










Phae	Paleozoic			Permian	Lopingian	Changhsingian	251.0 ±0.4	
						Wuchiapingian	253.8 ±0.7	
	Guadalupian	Capitanian	260.4 ±0.7					
		Wordian	265.8 ±0.7					
		Roadian	268.0 ±0.7					
	Cisuralian	Kungurian	270.6 ±0.7					
			275.6 ±0.7					
		Artinskian	284.4 ±0.7					
		Sakmarian	294.6 ±0.8					
	Carboniferous	Pennsylvanian	Upper		Asselian	299.0 ±0.8		
				Gzhelian	303.9 ±0.9			
			Middle	Kasimovian	306.5 ±1.0			
				Moscovian	311.7 ±1.1			
				Bashkirian	318.1 ±1.3			
		Mississippian	Upper	Serpukhovian	326.4 ±1.6			
				Visean	345.3 ±2.1			
			Lower	Tournaisian	359.2 ±2.5			

y

STÁŘÍ (Ma)	ERATEM		ÚTVAR	ODDĚLENÍ	STUPEŇ	
245	PALEOZOIKUM	SVRCHNÍ PALEOZOIKUM	PERM	SVRCHNÍ	thuring	
286				SPODNÍ	saxon	
					autun	
					stephan	
360			KARBON	SVRCHNÍ	PENNSYLVAN	westphal
						namur
						visé
				SPODNÍ	MISSISSIP	tournai

Obr. 50. Základní členění svrchního paleozoika v Západní Evropě, oddělení mississip a pennsylvan se vyčleňují na severoamerickém kontinentu.

The base of the Carboniferous System is defined at the first appearance of the conodont *Siphonodella sulcata* within the evolutionary lineage from *Siphonodella praesulcata* to *Siphonodella sulcata*. The Devonian-Carboniferous Boundary is at the base of Bed 89 in Trench E' at La Serre, France

The base of the Permian System is defined at the first occurrence of "isolated-nodular" morphotype of *Streptognathodus wabaunsensis* conodont chronocline, 27 m above the base of Bed 19, Aidaralash Creek, northern Kazakhstan.

The base of the Triassic System is defined at the first occurrence of the conodont species *Hindeodus parvus* in the evolutionary lineage *Hindeodus latidentatus* - *Hindeodus parvus* - *Isarcicella isarcica* at the base of Bed 27c in the Meishan Section, Changxing County, Zhejiang Province, China.

Radiometric Dating:

Zircon dating of the "White Clay" (Bed 25) using SHRIMP (ion-microprobe) dating gave a $^{206}\text{Pb}/^{238}\text{U}$ age of 251.2 ± 3.4 Ma.

Using incremental-heating $^{40}\text{Ar}/^{39}\text{Ar}$ analysis of sanidine grains (100-150 μ across) extracted from the "White Clay", obtained a plateau date of 249.91 ± 0.15 Ma

Typical Carboniferous facies

1) Uhelný vápenec (Kohlenkalk) – calcareous lagae, crinoids, foraminifers, brachiopods, bryozoans and corals

2) Culm facies – Carboniferous flysch, alternation of greywackes, conglomerates and shales

3) Coal – paralic and limnic basins. Paralic basins - cyclothems

Typical Carboniferous facies

1) Uhelný vápenec (Kohlenkalk) – calcareous lagae, crinoids, foraminifers, brachiopods, bryozoans and corals

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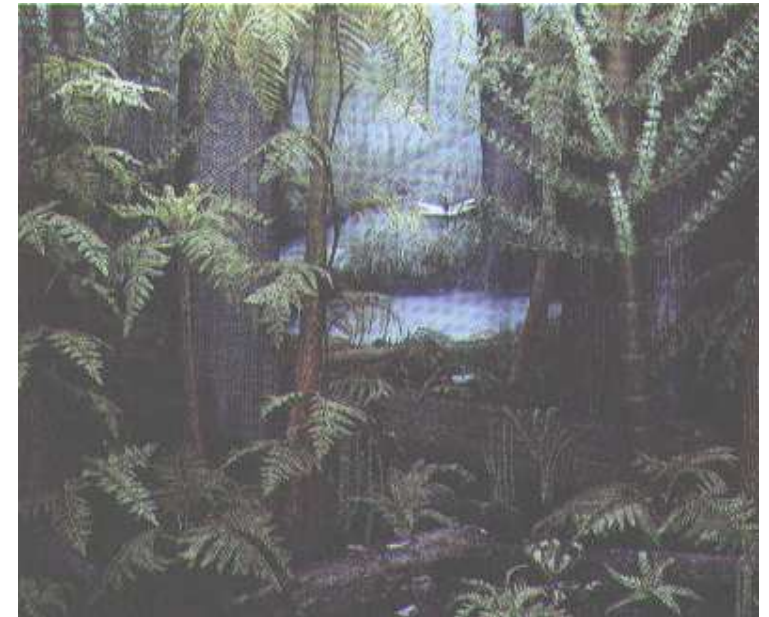
Plant Life on Land

- Coal deposits
 - lowland swamps
 - wetlands more extensive in Late Carboniferous

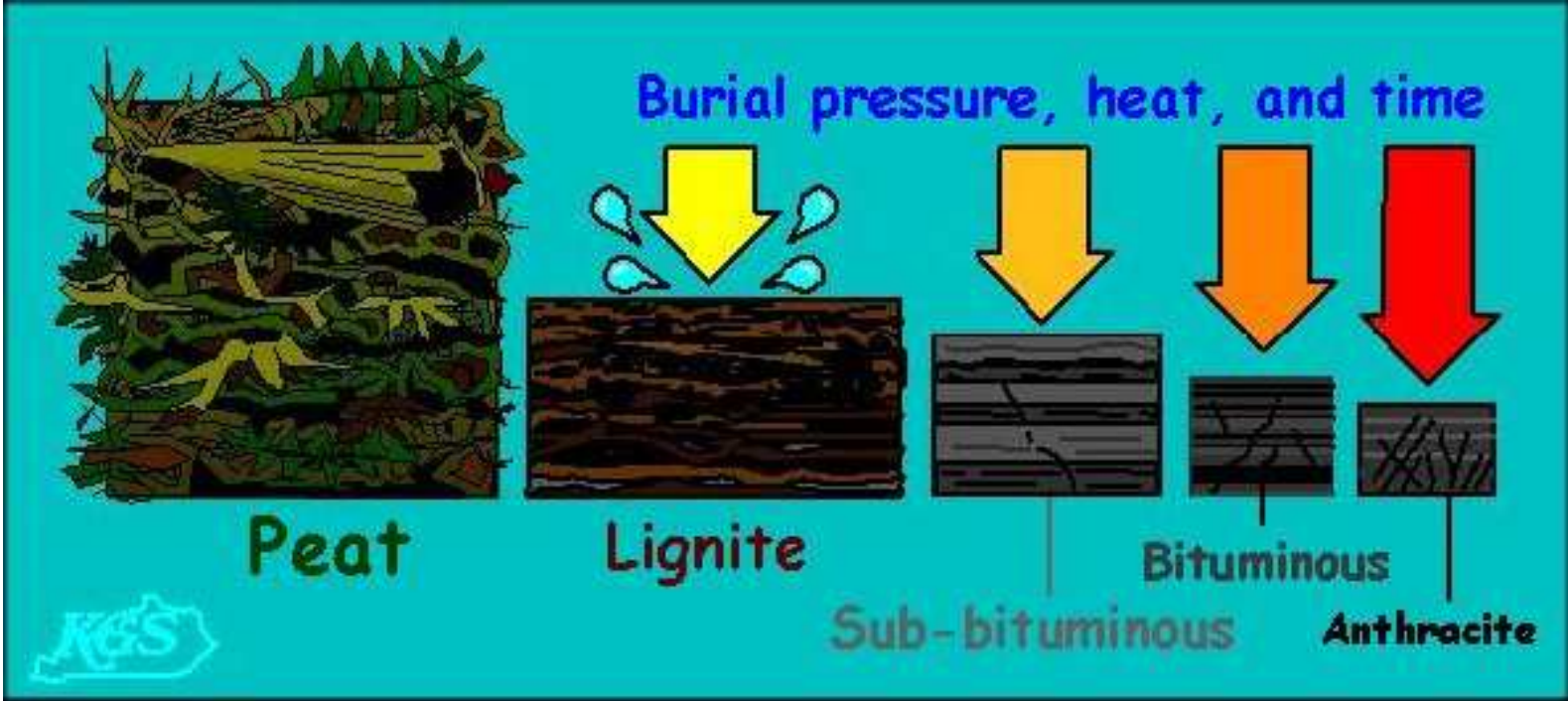


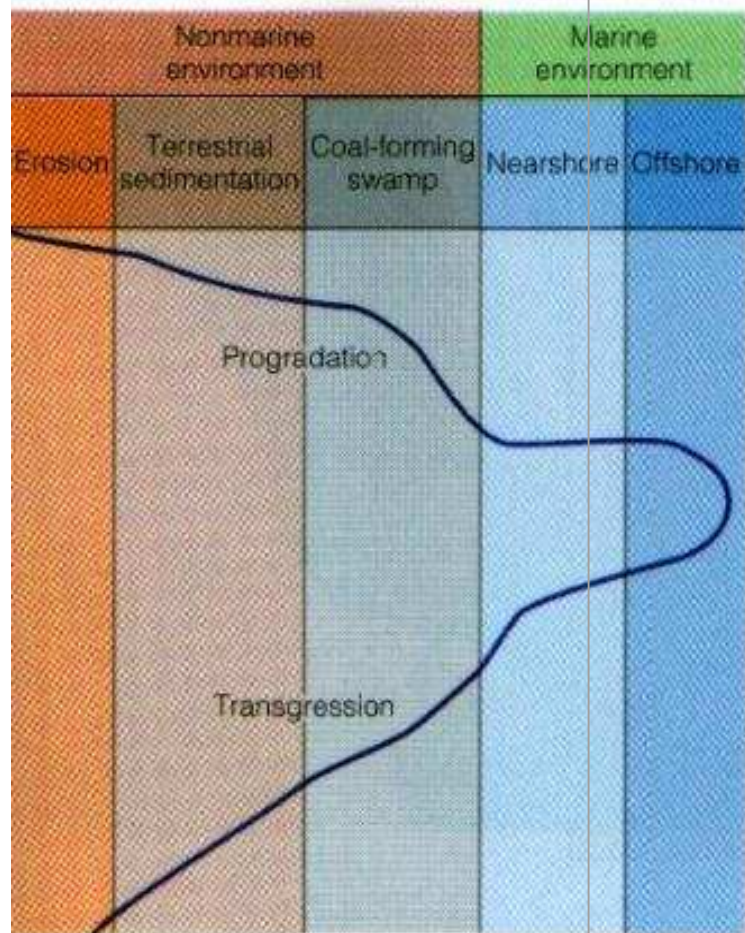
Coals

- Coal deposits accumulate in swampy areas
 - full of organic carbon from plants and animals
 - need abundant vegetation and reducing environment
 - vegetation dies, and is buried and preserved instead of oxidized and decayed
 - compacts to form peat (10:1 ratio)
 - continued burial and metamorphism produces coal



Florida Everglades,
Louisiana swamps
are modern analogs



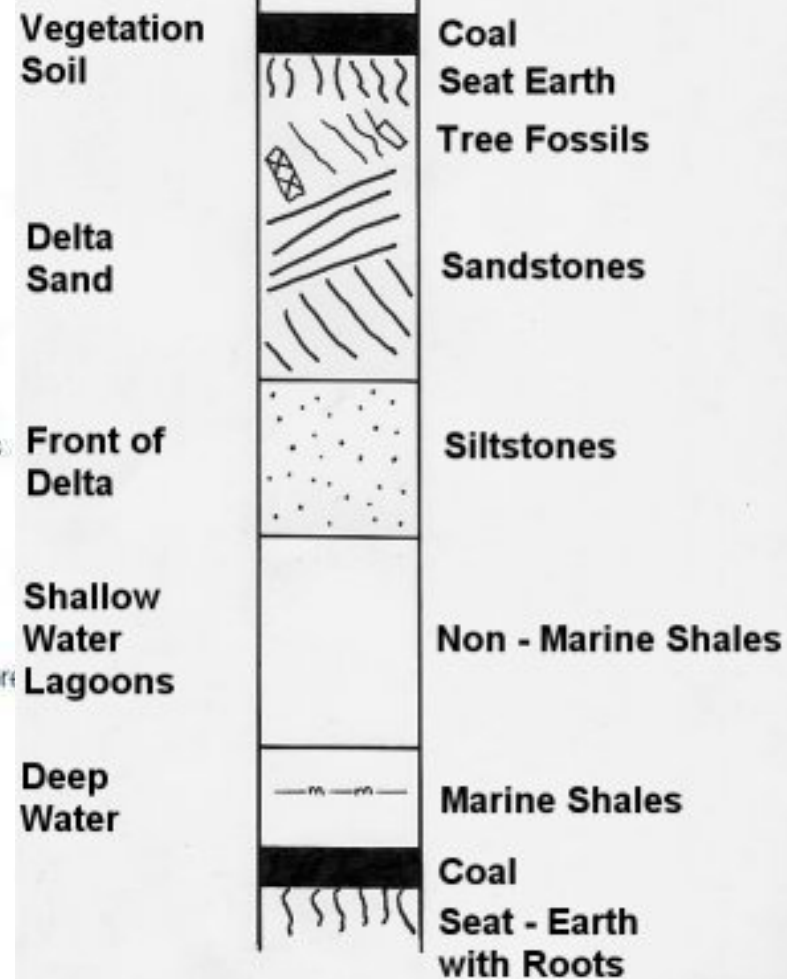


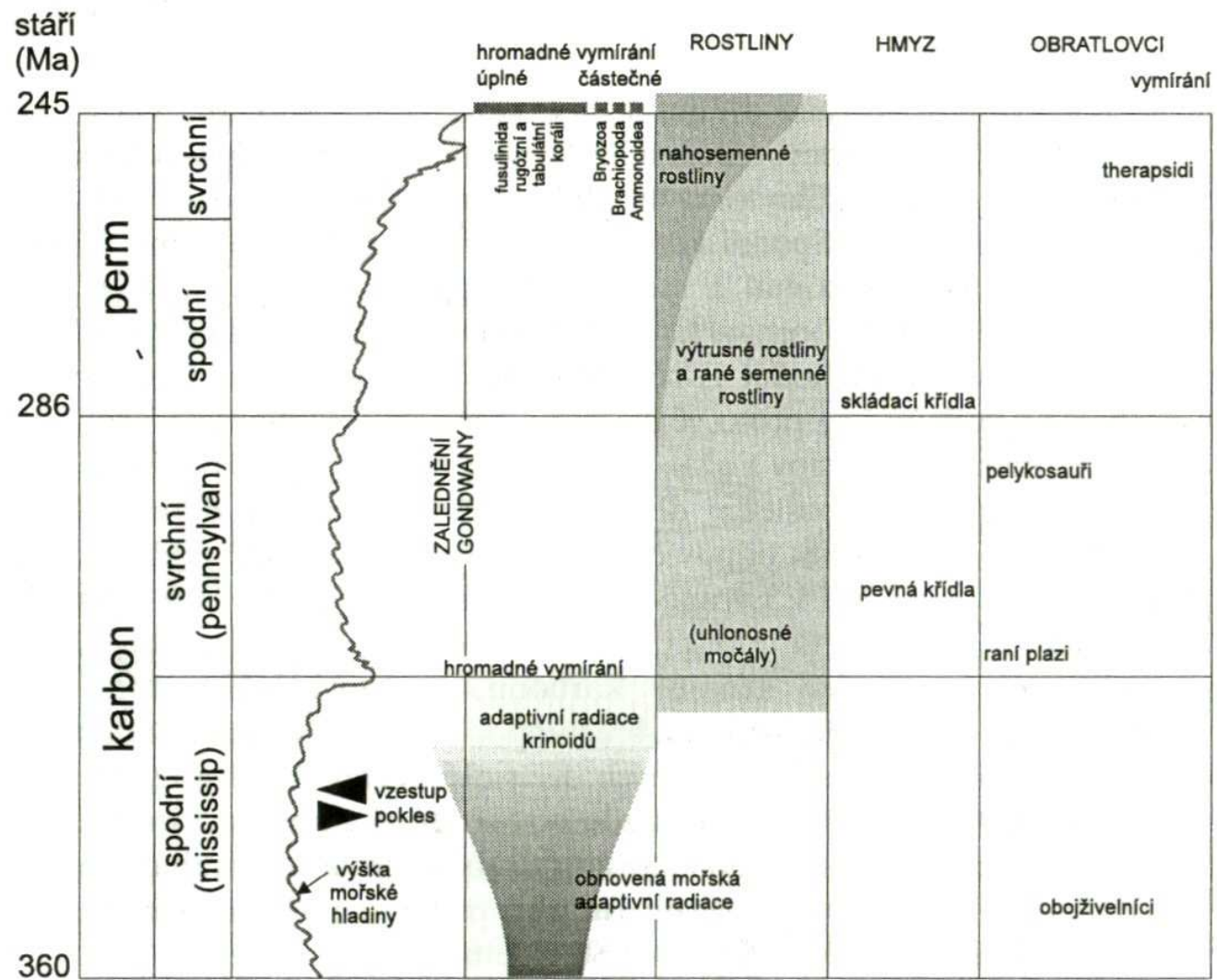
(a)



Disconformity
 Brackish and nonmarine shales
 Marine shales
 Algal limestones with nearshore and brackish water invertebrate fossils
 Limestones with offshore invertebrate fossils
 Limestones and shale with offshore invertebrate fossils
 Marine shales with nearshore invertebrate fossils
 Coal
 Underclay
 Nonmarine shales and sandstones
 Nonmarine sandstones
 Disconformity

A Coal Measure Cyclothem

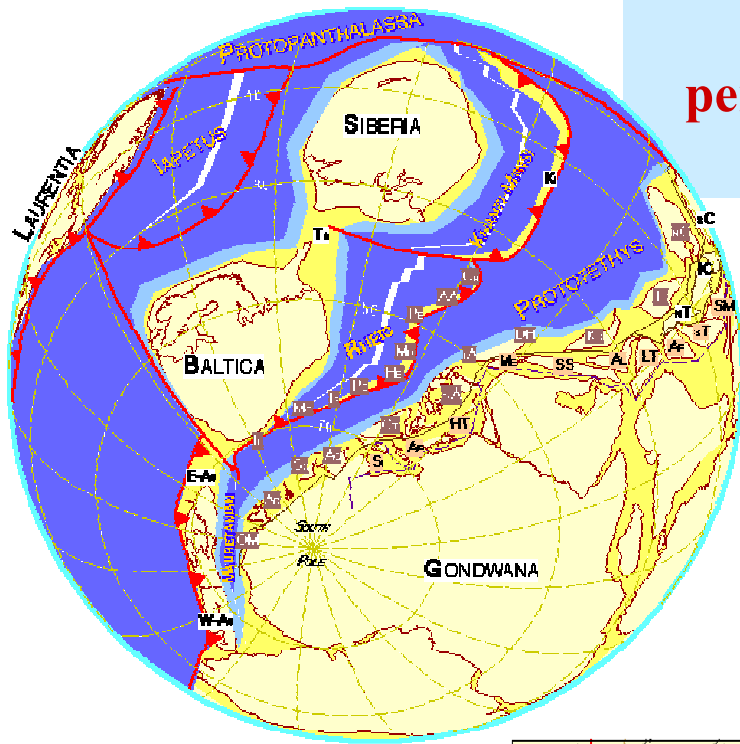




Obr. 51. Hlavní události svrchního paleozoika. Upraveno podle Stanley (1992).

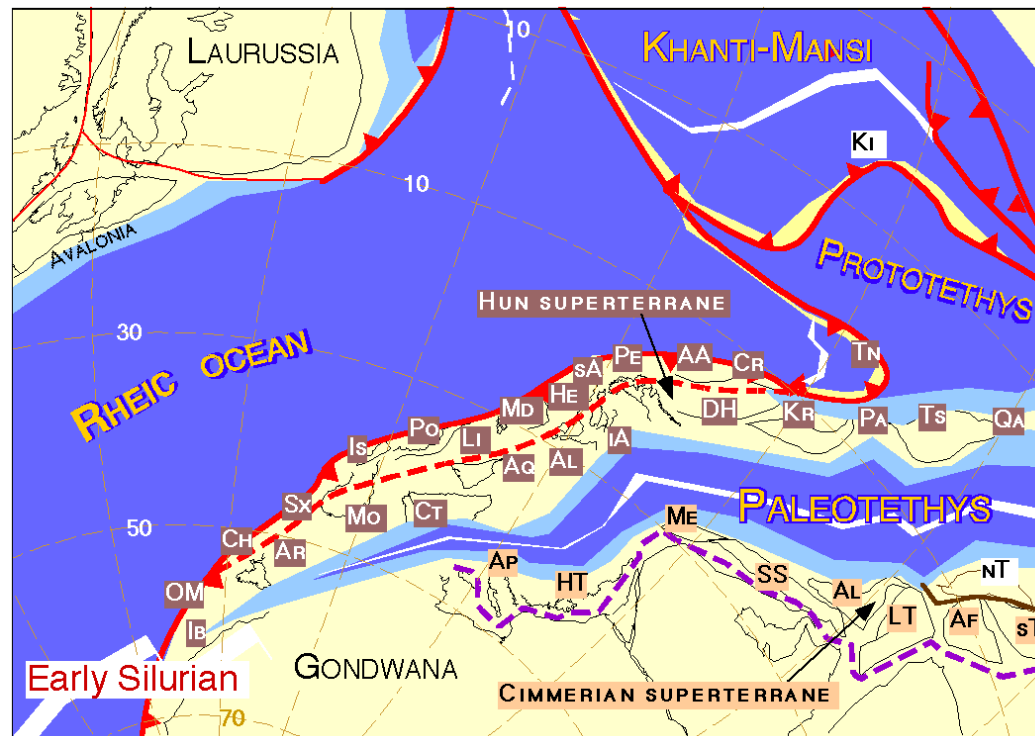
Paleogeography and tectonic processes

EARLY ORDOVICIAN
490Ma



Geologický vývoj perigondwanských teránů ve spodním paleozoiku

EARLY SILURIAN
(435 Ma)





Mississippian (345 - 335 Ma)



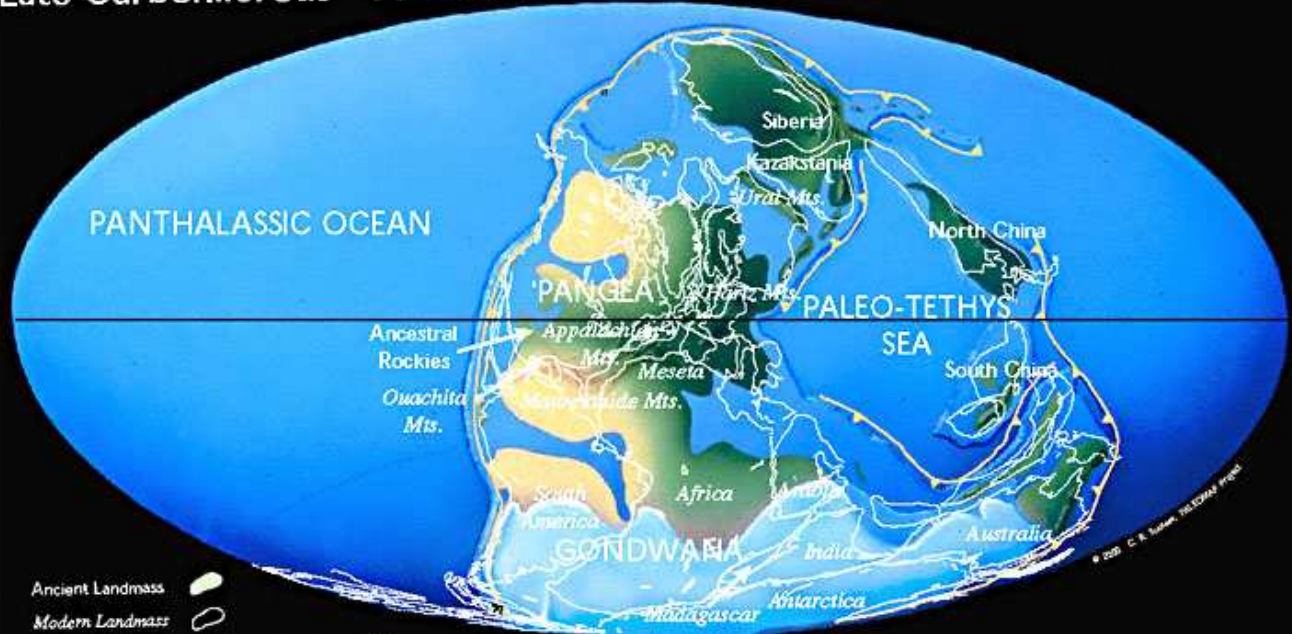


Pennsylvanian (310 - 300 Ma)



Pennsylvanian Tectonics and Climate

Late Carboniferous 306 Ma

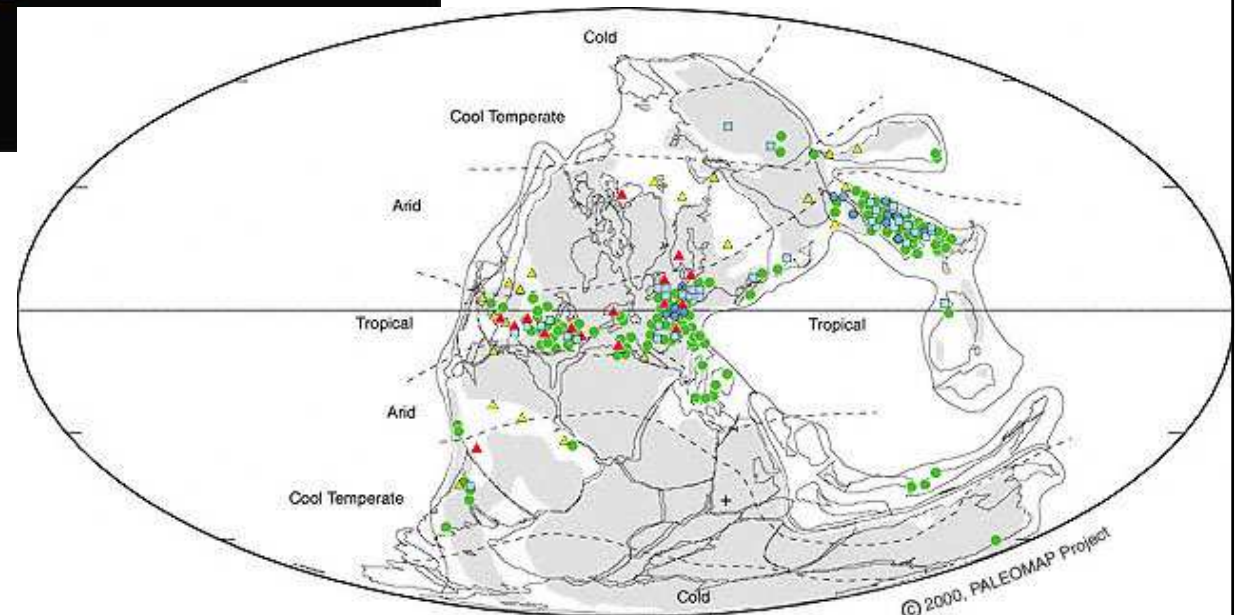


LEGEND

		WARM	COOL
WET	Tropical	● Coal ● Bauxite ● Laterite	Cool Temperate ● Coal & Tillites
		Warm Temperate □ Kaolinite (& coal & evaporite) 🌴 Crocodiles 🐊 🌴 Palms & Mangroves 🌴	
	DRY	Arid ▲ Evaporite ▲ Calcrete	Cold + Tillite ⊕ Dropstone ● Glendonite

"Paratropical" = High Latitude Bauxites

Tropical rainforests in middle of Pangea; vast coal swamps at equator; deserts, glaciers cover Gondwana



Upper Carboniferous (Gzelian)

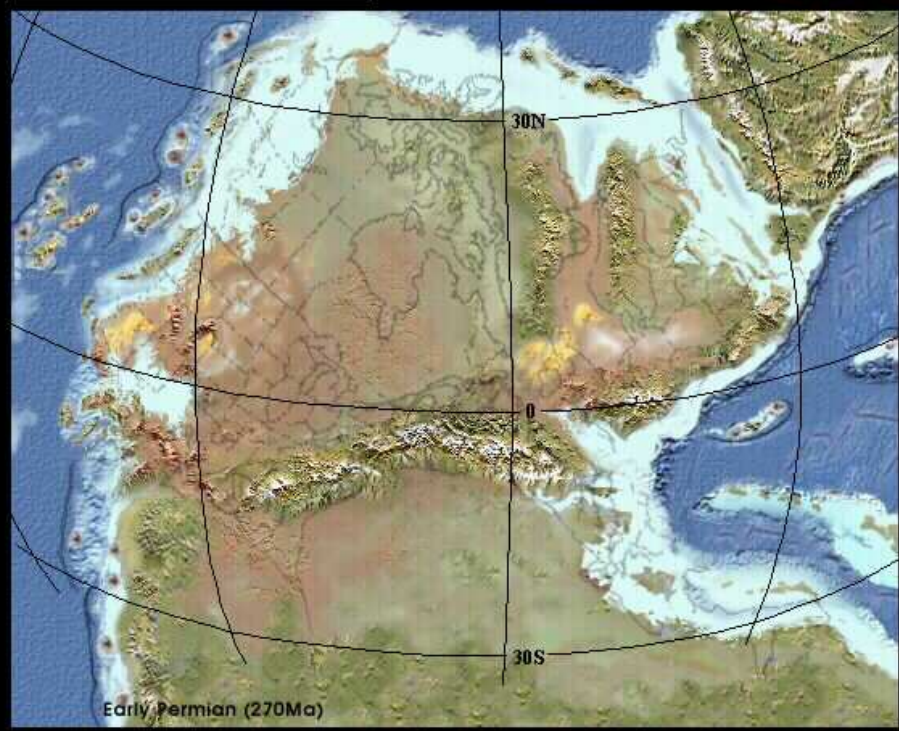
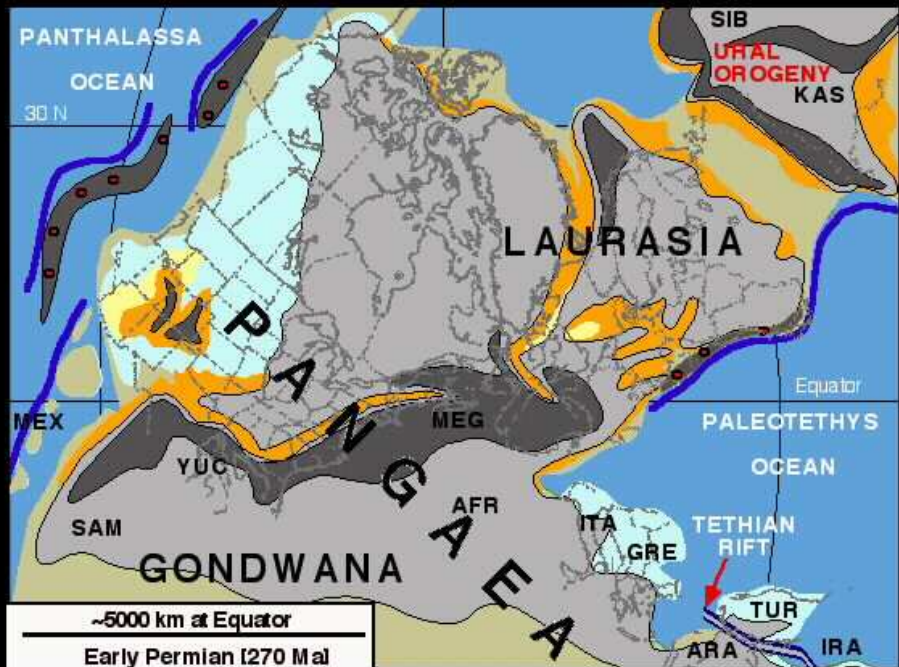
Permo-Carboniferous Glaciation I

- ❖ Carboniferous to Permian period (350-280 million years ago)
- ❖ **Most severe glaciation of the entire Phanerozoic**
- ❖ Last glaciation prior to Quaternary ice ages
- ❖ Gondwanaland ice sheet centered on Antarctica and S. Africa
- ❖ Maximum - 2X area of the current Antarctic ice sheet
- ❖ Gondwanaland ice sheet believed to radially flow from a cap
(over South America, southern Australia, and southern India)
- ❖ Dwyka series in Africa
 - 600 meter thick tillites
 - Underlying bedrock, grooves, striations and polish
 - Indicates paleo flow directions
- ❖ Evidence for the breakup of Pangea
- ❖ **No evidence of glaciation in the northern continents - Duh?**

Permo-Carboniferous Glaciation II

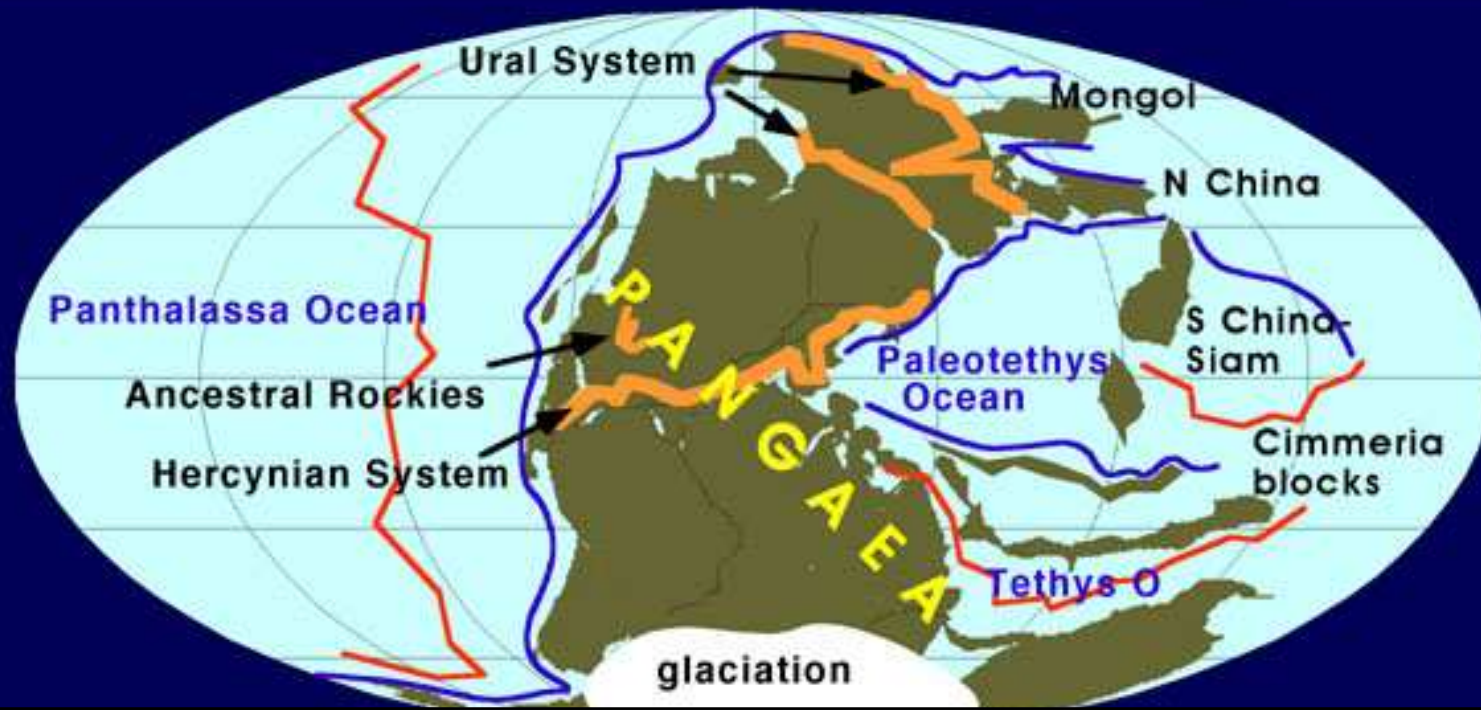


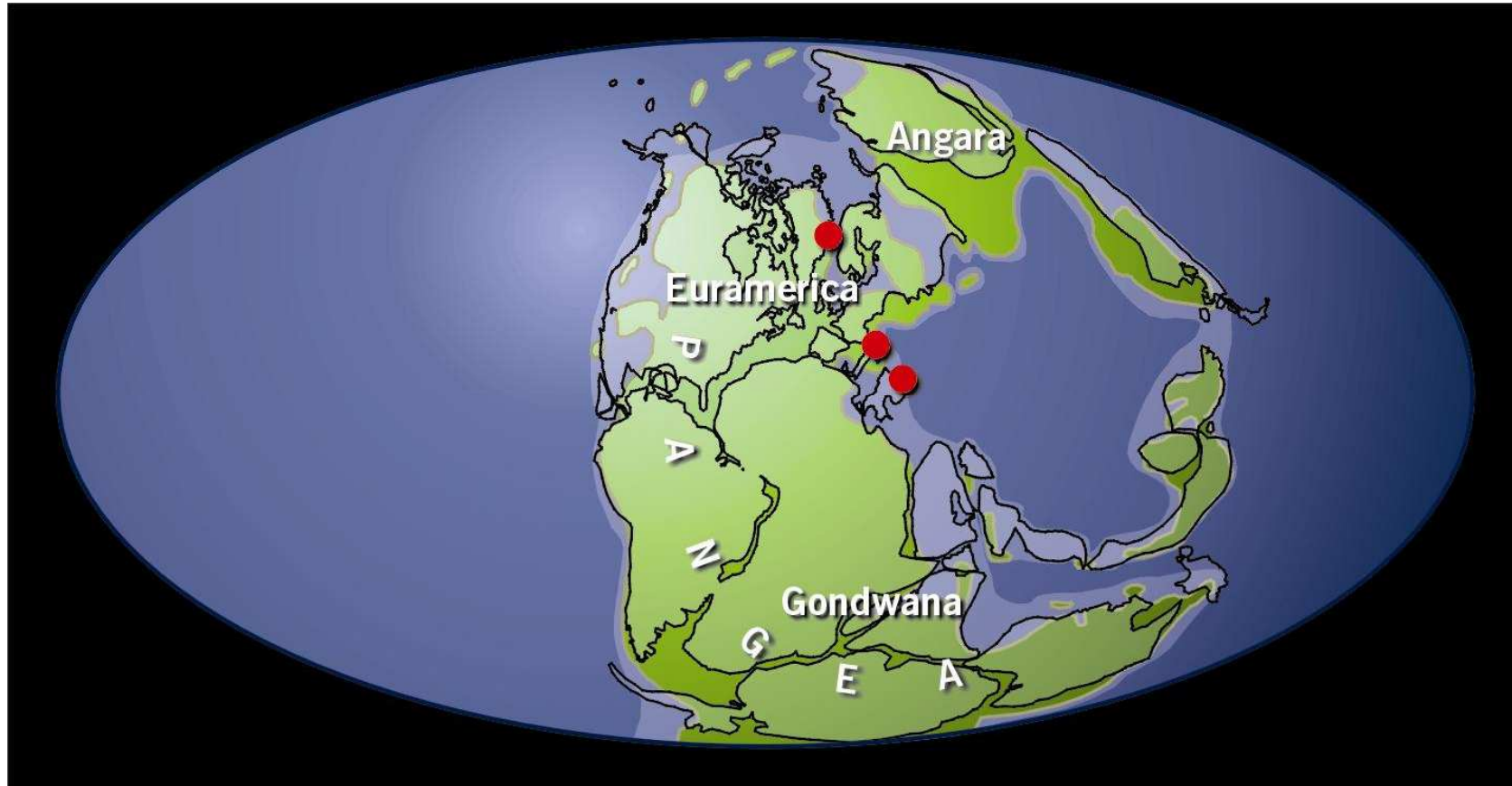
Deep striations cut in soft sand by ice sheets during the Permian-Carboniferous Gondwana glaciation, Oorlogskloof, South Africa



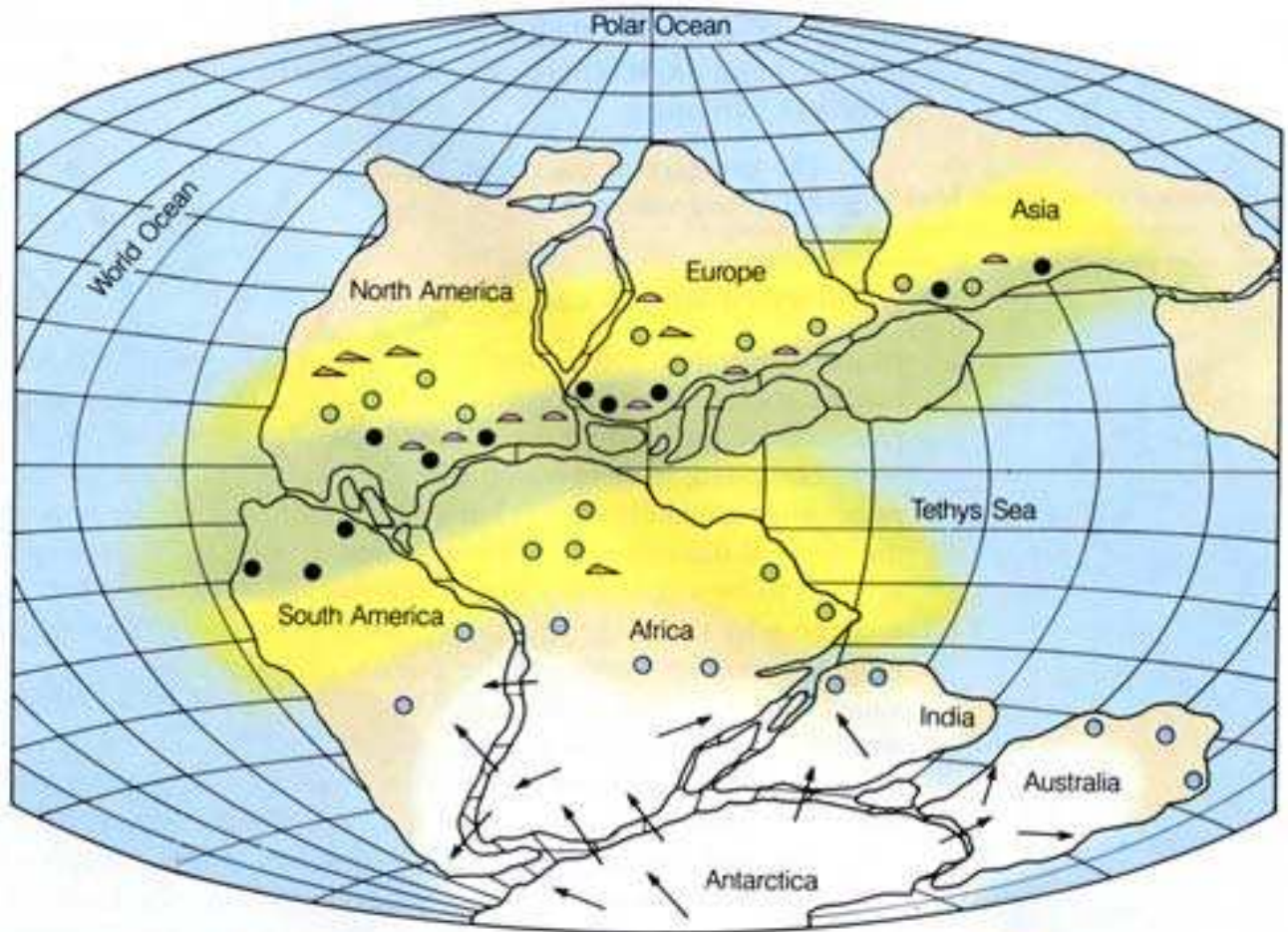


Permian (270 - 260 Ma)



