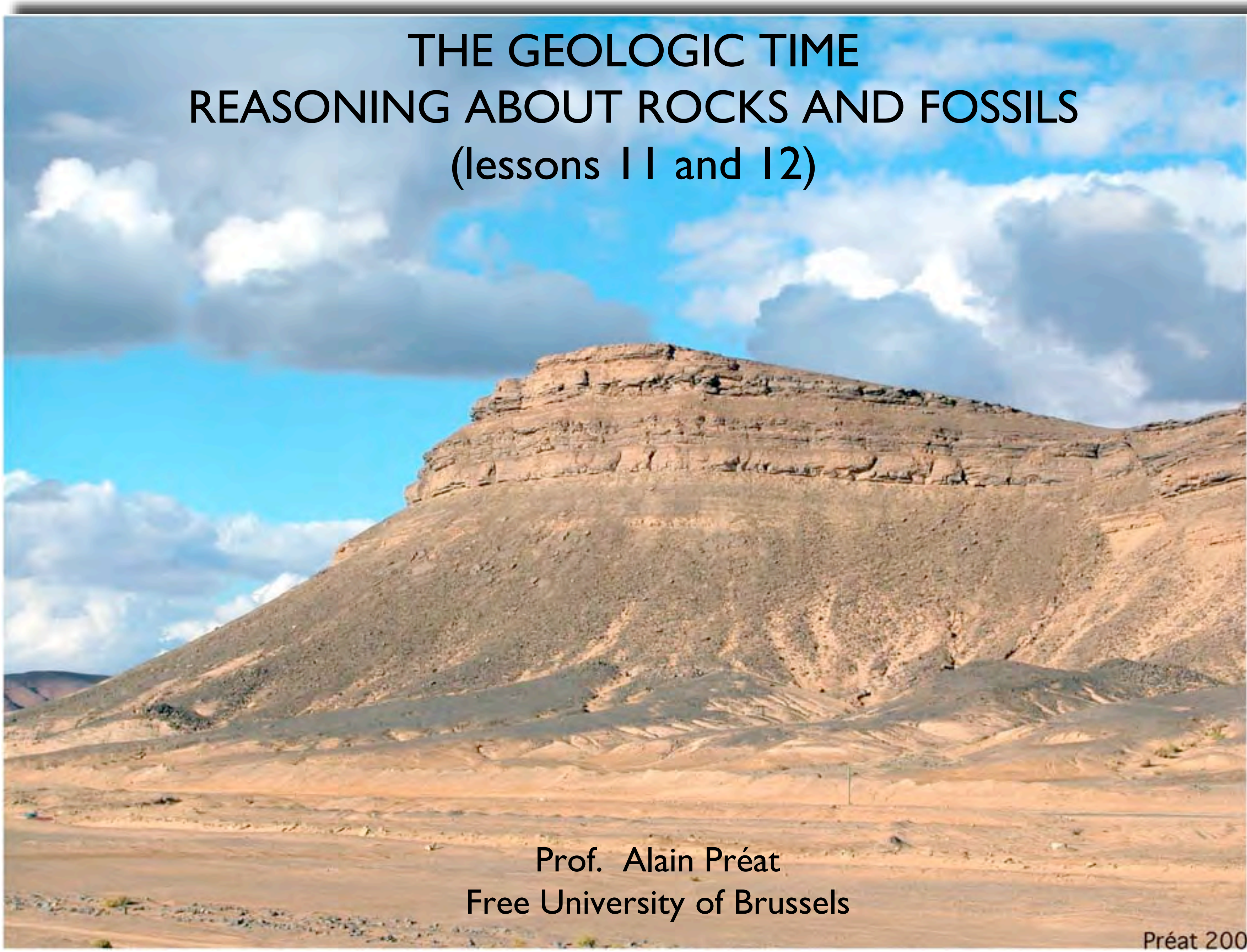
GEOL.F.203

THE GEOLOGIC TIME
REASONING ABOUT ROCKS AND FOSSILS
(lessons 11 and 12)



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Préat 2004

PRINCIPLES 1 – 2 – 3

=

STRATIGRAPHICAL SCALE

BY SEARCH OF ‘DISCONTINUITIES’

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 intervasl that are isochronous and time planes 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 deal with time and age ==> **ALLOSTRATIGRAPHY**

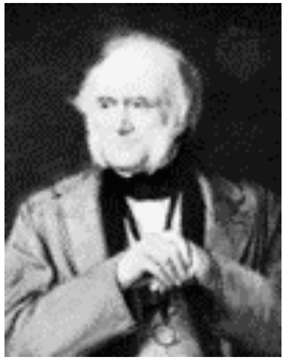
An allostratigraphic unit is a mappable stratiform body of sedimentary rock that is defined and identified on the basis of its bounding discontinuities.

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

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

Uniformitarism : Charles Lyell

('gentleman geologist')




Charles Lyell (1797-1875) was born at Kinnordy, Scotland. His father, an amateur botanist, and his grandfather, a navigator, gave him very soon a taste for the observation of the Nature. He went to the Oxford University to study classical literature, but he also followed the geological course of William Buckland. After having been employed as **jurist** for some years, in 182 he decided on a career of **geologist** and held the chair of geology of the King's College of London, from 1831 on. He was a contemporary of Cuvier, Darwin, von Humboldt, Hutton, Lavoisier, and was elected membre correspondant' of the Académi des sciences, France', in January 1862. Charles Lyell is one of the eminent geologists who initiated the scientific thinking in geology, <u>in which his famous volumes of the Principles of Geology were taken as the authority</u>. These reference volumes are based on multiple observations and field works collected during numerous fieldtrips in western Europe (principally Spain, France, and Italy) and North America. To his name are attached, among others: (i) the concept of **uniformitarism** (or actualism), which was opposed to the famous <u>catastrophism</u>, in vogue at that time, and which may be summarized by the expression "The present is the key to the past"; (ii) **the division of the Tertiary** in three series denominated Eocene, Miocene, and Pliocene, due to the study of the age of strata by fossil faunas; (iii) the theory according to which the **orogenesis** of amountain chain, as the Pyrenees, results from different pulsations **on very long time scales** and <u>was not induced by a unique pulsation</u> during a short and intense period. The uniformity of the laws of Nature is undeniably a principle Charles Lyell was the first to state clearly and to apply to the study of the whole Earth's crust, which opened a new era in geology.
(from http://www.em-consulte.com/article/69664).

http://evolution.berkeley.edu/evolibrary/article/history_12
http://www.victorianweb.org/science/lyell.html

LOCAL or REGIONAL STRATIGRAPHY

or ‘step by step’ correlations

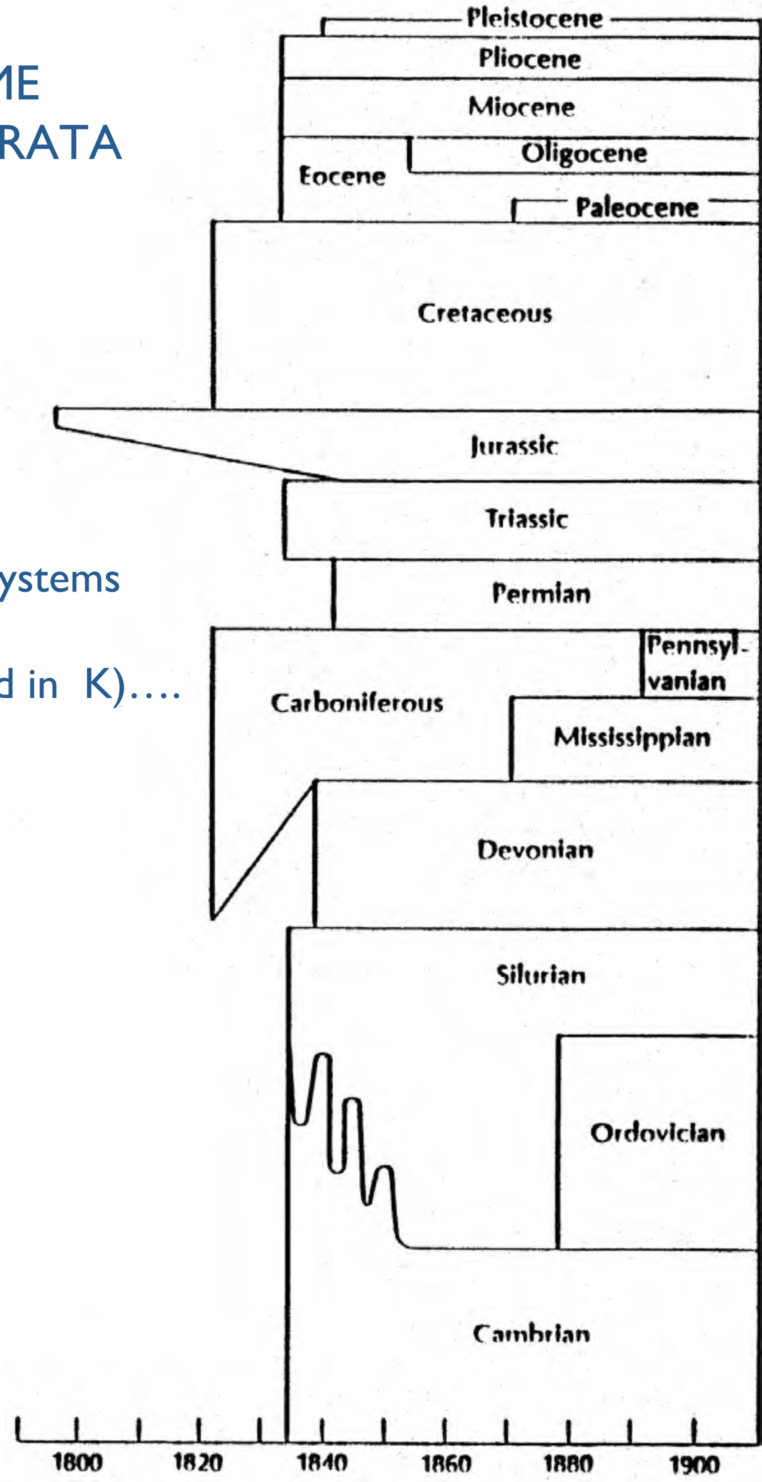
==> **CHRONOSTRATIGRAPHICAL DIVISIONS**

= historically hierarchy of time-rock divisions, orignally conceived as divisions of rock representing specific division of time. The birth of ‘modern ’chronostratigraphy is 1971.

The process of **standardization** of chronostratigraphy, or better, of a **global standard stratigraphy**, continues actively by international effort… => ‘stratotypes’
The important divisons in the chronostratigraphical scale are the **system**, **series** and **stages**
⇒ this hierarchy has evolved since the 19th century until the names of the systems, at least, are in general use

Periods = TIME
Systems = STRATA

Lithostratigraphy 1795-1841
⇒ most of the present-day systems
Biostratigraphy 1842
d'Orbigny => Stages (in J and in K)….



(modified form Moore, 1955)

unclear today despite the 'La Serre' GSSP'
see GTS 2004, 2008

Periods = TIME
Systems = STRATA

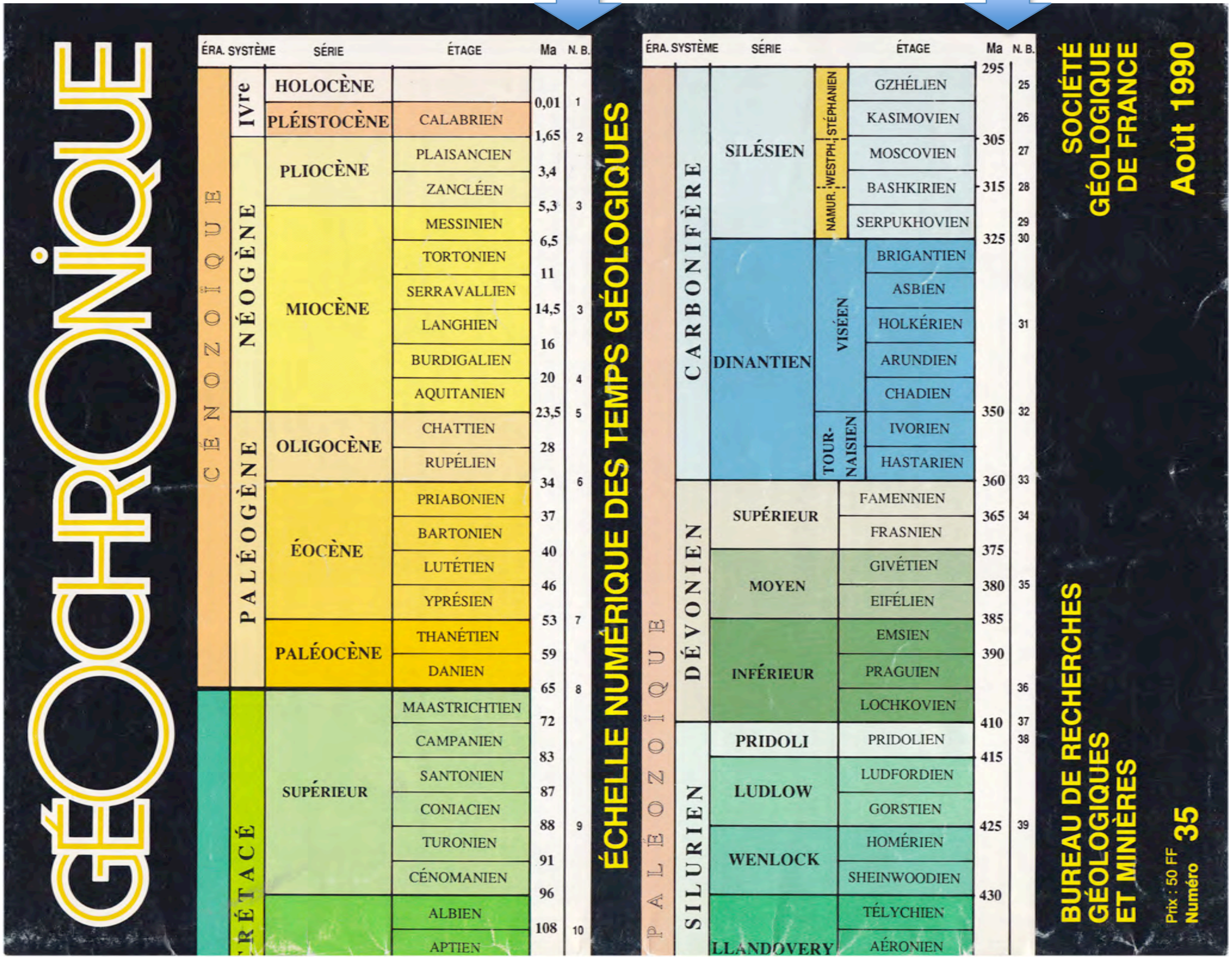
One cannot say that the dinosaurs lived in the Jurassic System…

Erathems		Systems	
Cenozoic		Quaternary	'Human evolution'
	Tertiary	Neogene	Paleontological origin, beginning with Charles Lyell's comparison between their faunas and those of the present day
		Palaeogene	
Mesozoic		Cretaceous	'chalk'
		Jurassic	Jura Mountains in France and Swizterland
		Triassic	Threefold expression of those rocks in Germany
Palaeozoic	Upper	Permian	Province of Perm, Ural mountains
		Carboniferous	'coal'
		Devonian	Devonshire, UK
	Lower	Silurian	ancient tribe in the Welsh Borderland = *Silures*
		Ordovician	ancient tribe in Wales = *Ordovices*
		Cambrian	old name for Wales

http://comp.uark.edu/~sboss/geotimenames.htm

Doyle & Bennett 1998

1990 (the table is not complete)



GÉOCHRONIQUE

ÈRA	SYSTÈME	SÉRIE	ÉTAGE	Ma	N.B.
CÉNOZOÏQUE	IVre	HOLOCÈNE		0,01	1
		PLÉISTOCÈNE	CALABRIEN	1,65	2
	NÉOGÈNE	PLIOCÈNE	PLAISANCIEN	3,4	
			ZANCLÉEN	5,3	3
		MIOCÈNE	MESSINIEN	6,5	
			TORTONIEN	11	
			SERRAVALLIEN	14,5	3
			LANGHIEN	16	
			BURDIGALIEN	20	4
			AQUITANIEN	23,5	5
	PALÉOGÈNE	OLIGOCÈNE	CHATTIEN	28	
			RUPÉLIEN	34	6
		ÉOCÈNE	PRIABONIEN	37	
			BARTONIEN	40	
			LUTÉTIEN	46	
			YPRÉSIEN	53	7
		PALÉOCÈNE	THANÉTIEN	59	
			DANIEN	65	8
	CRÉTACÉ	SUPÉRIEUR	MAASTRICHTIEN	72	
			CAMPANIEN	83	
			SANTONIEN	87	
			CONIACIEN	88	9
			TURONIEN	91	
			CÉNOMANIEN	96	
			ALBIEN	108	10
			APTIEN		

ÉCHELLE NUMÉRIQUE DES TEMPS GÉOLOGIQUES

ÈRA	SYSTÈME	SÉRIE		ÉTAGE	Ma	N.B.
PALÉOZOÏQUE	CARBONIFÈRE	SILÉSIEN	STÉPHANIEN	GZHÉLIEN	295	25
				KASIMOVIEN	305	26
			WESTPH.	MOSCOVIEN	315	27
				BASHKIRIEN		28
			NAMUR.	SERPUKHOVIEN	325	29
		DINANTIEN	VISÉEN	BRIGANTIEN		30
				ASBIEN		
				HOLKÉRIEN		31
				ARUNDIEN		
				CHADIEN	350	32
			TOURNAISIEN	IVORIEN		
				HASTARIEN	360	33
	DÉVONIEN	SUPÉRIEUR		FAMENNIEN	365	34
				FRASNIEN	375	
		MOYEN		GIVÉTIEN	380	35
				EIFÉLIEN	385	
		INFÉRIEUR		EMSIEN	390	
				PRAGUIEN		
				LOCHKOVIEN	410	36 37 38
	SILURIEN	PRIDOLI		PRIDOLIEN	415	
		LUDLOW		LUDFORDIEN		
				GORSTIEN	425	39
		WENLOCK		HOMÉRIEN		
				SHEINWOODIEN	430	
		LLANDOVERY		TÉLYCHIEN		
				AÉRONIEN		

SOCIÉTÉ GÉOLOGIQUE DE FRANCE

Août 1990

BUREAU DE RECHERCHES GÉOLOGIQUES ET MINIÈRES

Prix : 50 FF

Numéro 35

1990

N.B.

NOTA BENE (ÉCHELLE STRATIGRAPHIQUE EN COULEURS)

29 - Le Serpukhovien (Ukraine) se subdivise en Pendléien, Arnsbergien, Chokiérien et Alportien. Les 18 subdivisions du Silésien sont difficiles à mémoriser mais, surtout, il paraît peu raisonnable de subdiviser en 18 intervalles, une durée de l'ordre de 30 Ma ; ces « étages » seraient délicats à reconnaître hors de leur bassin de définition. D'un autre côté, une durée moyenne de 6 Ma pour les 5 subdivisions retenues est tout à fait conforme aux durées des étages des autres systèmes.

30 - L'équivalence entre la base du **Namurien continental** et celle du **Serpukhovien marin** n'est pas précisément assurée. L'âge de 325 Ma admis généralement correspond à la limite Dinantien-Silésien mais ces 2 termes tendent à disparaître.

La subdivision du Carbonifère en 2 sous-systèmes : **Mississipien** (vieux) et **Pennsylvanien** (jeune) est utilisé en Amérique du Nord ; leur limite serait plutôt située entre Serpukhovien et Bashkirien. La sous-commission spécialisée tend à proposer 2 sous-systèmes carbonifères dont la limite serait dans le Serpukhovien. Des définitions modernes restent à établir.

31 - La subdivision du « super étage » Viséen en 5 étages est raisonnable si l'on considère le facteur durée. Aucun âge n'est actuellement cité pour leurs limites ; ces 5 subdivisions « anglaises » correspondent aux 3 subdivisions « belges » Moliniacien, Livien, Warnatien.

32 - La limite est mal datée mais la durée relative du **Viséen** et du **Tournaisien** paraît bien respectée par les âges proposés. Les 2 étages tournaisiens sont nommés en Belgique.

33 - Pour la limite **Dévonien-Carbonifère,** un âge autour de 355 Ma est aussi très plausible ; d'après Claoué-Long (1990), des résultats U-Pb par microsonde ionique suggèrent un âge de 353 ± 4 Ma en Allemagne et Australie.

34 - Le Frasnien semble plus long que le **Famennien.**

35 - Au Dévonien moyen, les durées égales à 5 Ma (ou à 10) indiquent seulement que l'on a peu d'assurance ; ces estimations de durées arrondies sont indicatives et peut-être erronées.

36 - Au Dévonien inférieur, Lochkovien et Praguien remplacent désormais Gédinnien et Siegenien ; l'âge de leur limite commune n'est pas encore estimé (pas d'âges radiométriques). La limite Praguien-Emsien est à définir ; pour Robardet, l'Emsien est le plus long des 3 étages.

37 - Pour la limite Silurien-Dévonien, un âge de 395 Ma est parfois retenu mais un âge proche de 410 Ma semble plus probable. La marge d'incertitude sur l'âge proposé ici est de l'ordre de

durées courtes en moyenne. Le critère durée n'est pas partie intégrante de la définition d'un étage mais est discuté ici dans un but de simplification de la séquence proposée.

39 - La limite Wenlock-Ludlow a été estimée par des datations directes et semble bien localisée entre 420 et 425 Ma.

40 - La limite Ordovicien-Silurien est proposée diversement entre 435 et 440 Ma. L'âge jeune est retenu car diverses datations autour de 440 sont publiées par le Caradoc.

41 - La série Ashgill est parfois subdivisée en 4 étages : Pusgillien, Cautléien, Rawthéien, Hirnantien de bas en haut. La base est datée de 440 à 450 Ma.

42 - La série Caradoc se subdivise en 7 : Costonien, Harnagien, Soudléien, Longvillien, Marshbrookien, Actonien et Onnien. La base est imprécisément repérée entre 450 et 460 Ma ; ce dernier âge serait favorisé par les mesures récentes de R. Tucker. Si les séries **Ashgill et Caradoc** sont plus longues que des étages moyens, les subdivisions en 4 et 7 étages, respectivement, paraissent trop fines.

43 - La limite Llanvirn-Llandeilo n'est pas définie. Ces 2 séries, non subdivisées, sont probablement courtes (assez près de 5 Ma), et équivalent à des étages, ce qui conduirait à utiliser les termes Llanvirnien et Llandeilien.

44 - Les limites de l'Arénig sont repérées à ± 5 Ma (sommet) et ± 10 Ma (base) ; les résultats de J.-L. Bonjour, en Bretagne, suggèrent plutôt un âge de 465 Ma pour le sommet ; par ailleurs, la base pourrait être plus vieille que 485 Ma, ce qui justifierait la subdivision en Moridunien, Whitlandien et Fennien.

45 - Des âges de 490 Ma ou de 510 Ma sont également cités pour la base du **système Ordovicien.**

46 - Pas de données radiométriques pour le **Cambrien moyen et supérieur** ; la limite entre ces 2 sous-systèmes formels ne coïncide peut-être pas avec la limite Mayaien-Dresbachien. La subdivision en Georgien-Acadien-Postdamien (= Cambrien inférieur, moyen et supérieur) tend à disparaître.

47 - Au Cambrien inférieur, le Lénien ou un intervalle de temps aux limites voisines, est subdivisé en Botomien puis Toyonien.

48 - Au Cambrien inférieur, des données que nous avons discutées par ailleurs tendent à montrer que l'apparition des Trilobites, à la base de l'**Atdabanien,** se fait à 530 ± 10 Ma. Des âges bien plus vieux sont souvent conservés.

49 - La définition de la base du Tommotien, étage prétrilobitique de l'ère Phanérozoïque est débattue. Elle n'a pas fait l'objet d'une convention récente. La question est de

1 - L'unité Quaternaire ne justifie sa position qu'au rang d'étage (voire de biozone) si le critère de durée est seul pris en compte. La singularité de cet intervalle de temps (officiellement un érathème et non un système comme dessiné ici) est mise en évidence par l'abandon des termes de racine comparable : Primaire-Secondaire-Tertiaire.

Pour M.B. Cita, le Calabrien en cours de redéfinition, ne constituera que l'étage inférieur du Pléistocène.

2 - On pourrait s'accorder pour situer la base du **Quaternaire** au sommet de l'événement d'Olduvaï (séquence magnétique) lequel n'est pas clairement identifié dans le stratotype (SPSG) de Calabre.

Un âge de 1,6 à 1,85 Ma est indiqué par des datations. L'âge conventionnel de 1,65 Ma est préliminaire. Le changement de faune des Mammifères serait près de 2,5 Ma.

3 - L'âge du sommet du **Messinien** noté ici correspond à la base de l'époque magnétique Gilbert ; Cita indique qu'il se situe plutôt dans cette époque, au sommet du premier intervalle inverse de l'époque ; son âge serait alors proche de 4,9 Ma. L'âge de la base de étages **Burdigalien à Messinien** est, soit extrapolé, soit résulte de datations effectuées hors des bassins stratotypiques. Des définitions en milieu marin pélagique manquent ; mais des datations radiométriques récentes et en cours (Montanari) existent. Les estimations varient de 14 à 15 Ma pour la limite **Langhien-Serravallien.**

4 - Pour la limite **Aquitanien-Burdigalien,** les estimations varient (19 à 21,5 Ma) selon les correspondances établies entre datations et limite. Des études en cours (Montanari) indiquent un âge de 20,9 ± 0,6 Ma pour la limite acceptée dans les Apennins.

5 - La définition biostratigraphique de la limite **Oligocène-Miocène** reste à l'étude. Les résultats radiométriques placent celle-ci entre 22,5 et 24,0 Ma.

6 - Après 15 années de controverse, la limite **Éocène-Oligocène** est maintenant redé-

9 - L'âge de la base des étages **Cénom**
nien à Maastrichtien est admis avec ur
marge d'incertitude de ± 1 Ma grâce à
coïncidence entre résultats sur géochronom
tres volcaniques et sédimentaires. Noter que
Campanien seul est plus long que l'ensemb
des 3 étages précédents.

10 - La datation de l'**Albien** de l'Aube su
gère l'âge de 107 Ma ; d'après des laves c
Tibet, Maluski pense qu'un âge proche c
111 Ma est concevable.

11 - L'âge de la base des étages **Bath**
nien à Hauterivien est régulièrement propos
8 à 10 Ma plus ancien par Palmer. Ceci s'éter
jusqu'à la base de l'Aptien dans certaine
estimations ; ceci reflète un manque d'inform
tion radiométrique. Les présentes propositio
s'entendent avec une marge de ± 4 à 5 Ma.

12 - La nomenclature et la définition de
étages entourant la limite **Jurassique-Crétac**
sont variées.

Nous recommandons ici le néologisme **T**
thonien au lieu du terme usuel Tithonique q
fait penser à un faciès. L'étage type Tithonie
identifiable dans tout le domaine téthysien
ses dépendances, a une base identique à cel
du Portlandien (au sens français) et au Volgie
de Russie.

Ce dernier terme reste utilisé alors qu
Portlandien est déconseillé à cause de s
différentes définitions historiques. Le somm
du Portlandien (au sens large), estimé par no
vers 130 Ma en 1982, semble plus jeune que
limite actuelle Tithonien-Berriasien (en Téthys
ce qui conduit à vieillir la limite J/C vers 135 M

Les résultats géochronologiques situent l
diverses acceptations de la limite J/C entre 1
et 140 Ma, les 2 bornes ne peuvent être e
clues. Un âge proche de 145 Ma proposé da
la littérature ne tient pas compte des résulta
géochronologiques publiés. Selon Ogg et Lo
rie, le problème de la définition et de l'âge de
limite J/C pourrait être solutionné en localisa
et reconnaissant la base de l'inversion magn
tostratigraphique M 18 dans les séquences fa

by O H Walliser, P Bultynck, K Weddige, R T Becker and M R House

Fh/mhs VII/3 1°7-

1995

Definition of the Eifelian–Givetian Stage boundary

= MECH IRDANE

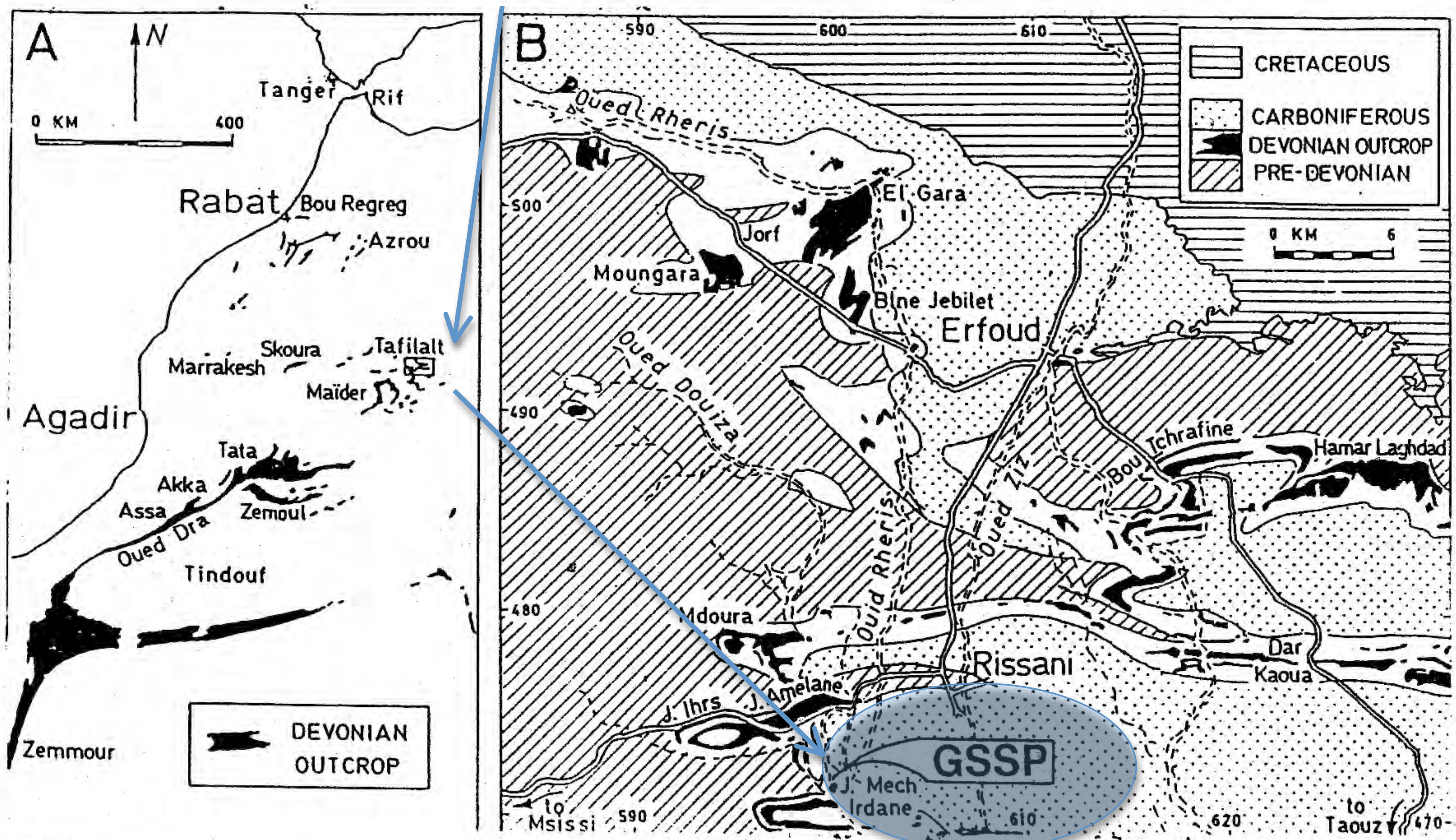
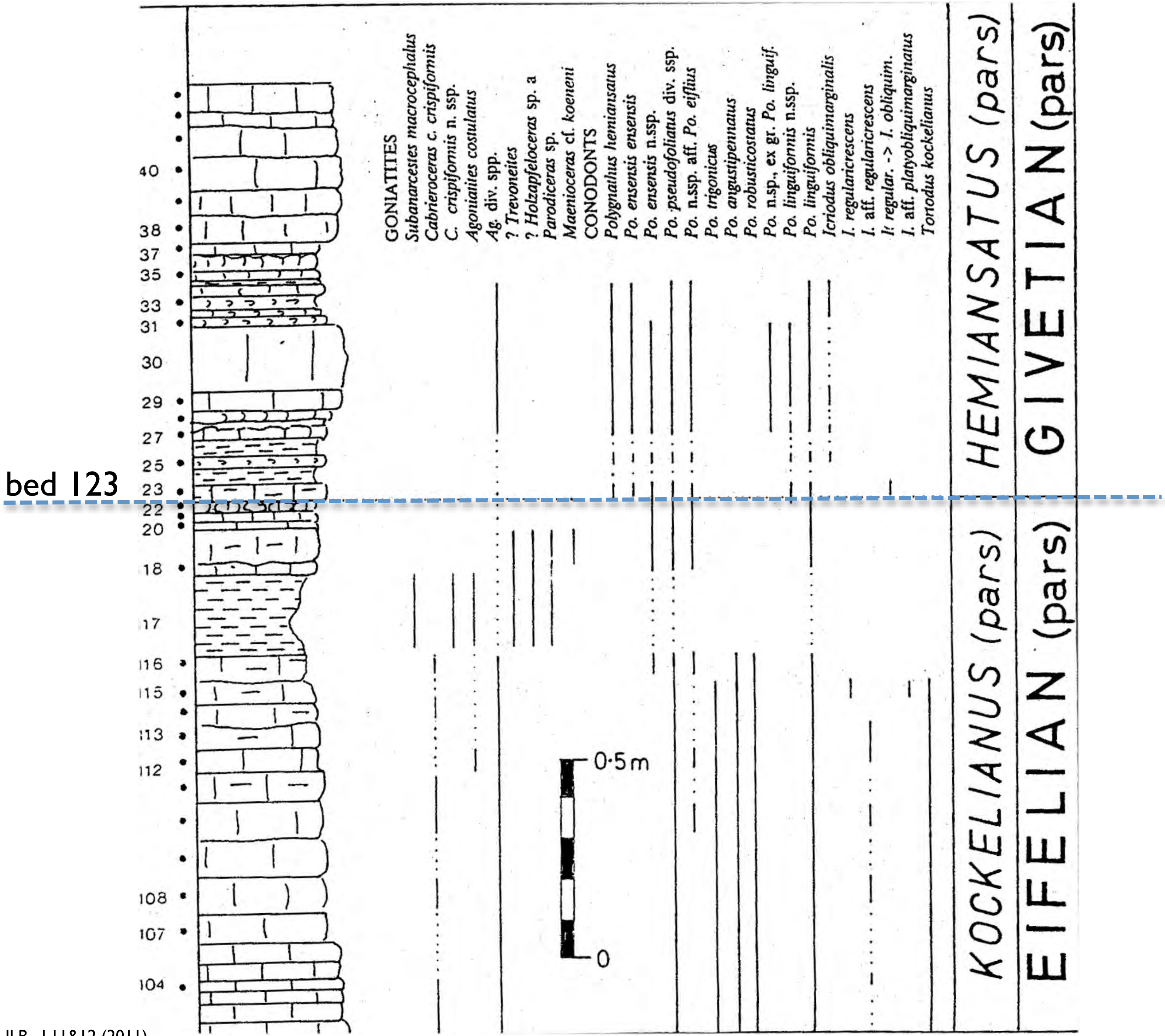


Figure 1

A, Map showing the outcrop of Devonian rocks in Morocco and adjacent areas showing by a small rectangle in the Tafilalt the area covered in the detailed map.

