Tucson Geologic History: Paleozoic (542-253.8 Ma)

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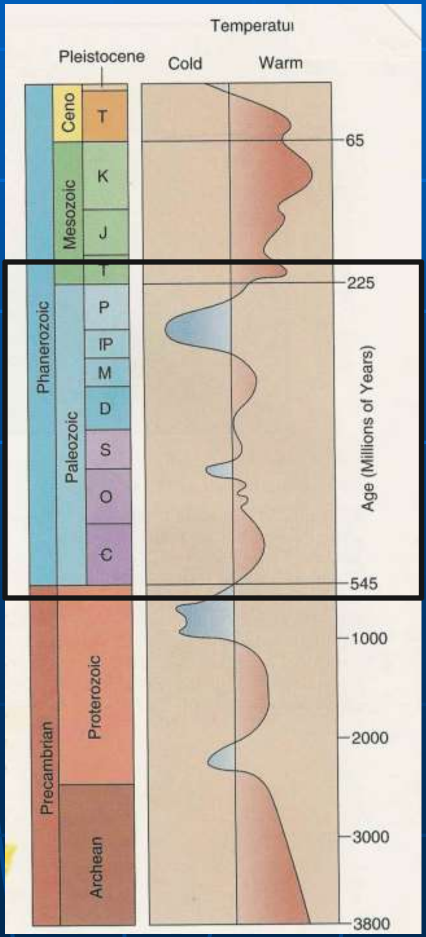
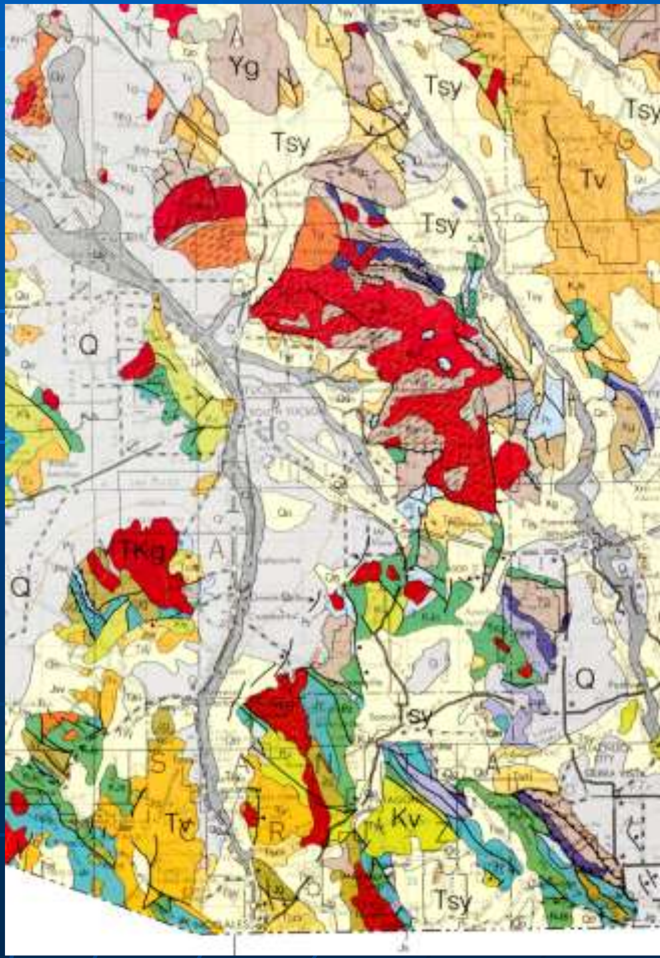




Temp. & Geologic Time Scale

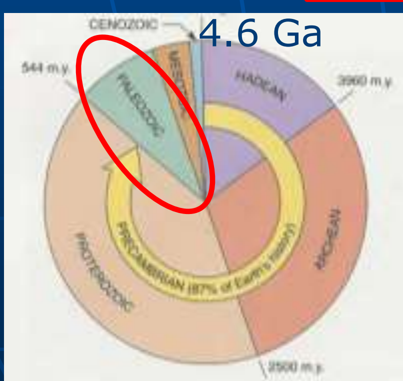
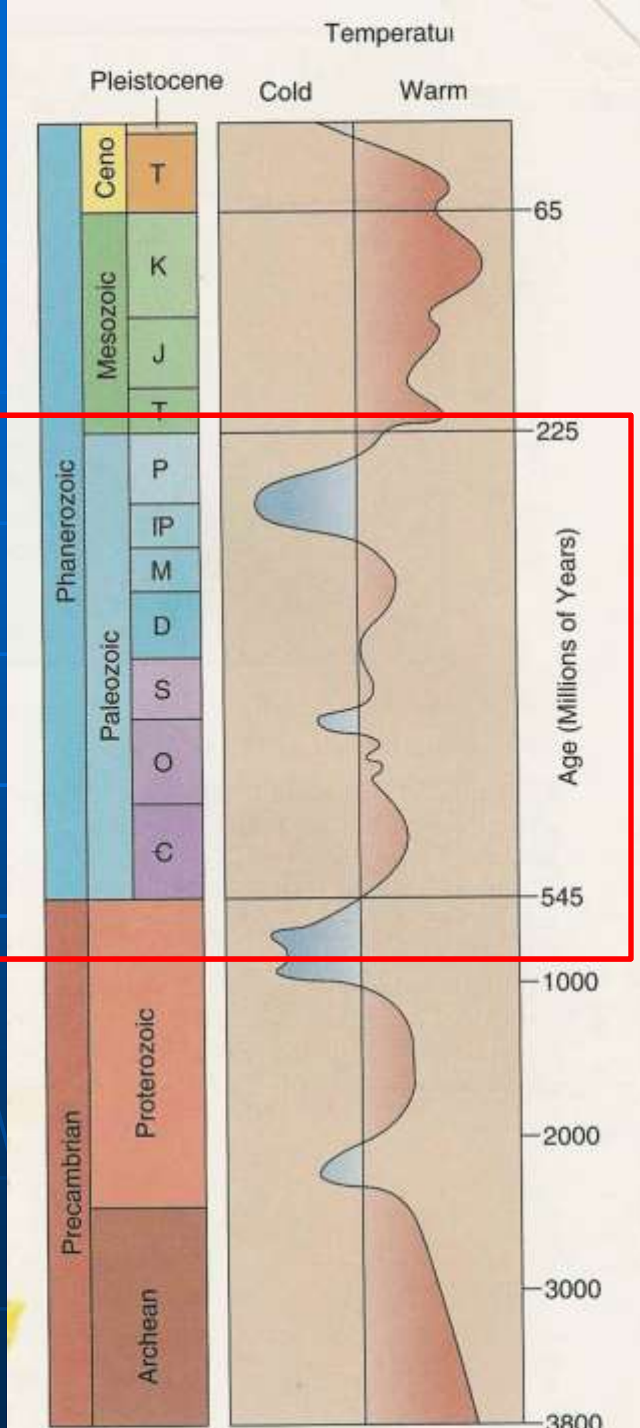


FIGURE 8-1 Proportions of geologic time encompassed by the Precambrian and its Hadean, Archean, and Proterozoic eons.



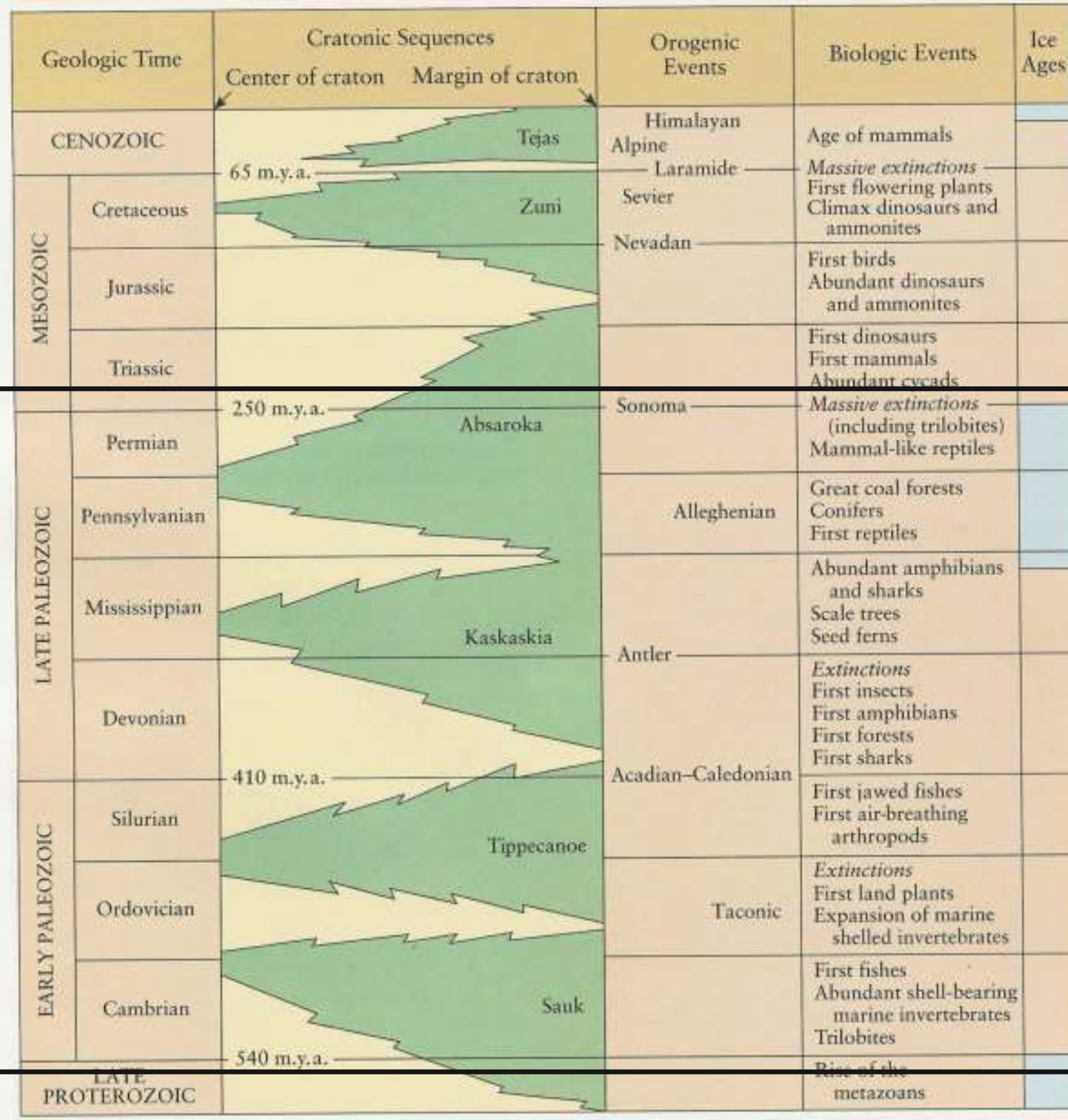
EON	ERA	PERIOD		EPOCH		Ma
Phanerozoic	Cenozoic	Quaternary		Holocene		0.01
				Pleistocene	Late	0.8
					Early	1.8
		Tertiary	Neogene	Pliocene	Late	3.6
					Early	5.3
				Miocene	Late	11.2
					Middle	16.4
					Early	33.7
				Oligocene	Late	28.5
					Early	33.7
			Paleogene	Eocene	Late	41.3
					Middle	49.0
					Early	54.8
				Paleocene	Late	61.0
					Early	65.0
	Mesozoic	Cretaceous			Late	99.0
					Early	144
		Jurassic			Late	159
					Middle	180
					Early	206
		Triassic			Late	227
					Middle	242
					Early	248
	Paleozoic	Permian			Late	256
					Early	290
		Pennsylvanian				323
		Mississippian				354
		Devonian			Late	370
					Middle	391
					Early	417
		Silurian			Late	423
					Early	443
		Ordovician			Late	458
					Middle	470
					Early	490
		Cambrian			D	500
					C	512
					B	520
					A	543
Precambrian	Proterozoic	Late				900
		Middle				1600
		Early				2500
	Archean	Late				3000
		Middle				3400
		Early				3800?

Cratonic sequences

Unconformity bounded

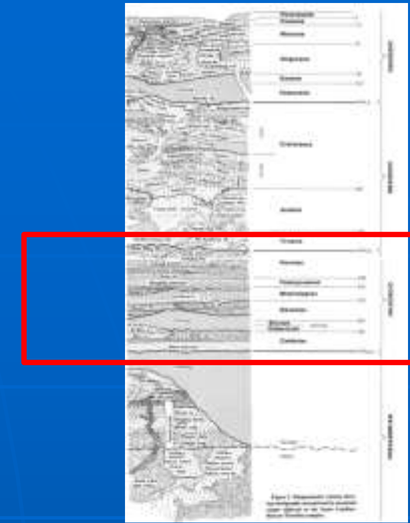
Continental assembly

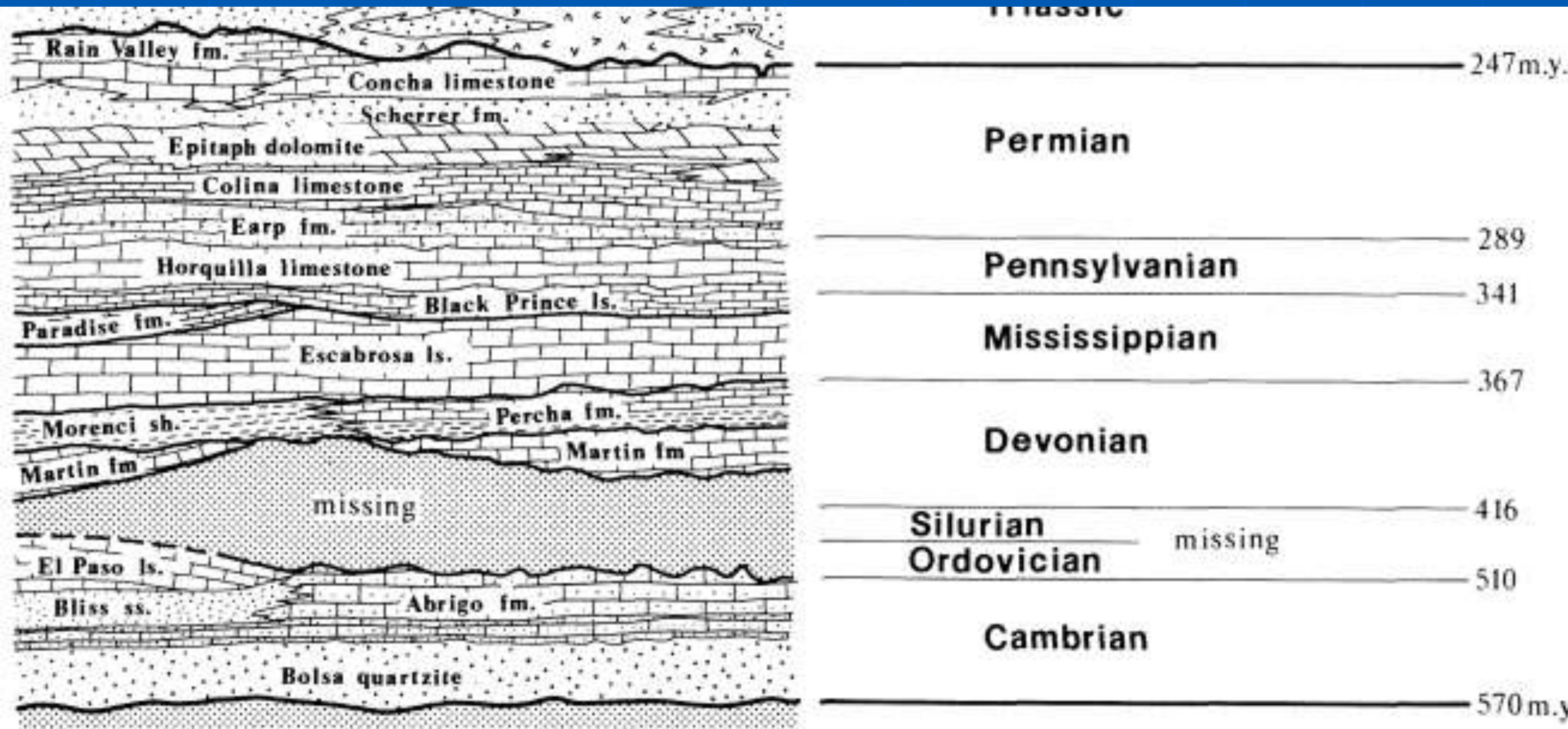
TABLE 8-1 Cratonic Sequences of North America*



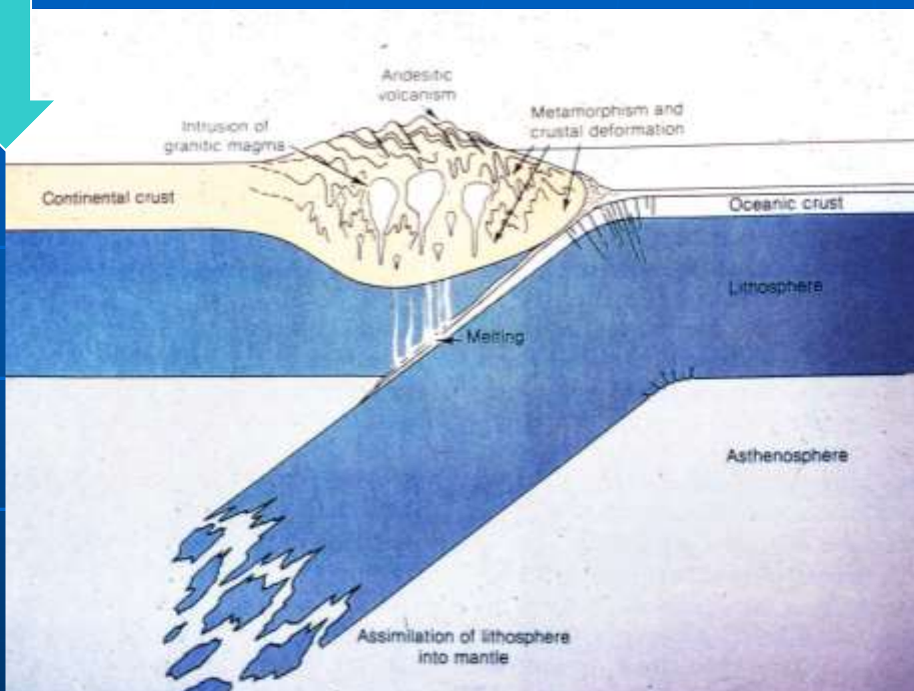
*The green areas represent sequences of strata. They are separated by major unconformities, indicated in yellow. Note that the rock record is most complete near cratonic margins, just as the time spans represented by unconformities are greatest near the center of the craton. Major biologic, orogenic, and glacial events are added for reference. (Cratonic sequence model after Sloss, L. L. 1965. *Bull Geol. Soc. Amer.* 74:93–114.)

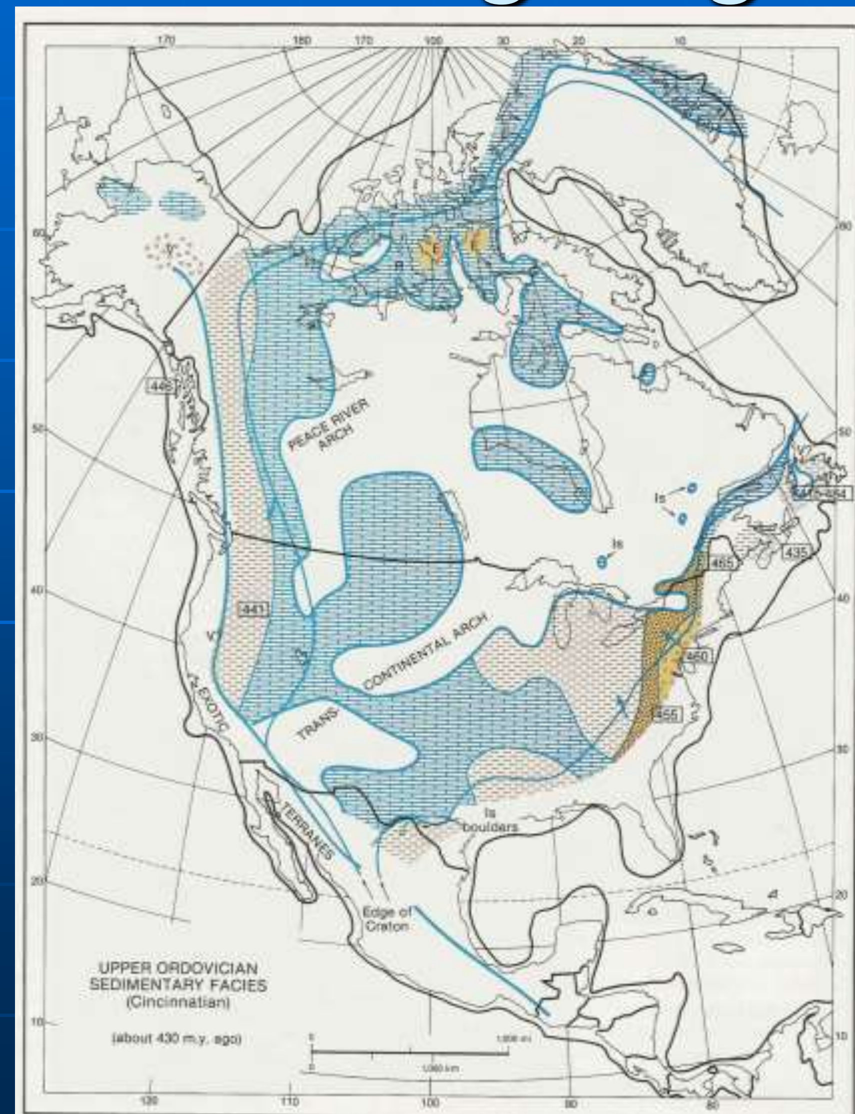
Paleozoic Formations in the Tucson area





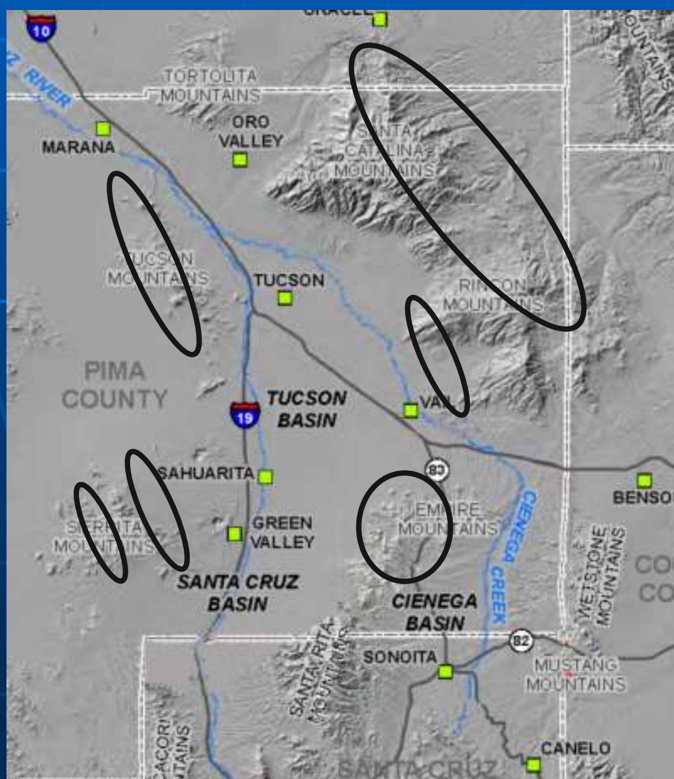
Mountain building along Appalachians, AZ on trailing edge

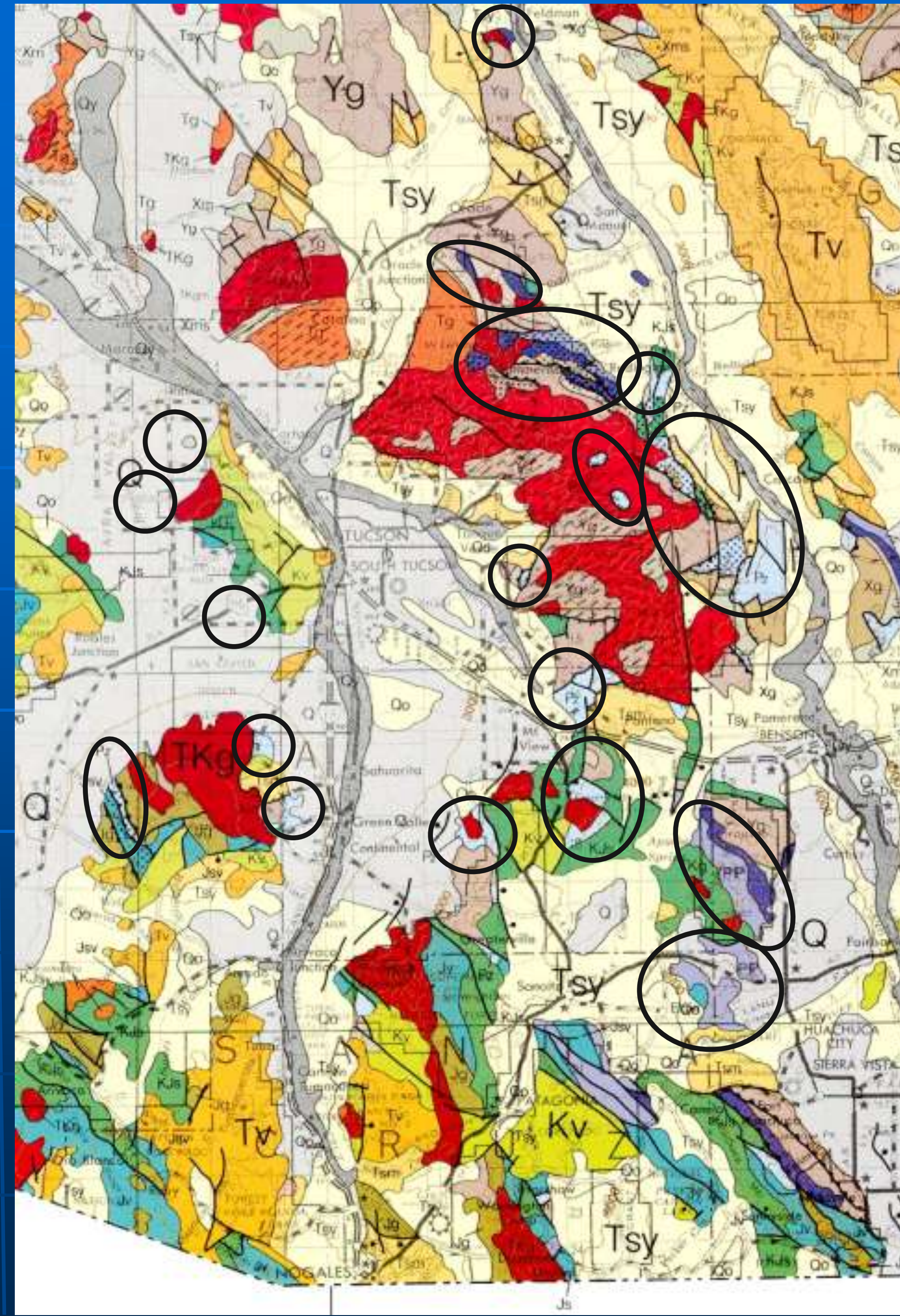




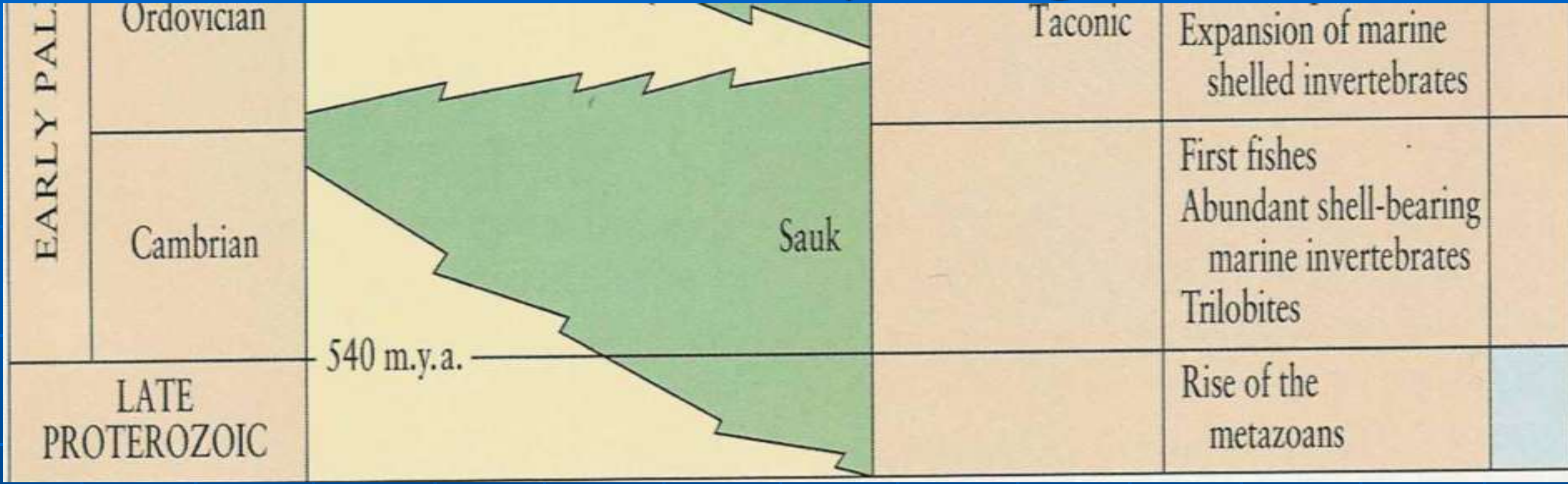
Seas go in, seas go out in the West, depending on mountain building on East coast