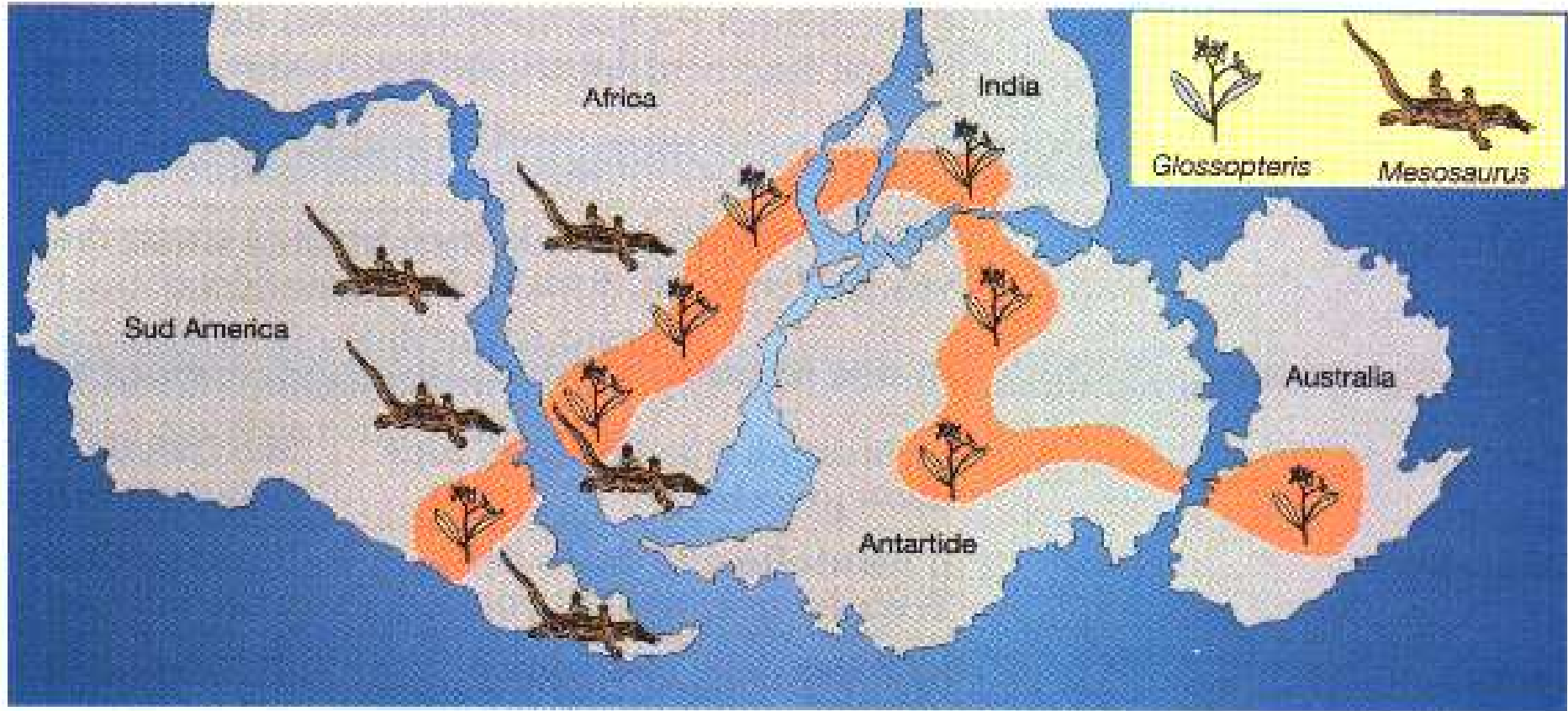


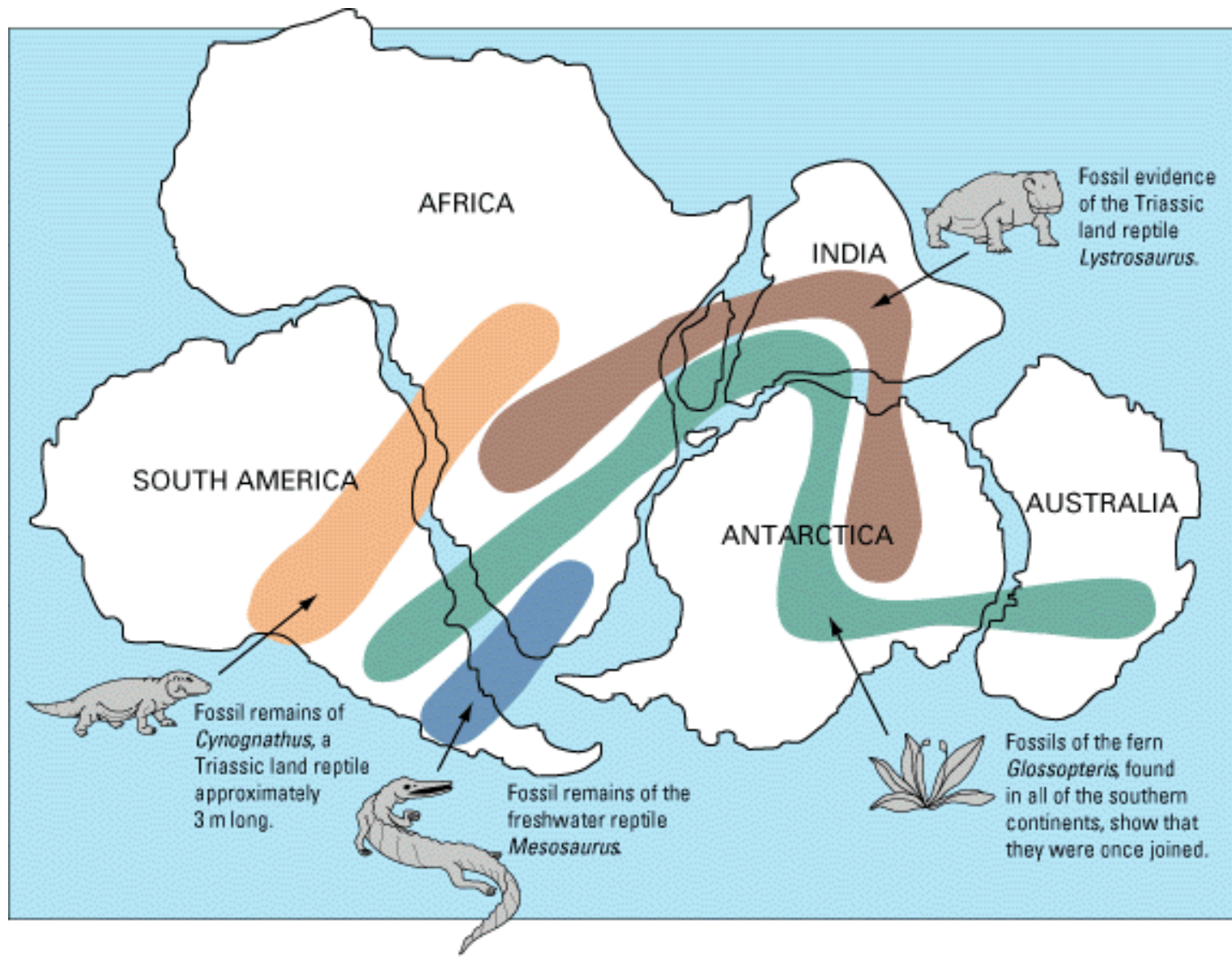
late Permian continent configuration paleogeography after Scotese (1997)



- | | | |
|---|---|--|
|  Ice-rafted boulders |  Coal |  Low-latitude deserts |
|  Evaporite deposits |  Desert dune deposits |  Tropics |
|  Coral reef |  Direction of ice movement |  Glacier |

Palaeoenvironmental indicators show what the climate of Pangea was like. Australia for example was antarctic-like with glaciers dominating its southern parts. Coral reefs indicate warm tropical waters, evaporites such as gypsum, indicate hot dry desert conditions





Phases of Variscan orogeny

- 1) **Breton phase – D-C boundary**
- 2) **Sudetic phase Vissean/Namurian boundary**
- 3) **Krušné Hory phase – late namurian –early Westphalian**
- 4) **Astur phase – westphalian/Stephanian boundary**
- 5) **Saal phase – Permian**
- 6) **Falc phase – P/Tr boundary**



Západní Evropa

Symetrické uspořádání

Severní křídlo

Subvariská zóna

Avalonie

Renohercynsko-jihoportugalská
zóna

Dorzální pásmo

Sasko-durynská zóna
Moldanubická zóna

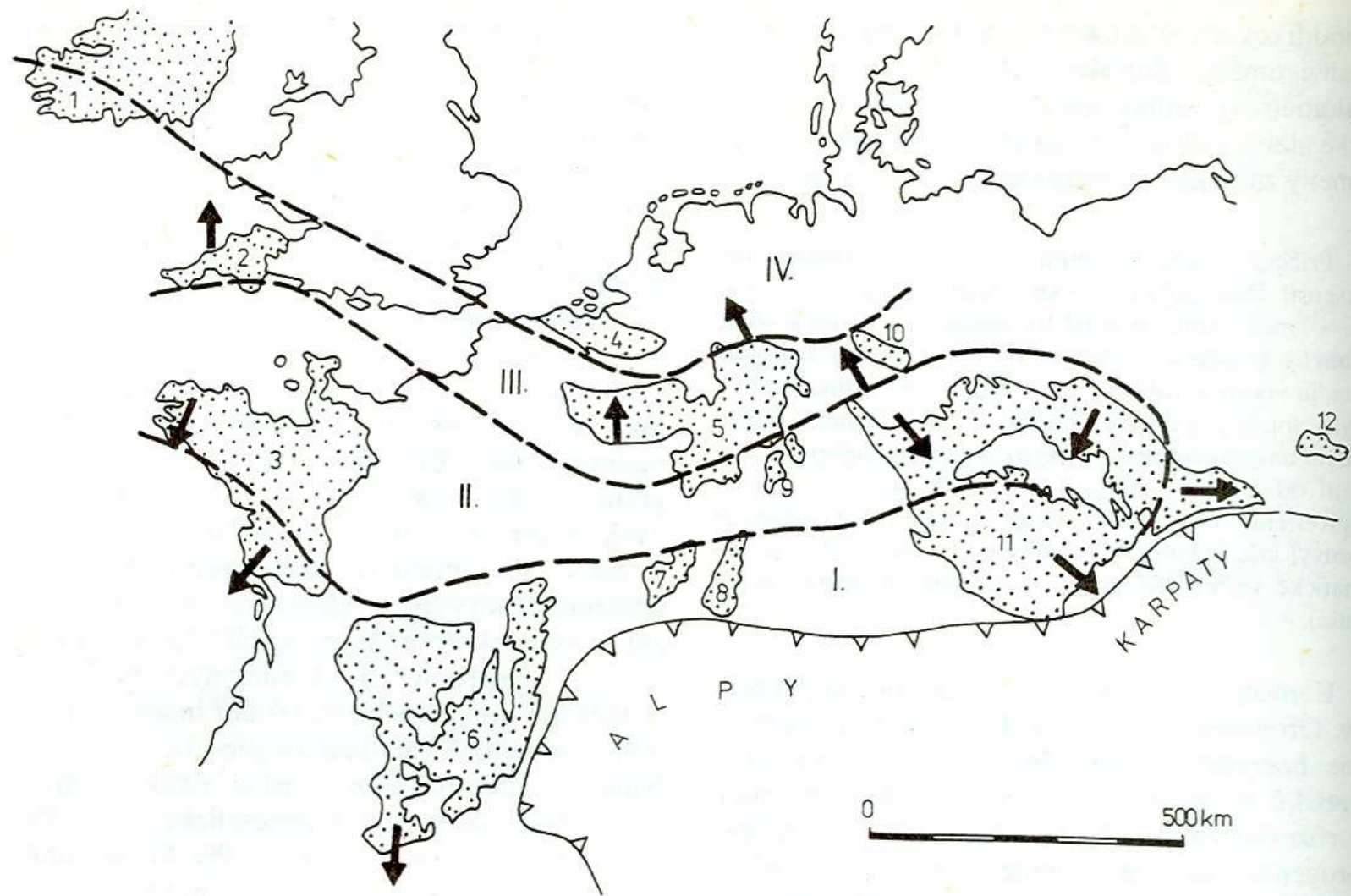
Armorické společenstvo
teránů

Jižní křídlo

Vendésko-limousinská zóna

Iberie

Cevenská zóna (Iberia)



Obr. 278. Zjednodušená schéma variscíd strednej a západnej Európy (upravené podľa F. PATOČKU, 1980, s použitím dát M. G. RUTTENA, 1969, C. F. BURRETTA a J. GRIFFITHSA, 1977 a W. KREBSA, 1975).

I moldanubická zóna a jej ekvivalenty, II sasko-durýnska zóna a jej ekvivalenty, III rhenohercýnska zóna a jej ekvivalenty, IV subvariská zóna a predpolie variského orogénu. Na povrch vystupujúce časti variscíd (vybodkované): 1 južné Írsko, 2 Cornwall, 3 armorický masív, 4 brabantský masív, 5 Ardeny a Porýnska bridličnatá vrchovina, 6 Massif Central, 7 Vogézy, 8 Schwarzwald, 9 Odenwald a Spessart, 10 Harz, 11 český masív, 12 Svätokrižske hory. Šípky znázorňujú prevládajúcu vergenciu vrás

Severní křídlo variscid - charakteristika

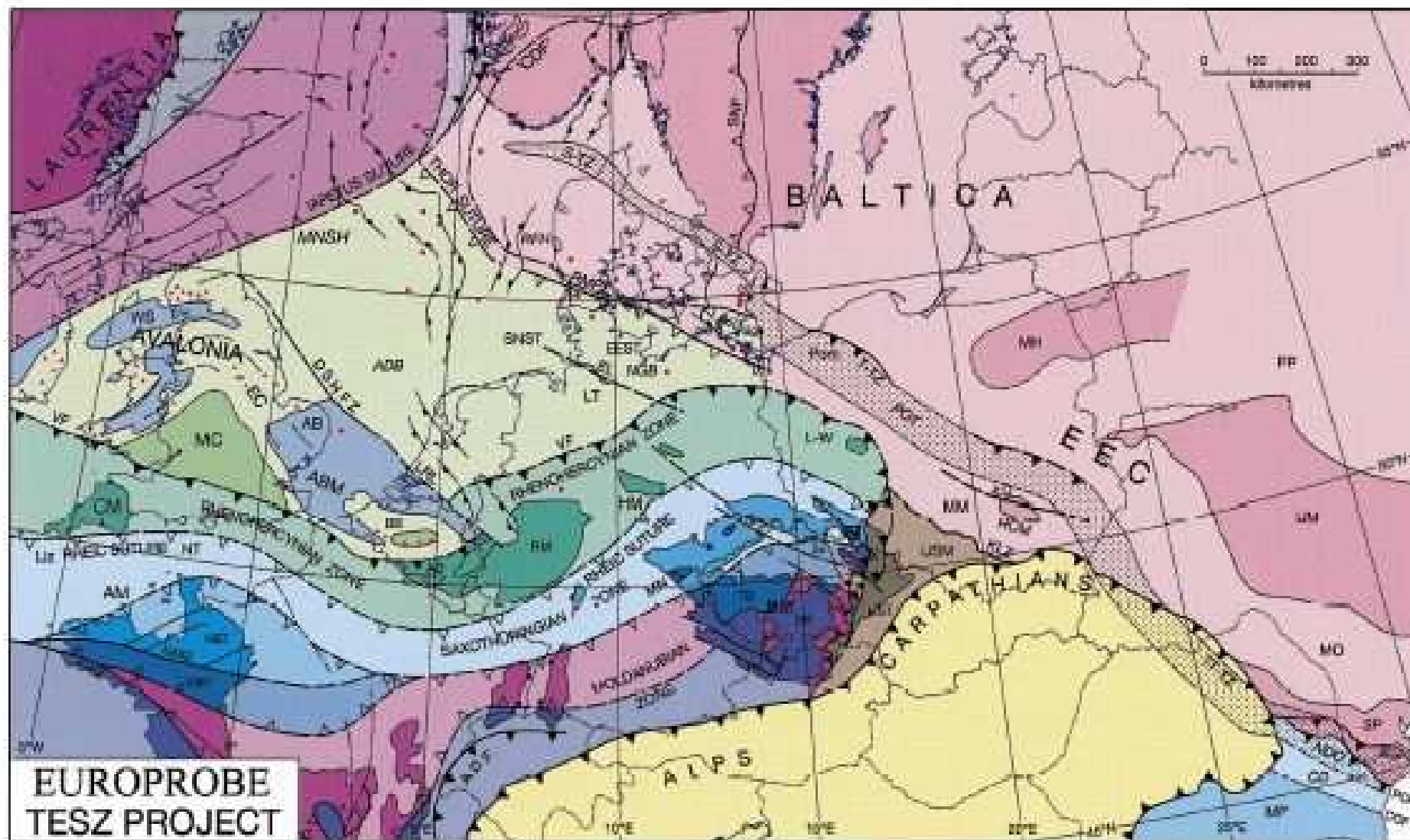
Subvariská zóna – dozvuky variského vrásnění – slabě zvrásněné nebo nezvrásněné sedimenty.
Molasové paralické uhelné pánve

Renohercynské-jihoportugalská zóna – extenzní zóna variské kolize (devon-spod. karbon),
Okraj Avalonie, brunovistulika, příkrovová stavba, bimodální vulkanismus, slabá
nebo žádná metamorfóza, typický flyš (kulm)

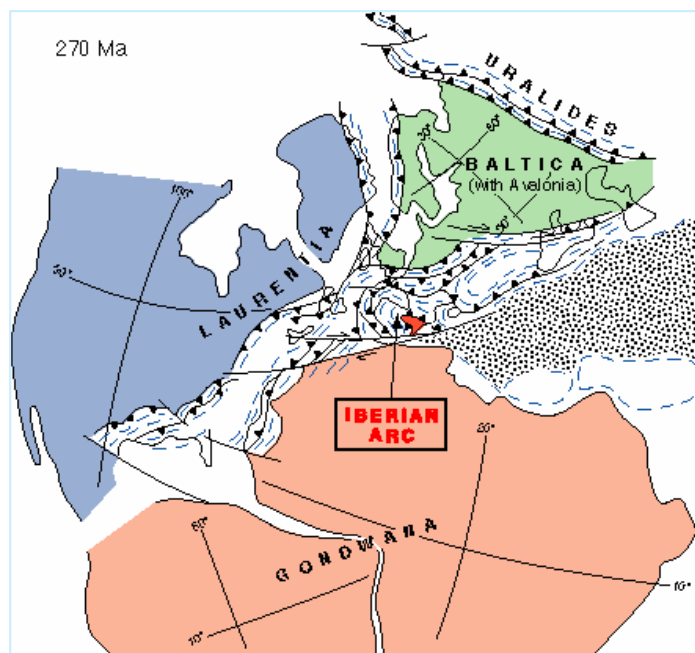
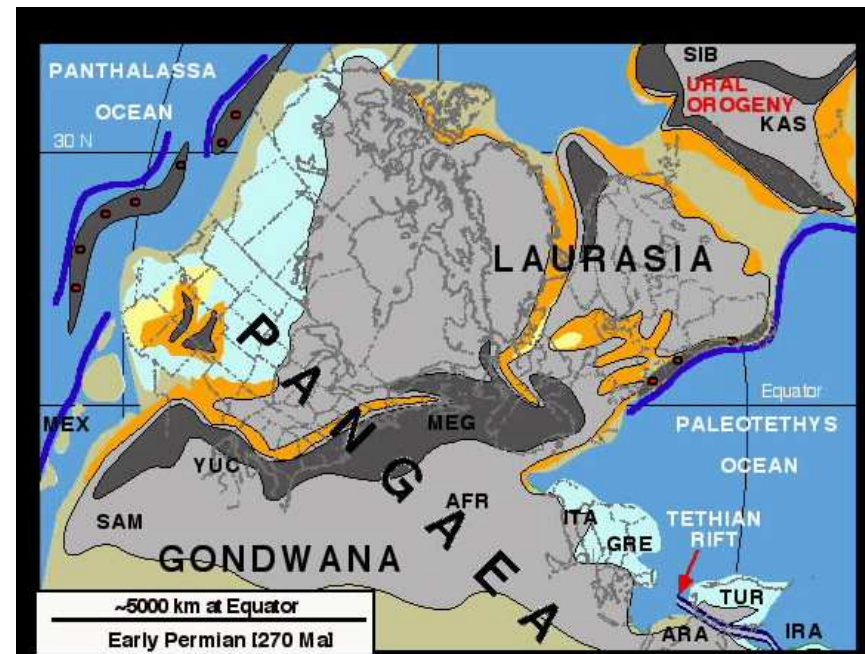
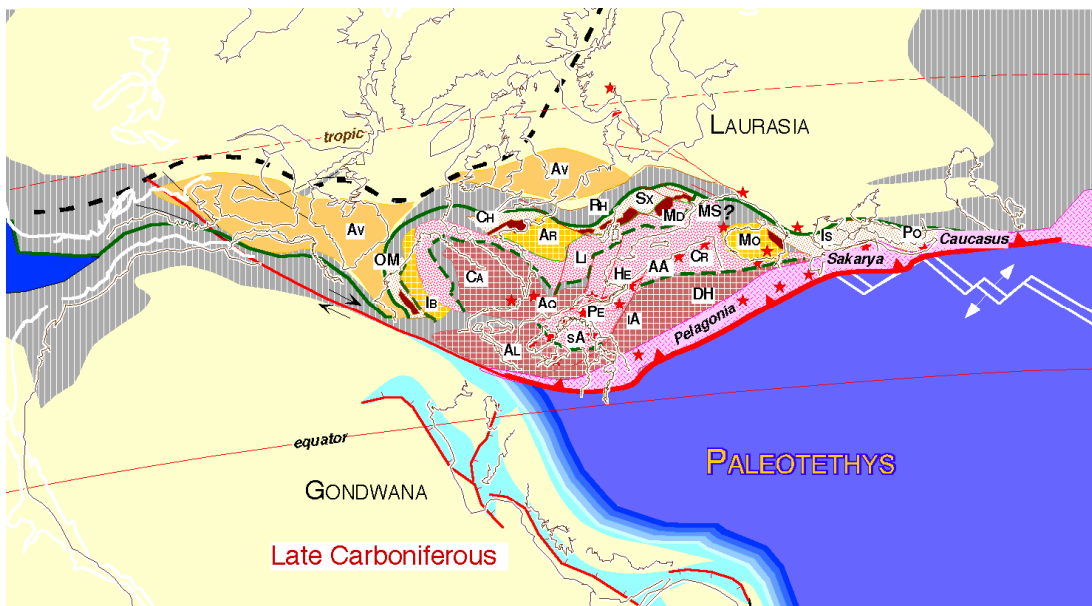
Středoněmecký krystalinický práh – metamorfované svrchnoproterozoické-ordovické
sedimenty a vulkanity, původně okraj terány saxothuringika. Od renohercynské
zóny oddělen fylitovou zónou

Sasko-durynská zóna – značná metamorfóza a grantizace slábnoucí k severu, postorogenní
plutonismus. Počátek vrásnění v spodním devonu, hlavní fáze spodní karbon.
Divolý flyš – sv. devon-sp, karbon. Terán saxothuringika oddělen od moldanubika
ebersdorfskou linií (litoměřický zlom), marianskolázeňský ultrabazický komplex

Moldanubická zóna – intenzivní metamorfóza, grantizace a plutonismus. Hlavně devonské fáze
vrásnění. Moldanubický terán (Perunica). Na západě a severu tekton. Kontakt s
saxothuringikem, na jihu s perimediterránním teránem a na východě s brunovistulikem



Geologický vývoj variských perigondwanských teránů ve svrchním karbonu a permu



420 Ma

Appalachian orogeny

- Final suture of Laurasia and Gondwanaland
 - Himalayan style continent-continent collision
 - folding and thrusting from Nova Scotia to Florida
 - persisted into the Permian
 - Abundant Permian non-marine red beds attest to major period of uplift and erosion
 - Included belts
 - Marathon, Ouachita, Blue Ridge, PA Ridge and Valley, New England/Maritime
 - Overprinted Ca

Tectonic Evolution of the Appalachians

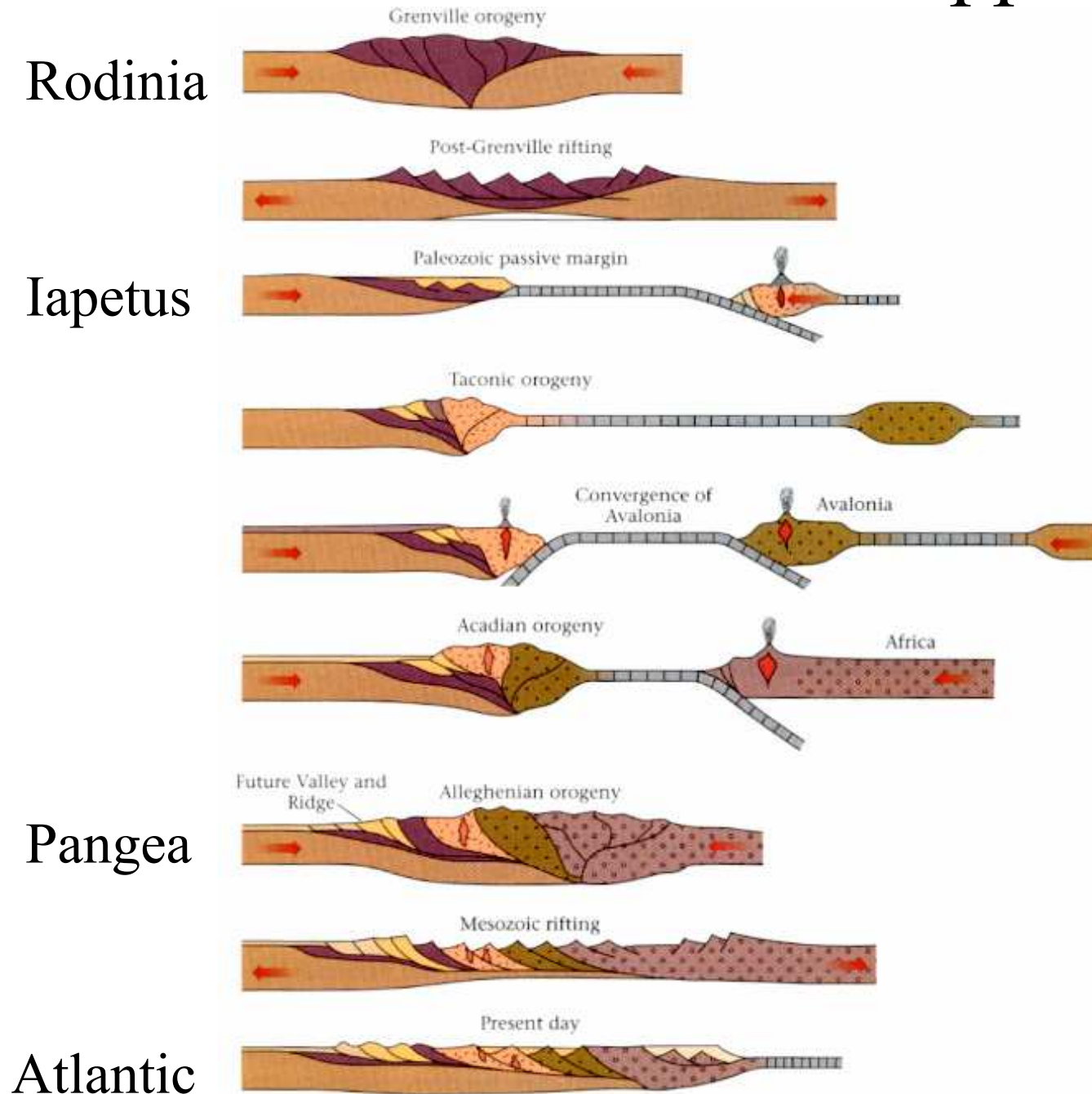


FIGURE 11.36 These idealized stages show the tectonic evolution of the Appalachian Mountains. Note that while mountains do form during rifting events, geologists traditionally assign names only to the collisional or convergent events.

Late Paleozoic flora

**Green Algae – rock forming importance of Dasycladaceae and Codiaceae
Koninckopora - Visean**

Red algae - Corallinacea

Plankton – Acritarcha, retreat

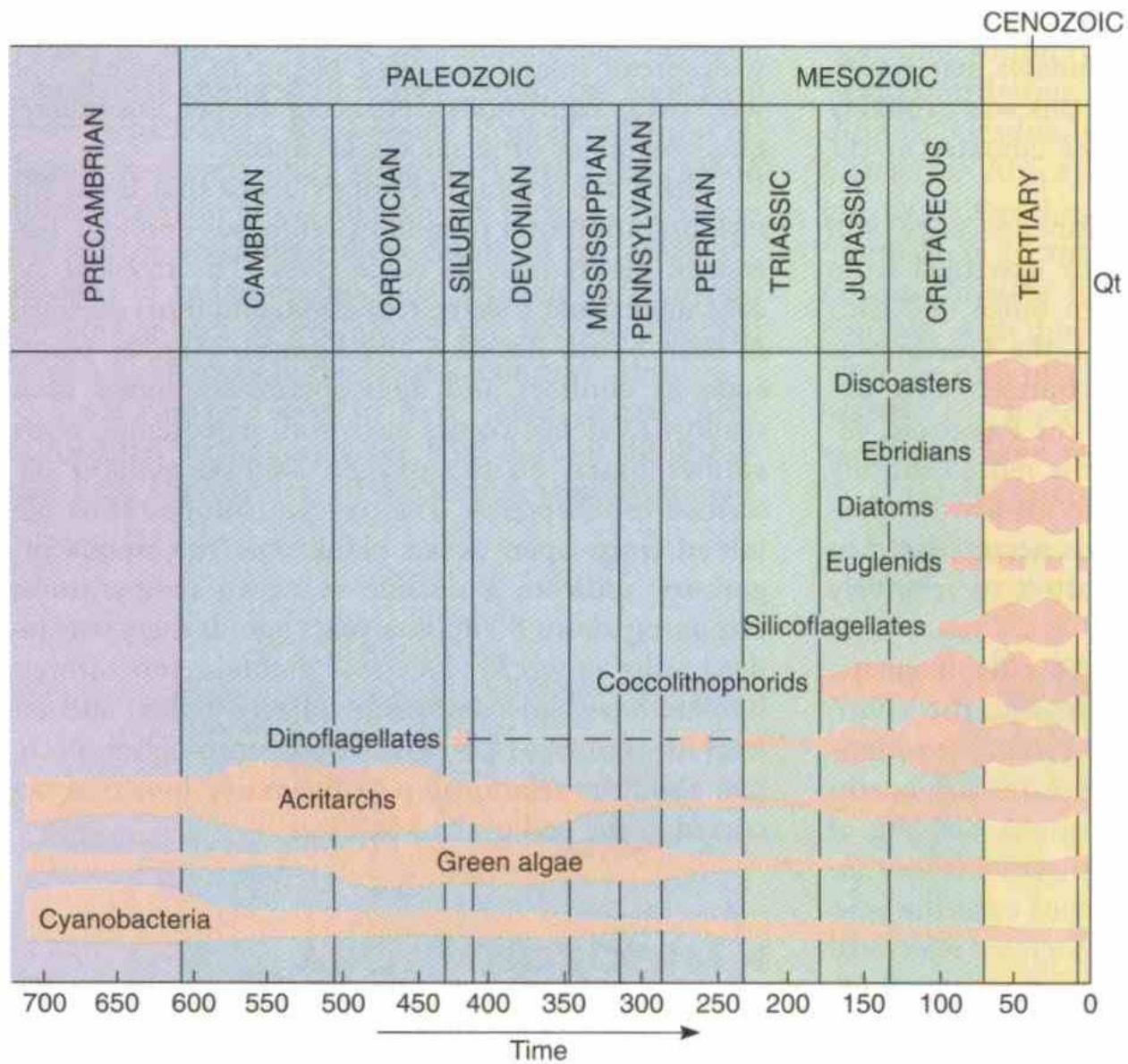


FIGURE 12-2 Geologic distribution and abundances of phytoplankton. (From Tappan, H., and Leoblich, A. R., Jr. 1970. Geol. Soc. Am. Special Paper 127:257.)

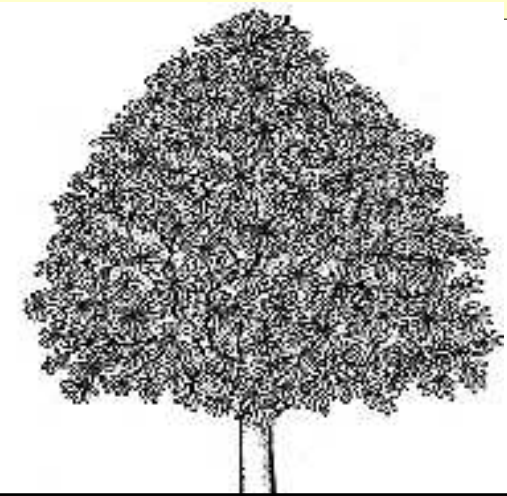
Higher plants

Carboniferous jungle – different floors. Highest one lycophyts *Sigillaria* and *Lepidodendron*, less cordaites
Lower floor – ferns, seed ferns and sphenophyts (*Calamites*)
More xerophilous – forests formed by seed plants – seed ferns, cordaites, conifers

Early/late Permian -boundary between Paleophytikum and Mesophytikum

Upper Permian – dominance of gymnosperms, especially conifers (*Voltziales*)

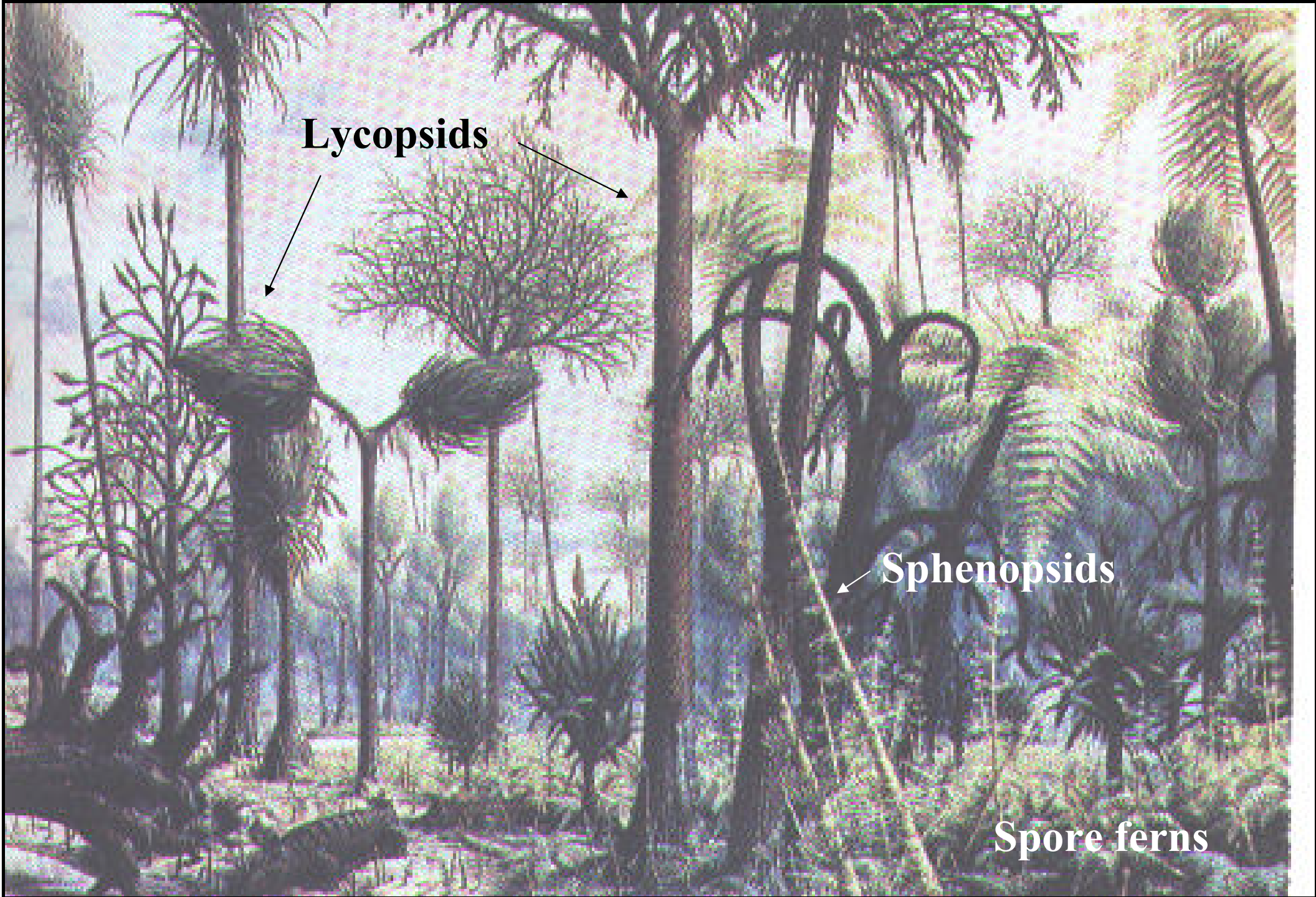
Different floristic bioprovincies. Glaciated Gondwana – glossopteris flora, similar cold adapted flora in Siberian province



