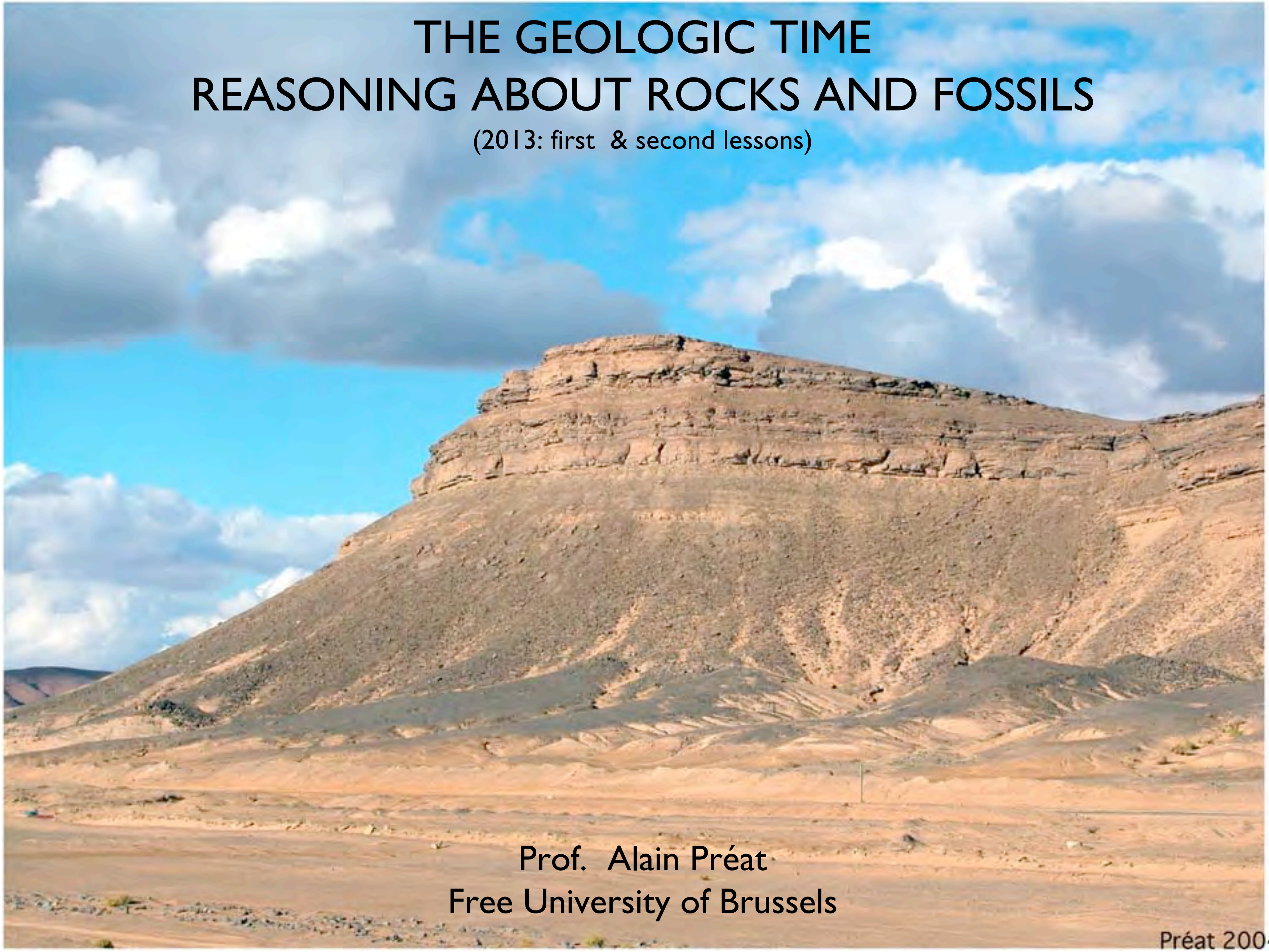
GEOL.F.104

THE GEOLOGIC TIME
REASONING ABOUT ROCKS AND FOSSILS

(2013: first & second lessons)



Prof. Alain Préat
Free University of Brussels

plan presentation

1. GEOMETRY

   Time lines are generally oblique (sedimentary bodies)
   Then the series is folded, thrusted ('jagged')

2. ABSOLUTE AND RELATIVE TIME

   Both remain necessary

3. RATE

   The kinetics of the phenomena depends of time resolution

1.GEOMETRY =>2. REL/ABS TIME =>3. KINETICS

1. REL/ABS TIME =>2.GEOMETRY =>3. KINETICS

2. GEOMETRY

>1960

Time lines are generally oblique (sedimentary bodies)
Then the series is folded, thrusted ('jagged')

1a. ABSOLUTE AND RELATIVE TIME

<1800

Both remain necessary

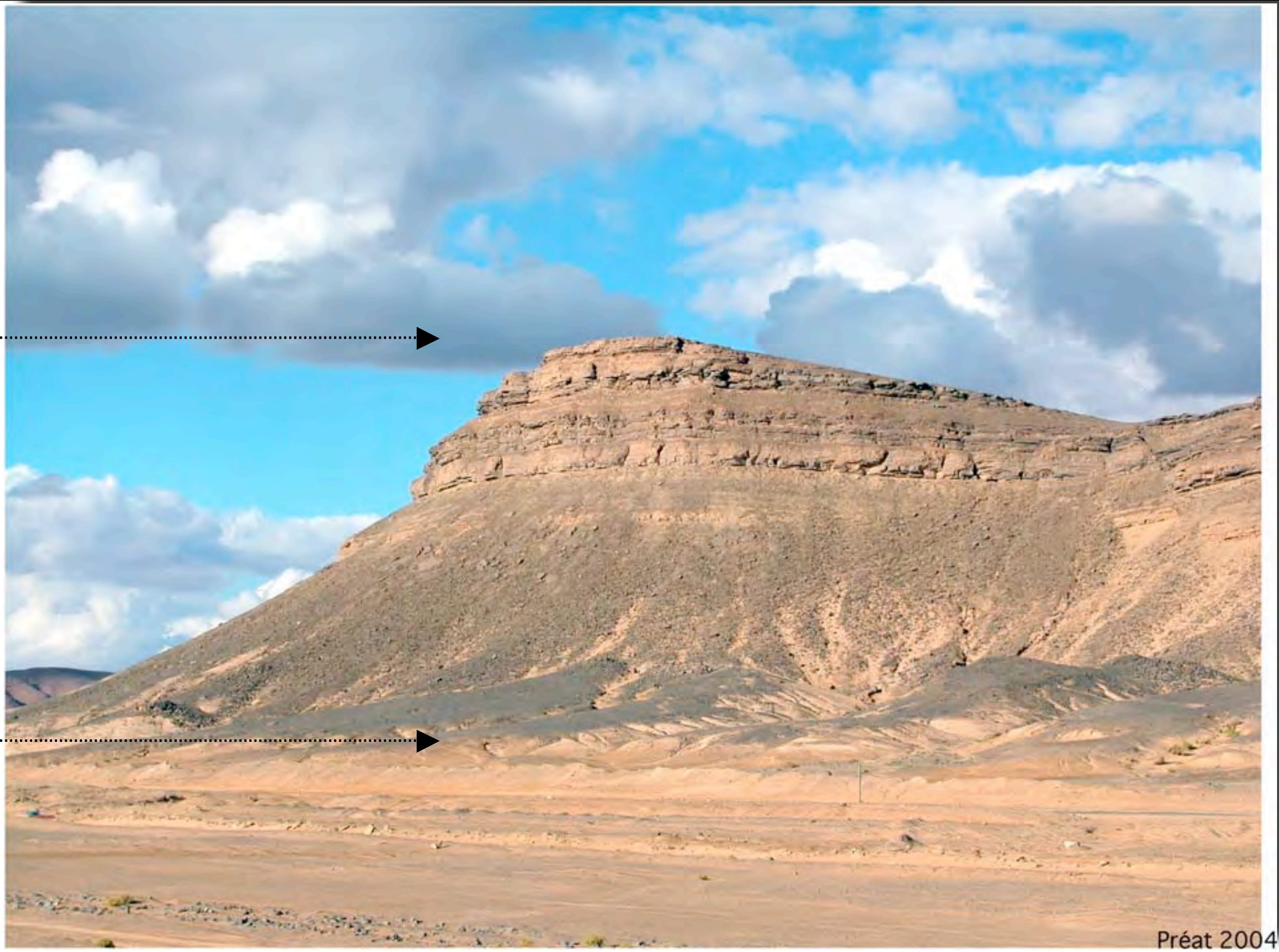
>1900

3. RATE

The kinetics of the phenomena depends of time resolution

>1980-1990

TIME IN GEOLOGY
a false intuition....



0.5
to
5%

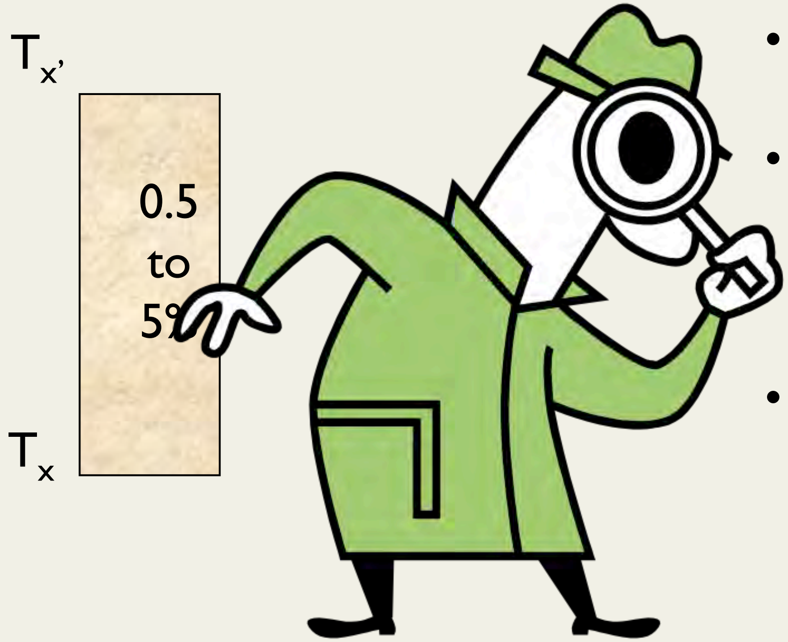
A ‘normal’ and ‘continuous’ geological succession

TIME IN GEOLOGY
a false intuition....

0.5
to
5%

So 95 à 99.5% of time is missing

A ‘normal’ and ‘continuous’ geological succession?



- Are we sure? Yes
- Is it the rule? Yes
- Consequences? Many
- Is there a solution? No
- Since when do we know? >1950

Other disciplines have also had their(s) and through yet their(s) limit(s): physics, biology ...

Physics

- ether or hypothetical hardware support vibration of an electromagnetic wave (like light) does not exist (Michelson-Morley experiments, the 1880 'with Nobel Prize in Physics in 1907 for Michelson).
- Heisenberg's uncertainty principle (1927) unable to determine BOTH position and velocity of a particle (see quantum mechanics). Always true.

Biology

- spontaneous generation must wait Pasteur (1862) to close debate of 2500 years initiated by Aristotle ('fish shellfish ... ... insects are born spontaneously in mud, dew or snow. Later ... the blow flies' .

Geology

-'transcontinental bridges' and other fanciful explanations before the establishment of plate tectonics (1968).

1. GEOMETRY

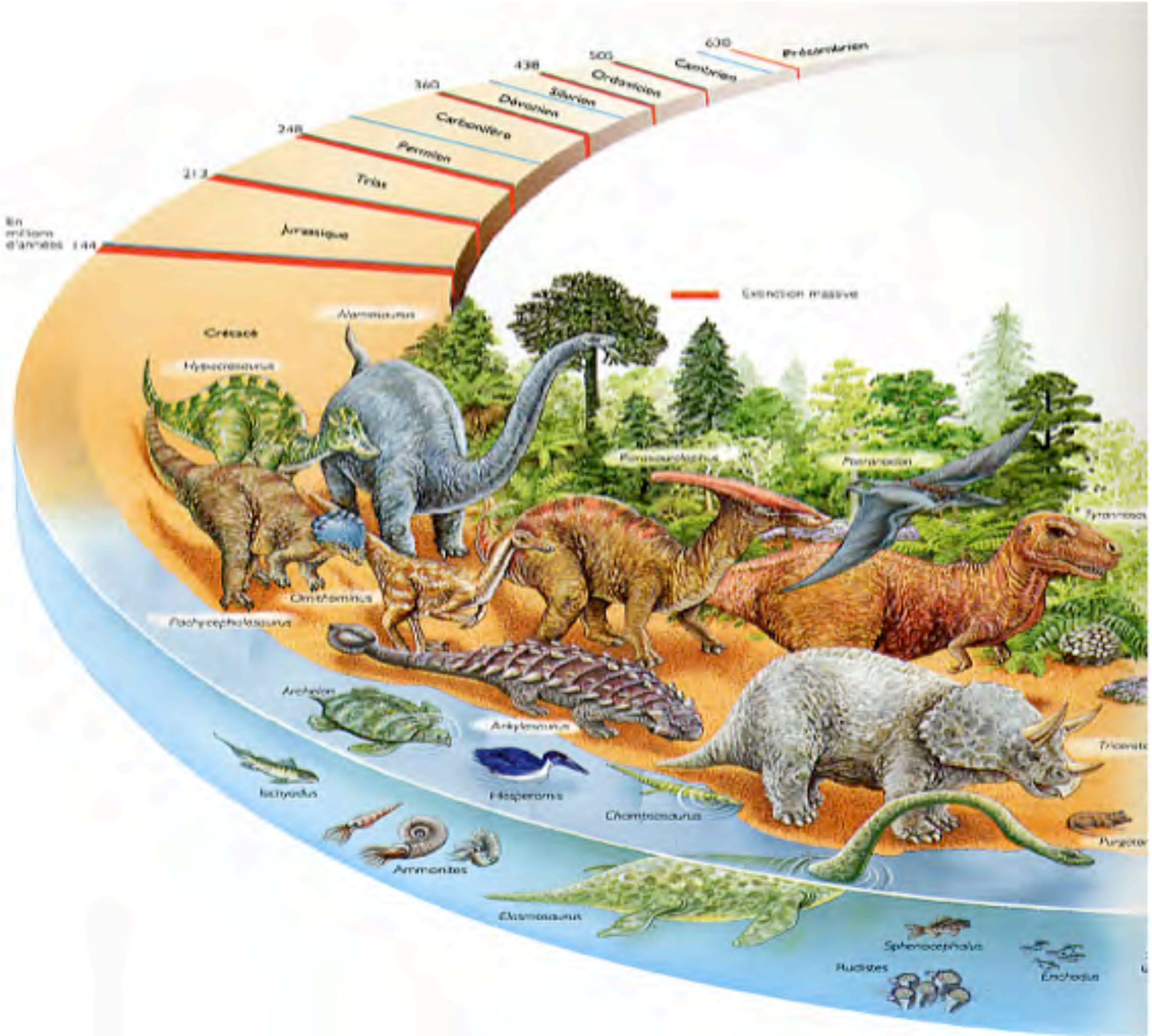
   Time lines are generally oblique (sedimentary bodies)
   Then the series is folded, thrusted ('jagged')

2. ABSOLUTE AND RELATIVE TIME

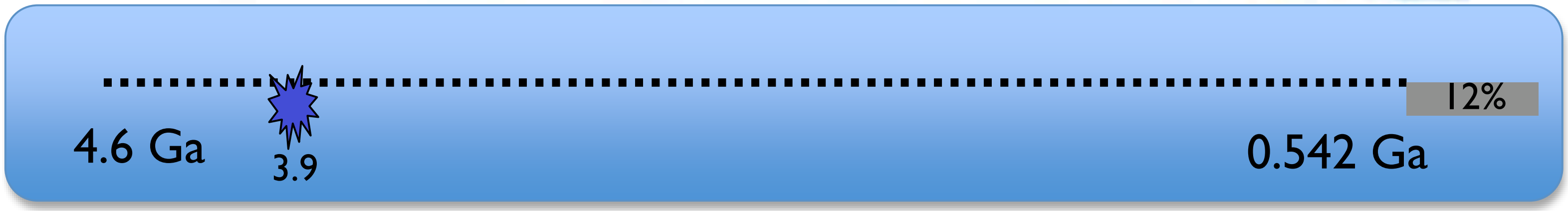
   Both remain necessary

3. RATE

   The kinetics of the phenomena depends of time resolution



En millions d'années
144
213
248
360
438
505
630
Précambrien
Cambrien
Ordovicien
Silurien
Dévonien
Carbonifère
Permien
Trias
Jurassique
Crétacé
Extinction massive
Archelon
Ankylosaurus
Hesperornis
Ammonites
Elasmosaurus
Rudistes



12%
4.6 Ga
3.9
0.542 Ga

1.GEOMETRY =>2. REL/ABS TIME =>3. KINETICS

BIOSTRATIGRAPHY

Paleozoic

Mesozoic

4.6 Ga

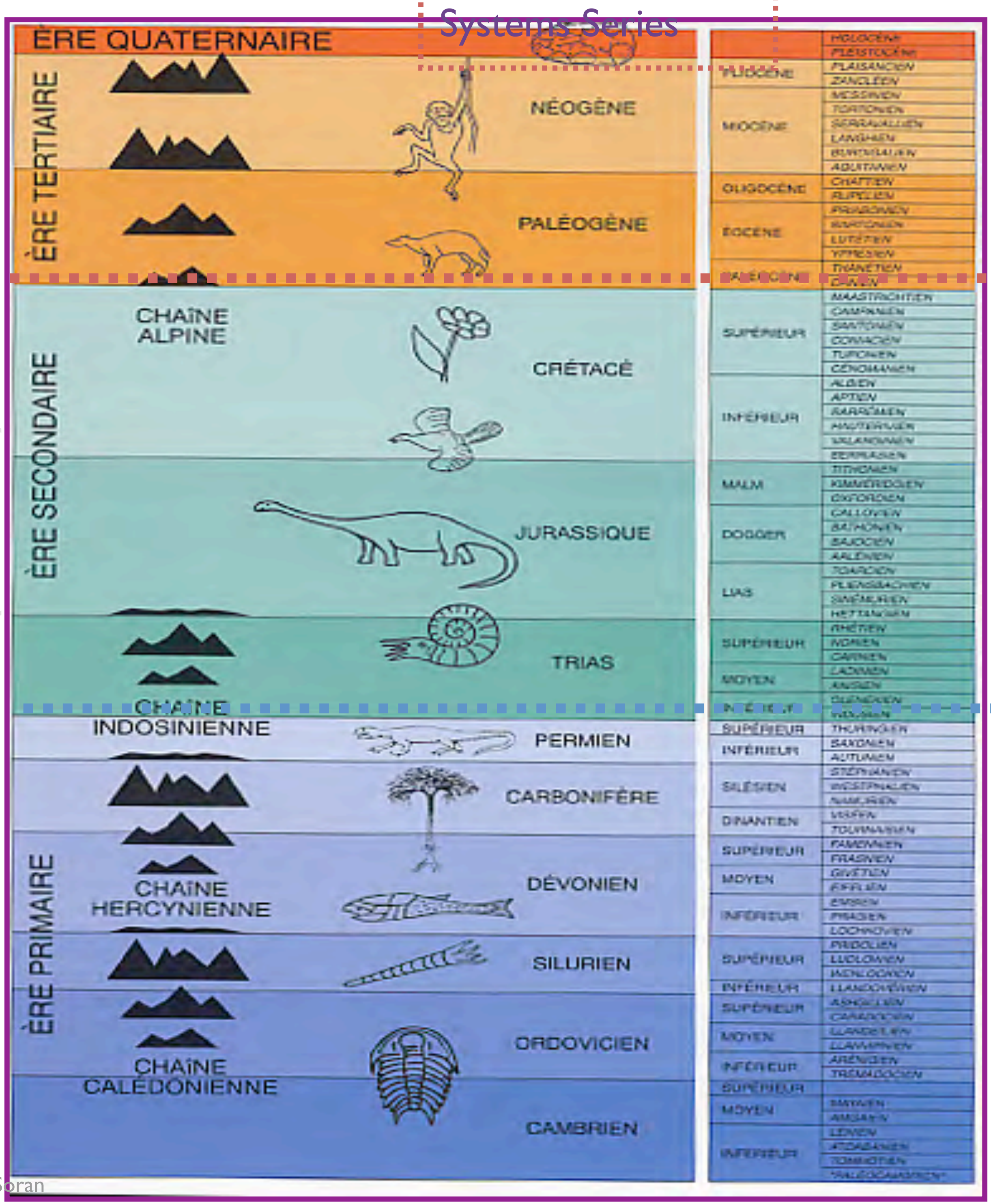
3.9

12%

0.542 Ga

ERA

1760 Giovanni ARDUINO (Venitian)

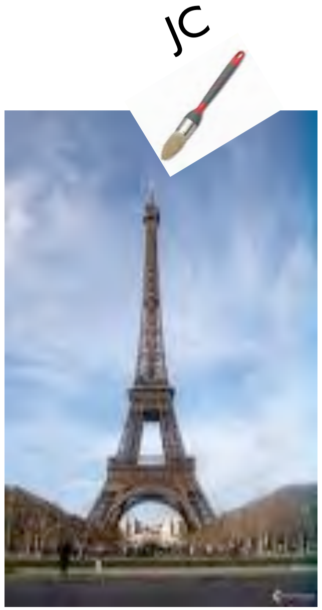


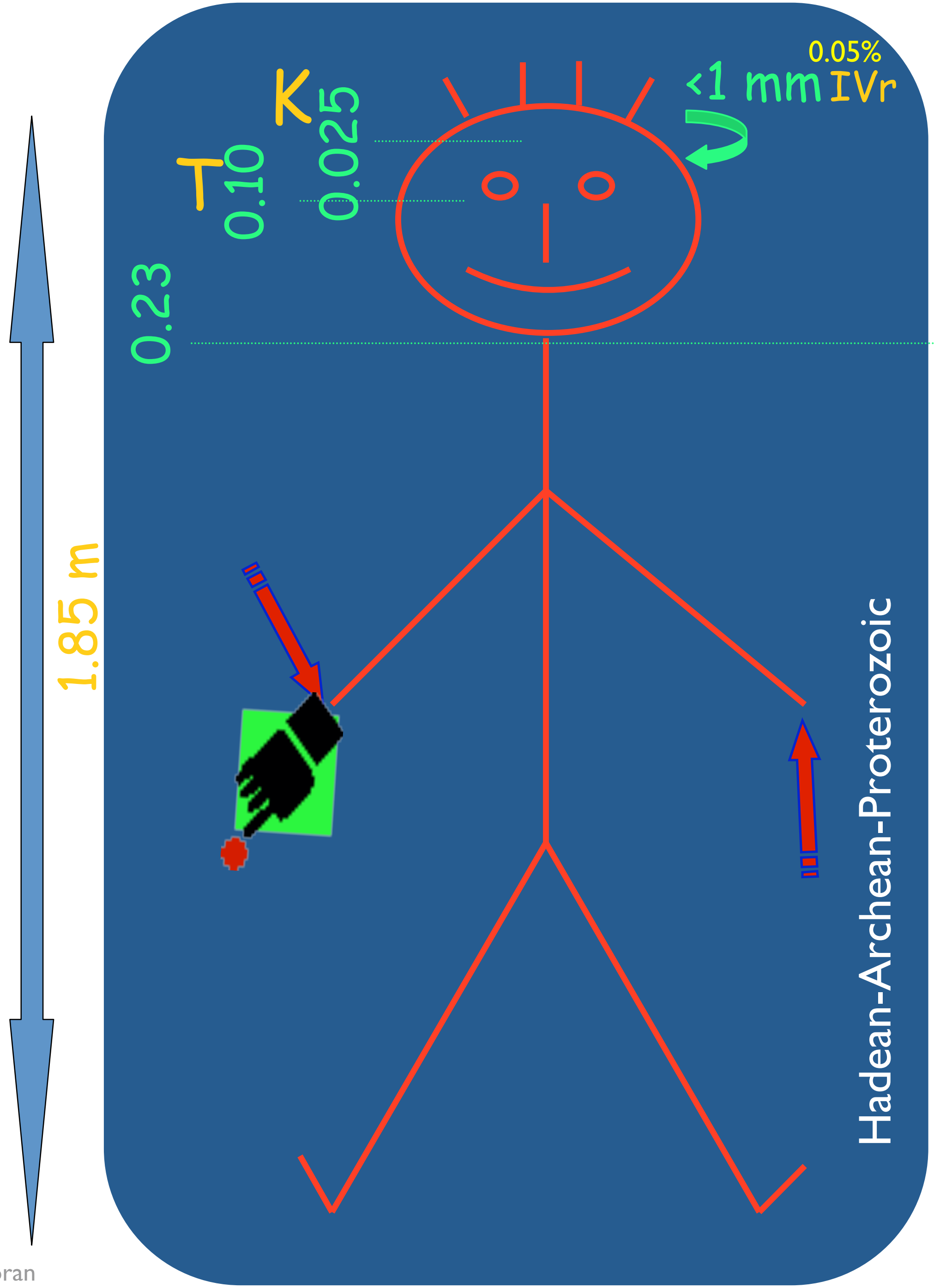
STAGES

1842

HIERARCHY

1.GEOMETRY =>2. REL/ABS TIME =>3. KINETICS





Phanerozoic
~ 1/9

0.542

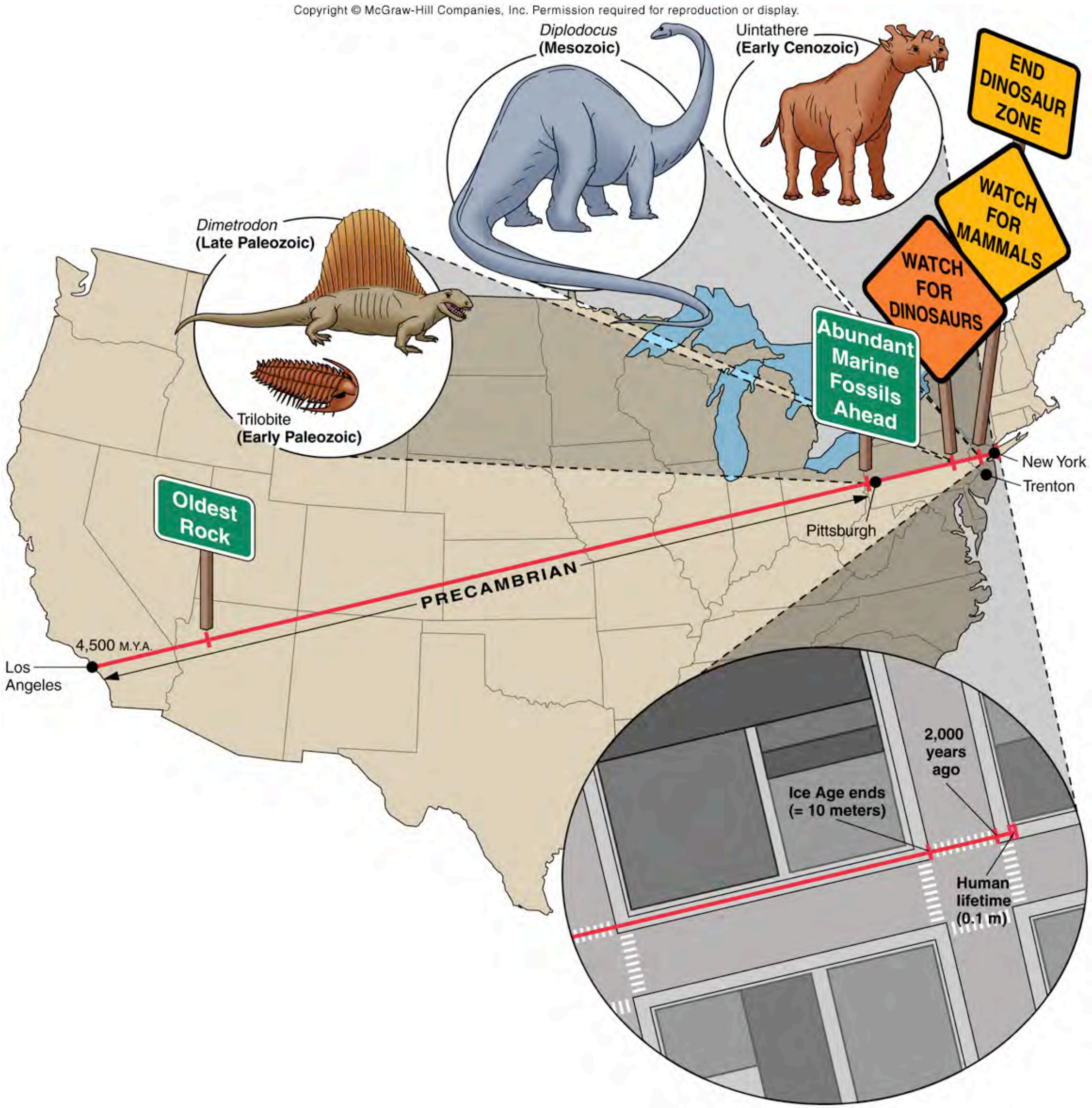
Precambrian
~ 8/9

4.6 Ga

A. PREAT U.Brussels/U. Soran

Numerical dating gives absolute age for Earth of about 4.56 billion years

AGES EN KILOMETRES

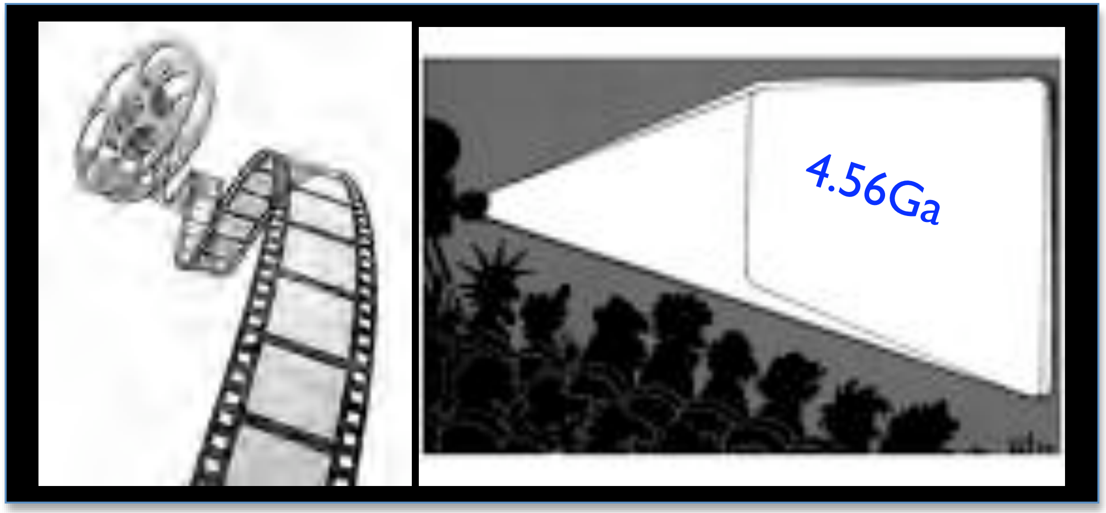


NEW YORK

LOS ANGELES

A long human lifetime (100 years) represents only about 0.000000002% of geological time

Geological time - very, very, very long!



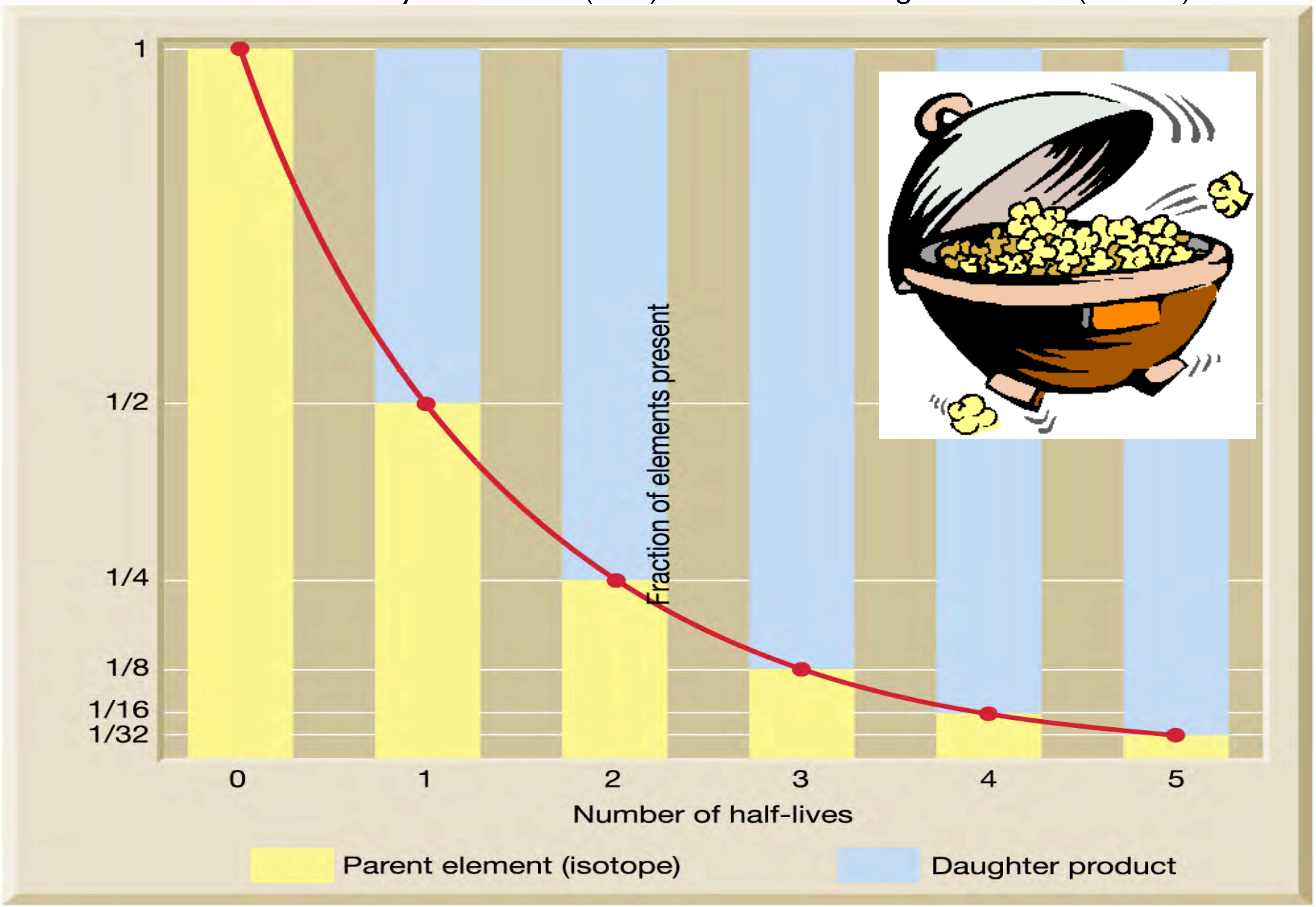
Movie : 32 images/sec

If one image = 100 yr

- Christian Era (BC) : -3/4 second
- Glacial Age : -7 second
- Dinosaur Extinction (K/T) : -6 hours
- Metazoa (Pcm/Cm) : - 2 days
- Beginning of Earth History : -16 days

ABSOLUTE or ISOTOPIC CHRONOLOGY

Natural Radioactivity => datation (time) + transfert tracing of elements (kinetics)



Ex: ^{99m}Tc *===> 6.01h =* ^{99}Tc *(m = metastable), after 24h it remains 6%...*

We can give an age for samples up to ten times of half-live periods, i.e. not containing less than $1/2^{10}$, or one thousandth of their initial content

ABSOLUTE or ISOTOPIC CHRONOLOGY

^{138}La ===> ^{138}Ce (2.67 x10^{11} years)

^{87}Rb ===> ^{87}Sr (5 x10^{10} years)

^{232}Th ===> ^{208}Pb (13.9 x10^{9} years)

^{40}K ===> ^{40}Ar (11.9 x10^{9} years)

^{238}U ===> ^{206}Pb (4.6 x10^{9} years)

^{235}U ===> ^{207}Pb (7 x10^{8} years)

^{234}Th ===> ^{230}Th (250 000 years)

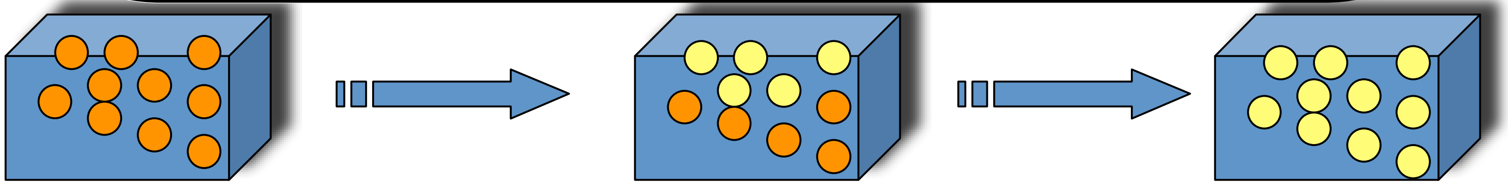
^{230}Th ===> ^{226}Ra (75 200 years)

^{14}C ===> ^{14}N (5 568 years)

^{3}T ===> ^{2}H (12.26 years)

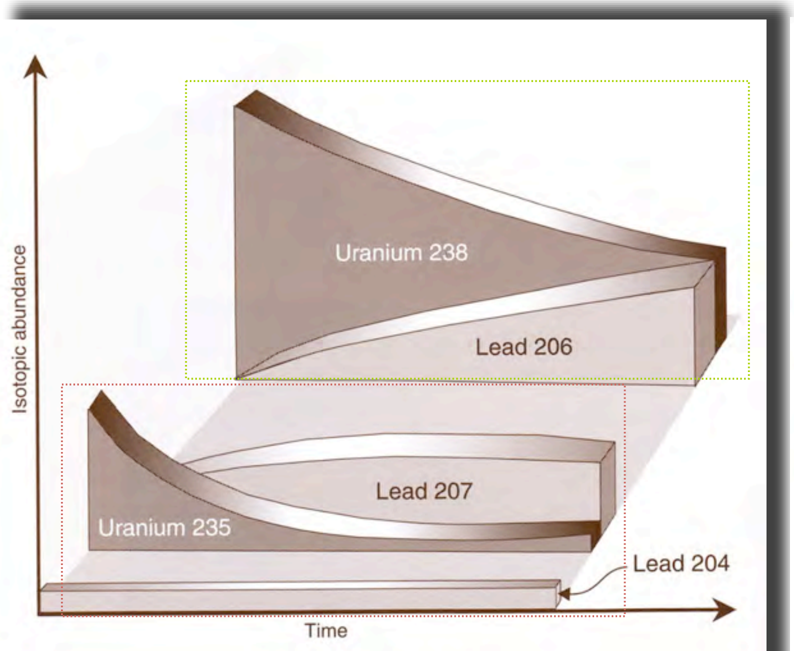
PRECISION

REL. CHR

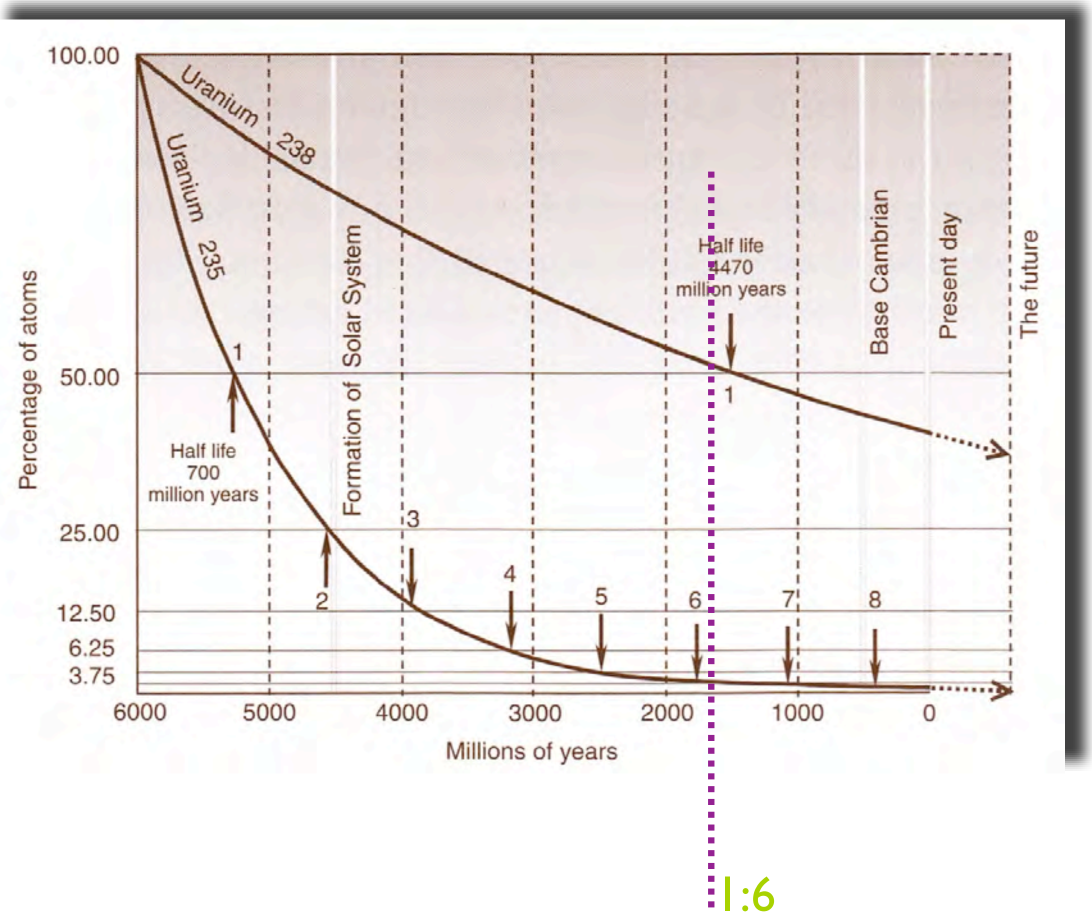


The system has to be closed ... all the time (= new problem)

Lewis 2000



Nier's three geological clocks.
Clock 1, uranium 238 → lead 206. Clock 2, uranium 235 → lead 207.
Clock 3, the growth of lead 206 and 207, relative to 204.