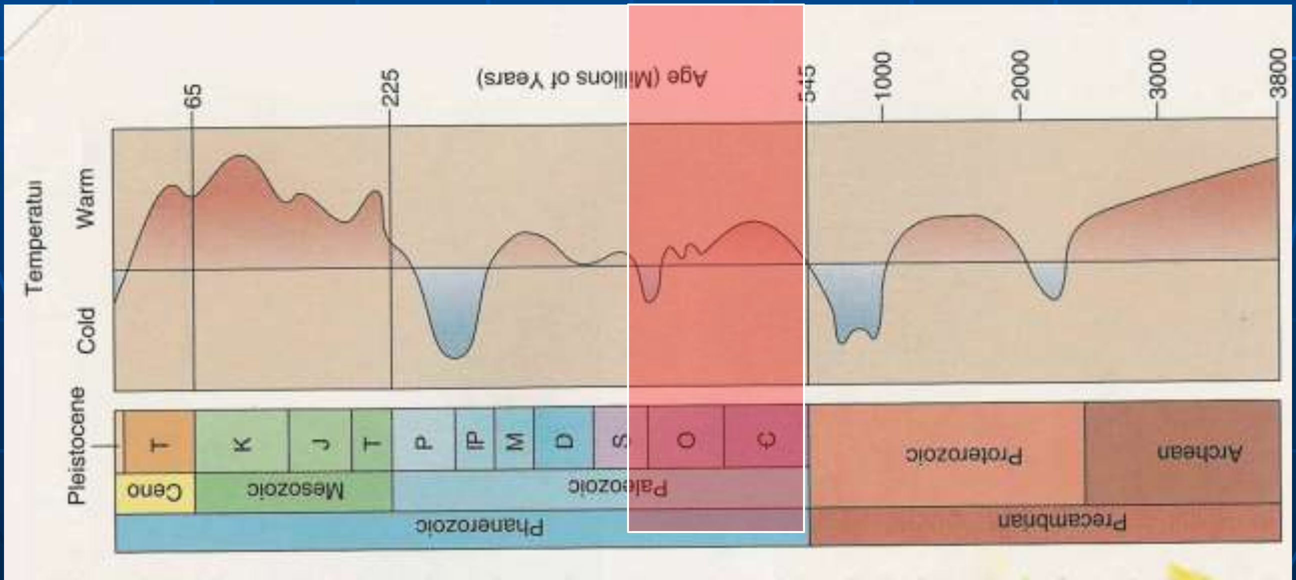
Paleozoic outcrops around Tucson

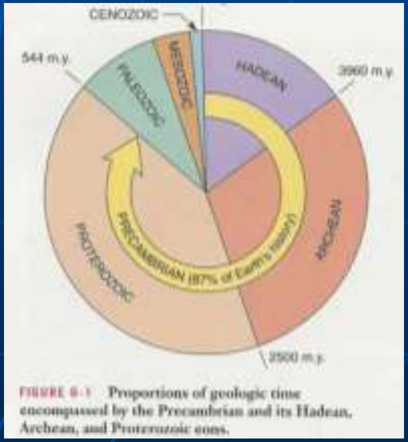




Cambrian – Early Ordovician
542 - 470 million years ago (Ma)







4. A GREAT TRANSGRESSION

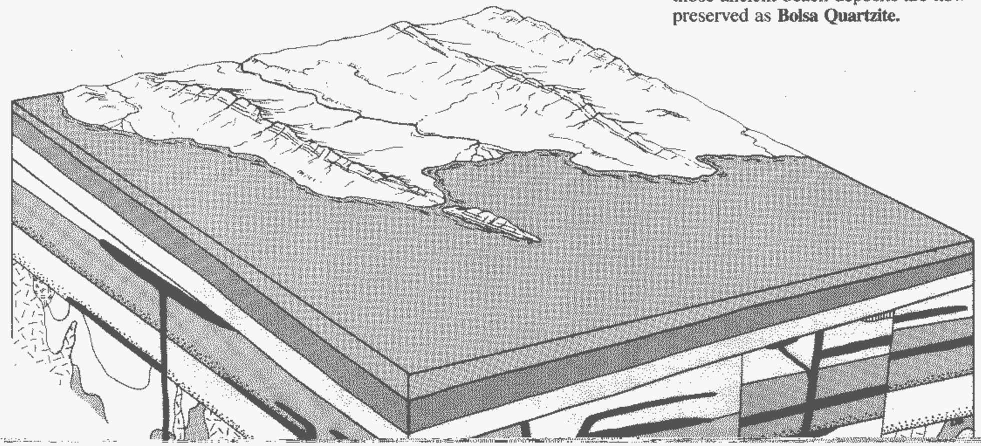
SANTA CATALINA MOUNTAINS REGION
early Paleozoic Era (~ 550-390 million years ago)

When Precambrian time drew to a close (a little more than 1/2 billion years ago), another long interval of erosion again resulted in a general leveling of the landscape. This long erosional interval was not as thorough as the previous episode; so when the seas eventually returned during the Cambrian Period, scattered elongate ridges, formed of resistant layers of slightly tilted Apache Group rocks, persisted as low islands in some areas of the region.

This great early Paleozoic transgression of the seas was the premier event of the Phanerozic Eon all along the western part of ancient North America. By the end of the Cambrian Period even the offshore islands had been worn down and innundated, and the coast of the shrunken continent now lay hundreds of miles to the northeast of Arizona.

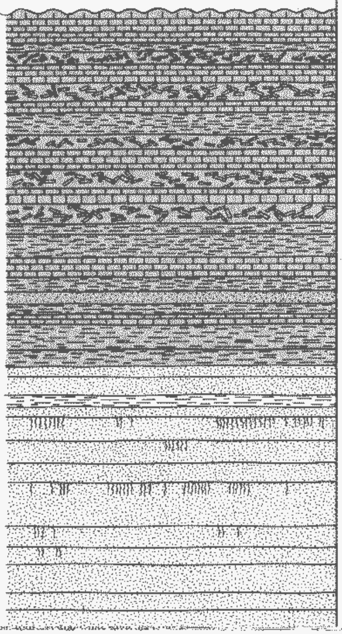
As Cambrian seas transgressed across the low-lying continent from south and west, the shores of the mainland migrated inland and its beaches accumulated a variety of coarse sandy sediments. As the seas deepened, beach sands were progressively covered by offshore muds and limey deposits secreted by marine organisms.

The mud flats and limey organic deposits laid down during Cambrian time are now shales and limestones of the **Abrigo Formation,** while sands of those ancient beach deposits are now preserved as **Bolsa Quartzite.**



CAMBRIAN STRATA

Ordovician (and perhaps Silurian) sediments might have once overlain youngest Cambrian strata, but virtually nothing is known of these periods; the upper parts of this section were completely eroded away from this region during a withdrawal of the seas that lasted through the beginning of Devonian time.

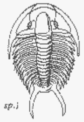


ABRIGO FORMATION

— consists of thin layers of limestone and shale that are not very resistant to weathering and erosion, and thus are seldom well exposed.

Distinctive flat-pebble or "edgewise" conglomerates are characteristic of the Abrigo Formation. These strata were formed from ripped-up layers of nearby mud flats, attesting to great ocean storms, even in those ancient times.

Some rocks of Cambrian age preserve evidence of ancient sea creatures. Fragments of rare trilobites have been found.



TRILOBITE:
(Tricrepicephalus sp.)

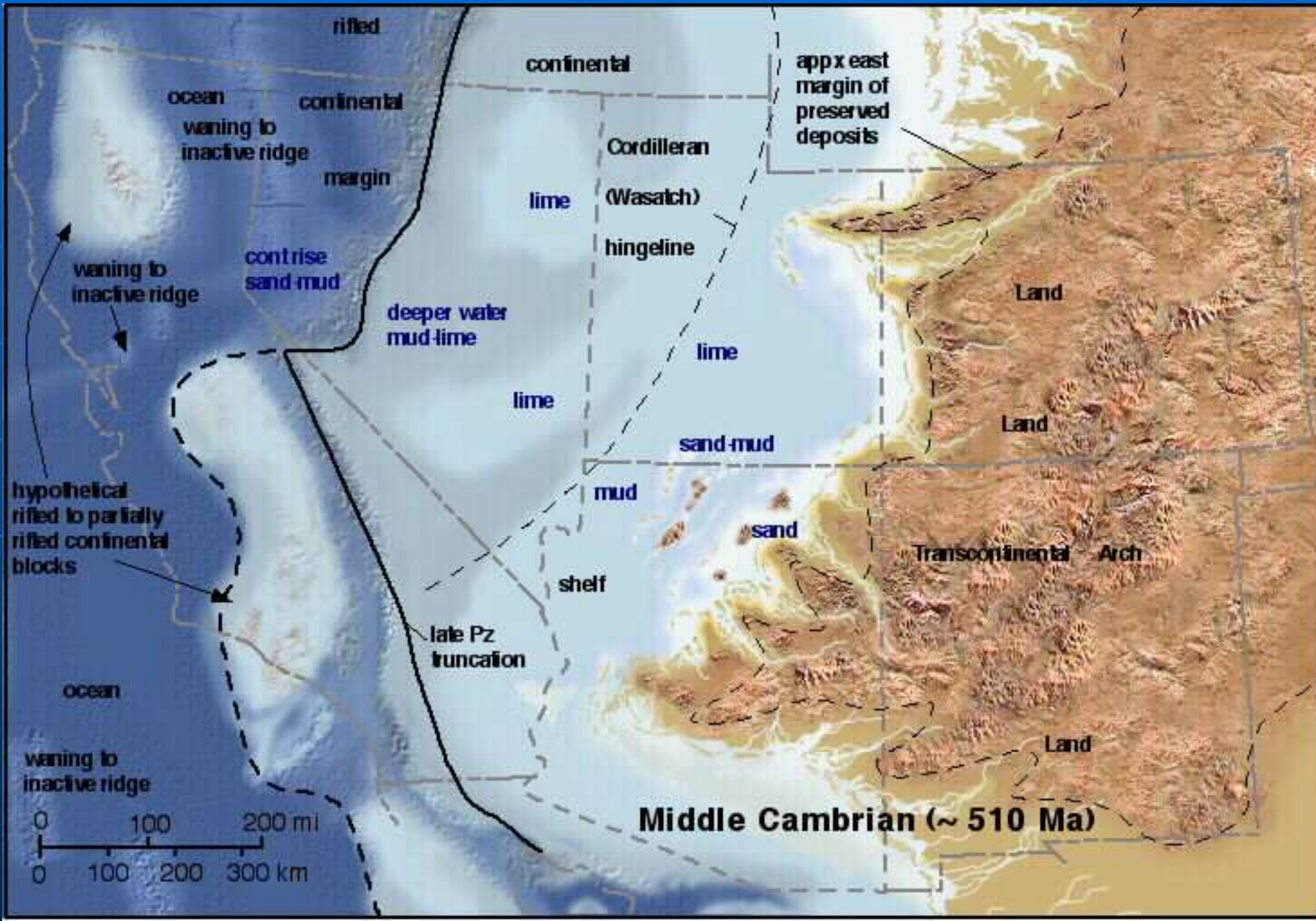
BOLSA QUARTZITE

— originally laid down as beach deposits, some of its lowermost layers contain a variety of different minerals and are preserved as sandstone. Most of this formation, however, is composed of pure quartz sand that was eventually saturated with hard silica cement, causing the Bolsa to now be typically preserved as quartzite.

A layer of Cambrian beach sands eventually covered nearly all of western North America. Such strata commonly include numerous filled burrows of presumably worm-like organisms known as *Scolithus.* These most usually occur in upper layers of Bolsa Quartzite.

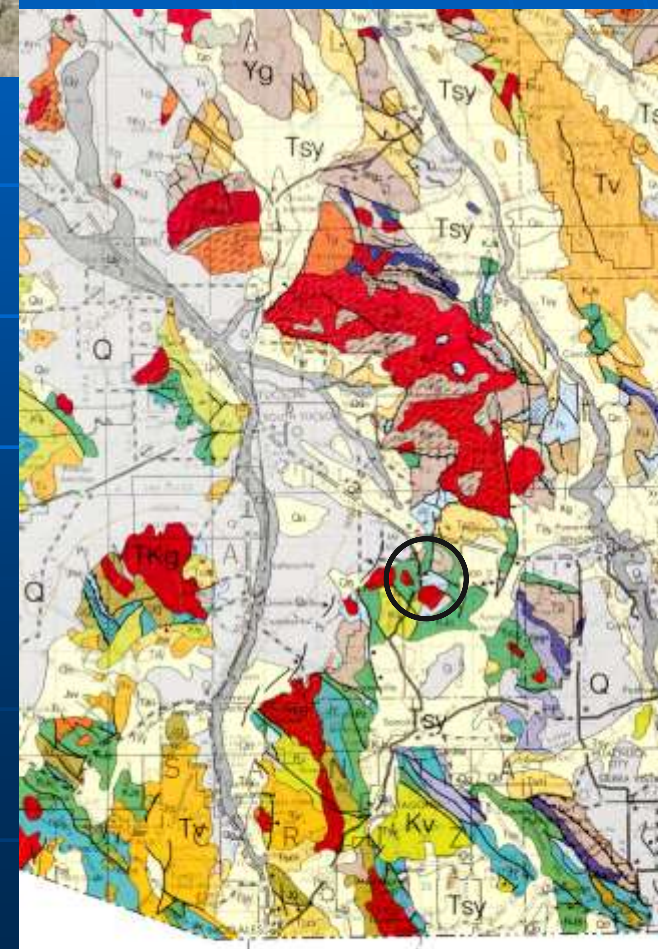
Bolsa Quartzite is a very hard, durable formation that commonly forms cliffs and

Cambrian (543-490 Ma)



Early Paleozoic – Cambrian Santa Rita Mts. - basal

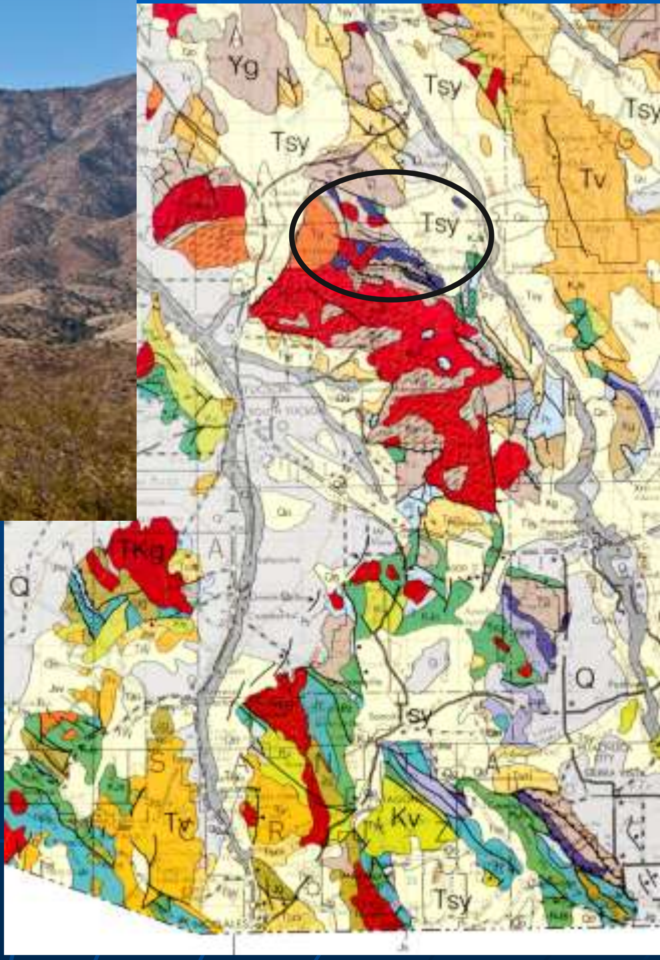
Bolsa Quartzite



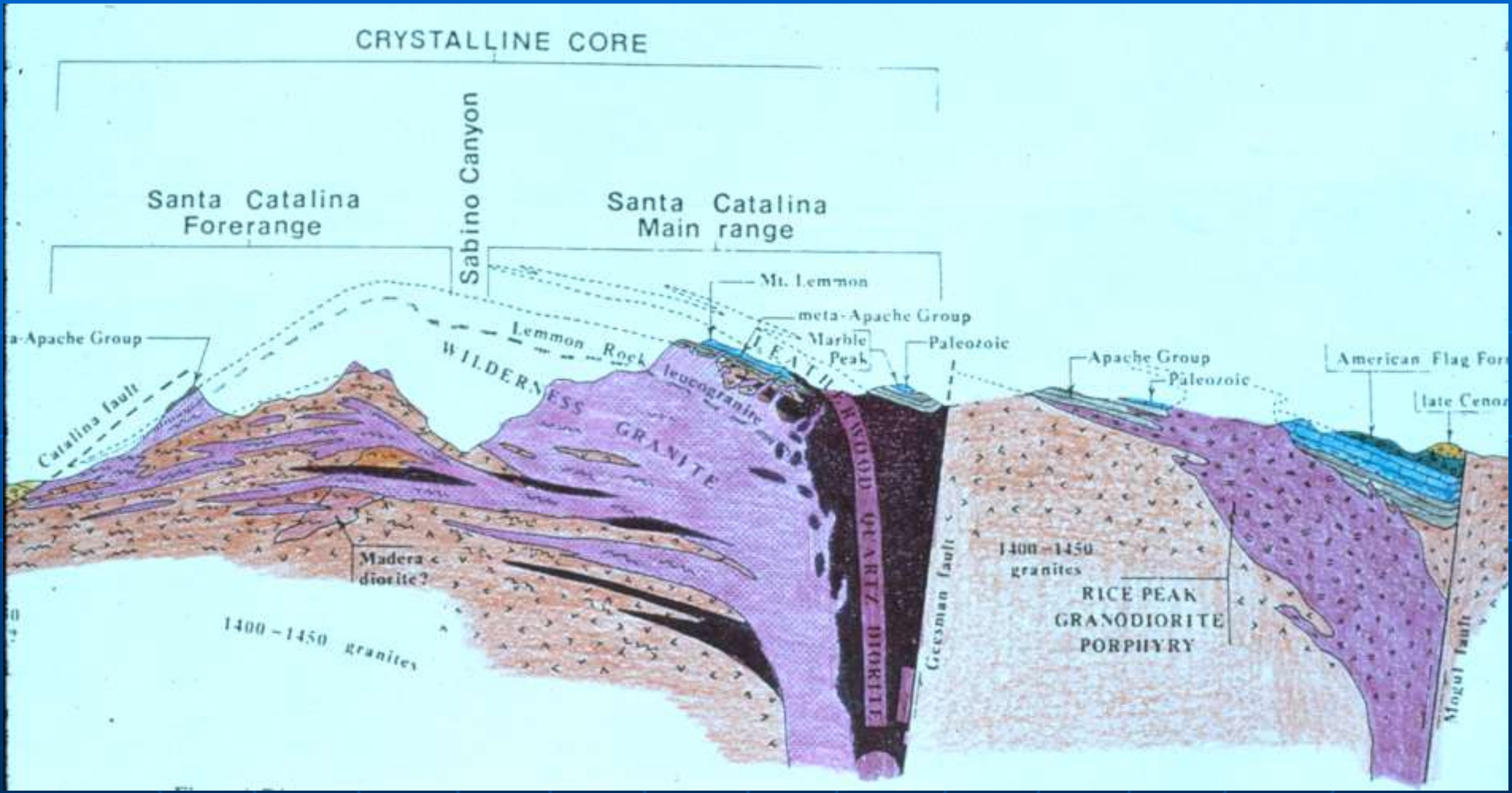
Early Paleozoic – Cambrian Santa Catalina Mts.

Marble Peak – N side

Bolsa Quartzite

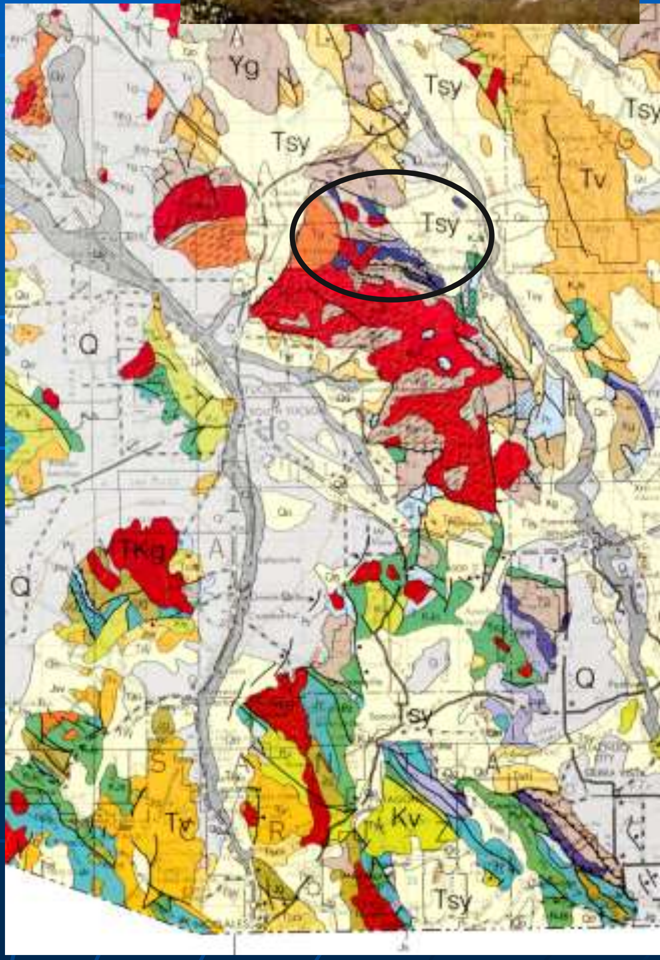


Catalina cross section – look West



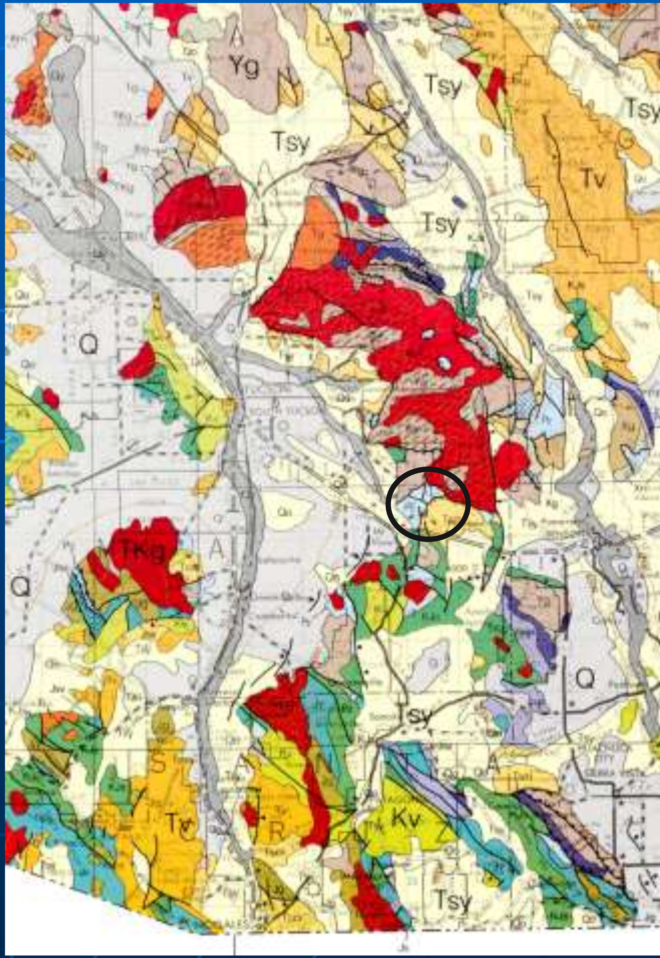
Early Paleozoic – Cambrian Santa Catalina Mts. – above base

Abrigo Limestone



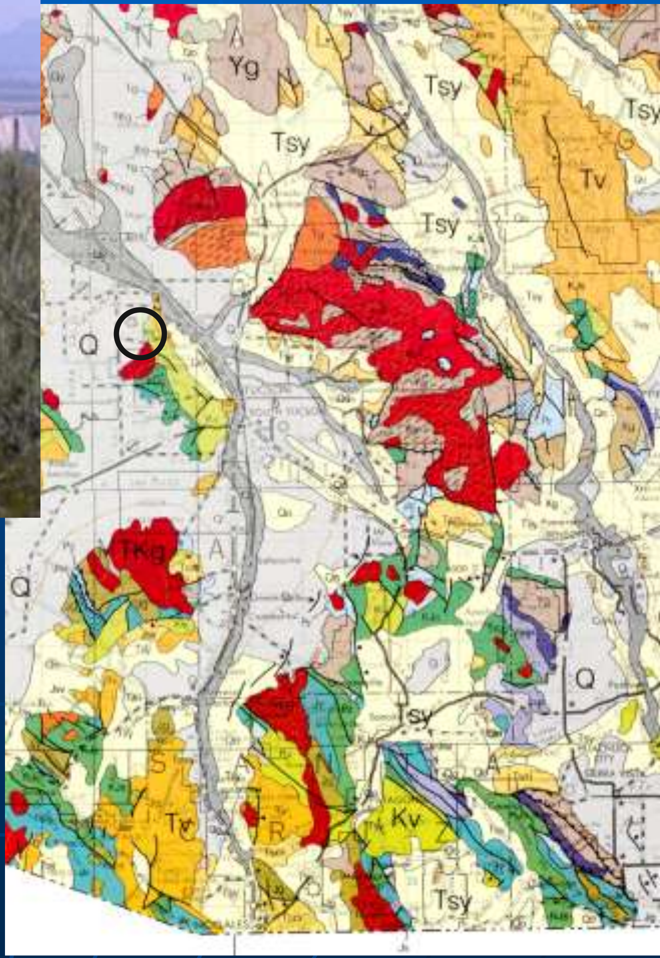
Early Paleozoic – Cambrian Rincon Mts. - Bolsa & Abrigo

Photo by Bill Peachey, near Colossal Cave



Early Paleozoic – Cambrian - N. Tucson Mts.