B, Detailed map showing the geology of the Erfoud area and the position of the Eifelian–Givetian GSSP at Jebel Mech Irdane. (Based on maps published by the Ministère de l'Energie et des Mines, Rabat; after Becker and House, 1994a).


GSSP
MECH IRDANE
bed 123
Préat 2004


bed 123
GONIATITES
Subanarcestes macrocephalus
Cabrieroceras c. crispiformis
C. crispiformis n. ssp.
Agoniatites costulatus
Ag. div. spp.
? Trevoneites
? Holzapfeloceras sp. a
Parodiceras sp.
Maenioceras cf. koeneni
CONODONTS
Polygnathus hemiansatus
Po. ensensis ensensis
Po. ensensis n.ssp.
Po. pseudofoliatus div. ssp.
Po. n.ssp. aff. Po. eiflius
Po. trigonicus
Po. angustipennatus
Po. robusticostatus
Po. n.sp., ex gr. Po. linguif.
Po. linguiformis n.ssp.
Po. linguiformis
Icriodus obliquimarginalis
I. regularicrescens
I. aff. regularicrescens
I: regular. -> I. obliquim.
I. aff. platyobliquimarginatus
Tortodus kockelianus
0·5m
0
40
38
37
35
33
31
30
29
27
25
23
22
20
18
17
116
115
113
112
108
107
104
HEMIANSATUS (pars)
GIVETIAN (pars)
KOCKELIANUS (pars)
EIFELIAN (pars)

It is important to realize that there are NO IDEAL SECTIONS, it is unreasonable to expect the fullfilment IN ONE PLACE of all those criteria referred as necessary. We must make do with the BEST presently data available.

http://www.stratigraphy.org/

Categories and ranks of stratigraphic units (NACSN, 1989)

Material units

Lithostratigraphic	Lithodemic		Magnetopolarity	Biostratigraphic	Pedostratigraphic	Allostratigraphic
Supergroup	Supersuite	Complex				
Group	Suite		Polarity Superzone			Allogroup
Formation	*Lithodeme*		*Polarity zone*	*Biozone* (interval assemblage or abundance)	*Geosol*	*Alloformation*
Member (or lens or tongue)			Polarity Subzone	Subbiozone		Allomember
Bed(s) or flow(s)						

Temporal and related chronostratigraphic units

Chronostratigraphic	Geochronologic, geochronometric	Polarity chronostratigraphic	Polarity chronologic	Diachronic	
Eonothem	Eon	Polarity Superchronozone	Polarity Superchron		*Episode*
Erathem (Supersystem)	Era (Superperiod)				
System (Subsystem)	*Period* (Subperiod)	*Polarity* Chronozone	*Polarity* Chron	Diachron	
Series	Epoch				Phase
Stage (Substage)	Age (Subage)	Polarity Subchronozone	Polarity Subchron		Span
Chronozone	Chron				Cline

Fundamental units are italicized.

Categories and unit terms of stratigraphy (in Brookfield 2004)

Stratigraphic categories	Principal stratigraphic unit terms
Lithostratigraphic	Group Formation Member Bed(s), Flow(s)
Unconformity-bounded	Synthem
Biostratigraphic	Biozones: Range zones Interval zones Lineage zones Assemblage zones Abundance zones Other kinds of biozones
Magnetostratigraphic polarity	Polarity zone
Other (informal) stratigraphic categories (mineralogic, stable isotope, environmental, seismic, etc.)	-zone (with appropriate prefix)
Chronostratigraphic	Eonothem Erathem System Series Stage Substage (Chronozone)
Equivalent geochronologic units	Eon Era Period Epoch Age Subage (or Age) (Chron)

HIERARCHY

1. Geochronologic (time)[1, 2]	2. Chronostratigraphic (time-rock)[3]	3. Biostratigraphic (Biozone)		4. Lithostratigraphic (rock)
Eon	Eonothem			Supergroup
Era	Erathern			Group
Period	**System**			**Formation**
Epoch	Series			Member (also, Lens, Tongue, Bed, or Flow)
Age	Stage			
Chron[4]	Chronozone[5]	**Biozone**		
		Subbiozone		

Rock units (lithostratigraphy)	Relative time units (chronostratigraphy)	Numerical time units (geochronology)
Supergroup	Eonothem (e.g. Phanerozoic)	Eon
Group	Erathem (e.g. Paleozoic)	Era
Formation	System (e.g. Ordovician)	Period
Member, etc.	Series (e.g. Viruan)	Epoch
Bed, etc.	Stage (e.g. Uhaku)	Age
	Zone (e.g. *G. teretiusculus*)	Chron

I. Magnetostratigraphic units:		
A. Polarity-Chronologic	**B. Polarity-Chronostratigraphic**	**C. Magnetopolarity**
Polarity Superchron	Polarity Superchronozone	Polarity Superzone
Polarity Chron	**Polarity Chronozone**	**Polarity Zone**
Polarity Subchron	Polarity Subchronozone	Polarity Subzone

II. Lithic units, an informal grouping of the following three formal units:			
A. Lithostratigraphic	**B. Lithodemic**		**C. Pedostratigraphic**
Supergroup	Supersuite	Complex[1]	
Group	Suite		
Formation	**Lithodeme**		**Geosol**
Member; Lens; Tongue			
Bed; Flow;			

III. Diachronic units:	
Episode	Diachron
Phase	
Span	
Cline	

[1] Complex is an unranked unit of two or more genetic classes of rock (i.e., igneous and metamorphic). It is comparable to a Supersuite or Suite in rank.

Unconformity-related units, an informal grouping of the following units:
A. Allostratigraphic (these units are formal in the Code, and moderately used)
Allogroup
Alloformation
Allomember
B. Unconformity-Bounded (these units are formal in the Guide, but uncommonly used)
Supersynthem
Synthem
Subsynthem
C. Sequence-stratigraphic (these units are informal, but are the most commonly used)
Sequence (depositional sequence; T-R sequence; genetic stratigraphic sequence)

SEISMOSTRATIGRAPHY

3rd order >10 000's yr -1 [3-10] myr, probably around 0.5 myr

INFORMAL TIME and PLACE WORDS

Time	Place
late	upper
middle (medial)	middle
early	lower
young(er)	high(er)
old(er)	low(er)
post-	super-
pre-	sub-
after	above, over
before	below, under
when	where
then	there
now	here
while	whereas
sometime(s)	someplace(s)
often, frequent	abundant, common
occasionally	locally
during	in

The' Fondry des Chiens' bioherm is of **Late** Eifelian and **below** the Trois-Fontaines Formation (which is of **Early** Givetian age …)

Upper Thuesday > < Late Thuesday …

How to use stratigraphic terminology in papers, illustrations, and talks

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ABSTRACT: Some writers, speakers, and students have problems with clear usage of stratigraphic terminology, a topic made more acute by the appearance of the complex 1983 North American Stratigraphic Code, its 2005 revision, and new editions of the International Stratigraphic Guide. The basic categories of stratigraphic units are: 1) material; 2) non-material; 3) hybrid. Examples are the well-known rock (lithostratigraphic), time (geochronologic), and time-rock (chronostratigraphic) units, respectively. Biostratigraphic units (biozones) are used to describe and correlate time-rock units. Lesser-known categories include magnetostratigraphic, lithodemic, pedostratigraphic, diachronic, and unconformity-related units. Sequence-stratigraphic nomenclature, still developing, is in a state of turmoil at present.

Both formal and informal stratigraphic units are recognized. All words in formal units are capitalized, except for species names in biozones. Only the geographically derived name in informal units is generally capitalized. Inadequate distinction between time and place words, both formal and informal, leads to unnecessary confusion. Misuse of early versus lower, late versus upper, and Ma for Myr is epidemic.

Web sites and publications such as lexicons, geologic time scales, and correlation charts are recommended as initial sources of stratigraphic information. Naming, revising, and abandoning formal stratigraphic names are governed by specific rules for names to be accepted. In illustrations of stratigraphic units, it is important to distinguish clearly between scales of time and position. Strata are not measured in years, or time in meters!

Stratigraphy 2009 , vol.6,2 p.106-116
http://www.agiweb.org/nacsn/10570_articles_article_file_1642.pdf

J. Sed. Petrology, 1987, 57/2, 363-372

COMMENTARY: USAGE OF STRATIGRAPHIC TERMINOLOGY IN PAPERS, ILLUSTRATIONS, AND TALKS[1]

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ABSTRACT: Some writers and speakers have problems with clear usage of stratigraphic terminology, a topic made more acute by the appearance of the complex 1983 North American Code and revisions in progress of the 1976 International Guide. The basic categories of stratigraphic units are 1) material; 2) nonmaterial; 3) hybrid. Examples are the well-known rock (lithostratigraphic), time (geochronologic), and time-rock (chronostratigraphic) units, respectively. Lesser-known categories include magnetostratigraphic, lithodemic, pedostratigraphic, unconformity-bounded, and diachronic units.

Both formal and informal stratigraphic units are recognized. All words in formal units are capitalized. Only the geographically derived name in informal units is generally capitalized. Inadequate distinction between time and place words, both formal and informal, leads to unnecessary confusion. Misuse of early versus lower and late versus upper is prevalent.

Publications such as lexicons and correlation charts are recommended as initial sources of stratigraphic information. Naming, revising, and abandoning formal stratigraphic nomenclature is governed by specific rules laid down in the Code and Guide.

In illustrations of stratigraphic units, it is important to distinguish clearly between scales of time and position. Strata are not measured in years, nor time in meters!

INTRODUCTION

Since the appearance of the new North American Stratigraphic Code [North American Commission on Stratigraphic Nomenclature (N.A.C.S.N., 1983)], it has become apparent that some writers and speakers have problems with clear usage of stratigraphic nomenclature. This is a continuing problem, made more complex because the 1983 Code has many more categories of stratigraphic units and much more detail than its predecessor [American Commission on Stratigraphic Nomenclature (A.C.S.N., 1961 and 1970)]. Stratigraphic nomenclature has recently undergone an expansion well outside the realm of sedimentary rocks into formal units that do not conform to the Law of Superposition. Also, authors working on areas outside North America should be advised that the International Stratigraphic Guide (Hedberg 1976) is being revised by the International Subcommission on Stratigraphic Classification (I.S.S.C.). Therefore, developments in international practice should be followed closely.

As a consequence of recent developments regarding the North American and international standards for stratigraphic terminology (Code and Guide as referred to in this article), it seems appropriate to update my previous attempt at practical advice on usage of stratigraphic terminology (Owen 1978). The purposes of this paper are 1) to summarize the currently available types of formal stratigraphic units and their usage; and 2) to review some informal conventions that are standard procedure in stratigraphic editing, but which are not written in the Code, Guide, or any other readily available source.

rock; 2) nonmaterial units, based on the abstract concept of geologic time. A combination of these two categories, a chronostratigraphic unit, is also commonly recognized. A chronostratigraphic unit is a body of rock that serves as the referrant for the geologic time represented by that body of rock.

Well-Known Units

For most geologists composing most papers, the old "holy trinity" of stratigraphic units (Schenck and Muller 1941) (Table 1) that students are supposed to learn will suffice: 1) lithostratigraphic units (= material rock units); 2) geochronologic units (= abstract "time units")[3]; 3) chronostratigraphic (and biostratigraphic ?) units (= hybrid time-rock units).

The status of the third group of units is slightly controversial. Separate terms for chronostratigraphic and biostratigraphic units are well established in official codes and guides, but a small group of dissenters maintains that chronostratigraphic units are unnecessary because they are based on biostratigraphic units (Weidmann 1970; Hancock 1977; Johnson 1979; Watson 1983; and Witzke et al. 1985). Most authors will find it easier to follow the practice of the establishment by adhering to the Code and Guide, which have been adopted by many publishers.

Lesser-Known Units

During the past few years, other types of stratigraphic units have been proposed, many of them in the 1983

LITHO-
GEO-
CHRONO-
(BIO-)

LITHOSTRATIGRAPHIC UNIT is a stratum or body of strata, generally but not invariably layered, which conforms to the Law of Superposition and is distinguished and delimited on the basis of **lithic** characteristics and stratigraphic position. Example : Navajo Sandstone

BIOSTRATIGRAPHIC UNIT is a body of rock defined and characterized by its **fossil** content. Example : *Discoaster mutliradiatus* Interval Zone

CHRONOSTRATIGRAPHIC UNIT is a body of rock established to serve as the **material reference for all rocks** formed during the span of time. Example: Devonian System. Each boundary of a chronostratigraphic unit is synchronous.

GEOCHRONIC UNIT is a division of time distinguished on the basis of the rock record preserved in a chronostratigraphic unit. Example : Devonian Period

LITHODEMIC UNIT is a defined body of predominantly intrusive, highly metamorphosed, or intensively deformed rock that, because it is intrusive or has lost primary structure though metamorphism or tectonism, generally **does not conform** to the Law of Superposition

MAGNETOPOLARITY UNIT is a body of rock identified by its remanent magnetic polarity (= also MAGNETOSTRATIGRAPHIC UNIT)

PEDOSTRATIGRAPHIC UNIT is a body of rock that consists of one or more pedologic horizons developed in one or more lithic units now buried

ALLOSTRATIGRAPHIC UNIT is a mappable stratiform body of sedimentary rock defined and identified on the basis of bounding discontinuities.

(NACSN, 1983)

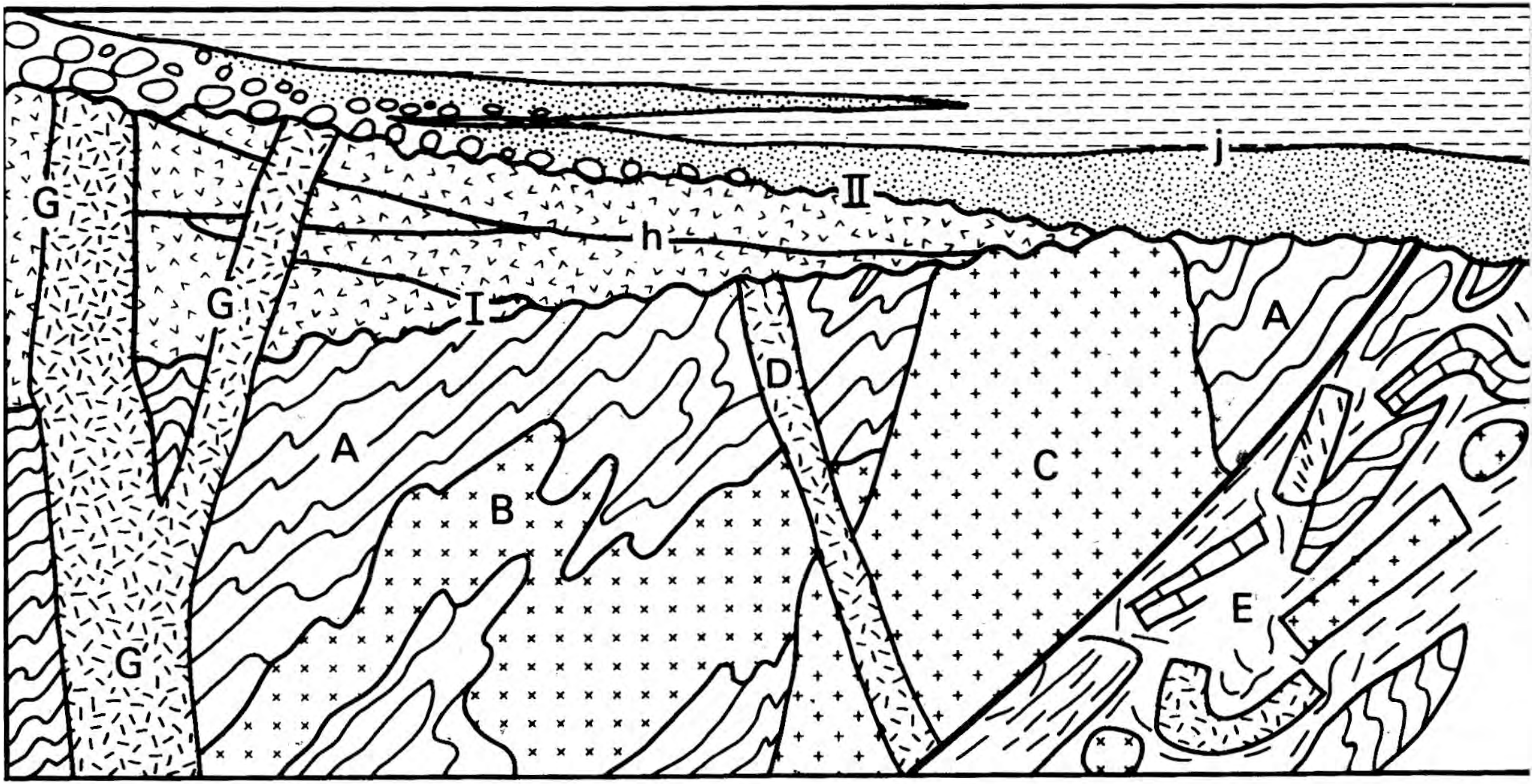


FIG. 3.—Lithodemic (upper case) and lithostratigraphic (lower case) units. A *lithodeme* of *gneiss* (A) contains an *intrusion* of diorit (B) that was deformed with the gneiss. A and B may be treated jointly as a *complex*. A younger *granite* (C) is cut by a dike of *syenit* (D), that is cut in turn by unconformity I. All the foregoing are in fault contact with a *structural complex* (E). A *volcanic complex* (G is built upon unconformity I, and its feeder dikes cut the unconformity. Laterally equivalent volcanic strata in orderly, mappable suc cession (h) are treated as lithostratigraphic units. A *gabbro* feeder (G′), to the volcanic complex, where surrounded by gneiss is readil distinguished as a separate lithodeme and named as a *gabbro* or an *intrusion*. All the foregoing are overlain, at unconformity II, b sedimentary rocks (j) divided into formations and members.

ALLOSTRATIGRAPHIC UNITS

• are unconformity-bounded units at all scales and ranks (from supergroup to member, **also many of the Systems**…). They should be extended only as far as both (lower and upper) of their bounding unconformities are identifiable
⇒ **an unconformity** is defined as a surface of erosion and/or nondeposition between rock bodies
==> **significant hiatus or gap** in the stratigraphic succession caused by interruption of deposition for a considerable span of time

• they can include any other kind of stratigraphic units

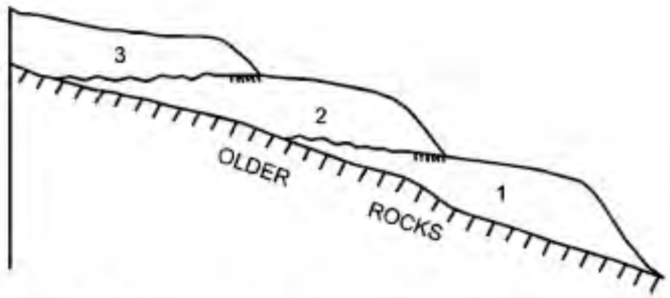
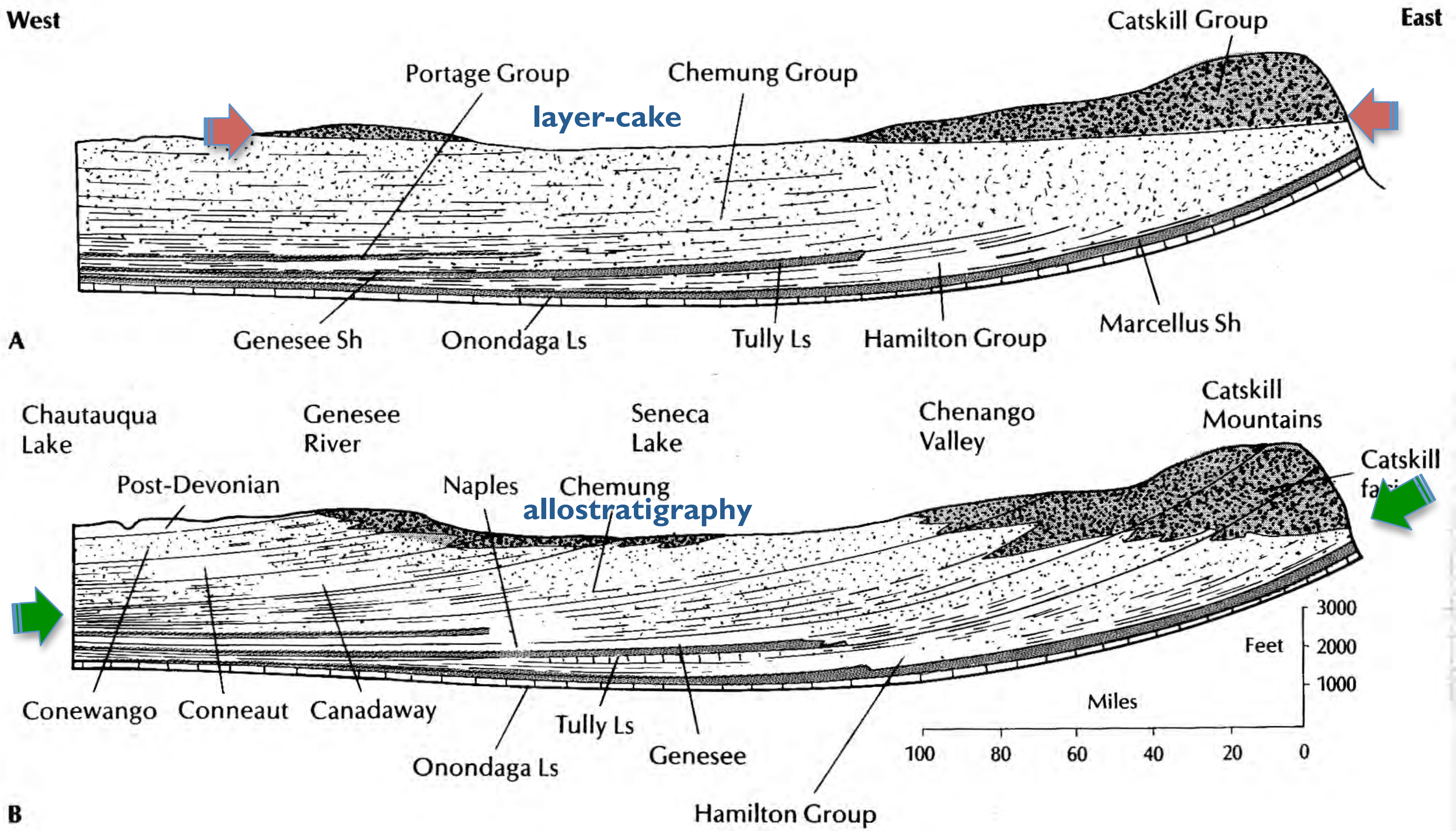


Figure 8. Example of allostratigraphic classification of contiguous deposits of similar lithology. Allostratigraphic units 1, 2, and 3 are physical records of three glaciations. They are lithologically similar, reflecting derivation from the same bedrock, and constitute a single lithostratigraphic unit.

NACSN, 1983

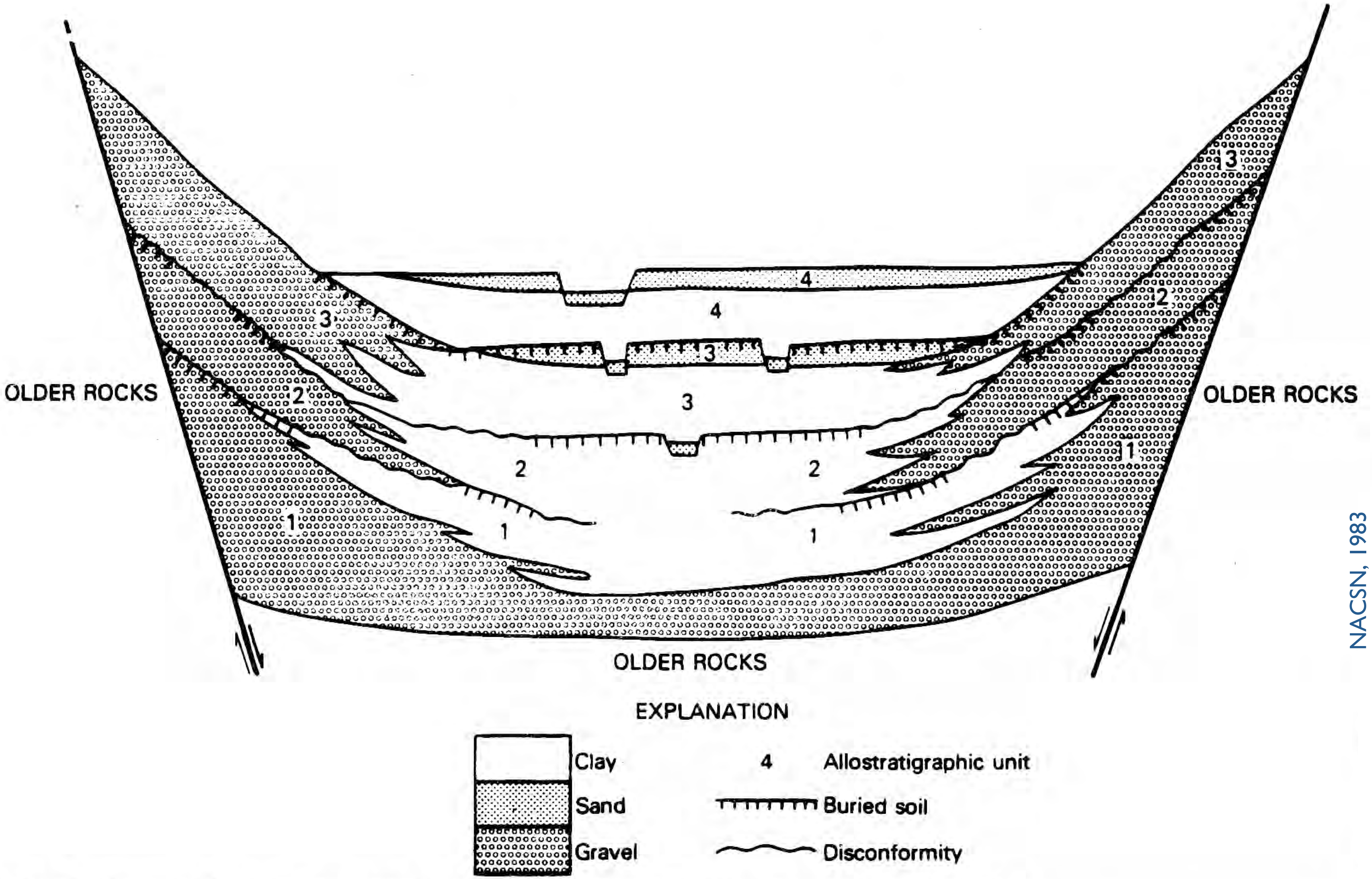


East-west cross sections across the Devonian Catskill sequences of southern New York showing the differences between "lithostratigraphy" and "allostratigraphy".

(A) Traditional lithostratigraphic interpretation (pre-1930), which treated the units a **layer-cake** sequence of Hamilton and Portage shales, Chemung sandstones, and Catskill redbeds.

(B) Present allostratigraphic interpretation, following Chadwick and Cooper that incorporates modern concepts of facies change. **Time planes are shown by curved lines**, each unit consists of Catskill redbeds in the east, sandy facies in the center, and shales in the west

(After Dunbar and Rodger, 1957; copied directly from Prothero and Schwab, 1996).

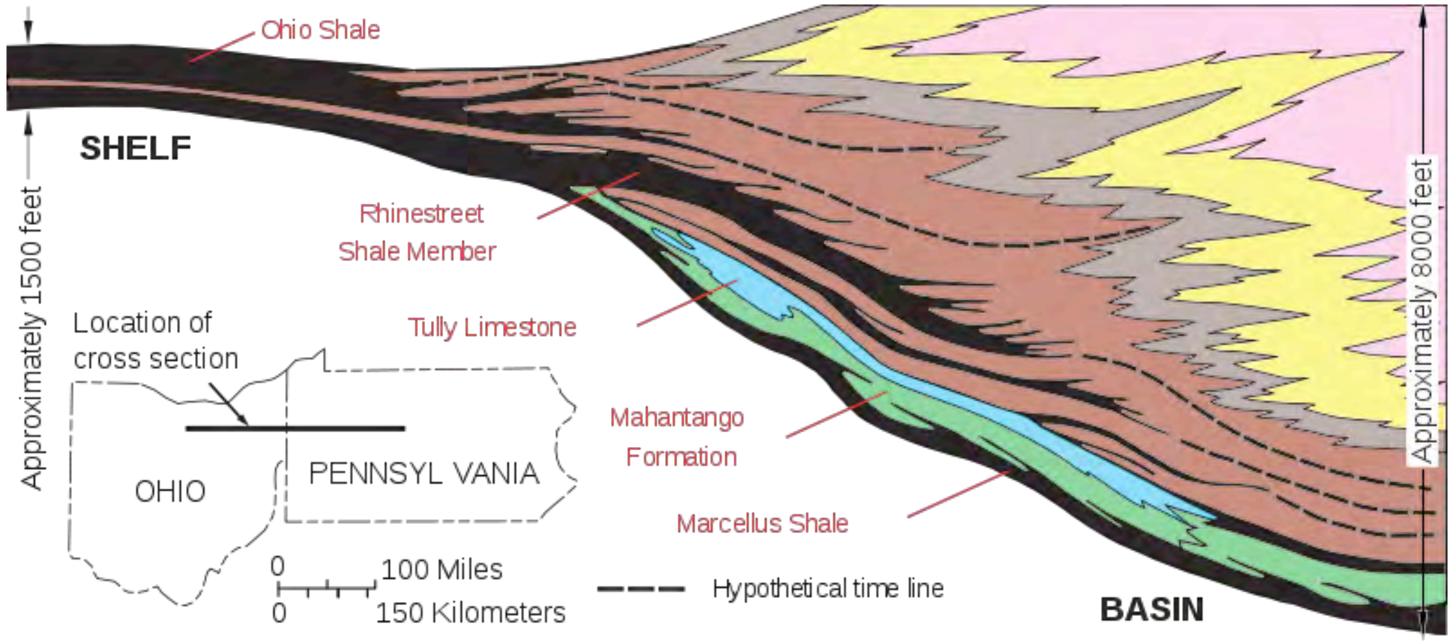


NACSN, 1983

FIG. 7.—Example of allostratigraphic classification of alluvial and lacustrine deposits in a graben.
The alluvial and lacustrine deposits may be included in a single formation, or may be separated laterally into formations distir guished on the basis of contrasting texture (gravel, clay). Textural changes are abrupt and sharp, both vertically and laterally. Th gravel deposits and clay deposits, respectively, are lithologically similar and thus cannot be distinguished as members of a formatior Four allostratigraphic units, each including two or three textural facies, may be defined on the basis of laterally traceable discontinu ties (buried soils and disconformities).

