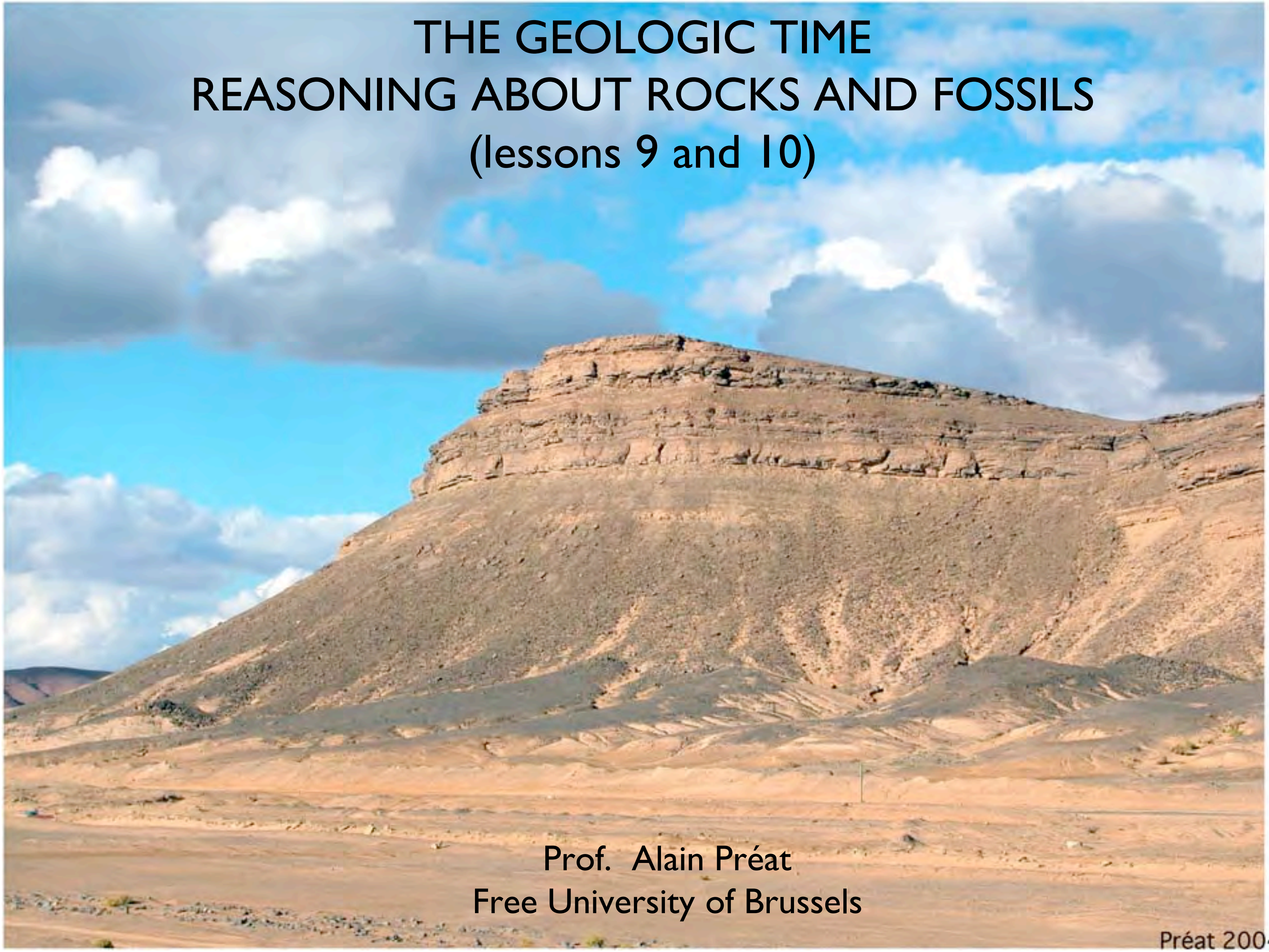
THE GEOLOGIC TIME
REASONING ABOUT ROCKS AND FOSSILS
(lessons 9 and 10)

GEOL.F.203



Prof. Alain Préat
Free University of Brussels

Préat 2004

PRINCIPLES 1 – 2 – 3

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STRATIGRAPHICAL SCALE

BY SEARCH OF ‘DISCONTINUITIES’

ANALYSIS OF CONTINUITY-THICKNESS OF SEDIMENTARY SERIES

TWO MAIN COMPLEMENTARY CATEGORIES OF SERIES

(A) COMPREHENSIVE and CONDENSED

No relation between thickness and duration

(B) CONTINUOUS and DISCONTINUOUS

Notion of lacuna or hiatus

What is the meaning of a lacuna?

CONTINUOUS SERIES

the strata follow one another **without** interruption

DISCONTINUOUS SERIES

strata are **missing** => there is a LACUNA => what does it mean?

Sandy flysch, Eocene, High Alps Debelmas 1982

1. SIMPLE LACUNA =INTERRUPTION OF SEDIMENTATION

• for a particular reason => interruption of deposition => bedding planes, diastems, sometimes hardgrounds… ==> **a bedding plane is a mini-unconformity**

• the sedimentation re-starts or continues as previously

⇒ sequence of series are **CONCORDANT** (conformable) = **parallel strata**

• = 'CONTINUOUS SERIES' despite it is virtually impossible to demonstrate that a given sequence is free from stratigraphic breaks => layering and parallel stratification may be a result of the nature of the deposited sediment fluctuating over time … AND/OR **more commonly** may be the result of shorter or longer periods of temporary non deposition with or without some erosion (in this last case =>2.)

2. SIMPLE INTERRUPTION OF SEDIMENTATION **WITH** SOME EROSION

• related to transgression, to regression … (global *vs* relative sea level fluctuations)

=> Late K +250-350m > < Oligocene -150m, Wilson first order cycle)

=> 'Tectono-eustatism' (2^{nd} and ?3^{rd} orders…)

⇒ glacioeustatism: 10-100's metres (4-5^{th} orders, cyclostratigraphy,), etc.

⇒ **diastems** : very minor (temporally) pauses or breaks in sedimentation with little or no erosion before deposition is resumed. They are equivalent to 'paraconformities' or 'disconformities' and are commonly 'cryptic'.

⇒ **hiatus** : geological time is not represented at a certain point (such as at unconformity or between particular beds) OR refers only to time that was never represented by the deposition of rock in a particular stratigraphic section or sequence

=> **lacuna** : gap or break in the stratigraphic record destroyed at an erosional surface (previously deposited strata are removed = 'erosional vacuity') and time was never represented by a rock record.

CONCORDANT (CONFORMABLE) STRATA

• most common case in the 'transgressive' basin
⇒ regional transgression with low amplitude
=
E P E I R O G E N E S I S

-'**epeirogenic movements**' (suggested by Gilbert in 1890)
are primarily flexural and **vertical** and affect large areas
of craton crust or surface **WITHOUT significant folding or fracture**
<u>Example</u> : central Appalachians have been
'epeirogenically uplifted as much as 7 km with an erosion of >15km.
<u>Other examples</u> : Ouachata Mountains, shoreline uplift surrounding
Lake Bonneville in Utah, Colorado Plateau [100m/Ma], Dekkan Plateau [15m/Ma]…)
= **NO OBVIOUS RELATION TO INTERACTION AT PLATE MARGINS**
⇒ intracontinental basins, abyssal plains…
⇒ epeirogenic movements = '**broad undulations**' (large curvature radius 10-100'km)
with depressed (= subsidence) and uplifted extensive areas (forming plateaus like
Anatolia Plateau, Bolivian Altiplano, Colorado Plateau, Tibetan Plateau… despite these
plateaus are rimmed by active fold beds. African plateaus are distant from plate
margins and UNCONNECTED with collision tectonics)

. if uplift or elevation => ‘REGRESSION’
. if subidence or depression => ‘TRANSGRESSION’
. if epeirogenesis occurs in shallow marine domains
=> EPEIRIC SEAS, EPICONTINENTAL ‘PLATFORM’

-**the surface relief** becomes greatly modified by denudation and deposition, and locally by volcanic activity
⇒ if the evolution is progressive ==> **PARTICULAR DEPOSITS** underlining the epeirogenesis


cutting laterite bricks in India
(from wilkipedia)

the best known = **CONGLOMERATE** (erosion) and
the **PALEOALTERITES** : products of intense weathering made up of mineral assemblages that may include **iron** or **aluminium** oxides, oxyhydroxides or hydroxides, kaolinite and quartz …

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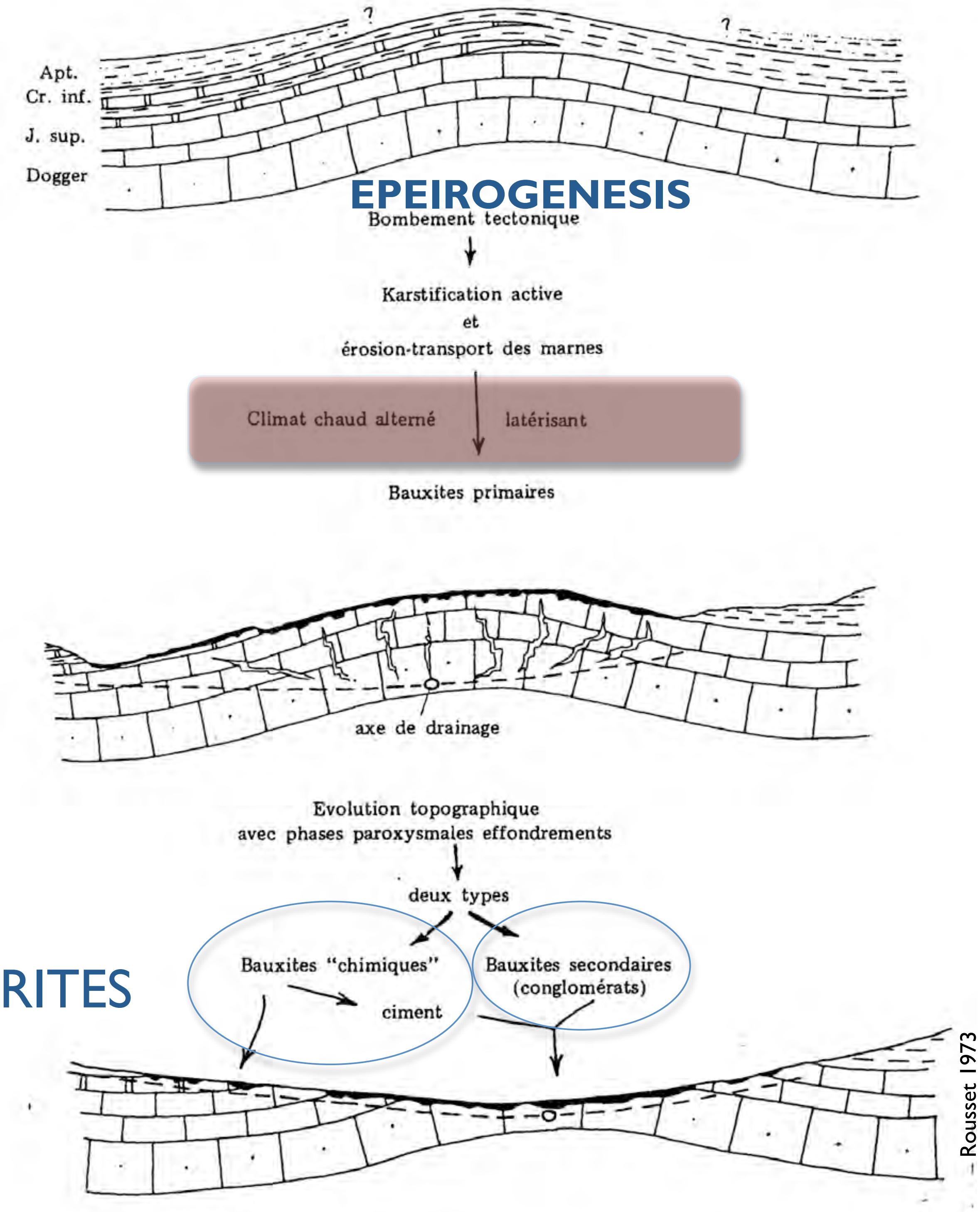
LATERITES in a large intertropical climatic area
(nb from the Latin *later* = brick)

Jurassic

EPEIROGENESIS



(PALEO)ALTERITES

– Rousset 1973

Bauxite = is the most common ore of aluminium

it is a residual 'rock' or residual soil material (surperficial alteration) composed mainly (> 40%) of Al-oxides/hydroxides-gibbsite $Al(OH)_3$, boehmite-diaspore $AlO(OH)$ + Fe-oxides, clays ….

- mainly in tropical and subtropical areas = washing or leaching of minerals from lateritic soils
- pisolitic structures
- used in the manufacture of abrasives

Bauxite in kaolinitc sandstone (white), Australia –from Wilkipedia

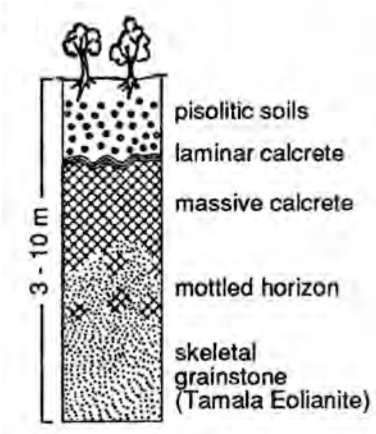
http://catalogs.indiamart.com/products/bauxite-ore.html

- origin : **BAUX**-de-Provence (Alpilles) , France, 1858

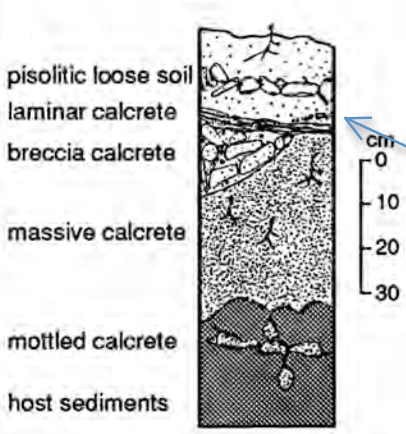
Mesozoic, Cretaceous 'Urgonian' > < 'Vocontian' Trough (warm climate, south Tropic)

EPEIROGENESIS => importance of particular levels of
'pisolites', 'caliches', CALCRETES, SILCRETES, FERRICRETES, GYPSICRETES
…. + 'carapaces', 'cuirasses' with or without nodules….

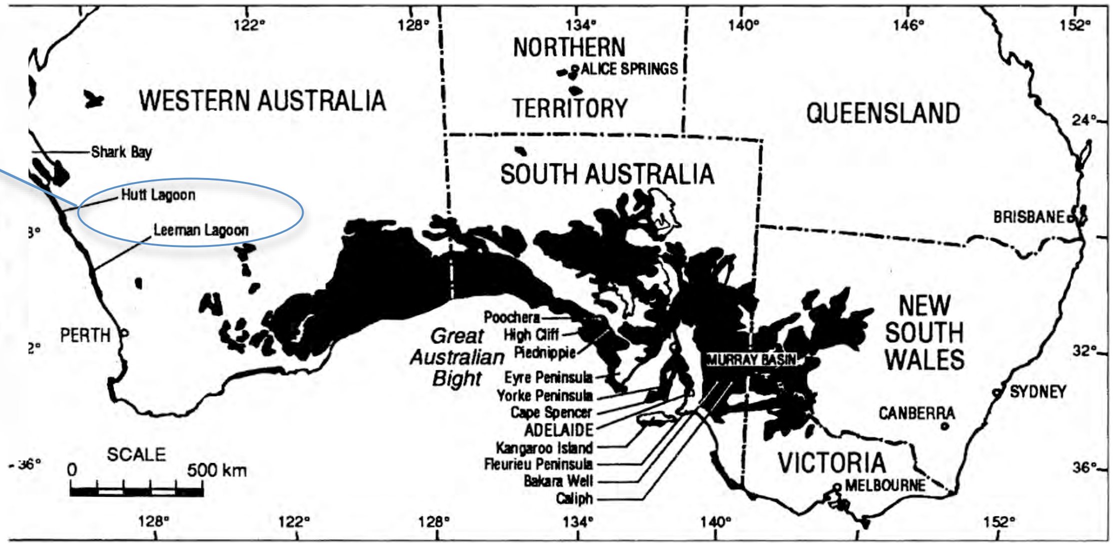
= PALEOALTERITES : **DURICRETES** and PALEOSOILS



Idealized calcrete profile
(Read 1974)



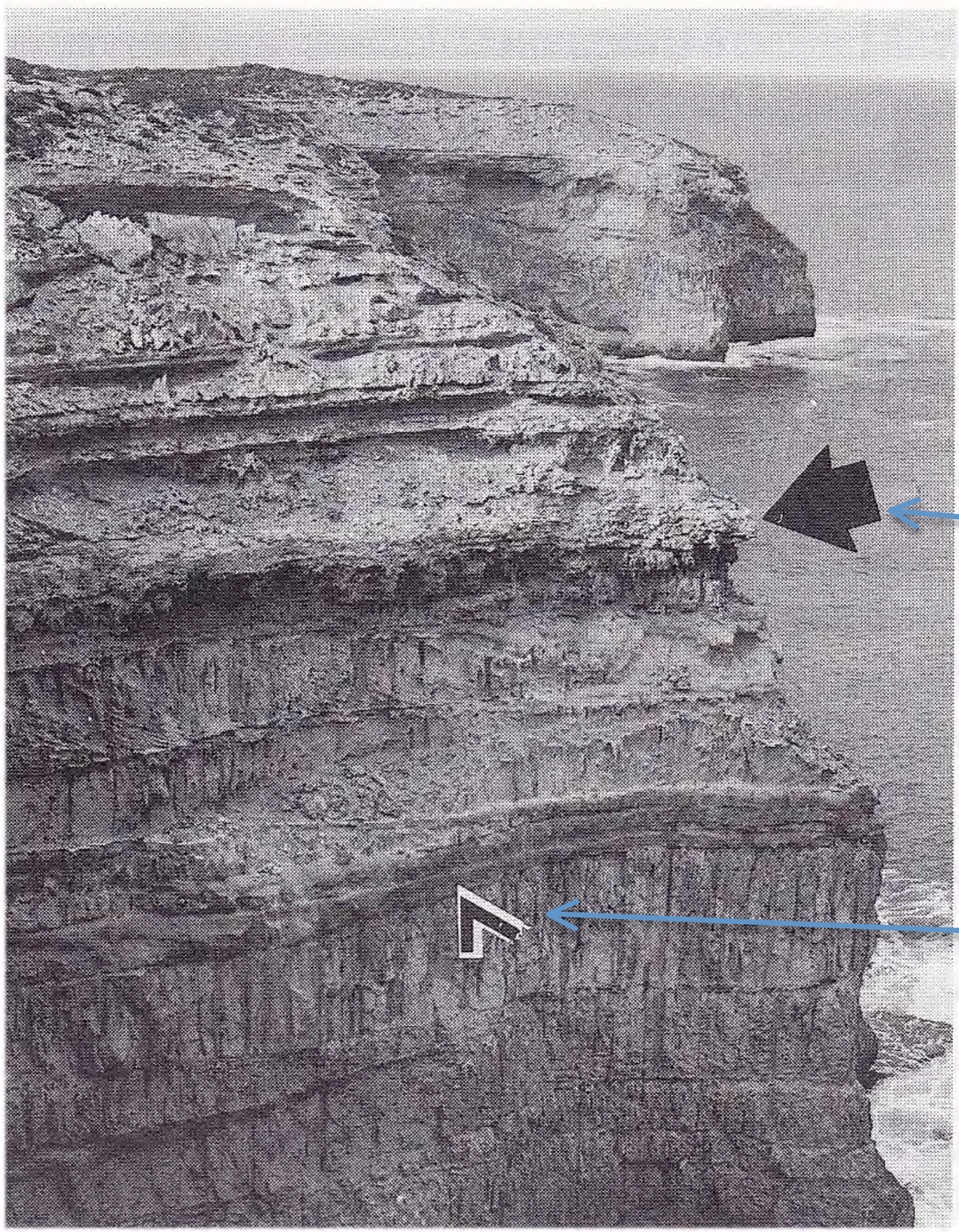
Typical calcrete profile
Arakel 1982)



Distribution of calcretes and calcareous soils in S Australia (Northcote et al 1975)
from EOCENE to PLIOCENE LIMESTONES

Coastal cliff (80 m) though cross-bedded bioclastic sands (grainstones) dunes with INTERBEDDED RED PALEOSOILS and overlying sequence of calcareous sand and silt sheets with associated CALCRETE CRUSTS

Cap Spencer, Australia, Milnes, 1992



CALCRETE CRUSTS

RED PALEOSOILS

LATERITES

in the carbonates
and sandstones of the
Precambrian (Gabon)

Préat 2008

IT RESULTS TWO FUNDAMENTAL **GEOMETRIC** TYPES
on the field and seismic

CONCORDANT (CONFORMABLE) STRATA

DISCORDANT (UNCONFORMABLE) STRATA
'between 'transgressed' and 'transgressive' strata

= dip variation between two sets of strata in which the bedding planes of the two sets are not parallel to one another
= > the two sets of strata are ANGULARLY DISCORDANT
• **recognized for the time in1787** by Stratchey and explained by Hutton in 1788

=

ANGULAR UNCONFORMITY

James HUTTON (1726-1797)
Founder of modern geology

James Hutton (1726–1797), a Scottish farmer and naturalist, is known as the founder of modern geology. He was a great observer of the world around him. More importantly, he made carefully reasoned geological arguments. Hutton came to believe that the Earth was perpetually being formed; for example, molten material is forced up into mountains, eroded, and then eroded sediments are washed away. He recognized that the history of the Earth could be determined by understanding how processes such as erosion and sedimentation work in the present day. His ideas and approach to studying the Earth established geology as a proper science.

SICCAR POINT (east coast of Scotland)

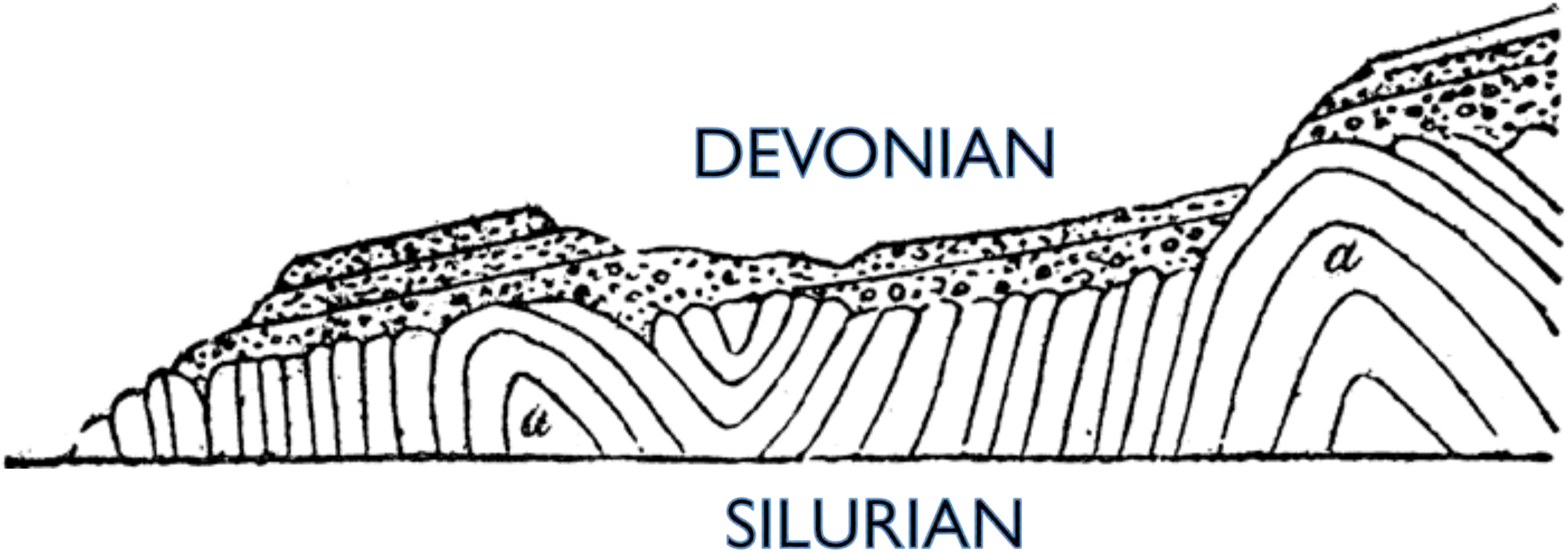
Dev O.R.S.

vertical Sil greywacke

Around 1768 he moved to Edinburgh, where a visitor a few years later described his study as "so full of fossils and chemical apparatus that there is hardly room to sit down." In a paper presented in 1788 before the Royal Society of Edinburgh, a newly-founded scientific organization, Hutton described a universe very different from the Biblical cosmos: one formed by a continuous cycle in which rocks and soil are washed into the sea, compacted into bedrock, forced up to the surface by volcanic processes, and eventually worn away into sediment once again. "The result, therefore, of this physical enquiry," Hutton concluded, "is that we find no vestige of a beginning, no prospect of an end." Relying on the same methods as do modern field geologists, Hutton cited as evidence a cliff at nearby Siccar Point, where the juxtaposition of vertical layers of gray shale and overlying horizontal layers of red sandstone could only be explained by the action of stupendous forces over vast periods of time. There Hutton realized that the sediments now represented by the gray shale had, after deposition, been uplifted, tilted, eroded away, and then covered by an ocean, from which the red sandstone was then deposited. The boundary between the two rock types at Siccar Point is now called th Hutton Unconformity.

The fundamental force, theorized Hutton, was subterranean heat, as evidenced by the existence of hot springs and volcanoes. From his detailed observations of rock formations in Scotland and elsewhere in the British Isles, Hutton shrewdly inferred that high pressures and temperatures deep within the Earth would cause the chemical reactions that created formations of basalt, granite, and mineral veins. He also proposed that internal heat causes the crust to warm and expand, resulting in the upheavals that form mountains. The same process causes rock stratifications to tilt, fold and deform, as exemplified by the Siccar Point rocks.

SICCAR POINT



Angular unconformity between dipping Eocene limestone beds and horizontal Oligocene beds, near Graus, Spain (in Nichols 1999)

It implies : **FOLDING-(EMERSION)-EROSION** of the 'older' strata (which will be transgressed) and DEPOSITION of 'younger' strata (they are transgressive) which are essentially horizontal (at least when originally deposited on the older strata). The older strata may have been steeply tilted, perhaps folded or crumpled, and were eroded **before** deposition of younger strata => **GAP of TIME**

==> **ANGULAR UNCONFORMITIES are the most obvious and conspicuous breaks in the stratigraphic record**
==> **useful as MAJOR SUBDIVISIONS of the stratigraphic scale**

An ANGULAR UNCONFORMITY implies
1. **sedimentation** period (x Ma)
2. **tectonic** phase with structural events (folding, faulting, uplift, igneous intrusion, metamorphic events)
3. **emersion** and **erosion** to form th surface of the unconformity (peneplain)
4. new sedimentation period (marine or continental)

3 => 4 with a LARGE GAP in the stratigraphic record

Unfortunately the terminology is ‘confuse’ : the term ‘unconformity’ is used broadly to apply to several different types of stratigraphic contacts

•**ANGULAR UNCONFORMITY** (‘**Discordance angulaire**’ in French) separates two units of stratified rocks which are not parallel.
Not to confound with ‘similar’ structures produced by submarine slides, cross-bedding and so on…

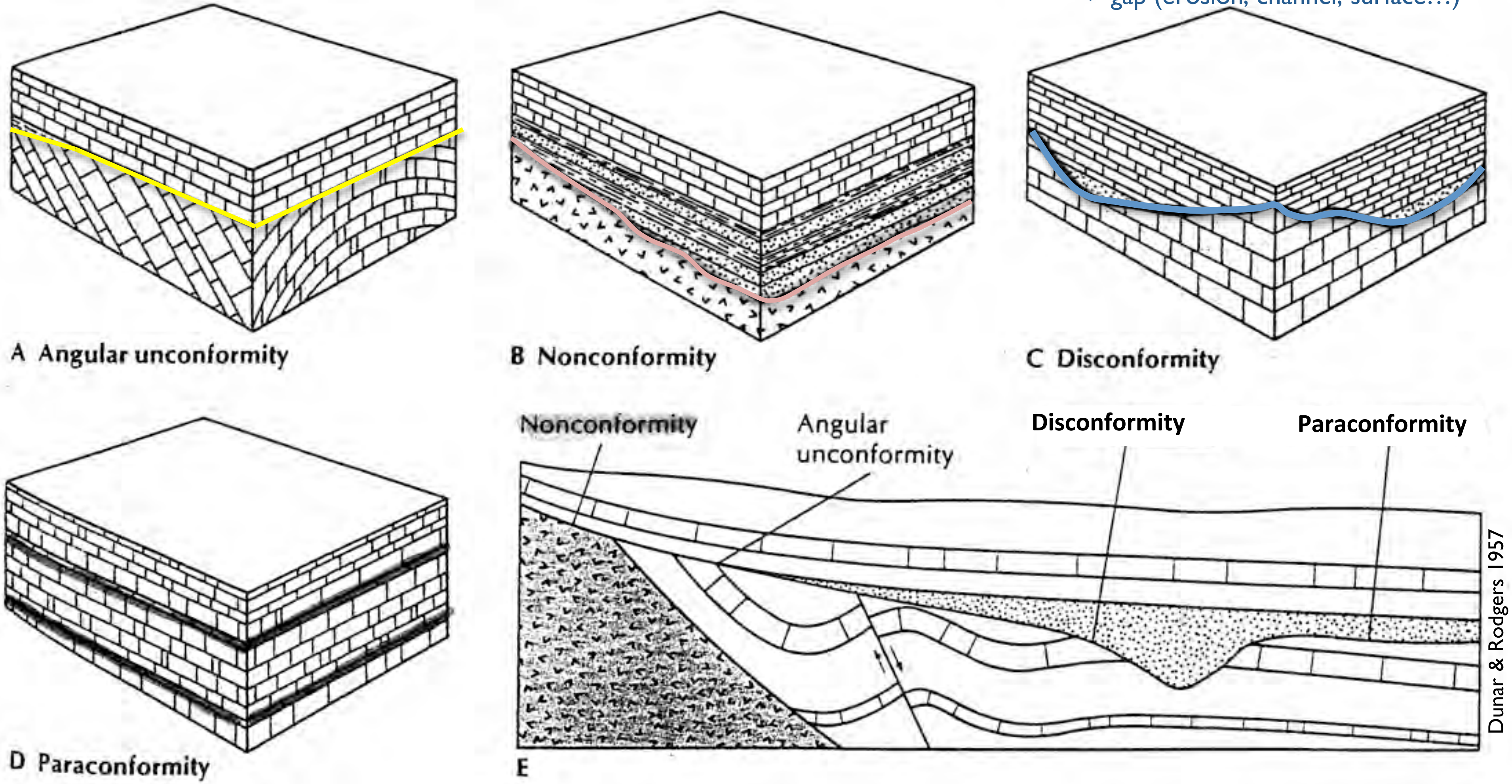
• **DISCONFORMITY** (‘**Discontinuité**’ in French)
the bedding of rocks is essentially parallel above and below the surface of unconformity => lithostratigraphic erosional breaks in parallel sequences (**subaerial erosion, weathering = physical evidence of hiatus**)

• **PARACONFORMITY** (‘**Concordance**’ in French)
the beds are parallel and the contact is a simple bedding plane (**periods of non deposition**). They are biostratigraphicaal discontinuities of parallel strata, based and evaluated solely on paleontological data. They usually coincide with a conspicuous bedding plane, but they may fall between conspicuous lithologic surfaces. They may laterally grade into disconformities

• **NONCONFORMITY** (‘**Non conformité**’ in French)
stratified rocks lying unconformably on older non stratified rocks (plutonic igneous rocks or metamorphic rocks). A distinct erosional surface or features may have developed on the non stratified rocks before they were covered by the sediments.

• **DIASTEM, HIATUS, LACUNA** (see before)

two conform sets of strata
=> gap (erosion, channel, surface…)



ANGULAR UNCONFORMITY

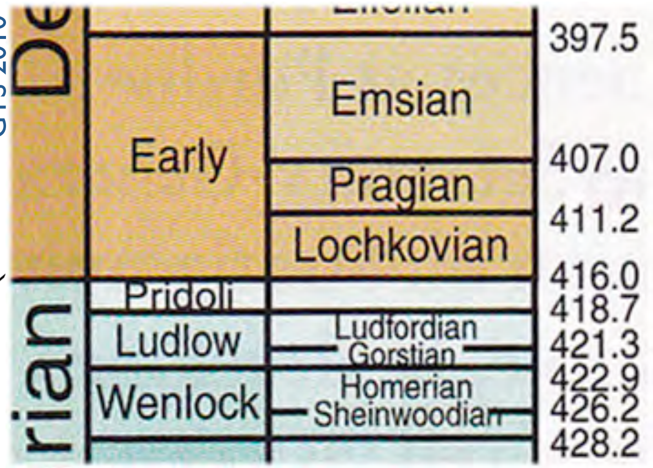
is the most important : it delimits an unconformity-bounded unit representing a body of rock bounded above and below by a specifically succession of **regional or inter-regional extent**
⇒ it constitutes very frequently the base of the series of a basin *i.e.* its **SUBSTRATUM** or 'SOCLE' or BASEMENT

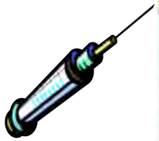
==> easily highligthed by SEISMIC…. and OIL EXPORATION
Geophysics: AIRMAG, GRAVITY, MAGNETO-TELLURIC
(application : namely organic matter evolution, oil window, structural heritage important for drillings….)

===> Example in Belgium : angular discordance of the Lower Devonian (former 'Gedinnian', poudingue and arkose of Haybes) on the Lower Paleozoic (Caledonian or Cambro-Silurian =substratum)

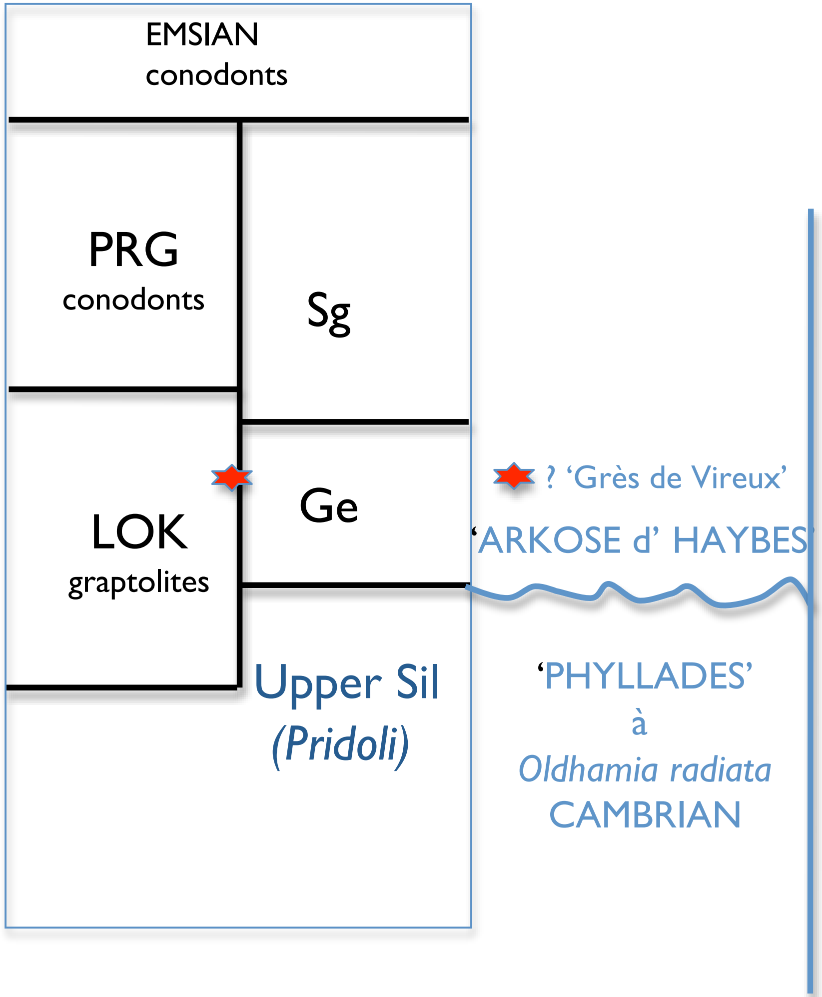
ANGULAR UNCONFORMITY IN BELGIUM

GTS 2010

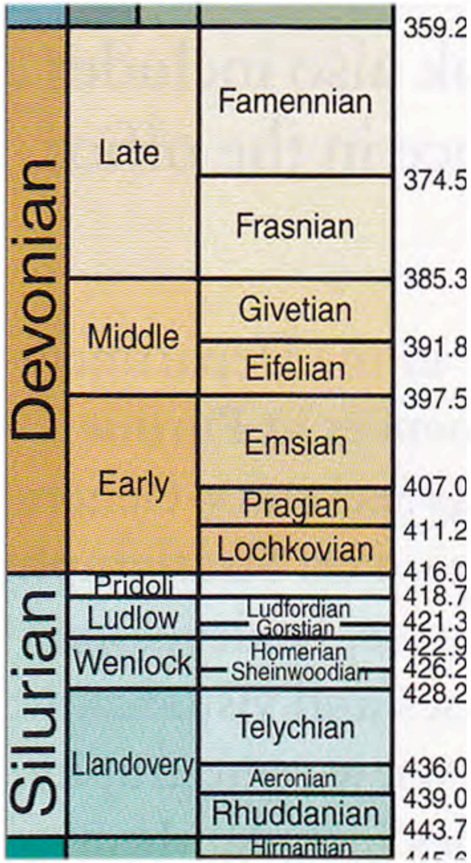




Sintubin 2010



Episodes, 2003, vol 26/1, 10-15



by Ivo Chlupáč and František Vacek

Thirty years of the first international stratotype: The Silurian-Devonian boundary at Klonk and its present status

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The first international stratotype, selected according to modern stratigraphic principles, is the section with the Silurian-Devonian boundary at Klonk in the Barrandian area, Czech Republic. Its approvement at the XXIV IGC in Montreal, 1972 deeply influenced the further development of stratigraphic principles and praxis in achieving an objective base for definition of global chronostratigraphic units, later followed in establishments of GSSP in different parts of the global stratigraphic column. The procedure of the establishment, present status and correlative value of the Silurian-Devonian boundary stratotype are reviewed, confirming the suitability of its selection.