Lycopsids

Sphenopsids

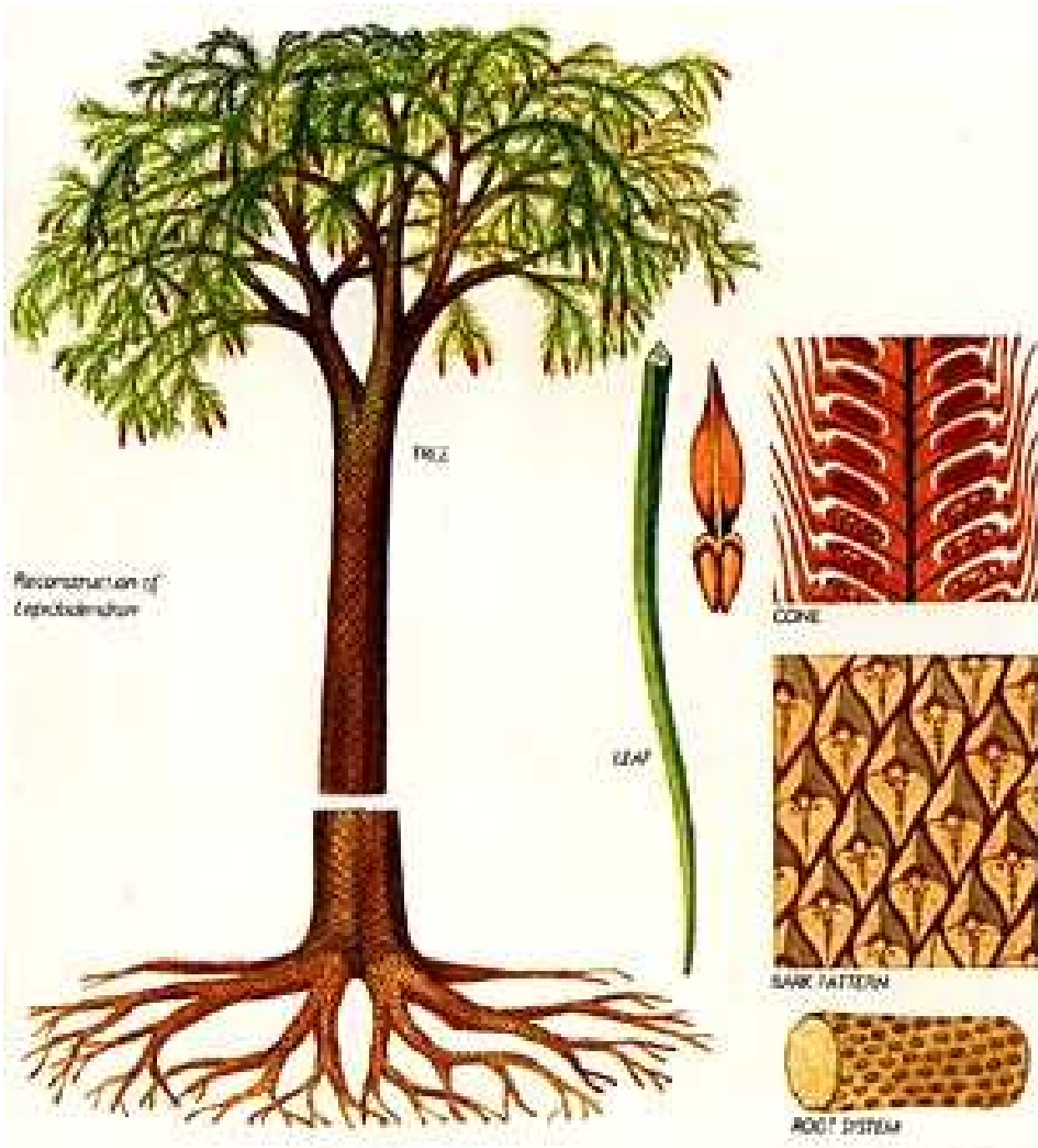
Spore ferns



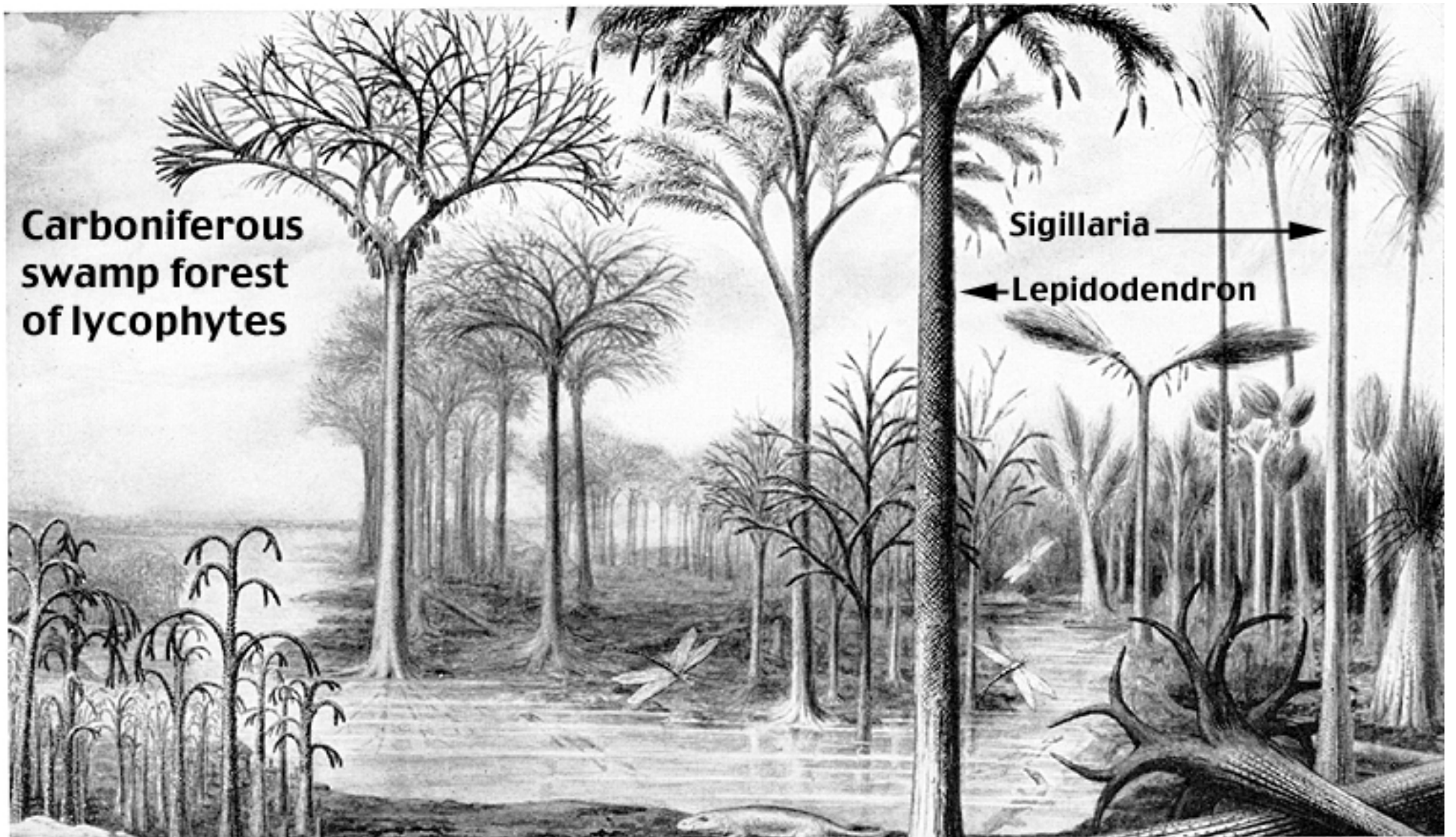
Lycophyta



Sigillaria



**Carboniferous
swamp forest
of lycophytes**



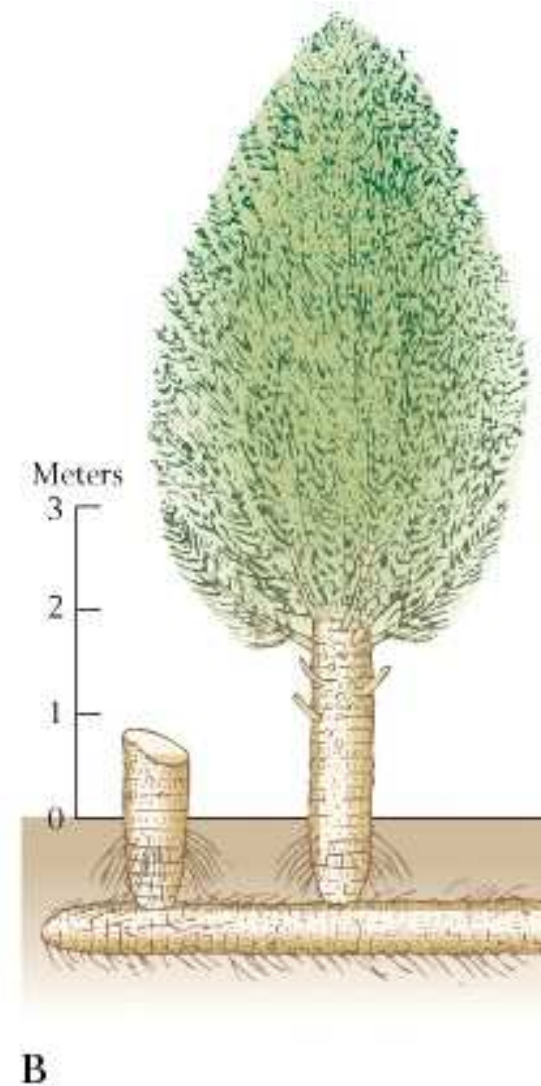
Sphenophyta

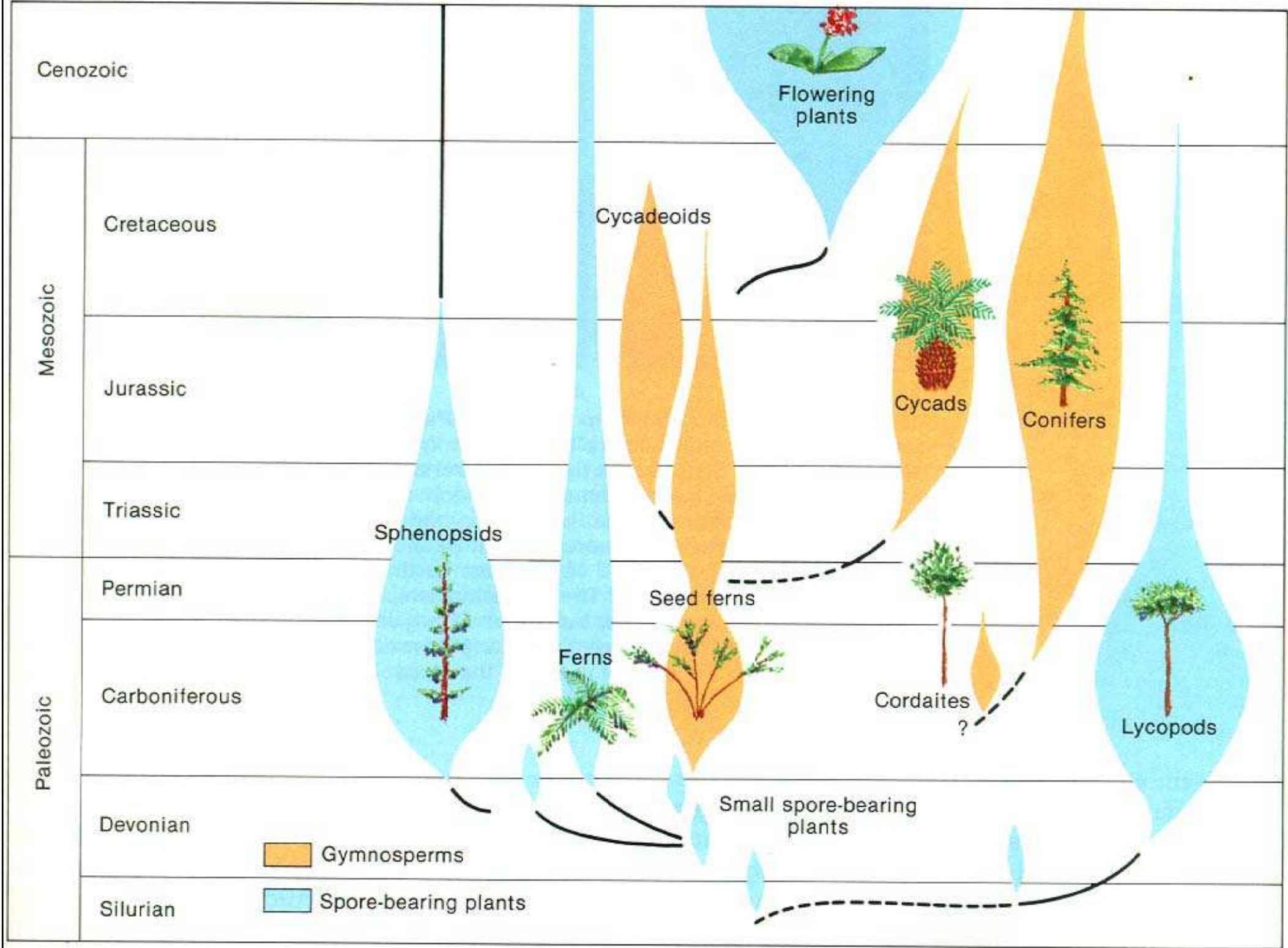


Calamites

- higher ground: ‘sphenopsids’

Calamities





Gymnosperms

- In the case of the **gymnosperms**,
 - or flowerless seed plants,
 - these are male and female cones
- The male cone produces pollen,
 - which contains the sperm
 - and has a waxy coating to prevent desiccation,
 - while the egg,
 - or embryonic seed,
 - is contained in the female cone
- After fertilization,
 - the seed then develops into a mature, cone-bearing plant



Glossopteris is a Permian tree-fern important in the plate tectonic story.



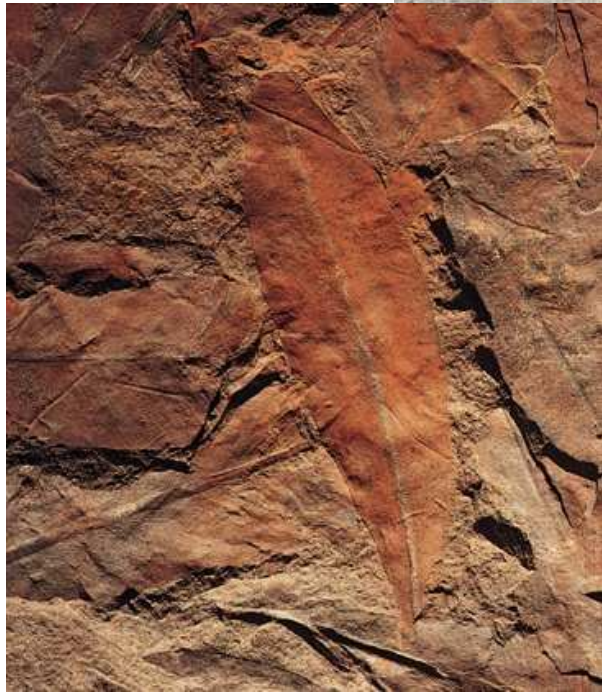
Tree ferns behind giant rushes in Devonian scene

Glossopteris

- Another important non-swamp dweller was Glossopteris, the famous plant so abundant in Gondwana,
 - whose distribution is cited as critical evidence that the continents have moved through time



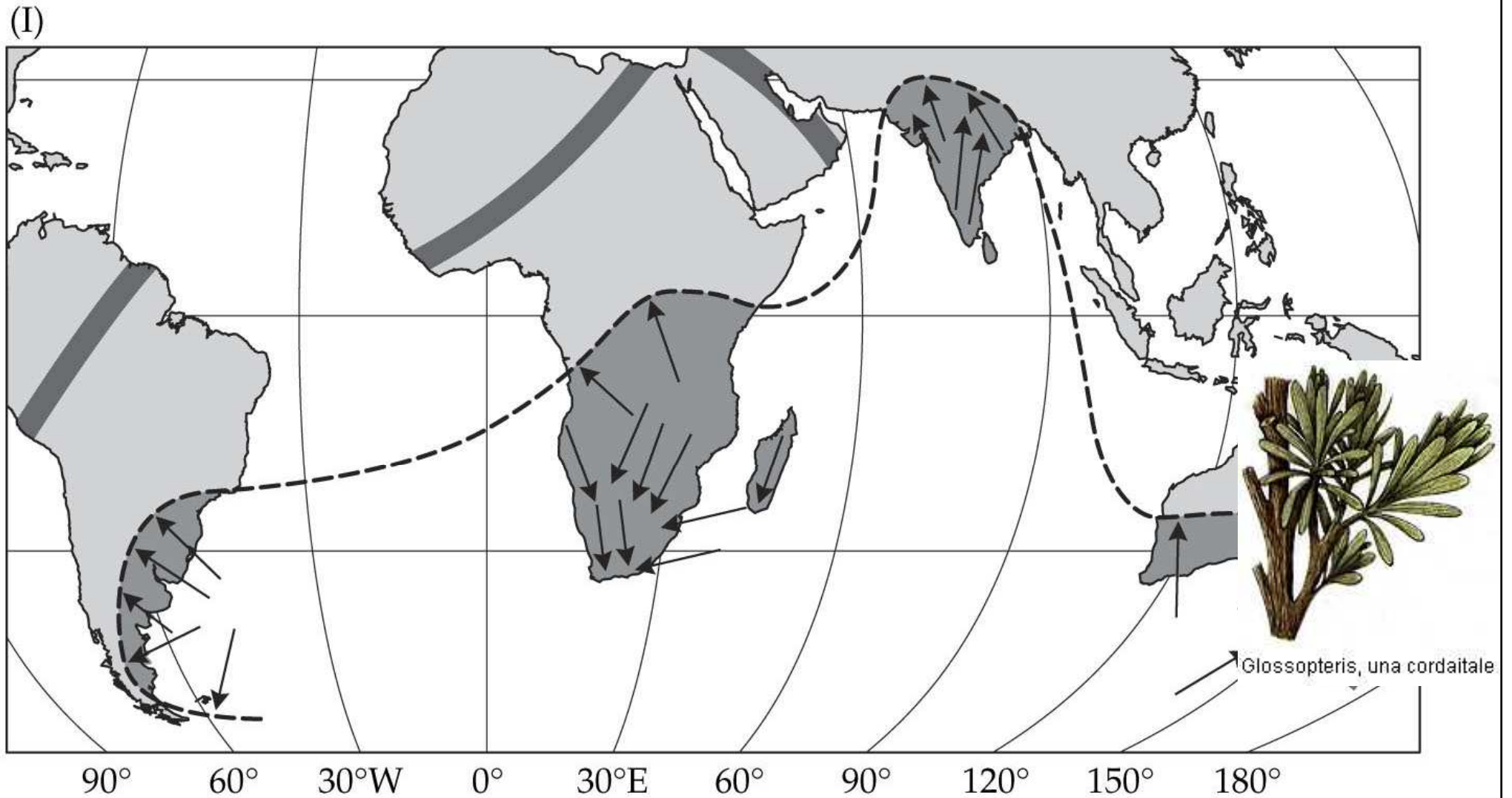
- at the feet of treelike plants: *seed ferns*

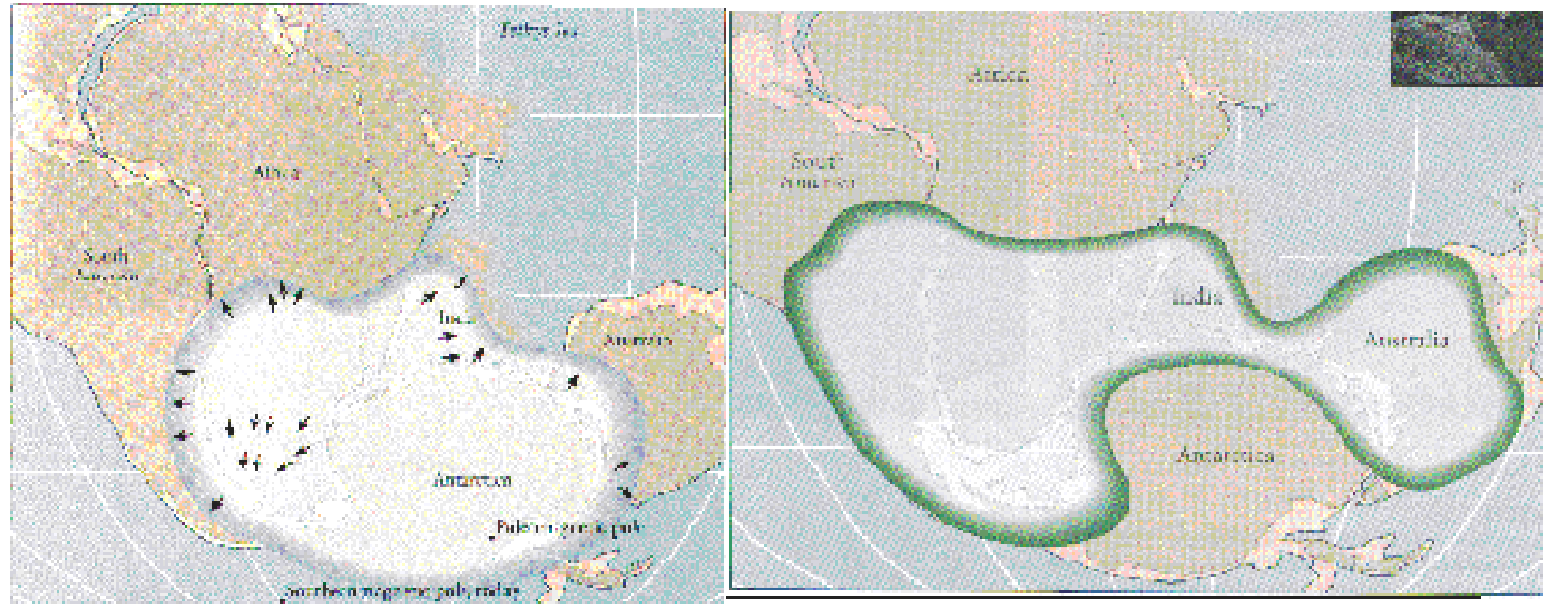


Glossopteris



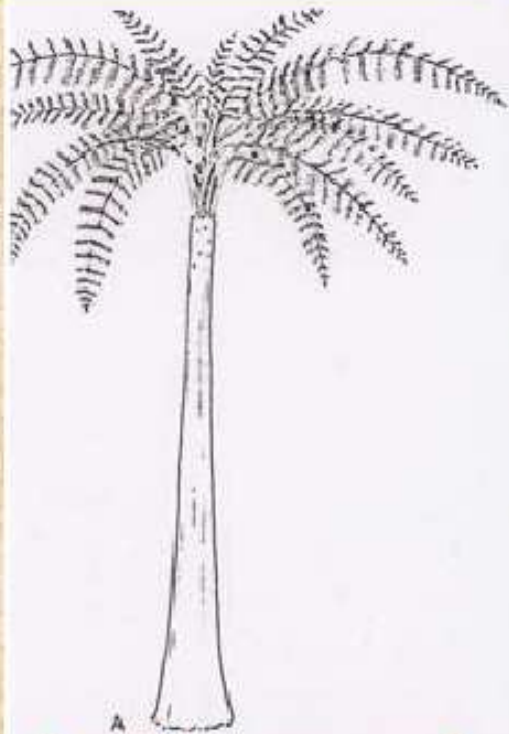
Glossopteris Flora – Permian Ferns





Left. Reconstruction of glacial coverage of *Pangea*. On all of these continents, South America, Africa, India, Australia and Antarctica, there is evidence for glacial activity. The arrows give the direction of movement.

Right. Geographic extent of the Carboniferous age fossil *Glossopteris*, a fern. If the continents are all put together, its geographic extent is well explained.



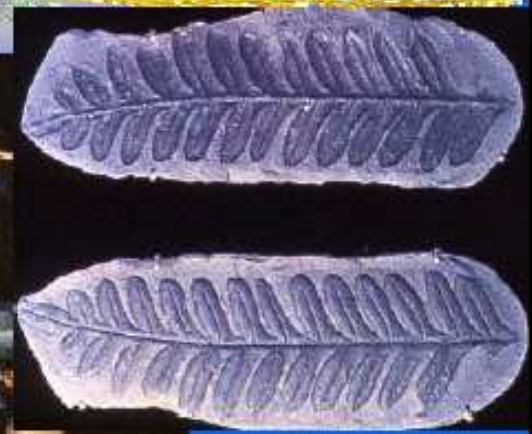
"Tree Fern"
- pteropsids
3-5m



Pennsylvanian
seeds of seed
fern *Neuropteris*



Primitive
insect
Stenodictya



Seed ferns (Pteridosperms) are primitive seed bearing gymnosperms.

Carboniferous (carbon-bearing period) coal swamp plants included tree ferns, seed ferns and true ferns.

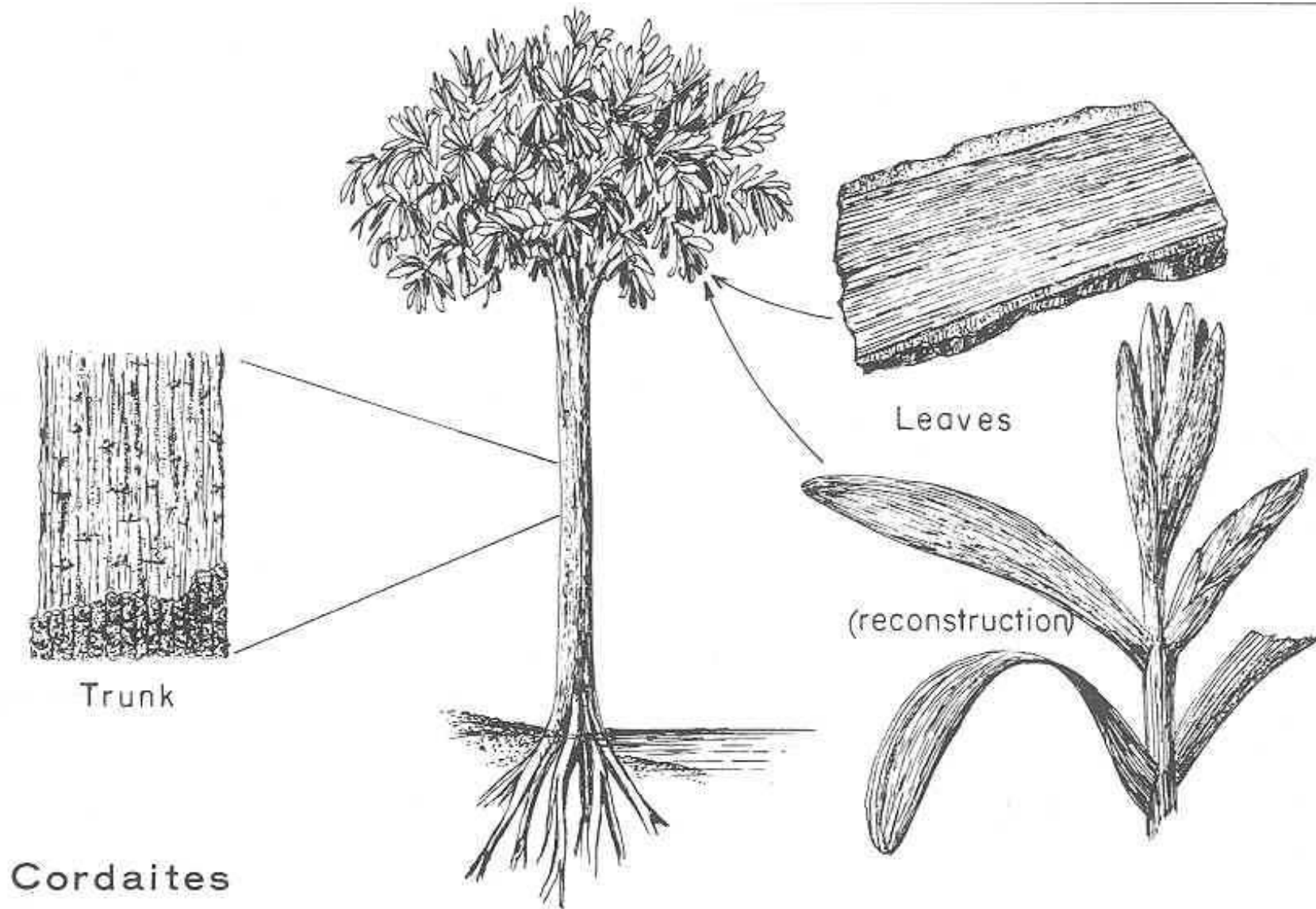
Gymnosperms Free to Migrate

- In this way the need for a moist environment
 - for the gametophyte generation is solved
- The significance of this development
- is that seed plants,
 - like reptiles,
 - were no longer restricted
 - to wet areas
 - but were free to migrate
 - into previously unoccupied dry environments

Plants on Higher and Drier Ground

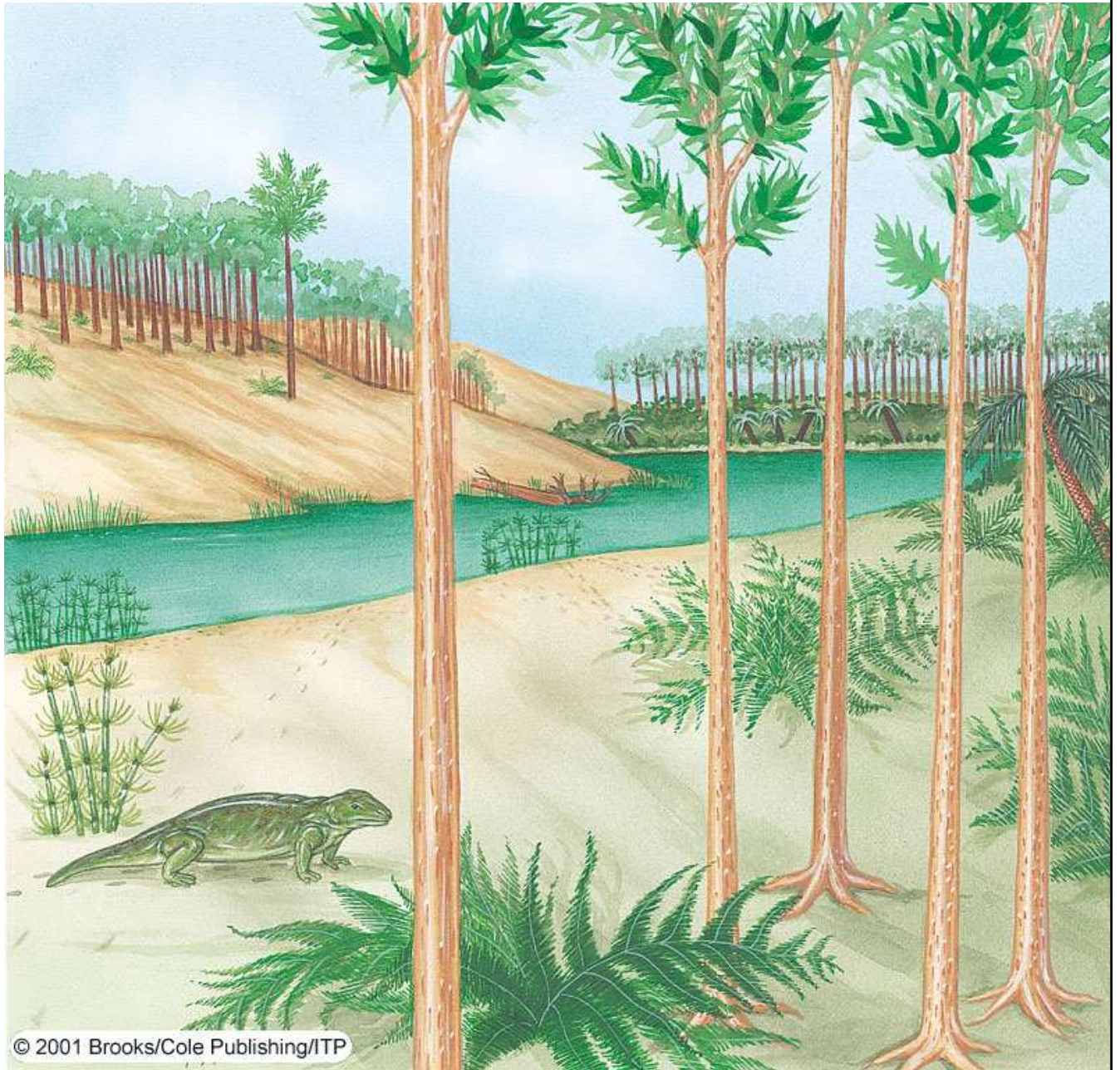
- Not all plants were restricted to the coal-forming swamps
- Among those plants occupying higher and drier ground were some of the *cordaites*,
 - a group of tall gymnosperm trees
 - that grew up to 50 m
 - and probably formed vast forests

1. **Cordaites** were tall trees (up to 100 ft). **Seed plants**. A type of **gymnosperm**.



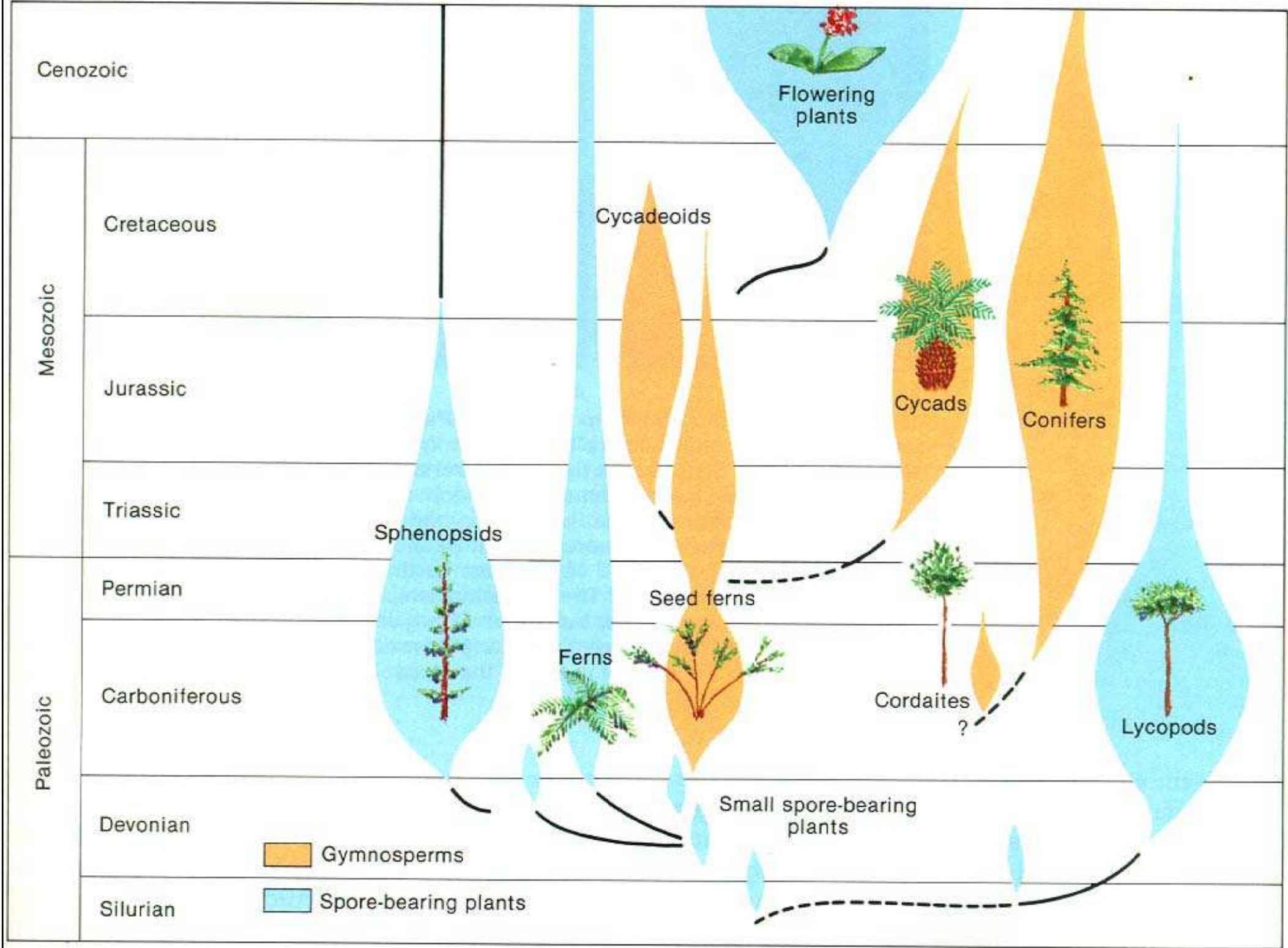
A Cordaite Forest

- A cordaite forest from the Late Carboniferous
- Cordaites were a group of gymnosperm trees that grew up to 50 m tall



Climatic and Geologic Changes

- The floras that were abundant
 - during the Pennsylvanian
 - persisted into the Permian,
 - but due to climatic and
 - geologic changes resulting from tectonic events,
 - they declined in abundance and importance
- By the end of the Permian,
 - the cordaites became extinct,
 - while the lycopsids and sphenopsids
 - were reduced to mostly small, creeping forms



Gymnosperms Diversified

- Those gymnosperms
 - with lifestyles more suited to the warmer and drier Permian climates
 - diversified and came to dominate the Permian, Triassic, and Jurassic landscapes

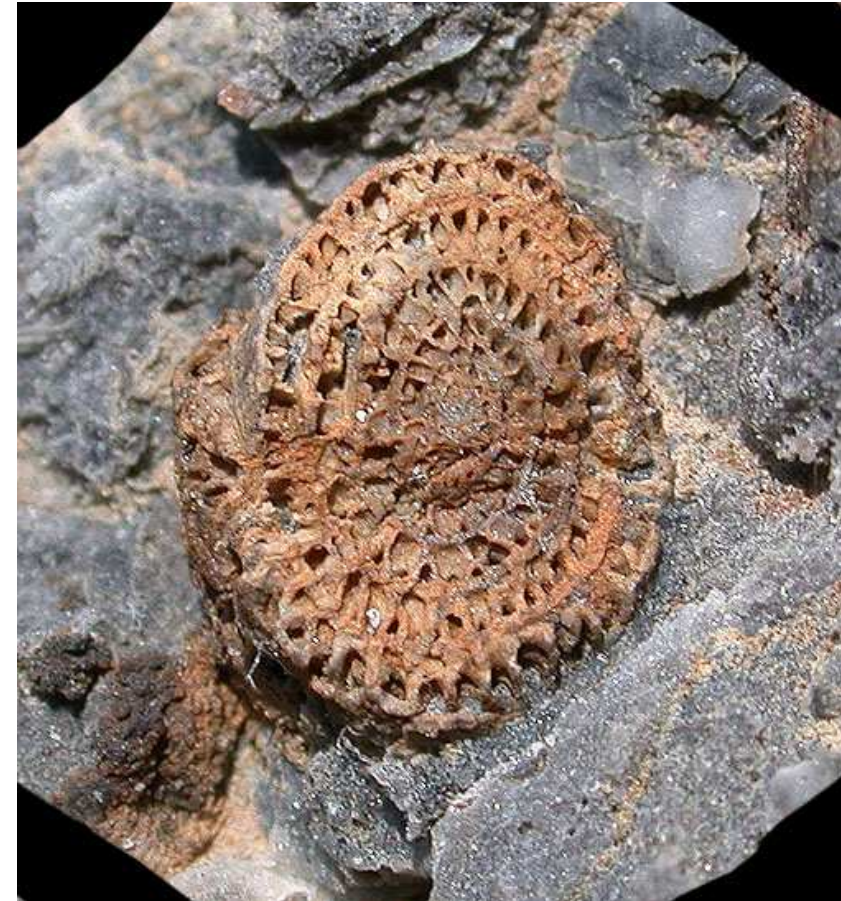
FAUNA

Foraminifers – endothyrid type dominate in lower Carboniferous, since upper Carboniferous dominated by fusulinids.

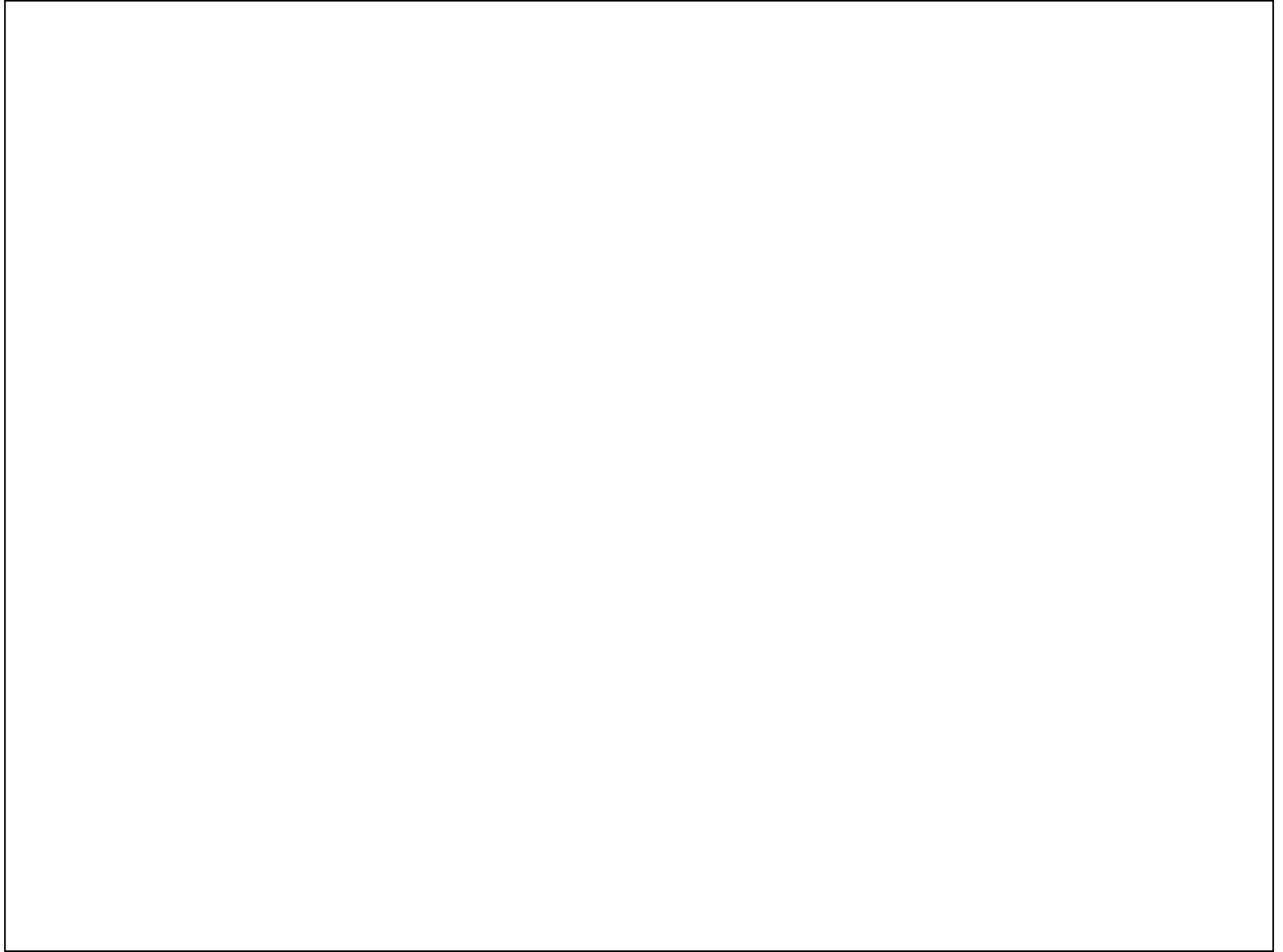
They were quite large – several cm. Rock-forming – fusulinid limestones.

Fusulinid

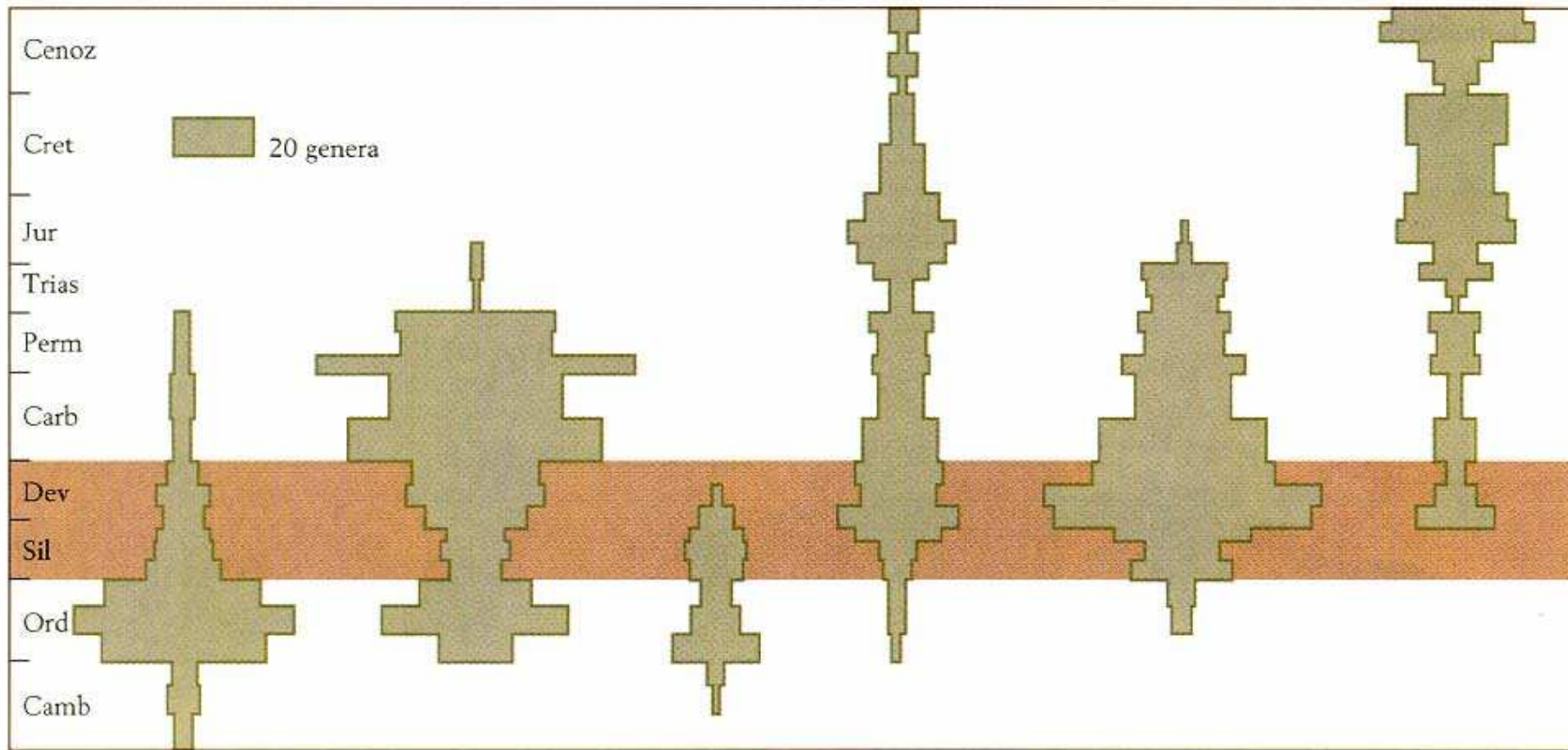
foraminifera: *Parafusulina* sp.. Scale bar is 1 cm long.