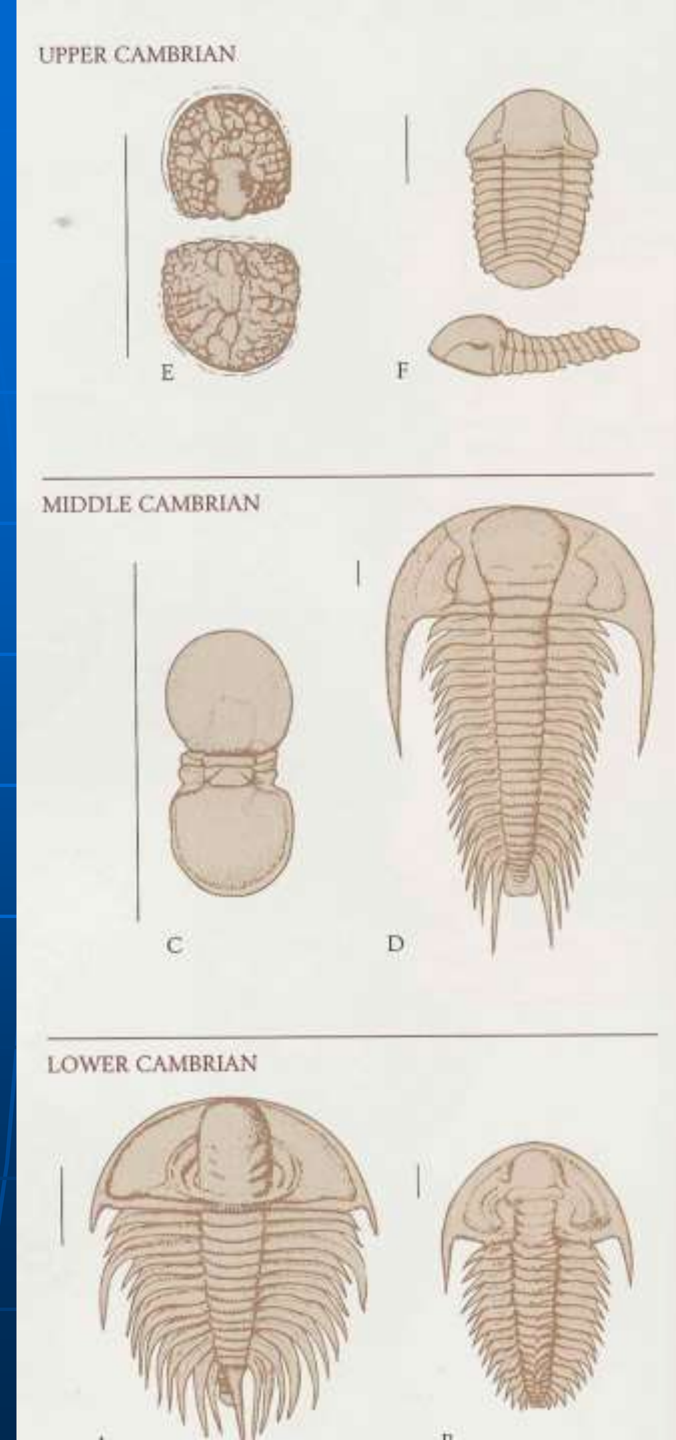
Twin Peaks Quarry, looking N, 1987



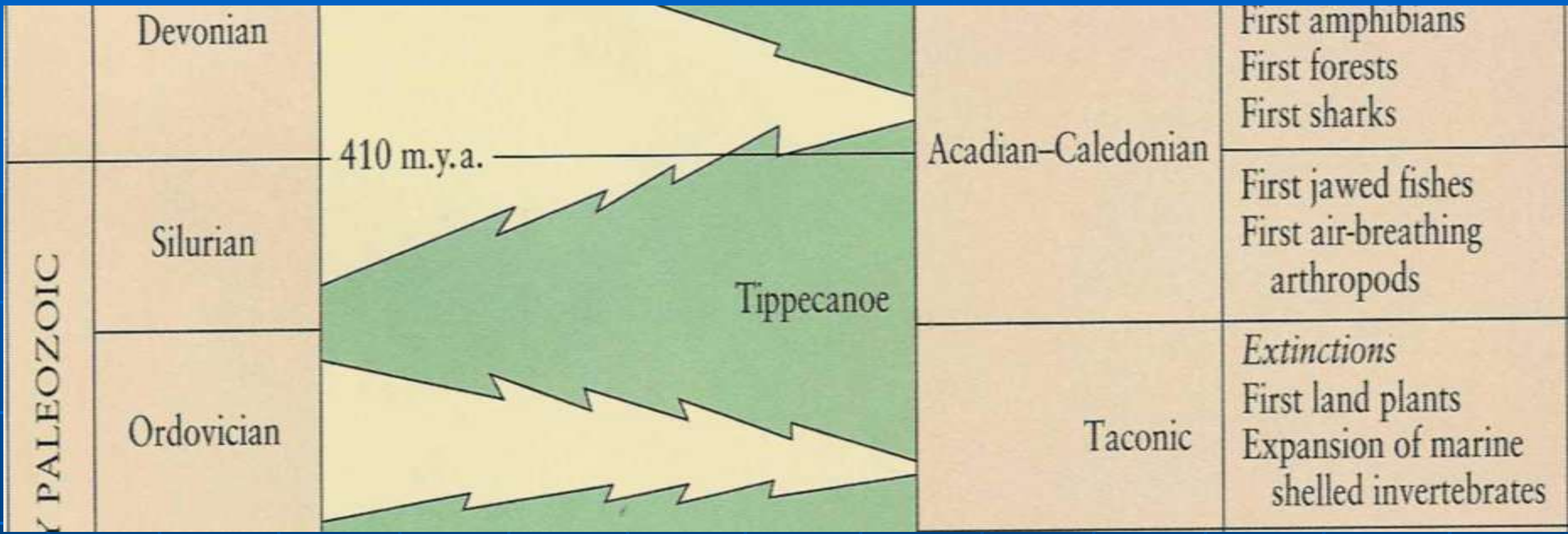
Trilobites

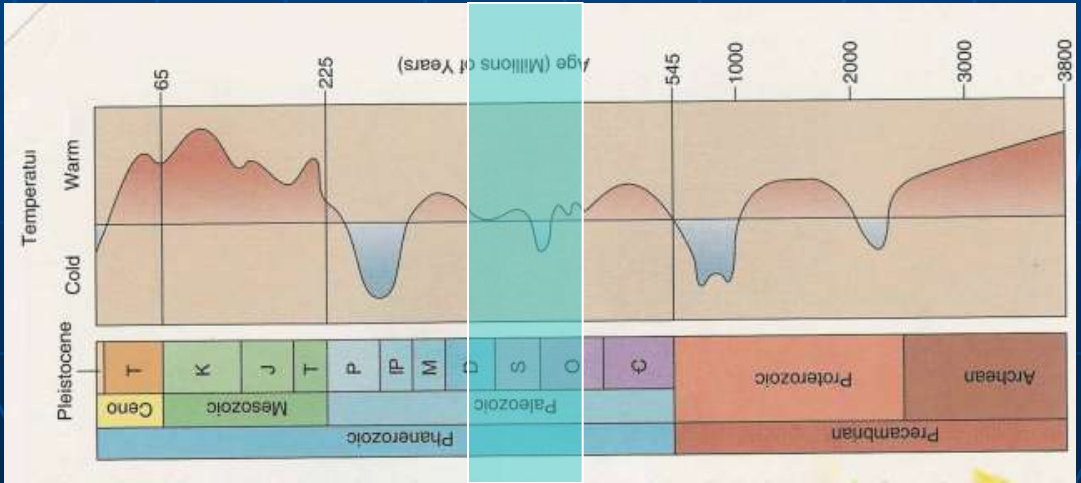
A B

Figure 13-2 **Typical Cambrian trilobites.** *A. Olenellus. B. Holmia. C. Lejopyge. D. Paradoxides. E. Glyptagnostus. F. Illaenurus.* Trilobites were arthropods (invertebrate animals with segmented bodies and jointed legs). The soft body and the many legs were positioned beneath the flexible, jointed skeleton. Trilobites had mouthparts for chewing small pieces of food. Most species crawled over the seafloor, but some burrowed in sediment, and a few small specie

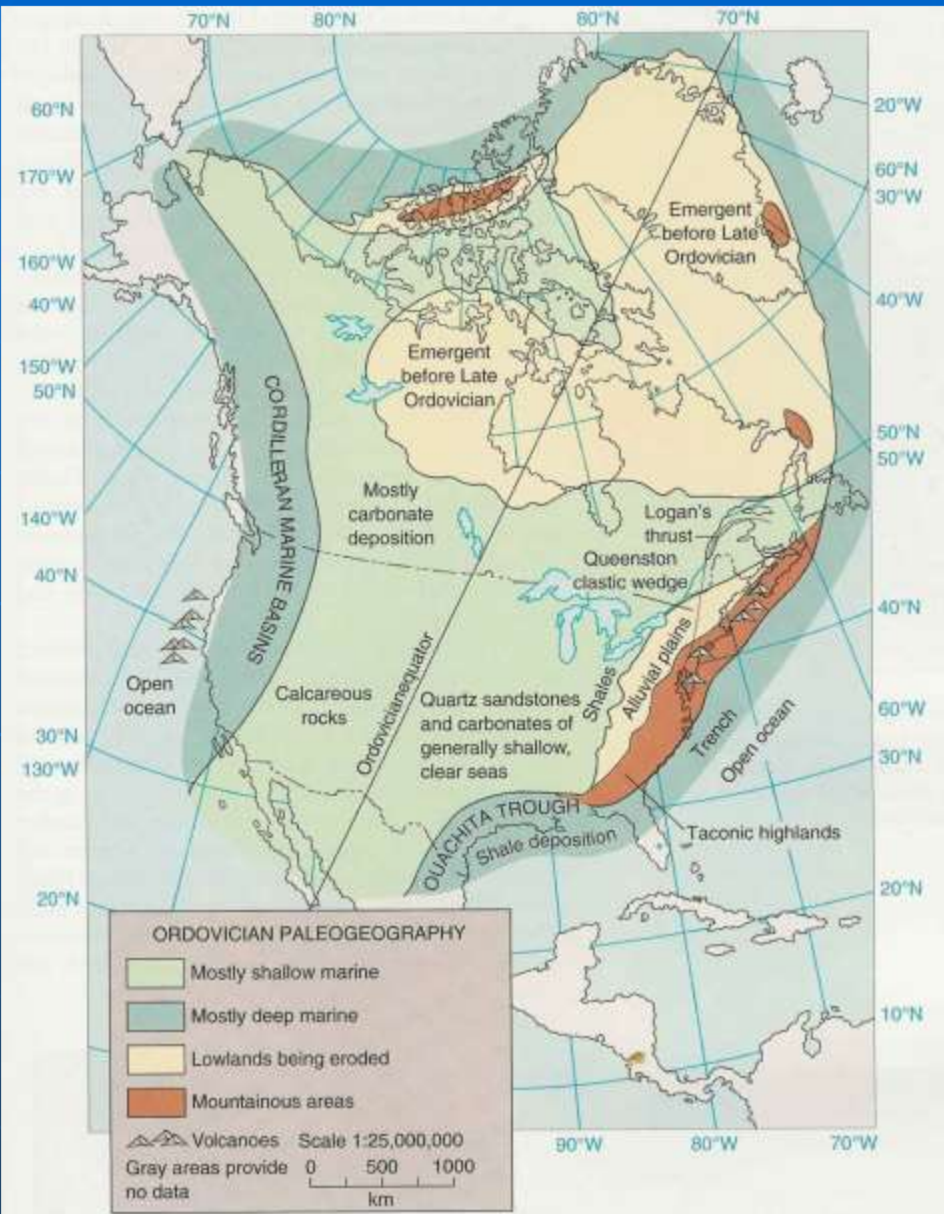


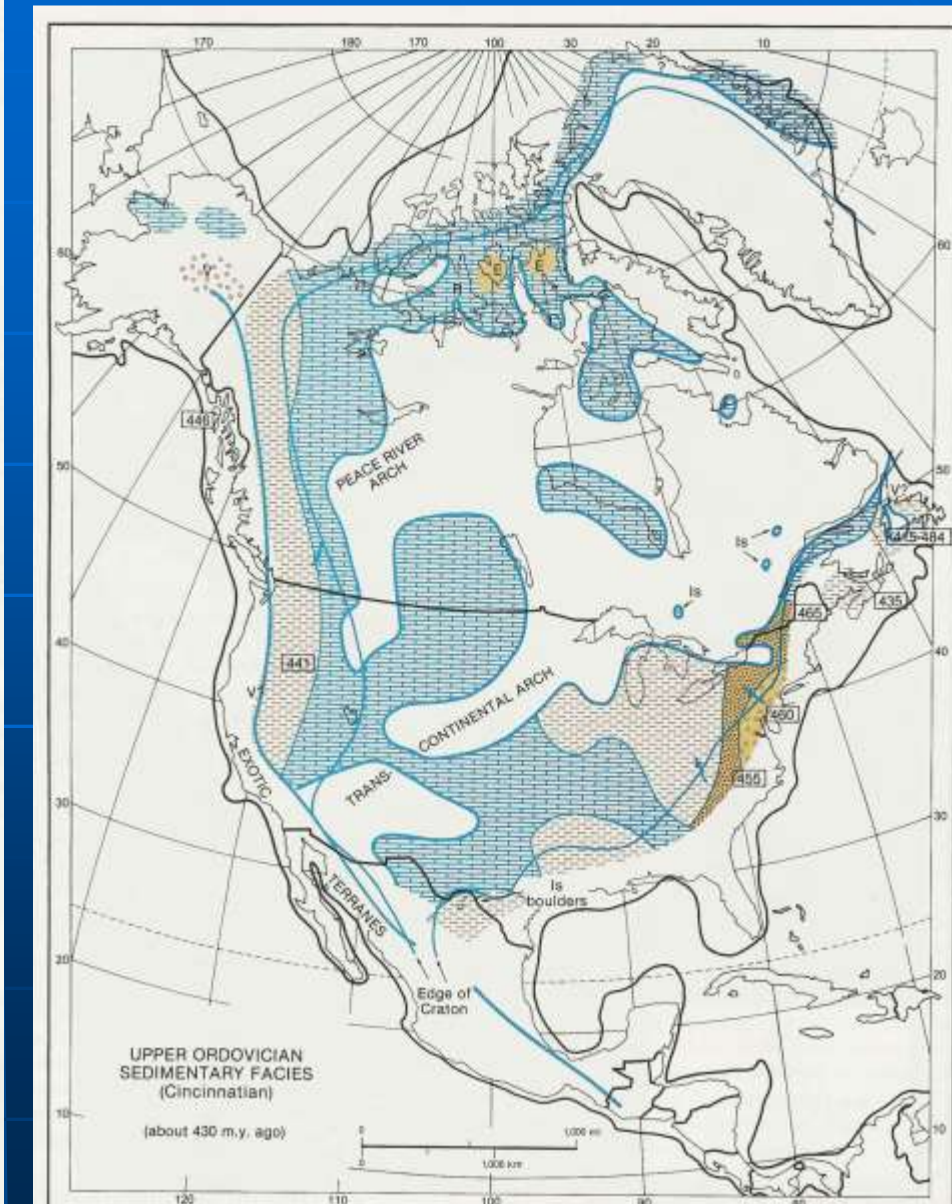
Middle Ordovician – Early Devonian (~470-400 Ma)



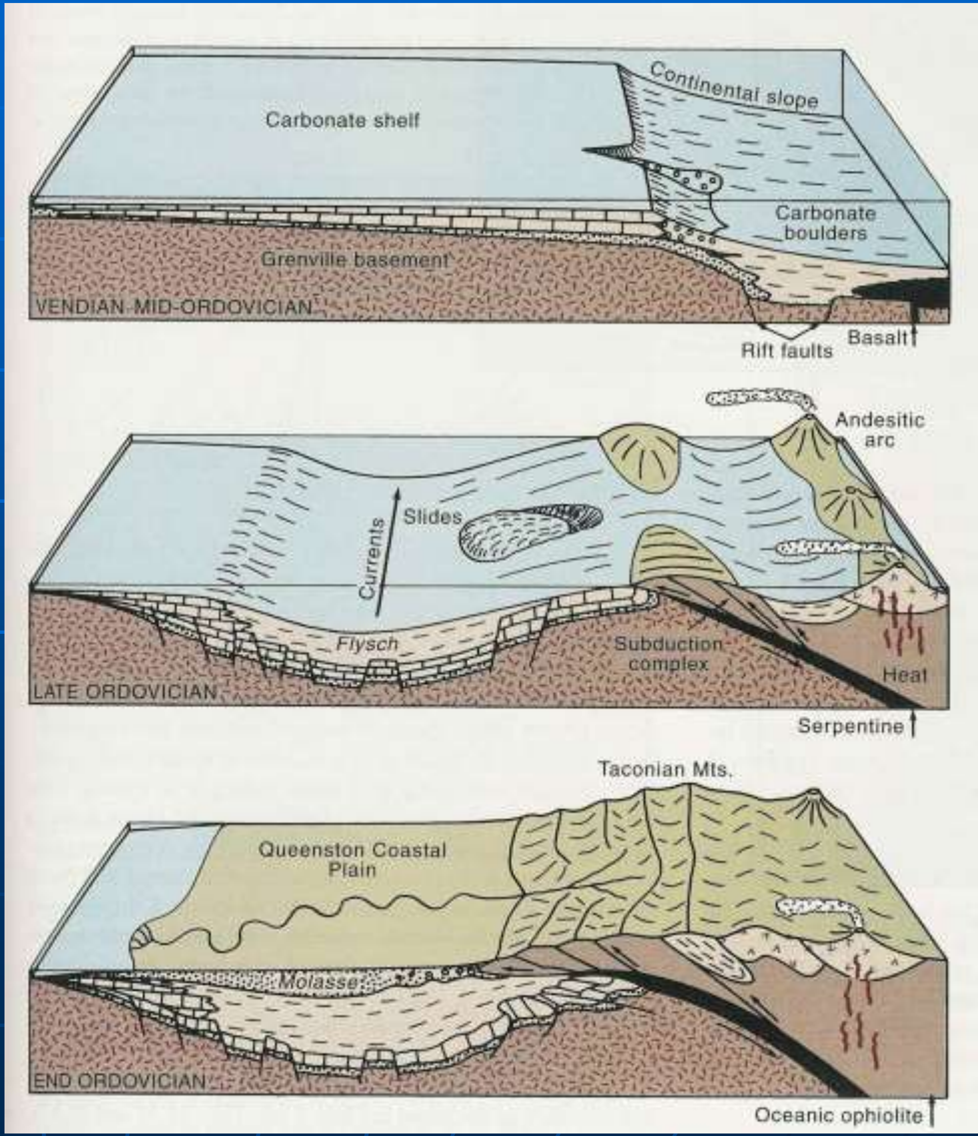


Late Ordovician environments (430 Ma)

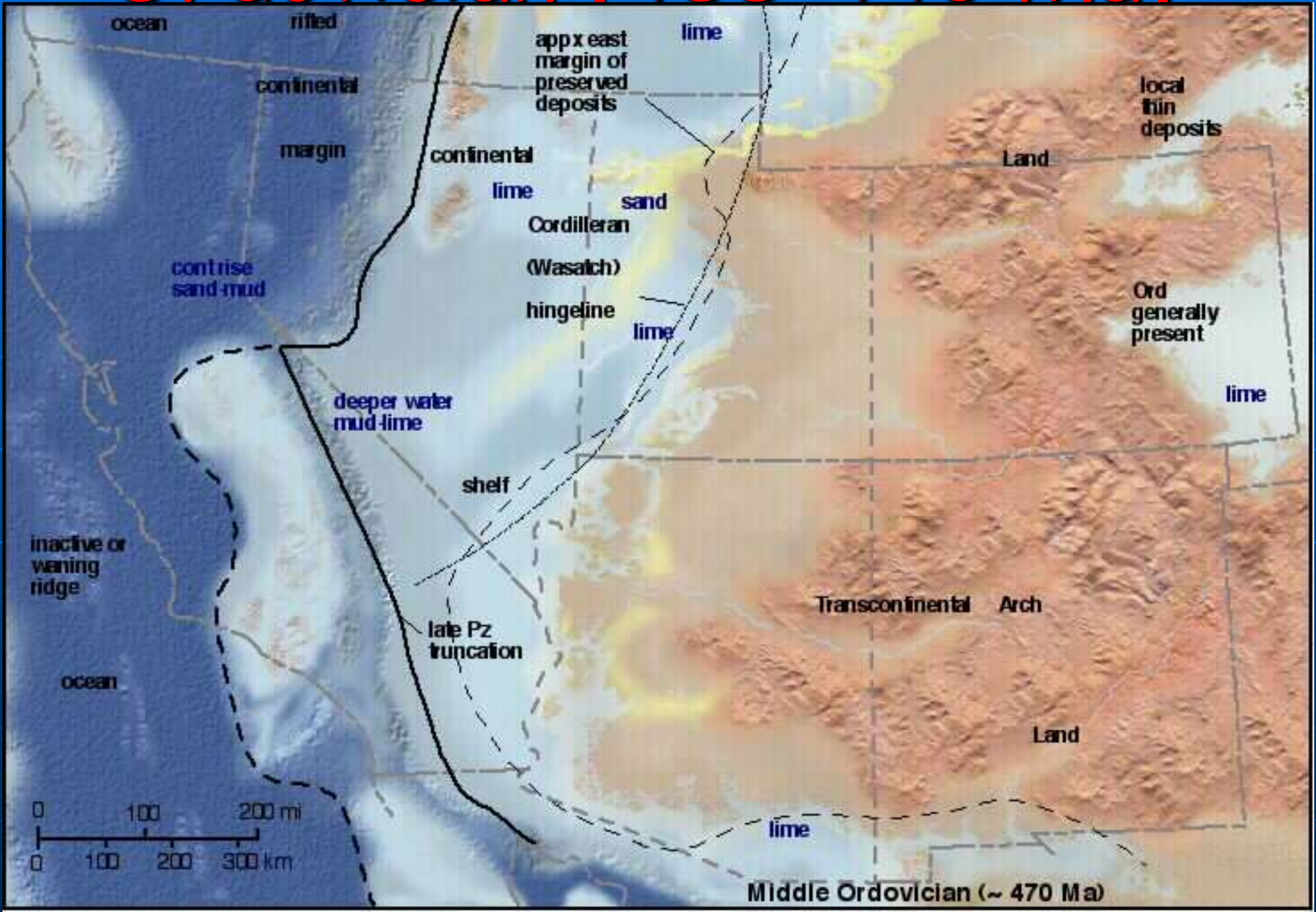




Early Paleozoic plate tectonics – Ordovician Taconic Orogeny



Ordovician (488-443 Ma)



Ordovician life

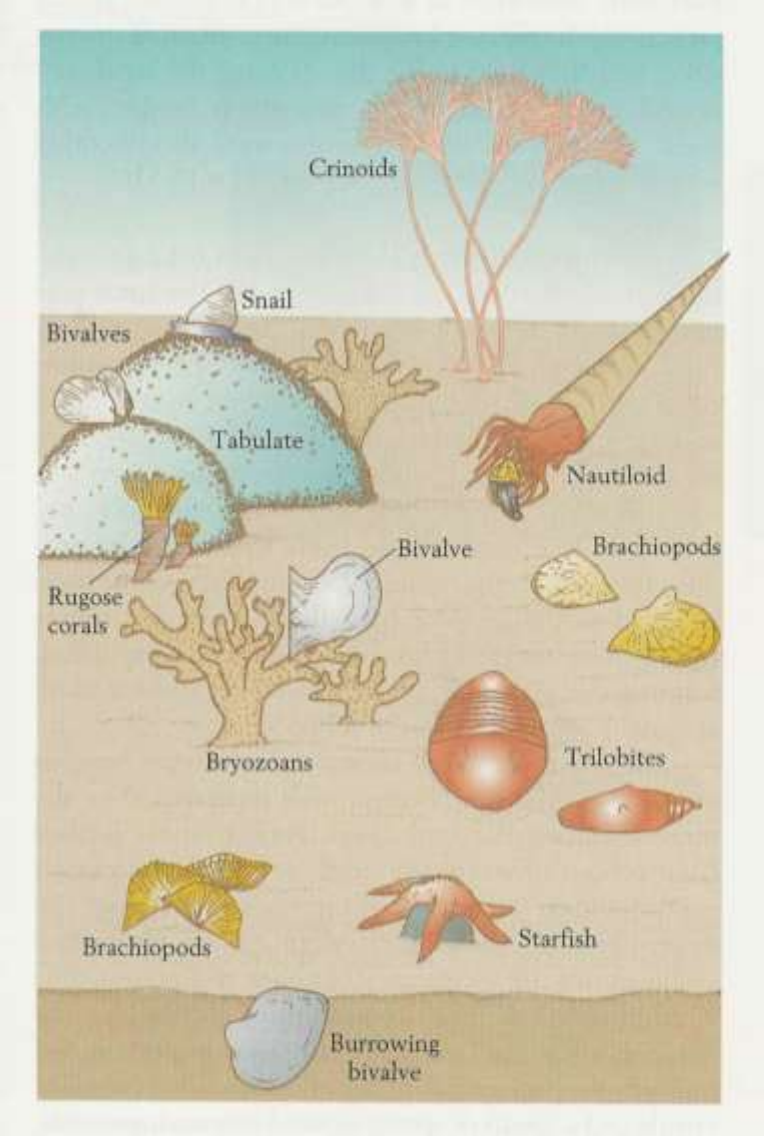
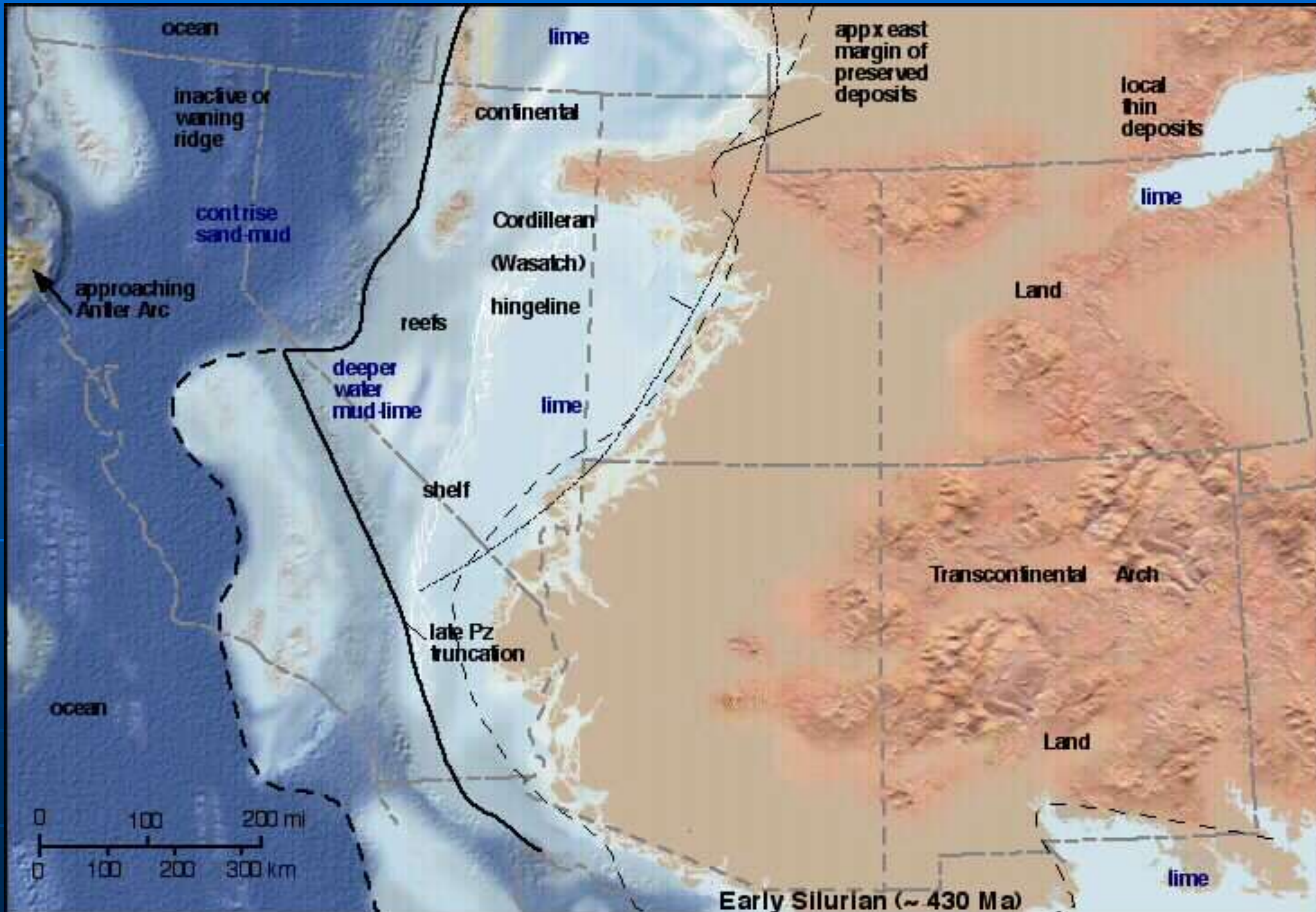


Figure 13-11
Ordovician invertebrate fossils. *A.* A straight-shelled nautiloid about 15 centimeters (6 inches) long. *B.* A spiny trilobite that lived on the sediment surface. *C.* A smooth-shelled burrowing trilobite. *D.* A snail (gastropod). *E.* and *F.* Two kinds of articulate brachiopods. *G.* A bivalve mollusk that lived on the sediment surface. *H.* A branched bryozoan colony. *I.* A tabulate coral colony. *J.* A stromatoporoid colony. *K.* A rugose coral. (Courtesy Smithsonian Institution, photo by Chip Clark.)

