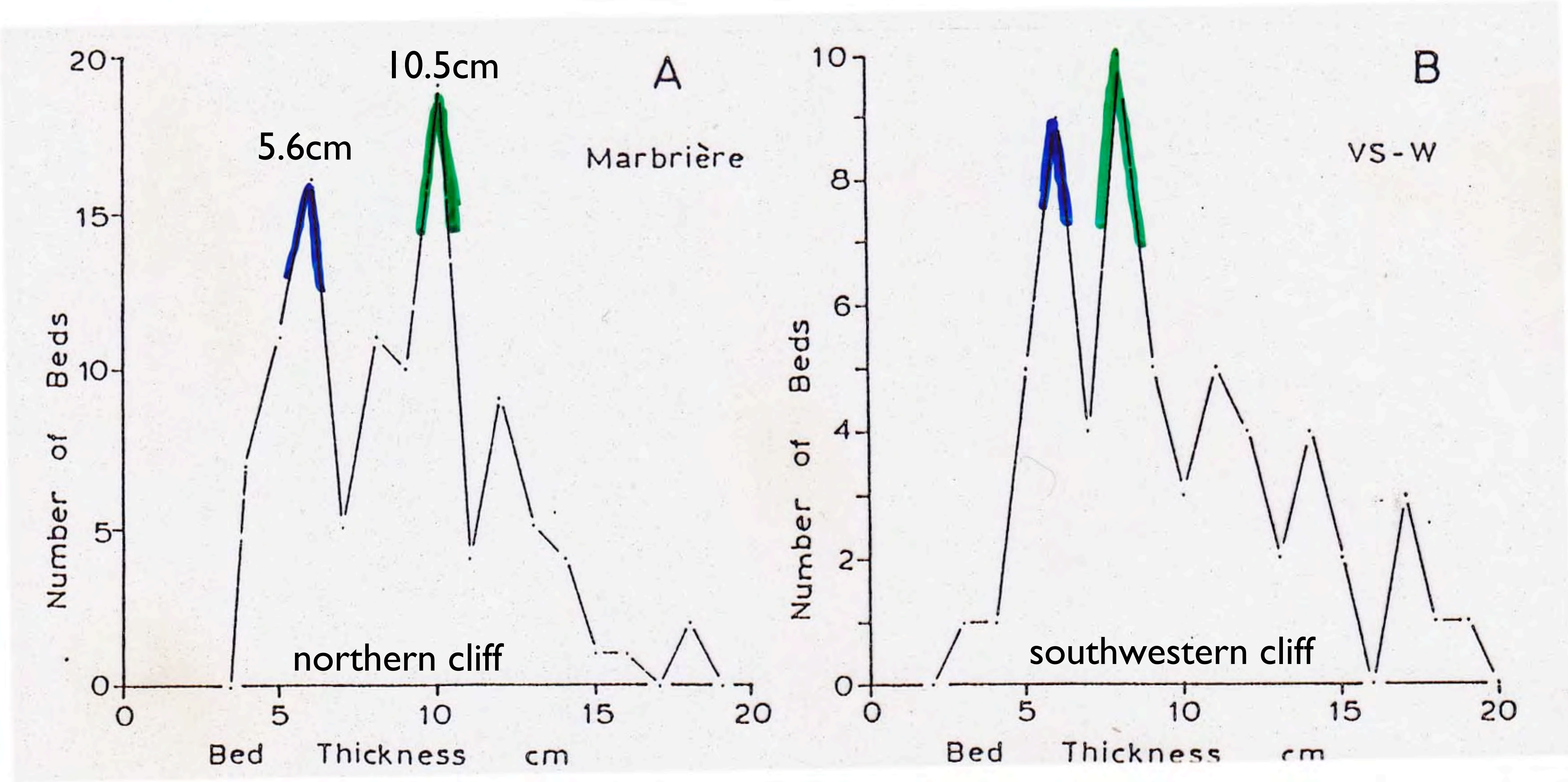
FINE-SCALE MICRORHYTHMICITY



INTERPRETATION

Microrhythms are due to the precessional orbital forcing climatic signature

= BIMODAL COUPLETS WITH AVERAGE THICKNESSES of 5.6cm (p?) and10.5cm (o?) (n = 107 beds)