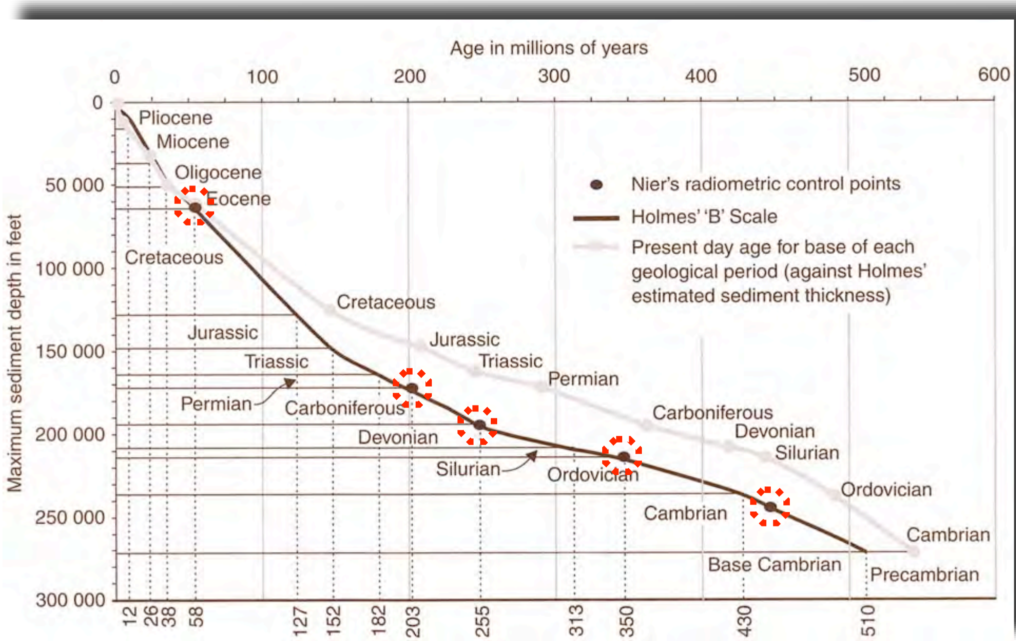


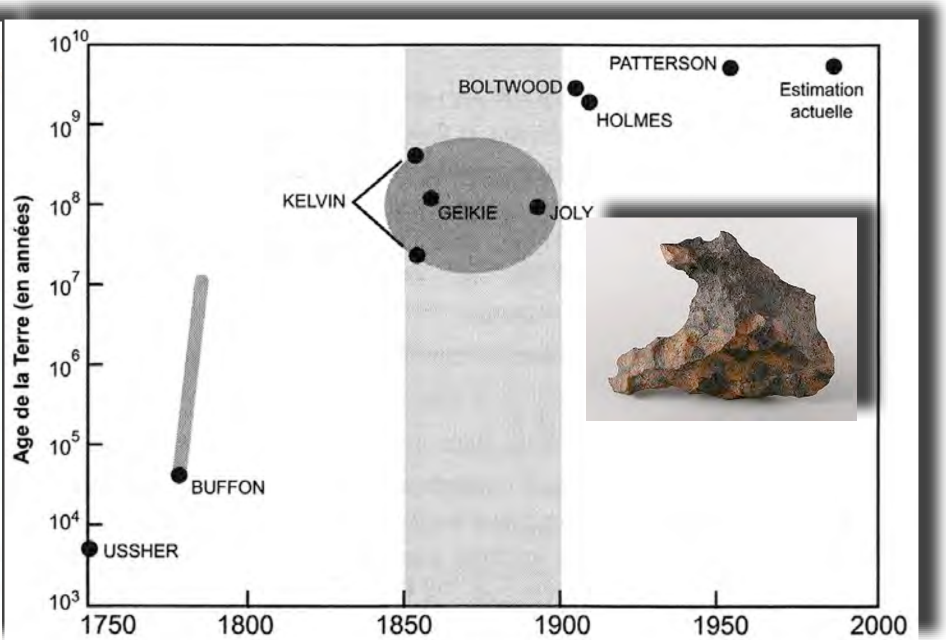
CONCORDIA Method
Two independent 'clocks', each with their half-life period,
giving each Pb (206 and 207) that is compared to ^{204}Pb, or
ordinary Pb which has a constant content (it does not derive from radioactive desintegration)

ABSOLUTE or ISOTOPIC CHRONOLOGY

±1600 Archbishop Ussher (Irl) : Bible, creation began in 4004 BC, October 22 at 9am
1721 Henri Gautier (Igr Ponts et Chaussées) : ablation relief… => 35 000yr. In resuming HIS calculations => few Ma! ==> Gautier would have voluntarily published 'false ages'…. to avoid problems … (Bible)
1779 Jean Etienne Guettard : the valleys of Etampes (France) area have >10 000 yrs i.e. >6000yr (Bible) => he renounced…
1850 Lord Kelvin : cooling of the Earth =>24 to 400 Ma, finally 100 Ma
1859 Darwin (digging and widening of a valley SE U.K.) => 300 Ma from the end of Mesozoic
…. … 1897 John Joly (Dublin) ocean salinisation => 80 to 89 Ma (actually = 13 Ma due to dynamics…)

Lewis 2000

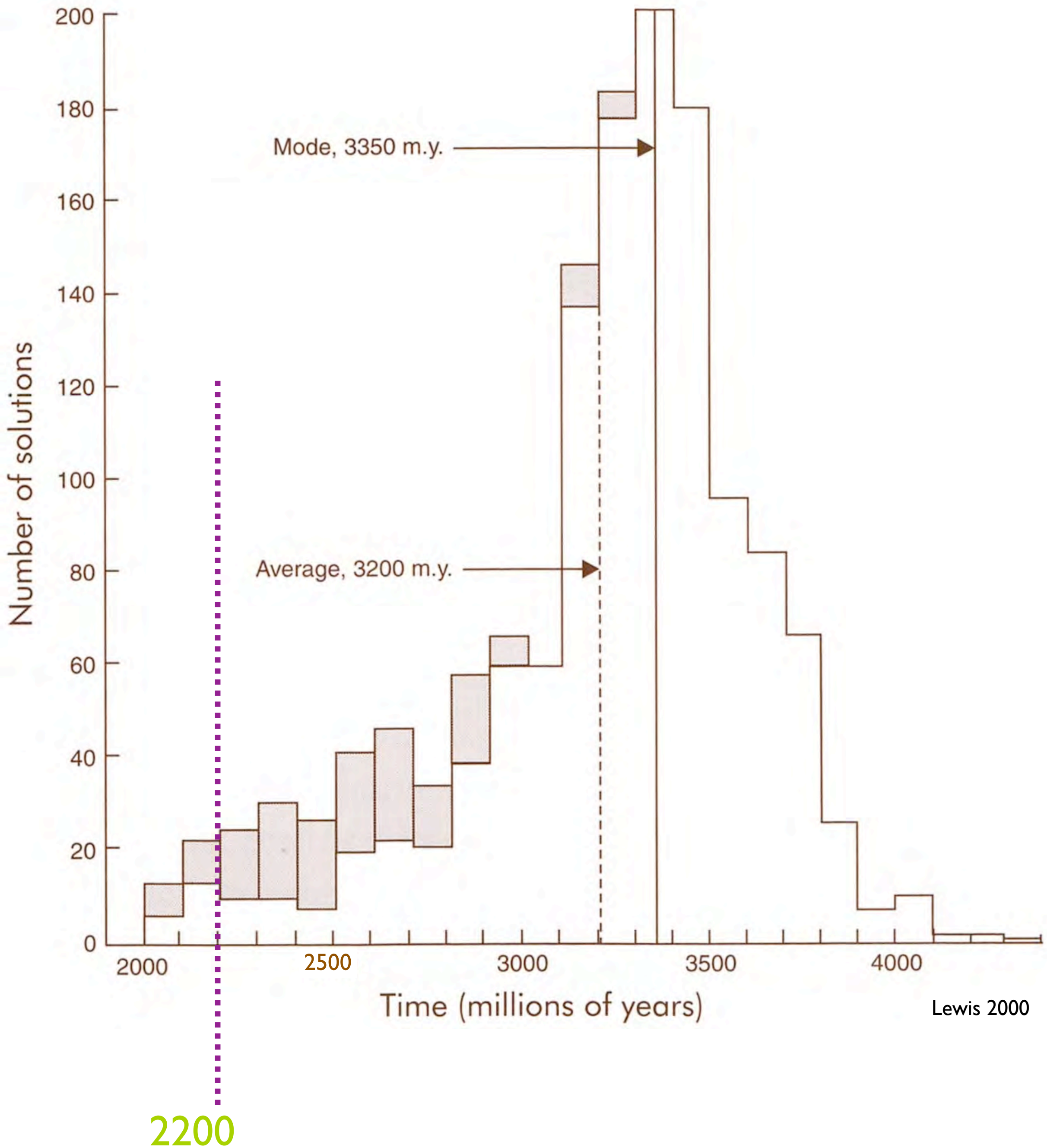




1947 - A. HOLMES
FIRST SCALE OF
GEOLOGICAL TIMES
(absolute time vs max thicknesses)

1953 - C. PATTERSON
Meteorite of Canyon Diablo
AGE OF THE EARTH : 4.55 Ga ± 70Ma

ABSOLUTE or ISOTOPIC CHRONOLOGY

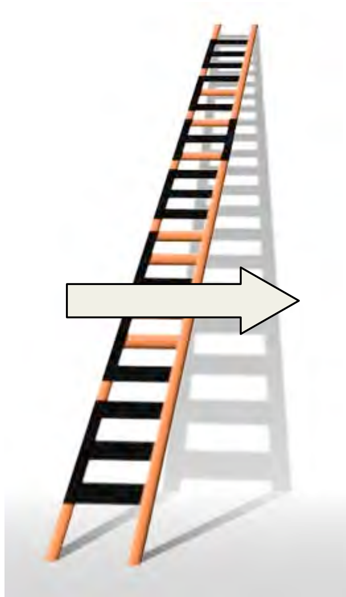


Pb/Pb Method
= 2 internal timers

A. Nier
Years 30'-40'
25 samples
pegmatite of Manitoba

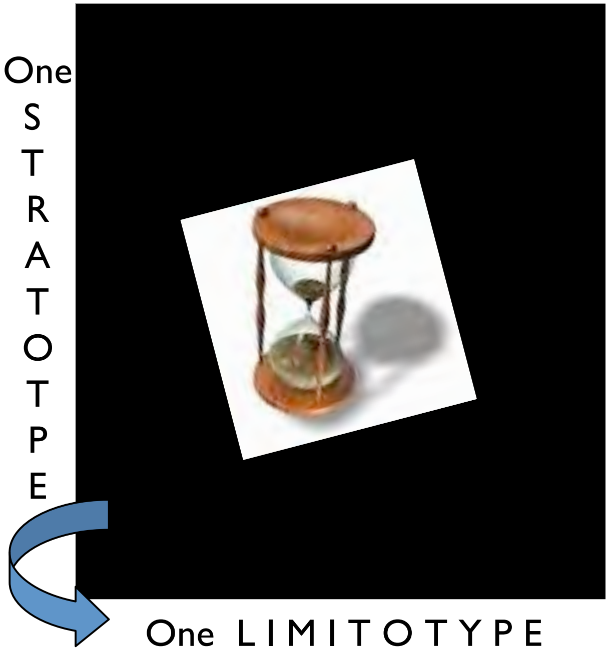
2200 Ma
was rejected
because older than
2000 Ma
estimated age of the Universe
at that period
....

UNITS AND CHRONOSTRATIGRAPHICAL CORRELATIONS



No
'material'
references for
Precambrian
[8/9th geol time]

One
S
T
R
A
T
O
T
P
E



One L I M I T O T Y P E

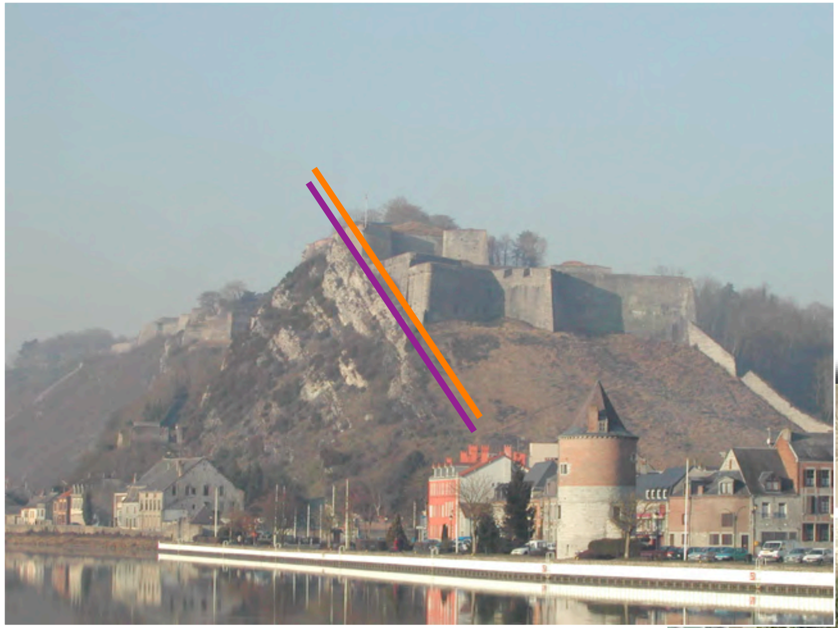
STRATOTYPE and/or LIMITOTYPE

GSSP Global Stratotype Section and Point

Jebel Mech Irdane (Erfoud, Anti-Atlas, Maroc)
[Conodonts, Goniatites, Trilobites ...]
391.8Ma ± 2.7Ma

G
I
V
E
I
F

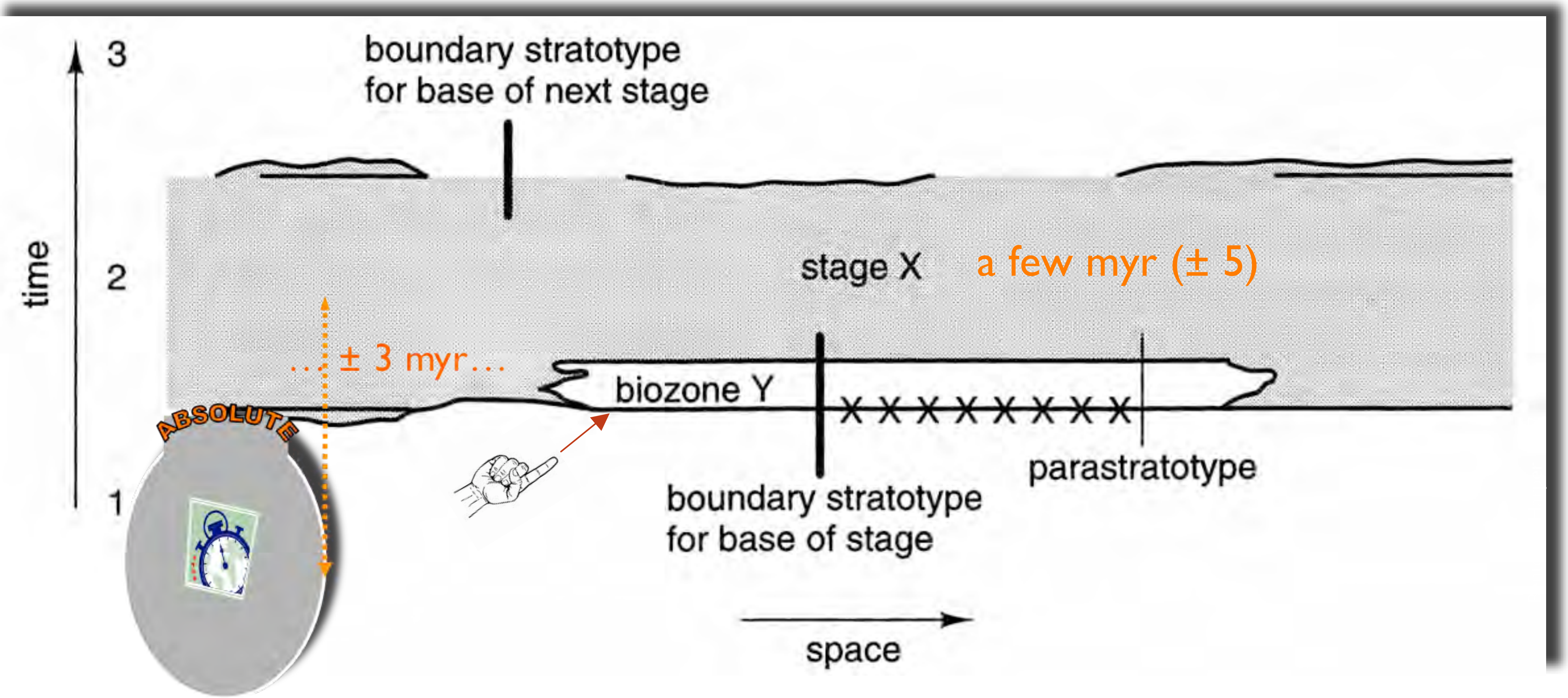
A. PREAT U.Brussels/U. Soran



HISTORICAL STRATOTYPE
Gosselet 1879

Finally lithologies are almost always independent of chronostratigraphical boundaries ...

LIMITOTYPE : the base of stage X is defined by the base of biozone Y



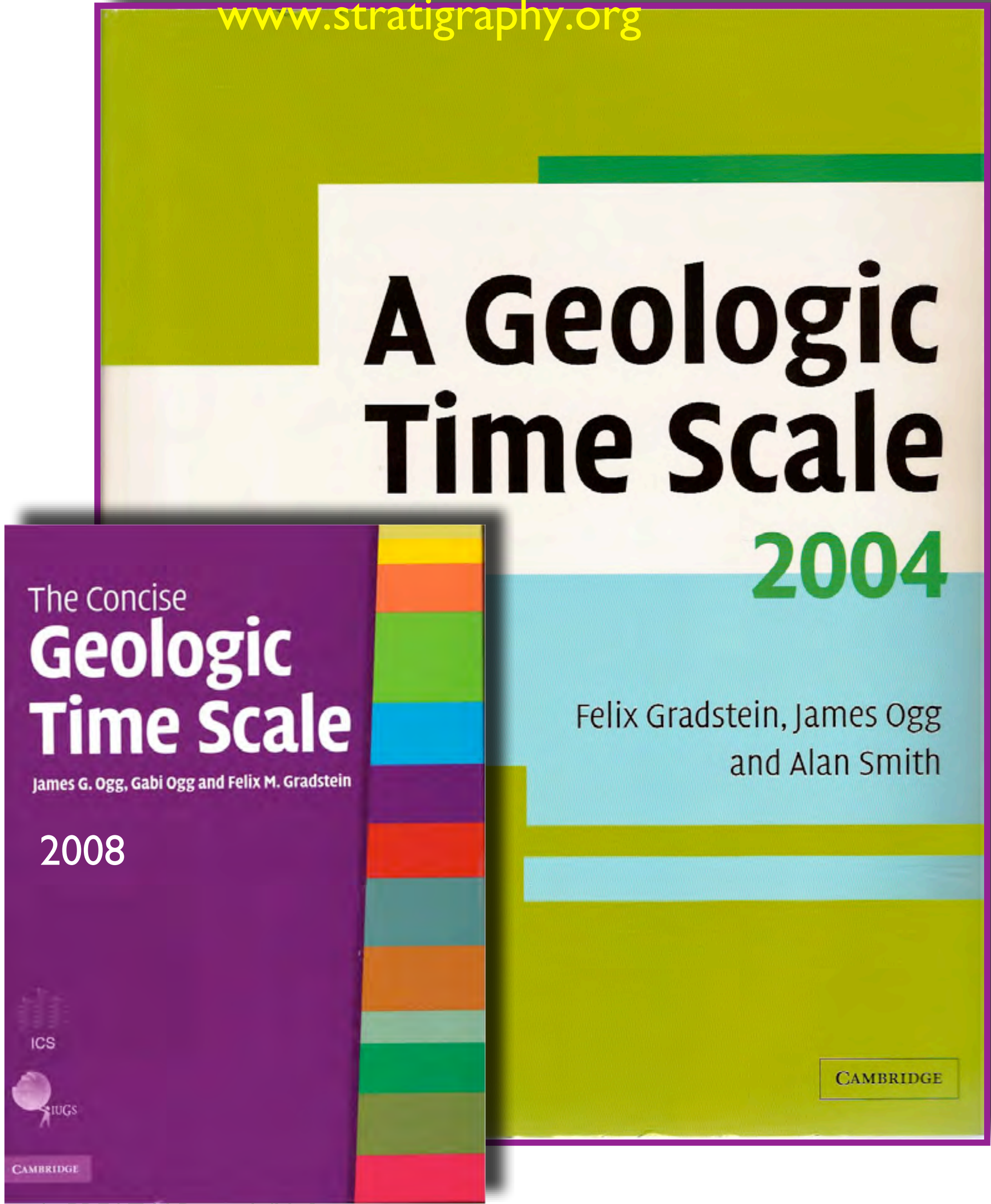
The parastratotype is outside of the basin and also defined by the base of biozone Y

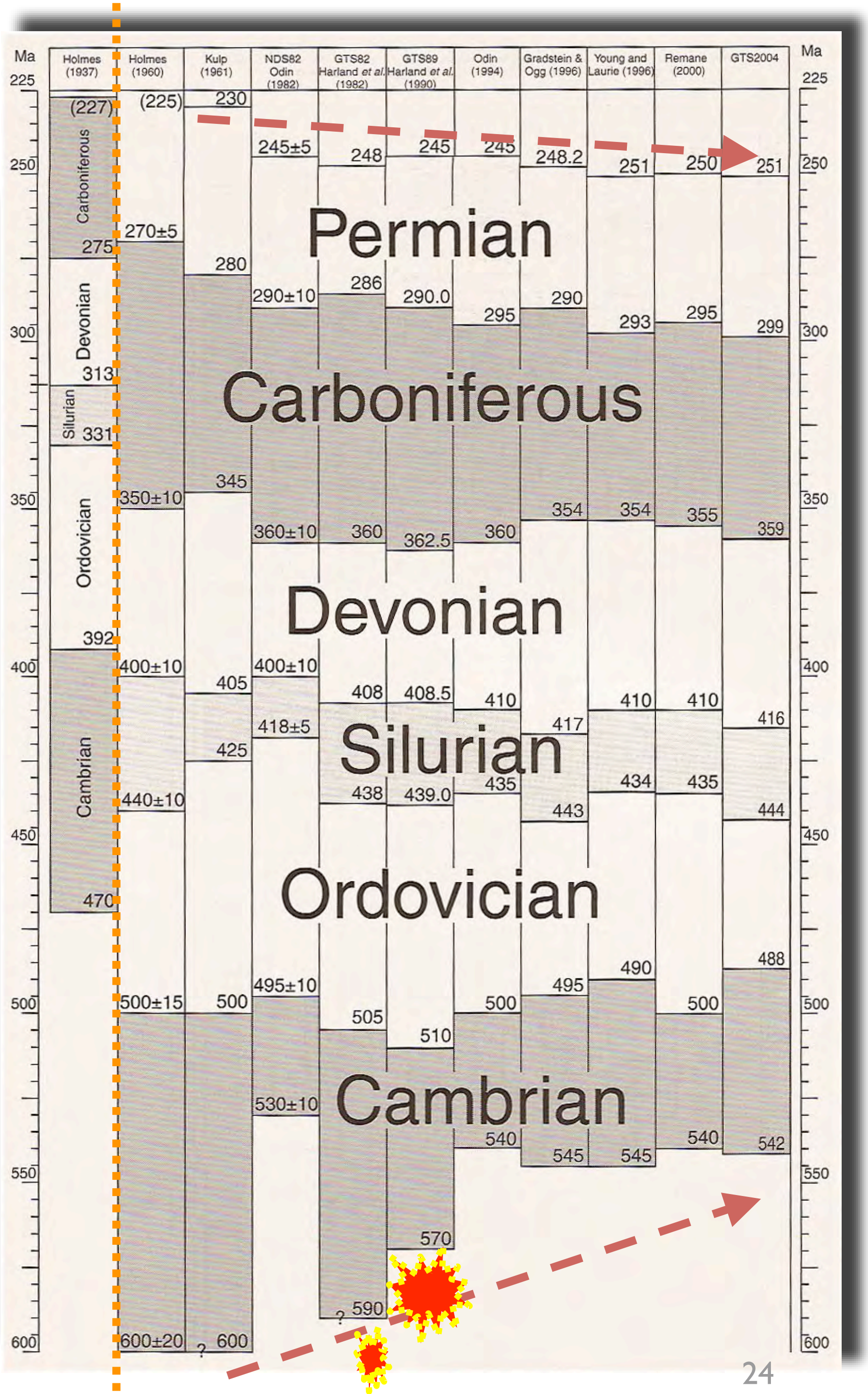
(there is a little less than100 geological stages, excluding the PCm)

1.GEOMETRY =>2. REL/ABS TIME =>3. KINETICS

Finally lithologies are almost always independent of chronostratigraphical boundaries …
Also independent of biostratigraphy and radiochronology….

www.stratigraphy.org

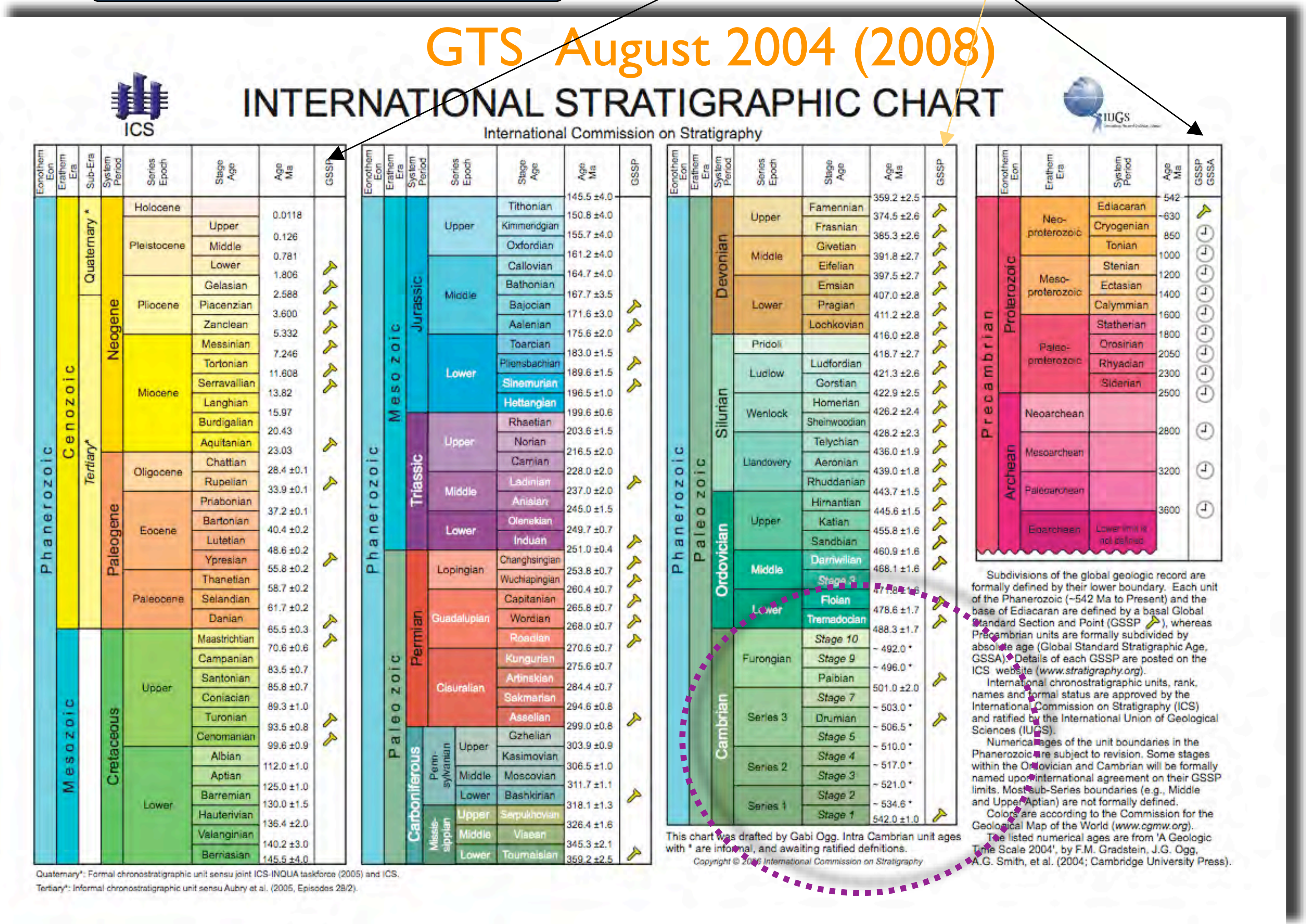




I.GEOMETRY =>2. REL/ABS TIME =>3. KINETICS

GOLDEN SPIKE

GTS August 2004 (2008)

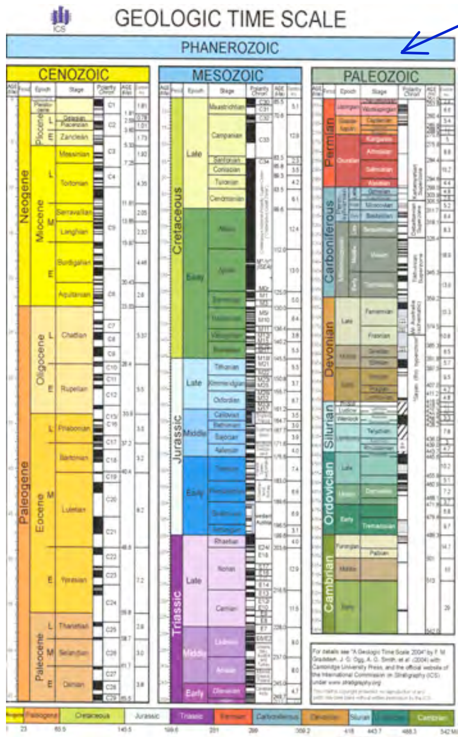


www. stratigraphy.org

DERNIERE MISE A JOUR: 08-2012

387.7±0.8 (2012)

Août 2004-2008



Giv

391.8

± 2.7

Eif

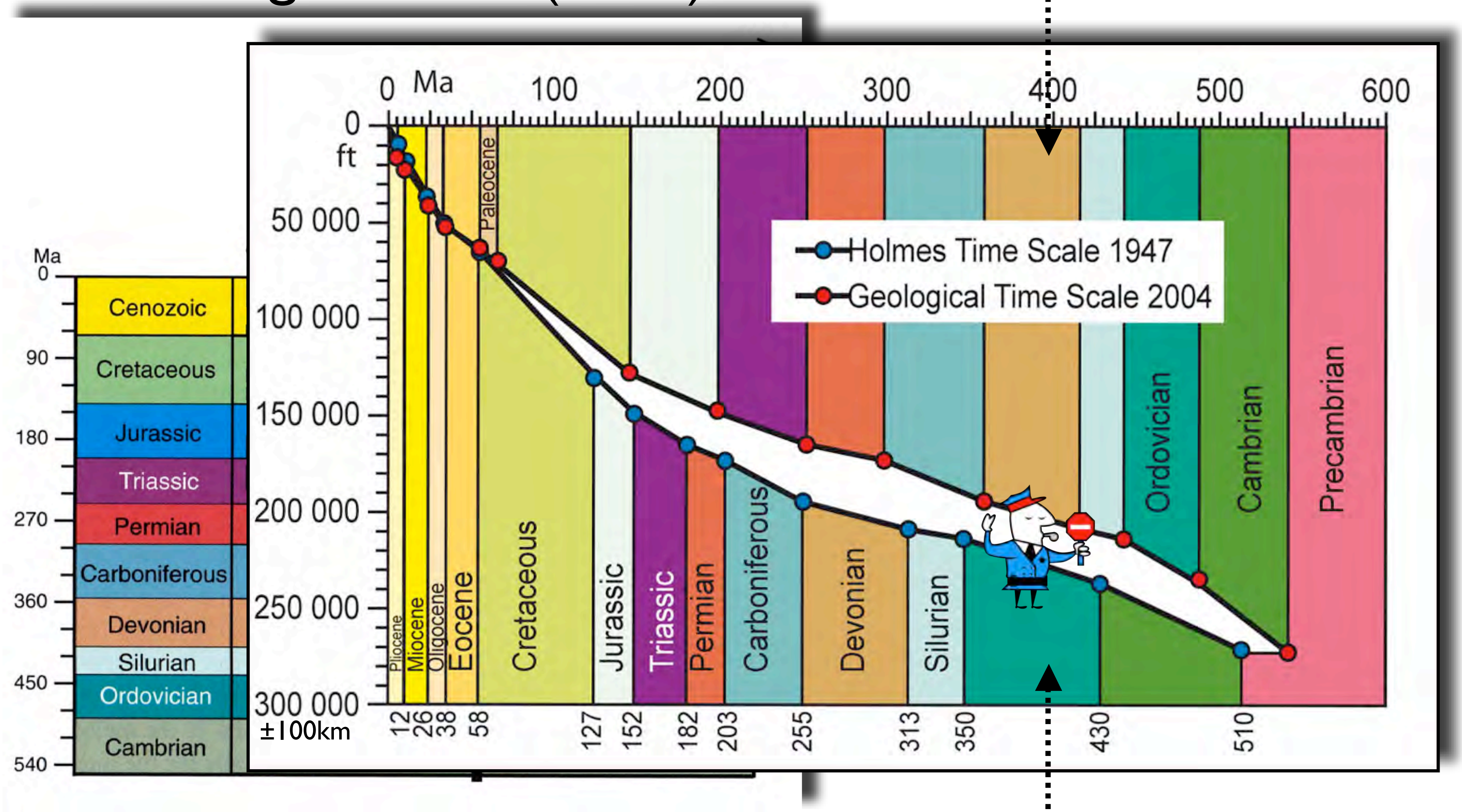
et non plus
380 Ma!
± 5
(en 1995)

PROCHAINE MISE A JOUR: 08-2016

www. stratigraphy.org

Dev

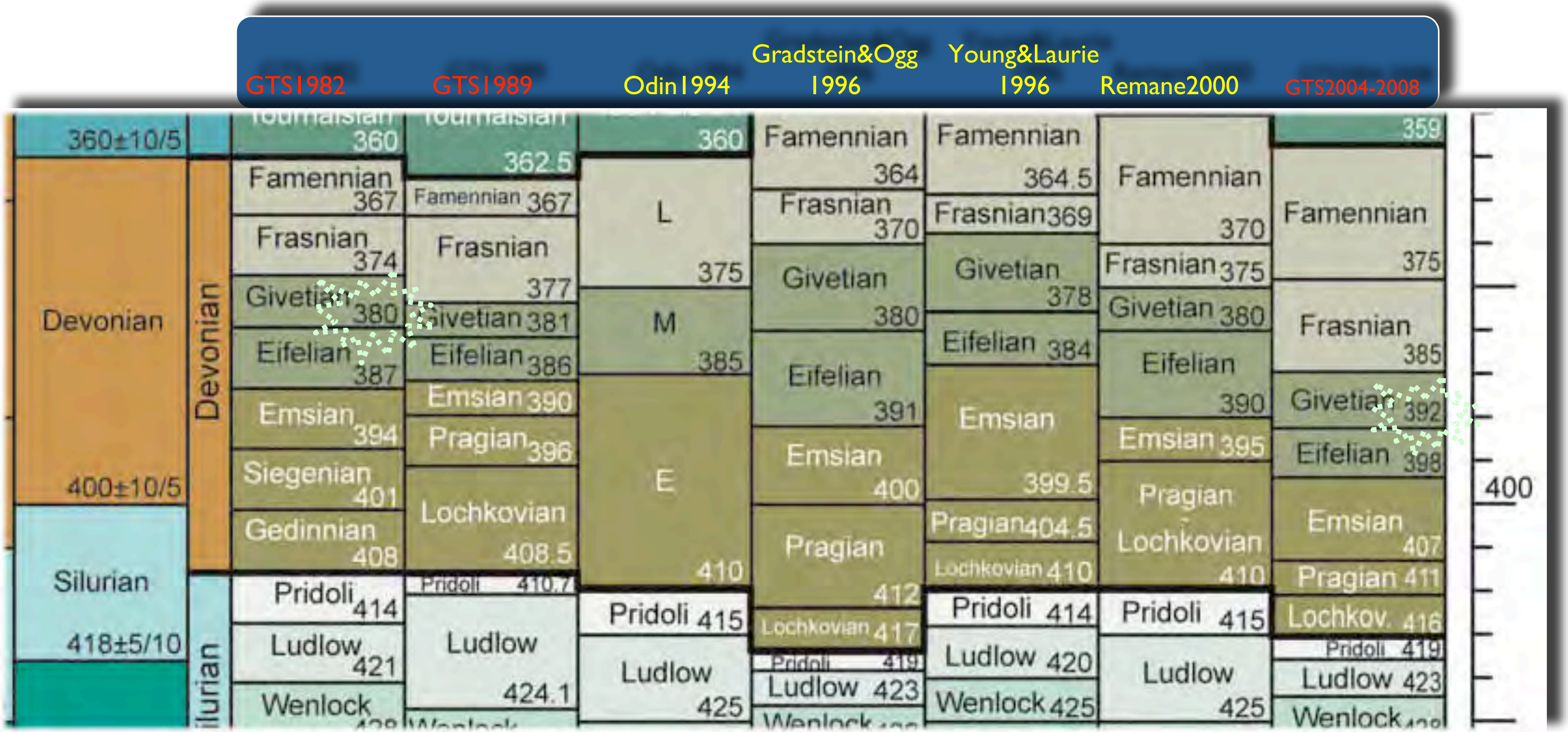
GTS August 2004 (2008)