A natural cross-section of a silicified *Stewartina* sp. fusulinid from the Lower Permian Owens Valley Group, Inyo County, California; an iron mineral called limonite has created the reddish-brown coloration of the specimen, which here reveals in splendid fashion



Brachiopods — decreasing diversity, Strophomenida, Productus, Gigantoproductus in Carboniferous, in Permian also thick-walled forms as Horridonia and Richthofenia



Orthida

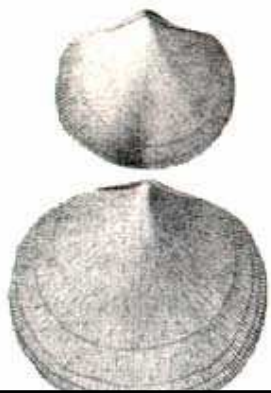
Strophomenida

Pentamerida

Rhychonellida

Spiriferida

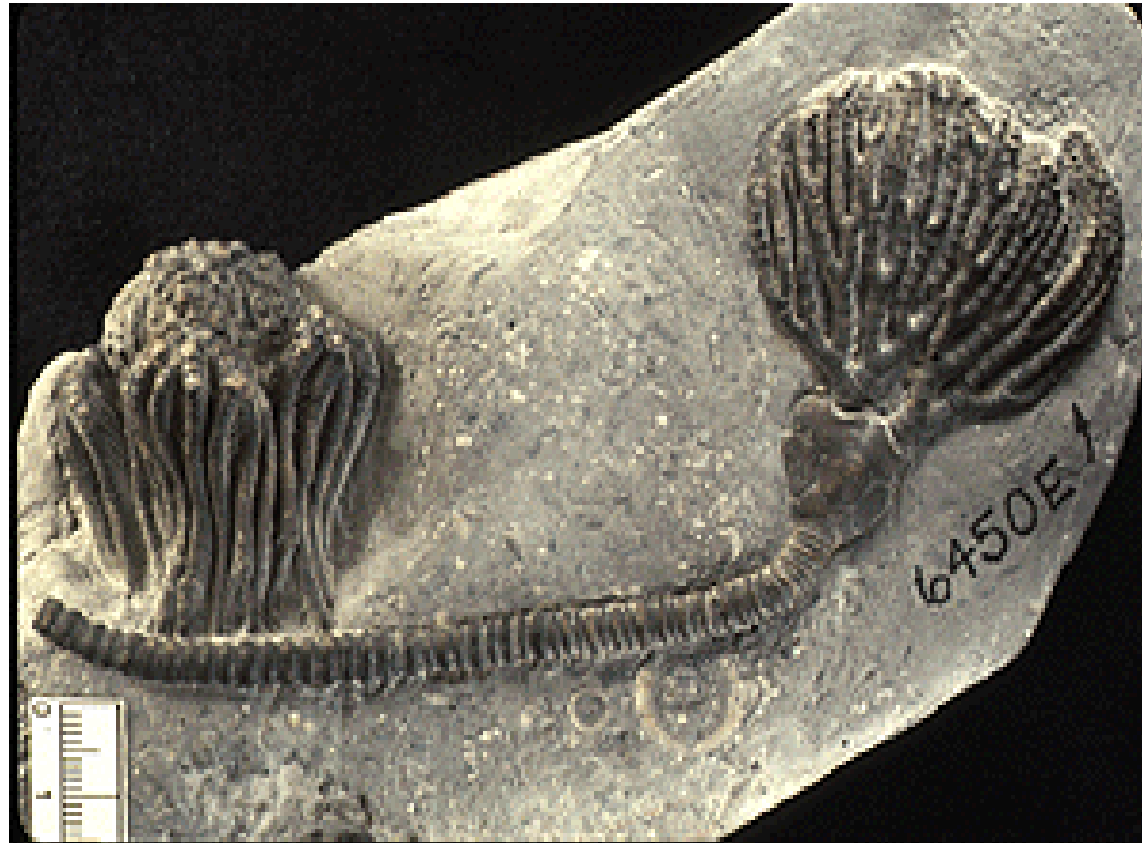
Terebratulida



Crinoids – rock-forming significance, increasing representtaion of **echinoids**.



*Pachylocrinus
aequalis* (Hall)
Early
Mississippian,
Crawfordsville,
Montgomery Co.,
Indiana
Recrystallized



- *Cyathocrinites multibrachiatus* (Lyon & Casseday)
- Early Mississippian, Crawfordsville, Montgomery Co., Indiana
- Recrystallized

Echinodermata - Crinoidea



*Barycrinus
hoveyi* (Hall)

Early
Mississippian,
Crawfordsville,
Montgomery Co.,
Indiana

Recrystallized

Tabulate and rugose corals - Kohlenkalk

Rugose Coral
Location: Near Sonoita Az.
Age: Permian

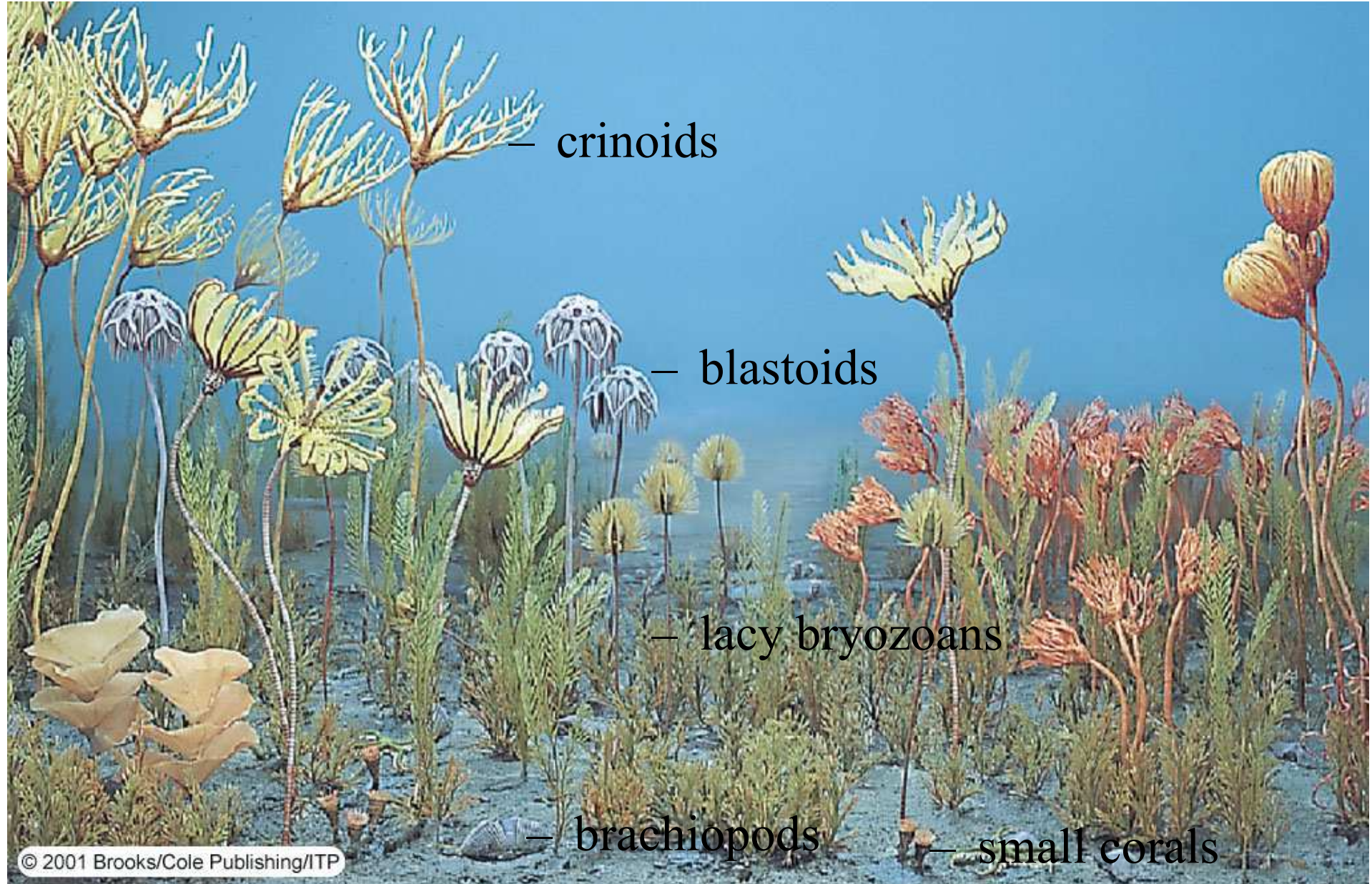


Bryozoans-rock-forming significance

Class: Stenolaemata
Order: Fenestrata
Bryozoa
Location: Near Sonoita Az.
Age: Permian

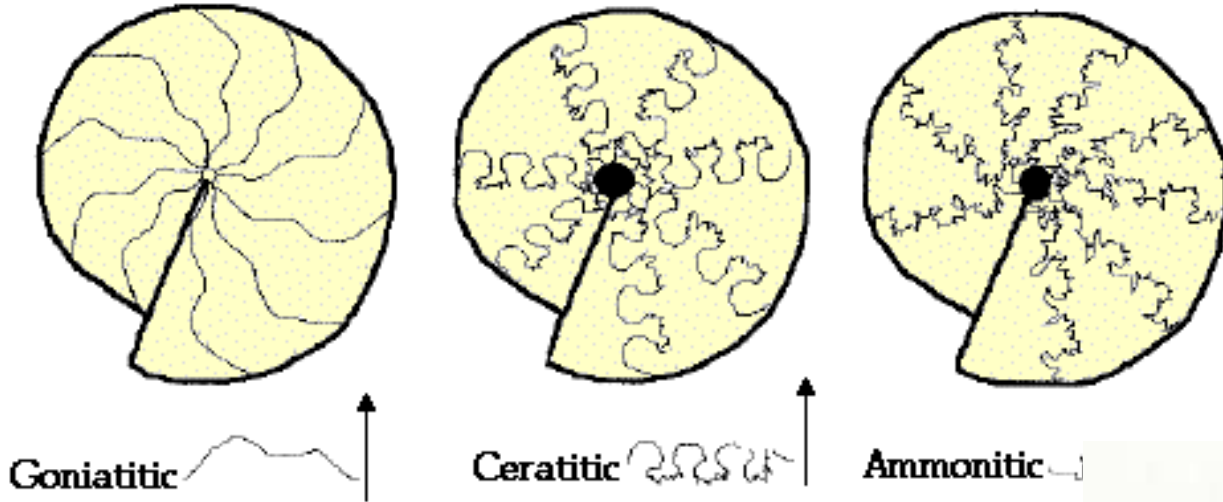


Reconstructed Upper Mississippian carbonate bottom at Crawford, Indiana. Invertebrate animals shown include:



Molluscs

Ammonites with goniatite type of suture, in upper Permian ceratite type of suture.



of aperture

Goniatites



Bivalves — in Carboniferous widespread epiplanctonic groups as *Posidonia becheri*



Colonization of fresh-water environment –
Carbonicola

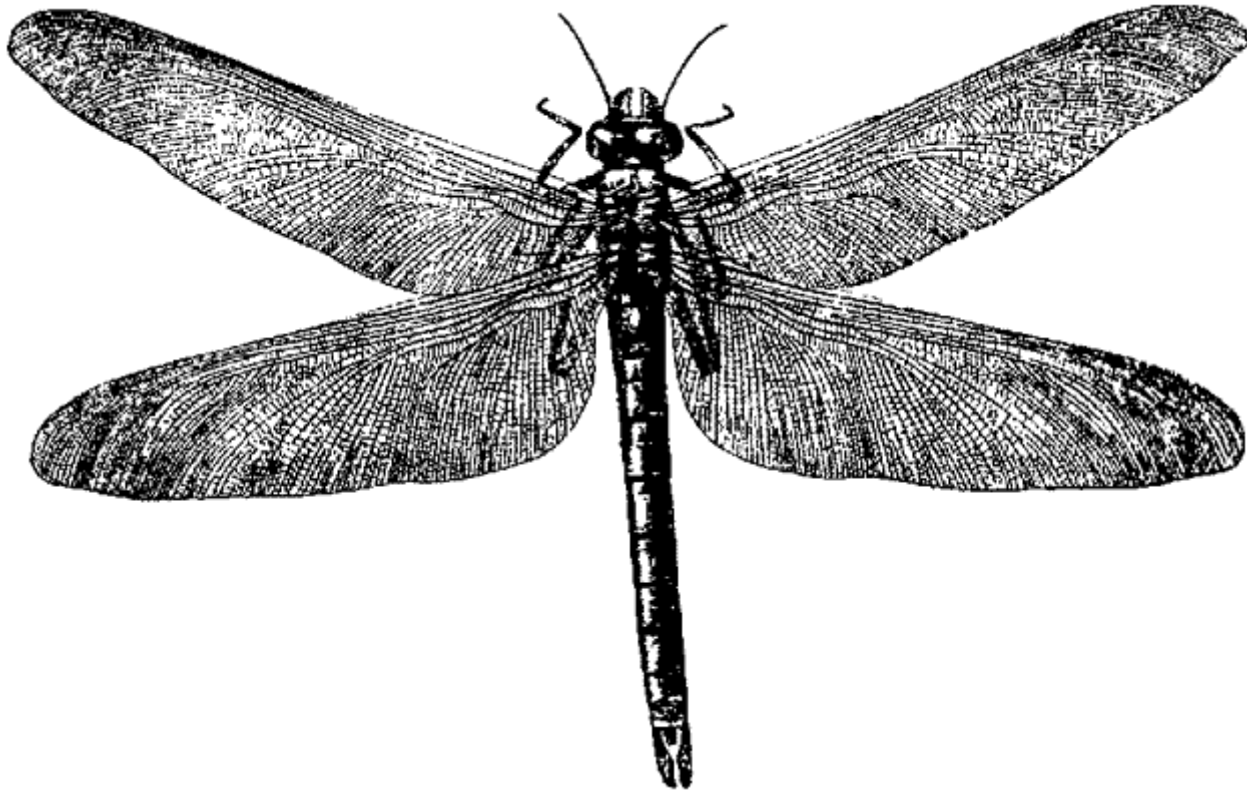


Carbonicola acuta
Laura. Westfalien A. Coll. Bart Vernooy.
Length 2.5 cms

Gastropods — first representatives of Pulmonata

Trilobites — decreasing representation, Proetida

Radiation of terrestrial arthropods, especially of insects. Winged Insects, Paleoptera. Also Neoptera, in Permian dominate. Arthropleura.



Meganuera monyi - order Meganisoptera
a giant dragonfly (order [Protodonata](#))
wingspan 60 to 75 cm
[Carboniferous](#) of Europe.

Late Pennsylvanian
myriapod (millipede)



Late Pennsylvanian
centipede from
Mazon Creek



Age of Cockroaches (15 cm)
and dragonflies with .5 m

Insect similar
to katydid

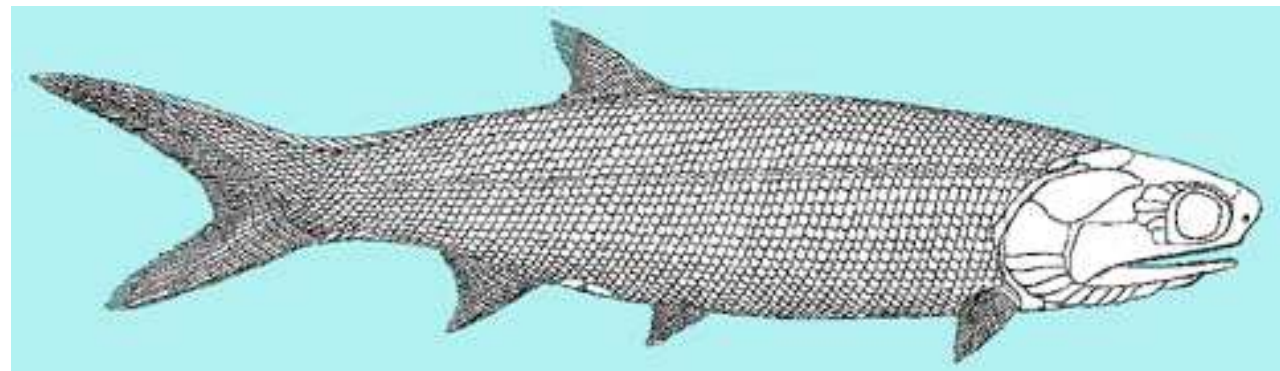


Conodonts — stratigraphically important. *Suiphonodella*, *Scaliognathus*, *Gnathodus*

Sharks — also rivers and lakes. *Xenacanthus*, *Ctenacanthus*.



Actinopterygii — predominately *Chondrostei*, *Paleoniscida*, *Paleoniscus*



Amphibia — Stegocephali. Carboniferous – age of amphibians.



Discosauriscus

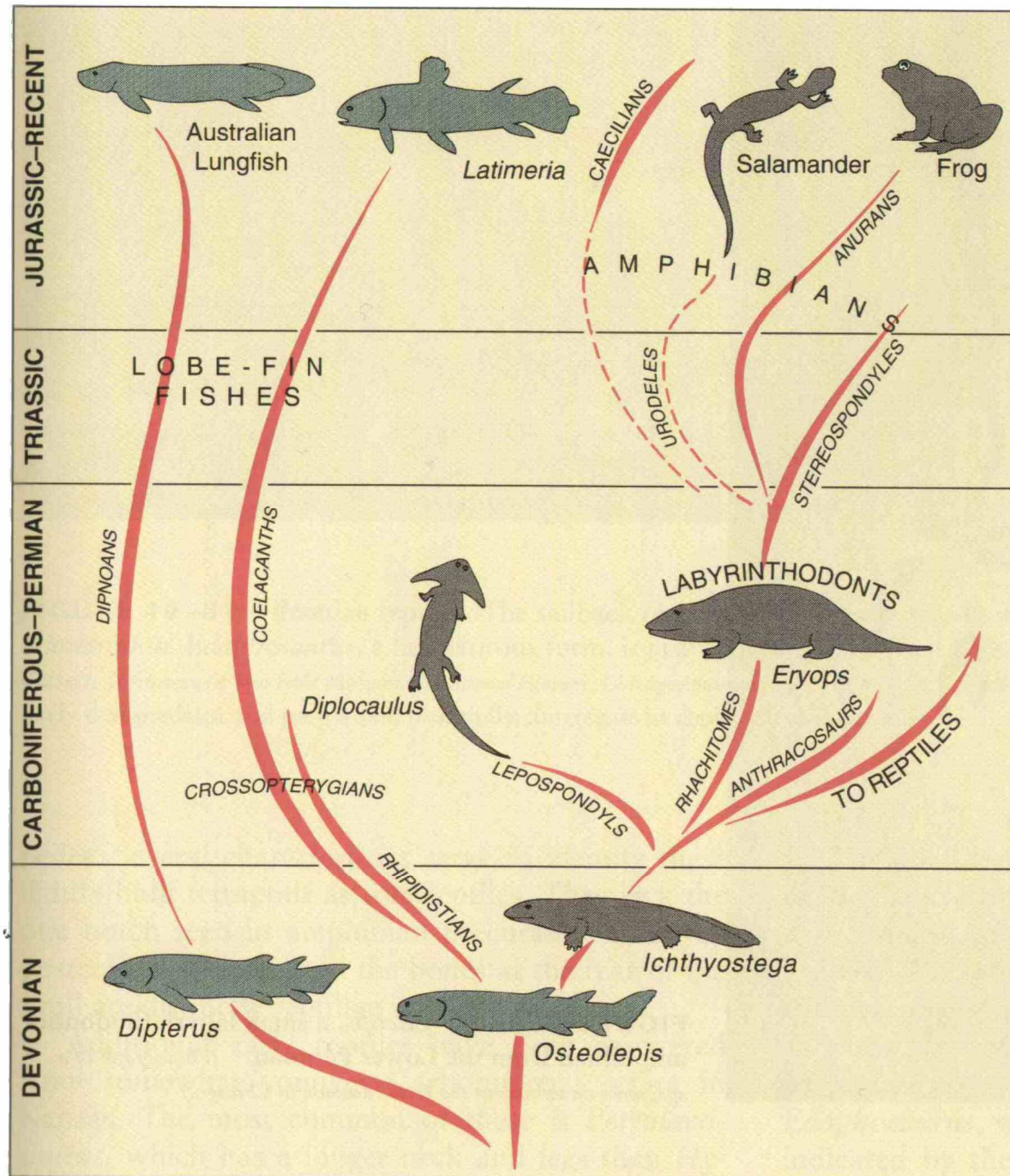


FIGURE 10-78 The evolution of amphibians and lobe-fin fishes. (From Colbert, E. H., and Morales, M. 1991. *Evolution of the Vertebrates, 4th ed.* New York: John Wiley. With permission of the author, artist Lois Darling, and the publisher.)

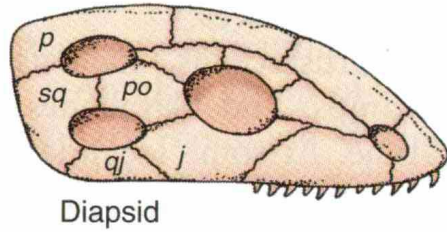
Reptiles

Cotylosauria (anapsids) - first reptiles in middle Carboniferous)

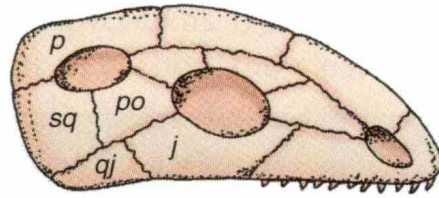
Pelycosauria mammal-like reptiles, synapsids, first in Late Carboniferous, extinct in middle Permian

Therapsida – synapsids, predecessors of mammals, middle Triassic

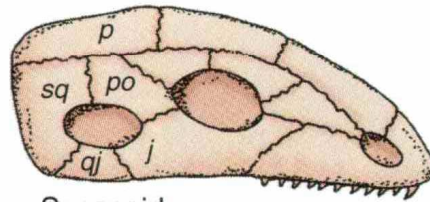
Notosaurs (euryapsids), Tcecodonts (diapsids) – late Permian



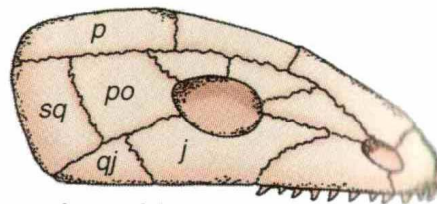
Diapsid



Euryapsid



Synapsid



Anapsid

FIGURE 12–23 Reptile skull types. (*p*, parietal; *sq*, squamosal; *po*, postorbital; *j*, jugal; *qj*, quadratojugal.)

🕒 In which of the above groups are dinosaurs placed?

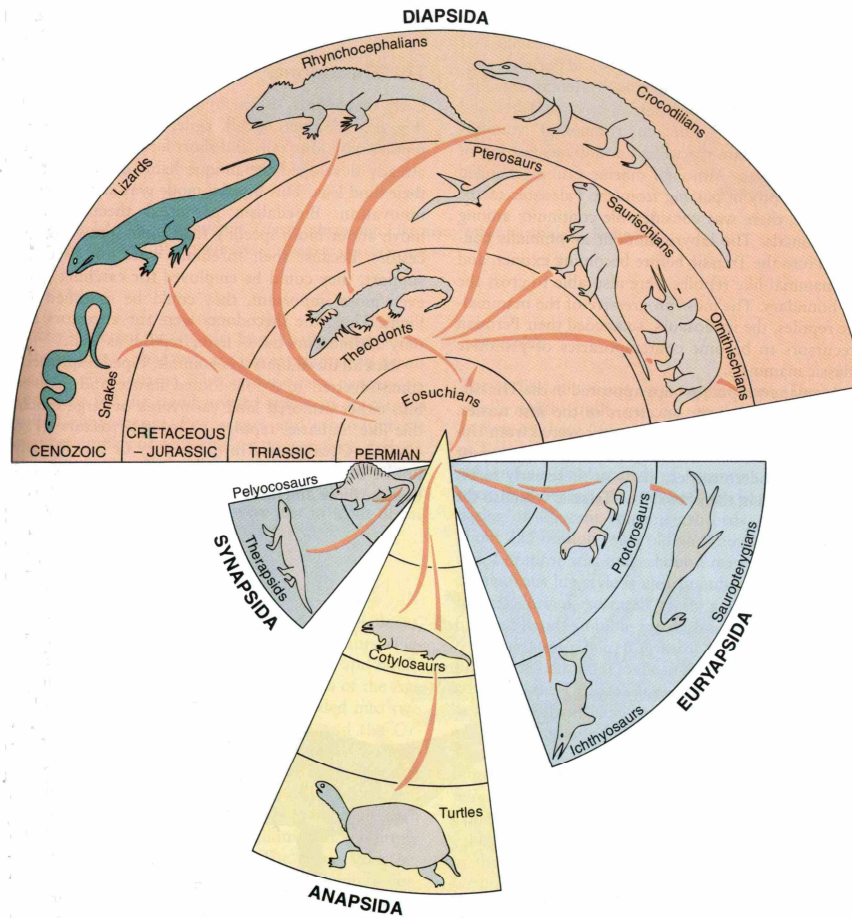
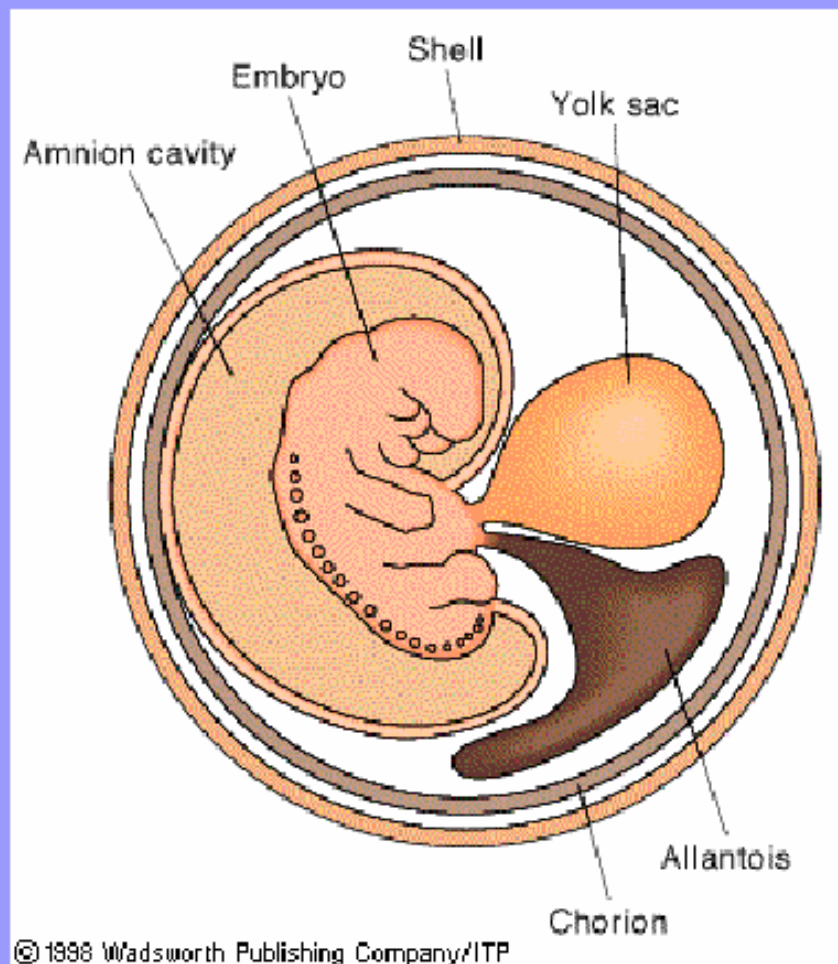


FIGURE 12-24 Evolution and general classification of reptiles. In this classification, reptiles are grouped according to the position and number of temporal openings in the skull (see Fig 12-23). Anapsida have no openings. Diapsida have two, Synapsida have one located low on the skull, and Euryapsida have one located higher on the skull. Rhynchocephalians, crocodilians, pterosaurs, saurischians, ornithischians, and thecodonts are diapsids of the superorder Archosauria. (From Colbert, E. H. 1969. *Evolution of the Vertebrates*. New York: John Wiley & Sons.)

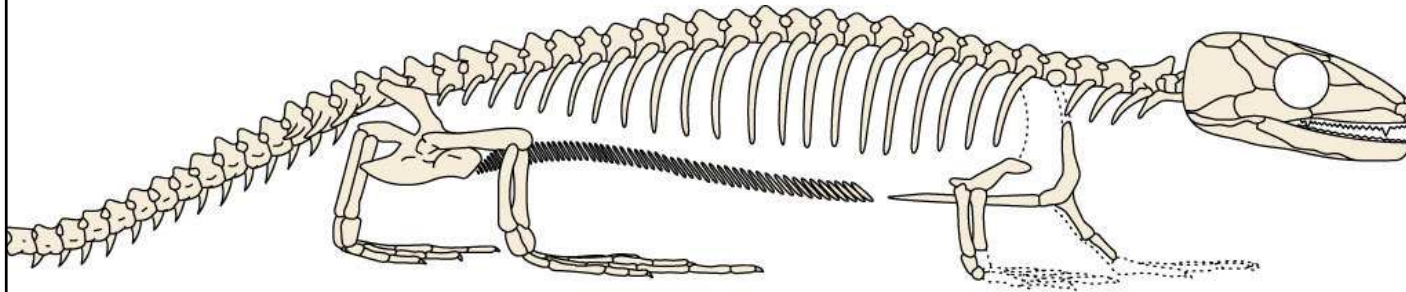
Evolution of the Reptiles - The Land is Conquered

- The evolution of the **amniote egg** freed reptiles from the constraint of returning to water to reproduce
 - amnion - liquid filled sac surrounding the embryo
 - allantois - waste sac
 - a tough shell protects the developing fetus
 - reptiles were able to colonize all parts of the land

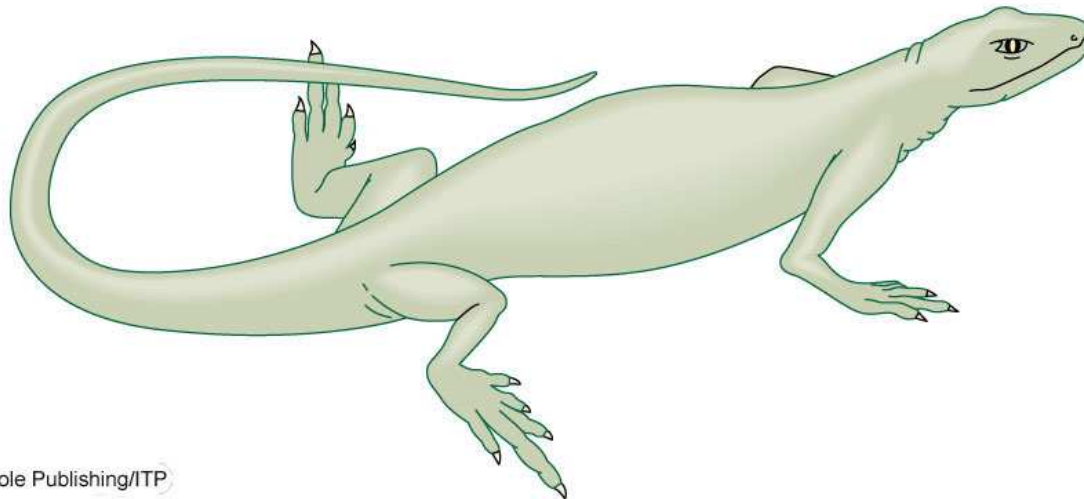


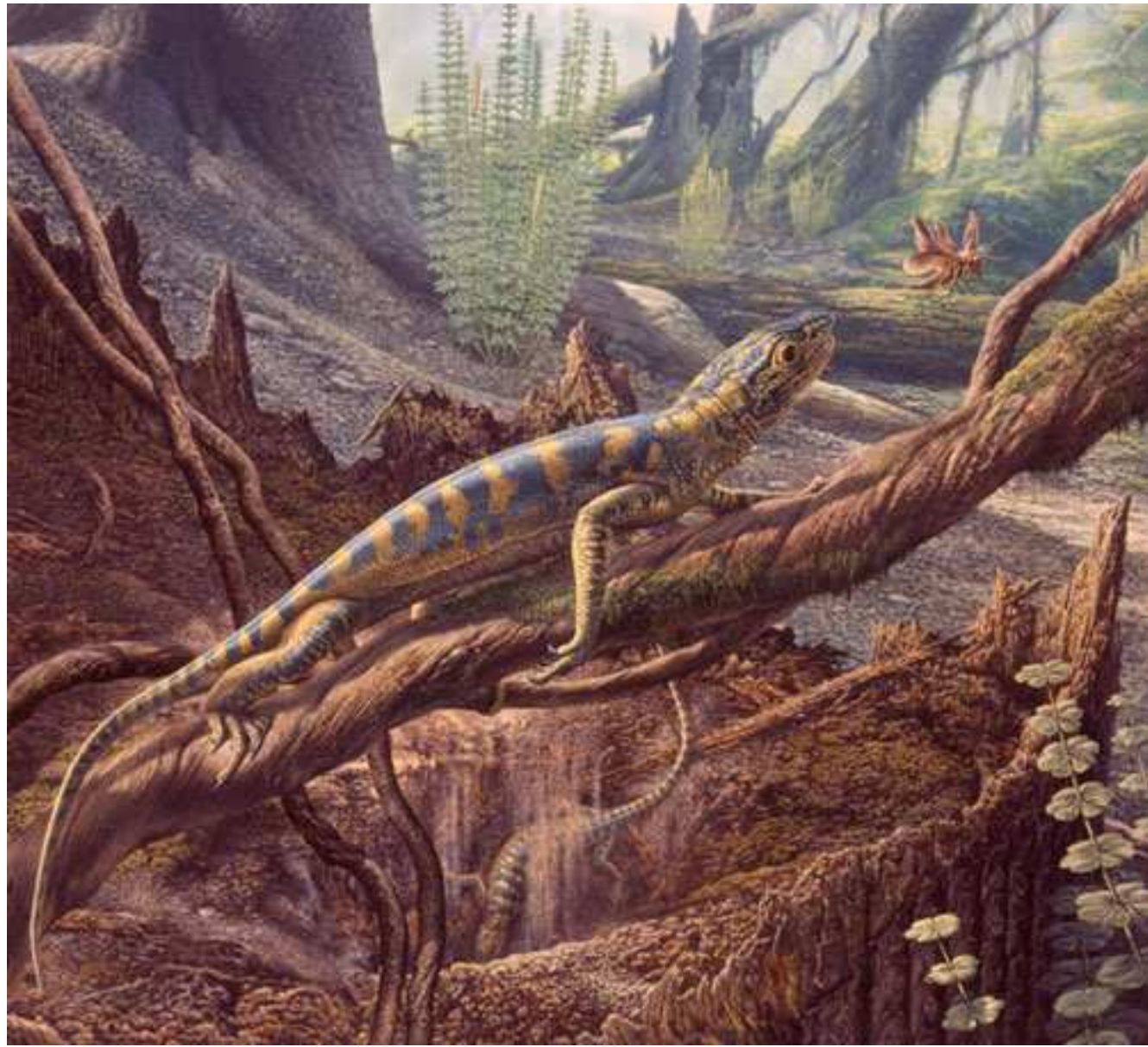
One of the Oldest Known Reptiles

- Reconstruction and skeleton of *Hylonomus lyelli* from the Pennsylvanian Period



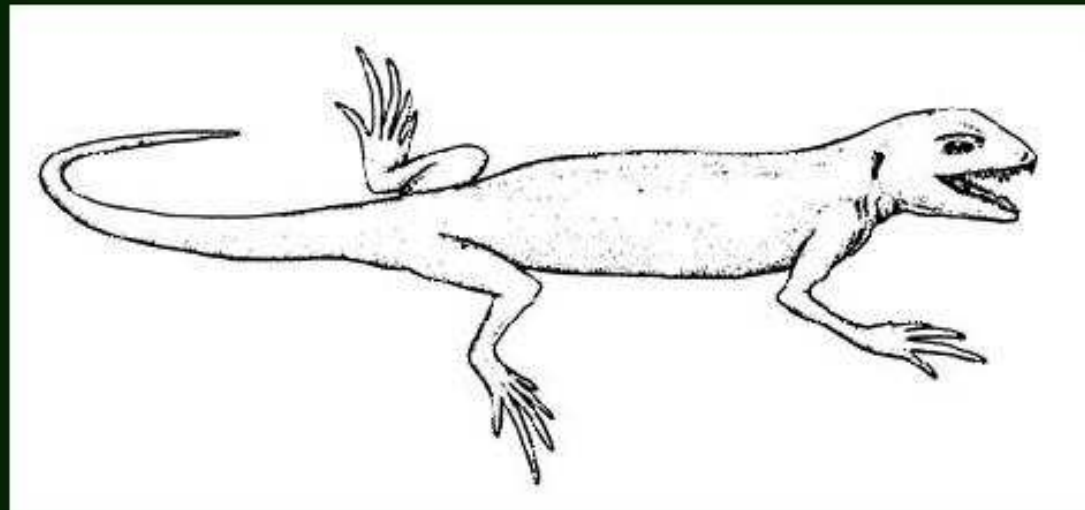
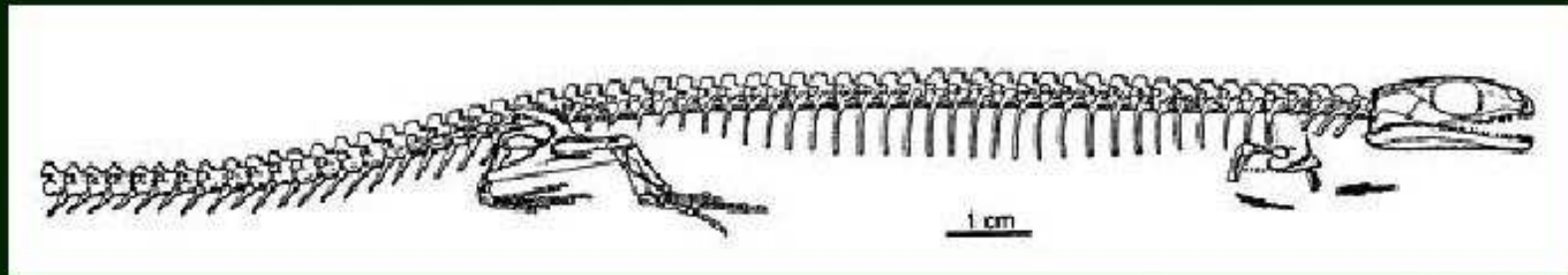
– *Hylonomus lyelli*
was about 30 cm
long





Oldest known reptile - Mississippian

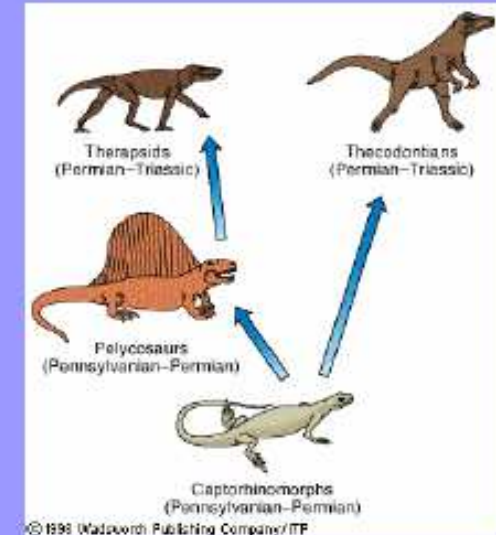
Westlothiana and anthracosaurs



Westlothiana (top) may be the oldest known probable amniote.
Cephalerpeton (bottom) is an anthracosaur, another amniote relative.

Evolution of the Reptiles - The Land is Conquered

- The earliest reptiles are from the Lower Pennsylvanian
 - called protorothyrids, they were small, agile, and fed on grubs and insects
 - success due to advanced reproductive methods, more advanced jaws and teeth, and speed
 - Pelycosauurs evolved from this group and were the dominant reptile by Permian



TRIASSIC

ICTIOSAUERS



Cynognathus



Dicynodon

THERAPSID

PERMIAN

PELYCOSAURS



Edaphosaurus

EDAPHOSAURS



Dimetrodon

OPHIACODONTS



Ophiacodon

SPHENACODONTS

THERIODONTS
DINOCEPHALIANS



Moschops

ANOMODONTS

Pelycosaurs were abundant at low latitudes in early Permian, but disappeared by mid-Permian.

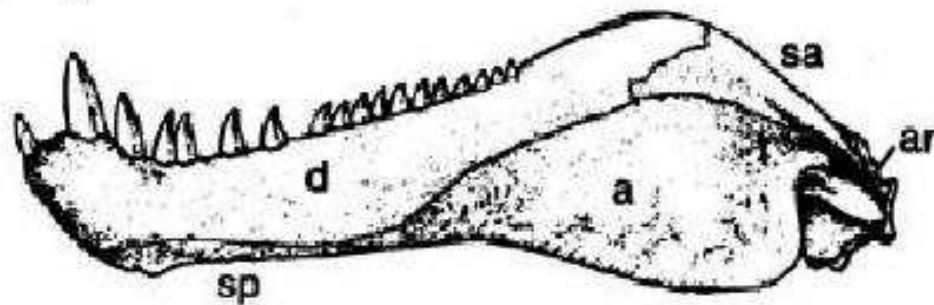
At low latitudes, **Diapsid Reptiles** became important.

At high latitudes, **Therapsids** (descendants of pelycosaurs) and **Anapsid Reptiles** became important.