Silurian (443-417 Ma)



Silurian - Devonian fossils

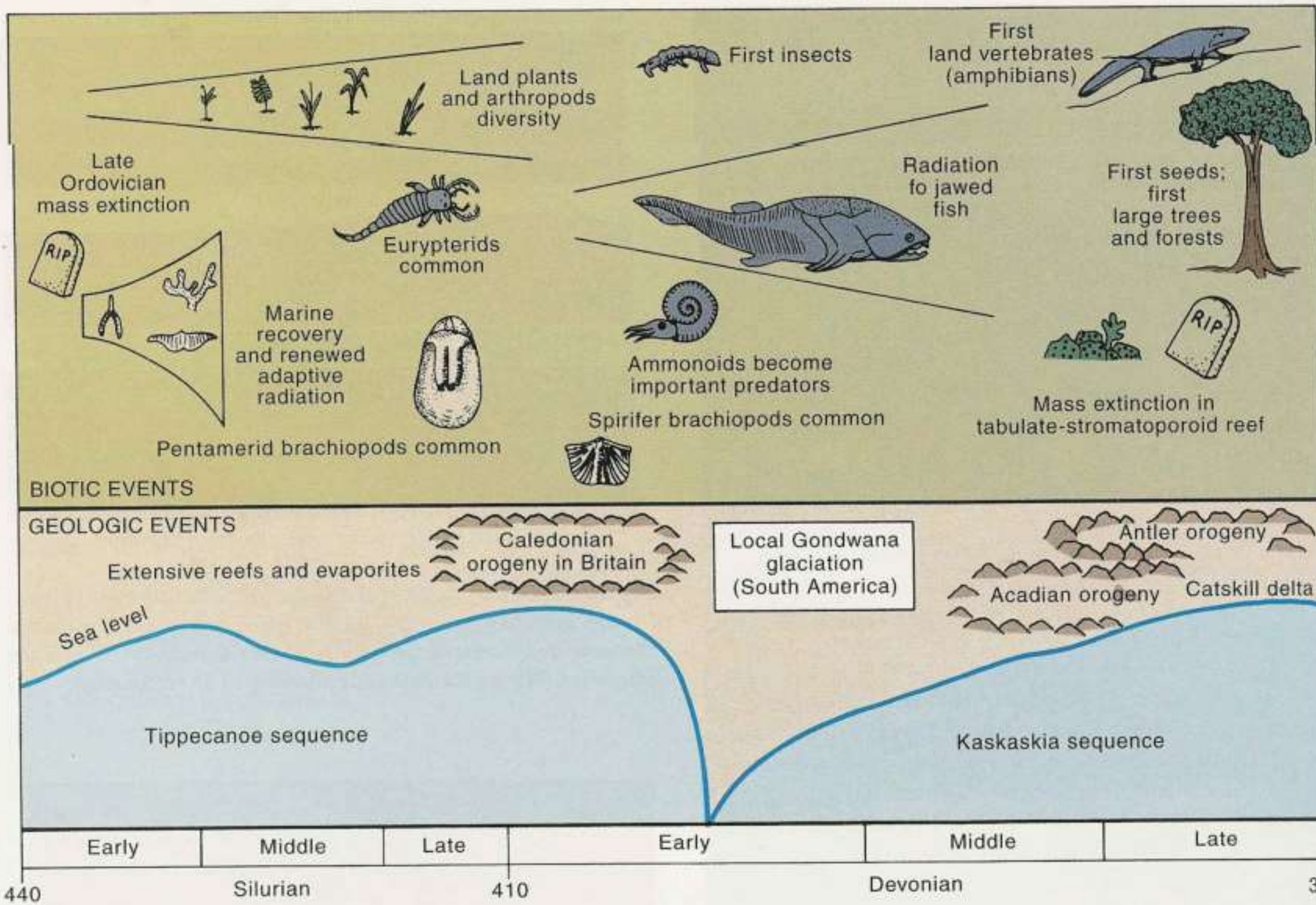
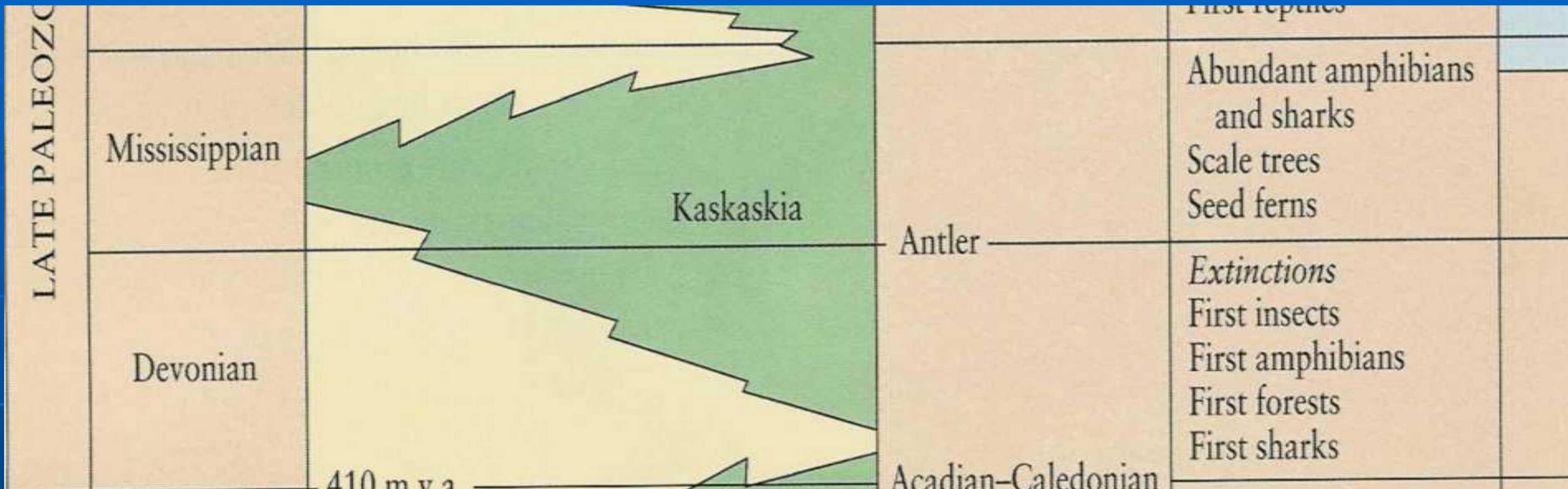
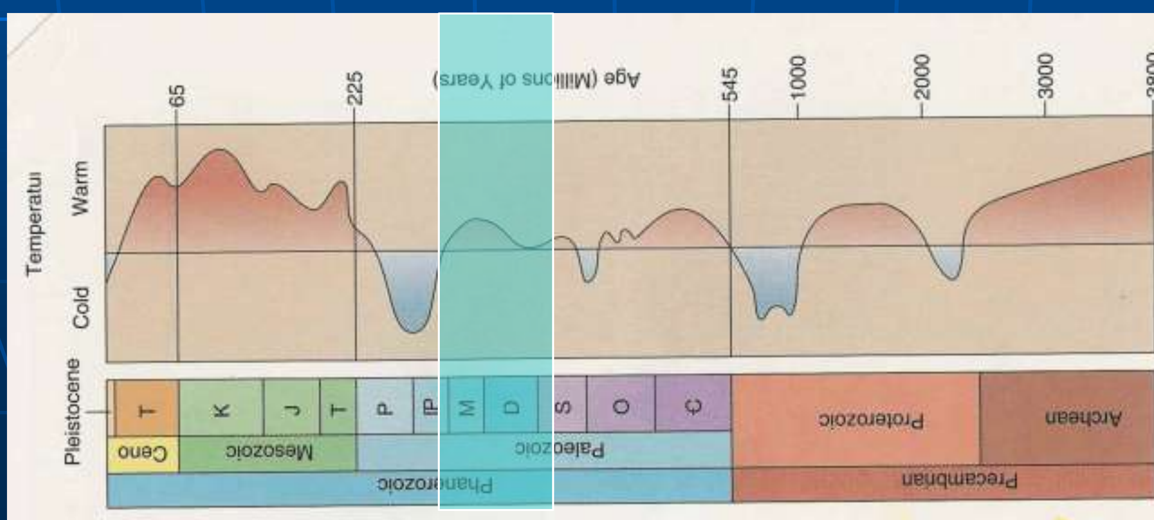


Figure 12.50 Summary time line of events of the Silurian and Devonian.

Devonian – Mississippian
416-359 – 318 Ma





Devonian environments

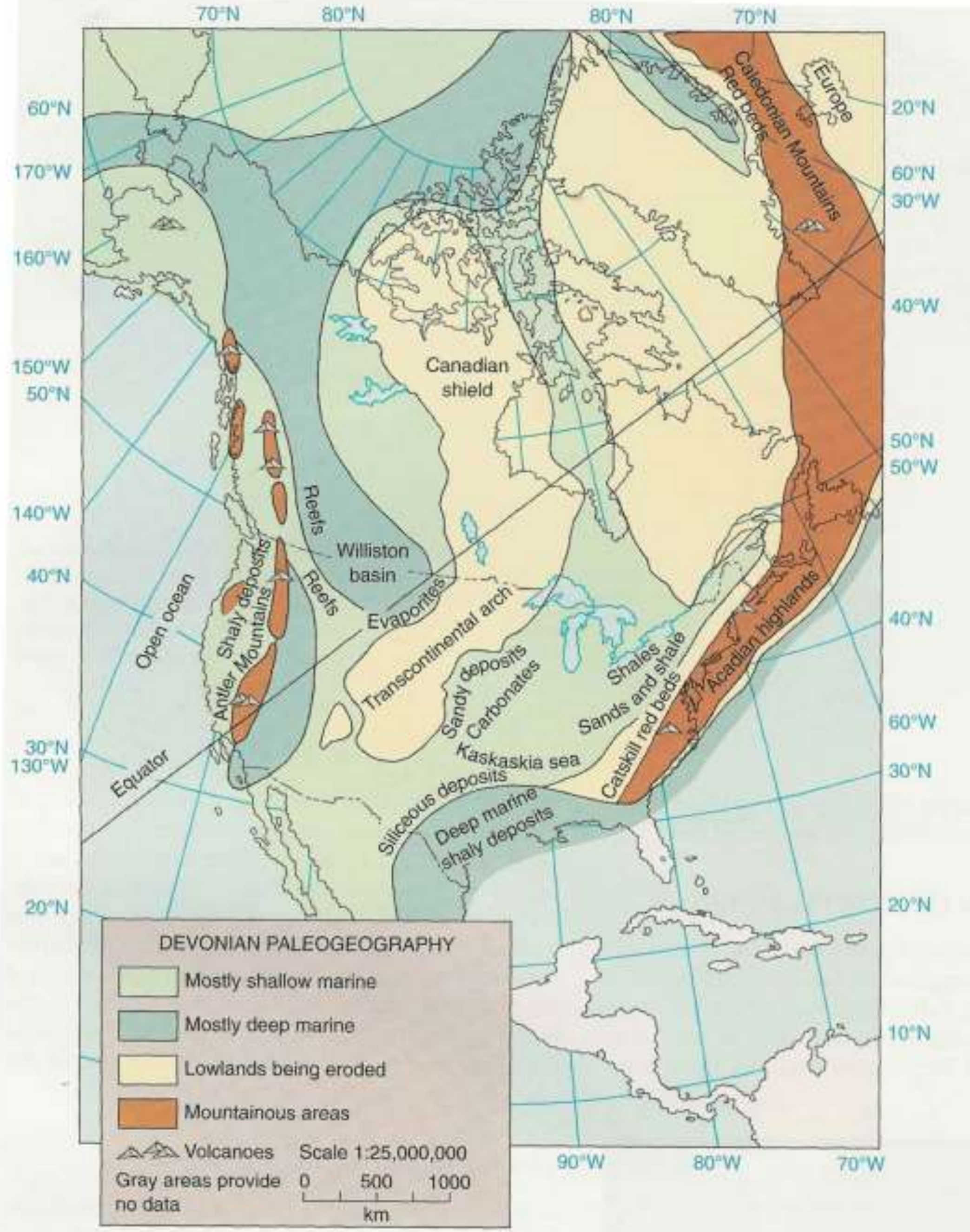
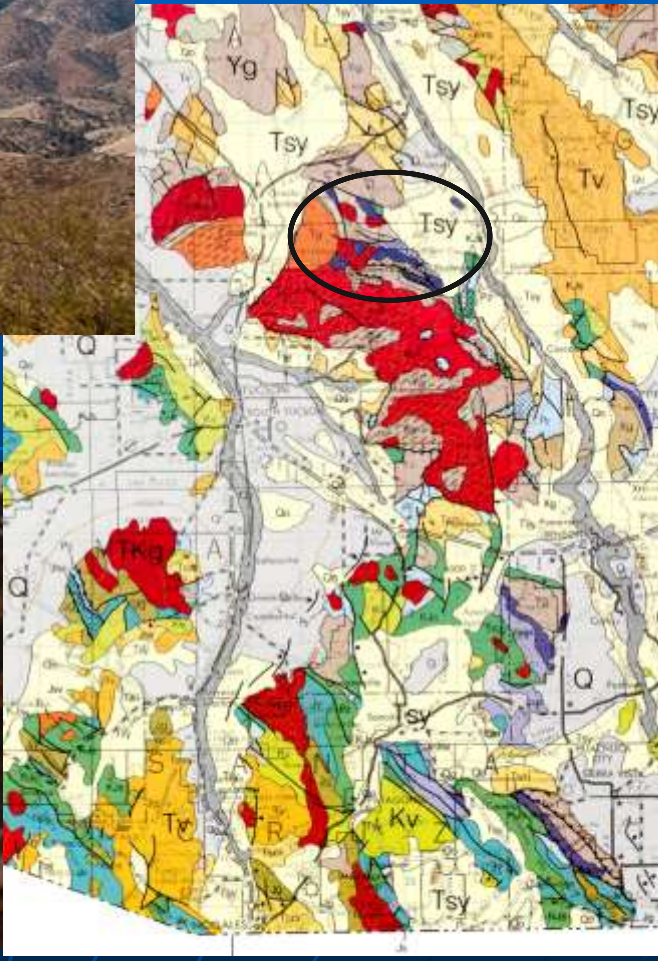


FIGURE 9-4 Paleography of North America during the Devonian Period.

Devonian (416-359 Ma)

Early Paleozoic – Devonian
Santa Catalina Mts.

Martin Formation



Devonian armored "fish"

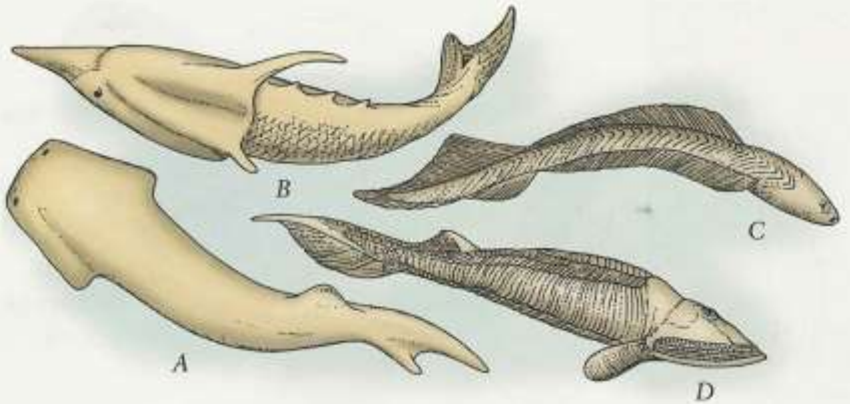


FIGURE 10-60 **Early Paleozoic ostracoderms.** (*A*) *Thelodus*, (*B*) *Pteraspis*, (*C*) *Jamoytius*, and (*D*) *Hemicyclaspis*, drawn to the same scale.

FIGURE 10-62 **The gigantic armored skull and thoracic shield of the formidable late Devonian placoderm fish known as *Dunkleosteus*.** *Dunkleosteus* was over 10 meters (about 30 feet) long. The skull shown here is about 1 meter tall. It is equipped with large bony cutting plates that functioned as teeth. Each eye socket was protected by a ring of four plates, and a special joint at the rear of the skull permitted the head to be raised, thereby making an extra large bite possible. *Dunkleosteus* ruled the seas 350 million years ago. (*Courtesy of the U.S. National Museum of Natural History, Smithsonian Institution; photograph by Chip Clark.*)

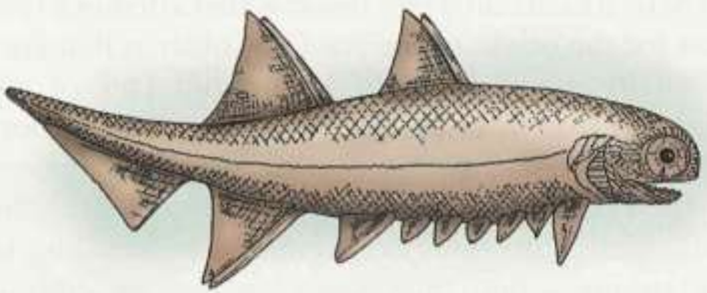


FIGURE 10-61 **The Early Devonian acanthodian fish *Climatius*.** (*After Romer, A. S. 1945.* Vertebrate Paleontology. *Chicago: University of Chicago Press.*)

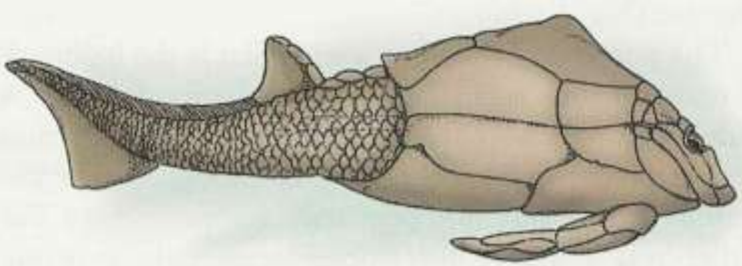


FIGURE 10-63 **The Devonian antiarch fish *Pterichthyodes*.** (*From Romer, A. S. 1945.* Vertebrate Paleontology. *Chicago: University of Chicago Press, p. 54, fig. 38.*)

Dinichthyes – armored fish-like

Devonian coral fossils

Syringopora

solitary horn coral *Zaphrenthis*

Lithostrotionella

Hexagonaria

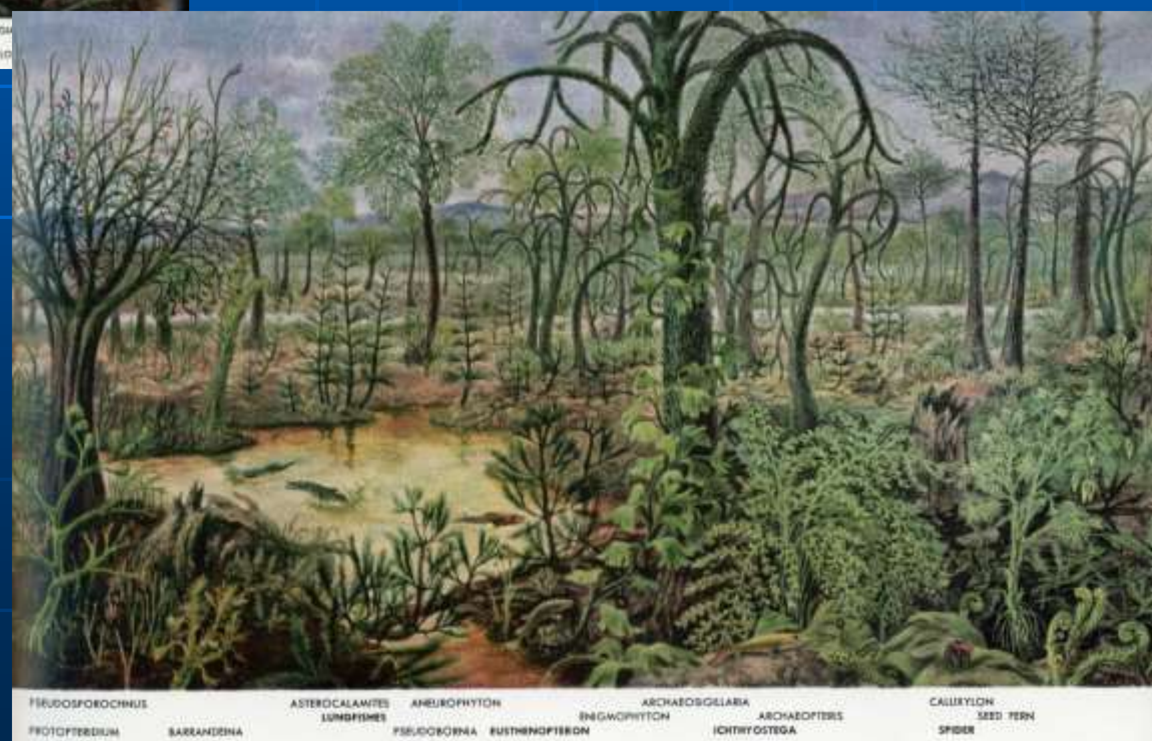
Devonian brachiopod fossils

Spirifer

Derbyia - brachiopod

Platyrachella (

Devonian plants



Source: Time-Life, The World We Live In, 1955

Devonian - Mississippian Formations in the Tucson area

Mississippian environments

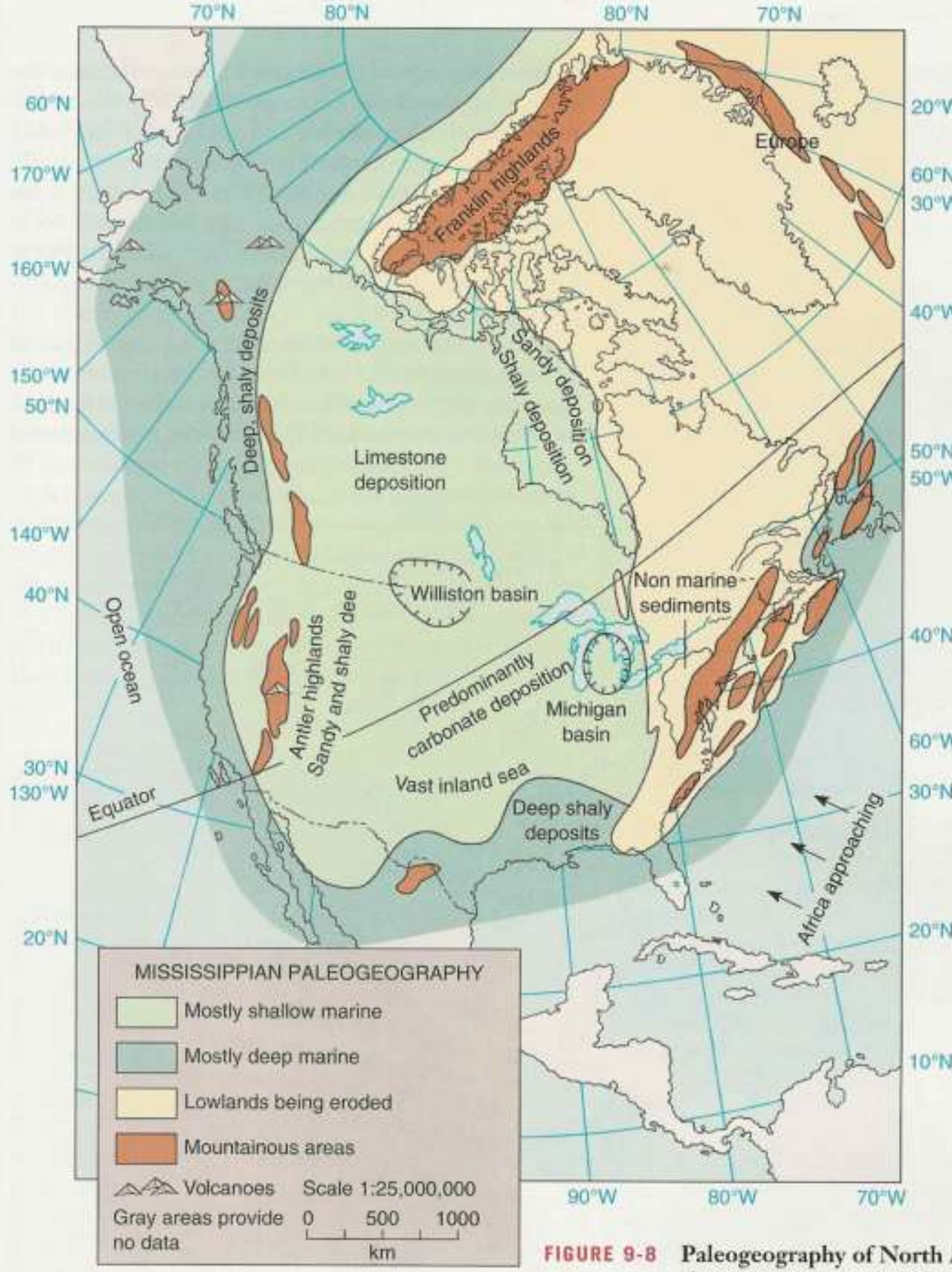
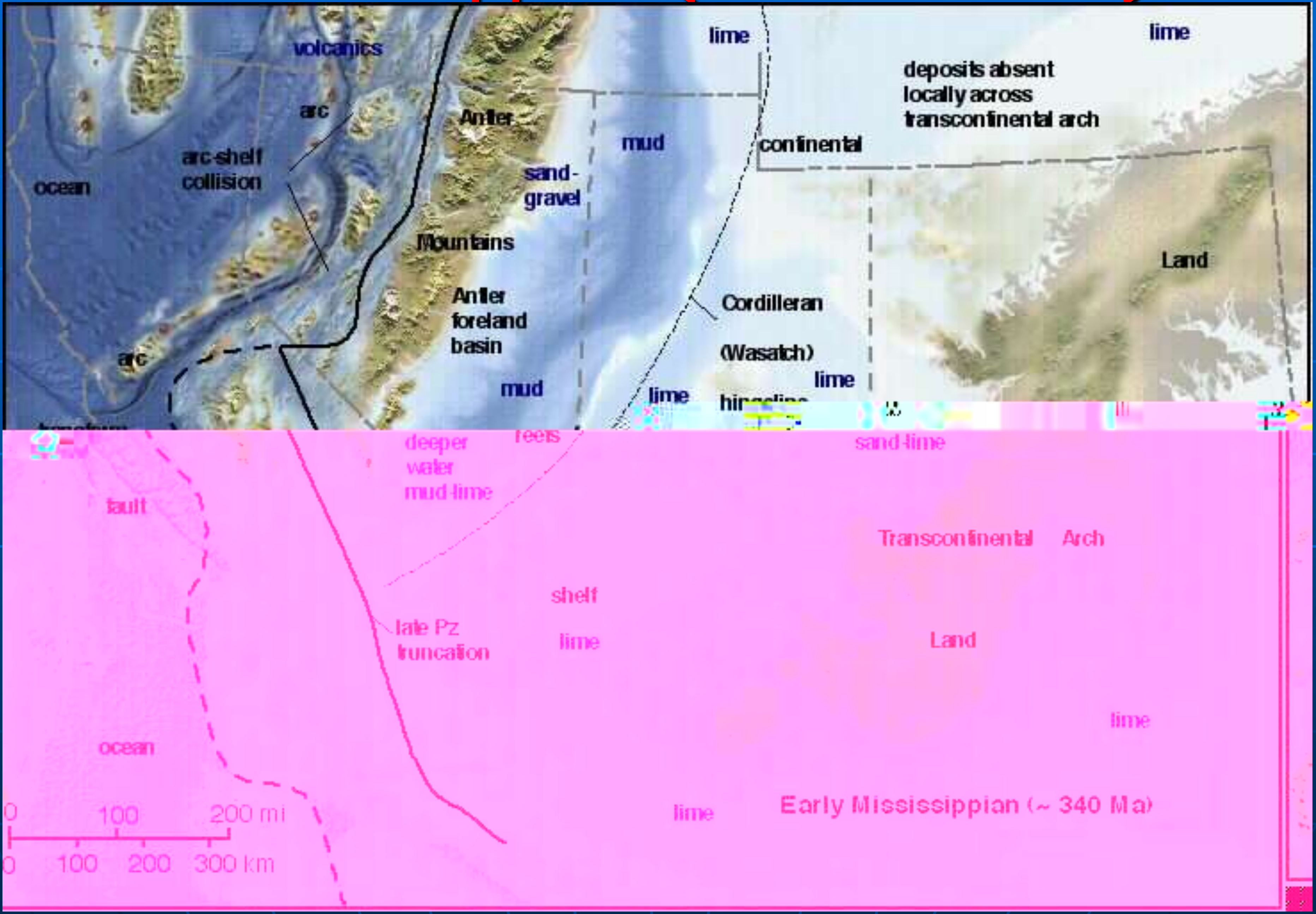


FIGURE 9-8 Paleogeography of North America during the Mississippian Period.