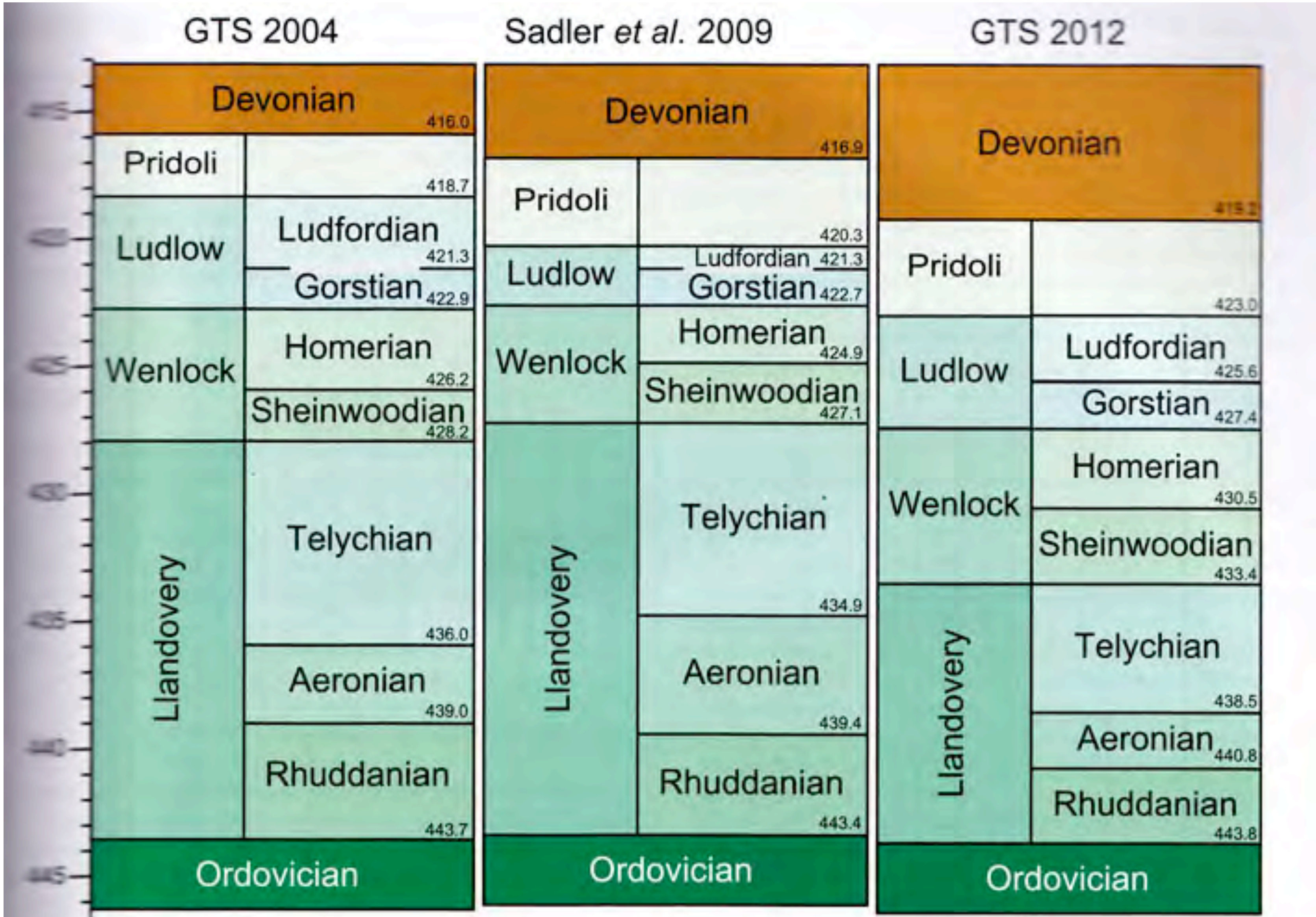
Ord

Absolute time cannot be used to set the scale of geological times

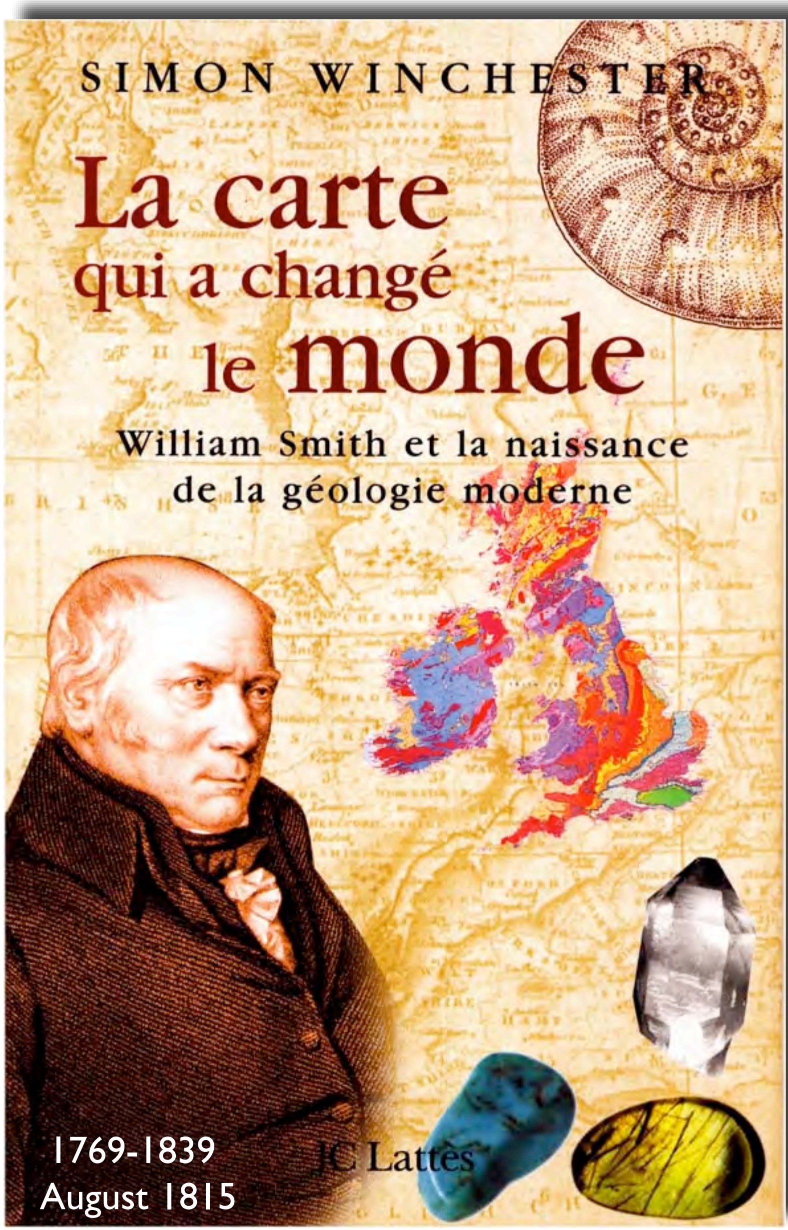
(the names), the ages and therefore the durations change

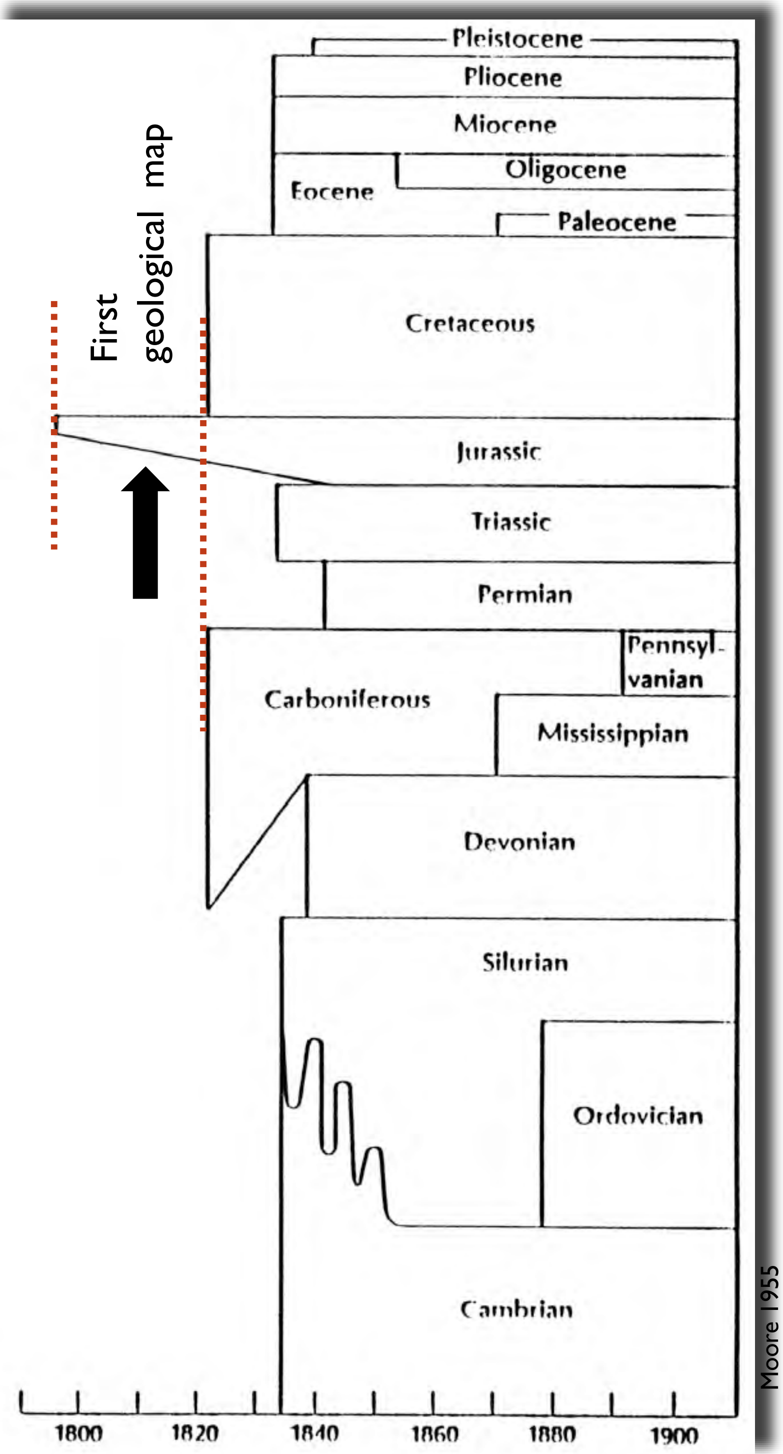


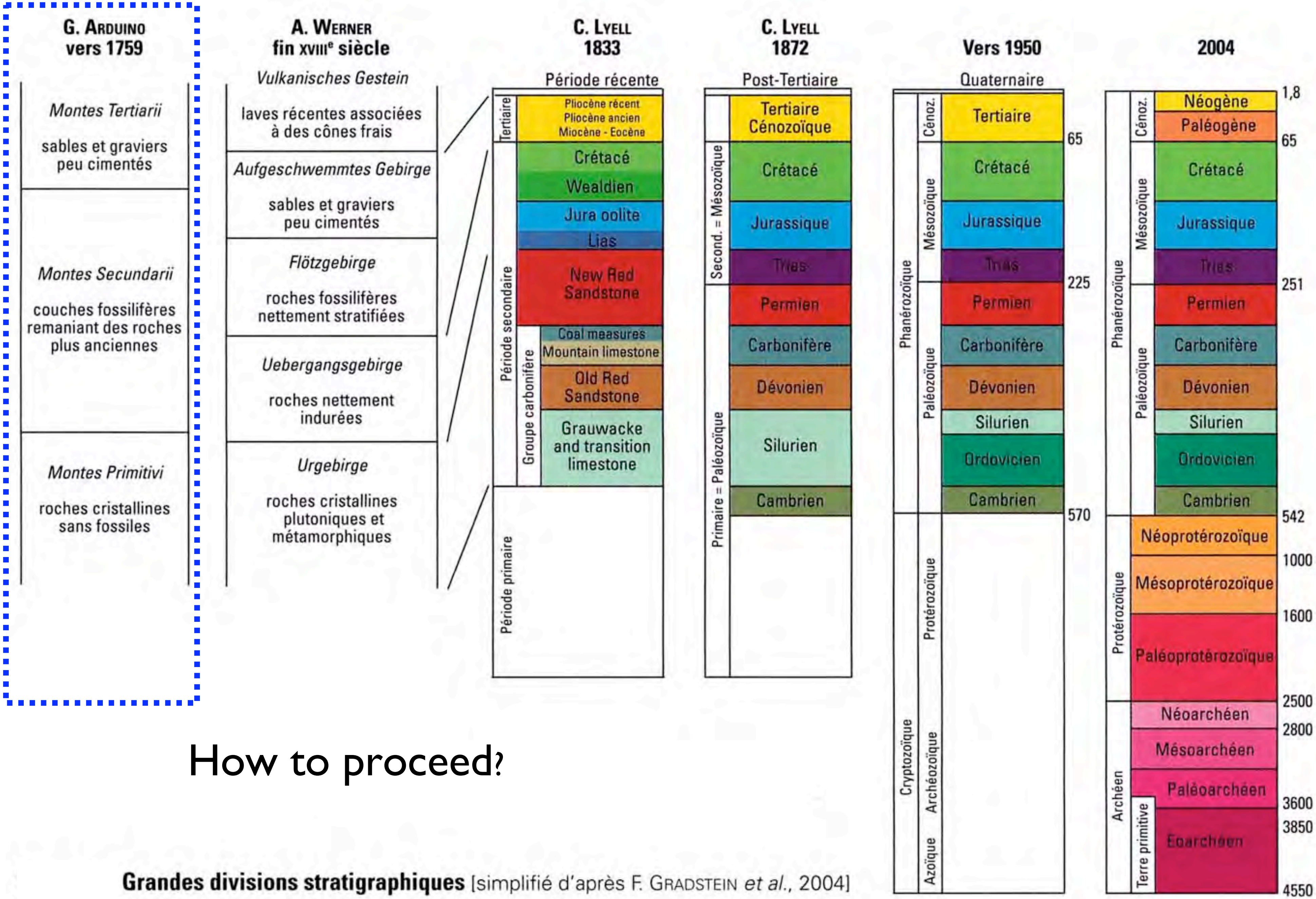
How to get these scales?



Comparison of the CONOP time scales of Melchin *et al.* (2004, GTS2004), Sadler *et al.* (2009), and present (GTS2012), showing series … Note that in the Melchin *et al.* (2004) and Sadler *et al.* (2009) papers, the base of the Wenlock was drawn at a level correlative with the base of the *C.* … Zone, whereas in the GTS2012 column it is drawn at the base of the overlying *C. murchisoni* Zone (see text for explanation).


SIMON WINCHESTER
La carte
qui a changé
le monde
William Smith et la naissance
de la géologie moderne
1769-1839
August 1815
JC Lattès


Pleistocene
Pliocene
Miocene
Oligocene
Eocene
Paleocene
Cretaceous
Jurassic
Triassic
Permian
Pennsyl-
vanian
Carboniferous
Mississippian
Devonian
Silurian
Ordovician
Cambrian
First geological map
1800
1820
1840
1860
1880
1900
Moore 1955



How to proceed?

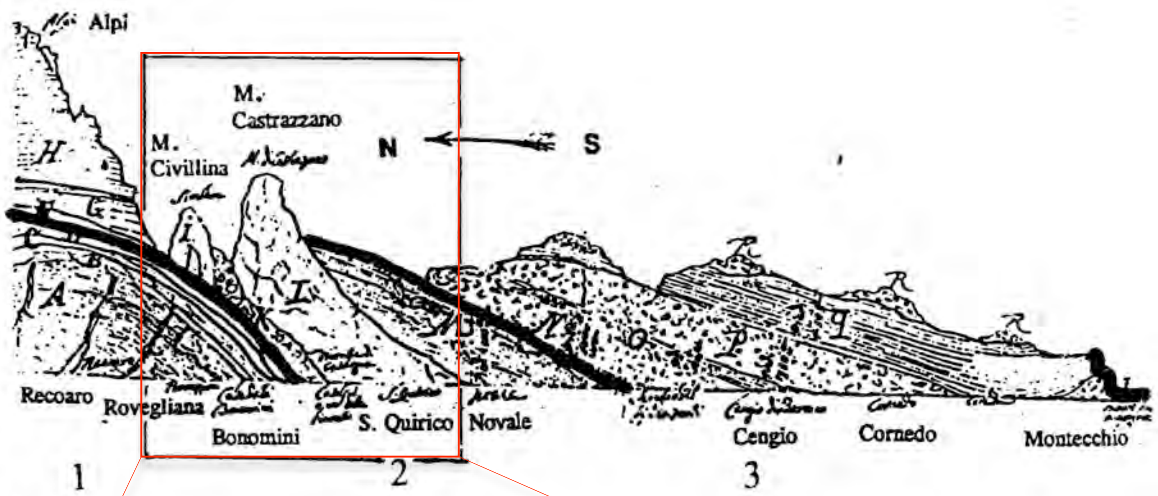
Grandes divisions stratigraphiques [simplifié d'après F. Gradstein *et al.*, 2004]

In Mascle 2008

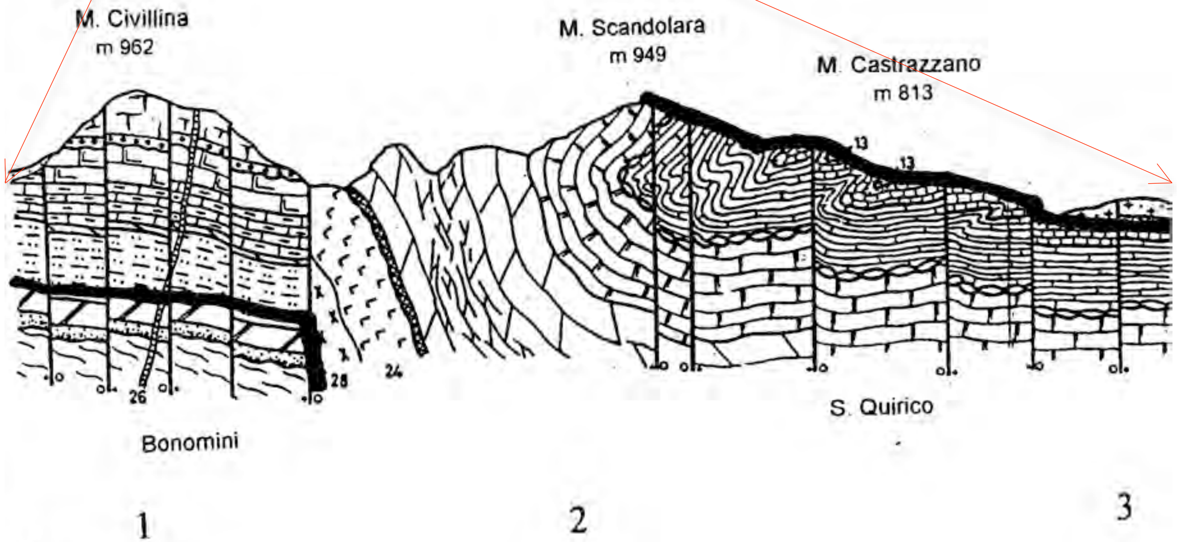
ARDUINO'S LITHOSTRATIGRAPHICAL THEORY (1760-1775)

Units (*Ordini*)	Mountain type	Rock type	Causes
1	Basement/primeval rock (*roccia primigenia*)	Crystalline schist *schisto*	Fire Cooling of the original Earth surface
1	Primary or mineral mountains (*monti primari o minerali*) a. First subdivision b. Second subdivision	Granite, porphyry, and mineral-bearing crystalline rocks (*rocce vetrescibili*); sandstone and conglomerates without fossils	Fire, wind, and water a. Volcanism b. Volcanism and erosion due to wind and water
2	Secondary mountains (*monti secondari*)	Marbles and stratified limestones with fossils; stratified rocks like *vetrescibili* but without mineral veins	Water and fire Marine sedimentation and modifications due to the reprise of volcanism
3	Tertiary mountains (*monti terziari, colline*)	Gravel, clay, fossiliferous sand, volcanic material	Fire and water Volcanism and sedimentation within sea waters
4	Plains (*pianure*)	Alluvial deposits, sometimes stratified	Water Erosion caused by rain and rivers

in Vaccari 2006



A Modified profile from the sketch by G. Arduino



B Modified profile from G. Barbieri et al. 1980

Vaccari 2006

the
GOAL

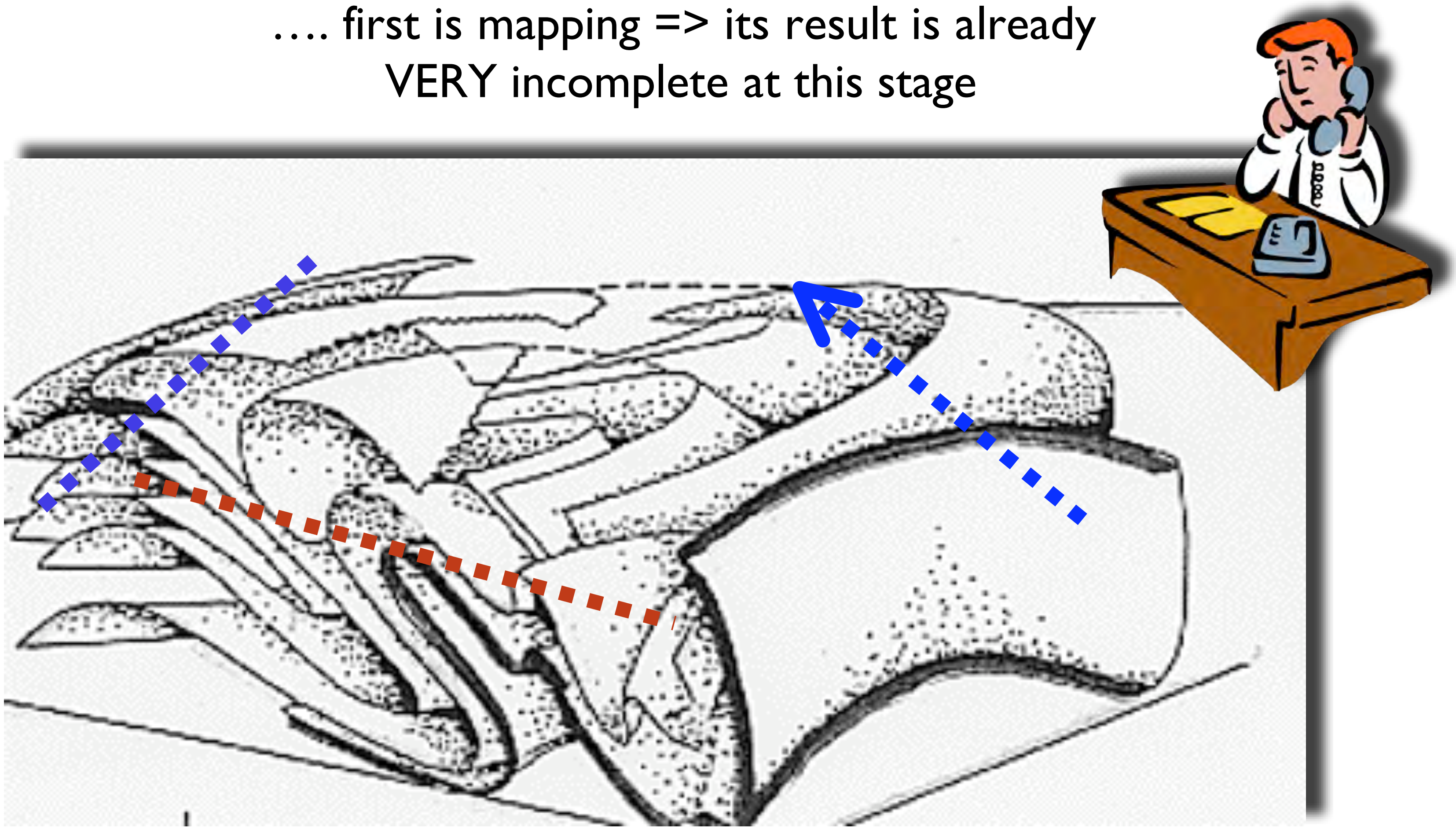
ESTABLISH A CHRONOLOGY or A CHRONOSTRATIGRAPHY

= infer the event chronology having affected the Earth

= establish synchronisms between coeval formations (same age) which are geographically separated, and display various features (lithology, paleontology …)

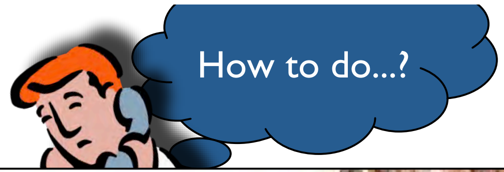
OUTCROPS
=folded notebook,
jagged... =mapping

Outcrops = folded, jagged notebook
…. first is mapping => its result is already VERY incomplete at this stage



metamorphism <==> compression
South APPALACHIAN (Caroline)
The foldings are so often complex that is difficult to represent them even as diagrams!

‘local’ 2D (disconnected)



apparent simplicity …

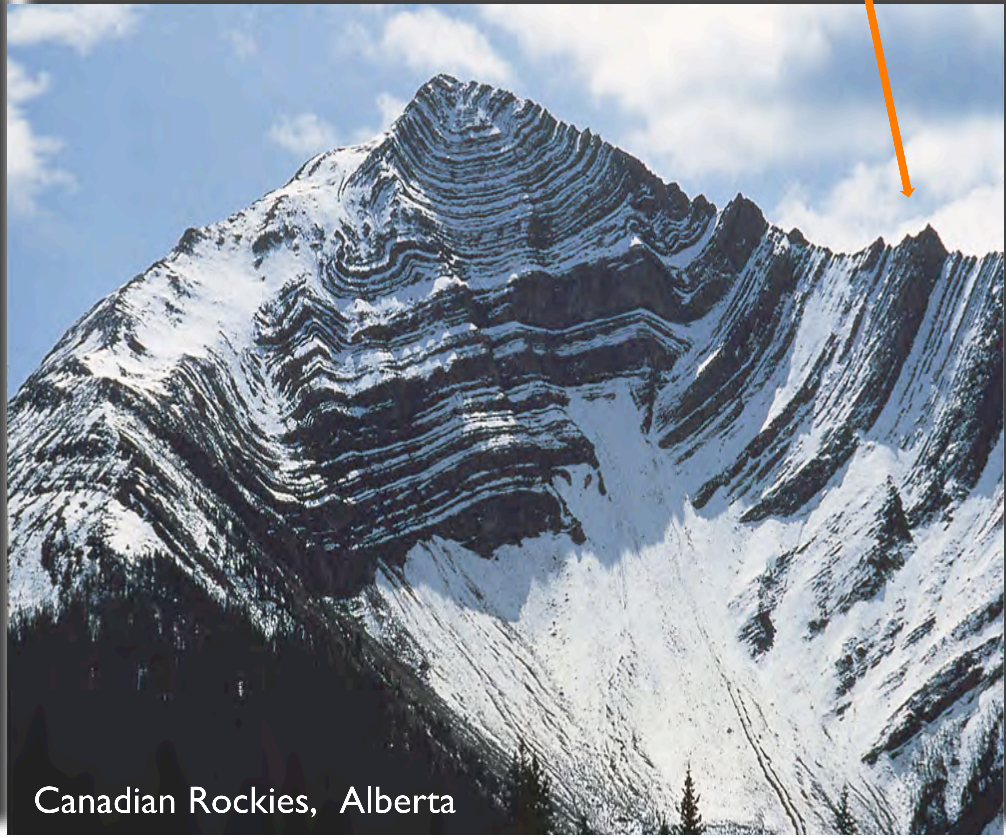
1. Principle of superposition

2. Principle of continuity

3. Principle of palaeontological identity

Principle of superposition (horizontality at the origin)

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



Application on the field.... not so easy ....

younger older

Principle of superposition (horizontality at the origin)

Application on the field…. not so easy ….

Principle of superposition (horizontality at the origin)

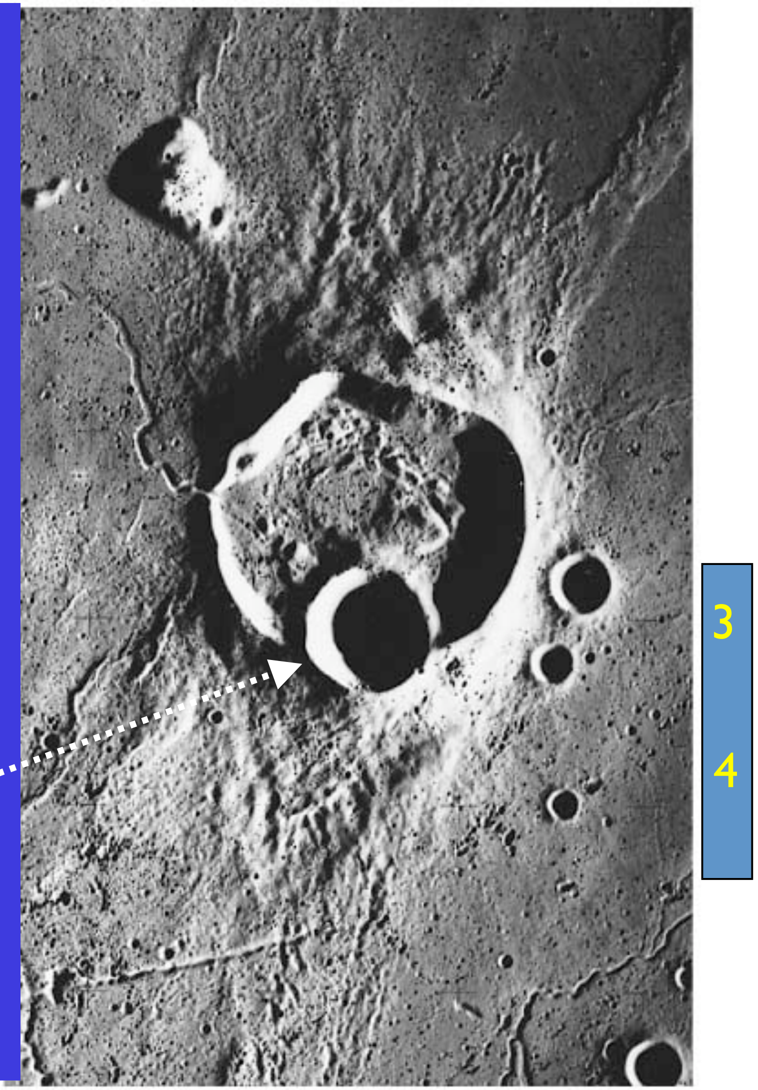
Principle of superposition valid at all scales

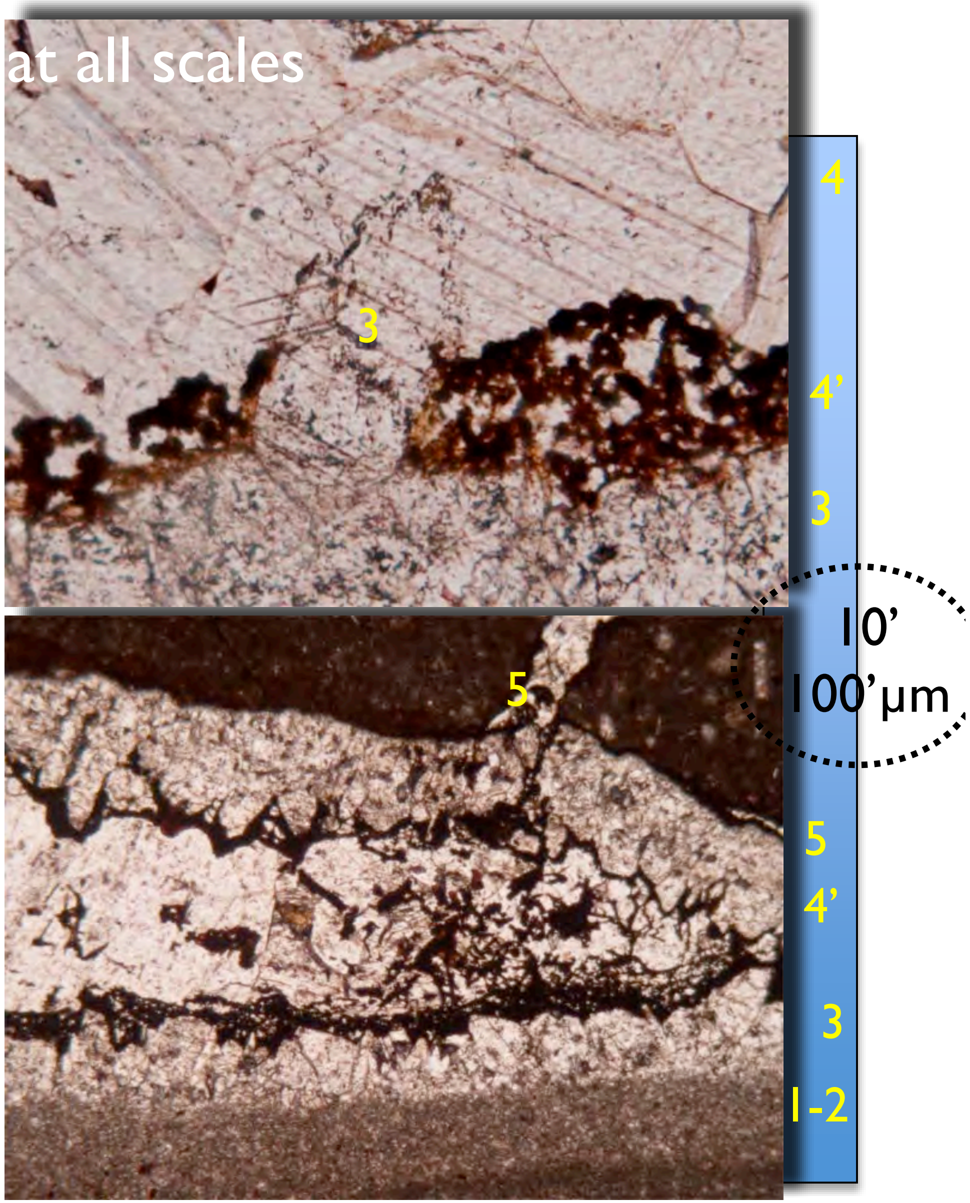
10'
100'km

Easy

All the others

are difficult





1. Principle of superposition

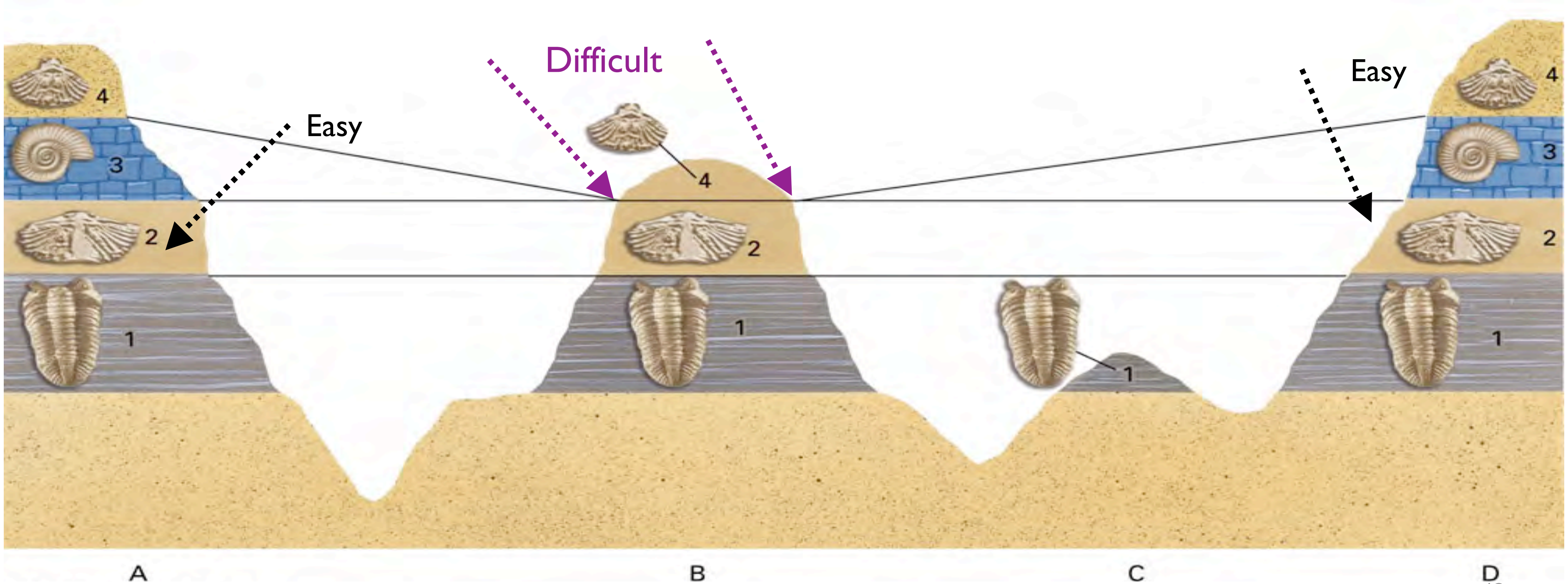
2. Principle of continuity

3. Principle of paleontological identity

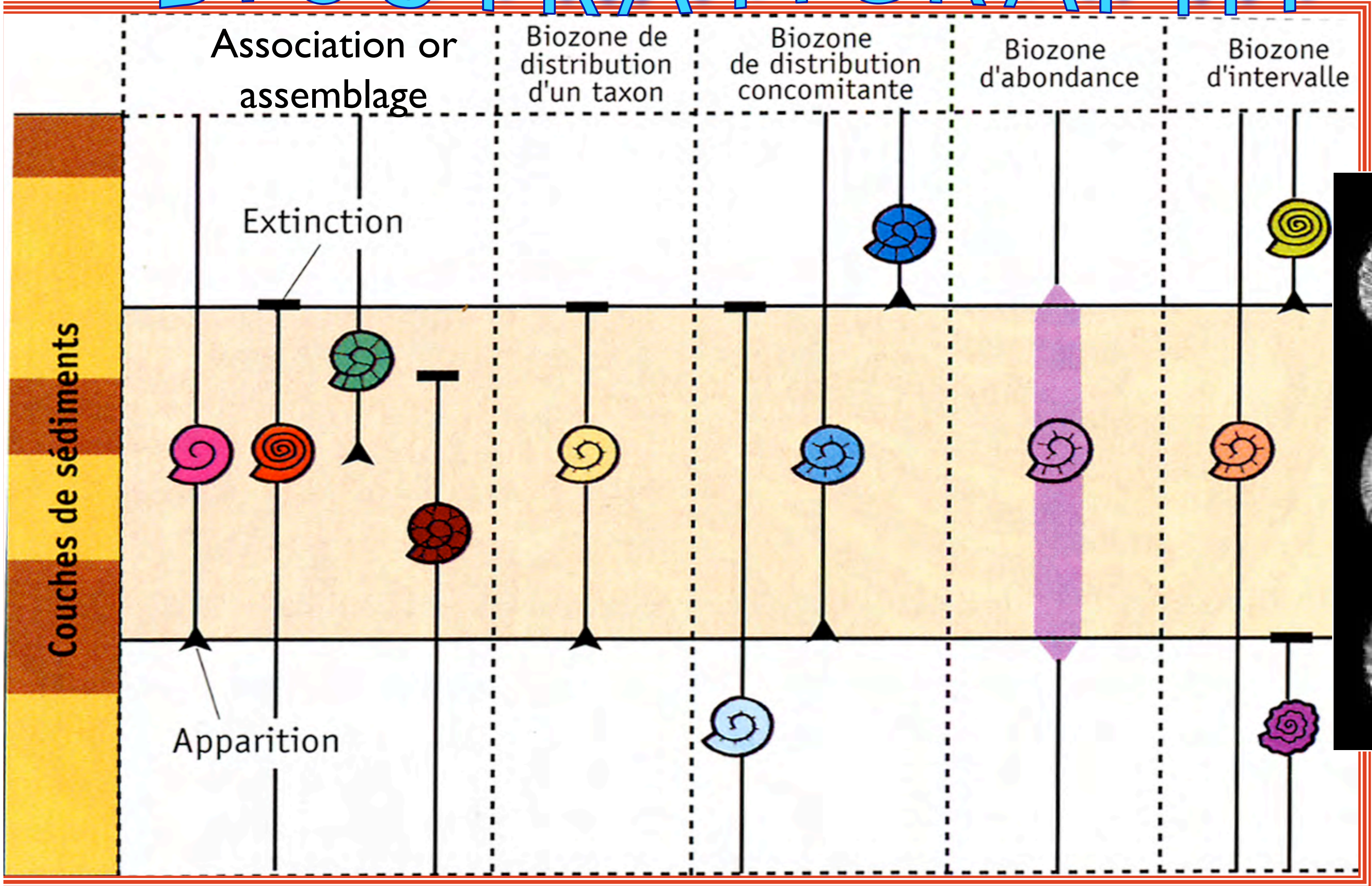
= 'Index Fossils'