348 couplets x 5,6 cm x 16 678 yr = 6,5 myr

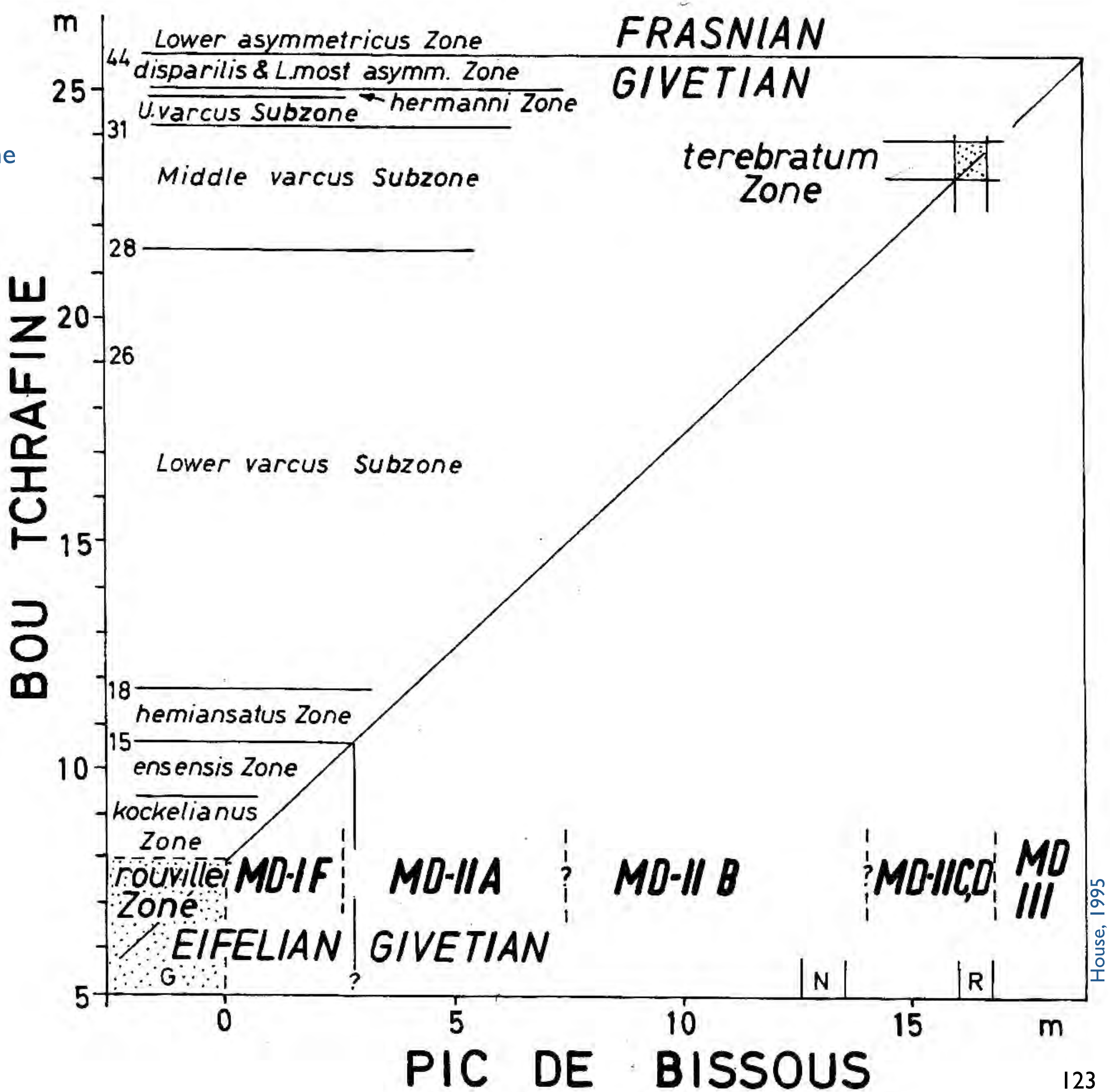
Table 2. *Calculation of orbital frequencies (from Berger* et al. *1989*a, b*)*

Cycle		Present-day	Mid-Devonian
Precession	(1)	19.0 ka	16.8 ka
	(2)	23.0 ka	19.9 ka
Obliquity	(1)	41.0 ka	32.1 ka
	(2)	54.0 ka	39.5 ka
Eccentricity	(1)	123.0 ka	123.0 ka
	(2)	413.9 ka	413.9 ka