Mississippian (359-318 Ma)



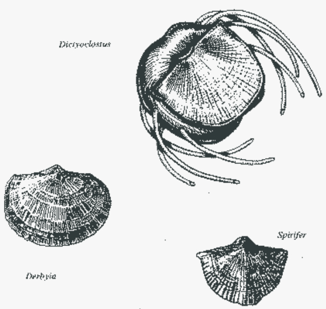
5. SEAS TEEMING WITH LIFE

SANTA CATALINA MOUNTAINS REGION
mid to late Paleozoic Era (~390-230 million years ago)

There is no record of Ordovician or Silurian times in the Santa Catalina Mountains, but during the remainder of the Paleozoic Era, southern Arizona was subjected to repeated additional inundations and withdrawals of the sea. Various distinctive strata were left as evidence of different visits by the sea during successive Paleozoic periods.

Limestone deposits represent the Permian, Pennsylvanian, and Mississippian Periods, and occur throughout SE Arizona. Devonian deposits are sandy or shaly at some places, but are most usually a magnesium-rich kind of limestone called **"dolomite".**

Fossils of ocean-dwelling organisms that lived in this region during these geologic periods may be found in different limestone formations of the northern Santa Catalina Mountains.



BRACHIOPODS

Mid to late Paleozoic rock formations formed during successive geologic periods are present in the exhibit wall in their original horizontal positions along the right side of the previous panel. Parts of this Paleozoic "section" are also present as tilted strata in two disturbed fault blocks—one extending above and below this panel, and another to its left.

Bivalved **brachiopods,** the bases of solitary **"horn" corals,** and stems of anchored starfish called **crinoids** are the most common fossils in these rocks. Examples of all these fossil marine organisms are present in various mid to late Paleozoic limestone layers of the exhibit wall.

HORN CORALS

Some of these fossil remains have been converted to silica, which is much more resistant to erosion than their original calcium carbonate. Such silicified fossils are commonly etched into bold relief and stand out from their previously enclosing limestone matrix.

Many limestones of southern Arizona contain segregations and/or nodules of **chert,** a flinty siliceous material identical to quartz, precipitated in these rocks by groundwater.

Paleozoic strata of southern Arizona represent many different episodes of inundation by the sea, occasionally interrupted by times of emergence and erosion. But no great crustal disturbance is evident in the rocks formed during this very long span of time; continued crustal stability was the hallmark of our region for more than a quarter billion years!

Faulting, tilting, and metamorphism now seen in many of these strata took place long after they were formed, through events described in the next several panels.

NACO GROUP

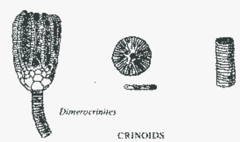
—young Paleozoic strata present in this region today include the very dark grey to black **Colina Limestone** of Permian age, and underlying light grey **Earp Formation** of Permian and Pennsylvanian ages. Earp Formation contains resistant layers of limestone, as well as non-resistant layers of mudstone.

A distinctive stratum within the Earp Formation comprises many angular to partly rounded fragments of red chert, weathered out of older rocks of the Paleozoic section. The Pennsylvania-Permian time boundary lies very near this layer of gravel which is informally known as the "jelly bean conglomerate".

Grey limestone layers of the Earp Formation often contain abundant small fossils of fusilinids—tiny football-shaped shells of single-celled plankton related to modern-day amoebae. Such microfossils represent a family designated **Foraminiferae,** and geologists commonly call them "forams".

FUSILINIDS

Pennsylvanian age, contains abundant silicified remains of crinoids and brachiopods. Grey limestones of Horquilla formation are frequently interbedded with maroon mudstones.



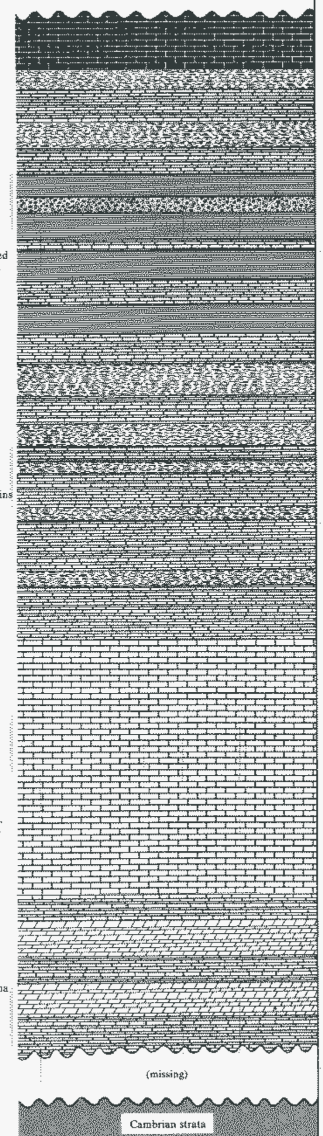
CRINOIDS

ESCABROSA LIMESTONE

—typically a cliff-forming formation, usually several hundred feet thick. Its dark grey limestone is often packed with crinoid remains, and silicified horn corals are also common. Escabrosa Limestone is of Mississippian age. It is generally equivalent to the Redwall Limestone of central and northern Arizona, which forms the "great red wall" in the middle depths of the Grand Canyon.

MARTIN FORMATION

—initial deposit of the region when the seas returned during the Devonian Period to cover most of Arizona after the Ordovician-Silurian hiatus. It lies on Cambrian strata with "disconformity".



In the exhibit wall, only a small amount of Colina Limestone is present— it is the almost black, tilted layer seen over the left side of this panel. Younger Paleozoic strata in the exhibit wall have been metamorphosed into quartzite and marble above and below the right side of this panel.

"Jelly bean" conglomerate from the Earp Formation forms the top of the exhibit wall to the right of the fault that emerges from the top of panel #4. "Jelly bean" conglomerate is also present in the tilted fault blocks; can you find it?

The grey limestone layer below the "jelly bean" conglomerate is more typical Earp Formation. This particular layer is rich in "forams"; they look like "petrified wheat grains".

Grey layers of Horquilla Limestone with brachiopods and other fossil fragments, now converted to salmon-colored silica, and maroon mudstone with brachiopod molds are present extending to the right from the upper part of panel #4. Crinoid stems are especially obvious in limestone Horquilla layers in the tilted blocks, such as can be seen immediately left of the center of this panel.

Thick layers of dark grey Escabrosa Limestone appear in the exhibit wall extending to the right from the lower half of panel #4, where they contain a veritable hash of crinoid stems and other fossil fragments. Silicified horn corals are evident in a tilted Escabrosa layer below this panel. They look like tiny ice cream cones.

In the northern Santa Catalina Mountains and elsewhere in the region, Devonian time is represented by the **Martin Formation.** Dolomite of the Martin Formation locally weathers to curious tan surfaces known as "elephant hide" texture.

In the exhibit wall, Martin Formation is the layer extending to the right from the right base of panel #4. The curious, dark, resistant material at the top of the Martin layer is a discontinuous layer of chert.

art work by JANIS BLAINER-FLEMING and RICHARD R. DUPONT; prepared for TOHONO CHUL PARK © 1988 by D. W. SHAKEL

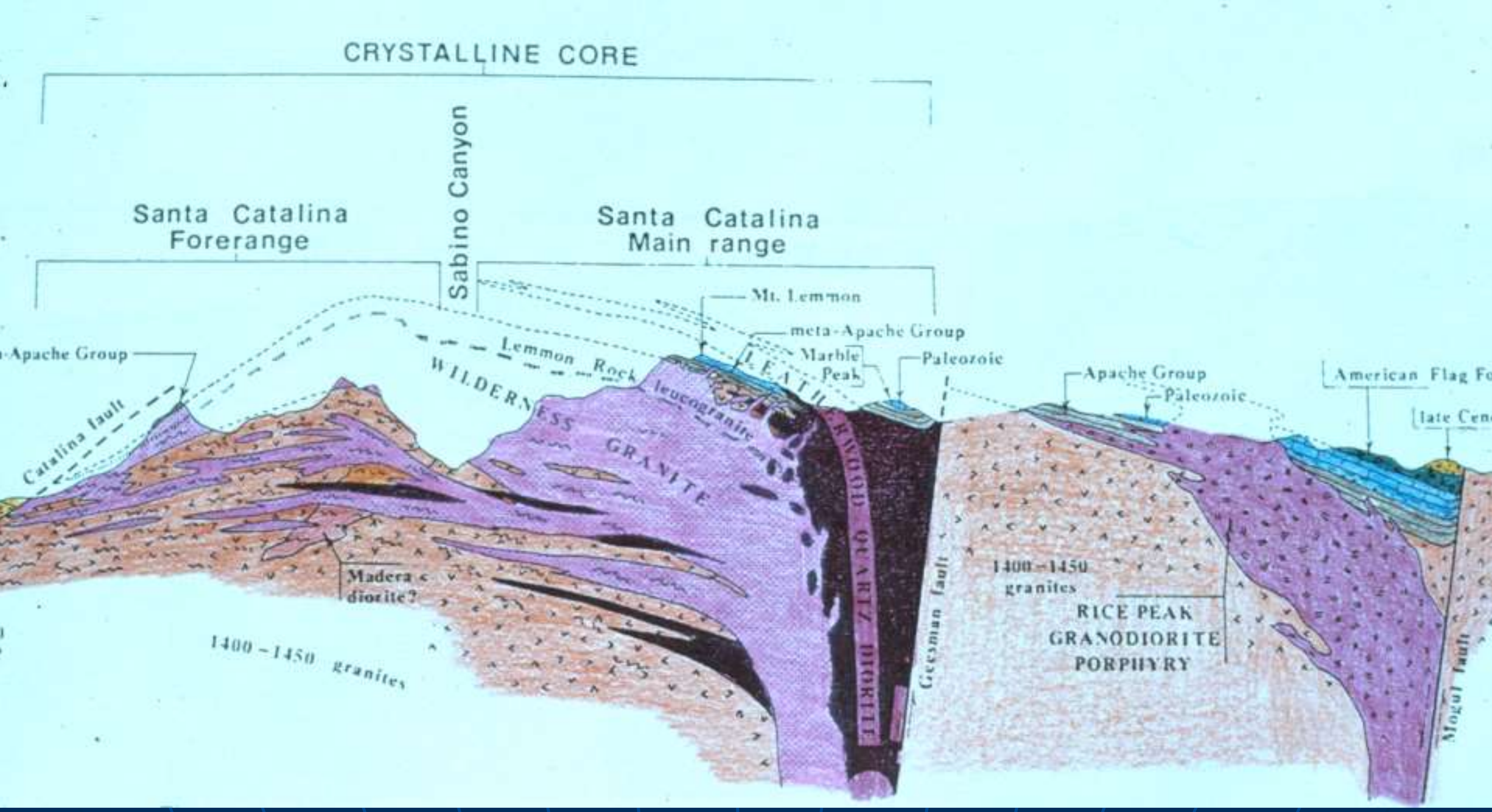
Escabrosa Ls. – north of Bisbee

Mid-Paleozoic – Mississippian – Santa Catalina Mts.

Marble Peak look S

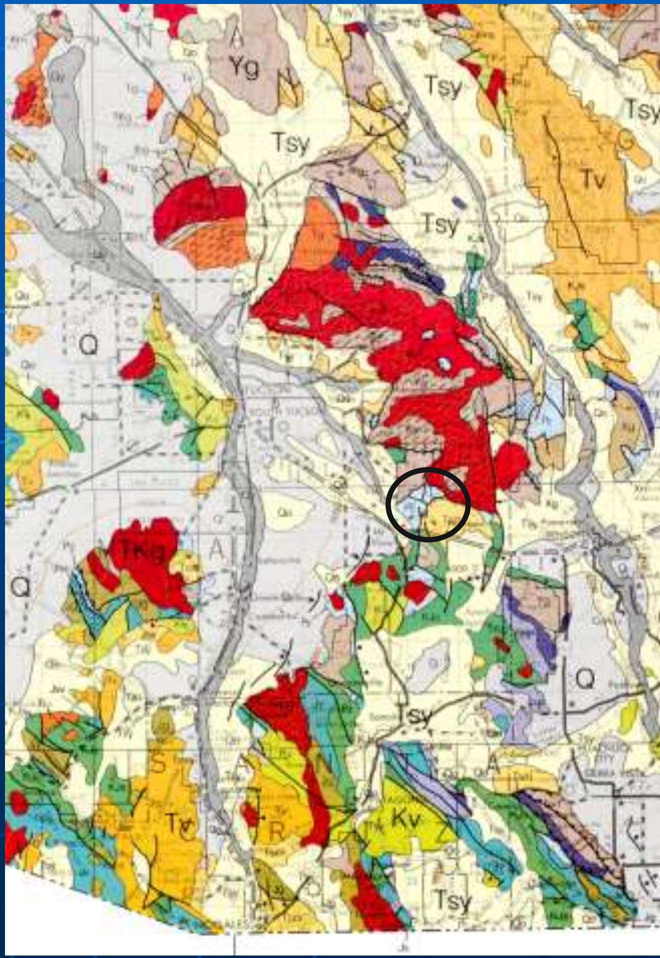
Escabrosa Limestone

Catalina cross section



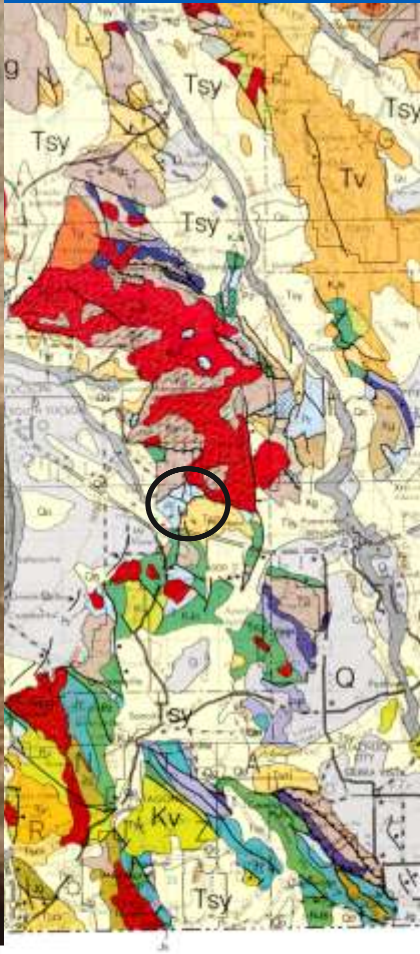
Mid-Paleozoic – Mississippian Rincon Mts. – Escabrosa Ls.

Photo by Bill Peachey, near Colossal Cave



Mid-Paleozoic – Mississippian Rincon Mts. – Escabrosa Ls.

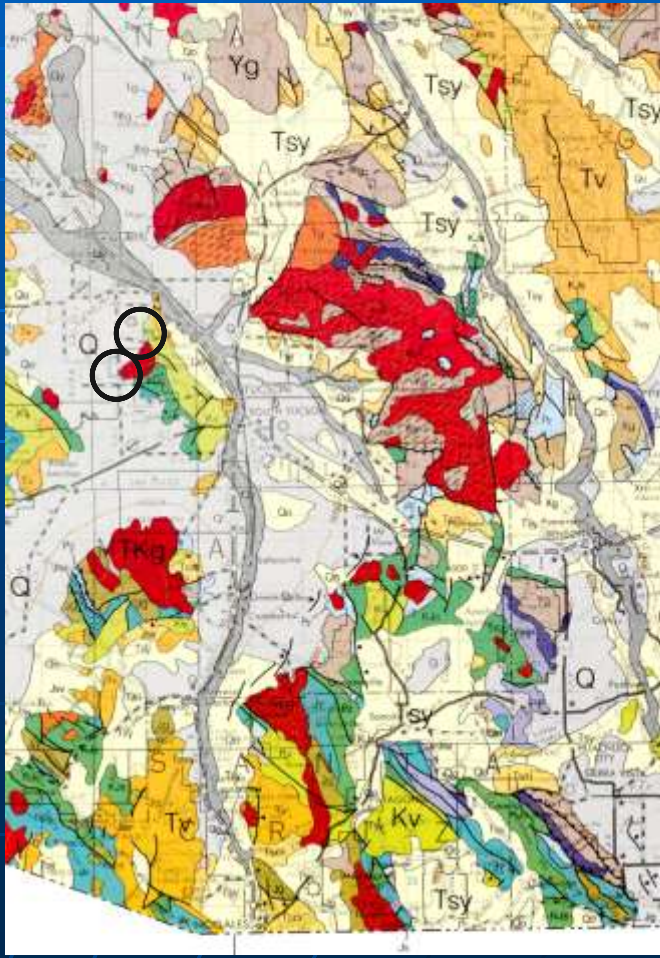
Photo by Bill Peachey, near Colossal Cave



Early Paleozoic – Mississippian - N. Tucson Mts.

Twin Peaks Quarry, looking N, 1987

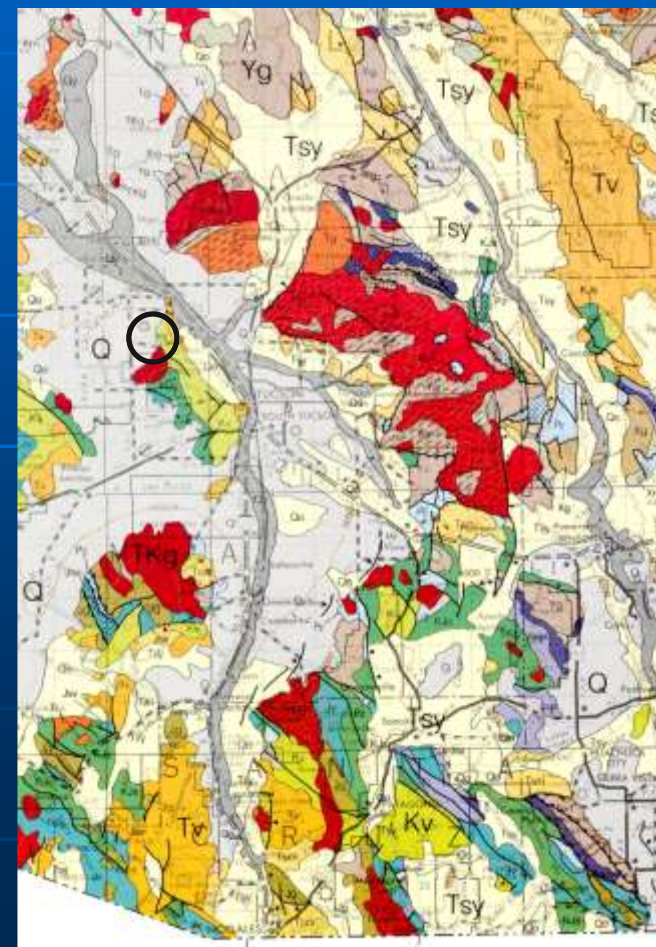
Sus Hills, looking Northwest from picnic area



Mid-Paleozoic – Mississippian - N. Tucson Mts.

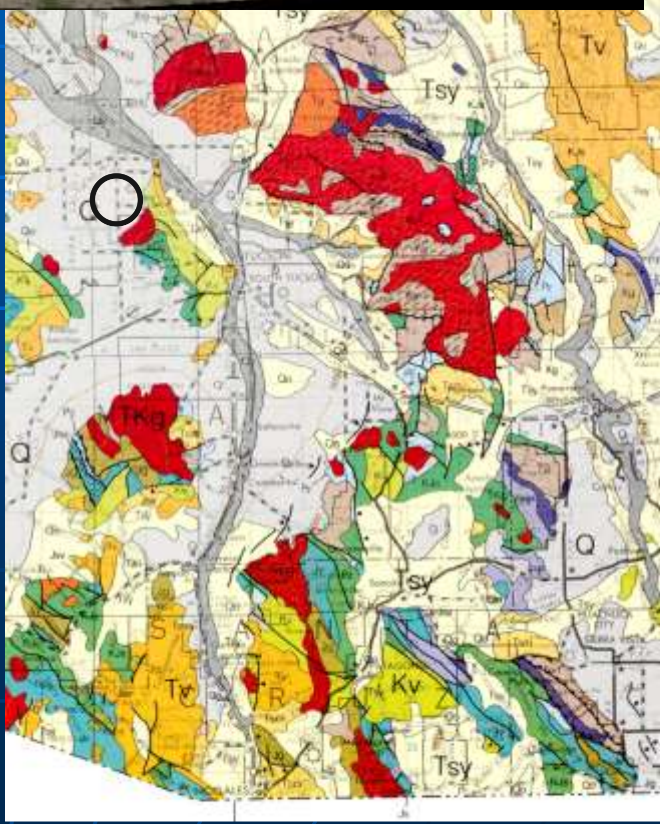
2008

Twin Peaks Quarry, looking North, 1987

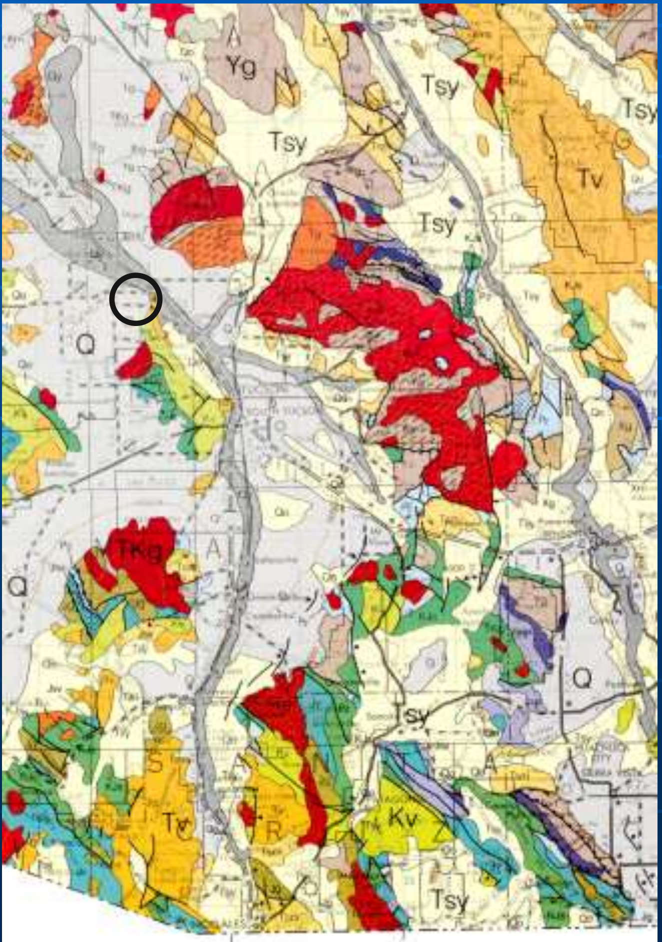


Twin Peaks Limestone Mine

~2008



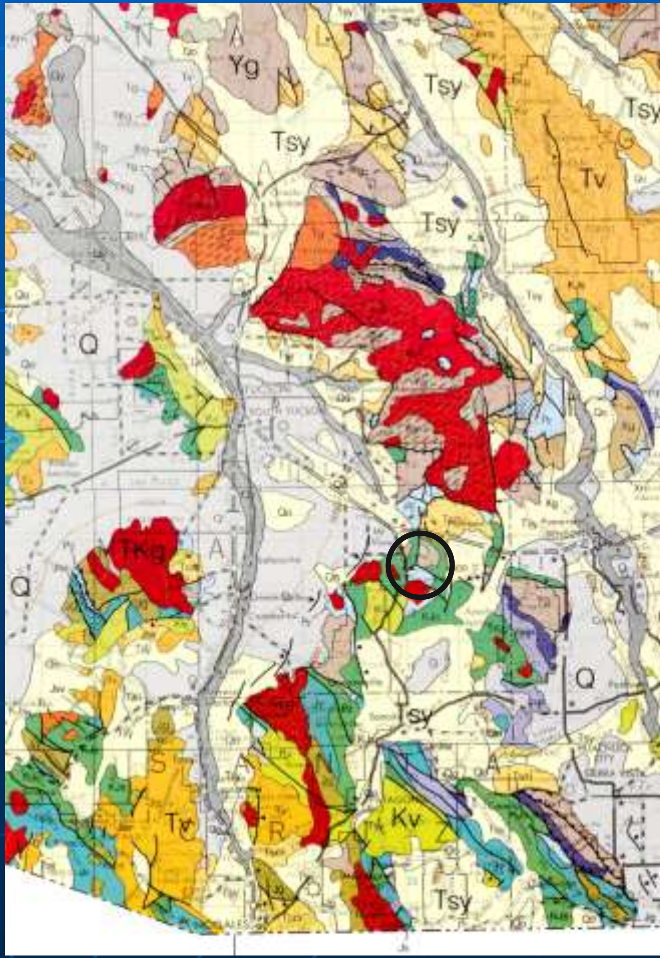
Rillito Portland Cement Plant



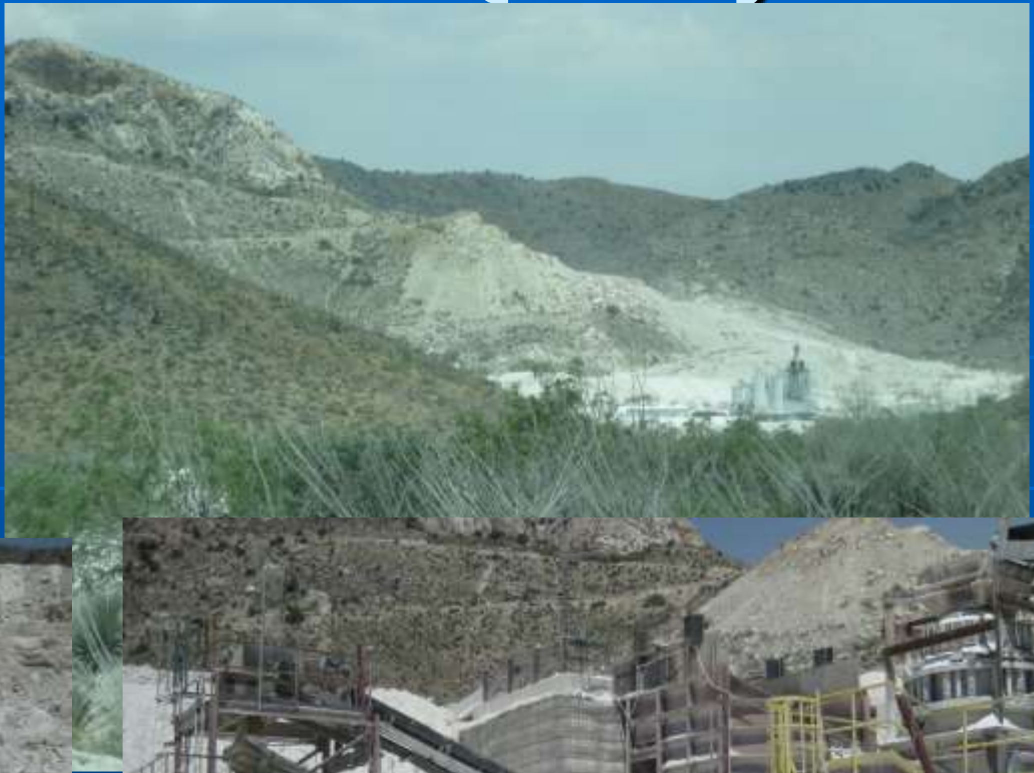
Mid-Paleozoic – Mississippian – Santa Rita Mts.