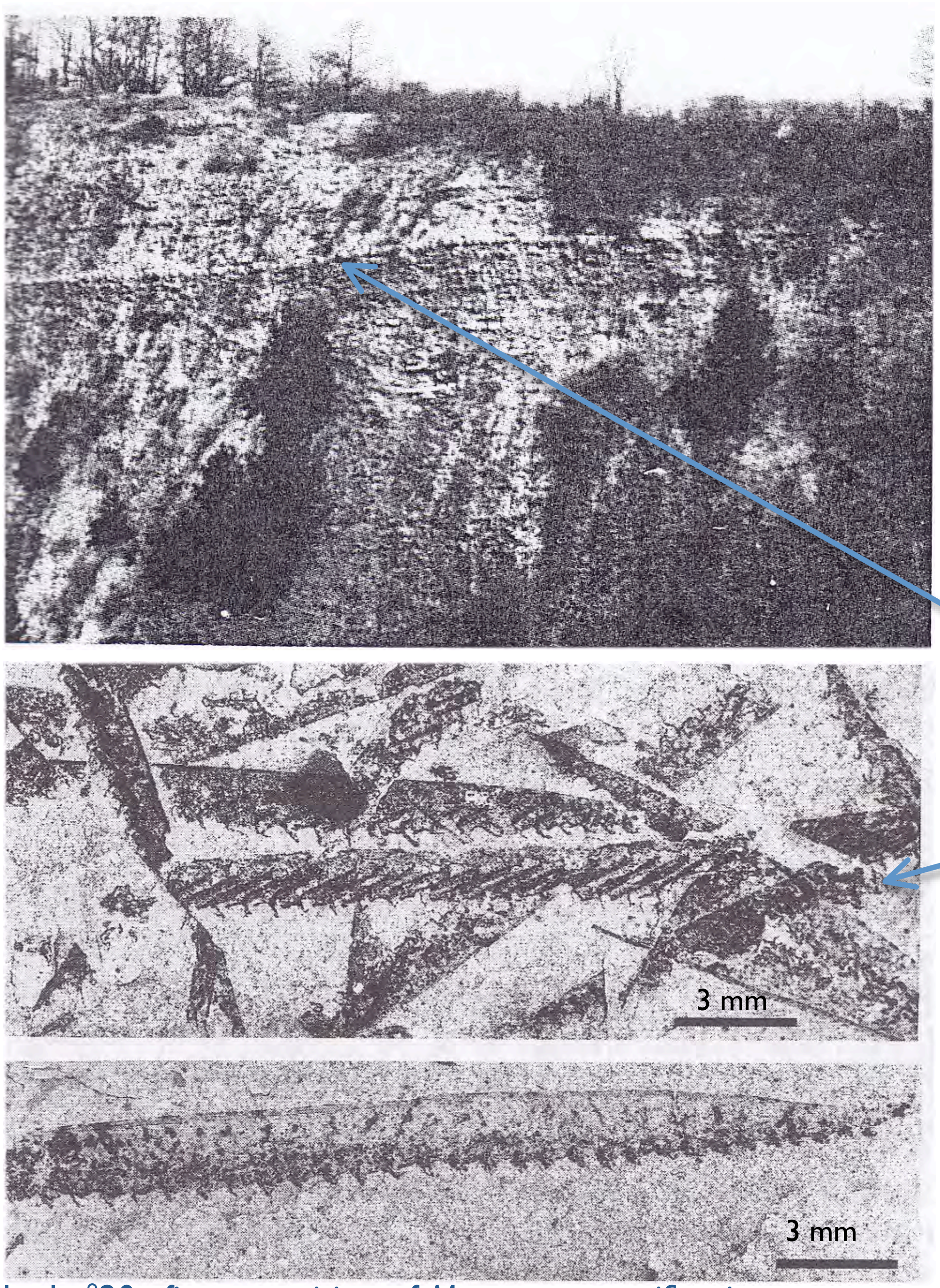
Introduction and history

In August 2002 we commemorated the official acceptance of the first global stratotype, i.e. the stratotype of the Silurian-Devonian bound-

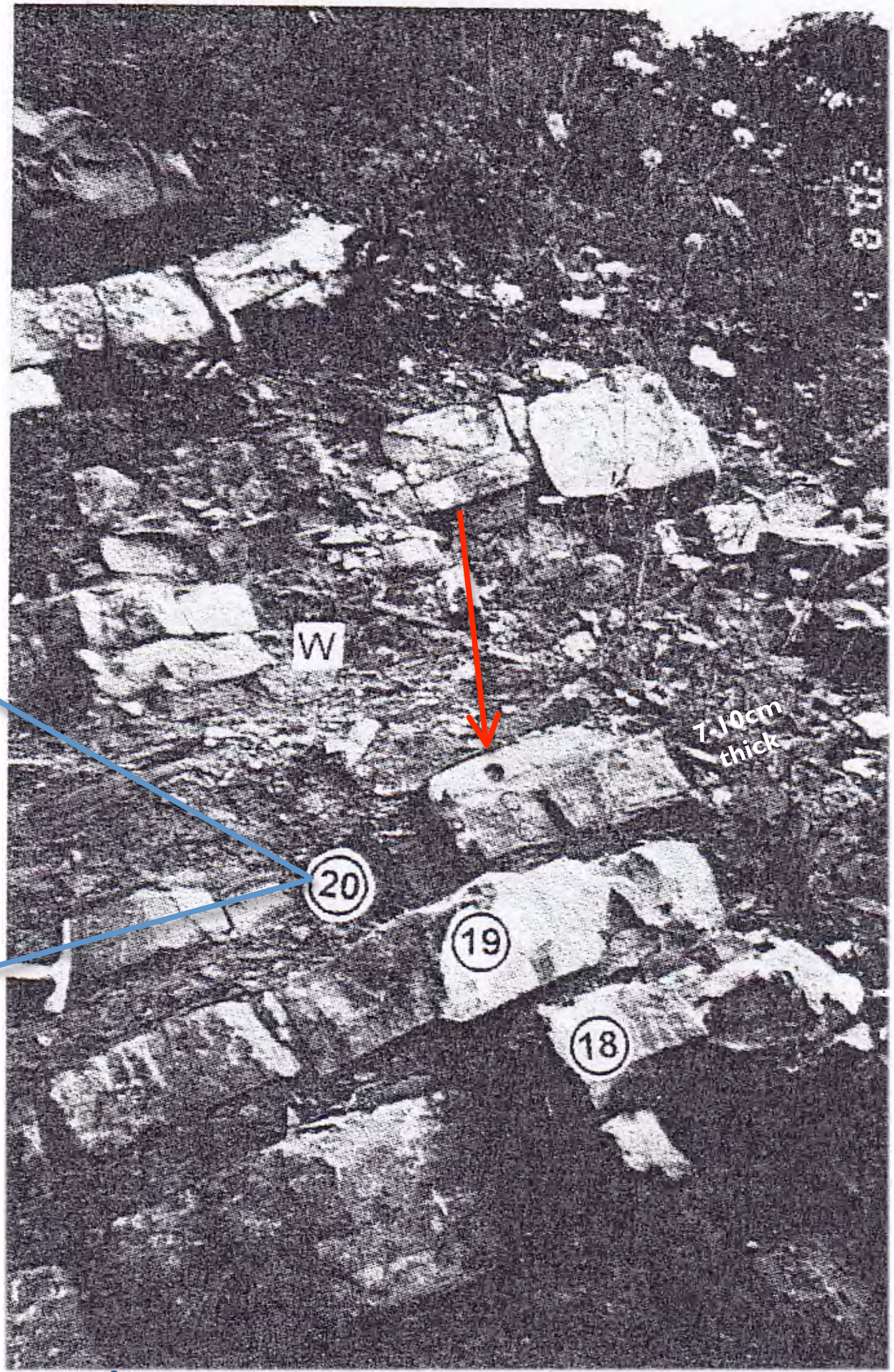
The Committee evolved a great activity. Whilst up to 1964 new results of investigation were concentrated in Circulars, since 1965 it became clear that direct visits and inspections of relevant regions and concrete sections are necessary. These were started in 1966 when diverse European regions were visited and the Chairman, Prof. Erben, achieved a broad collaboration with different working groups around the world and official bodies, namely the International Commission on Stratigraphy and the International Union of Geological Sciences.

A marked progress was reached at the International Symposium on the Devonian System held in Calgary, Alberta, 1967, where the majority of members of the Committee accepted the proposal to define the S-D boundary at the base of the *Monograptus uniformis* graptolite Zone, which was later confirmed by the preliminary ballot votes (25 Committee members in favour from the total number 32).

In 1968 D. J. McLaren, after resignation of Prof. Erben, accepted the chairmanship of the Committee and evolved his fruitful activities. The Third International Symposium on the Silurian-Devonian Boundary and Stratigraphy held in Leningrad in 1968 and connected with 6 meetings of the Committee and field-trips into different parts of the former Soviet Union, summarized the progress. At the 23rd International Geological Congress in Prague, on August 22, two proposals were made, namely to chose the S-D boundary in rela-

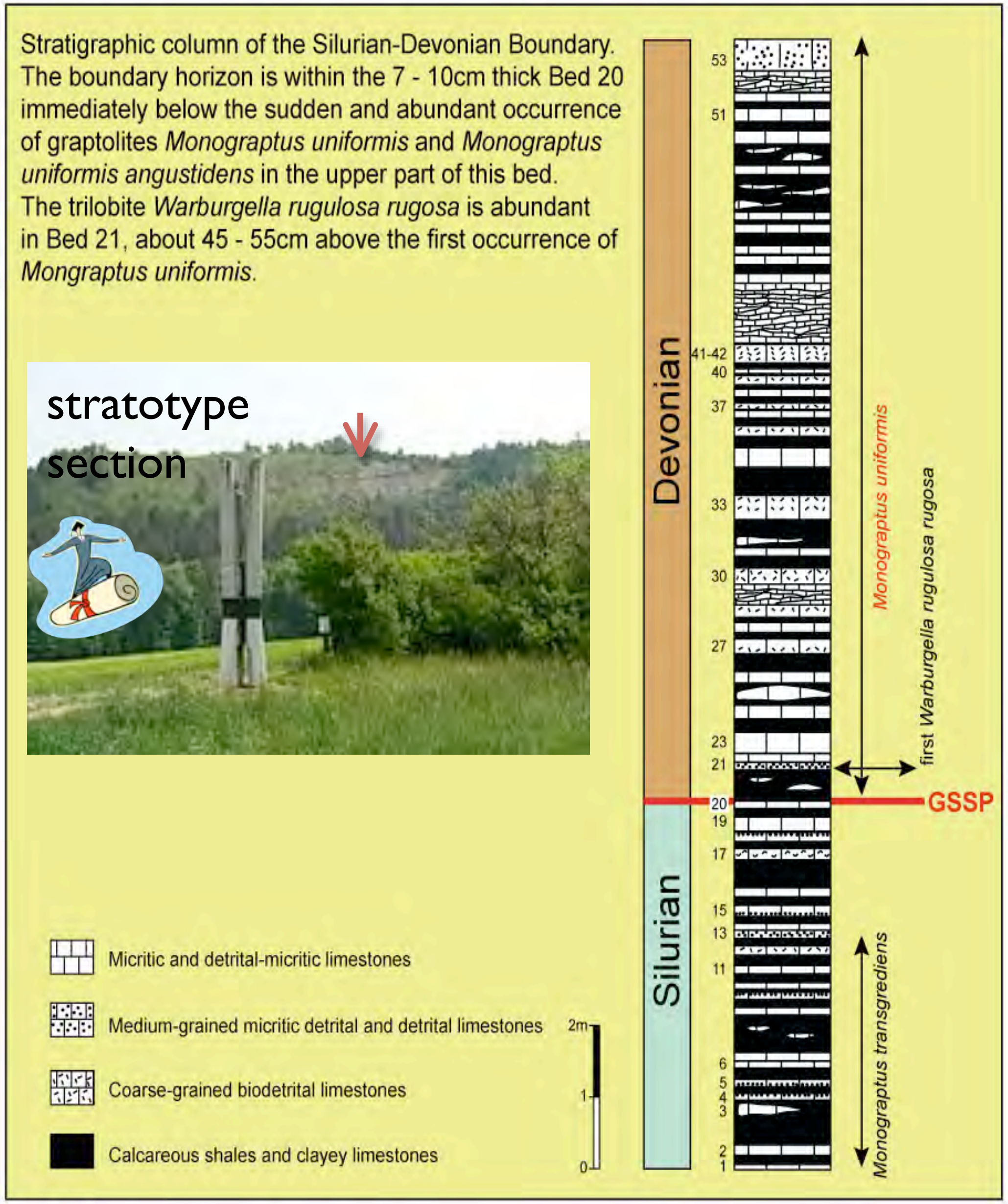


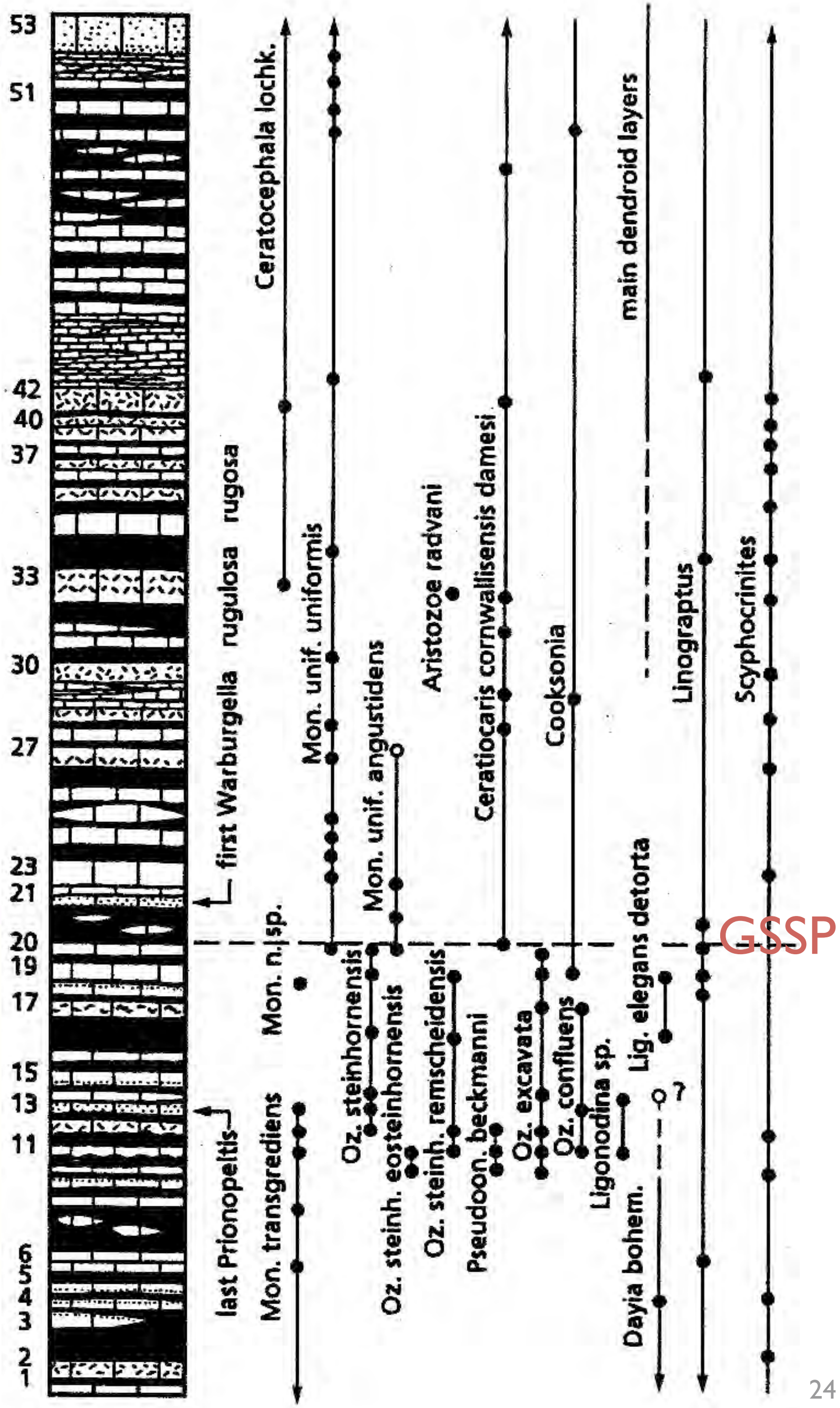
bed n°20 : first apparition of *Monograptus uniformis*



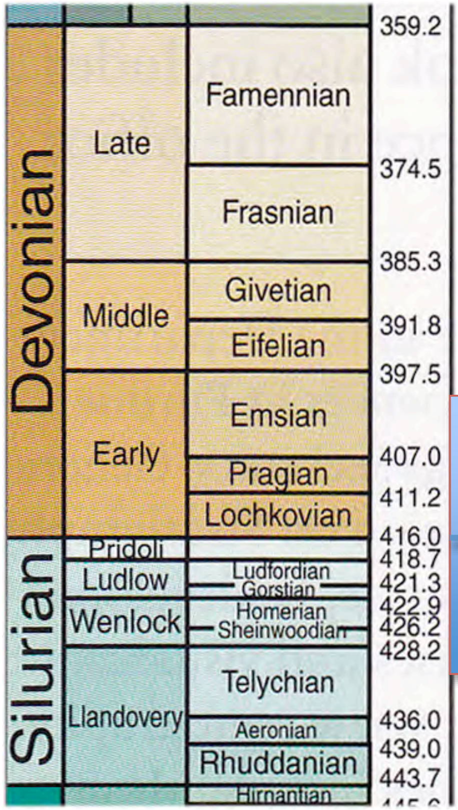
bed n°21 = 'W' : first apparition of *Warburgella rugulosa rugosa* (Trilobite)

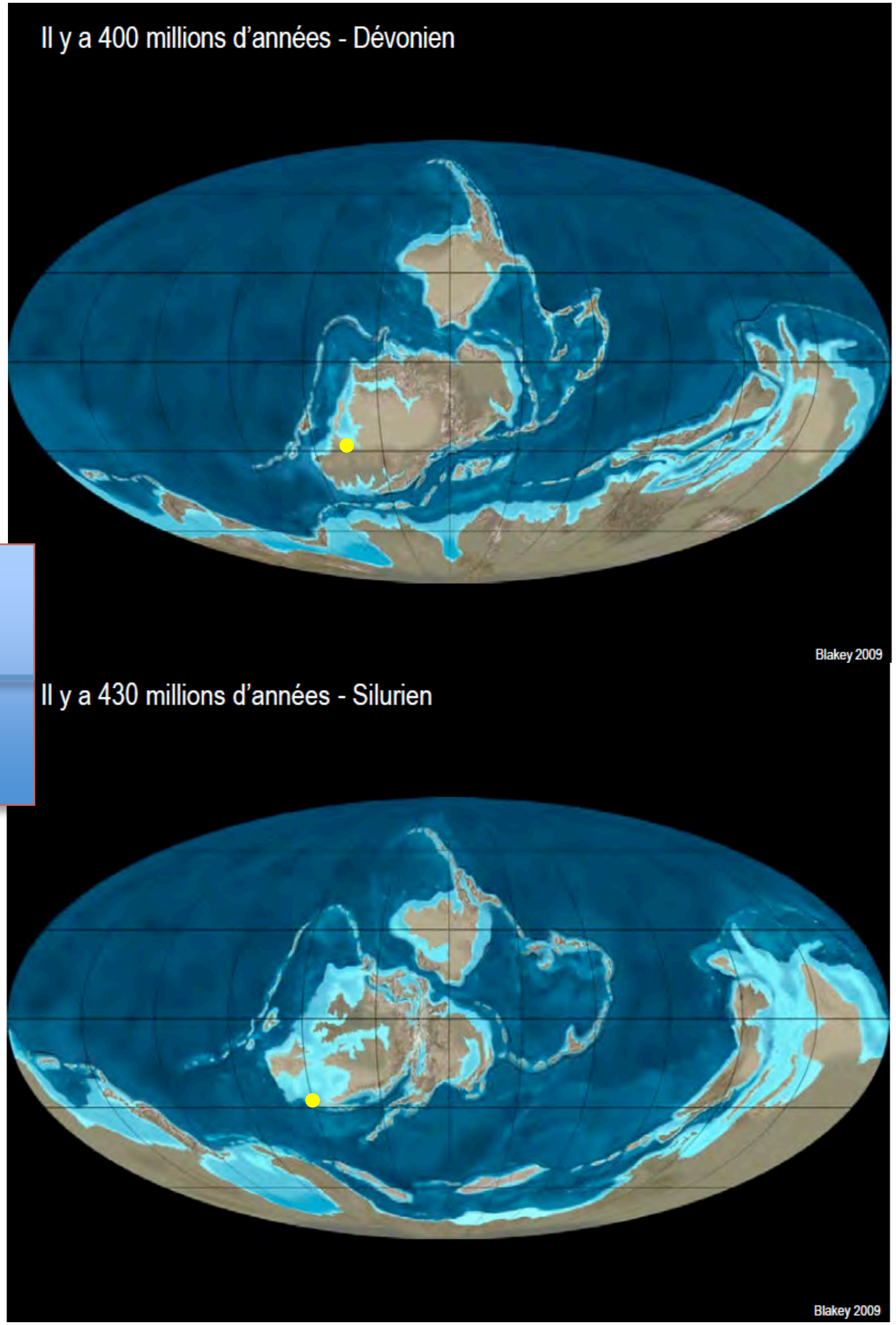
Litho- and Biostratigraphy of the Silurian - Devonian Boundary Section at Klonk near Suchomasty, 35km south-west of Prague





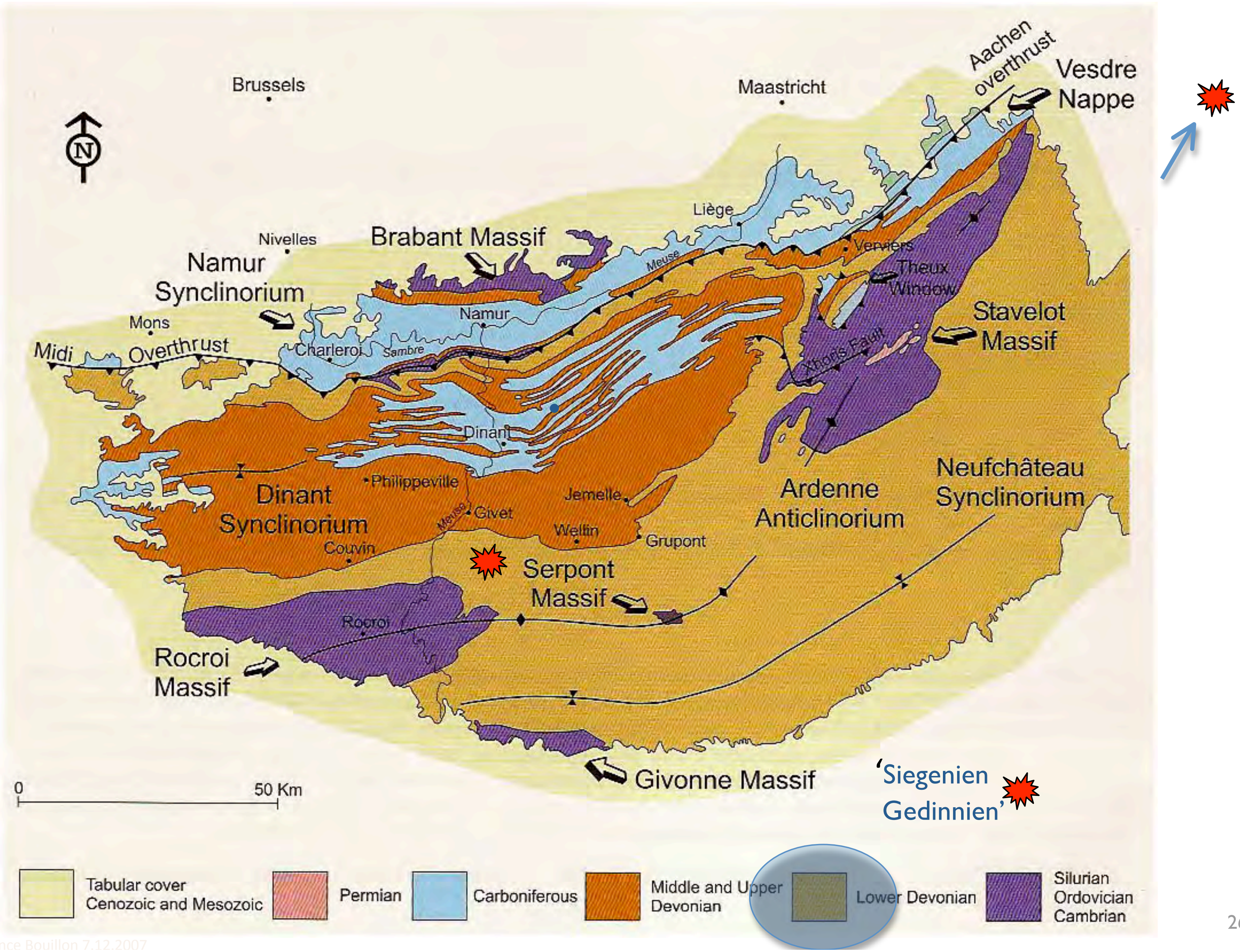
graptolites-trilobites-chitinozoa-conodonts-bivalves-cephalopods-brachiopods-crinoids-custaceans + magnetostratigraphy… = ‘BIOEVENT…’


Devonian
Late
Famennian
Frasnian
Middle
Givetian
Eifelian
Early
Emsian
Pragian
Lochkovian
Silurian
Pridoli
Ludlow
Ludfordian
Gorstian
Wenlock
Homerian
Sheinwoodian
Llandovery
Telychian
Aeronian
Rhuddanian
Hirnantian
359.2
374.5
385.3
391.8
397.5
407.0
411.2
416.0
418.7
421.3
422.9
426.2
428.2
436.0
439.0
443.7


Il y a 400 millions d'années - Dévonien
Blakey 2009
Il y a 430 millions d'années - Silurien
Blakey 2009

Synclinorium éodévonien de Neufchâteau-Eifel

(soubassement calédonien accessible dans les petits massifs cambriens de Serpont et Givonne)



dépression calcaire, puis schisteuse [Famenne]

Couverture Mésozoïque [Gaume]

ANGULAR UNCONFORMITY IN BELGIUM

LE CAILLOU-QUI-BIQUE

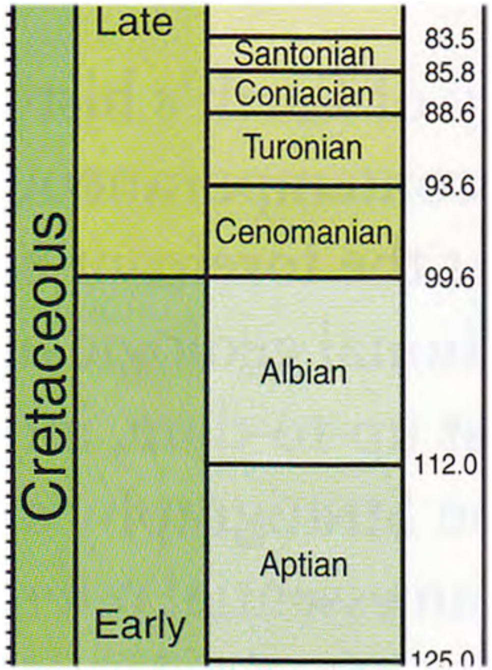
Il s'agit d'un rocher naturel de 20 à 25 mètres d'élévation. Monsieur *HECART*, dans son dictionnaire du patois de Valenciennes, explique la terminaison du nom de notre rocher de la manière suivante: "Une pièce bique lorsqu'elle dépasse celle sur laquelle elle est placée et qu'elle est comme en équilibre". Le caillou-qui-bique est un poudingue ou roche composée de fragments de substances quartzeux réunies soit sans ciment visible, soit par un ciment quartzeux ou quarto argileux non calcarifère.

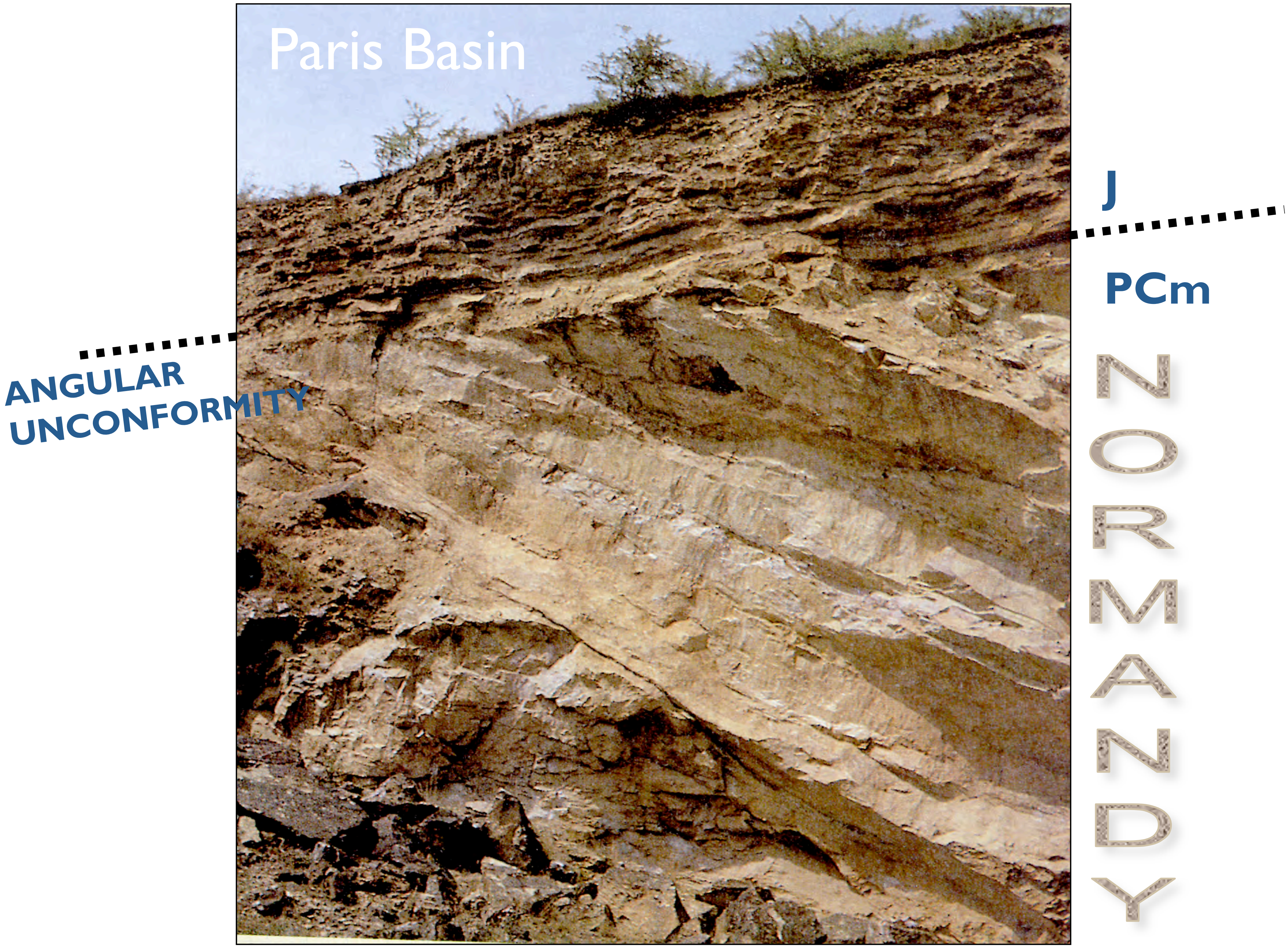
ROISIN-Le caillou-qui-bique.

http://users.skynet.be/cbou/roisin/caillou.htm

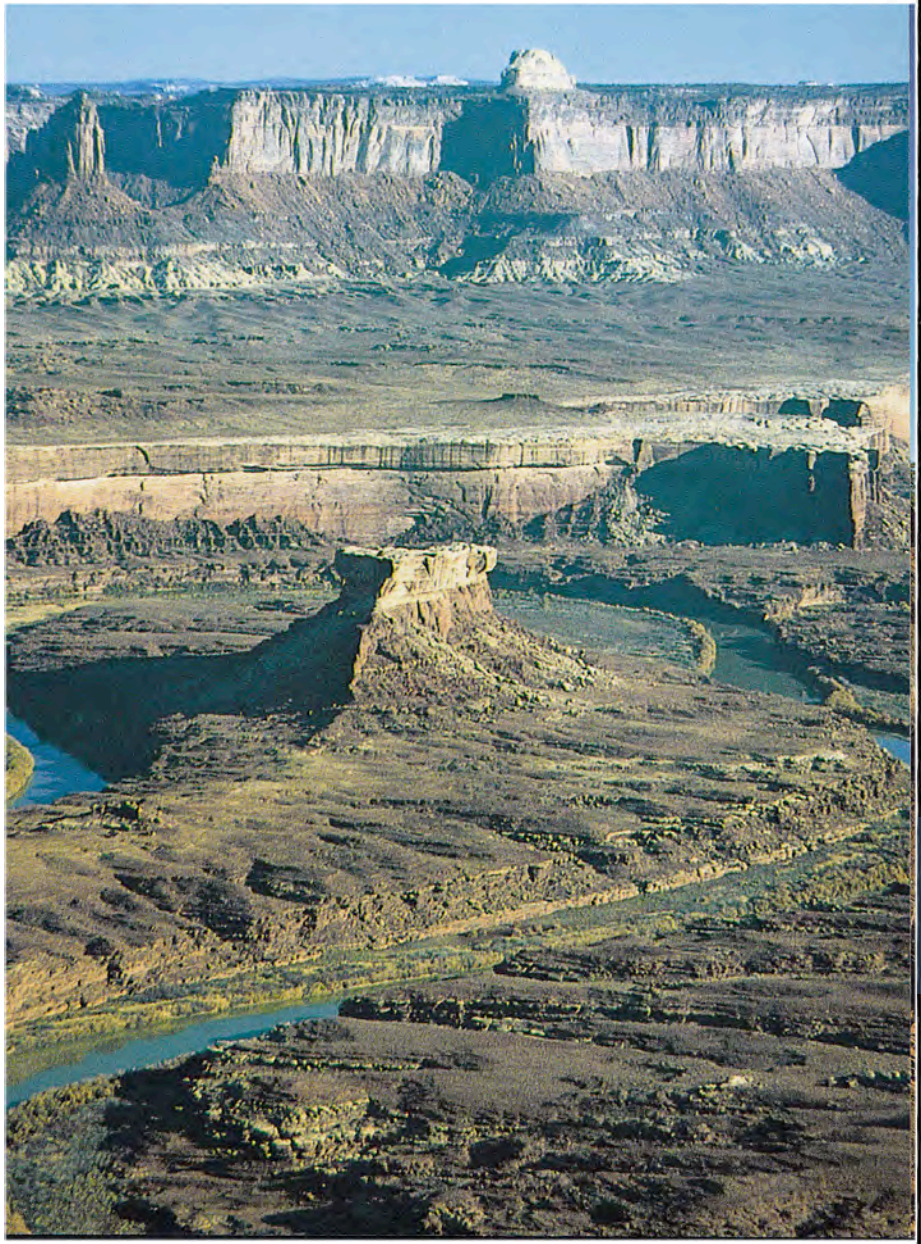
Un géologue belge, d'*Omallus d'Halloy* désigne ce poudingue sous le nom d'étage du poudingue de Burnot, entre Namur et Dinant. Ces poudingues forment souvent des pierres très solides dont on fait des pavés, des meules de moulins, des ouvrages de hauts-fourneaux. Le poudingue qui compose le caillou-qui-bique, de nature plus friable que celui de la province de Namur donne un marbre des plus remarquables, malheureusement, il n'est guère possible de l'exploiter.