MAGNAFACIES older term introduced with the same purpose by the American Geological Institute (AGI) Glossary Geology as a major, continuous, and homogeneous belt of deposits that is distinguished by similar lithologic and paleontologic characters and that extends **obliquely across time planes** or **though several defined chronostratigraphic units**

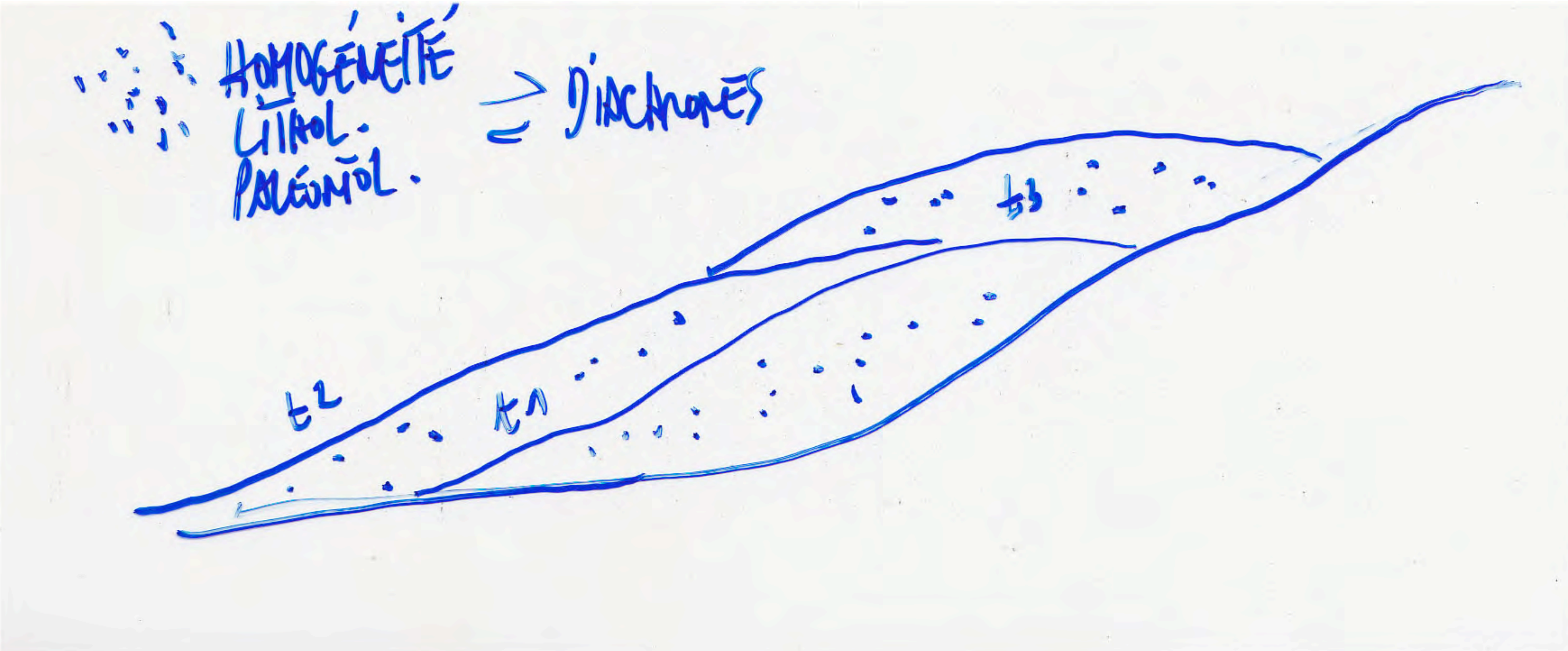
Example: the 'Catskill magnafacies' of the Paleozoic clastic wedges derived from the Appalachian orogen = relatively homogeneous but bodies of rock (here syntectonic clastic wedges)



Generalized cross section of Catskill delta magnafacies across western Pennsylvania and Ohio (adapted from Harper, 1999). The lower part of the section, from the Hamilton Group (Marcellus Shale and Mahantango Formation) to the Tully Limestone, is Middle Devonian in age. The remainder of the section is Upper Devonian.

ALLOSTRATIGRAPHIC UNITS

they are objective, noninterpretative units
(despite often related to orogenic episodes, epeirogenic cycles
and eustatic sea-level changes)



SUMMARY : BASIC DIVISION IS INTO ROCK (=LITHOSTRATIGRAPHY), RELATIVE TIME (=CHRONOSTRATIGRAPHY) AND NUMERICAL TIME (=GEOCHRONOLOGY or **TIME-ROCK**)

MATERIAL Rock units (lithostratigraphy)	TIME Relative time units (chronostratigraphy)	**HYBRID** Numerical time units (geochronology)
Supergroup	Eonothem (e.g. Phanerozoic)	Eon
Group	Erathem (e.g. Paleozoic)	Era
Formation	System (e.g. Ordovician)	Period
Member, etc.	Series (e.g. Viruan)	Epoch
Bed, etc.	Stage (e.g. Uhaku)	Age
	Zone (e.g. *G. teretiusculus*)	Chron

⇒ chronostratigraphic units are erected on the time of formation of rock bodies and, as currently used and named, are based on relative methods ==> these methods are then **calibrated** with numerical (geochronologic) methods, though in the Precambrian, where relative methods are very coarse, units are defined numerically and are purely geochronologic.

⇒ **systems of stratigraphic nomenclature need to be flexible and adjustable, not rigid and fixed …**

ASCN Code 1961 (American Stratigraphic Code Nomenclature)

CAPITALIZATION = FORMAL vs informal NAMES

Simple rule **: all words in every formally named stratigraphic unit begin with capital letters except for the specific name in a biozone**
Example : the Whitewater Arroyo **S**hale **T**ongue of the Mancos **S**hale, in northwestern New Mexico , is contained in the **C**enomanian **S**tage, which was deposited during the early part of the **L**ate Cretaceous **E**poch

IMPORTANT : in some instances, stratigraphic units are used **INFORMALLY, even if they have geographic names**
⇒ especially in subsurface work or when insufficiently recognized-defined-characterized
Example : the Spiro sandstone (very well defined trough subsurface works but inacessible to the 'normal' scientific community > < Spiro **S**andstone (= 'poor' outcrops in the same area).
Example : **E**arly, **U**pper …. < > early, upper ….. = **F**ormal vs informal
=> in some situation, an author may wish to use formal terms **in informal way**, usually **because definitive data are lacking**
Example : one might want to place a rock unit **approximatively** in the upper part of the **C**retaceous without really knowing whether some part of it might be slightly lower than the formally defined **U**pper **C**retaceous **S**eries

Capitalization

www.nwrc.usgs.gov/techrpt/sta08.pdf

Rules of Capitalization

_ Capitalize formally named lithostratigraphic units; do not capitalize informal units. Follow the conventions established by the North American Commission on Stratigraphic Nomenclature when reporting the names of lithostratigraphic units (members, formations, groups, etc.). Consult the USGS Geolex, available online at http://ngmsvr.wr.usgs.gov/Geolex/geolex.html for formally named United States units.

_ Do not capitalize the names of countries, regions, counties, cities, and topographic features when they are used in a generic sense. Example: Tulsa and Rogers counties.

_ Do not capitalize the names of formal stratigraphic terms when they are used in a generic sense. Example: Dakota and Strawn formations.

_ Capitalize names of eras, eons, periods, and epochs. Capitalize subdivisions within the periods only when formal. The adjectives have initial caps only when used in a formal sense; i.e., as part of the proper name of series and epochs: Upper or Late Devonian, but upper or late Paleozoic, upper or late Miocene, etc.

_ Capitalize terms such as basin, arch, rise, trough, etc., when they are part of a name if the terms are geographic. Do not capitalize if they are geologic. Note: Undersea features are geographic; land features are geologic.

_ Retain the initial capital letter for a proper noun or adjective joined to a prefix; for example, post-Paleozoic.

_ Use the following rules for title capitalization. Capitalize the first and last words and all nouns, pronouns, adjectives, verbs, adverbs, and subordinating conjunctions (if, because, as, that, etc.). Lower case articles (a, an, the), coordinating conjunctions (and, but, or, for, nor), prepositions, regardless of length, and the word “to” in infinitives.

Mémoires pour servir à l'Explication
des Cartes Géologiques et Minières
de la Belgique
Mémoire N° 30

Toelichtende Verhandelingen
voor de Geologische en Mijnkaarten
van België
Verhandeling N° 30

LES FORMATIONS DU DEVONIEN MOYEN DE LA BELGIQUE

par

P. BULTYNCK, M. COEN-AUBERT, L. DEJONGHE,
J. GODEFROID, L. HANCE, D. LACROIX, A. PREAT,
P. STAINIER, Ph. STEEMANS, M. STREEL et F. TOURNEUR.

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Mém. Expl. Cartes Géologiques et Minières de la Belgique	**1991**	**N° 30**	**106 p.**	**38 fig.**	**7 pl.**
Toelicht. Verhand. Geologische en Mijnkaarten van België			**blz.**	**5 tabl.**	

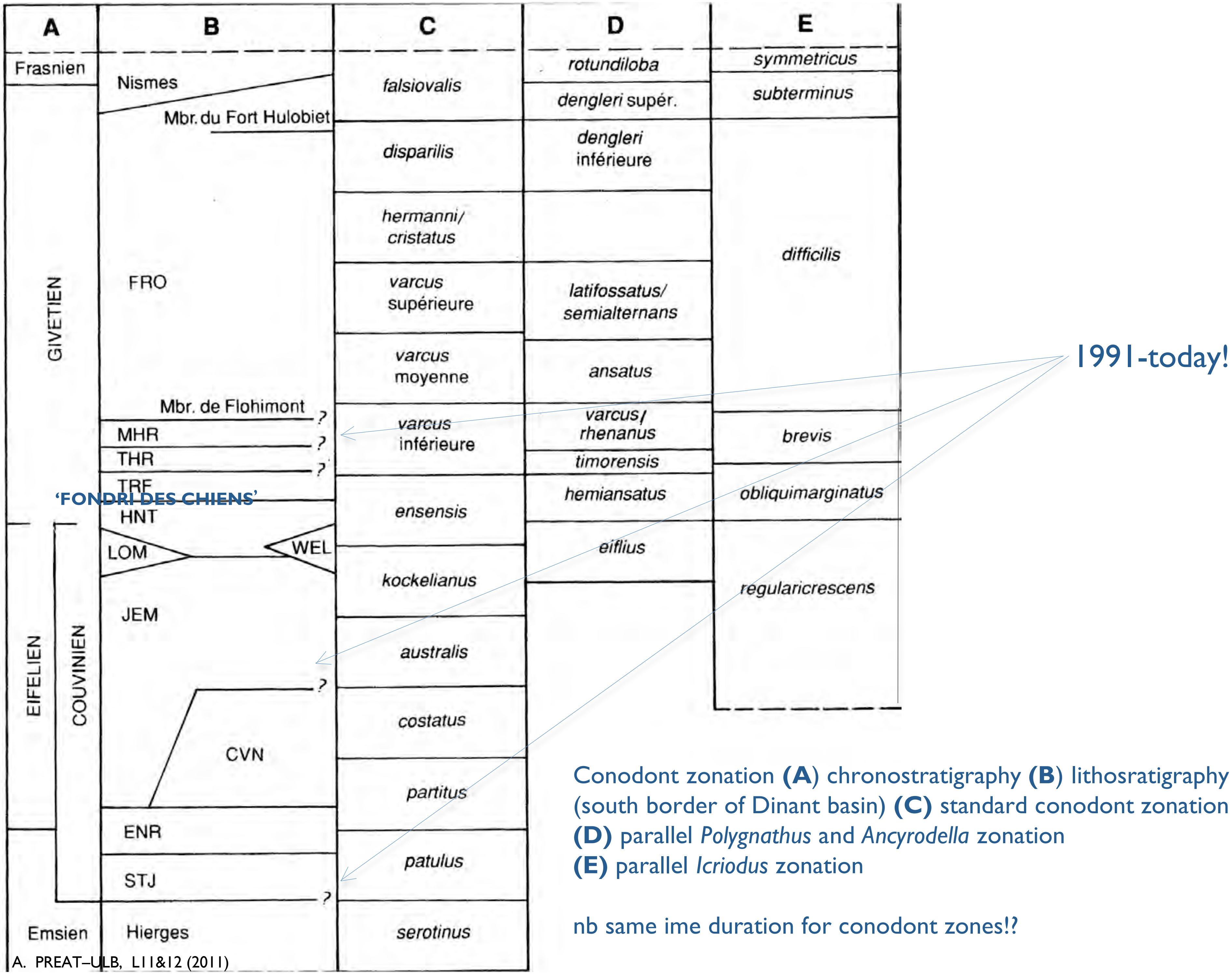
ABSTRACT

The authors present proposals to standardize the subdivision into formations of the Middle Devonian strata of the Dinant Synclinorium, the Namur Synclinorium and the Vesdre Massif. They recognize ten formal formations, and one informal, in the Couvinian (uppermost Emsian and Eifelian) and the Givetian strata of the southern flank of the Dinant Synclinorium. These formations are from older to younger : the St.-Joseph Fm, the Eau Noire Fm, the Couvin Fm, the Jemelle Fm, the Lomme Fm, the «X» Formation at Wellin, the Hanonet Fm, the Trois-Fontaines Fm, the Terre d'Haurs Fm, the Mont d'Haurs Fm and the Fromelennes Fm. The Middle Devonian succession of the northern flank of the Dinant Synclinorium and of the southern flank of the Namur Synclinorium comprises the Rivière Fm, the Névremont Fm and the Le Roux Fm. On the northern flank of the Namur Synclinorium, the Middle Devonian is represented by the Bois de Bordeaux Fm. In the Middle Devonian succession of the Vesdre Massif, the authors recognize the Vicht Fm, the Pépinster Fm, the Névremont Fm and the Le Roux Fm.

The authors describe and figure a stratotype and, in some cases, an other reference section for each formation. Lateral changes and age of the formations are also discussed.

TABLE DES MATIERES

FONDRI DES CHIENS



Conodont zonation **(A)** chronostratigraphy **(B)** lithosratigraphy (south border of Dinant basin) **(C)** standard conodont zonation
(D) parallel *Polygnathus* and *Ancyrodella* zonation
(E) parallel *Icriodus* zonation

nb same ime duration for conodont zones!?

ENR
FORMATION DE L'EAU NOIRE

P. BULTYNCK

1880 - DEWALQUE - Assise inférieure du schiste et calcaire de Couvin : schiste à *Spirifer cultrijugatus* (*pro parte*, seulement la partie supérieure; parties inférieure et moyenne = la Formation de Hierges et la Formation de St-Joseph).
1892 - Légende de la Carte géologique détaillée de la Belgique- Btb. Schistes de Bure. *Spirifer cultrijugatus* (*pro parte*, voir 1880).
1896 - Légende de la Carte géologique détaillée de la Belgique- Coa schistes, grauwacke et grès de Bure. Oligiste oolithique. *Spirifer cultrijugatus* et *Spirifer arduennensis* (*pro parte*, voir 1880 et remarques).
1912 - MAILLIEUX - Schistes calcareux à *Spirifer cultrijugatus pro parte* : Schistes calcareux à *Spirifer cultrijugatus*, *Spirifer elegans*, *Conocardium cuneatum*, *Rh. orbignyana* etc. (Co1b) et Calcaire schisteux à *Dielasma loxogonia*, *Retzia ? parvula* (Co1c).
1929 - Légende générale de la Carte géologique détaillée de la Belgique - Coa - Schistes calcareux, grauwacke (Grauwacke de Bure). *Spirifer cultrijugatus*, *Rhynchonella* (*Uncinulus*) *orbignyana* (*pro parte*, seulement la partie supérieure; partie inférieure = Formation de St-Joseph).
1970 - BULTYNCK - Co1b + Co1c.
1974 - BULTYNCK et GODEFROID - Eau Noire Formation.
1974 - TSIEN - Bure Formation, Eau Noire Member.

SITE DE REFERENCE

Stratotype : Couvin, lieu-dit La Foulerie, coupe de la rive gauche de l'Eau Noire (fig. ENR/CVN-1: coupe 1,2; fig. ENR/CVN-3, e à h).

LITHOLOGIE, LIMITES ET EPAISSEUR DU STRATOTYPE

Dans le stratotype, la Formation de l'Eau Noire débute par deux bancs décimétriques de calcaire argileux fin (= bc7 dans BULTYNCK et GODEFROID, 1974, p.5), surmontant le dernier gros banc calcaro-schisteux coquillier de la Formation de St-Joseph; elle se termine au sommet du dernier gros banc de schiste calcaire, surmonté par le Calcaire de Couvin. La succession dans le stratotype permet de distinguer deux parties.

La partie inférieure, d'une épaisseur de 30 m, comprend des schistes calcaires gris-vert et riches en organoclastes avec nodules de calcaire argileux et intercalations de petits bancs de calcaire argileux (fig. ENR/CVN-3, subdivision e).

La partie supérieure épaisse de 30 m montre une alternance régulière de schistes calcaires, gris-vert ou gris-bleu, riches en organoclastes et de calcaires noduleux, subnoduleux ou en bancs décimétriques réguliers (fig. ENR/CVN-3, subdivisions f, g et h).

VARIATIONS LATERALES

La formation est reconnue aux bords sud et sud-est du Synclinorium de Dinant; elle atteint sa plus grande puissance dans la région de Wellin où elle a une épaisseur de 160 m (voir Godefroid, 1968). A partir de Villers-Ste-Gertrude, la distinction entre la Formation de St-Joseph et la Formation de l'Eau Noire devient moins nette car des bancs coquilliers et des schistes gréseux, caractéristiques de la Formation de St-Joseph se maintiennent sporadiquement dans la Formation de l'Eau Noire. Ensemble, ces deux unités y sont épaisses de 50 m.

VARIATIONS LATERALES

La formation est reconnue au bord sud du Synclinorium de Dinant entre Mâcon à l'ouest et la Meuse à l'est. L'épaisseur de la formation diminue progressivement entre Nismes et Givet.

AGE

Dans les différentes légendes de la Carte géologique détaillée de la Belgique, les couches formant le Calcaire de Couvin appartiennent au Couvinien supérieur.

- conodontes : la présence d'*Icriodus retrodepressus* à la base du Calcaire de Couvin permet d'attribuer cette partie à la Zone à *Polygnathus costatus partitus*, dont la base coïncide avec le début de l'Eifelien. La plus grande partie du membre de la Foulerie appartient à la Zone à *Polygnathus costatus costatus*. Le membre de l'Abîme est caractérisé par la présence d'*Eognathodus bipennatus montensis*; il peut encore appartenir à la Zone à *Polygnathus costatus costatus*, bien qu'une attribution à la Zone à *Tortodus kockelianus australis* ne soit pas exclue.

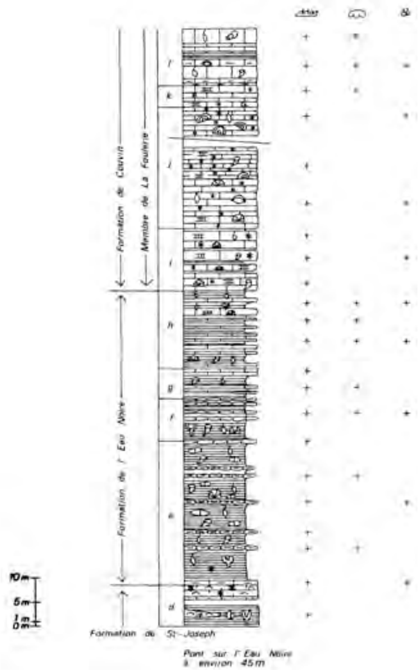
- tabulés : assemblage riche et varié, reconnu entre Macon et Couvin, et aussi en pointements isolés dans la région de Pondrôme; parmi d'autres, on trouve des Heliolitidae, des Chaetetidae, des Favositidae, des Alveolitidae, *Caliapora* (*Mariusilites*) *chaetetoides*, *Roemeria cubiniensis*.

USAGE

Anciennement exploité pour la fabrication de chaux hydraulique et pour la construction.

REMARQUES

Les trois parties reconnues dans le Membre de la Foulerie pourraient être considérées comme des membres formels. Vu l'extension latérale limitée du Calcaire de Couvin, une subdivision plus poussée est considérée comme inutile pour la cartographie.



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Towards a "Common Language" in Stratigraphy

Episodes, 1985, vol.8/2, p.87…

by M.G. Bassett

The establishment of internationally agreed definitions and terminology for subdivisions of the stratigraphical column is a prerequisite for the unambiguous discussion of widespread geological phenomena. This article represents the formal announcement of ratification by IUGS of a number of standard stratigraphical units and boundaries as proposed in 1984 by various bodies of the International Commission on Stratigraphy.

Introduction

From its origins and infancy as a science in the early 19th Century, stratigraphy has formed a linking theme between all branches of geology - a framework within which other disciplines are set in order to attempt to trace both synchronous events and sequential steps in earth history. Not surprisingly, the parameters of this framework first developed, at varying rates and scales in different regions and countries, as local rock successions. Lateral variations were established through primary geological mapping, and local terminologies for stratigraphical divisions accompanied these developments.

The increasing rigour of geological investigations eventually demanded refinement of correlation between different regions, but this was often hampered and mistakes compounded by differences in definitions, standards, and terminologies. With the growth of studies of global processes and events, the need for increasingly accurate and widespread stratigraphical correlations has become paramount in the last few decades, bringing with it the need for a clear vocabulary as a means of communicating results unambiguously. Hedberg summarized this well in his introduction to the International Stratigraphic Guide (1976, p.v).

"Stratigraphy is a global subject, and international (global) communication and cooperation are necessary if we are to adequately comprehend the picture of the rock strata of the Earth as a whole, and to restore the history of how, when and why these strata came to be what and where they are today. Agreement on stratigraphic principles, terminology, and classificatory procedure 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 in futile argument and fruitless controversy arising because of discrepant basic principles, divergent usage of terms, and other unnecessary impediments to mutual understanding."

Role of the International Commission on Stratigraphy

Within the International Union of Geological Sciences, the statutory objectives of the International Commission on Stratigraphy (ICS) include clarification of principles of stratigraphical classification and unification of terminology, development of a standard global stratigraphical scale, distribution of information on each of the major subdivisions of the standard scale, establishment of their boundaries, and correlation of their subdivisions. International cooperation is implicit in these aims.

In its long history (see Martinsson and Bassett, 1980), ICS has evolved into a vigorous coordinator of research in many disciplines. Since 1968, under the successive chairmanship of Academician V.V. Menner (Soviet Union, Fig. 1), Dr. D.J. McLaren (Canada, Fig. 2) and the late Prof. A. Martinsson (Sweden, Fig. 3), various Subcommissions and Working Groups have devoted particular attention to the elaboration and correlation of standard Series and Stage divisions within each geological System, together with the precise definition of boundaries between them. With regard to the latter effort, the principle has become firmly accepted of defining the base of each division at a unique point in a rock sequence, representing a unique point in time to serve as a standard against which other sequences can be correlated; correlation is achieved by the analysis of all available data, such as evidence from fossils, radiometric ages, and remanent magnetic signatures. The standard points and sections are referred to as stratotypes.

This work should not be seen as an end in itself. The amount of new research generated within ICS bodies as a result of focussing on stratigraphical objectives is impressive by any standards. Discussions in the field (Fig. 4) and at related conferences provide an important forum for disseminating results and making decisions. Numerous internal working documents (Fig. 5) and more formal publications (Fig. 6) are visible results of progress, whereas even the non-scientific productions (Fig. 7) reflect a marvellous spirit of effort and collaboration.

Figure 1: Academician Vladimir Vasilievich Menner, Chairman of ICS 1968-1972.

Figure 2: Dr. Digby McLaren, Chairman of ICS 1972-1976.

Figure 3: The late Professor Anders Martinsson, Chairman of ICS 1976-1983.

Proposals, Procedures and Decisions

In 1983 all bodies within ICS were encouraged by the Chairman to speed up their work on establishing standards, and where possible to submit formal proposals for consideration at the 27th Session of the International Geological Con-

STRATOTYPES

= TYPE SECTIONS : traditionally used in stratigraphy
⇒ material basis and standard of definition of stratigraphic units which is 'regarded' rightly or wrongly, as 'typical' of the particular stratigraphic unit it defines

ISG (Hedberg, 1976, p24) *« a stratotype or type section is 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 consititting the standard definition and recognition of the stratigraphic unit or boundary'*

⇒ **unit-stratotypes** (= type-section of strata that defines the content (normally with the upper and lower boundaries…)
=> **boundary-stratotypes** (= the specific point in a particular sequence of rock strata thatdefines a particular stratigraphic boundary, = 'limitotype')
=> **composite-stratotypes** (= formed by the combination of several specific type intervals of strata (if the particular stratigraphic unit is not exposed completely in a single section…)

Guidelines for Boundary Stratotypes

by John W. Cowie

Episodes, 1986, vol.9/2, p.78-82

Current activity in the International Commission on Stratigraphy has necessitated the revision of guidelines for submissions on boundary stratotypes, so that decisions will be clear and unequivocal to the specialist stratigrapher and the general geologist alike. This is especially so in view of the many proposals now being prepared for submission. In this article the ICS Chairman reviews both general problems of procedure and technical recommendations for the submission of stratotype candidates. (Ed.)

Introduction

The International Commission on Stratigraphy (ICS) of IUGS is responsible for the coordination of international stratigraphy, from the earliest part of the Archaean through the Proterozoic and the Phanerozoic: physical, chemical and biological aspects. A major current focus is the selection and definition of boundary stratotypes (Fig. 1). Other branches of stratigraphy are of great importance too, and future changes and additions in the guidelines may well be required.

Following establishment of the Silurian-Devonian Boundary Stratotype in 1972, a period of great activity by the Commission resulted in the ratification in 1985 by IUGS of boundary stratotypes for Ordovician-Silurian, the Series and Stages of the Silurian System, the Series of the Devonian System, and the Pliocene-Pleistocene (Bassett, 1985).

The submissions to ICS for these and other stratigraphic boundaries illustrate the progress that has been made during historical precedents may need to be set aside by an authoritative international decision, even though this may violate some established usage.

The International Stratigraphic Guide (Hedberg, 1976) prepared and published by the Subcommission on Stratigraphic Classification contains valuable discussion and recommendations, but it was never adopted by ICS as a statutory policy document. The new guidelines and the recently revised ICS Statutes should be used when and where there is a difference between them and the International Stratigraphic Guide.

Boundary Statotypes

Historical geology depends on positional relationships of rock and mineral bodies and identification of evolutionary trends. "The importance of the boundary stratotype lies in its role as a future anchor to which all subsequent correlations can be tied, even if new palaeobiological or physical methods become available." It is "the only place where we actually know (by definition) that time and rock coincide within our classification" (Holland, 1984, p. 149).

A Global Boundary Stratotype Section and Point (GSSP) is the designated stratigraphic boundary, identified in published form and marked in a particular place in a specific sequence of rock strata. It constitutes the standard for the defining and recognizing the boundary between two named global standard stratigraphic (chronostratigraphic) units. A GSSP is a unique signal for the world geological stratigraphic time scale. A submission to the Commission for a new GSSP cannot be ratified on the basis of a recommended stratigraphic level only: the geographic (type) locality where the stratotype is situated must be exactly and precisely given.

Continuity of sedimentation should be demonstrated through the boundary interval - preferably a marine succession without major facies change. A continuous monofacial section will reduce possible errors resulting from stratigraphic gaps and biostratigraphic limitations. Completeness of exposure is also a requirement. The candidate should not be in an isolated position, but it should be in a succession that can be followed easily above and below the GSSP, and preferably laterally as well. An adequate thickness of sediments should be present.

An abundance and diversity of well-preserved fossils is also necessary. Appearances and disappearances of single fossil species can be expected to be diachronous and therefore a bad guide for the location of a GSSP. Multispecies fossil zones may be preferable, and it would be ideal to exclude from consideration taxa that are palaeoecologically tied to a particular facies, though all fossils are to some extent facies controlled. In order to minimize possible effects of environmental controls on different fossil groups, recognition of the boundary level should be based on all available faunal and floral data.

also

- no structural complication or metamorphism and alteration
- no disconformities, unconformities, cryptic paraconformities…. time breaks…
- amenability to magnestostratigraphy and geochronometry
- sites for GSSP must be accessible and have the potential of conservation

….

Series and Stages of the Silurian System

Episodes, 1985, vol.8/2, p.101…

by C.H. Holland

The Subcommission on Silurian Stratigraphy has recently completed an eight-year program resulting in the formal adoption of four standard Series and seven standard Stages for the Silurian System. This review summarizes the background to the chronostratigraphical subdivisions now established as units of global applicability.

Introduction

The top of the Silurian System, that is to say the base of the Devonian, is taken at a point coincident with the base of the Monograptus uniformis Biozone in a boundary stratotype section in the Barrandian area of the Prague Basin, Czechoslovakia. Decisions concerning this boundary were approved by the Commission on Stratigraphy as long ago as 1972, and very full details of the whole subject are given in Martinsson (1977).

Figure 1: Members of the Subcommission on Silurian Stratigraphy and of the Ordovician-Silurian Boundary Working Group at Ludlow, Welsh Borderland, April 1979 (C.H. Holland).

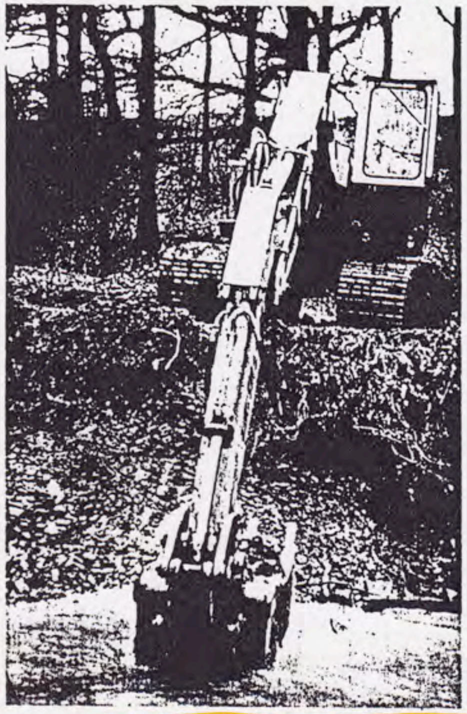

Figure 2: The boundary stratotype for the base of the Wenlock Series at Hughley Brook, Wenlock district, Welsh Borderland during clearing (R.J. Aldridge).

Figure 3: The boundary stratotype for the base of the Ludlow Series at Pitch Coppice, Ludlow district, Welsh Borderland. Hammer head is on the boundary (P.G. Bartlett).

A. PREAT–ULB, L11&12 (2011)

CRETACEOUS STAGE BOUNDARIES

COPENHAGEN 1983

Episodes, Vol. 8, No. 2, June 1985

STRATOTYPES

HOLOSTRATOTYPE : original stratotype that was designated by the original author(s) when first establishing a stratigraphic unit or a boundary of a stratigraphic unit. In principle a 'good holostratotype' must be chosen where sedimentation is the most 'continuous' i.e. outside the margins of basin (emersion, hiatuses….)
PARASTRATOTYPE : supplementary stratotype section designated by the original author(s) in the original publication to complete the holostratotype definition (example basin *vs* platform)
LECTOSTRATOTYPE : is chosen after the fact (after the original publication establishing a stratigraphic unit or boundary) if an original stratotype (=holostratotype) was not adequately designated
NEOSTRATOTYPE : is a 'new' stratotype selected to replace an older one which has been destroyed or 'nullified' (rejected)
HYPOSTRATOTYPE : reference section or auxiliary reference section that is designated to complete the knowledge of the holostratotype in a different geographic area or in a different facies (limestones *vs* sandstones, *vs* clays….)