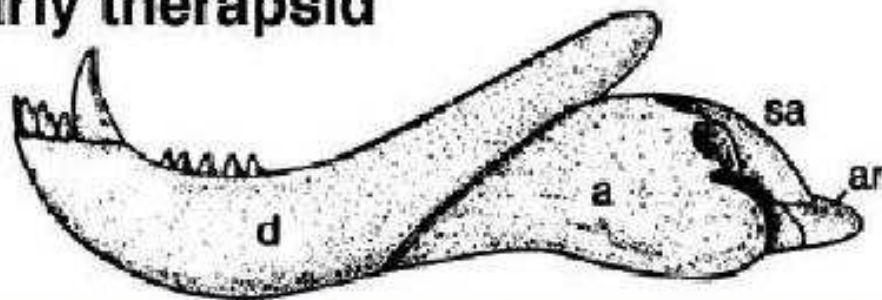
Pelycosaur

Pelycosaur vs. Therapsid Jaw

pelycosaur



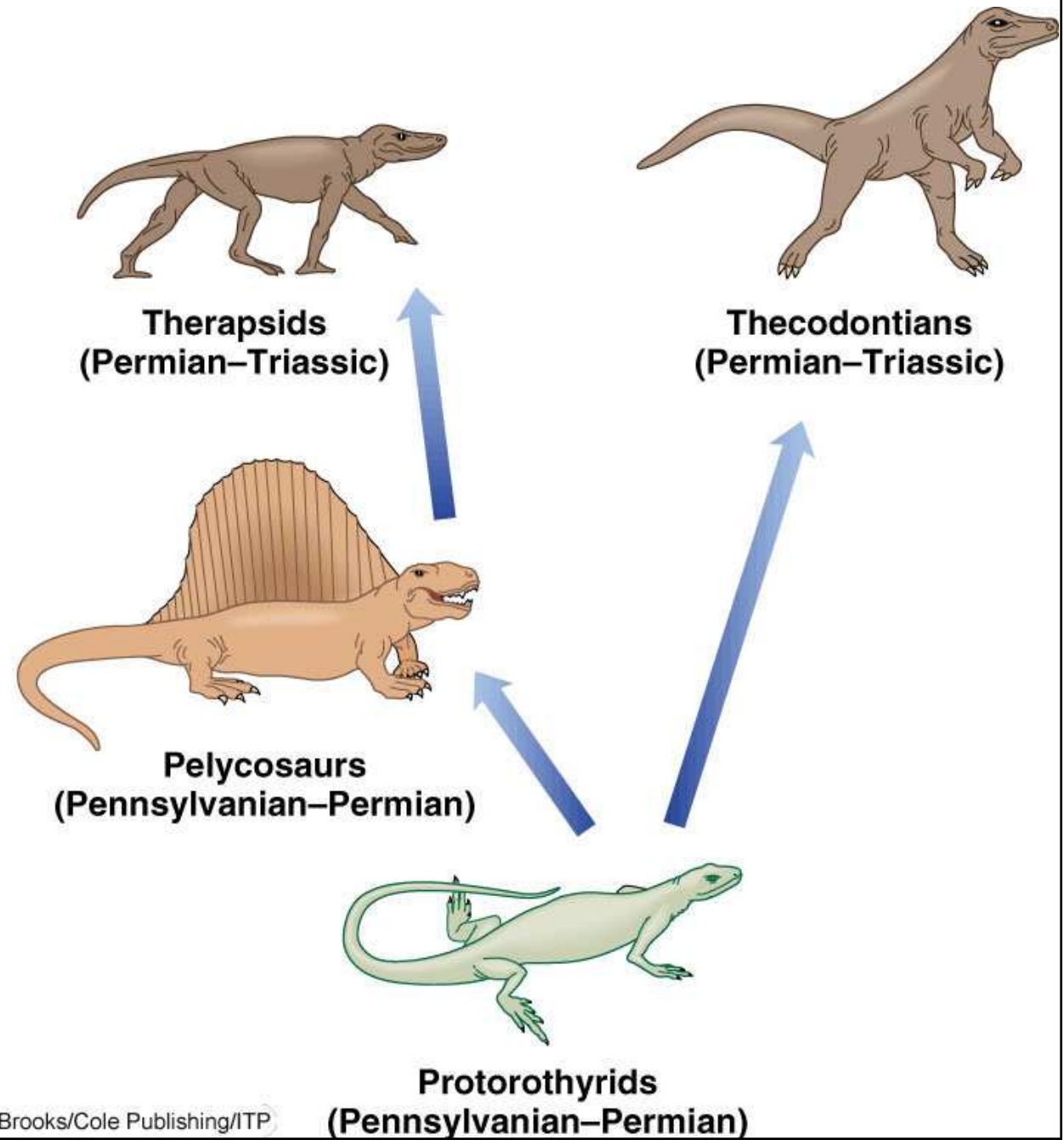
early therapsid



Although Therapsids resemble pelycosaurs in some ways, they had a much larger hole in the outer skull armor, flange on lower jaw for muscle attachment, and shorter heads. All these differences from pelycosaurs are related to more elaborate chewing. In addition, some had a more upright posture.

Paleozoic Reptile Evolution

- Evolutionary relationship among the Paleozoic reptiles



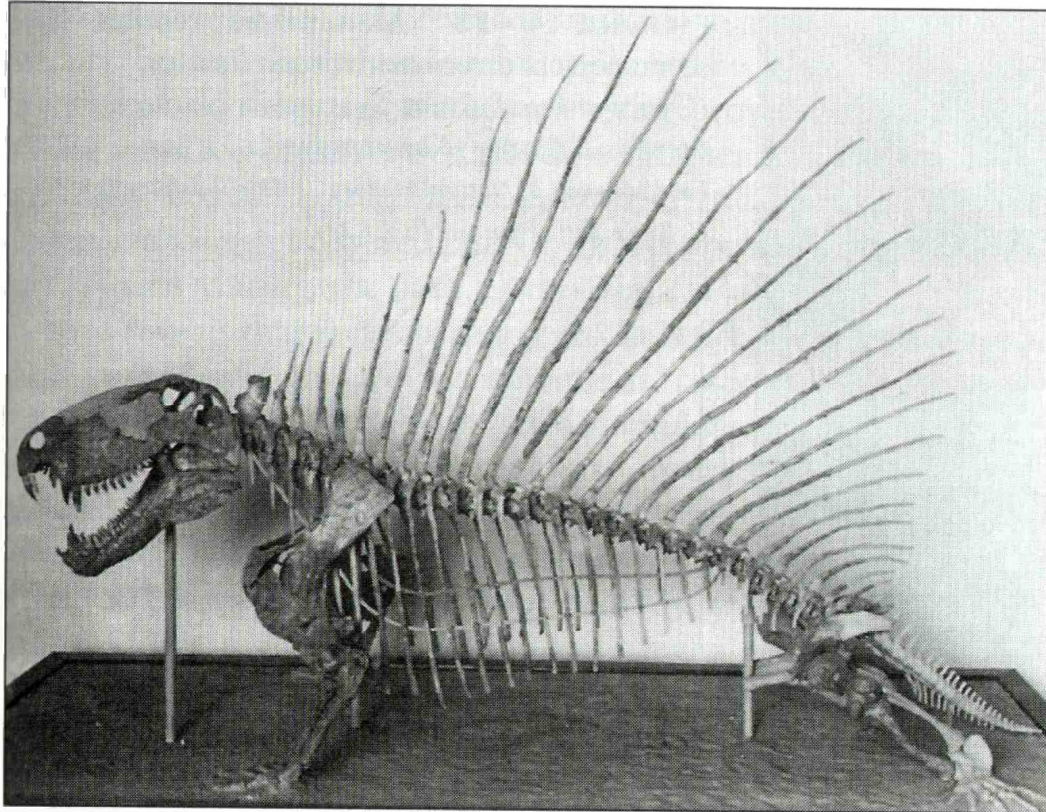


FIGURE 10–82 Mounted skeleton of the Permian “sail-reptile” *Dimetrodon gigas*. The tail was actually somewhat longer. (Courtesy of the U. S. National Museum of Natural History, Smithsonian Institution.)

Pre-	Є	Є	O	S	D	M	P	Pr	Tr	J	K	T	Q
------	---	---	---	---	---	---	---	----	----	---	---	---	---

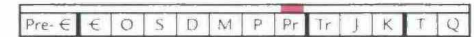
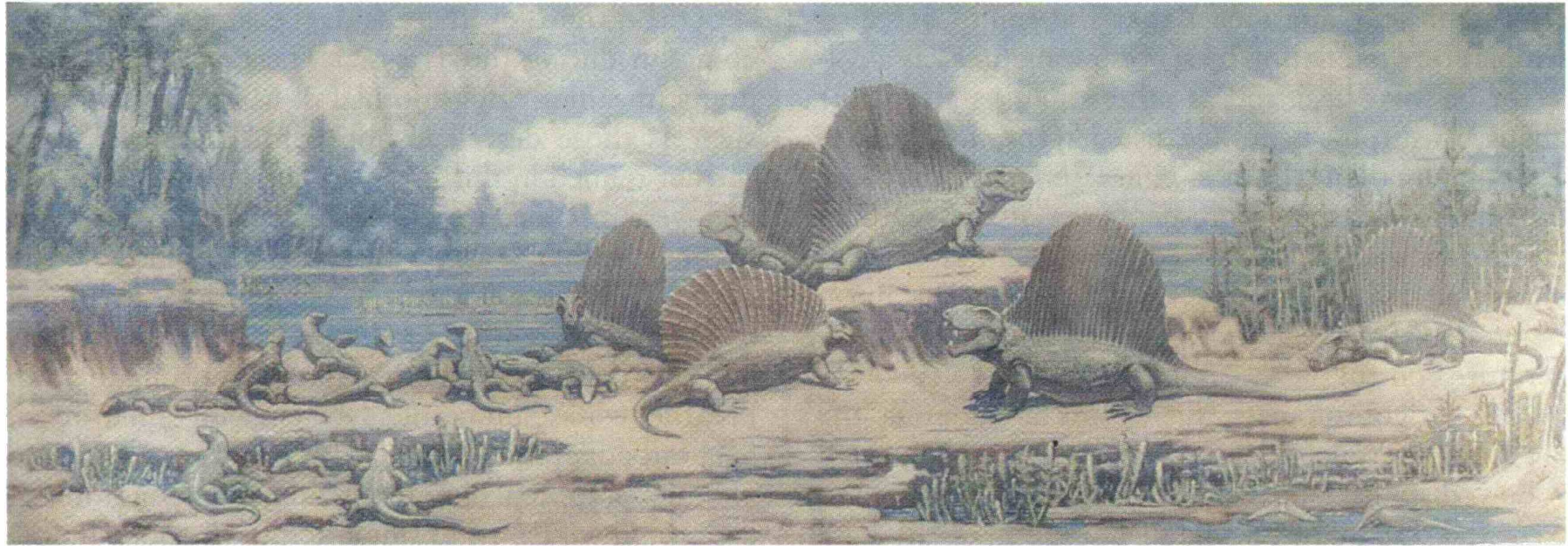


FIGURE 10–81 Permian reptiles. The sailback reptiles with the larger skulls and teeth are *Dimetrodon*. *Edaphosaurus*, a herbivorous form, is just right of center. The smaller lizardlike reptiles are *Casea*. (Courtesy of The Field Museum of Natural History, Chicago; painting by C. R. Knight; Negative No. CK45T.) 🤖 Is it likely that predator and prey would peacefully congregate as depicted in this mural?

Therapsids



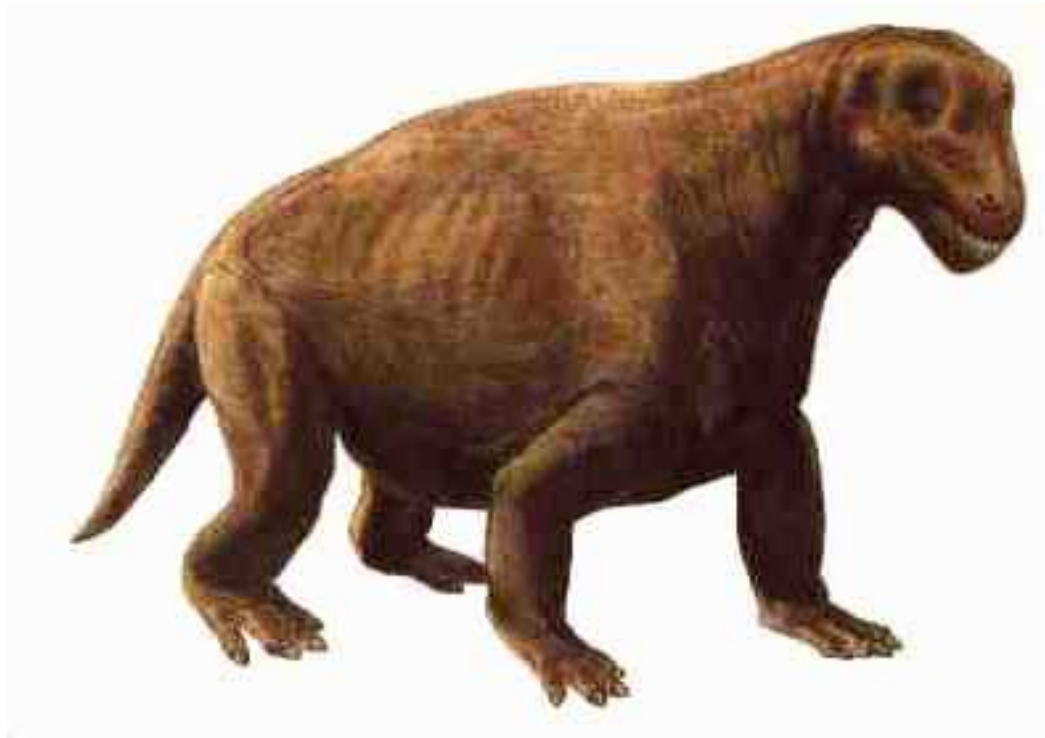
Der Sauroctonus wies bereits ein mächtiges, differenziertes Gebiss auf und wird eines der großen Raubtiere des Perms gewesen sein.(Werk des Künstlers Z. Burian)

Evolution of the Reptiles - The Land is Conquered

- Therapsids succeeded the pelycosaur during the Permian
 - mammal-like reptiles that quickly evolved into herbivorous and carnivorous forms
 - they displayed fewer bones in the skull, enlargement of the lower jawbone, differentiation of the teeth, and a more vertical position of their legs
 - therapsids may have been endothermic, which may help explain their distribution over wide latitudes
- The Permian extinction eliminated about 66% of all amphibians and reptiles



The bear-sized [gorgonopsid](#) *Inostrancevia alexandri* assaulting the ox-sized armoured [pareiasaur](#) herbivore *Scutosaurus karpinski*



Moschops

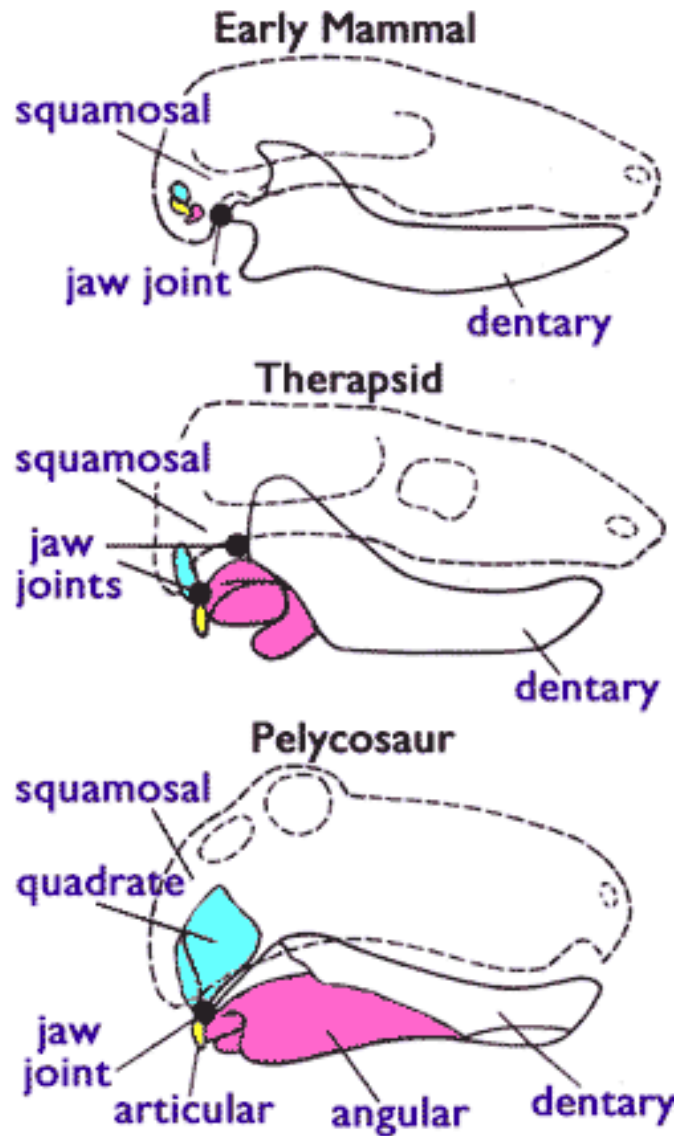
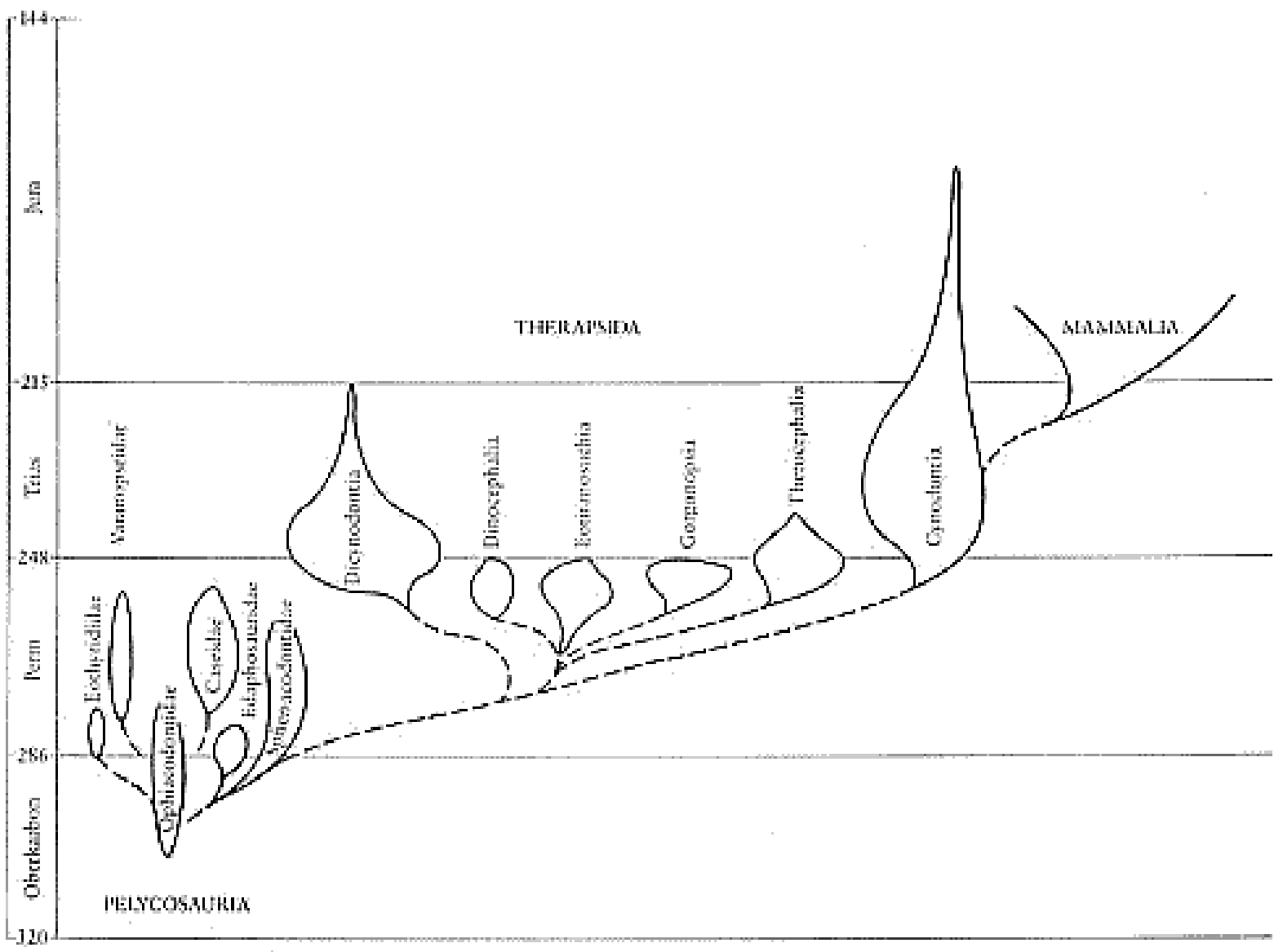
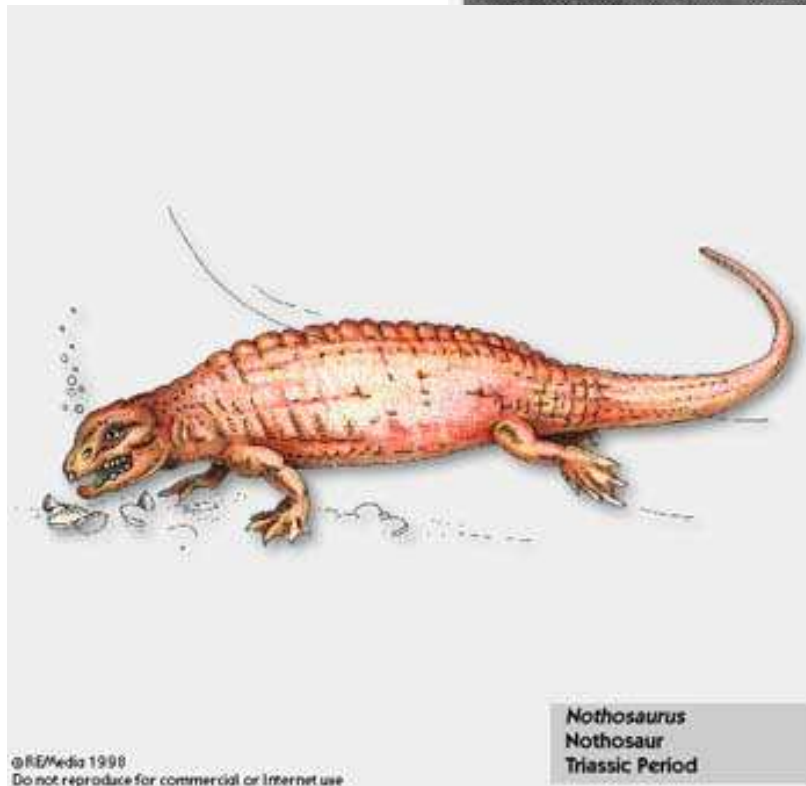
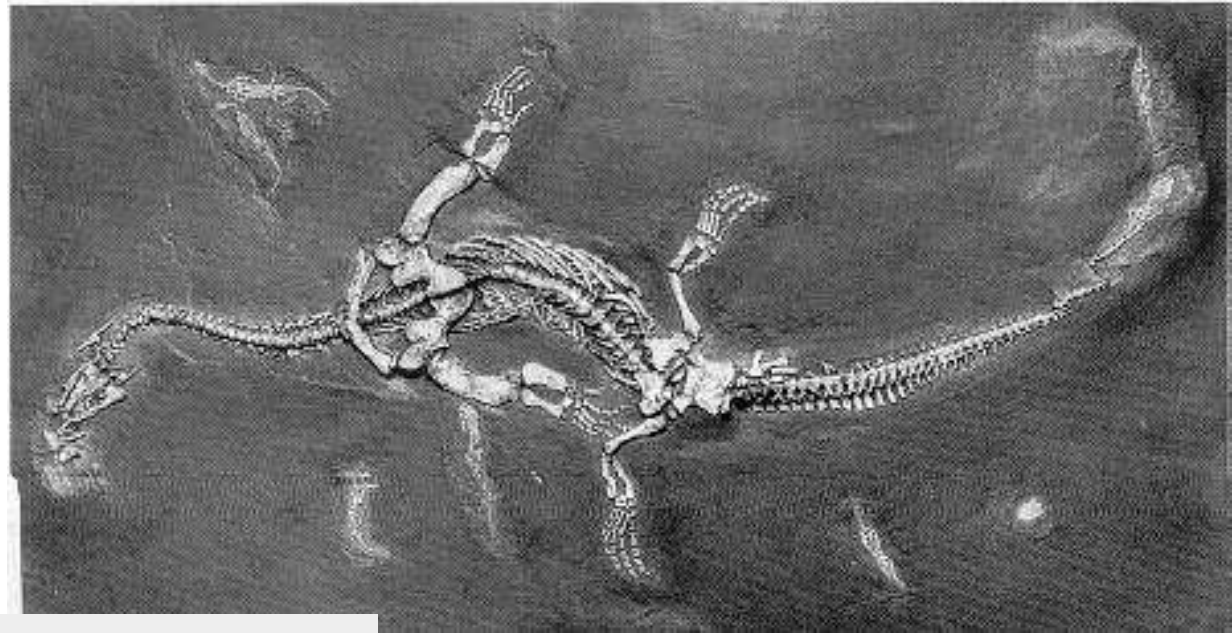


Figure 1.4.1. The jaws of three vertebrates—mammal, therapsid, and pelycosaur. A side view of three idealized skulls of mammals, therapsids (mammal-like reptiles), and pelycosaur (early reptiles). The figure shows the differences between mammal and reptilian jaws and ear-bone structures. The jaw joint is shown as a large black dot, the quadrate (mammalian anvil or incus) is in turquoise, the articular (mammalian hammer or malleus) is in yellow, and the angular (mammalian tympanic annulus) is in pink. Note how, in the reptile, the jaw joint is formed between the blue quadrate and the yellow articular (with the pink angular close by), and how, in the mammal, the jaw joint is formed between the squamosal above and the dentary below. In the reptile, the squamosal is just above and contacting the quadrate. Advanced therapsids have two jaw joints: a reptile-like joint and a mammal-like joint (Figure based on Kardong 2002, pp. 275, reproduced with permission from the publisher, Copyright © 2002 McGraw-Hill)



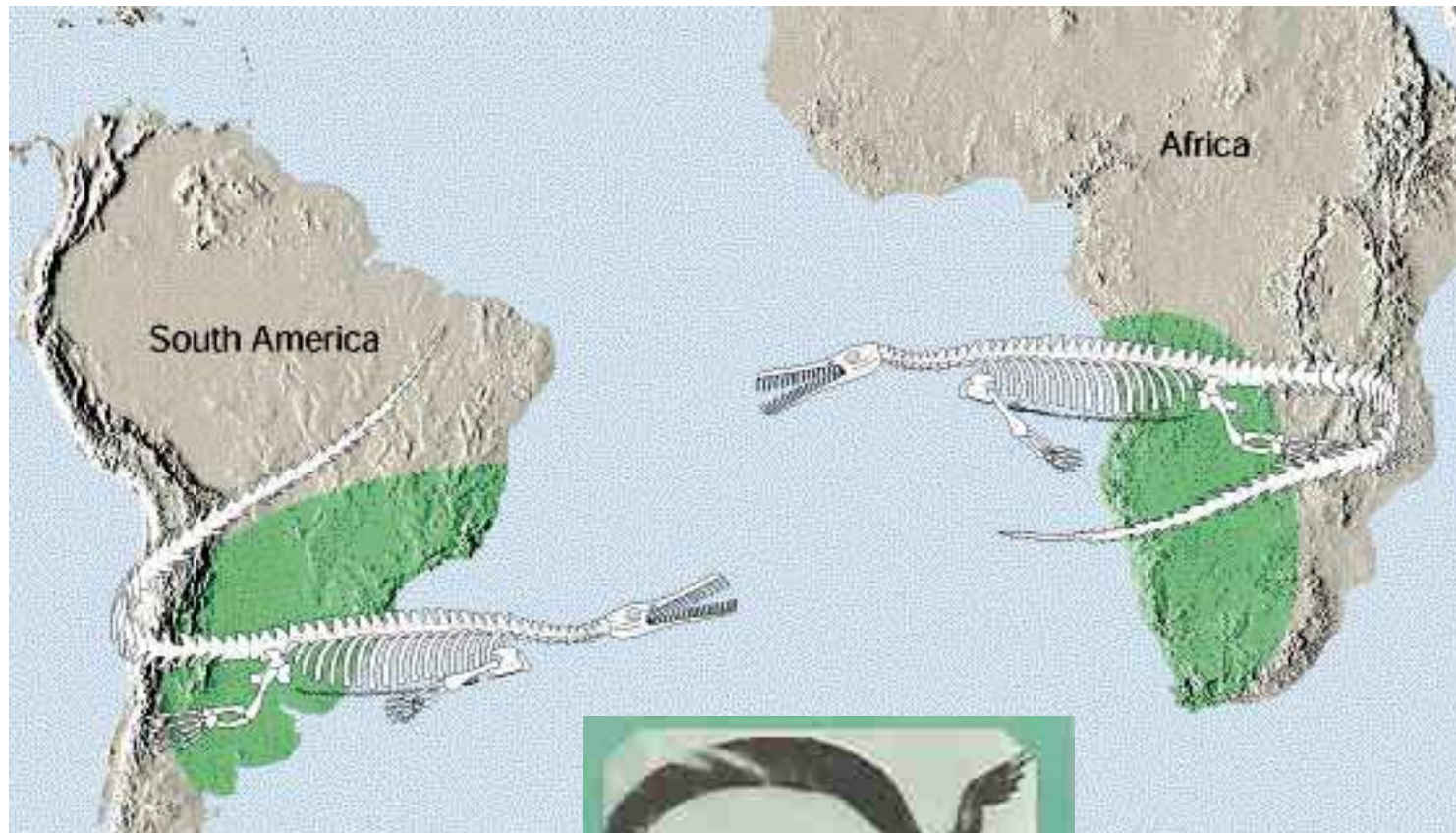
Euryapsida

Notosaurs -



Nothosaurus
Nothosaur
Triassic Period

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Diapsida

A great small many insectivorous lizard-like [diapsid](#) reptiles, like *Paliguana*, inhabited the landscape, most of which, curiously, had hind-legs much longer than their forelimbs (clearly an adaptation to bipedal locomotion, like the frill-necked lizard of Australia today)

Late Permian Extinctions

- Biggest mass extinction of all time

JUST PLAIN GONE

- fusulinids
- rugose coral
- tabulate coral
- trilobites

HIT PRETTY HARD

- 20% therapsids
- ammonoids
- brachiopods
- bryozoans
- Stalked echinoderms
- bivalves
- gastropod mollusks

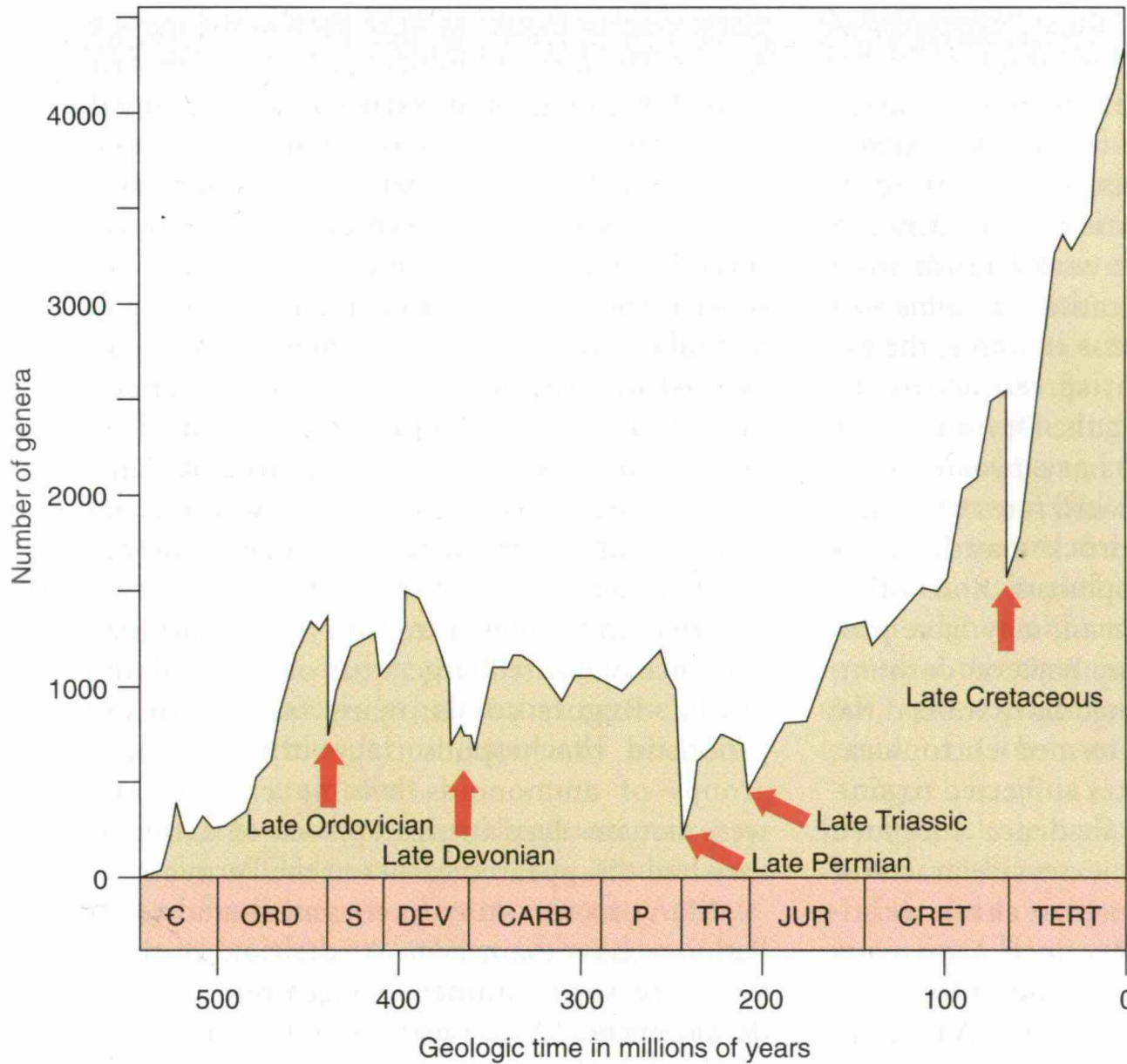
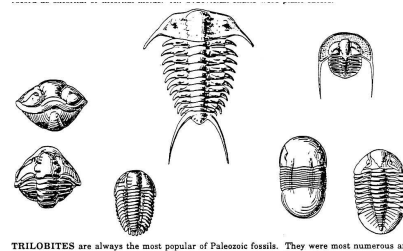


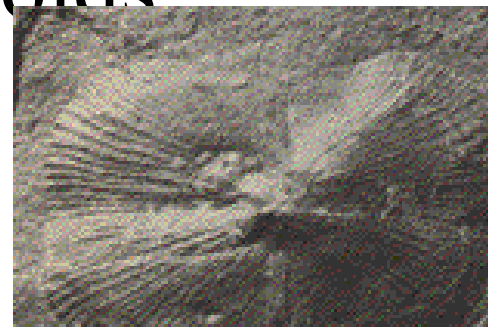
FIGURE 10-84 Diversity of marine animals compiled from a database recording first and last occurrences of more than 34,000 genera. The graph depicts five major episodes of mass extinction (global extinctions over a short span of geologic time). (Adapted from Sepkoski, J. J., Jr. 1994. *Geotimes* 39(3):15-17.)

Just before the Mesozoic: Permian\Triassic Extinctions

- Many major groups extinct
- a) Trilobites
- b) Rugose and tabulate corals
- c) Blastoids
- d) Fusulinid foraminifera
- e) Brachiopods and crinoids severely reduced

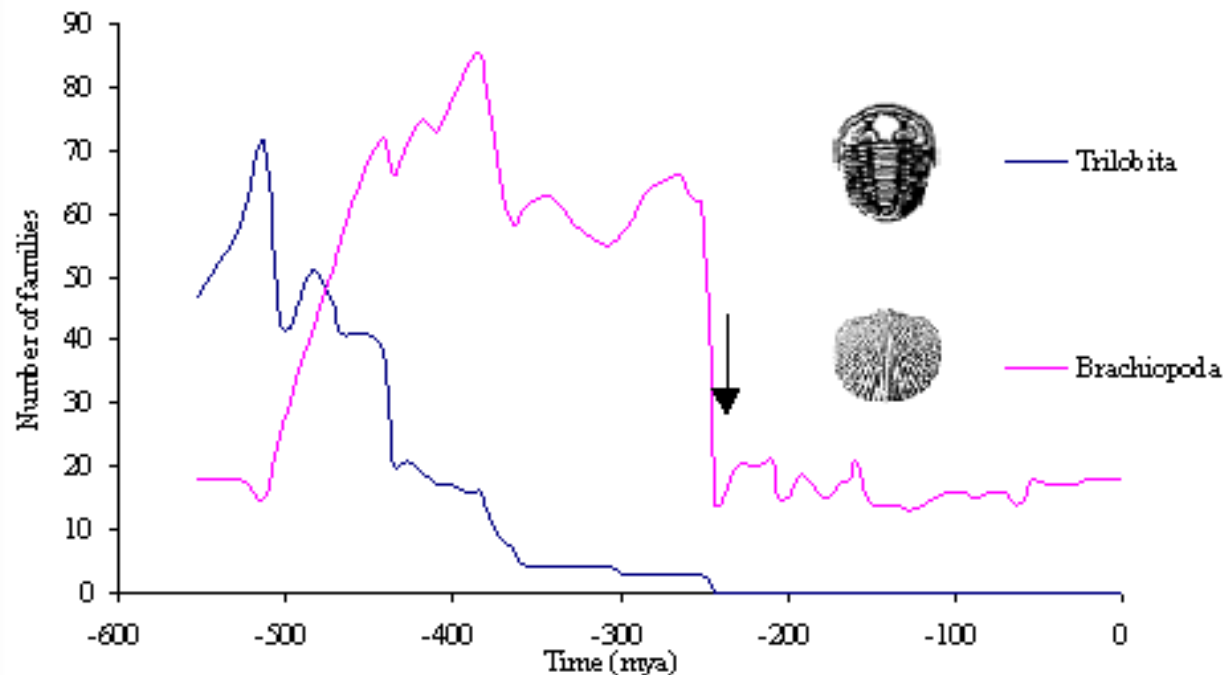


TRILOBITES are always the most popular of Paleozoic fossils. They were most numerous and



The end-Permian mass extinction event ranks as the most devastating to terrestrial faunas in the history of the Earth. Marking the end of the great Palaeozoic era, it saw the death of about **95% of marine species and 70% of land families**. This is the most extensive extinction event ever, the closest that metazoans have come to being exterminated in the 600 million years since they first evolved in the Cambrian radiation.

Figure 4 Showing the effect of the P-T extinction, indicated with an arrow, upon the diversification levels of two organismal groups (Benton, 1993)



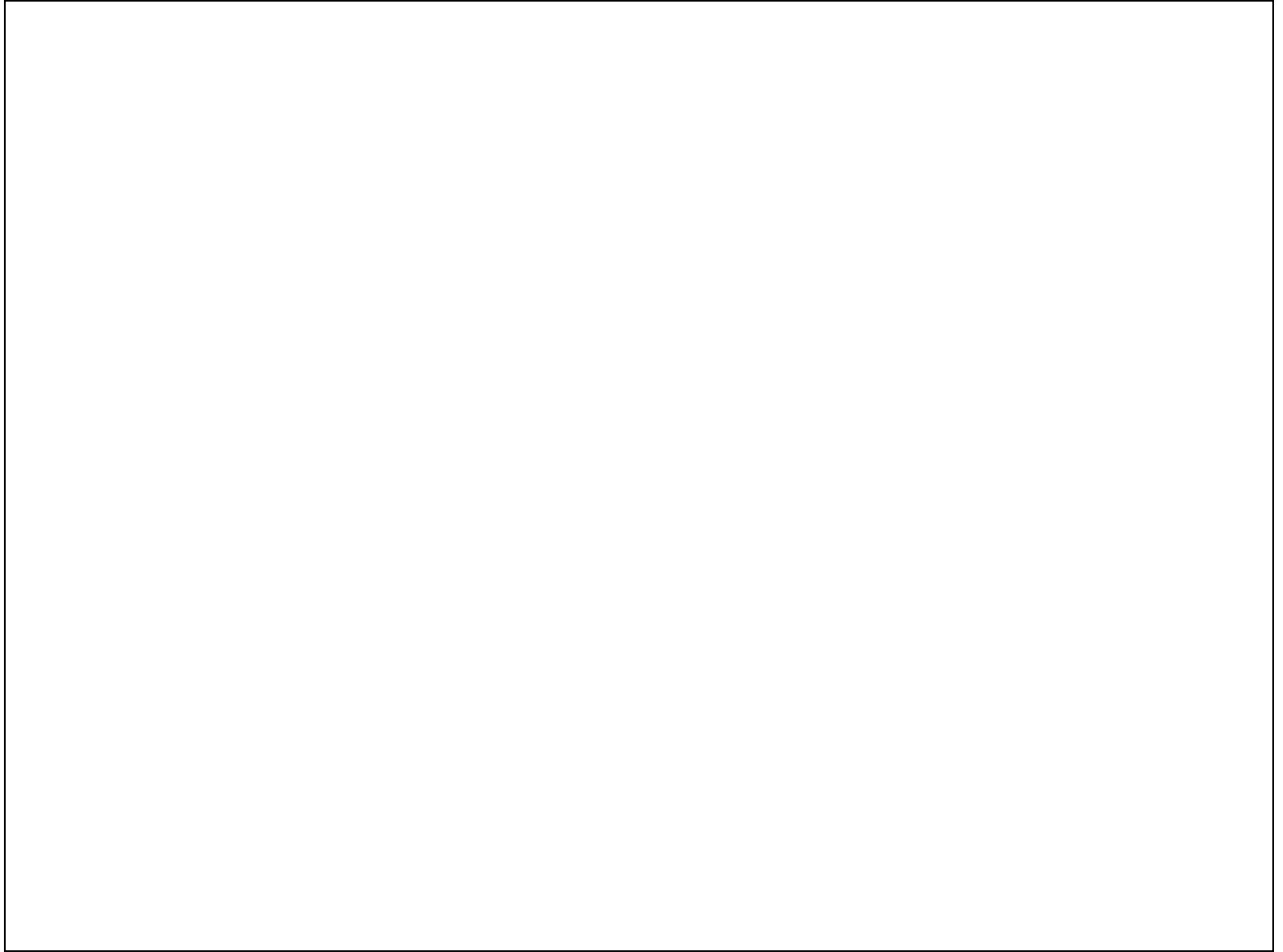
THE PERMIAN EXTINCTION

 Many theories of what caused this extinction have been considered:

- The glaciation of Gondwana, the primary theory for the two previous mass extinctions,
- the increased fluctuation of global temperatures caused by north and south pole glacier events,
- volcanic eruptions occurring in Siberia, flood basalts released huge amounts of CO₂
- The formation of super-continent Pangaea, which possibly caused a reduction of space on the continental shelf. (However, this last theory is especially subject to criticism, because this occurred before the mass extinction did.)
- Drop in oxygen content of surface ocean water

Which theory is correct?