Abundant (preservation) – Large geographical distribution

Fast evolution (tachytely) – Easily recognizable



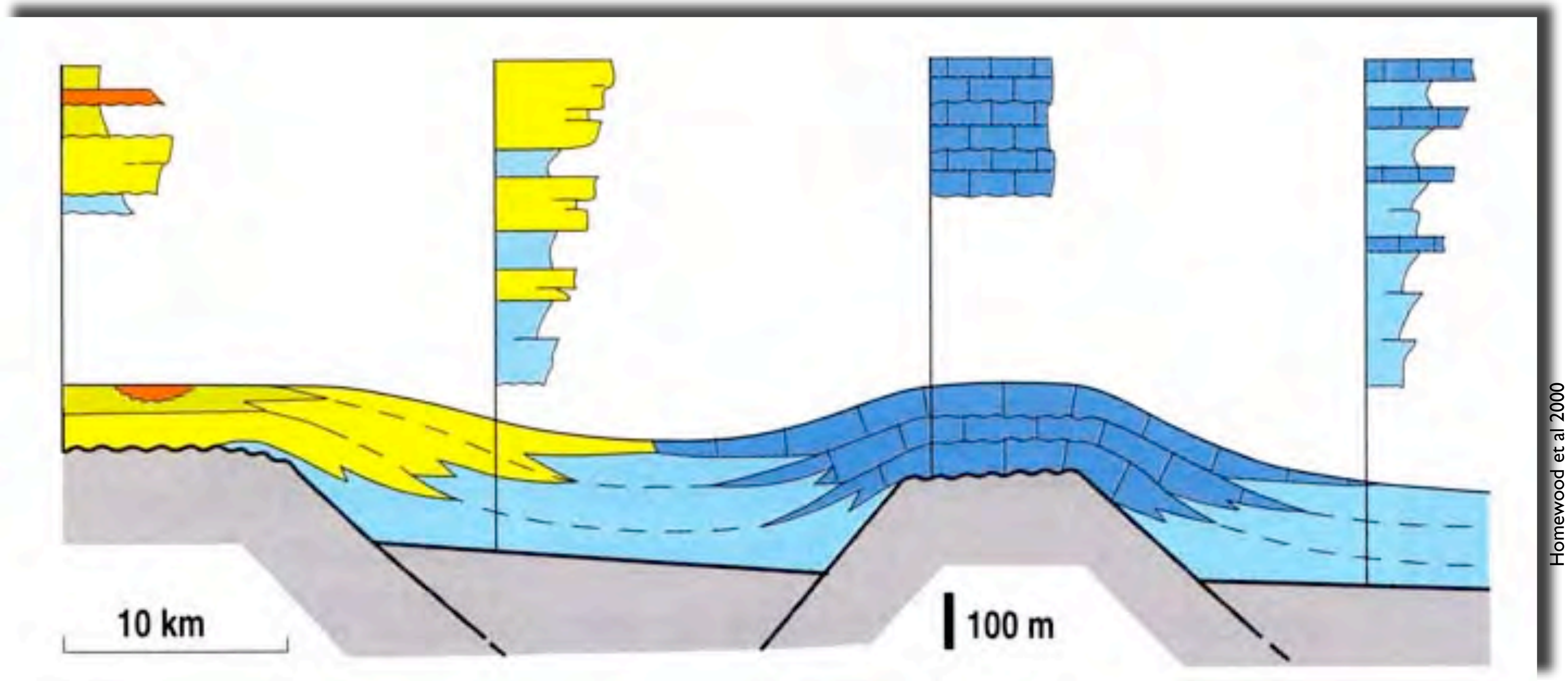
BIOSTRATIGRAPHY



A fossil 'alone' is not helpful..... (unfortunately...)

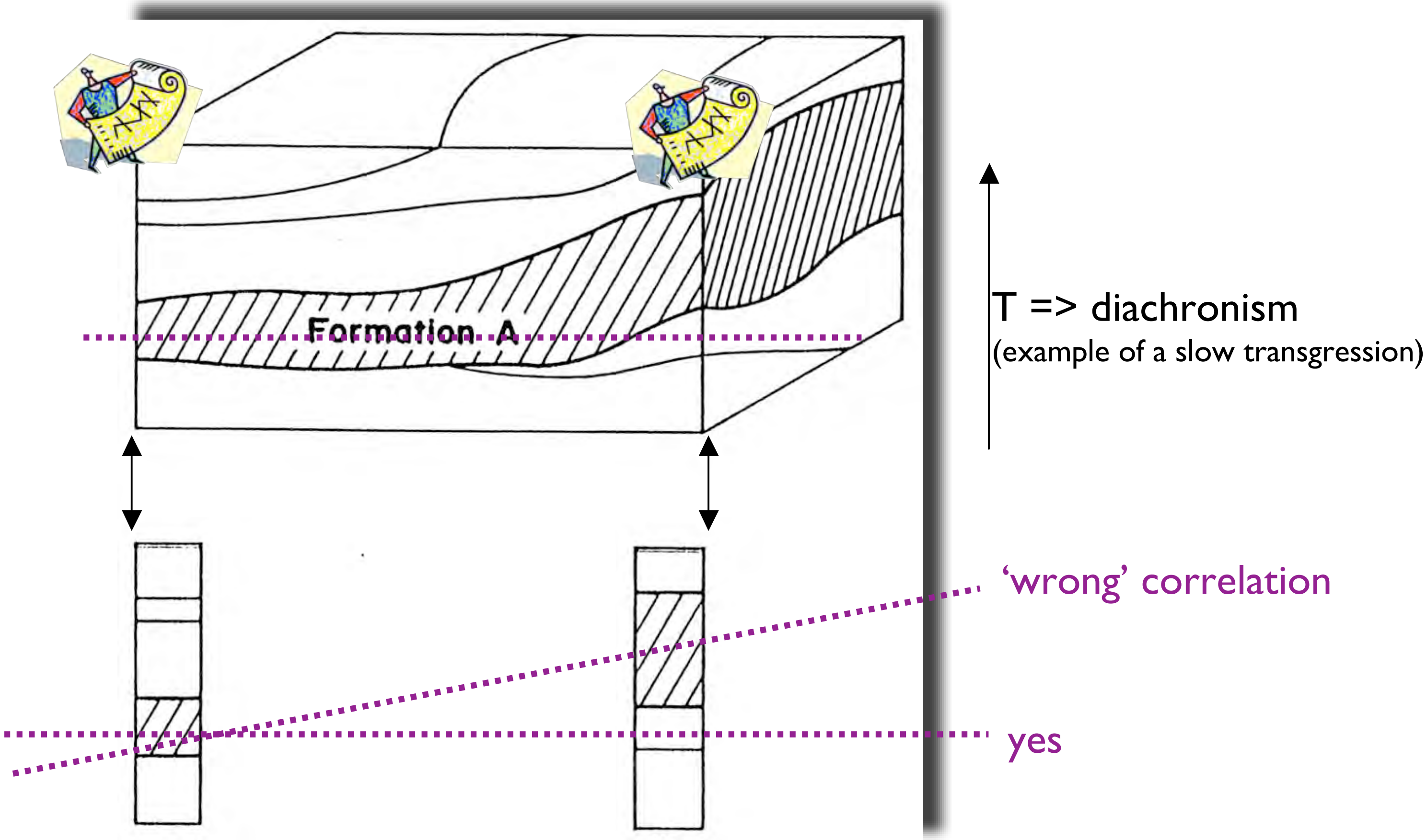
WHY THE PRINCIPLE OF SUPERPOSITION
(and the other two)
DO IT RESOLVES NOT IMMEDIATELY
PROBLEMS WITH CORRELATIONS?

The lateral facies variations are the rule
Facies fossils vs Stratigraphic fossils



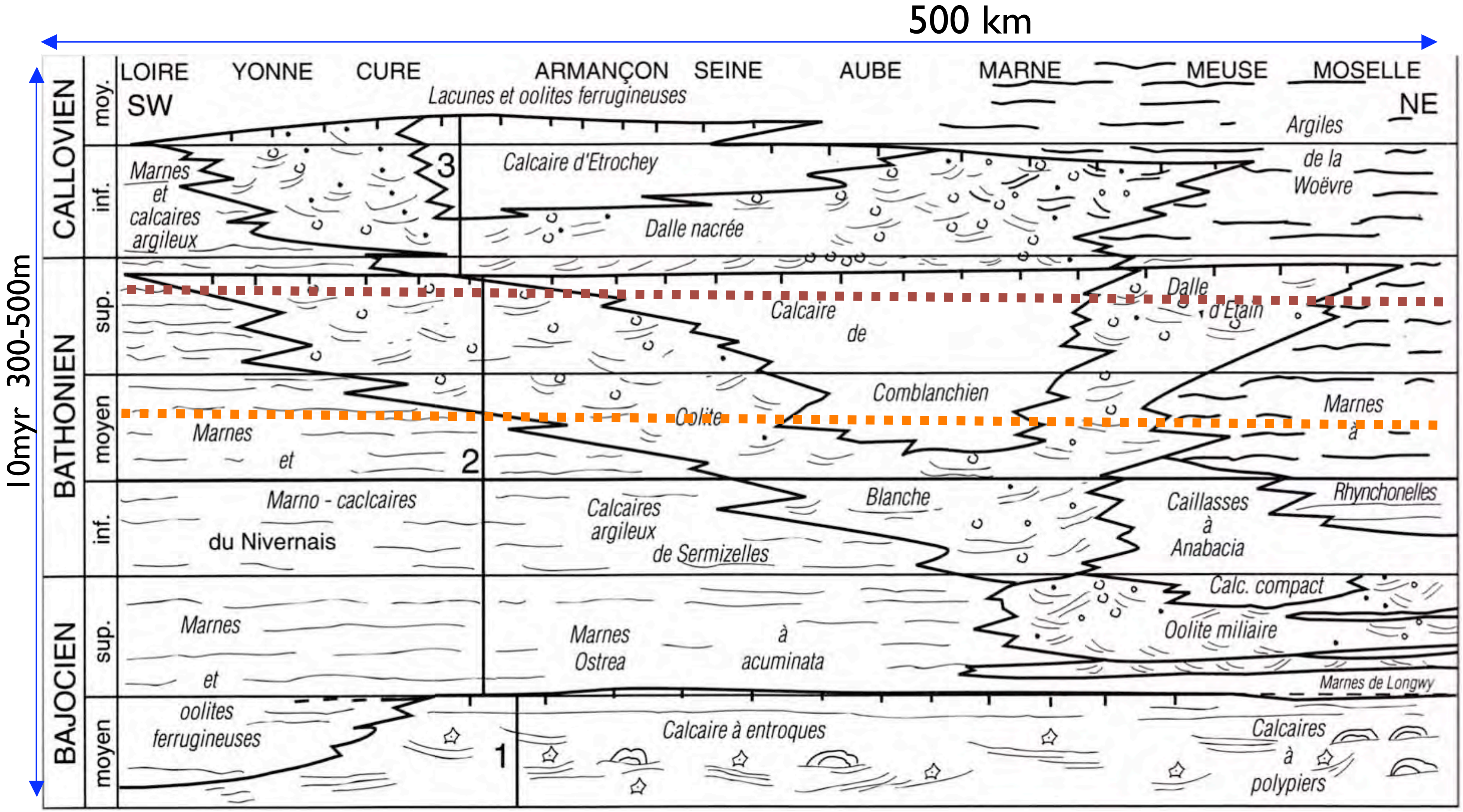
Homewood et al 2000

The lateral facies variations are the rule (all scales)



Example: all the clastic Lower Devonian of Belgium ... and many European areas

‘reconstructed’ 2D



Cavelier et al 1980

DOGGER – PARIS BASIN

progradational sedimentary systems

HOW TO DO?

BASIC PRINCIPLE(S)
is
I N T U I T I V E

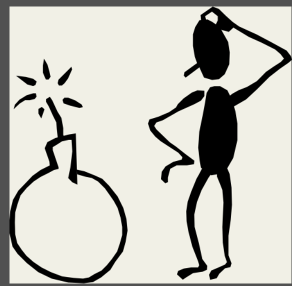
namely that the filling of a certain amount of material (thus the thickness of a layer) = a certain period of time (...which increases with the amount....)

...it worked like that for two centuries!

WRONG and COMPLETELY WRONG

Samuel Haughton (1821-1897, Irish geologist)
« the maximum thicknesses of the strata are proportional to the times of their formation »
=> 'one foot = 8616 years!....'

So one year= 0,03 mm



A. PREAT U.Brussels/U. Soran

‘normal’ and ‘continuous’ geological series
Why is it wrong, completely wrong?

condensed series *vs* comprehensive series (Frasnian of ‘Coumiac’ *vs* Belgian Frasnian)
many other examples => 1:10 à 1:1000 (thicknesses ratio)

- differential subsidence : rifts series = tilted blocks over a few km, 10’km or 100’km
- joints/no joints : examples of carbonate series (=> also ‘cryptic’ discontinuities = ‘diastems’)
- differential compaction : clayey series *vs* others

....

....

exceptional preserved events (tempestites) : Gulf of Mexico with coastal accumulation of 10cm/1000yr (very high). Each coastal segment has a 95% probability to be hit by a hurricane which erodes > 30 cm (very frequent at geological scale)
=> in a few sec, min, h => erosion of 3000yr of sedimentation ...

- ...

THE SEDIMENTATION IS NOT CONTINUOUS
THEY ARE MORE ‘GAPS’ THAN ‘RECORDS’

HOW TO DO?

INITIALLY based on successive apparitions/disparitions of groups of organisms
=>not in metamorphic, magmatic (or volcanic) successions
=> ONLY sedimentary series (mainly marine)

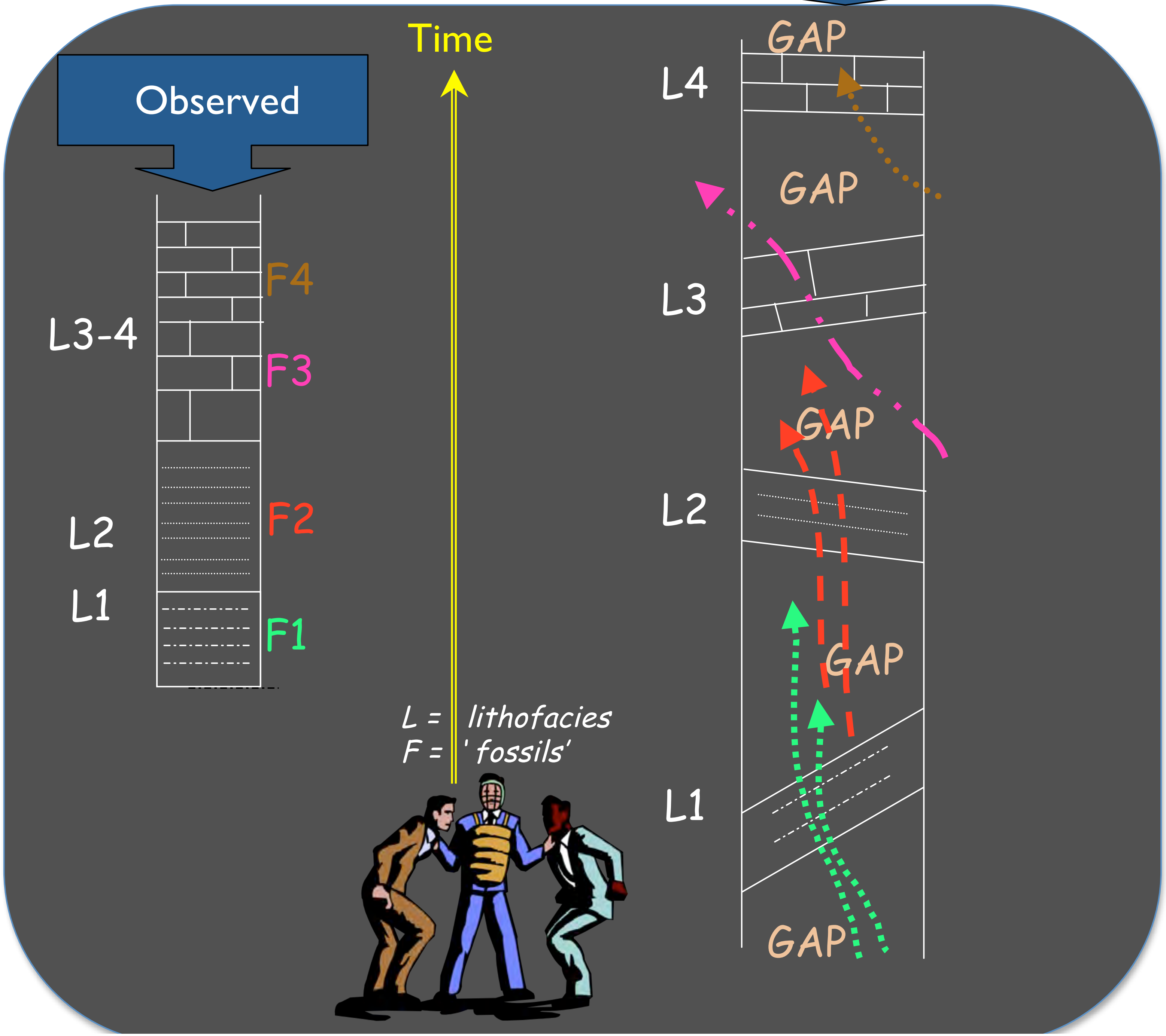
STRATIGRAPHY = RELATIVE CHRONOLOGY
already in the 18th century

and series ages are expressed relative to each other
WITHOUT TIME UNIT

HOW TO DO?

1.GEOMETRY =>2. REL/ABS TIME =>3. KINETICS

Reality is not observed



+ DECOMPACTION

MANY CONSEQUENCES
Example of representation of diagrams

(including the 'rock-time' vocabulary)

LITHOSTRATIGRAPHY

SERIES	FORMATION	
Upper Cretaceous	*Obscura Shale*	400 m
	Perfecta Sandstone	150 m
	disconformity	
Upper Jurassic	*Horrorosa Formation*	350 m

observed

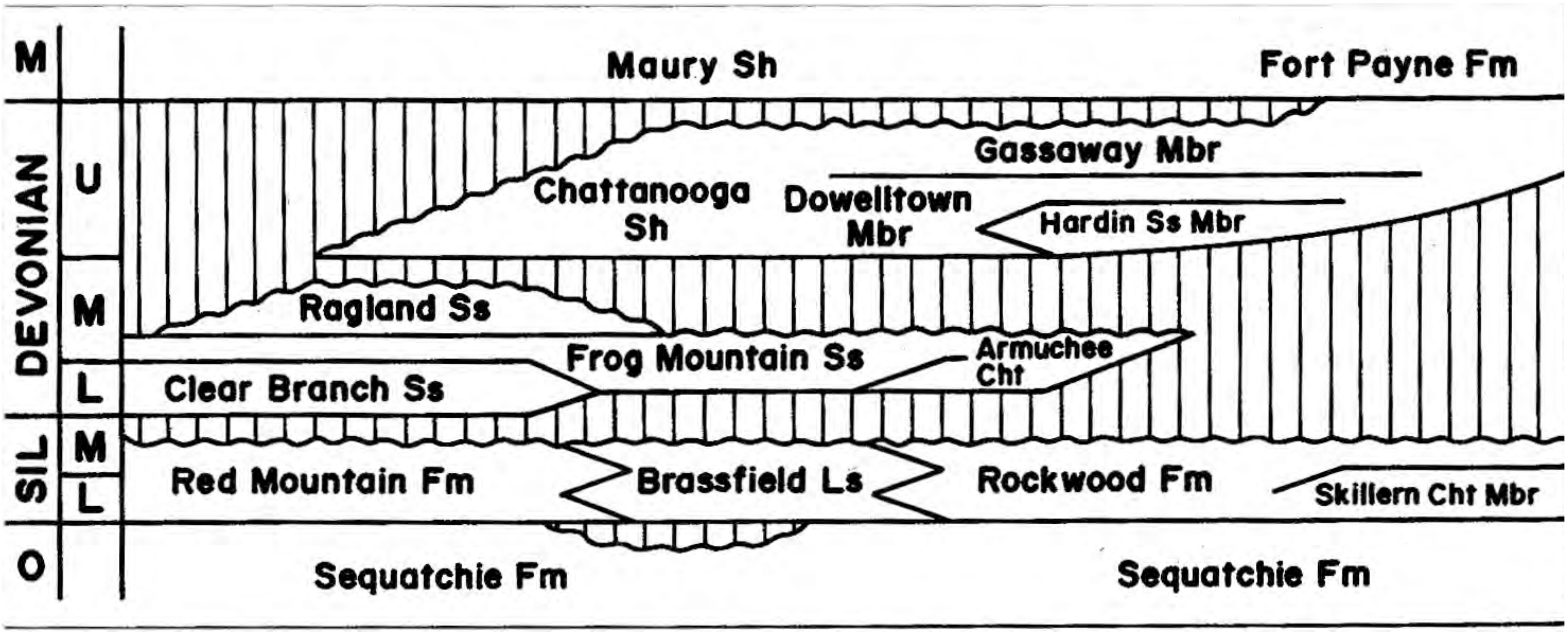
CHRONOSTRATIGRAPHY

	EPOCH	FORMATION
_70Ma _100Ma	Late Cretaceous **30 myr**	*Obscura Shale* *Perfecta Sdst*
	Early Cretaceous	HIATUS
_140Ma _180Ma	Late Jurassic	*Horrorosa Fm*

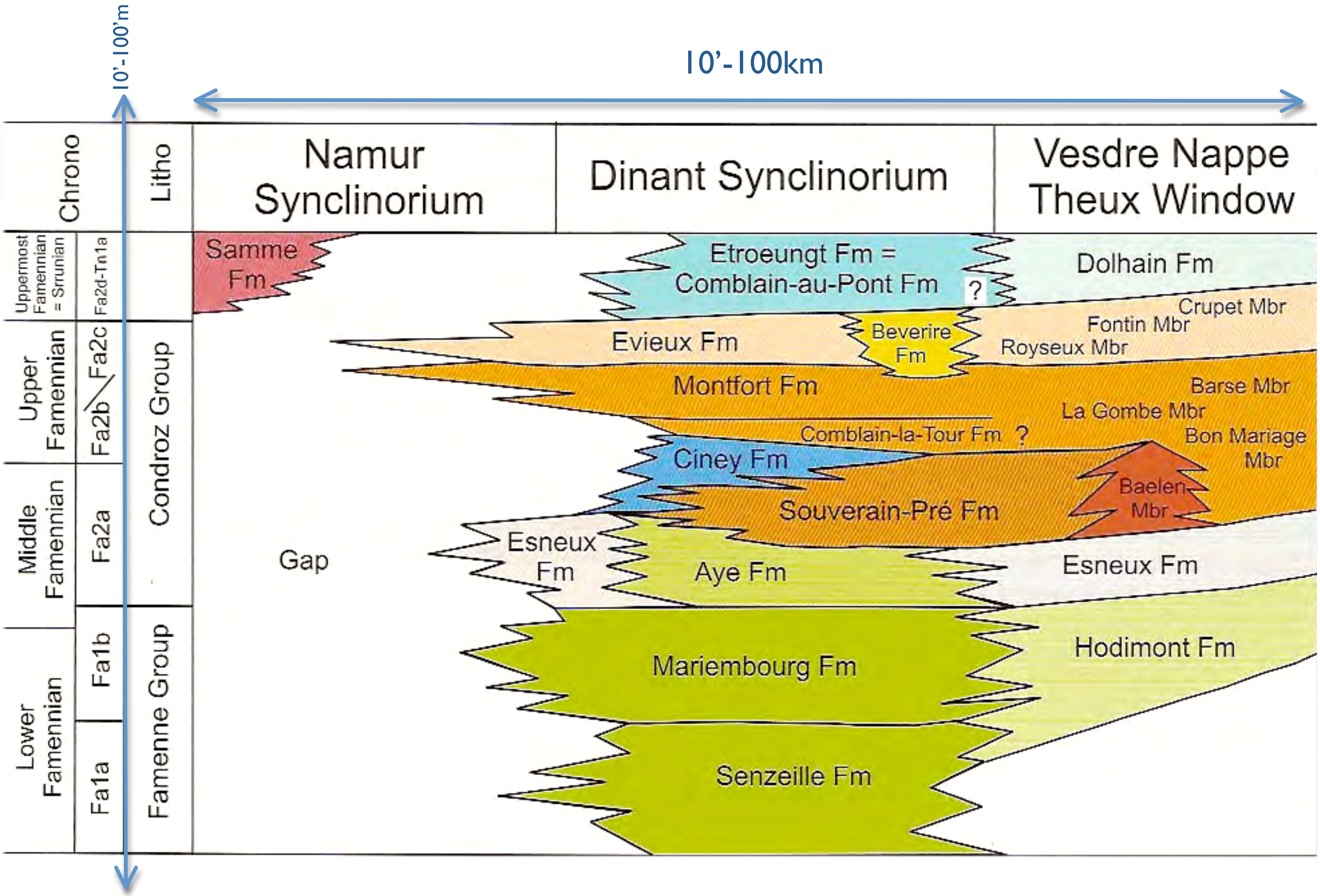
not observed

deduced

CORRELATION CHART SHOWING **APPROXIMATE** TEMPORAL RELATIONS AMONG THE FORMAL ROCK UNITS OF DIFFERENT REGIONS

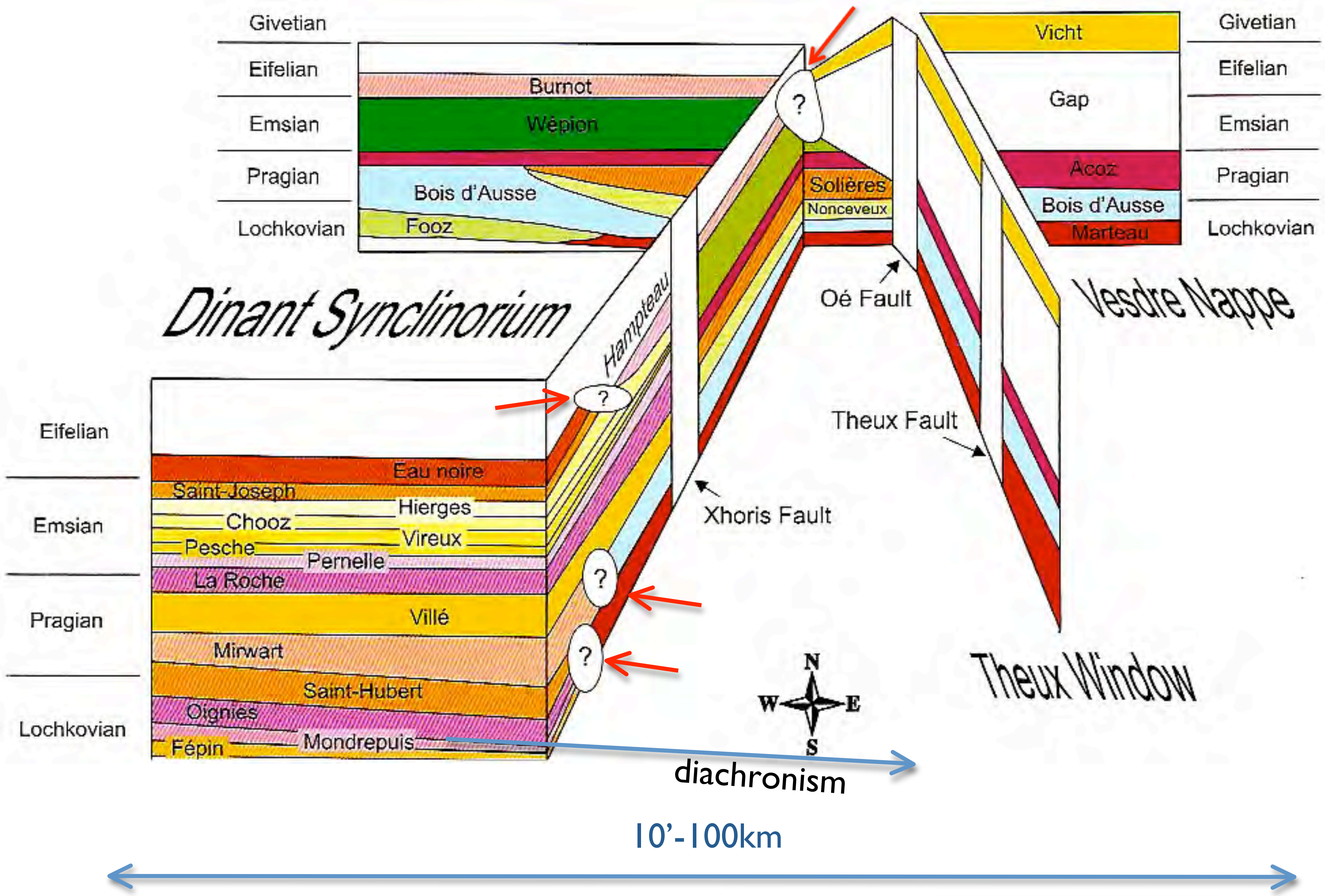


in McLane 1995

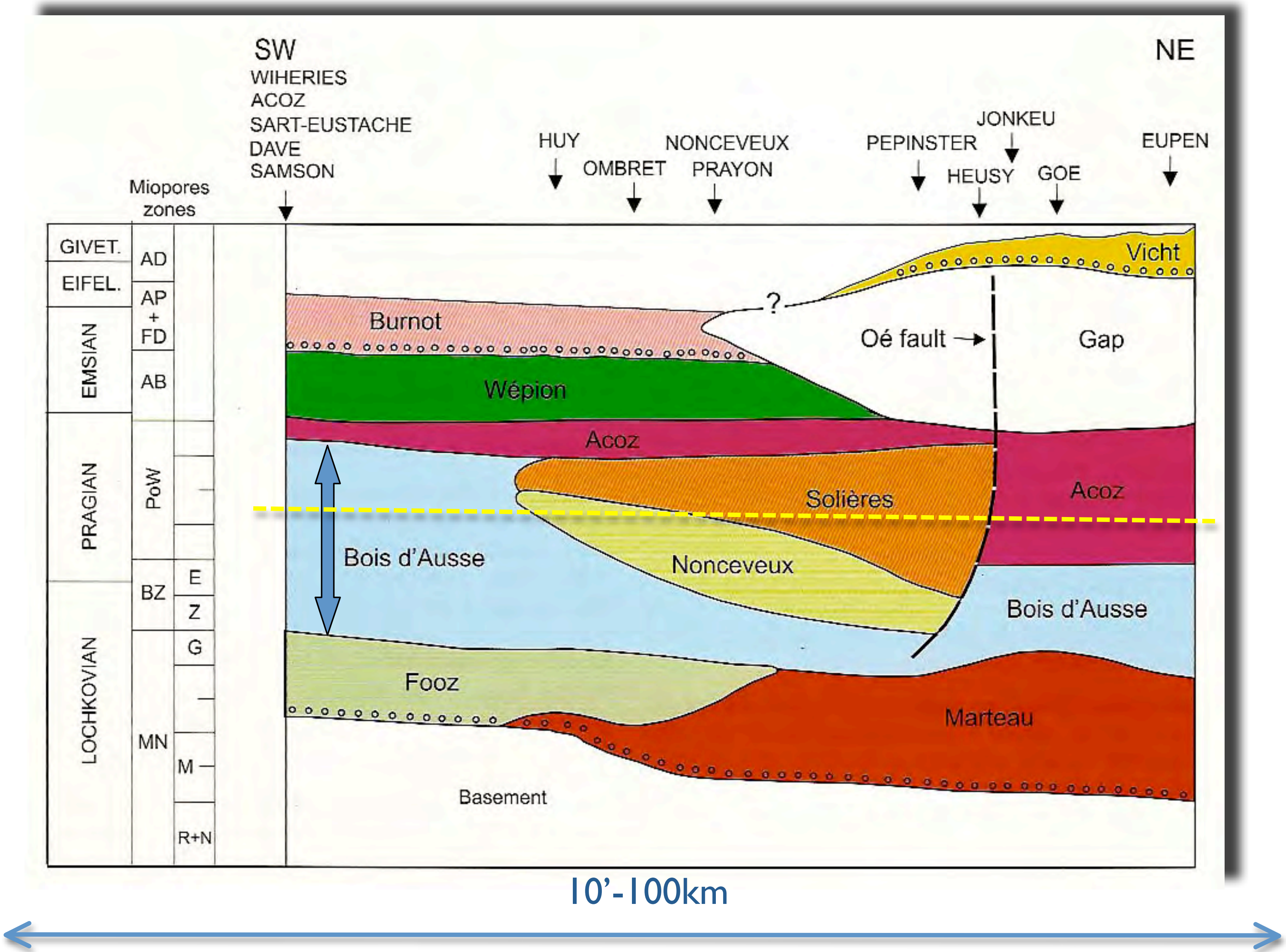


10'-100km
10'-100'm
Chrono
Litho
Namur Synclinorium
Dinant Synclinorium
Vesdre Nappe Theux Window
Uppermost Famennian = Srunian
Fa2d-Tn1a
Upper Famennian
Fa2c
Fa2b
Middle Famennian
Fa2a
Lower Famennian
Fa1b
Fa1a
Condroz Group
Famenne Group
Samme Fm
Etroeungt Fm = Comblain-au-Pont Fm
?
Dolhain Fm
Crupet Mbr
Fontin Mbr
Royseux Mbr
Evieux Fm
Beverire Fm
Montfort Fm
Barse Mbr
La Gombe Mbr
Comblain-la-Tour Fm ?
Bon Mariage Mbr
Ciney Fm
Baelen Mbr
Souverain-Pré Fm
Gap
Esneux Fm
Aye Fm
Esneux Fm
Mariembourg Fm
Hodimont Fm
Senzeille Fm