Sahuarita Quarry, looking S from S. Houghton Rd.

Sahuarita Quarry, looking W from Rosemont



Sahuarita Marble Quarry



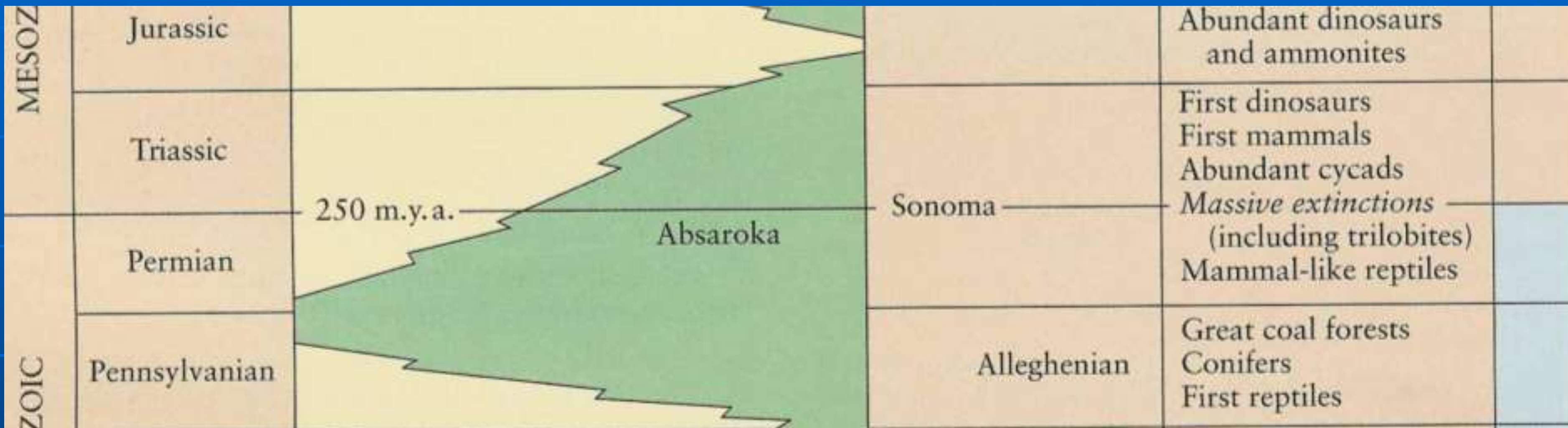
Photos by Pam Wilkinson, 2011

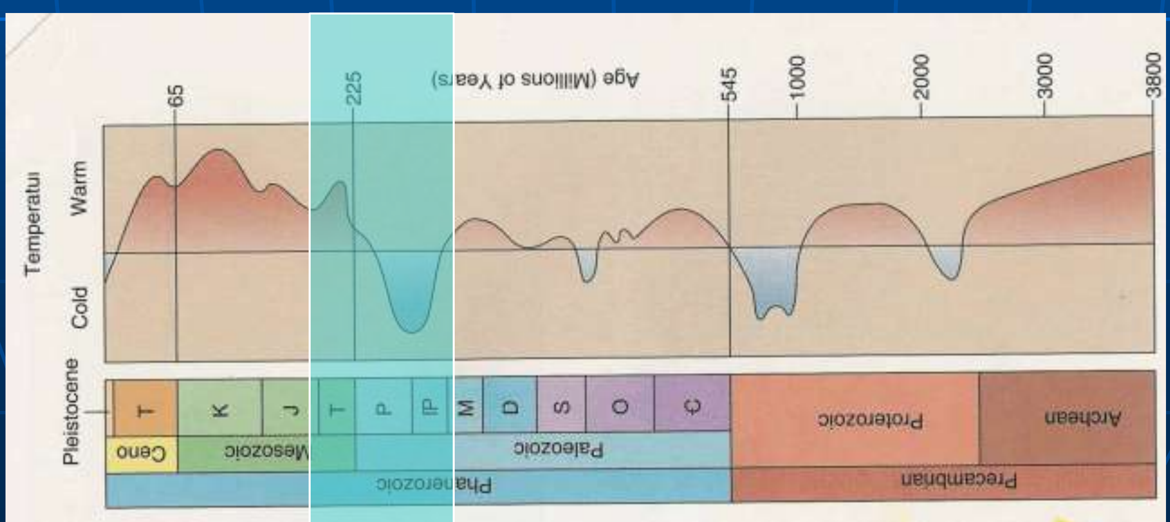
Mississippian Crinoids

Crinoids

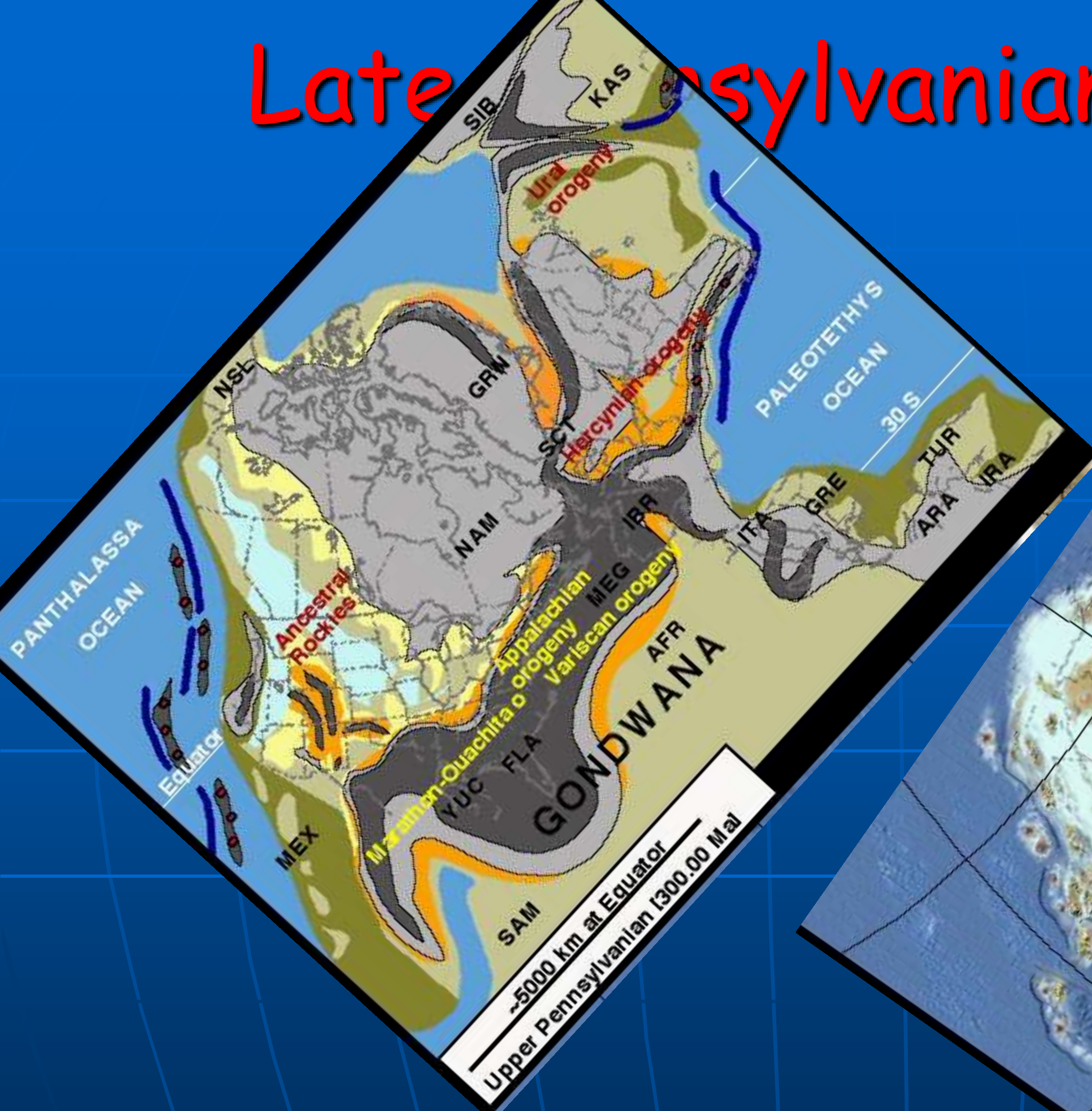
(echinoids related to starfish, called sea lilies)

Pennsylvanian (318-299 Ma) – Permian (299-251 Ma)

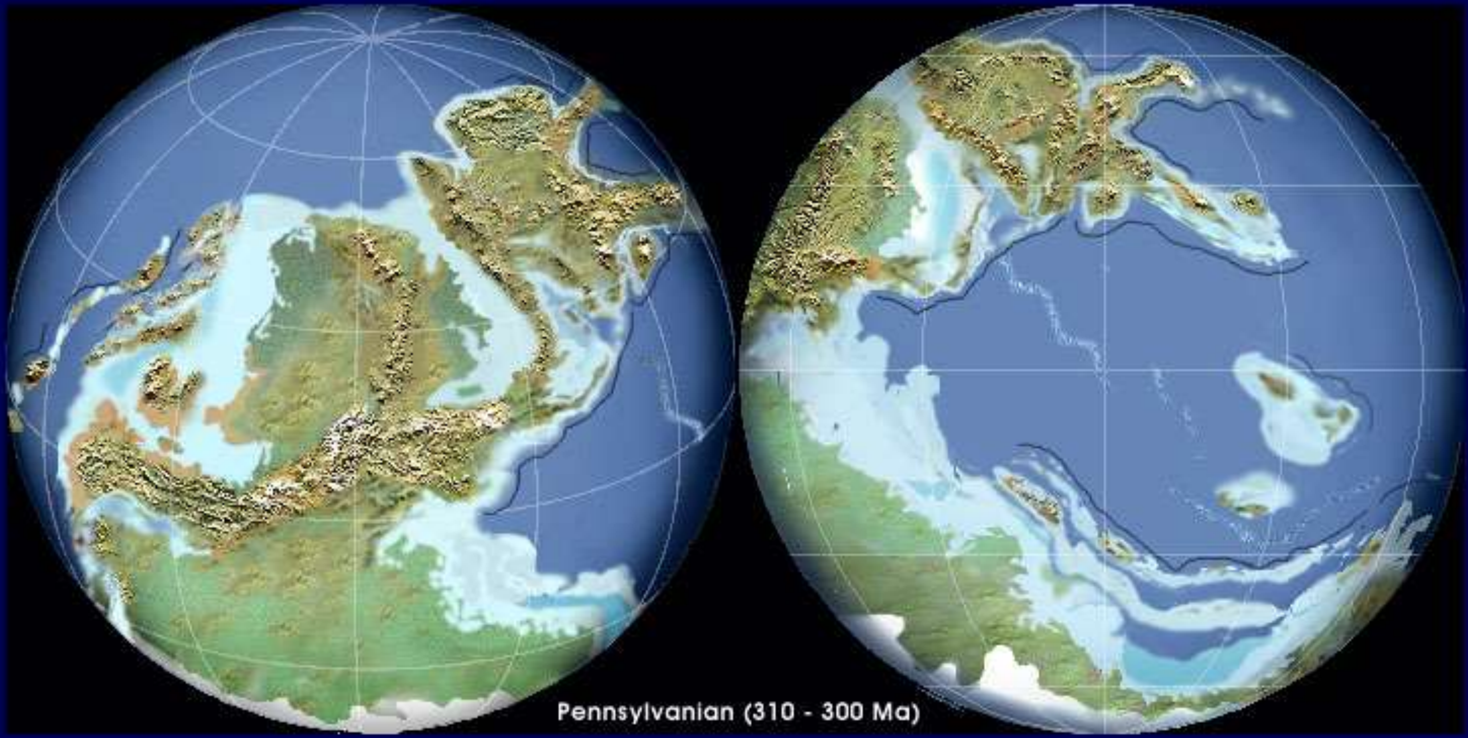




Late Pennsylvanian (300 Ma)

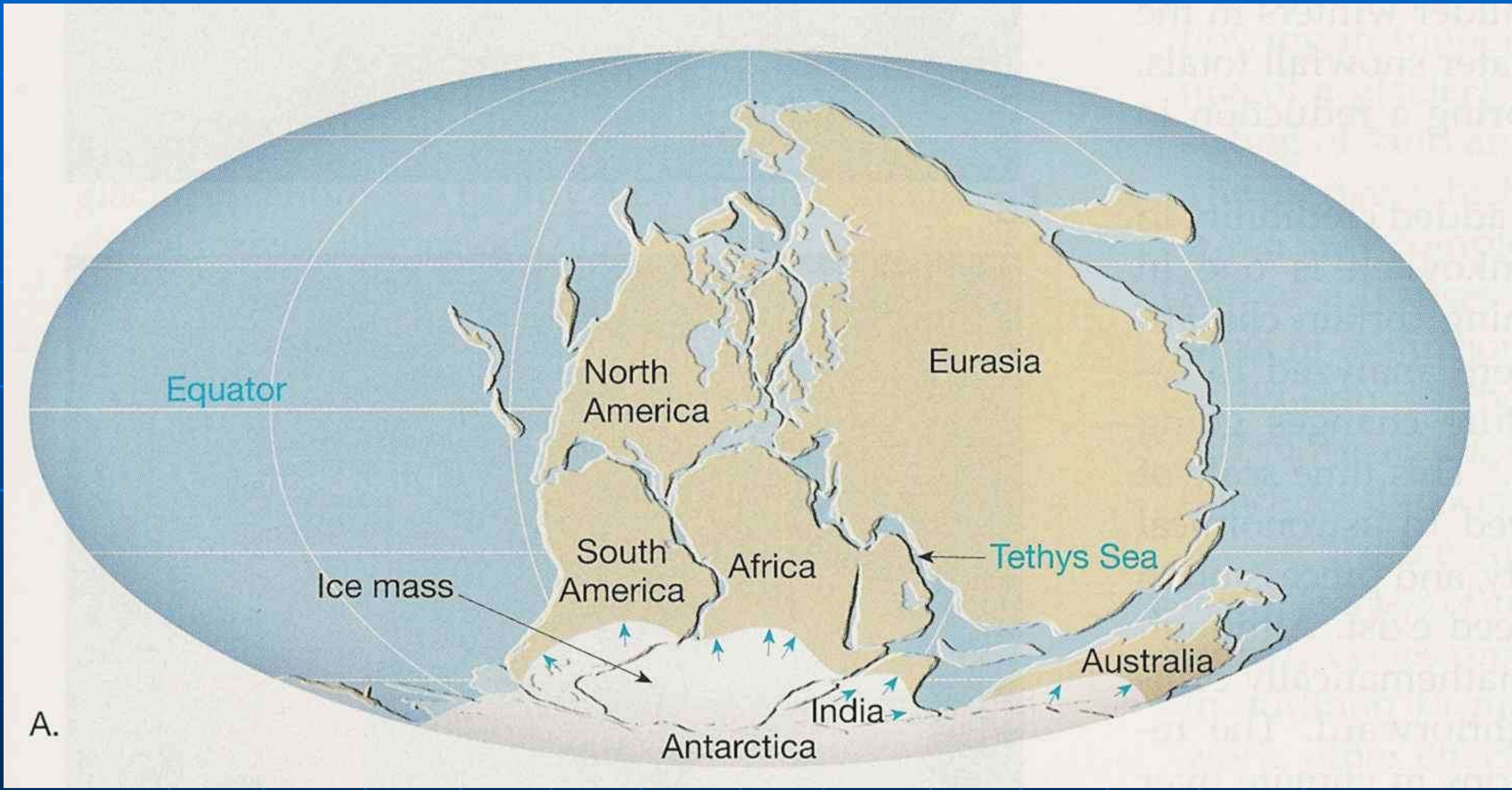


Pennsylvanian paleogeography globes



Late Pennsylvanian 300 Ma

Pennsylvanian-Permian Ice Age



Pennsylvanian environments

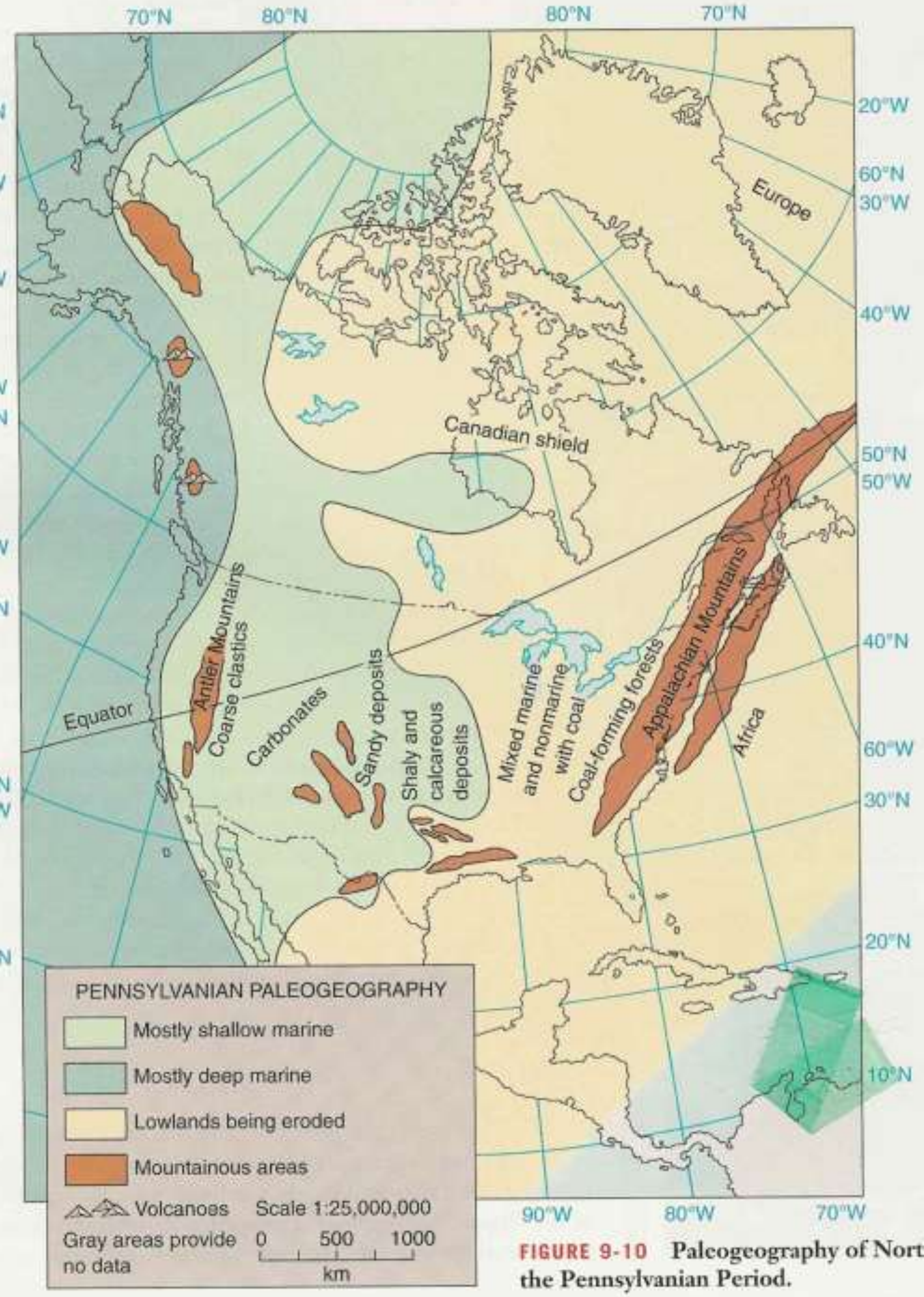
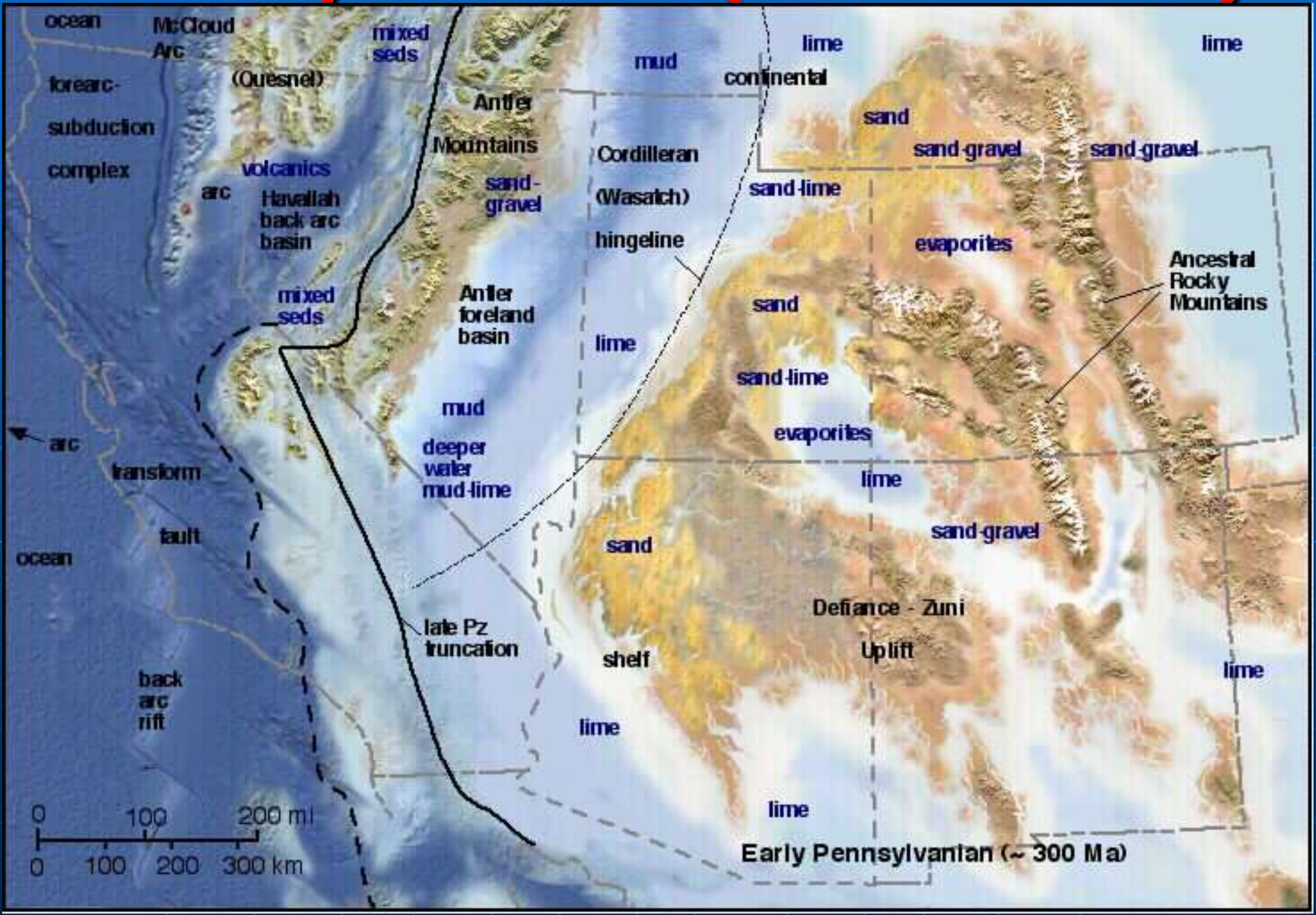


FIGURE 9-10 Paleogeography of Nort the Pennsylvanian Period.