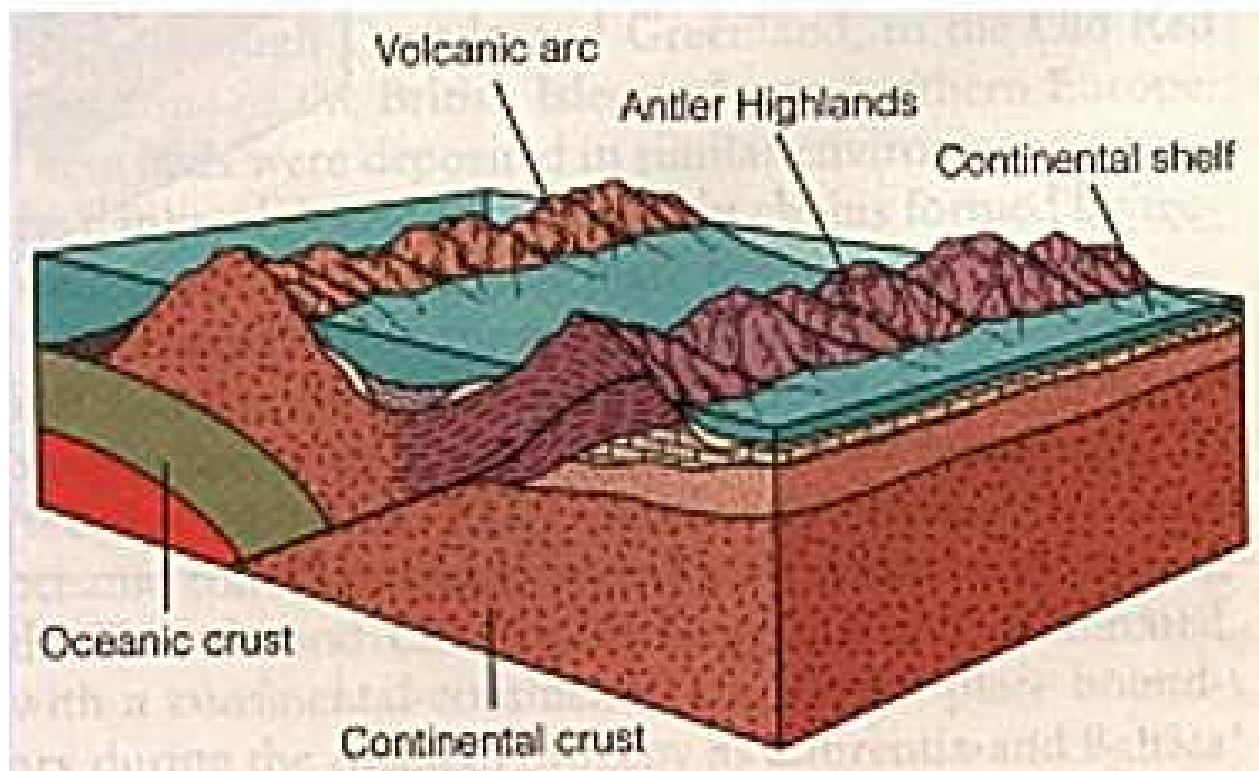
- Maybe all of them.
- Maybe none of them.
- They all deal with climate changes and changes in the total area that animals could live.
- Most likely...a combination of all of them.



Geological development

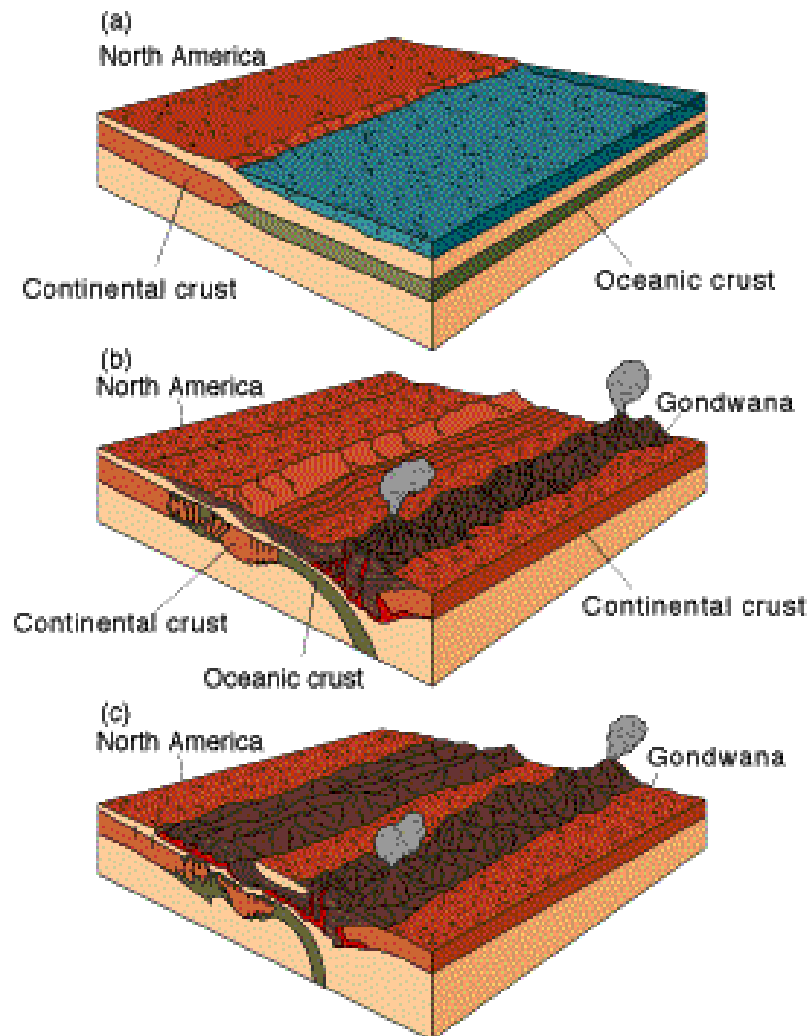
Cordilleran Mobile Belt

- The cordillera was a passive continental margin for much of the Proterozoic and Paleozoic
 - collision with an island arc took place in Early Mississippian time - the Antler orogeny
 - sediments eroded from these highlands were deposited to the east



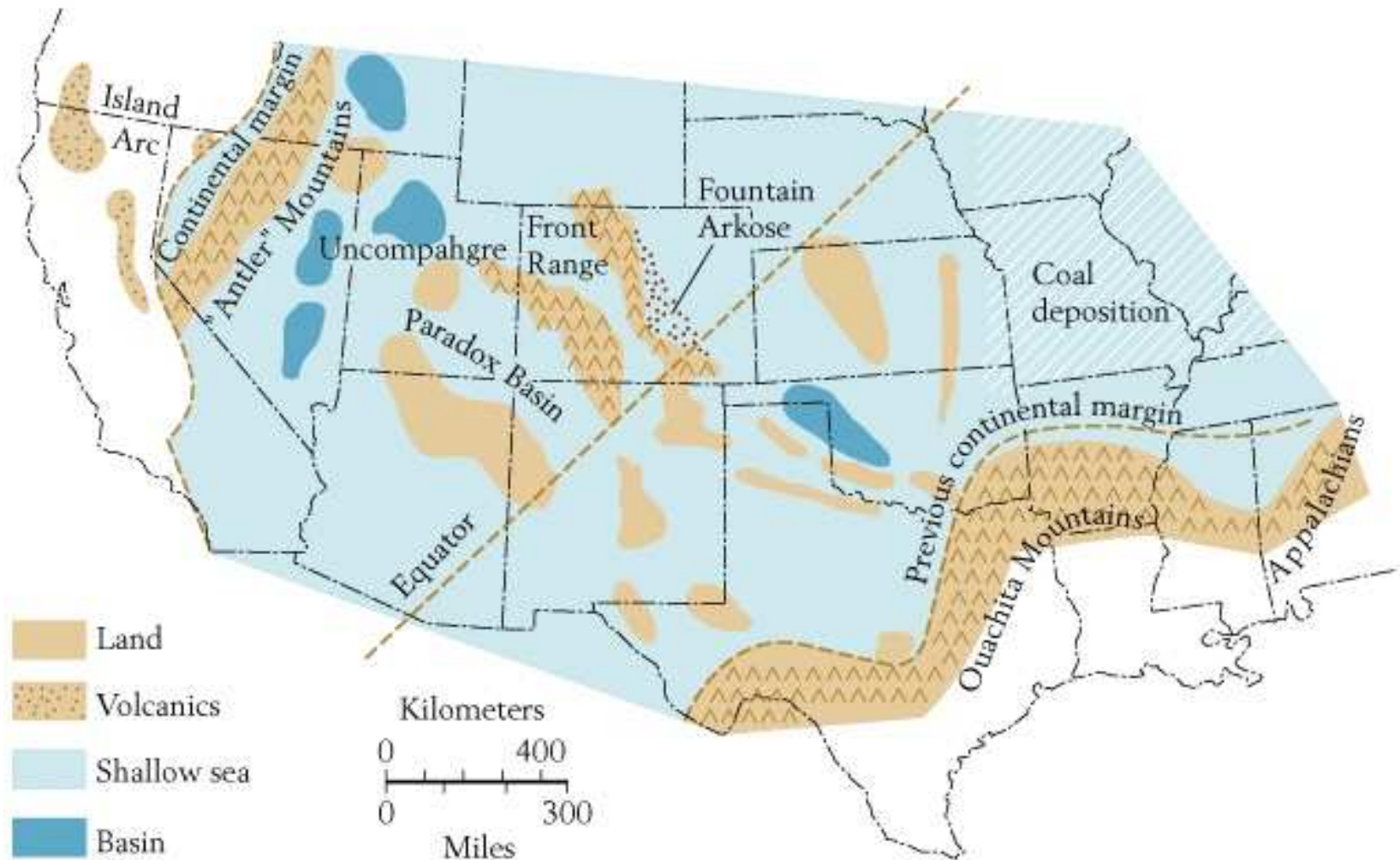
Ouachita Mobile Belt

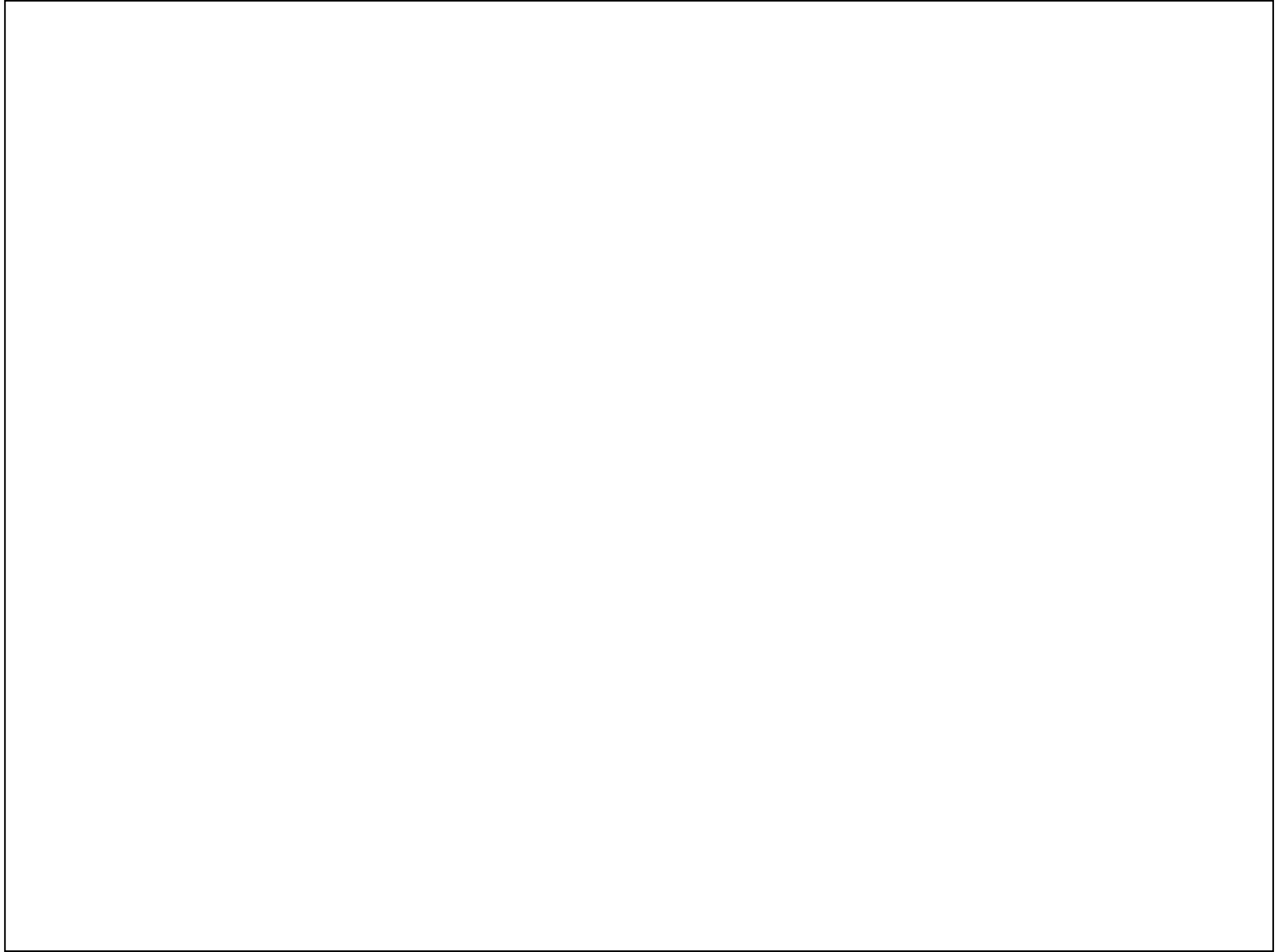
- Extends from the subsurface of Mississippi to Texas
 - the Ouachita Mts. and Marathon Mts. are exposed areas of shallow-water clastic and carbonate sediments deformed by compressive forces generated as Gondwana collided with Laurasia



- Ouchita orogeny

Front Range and Uncompahgre uplifts
= ‘Ancestral Rocky Mountains’

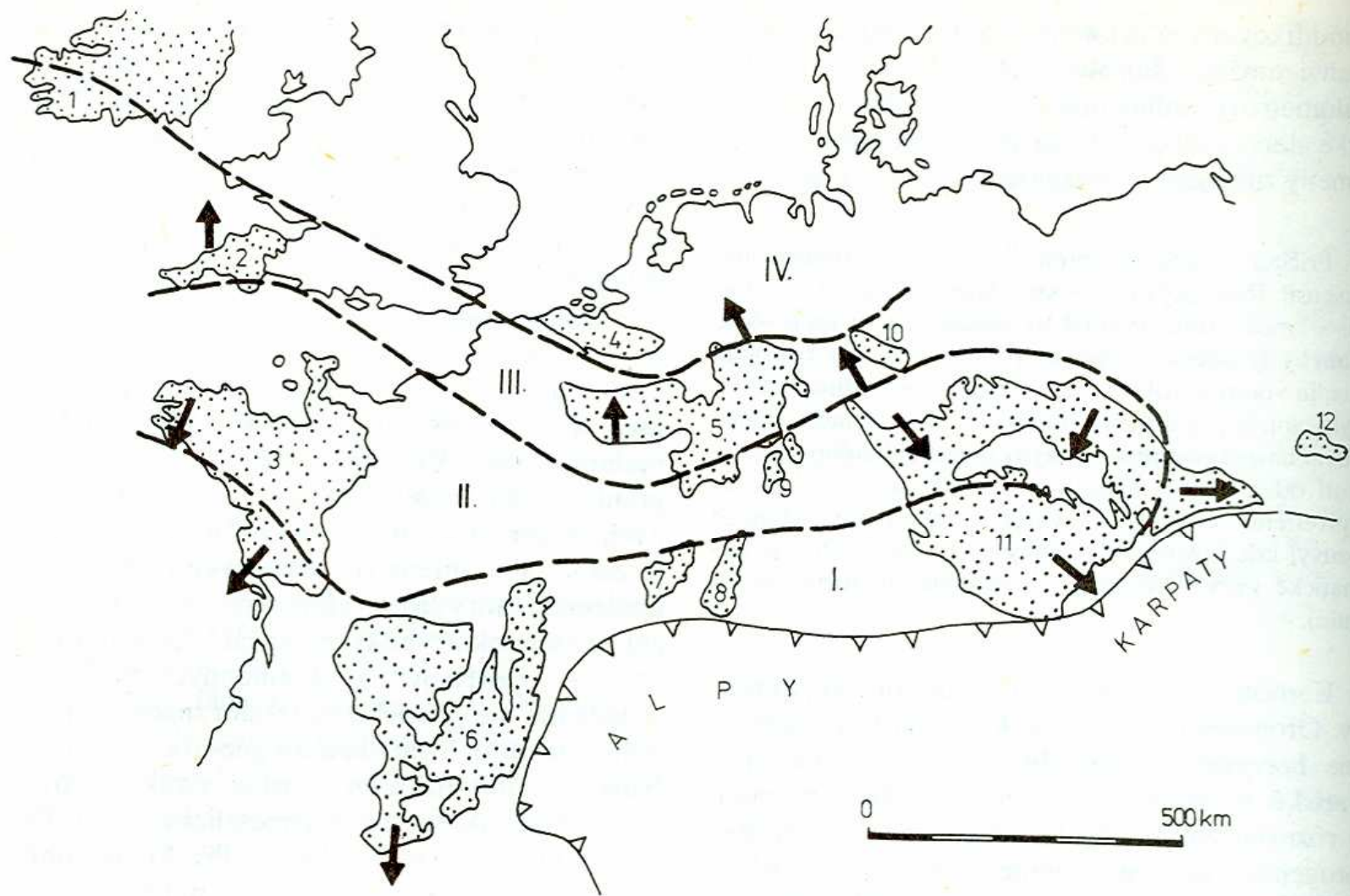




Variscides







Obr. 278. Zjednodušená schéma variscíd strednej a západnej Európy (upravené podľa F. PATOČKU, 1980, s použitím dát M. G. RUTTENA, 1969, C. F. BURRETTA a J. GRIFFITHSA, 1977 a W. KREBSA, 1975).

I moldanubická zóna a jej ekvivalenty, II sasko-durýnska zóna a jej ekvivalenty, III rhenohercýnska zóna a jej ekvivalenty, IV subvariská zóna a predpolie variského orogénu. Na povrch vystupujúce časti variscíd (vybodkované): 1 južné Írsko, 2 Cornwall, 3 armorický masív, 4 brabantský masív, 5 Ardeny a Porýnska bridličnatá vrchovina, 6 Massif Central, 7 Vogézy, 8 Schwarzwald, 9 Odenwald a Spessart, 10 Harz, 11 český masív, 12 Svätokrižske hory. Šípky znázorňujú prevládajúcu vergenciu vrás

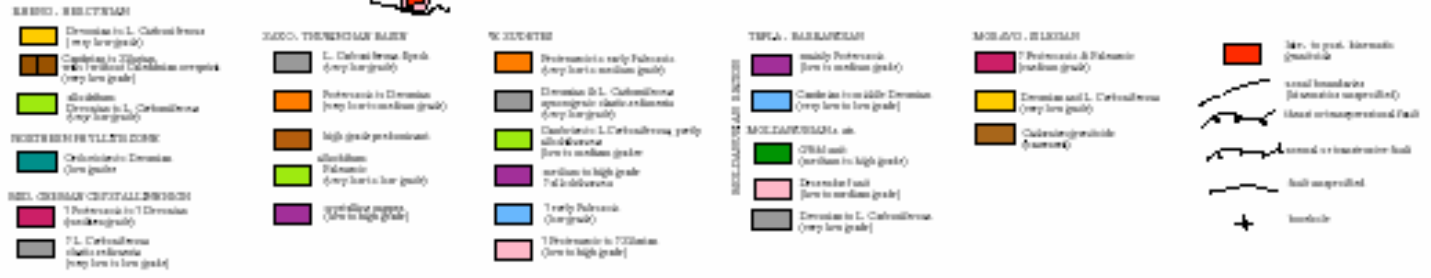
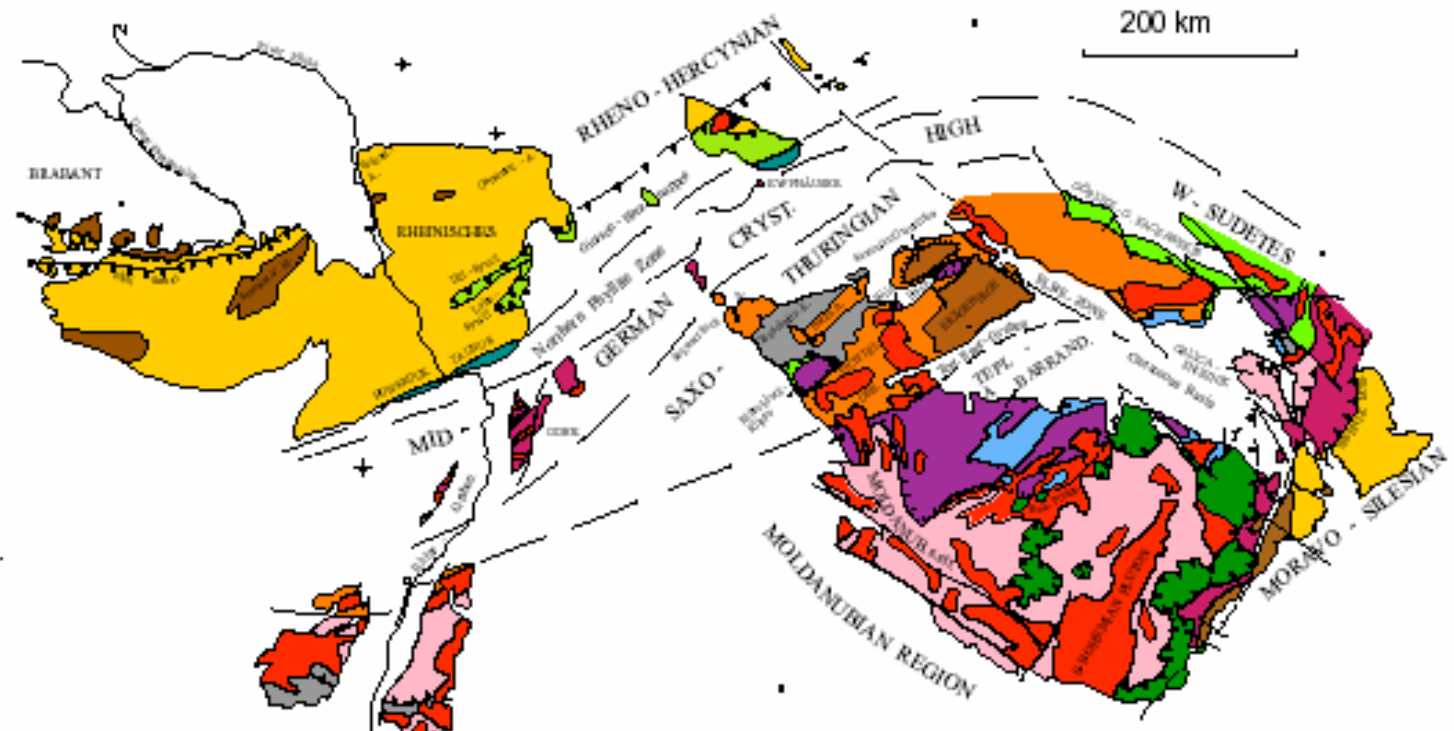
Subvariská zóna – dozvuky variského vrásnění – slabě zvrásněné nebo nezvrásněné sedimenty.
Molasové paralické uhelné pánve

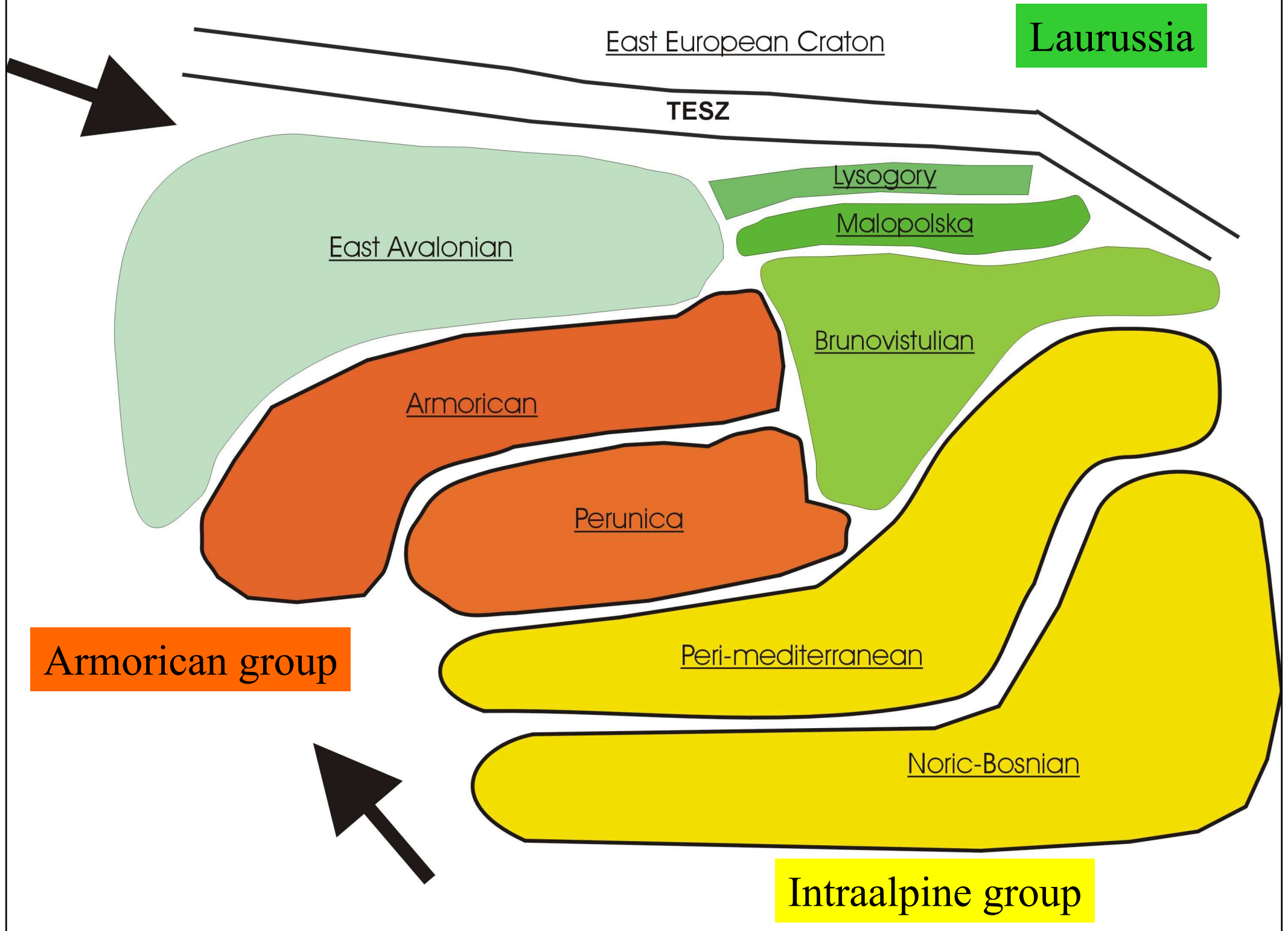
1) Rhenohercynské-jihoportugalská zóna – extenzní zóna variské kolize (devon-spod. karbon),
Okraj Avalonie, brunovistulika, příkrovová stavba, bimodální vulkanismus, slabá
nebo žádná metamorfóza, typický flyš (kulm)

Středoněmecký krystalinický práh – metamorfované svrchnoproterozoické-ordovické
sedimenty a vulkanity, původně okraj terány saxothuringika. Od rhenohercynské
zóny oddělen fylitovou zónou

2) Sasko-durynská zóna – značná metamorfóza a grantizace slábnoucí k severu, postorogenní
plutonismus. Počátek vrásnění v spodním devonu, hlavní fáze spodní karbon.
Divolý flyš – devon-sp, karbon. Terán saxothuringika oddělen od moldanubika
ebersdorfskou linií (litoměřický zlom), marianskolázeňský ultrabazický komplex

3) Moldanubická zóna – intenzivní metamorfóza, grantizace a plutonismus. Hlavně devonské fáze
vrásnění. Moldanubický terán (Perunica). Na západě a severu tekton. Kontakt s
saxothuringikem, na jihu s perimediterránním teránem a na východě s brunovistulikem





East European Craton

Laurussia

TESZ

East Avalonian

Lysogory

Malopolska

Brunovistulian

Armorican

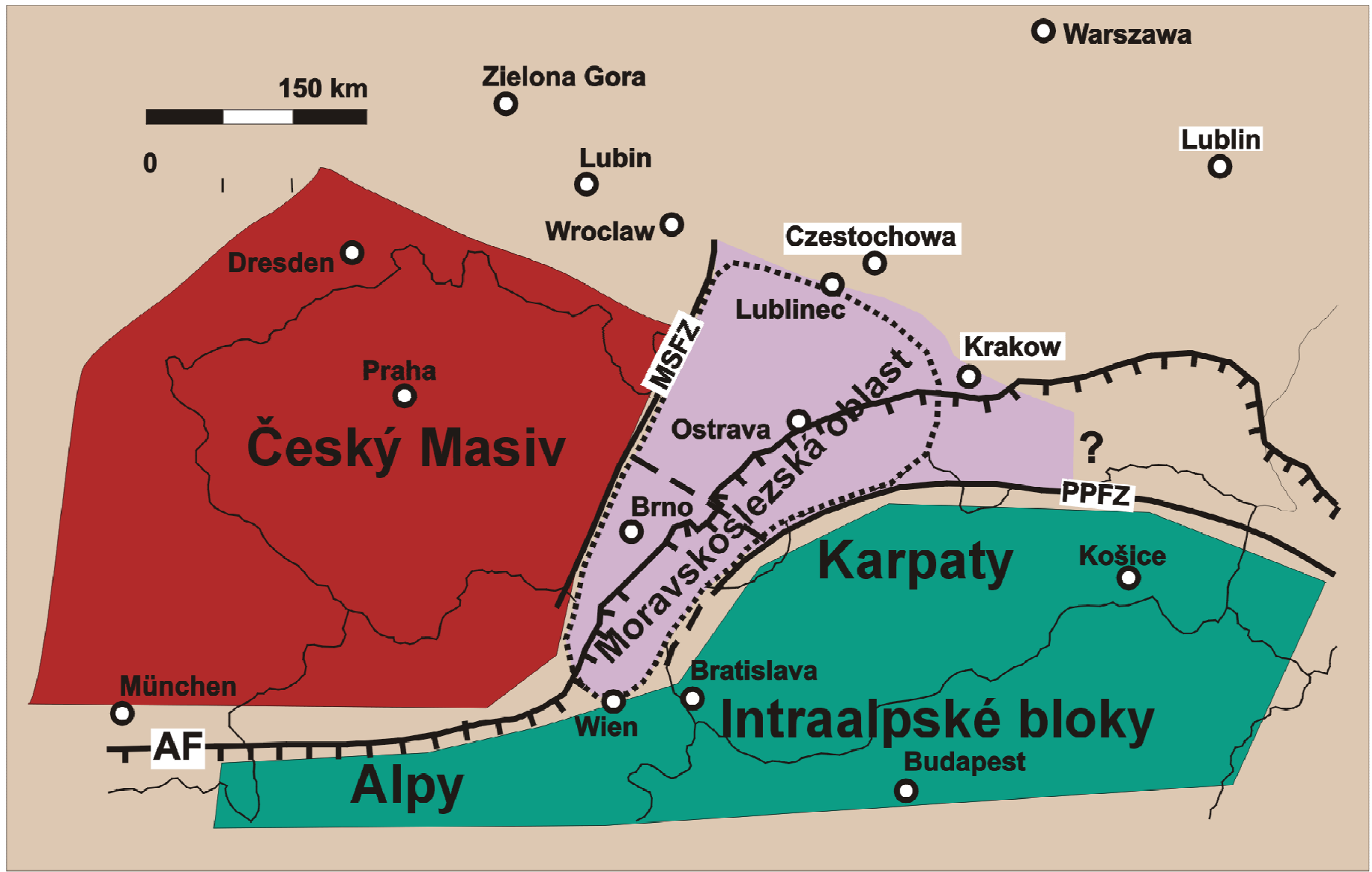
Perunica

Peri-mediterranean

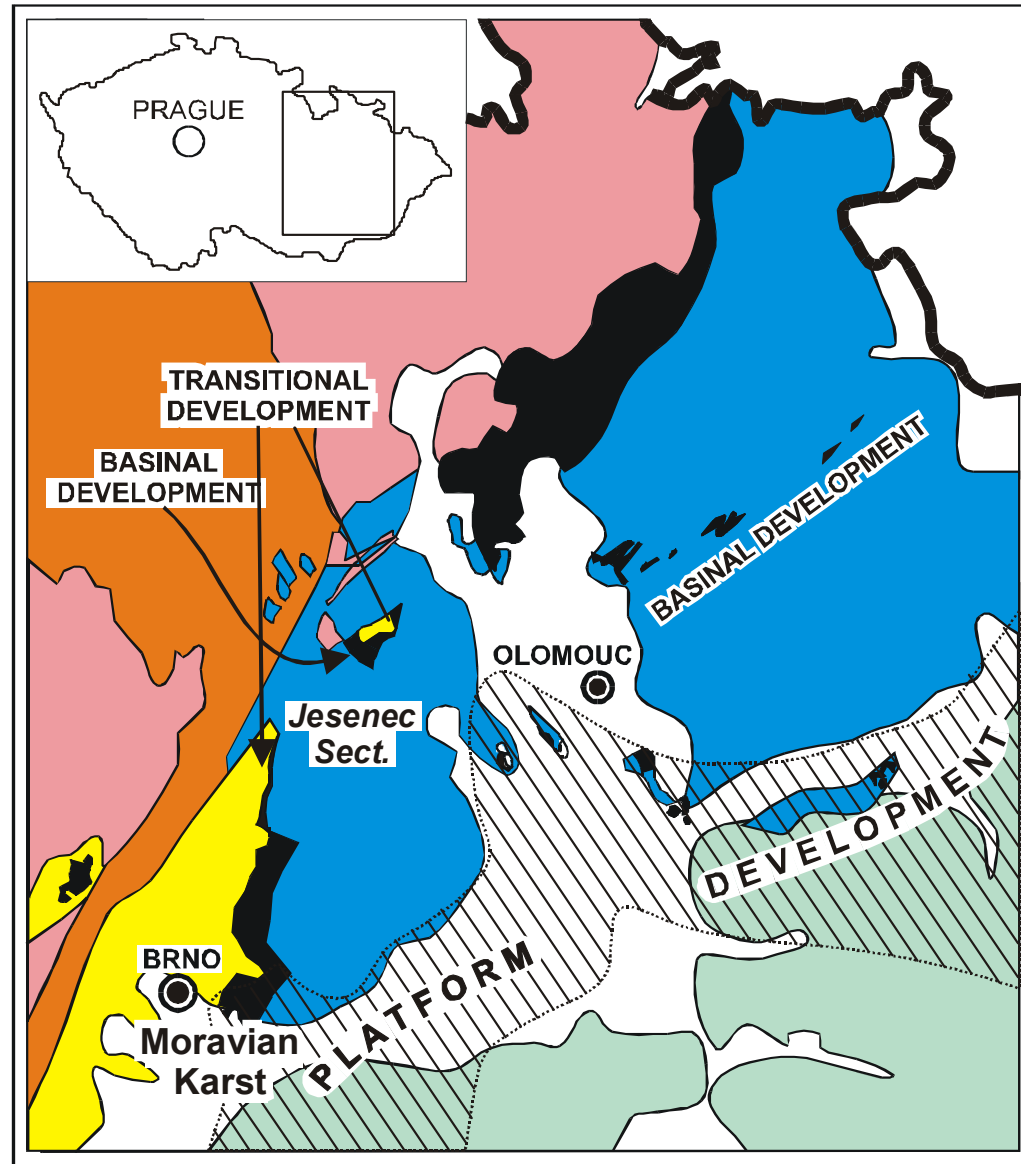
Noric-Bosnian

Armorican group











Intraalpine group



Moravosilesian region



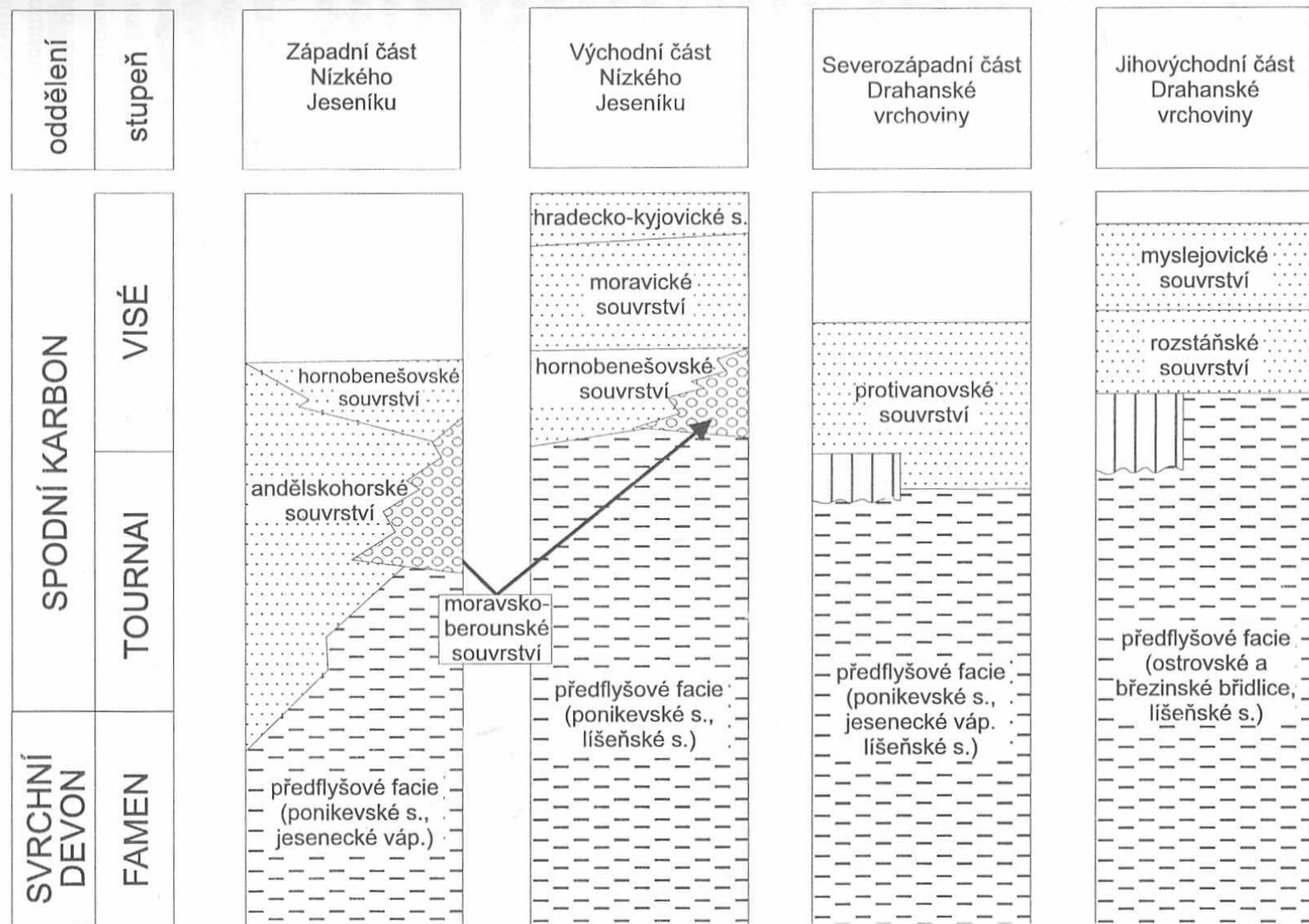
LEGEND:

- | | | | |
|---|---|---|---|
|  | Brunovistulian terrane (Laurussian basement) |  | Western Carpathian flysch |
|  | Variscan crystalline rocks |  | Neogene - Quaternary cover |
|  | Devonian - Lower Carboniferous pre-flysch rocks |  | Hypothetical subsurface limit of Platform Development |
|  | Lower Carboniferous flysch (Culm facies) |  | Section locations |
|  | Permian - Cretaceous sedimentary cover |  | Major city |

V moravskoslezské oblasti se setkáváme především s faciemi **rhenohercynské** a **subvariské** zóny.