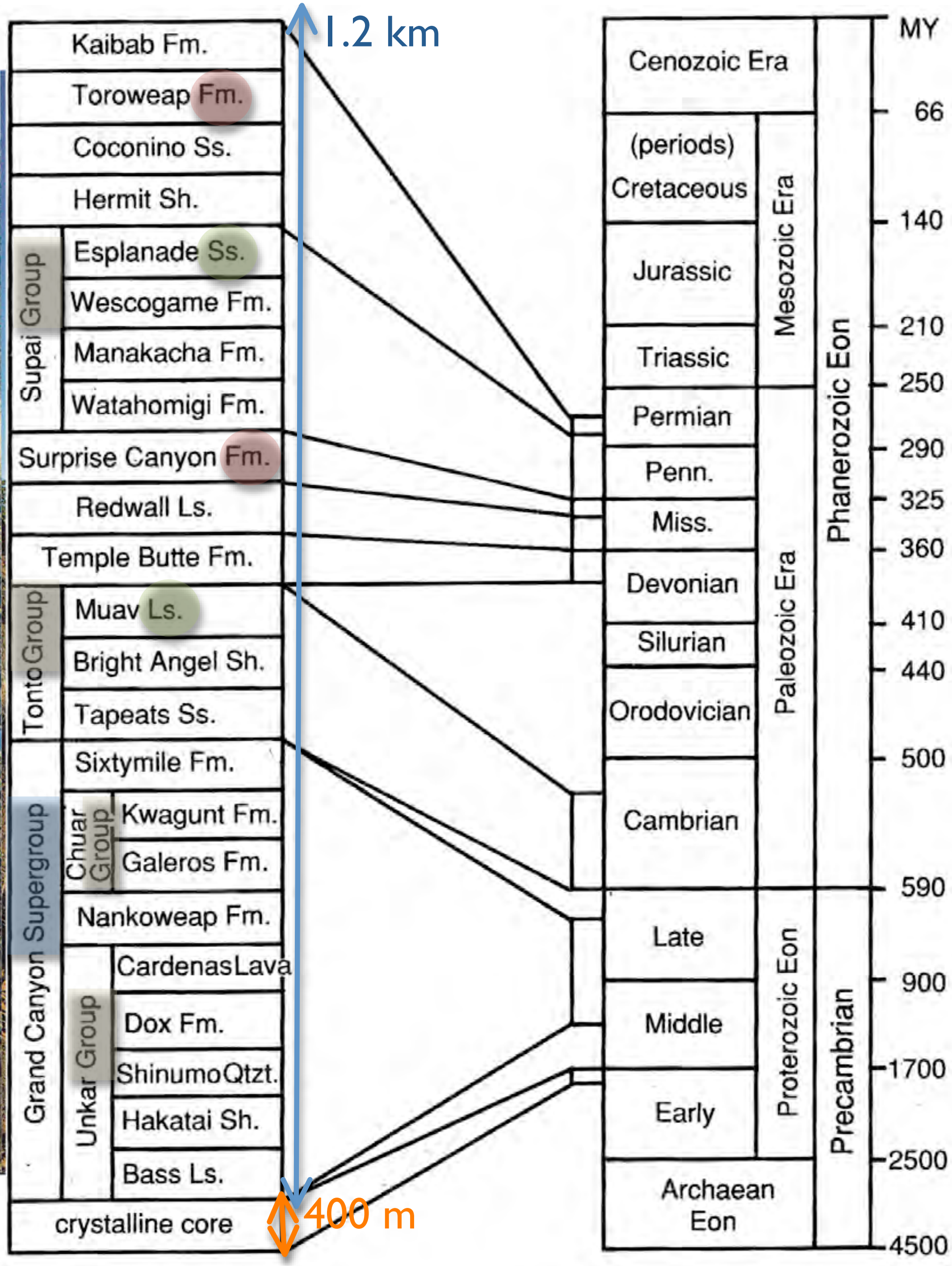
N Bavay, Mons Basin
Vallée de la Honnelle

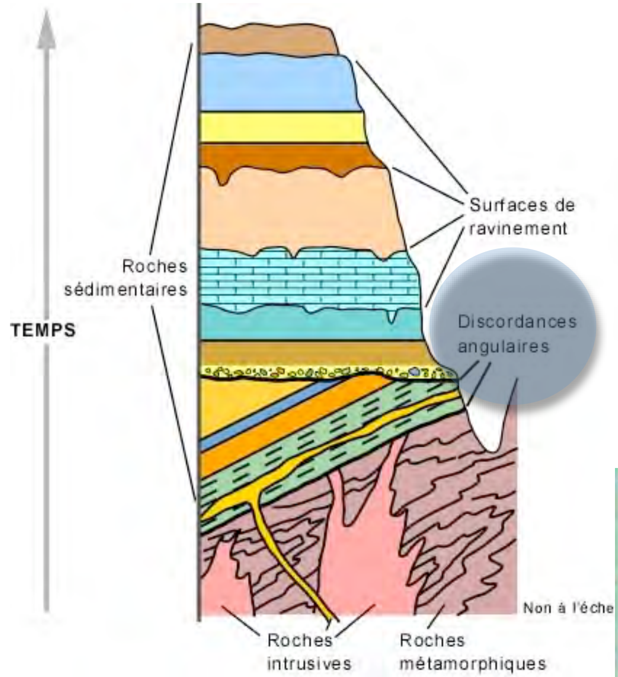


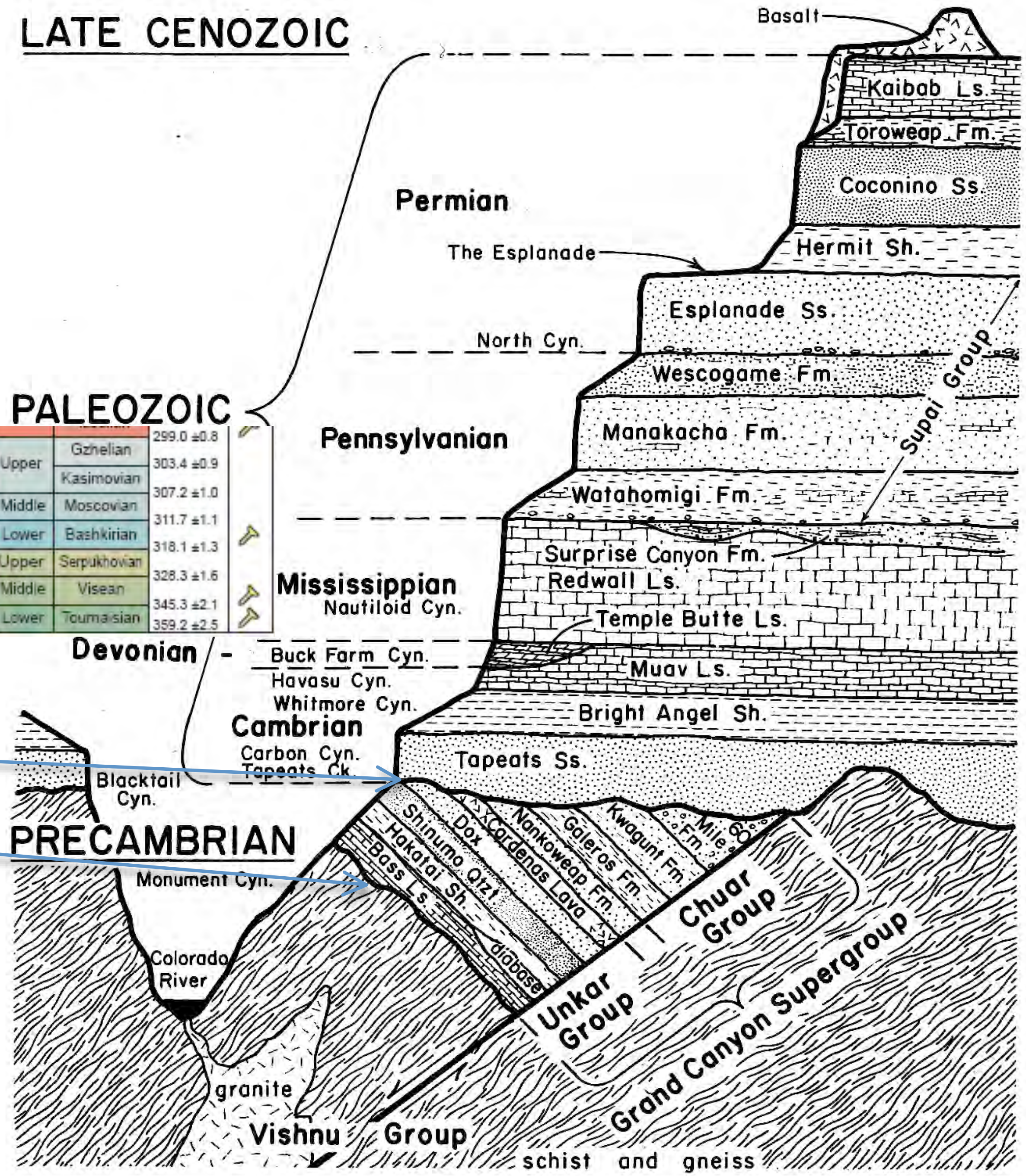

Paris Basin
J
PCm
ANGULAR UNCONFORMITY
NORMANDY

GRAND CANYON









Carboniferous	Penn-sylvanian	Upper	Gzhelian	299.0 ±0.8
			Kasimovian	303.4 ±0.9
		Middle	Moscovian	307.2 ±1.0
		Lower	Bashkirian	311.7 ±1.1
	Missis-sippian	Upper	Serpukhovian	318.1 ±1.3
		Middle	Visean	328.3 ±1.6
		Lower	Tournaisian	345.3 ±2.1
				359.2 ±2.5

HURONIAN ANGULAR UNCONFORMITY

HUDSONIAN ANGULAR UNCONFORMITY

NORMANDIE

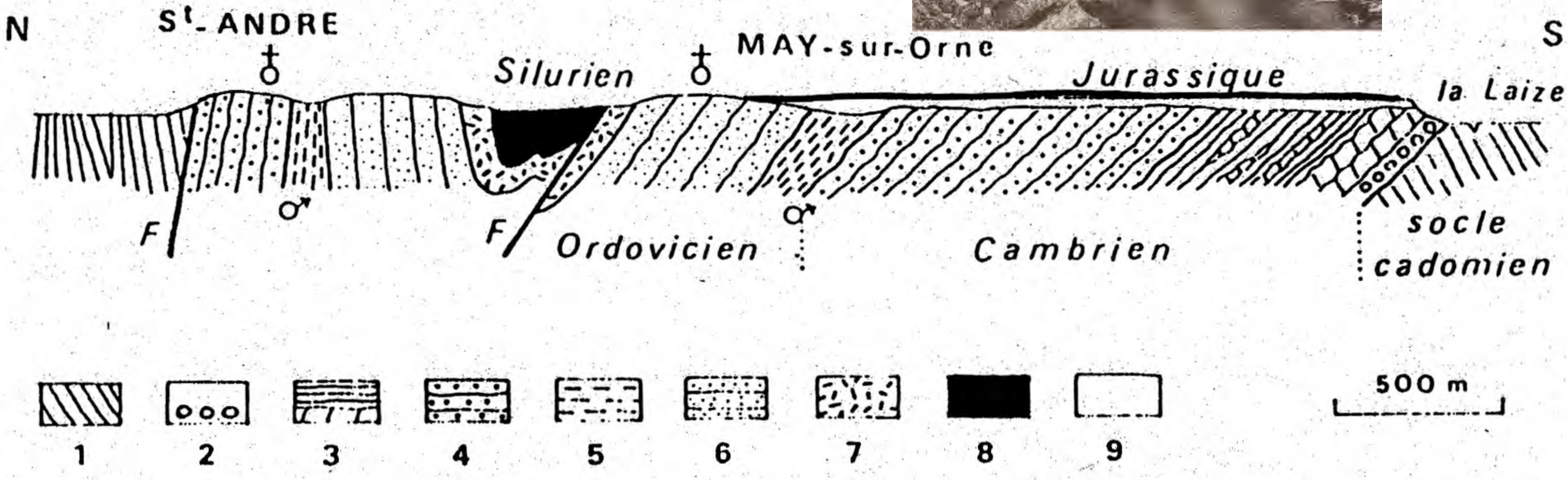


Fig. 12. – *Coupe nord-sud du synclinal de May.*

1. Flysch du Briovérien supérieur. – 2. Poudingue et arkoses. – 3. Schistes et calcaires. – 4. Grès feldspathiques. – 5. Schistes d'Urville. – 6. Grès de May. – 7. Tillite de Feuguerolles. – 8. Ampélites. – 9. Calcaires liasiques et bajociens.

NORMANDIE

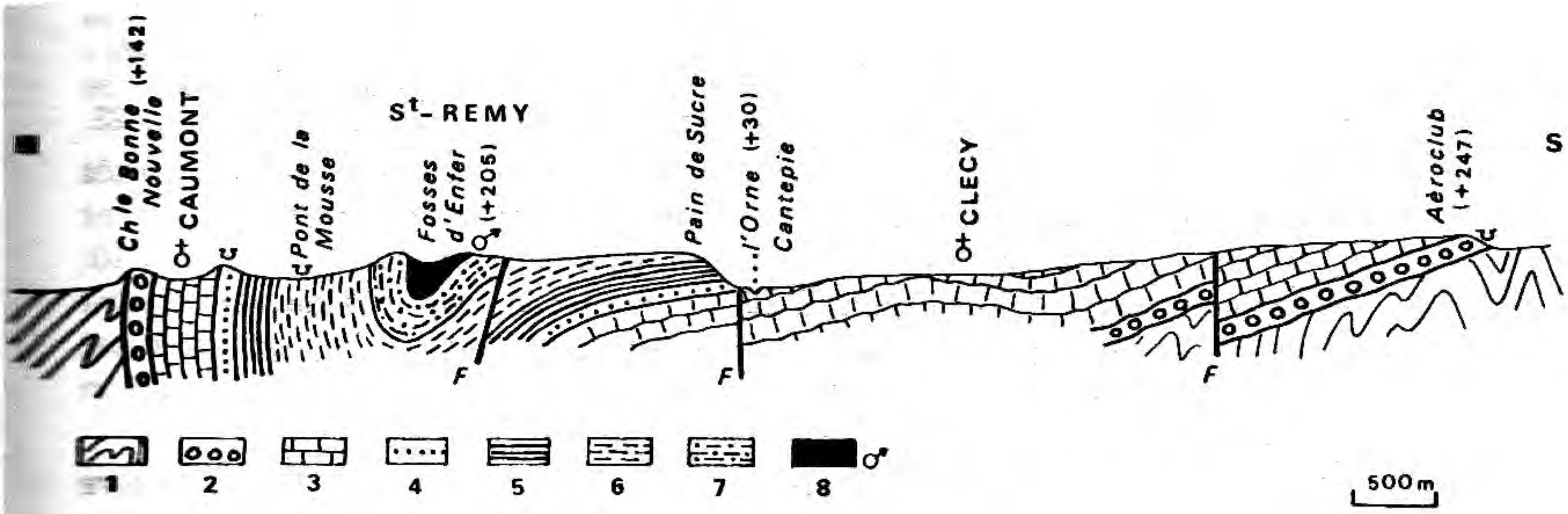
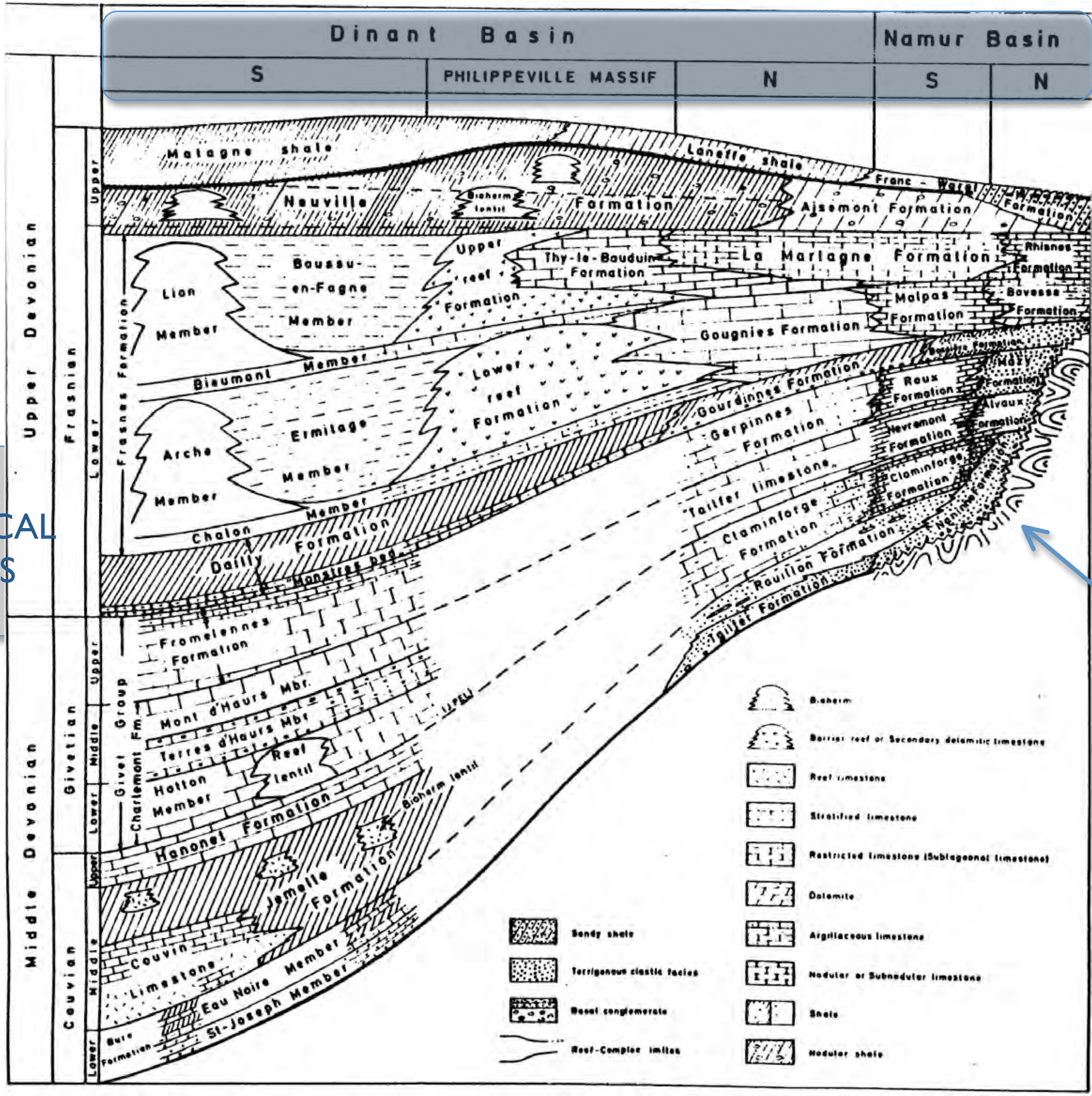
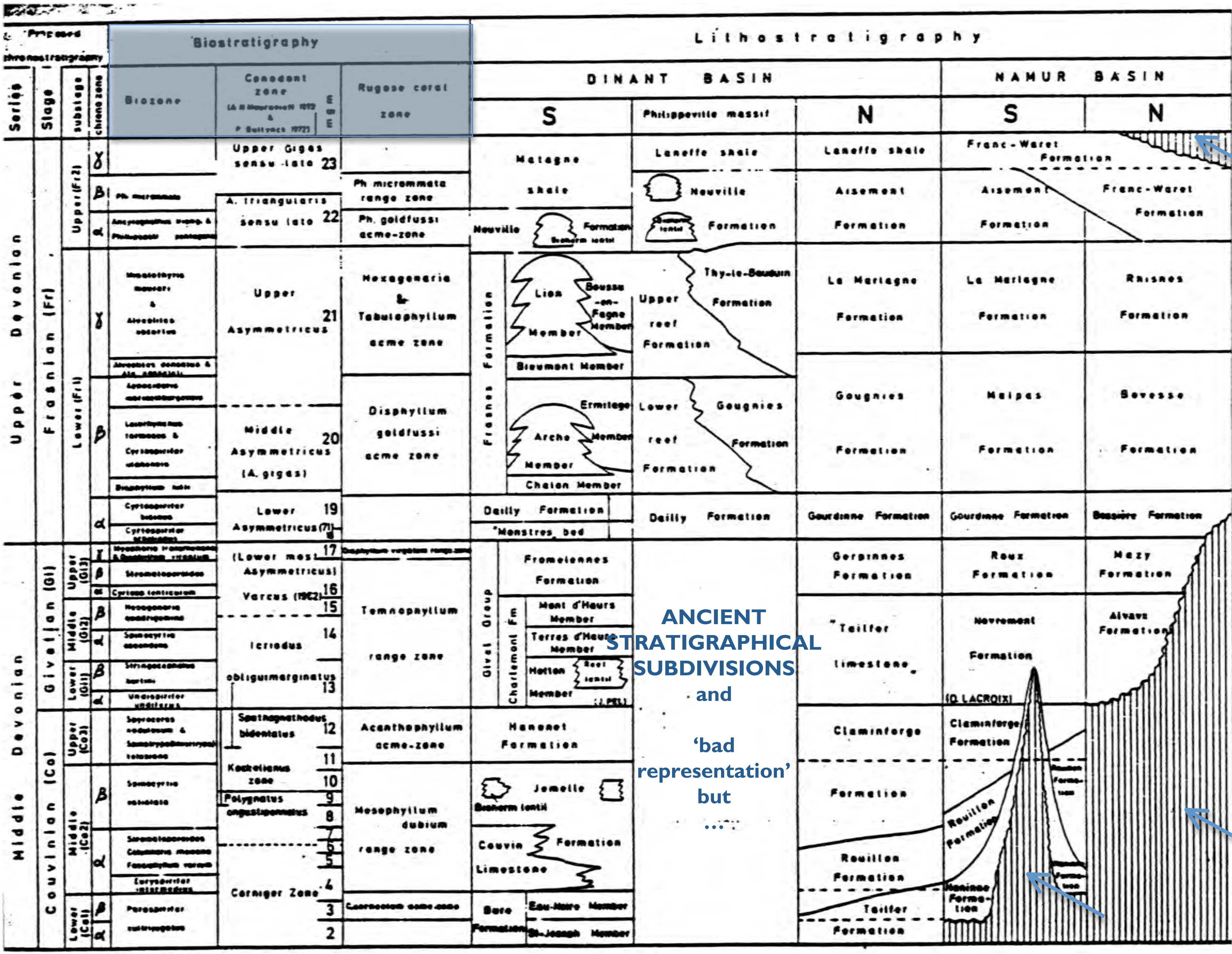


Fig. 16. – *Coupe nord-sud de la Zone bocaine par la vallée de l'Orne.*
1. Flysch briovérien supérieur. – 2. Poudingue et arkoses. – 3. Schistes et calcaires. – 4. Grès feldspathiques. – 5. Schistes de Gouvix. – 6. Schistes du Pont de la Mousse. – 7. Schistes de Saint-Rémy. – 8. Schistes d'Urville à minerai de fer.

Doré 1987

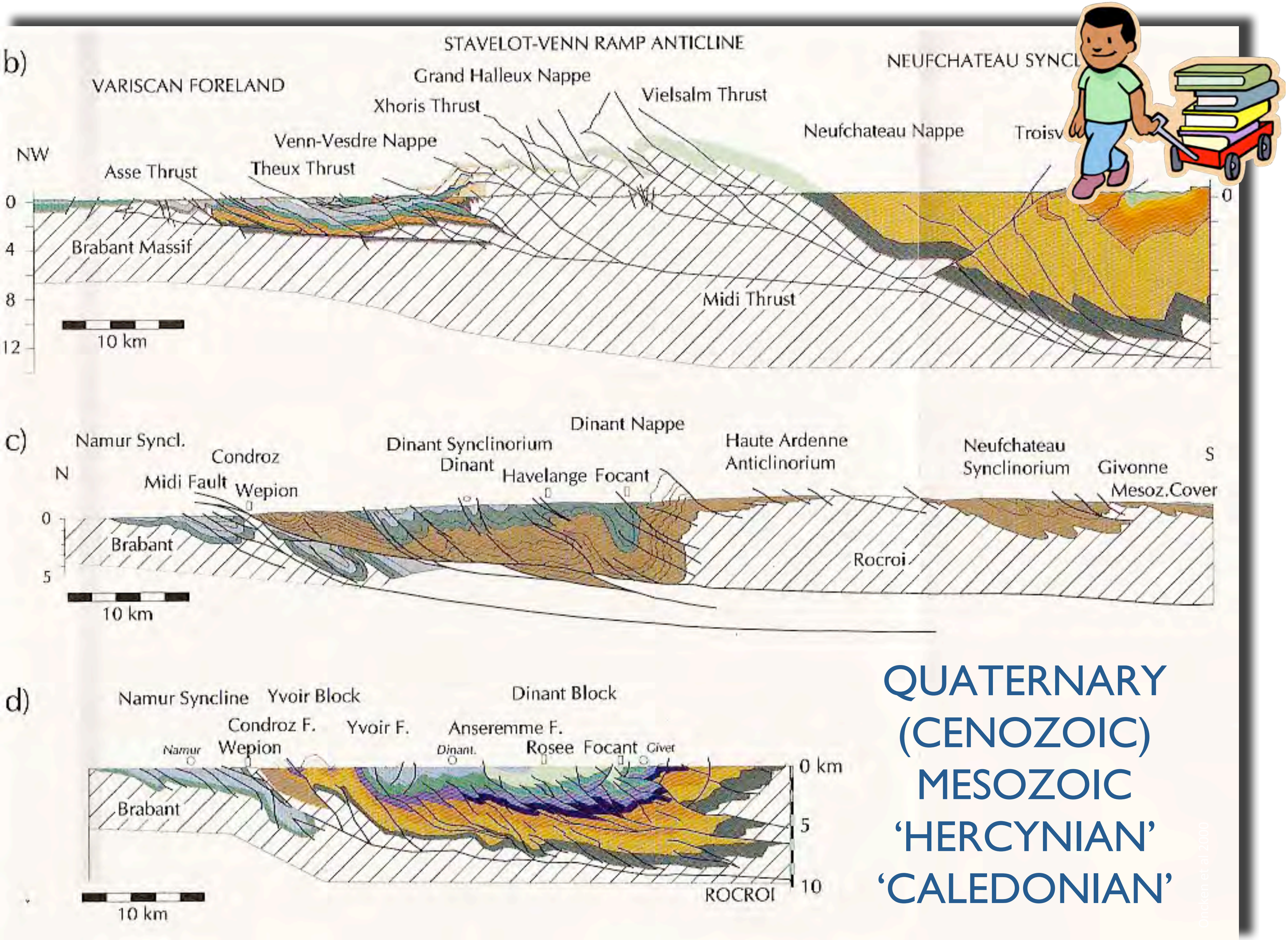


ANCIENT STRATIGRAPHICAL SUBDIVISIONS
do not use…



ANCIENT STRATIGRAPHICAL SUBDIVISIONS
and

'bad representation'
but
...



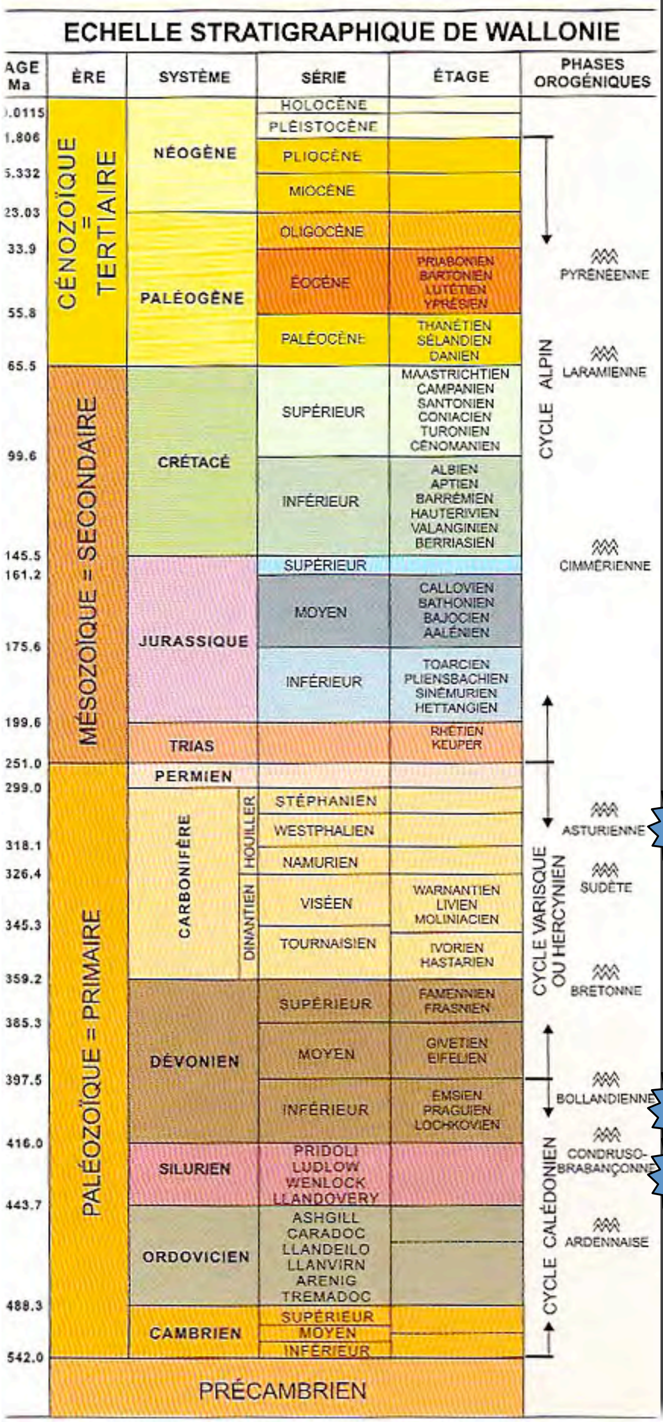
QUATERNARY
(CENOZOIC)
MESOZOIC
'HERCYNIAN'
'CALEDONIAN'

CENOZ

MESOZ

PAL SUP

PAL INF



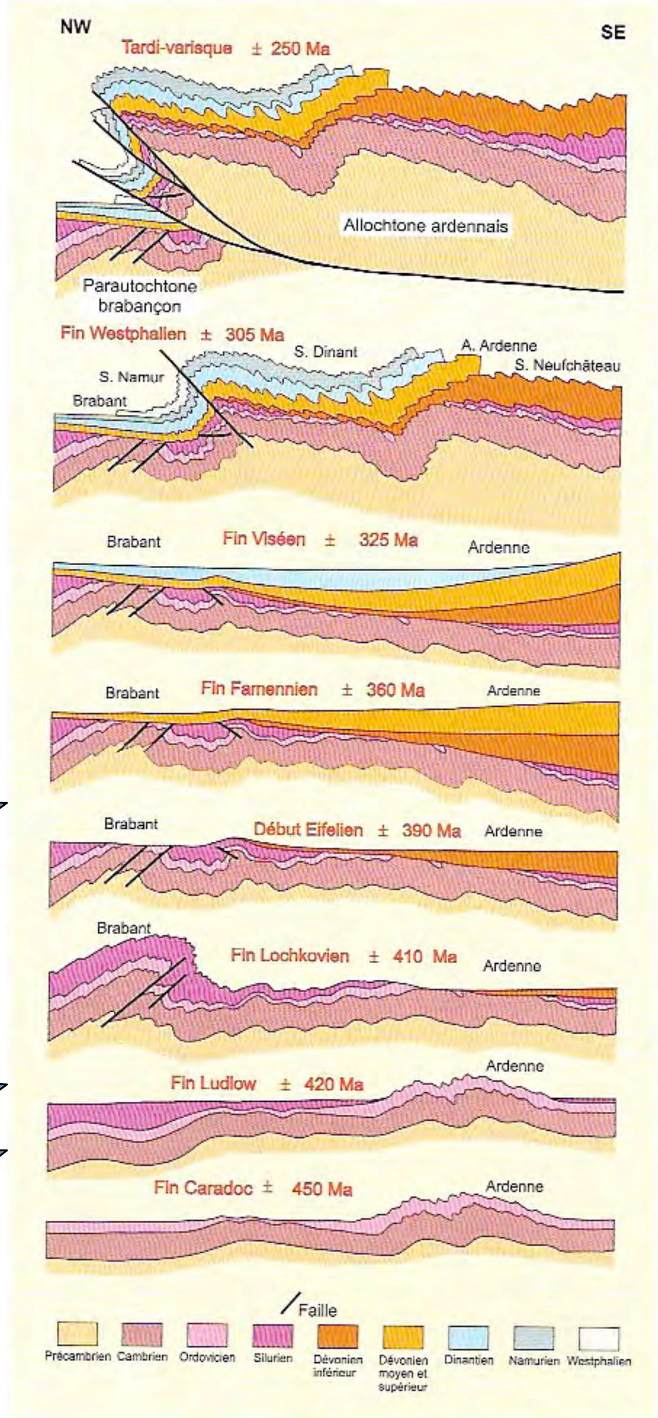
ECHELLE STRATIGRAPHIQUE DE WALLONIE

AGE Ma	ÈRE	SYSTÈME	SÉRIE	ÉTAGE	PHASES OROGÉNIQUES
0.0115	CÉNOZOÏQUE = TERTIAIRE		HOLOCÈNE		
1.806		NÉOGÈNE	PLÉISTOCÈNE		
5.332			PLIOCÈNE		
23.03			MIOCÈNE		
33.9		PALÉOGÈNE	OLIGOCÈNE		
55.8			ÉOCÈNE	PRIABONIEN BARTONIEN LUTÉTIEN YPRÉSIEN	PYRÉNÉENNE
65.5			PALÉOCÈNE	THANÉTIEN SÉLANDIEN DANIEN	LARAMIENNE
99.6	MÉSOZOÏQUE = SECONDAIRE	CRÉTACÉ	SUPÉRIEUR	MAASTRICHTIEN CAMPANIEN SANTONIEN CONIACIEN TURONIEN CÉNOMANIEN	
145.5			INFÉRIEUR	ALBIEN APTIEN BARRÉMIEN HAUTERIVIEN VALANGINIEN BERRIASIEN	CIMMÉRIENNE
161.2		JURASSIQUE	SUPÉRIEUR		
175.6			MOYEN	CALLOVIEN BATHONIEN BAJOCIEN AALÉNIEN	
199.6			INFÉRIEUR	TOARCIEN PLIENSBACHIEN SINÉMURIEN HETTANGIEN	
251.0		TRIAS		RHÉTIEN KEUPER	
299.0	PALÉOZOÏQUE = PRIMAIRE	PERMIEN			
		CARBONIFÈRE – HOUILLER	STÉPHANIEN		ASTURIENNE
318.1			WESTPHALIEN		
326.4			NAMURIEN		SUDÈTE
345.3		CARBONIFÈRE – DINANTIEN	VISÉEN	WARNANTIEN LIVIEN MOLINIACIEN	
359.2			TOURNAISIEN	IVORIEN HASTARIEN	BRETONNE
385.3		DÉVONIEN	SUPÉRIEUR	FAMENNIEN FRASNIEN	
397.5			MOYEN	GIVETIEN EIFELIEN	
416.0			INFÉRIEUR	EMSIEN PRAGUIEN LOCHKOVIEN	BOLLANDIENNE
443.7		SILURIEN	PRIDOLI LUDLOW WENLOCK LLANDOVERY		CONDRUSO-BRABANÇONNE
488.3		ORDOVICIEN	ASHGILL CARADOC LLANDEILO LLANVIRN ARENIG TREMADOC		ARDENNAISE
542.0		CAMBRIEN	SUPÉRIEUR MOYEN INFÉRIEUR		
	PRÉCAMBRIEN				