LOWER-(MIDDLE) DEVONIAN SOUTH BELGIUM

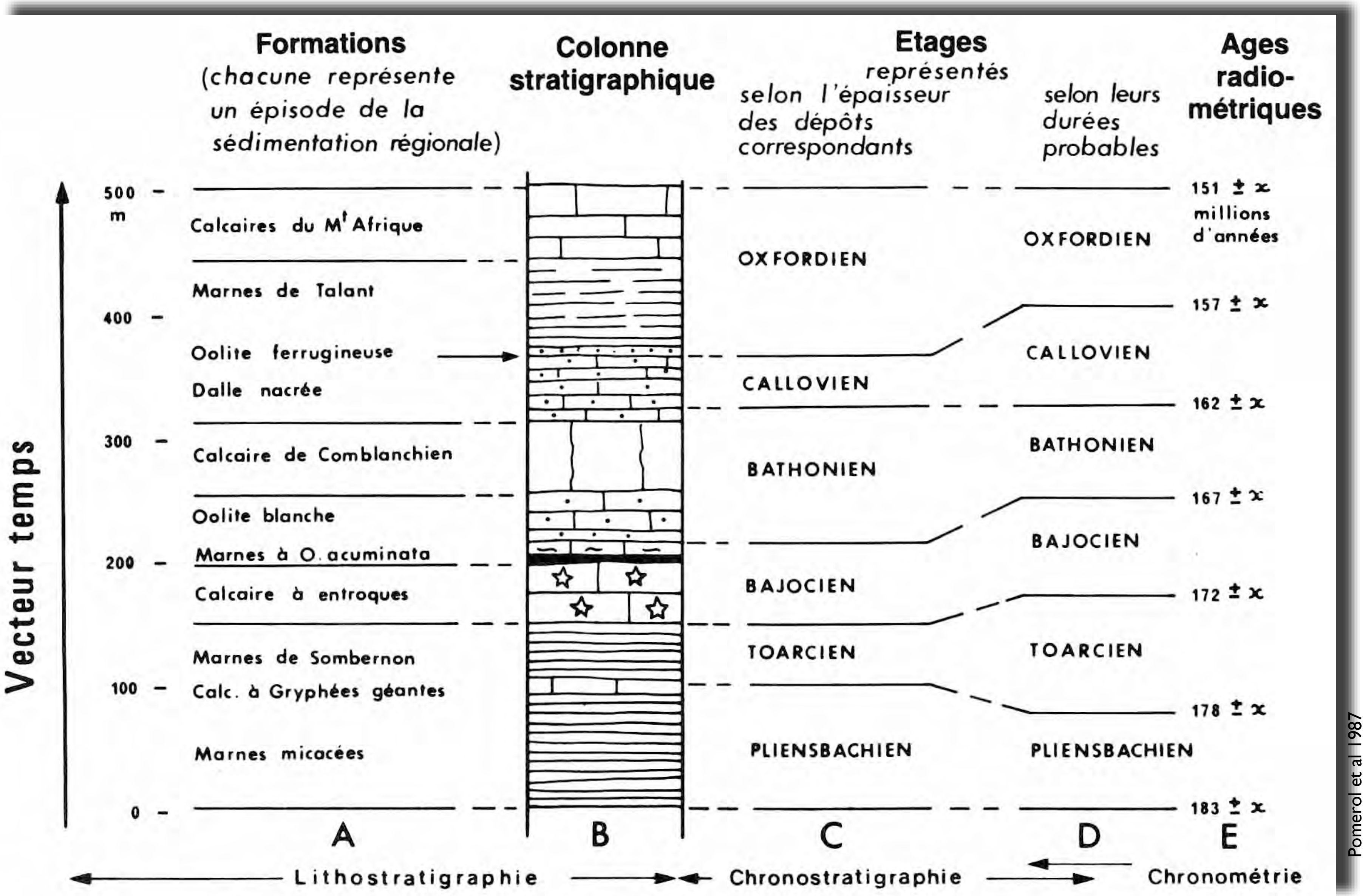


LOWER DEVONIAN SOUTH-EASTERN BELGIUM

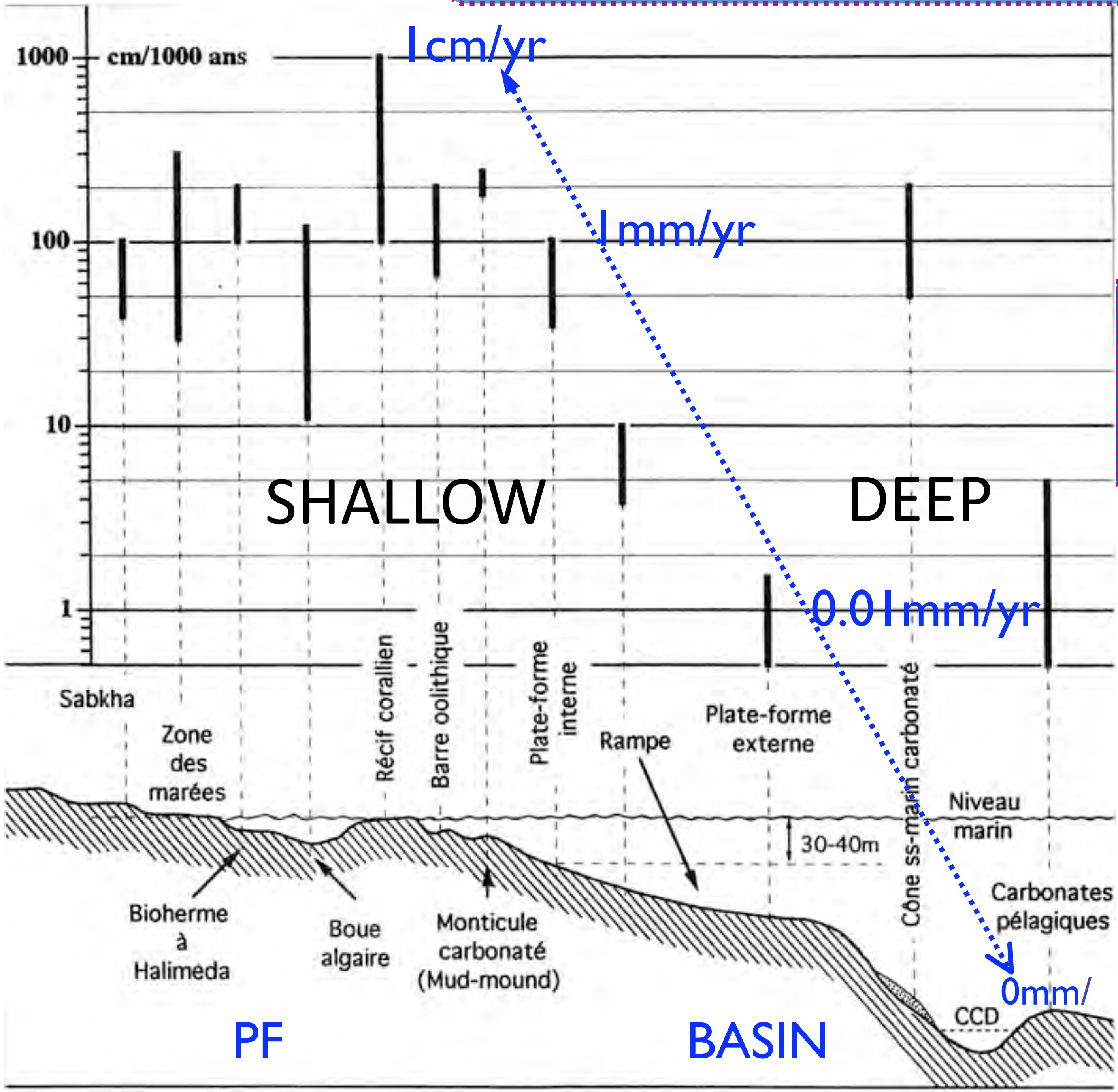


10'-100km

Observed	'Not observed'



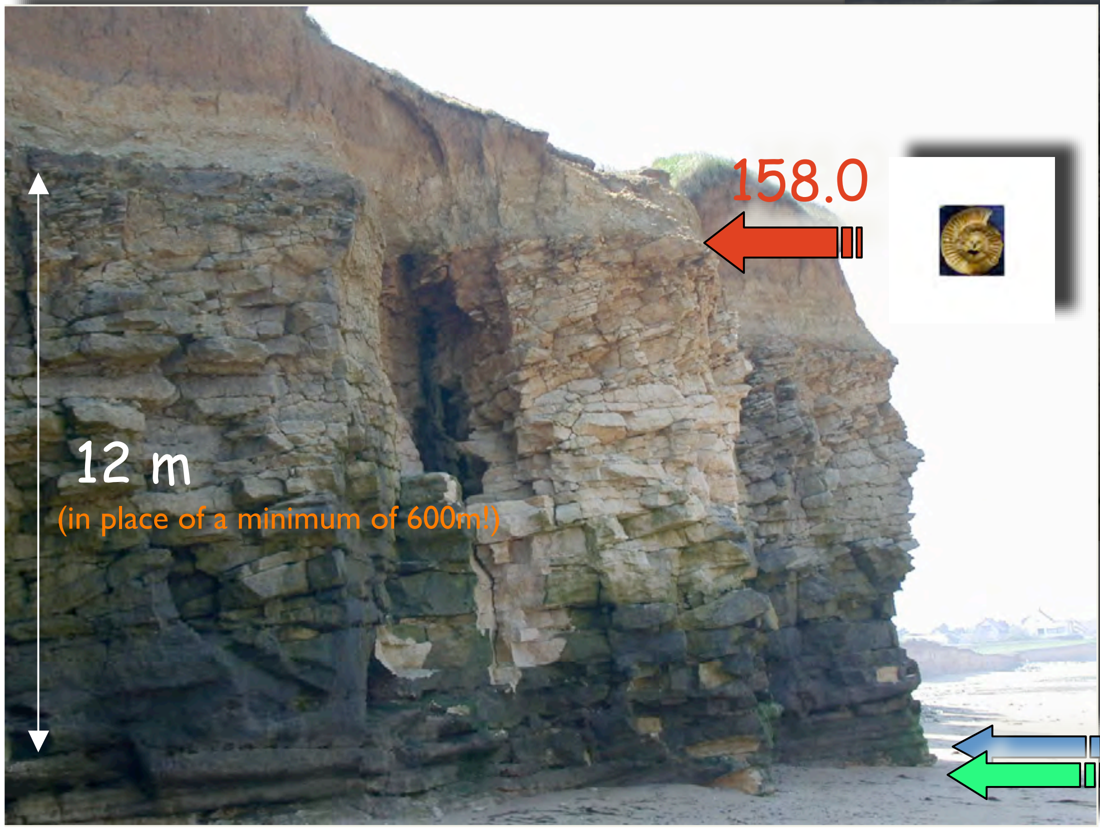
Why so much difference? First explanation...



Sedimentation rates
1:1000
+
No deposit
+
Erosion (syn-, post)

short term
vs
long term

UPPER BATHONIAN
LUC-SUR-MER



60cm/500 000 yrs= 0.001mm/yr

12m/500 000yr= 0.02mm/yr

= WRONG VALUE ..... =1mm minimu...ARE WE SURE?

i.e. 0.01mm/yr
for12.6m/1Ma
±1% of geological time
or much less

A. PREAT U.Brussels/U. Soran

Quarry
Energy?
Time?
Biostratigraphy?

1. GEOMETRY

Time lines are generally oblique (sedimentary bodies)
Then the series is folded, thrusted ('jagged')

2. ABSOLUTE AND RELATIVE TIME

Both remain necessary

3. RATE

The kinetics of the phenomena depends of time resolution

TIME IN GEOLOGY
a false intuition....

$T_{x'}$

0.5
to
5%

T_x

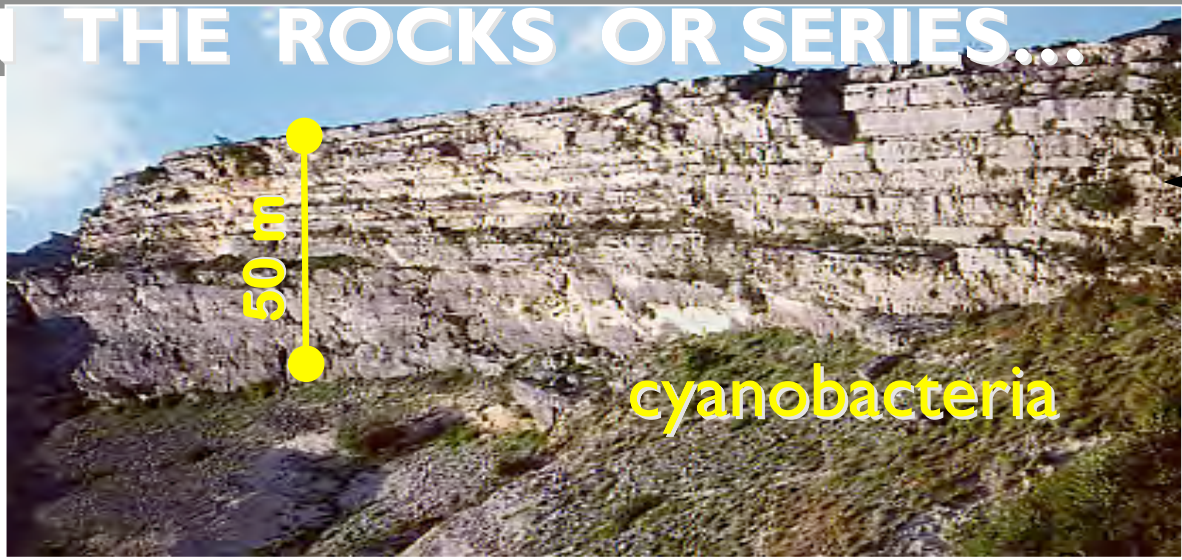
So 95 à 99.5% of time is missing

A ‘normal’ and ‘continuous’ geological succession?

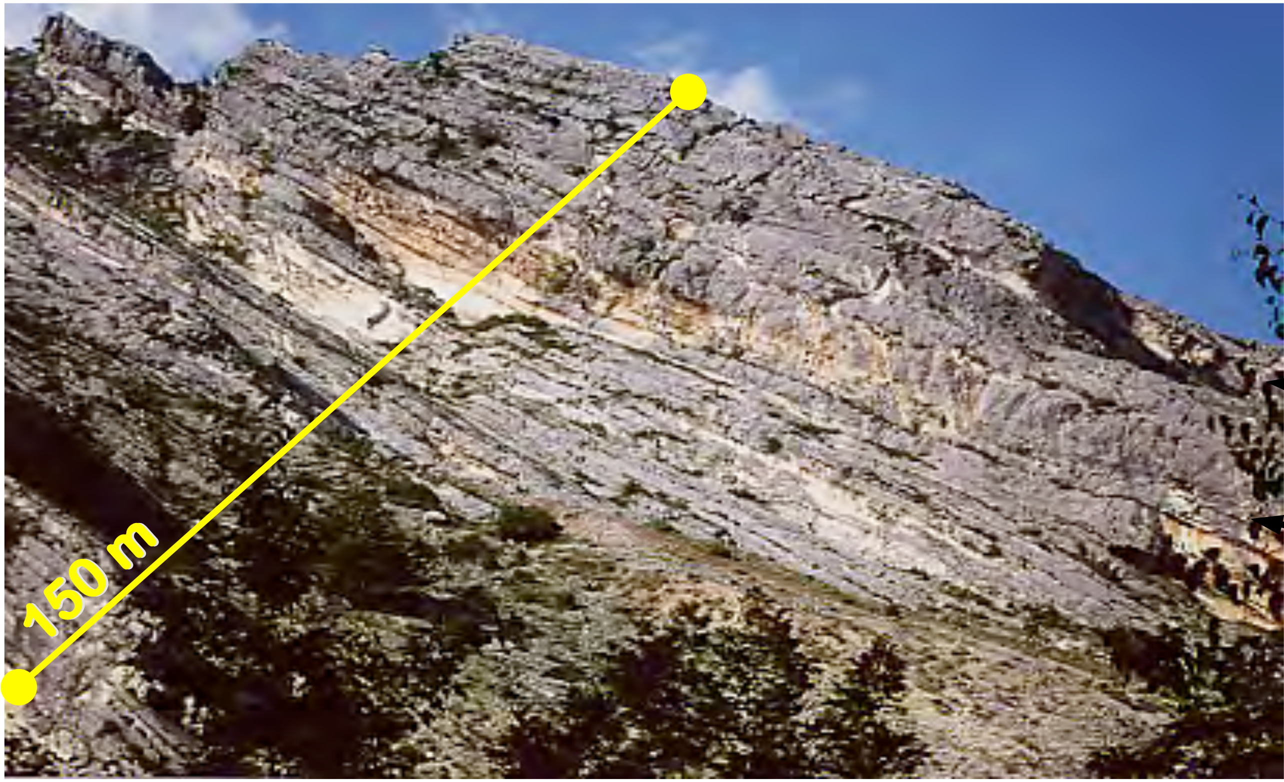
HOW TO PROVE?

REPRESENTATIVENESS OF 'GEOLOGICAL' TIME IN THE ROCKS OR SERIES...

Lower Cretaceous
Fara
San Martino



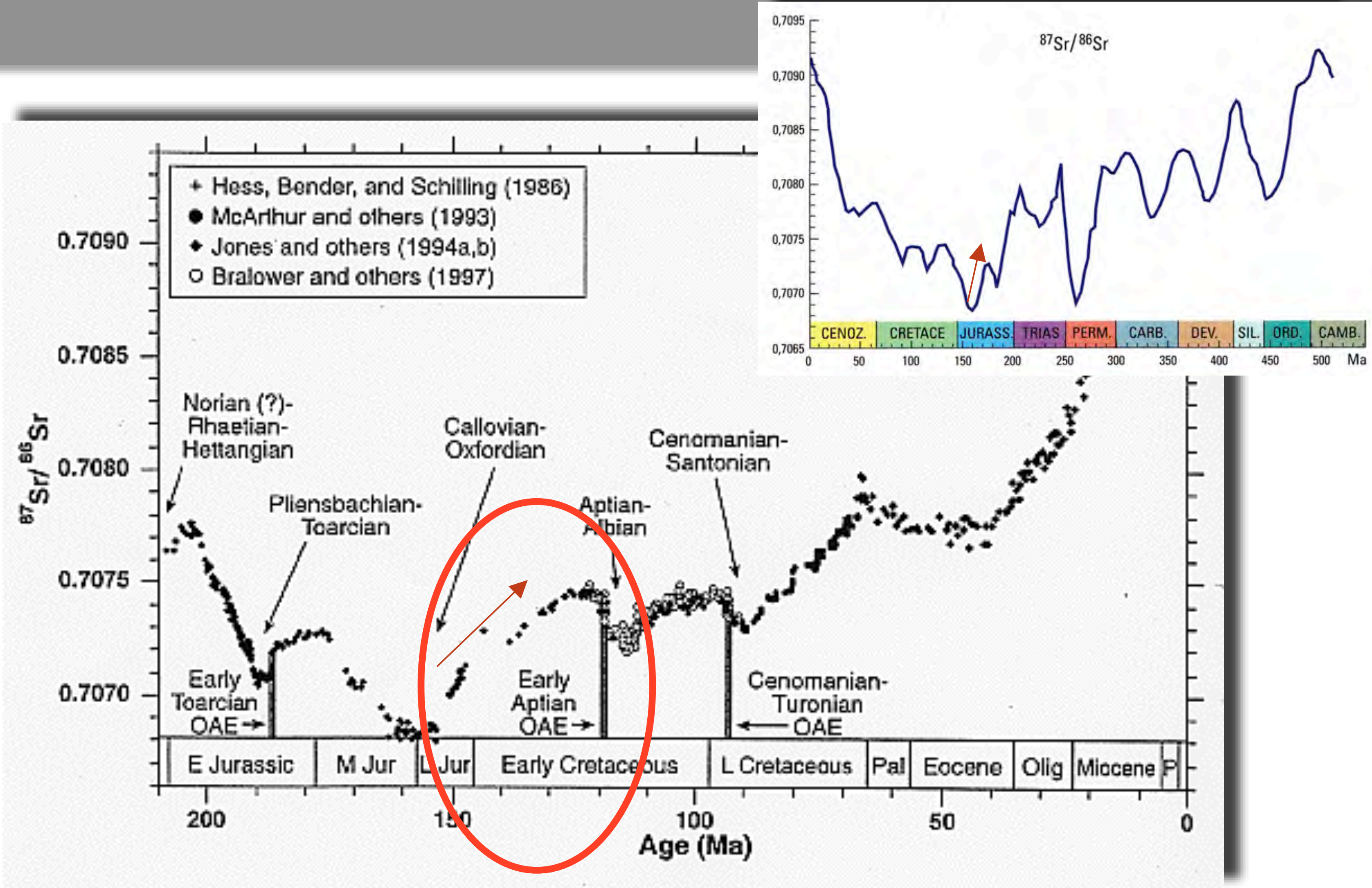
Maiella
Abruzzes



\+
LOFERITES
(tidal flats)
0.3-3 mm/yr

Use of « stable » radiogenic isotopes

ITALIAN LOWER CRETACEOUS : CARBONATE PLATFORM



25Ma

LOWER CRETACEOUS Central Italy

1000 yr

LOFERITES (tidal flats)
0.3-3 mm/yr

100 yr

0.3 mm ===> 300 m/myr
i.e.1myr/25myr = 4%
[or 0.4% if 3 mm/yr]

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THE SERIES IS THEREFORE NOT CONTINUOUS

96 à 99.6%

Stratification joints
+
LOFERITES
(tidal flats)
0.3-3 mm/yr
and diastems
(cryptic disc.)

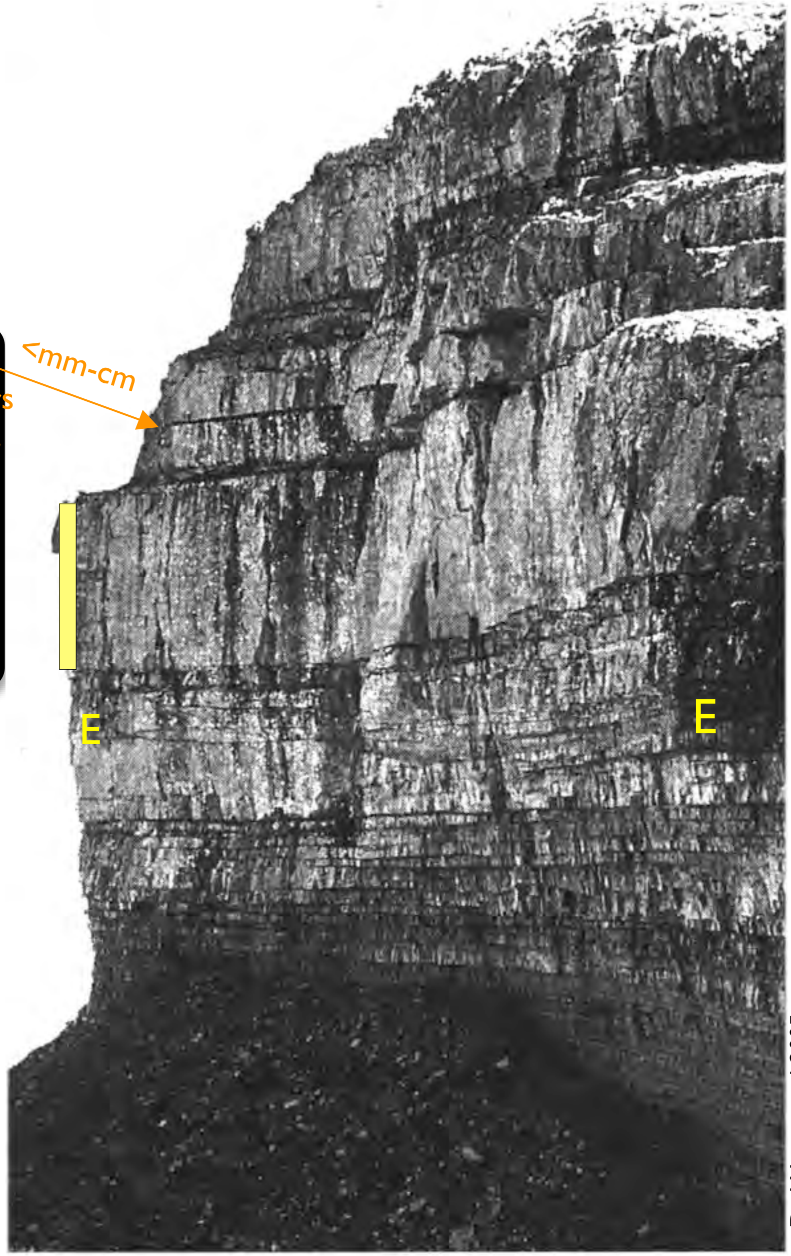
96 à 99.6%

SANDSTONE of ANNOT Oligocene 35Ma max 250m, NE Castellane

(France)

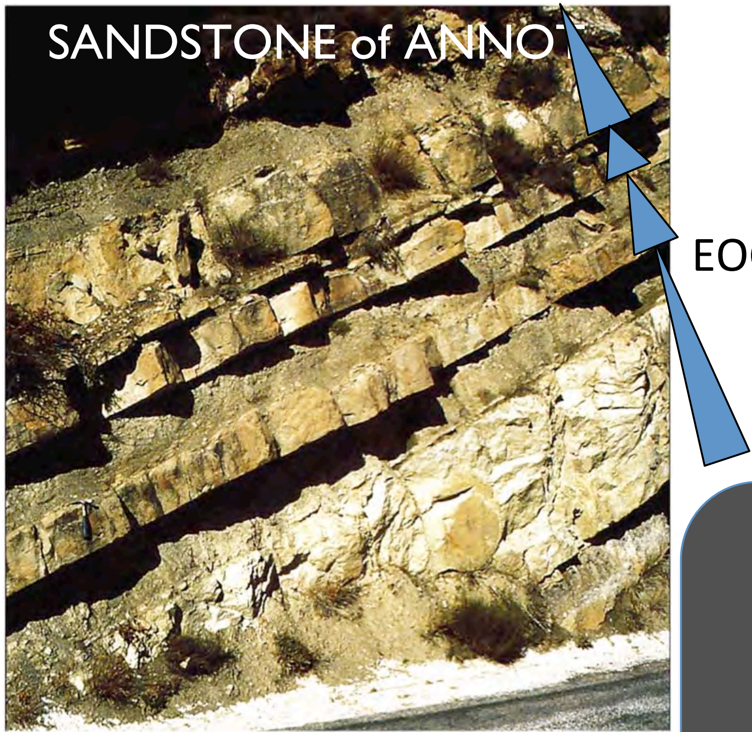
Joint
few 10^3yrs
to10^5yrs

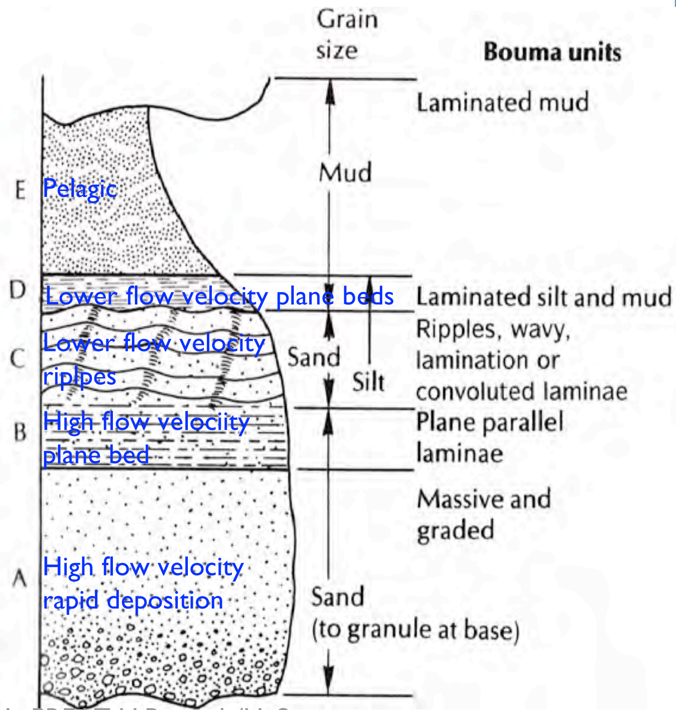
Bed
few h/d

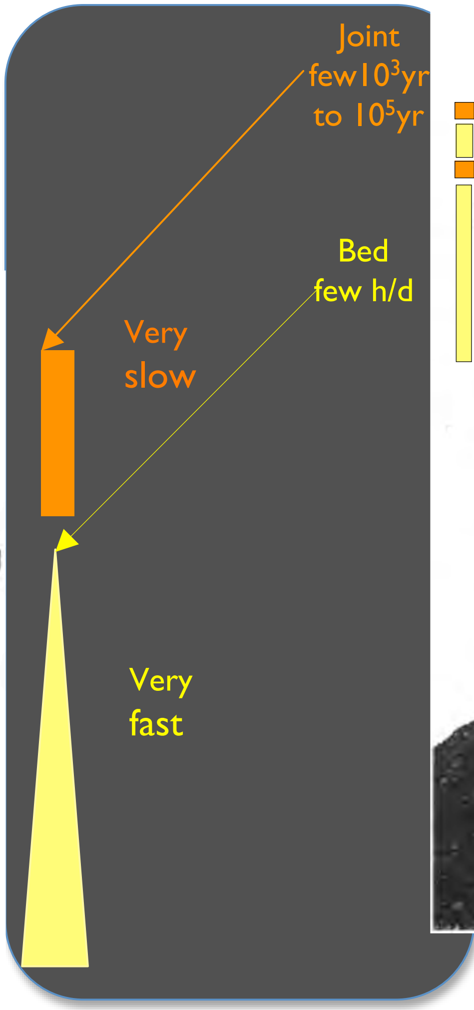


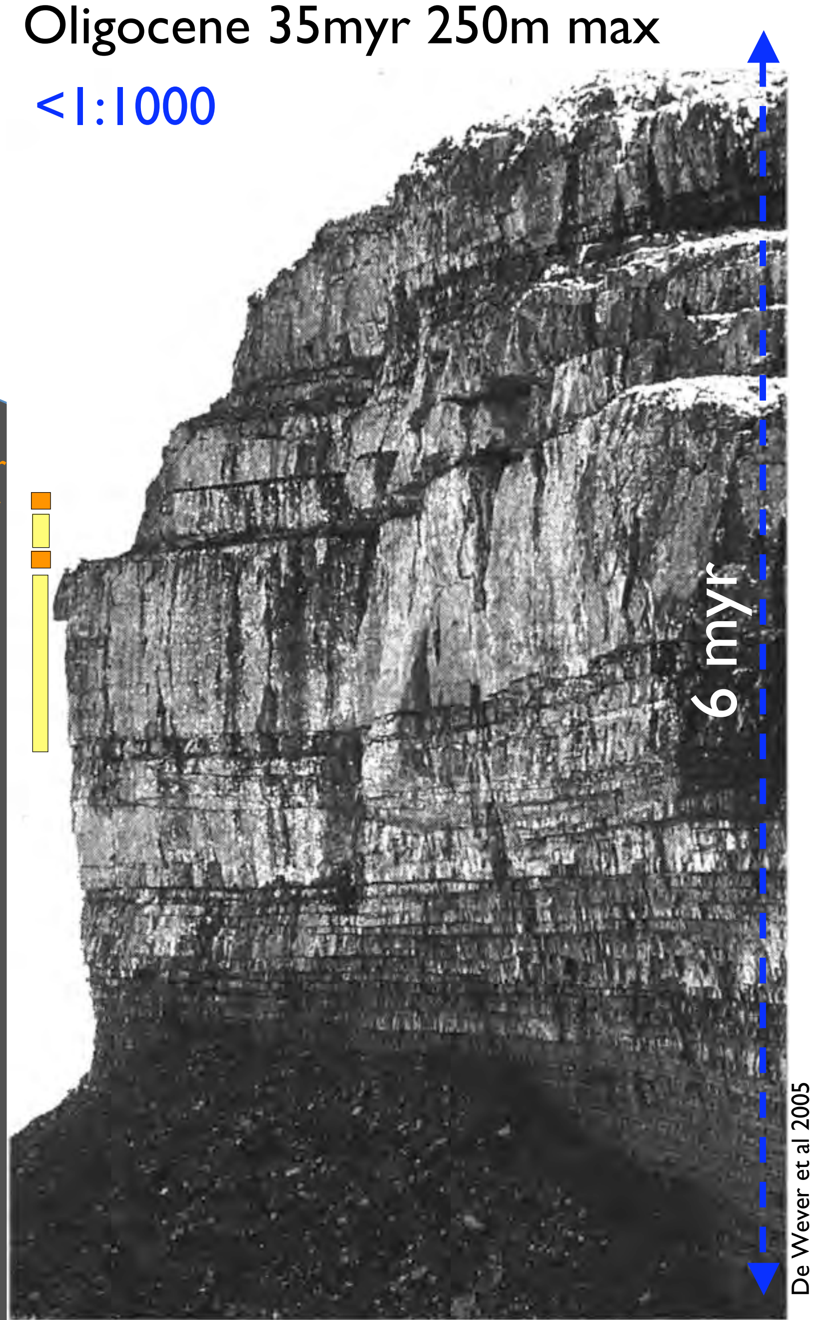
De Wever et al 2005

TURBIDITES



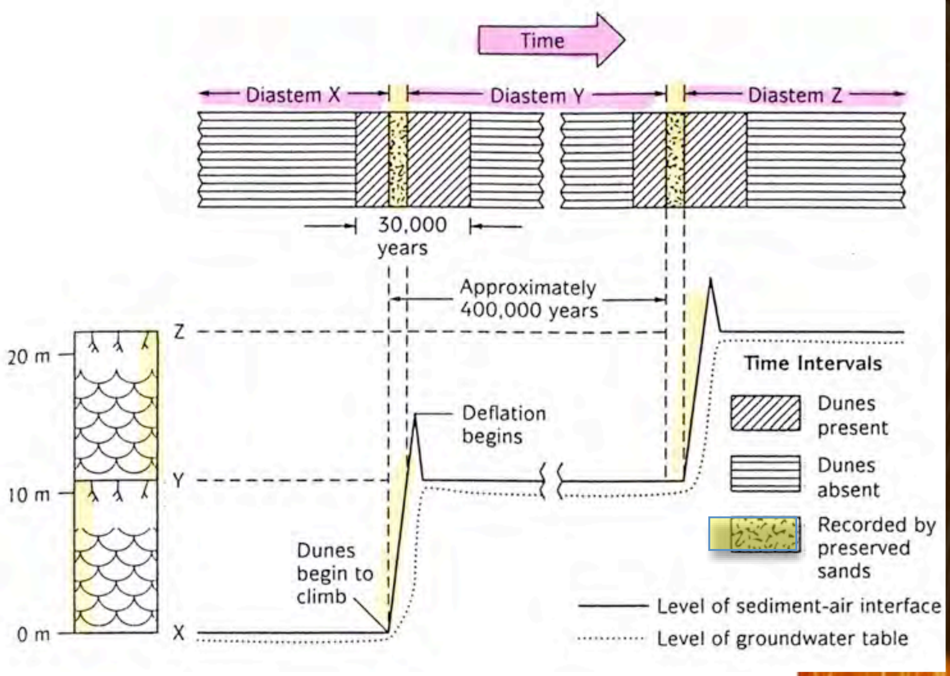


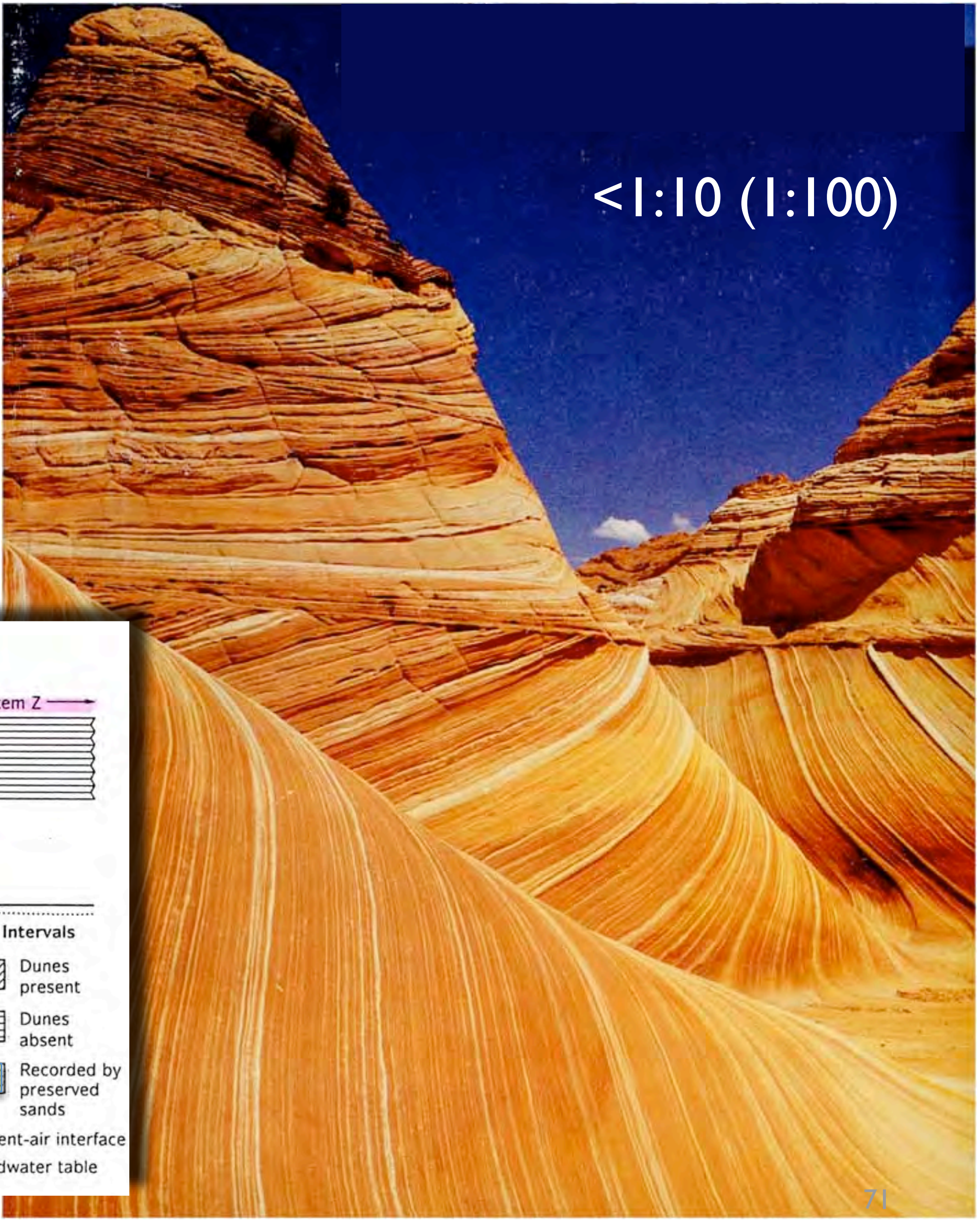




A. PREAT U.Brussels/U. Soran

Navajo Sdst
Utah-Arizona
±60 000km²
600m MAX-thickness
35mMax -1dune
J, eolian





.. many other examples....

The depositional period of a sedimentary body is

VERY SHORT and its upper surface corresponds

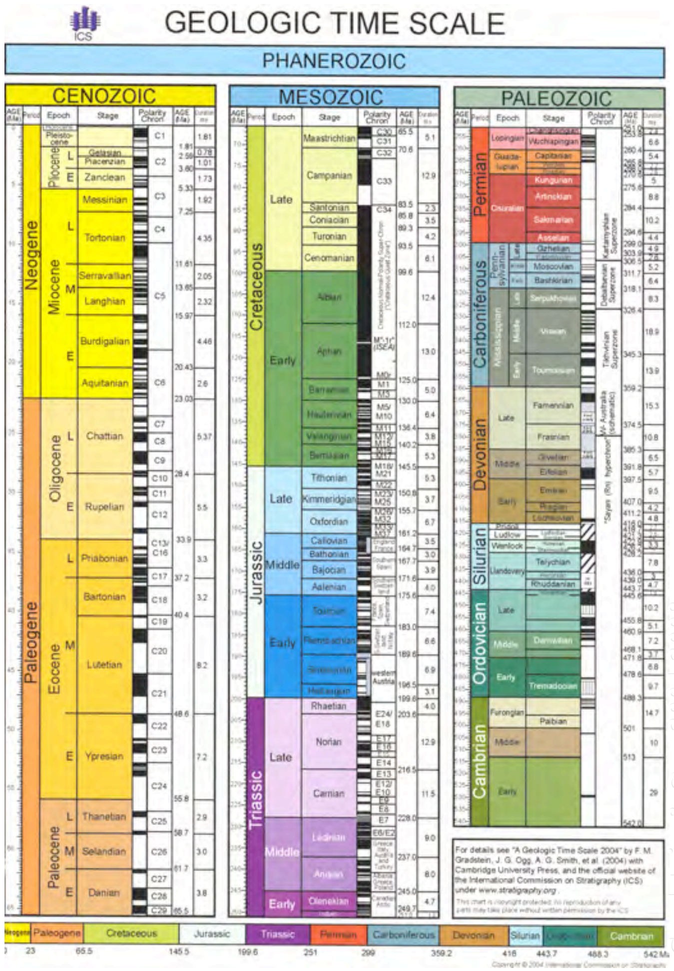
to a break of sedimentation, with or without erosion,

lasting 'impossible' to determine, but is

MUCH LONGER than the period of sedimentation

WHAT IS 'GOOD' SEDIMENTARY RECORD??

> REASONING BY THE ABSURD … NOT GEOLOGICAL!