Conclusion1 : only **holo-, lecto-** and **neo-**STRATOTYPES are true types of stratigraphic units or boundaries, **para- and hypo-**STRATOTYPES are supplementary or reference sections
Conclusion2 : ideally the best stratotype must contain the most possible time without time-break, its lower and upper boudaries and no structural complication(s).

https://engineering.purdue.edu/Stratigraphy/gssp/index.php?parentid=all

SUBCOMMISSION FOR STRATIGRAPHIC INFORMATION

PROVIDING INFORMATION ABOUT EARTH HISTORY

GSSP Table - All Periods

Global Boundary Stratotype Section and Point (GSSP) of the International Commission of Stratigraphy

Cenozoic Era | Mesozoic Era | Paleozoic Era | Precambrian | All Periods

Stage	Age (Ma) CGTS 2008	GSSP Location	Latitude, Longitude	Boundary Level	Correlation Events	Status	Reference
Phanerozoic Eon							
Cenozoic Era							
Quaternary System							
Holocene Series							
Holocene Stage	0.011784	NorthGRIP ice core, central Greenland	75.1000°N 42.3200°W	1492.45m depth in Borehole NGRIP2	Climatic -- End of the Younger Dryas cold spell, which is reflected in a shift in deuterium excess values	Ratified 2008	Episodes 31/2, 2008; J. Quaternary Sci., Vol. 24 pp. 3-17, 2009
Pleistocene Series							
Tarantian Stage	0.126	Amsterdam-Terminal borehole, Netherlands	52.3792°N 4.9144°E	63.5 m below surface	Climatic -- Base of the Eemian interglacial stage (= base of marine isotope stage 5e) before final glacial episode of Pleistocene. Base of Tyrrhenian regional stage of Mediterranean	Accepted by ICS in 2008, on hold by IUGS	Episodes 31/2, 2008
Ionian Stage	0.781	Candidate sections in Italy (Montalbano Jorica or Valle di Manche) and Japan (Chiba)			Magnetic -- Brunhes-Matuyama magnetic reversal (base of Chron 1n)	Anticipated 2010	
				base of the marine claystone			

Devonian System							
Upper Devonian Series							
Famennian Stage	374.5 ± 2.6	Coumiac Quarry, near Cessenon, Montagne Noire, France	43.4613°N 3.0403°E	Base of Bed 32a	Conodont FAD *Palmatolepis triangularis*, just above a major extinction horizon (Kellwasser Event) with conodont LADs *Ancyrodella* and *Ozarkodina*, and Goniatite LADs of *Gephuroceratidae* and *Beloceratidae*	Ratified 1993	Episodes 16/4, p. 433-441, 1993
Frasnian Stage	385.3 ± 2.6	Col du Puech de la Suque, Montage Noire, France	43.5032°N 3.0868°E	base of Bed 42' at Col du Puech de la Suque section E	Conodont FAD *Ancyrodella rotundiloba*	Ratified 1986	Episodes 10/2, p. 97-101, 1987
Middle Devonian Series							
Givetian Stage	391.8 ± 2.7	Jebel Mech Irdane, Morocco	31.2374°N 4.3541°W	base of Bed 123	Conodont FAD *Polygnathus hemiansatus*	Ratified 1994	Episodes 18/3, p. 107-115, 1995
Eifelian Stage	397.5 ± 2.7	Wetteldorf, Eifel Hills, Germany	50.1496°N 6.4716°E	21.25m above the base of the exposed section, base of sample station WP30	Conodont FAD *Polygnathus costatus partitus*	Ratified 1985	Episodes 8/2, p. 104-109, 1985
Lower Devonian Series							
Emsian Stage	407 ± 2.8	Zinzil'ban Gorge in the Kitab State Geological Reserve, Uzbekistan	39.2000°N 67.3056°E	base of Bed 9/5	Conodont FAD *Polygnathus kitabicus*	Ratified 1995	Episodes 20/4, p. 235-240, 1997
Pragian Stage	411.2 ± 2.8	Velká Chuchle, Prague, Czech Republic	50.0147°N 14.3726°E	base of Bed 12 in Velká Chuchle Quarry	Conodont FAD *Eognathodus sulcatus sulcatus* and *Latericriodus steinachensis Morph beta*	Ratified 1989	Episodes 12/2, p. 109-113, 1989
Lochkovian Stage	416 ± 2.8	Klonk, near Prague, Czech Republic	49.8550°N 13.7920°E	within Bed 20	Graptolite FAD *Monograptus uniformis*	Ratified 1972	IUGS Series A, 5, p. 96-109, 1977

Admin

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PROVIDING INFORMATION ABOUT EARTH HISTORY

Home | GSSPs | Charts & Books | Stratigraphic Guide | Resources | TS Creator | ICS subcommissions

Chapter 4. Stratotypes and Type Localities

C. Requirements for Stratotypes (Type Sections)

The following requirements apply to stratotypes:

1. Expression of concept. The most important requisite of a stratotype is that it adequately represents the concept for which it is the material type.

2. Description. The description of a stratotype is both geographic and geologic. The geographic description includes a detailed location map and/or aerial photographs and indication of the means of access to the type locality and the distribution of the unit in the area.
The geologic description covers the geologic, paleontologic, geophysical, and geomorphic features of the unit at the type section. The description contains two parts:a part that deals with the boundaries and a part that deals with the content of the unit.

3. Identification and marking. An important requirement of a stratotype is that it should be clearly marked. A boundary-stratotype is marked at a point, preferably by a permanent monument.
Unit boundaries should be clearly designated by reference to permanent geologic and geographic features at the type locality.

4. Accessibility and assurance of preservation. Stratotypes must be accessible to all who are interested in their study, regardless of political or other circumstances, and there should be reasonable assurance of their long-term preservation.

5. Subsurface stratotypes. Subsurface stratotypes are acceptable if adequate surface sections are lacking and if adequate subsurface samples and logs are available.

6. Acceptability. The usefulness of the stratotypes for stratigraphic units of international extent is directly related to the extent to which they are generally accepted or acknowledged as the standard of reference for the units.It is, therefore, desirable that the designation of a stratotype be submitted for approval to the geologic body having the highest standing in any particular case.
The IUGS International Commission on Stratigraphy is the body to which proposals for the designation of stratotypes of units of worldwide application are submitted. Stratotypes of local units require the approval from local or national surveys or stratigraphic commissions.

If all the required information has been fullfilled and accepted => FORMAL UNIT (CAPITALIZED
Its NAME can **never be** a name previously given for another unit whatever its rank, age and plac
= RULE OF 'ABSOLUTE' PRIORITY (to avoid confusion)

SO WHAT ABOUT THE informal UNITS?

• useful during a (first) field survey

Example : Treignes

Example : oil exploration of a basin

…

⇒ if not published = internal usage, generally ‘confidential’
⇒ they are named or defined on any criteria, even with colors (seismic diagrams, field works etc.)

LITHOSTRATIGRAPHIC UNITS = ROCK UNITS
(igneous, metamorphic or sedimentary)
(surface or subsurface)

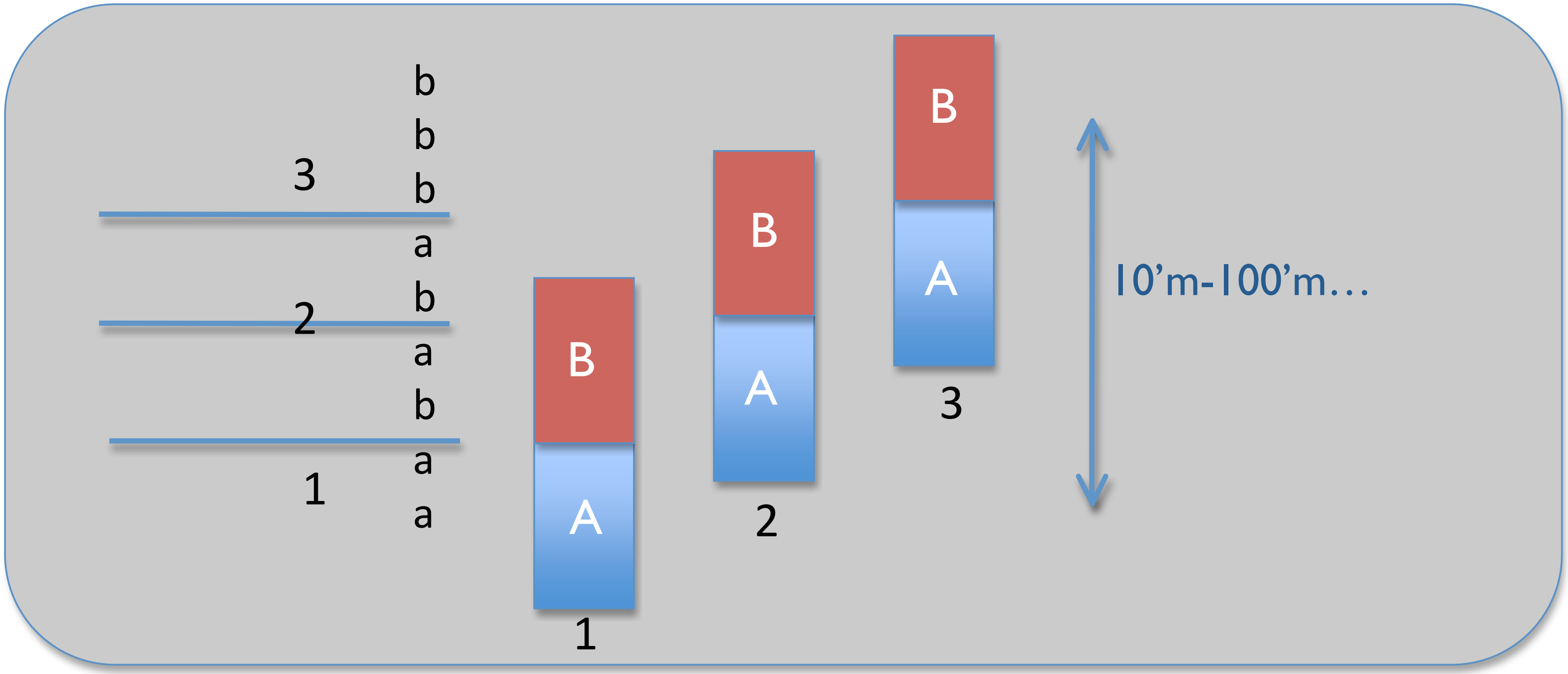
They are hierarchized into 'manageable units'

- GROUP (and SUPERGROUP)
- **FORMATION**
- MEMBER
- TONGUE or LENS
- BED (=strata = layer)

The FORMATION is the basic lithostratigraphic unit
it is a body of rock identified by lithic characteristics and stratigraphic position. It is prevailing but not necessarily tabular and is mappable at the Earth's surface or traceable in the subsurface

The FORMATION is the basic lithostratigraphic unit

- represented on the geological maps (convenient scale for field work or economic application, i.e. 1:25000 => 1:100000)
- thickness: ranging from a few m to 10s, 100s, sometimes km
- extension : a few square km to 10^9 square km
- one of the best criteria to name a **F**ormation = use in mapping (also formation)
- cautions: no 'large' disconformities despite a disconformity can be useful for the boundary(ies) of this unit
- contacts : based on obvious changes, gradual or abrupt => if gradual, the contacts are arbitrary and have to be explained

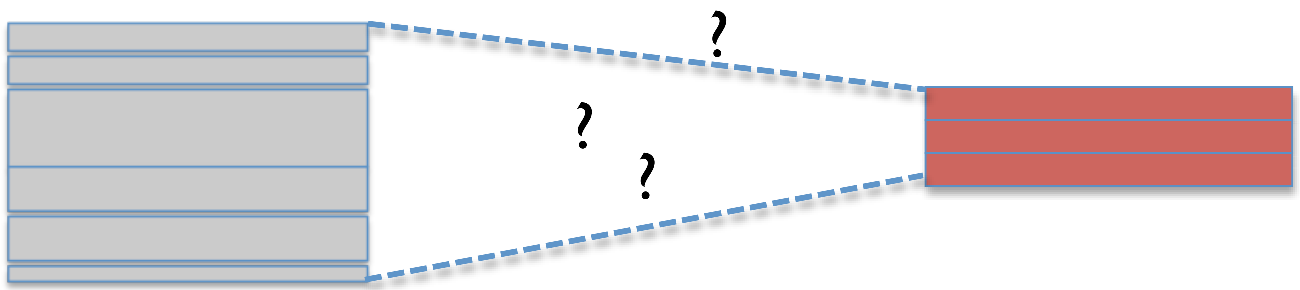


The GROUP

- higher in rank to formation
- may consist entirely of named fomations, or alternatively, need not be composed entirely of named formations
- defined to express the **natural relationsphips** of **associated** (and 'similar') formations => useful in small-scale mapping and regional stratigraphic analysis
- …

Example: Givetian (time) <=> ?Givet **G**roup => 3 formations AND today 6 formations (southern border of Dinant basin)

- Nismes Fm (*pro parte*)
- Fromelennes Fm
- Mont d'Haurs Fm
- Terres d'Haurs Fm
- Trois-Fontaines Fm
- Hanonet Fm (*pro parte*)



The GROUP

=> SUPERGROUP formal assemblage of related or superposed groups, or of groups and formations. Useful in regional and provincial **syntheses**. Supegroups should be named only where their recognition serves a clear purpose.
<u>Common in the Precambrian</u>

=> SUBGROUP to avoid

The FORMATION

⇒ **MEMBER** formal lithostratigraphic unit next in rank below the Fm, it is always a part of some Fm. = it possesses charactertics distinguishing it from adjacent part of the Fm.
A Fm. need not be divided into members (Mbr.) unless a useful puropose is served by doing so. A Mbr. may extent laterally from one Fm. to another.
⇒ **TONGUE or LENTIL**

⇒ **BED** (or beds) is the smallest formal lithostratigraphic unit of sedimentary rock = a thin 'bed' of a distinctive rock that is **widely** distributed. Such beds may be named, but usually are considered informal units. Individual key beds may be traced beyond the lateral limits of a particular formal unit.
Ex: 'placers', coalbeds, mineralized bodies (reef….or other), volcanic tuffs/ashes….

REVISION and ABANDONMENT of FORMAL UNITS

Formally defined and named geologic units may be redefined, revised or abandoned, but revision and abandonment require as much justification as establishment of a new unit

= redefinition, revision with

- change in lithic designation
- original lithic designation inappropriate
- boundary change
- change in rank
- change from area to area
- abandonment of names, of sections …(reasons?...)

The published description of a **new** or **revised** stratigraphic unit should include

- Name and rank of unit
- Location of type reference sections, including a map or air photo
- Detailed descritpion of the unit at the type section, including nature and height in section or well depth of contacts
- Comments on the local or regional extent of the unit and its variablility
- Graphic log of the unit (optional for lithostratigraphic units, but desirable and should include geophysical logs for subsurface sections)
- Statement of location of reference material
- Discussion of relationship of the unit to other contemporaneous stratigraphic units in adjacent areas i.e. lateral facies variations

LITHODEMIC UNITS = ROCK UNITS
predominantly intrusive, highly deformed and/or metamorhosed
do not conform the Law of Superposition (Principle 1)

They are hierarchized into 'manageable units'

- 'COMPLEX'
- SUPERSUITE
- SUITE
- **LITHODEME (comparable to 'Fm.' for cartography)**

The COMPLEX is an unranked unit, comparable to SUITE or SUPERSUITE = an assemblage or mixture of rocks of **two or more genetic classes**, i.e., igneous, sedimentary or metamorphic, with or without highly complicated structure.
Example : Franciscan Complex …

« Franciscan Assemblage » From Wikipedia

The Franciscan Assemblage is a geological term for an accreted terrane of heterogeneous rocks found on and near the San Francisco Peninsula. It was named by geologist Andrew Lawson who also named the San Andreas Fault which bounds the Franciscan Assemblage. Also known as the "Franciscan Formation," "Franciscan Series," "Franciscan Group," "Franciscan assemblage," or "Franciscan Complex," it includes altered mafic volcanic rocks (greenstones), deep-sea radiolarian cherts, greywacke sandstones, limestones, serpentinites, shales, and high-pressure metamorphic rocks, all of them faulted and mixed in a seemingly chaotic manner.It forms the major component of the Pacific Coast Ranges of California.

LITHOSTRATIGRAPHY : OBJECTIVES/PRACTICAL USES

= mapping and correlation procedures
INFORMAL USE
⇒ FIELD WORKS (natural outcrops, roads, state or public works …. = National Geological Surveys)
= SUBSURFACE (boreholes, well-logs, seismic ….)

Example: student stage/training at Treignes
⇒ definition of **informal units**
Example : 'Lithozone' : clayey, coal, sandy, pebbly…. color…
Example : Industrial interest (very common)
=>' aquifer levels', 'oil sands', 'marker bed in exploited quarry', mineralized reefs' …

BIOSTRATIGRAPHIC UNITS = ROCK UNITS
characterized by their fossils content
BIOZONE (different categories)

- Independence from lithostratigraphic units
- Independence from chronostratigraphic units
  (the boundaries of most biostratigraphic units, unlike the boundaries of chronostratigraphic units, are both characteristically and conceptually diachranous (excepted the 'abundance biozone boundary' = mass mortality event)

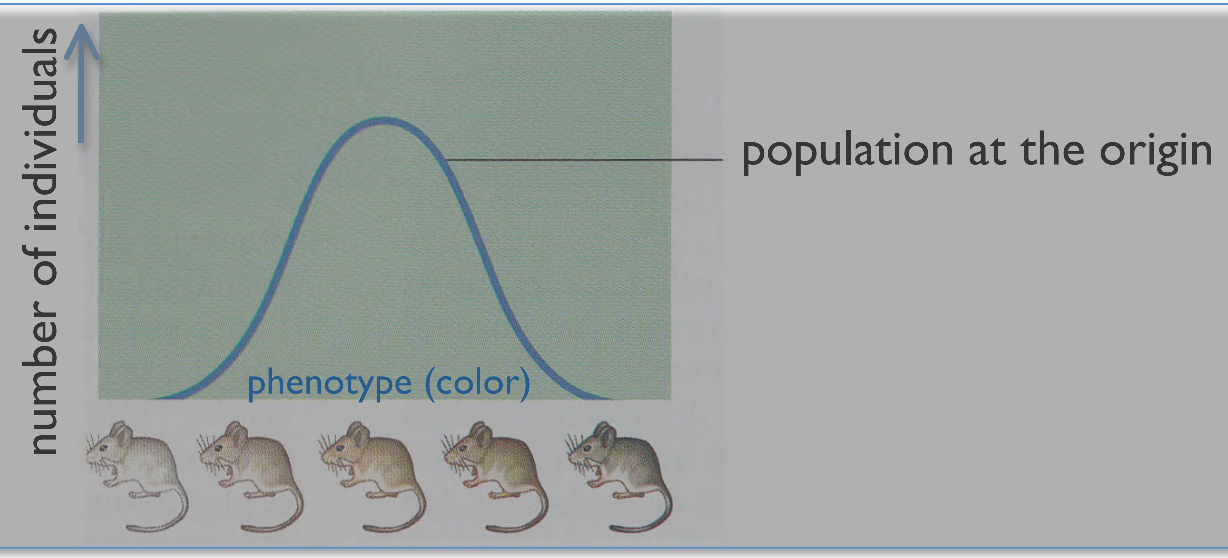
Biostratigraphy is basically an empirical, descriptive science based on the gradual (or not) changes through time of faunas and floras related to **EVOLUTION** or **PHYLOGENY** of groups of organisms
⇒ importance of the evolution pattern types (see biologists)

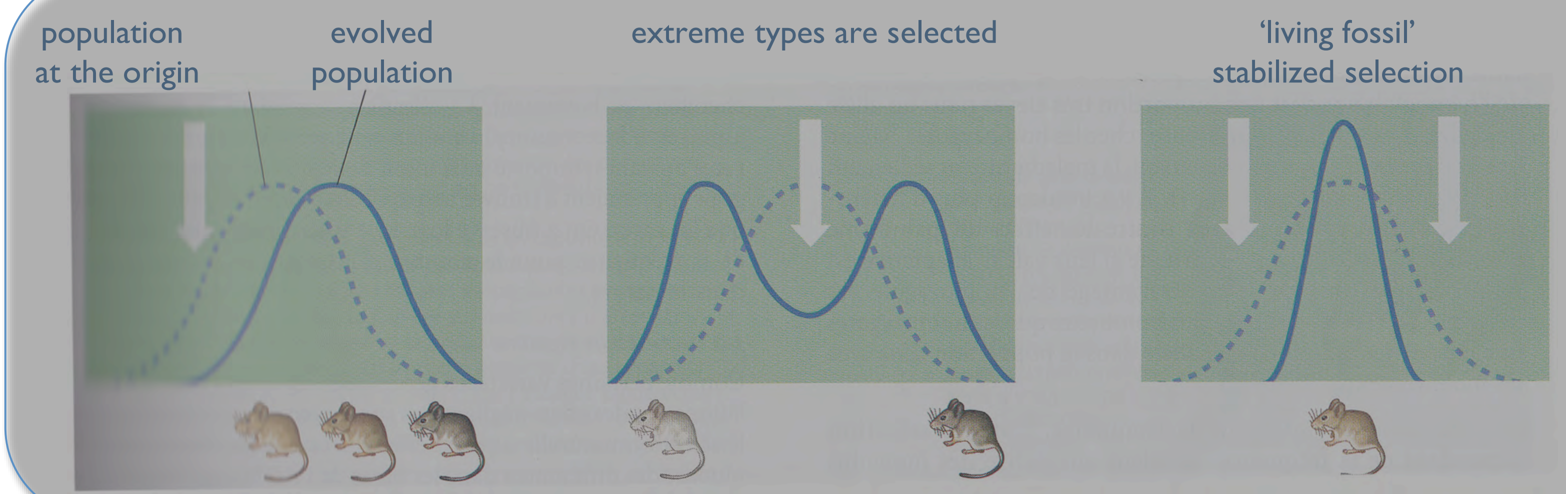
1. **PHYLETIC GRADUALISM**
2. **PUNCTUATED EQUILIBRIUM**
3. **RETICULATE SECIATION**

1. **PHYLETIC GRADUALISM** = long term evolutionary change, typically in response to geographical, climatic, or other environmental pressures (…) => taxa that evolve by phyletic gradualism **have the most potential for refined biostratigraphic zonation**, but they require specialist study to recognize the very subtle changes between the varieties

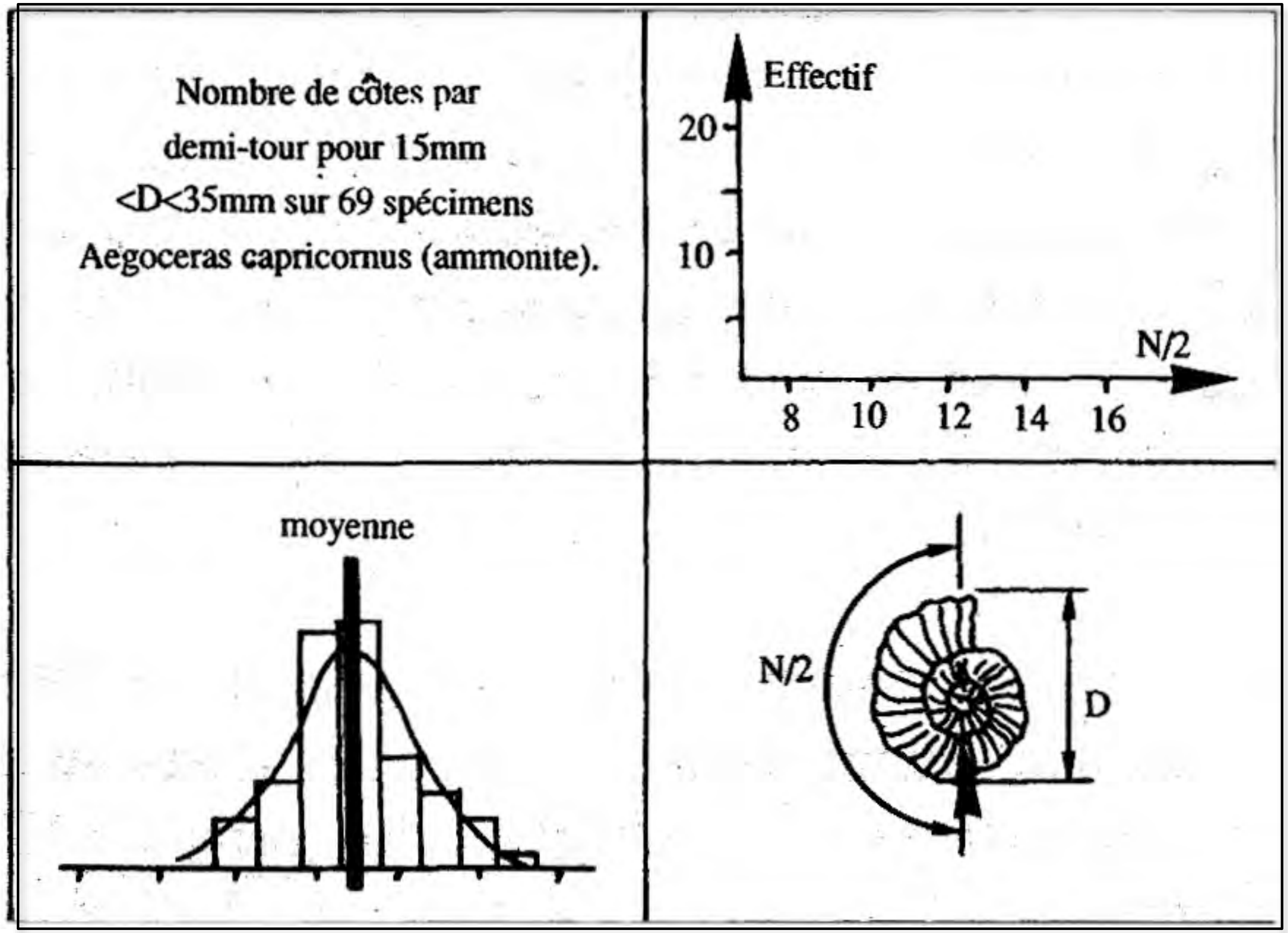
2. **PUNCTUTATED EQUILIBRIUM** = **spasmodic occurrence of bursts** of relatively rapid evolutionary change ('extreme variants' are selected by environmental pressure on the fringe of the species range (Eldridge & Goulds, 1972) ⇒ this produces major but infrequent taxonomic changes (**index fossils**), easily recognizable without specialist training

3. **RETICULATE SPECIATION** = combines, on a small-scale, the mechanisms of both the other two evolutionary styles. Concerns only the Pleistocene with infinite data => only for specialists and until now not applicable in the geologic record…