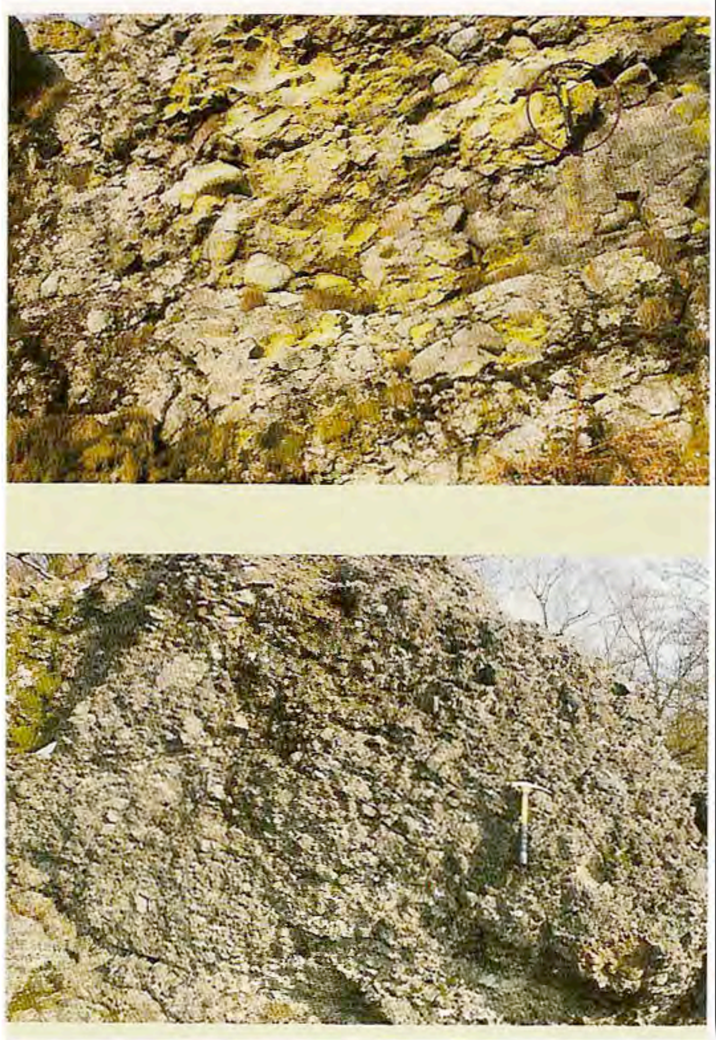
CYCLE ALPIN

CYCLE VARISQUE OU HERCYNIEN

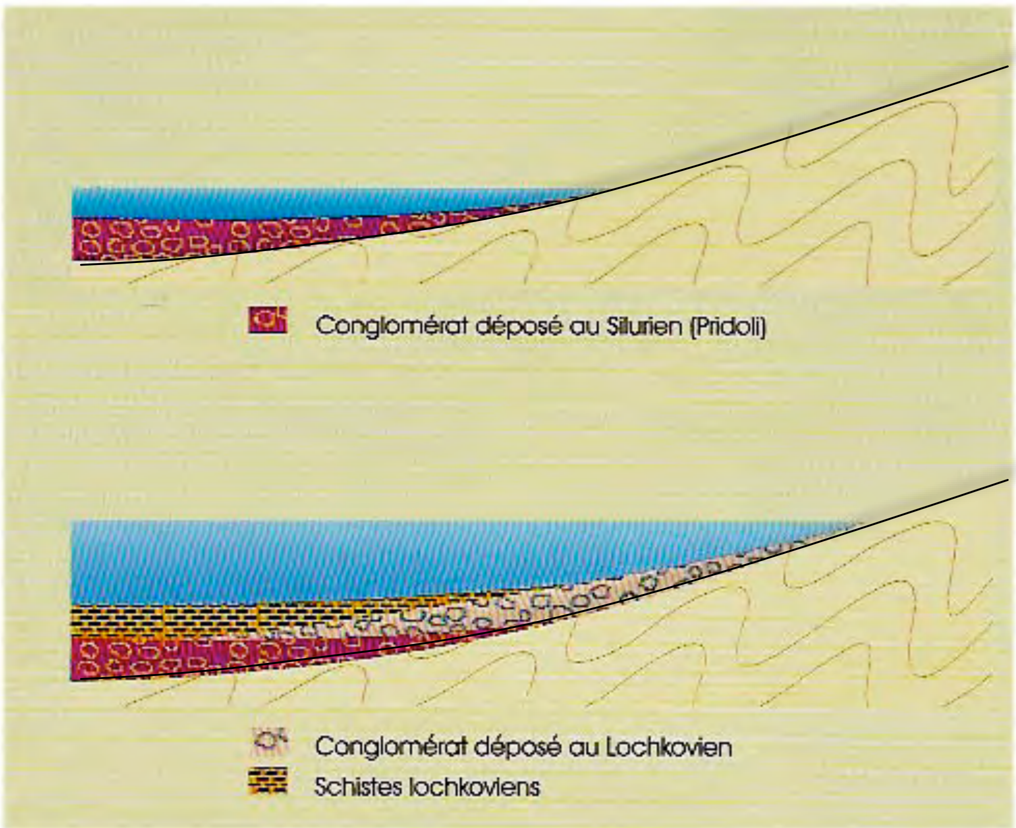
CYCLE CALÉDONIEN



LE MASSIF DE ROCROI



Dejonghe, Jumeau 2007

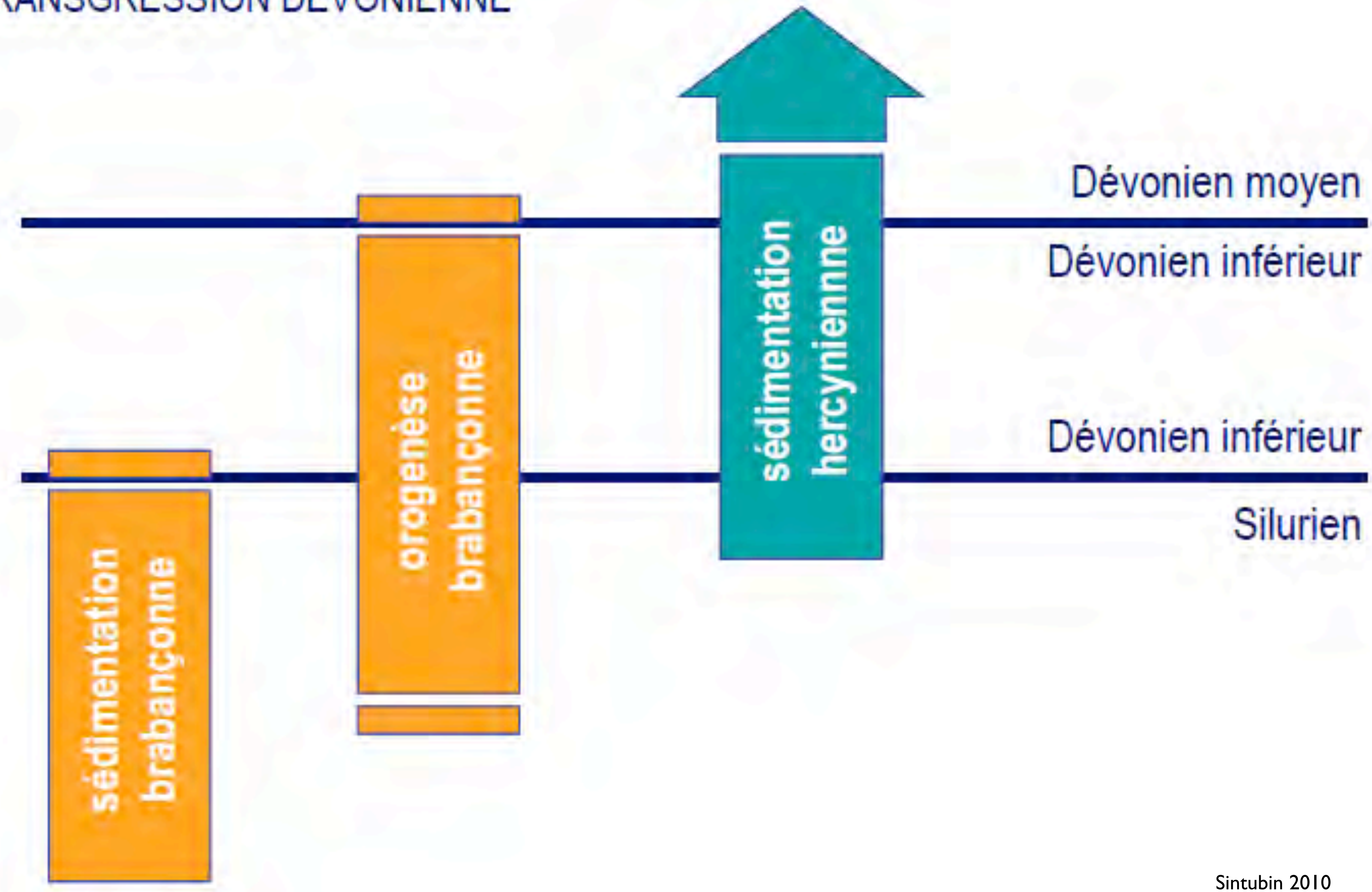


Conglomérat de Fépin [Dumont 1848]

5 à 70m sur 600m de distance à Fépin
= dépôts fluviatiles et tidalites marines
Base de la transgression marine sur le socle calédonien
= blocs de grès et quartzites hétérométriques (cm-50cm),
formes anguleuses arrondies dans matrice fine, argilo-sableuse

Le conglomérat est d'âge Silurien et de + en + jeune vers le Nord [de Silurien-Pridoli à Lochkovien]
=> **d i a c h r o n i s m e** du conglomérat [cf. acritarches, spores ...] jusqu'au Praguien (moyen)
LA TRANSGRESSION EODEVONIENNE S'EST DEPLACEE DU SE AU NW
nb au NE Ardenne, il y a REGRESSION à la fin du Lochkovien = soulèvement local Massif Brabant

× TRANSGRESSION DÉVONIENNE



Sintubin 2010

phase palatine
phase saalienne

phase ASTURIENNE

OROGENESE HERCYNIENNE (VARISQUE) ±315

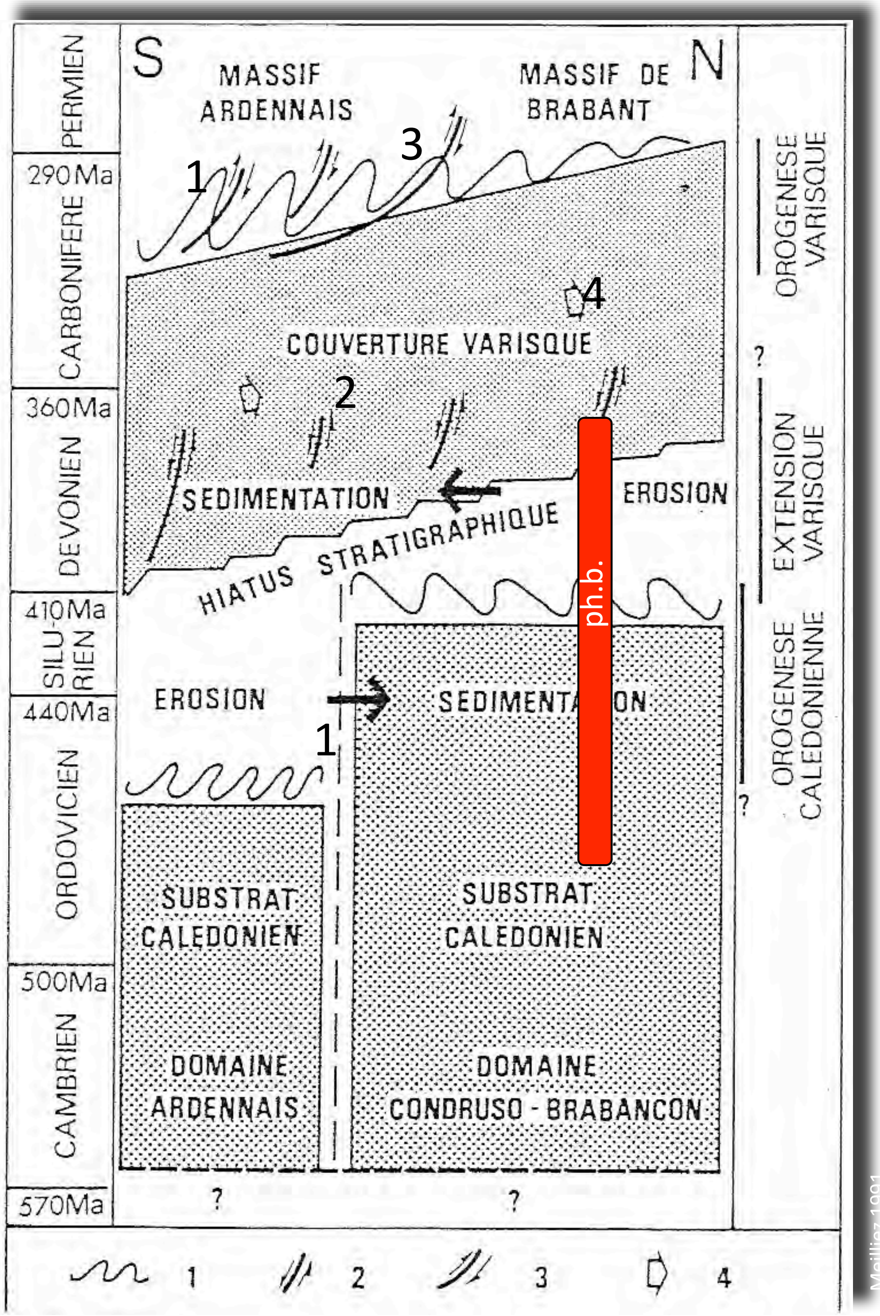
phase sudète
phase bretonne

phase ARDENNAISE

OROGENESE CALEDONIENNE ±420

phase taconique
phase sarde
phase cadomienne

1 plissements
2 failles listriques normales
3 idem, mais réactivées
en failles de chevauchement et de charriage
4 sens de la progression des mers varisques



nb: phase «brabancienne» '30Ma' Ord inf -Emsien (id. U.K.) [in Debacker et al. 2005]

PRINCIPLES 1, 2, 3 => NOTION OF MAJOR 'BREAKS'

SYNTHESIS = '4'

'SEDIMENTARY CYCLES and OROGENIC CYCLES'

A SEDIMENTARY cycle contains 3 terms: TRANSGRESSION-SEDIMENTATION-REGRESSION
AN OROGENIC cycle contains 3 terms: TRANSGRESSION-SEDIMENTATION-OROGENESIS
nb Orogeny is a collective name for deformation processes
at ***convergent*** *plates boundaries*

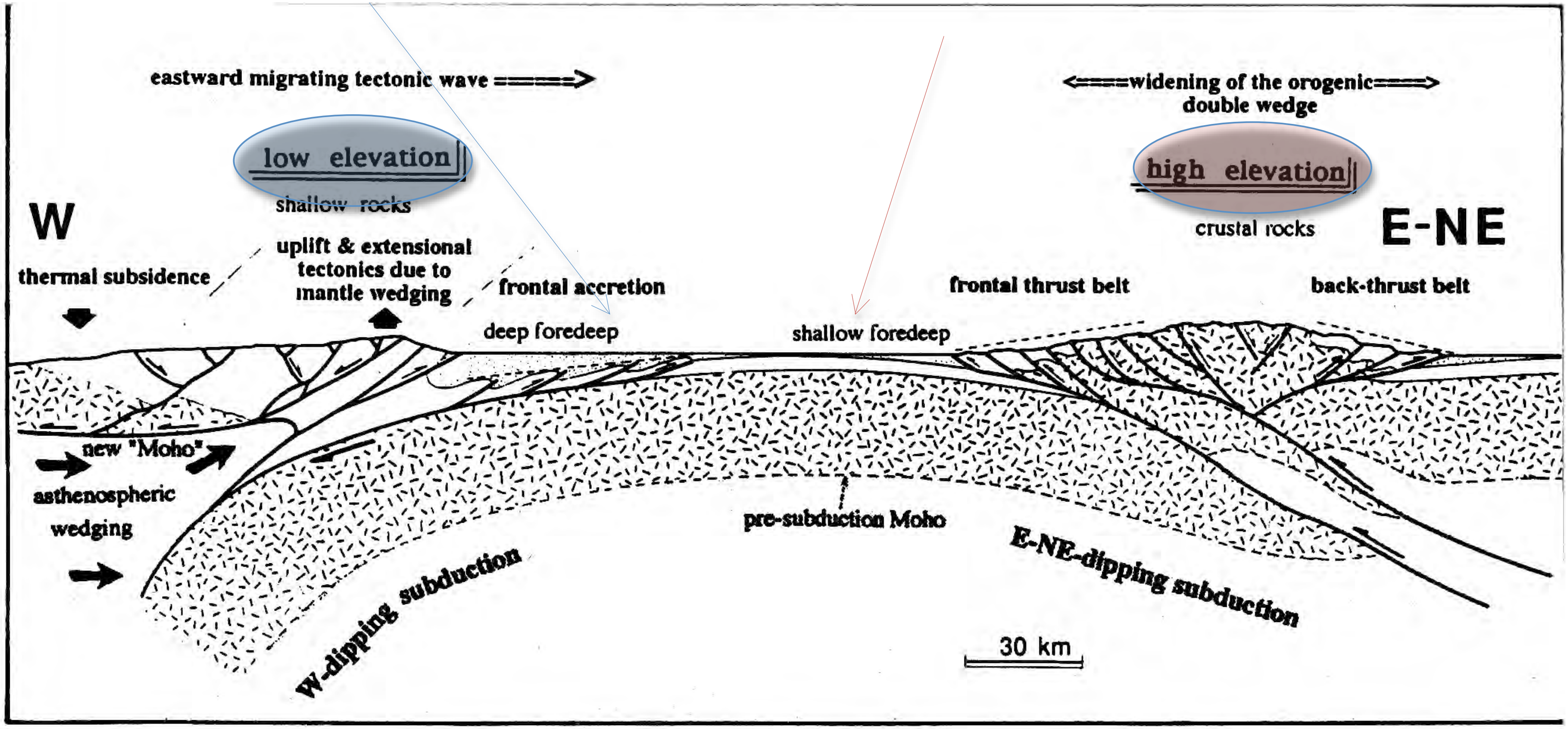
uplift
erosion
denudation
peneplanation)
AND
ANGULAR UNCONFORMITY

KEY INTERPRETATION: **the OROGENIC cycle is a higher subdivision** with respect to the sedimentary cycle

THRUST-BELTS and OROGENY
DOGLIANI **MODEL**

high subsidence => deep foredeep
(West Pacific accretionary wedges,
Barbados, S Sandwich Islands, Carpathians, Apennines…)

low subsidence ==> shallow foredeep
(Andes, Alps, Dinarides, Taurides, **Zagros**, Himalayas…)



Dogliani 1993

potential good **major** subdivisions at a worldwide scale
based on the presence of the angular unconformities

Example: at least 16 orogenies in the Precambrian (cf. Wilson Cycle)

Example of the Dinant Basin : numerous TR and REG phases (absolute or relative)

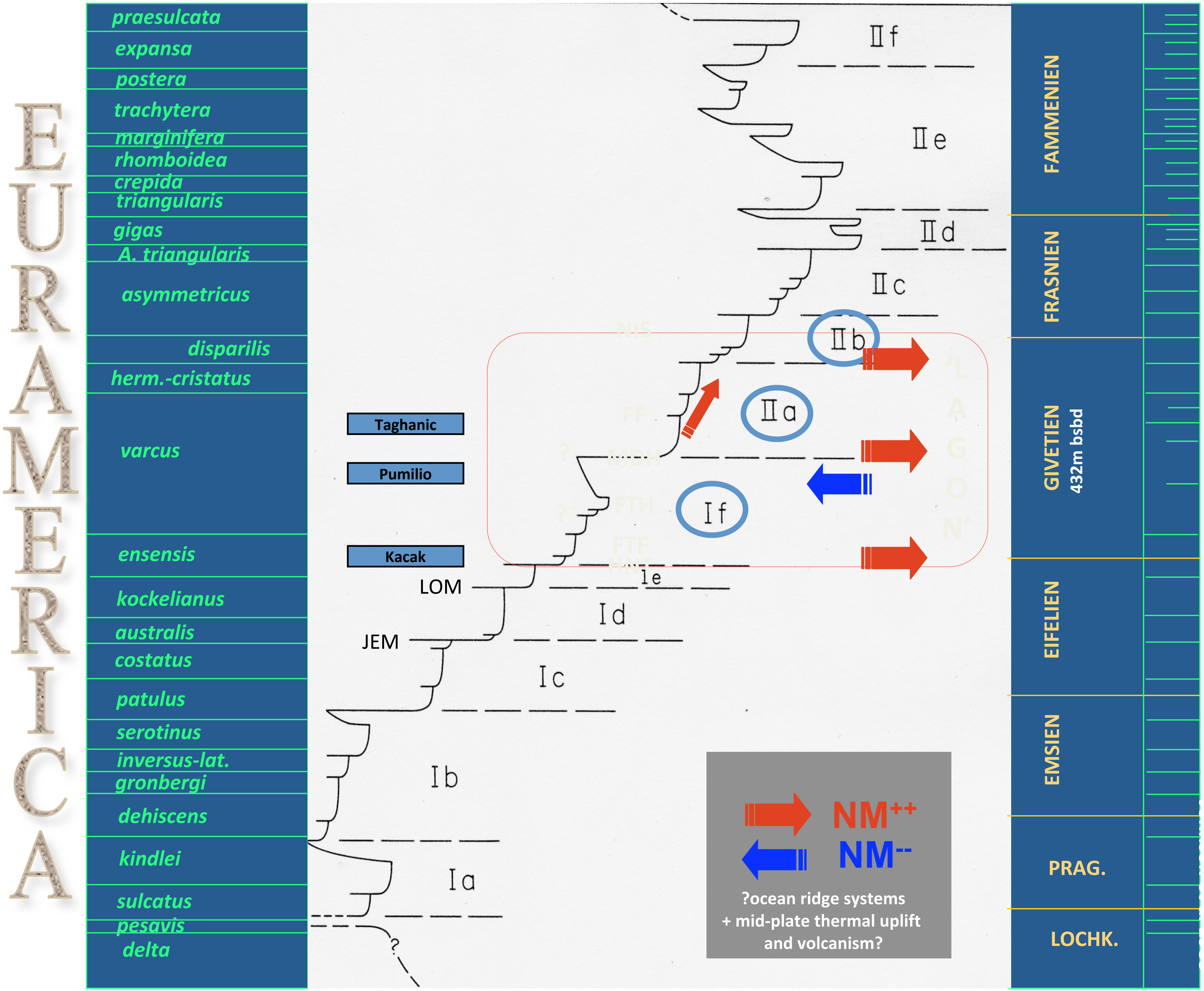
• Lower Dev-Eif (TR)/Giv (REG)/

••/Fr(TR)/Fa(REG)/

•••/Tn(TR)/Vn(REG)/Houiller(REG)…

$\Rightarrow$Wn C/D

VALID for the 'Euramerica Plate' ('Global' Scale')


EURAMERICA
praesulcata
expansa
postera
trachytera
marginifera
rhomboidea
crepida
triangularis
gigas
A. triangularis
asymmetricus
disparilis
herm.-cristatus
varcus
ensensis
kockelianus
australis
costatus
patulus
serotinus
inversus-lat.
gronbergi
dehiscens
kindlei
sulcatus
pesavis
delta
Taghanic
Pumilio
Kacak
LOM
JEM
IIf
IIe
IId
IIc
IIb
IIa
If
Ie
Id
Ic
Ib
Ia
NM++
NM--
?ocean ridge systems
+ mid-plate thermal uplift
and volcanism?
FAMMENIEN
FRASNIEN
GIVETIEN
432m bsbd
EIFELIEN
EMSIEN
PRAG.
LOCHK.

CONCLUSION

They are numerous SEDIMENTARY CYCLES
in **one** OROGENIC CYCLE
(here Hercynian)
with only **one** angular unconformity at the base,
above the ‘caledonian rocks’ ± 410 Ma
(and another one at the top, Wn C/D =± 310 Ma)

nb angular unconformities in the Precambrian : geometry?

SUMMARY

Principles I, 2, 3 => Major **regional** subdivisions

(with absolute chronology, i.e. ± 5-10 Ma)

<u>nb without correlation, successions in time derived in one area are unique and contribute nothing to understand Earth history!</u>

Orogen(s) 4 => group regional subdivisions in larger 'units'

==> INTERNATIONAL DIVISIONS of GEOLOGIC TIME and GLOBAL BOUNDARIES

Principles (I, 2, 3) + Orogens (4) ⇔ PLATE TECTONICS
working since crust growth was stationary (ca ± 2.5 Ga)

⇒ geodynamic evolution of continents/oceans
PASSIVE/ACTIVE/TRANSFORM MARGINS
= continental 'platform'/slope/rise/abyssal plain/ridges (rifts and oceanic)

nb Geologists decided to call the stable areas 'plates' and the unstable zones around them 'plate margins' = plate tectonics

Order of magnitude of the orogenic cycles

Example of the European areas

4.ALPINE ±230 => ‘0’

3. HERCYNIAN or ‘VARISCAN’ ± 390 => ± 230 Ma

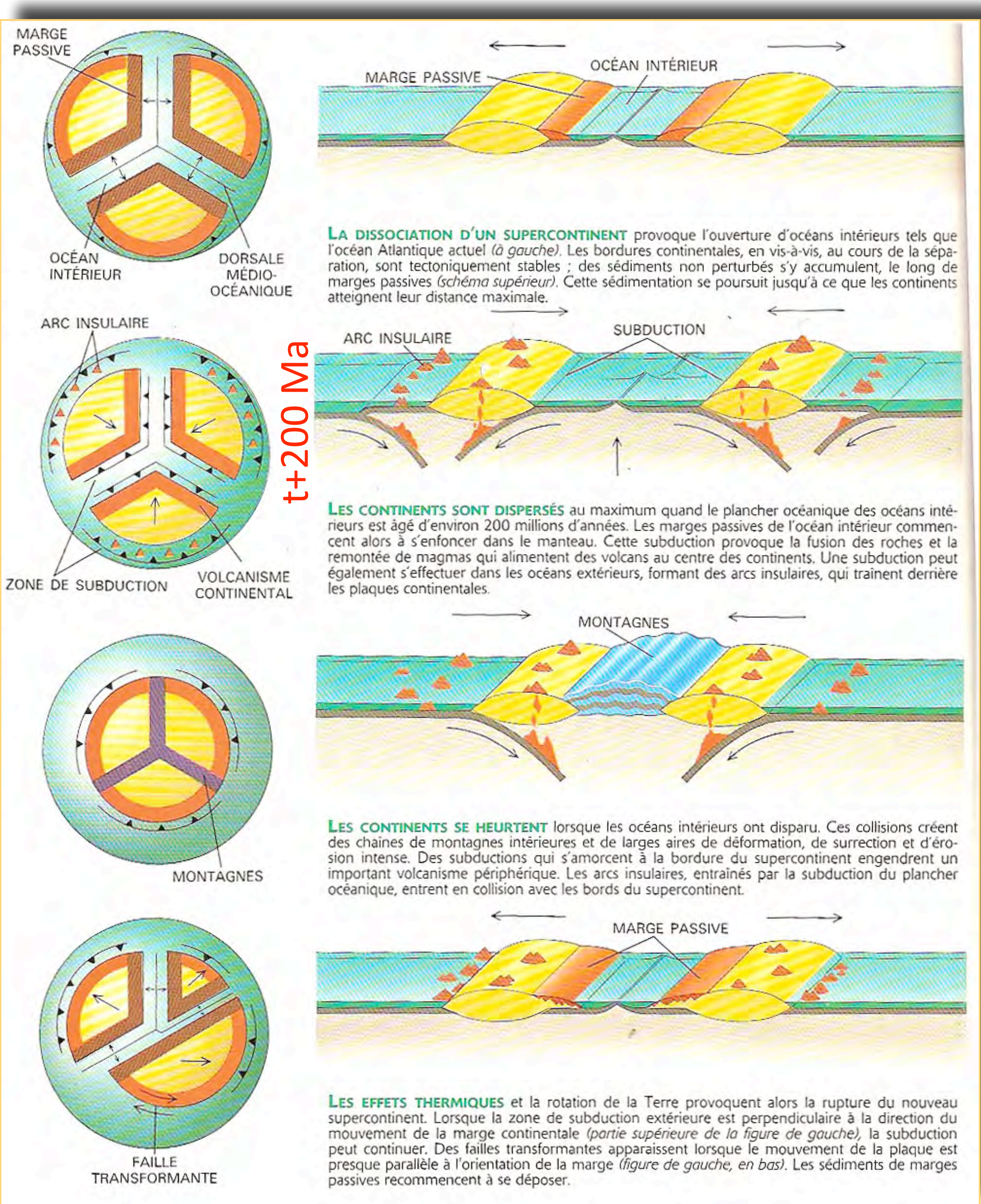
2. CALEDONIAN ± 500 => ± 390 Ma

1. CADOMIAN (PANAFRICAIN…) ± 650? => ±500 Ma

Each cycle is characterized by a few TECTONIC PHASES
Example of the Caledonian ‘cycle’

ARDENNE PHASE [phase ardennaise] -395 Ma (U. Sil/’Ge’)
TACONIC PHASE -435 Ma (U. Ord/L. Sil)
SARDE PHASE -500 Ma (U. Cm/L. Ord)
=
CLOSURE OF IAPETUS OCEAN
from N to S, between Laurentia and Baltica

WILSON CYCLE or CYCLE of SUPERCONTINENTS



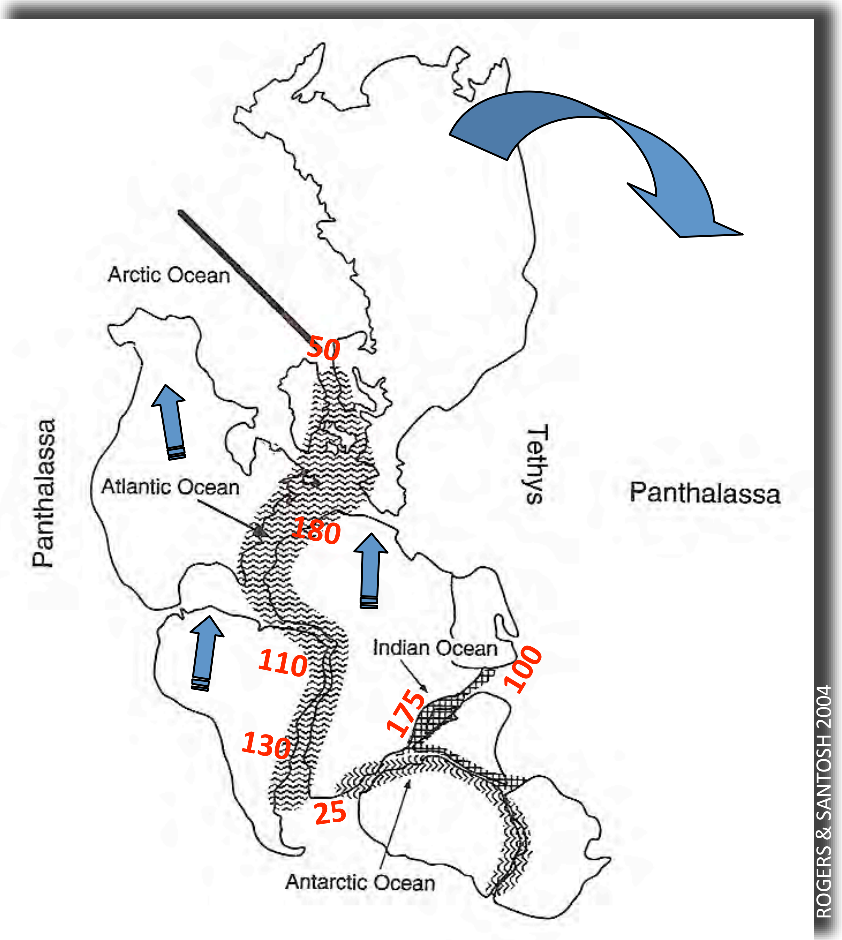
La dissociation d'un supercontinent provoque l'ouverture d'océans intérieurs tels que l'océan Atlantique actuel *(à gauche)*. Les bordures continentales, en vis-à-vis, au cours de la séparation, sont tectoniquement stables ; des sédiments non perturbés s'y accumulent, le long de marges passives *(schéma supérieur)*. Cette sédimentation se poursuit jusqu'à ce que les continents atteignent leur distance maximale.

Les continents sont dispersés au maximum quand le plancher océanique des océans intérieurs est âgé d'environ 200 millions d'années. Les marges passives de l'océan intérieur commencent alors à s'enfoncer dans le manteau. Cette subduction provoque la fusion des roches et la remontée de magmas qui alimentent des volcans au centre des continents. Une subduction peut également s'effectuer dans les océans extérieurs, formant des arcs insulaires, qui traînent derrière les plaques continentales.

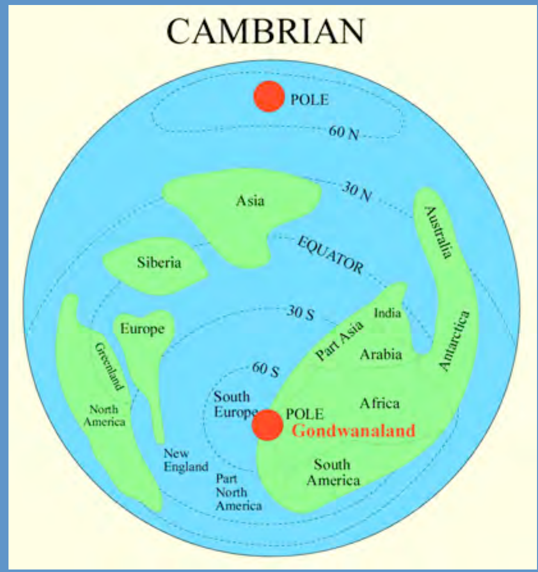
Les continents se heurtent lorsque les océans intérieurs ont disparu. Ces collisions créent des chaînes de montagnes intérieures et de larges aires de déformation, de surrection et d'érosion intense. Des subductions qui s'amorcent à la bordure du supercontinent engendrent un important volcanisme périphérique. Les arcs insulaires, entraînés par la subduction du plancher océanique, entrent en collision avec les bords du supercontinent.

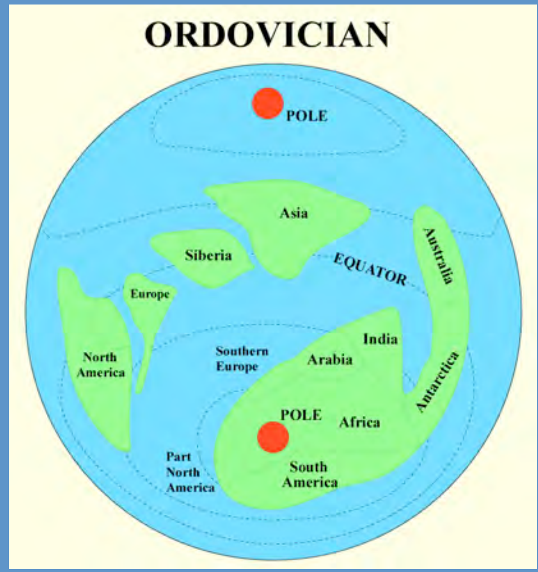
Les effets thermiques et la rotation de la Terre provoquent alors la rupture du nouveau supercontinent. Lorsque la zone de subduction extérieure est perpendiculaire à la direction du mouvement de la marge continentale *(partie supérieure de la figure de gauche)*, la subduction peut continuer. Des failles transformantes apparaissent lorsque le mouvement de la plaque est presque parallèle à l'orientation de la marge *(figure de gauche, en bas)*. Les sédiments de marges passives recommencent à se déposer.