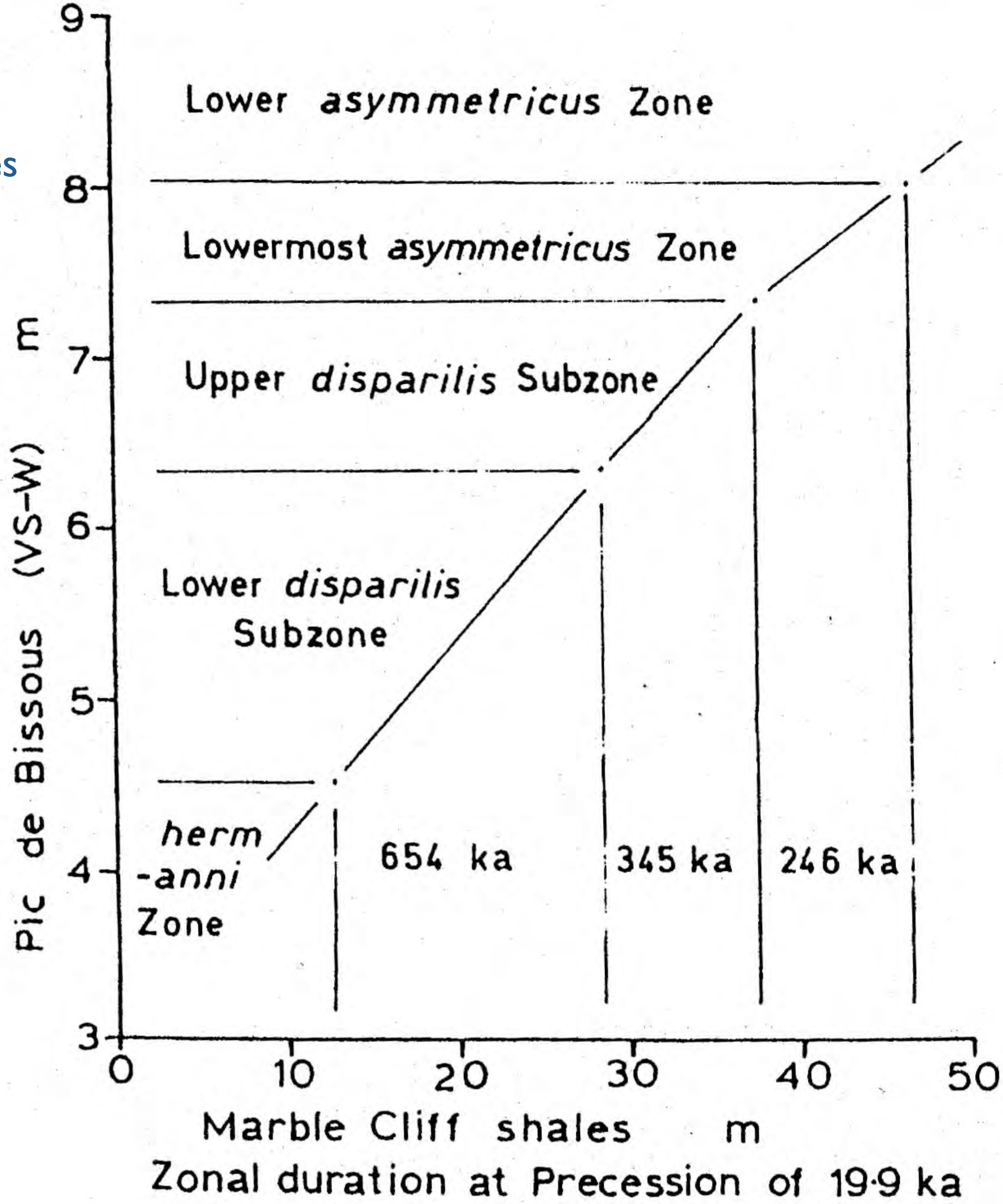
…

BE CAREFUL : LASKAR….

Correction between
the Givetian sequence
'Pic de Bissous-Bou Tchrafine
(France-Morocco)
showing a timescale
with principal micro-
rhythms due to
precessional orbital
forcing



Idem with the
Marble Cliff shales
(U.K.)
House, 1995



Givetian conodont Zone	Estimated duration (Ma)
Lowermost *asymmetricus* Zone	0.25
Upper *disparalis* Subzone	0.35
Lower *disparilis* Subzone	0.65
hermanni Zone	0.36
Upper *varcus* Subzone	0.21
Middle *varcus* Subzone	0.92
Lower *varcus* Subzone	4.05
hemiansatus Zone	0.43

TOTAL : 7.2

CONCLUSION

« Whatever corrections may be needed to the estimates presented for ZONAL and STAGE durations of the Givetian (…or other), one thing is clear:
the zonal estimates given by the orbital forcing are CONSIDERABLY nearer the truth
than the naïve assumption currently made by many that biostratigraphical zones are of equal duration… »
In House, 1995