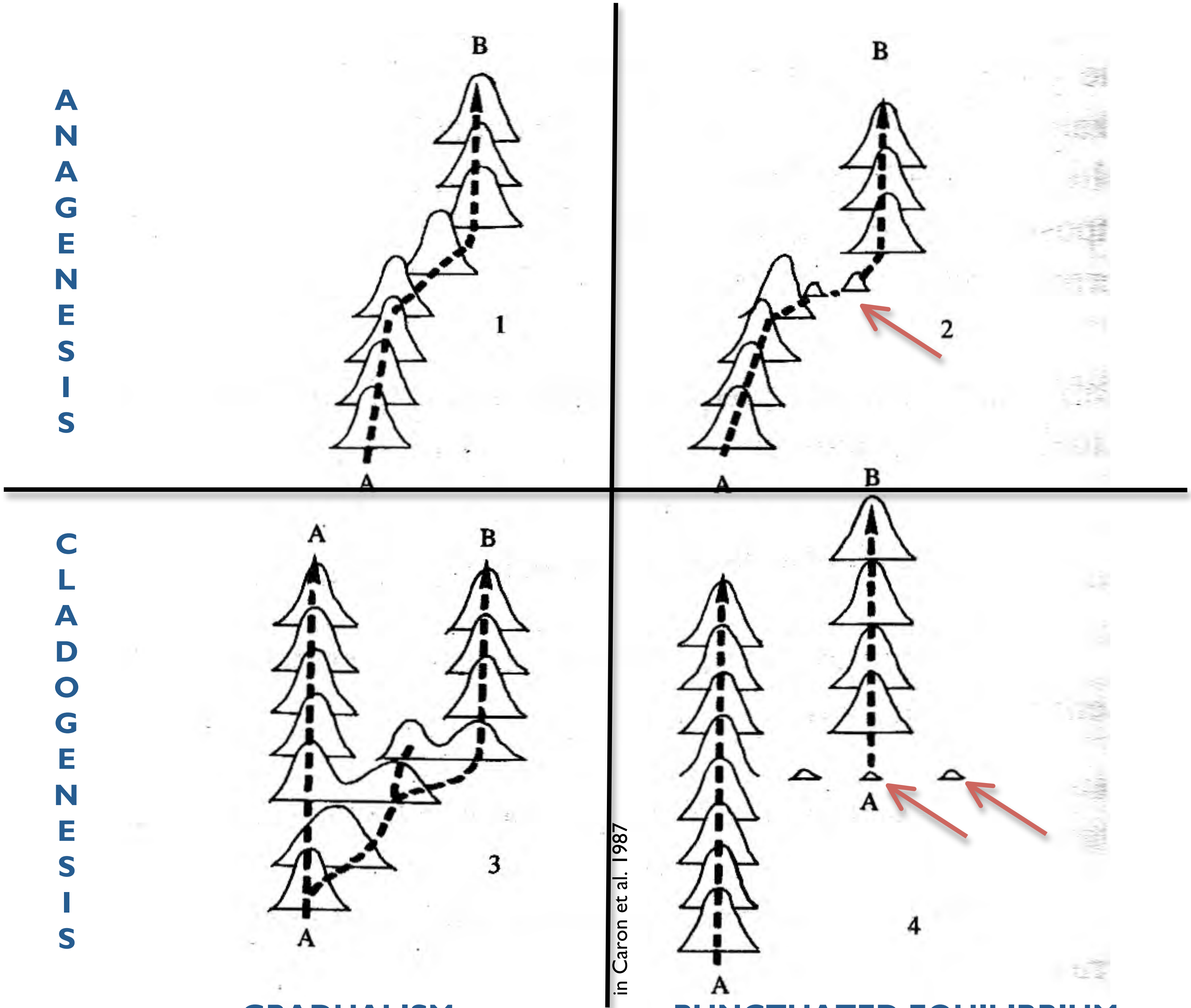
Campbell & Reece 2007



in Caron et al. 1987

ANAGENESIS

CLADOGENESIS



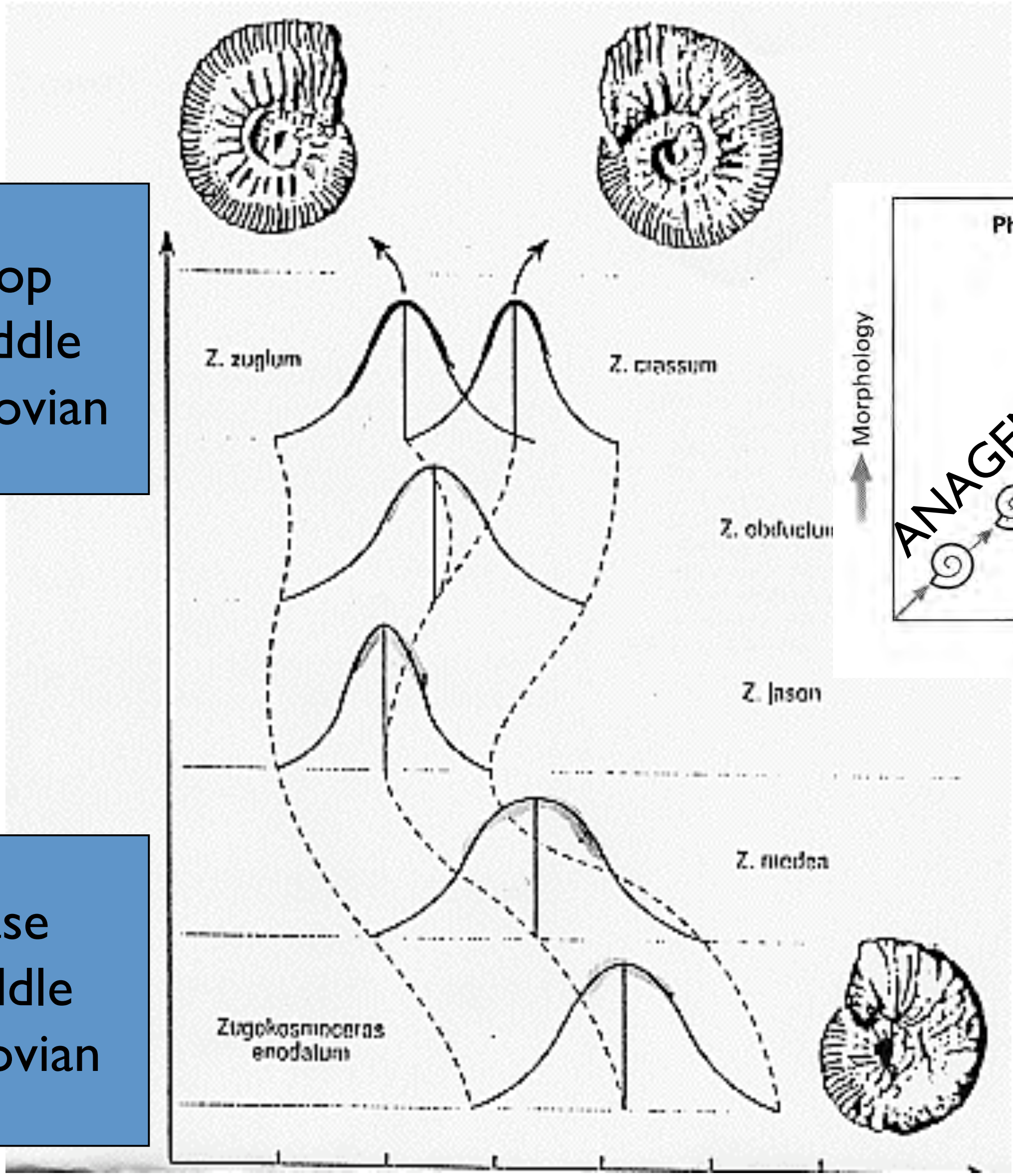
GRADUALISM **PUNCTUATED EQUILIBRIUM**

NUMEROUS CONSEQUENCES
Example of species evolution

quantic cladogenesis
PUNCTUATED EQUILIBRIUM

Top Middle Callovian

Base Middle Callovian



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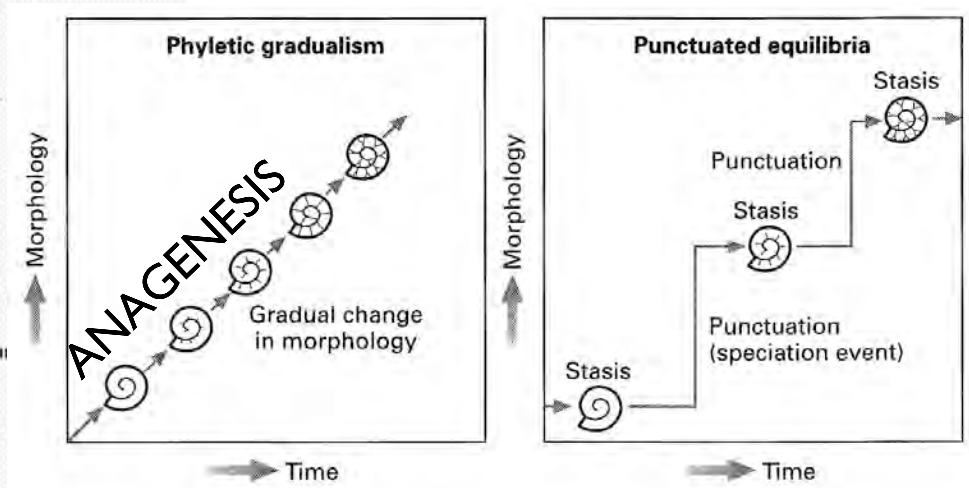
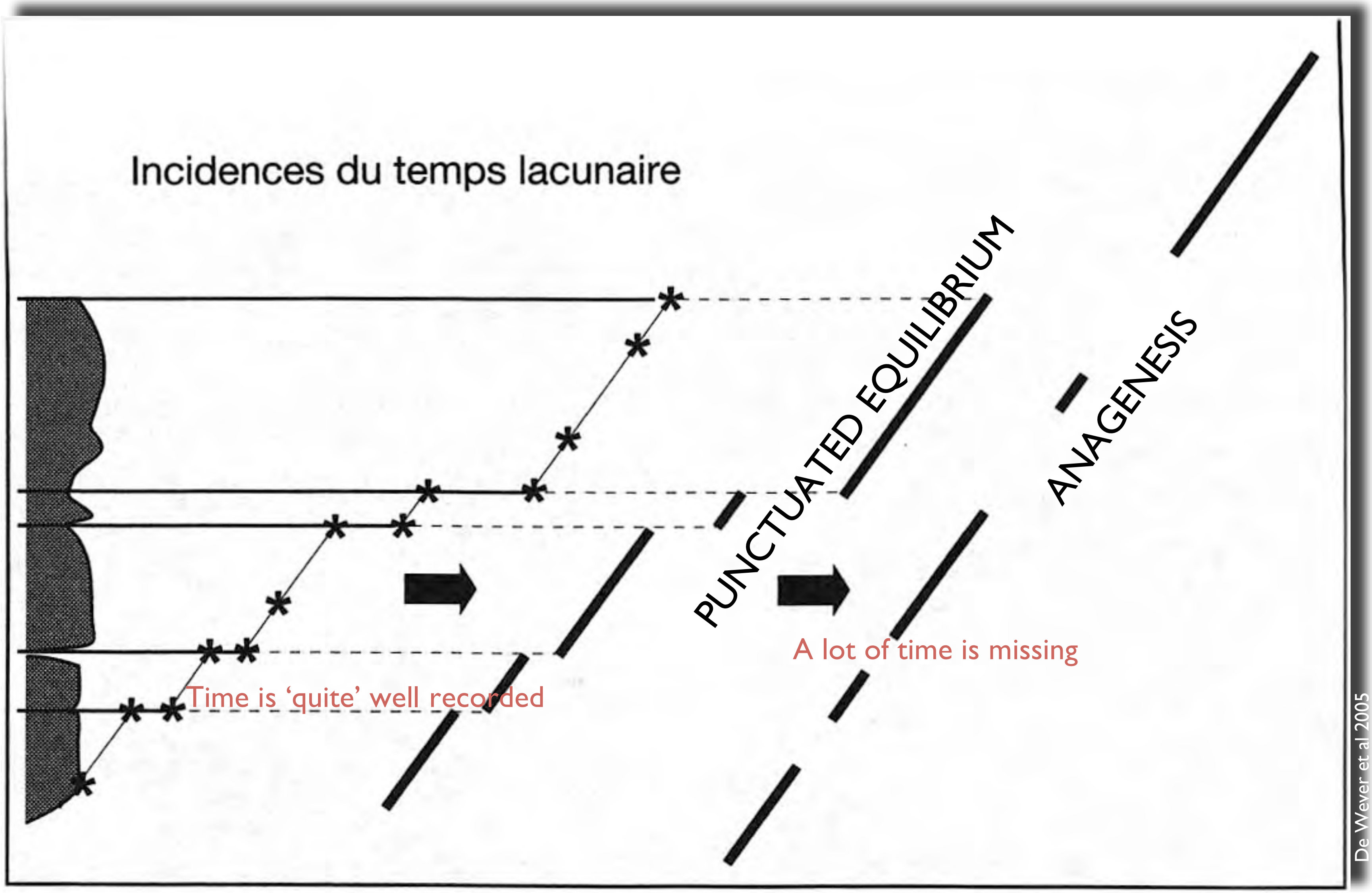


ANAGENESIS

Nichols 1999

IMPACT OF TIME GAPS



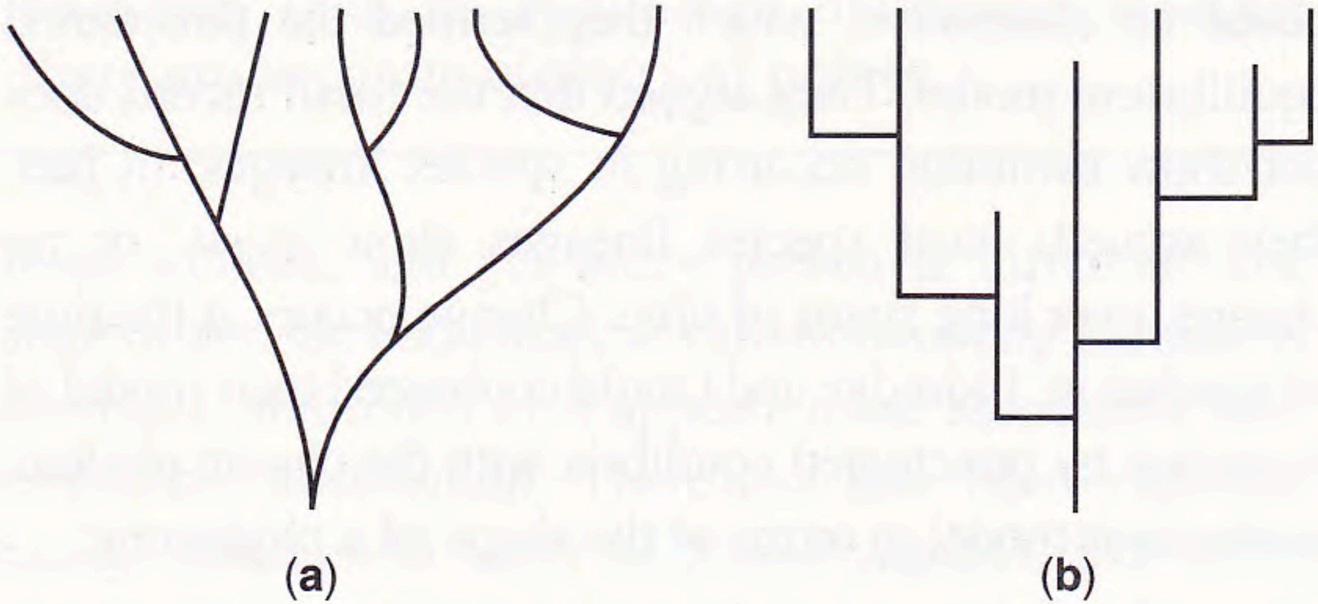
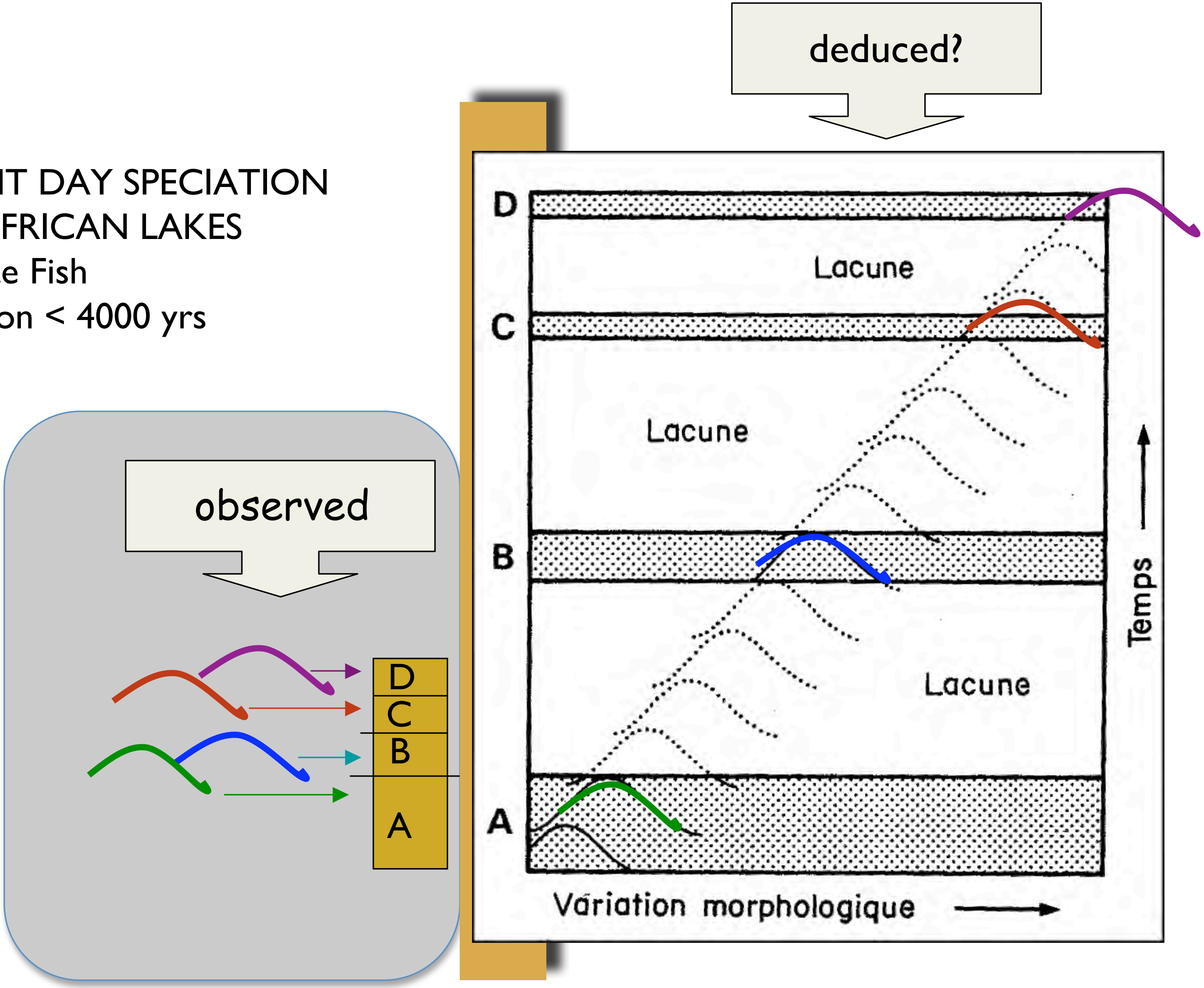


Fig 3.8 Two models of speciation and lineage evolution. (a) Phyletic gradualism, where evolution takes place in the lineages, and speciation is a side-effect of that evolution. (b) Punctuated equilibria, where most evolution is associated with speciation events, and lineages show little evolution (stasis).

Benton & Harper 1997

PRESENT DAY SPECIATION
EAST-AFRICAN LAKES
Cichlidae Fish
Speciation < 4000 yrs



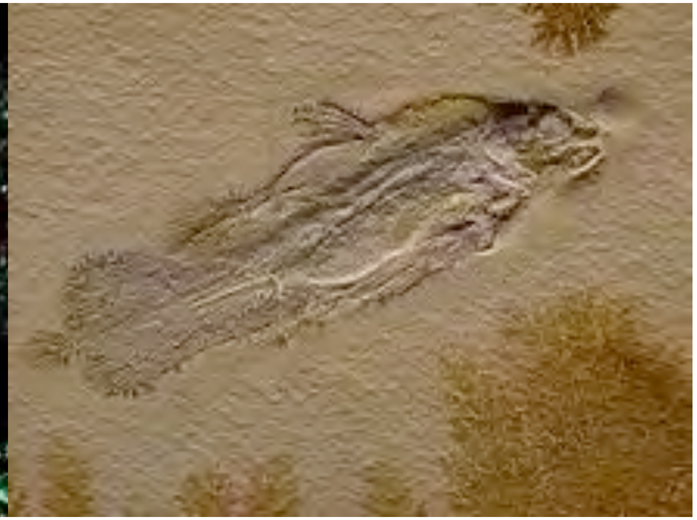
The interpretation may be dependent of the 'temporal' sampling

BIOSTRATIGRAPHIC UNITS

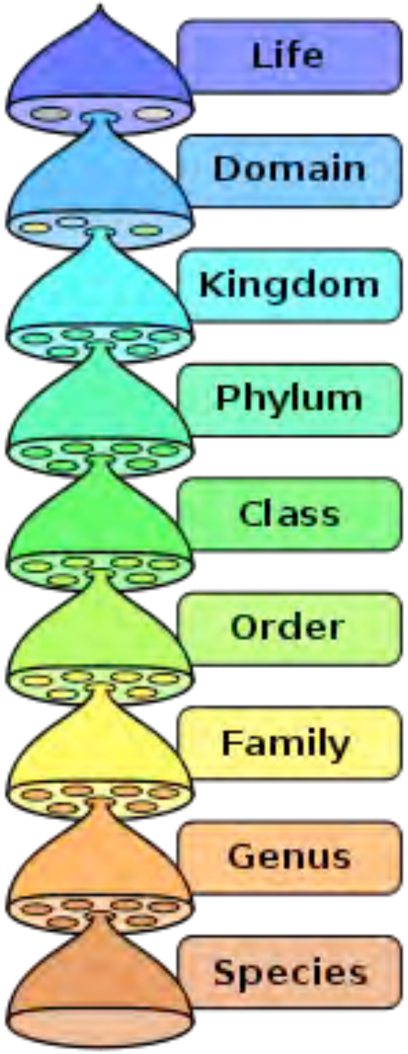
AVERAGE AGE OF A SPECIES IS ONLY A FEW MILLION YEARS

It has been estimated that more than 99 per cent of all species that have ever lived on Earth are now extinct. While species of some prokaryotes may be extremely long-lived, species of multicellular eukaryotes in the Phanerozoic fossil record commonly become extinct within 10 million years of their time of origin, with some surviving for less than a million years
Exception : **'Living fossils'** example of *Triops cancriformis,* small crab of the Trias still living (> 200 myr!) + Coelacanth (Paleozoic), Dipneusts (O.R.S.), Nautilus….


Today, discoverd 1938


Jurassic (fossil)

NUMBER of SPECIES (⇔ biodiversity)



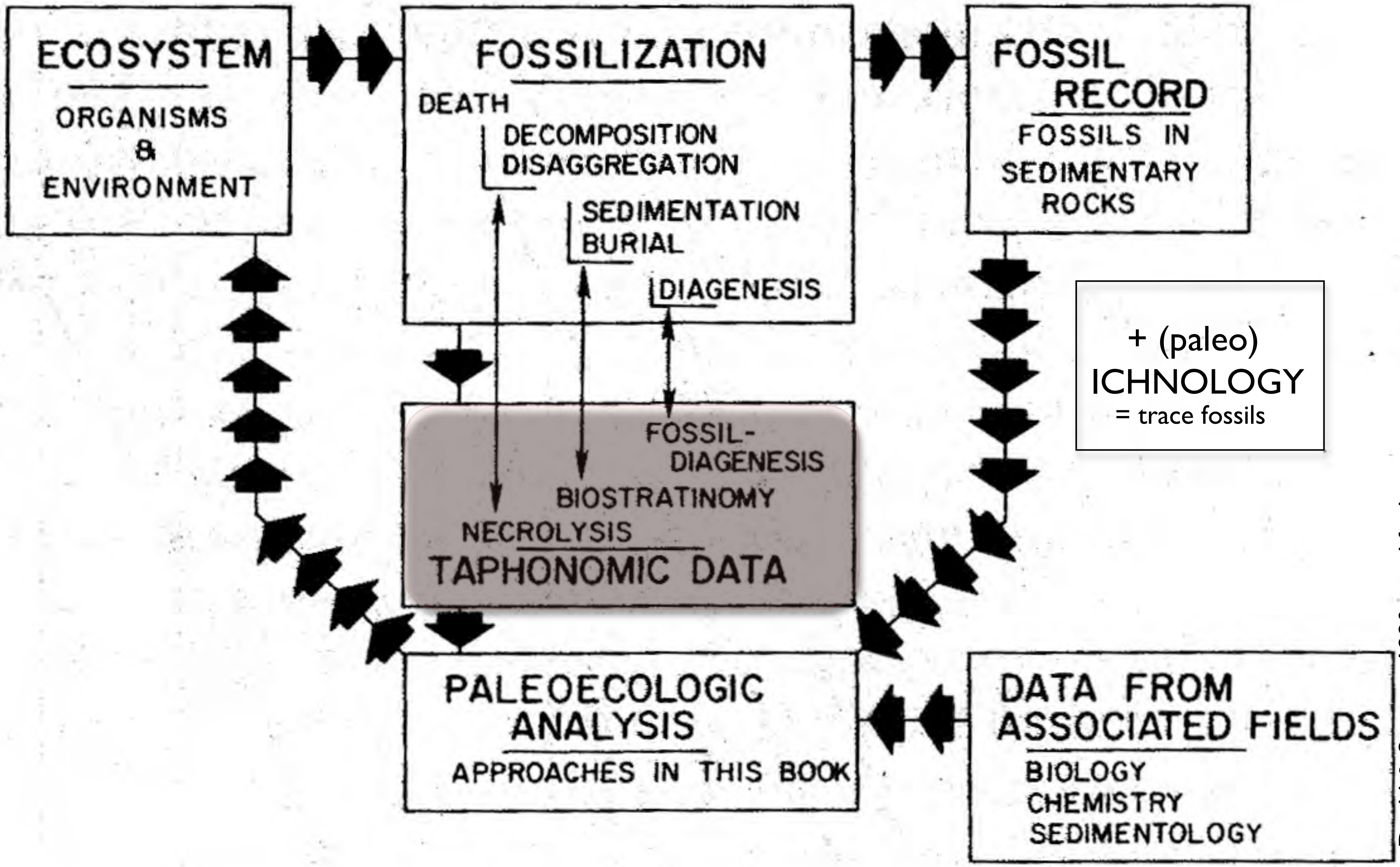
• The total number of non-bacterial species in the world has been estimated at **8.7 million**, with previous estimates ranging from **two million to 100 million**
85% = arthropods, 10% = non athropod invertebrates, 5% = vertebrates
= 0.01 to 0.001% Phanerozoic
= ?10^9 Pcm (bacteria…)

• 'only' around 200,000 fossil species have been described
=> a lot have not been discovered yet and a lot **have not been fossilized**
=> Valentine (1970) : 100,000 fossilized sp. from an estimated total of 6 million of phanerozoic **marine** sp.
=> Leakey (1997) : 30 billion sp. present since the multicellular apparition

CONCLUSION : NO AGREEMENT BOTH IN THE PAST AND PRESENT DAY
real observed species is linked to the preservation conditions
= TAPHONOMY

A ' humorist statistician': at first approximation, all the species are extinct…

TAPHONOMY is the study of POSTMORTEM history of fossils



Dodd & Stanton 1990, modified

TAPHONOMY: preservation is RARE

except if the skeleton is resistant, if burial is rapid and gentle, if low oxygen levels present…. => < 30% of the sp. in modern benthic communites are likely to be fossilized….

Taphonomic processes
NECROLYSIS => microbial alteration
==> terrestrial organisms have very poor chance of preservation
Example: Vertebrates and Hominidae….
'BIOSTRATONOMY-SEDIMENTOLOGY' => turbulence, burrowing, sedimentation rate (must be very fast), transportation, texture and sorting of the sediments…
DIAGENESIS => mineralogy of the skeletons, circulating fluids…

Conclusion : <u>higher preservation potential in the marine domain</u> and weak preservation potential in the continental realm
⇒'bias' of the fossilization. There was probably 10 to 100 times more terrestrial organisms than marine organisms in the past (as today).

(paleo)BIOGEOGRAPHY

= geographic distribution of ancient organisms or of taxa (it is an aspect of large-scale or 'big-picture' paleoecology)

=>' biotic province'

⇒ 1° reflects ecological restriction and 2° geographic isolation of populations

FOR FOSSILIZED COMMUNITIES

- **TAPHOCENOSE** : organisms perished together, but not necessarily lived together
- **THANATOCENOSE** : lived together, then transported in different places
- **BIOCENOSE** : exceptional in geology (ex. algae, only the calcareous may be fossilized)

… 1°reflects ecological restriction

(a) benthonic taxa : bottom-dwelling mode of life

- *inside the sediment = endobiont*
- *at the surface of substratum sessil epibiont (if attached) or vagile epibiont (mobile)*

(b) nektonic taxa : swimming habit (active)

(c) planktonic taxa (zoo-, phyto-) : floating habit

(b) and (c) better for biostratigraphic purposes but in practice (a) is widely used because many benthonic taxa have a planktonic larval stage that ensures wide distribution via marine circulation (corals ….)

…2° geographic isolation of populations

2° geographic isolation of populations (random events = 'jump dispersal')

• MIGRATIONS faunal territorial extensions are generally fast, i.e. 1000's yrs
⇒not useful in geology, only Plio-Quaternary

• ISOLATION ⇔ also related to paleogeography and geotectonic whose fluctuations reinforce or **prevent**
- the dispersions
- the changes
- induce **isolations** of populations

⇒ 'archaic' or 'relict' forms may be locally protected for a long time
⇒ BUT this may lead to SPECIATION
= **sympatric speciation** : if the geographic overlap of populations of the ancestral species is extensive with 'genetic drift' => new 'alleles' by mutation …
= **parapatric speciation** : if the populations are largely **allopatric** (i.e. occurring in different geographical places that are mutually exclusive) but overlap in a narrow zone where depressed fitness of interpopulations matings leads to selection for isolating mechanisms (also genetic drift…)

⇒ **PERIPHERAL ISOLATES (OR POPULATIONS) = isolated patches of habitat** (example oceanic islands, barriers, previous uninhabited region etc). Genetic drift may play a greater role relative to selection, and divergence may be more rapid, at least initially …

Some speciation events at least appear to be geologically rapid (1000-2000 yrs)
Hard to document because they usually take place in small isolated patterns + time resolution

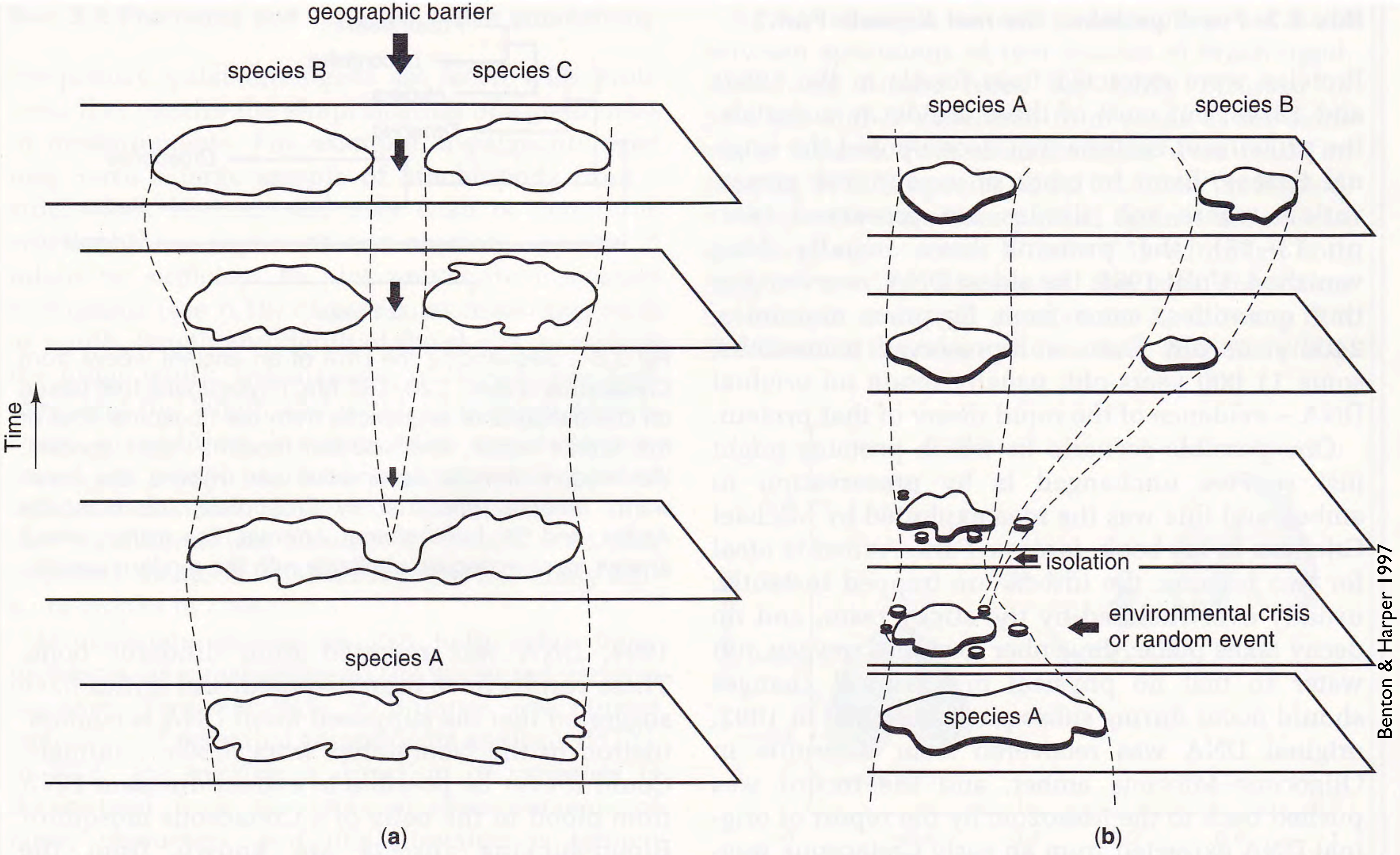


Fig 3.7 Allopatric speciation models, occurring either symmetrically (a), where the parent species is divided into two roughly equal halves by a geographic barrier, or asymmetrically (b), where a small peripheral population is isolated by a barrier. In the first case, two new species may arise; in the second, the parent species may continue unaltered, and the peripheral population may evolve rapidly into a new species.

(paleo)BIOGEOGRAPHY

= geographic distribution of ancient organisms or of taxa (it is an aspect of large-scale or 'big-picture' paleoecology)

=>' biotic province' ==> **PALEO**PROVINCES : may help in our understanding plate tectonics history (and other geologic subdisciplines)

nb Woodward (1856) first defined marine provinces based on molluskan species distribution, then Darwin (1860's) , Wallace (1876) with terrestrial biotas…

nb Woodward (1856) *'a province is an area in which 50% of the species are* ***endemic****…'*

- example : **molluskan** faunas of Jurassic age => three provinces Tethyan, Boreal, Pacific, also defined on the basis of **ammonites** and **belemnites**. The boundary is emphasized by a widespread change between northern and southern Europe (Normandy with 'cold ammonites' and 'warm ammonites'… Latitudes and T°are the major parameters and influenced the distribubtion of the **rudists**.
- example : Early Paleozoic Iapetus Ocean with **trilobite** provinces
  Lower Cambrian : *Olennellus* province (Scandinavia, Scotland, N America …) and Redlichia province (Asia, Australia…). Transition zone : Morocco, Spain
  Middle Cambrian *Olenoides* province and *Paradoxides* province
  Upper Cambrian …..

=> **PALINSPATIC MAPS** : maps with the original position of the paleoprovinces

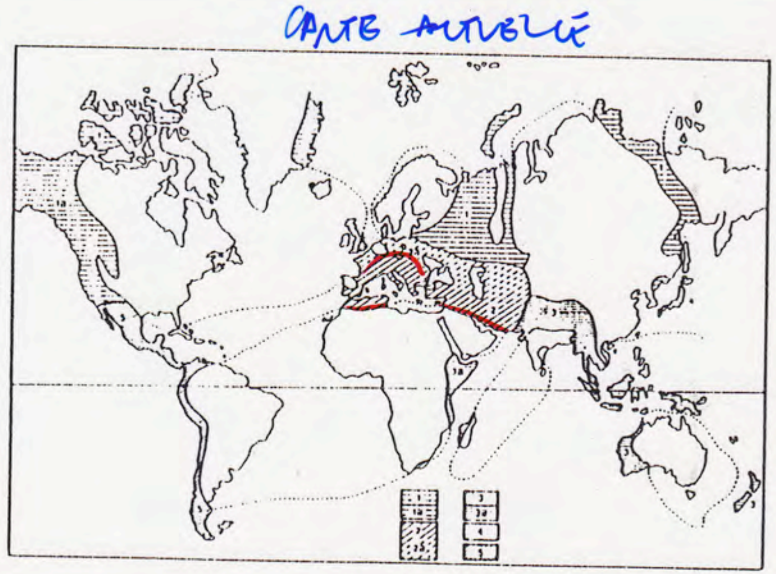


Figure 180. Provinces faunistiques du Jurassique terminal et du début du Crétacé portées sur une carte géographique actuelle. 1 : Province boréale; 1a : Sous-province nord-andine; 2 : Province méditerranéo-caucasienne; 2a : Zone néritique marginale; 3 : Province himalayenne; 3a : Sous-province éthiopienne; 4 : Province japonaise; 5 : Province sud-andine (d'après Uhlig, 1911).