PANGEA ± 250 Ma

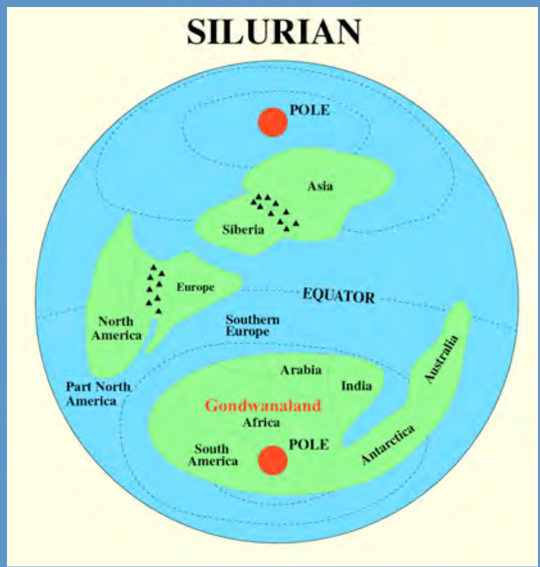


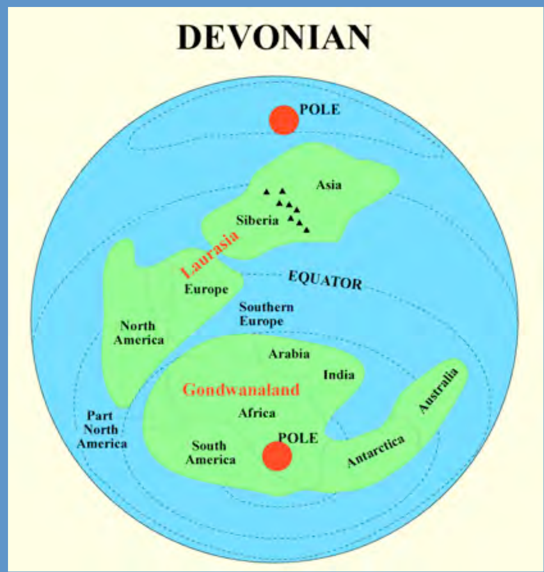
RIFTING
Cambro-Ordovician

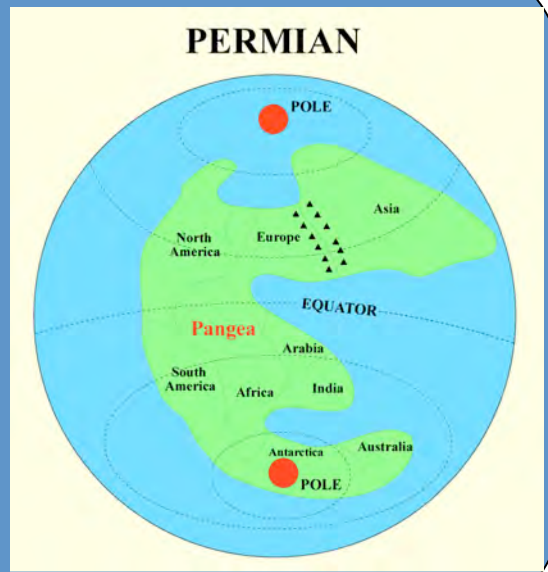




CONVERGENCE
'caledonian'
'hercynian'

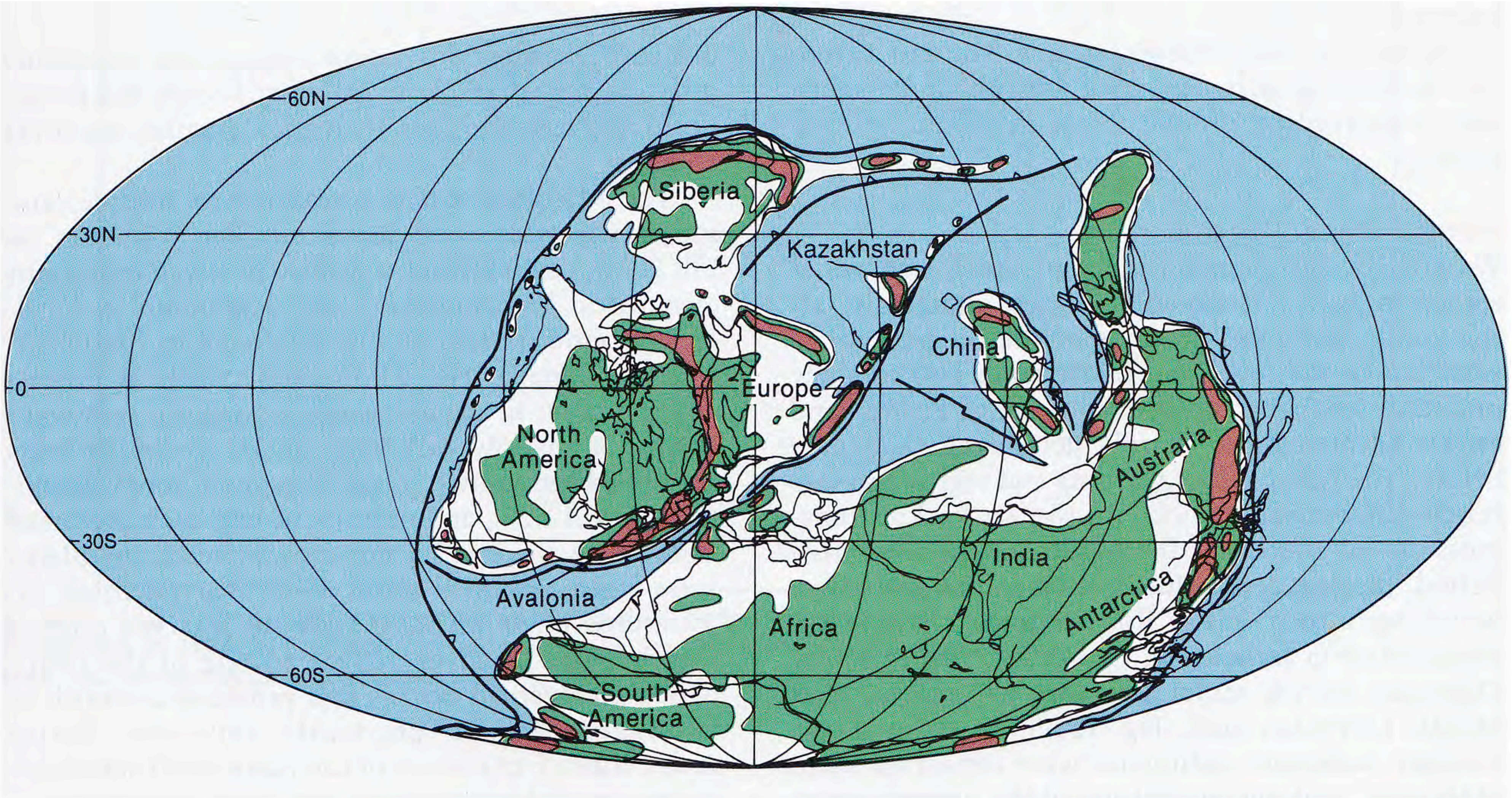






DISTRIBUTION OF CONTINENTS AND CLIMATIC BELTS IN THE DEVONIAN

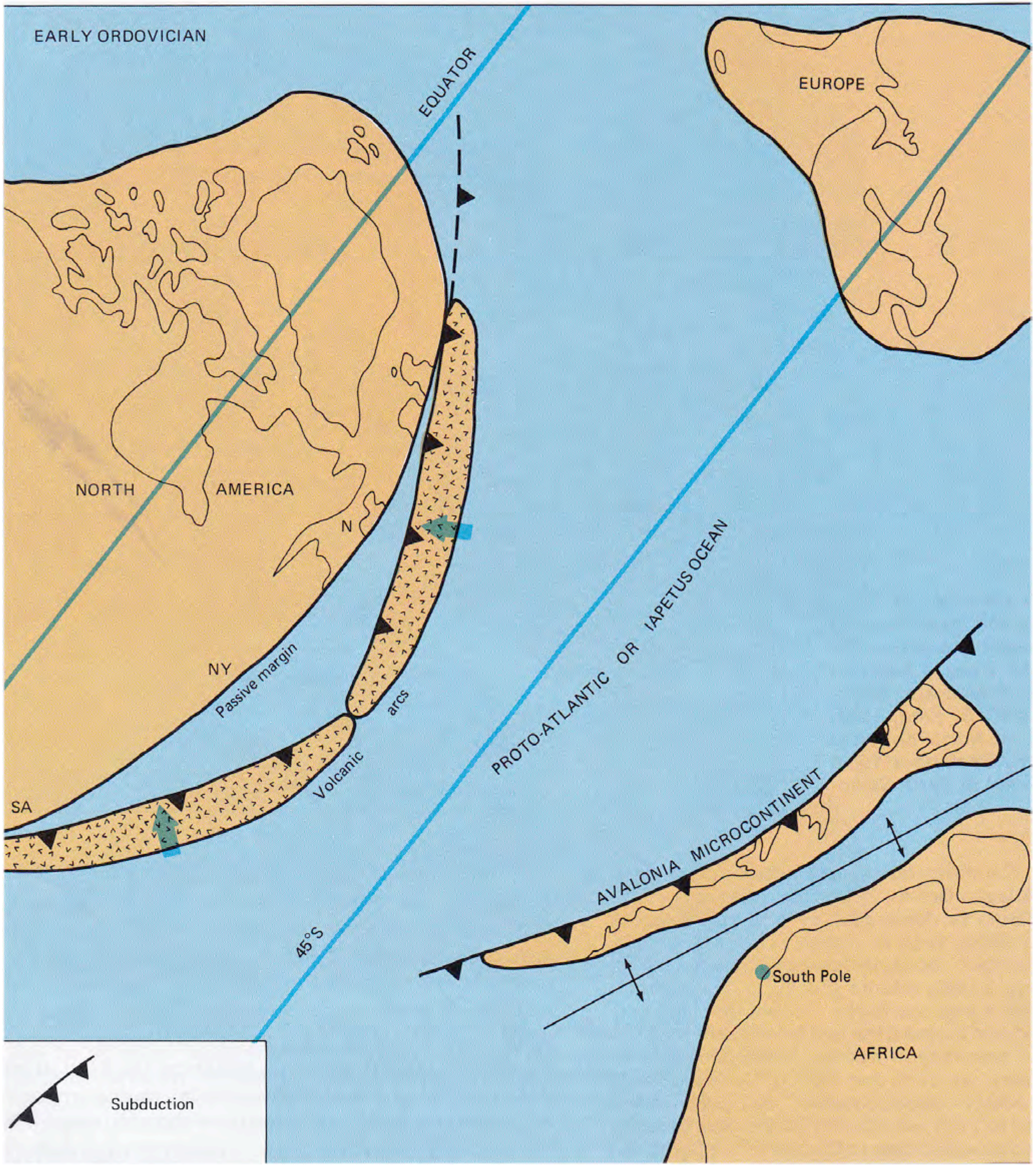
(from Scotese & Golonka 1992)



Early Ordovician paleotectonic map showing infered relationships of N America to Europe and Africa. Volcanic arcs of the Piedmont terrane were impinging upon eastern N America, and the AVALONIA micro-continent was rifted from NW Africa

N= Newfoundland
NY= New York State
SA= southern Appalachian region

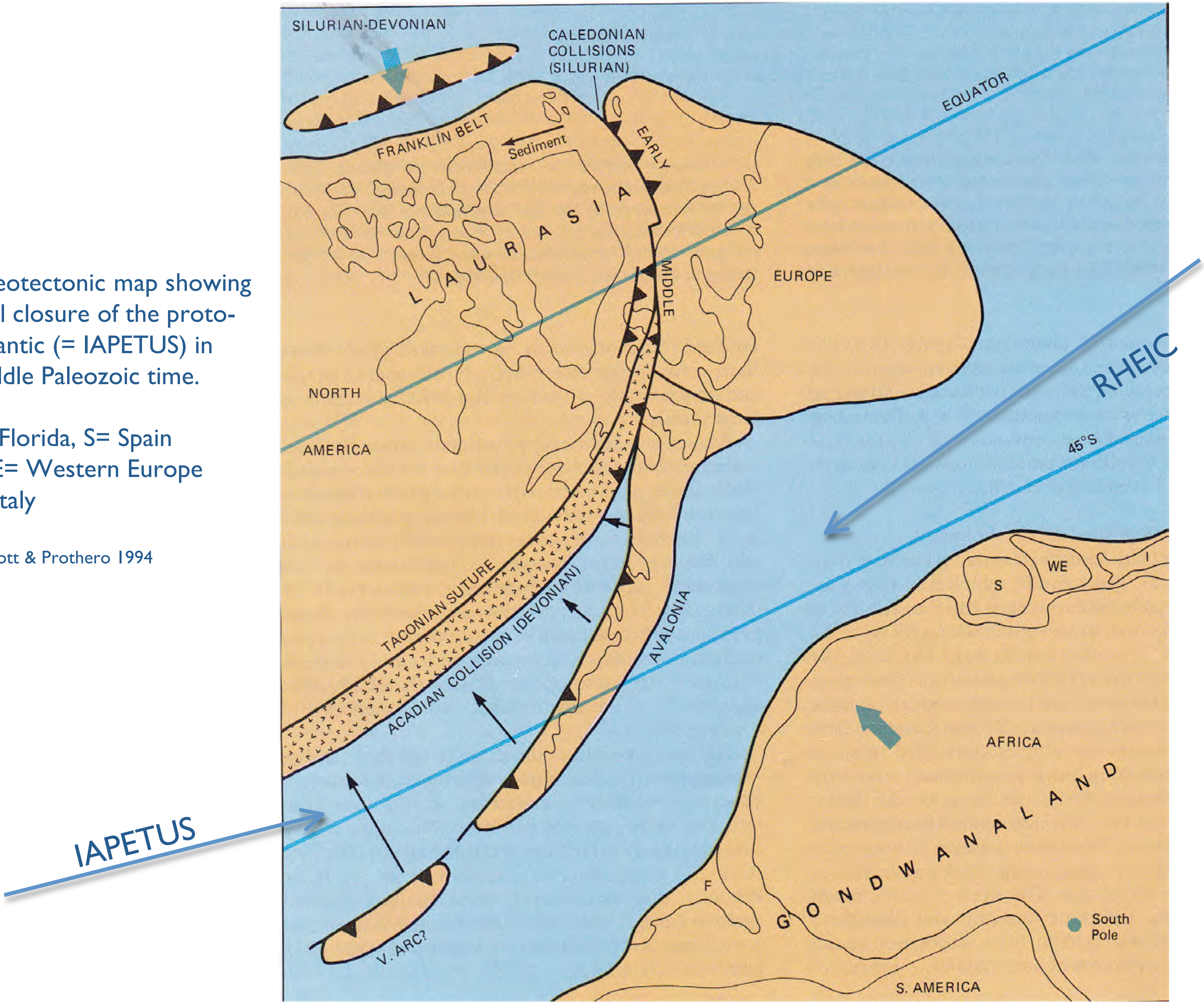
in Prothero & Dott 1994



Paleotectonic map showing final closure of the proto-Atlantic (= IAPETUS) in middle Paleozoic time.

F= Florida, S= Spain
WE= Western Europe
I= Italy

in Dott & Prothero 1994



PROGRESSIVE
and
DEFINITIVE
CLOSURE
of
IAPETUS

Systèmes	Séries		Étages	Ma
SILURIEN	Pridoli		Pridolien	410
	Ludlow		Ludfordien Gorstien	
	Wenlock		Homérien Sheinwoodien	
	Llandovery		Télychien Aéronien Rhuddanien	
	(Parakidograptus acuminatus)			445
ORDOVICIEN	supérieur	Ashgill	étage 6	
		Caradoc	étage 5	
	moyen = Llanvirn	Llandeilien	Darriwilien	
		Abereiddien		
	inférieur	Arenig	étage 3 étage 2	
		Tremadoc	Tremadocien	
	(Iapetognathus fluctivagus)			490
CAMBRIEN	supérieur		Trempéaléauien Franconien Dresbachien	
	moyen		Mayaien Amgaien	
	inférieur		Toyonien Botomien Atdabanien Tommotien Nemakyt-Daldynien	
	(« Phycodes » pedum)			545

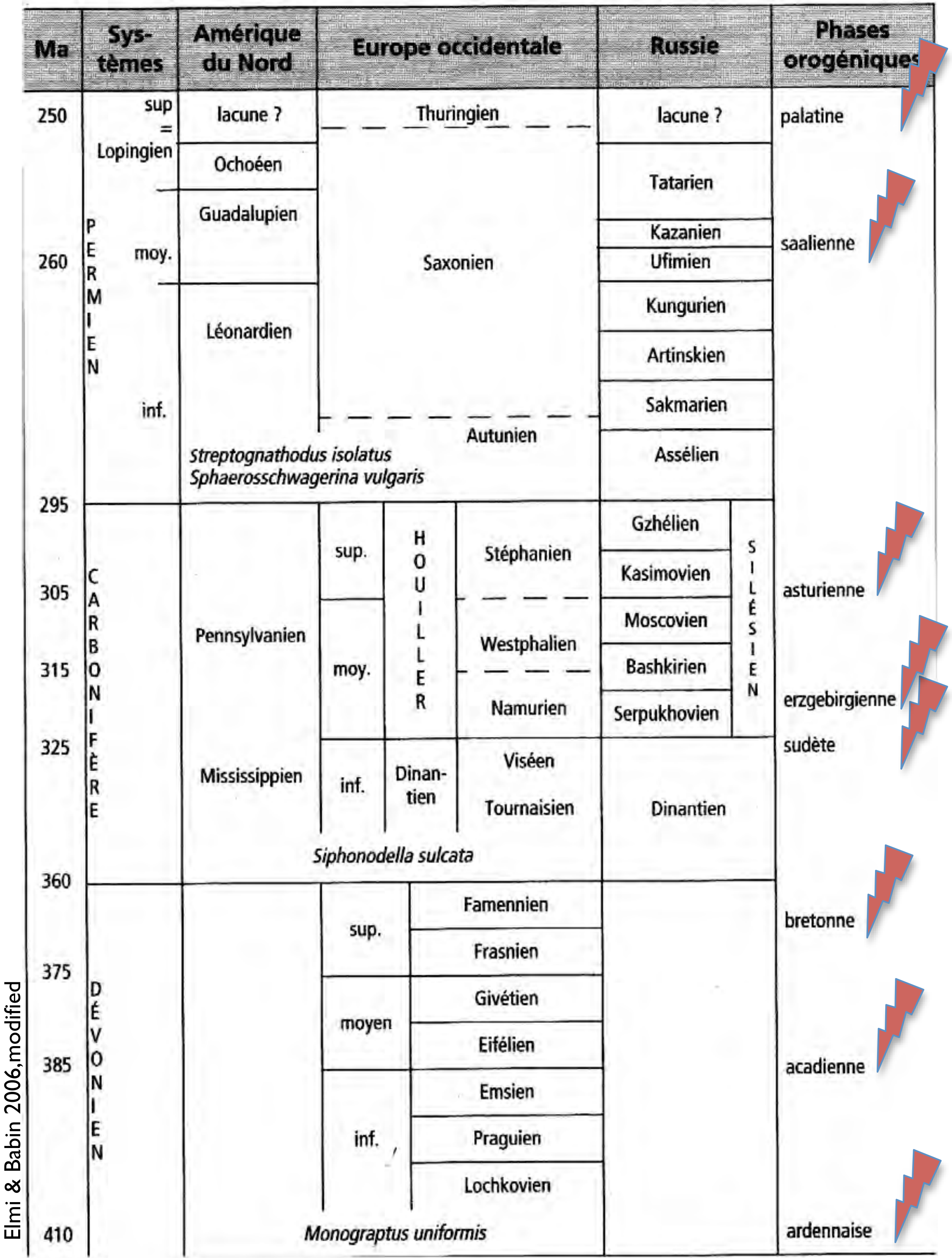
ardennaise phase

taconic phase

sarde phase

Elmi & Babin 2006,modified

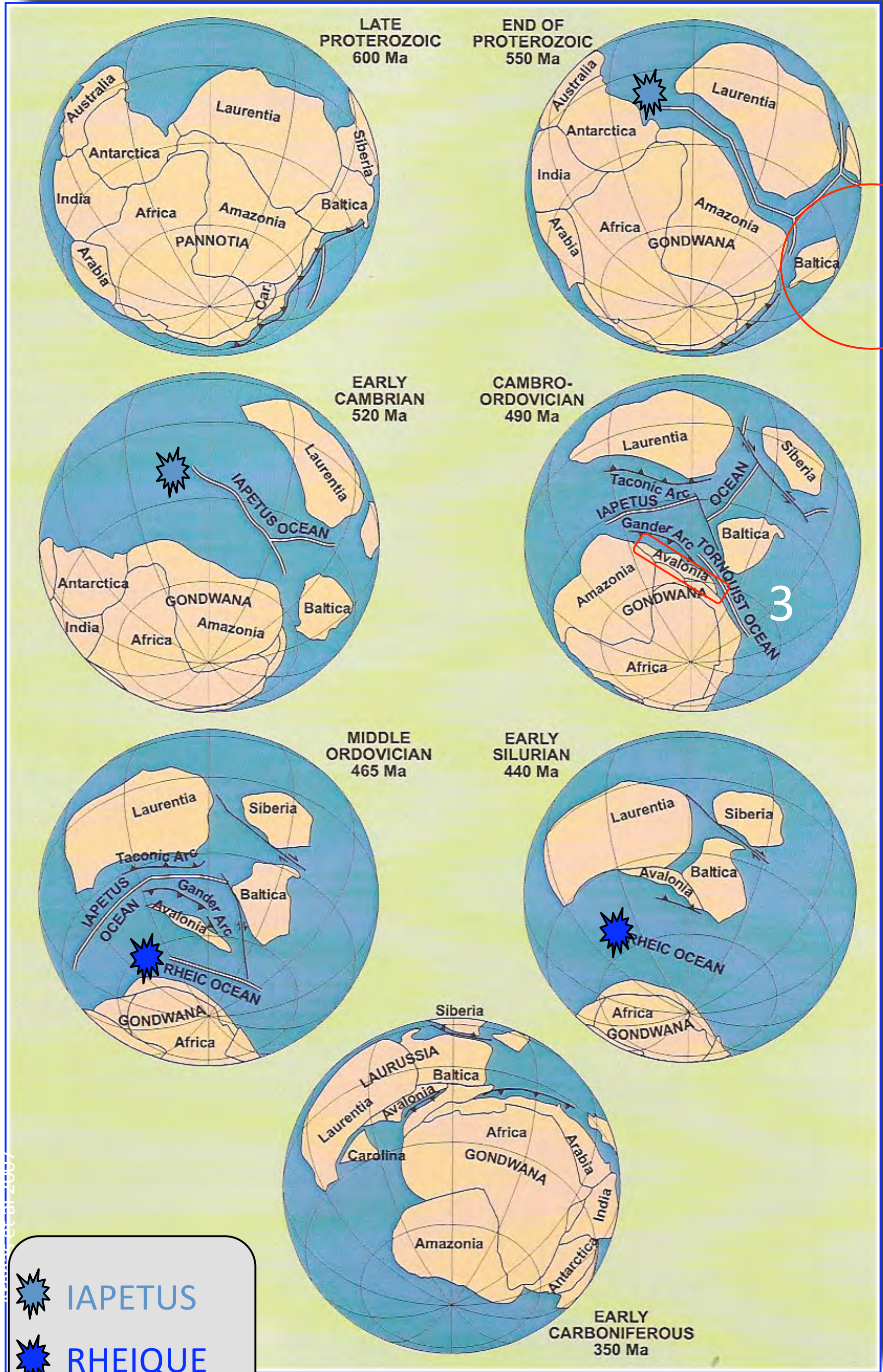
PROGRESSIVE
and
DEFINITIVE
CLOSURE
of
RHEIC
OCEAN

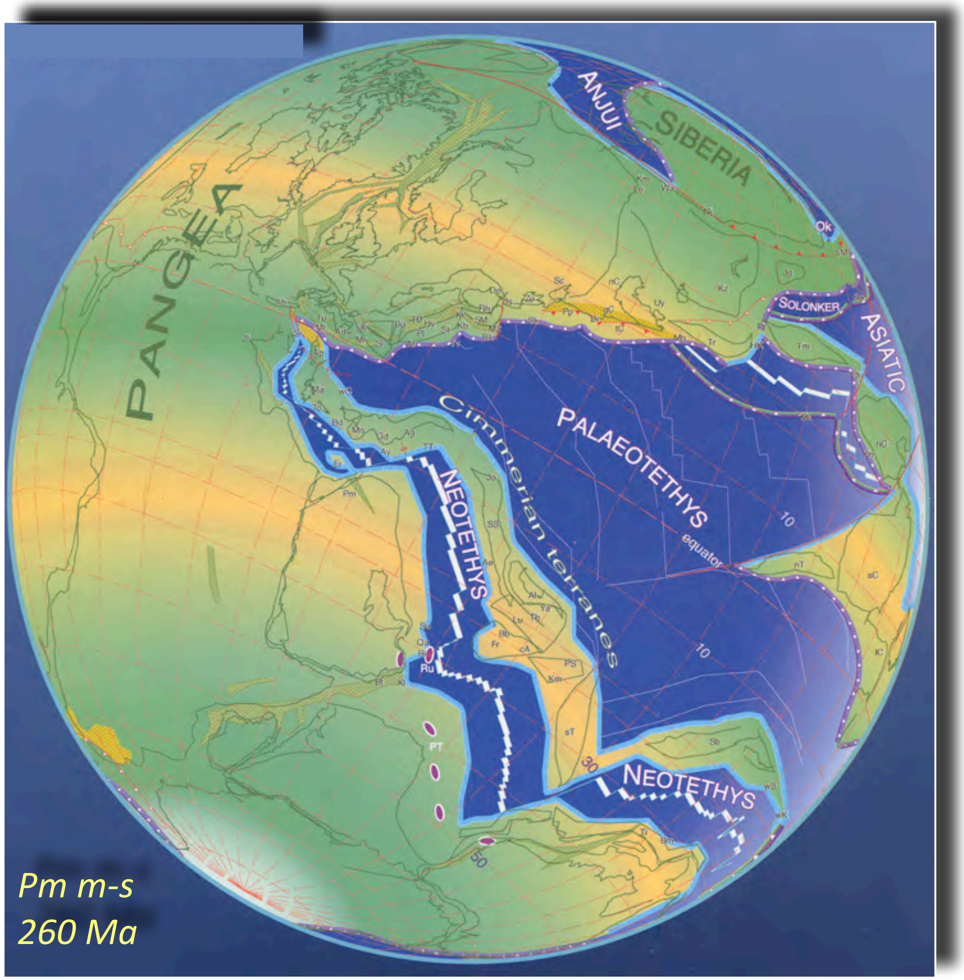


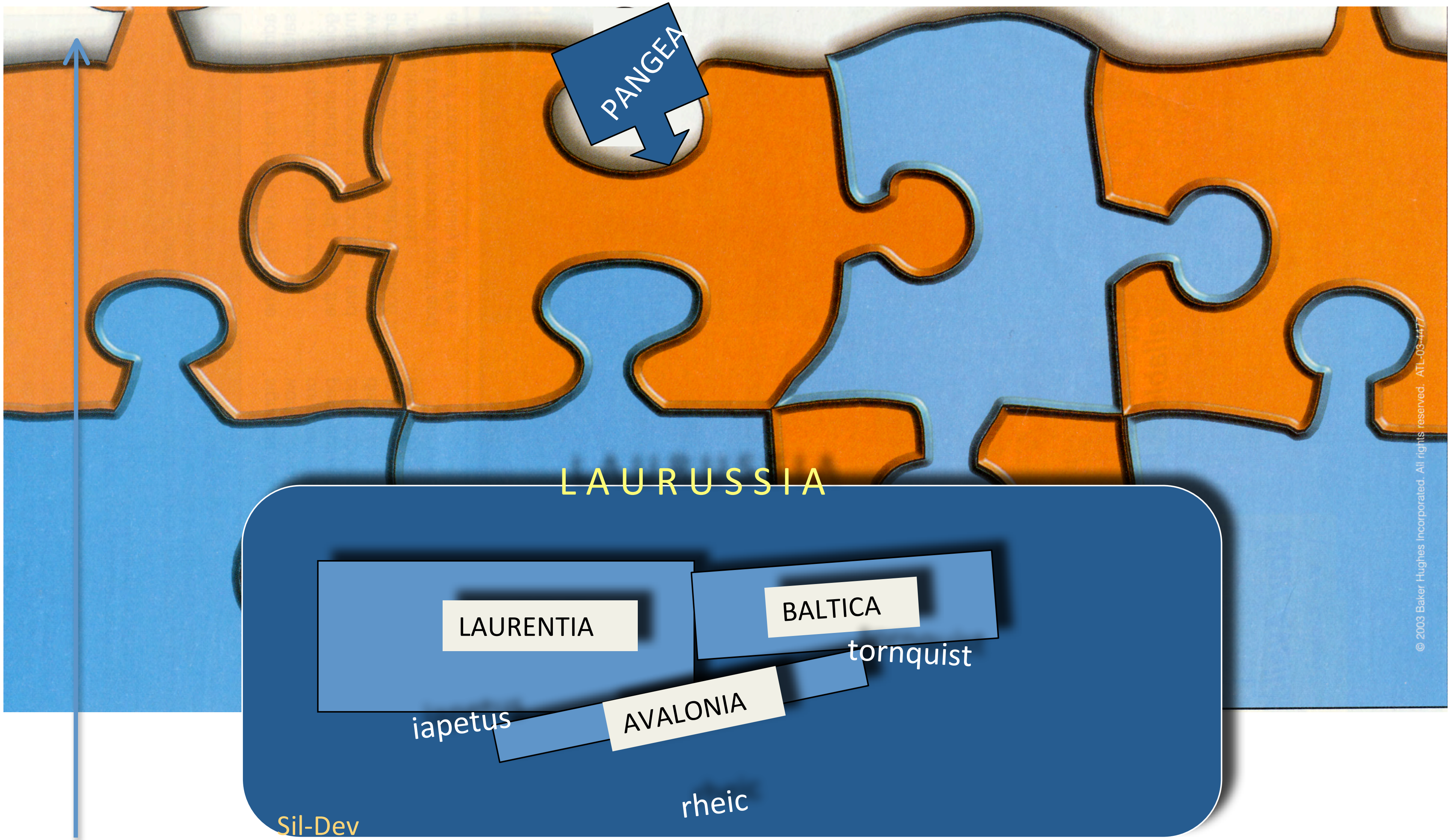
Ma	Systèmes		Amérique du Nord	Europe occidentale		Russie	Phases orogéniques
250	PERMIEN	sup = Lopingien	lacune ?	Thuringien		lacune ?	palatine
			Ochoéen			Tatarien	
			Guadalupien			Kazanien	saalienne
260		moy.		Saxonien		Ufimien	
			Léonardien			Kungurien	
						Artinskien	
		inf.				Sakmarien	
				Autunien		Assélien	
			Streptognathodus isolatus *Sphaerosschwagerina vulgaris*				
295	CARBONIFÈRE		Pennsylvanien	sup. — HOUILLER	Stéphanien	Gzhélien — SILÉSIEN	
						Kasimovien	asturienne
305					Westphalien	Moscovien	
315				moy.		Bashkirien	erzgebirgienne
					Namurien	Serpukhovien	
325			Mississippien	inf. — Dinan-tien	Viséen	Dinantien	sudète
					Tournaisien		
				Siphonodella sulcata			
360	DÉVONIEN			sup.	Famennien		bretonne
					Frasnien		
375				moyen	Givétien		
385					Eifélien		acadienne
				inf.	Emsien		
					Praguien		
					Lochkovien		
410				*Monograptus uniformis*			ardennaise

Elmi & Babin 2006,modified

FROM ONE SUPERCONTINENT TO ANOTHER ONE



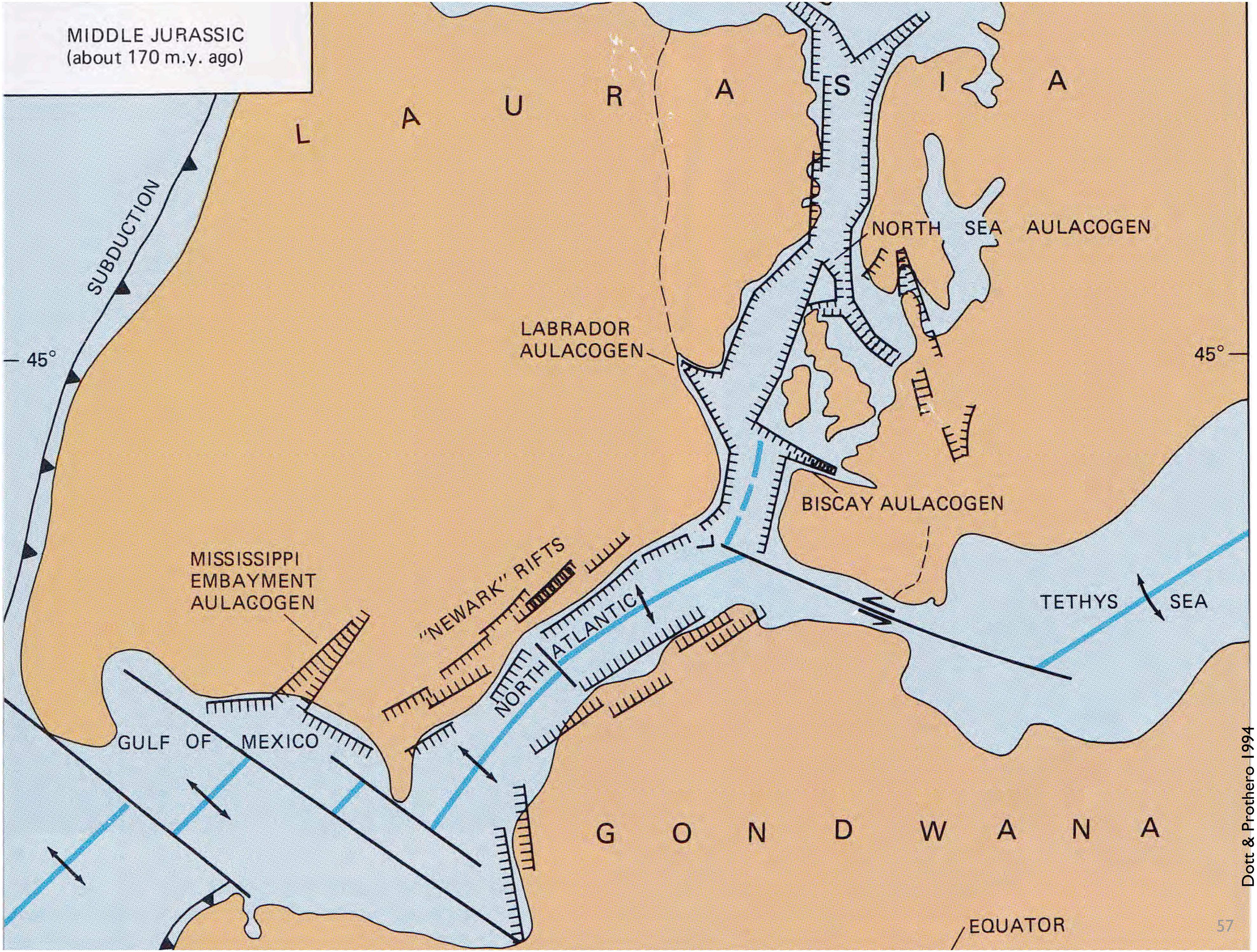




TIME

GONDWANA(LAND)-BRAZILEIRO

Iapetus: ±600/645 Ma [separation Laurentia//Baltica//Gondwana] - 320 Ma [.... Acadian]
Rheic: 500 Ma - ± 230 Ma [..... Palatine]
Opening Oc. Rheic => beginning of Iapetus subduction and Laurentia[ ]Baltica
At 460 Ma beginning of Rheic and Gondwana [ ]Laurentia[ ]Baltica



Dott & Prothero 1994

OROGENIC 'CYCLES'

$\Rightarrow$ duration between 150 and 200 myr (they are parts of higher 'cycle' or WILSON CYCLE = assemblage and fragmentation of supercontinents at a 400-500 myr time scale (= FIRST ORDER 'CYCLE')

$\Rightarrow$ **they contain compressive or tectonic phases**

Alpine chain : tectonic phases = ± 10 myr (sometimes 1-5 myr)

Andean chain : 5-10 myr

- (very) fast, particularly if compared with the sedimentation phases they contain (= Sedimentary 'Cycles' of 10's myr)
- **'diachronous' since the whole Earth can't folded in the same time**

Example of the HERCYNIAN PAROXYSMAL PHASES which are clearly diachronous (at a larger scale)

-230

3. PALATINE PHASE Pm-T, Oural
2. APPALACHAIN PHASE Pm, N America
1. ASTURIAN PHASE Mid-Carboniferous (WnC/D), Europe

-295/305

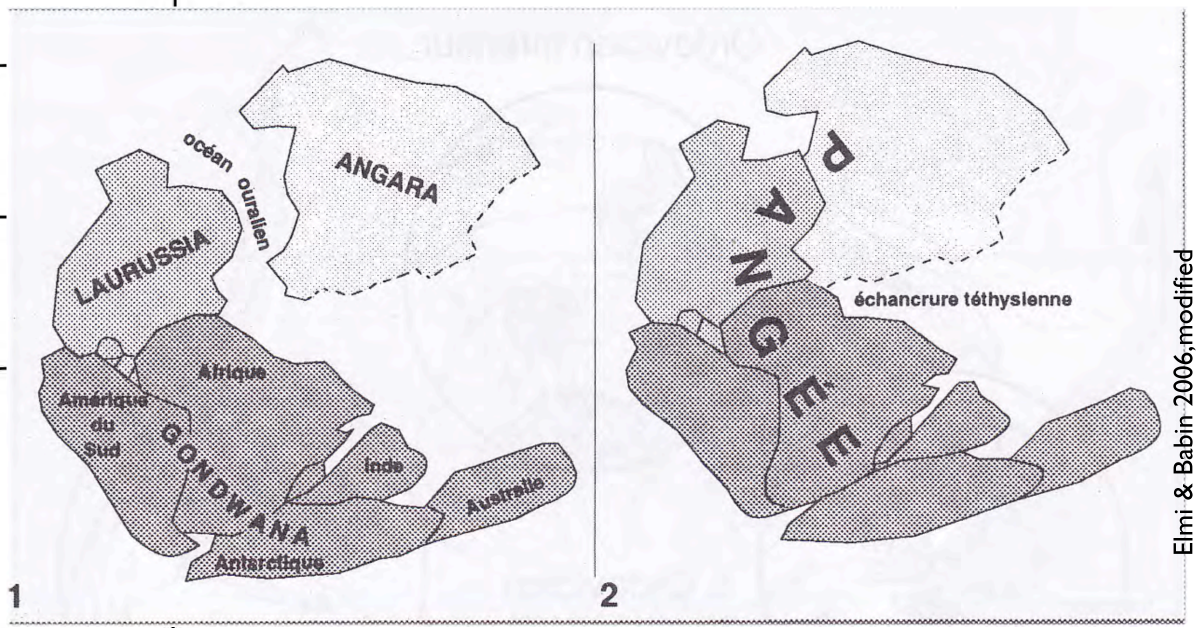
ΔT = 60-75 myr! with tectonic phases of ± 10 myr

nb could also be longer: Pyreneans, compressive phases 20 myr

nb sometimes a 'complete' orogenic cycle = 30 myr (PCm in Africa)

	Domaine ouest-européen	Oural	Appalaches
245 Ma THURINGIEN 260	phase palatine	orogenèse ouralienne	
SAXONIEN 270	phase saalienne		
AUTUNIEN 295			orogenèse alleghanienne
STÉPHANIEN 305	phase asturienne		
WESTPHALIEN 315	phase erzgebirgienne		
NAMURIEN 325	phase sudète		
DINANTIEN 360	phase bretonne		

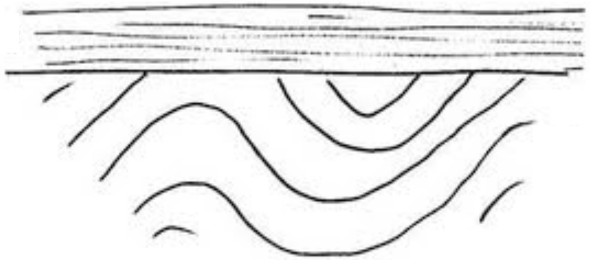
TECTONICS
there is always something
....