Pennsylvanian (318-299 Ma)



Temp. & Geologic Time Scale

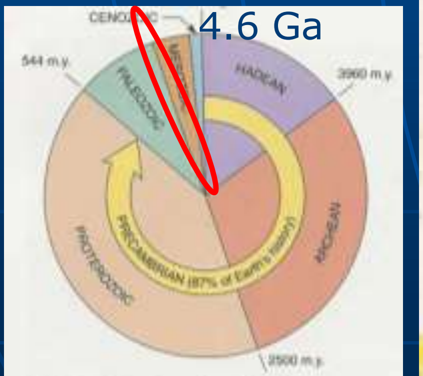
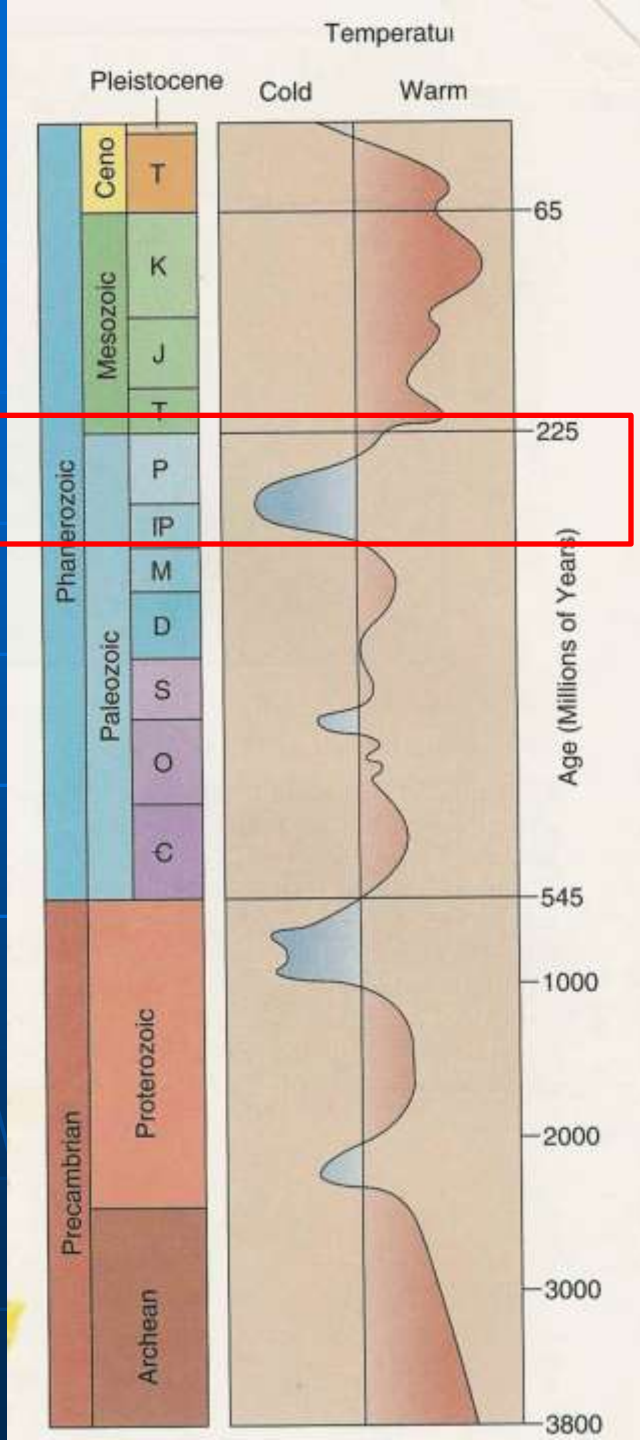
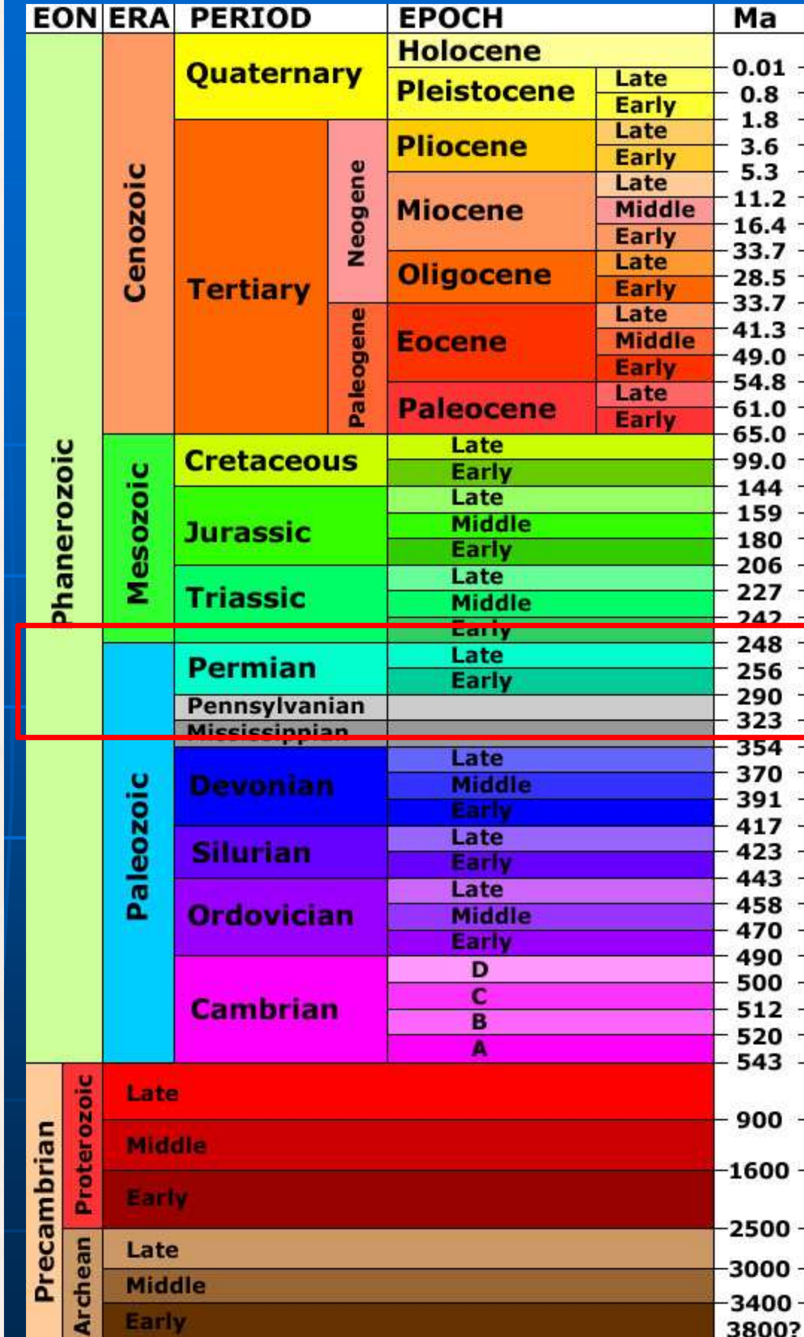


FIGURE 8-1 Proportions of geologic time encompassed by the Precambrian and its Hadean, Archean, and Proterozoic eons.





EON	ERA	PERIOD		EPOCH		Ma
Phanerozoic	Cenozoic	Quaternary		Holocene		0.01
				Pleistocene	Late	0.8
					Early	1.8
		Tertiary	Neogene	Pliocene	Late	3.6
					Early	5.3
				Miocene	Late	11.2
					Middle	16.4
					Early	33.7
				Oligocene	Late	28.5
					Early	33.7
			Paleogene	Eocene	Late	41.3
					Middle	49.0
					Early	54.8
				Paleocene	Late	61.0
					Early	65.0
	Mesozoic	Cretaceous		Late		99.0
				Early		144
		Jurassic		Late		159
				Middle		180
				Early		206
		Triassic		Late		227
				Middle		242
				Early		248
	Paleozoic	Permian		Late		256
				Early		290
		Pennsylvanian				323
		Mississippian				354
		Devonian		Late		370
				Middle		391
				Early		417
		Silurian		Late		423
				Early		443
		Ordovician		Late		458
				Middle		470
				Early		490
		Cambrian		D		500
				C		512
				B		520
				A		543
Precambrian	Proterozoic	Late				900
		Middle				1600
		Early				2500
	Archean	Late				3000
		Middle				3400
		Early				3800?

Cyclothem rocks

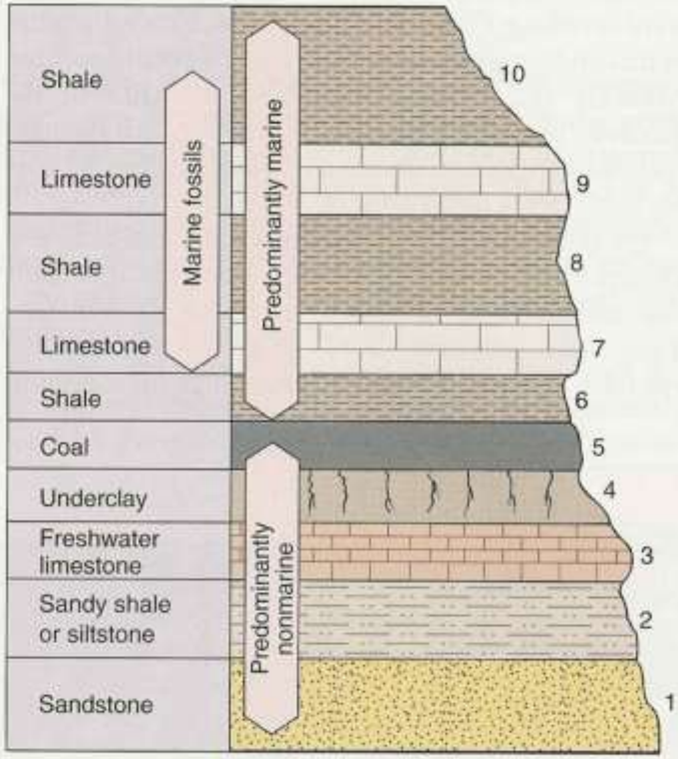


FIGURE 9-11 An ideal coal-bearing cyclothem, showing the typical sequence of layers. Many cyclothems do not contain all 10 units, as in this illustration of an idealized sequence. Some units may not have been deposited because changes from marine to nonmarine conditions may have been abrupt and/or units may have been removed by erosion following marine regressions. The number 8 bed usually represents maximum inundation and, correlated with the same bed elsewhere, provides an important correlative stratigraphic horizon. ? *If you came across a limestone that was part of a cyclothem, how might you ascertain that it was a marine rather than a freshwater limestone?*

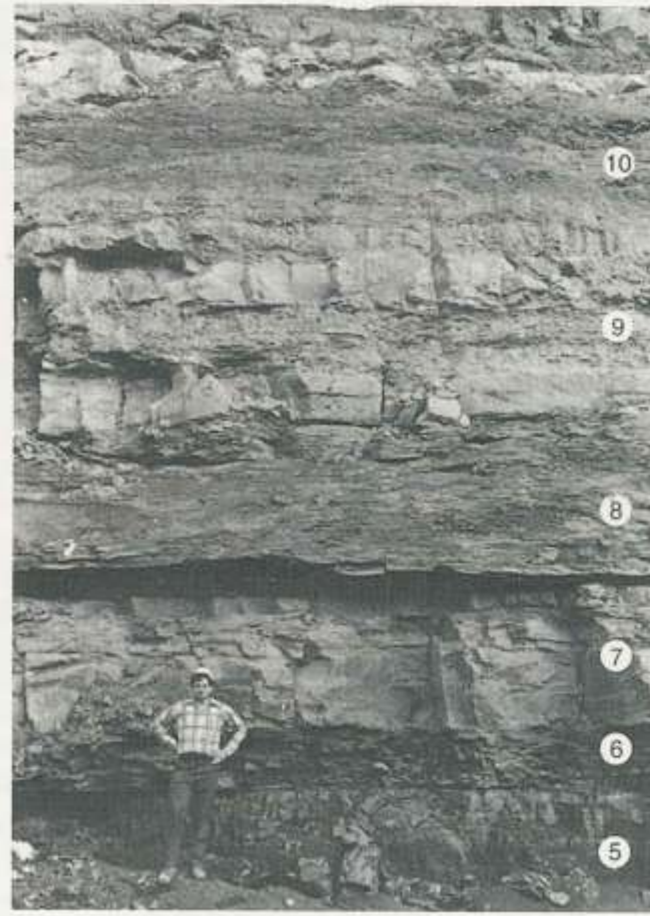


FIGURE 9-12 Part of an Illinois cyclothem. The lowermost layer is the coal seam (cyclothem bed 5), followed upward by shale (bed 6) near the geologist's hand, limestone (bed 7), shale (bed 8), another limestone (bed 9), and the upper shale (bed 10). Part of another sequence caps the exposure. This cyclothem is part of the Carbondale Formation. (*Photograph courtesy of D. L. Reinertsen and the Illinois Geological Survey.*) ? *Would rocks deposited above bed 10 be predominantly marine or nonmarine?*

Pennsylvanian plants

Calamites

FIGURE 10-88 ***Calamites*, a sphenopsid.** Plants shown are about 3 to 5 meters tall.

Extinction overtook many plant groups near the end of the Permian Period. Many species of lycopsids, seed ferns, and conifers disappeared. Small ferns that grow in damp areas, however, were not profoundly affected by the crisis.

FIGURE 10-89 ***Annularia*, an abundant sphenopsid of Pennsylvania age.**

FIGURE 10-90 ***Pecopteris*, a true fern from the Pennsylvanian of Illinois** (the penny is for scale).

FIGURE 10-91 **End of a branch of *Cordaites*, showing the straplike leaves of these trees.** Not uncommonly, the leaves attained lengths of 1 meter. The clustered bodies produced the plant's male gametes. (*Adapted from Grand'Eury, C. 1877. Flore Carbonifère de Départment de la Loire et du centre de la France.* Mem. Acad. Sci. Institut France. *24:624 pp.*)

MASS EXTINCTIONS

For most of the Paleozoic, the Earth was populated by a rich diversity of life. There were, however, times when the planet was less hospitable, and large groups of organisms suffered extinction (Fig. 10–92). Early geologists saw evidence of these mass extinctions in the fossil record and used the abrupt termination of fossil ranges to define the boundaries between geologic

Pennsylvanian Coal Forest

Pennsylvanian-Permian Horquilla Limestone, Government Draw, South of Tombstone Horquilla Limestone, Earp Fm., Colina Ls.

Late Paleozoic – Pennsylvanian Santa Catalina Mts.

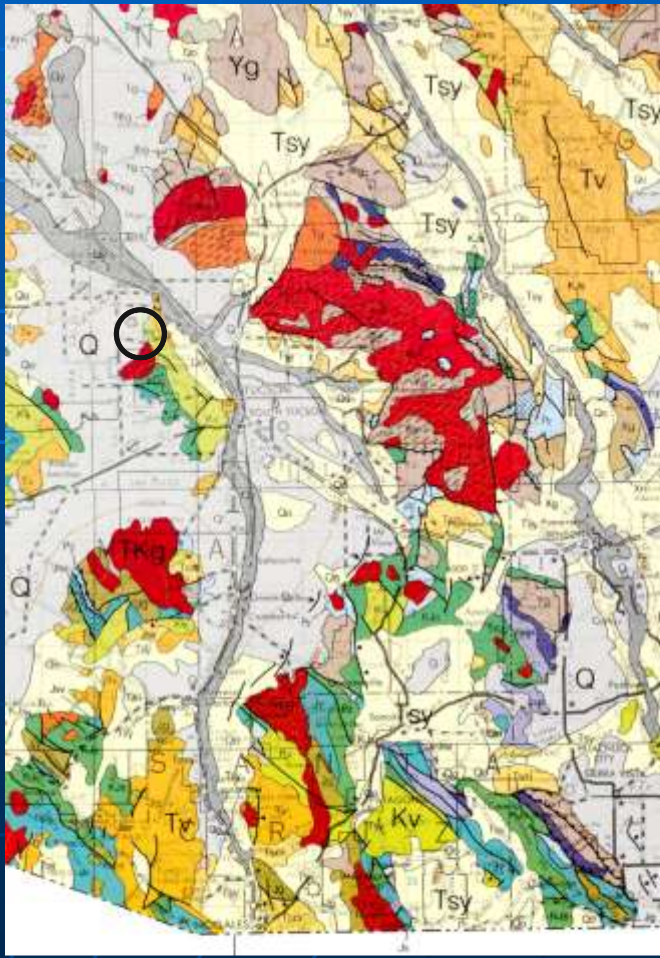
Horquilla Limestone,
Earp Formation jelly bean conglomerate

Late Paleozoic – Pennsylvanian
Rincon Mts. – Horquilla Limestone

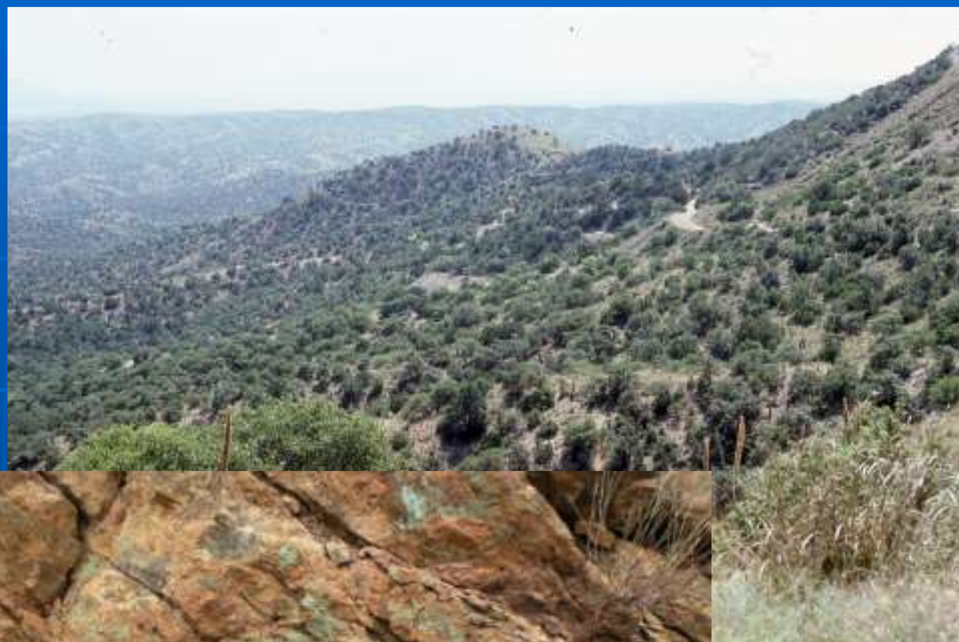
Photo by Bill Peachey, near Colossal Cave

Late Paleozoic – Pennsylvanian - N. Tucson Mts.

Twin Peaks Quarry, looking N, 1987

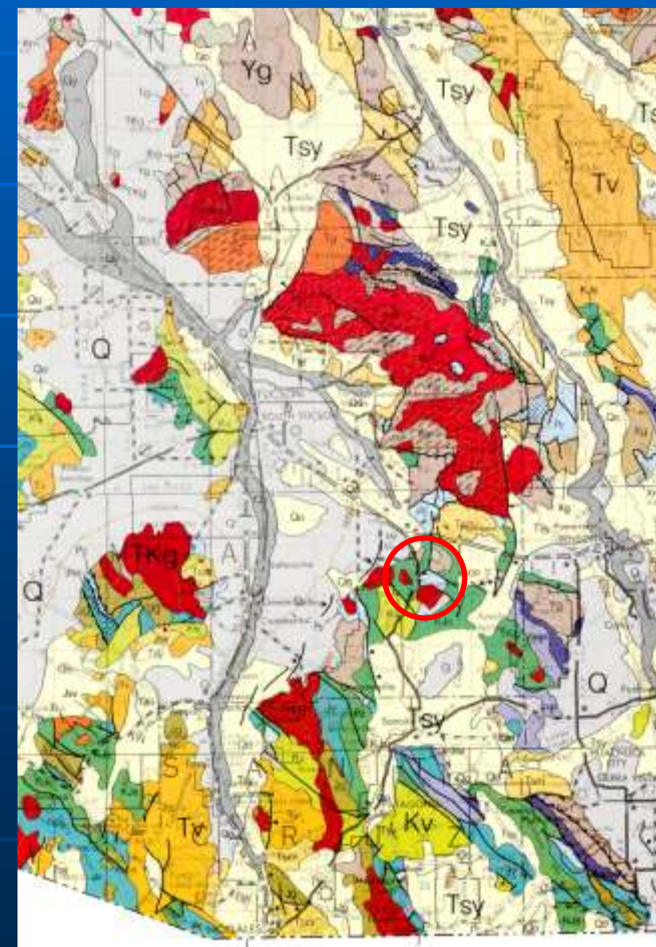


Late Paleozoic – Pennsylvanian
Santa Rita Mts.



Horquilla
Limestone

Photo by Cori
Hoag



Appalachian paleogeography Permian

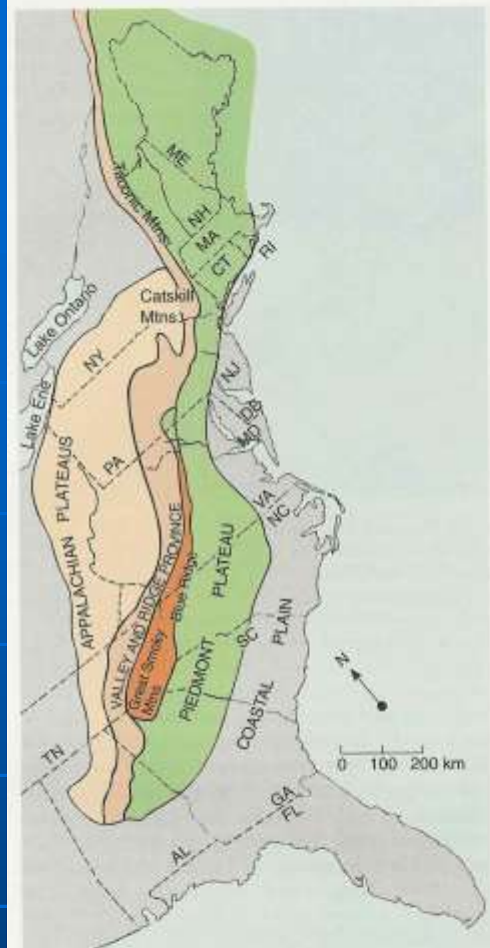


FIGURE 9-28 **Physiographic provinces of the eastern United States.**

The effects of the Allegheny orogeny were profound and included Permian compression of early continental shelf and rise sediments as well as strata deposited along the bordering tract of the craton. The great folds now visible in the Ridge and Valley Province were developed during this orogeny. Less visible at the surface but

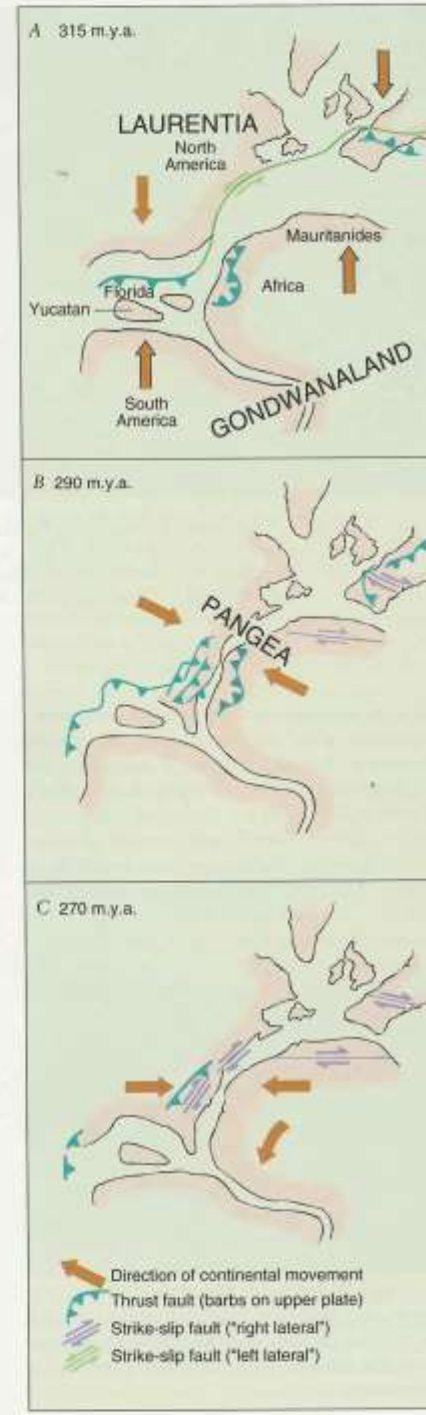


FIGURE 9-29 **Plate tectonic model for late Paleozoic continental collisions,** proposed by P. E. Sacks and D. T. Secor, Jr. (*A*) Early Pennsylvanian, (*B*) Late Pennsylvanian, (*C*) Permian. (*Adapted from Sacks, P. E., and Secor, D. T., Jr. 1990. Science 250:1702–1705.*)

Permian environments

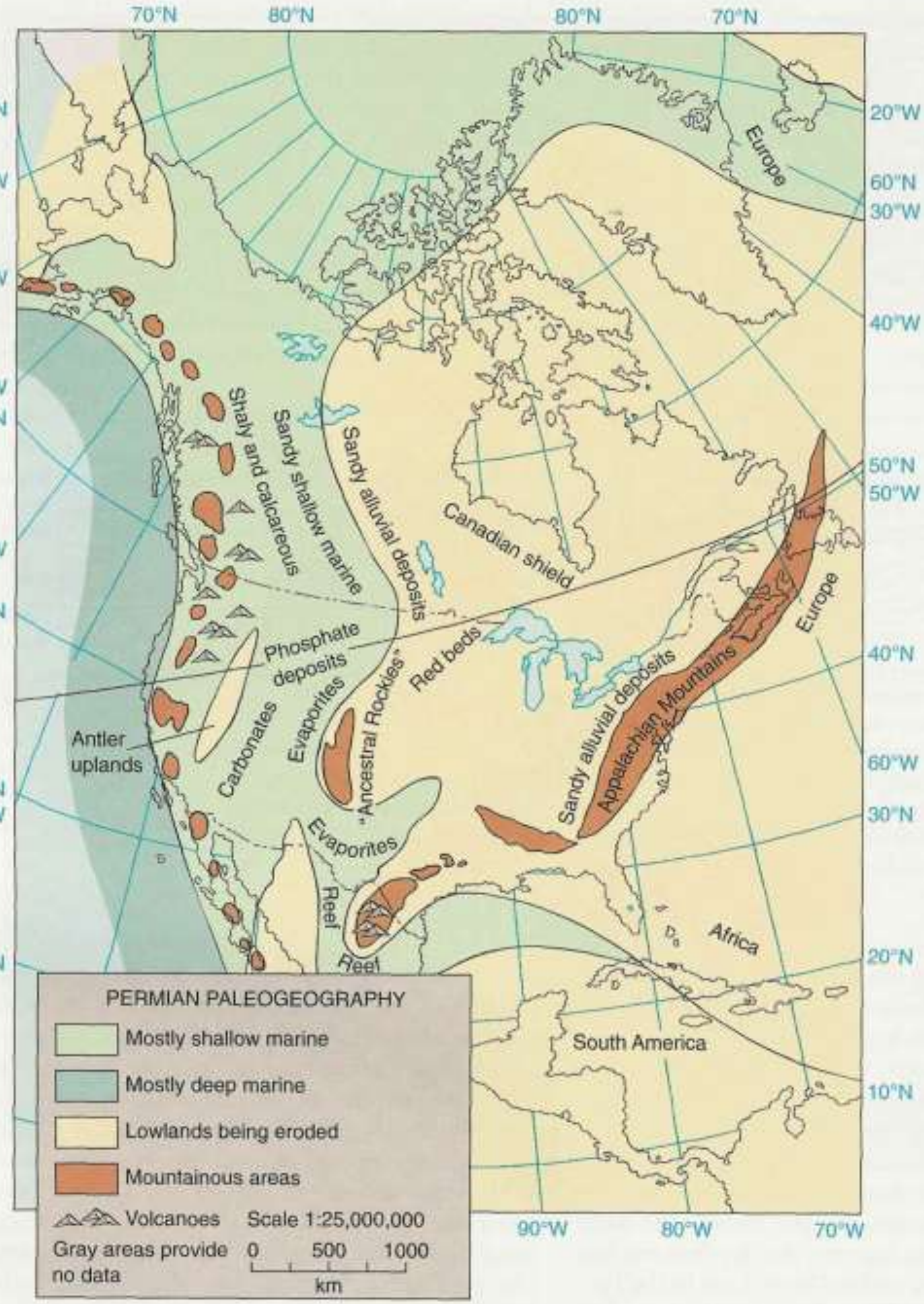
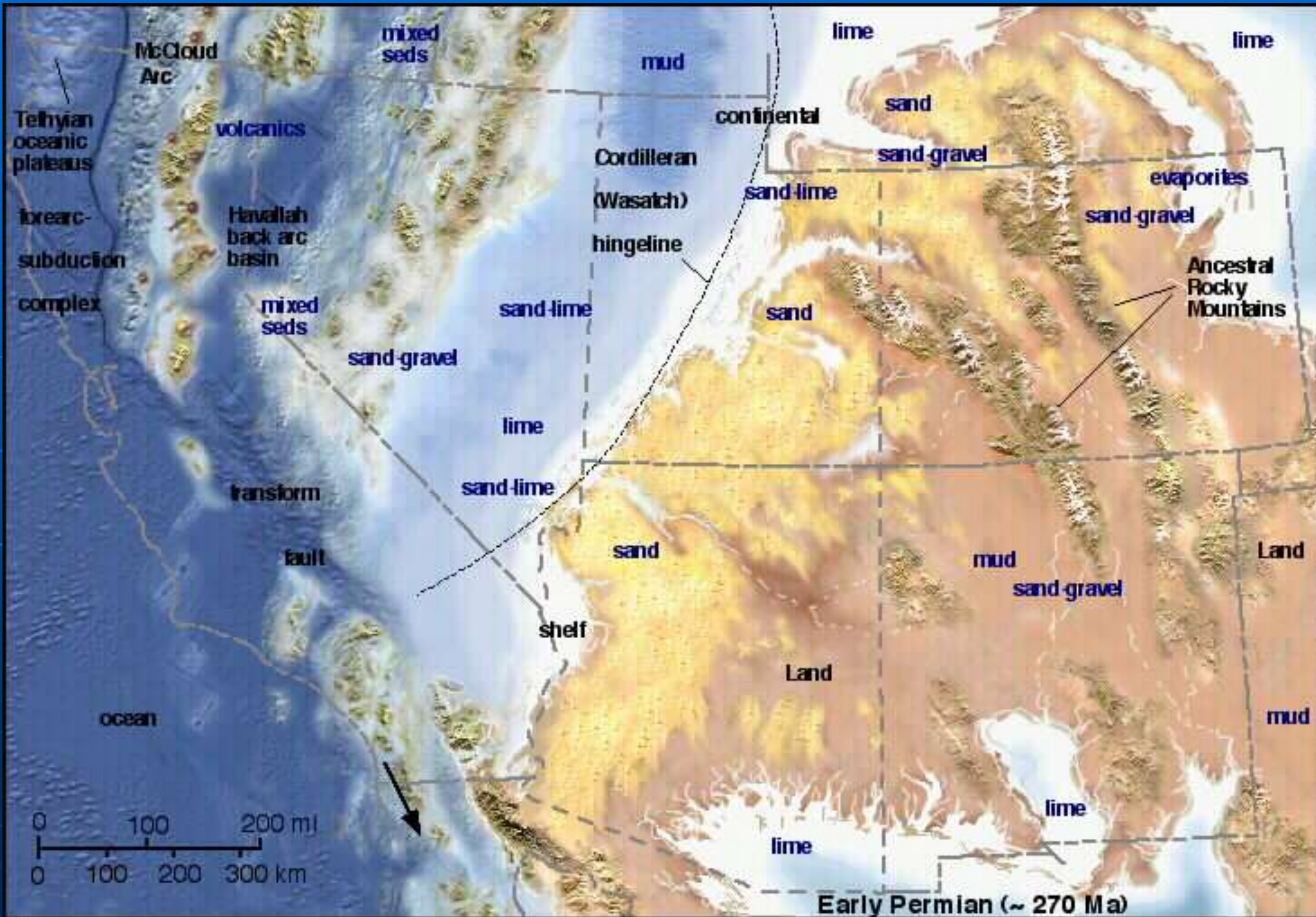


FIGURE 9-18 Generalized paleogeographic map for the Permian Period.