PHANEROZOIC

(Holocene) 0
(Pleistocene)
Pliocene
Miocene …km
Oligocene
Eocene
Paleocene
Cretaceous 15.8km
Jurassic
Trias

Permian …km
Carboniferous
Devonian 11.7km
Silurian …km
Ordovician 13.8km
Cambrian 11.8km
542Ma

M
A
X

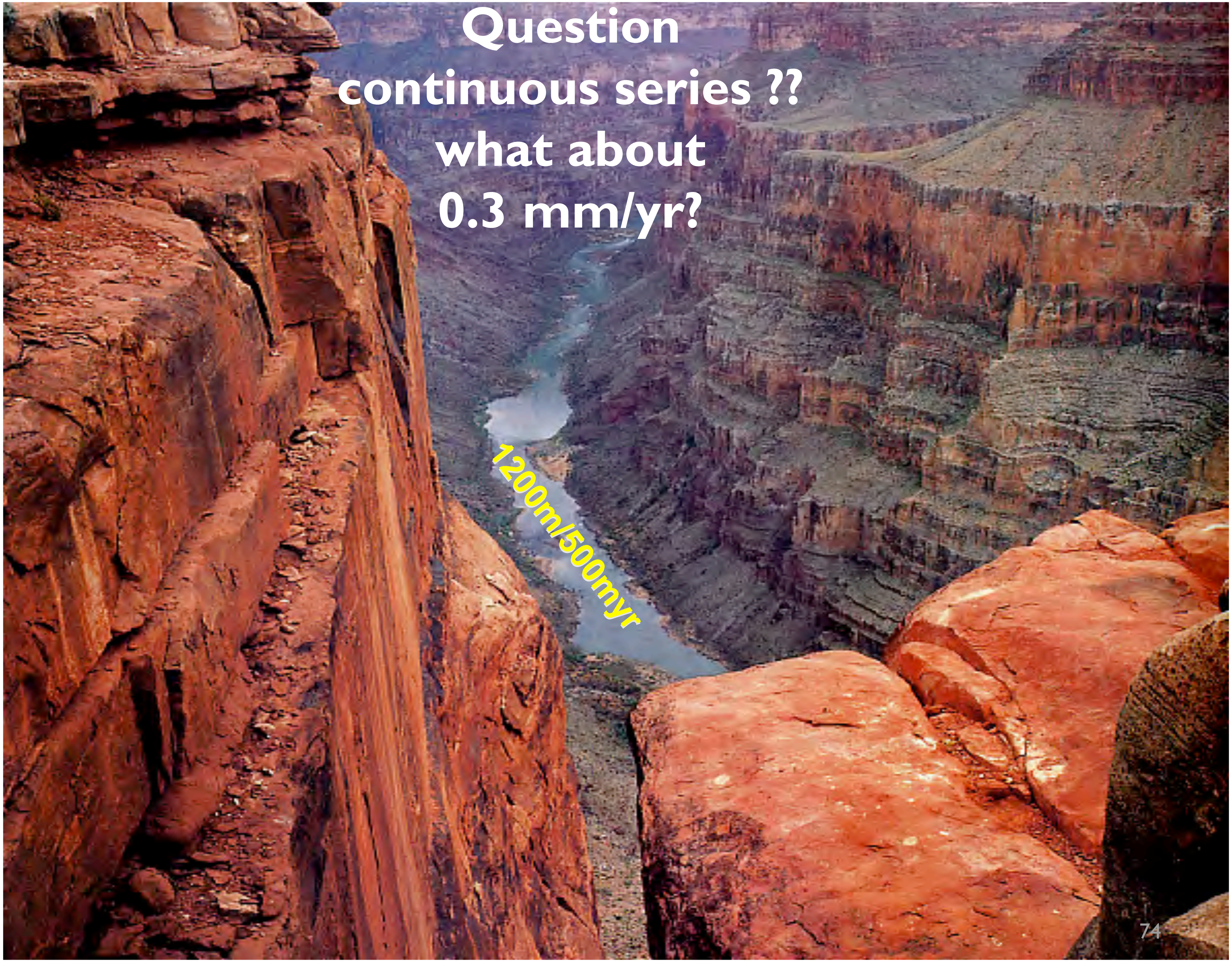
154Km
=
0.28 mm/yr

including 'gaps' and discontinuities

i.e. ± 0.3 mm/yr

(in place of 1mm/yr)

GRAND CANYON



M
A
X

PHANEROZOIC

154km = 0.28 mm/yr

including 'gaps' et discontinuities

the most realistic situation

GD CANYON (USA)

1.2Km = 500 myr

1yr = 0.0024 mm excluding the PCm

~100x LESS!

~1000x LESS!

If compared with RECENT

nb : **STYLOLITES** pressure-solution (burial >200m?, >500m)
if clays=> 'seams' and 'flat'

STYLOLITES accumulation of insoluble residues
(clays, oxides, pyrite….)
HERE = oblique stylolites (tectonic superimposed)

The geological series is therefore temporal gaps (like Swiss cheese!)

MANY CONSEQUENCES

- 'Massive' Extinctions
- Speciation
- Meteoritic impact
- Volcanic eruption
- Clathrates degassing
- Correlations
- .... metallogeny, hydrology etc ...

SPECIALISTS-PALEONTOLOGY

RELATIVE / ABSOLUTE

1975	M.R.H. Gon.	G.K. Conod.	J.T.D. Brach.	W.A. O. Corals	A.R.O. Trilobites	1982 Absol.	1989 Absolute
Famennian	23.0%	22.9%	20.4%	15.0%	14.6%	14.6%	9.8%
Frasnian	15.3	18.7	14.2	13.3	16.6	14.6	22.6
Givetian	15.3	12.5	14.2	16.6	18.7	12.5	7.4
Eifelian	15.3	12.5	10.2	16.6	12.5	14.6	11.3
Emsian	7.7	12.5	20.4	8.3	20.8	14.6	9.5
Praguian	15.3	8.3	10.2	16.6	4.2	14.6	12.8
Lochkovian	7.7	12.5	10.2	13.3	12.5	14.6	26.5

ABSOLUTE

	1986	1990	1982	1989	2008	
						359.2
Famennian	13 Ma	10	7	13	15.3±2.5	
Frasnian	9	5	7	9	10.8±2.6	
Givetian	12		6	12	6.5±2.7	
Eifelian	7		7	7	5.7±2.7	
Emsian	6		7	6	9.5±2.7	
Praguian	4		7	4	4.2±2.8	
Lochkovian	9		7	9	4.8 ±2.8	416.0

GTS

359.2 Ma — 360.7 Ma

	1986	1990	1982	1989	2008	2006
Famennian	13 Ma	10	7	13	15.3±2.5	15.4±2.7
Frasnian	9	5	7	9	10.8±2.6	7.6±3.6
Givetian	12		6	12	6.5±2.7	4.4±3.1
Eifelian	7		7	7	5.7±2.7	3.8±2.6
Emsian	6		7	6	9.5±2.7	17.2±3.4
Praguian	4		7	4	4.2±2.8	3.2±3.8
Lochkovian	9		7	9	4.8 ±2.8	5.8±3.0

416.0 Ma — 418.1.0 Ma

Kaufmann 2006

U-Pb method on zircon and monazite (volcanic ashes = bentonites-K)

57.4±5.4 for 57 conodont biozones
=> 1 bioZ = ± 1myr (0.6-5.5)

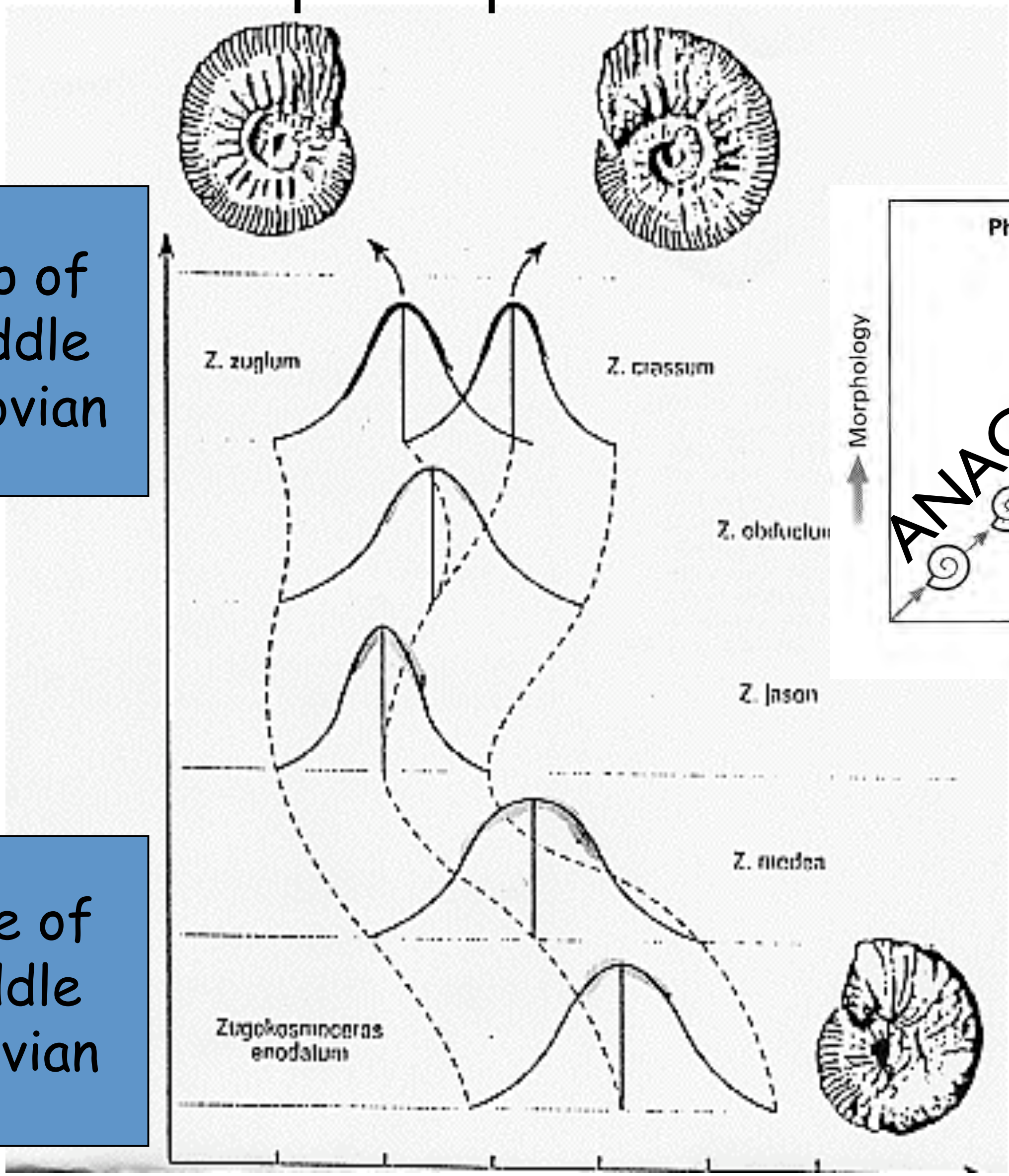
MANY CONSEQUENCES

Example of species evolution

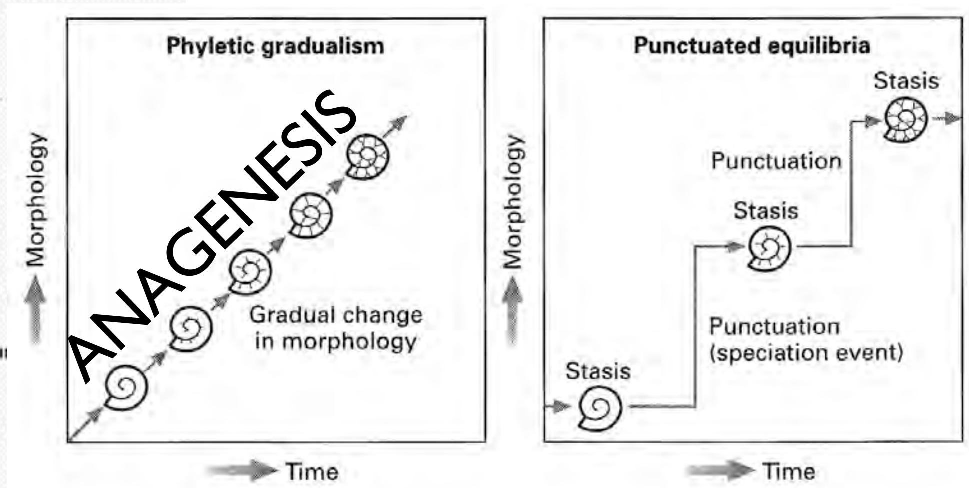
quantic cladogenesis
PUNCTUATED EQUILIBRIUM

Top of middle Callovian

Base of middle Callovian



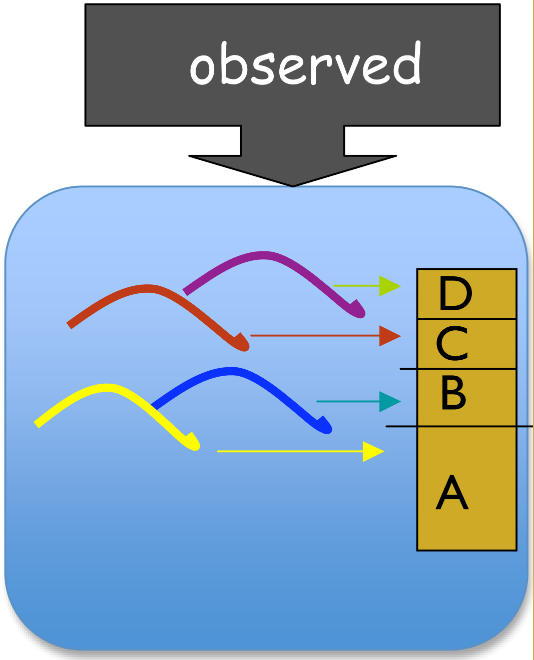
Tintant 1963

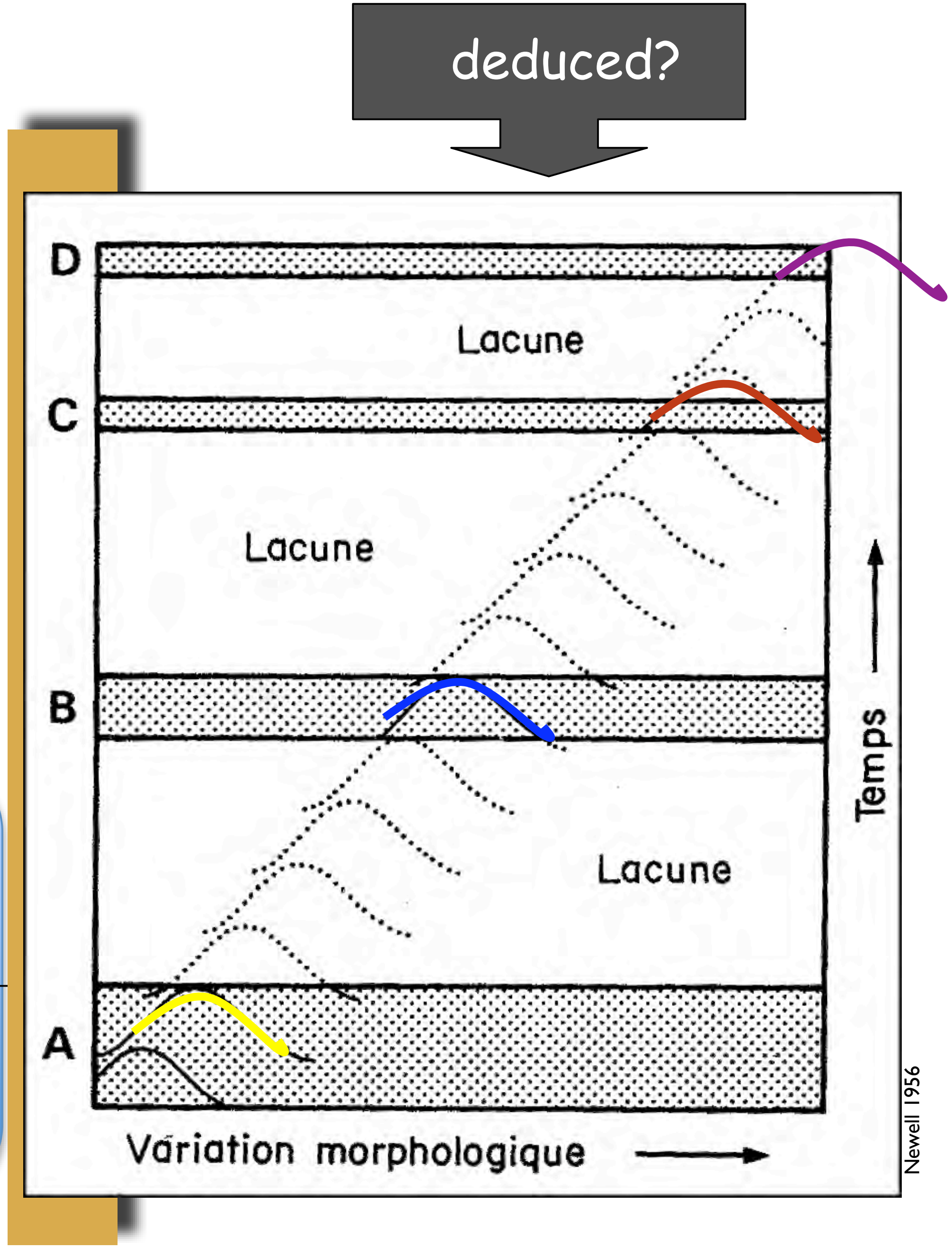


RECENT SPECIATION
EAST-AFRICAN LAKES

Fishes: Cichlidae

Speciation < 4000yr





Interpretation depends of sampling (temporal)

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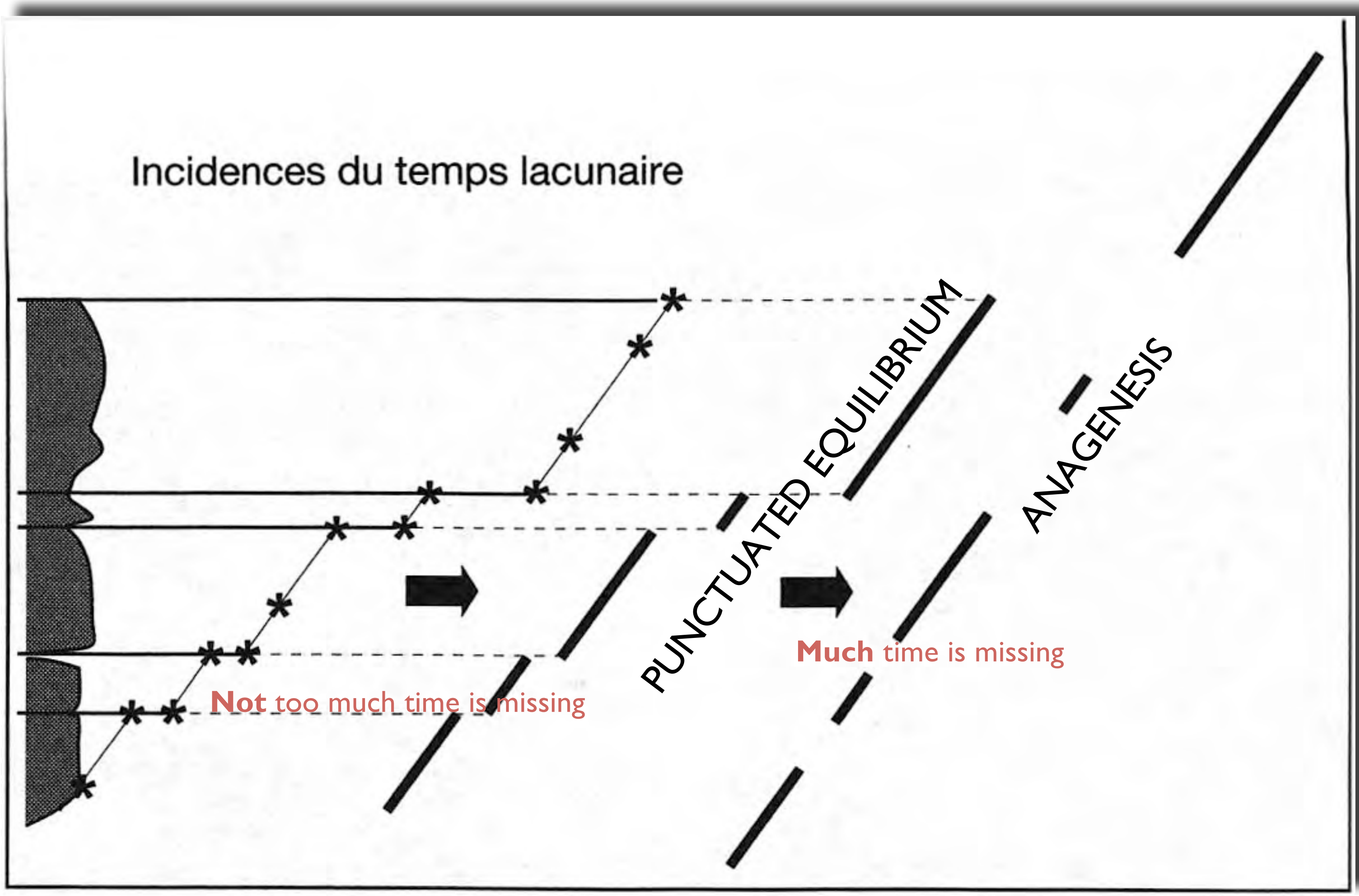
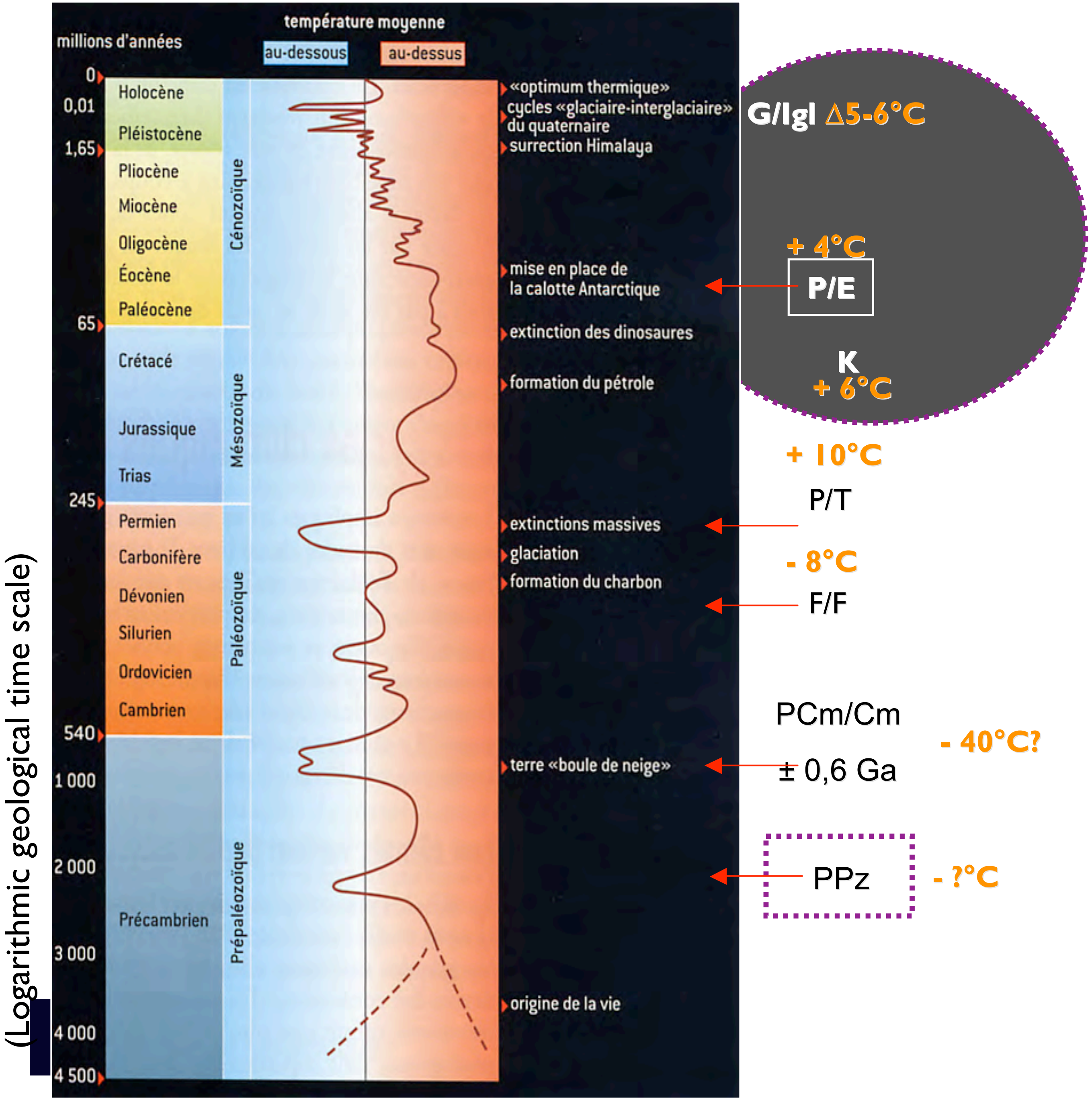
MANY CONSEQUENCES

Example of species evolution



De Wever et al 2005

Variations of the average Earth Temperature



SYNTHESIS

At a small scale, it is the most reliable

GEOMETRY

It is complex (sloping surfaces) and then hyper-complex (folding)

But it must be calibrated on a large scale

RELATIVE AND ABSOLUTE TIME

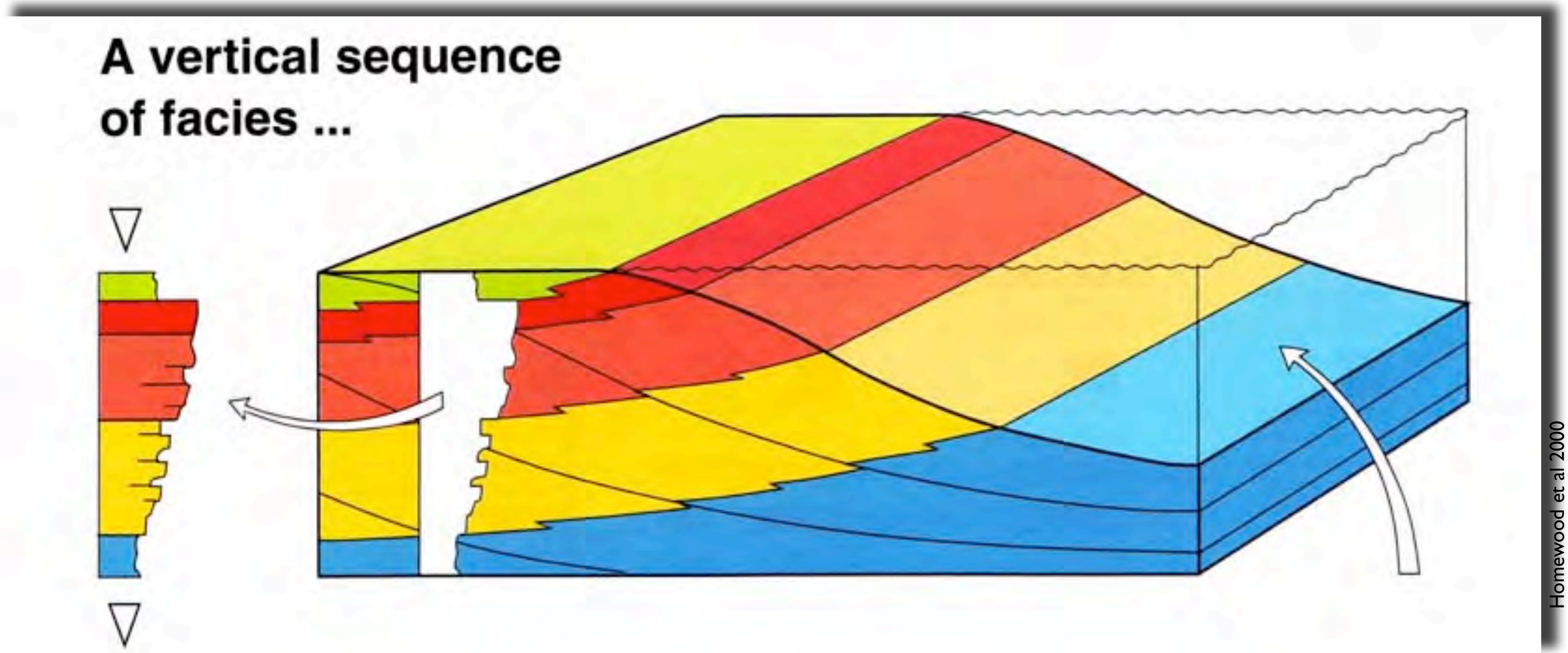
The recording time is the exception … the time series are 'gruyères' (Swiss cheese)

'VELOCITY'-KINETICS

Only then can the process be quantified 'spatio-temporally'

SOME CONCLUSIONS…

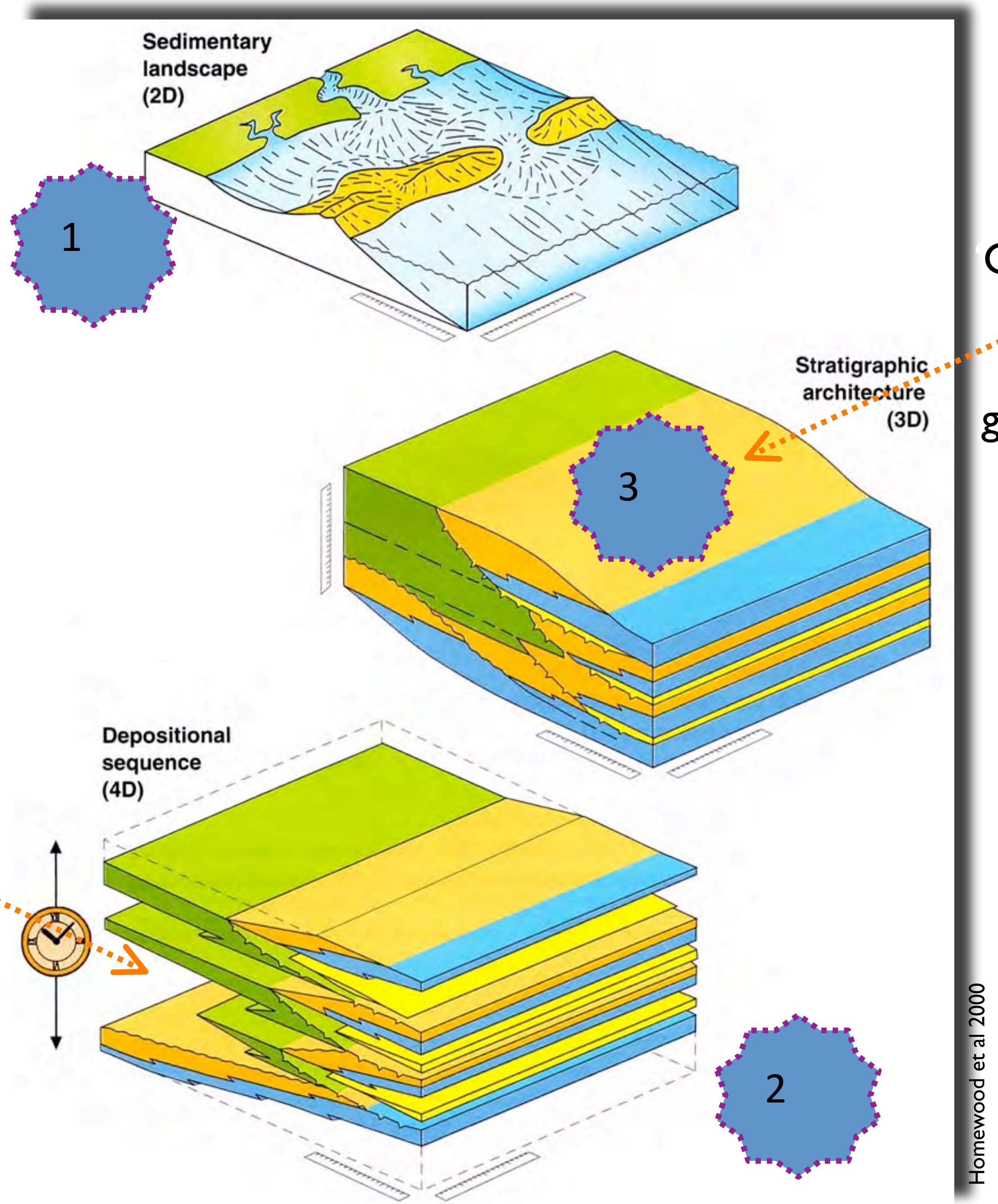
The layers are not strictly horizontal everywhere
Rather, they are prograding 'sigmoid' sedimentary bodies



Field> < Seismic (+KISS?)

Time is almost not recorded and it is not seen

SOME CONCLUSIONS…



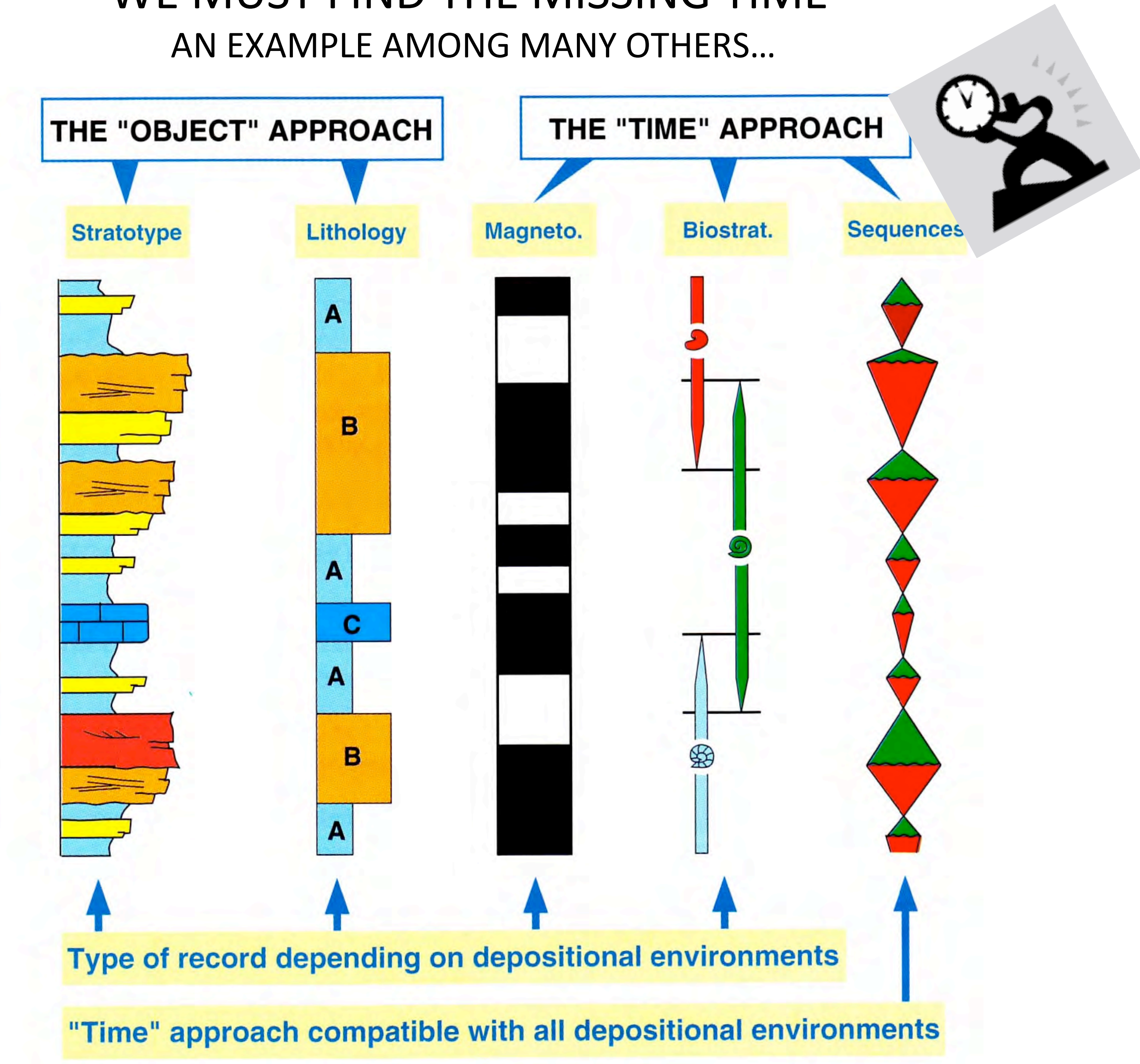
Our final product' = our geological 'object'

Time is 'hidden'

WE MUST FIND THE MISSING TIME

AN EXAMPLE AMONG MANY OTHERS...

SOME CONCLUSIONS...