Elmi & Babin 2006,modified

	Appalaches	Scandinavie	Grande-Bretagne	Domaine varisque d'Europe
360 Ma DÉVONIEN INFÉRIEUR 410	orogenèse acadienne			phase ardennaise
SILURIEN 435		phase érienne	phase érienne	
ORDOVICIEN 500	phase taconique	phase d'Ekné phase de Trondjem	phase de Trondjem phase grampienne	phase ardennaise (prémisses)
CAMBRIEN 540		phase de Trysil		phase sarde
PROTÉROZOÏQUE TERMINAL				= fin de l'orogenèse panafricaine ou cadomienne

CONCLUSION : TECTONICS IS 'GLOBAL and CONTINUOUS'



one orogenic cycle

FINALLY WHAT DOES AN OROGENIC CYCLE REPRESENT ?

Orogeny involves plate tectonic forces which result in a variety of associated phenomena, including **magmatization**, **metamorphism**, **crustal melting** and **crustal thickening**. Just what happens in a specific orogen depends unpon the strenght and rheology of the continental lithosphere and how these properties change during orogenesis.
In addition to orogeny, the orogen once formed is subject to **erosion**.

The sequence of repeated cycles of sedimentation, erosion, followed by burial and metamorphism, and then by formation of granitic batholiths and tectonic uplift to form mountain chains is the **orogenic cycle**.

They are **different orogenic types** => all orogenic belts have same similarities
==> lateral compression (with rock deformation and crustal thickening), magmatic rocks from various sources (due to the subducted lithosphere…)

1. 'INTERCRATONIC' OROGENS = closure of ocean basins = 'CLASSICAL OROGEN'
   (the Alps …Himalayas … from Cretaceous to 'today')
2. 'INTRACRATONIC' OROGENS = within continental areas with no pre-existing ocean basins
   (the Rocky Mountains of western N America …L. K/E. Tertiary)
3. 'CONFINED' OROGENS = closure of small ocean basins that existed as indentations into continental blocks (that had not been completely split apart)
   (Aracuai belt, eastern Brazil 2Ga, Sao Francisco craton (eastern S America+Congo craton, western Africa 2Ga …. +? Ord-Sil Caledonide belt of N Europe and Greenland…)

FINALLY WHAT DOES AN OROGENIC CYCLE REPRESENT ?

simplified: an orogenic cycle corresponds to the opening of an oceanic domain and its future closure
=> tectonic phases constitute the major and 'global' events of the orogenic evolution

<u>Example of an oceanic domain in a convergent margin</u>

By simplifying (extremely) => successive episode evolution lasting 100-150 Ma
= ± ½ WILSON CYCLE

1. Sea prior compression = shallow sedimentation => deep sedimentation
2. Beginning of subduction: formation and uplift of mountains => very fast
   i.e. a few mm/yr [= a few m/1000 yrs] ==> Papua New Guinea 33m/1000 yrs
   measured from reefal terrace uplifts > 600m during the Pleistocene/Holocene
   (nb 33m/1000yr = 33km/Ma!...)
3. Progressive widening of the chain and protrusion of the reliefs in the nearby continents = 0.5-1cm/yr [5-30km/Ma!]
   => with sinking of plate at -30km, > 600°C and metamorphism + sediments/ rock fusion (formation of magmas => upward migration, cooling, crystallization)
   ==> thickening of the chain roots = 70 km (low density 2-2.5 < mantle 3 or more)
4. Thinning due to erosion and return to initial thickness (continental crust ± 30 km)
5. Flattening-peneplanation and return of the sea (other part of the WILSON CYCLE)

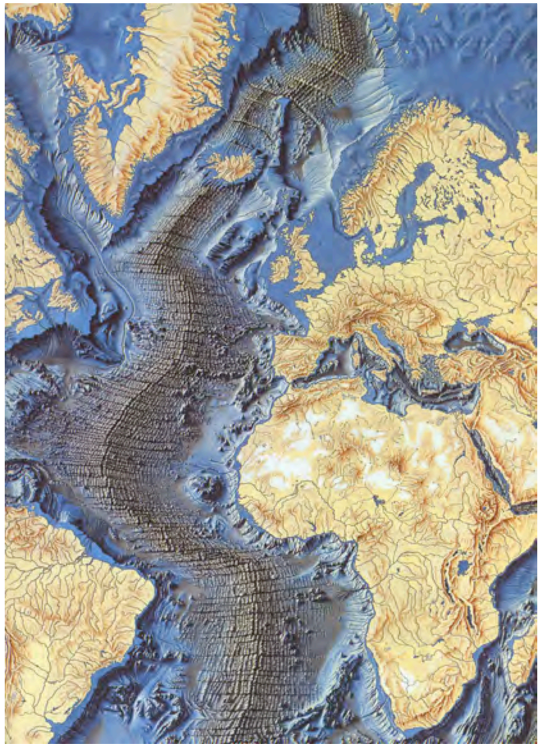
WILSON CYCLE

1. Opening phase due to sea-floor spreading
2. Period of closure by subduction-obduction of oceanic lithosphere
3. Continental collision resulting in deformation

1 ==> 5: 100-150 Ma and ANGULAR UNCONFORMITY
then
80-100Ma (heat accumulation)
+ 100-150 Ma = divergent margins

CONCLUSION: THE WILSON CYCLE IS THE MOST COMPLETE
= FIRST-ORDER CYCLE

=SECOND-ORDER CYCLE : MID-OCEANIC RIDGES 10-70Ma



Length > 75 000 km
> 75 % of Earth volcanism
> 1mm up to 20 cm/yr
  i.e.. 10-200 km/myr
> 50 % of oceanic basinal
  surface

T

K

u.K

CRETACEOUS

l.K

AGE (Ma)	PERIOD	AGE	AGE 95% confidence level	DURATION m.y.
65			[illegible]	
70	CRETACEOUS L	Maastrichtian	71.3 ±0.5	6.3
80		Campanian	83.5 ±0.5	12.2
		Santonian	85.8 ±0.5	2.3
90		Coniacian	89.0 ±0.5	3.2
		Turonian	93.5 ±0.2	4.5
100		Cenomanian	98.9 ±0.6	5.4
110	E	Albian	112.2 ±1.1	13.3
120		Aptian	121.0 ±1.4	8.8
		Barremian	127.0 ±1.6	6.0
130		Hauterivian	132.0 ±1.9	5.0
		Valanginian	136.5 ±2.2	4.5
140		Berriasian	142.0 ±2.6	5.4
			144.2 ±2.6	
150	JURASSIC L	Tithonian	150.7 ±3.0	8.8

Gradstein & Ogg 1996

?

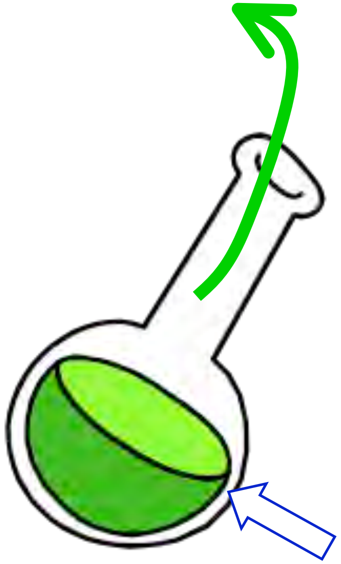
Sedimentary basin
=
Receptacle
Filling
....

SL: +250m [350m]

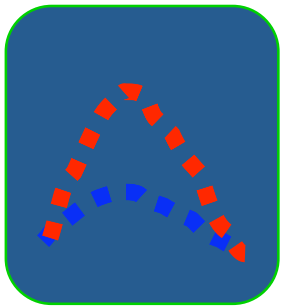
biological proliferation
= sequestration of C ==> oil

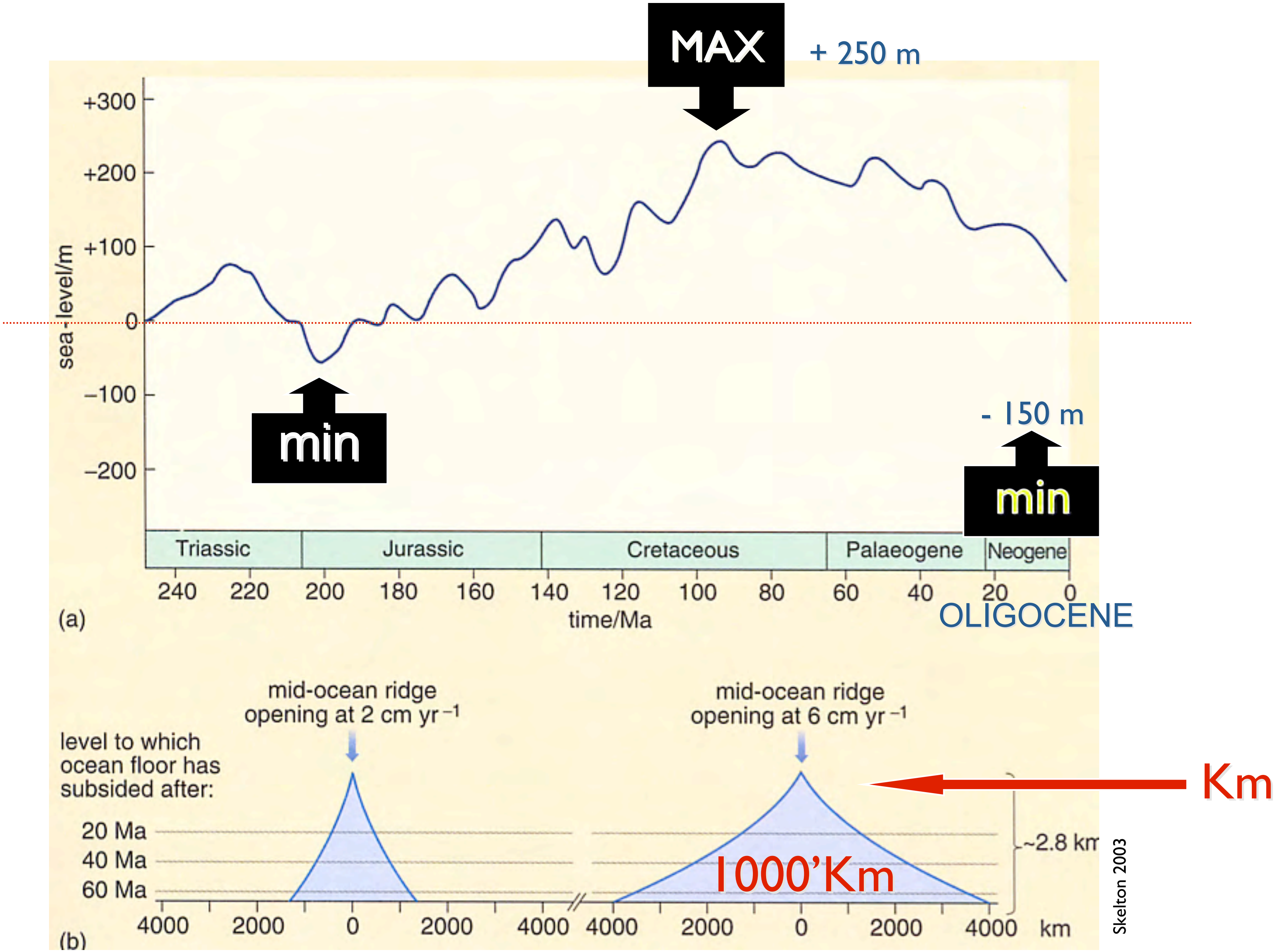
SL +200-300m

'TECTONIC'
ANOXIA



Δ volume




MAX
+ 250 m
+300
+200
+100
0
−100
−200
sea-level/m
min
- 150 m
min
Triassic
Jurassic
Cretaceous
Palaeogene
Neogene
240 220 200 180 160 140 120 100 80 60 40 20 0
time/Ma
(a)
OLIGOCENE
mid-ocean ridge
opening at 2 cm yr −1
mid-ocean ridge
opening at 6 cm yr −1
level to which
ocean floor has
subsided after:
20 Ma
40 Ma
60 Ma
Km
~2.8 km
1000'Km
4000 2000 0 2000 4000 4000 2000 0 2000 4000 km
(b)
Skelton 2003

THE WILSON CYCLE IS THE MOST COMPLETE CYCLE IN GEOLOGY
= FIRST-ORDER CYCLE

1. STAGE OF DISTENSION (= rift)
   Today : **Alsace, Limagne, Great Lakes in East Africa**…
2. STAGE OF NARROW OCEAN : **Red Sea** => sea water stratification
   ==> evaporative basins (Example of Aptian, S Atlantic, thickness 5 km)
3. STAGE OF LARGE OCEAN : **present day Atlantic** with ‘free’ oceanic circulation => oxydation of organic matter
4. STAGE OF SUBDUCTION : transition from passive to active margin
   => decoupling oceanic/continental crusts ==> oceanic trough
   = **present day Pacific**
5. STAGE OF COLLISION : the magnitude of the shortening is generally
   < than the present day widht of the chain
   Example: the Himalayas, average width is ±300 km between the Gange River and the Tibetan Plateau = shortening of 300 km
   Example: Pyreneans, width 200 km, shortening ‘only ‘ 100 km
   Example: ‘Haut Atlas’ Morocco, width 200 km, shortening 50 km
   => great differences as a consequence of highly variable crustal thickening (maximum crustal thickening is ± 70 km).

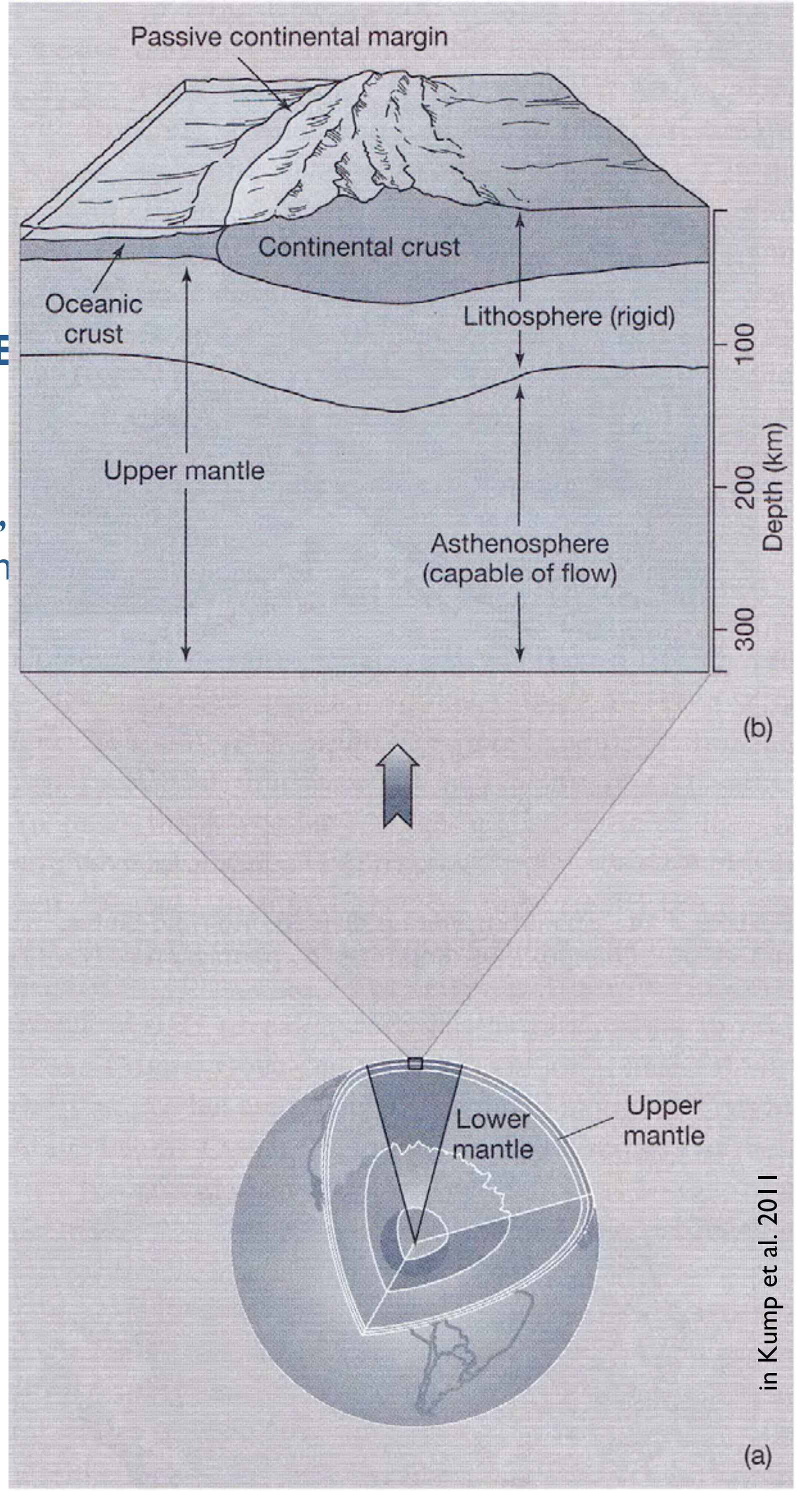
BEAR IN MIND …

Mechanism = plate tectonics (global scale geodynamic)

To explain the drift of the continent : **ASTHENOSPHERE** located below the lithosphere

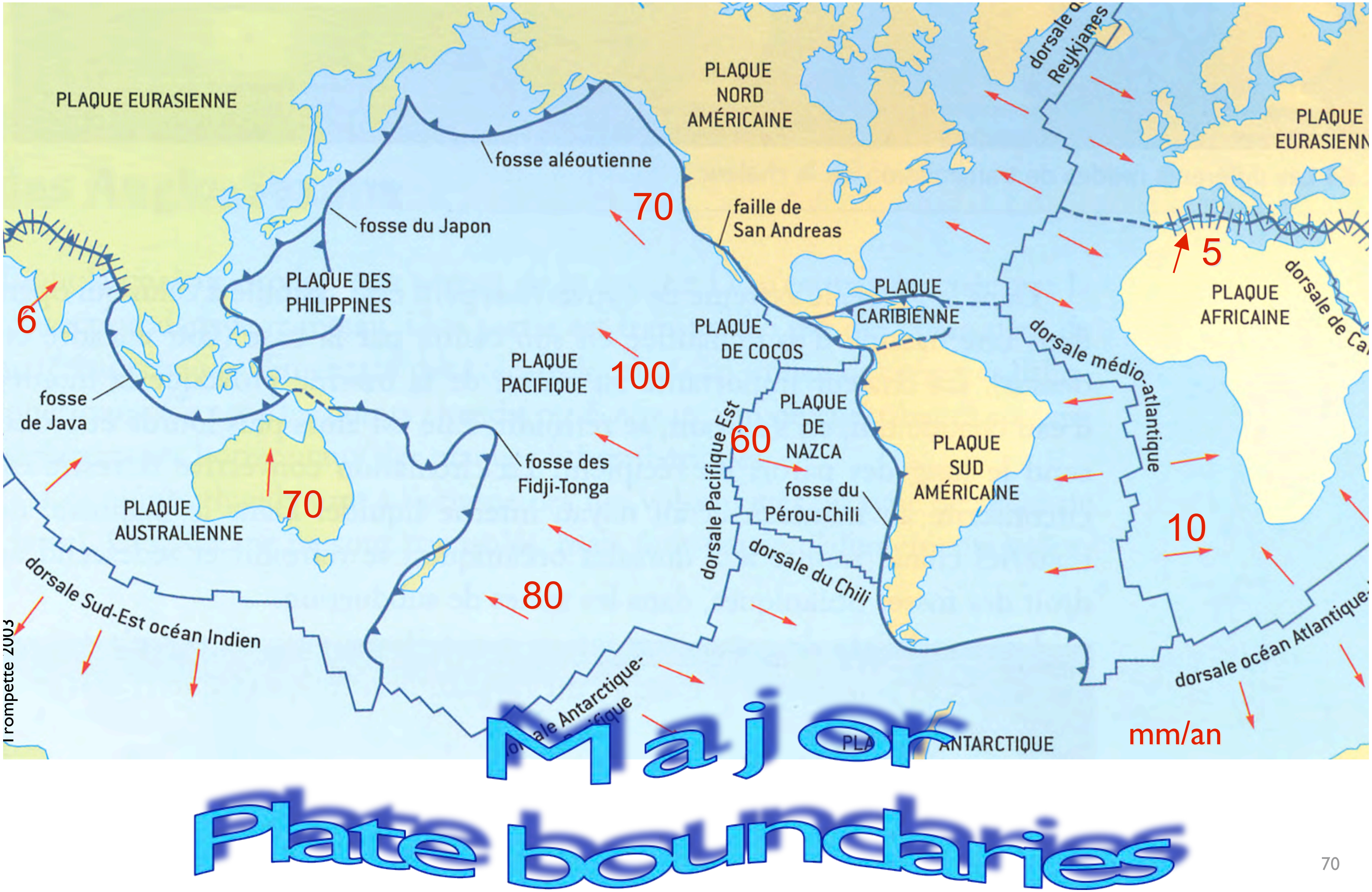
The astenosphere is **ductile** (it flows plastically, or deform easily, in response to stress) and extends through the mantle's transition zone to a depth of around 700 km.
Its thickness is generally 300 km and T° around 1100°C.

'Vertical' convection cells : ± 10cm/yr as plate movements (Hztal)



in Kump et al. 2011

± 12 (micro) tectonic plates or lithospheric plates



TODAY : BASIN ANALYSIS (+ GEODYNAMIC)

= RECEPTACLE
'CONTENANT'
Substratum, Socle

↓

GLOBAL TECTONIC
'GEOPHYSICS'

↓

2nd order

↓

1st order
Wilson Cycle

= FILLING
'CONTENU'
Sediment+Water
(Rocks)

↓

SEQUENCE STRATIGRAPHY
'SISMOSTRATIGRAPHY'

↓

3rd order

↓

4th-5th orders
p,o,e

THREE IMPORTANT OROGENIC CYCLES IN EUROPE

CALEDONIAN => STRUCTURATION OF NORTHERN EUROPE

HERCYNIAN (**VARSICAN**) => STRUCTURATION OF MID-EUROPE

ALPINE => STRUCTURATION OF SOUTHERN EUROPE

= SUCCESSIVE 'COLLAGES' => **GEOSUTURES**

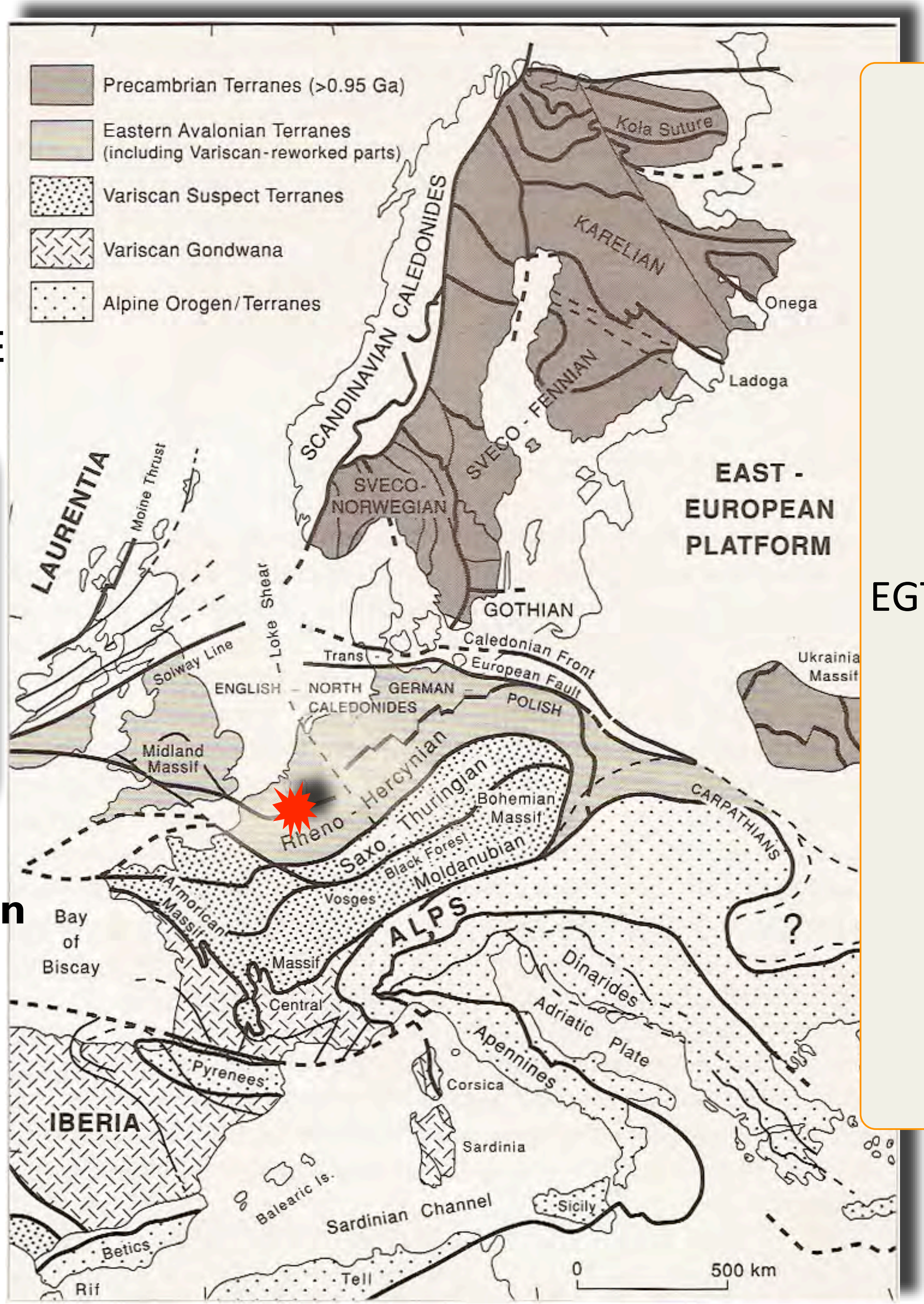
i.e. Europe's continental crust formation and **assemblage**
(it started *ca*. 3.5 Ga ago [Archean] in present Russian Karelia …)

THE EUROPEAN GEOTRAVERSE

The ‘terrane **collage**’ of Precambrian and Phanerozoic Europe (simplified sketch).

SUTURES and OROGENIC fronts = bold lines
=> younging is from S to N

Each suture = closure of a ocean
⇒± 200 Ma…
[maximum present day oceanic crust age is 180Ma L/M Jurassic Atlantic]

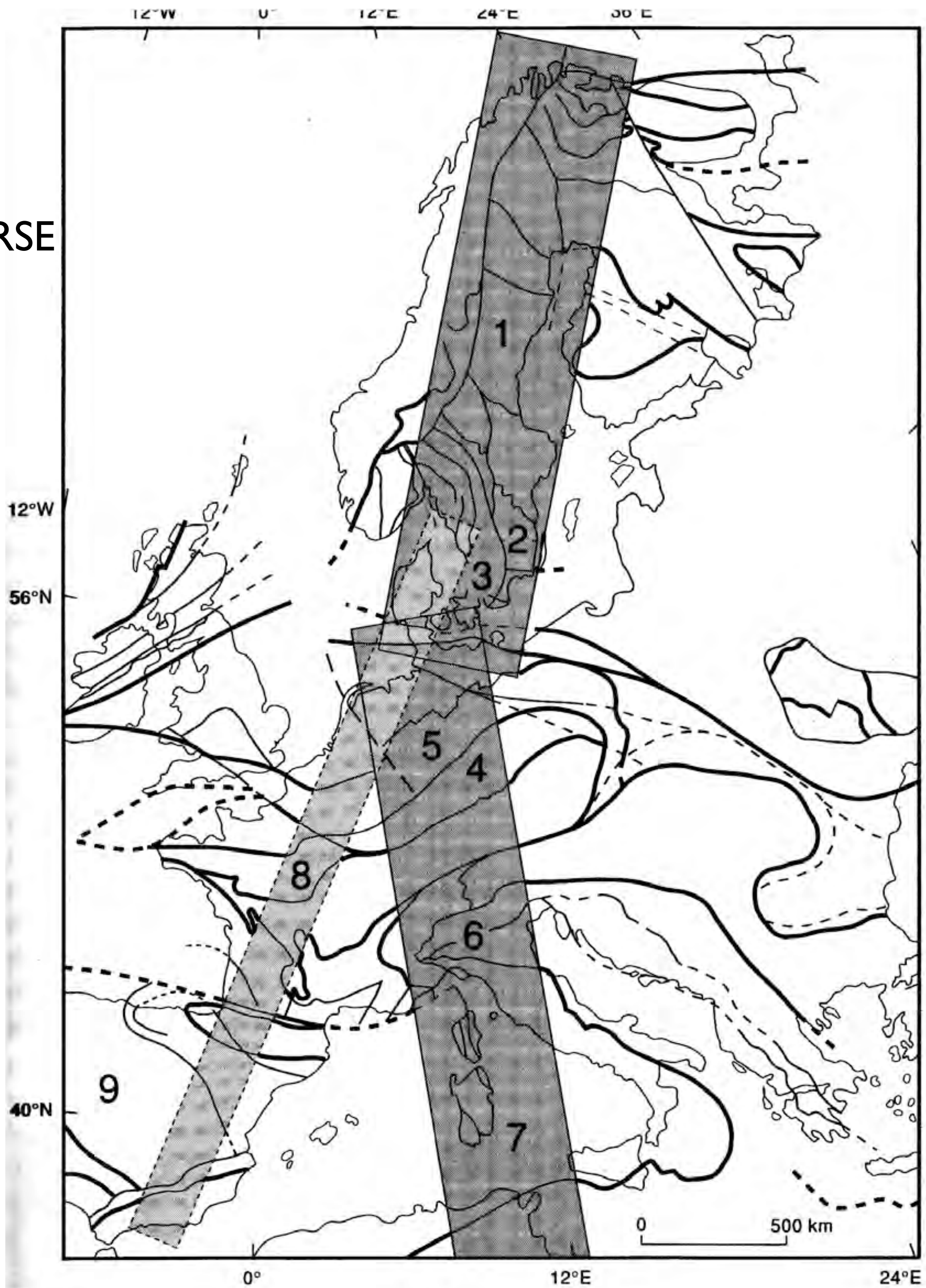


EGT

Blundell et al 1992

THE EUROPEAN GEOTRAVERSE
'experiments'- programs
1992
Heat-flow
Magnetotelluric studies
Seismic reflection
Deep seismic
Geomagnetic
Bouguer gravity
Tectonics
etc.