Drahanská vrchovina

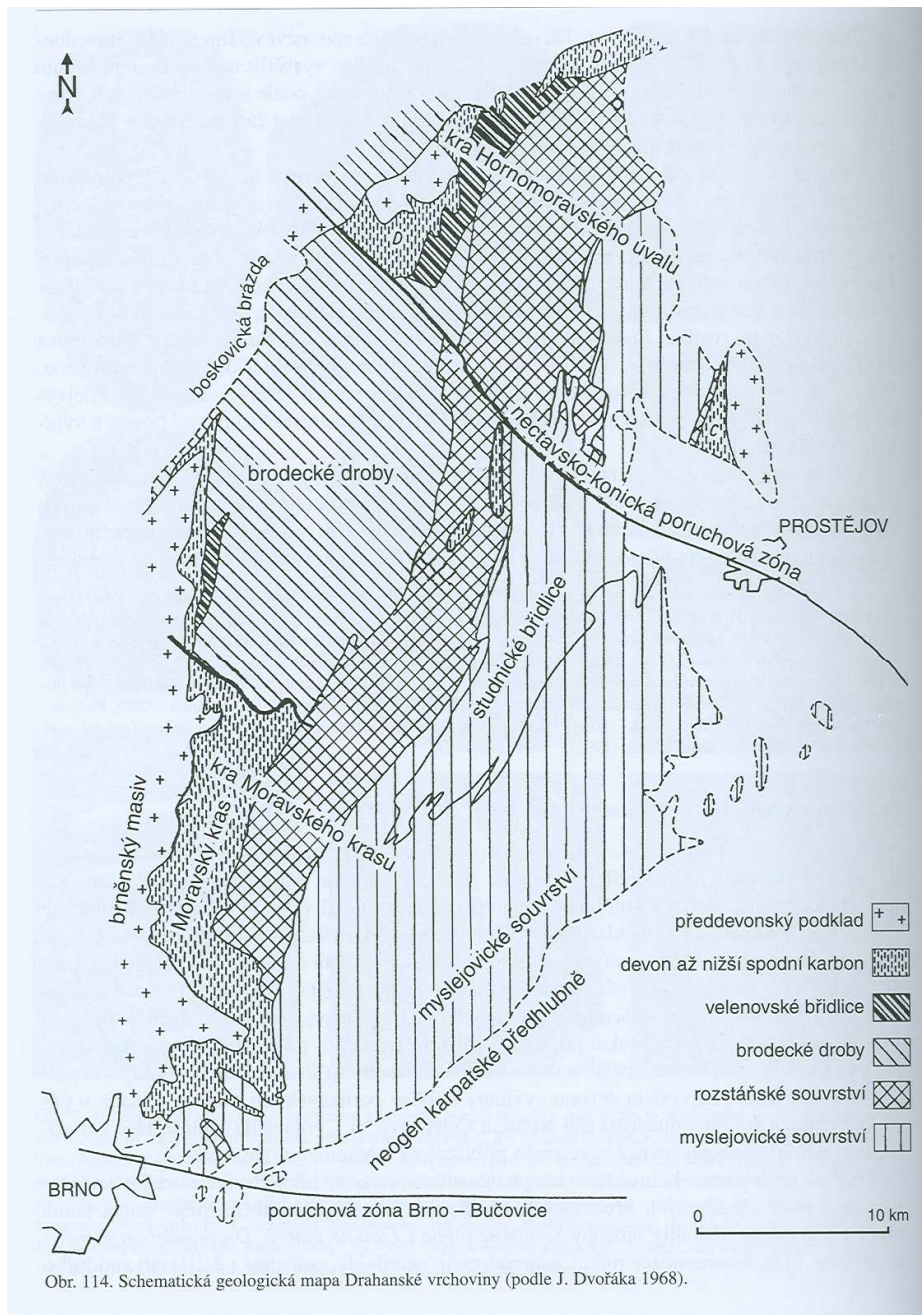
V **drahanském vývoji** a **ludmírovském vývoji** se v tournai podobně jako ve famenu laterálně zastupují facie s převahou kalciturbiditů (**jesenecké vápence**) a facie břidlic s radiolarity (**ponikevské souvrství**). Ve vývoji **Moravského krasu** v tournai pokračuje ukládání facií **hádko-říčských** a **křtinských** vápenců. Zatímco u hádko-říčských vápenců se jedná v drtivé většině o kalciturbidity, křtinské vápence jsou reprezentovány jednak polohami kalových kalciturbiditů, jednak hemipelagickými faciemi svrchní části kontinentálního svahu. Ve svrchním tournai až středním visé se hádko-říčské vápence laterálně zastupují s **březinským souvrstvím**, jehož plošné rozšíření směrem do nadloží narůstá. Březinské souvrství je tvořeno břidlicemi a prachovci místy jsou hojné vložky kalciturbiditů i arenitických siliciklastických turbiditů (droby, vápnité pískovce, arkózy). V břidlicích je místy bohatá trilobitová fauna. Březinské souvrství reprezentuje přechod k flyšové kulmské sedimentaci.



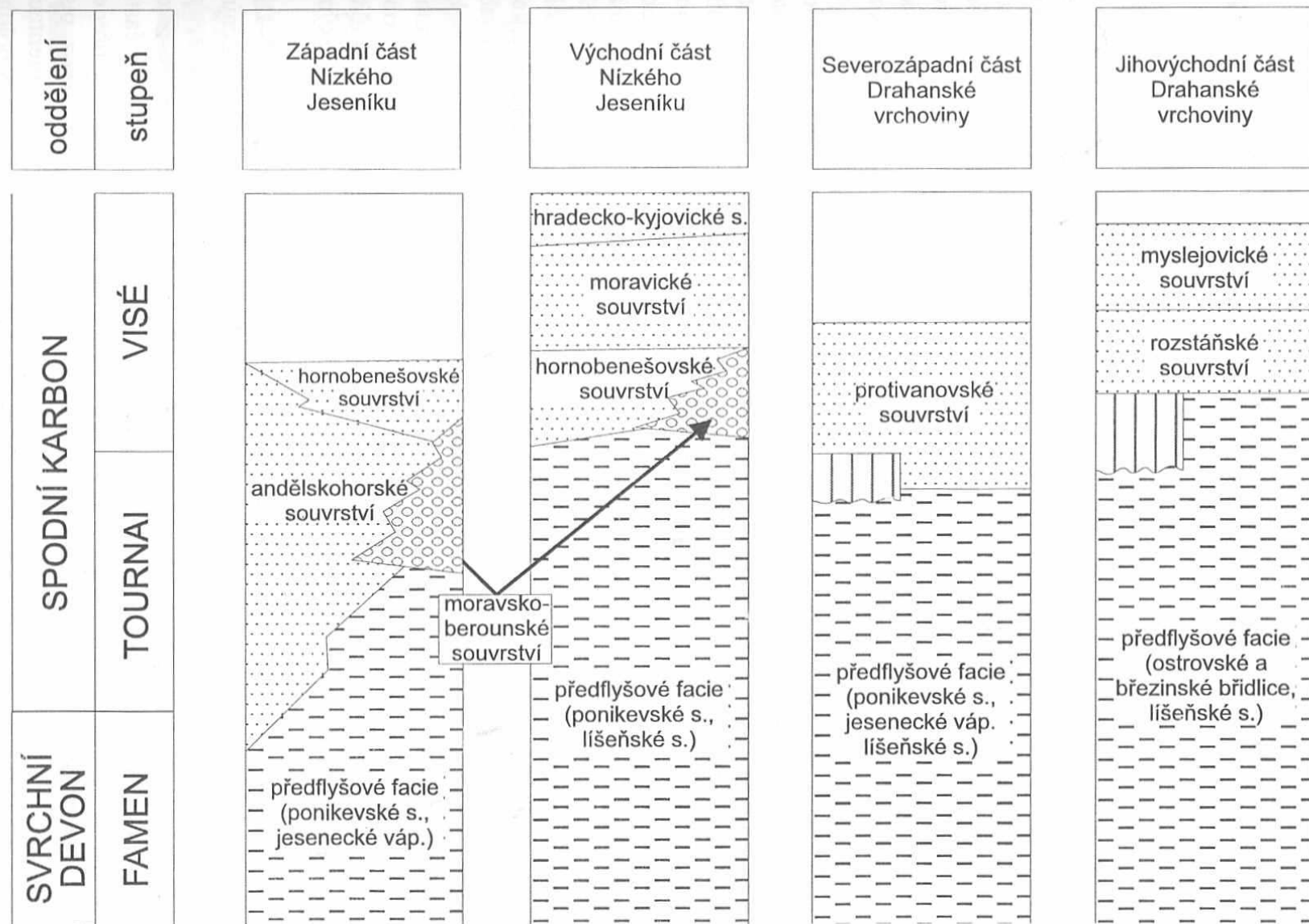
Obr. 61. Litostratigrafické členění sedimentů kulmské facie moravskoslezské oblasti, upraveno podle různých zdrojů.

Kulmská flyšová sedimentace v oblastech s **drahanským** a **ludmírovským** vývojem nastupuje poblíž hranice tournai a visé a je reprezentována **protivanovským souvrstvím**. Na bázi vystupují břidlice velenovské, výše potom brodecké droby. Stratigraficky významné jsou polohy kořeneckého slepence obsahující valouny vápenců vyššího spodního visé. Nad ním se ukládají facie **rozstáňského souvrství** (střední až počátek svrchního visé) reprezentované jemně rytmičným flyšem.

Nejmladší kulmskou jednotkou v nadloží rozstáňského souvrství reprezentuje **souvrství myslejovické**. Je tvořeno slepenci, drobami a břidlicemi. Významné jsou zejména materiálově odlišné polohy **slepenců račických** (starší) a **lulečských** (mladší). Břidlice obsahují faunu nejvyššího visé (*Arhegonus moravicus*, *Posidonia becheri*, zástupci rodu *Goniatites*). Za distální ekvivalent myslejovického souvrství jsou považovány sedimenty moravického a hradecko-kyjovického souvrství v Nížkém Jeseníku.



Obr. 114. Schematická geologická mapa Drahané vrchoviny (podle J. Dvořáka 1968).

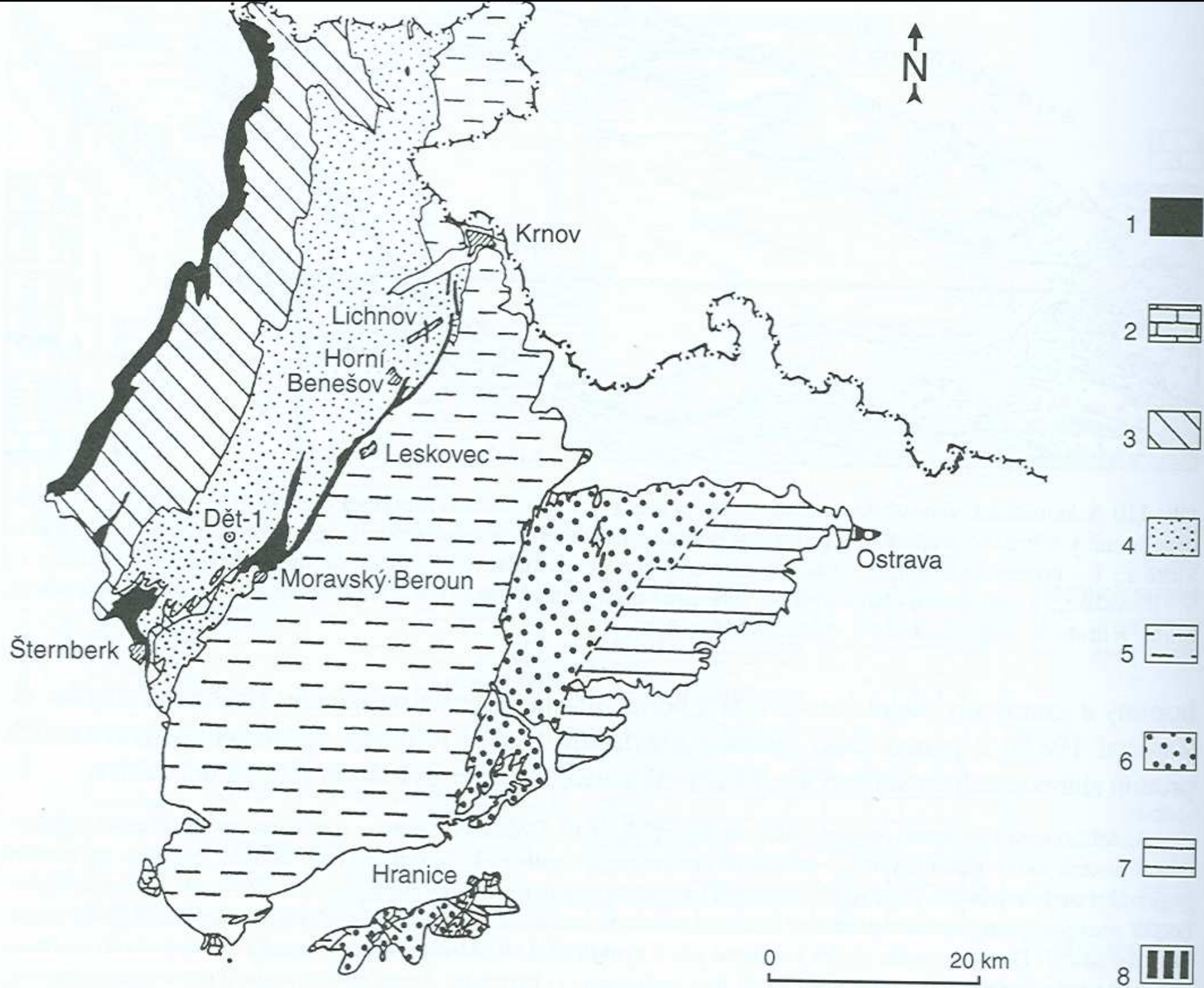


Obr. 61. Litostratigrafické členění sedimentů kulmské facie moravskoslezské oblasti, upraveno podle různých zdrojů.

Nízký Jeseník

V nejnižší části spodního karbonu pokračuje **předflyšová sedimentace** ukládáním pánevních facií **ponikevského souvrství**, které se laterálně zastupují v blízkosti vulkanických elevací s **jeseneckými vápenci**. Ve východnějších oblastech se vlivy karbonátové platformy projevují v ukládání facií **líšeňského souvrství**.

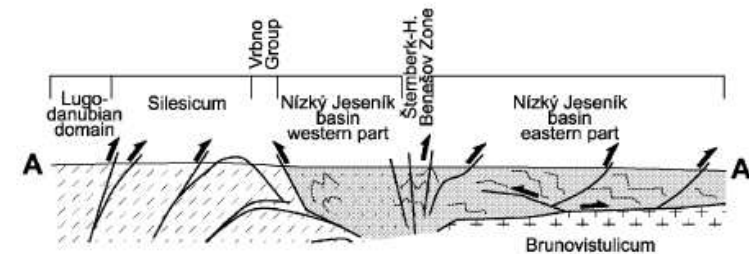
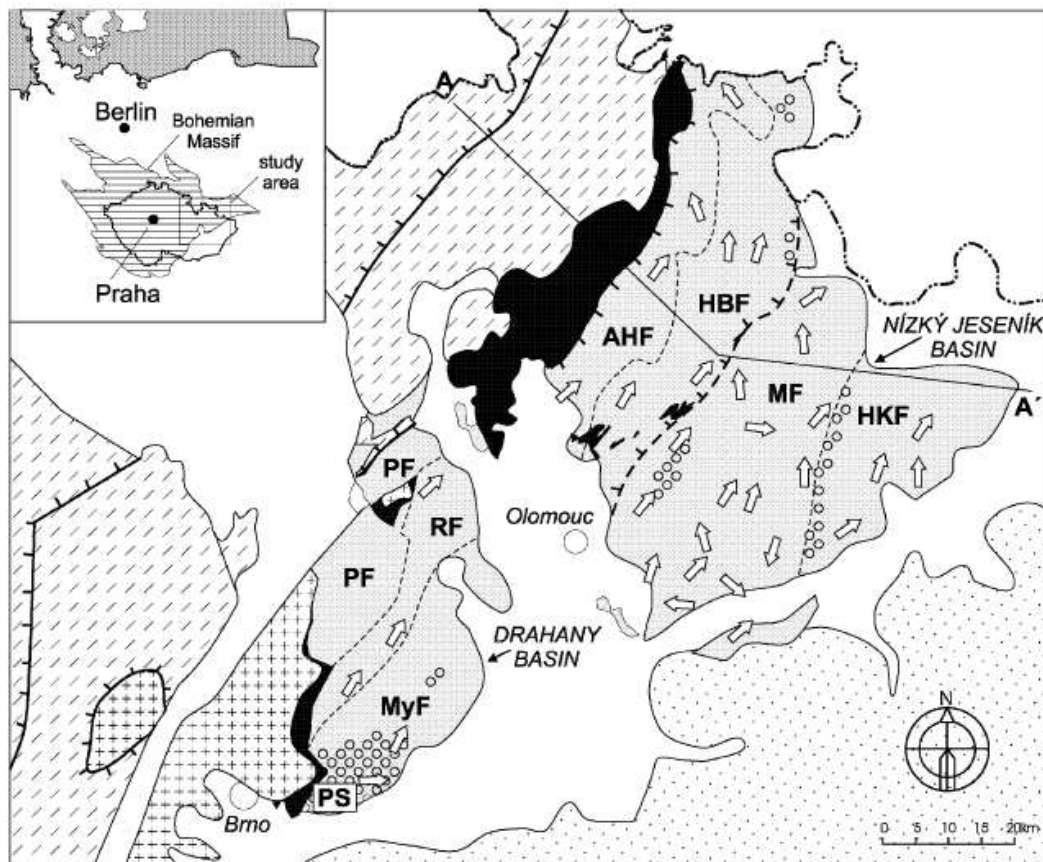
Kulmská flyšová sedimentace vykazuje výraznou polaritu. Nejstarší dílčí pánve vznikaly na západě a jejich depocentra se spolu se sunutím příkrovů přesouvala postupně na východ a vytlačovala karbonátovou sedimentaci. Nejstarší **andělskohorské souvrství** je tvořeno rytmicky zvrstvenými drobami a prachovci s polohami slepenců. Ve spodní části se laterálně zastupuje s ponikevským souvrstvím, ve vyšší části potom se souvrstvím hornobenešovským, do kterého přechází i do nadloží. **Hornobenešovské souvrství** je tvořeno převážně drobami a představuje časový i materiálový ekvivalent protivanovského souvrství. V **moravickém souvrství** převažují distální turbidity reprezentované prachovci a břidlicemi. Jedná se o distálnější ekvivalenty myslejovického souvrství se kterým je pojí obdobná zdrojová oblast. Ve spodní části **hradecko-kyjovického souvrství** převažují droby s polohami slepenců na bázi, do nadloží přecházejí do prachovito-jílovitých rytmitů. Vývoj tohoto souvrství tak zachycuje přechod od flyšové do molasové sedimentace.














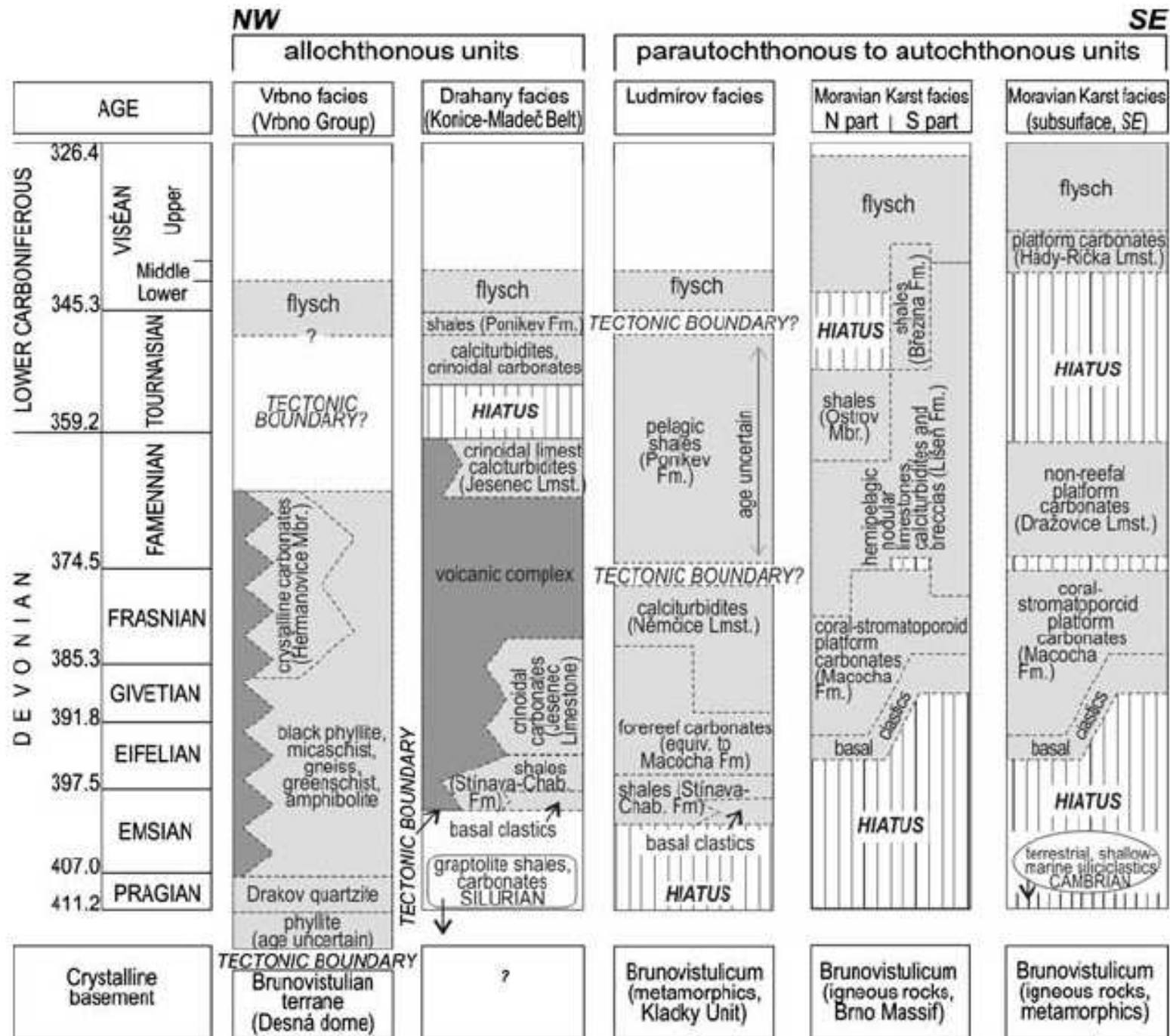
Obr. 111. Schematická mapa krkonošské oblasti. 1 - Krnovská hornatina; 2 - Krnovská hornatina; 3 - Krnovská hornatina; 4 - Krnovská hornatina; 5 - Krnovská hornatina; 6 - Krnovská hornatina; 7 - Krnovská hornatina; 8 - Krnovská hornatina.

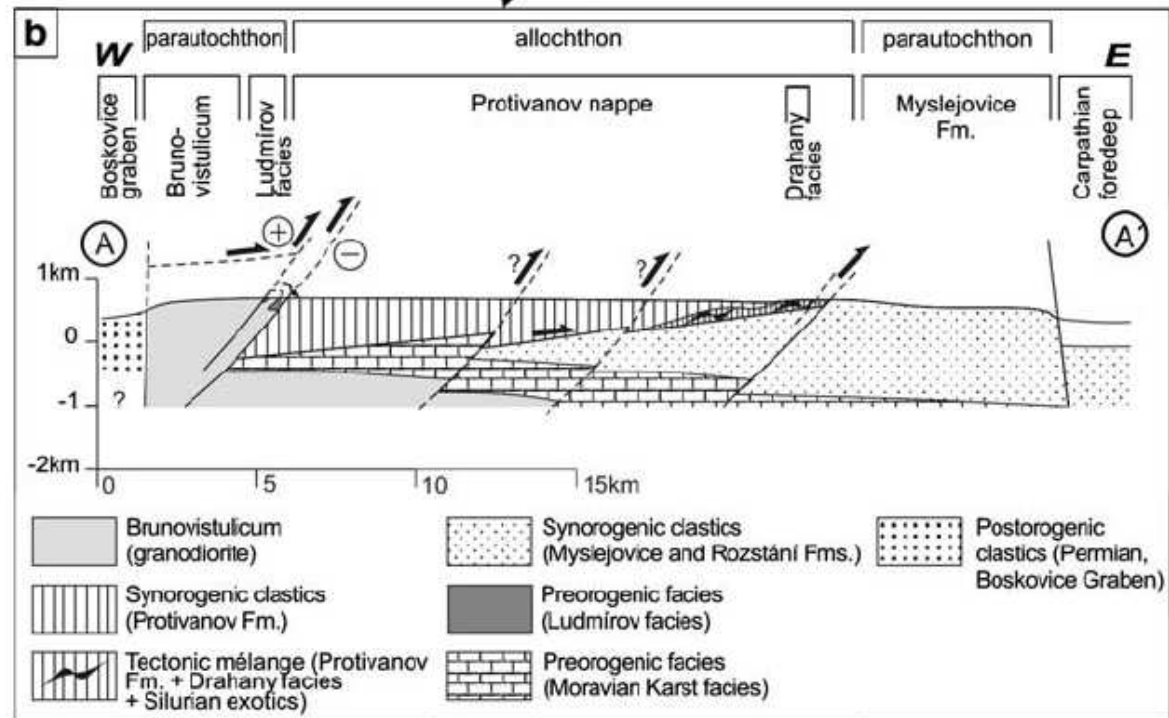
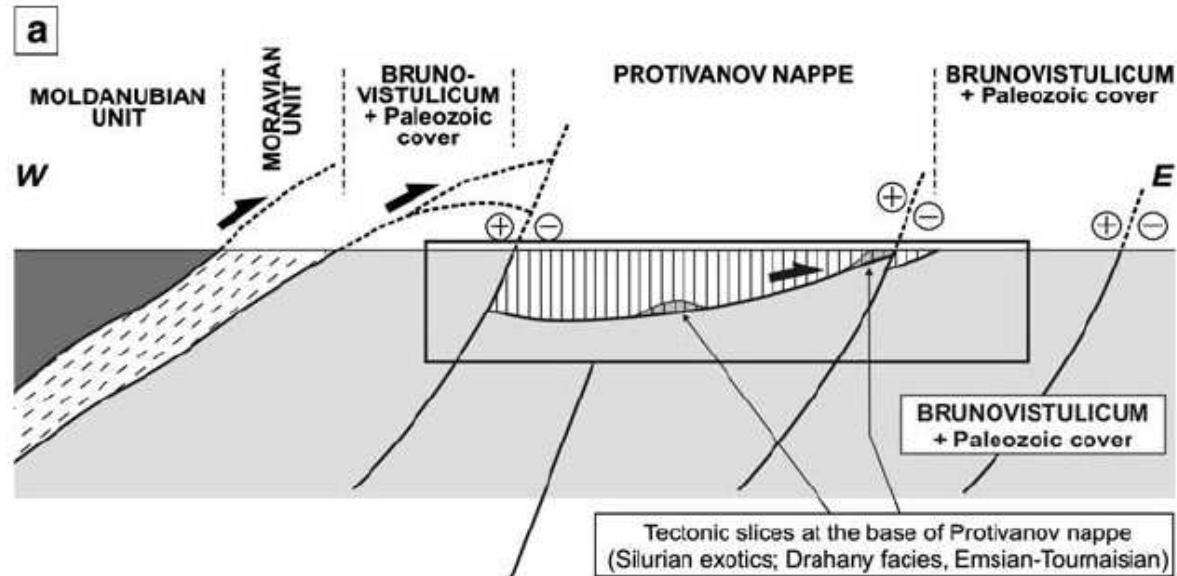
Hornoslezská pánev

Z Polska na naše území zasahuje pouze jihozápadní výběžek. Představuje **molasovou pánev** v předpolí orogénu, tj. v **subvariské zóně**. Ve spodní části se uložilo **ostravské souvrství** (namur A-B) v paralickém vývoji s cyklotémami. Je tvořeno především drobovými nebo arkózovými karbonatickými pískovci, prachovci a jílovci o mocnosti přes 2,5 km obsahuje asi 100 těžitelných hlavních slojí. Nadložní **karvinské souvrství** se ukládalo v limnickém prostředí. Obsahuje menší počet slojí, které však dosahují větších mocností.



- | | | | |
|---|---|---|---|
|  | Variscan crystalline nappes (Lugodanubicum, Moravicum, Silesicum) |  | paleocurrent directions |
|  | Variscan (par)autochthonous crystalline rocks (Brunovistulicum) |  | major point source for flysch basins |
|  | Variscan pre-flysch facies (Devonian-Lower Carboniferous) |  | lithologic boundary between flysch formations |
|  | Variscan flysch (Culm facies) (Carboniferous) |  | major tectonic boundary |
|  | conglomerate facies within flysch clastics | PF | Protivanov Formation |
|  | Flysch Zone of Western Carpathians (Jurassic-Oligocene) | RF | Rozstání Formation |
|  | post-Variscan cover (Permian-Quaternary) | MyF | Myslejovice Formation |
| | | AHF | Andelská Hora Formation |
| | | HBF | Horní Benešov Formation |
| | | MF | Moravice Formation |
| | | HKF | Hradec-Kyjovice Formation |





Permocarboniferous basins

Coal-bearing, mainly from Westphalian to Stephanian

Most complete sedimentation - Innersudetic Basin, communication with Podkrkonoše Basin.

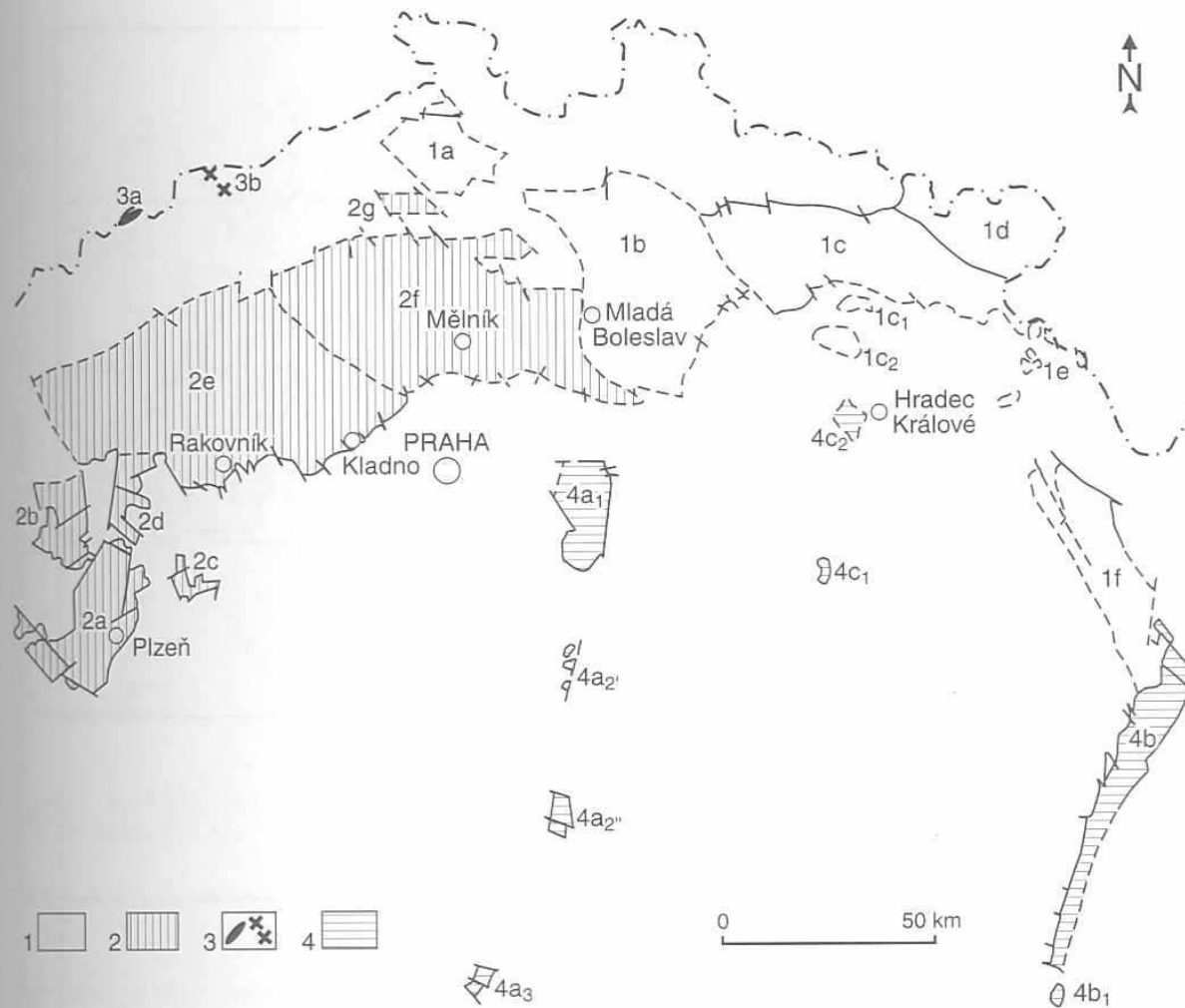
Central Bohemian basins

Boskovice furrow. Halfgraben basin, originated during the gravitational collapse of the Variscan orogeny.
From Městečko Trnávka to Moravský Krumlov. Stephanian – lower Permian. Carboniferous Balin Conglomerates at the western margin. Permian Rokytná conglomerates at the eastern margin.

2.4.2.4.4. PERMOKARBONSKÉ PÁNVE

Patří sem pánve, které vznikly většinou až po hlavních fázích variského vrásnění ve svrchním karbonu, a jejichž limnické sedimenty nebyly výrazněji tektonicky postiženy. Od stephanu se v nich začíná vyskytovat v hojnější míře červené zbarvení, které ukazuje postupné zvyšování aridity, tak typické později pro perm. Sblížený faciální vývoj a nedostatek fosílií zapříčiňuje nejistoty při stanovení přesných hranic, proto se často používá pro sedimentární výplň těchto pánví souborný název permokarbon.

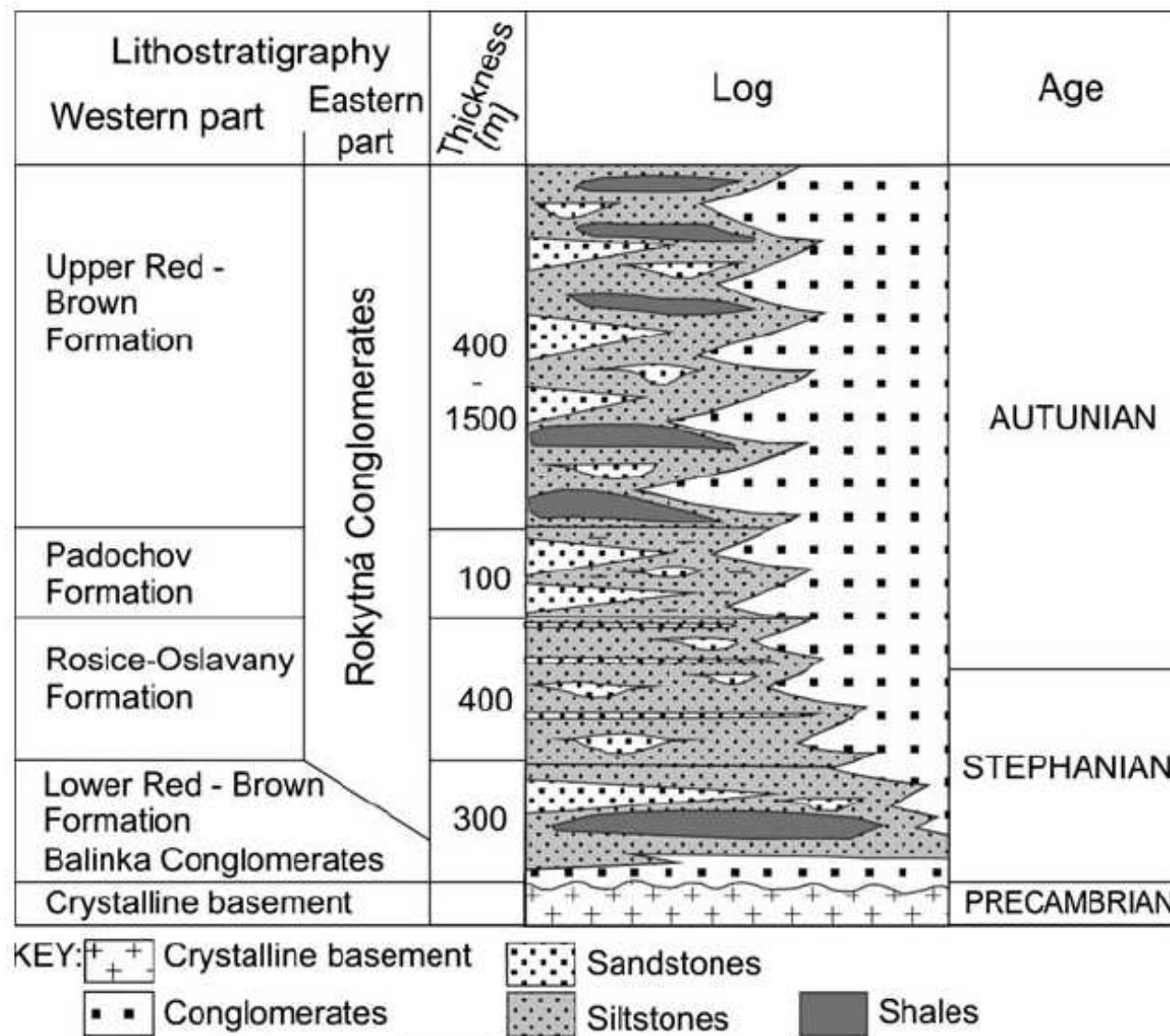
Hlavní výskyt pánví je soustředěn do obloukovitého prostoru **mezi moldanubickou a saskodurynskou zónou** (oblast středočeského permokarbonu a oblast v severovýchodní části Českého masivu - podkrkonošská a dolnoslezská pánev). Další mladší pánve vznikaly podél tektonických linií severojižního směru a patří k nim blanická a boskovická brázda. Nejúplněji je sedimentace permokarbonu vyvinuta v **dolnoslezské pánvi**, kde přechází až do triasu. **Podkrkonošská pánev** má do určité míry obdobný vývoj jako sousední dolnoslezská pánev a komunikovala i se středočeskými pánvemi.

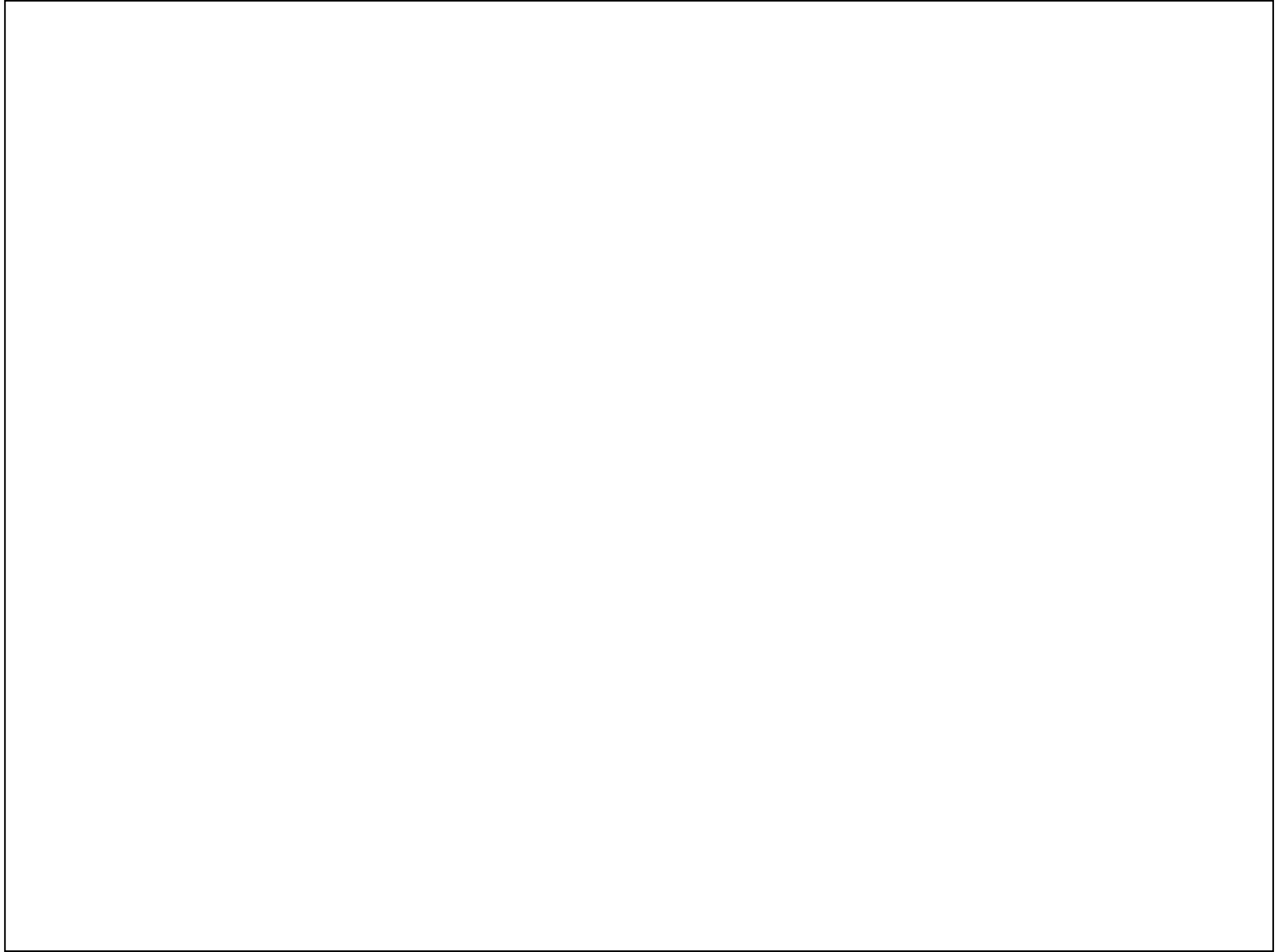


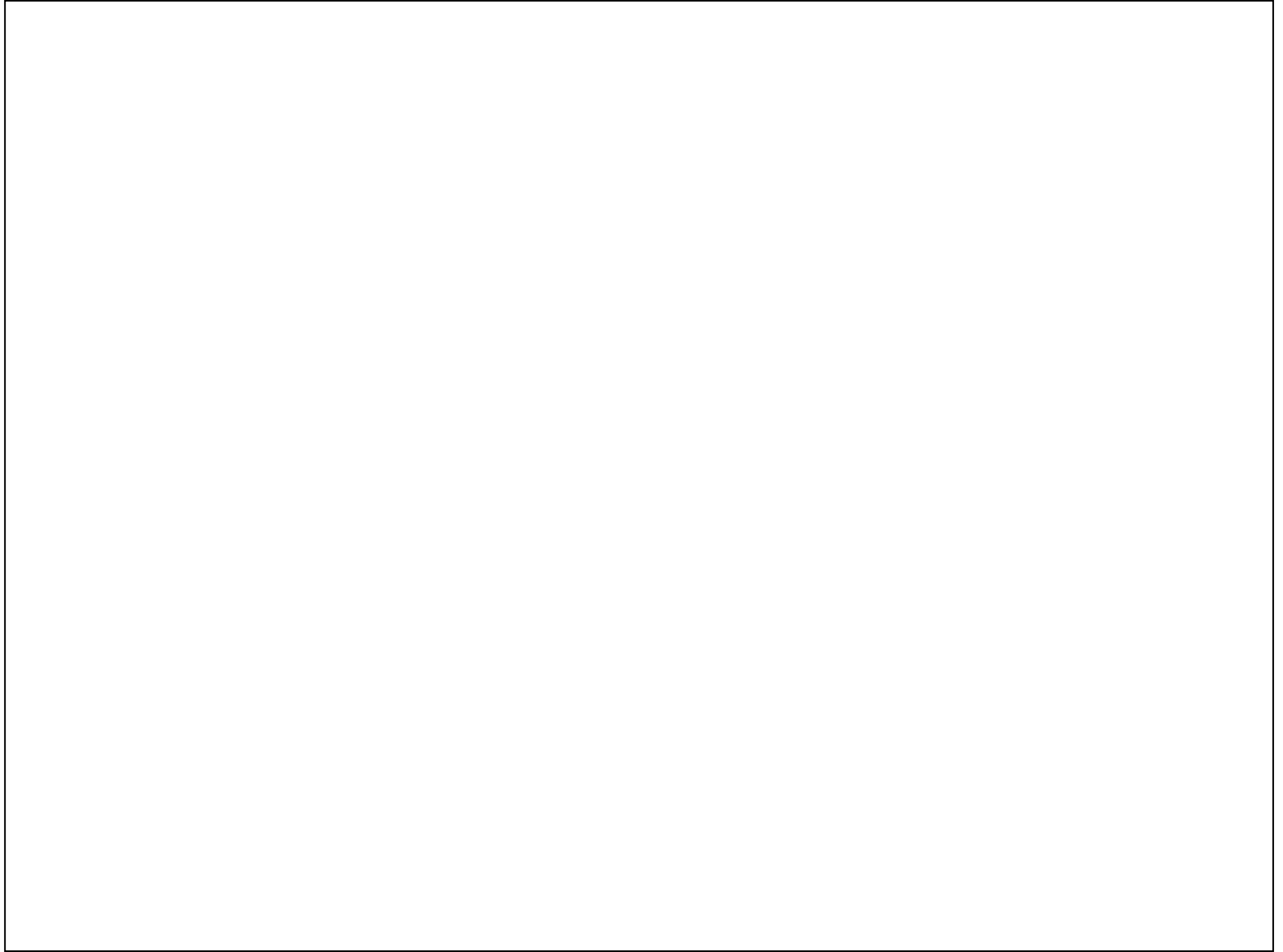
Obr. 120. Rozšíření limnických permokarbonských pánví (podle přijatého návrhu Čs. stratigrafické komise, V. Holub – J. Pešek 1992). 1 – sudetské mladší paleozoikum: 1a – českokamenická pánev, 1b – mnichovohradištská pánev, 1c – podkrkonošská pánev (s výskytem na Zvičině – 1c₁ a Hořickém hřbetu – 1c₂), 1d – vnitrosudetská pánev (česká část), 1e – výskyt permu v Orlických horách, 1f – orlická pánev; 2 – středočeské a západočeské mladší paleozoikum: 2a – plzeňská pánev, 2b – manětínská pánev, 2c – radnická pánev, 2d – žihelská pánev, 2e – kladensko-rakovnická pánev, 2f – mšensko-roudnická pánev, 2g – výskyt u Kravař; 3 – krušnohorské mladší paleozoikum: výskyt u Brandova (3a) a mezi Moldavou a Teplicemi (3b); 4 – mladší paleozoikum brázd: 4a – blanická brázda, 4a₁ – severní díl (Českokobrodsko), 4a₂ – střední díl, (4a₂' – výskyt na Vlašimsku, 4a₂'' – výskyt u Tábora,) 4a₃ – jižní díl (u Českých Budějovic), 4b – boskovická brázda (4b₁ – výskyt u Miroslavi), 4c – jihlavská brázda (4c₁ – výskyt v Železných horách, 4c₂ – výskyt u Hradce Králové).