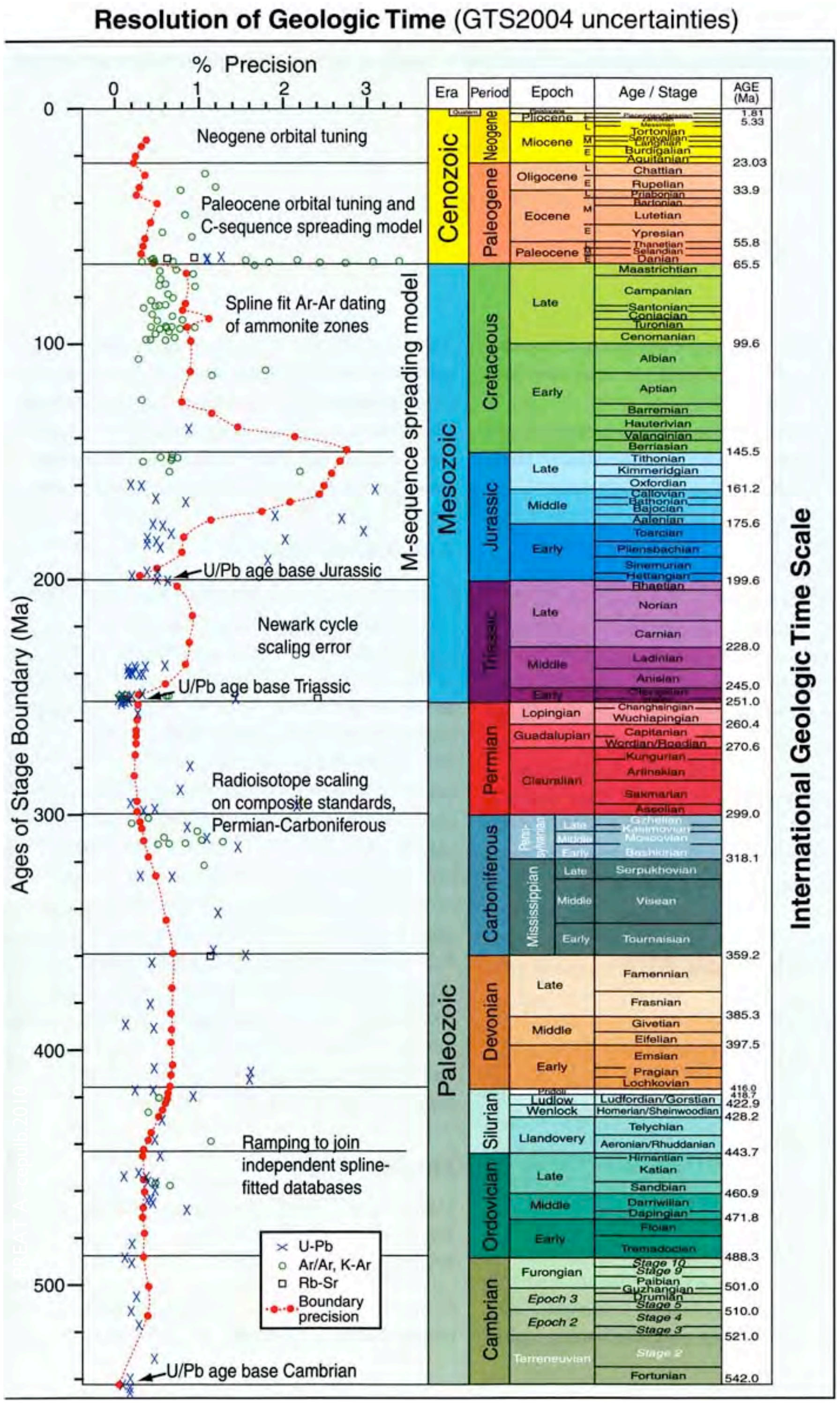
SOME CONCLUSIONS…

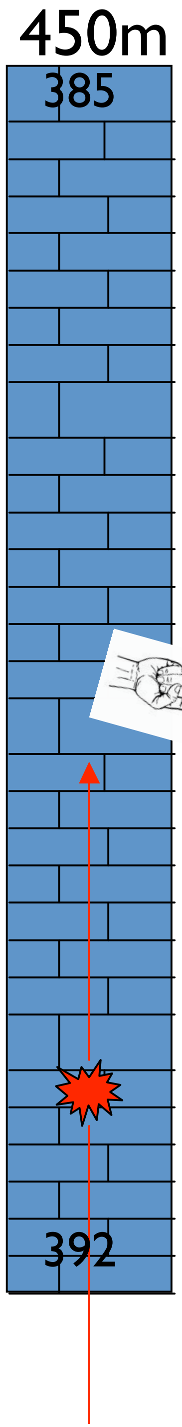
A few %

The depositional period of a sedimentary body is VERY SHORT and its upper surface corresponds to a break in sedimentation, with or without erosion, lasting 'impossible' to determine but much LONGER than the period of sedimentation

A geological instant? (here a coral)
(over 10' – 100km)

SOME CONCLUSIONS…



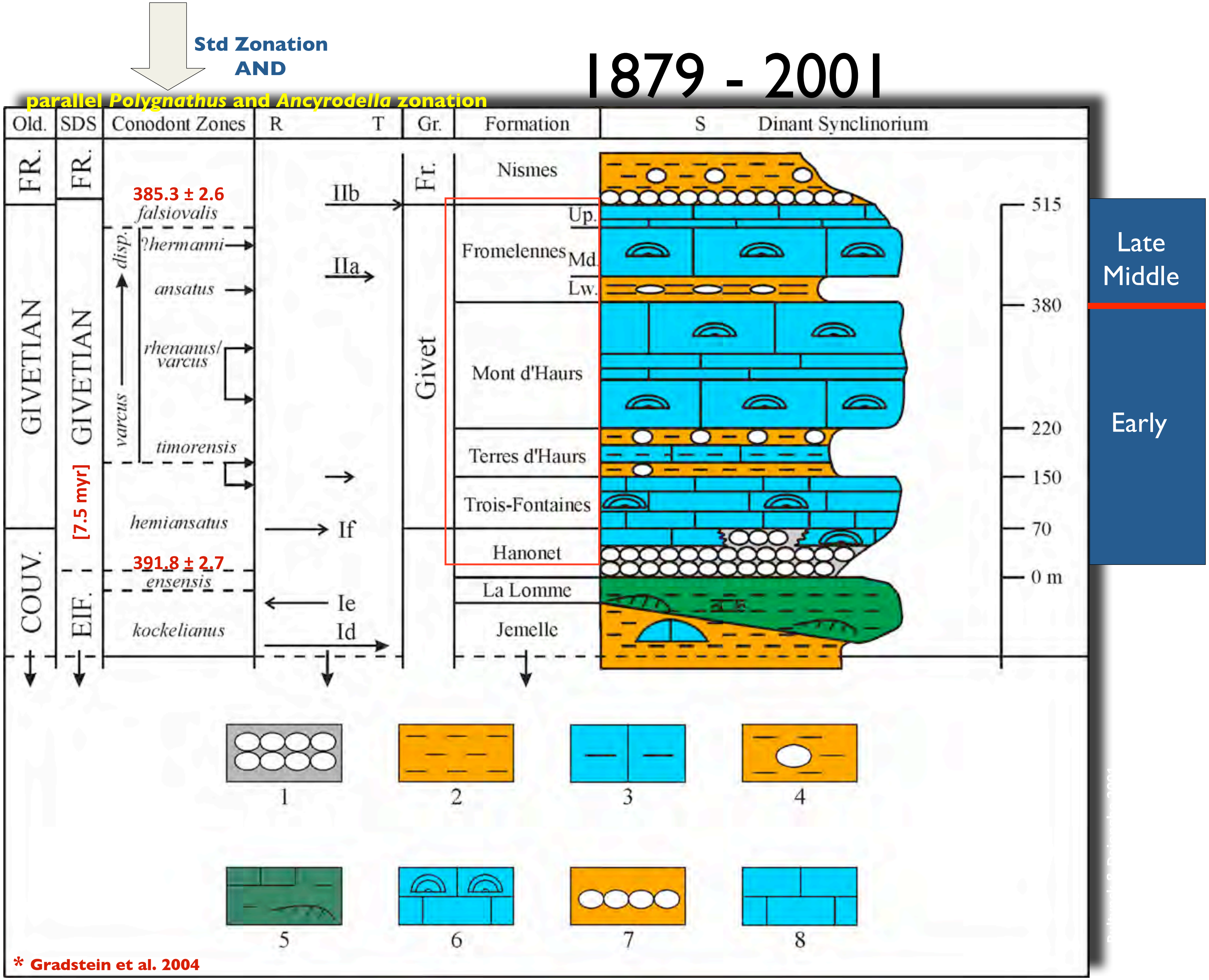


GTS August 2004 (2008)

The absolute chronology is ' imprecise...'

HISTORICAL STRATOTYPE

1879 - 2001



Std Zonation
AND
parallel Polygnathus and Ancyrodella zonation
Old.
SDS
Conodont Zones
R
T
Gr.
Formation
S
Dinant Synclinorium
FR.
GIVETIAN
COUV.
EIF.
[7.5 myr]
385.3 ± 2.6
falsiovalis
disp.
?hermanni
ansatus
rhenanus/varcus
varcus
timorensis
hemiansatus
391.8 ± 2.7
ensensis
kockelianus
IIb
IIa
If
Ie
Id
Fr.
Givet
Nismes
Up.
Fromelennes
Md.
Lw.
Mont d'Haurs
Terres d'Haurs
Trois-Fontaines
Hanonet
La Lomme
Jemelle
515
380
220
150
70
0 m
Late
Middle
Early
1
2
3
4
5
6
7
8
* Gradstein et al. 2004

TIME IN GEOLOGY
a false intuition....

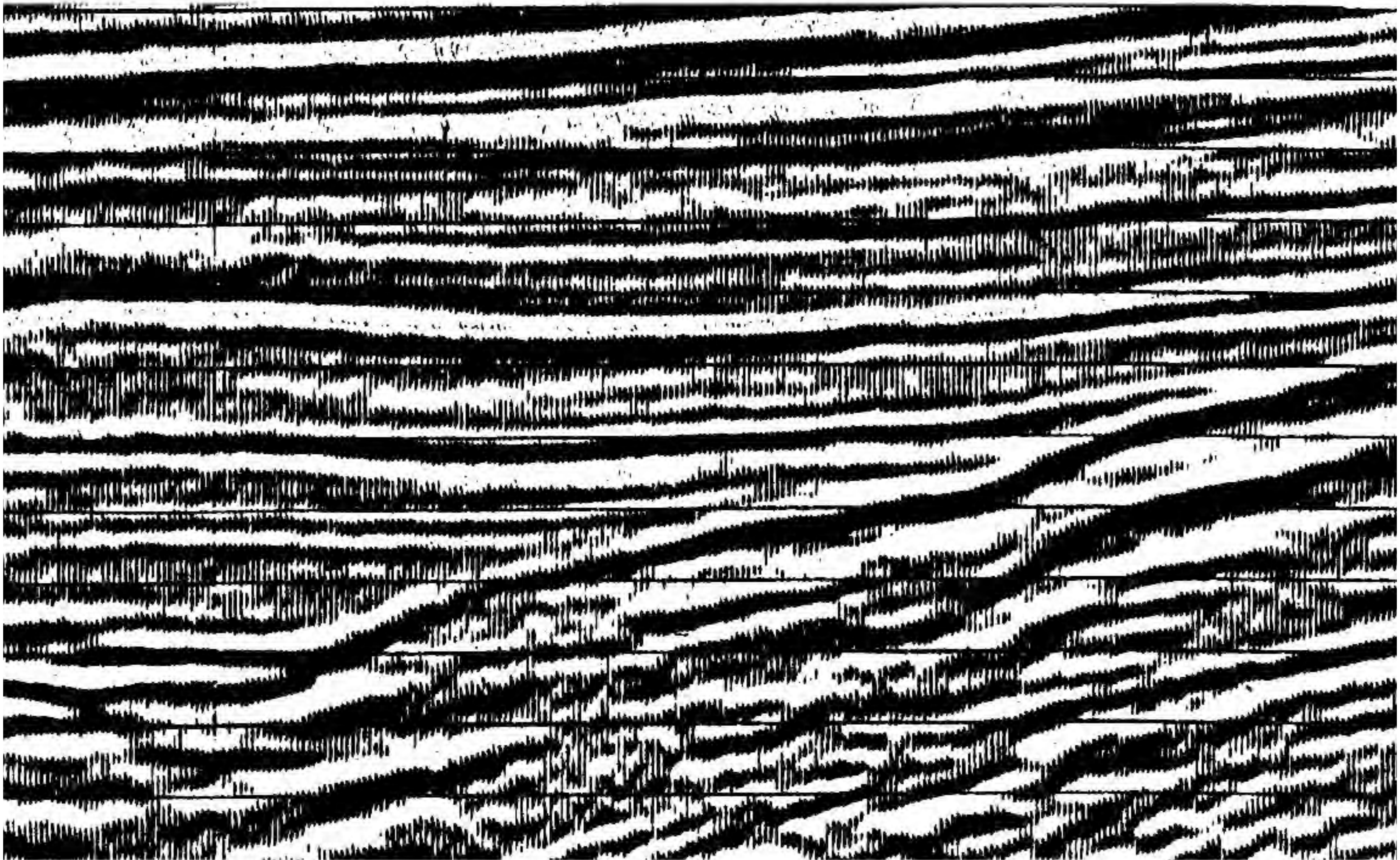
$T_{x'}$

T_x

0.5 to 5%

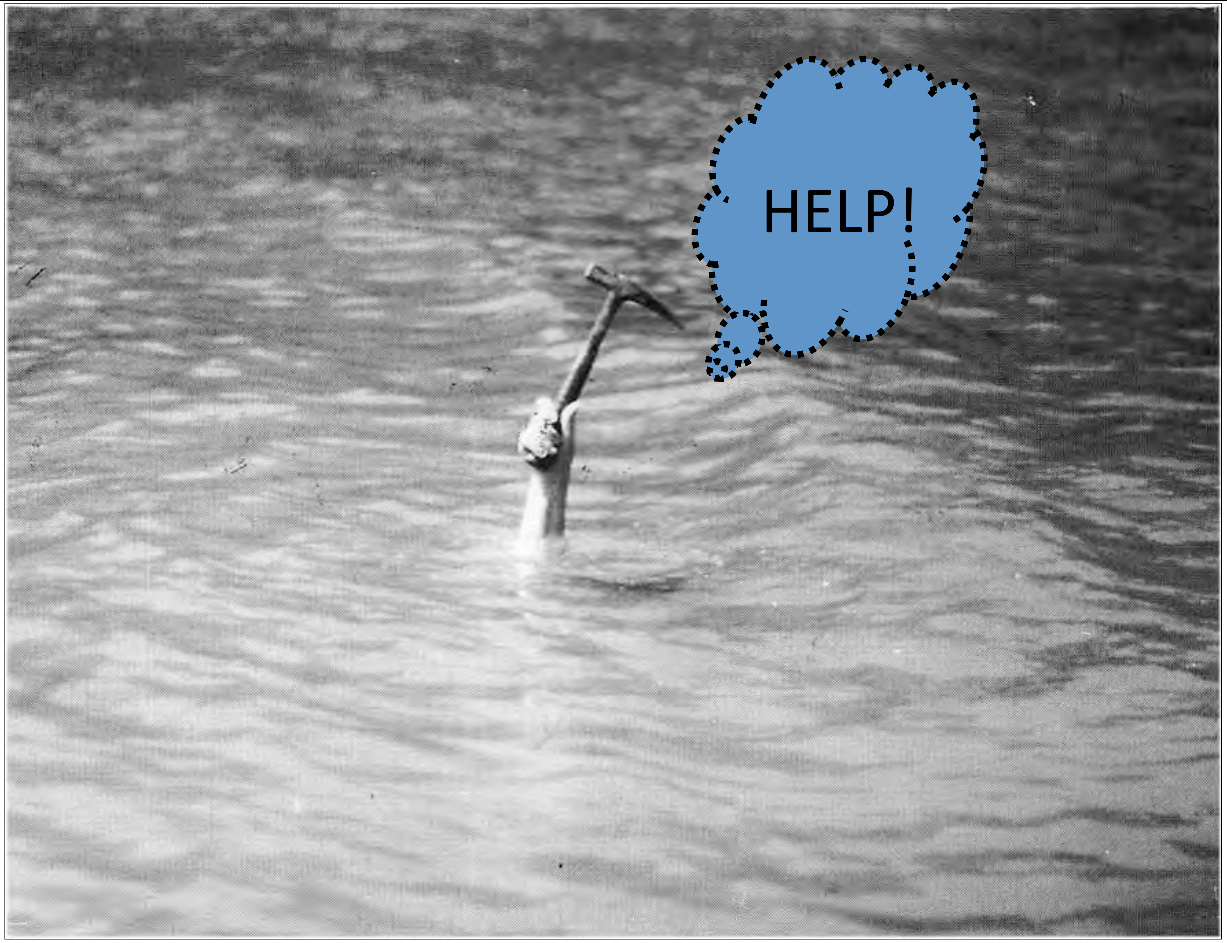
Is this a ‘normal’ and ‘continuous’ geological succession?

THE GREAT CONCLUSION



P. KRYNINE (1901-1964)

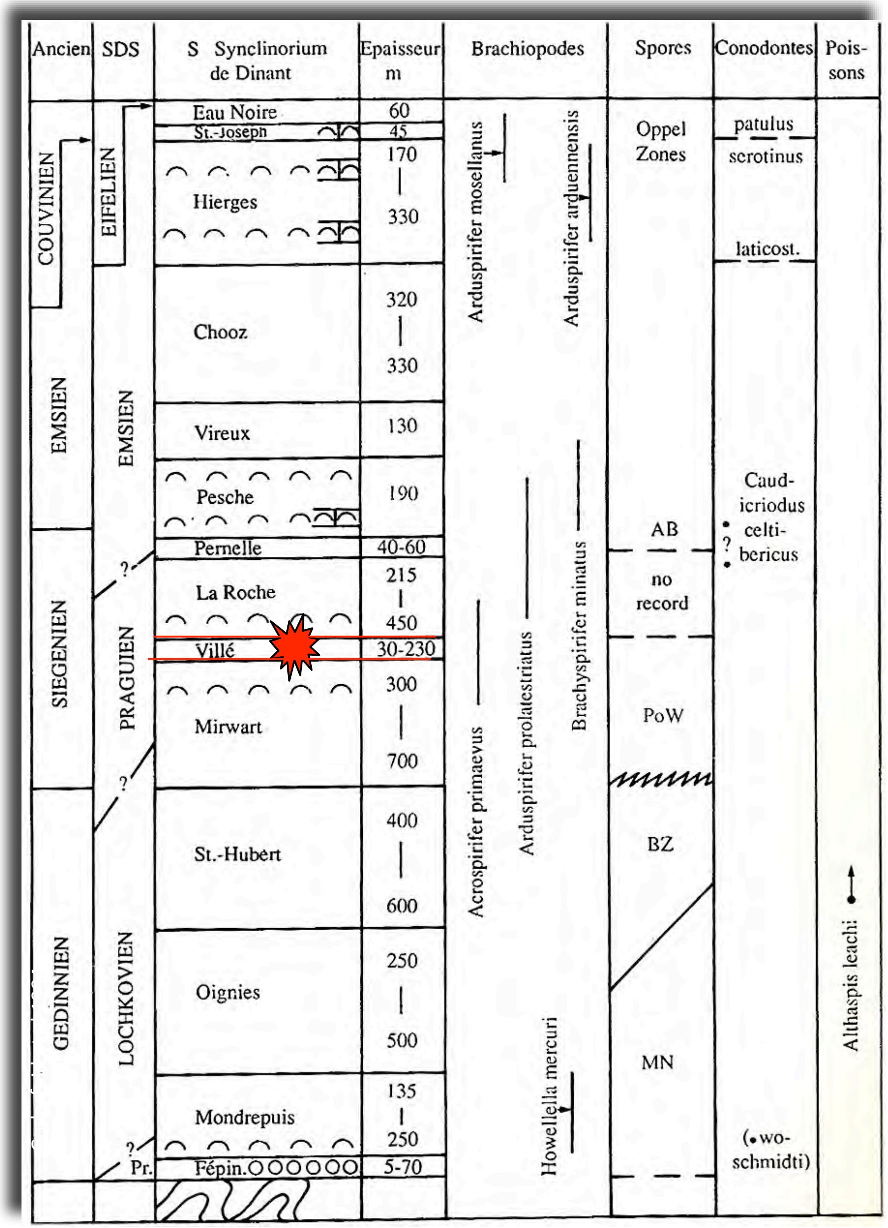
« STRATIGRAPHY MAY BE DEFINED AS THE COMPLETE TRIUMPH OF TERMINOLOGY OVER FACTS AND COMMON SENSE! » ...



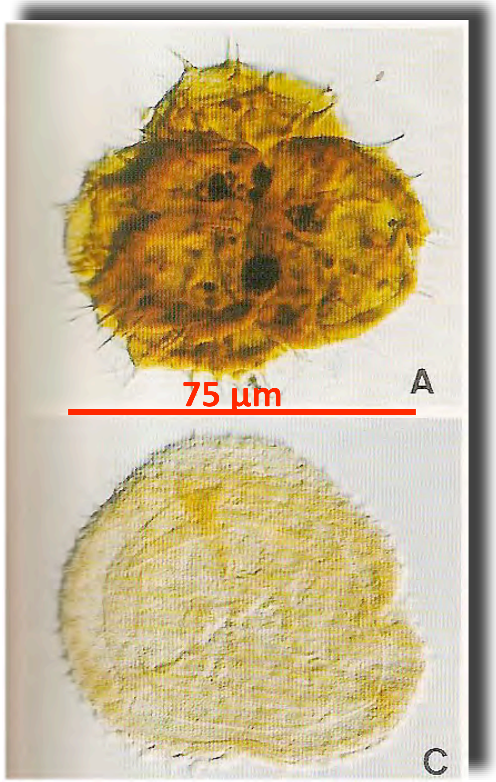
A. Gale in Selley 1996

NOT TO STUDY

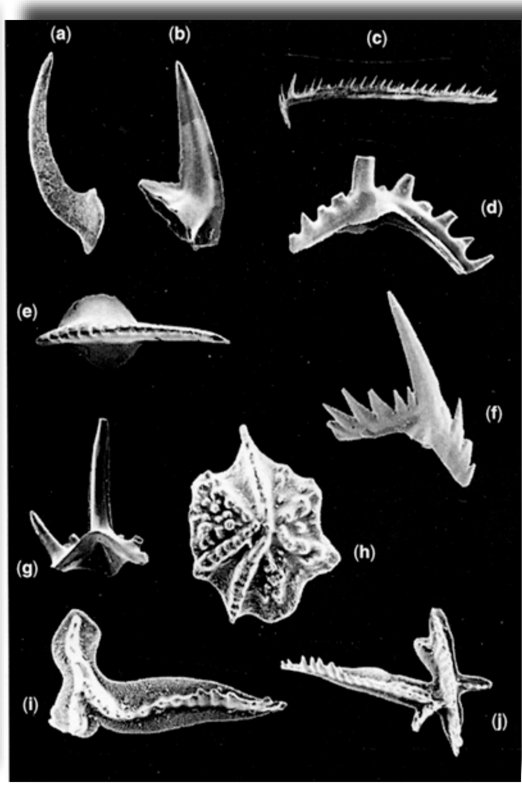
CHRONO-LITHOSTRATIGRAPHICAL UNITS



SPORES

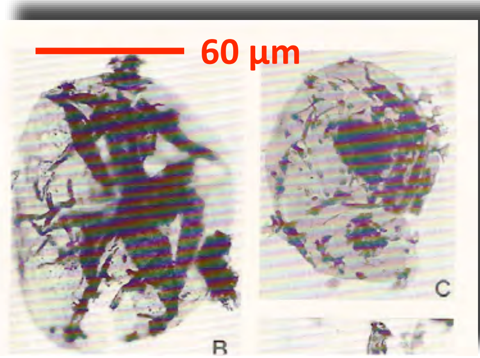


CONODONTS

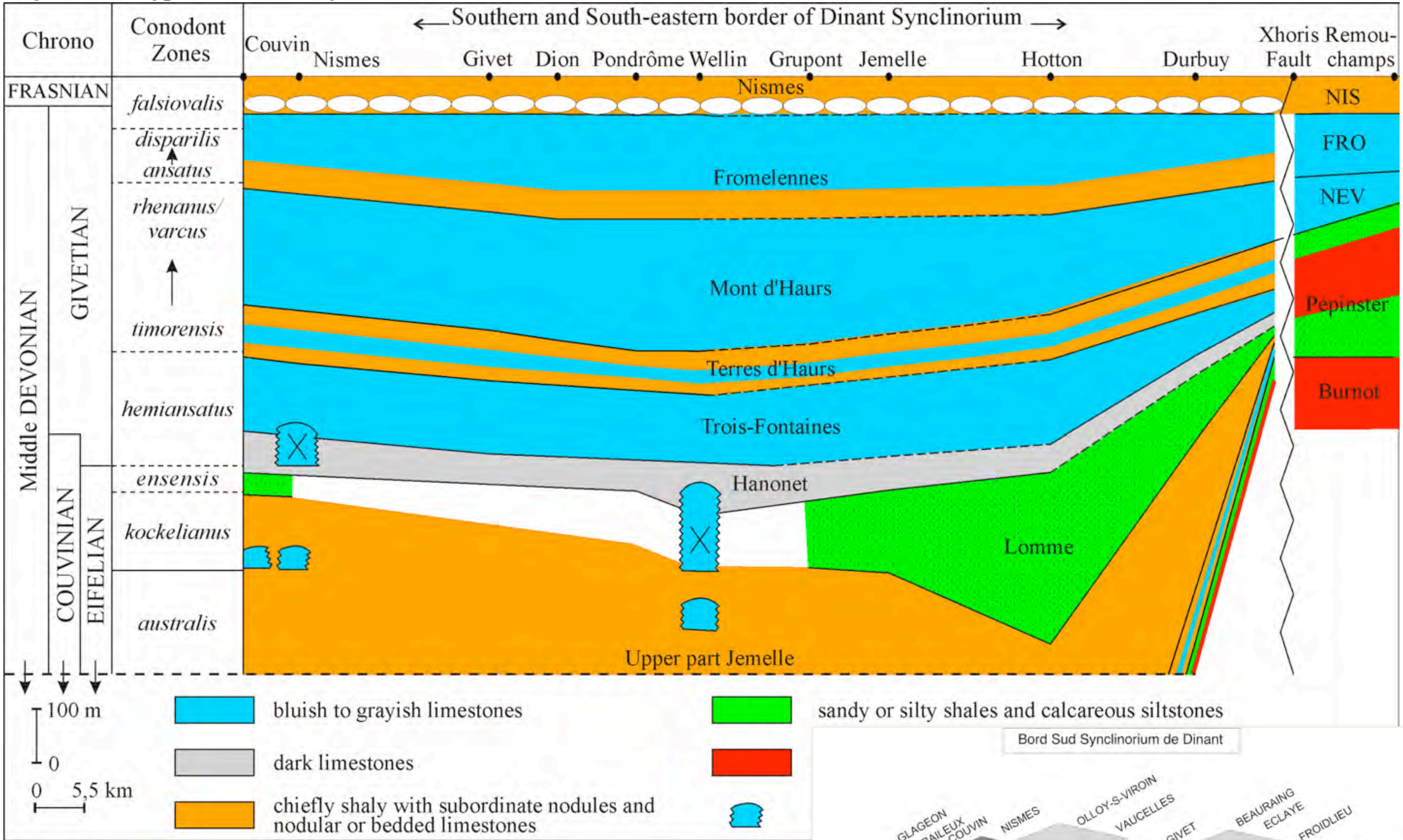


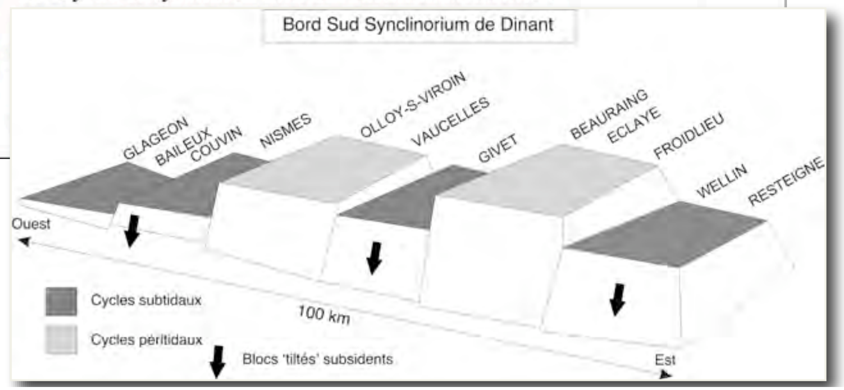
Cm – Triassic
Phosphatic elements
mm …

ACRITARCHS



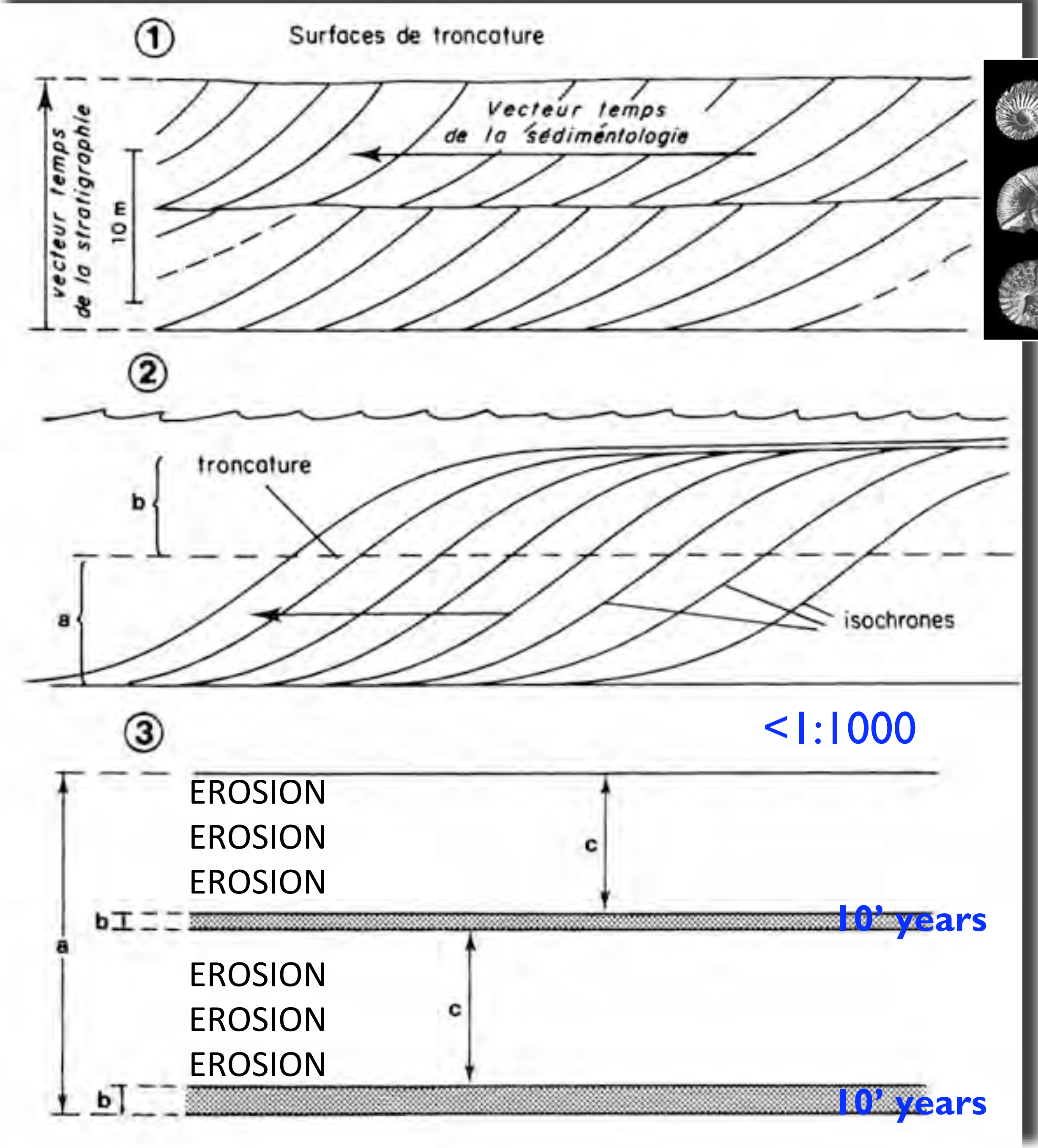
Std Zonation
AND
parallel *Polygnathus* and *Ancyrodella* zonation





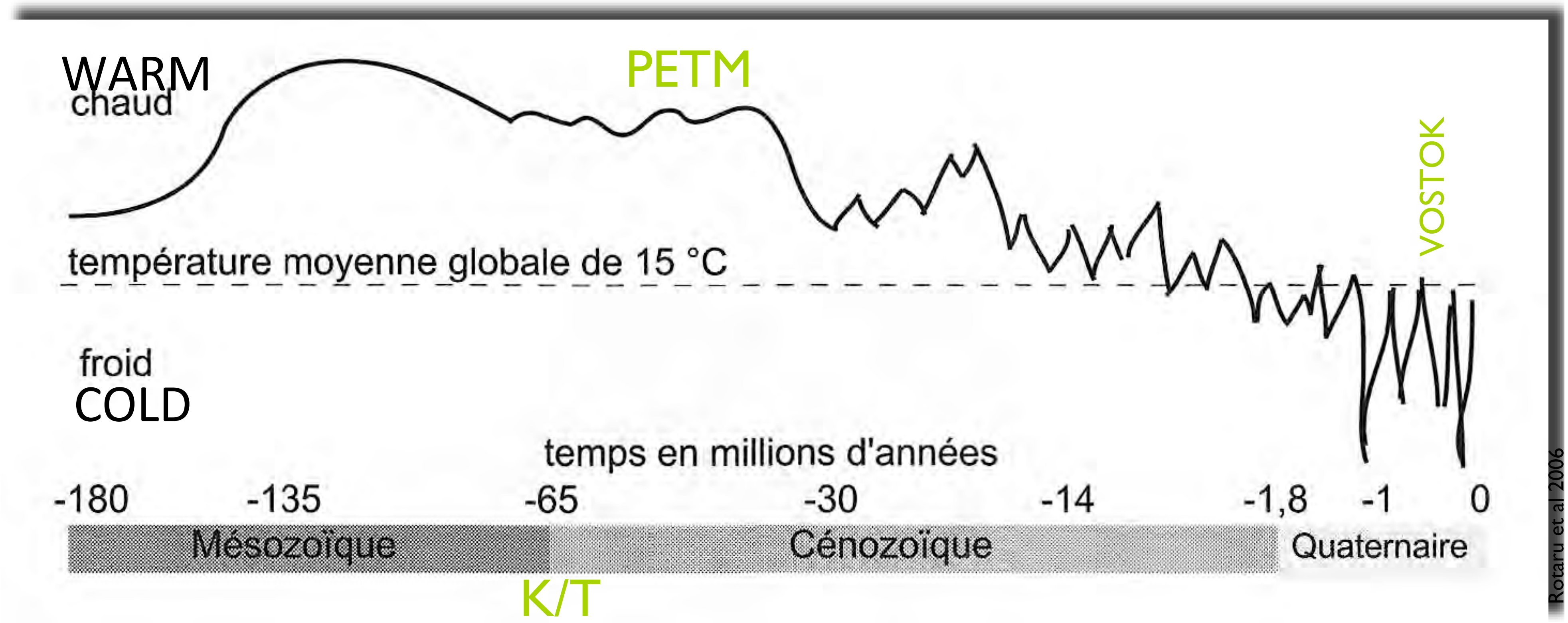
Bultynck & Dejonghe 2001

Bajocian crinoidal limestones of Burgundy (France)

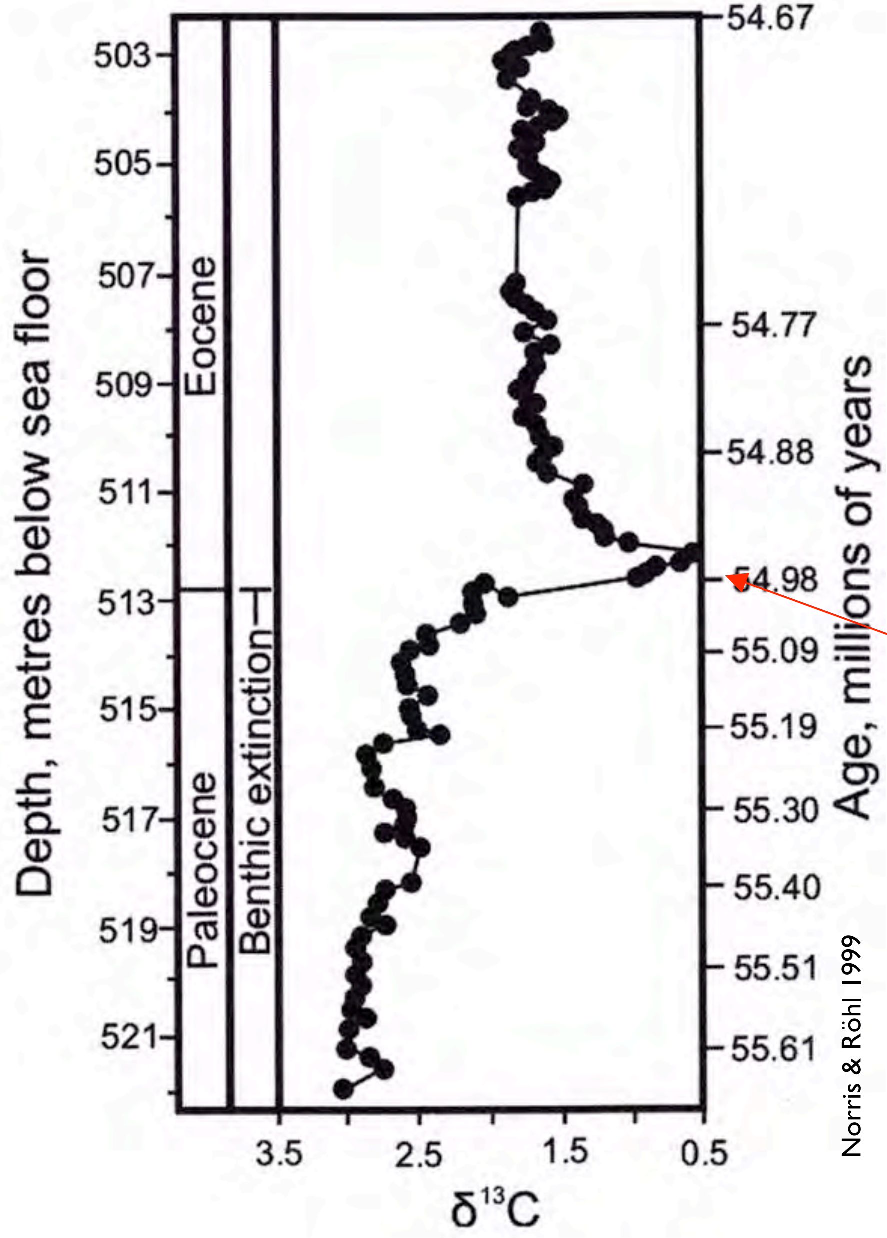


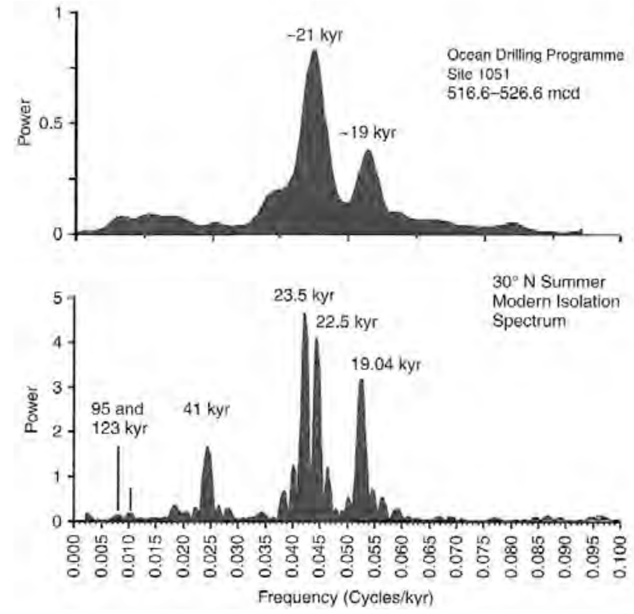
200 000 years

Pomerol et al 1987


WARM
chaud
PETM
VOSTOK
température moyenne globale de 15 °C
froid
COLD
temps en millions d'années
-180
-135
-65
-30
-14
-1,8
-1
0
Mésozoïque
Cénozoïque
Quaternaire
K/T
Rotaru et al 2006

1.GEOMETRY =>2. REL/ABS TIME =>3. KINETICS



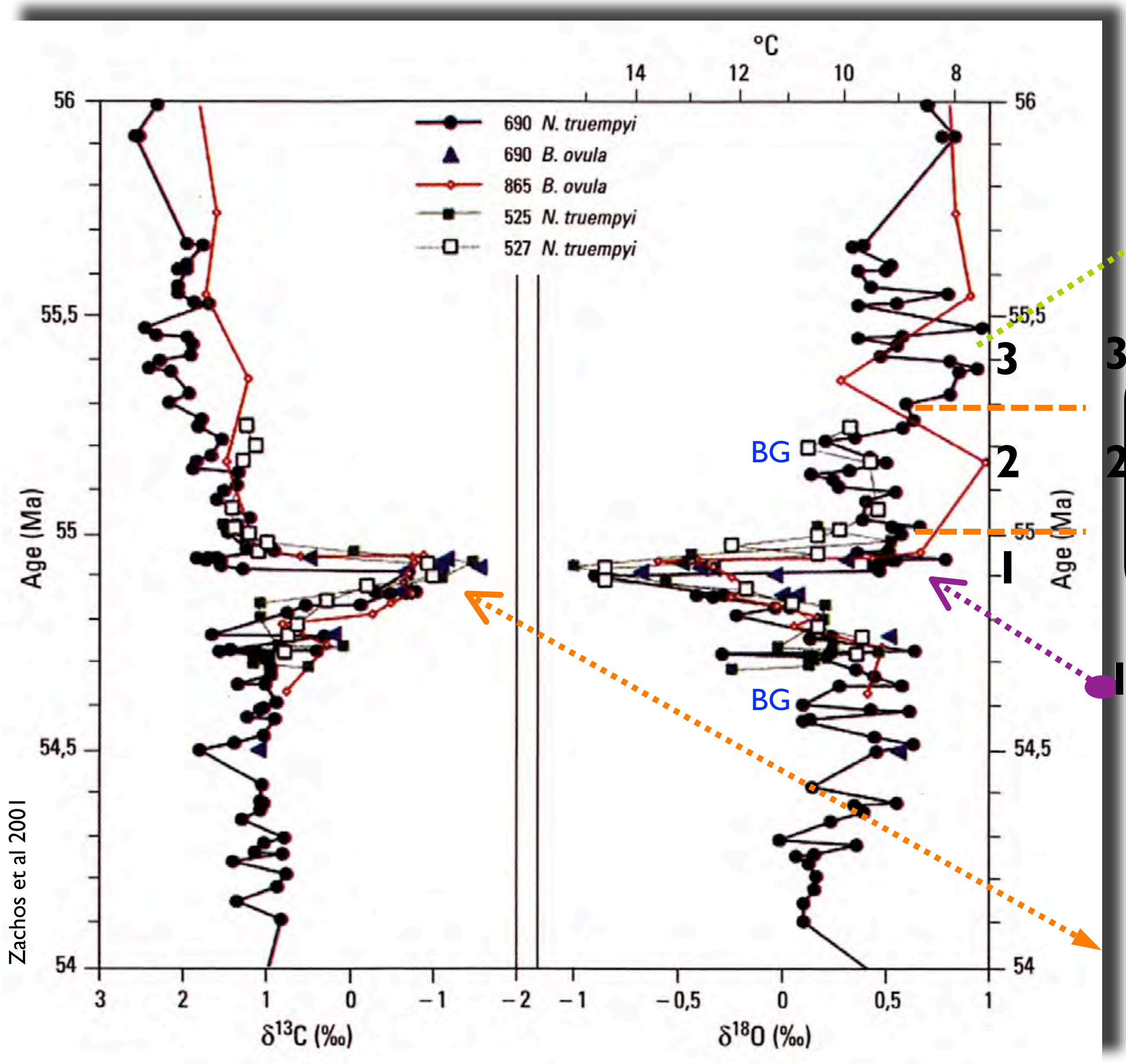


PETM or LPTM Lower Paleocene Thermal Maximum

Fast degassing (^{12}C)
= clathrates ($\delta^{13}C$ = -60‰)
or OM-rich source rock
FAST i.e.
a few 1000'yr and NOT myr!
+
Extinction of benthos starting at 54.98Ma
and crisis (biodiversity of 30-50%) among
Foraminifers due to the acidification ... + ...