⇒ sections : 10'-70'km deep
up to 500 or > deep



Blundell et al 1992

Some important definitions related to the notion of FACIES = principles 1+2+3 + orogenic ‘cycles’ + ‘facies’

a. **ISOPIC** FACIES/ZONES : same facies (characteristics), same ages
b. **HETEROPIC** FACIES/ZONES : same ages, different facies (characteristics)
   = lateral variations
c. **HOMOTAXY** or **EQUIVALENT** FACIES/ZONES : different ages, same facies

Examples: Dinant basin, Paris Basin etc….
Important for mapping, for paleogeographic reconstruction…

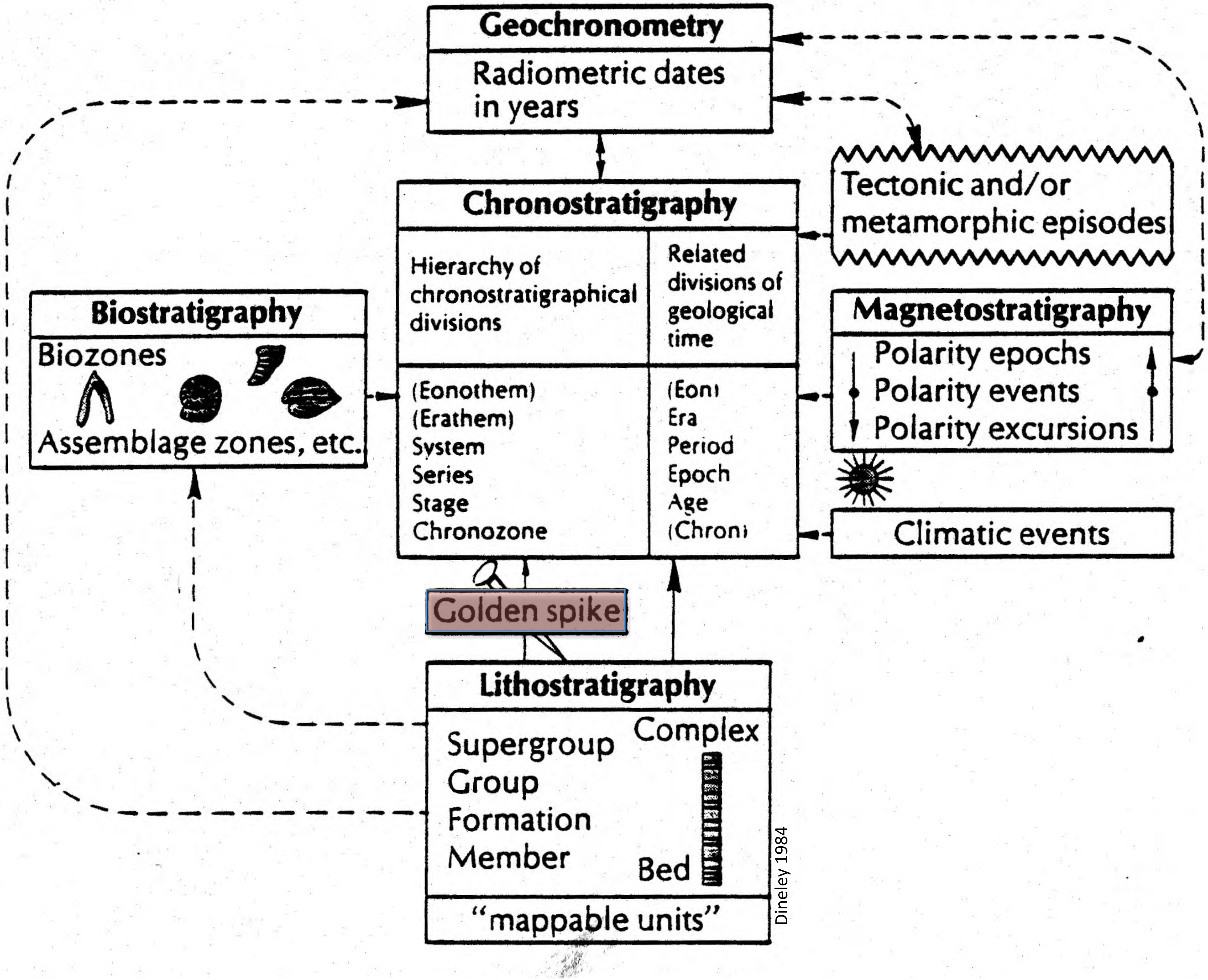
(OROGENIC) CYCLES + PALEONTOLOGY => 'GLOBAL' STRATIGRAPHICAL DIVISIONS

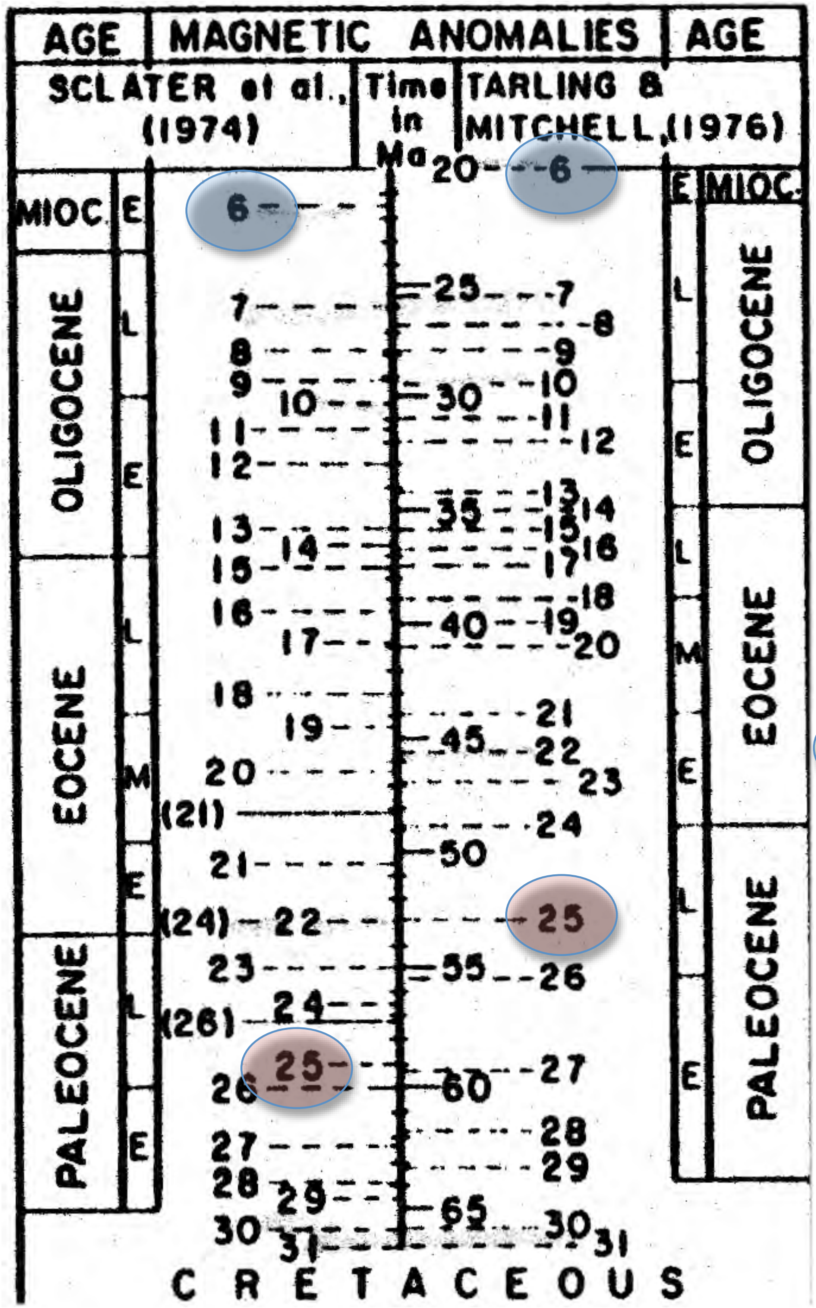
At the beginning : ± local because lithostratigraphy (= sedimentology etc.) is dependent of climate, of subsidence rate ….=**> great variations on short distances and diachronisms at different scales**

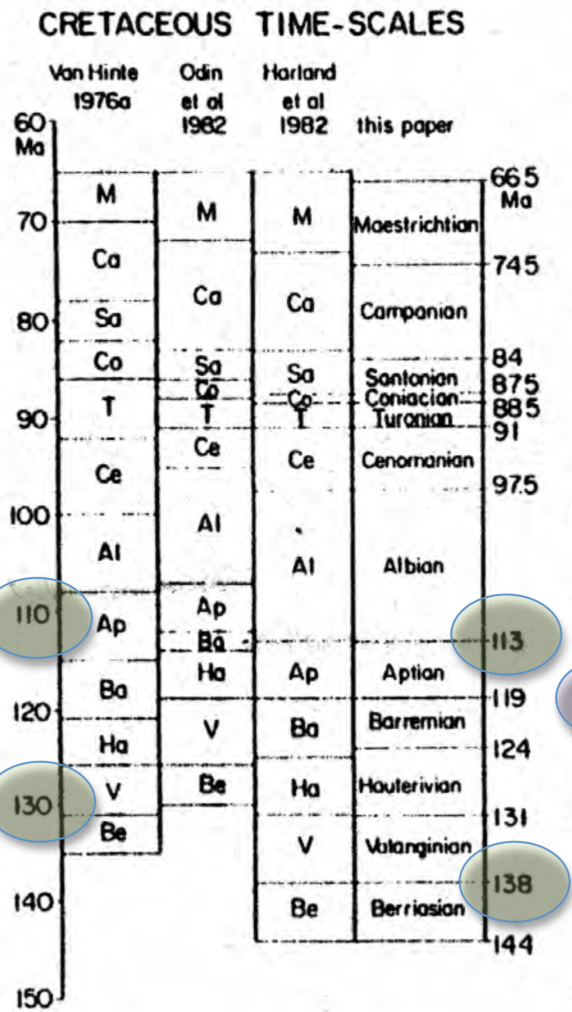
- lithostratigraphy (with lateral facies variations)
- biostratigraphy (with ecological imprint)
-
-
-
- magnetostratigraphy (mainly from the Upper Jurassic)
-
- chemostratigraphy (traces, isotopes as 'identity-card signature'
- seismic reflection (high resolution 5-12 m, only at shallow depth)
-

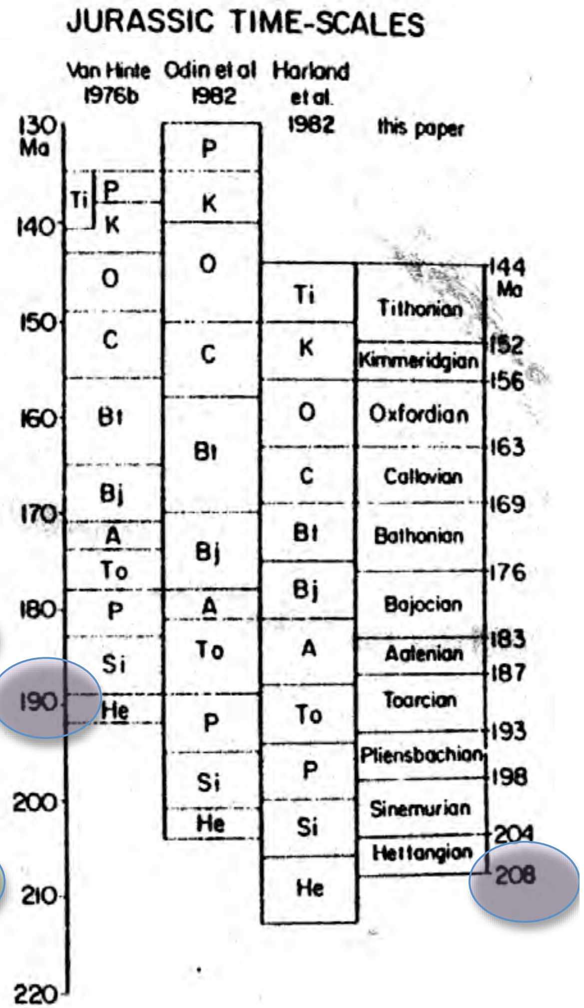
⇒ definition at a 'local' scale of UNITS and their boundaries

= S T R A T O T Y P E S


Geochronometry
Radiometric dates in years
Chronostratigraphy
Hierarchy of chronostratigraphical divisions
Related divisions of geological time
(Eonothem)
(Erathem)
System
Series
Stage
Chronozone
(Eon)
Era
Period
Epoch
Age
(Chron)
Tectonic and/or metamorphic episodes
Biostratigraphy
Biozones
Assemblage zones, etc.
Magnetostratigraphy
Polarity epochs
Polarity events
Polarity excursions
Climatic events
Golden spike
Lithostratigraphy
Supergroup
Group
Formation
Member
Complex
Bed
"mappable units"
Dineley 1984


AGE
MAGNETIC ANOMALIES
AGE
SCLATER et al., (1974)
Time in Ma
TARLING & MITCHELL (1976)
MIOC.
OLIGOCENE
EOCENE
PALEOCENE
CRETACEOUS


CRETACEOUS TIME-SCALES
Van Hinte 1976a
Odin et al 1982
Harland et al 1982
this paper
Maestrichtian
Campanian
Santonian
Coniacian
Turonian
Cenomanian
Albian
Aptian
Barremian
Hauterivian
Valanginian
Berriasian


JURASSIC TIME-SCALES
Van Hinte 1976b
Odin et al 1982
Harland et al. 1982
this paper
Tithonian
Kimmeridgian
Oxfordian
Callovian
Bathonian
Bajocian
Aalenian
Toarcian
Pliensbachian
Sinemurian
Hettangian

Need and use of **STRATOTYPES** = '**TYPE SECTIONS**'
as the material basis and standard of definition of stratigraphic units

'Ideally' a stratotype is regarded as 'typical' of a particular stratigraphic unit it defines

⇒ INTERNATIONAL STRATIGRAPHIC GUIDE or HEDBERG CODE (1976)

*p.24 a stratotype is defined as the original or **subsequently** designated type of a named stratigraphic unit or a stratigraphic boundary, identified as a specific interval or a specific point in a specific sequence of rock strata, and constituting the standard for the definition and recognition of the stratigraphic unit or boundary'*

Stratotypes are applicable to various categories of stratigraphic units, especially lithostratigraphic and chronostratigraphic units.
Certain types of stratigraphic units, for example, some biostratigraphic units , may not have stratotypes.

The GUIDE (Hedberg, 1976) distinguishes 3 basic forms of stratotypes for those units to which the concept of stratotype is applicable

1.UNIT-STRATOTYPES
2.BOUNDARY-STRATOTYPES
3.COMPOSITE-STRATOTYPES

1.a **unit-stratotype** is simply **the type section** of strata that defines the **content**, and normally also the upper and lower boundaries, of a particular unit (such a formation….) = a single very complete section with well exposed strata

2.a **boundary-stratotype** or **limitotype** is the specific point in a particular sequence of rock strata that defines a particular stratigraphic boundary (stage, system….) => it is bounded by two boundary-stratotypes marking the lower and upper boundaries of the stratigraphic unit **(**not necessarily occuring in the same stratigraphic section, or **even in the same geographic region). It also may stand alone, independent of unit-stratotype.**

3.a **composite-stratotype** is unit-stratotype formed by the combinaison of several specified type intervals of strata (for example when a stratigraphic unit is NOT exposed completely in a single stratigraphic section…)

What is IUGS?

in EPISODES, vol12/2, 1989

What is IUGS?

The International Union of Geological Sciences (IUGS) is one of the largest and most active scientific associations in the world. A voluntary professional organization, it is non-governmental, non-political and non-profit-making. It aims to

- encourage the study of geoscientific problems, particularly those of worldwide significance.
- facilitate international and interdisciplinary cooperation in geology and its related sciences;
- provide continuity to such cooperation, and
- support and provide scientific sponsorship to the quadrennial International Geological Congress (IGC).

How did it originate?

The Union was founded in March 1961, in response to a need to coordinate international geoscientific research programs on a continuing basis. Geoscientists felt that a mechanism was required to take action on global geological problems between the International Geological Congresses, traditionally held every four years.

IUGS was also to serve as a vital link in solving problems requiring interdisciplinary input from other international scientific unions operating under the aegis of the International Council of Scientific Unions. Compared to these, IUGS was a "latecomer," although some of its responsibilities had been carried out by the International Geological Congress - a venerable institution over a century old.

Since 1961, IUGS has experienced rapid growth in membership, scientific scope and expertise, as well as international prestige.

What does it do?

Who carries out IUGS' scientific work?

The Union has several standing Commissions dedicated to studying a particular geological field, methodology or problem. At present, IUGS Commissions include the

* Commission on Comparative Planetology,
* Commission on Geological Documentation,
* Commission on Geology Teaching,
* Commission on Global Sedimentary Geology,
* Commission on the History of Geological Sciences,
* Commission on Igneous and Metamorphic Petrogenesis,
* Commission on Marine Geology,
* Commission on Storage, Automatic Processing and Retrieval of Geological Data,
* International Commission on Stratigraphy,
* Commission on Systematics in Petrology,
* Commission on Tectonics,
* Commission on Fossil Fuels (to be confirmed).

Commissions vary in size, though each is composed of a suitable number of geographically representative experts. Some are subdivided into Subcommissions, Regional Committees or Working Groups according to the specific tasks charged to them. Much of the work of the Commissions is done by correspondence.

Committees, task groups or working groups carry out short-term or temporary assignments, often to determine the extent of IUGS effort required in areas not covered by Commissions or associations affiliated to IUGS. Advisory Boards provide expert advice to the Executive Committee, convene meetings, conduct reviews, and prepare reports and recommendations, generally on an annual basis.

The Advisory Board for Research Development is a group of widely recognized scientific experts and successful managers of major scientific programs in industry, and in ship, scientific scope and expertise, as well as international prestige.

What does it do?

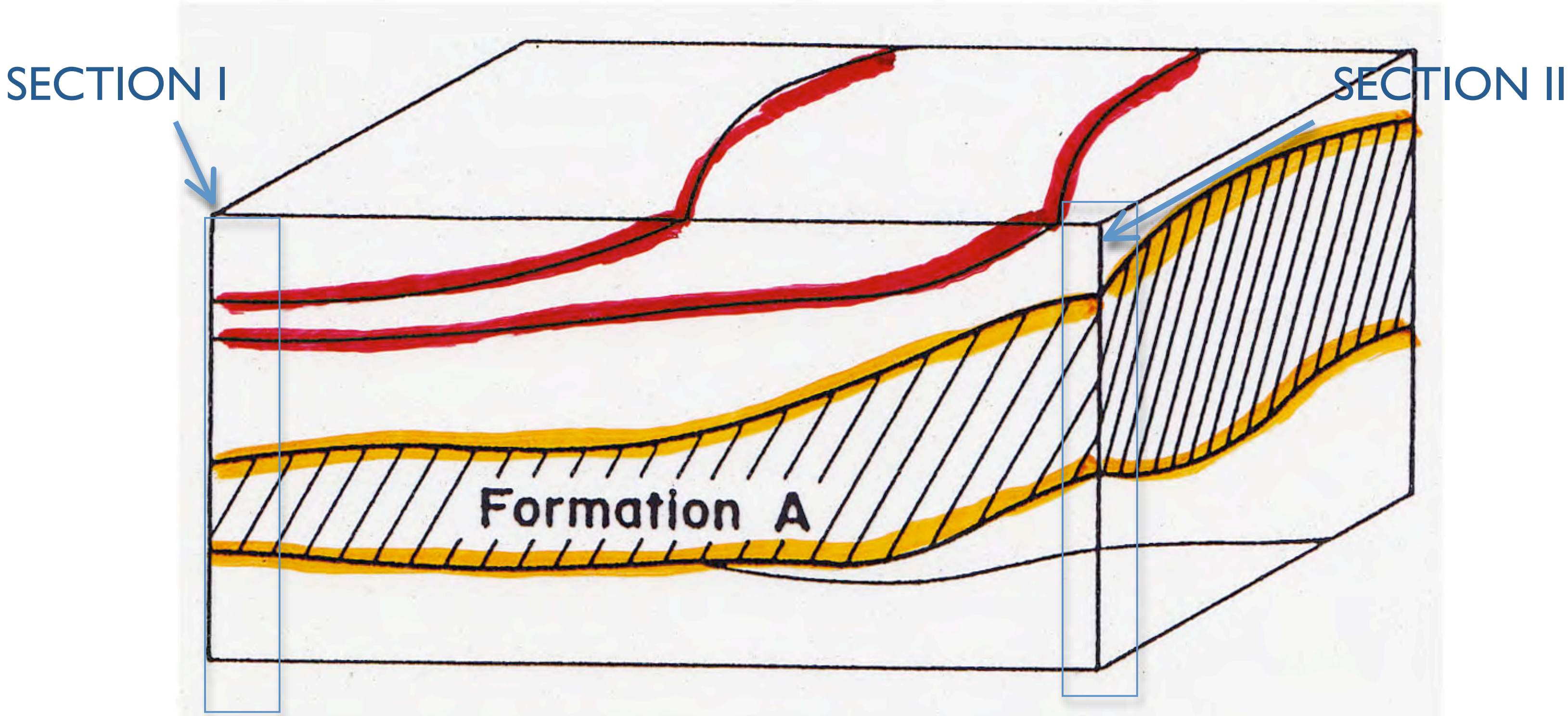
IUGS fosters communication among the various specialists in earth sciences around the world. It achieves this by organizing international projects and meetings, sponsoring symposia and scientific field trips, and producing publications.

Topics addressed range from fundamental research to its economic and industrial applications, from scientific, environmental and social issues to educational and developmental problems. For example, IUGS is currently involved in

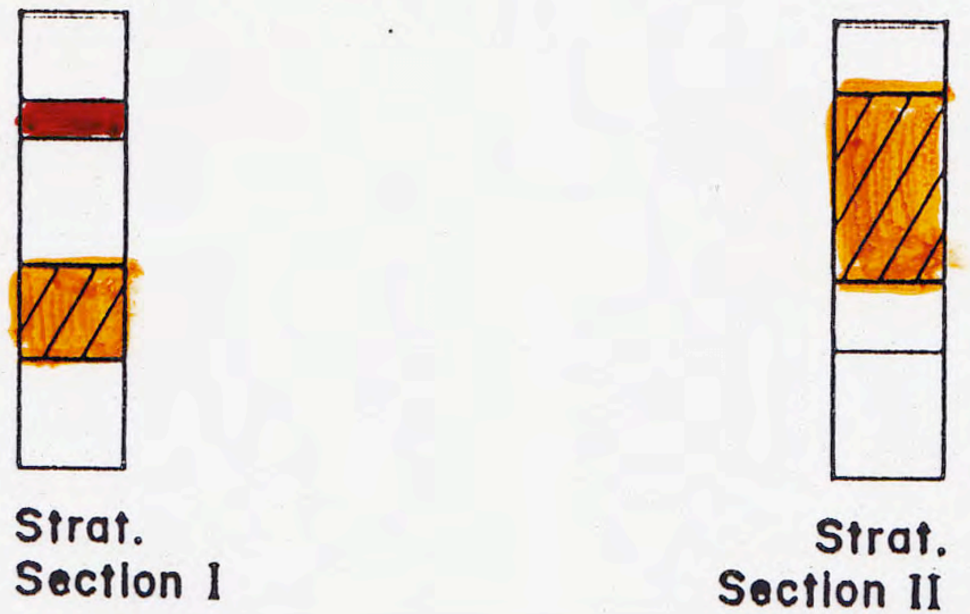
* working toward international agreement on nomenclature and classification of stratigraphical units,
* storing, retrieving and processing geological information,
* supporting efforts to harmonize human societies with their environment,
* establishing systematic nomenclature in petrology,
* applying results in remote sensing to geology,
* studying planetary geology and its relevance to the understanding of earth history,
* assessing the geology of the ocean basins and their economic potential,
* elucidating the nature, dynamics, origin and evolution of the Earth's deep crust,
* studying mineral deposits to aid future exploration efforts.

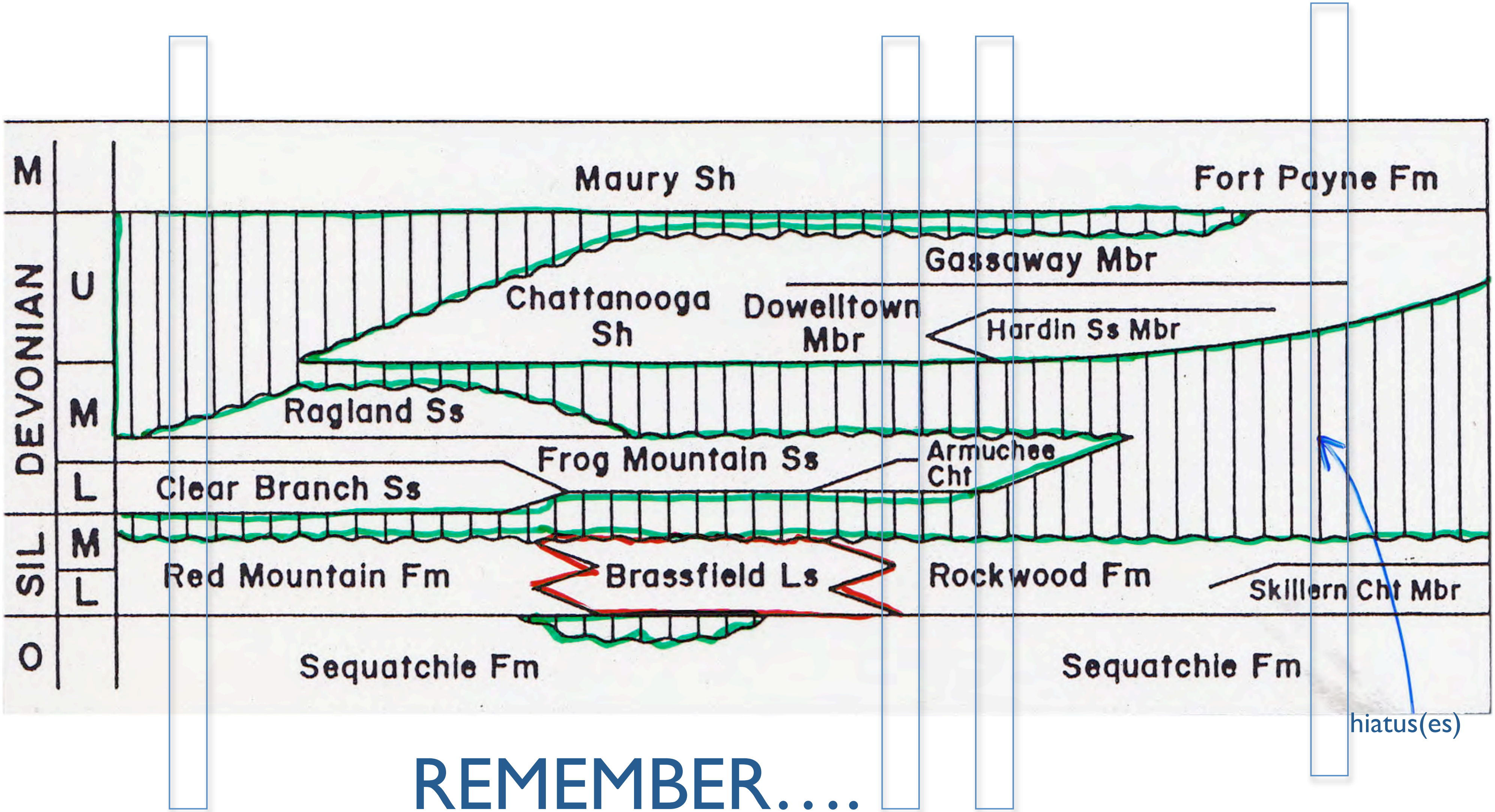
The Advisory Board for Research Development is a group of widely recognized scientific experts and successful managers of major scientific programs in industry, and in

Figure 1. Geologists examine a granite outcrop in northern Brazil.


SECTION I
SECTION II
Formation A

REMEMBER….


Strat.
Section I
Strat.
Section II


M
DEVONIAN
U
M
L
SIL
M
L
O
Maury Sh
Fort Payne Fm
Gassaway Mbr
Chattanooga
Sh
Dowelltown
Mbr
Hardin Ss Mbr
Ragland Ss
Frog Mountain Ss
Armuchee
Cht
Clear Branch Ss
Red Mountain Fm
Brassfield Ls
Rockwood Fm
Skillern Cht Mbr
Sequatchie Fm
Sequatchie Fm
hiatus(es)

REMEMBER….

PELAGIC SERIES
= 'basin'

'PLATFORM' SERIES
= 'shallow'

stratigraphic fossils s.s.
sedimentation rate mm/1000-10000yr

facies fossils
sedimentation rate dm-m-Dm/1000yr

STRATOTYPES and PARASTRATOTYPES
and/or LIMITOTYPES

Edited by Michael A. Murphy[1] and Amos Salvador[2]

International Subcommission on Stratigraphic Classification of IUGS International Commission on Stratigraphy

International Stratigraphic Guide — An abridged version

1 Geology Department, University of California, Davis, California 95616, USA.
2 Department of Geological Sciences, University of Texas at Austin, Austin, Texas 78712, USA; e-mail: amos.salvador@mail.utexas.edu

Effective communication in science requires accurate and precise internationally acceptable terminology and procedures. The Abridged Version of the International Stratigraphic Guide, like the Guide itself, was developed to promote international agreement on principles of stratigraphic classification and to develop an internationally acceptable stratigraphic terminology and rules of procedure in the interest of improved accuracy and precision in international communication, coordination, and understanding. It is not a revision of the Guide but a short version that omits history, explanatory text, and exemplification, the glossaries and the bibliography.

Preface

The second edition of the *International Stratigraphic Guide*, edited by Amos Salvador, was prepared by the International Subcommission on Stratigraphic Classification of the International Commission on Stratigraphy and co-published in 1994 by the International Union of Geological Sciences and the Geological Society of America. Like the first edition, edited by Hollis D. Hedberg and published in 1976, the second edition of the *Guide* has been widely accepted and used by stratigraphers throughout the world. Copies can be obtained from the Geological Society of America, Publication Sales, P.O. Box 9140, Boulder, CO 80301, Fax 303-447-1133.

Despite the wide acceptance and distribution of the second edition of the *Guide*, stratigraphers and students of stratigraphy around the world have commented on difficulty in gaining access to the *Guide* mainly because of remote availability of copies and of cost. The present abridged version of the second edition of the *Guide* is an attempt to overcome these problems.

This abridged version is not a revision of the substance of the *Guide*; all essential tenets of the full second edition concerning stratigraphic classification, terminology, and procedure have been retained. Moreover, the abridged version has maintained the same organizational framework to the level of chapters, headings, and subheadings, so that the user can readily refer to the full version of the *Guide* for supplementary detail; and where non-essential discussions of certain sections have been eliminated, headings have still been retained so that the user can easily find the corresponding section in the full version of the *Guide*. The principal victims of the abridgement have been some explanatory text, examples of stratigraphic procedures, the Glossary of Stratigraphic Terms, the List of National or Regional Stratigraphic Codes, and the extensive Bibliography of Stratigraphic Classification, Terminology and Procedure.

The editors express their appreciation to the editor of *Episodes* for helping to meet the aims of this abridged version of the *International Stratigraphic Guide* by publishing it in his journal, and for agreeing to prepare and market covered reprints of this document at cost. These actions ensure that the basic tenets of stratigraphic classification, terminology, and procedure can now reach stratigraphers and students of stratigraphy everywhere in the world.

As the notice accompanying this issue of *Episodes* states, individual covered reprints of the abridged version of the second edition of the *Guide* can be obtained from *Episodes*, P.O. Box 823, 26 Baiwanzhuang Road, 100037 Beijing, People's Republic of China, for a few dollars plus postage charges.

Chapter 1 Introduction

A. Origin and Purposes of the *Guide*

The purposes and spirit of this short version are the same as those of the second edition of the Guide: to promote international agreement on principles of stratigraphic classification and to develop an internationally acceptable stratigraphic terminology and rules of stratigraphic procedure—all in the interest of improved accuracy and precision in international communication, coordination, and understanding.

B. Composition of Subcommission

The membership of the Subcommission represents a worldwide geographic spread of stratigraphers and stratigraphic organizations and a wide spectrum of stratigraphic interests, traditions and philosophies. Over the years, the number of members has ranged from 75 to 130 representing 30 to 45 countries.

C. Preparation and Revision of the *Guide*

D. Spirit of the *Guide*

Like the second edition of the *International Stratigraphic Guide*, this abridged version is offered as a recommended approach to stratigraphic classification, terminology, and procedure, not as a "code".

E. National and Regional Stratigraphic Codes

The ISSC has always supported the development of national and regional stratigraphic codes; these codes have helped in the past

SHORT HISTORICAL SUMMARY

First International Geological Congress : 1878 (Paris)

The First International Geological Congress (1878)

Abstract

The International Geolological Congresses have, for the past 120 years, provided the geological community with an opportunity to create an organizational framework for meeting at regular intervals in a spirit of fraternal cooperation that transcends oceans, languages and wars. This article retraces the history of the first International Geological Congress and also offers some candid and critical reflections on its scientific accomplishments.

Introduction

The need for an International Geological Congress had been recognized for some time before it took place in 1878. As early as 1874, Giovanni Capellini of Bologna had attempted to convene in Italy an international congress aimed at standardizing geological terminology and map colour schemes. In 1867 and again in 1876, Jean Vilanova of Madrid had approached the Geological Society of France with the proposal that an international congress be organized to standardize geological nomenclature.

The decisive push, however, came from America. On August 25, 1876, following the International Exhibition held in Philadelphia the ceremonies commemorating the Independence Centennial, the American Association for the Advancement of Science unanimously adopted the resolution:

- That a Committee of the Association be appointed by the Chair to consider the propriety of holding an International Congress of Geologists at Paris, during the International Exhibition in 1878, for the purpose of getting together comparative collections, maps and sections, and for the settling of obscure points relating to geological classification and nomenclature" (Am. J. Sci., 1876, v.XII, p. 463).

Scientific Program 1878

The program of the Congress listed the following issues as topics for debate:

1. Standardization of geologic maps and reports with regard to nomenclature and symbols

2. Discussion of the boundaries and characteristics of certain rock systems;

3. Representation and coordination of linear features (faults and veins);

4. Respective importance of fauna and flora in the delineation of rock systems; and

5. Importance of the mineralogy and texture of rocks in terms of their origin and age.

Boundaries and Characteristitics of Rock Systems

The second theme concerned the boundaries and characteristics of some rock systems. The problems in question related mainly to the Lower Palacozoic and to the Permo-Carboniferous. It is a bit surprising to learn that in 1878 the necessity of a Cambrian system was fiercely debated by the eminent geologists at the Paris Congress.

http://www.google.be/search?q=First+International+Geological+Congress+&ie=utf-8&oe=utf-8&aq=t&rls=org.mozilla:fr:official&client=firefox-a

…1952 First International Meeting for Correlation Problems
= 19th International Geological Congress at Alger

⇒ creation of the ICST International Commission on Stratigraphy Terminology
which is now named **ISSC** International Subclommission on Stratigraphy Classification
under the control of **IUGS** (or EPISODES)
==> following the Congress of Alger: > 40 countries have established a first valuable
codification of these problems ===> edited by HEDBERG (1976) in the ISSC frame

…1976
INTERNATIONAL STRATIGRAPHIC GUIDE – HEDBERG 1976
OBJECTIVE = TOWARDS A COMMON LANGUAGE…
‘ agreement on stratigraphic principles, terminology, and classification procedures is ***essential*** *to attaining a* ***common language*** *of stratigraphy that will serve geologists* ***worldwide****. It will allow their efforts to be concentrated effectively on the many real scientific problems of stratigraphy, rather than being* ***wastefully*** *dissipated and fruitless controversy arising because* ***of discrepant basic principles, divergent usage of terms****, and other unecessary impediments to mutual understanding’*

….

…

…TODAY: general agreement except for the PRECAMBRIAN and the QUATERNARY
Next step: integration of new and valuable data from the magnetic inversions

...1983 NASC = North American Stratigraphic Code

by the North American Commission on Stratigraphic Nomenclature

FOREWORD

This code of recommended procedures for classifying and naming stratigraphic and related units has been prepared during a four-year period, by and for North American earth scientists, under the auspices of the North American Commission on Stratigraphic Nomenclature. It represents the thought and work of scores of persons, and thousands of hours of writing and editing. Opportunities to participate in and review the work have been provided throughout its development, as cited in the Preamble, to a degree unprecedented during preparation of earlier codes.

Publication of the International Stratigraphic Guide in 1976 made evident some insufficiencies of the American Stratigraphic Codes of 1961 and 1970. The Commission considered whether to discard our codes, patch them over, or rewrite them fully, and chose the last. We believe it desirable to sponsor a code of stratigraphic practice for use in North America, for we can adapt to new methods and points of view more rapidly than a worldwide body. A timely example was the recognized need to develop modes of establishing formal nonstratiform (igneous and high-grade metamorphic) rock units, an objective which is met in this Code, but not yet in the Guide.

The ways in which this Code differs from earlier American codes are evident from the Contents. Some categories have disappeared and others are new, but this Code has evolved from earlier codes and from the International Stratigraphic Guide. Some new units have not yet stood the test of long practice, and conceivably may not, but they are introduced toward meeting recognized and defined needs of the profession. Take this Code, use it, but do not condemn it because it contains something new or not of direct interest to you. Innovations that prove unacceptable to the profession will expire without damage to other concepts and procedures, just as did the geologic-climate units of the 1961 Code.

This Code is necessarily somewhat innovative because of: (1) the decision to write a new code, rather than to revise the old; (2) the open invitation to members of the geologic profession to offer suggestions and ideas, both in writing and orally; and (3) the progress in the earth sciences since completion of previous codes. This report strives to incorporate the strength and acceptance of established practice, with suggestions for meeting future needs perceived by our colleagues; its authors have attempted to bring together the good from the past, the lessons of the Guide, and carefully reasoned provisions for the immediate future.