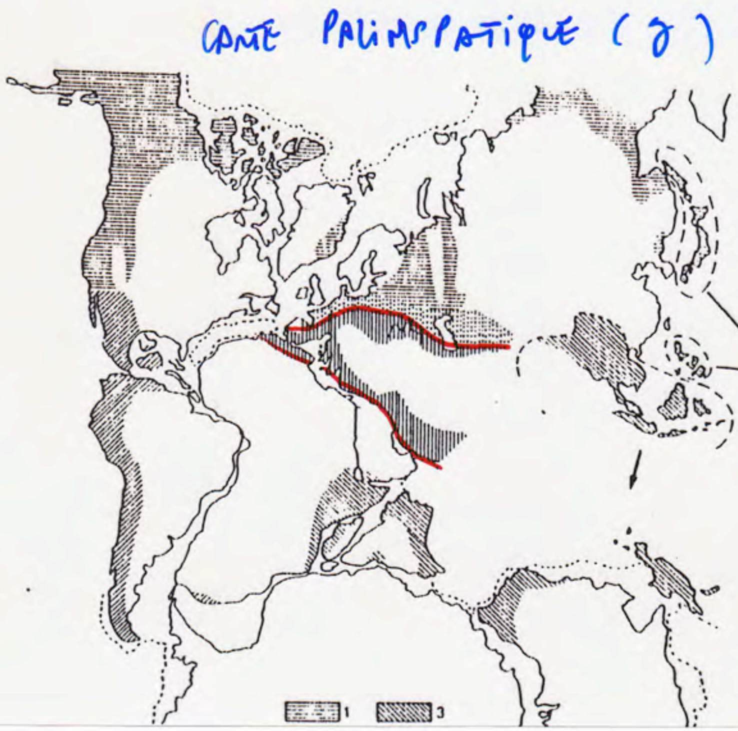
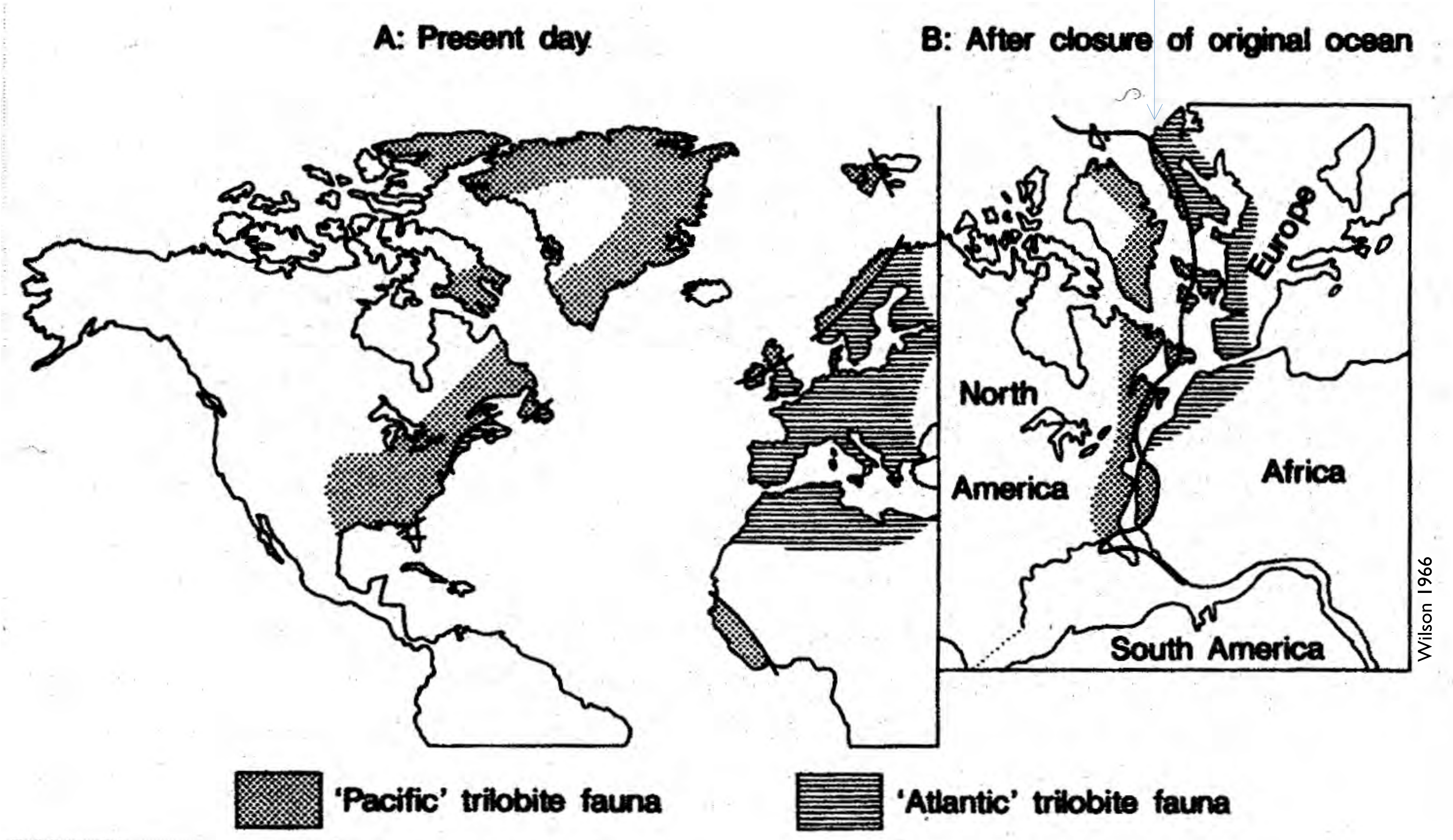


Figure 181. Provinces faunistiques définies par Uhlig (1911) et reportées sur la reconstitution paléogéographique proposée par Smith *et al.* (1973) pour le Jurassique. 1 : Province boréale; 2 : Province méditerranéo-caucasienne; 2a : Zone néritique marginale = sous-province subméditerranéenne; 3 : Province himalayenne = sous-province éthiopienne; 4 : Province japonaise (? une partie de la province subméditerranéenne), les Philippines sont incluses ici; 5 : Province sud-andine = sous-province pacifique ou cubaine. Les flèches indiquent la localisation supposée de parties de continents, différant de celle sug-

PALINSPATIC MAPS : maps with the original position of the paleoprovinces Cambrian (Iapetus Ocean)



PROVINCIALISM > < COSMOPOLITISM

FRAGMENTATION SUPERCONTINENTS
DISRUPTION OF ‘PLATFORMS’
ex: J/K ammonites
ex : Cm trilobites
…

ASSEMBLAGES
and
COLLISIONS
…

GEOTECTONIC
and
PALEOGEOGRAPHY

last part.....

TAXONOMY

In the strictest sense, the study of the names of organisms, but often used for entire process of classification (= SYSTEMATICS or study of evolutionary relationships between organisms)

SPECIES

The fundamental taxonomic category or unit for organisms, variously defined and diagnosed using different species concepts
= BIOLOGY

• They are different concepts of the species (since Platon!)
Today = biological species concept : groups of interbreeding organisms which are reproductively isolated from other such groups and producing fertile offspring (Mayr 1940'…)
=> **species is a reproductive unit composed of individuals forming a group of natural populations.** The reproductive criteria is not an absolute characteristic
==> they are sterile interspecific interbreeding (example of zebras and horses…)
===> with this definition, the (biological) species is studied from its individuals which form the populations
nb Species that are believed to have the same ancestors are grouped together = **a genus**

WHAT ABOUT BEFORE?

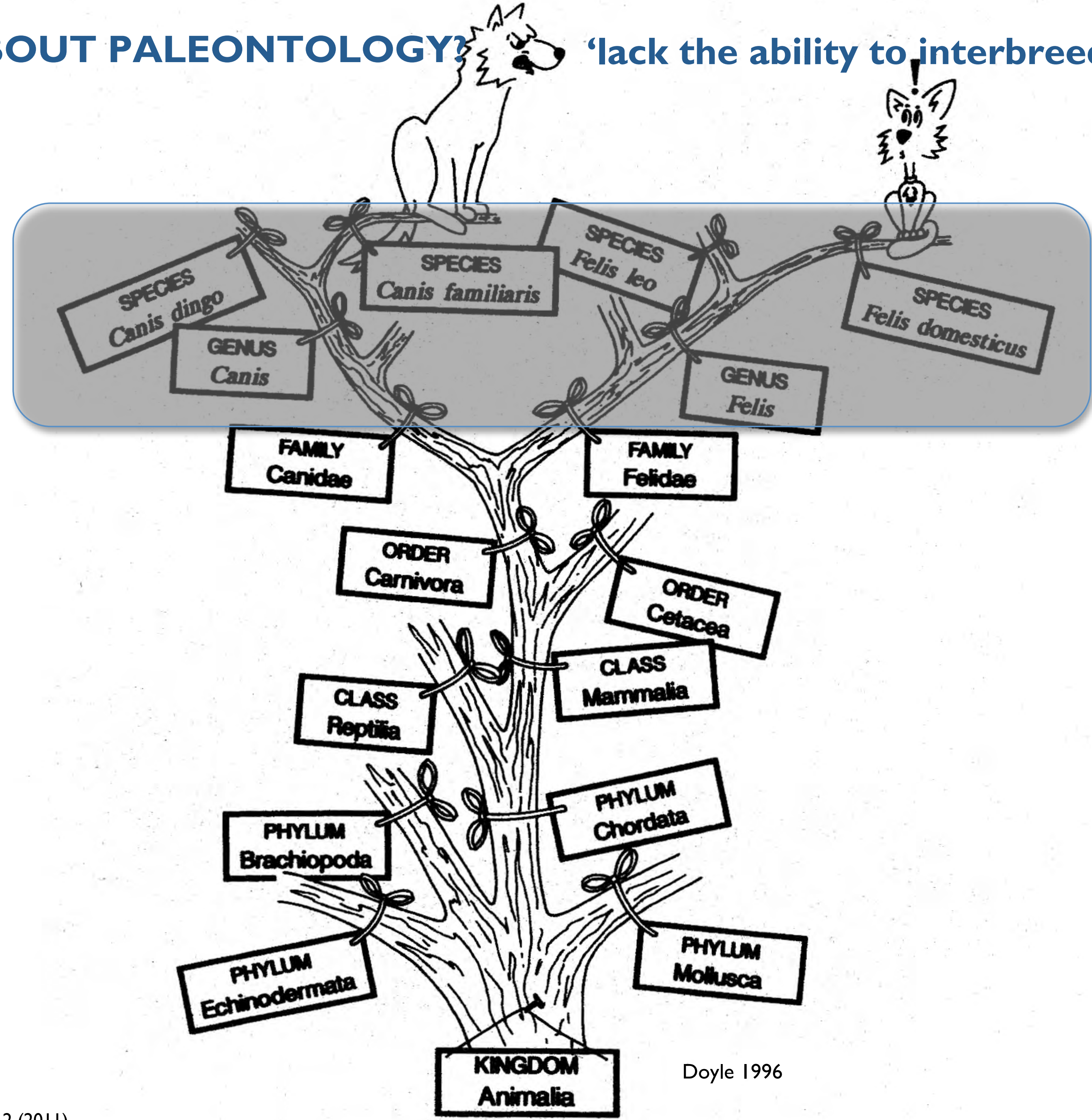
1. individuals are alike => indeed this similarity criteria has been used before the biological con
2. this leads to a **TYPOLOGICAL SPECIES CONCEPT** related to an **'ideal'** representation, i.e. the idea of a reference/comparison to **an average ideal form or type or ideal plan** => all members of a species shared characteristics of this ideal plan
3. in practice, this is equivalent to a **MORPHOLOGICAL SPECIES CONCEPT**, the species is then defined with a **DIAGNOSIS** establishing its **original** characteristics
4. study of a new specimen = comparison, and if no comparaison is possible => creation of a **NEW NOMENCLATURAL TYPE**

• 1 => 4 : Conclusions = expertise, intuition…. i.e. subjectivity and artificial multiplication of the species….

• wih regards to the biological concept (interbreeding)
⇒ study of individuals and **quantification** of the morphology
= CONTINUOUS VARIABLE : the characters of different conspecific variants display following the normal Gauss-Laplace Law

WHAT ABOUT PALEONTOLOGY?

WHAT ABOUT PALEONTOLOGY? ‘lack the ability to interbreed’…



Doyle 1996

WHAT ABOUT PALEONTOLOGY?
'lack the ability to interbreed'…

- ONLY morphological characteristics ('interbreeding definitively lost')
- Moreover these characteristics are in the most cases **INCOMPLETE** i.e. **PARTIAL** and the number of individuals is strongly **LIMITED** or **REDUCED**

⇒ the **traditional** studies of descriptions and comparisons are still the rule.
- only improvement = increase the number of quantitative studies (both characteritics and number of specimens)
- and in order to have a better objectivity, use statistical analysis (geostatistics, multivariate analysis …)

nb under the **biological species concept** the unknown specimen is compared not only to the range of morphological for the species, but also to its growth characteristics, paleoenvironmental habitats, and associated fauna. If the characteristics of the specimen are consistent with known material, it may be classified as a member of that species

Living organism $\xrightarrow{99.9\%}$ composts (or HC, or fossil)

Example: one bone/10^9 is fossilized
all US people =(300.10^6 x 206 bones)/10^9 => 50 bones or ¼ skeleton
⇒¼ skeleton on 9.6×10^6 km^2 (USA) will probably never be discovered

?< 1sp./10,000 occurs in the geological series
On Earth*: = 30. 10^9 sp => 1sp over 120,000 is fossilized
if 4000×10^9 sp => 1 sp over 1.5×10^6 is fossilized
* 250,000 fossil species are known (mainy marine…)

Edward O. WILSON => BIODIVERSITY (status…)

- *'we have no order of magnitude for the present-day species'*
- 3 to 200 million? (97% are still to be discovered, with 100 million of insects and 400 million of bateria-fungi)
- They are 10,000 active taxonomists in the world, they discover 15,000 sp/yr => they will finish in 15,000 years…

REMEMBER

Because each species might consist of nearly uncountable numbers of individual specimens, each of which varies somewhat from the other, assignment of an unknown specimen by reference to a species description is not an easy task.

Also sexual dimorphism….

A **single specimen**, called simply the **type** serves as the name-bearer and final standard. The philosophy of classification in which the type is the basis of a taxon's definition is known as **typology**.

1735


CAROLI LINNÆI
Naturæ Curiosorum Dioscoridis Secundi
SYSTEMA
NATURÆ
IN QUO
NATURÆ REGNA TRIA,
SECUNDUM,
CLASSES, ORDINES, GENERA, SPECIES,
SYSTEMATICE PROPONUNTUR.

TAXONOMY – SYSTEMATICS
BINOMIAL NOMENCLATURE

Paleontology has its root in the work of Carolus LINNE (1758) who grouped species according to shared physical (morphological) characteristics.

- The classification is based on the BINOMIAL principle

⇒ each fossil (or species) is designated with a name consisting of **two words**,
first the name of the **genus** to which that species belongs and,
second, a designation for that particular **species**

- No two species can have the same name.
- The names are always Latin (or Latinized) and the genus is capitalized while the specific name is not
- **Both names are customarily written in *italics*** (underlined if hand-written or typed)
- The correct name for any species, according to the present rules laid down in the International Rules of Botanical Nomenclature and in the International Rules of Zological Nomenclature is usually the oldest validly proposed name
- The same Latin scientific names are used throughout the world
- The uniformity usage ensures that each scientist will know exactly which species another scientific is discussing.

The two words together are called the scientific name of the species

⇒ the first word (*in latin*) is **C**apitalized = the ***G****enus*
⇒ the second word (*in latin*) is **not c**apitalized = the *species*
⇒ then one adds the NAME OF THE AUTHOR(S) (not in italics, but CAPITALIZED or normal)
⇒ the a comma = ,
⇒ finally, the date of creation

Examples
Globigerina bulloides D'ORBIGNY, 1826
Globigerina bulloides D'Orbigny, 1826
Globigerina bulloides D'ORBIGNY, 1826
Globigerina bulloides D'Orbigny, 1826

Tornaceras keyserlingi Müller, 1956
(nb = Devonian goniatite)

if author's name and date in (brackets) => this indicates that the author who created the species attributed INITIALLY this species to another Genus
*Tornaceras simplex (*Von Buch, 1932*)* because Von Buch initially placed his species into the *Ammonites* genus
==> LIST of SYNONYMY (often very –very- long…..)

TRINOMIAL NOMENCLATURE

If necessary the name of the subgenus is placed in (brackets), between the name of the genus and the name of the species

Tornaceras (*Aulatornaceras*) *keyserlingi* Müller, 1956

A subspecies has also a trinomial nomenclature, its name is followed by the author(s) who created it
= **A VARIETY, very important for speciation and theory of evolution**

Globorotalia cerroazulensis cunialensis TOURMAKINE et BOLLI, 1970 (=G. sp. spp.)

Pentamerus oblongus cylindricus Hall et Whitfield, 1867
(G = 5 parts, sp = general shell form, ssp.= particular form)

‘OPEN’ NOMENCLATURE…

An interesting fossil may be highlighted **WITHOUT** using a accurate designation ... for example if the specimen is partly known from a few specimen or form one specimen!

⇒*Tornaceras* sp. or if great uncertainty => *Tornaceras* sp. aff.

Advantages

- it avoids too many names in the list of synonymy (very useful if later someone shows that this sp. already existed!)
- stratigraphic purpose: it avoids hasty conclusions
- oil exploration (informal or ‘internal’ nomenclature) : example of biofacies during the Cretaceous rifting of South Atlantic (Gabon/Angola/Brazil…)

CREATION OF A NEW TAXON

species n.sp.

genus n.g.

‘FIRST’ PRIORITY LAW

This is a law that is more commonly exercised in paleontology than with living organisms. The law of first priority gives the right to name an organism to the **first person** who proposes it. This becomes complicated in paleontology when there is a dispute over how a sample should be classified (…)

=>**synonymy list of ALL previous studies!.**

HOW TO CREATE A NEW SPECIES?

• Needs publication in books or journals with a **diagnosis**, defining the main characters of the species, a fuller description and an **illustration** (photographic plates) of the species itself.

• On publication, the author's name and the date of publication are usually appended to the species name, in order to assist future researchers.

• Finally, the species has to be tied to a permanent point of reference = a **type specimen**, which should be clearly identified in the original publication and preserved for posterity in a museum, to allow **comparison** with other specimens and to assist further study.

• Where ''disputes' arise'… the International Commissions fro Zoological and Botanical Nomenclature can be called upon to give a ruling.

- **HOLOTYPE : 'the true type'** ideally preserved in a museum somewhere, so that other scientists might refer to it as necessary = comparison, new studies including re-interpretation.

Unfortunately original type are rarely accessible => importance of the descriptions in the publications with drawings and photographic illustrations or plates

- **SERYTYPE** the whole set of fossils (in the museum…) representing the species
- **SYNTYPE** any of two or more specimens listed in a species description where a holotype was not designated
- **NEOTYPE** a specimen **later** selected to serve as the single type specimen when an original holotype has been lost or destroyed, or where the original author never cited a specimen => chosen in the nearby original locality …
- **LECTOTYPE** a specimen **later** selected to serve as the single type specimen for originally described from a set of syntypes
- **PARATYPE** any additional specimen other than the holotype, listed in the type series where the original description designated a holotype. These are not name-bearing types.
- **PARALECTOTYPE** any additional specimen from among a set of syntypes, after a lectotype has been designated among them. These are not name-bearing types.

the TYPE notion has been extended to higher rank taxa

⇒ the **genus** nominal TYPE is defined with a **species-type**

=> the **family** nominal type is defined with a **genus-type** …

Sir Richard OWEN (1804-1892), British anatomist and paleontologist
1841 he created the term DINOSAURIA (and was the first to recognize them as different from today's reptiles).

1868 E.D. COPE [> < O.M. MARSH]
⇒ *Stegosaurus, Brontosaurus, Diplodocus, Triceratops*….
COPE discovered and created 1300 sp. (22 times the same!!!), manly dinosaurs and published 1600 articles

1898 'BONE CABIN QUARRY' : 50 tons of bones + 10's tons later
='Dinosaur Quarry'

1898 COPE died => before that he 'gave' his squeleton to represent the holotype of *Homo sapiens*

…

….

1859 Carolus LINNE (Upssala) is the holotype….

Bull. Mus. natn. Hist. nat., Paris, 4ᵉ sér., 9, 1987,
section C, n° 2 : 151-180.

165

Révision d'*Heliophyllum halli* Milne-Edwards et Haime, espèce-type du genre *Heliophyllum* Hall *in* Dana (Tétracoralliaire dévonien)

par Marie COEN-AUBERT

Résumé. — L'espèce est redécrite à partir du matériel original de H. MILNE-EDWARDS et J. HAIME (1851). Le néotype proposé, figuré jadis par ces deux auteurs provient du Groupe d'Hamilton de Moscow, aujourd'hui Leicester dans l'État de New York aux USA. A titre de comparaison, d'autres spécimens givétiens de l'espèce, prélevés dans les Formations de Ludlowville et de Moscow de la même région ainsi que dans la Formation d'Hungry Hollow de l'Ontario méridional au Canada, ont été examinés. Enfin, les *Heliophyllum halli* signalés au sommet de l'Eifélien du Maroc par D. LE MAÎTRE sont attribués à *H. halli moghrabiense* Le Maître, 1947.

Abstract. — The species is redescribed on the basis of the original material from H. MILNE-EDWARDS and J. HAIME (1851). A specimen from the Hamilton Group of Moscow, today Leicester, in New York State USA, figured formerly by these two authors, is proposed as neotype. For comparison, other Givetian coralla of the species collected from the Ludlowville and Moscow Formations of the same area and from the Hungry Hollow Formation of southern Ontario in Canada have been studied. *Heliophyllum halli* specimens reported from the top of the Eifelian in Morocco by D. LE MAÎTRE are assigned to *H. halli moghrabiense* Le Maître, 1947.

M. COEN-AUBERT, *Département de Paléontologie, Institut royal des Sciences naturelles de Belgique, rue Vautier 29, B-1040 Bruxelles, Belgique.*

En 1843, J. HALL (p. 209, fig. 87, 3 et n° 48, fig. 3) détermine comme *Strombodes helianthoides*? Goldfuss, 1826, un polypier du Groupe d'Hamilton de York situé dans le Comté de Livingstone de l'État de New York aux USA. Trois ans plus tard, ce spécimen sert de support au genre *Heliophyllum* Hall *in* J. D. Dana (1846 : 183). C'est sur lui également que H. MILNE-EDWARDS et J. HAIME (1850, p. LXIX) fondent l'espèce *Heliophyllum halli* utilisée depuis lors comme espèce-type d'*Heliophyllum* et considérée comme bien distincte de l'espèce de G. A. GOLDFUSS (1826). En 1851 (pl. 7, fig. 6, 6a et 6b), les mêmes auteurs publient trois figures de *H. halli* provenant probablement d'un même échantillon, sans toutefois préciser son origine.

D'après les articles 11i et 70c du Code international de Nomenclature zoologique (1985, 3ᵉ éd.), l'espèce-type d'*Heliophyllum* devrait être *H. helianthoides* Hall *in* Dana, 1846. Toutefois, suivant l'article 11e, *H. halli*, son synonyme, est un nom valide parce que publié avant 1961. Dès lors, selon les articles 23b et 79c, il n'y a aucune raison valable de remettre en cause cette nomenclature bien établie.

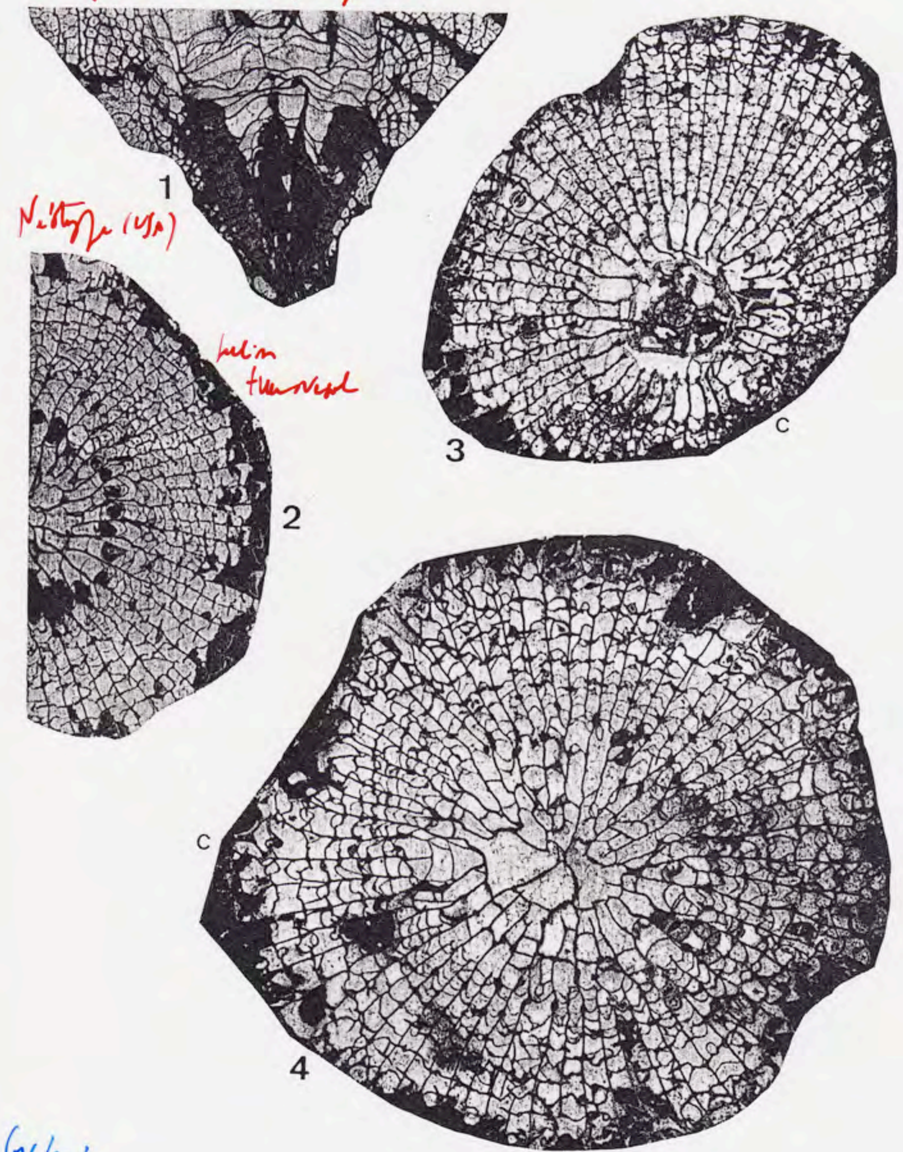
Comme l'espèce *H. halli* a été fondée sur le spécimen unique de J. HALL (1843), c'est ce

Heliophyllum halli halli Milne-Edwards et Haime, 1850

Néotype (USA) section longitudinale

Néotype (USA)

section transversale



Gv/m'

X3

PLANCHE I

Heliophyllum halli halli Milne-Edwards et Haime, 1850
(Pl. I à V)

Strombodes helianthoides?; J. Hall, 1843 : 209, fig. 87, 3, n° 48, fig. 3.
Heliophyllum halli Milne-Edwards et Haime, 1850 : lxix.
v [1] *Heliophyllum halli*; H. Milne-Edwards et J. Haime, 1851 : 408, pl. 7, fig. 6, 6a, b.
Heliophyllum halli; J. Hall, 1876, pl. XXIII, fig. 1-5, 12, pl. XXV, fig. 1-7; C. Rominger, 1876 : 99, pl. XXXV (tiers supérieur, 4 spécimens); H. A. Nicholson, 1878 : 46, fig. A, B; W. Haller, 1936, pl. 34, fig. 2; J. W. Wells, 1937 : 9, pl. I, fig. 1-3?, 4; C. L. Fenton et M. A. Fenton, 1938 : 211, fig. 6, pl. XVII, fig. 1-5, pl. XVIII, fig. 1; S. Smith, 1945 : 26, pl. 33, fig. 3; E. C. Stumm, 1949, pl. 9, fig. 8-11; M. Lecompte, 1952 : 475, fig. 118; T. Y. H. Ma, 1956 : 48, pl. XLI, fig.1, pl. XLII, fig. 1, pl. LVII, fig. 1-9, pl. LVIII, fig. 1-5; E. C. Stumm et J. H. Tyler, 1962 : 268, pl. I, fig. 15-16, pl. II, fig. 7-8?; E. C. Stumm, 1968 : 38, pl. 1, fig. 1, 2, pl. 3, fig. 13; D. Hill, 1981 : F296-F297, fig. 192, 1a-e; C. T. Scrutton, 1985, pl. 3.3.53.
e.p. *Heliophyllum halli*; H. W. Shimer et R. R. Shrock, 1944 : 97, pl. 31, fig. 8, 9-10?, 11; C. T. Scrutton, 1973 : 257, pl. 5, fig. 6-8, pl. 6, fig. 1-6?
? *Heliophyllum halli*; H. Milne-Edwards et J. Haime, 1853 : 235, pl. LI, fig. 3; W. J. Davis, 1887, pl. 77, fig. 1, 2, pl. 92, fig. 2, 3; L. M. Lambe, 1901 : 148; G. A. Stewart, 1927 : 19, pl. I, fig. 3; G. A. Stewart, 1938 : 37, pl. 6, fig. 7, 8; E. C. Stumm, 1942, pl. 82, fig. 11; E. C. Stumm, 1964 : 36, pl. 32, fig. 5, 6, 20-23; W. A. Oliver, 1971 : 196, pl. 3, fig. 1, 7, 9; J. E. Sorauf et W. A. Oliver, 1976 : 335, fig. 2.
non *Heliophyllum halli*; J. Hall, 1883 : 259, pl. 6, fig. 1; H. F. Cleland, 1911 : 28, pl. I, fig. 5; E. B. Branson, 1924 : 49, fig. 2, pl. 1, fig. 1; J. W. Wells, 1943 : 95, pl. 10, fig. 1, 2.
non *Heliophyllum halli*; J. Cottreau, 1940 : 192, pl. VII, fig. 6, 6a; v D. Le Maître, 1947 : 31, pl. I, II, III, fig. 1; G. Termier et H. Termier, 1950 : 100, pl. XLVIII, fig. 1-4, pl. XLIX, fig. 1-8; R. Mirouse, 1966 : 390, pl. XIII, fig. 1; G. Altevogt, 1967 : 764, pl. II, fig. 5; v D. Brice, 1970 : 263, pl. XVIII, fig. 6; P. Ghods, 1982 : 72, pl. 6, fig. 1, 2.
non *Heliophyllum halli*; E. D. Soshkina, 1952 : 90, pl. XXVII, fig. 94; N. Ia. Spassky, 1959 : 35, fig. 13; N. Ia. Spassky, 1960 : 54, pl. X, fig. 5; M. M. Smelovskaia, 1963 : 201, pl. XLI, fig. 1, 2, pl. XLII, fig. 1-4; V. A. Ivania, 1965 : 97, pl. CII, fig. 443-444.

Holotype : Fig. 87, 3 et n° 48, fig. 3 *in* J. Hall (1843). Spécimen égaré depuis la fin du siècle dernier. York, Comté de Livingstone, État de New York aux USA. Probablement Formation de Ludlowville, Groupe d'Hamilton, partie moyenne du Givétien.

Néotype (MNHN IP S.11661) : Pl. 7, fig. 6, 6a, b *in* H. Milne-Edwards et J. Haime (1851) désigné dans le présent travail.

Locus typicus : Leicester (anciennement Moscow), Comté de Livingstone, État de New York, USA.

Stratum typicum: Probablement Formation de Moscow, Groupe d'Hamilton, partie moyenne du Givétien.

Matériel et gisements : 26 polypiers dans lesquels 59 lames minces ont été exécutées. Le nombre et la provenance des spécimens sont indiqués entre parenthèses pour chaque gisement. État de New York : Moscow aujourd'hui Leicester (5 : néotype, échantillon MNHN IP S.11662 de la collection H. Milne-Edwards et collection Piret); York (1, collection Le Marchand); Calcaire de Centerfield en contrebas de la tranchée du chemin de fer située 4 kilomètres à l'ouest de East Bethany (12, récolte de R. Conil, 1969). Ontario : Formation de Hungry Hollow le long de l'Ausable River à Hungry Hollow, près

1. v (vidimus) = le matériel figuré a été revu par l'auteur; e.p. (ex parte) = la référence s'applique en partie seulement à l'espèce considérée.

d'Arkona (5, récolte de A. N. MOURAVIEFF, 1975) et à la tuilerie de Thedford (3, récolte de P. BULTYNCK, 1975).

RÉPARTITION GÉOGRAPHIQUE ET STRATIGRAPHIQUE : Le matériel décrit dans ce travail provient des Formations de Ludlowville et de Moscow dans l'État de New York ainsi que de la Formation de Hungry Hollow dans l'Ontario. Toutefois, W. A. OLIVER et J. E. SORAUF (1983 : 44) signalent que dans l'État de New York, *H. halli halli* apparaît dans le Membre d'Edgecliff, à la base du Calcaire d'Onondaga pour subsister dans tout le Groupe d'Hamilton jusque dans le Calcaire de Tully.

En dehors de l'État de New York et de l'Ontario, *H. halli halli* a été reconnu avec certitude dans la Dolomie de Tenmile Creek de l'Ohio du Nord-Ouest par E. C. STUMM (1968) et dans le Dévonien moyen du Venezuela par C. T. SCRUTTON (1973). D'après D. R. SPARLING (1985 : 1214), la Dolomie de Tenmile Creek date du début de la zone à *Polygnathus varcus* inférieure et est donc contemporaine du Calcaire de Centerfield et de la Formation de Hungry Hollow. Les autres occurrences nord-américaines et en particulier celles des Chutes de l'Ohio devraient être vérifiées par des lames minces, car elles sont basées sur l'aspect externe des polypiers.

DIAGNOSE : *Heliophyllum* possédant habituellement 70 à 78 septes des deux ordres, pour un diamètre variant de 2,7 à 4,3 cm. Septes majeurs et mineurs, longs, quoique de longueur variable, ébauchant parfois une structure axiale. Important dépôt de stéréoplasme au centre du polypier durant les premiers stades de l'ontogenèse.

DESCRIPTION

NÉOTYPE (pl. I, 1, 2)

Il s'agit d'un demi-polypier conique d'une hauteur de 3,5 cm, montrant quelques anneaux de croissance; son calice, profond de 0,7 cm et rempli de sédiment, est entouré d'une étroite plate-forme horizontale.

Section transversale : La paroi est mince et n'est conservée que localement. Les septes uniformément minces sur toute leur longueur sont parfois discontinus près de la paroi, du fait qu'ils y sont tronçonnés ou qu'ils sont totalement interrompus entre deux carènes voisines. Dans l'ensemble, ils portent de nettes carènes opposées dans le dissépimentarium, passant toutefois à l'un ou l'autre petit épaississement allongé à la bordure interne du dissépimentarium ou à l'entrée du tabularium. Ces carènes opposées ont souvent l'aspect de longues barres perpendiculaires aux septes, mais peuvent aussi être arquées vers l'intérieur ou l'extérieur du polypier. On observe en outre quelques petites carènes en zigzag, voire quelques carènes opposées à trois ou quatre branches.

Les septes majeurs laissent un espace vide au centre du tabularium ou atteignent l'axe du polypier. Deux d'entre eux s'y unissent en se recourbant et délimitent de la sorte une pseudo-fossule englobant quatre septes majeurs. Quant aux septes mineurs, ils couvrent tout, presque tout ou la moitié du dissépimentarium; occasionnellement, ils sont tronçonnés dans sa partie interne.