Boskovická brázda

představuje výrazně asymetrickou příkopovou propadlinu SSV-JJZ směru táhnoucí se od Moravského Krumlova až k Městečku Trnávka. Jedná se o denudační relikvium původně mnohem rozšířenější sedimentace v limnickém a fluviálním prostředí a v prostředí aluviálních kuželů kde probíhala sedimentace od stepanu až do spodního permu. Místy jsou vyvinuty polohy šedých bituminózních vápenců a pelitů s hojnou flórou (např. *Callipteris conferta*), faunou krytolebců (např. *Discosauriscus*), paprskoploutvých ryb (hlavně *Paleoniscus*) a hmyzu.







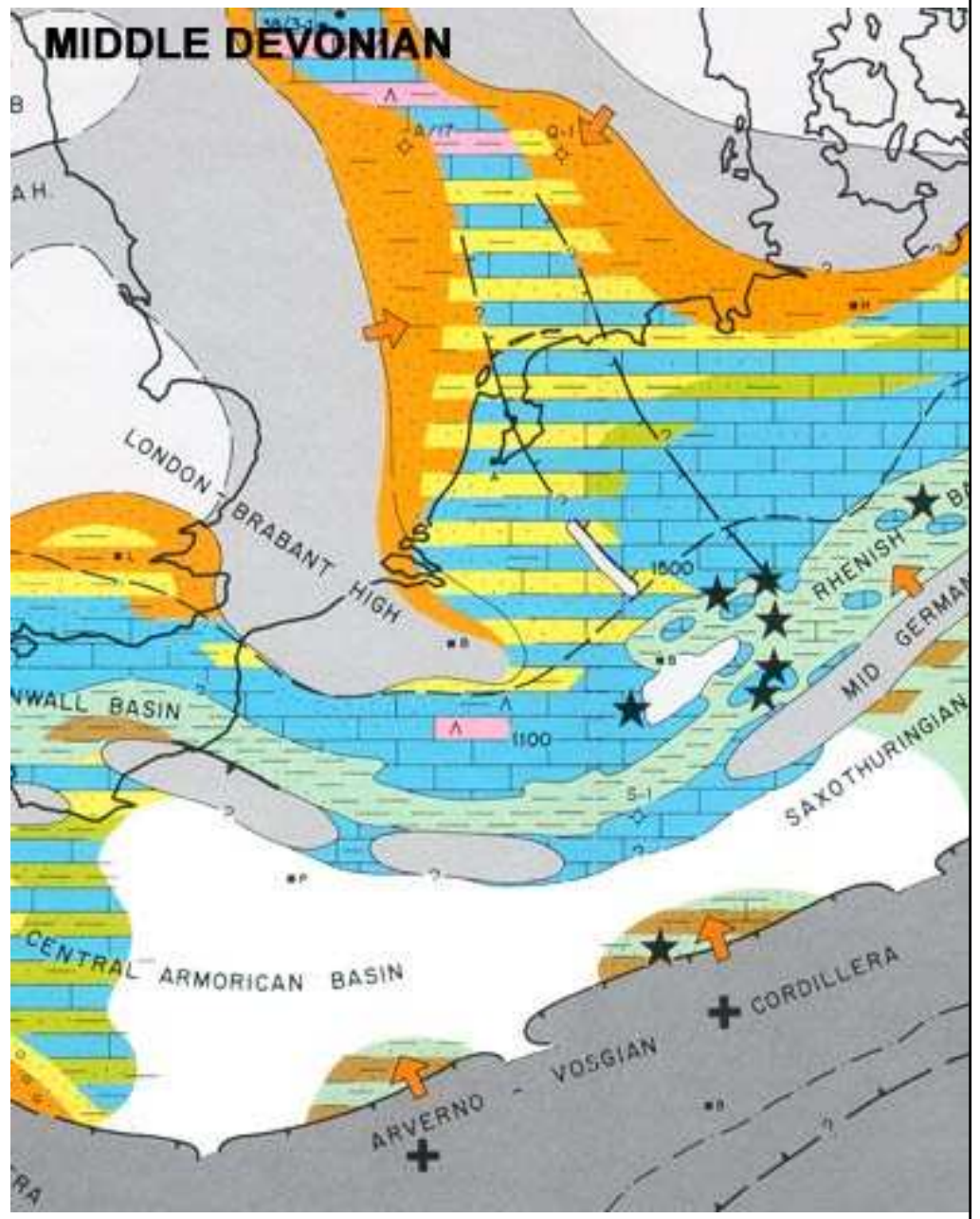
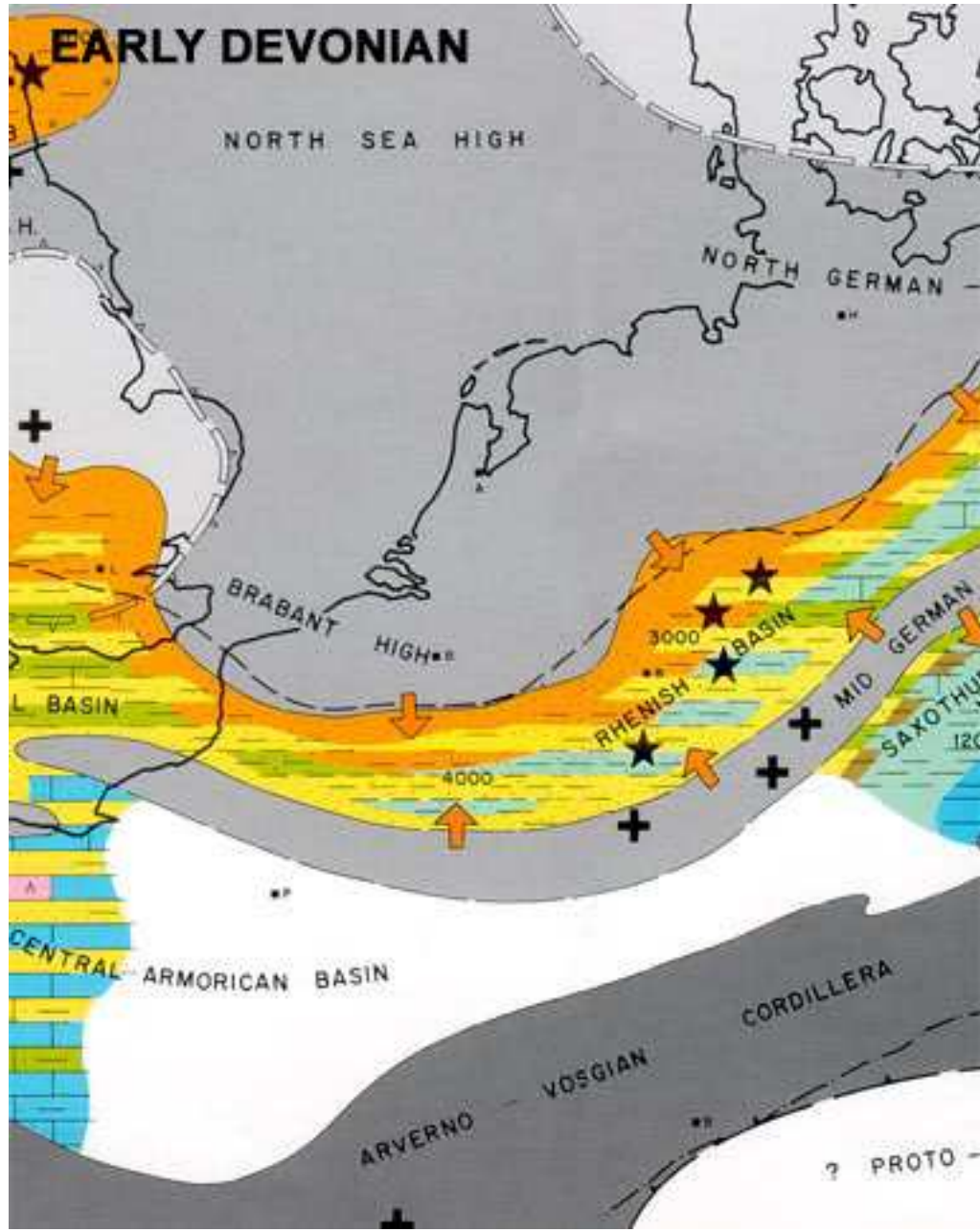


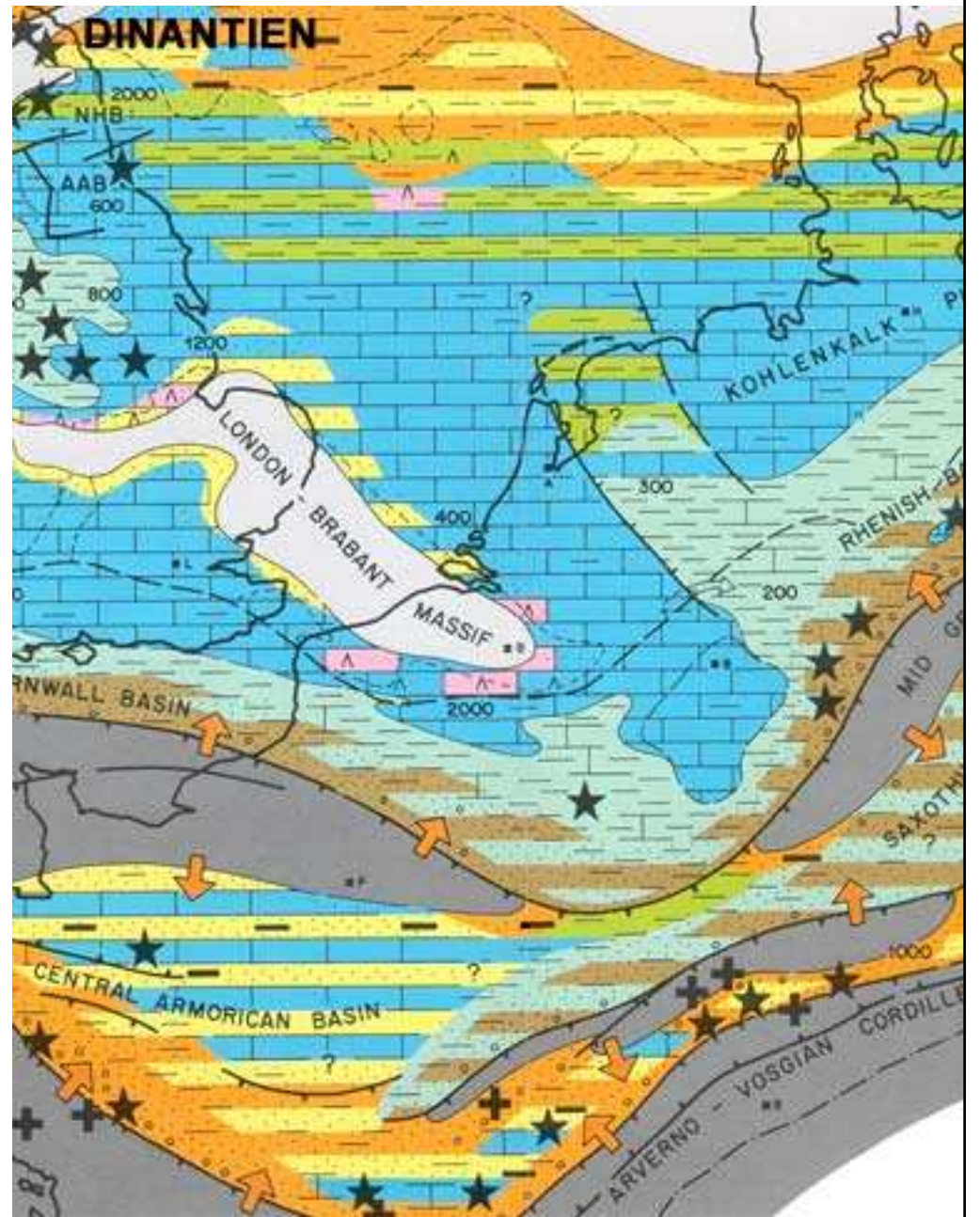
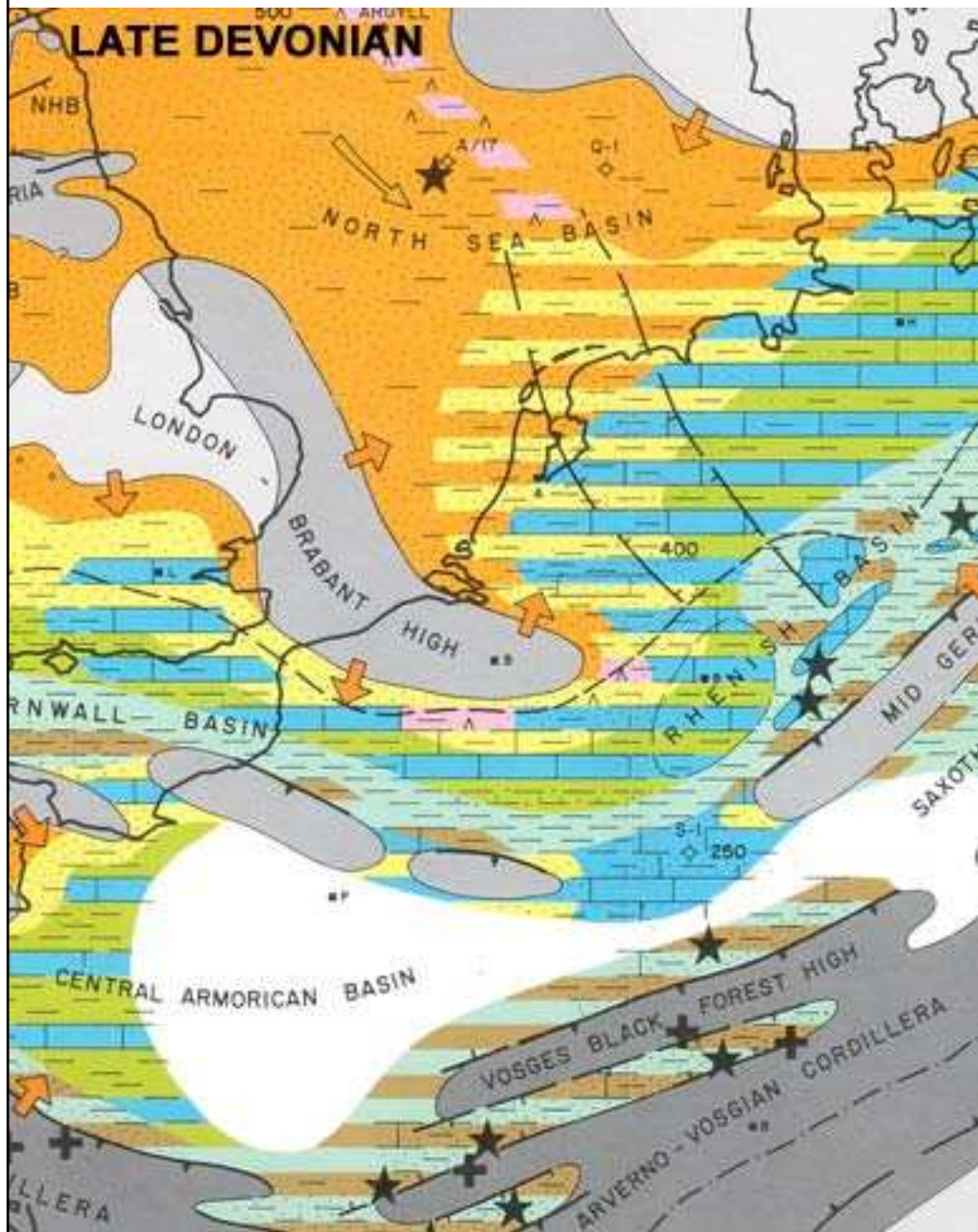
True conifer fossil
from Permian of
France.

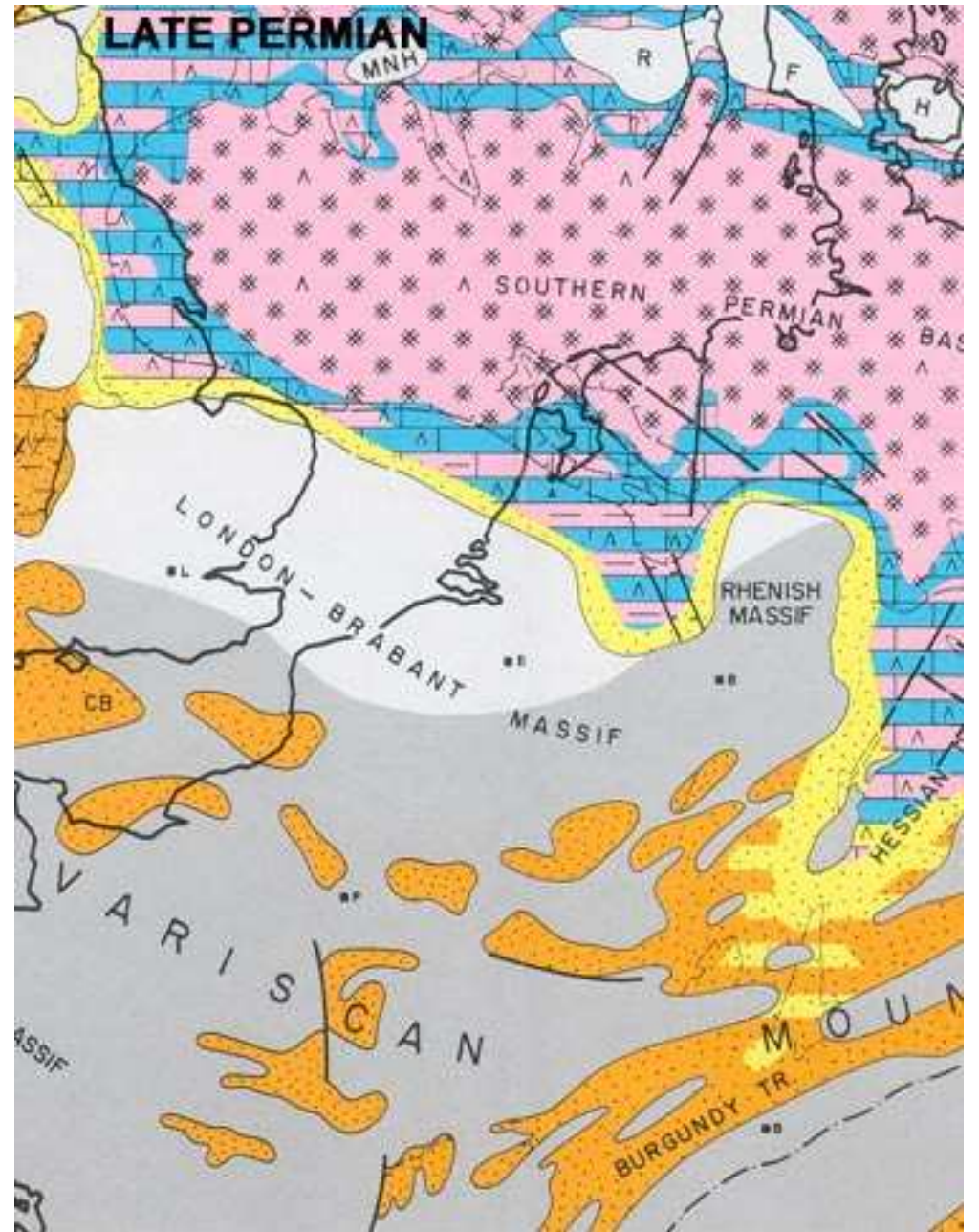
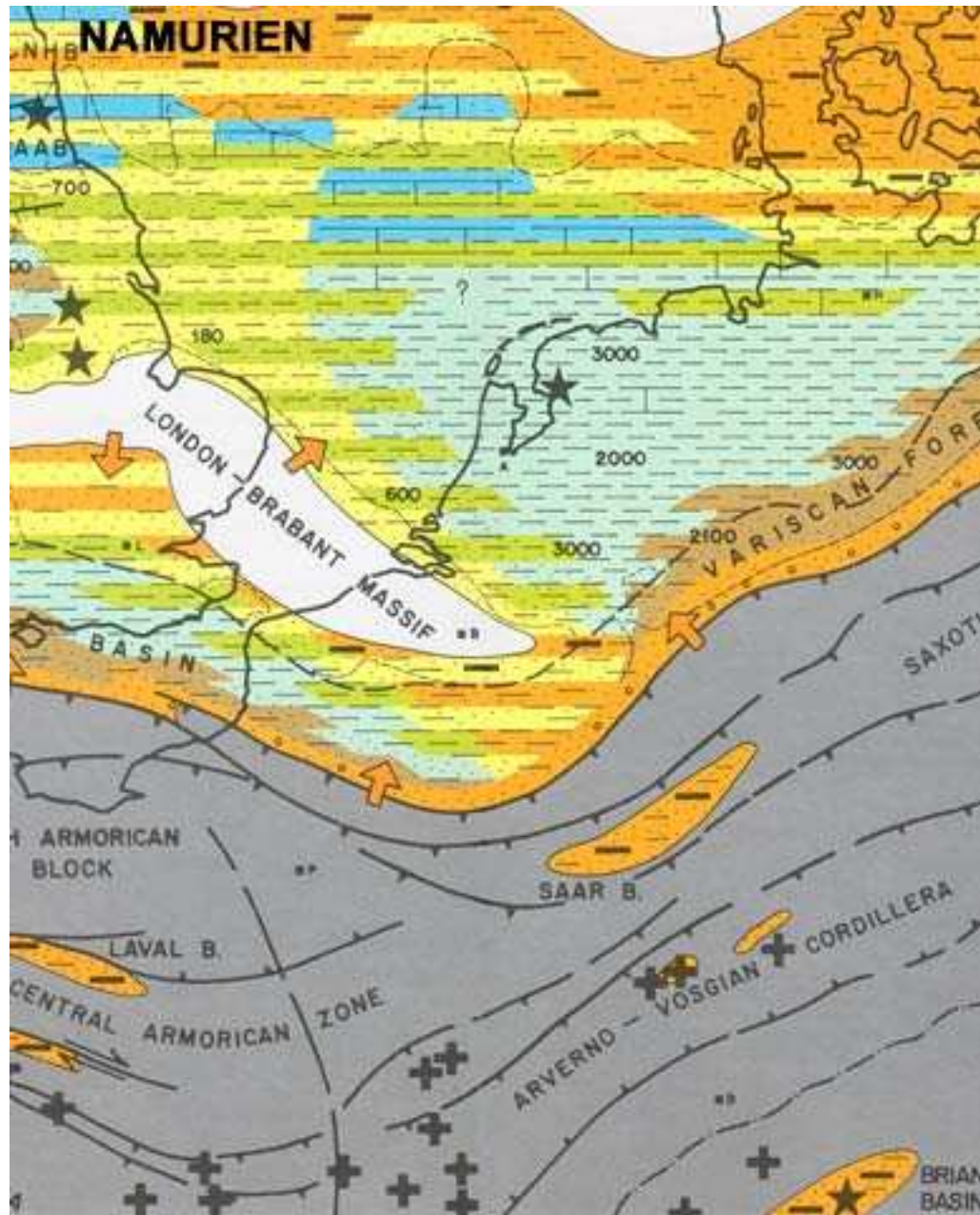
Petrified conifer logs from Late
Triassic Chinle Fm., Petrified Forest
National Monument, Arizona

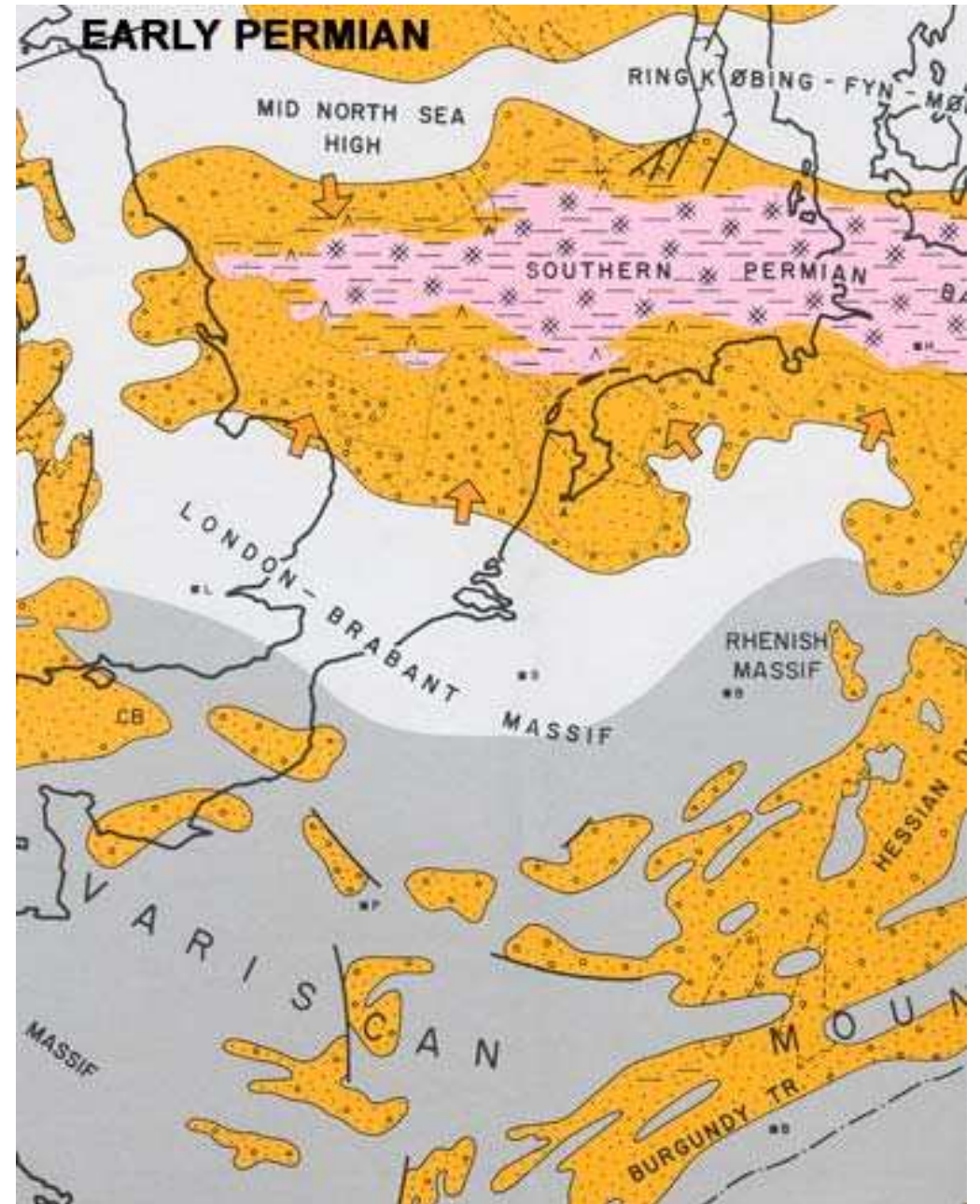
Seeds evolved when the formation of eggs and sperm no longer took place outside of tissue of the parental sporophyte. In seed plants (gymnosperms and angiosperms) the microspores develop into haploid pollen grains and megaspores into female sex cells in ovules while still attached to the plant (sporophyte; for example male and female cones of conifers). Pollen released to wind and larger cones in which ovules are fertilized by pollen.

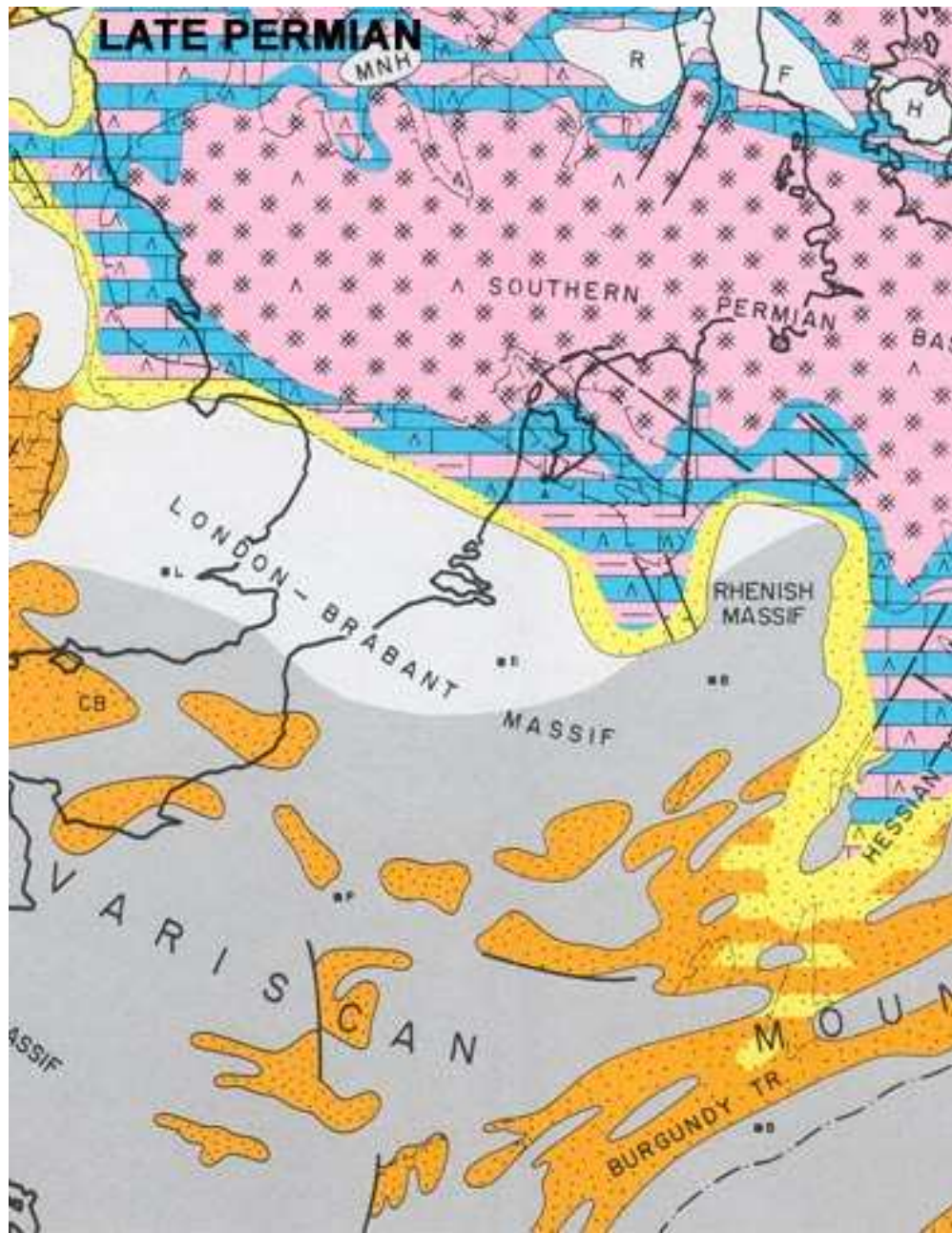


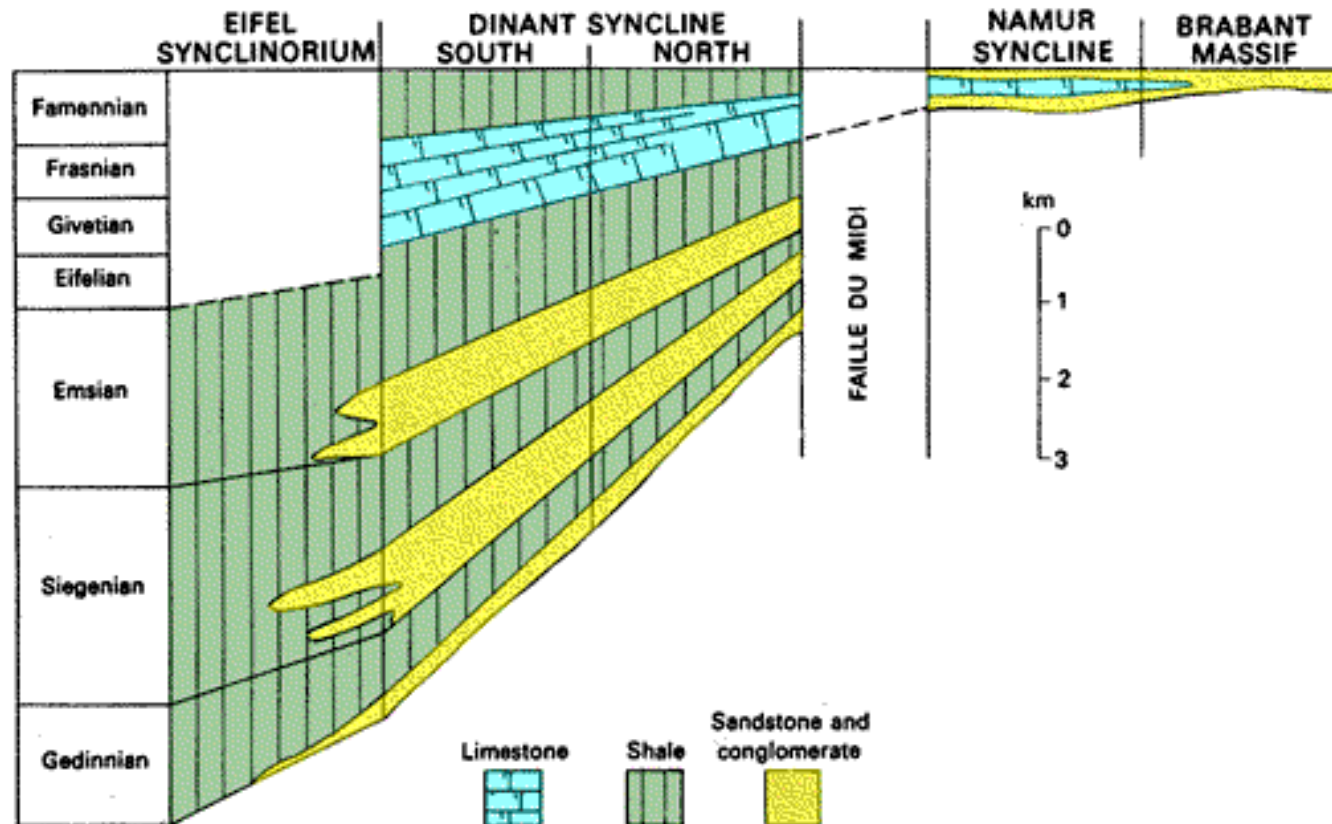












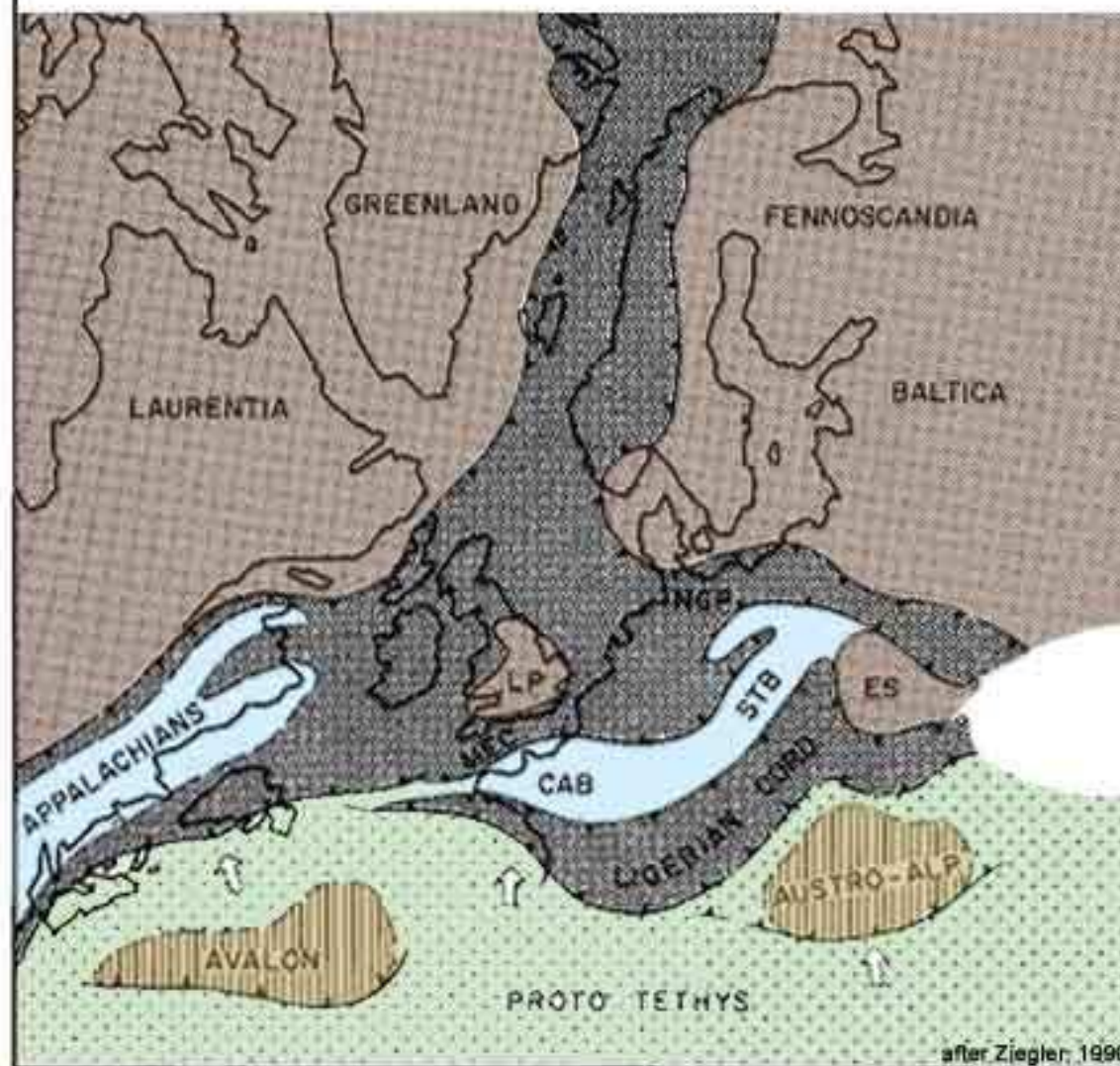
Variations of thickness and facies in the Devonian of the Ardennes (based on Fourmarier)


The Devonian of the Dinant basin shows a number of features indicative of its sedimentation at the southern border of the Old Red Continent. These are 1) the red colours of the siliciclastics as earliest Devonian sediment, unconformably covering the folded Older Paleozoic, 2) the southward transition of sandy facies into clayey deposits, 3) the thickening of the sediment pile towards the south. The discontinuity in sedimentation towards the Namur basin as on the above scheme, is ascribed to the absence at the surface of a series intermediate between Dinant and Namur basin due to the northward overthrusting of the Dinant basin over the "faille du Midi" or the "faille eifeliennne" (see [structural relation](#))



Univ. of Michigan Exhibit Museum of Natural History -- Life Through the Ages Diorama

LATE CALEDONIAN TECTONIC FRAMEWORK



-  Continental cratons
-  Active fold belts
-  Basins with continuous marine sedimentation across Silurian-Devonian boundary
-  Oceanic domains
-  Micro-continents
-  Deformation fronts of active fold belts

STB - Saxothuringian Basin
 CAB - Central Armorican Basin

LP - London Platform
 ES - East Silesian Massif

after Ziegler, 1990