Participants in preparation of this Code are listed in Appendix I, but many others helped with their suggestions and comments. Major contributions were made by the members, and especially the chairmen, of the named subcommittees and advisory groups under the guidance of the Code Committee, chaired by Steven S. Oriel, who also served as principal, but not sole, editor. Amidst the noteworthy contributions by many, those of James D. Aitken have been outstanding. The work was performed for and supported by the Commission, chaired by Malcolm P. Weiss from 1978 to 1982.

This Code is the product of a truly North American effort. Many former and current commissioners representing not only the ten organizational members of the North American Commission on Stratigraphic Nomenclature (Appendix II), but other institutions as well, generated the product. Endorsement by constituent organizations is anticipated, and scientific communication will be fostered if Canadian, United States, and Mexican scientists, editors, and administrators consult Code recommendations for guidance in scientific reports. The Commission will appreciate reports of formal adoption or endorsement of the Code, and asks that they be transmitted to the Chairman of the Commission (c/o American Association of Petroleum Geologists, Box 979, Tulsa, Oklahoma 74101, U.S.A.).

Any code necessarily represents but a stage in the evolution of scientific communication. Suggestions for future changes of, or additions to, the North American Stratigraphic Code are welcome. Suggested and adopted modifications will be announced to the profession, as in the past, by serial Notes and Reports published in the *Bulletin* of the American Association of Petroleum Geologists. Suggestions may be made to representatives of your association or agency who are current commissioners, or directly to the Commission itself. The Commission meets annually, during the national meetings of the Geological Society of America.

1982 NORTH AMERICAN COMMISSION
ON STRATIGRAPHIC NOMENCLATURE

[1]Manuscript received, December 20, 1982; accepted, January 21, 1983.
Copies are available at $1.00 per copy postpaid. Order from American Association of Petroleum Geologists, Box 979, Tulsa, Oklahoma 74101.

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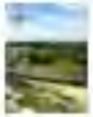
 March	 March	 March	 March	 March	 March	 March	 March	 March	 March
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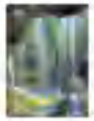
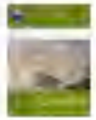
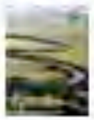
 September	 September	 September	 September	 September	 September	 September	 September	 September	 September
 December	 December	 December	 December	 December	 December	 December	 December	 December	 December

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by Isabella Premoli Silva and D Graham Jenkins

Decision on the Eocene–Oligocene boundary stratotype

Episodes 1993, vol 16/3

The Global Stratotype Section and Point for the Eocene–Oligocene boundary has been agreed upon. The new boundary is defined in the Massignano section near Ancona, Italy

Introduction

The first coordinated, worldwide study of the Eocene–Oligocene boundary was undertaken by the International Geological Correlation Programme's (IGCP) Project 174 (1980–1985), led by Charles Pomerol and Isabella Premoli Silva. At the final meeting of IGCP Project 174 in Paris in 1985, the project's participants decided to publish a volume of the papers presented at the meeting (Pomerol and Premoli Silva, 1986). Following this initial work, the Subcommission on Paleogene Stratigraphy continued the search for a suitable boundary stratotype. This involved (1) a worldwide postal survey followed by (2) the establishment of the international Working Group on the Eocene–Oligocene Boundary and (3) close collaboration with both IGCP Project 196 (Calibration of the Phanerozoic Time Scale) and the Subcommission on Geochronology (G S Odin, Chairman, France).

An international meeting of the Subcommission on Paleogene Stratigraphy was held in Ancona, Italy, in 1987 to consider the Eocene–Oligocene boundary. The meeting was attended by 38 participants, and 18 papers were published in a special volume known as the Ancona Volume (Premoli Silva and others, 1988). The participants concluded that the Massignano section, about 10 km southeast of Ancona, was the best available stratotype for the Eocene–Oligocene boundary. Subsequently, the Eocene–Oligocene working group, having been provided with the necessary details of the Bath section in Barbados and the Massignano section in Italy, concluded that the Massignano section was the best choice for the Eocene–Oligocene boundary stratotype and Global Stratotype Section and Point (GSSP). Ten of the members were in favour, one was undecided, and one did not reply.

Prior to the International Geological Congress in Washington DC in 1989, the 20 voting members of the Subcommission on Paleogene Stratigraphy were provided with copies of the Ancona Vol-

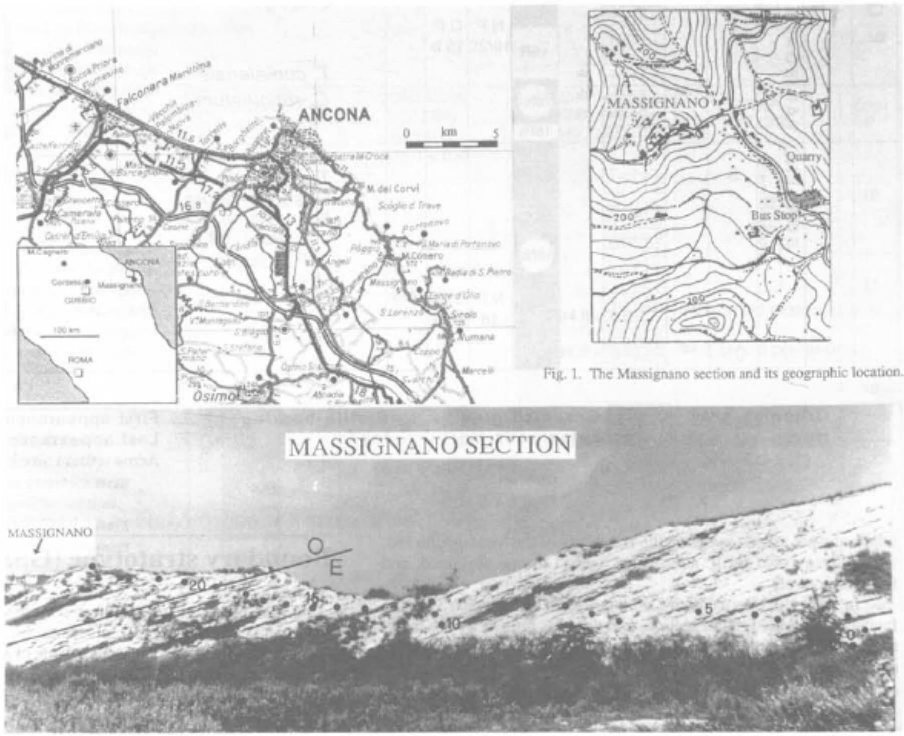

Fig. 1. The Massignano section and its geographic location.

Figure 1.—The Massignano section, located in a quarry about 10 km southeast of Ancona, Italy, at latitude 43°32'13" N and longitude 13°35'36" E. The numbers in the photograph of the section are distances in metres above the base of the measured section. The Eocene–Oligocene boundary GSSP is at 19 m. Contours on the map are in metres.

Abbreviations

E *Eocene*

O *Oligocene.*

Taken from Coccioni and others (1988).

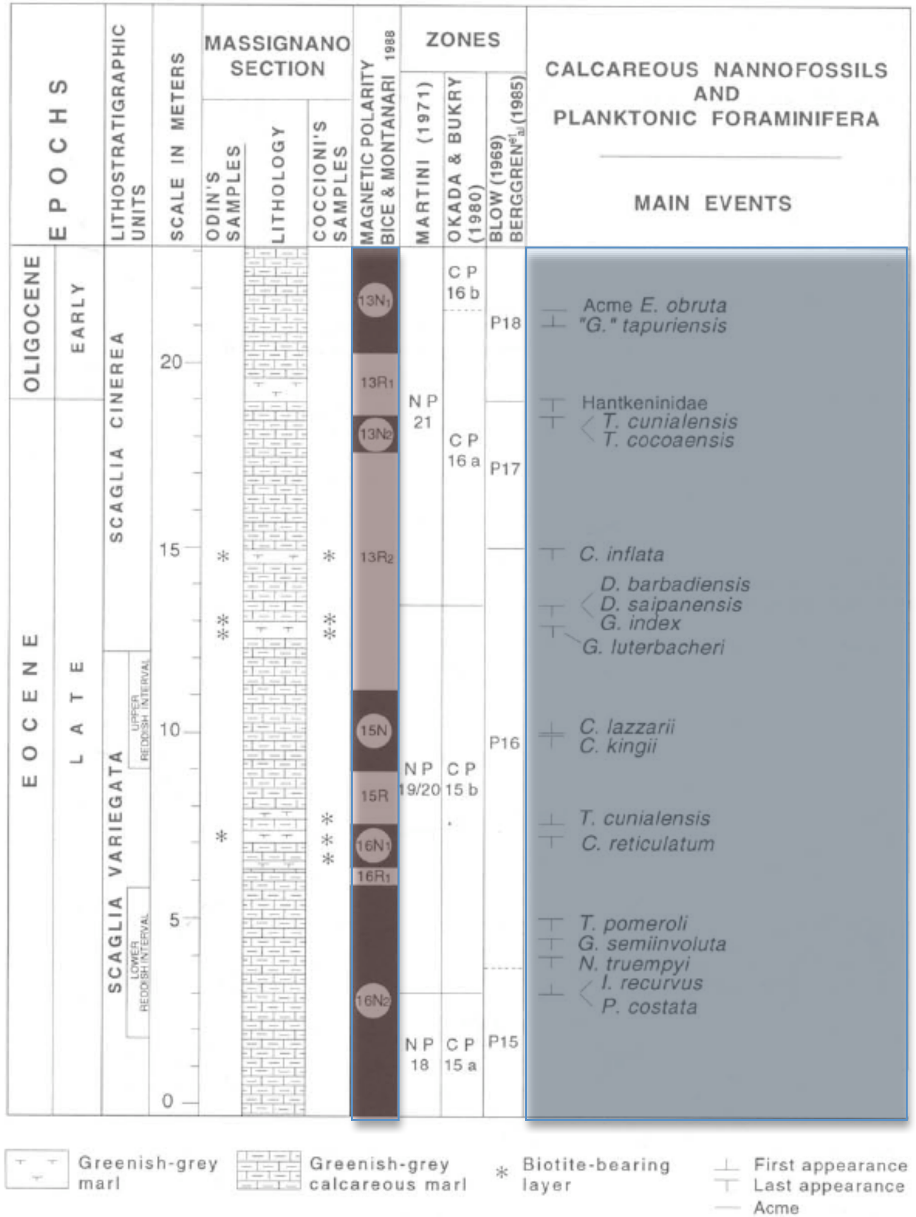

Figure 2.—Calcareous nannofossil and planktonic foraminiferal events in the Massignano section plotted against chrono-, litho-, magneto- and biostratigraphy.

Abbreviations

N_1, N_2 *normal*

R, R_1, R_2 *reverse*

N P *nannofossil zone*

C P *calcareous nannofossil zone*

P *planktonic foraminiferal zone*

Modified from Coccioni and others (1988).

ume and were asked to vote on the suitability of the Massignano section. Fifteen voted for it, none voted against it, one abstained, and four did not vote.

In 1992, the International Commission on Stratigraphy voted in favour of the Massignano section, and this was ratified by the International Union of Geological Sciences at the International Geological Congress in Kyoto in 1992.

Boundary stratotype (GSSP)

The Massignano section is located on the Adriatic coast of Italy in the Monte Conero area. It is an abandoned quarry on the east side of the Ancona–Sirolo road near the village of Massignano (figure 1). On the geological map of Italy (F.118, Ancona), the section is located at latitude 43°32′13″N and longitude 13°35′36″E. The quarry face is up to 4 metres high and does not constitute any serious hazard to vis-

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Decision on the Lochkovian – Pragian Boundary Stratotype (Lower Devonian)

by Ivo Chlupáč and William A. Oliver, Jr.

The Global Stratotype Section and Point (GSSP) for the Lochkovian-Pragian Stage (middle Lower Devonian) has now been agreed upon. The boundary is defined at the first occurrence of the zone conodont Eognathodus sulcatus sulcatus at the base of bed 12 in the Velká Chuchle Quarry, in the northwest part of Prague, Czechoslovakia.

Introduction

The Lower Devonian stages, from oldest to youngest, are Lochkovian, Pragian, and Emsian. The base of the Lochkovian coincides with the base of the Lower Devonian Series and of the Devonian System and has been formally defined as the Silurian-Devonian boundary (Martinsson, ed., 1977). The boundary between the Lochkovian and the Pragian is the subject of this paper. That between the Pragian and Emsian is undefined and is the subject of ongoing discussions within the International Subcommission on Devonian Stratigraphy (SDS), a unit of the International Commission on Stratigraphy (ICS) of IUGS. The names of the Lower Devonian Stages were adopted by SDS in 1983, recommended to ICS in 1984, and ratified by IUGS in 1985 (Bassett, 1985).

Regional Setting

The boundary beds have been studied in detail at several localities in the Barrandian area, southwest of Prague (Fig. 1). Three localities were described in detail by both Weddige (1987) and Chlupáč, Lukeš and Weddige (1988). The three, Černá rokle, Velká Chuchle and Cikánka Quarry,

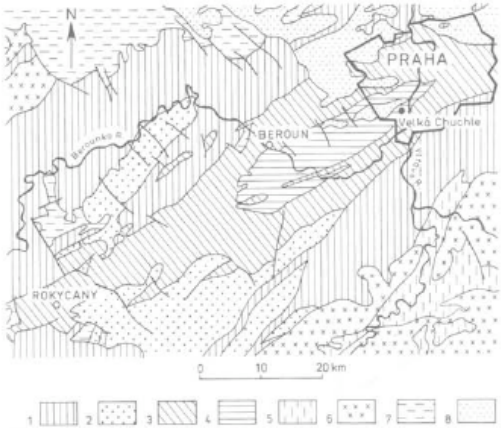


Figure 1: Geographic and geologic setting of the stratotype section in the Barrandian area of central Bohemia. 1- Proterozoic, 2- Cambrian, 3- Ordovician, 4- Silurian and Devonian, 5- metamorphic Proterozoic and lower Paleozoic, 6- granitoids, 7- continental Upper Carboniferous, 8- Upper Cretaceous and Tertiary sedimentary rocks.

represent a progression from low to high energy environments. Černá rokle has the best megafauna while Cikánka Quarry has the most abundant conodont fauna. Velká Chuchle is intermediate and was selected as stratotype because of the good intermixture of conodonts and megafossils.

Ranges of key species at the three localities are very similar; at each locality the sulcatus boundary is a short distance below the previously accepted megafossil boundary. Chlupáč and others (1985) published extensive range charts and lists of fossils from these and other boundary sections, together with discussions of the stratigraphic significance and usefulness of the major groups of fossils of the Lochkovian-Pragian interval.

The boundary is closely related to an event-stratigraphy level of probable global importance, namely the "Lochkovian-Pragian Boundary Event," which, however, lies close above the Pragian base. This event-boundary (most likely a eustatic fall in sea level) may be useful in identifying the broader boundary interval on a worldwide scale (compare the interval before Cycle Ia in Johnson, Klapper and Sandberg 1985, and applications in the stratotype area, in Chlupáč and Kukal 1986, 1988). Paleomagnetic studies are in progress by Dr. M. Krs in Prague. Preliminary results suggest that the Velká Chuchle section has been remagnetized. The color alteration index of Velká Chuchle conodonts is 3 (Schönlaub, written communication, 1989).

Prior to the naming of the Pragian Stage in 1958 and its acceptance by SDS in 1983, the "Siegenian Stage" was used by many workers for the middle stage of the Lower Devonian. This was based on benthic, near-shore fossils, principally brachiopods, and was sufficiently useful up to about 1950 when pelagic fossils such as conodonts began to predominate in long-range correlations. With continuing refinement of intercontinental correlations, it became clear that the "Siegenian Stage" could not be satisfactorily defined in its type area (West Germany) and the shift to Pragian resulted.

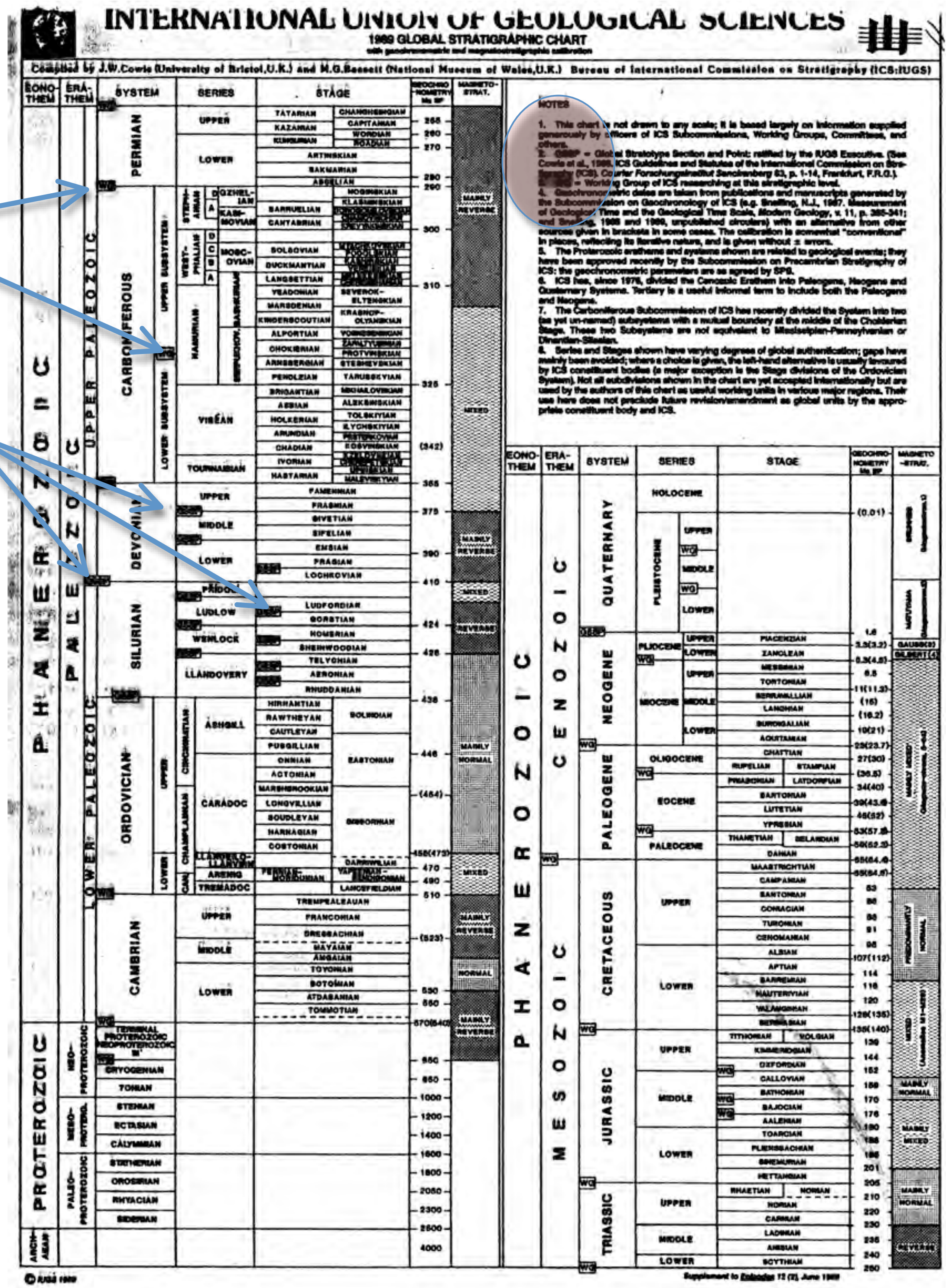
Recent studies in northern Spain, Brittany and West Germany show that the base of the Pragian is nearly correlative with the base of the "Siegenian" in the sense of Carls (1987). One option would have been to select a GSSP for the "Siegenian" in a pelagic facies (e.g., Czechoslovakia), but the SDS decision to use the term "Pragian" reflects the feeling that the term "Siegenian" is too closely regarded in terms of a Rhenish, near-shore clastic, benthic facies, whereas "Pragian" signifies a diverse fossil assemblage that includes widespread pelagic fossils.

Boundary Stratotype (GSSP)

The position of the Lochkovian-Pragian boundary and the GSSP for it were accepted by the International Subcommission on Devonian Stratigraphy in August-October 1988, and approved by the International Commission on Stratigraphy and ratified by the Executive Committee of IUGS during January-February 1989. The stratotype is to be marked by vol 12/2 -1989

WG
Working Group

GSSP
Global Stratotype
Section and Point



by Amos Salvador

A stable Cenozoic geologic time scale is indispensable

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A stable, standard geologic time scale is indispensable for the clear and precise communication among geologists; it is a basic tool of geologic work. Considerable progress has been made to achieve such a stable time scale. However, during the last few years several proposals have been made to modify the Cenozoic section of the geologic time scale that threaten to destabilize it. Seven articles published in Episodes *since 2000 that could contribute to this destabilization are discussed. They provide excellent examples of the profusion of different terminologies, hierarchies, and stratigraphic relationships that have been proposed: to eliminate the Tertiary and the Quaternary or to raise their rank to suberathems; to extend the Neogene to the present; to make the Quaternary a formal subsystem of the Neogene, or consider it an informal stratigraphic unit; to eliminate the Holocene, and to decouple the base of the Pleistocene from the base of the Quaternary. If adopted, these proposals would cause nothing but great confusion and controversy. They disregard the clear preferences of geologists the world over as reflected by the terminology they have been using for many decades. Common sense would dictate the continued use of this terminology in its current, widely accepted form.*

geologic time scale most widely accepted and used has the Cenozoic Erathem/Era comprising the Tertiary and the Quaternary systems/periods, with the Tertiary comprising the Paleogene and Neogene subsystems/subperiods. The Paleogene includes the Paleocene, Eocene, and Oligocene series/epochs, the Neogene comprises the Miocene and Pliocene series/epochs, and the Quaternary includes the Pleistocene and Holocene series/epochs (Figure 1).

Erathem (Era)	System and Subsystem (Period and Subperiod)		Series (Epoch)
Cenozoic	Quaternary		Holocene Pleistocene
	Tertiary	Neogene	Pliocene Miocene
		Paleogene	Oligocene Eocene Paleocene

***Figure 1** The most widely accepted Cenozoic time scale in current use.*

However, during the last few years several proposals have been made to modify this widely accepted Cenozoic time scale, each contributing in different ways to destabilize it. Only those proposals published in Episodes during the last 6 years will be discussed in this note. They provide an excellent example of the profusion of different terminologies, hierarchies and stratigraphic relationships proposed to modify the Cenozoic time scale.

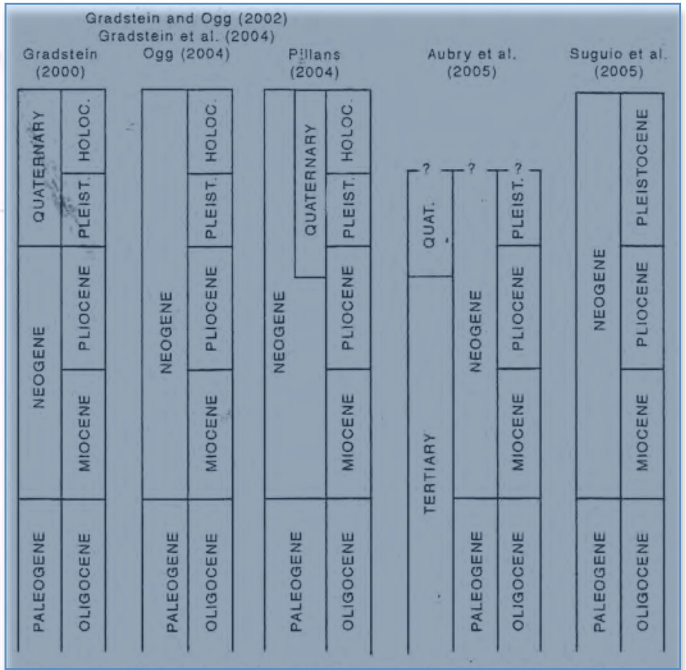

***Figure 2** The subdivision of Cenozoic time scale by different authors.*

Are these proposed modifications sensible and necessary?

This profusion of proposals for different terminologies, hierarchies, and stratigraphic relationships does not help to achieve a stable, standard geologic time scale for the Cenozoic, particularly because most of the proposals ignore the terminology, hierarchies, and stratigraphic relationships that geologists worldwide have accepted and used for many decades, and continue to use today.

To eliminate the Tertiary and the Quaternary from the Cenozoic time scale clearly ignores reality. As systems of the Cenozoic Erathem, they are too deeply rooted in the geologic literature to be willfully eradicated.

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So what would be preferable?

To eliminate the Tertiary and the Quaternary from the standard geologic time scale, or to raise their rank to sub-erathems/sub-eras; to extend the Neogene to the present; to make the Quaternary a formal subsystem of the Neogene, or to consider it an informal stratigraphic unit, to eliminate the Holocene; and to decouple the base of the Pleistocene from the base of the Quaternary would cause great confusion and controversy. These changes disregard the preference of geologists from around the world and ignore the terminology in common use today. Why not continue using the terminology, hierarchies, and stratigraphic relationships that geologists have been using for many decades and continue to use today? This is what common sense dictates.

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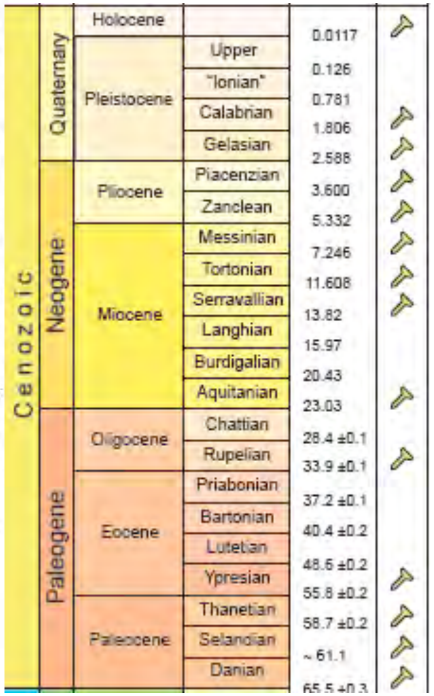

GTS 2010

by Loren E. Babcock[1], Richard A. Robison[2], Margaret N. Rees[3], Shanchi Peng[4], and Matthew R. Saltzman[1]

Episodes 2007, vol 30/2

The Global boundary Stratotype Section and Point (GSSP) of the Drumian Stage (Cambrian) in the Drum Mountains, Utah, USA

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biostratigraphy

chemostratigraphy

'sequence stratigraphy'

The Global boundary Stratotype Section and Point (GSSP) for the base of the Drumian Stage (Cambrian Series 3) is defined at the base of a limestone (calcisiltite) layer 62 m above the base of the Wheeler Formation in the Stratotype Ridge section, Drum Mountains, Utah, USA. The GSSP level contains the lowest occurrence of the cosmopolitan agnostoid trilobite Ptychagnostus atavus *(base of the* P. atavus *Zone). Secondary global markers near the base of the stage include the DICE negative $\delta^{13}C$ excursion, the onset of a long monotonic $^{87}Sr/^{86}Sr$ isotopic shift, and the transgressive phase of a eustatic event. Faunal turnovers close to the base of the Drumian Stage are recognized as the base of the* Bolaspidella *Zone (polymerid trilobites) in Laurentia, the historic base of the Floran Stage in Australia, the base of the* Dorypyge richthofeni *Zone (polymerid trilobites) in South China, and the base of the* Gapparodus bisulcatus-Westergaardodina brevidens *Assemblage-zone (conodonts) in Baltica and South China. The last occurrence of the cosmopolitan trilobite* Ptychagnostus gibbus *occurs in the lower part of the Drumian Stage, and the base of the* Hydrocephalus hicksii *Zone (polymerid trilobites) as used in Siberia and Baltica occurs near the base of the stage.*

Introduction

The aim of this paper is to announce the ratification of the Global boundary Stratotype Section and Point (GSSP) of the Drumian Stage. The Drumian Stage replaces stage 6 (a provisional name), the second stage of series 3 (a provisional name) of the Cambrian System (Babcock et al., 2005; Peng et al., 2006; Babcock and Peng, 2007; Figure 1). Coinciding with the GSSP horizon is one of the most clearly recognizable datum points in the Cambrian, the first appearance datum (FAD) of the intercontinentally distributed agnostoid trilobite *Ptychagnostus atavus* (Figures 1, 2). That, and secondary correlation techniques summarized here and elsewhere (Babcock et al., 2004; Zhu et al., 2006), allow the base of the stage to be correlated with precision through all major Cambrian regions. Among the methods that should be considered in the selection of a GSSP (Remane et al., 1996), biostratigraphic, chemostratigraphic, paleogeographic, facies-relationship, and sequence-stratigraphic information is available (e.g., Randolph, 1973; White, 1973; McGee, 1978; Dommer, 1980; Grannis, 1982; Robison, 1982, 1999; Rowell et al. 1982; Rees 1986; Langenburg et al., 2002a, 2002b; Babcock et al., 2004; Zhu et al., 2006); that information is summarized here.

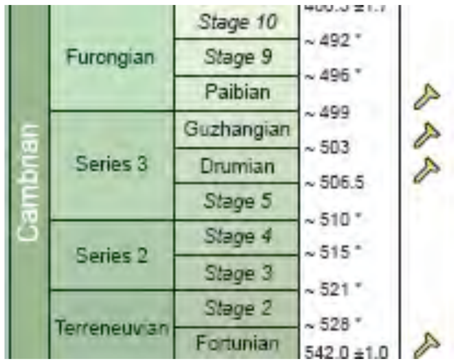
Voting members of the International Subcommission on Cambrian Stratigraphy (ISCS) accepted the proposal to define the Drumian Stage almost unanimously in early 2006. Later in the same year, the proposal was ratified by the International Commission on Stratigraphy (ICS) and the International Union of Geological Sciences (IUGS).

Background

Recent efforts by the ISCS to develop internal subdivisions of the Cambrian System applicable on a global scale are coming to fruition as work proceeds on horizons deemed potentially suitable for pre-

SYSTEMS	SERIES	STAGES	BOUNDARY HORIZONS (GSSPs) OR PROVISIONAL STRATIGRAPHIC TIE POINTS
Ordovician	Lower	Tremadocian	FAD of *Iapetognathus fluctivagus* (GSSP)
Cambrian	Furongian Series	Cambrian Stage 10 (Undefined)	FAD of *Lotagnostus americanus*
		Cambrian Stage 9 (Undefined)	FAD of *Agnostotes orientalis*
		Paibian Stage	FAD of *Glyptagnostus reticulatus* (GSSP)
	Cambrian Series 3 (Undefined)	Cambrian Stage 7 (Undefined)	FAD of *Lejopyge laevigata*
		Drumian Stage	FAD of *Ptychagnostus atavus*
		Cambrian Stage 5 (Undefined)	?FAD of *Oryctocephalus indicus*
	Cambrian Series 2 (Undefined)	Cambrian Stage 4 (Undefined)	?FAD of *Olenellus* or *Redlichia*
		Cambrian Stage 3 (Undefined)	FAD of trilobites
	Cambrian Series 1 (Undefined)	Cambrian Stage 2 (Undefined)	?FAD of SSF or archaeocyathan species
		Cambrian Stage 1 (Undefined)	FAD of *Trichophycus pedum* (GSSP)
Ediacaran			

Figure 1 Chart showing working model for global chronostratigraphic subdivision of the Cambrian System, indicating the position of the Drumian Stage (modified from Babcock et al., 2005).



GTS 2010

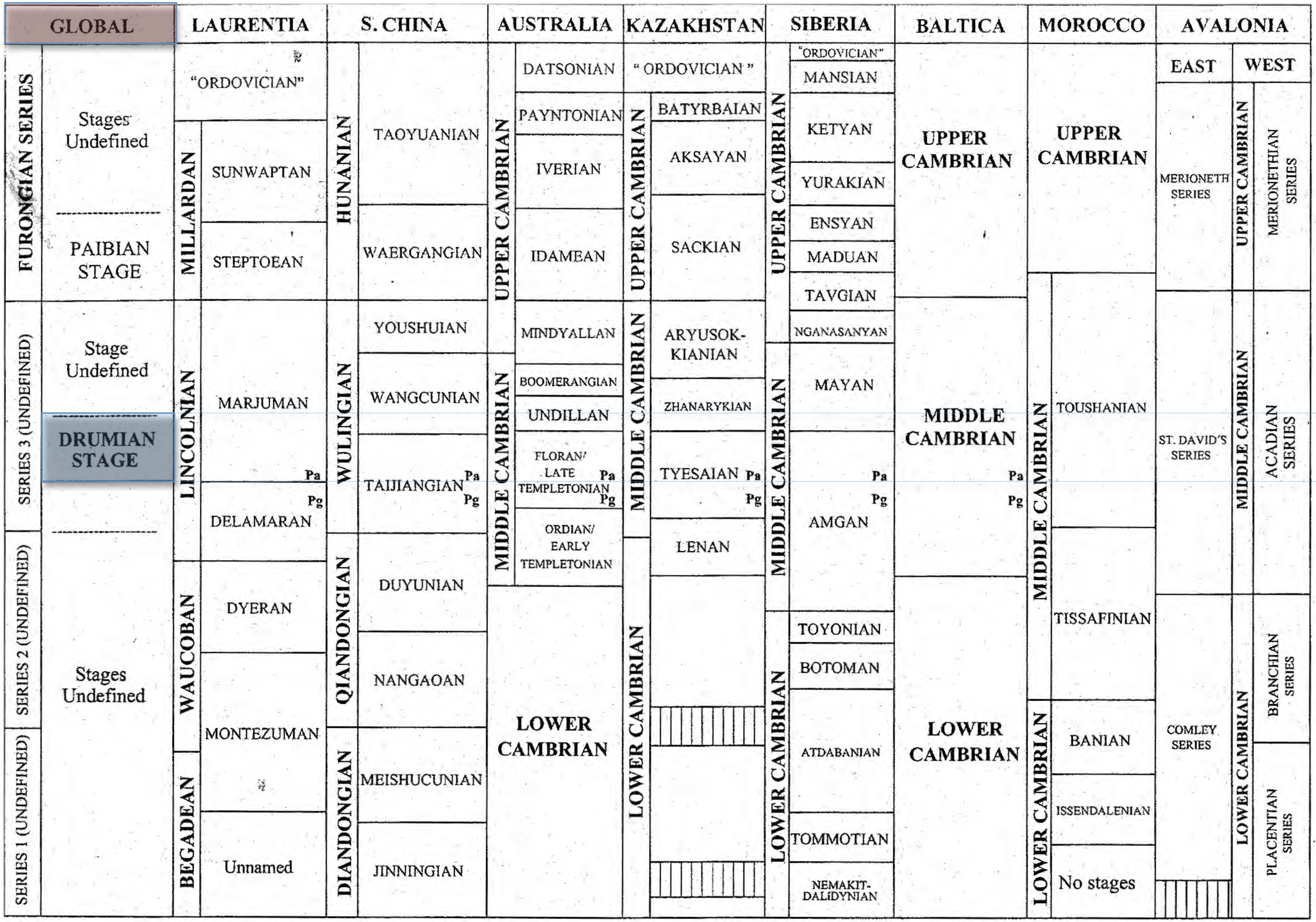


Figure 2 Correlation chart of the Cambrian showing the new global chronostratigraphic stage (Drumian; column at left) compared to regional usage in major areas of the world (modified from Peng et al., 2004b). Pa indicates the presence and horizon of Ptychagnostus atavus *in a region; Pg indicates the presence and horizon of* Ptychagnostus gibbus *in a region. Chart compiled from numerous sources, summarized principally in Geyer and Shergold (2000) and Babcock et al. (2004).*

CONCLUSION

CHRONOSTRATIGRAPHY is defined by the International Stratigraphic Guide (Hedberg, 1976) as the element of stratigraphy that deals with the **AGE** of strata and their **TIME** relations. The conceptual basis is the division, classification, and correlation of rocks and geologic time on the basis of time interval that are isochronous and time plane that are synchronous

⇒ **isochronous** = equal time duration (of rock bodies…)

=> **synchronous** = surfaces or time planes

North American Stratigraphic Code (NASCN, 1984) has introduced newer developments in stratigraphy **=> DIACHRONIC UNITS** : they are not strictly stratigraphic units because they are **temporal rather than material** units, despite they also deals with time and age ==> **ALLOSTRATIGRAPHY**

An allostratigraphic unit is a mappable stratiform body of sedimentary rock that is defined and identified on the basis of its bounding discontinuities.

They are unconformity-bounded units (= **EVENT** stratigraphy)

===>' allomember, alloformation, allogroup ….'