Section longitudinale : Le dissépimentarium comporte jusqu'à treize rangées de petits dissépiments globuleux, disposés en couches horizontales dans sa partie externe et incliné

LE NOM DU GENRE *ROTHPLETZELLA* WOOD 1948 (ALGUE CALCAIRE PALEOZOIQUE) EST LEGITIME ET CORRECT

E.DRICOT ET H.H.TSIEN

Dricot, E. et Tsien, H.H., 1977. Le nom du genre *Rothpletzella* Wood 1948 (algue calcaire paléozoïque) est légitime et correct. *Mém. Inst. géol. Univ. Louvain, t.29, 231-240.*

The type species of *Sphaerocodium* Rothpletz 1890 is, by monotype, *Sphaerocodium bornemanni* Rothpletz 1890, the type material of which came from the Triassic of the Alps. Wood (1948) restudied the Silurian type material of *Sphaerocodium gotlandicum* Rothpletz 1908 and *Sphaerocodium munthei* Rothpletz 1913 and found that it contained a mixture of *Girvanella, Wetheredella* and a new genus which he did not find in the type material of *Sphaerocodium bornemanni*. He therefore proposed the name *Rothpletzella* for the new genus and designated *Rothpletzella gotlandica* (Rothpletz 1908) Wood 1948 as the type species. In 1967, Wray proposed a new type species, *Sphaerocodium gotlandicum* Rothpletz 1908, for the genus *Sphaerocodium*. Since 1967, several authors (e.g. Wray, Wray and Playford, Riding, Pontet, Mamet and Roux, Termier H., Termier G. and Vachard continue to use the name *Sphaerocodium* in the sense which Wood proposed for *Rothpletzella*. However, according to the International Code of Botanical Nomenclature, the choice of another type species is illegitimate. Thus, the designation, by Wray, of *Sphaerocodium gotlandicum* Rothpletz 1908 as type species of the genus *Sphaerocodium* results in the creation of a new genus : *Sphaerocodium* Wray 1967 which is a junior synonym of *Rothpletzella* Wood 1948. Fifteen taxa have been described or attached to the genera *Sphaerocoium, Rothpletzella* and *Coactilium*. However, only five species and one variety may be attributed to the genus *Rothpletzella*. They are : *R.gotlandica* (Rothpletz 1908) Wood 1948 ; *R. munthei* (Rothpletz 1913) Wood 1948 ; *R.straelinii* (Lecompte 1936) comb.nov.; *R.straelinii* (Lecompte 1936) var. *devonica* (Maslov 1956) comb.nov. ; *R.exilis* (Wray 1967) comb.nov. ; *R.magna* (Wray 1967) comb.nov.

Eli Dricot et Hsien Ho Tsien, Université catholique de Louvain, Laboratoire de Paléontologie, Institut de Géologie et de Géographie, Place L. Pasteur, 3, B-1348 Louvain-la-Neuve. (Belgique)

Pl. 1, figs. 3-4, 9-10, 13-14; Text-fig. 2, figs. 2-4

1967 *Ancyrodella rotundiloba* BRYANT.--CLARK & ETHINGTON, pl. 2, fig.7 [only].
?1967 *Ancyrodella rotundiloba* subsp. A.--UYENO, pl. 1, fig. 3 [only].
*1970 *Ancyrodella pristina* sp. nov.--KHALYMBADZHA & CHERNYSHEVA, p. 89-90; pl. 1, figs. 3-8.
?1970 *Ancyrodella prima* sp. nov.--KHALYMBADZHA & CHERNYSHEVA, p. 88-89; pl. 1, figs. 1-2.
1970b *Ancyrodella rotundiloba* (BRYANT).--SEDDON, pl. 16, fig. 1.
?1974 *Ancyrodella rotundiloba* subsp. A.--UYENO, pl. 2, fig. 6 [same specimen as UYENO, 1967].
1974 *Ancyrodella rotundiloba binodosa* UYENO.--UYENO, pl. 1, fig. 2.
1981 *Ancyrodella binodosa* UYENO α morphotype.--BULTYNCK & JACOBS, pl. 8, figs. 1-10.
1981 *Ancyrodella binodosa* UYENO β morphotype.--BULTYNCK & JACOBS, pl. 8, figs. 13-14.
1981 *Ancyrodella binodosa* UYENO γ morphotype.--BULTYNCK & JACOBS, pl. 9, figs. 1-2, 6.
1981 *Ancyrodella binodosa* UYENO δ morphotype.--BULTYNCK & JACOBS, pl. 9, fig. 3 [only].
1982 *Ancyrodella binodosa* UYENO.--KHALYMBADZHA, pl. 1, fig. 3. [This is obviously a reillustration of the holotype of *A. pristina*].
1982 *Ancyrodella binodosa* UYENO α morphotype.--BULTYNCK, pl. 1, figs. 19-21.
1982 *Ancyrodella binodosa* UYENO β & γ morphotypes.--BULTYNCK, pl. 1, figs. 22-24.
1982 *Ancyrodella binodosa* UYENO.--MOURAVIEFF, pl. 1, figs. 4-5 [only].
1985 *Ancyrodella rotundiloba* (BRYANT), early form.--KLAPPER, pl. 1, figs. 1-14 [only]; pl. 2, figs. 5-8 [only].
1985 *Ancyrodella rotundiloba* (BRYANT), late form.--KLAPPER, pl. 2, figs. 1-2 [only].
1985 *Ancyrodella rotundiloba* (BRYANT), late form [corrected manually by author to early form].--KLAPPER, pl. 3, figs. 7-8, fig. 9[?].
1985 *Ancyrodella alata* GLENISTER & KLAPPER, early form.--KLAPPER, pl. 5, figs. 5-6.
1986 *Ancyrodella isabellae* n. sp.--GARCIA-LOPEZ, p. 448-449, pl. 1, figs. 15-16 [holotype], figs. 13-14 [=?, broken specimen].
1987 *Ancyrodella isabellae* GARCIA-LOPEZ.--GARCIA-LOPEZ, p. 61-62, pl. 1, figs. 11-12 [reillustration of holotype].

HOLOTYPE: The specimen illustrated by KHALYMBADZHA & CHERNYSHEVA (1970, pl. 1, figs. 5-7).
ORIGINAL DIAGNOSIS (translated from Russian): Platform rounded-triangular; carina that consists of separate large denticles projects beyond edge of platform. There is a single large high node on each lobe. These nodes correspond to the secondary carinas. The ornamentation is in the form of small nodes along the edge of the platform. The keel is sharply expressed. Lateral keels are rather short and do not reach the edge of the platform. The basal cavity is not large and extends for one-third the length of the keels in the form of a small trench.

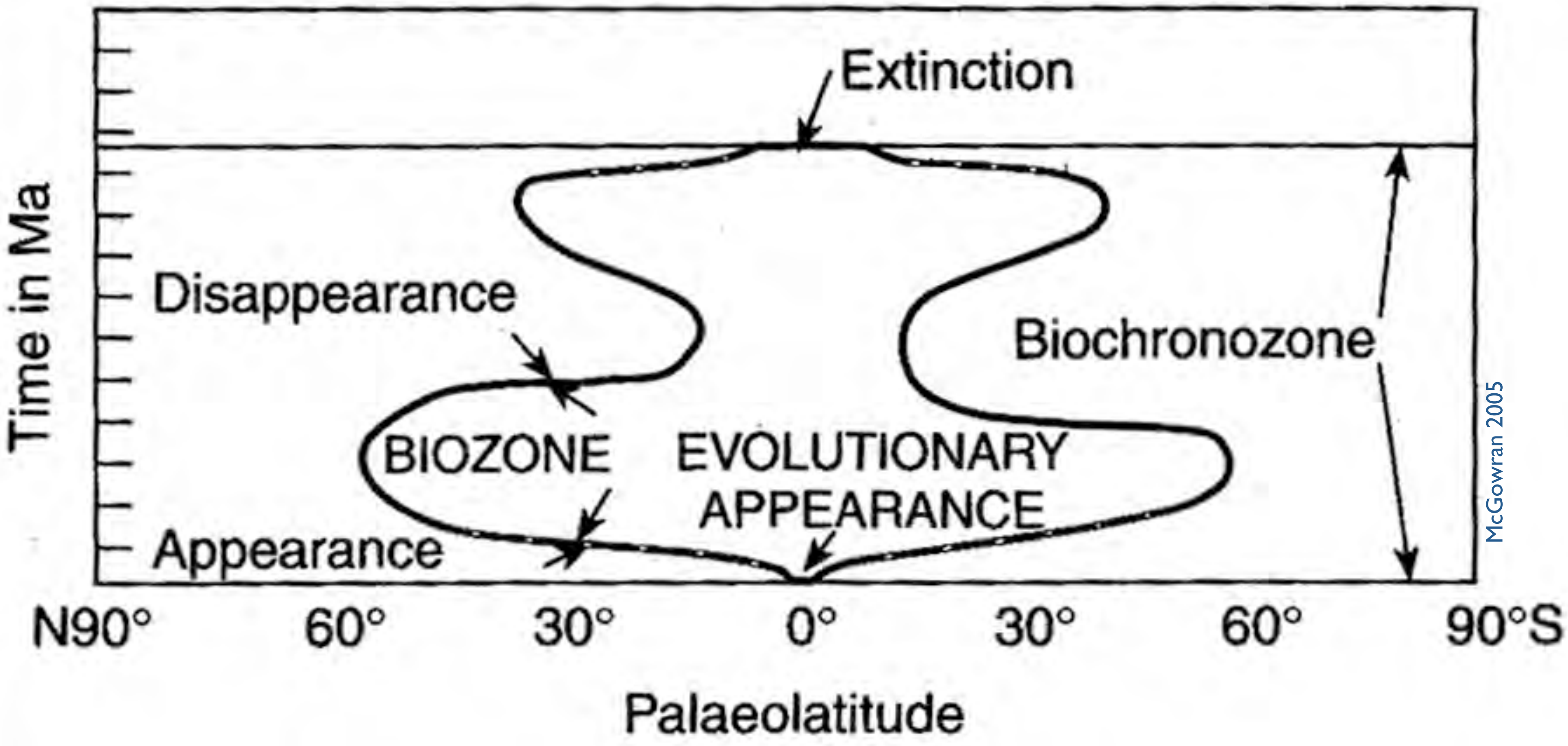
Definition of zones

Three new zones are named and defined herein (Text-fig. 1): the *falsiovalis* Zone, which spans the Middle-Upper Devonian boundary and replaces the former Lowermost *asymmetricus* Zone; the *transitans* Zone, which replaces the former Lower *asymmetricus* Zone, but which may have a shorter duration; and the *punctata* Zone, which is identical to the former Middle *asymmetricus* Zone. In both the original and revised schemes, zones are considered to represent time not rock, and to emphasize this, **Early** and **Late**, rather than Lower and Upper, are used for parts of the *falsiovalis* Zone. Some confusion still exists because of German to English translation. When (ZIEGLER, 1962a) proposed the original zonation, **Unter** was used in German for both Lower and Early and **Ober** was used for both Upper and Late. English-speaking authors have translated these terms as Lower and Upper despite the original intent. Modern German usage, however, now avoids time-rock confusion and employs **Früh** for Early and **Spāt** for Late. Although we believe that zones are better defined conceptually from taxonomic changes within a phyletic lineage, we nevertheless provide reference sections in which the zonal boundaries can be recognized in the rock record and suggest alternative, regional representative sections.

falsiovalis Zone

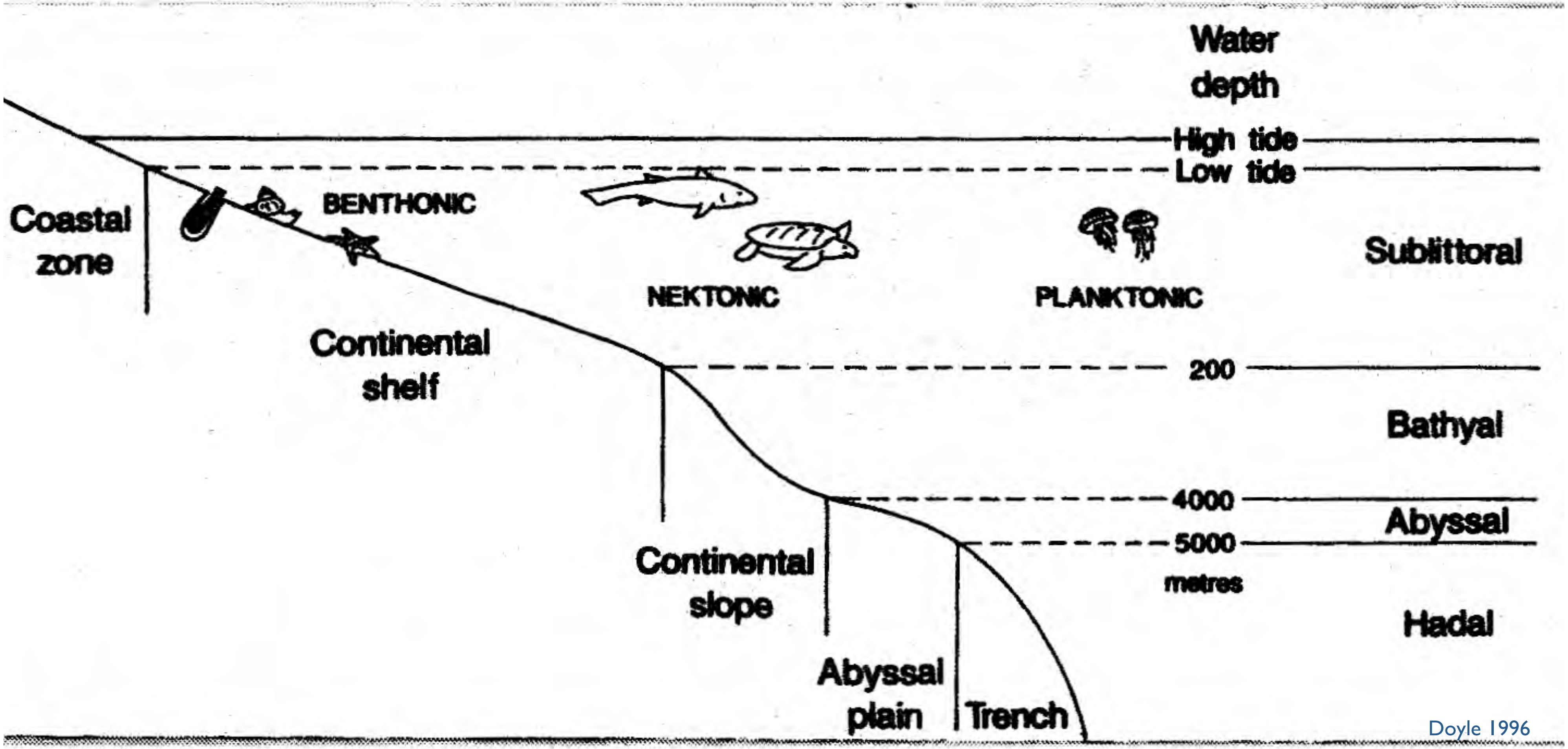
LOWER LIMIT: Defined by the first occurrence of *Mesotaxis falsiovalis* n. sp.
UPPER LIMIT: Defined by the first occurrence of *Palmatolepis transitans* MÜLLER.
SYNONYMY: Beginning at same time as former Lowermost *asymmetricus* Zone (ZIEGLER, 1971a), but slightly longer in duration.
SUBDIVISIONS: Two parts of this zone are recognized. An early part is characterized by the occurrence of *M. falsiovalis* before the appearance of *M. asymmetrica*, and a late part is characterized by the joint occurrence of both species. Late in the early part of the *falsiovalis* Zone (Text-fig. 4, samples I /8–I /10), transitional specimens of *M. falsiovalis*, with a slight asymmetry but without the wide outer platform half that characterizes *M. asymmetrica*, link the two species
REFERENCE SECTION: Blauer Bruch (Text-fig. 4), near Bad Wildungen, West Germany.
REGIONAL REPRESENTATIVE SECTIONS: Central Nevada (JOHNSON et al., 1980); Cornwall, southwest England (KIRCHGASSER, 1970); Montagne Noire, southern France (FEIST & KLAPPER, 1985).
CONODONT AIDS TO IDENTIFICATION: *Ancyrodella pristina*, *A. soluta*, and *A. rotundiloba* first occur in succession during this zone; *A. binodosa*, however, first occurs with or later than *A. pristina*. *Skeletognathus norrisi* first occurs at the start of and ranges mainly within the *falsiovalis* Zone, but its range includes part of the next younger, *transitans* Zone. A wide, smooth, unlobed form of *Ancyrognathus* that may be distinguishable from the narrower, younger *A. ancyrognathoideus* first occurs late in the early part of this zone (Text-fig. 4, sample H48 /5a). *Polygnathus ordinatus* ranges only into the early part of the *falsiovalis* Zone. Faunas consisting predominantly of *Pandorinellina insita* with a high fin (SANDBERG & ZIEGLER, 1979) composed of a single denticle occur mainly during this zone in the nearshore pandorinellinid biofacies.
OTHER IMPORTANT ASSOCIATED CONODONTS: *Klapperina ovalis*, *Mesotaxis? dengleri*, *"Polygnathus" cristatus*, and *Ozarkodina sannemanni* s.s. (with 1 to 3 nodes on the cups), as well as a morphotype without nodes, range throughout this zone.

TOWARDS THE CHRONOZONE…

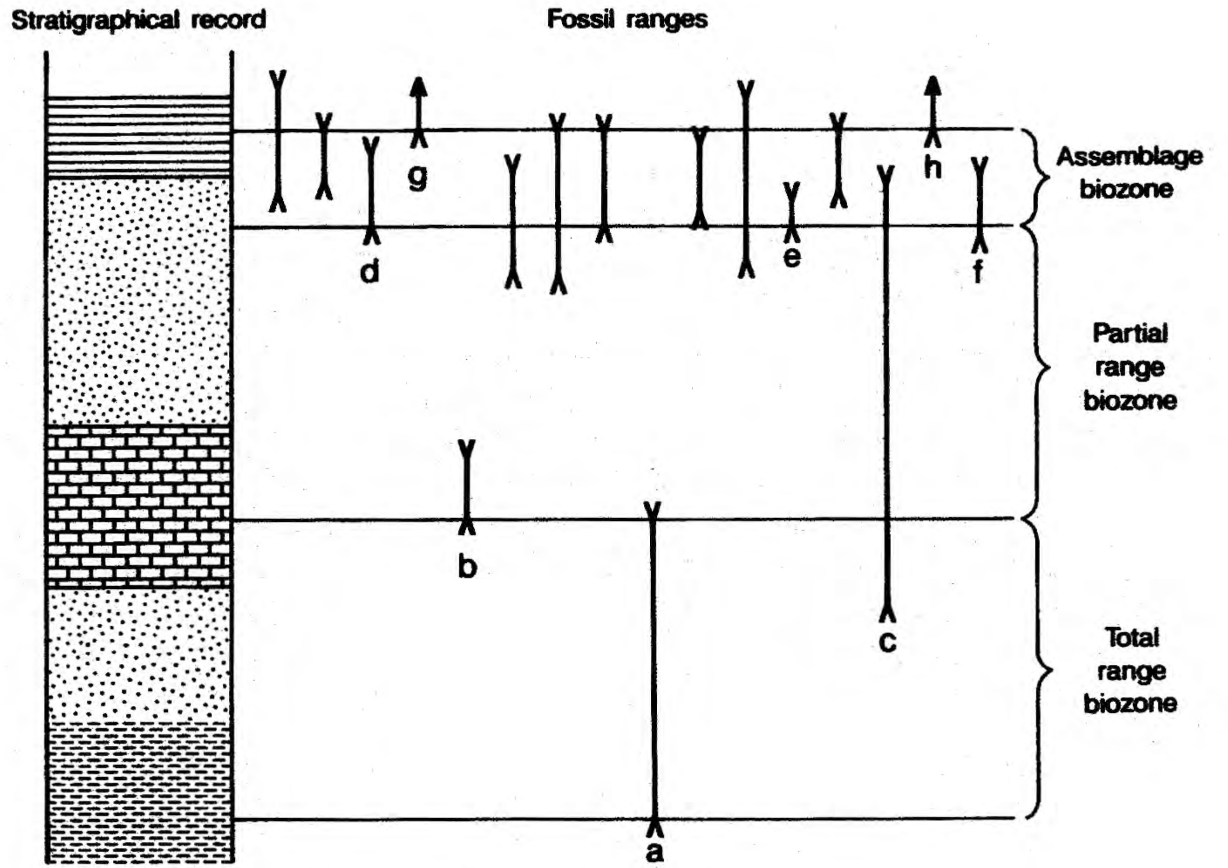


Biochronozone : the total time represented by a biozone ('lifetime', Hedberg 1976)
= span of time between the age of the' OKR' and 'YKR' of taxon
OKR = oldest known record < FAD, YKR youngest known record > LAD)

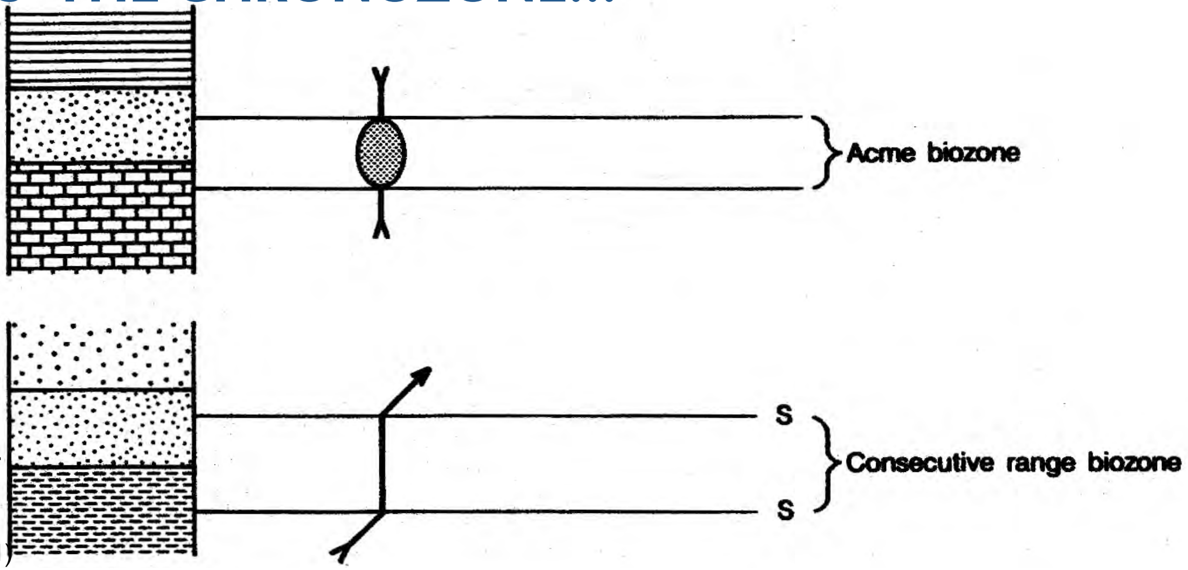
REMEMBER : FACIES FOSSILS vs STRATIGRAPHIC FOSSILS



Doyle 1996



TOWARDS THE CHRONOZONE…



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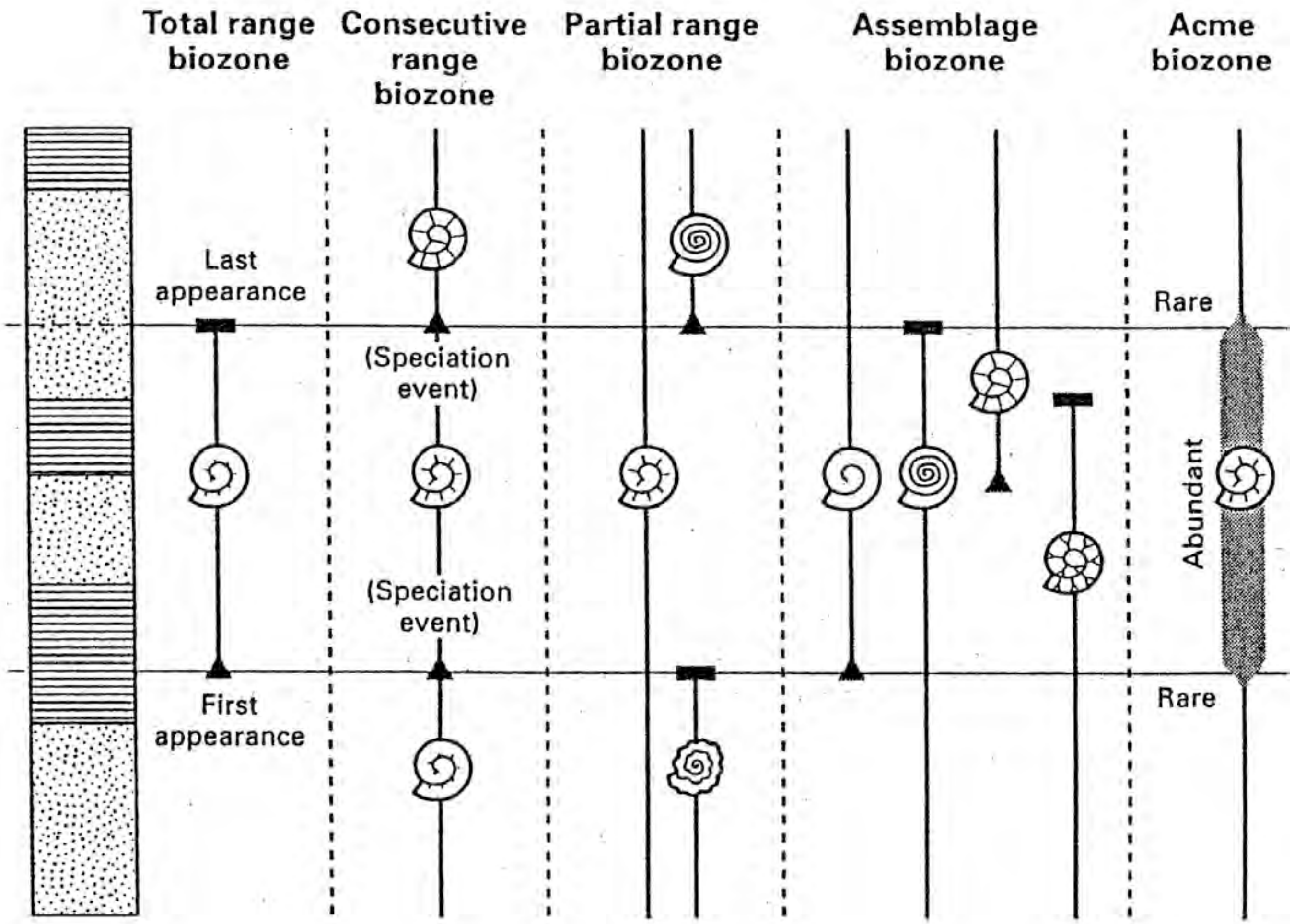
BIOSTRATIGRAPHIC UNITS

Five kinds of biozones are in common use : **assemblage** zones, **range** zones, **interval** zones, **abundance** zones and **lineage** zones. These types of biozones have no hierarchical significance, and are not based on mutually exclusive criteria. A single stratigraphic interval may, therefore, be divided independently into range zones, interval zones, etc., depending on the biostratigraphic features chosen.



Assemblage Zone = Association Zone = Cenozone

• The body of strata characterized by an assemblage **of three or more fossil taxa** that,
taken together, distinguishes it in biostratigraphic character from adjacent strata. • The boundaries of an assemblage zone are drawn at biohorizons marking
the limits of occurrence of the specified assemblage that is characteristic of the unit.

• Not all members of the assemblage need to occur in order for a section to be assigned to an assemblage zone, and the total range of any of its constituents may extend beyond the boundaries of the zone.

• The name of an assemblage zone is derived from the name of one of the prominent an diagnostic constituents of the fossil assemblage.

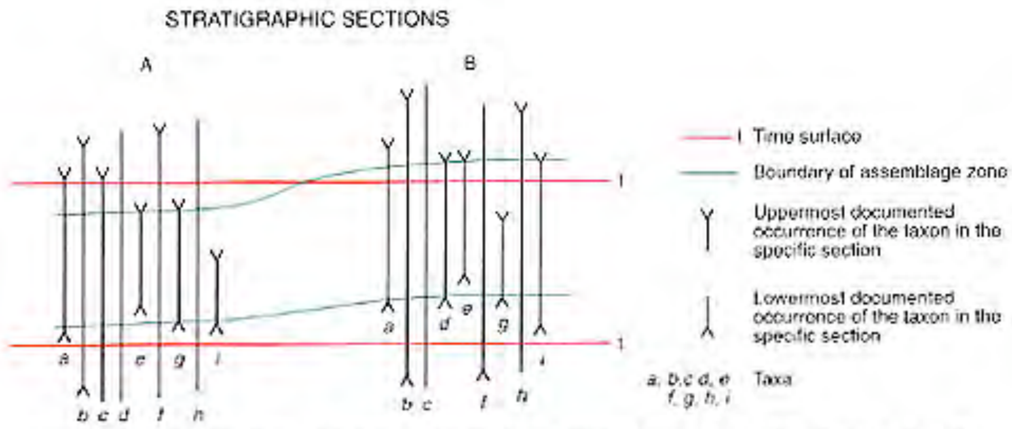


Figure 6: Assemblage Zone. In this example, the assemblage diagnostic of the zone includes nine taxa with diverse stratigraphic ranges. For this assemblage zone to be useful, it may be necessary to provide some explicit description of its boundaries: for example, the lower boundary can be said to be placed at the lowermost occurrence of taxa *a* and *g* and the upper boundary at the highest occurrence of taxon *e*. Most of the taxa of the assemblage characteristic of the zone should, however, be present.

RANGE ZONE (if local = teilzone or topozone or local range zone)
The body of strata representing the known stratigraphic and geographic range of occurrence of a particular taxon or combination of two taxa of any rank. Two principal types o : **taxon-range** zones and **concurrent-range** zones.

a1. **Taxon-range Zone**

- The body of strata representing the known range of stratigraphic and geographic occurrence of specimens of a particular taxon. It is the sum of the documented occurrences in all individual sections and localities from which the particular taxon has been identified.
- The boundaries of a taxon-range zone are biohorizons marking the outermost limits of known occurrence in every local section of specimens whose range is to be represented by the zone. The boundaries of a taxon-range zone in any one section are the horizons of lowest stratigraphic occurrence and highest stratigraphic occurrence of the specified taxon in that section.
- The taxon-range zone is named from the taxon whose range it expresses.

a2**. Local Range of a Taxon**. The local range of a taxon may be specified in some local sectio area, or region as long as the context is clear.

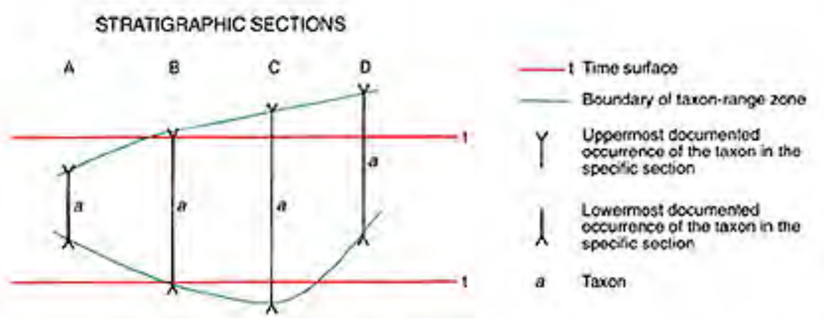


Figure 1: Taxon-range Zone. The lower, upper, and lateral limits of this zone are determined by the range of occurrence of taxon *a*.

(RANGE ZONE)

b. Concurrent-range Zone (= overlap zone, or concomitant zone)

- The body of strata including the overlapping parts of the range zones of two specified taxa. This type of zone may include taxa additional to those specified as characterizing elements of the zone, but only the two specified taxa are used to define the boundaries of the zone..
- The boundaries of a concurrent-range zone are defined in any particular stratigraphic section by the lowest stratigraphic occurrence of the higher-ranging of the two defining taxa and the highest stratigraphic occurrence of the lower-ranging of the two defining taxa
- A concurrent-range zone is named from both the taxa that define and c

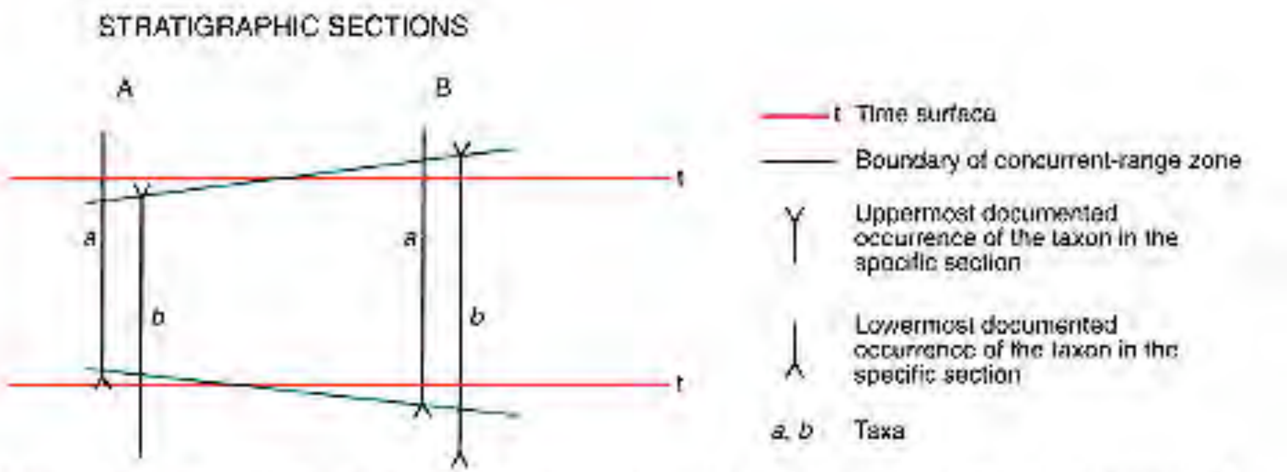


Figure 2: Concurrent-range Zone. The lower, upper, and lateral limits of this zone are determined by the range of concurrent occurrence of taxa *a* and *b*.