= WARMING
of 5 à 7°C in the deep ocean of high latitudes (SL +5 à +6m) in <20 000yr

PETM benthic shells with LIGHT δ13 et δ18 during ±10 000yrs

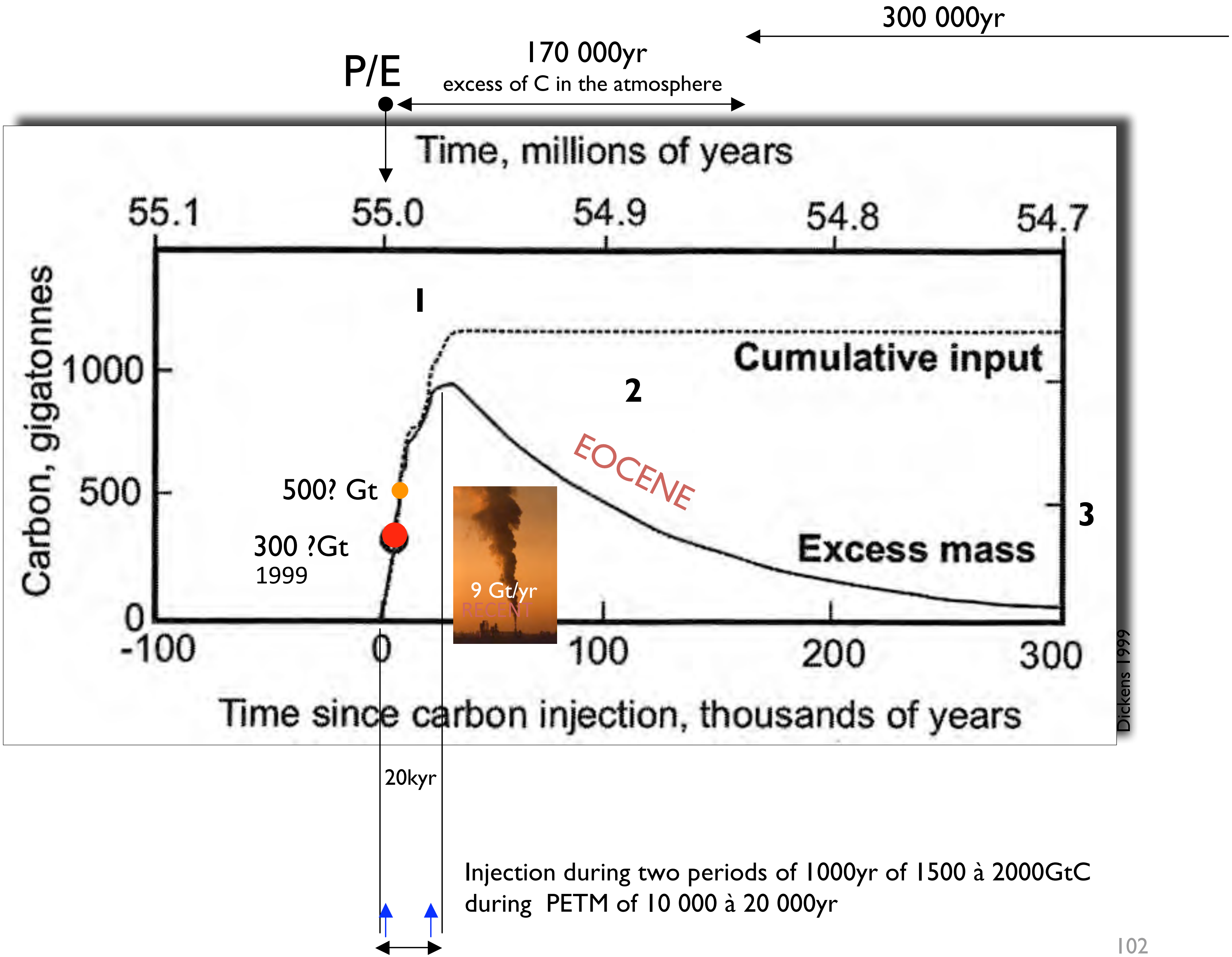


Negative feedback
Silicate alteration

The consequences of this (very fast) event became blurred in less than 300 000yr

The effects (T°, carbonate decrease, OM, acidification including deep basins...) are WELL PRONOUNCED during 170 000yr

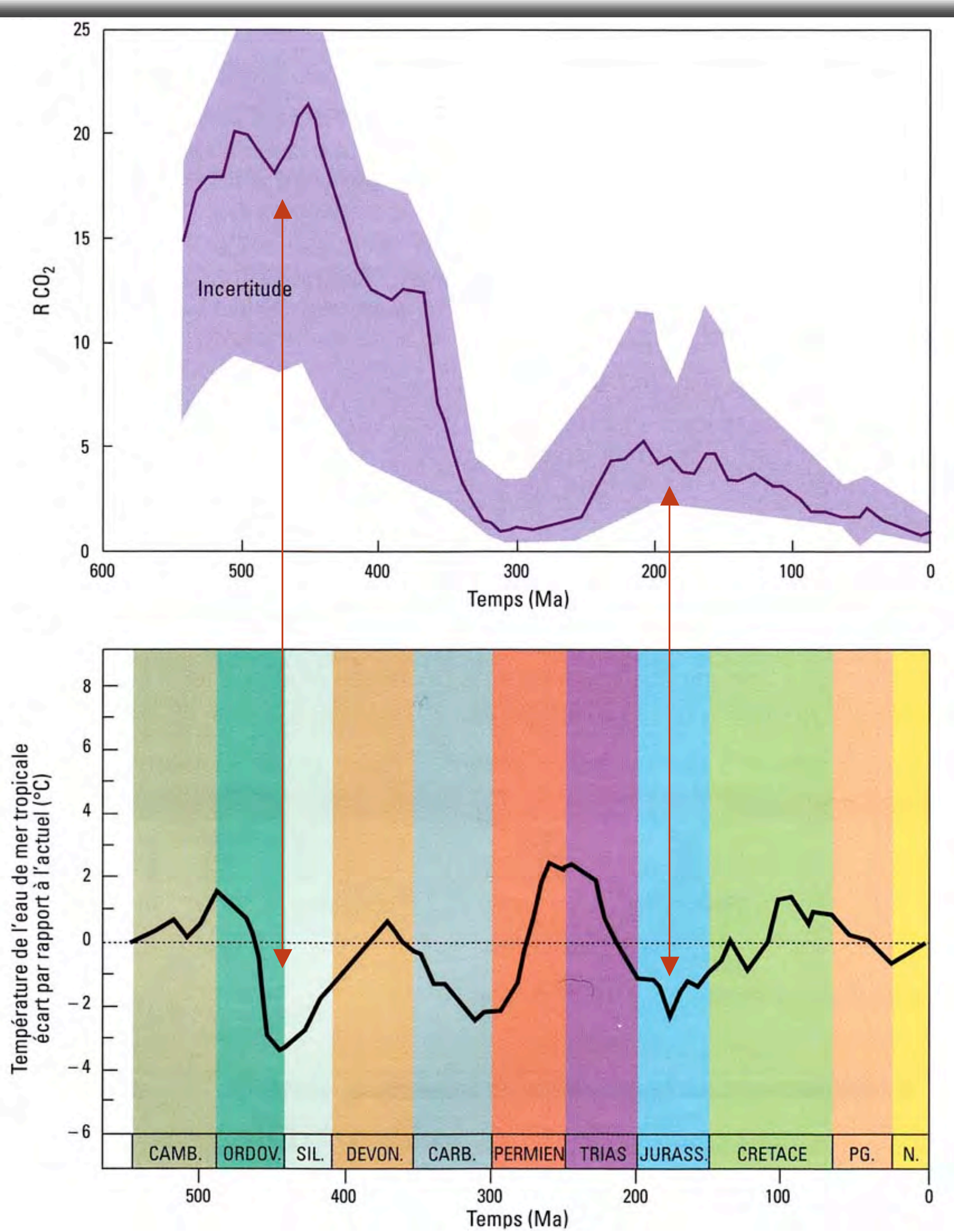
These events are THEREFORE related to the degassing of 2000GtC during 10 000yr (T° =+5°C)
pH7.6 and $C0_{2\ atm}$ 1800ppm (simulation)



Injection during two periods of 1000yr of 1500 à 2000GtC during PETM of 10 000 à 20 000yr

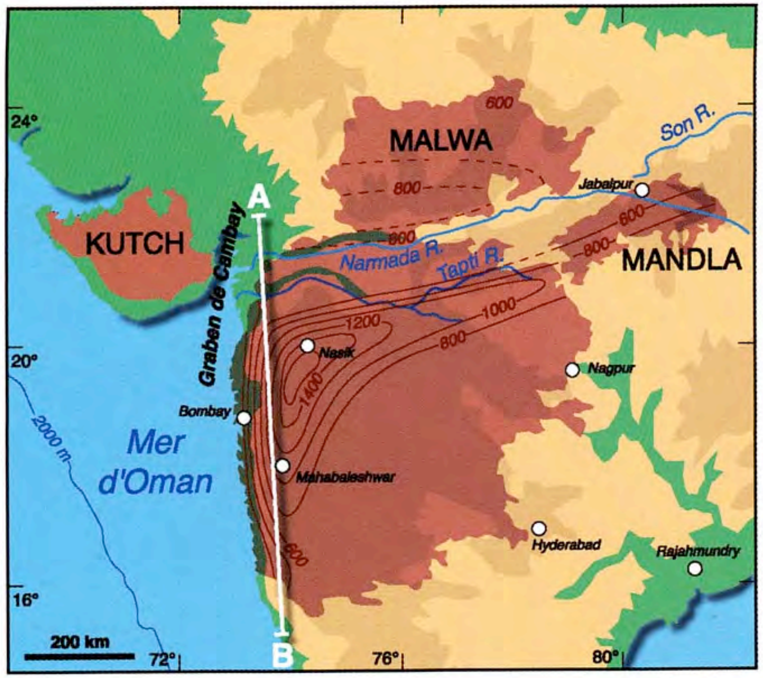
CO_2 atm

surface seawater T° Tropics



Berner 1998 Geocarb

Veizer et al 2000



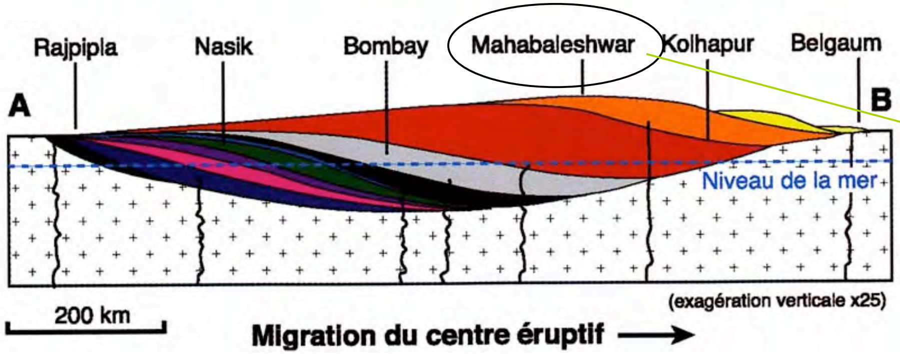
DEKKAN TRAPS

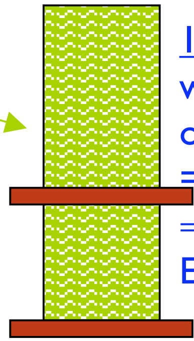
3000m (+1000m eroded)
500 000km^2
i.e. 2 millions km^3
(mantellic plume, diameter 1000km emplacement at -67Ma below the Indian lithosphere)

At the beginning : 30 à 70Ma?
then...

= p a l e o m a g n e t i s m
1800m in the SAME inverse magnetic polarity episod
i.e. few thousands years

t — t+x





1200m = 70 lava flows
with 6 'sets'or 'PULSES'
of 50 à 200m => a few 'packages'
= 2000 à ?10 000km^3
⇒= small number of major eruptions
Emplaced in a few 10'yr

Groupe	Sous groupe	Formation	Code	Pol.
PLATEAU BASALTIQUE DU DECCAN	WAI	Desur Panhala Mahabaleswar Ambenali Poladpur		200m C 29 N C 29 R
	LONAVALA	Bushe Khandala		1800m
	KALSUBAI	Bhismashankar Thakurvadi Neral Igatpuri Jawahar		

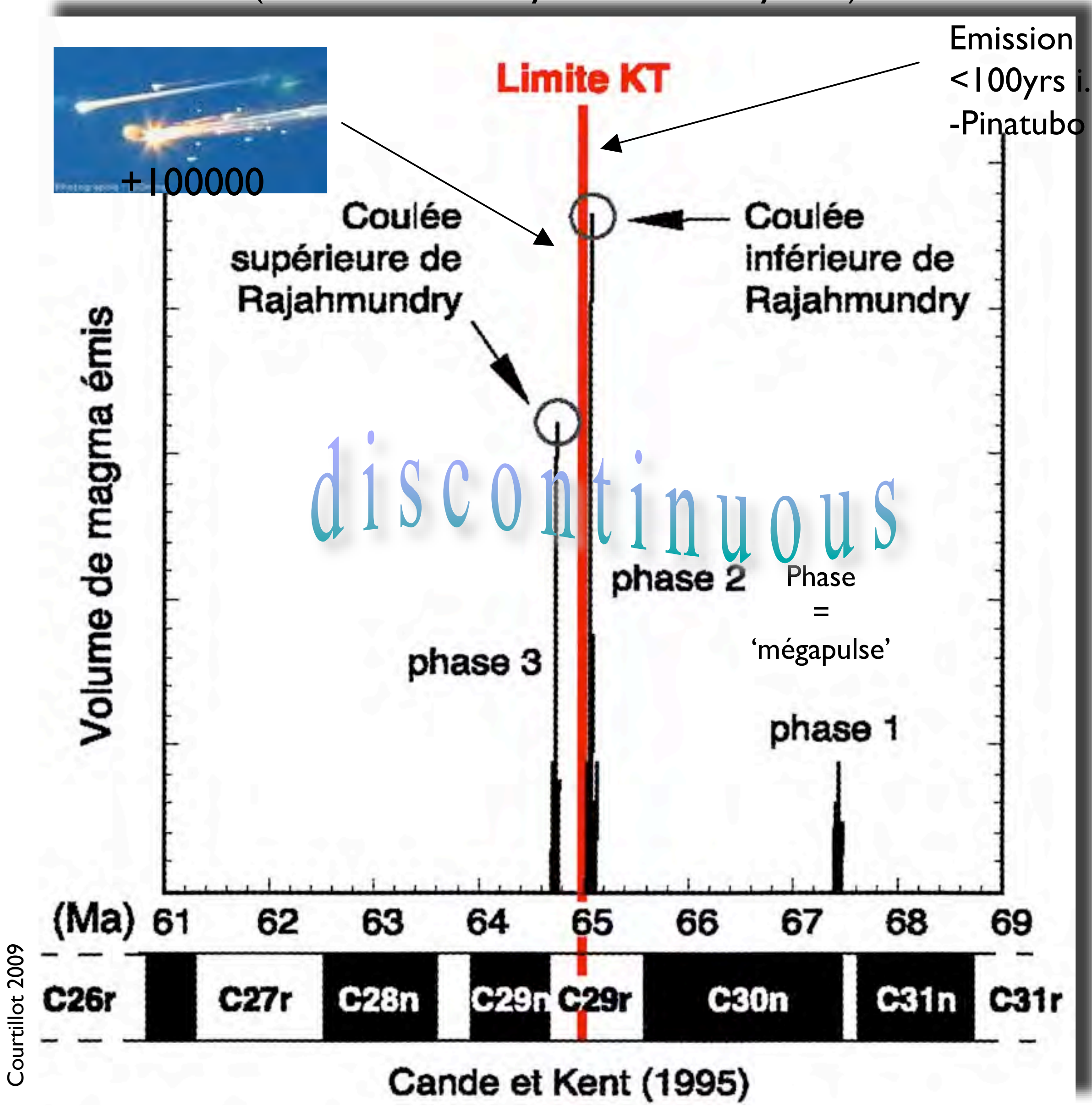
Courtillot 2009

Q? What is the time between the 'packages'?
R! =! Red Boles <1000yr (they are only a few),
The thinnest (a few dm) <10-100yr

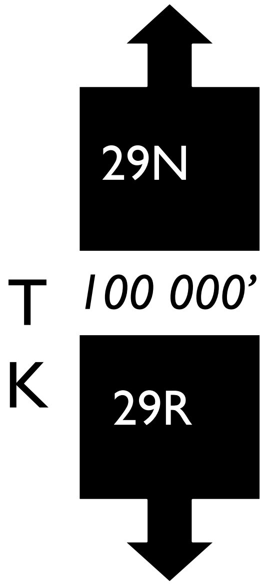
CONCLUSION 3000m < 10 000yr
and NOT 10'myr as estimated in 1980
and a long time ago….

CONCLUSION : 3000m < 10 000yr
(with 180m in 10yr, 40 m in10 yrs ...)

Emission of 5000Gt SO_2
<100yrs i.e.1 to 10Gt/yr
-Pinatubo 0.02Gt/yr

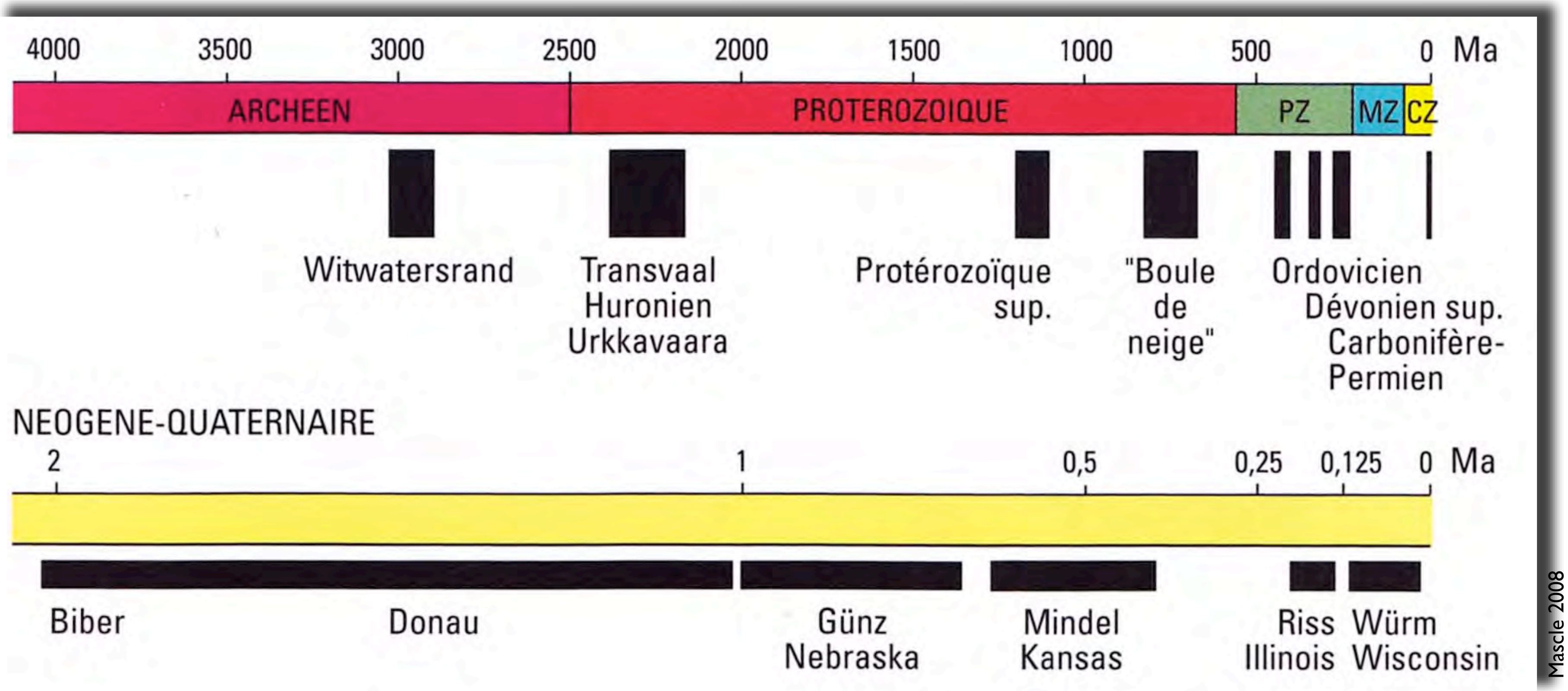


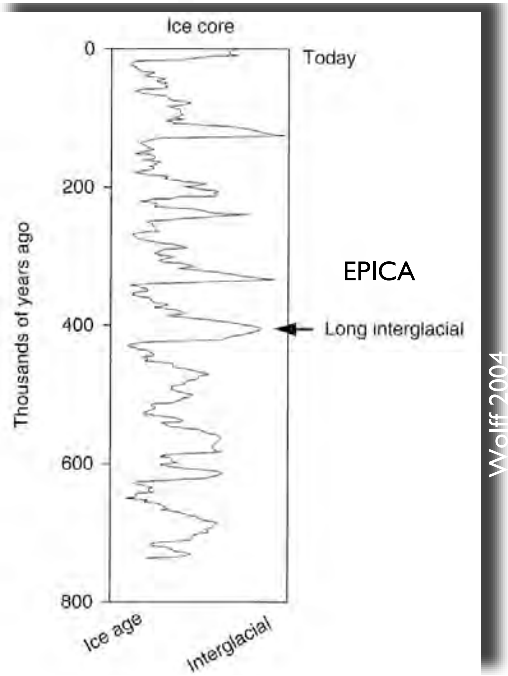
Total SO_2 emission
=10 000 Gt
i.e. 20 à 200X
Chicxulub

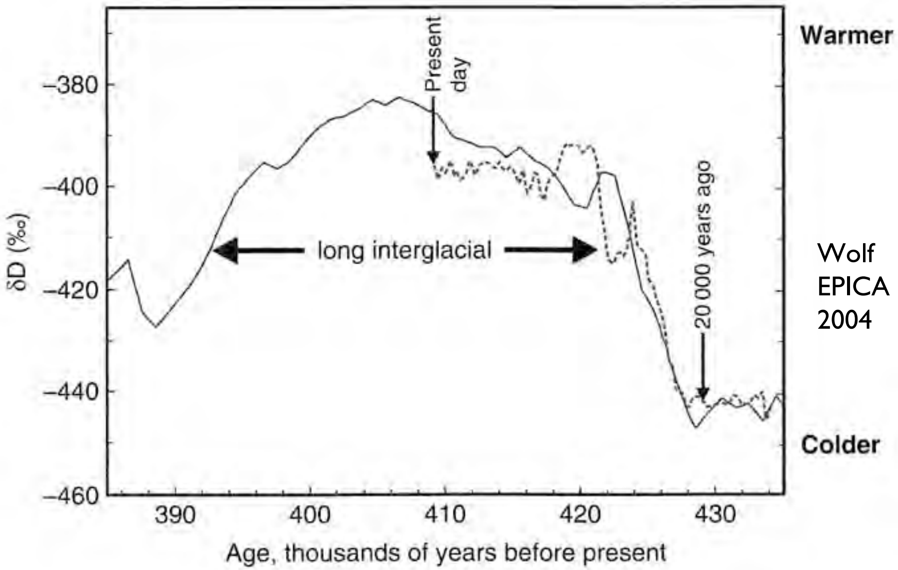


Limite K/T = 64.7Ma ±1%, ±0.6Ma
[65.5±0.3 GTS2008]

The ‘Dekkan Traps’ volcanism finally spreads during 2Ma and only was paroxysmal during three phases or ‘megapulses’ a few thousand years, the main two being separated by a few hundreds of thousands of years





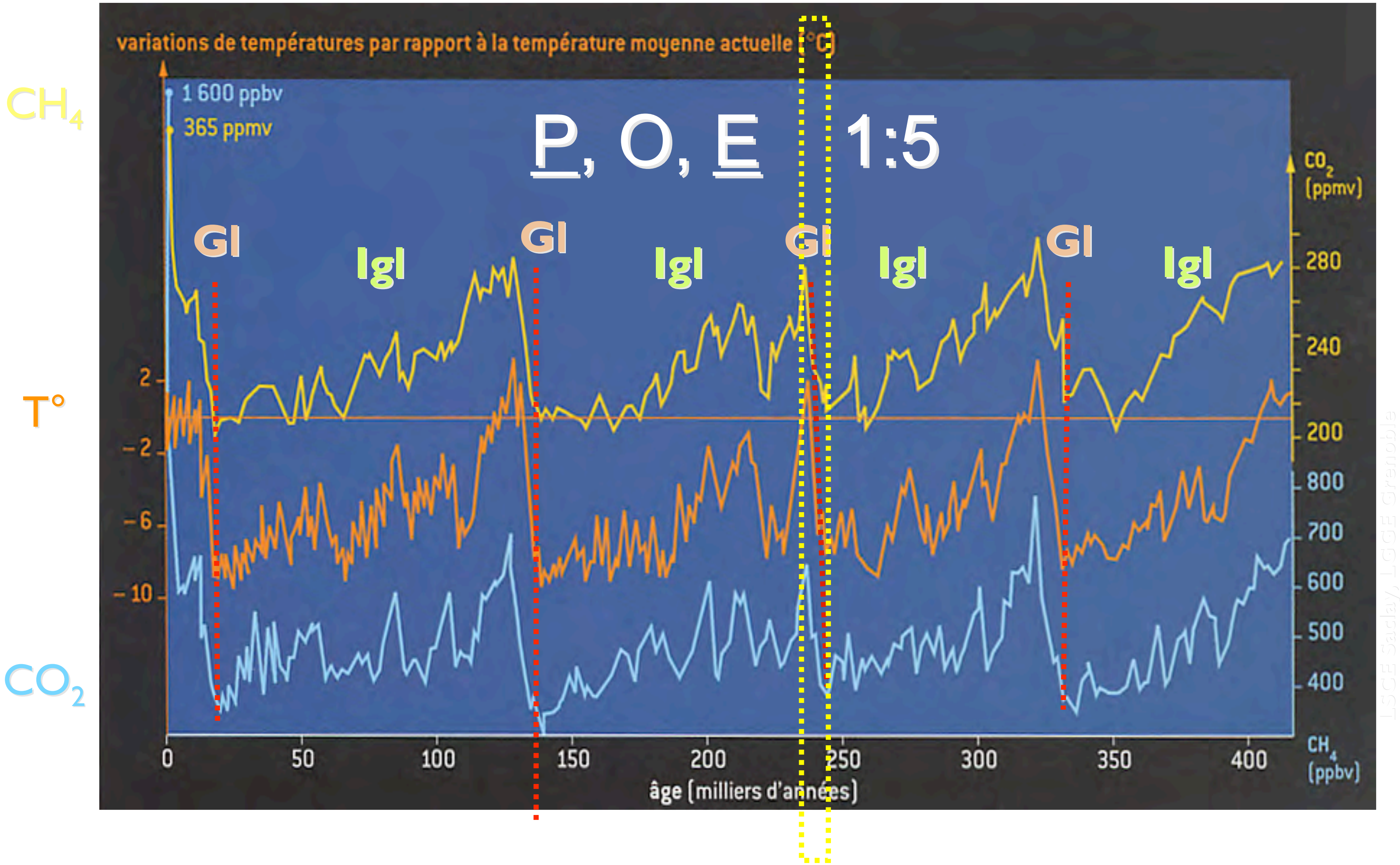


Wolf
EPICA
2004

Variations of T°, CO_2, CH_4 since 420 000 yr

Accurate data, glacial core, drillhole of VOSTOK, Antarctica

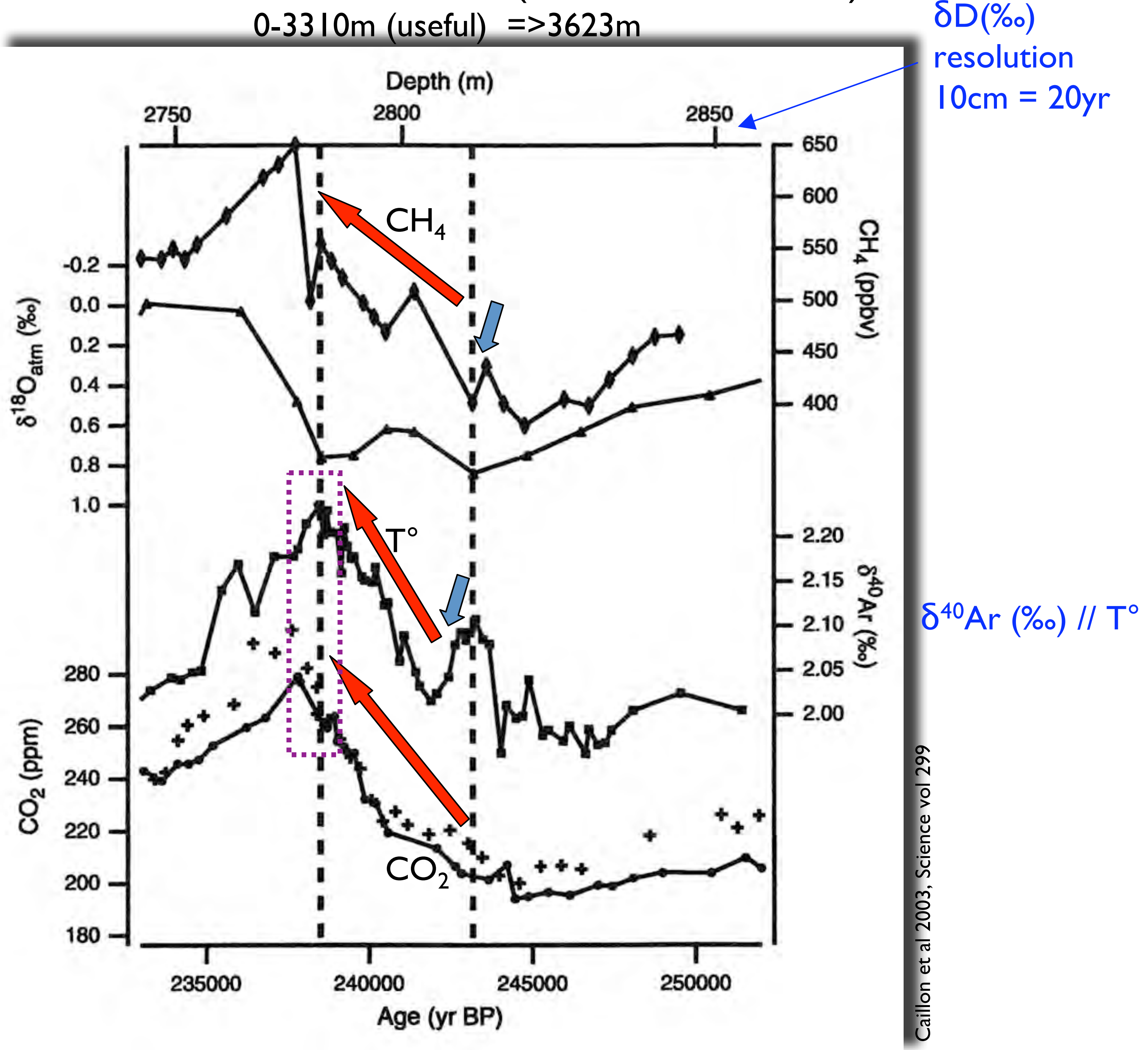
= 'M I L A N K O V I T C H' regular cycles or periodic variations of sunlight Earth===> RECENT WARMING?…



VOSTOK DRILLHOLE (ANTARCTICA)

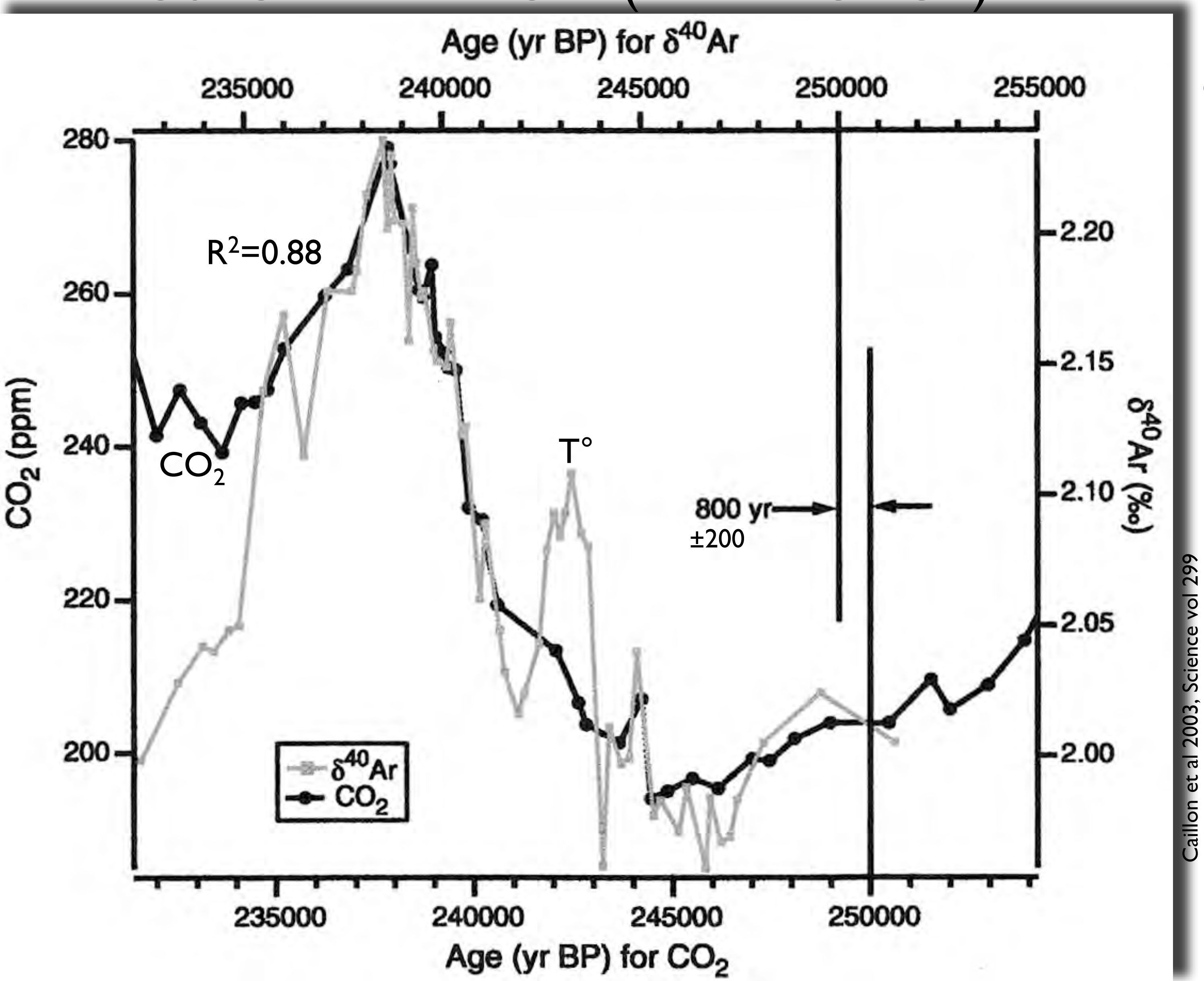
0-3310m (useful) =>3623m

- Deglaciation 6000yr before N Hemisphere
- +150ppmv CH_4 in ±5000yr



Caillon et al 2003, Science vol 299

VOSTOK DRILLHOLE (ANTARCTICA)



δ40Ar (‰)
//
T°

Caillon et al 2003, Science vol 299

CO_2 is NOT the forcing mechanism at the origin (=?sunshine)
Then, it exerted a 'greenhouse' effect for ± 5000yr AND preceded the Northern Hemisphere deglaciation
Origine: mix of 'vertical' oceanic waters?, changing surfaces floes??, biological productivity ....???