INTERVAL ZONE • The body of fossiliferous strata between two specified biohorizons. **is not itself necessarily** the range zone of a taxon or concurrence of taxa, it is defined and identified only on the basis of its bounding biohorizons

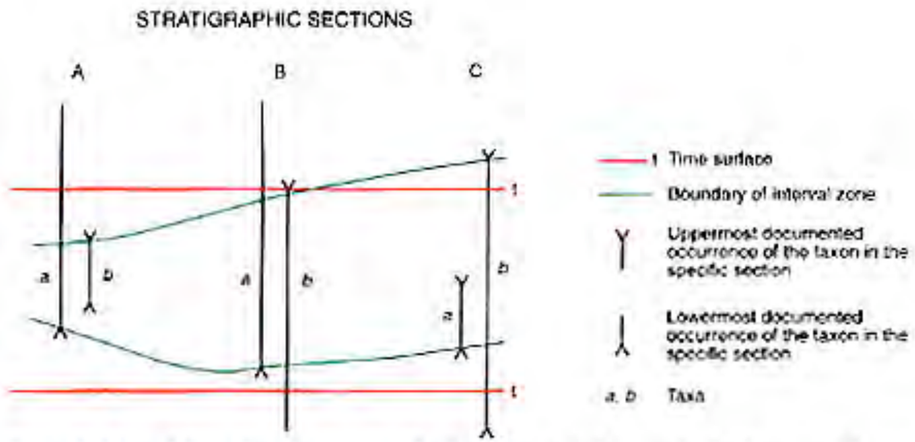


Figure 3: Interval Zone. In this example, the lower limit of the zone is the lowermost known occurrence of taxon *a*, and the upper limit is the highest known occurrence of taxon *b*. The zone extends laterally as far as both of the defining biohorizons can be recognized.

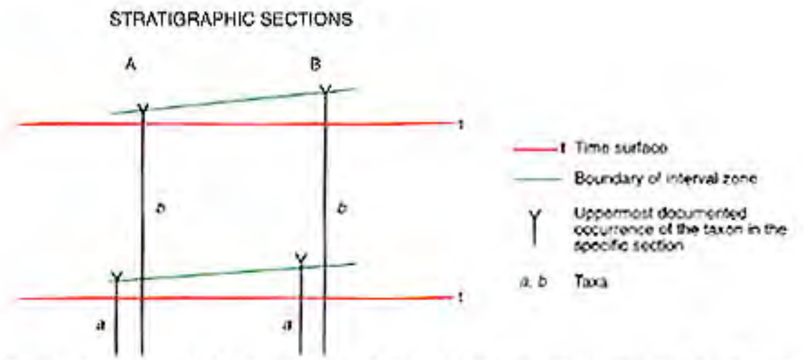


Figure 4: Interval Zone (Highest-occurrence Zone). This kind of interval zone is particularly useful in subsurface work.

- In subsurface stratigraphic work, where the section is penetrated from top to bottom and paleontological identification is generally made from drill cuttings, often contaminated by recirculation of previously drilled sediments and material sloughed from the walls of the drill hole, interval zones defined as the stratigraphic section comprised between the highest known occurrence (first occurrence downward) of two specified taxa are particularly useful .

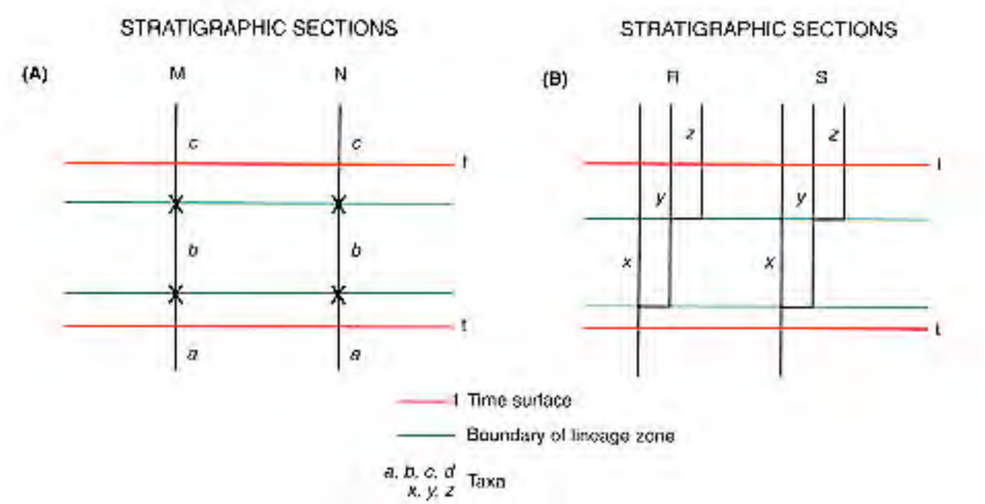
This type of interval zone has been called "last-occurrence zone" but should preferably be called "highest-occurrence zone".

• Interval zones defined as the stratigraphic section comprised between the lowest occurrence of two specified taxa ("lowest-occurrence zone") are also useful, preferably in surface work. • The boundaries of an interval zone are defined by the occurrence of the biohorizons selected for its definition. • The names given to interval zones may be derived from names of the boundary horizons, the name of the basal boundary preceding that of the upper boundary; e.g. *Globigerinoides sicanus-Orbulina suturalis* Interval Zone. • In the definition of an interval zone, desirable to specify the criteria for the selection of the bounding biohorizons, e.g. lowest occurrence, highest occurrence etc. • An alternative method of naming uses a single taxon name for the name of the zone.

The taxon should be a usual component of the zone, although not necessarily confined to it.

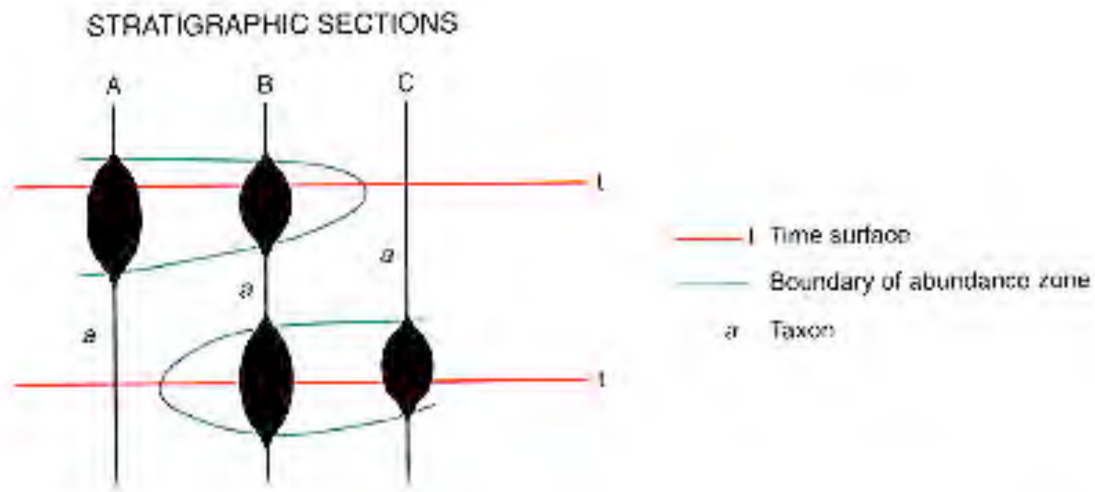
LINEAGE ZONES

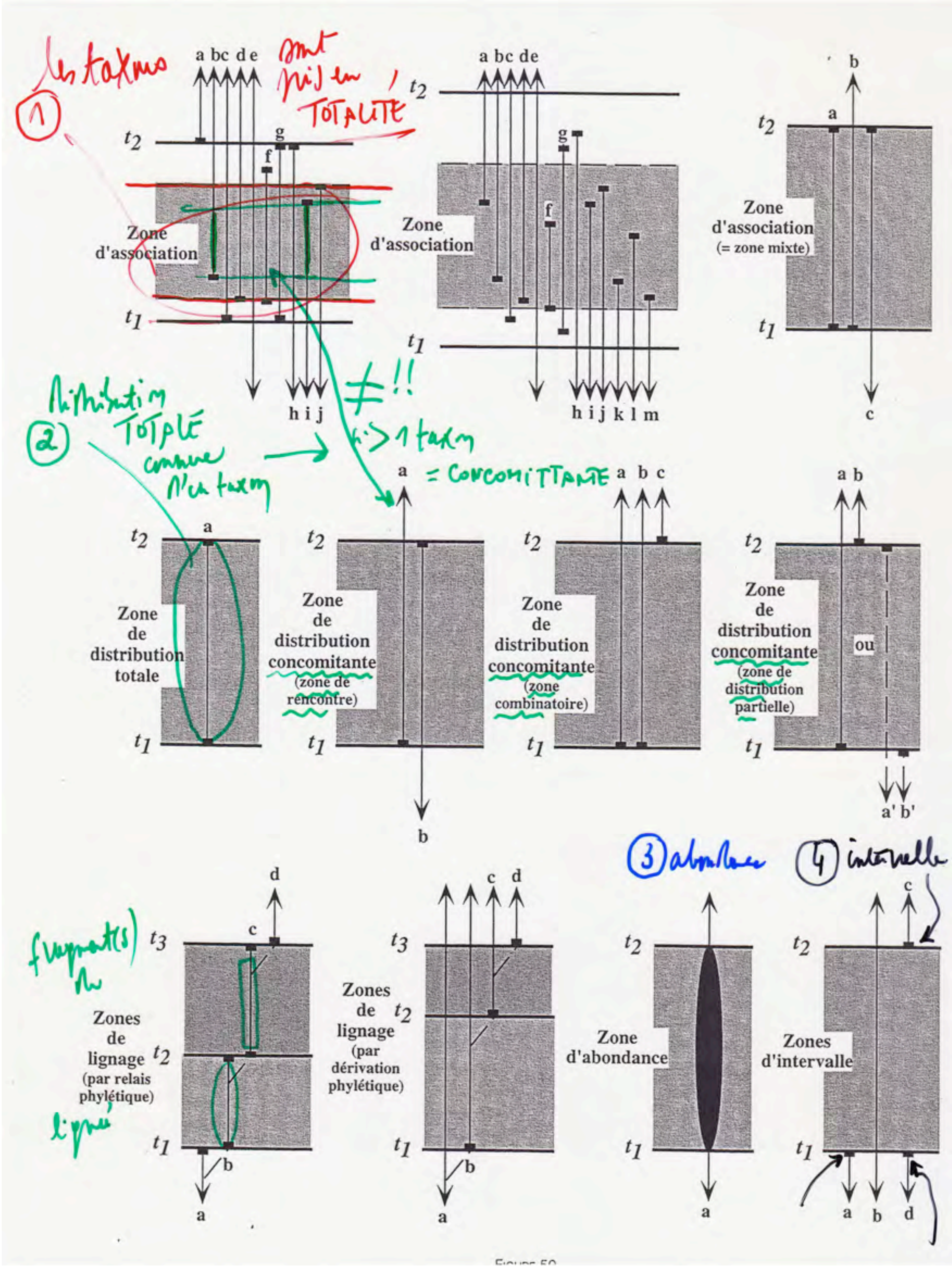
Lineage zones are discussed as a separate category because they require for their definition and recognition not only the identification of specific taxa but the assurance that the taxa chosen for their definition represent successive segments of an evolutionary lineage. • The body of strata specimens representing a specific segment of an evolutionary lineage. It may represent the entire range of a taxon within a lineage (Figure 5A) or only that part of the range of the taxon below the appearance of a descendant taxon (Figure 5B). • The bo lineage zones approach the boundaries of chronostratigraphic units. However, a lineage zone diffe chronostratigraphic unit in being restricted, as all biostratigraphic units are, to the actual spatial distribution of the fossils. **Lineage zones ar reliable means of correlation of relative time by use of the biostratigraphic method**. • The boundaries of a lineage zone are determined by the bic representing the lowest occurrence of successive elements of the evolutionary lineage under consideration. • A lineage z for the taxon in the lineage whose range or partial range it represents.



ABONDANCE ZONE

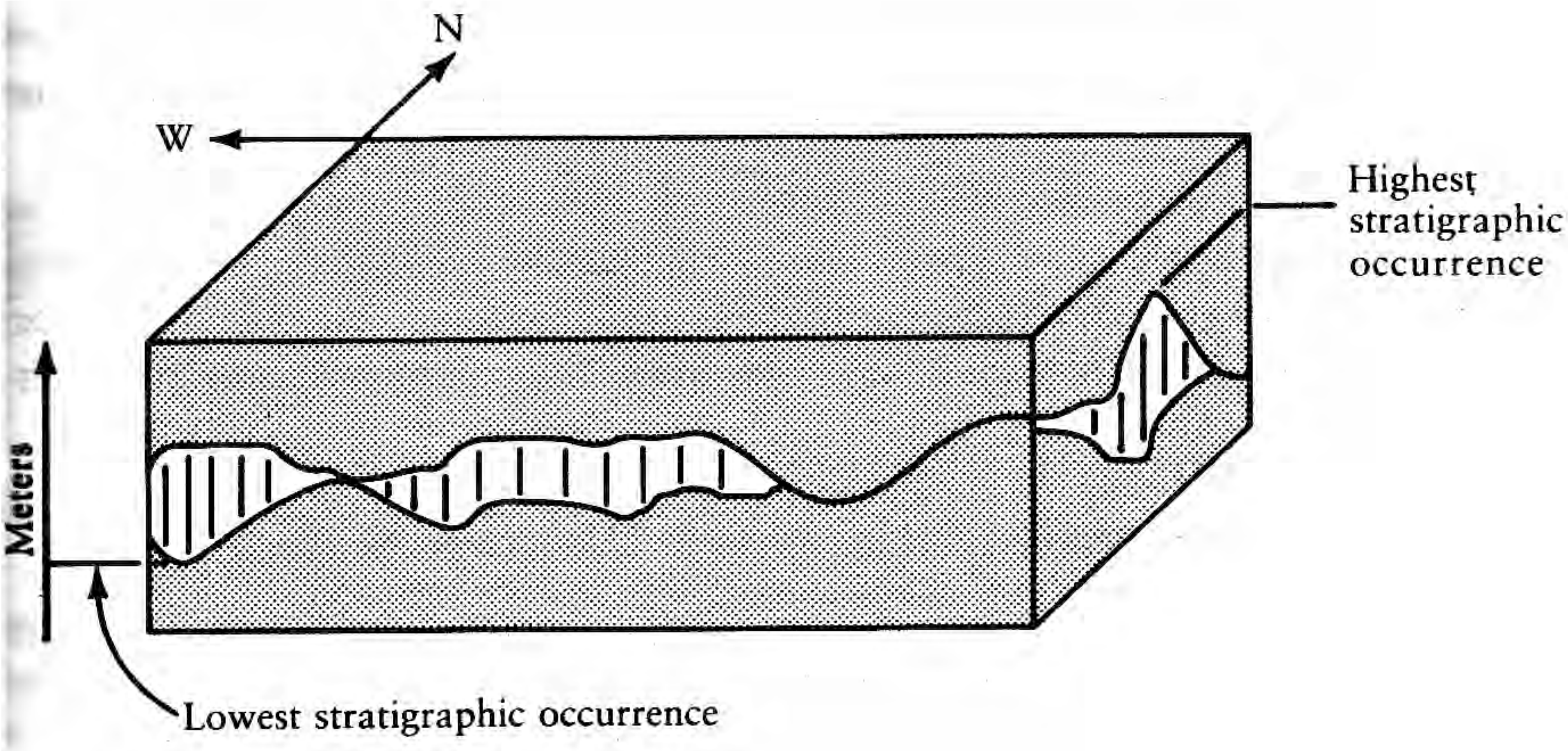
• The body of strata in which the abundance of a particular taxon or specified group of taxa is significantly greater than is usual in the adjacent parts of the section. Unusual abundance of a taxon or taxa in the stratigraphic record may result from a number of processes that are of local extent, but may be repeated in different places at different times.For this reason, the only sure way to identify an abundance zone is to trace it laterally. •The boundaries of an abundance zone are defined by the biohorizons across which there is notable change in the abundance of the specified taxon or taxa that characterize the zone. •The abundance zone takes its name from the taxon or taxa whose significantly greater abundance it represents.





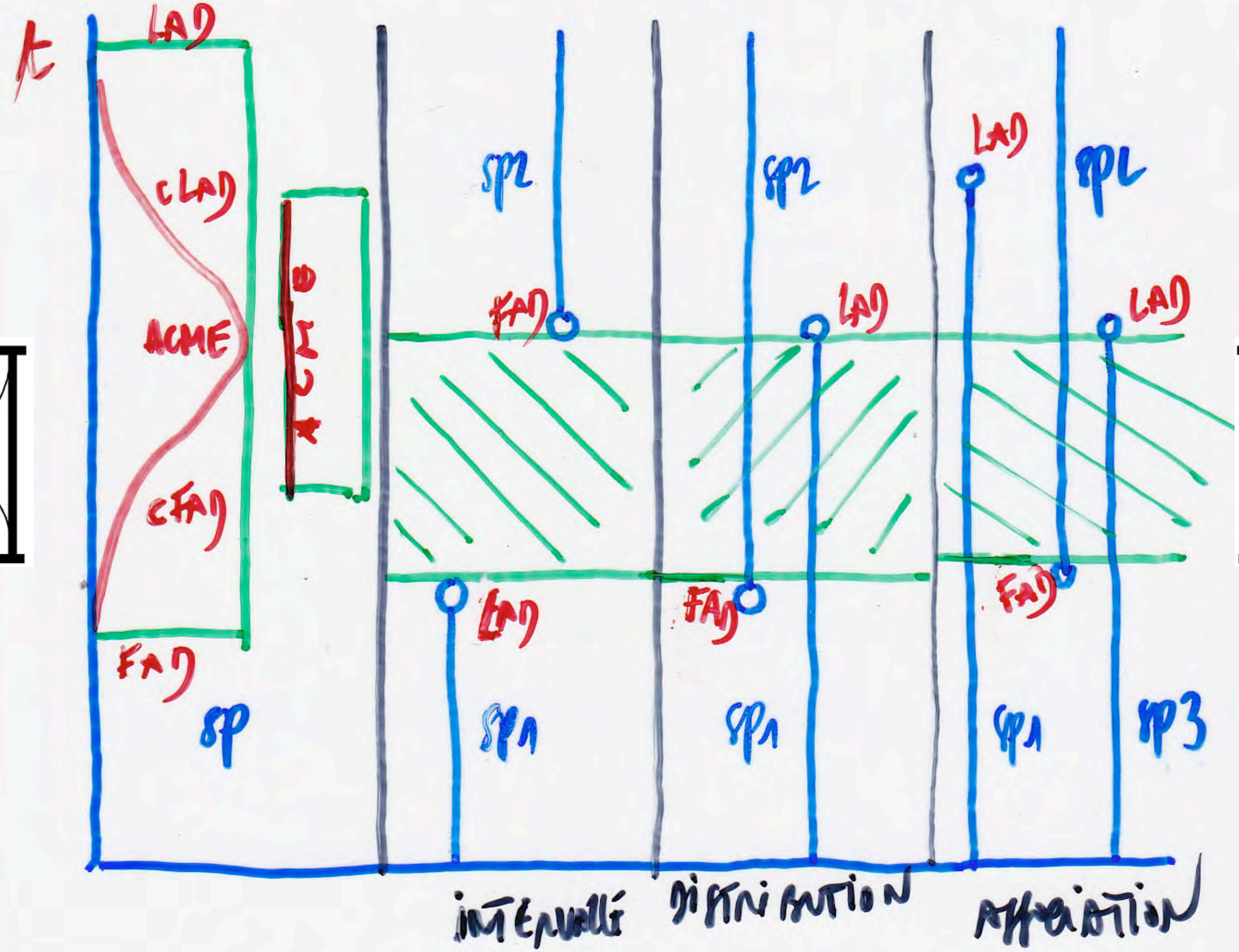
Zone d'association
Zone d'association
Zone d'association (= zone mixte)
Zone de distribution totale
Zone de distribution concomitante (zone de rencontre)
Zone de distribution concomitante (zone combinatoire)
Zone de distribution concomitante (zone de distribution partielle)
ou
Zones de lignage (par relais phylétique)
Zones de lignage (par dérivation phylétique)
Zone d'abondance
Zones d'intervalle

REMEMBER ‘the problem’….



Blatt et al 1991

Hypothetical biozone of a taxon indicated by geographic and vertical limits of fossil-bearing section. Lateral limits are established by the biogeographic range of the taxon. Vertical limits are controlled in part by the geologic persistence of the taxon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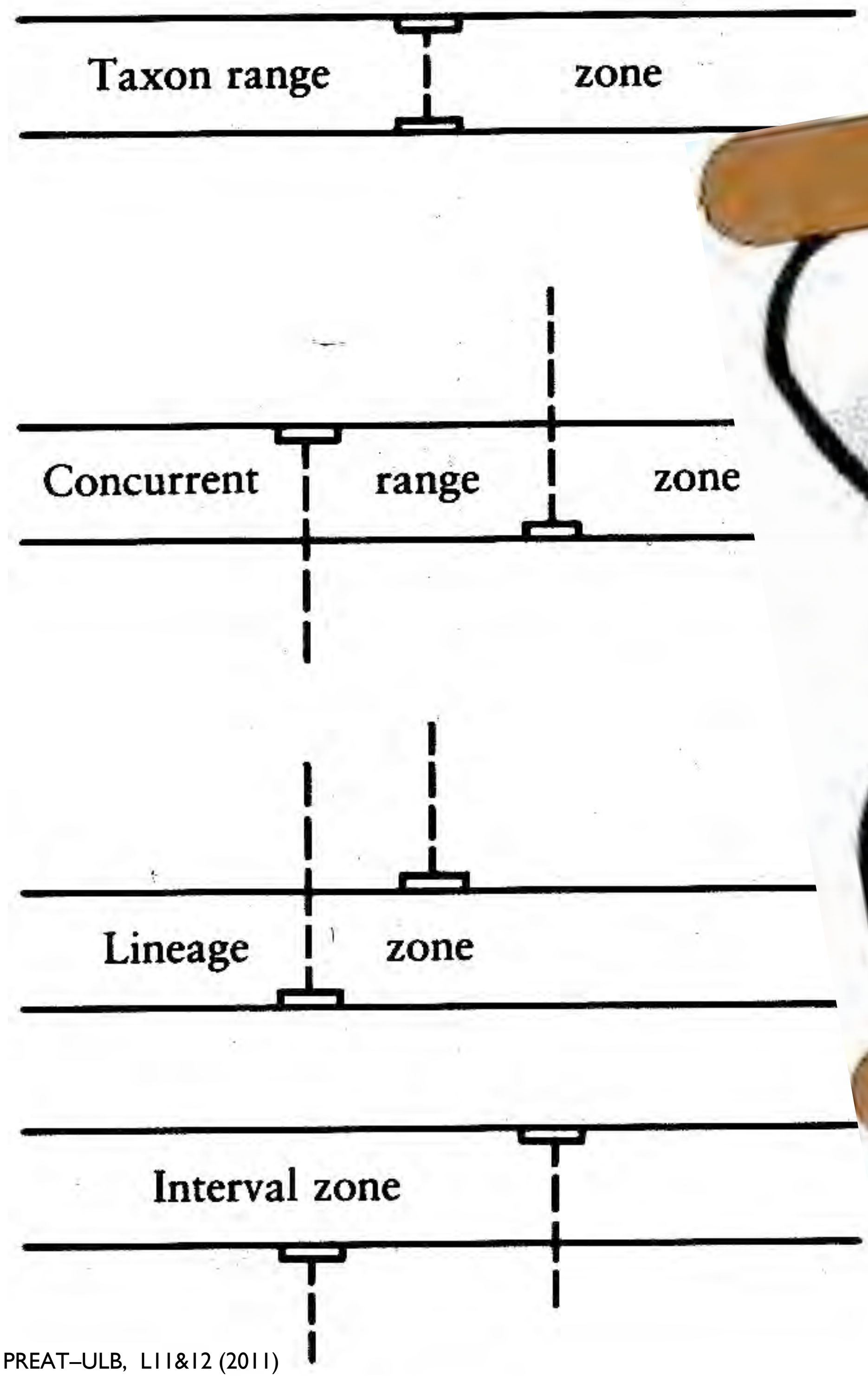
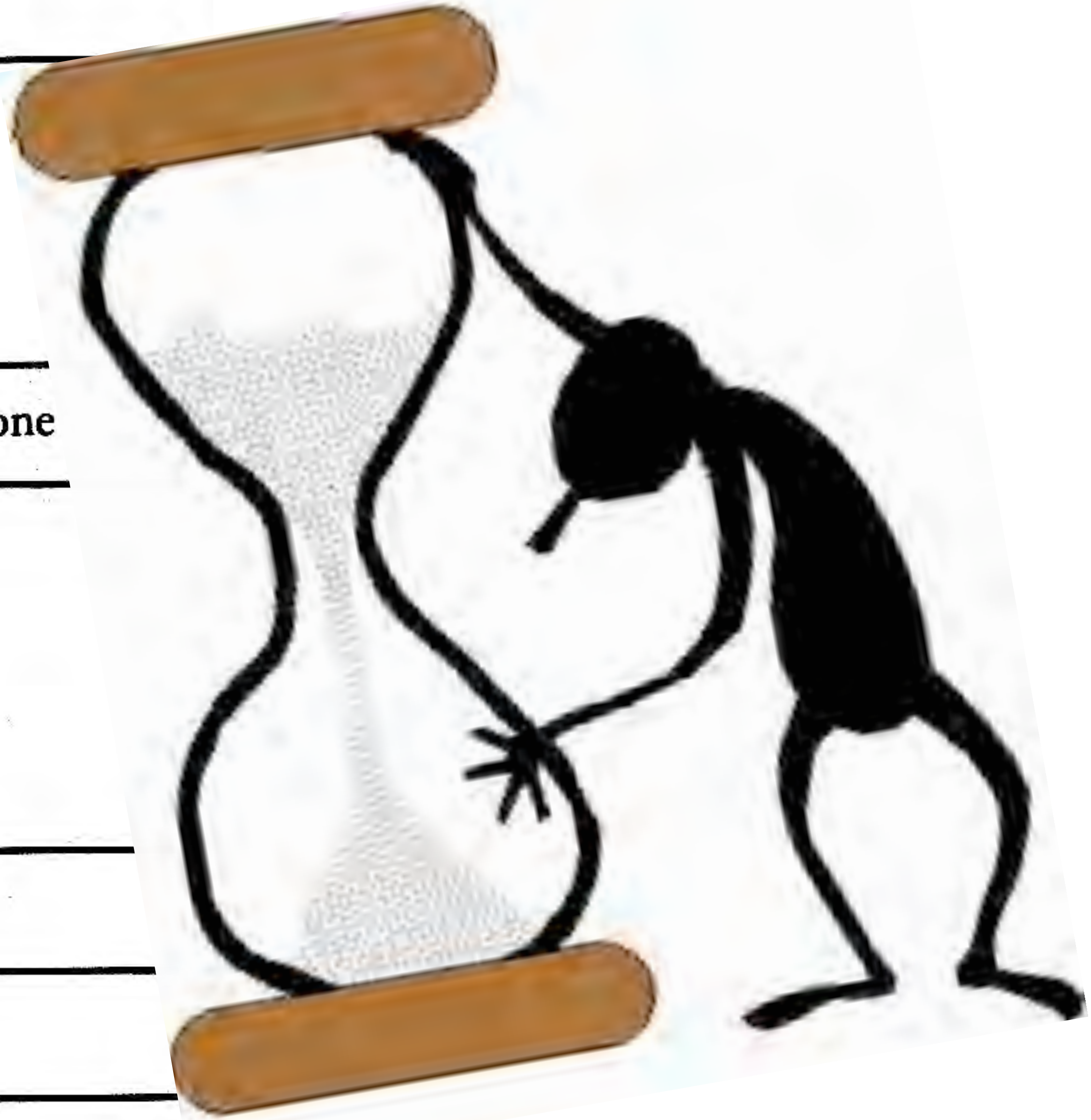
DISTRIBUTION
ASSOCIATION

BIOZONES



Blatt et al 1991



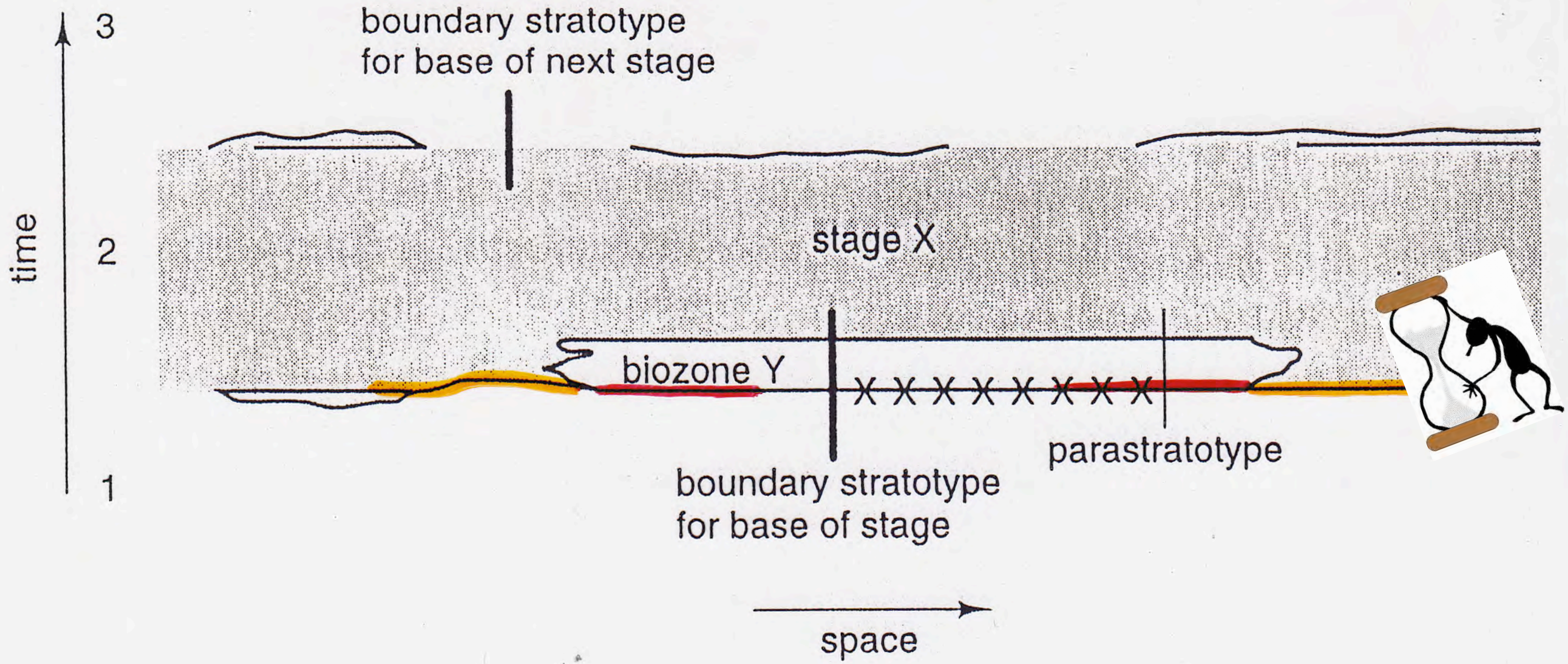


Fig 2.2 Key concepts in the definition of stratotypes and parastratotypes applicable to all stratigraphical units. The base of Stage X is defined at a suitable type section, coincident with the base of Biozone Y, which can be used to correlate the base of the stage. The type section is usually conserved and collecting across the interval is restricted to an adjacent parastratotype section. Base of stage: X X X X

GTS/ 2004/GSSP

Cenozoic 10 (remainder 10)
Mesozoic 11 (remainder 22)
Paleozoic 28 (remainder ±20)
Precambrian 2 (remainder >10's)

GSSP base of Ediacaran (Australia) 'Golden Spike' 635Ma

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....

$T_{x'}$

0.5
to
5%

T_x

So 95 à 99.5% of time is missing

A ‘normal’ and ‘continuous’ geological succession

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