Permian (290-248 Ma)

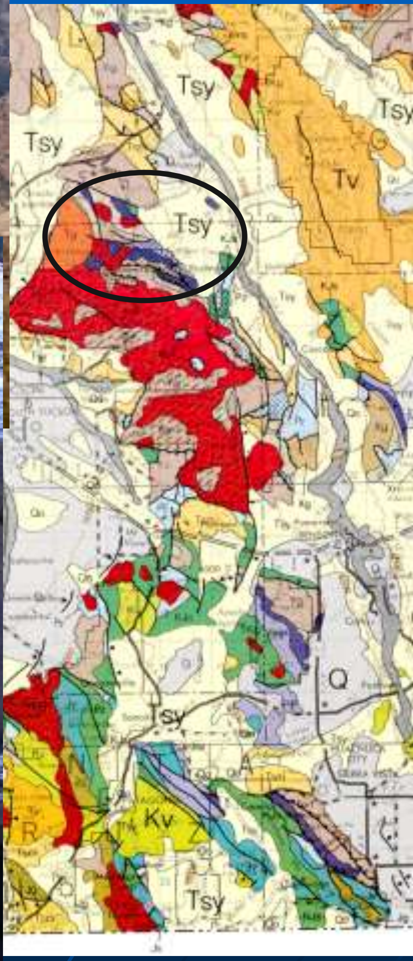


Earp Formation,

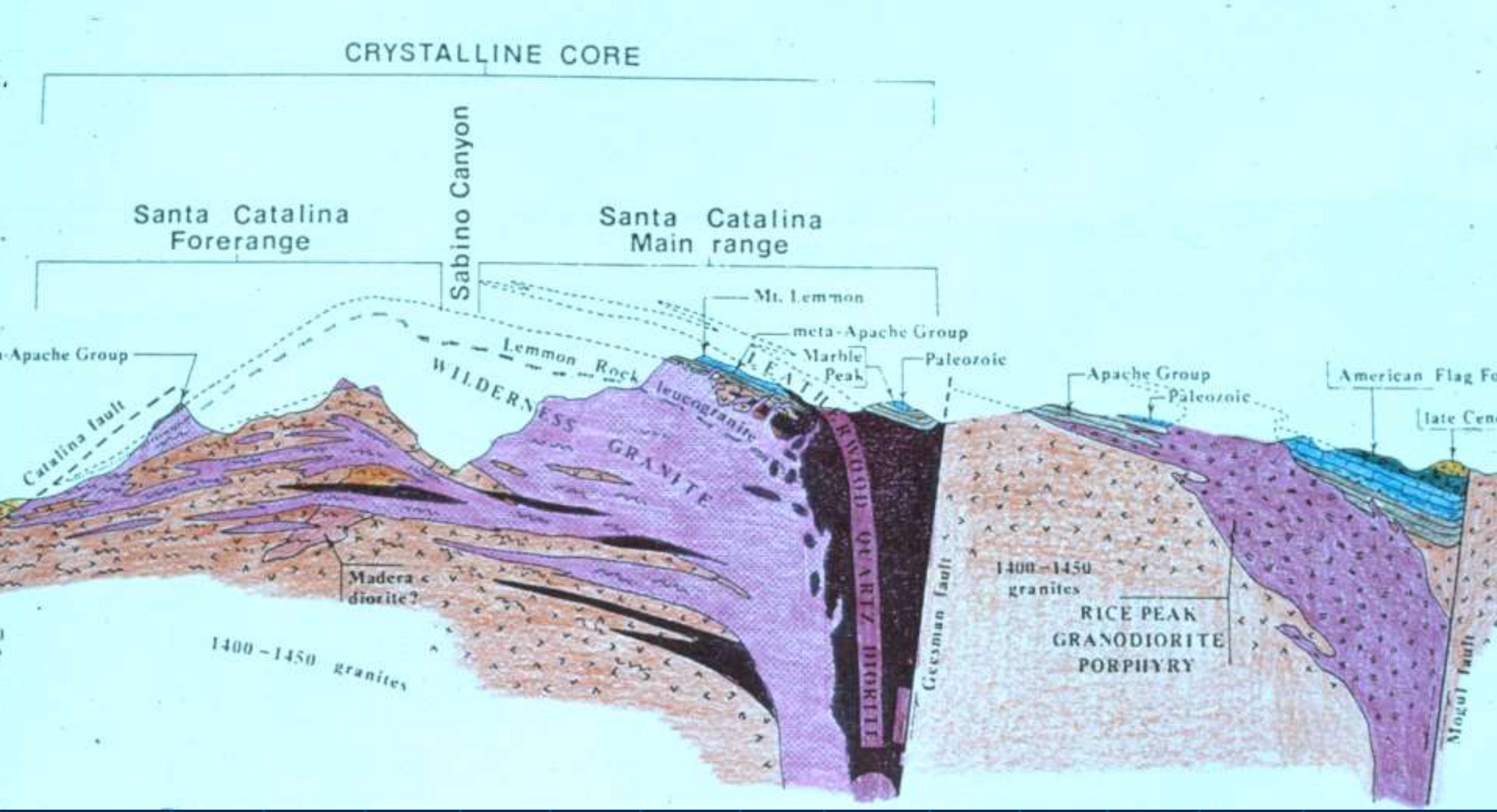
base of Government Draw SE of Tombstone

Late Paleozoic – Permian Santa Catalina Mts.

Colina Limestone, Epitaph Dolomite

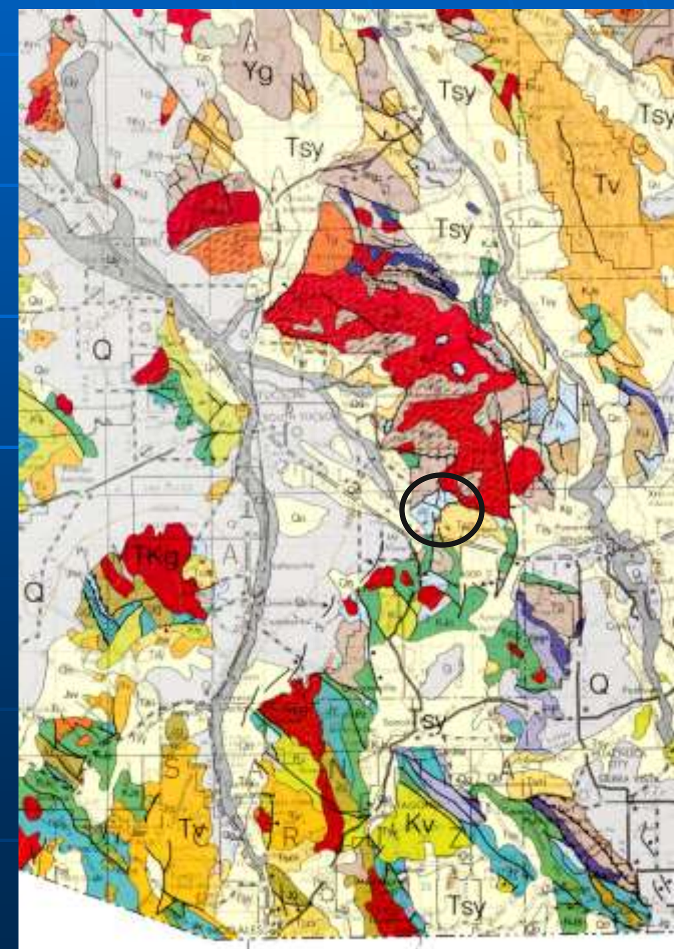


Catalina cross section



Looking west from about Sabino Canyon

Late Paleozoic – Permian Rincon Mts. – Earp Fm.,Colina Ls.



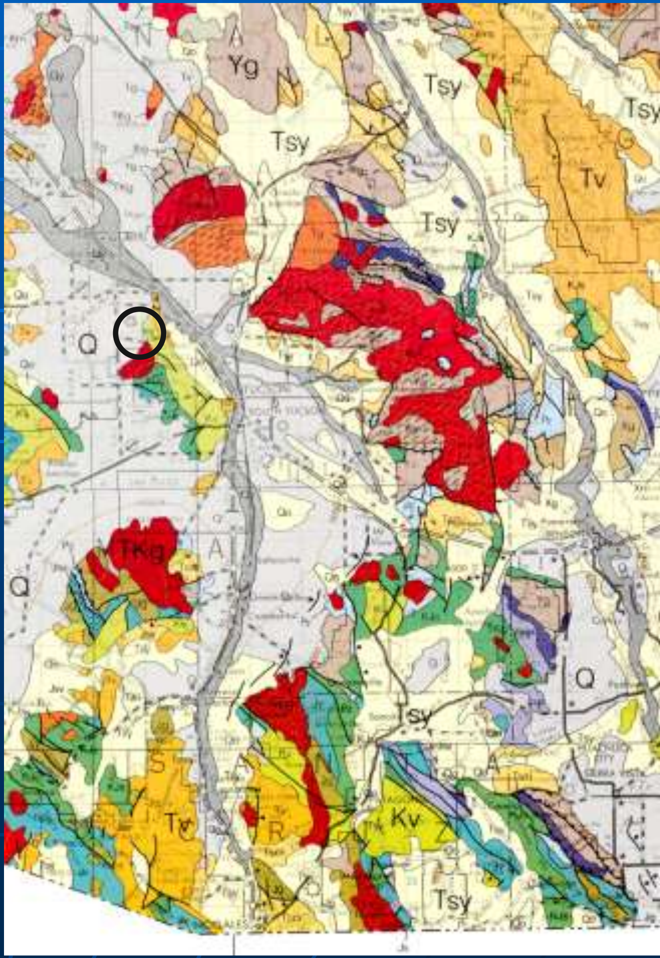
Tight folds in Permian Limestone, near Colossal Cave

Photo by Bill Peachey

Late Paleozoic – Permian - N. Tucson Mts.

Twin Peaks Quarry, looking North, 1987

Permian Ls. Cochise Co.

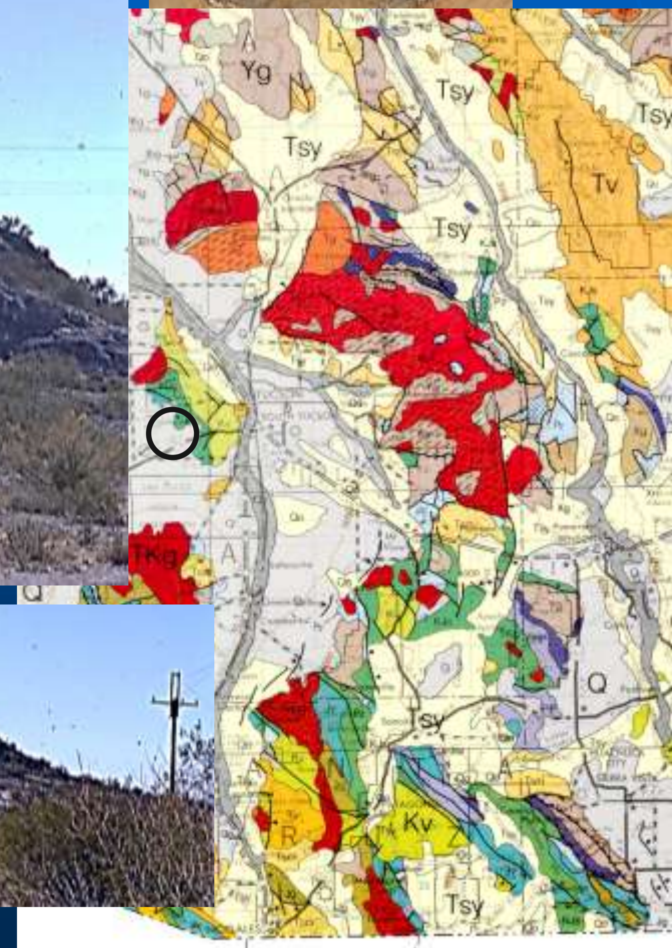


Sus Hills, looking NE

Sus Hills, Permian Ls.

Late Paleozoic – Permian - SW Tucson Mts.

Snyder Hill

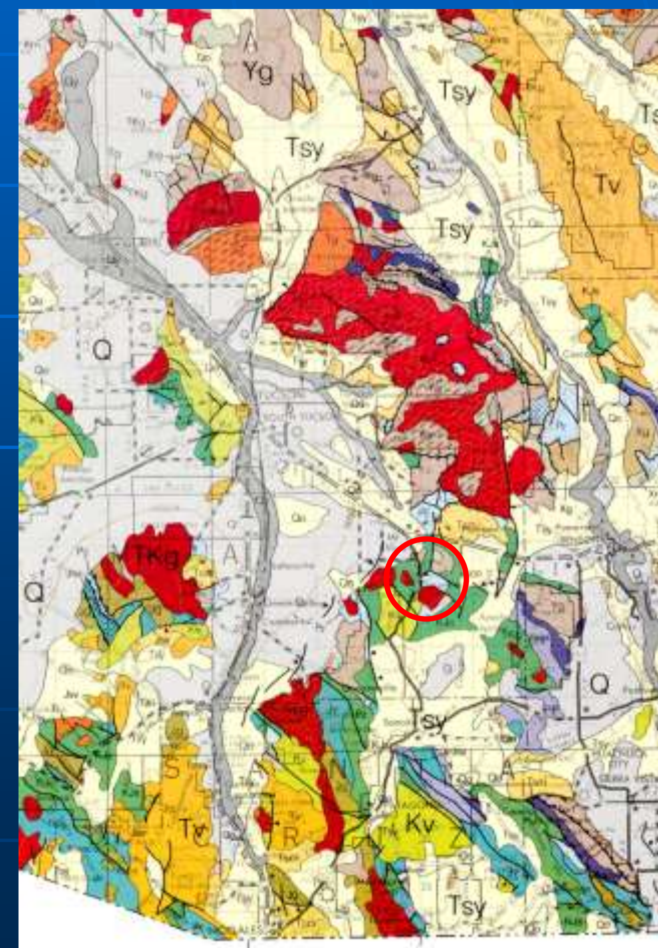


Snyder Hill, Permian Ls.

Late Paleozoic – Permian - Santa Rita Mts.

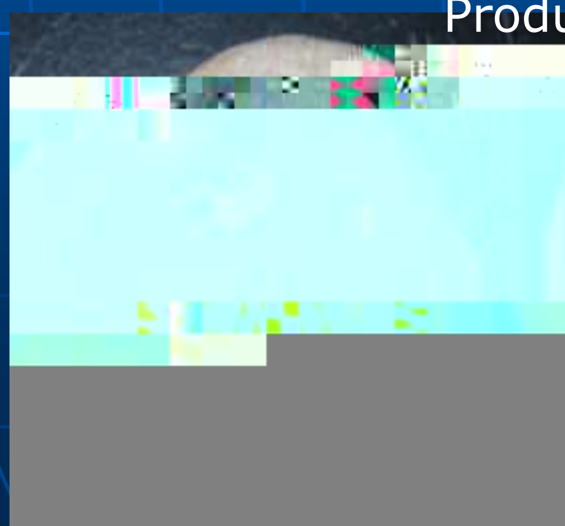
Epitaph Dolomite

Photo by Cori Hoag



Late Paleozoic brachiopod fossils

Composita



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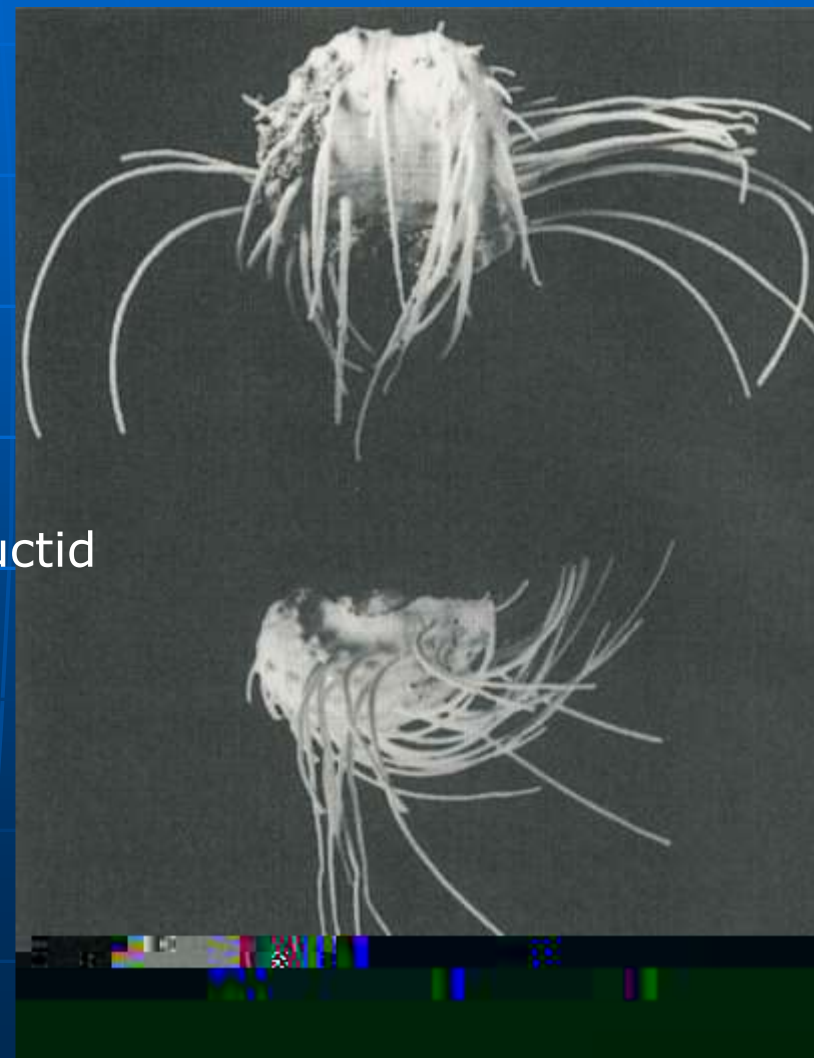


Amphibian fossils

FIGURE 10-77 *Cacops*, a small labyrinthodontic amphibian from the Lower Permian. (*Photograph of a specimen on exhibit at the Field Museum in Chicago.*)

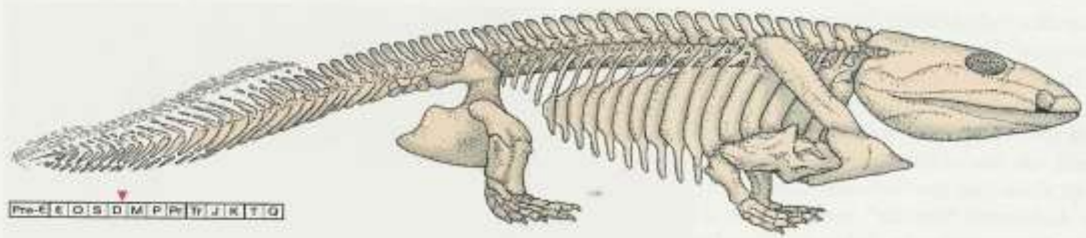


FIGURE 10-76 The skeleton of *Ichthyostega* still retains the fishlike form of its crossopterygian ancestors. (*From Levin, H. L. 1975.* Life Through Time. *Dubuque, Iowa: William C. Brown Co.*)

Mammal-like Reptiles

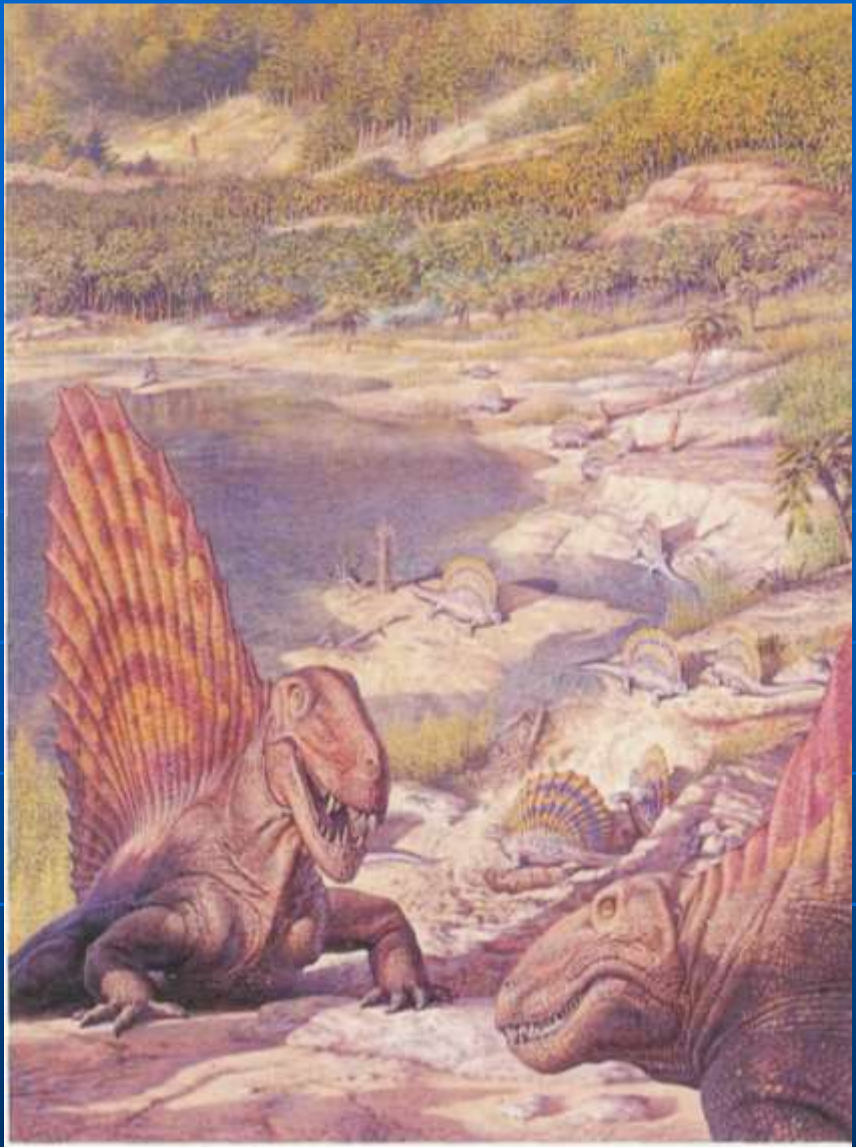


FIGURE 10-78 **Permian reptiles.** The prominent sailback reptile in the left foreground, with a larger skull and daggerlike teeth, is the carnivore *Dimetrodon*. The sailbacks with smaller heads and blunt cheek teeth, in the foreground at right and in the distance, are plant-eaters of the genus *Edaphosaurus*. (*Copyright J. Sibbick.*) ? *Is it likely*

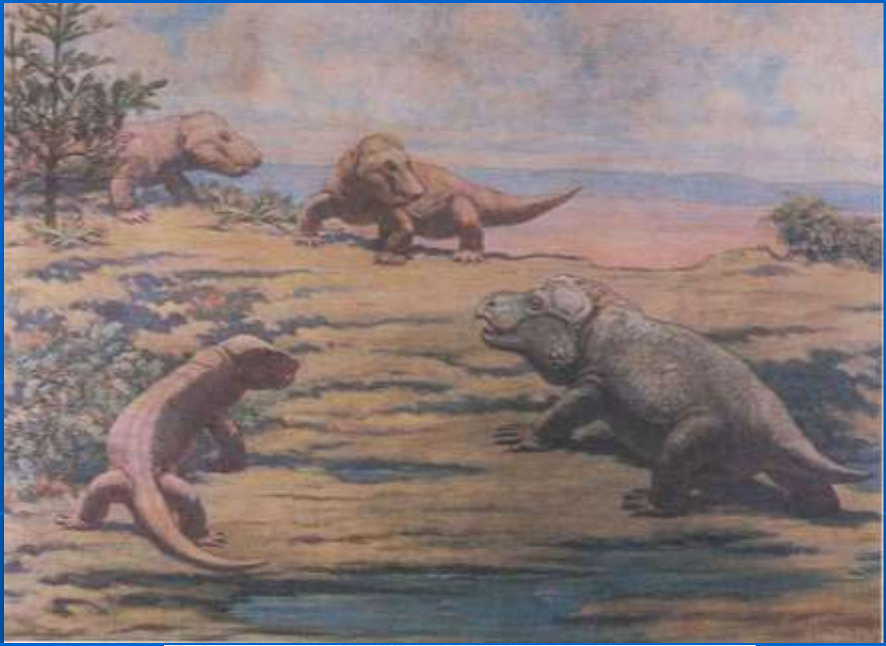
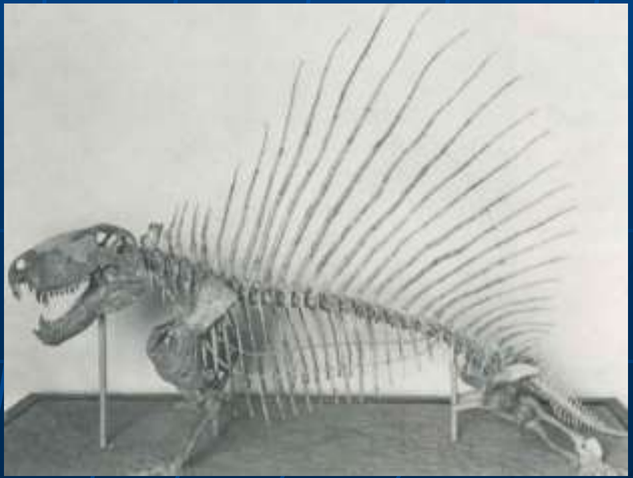
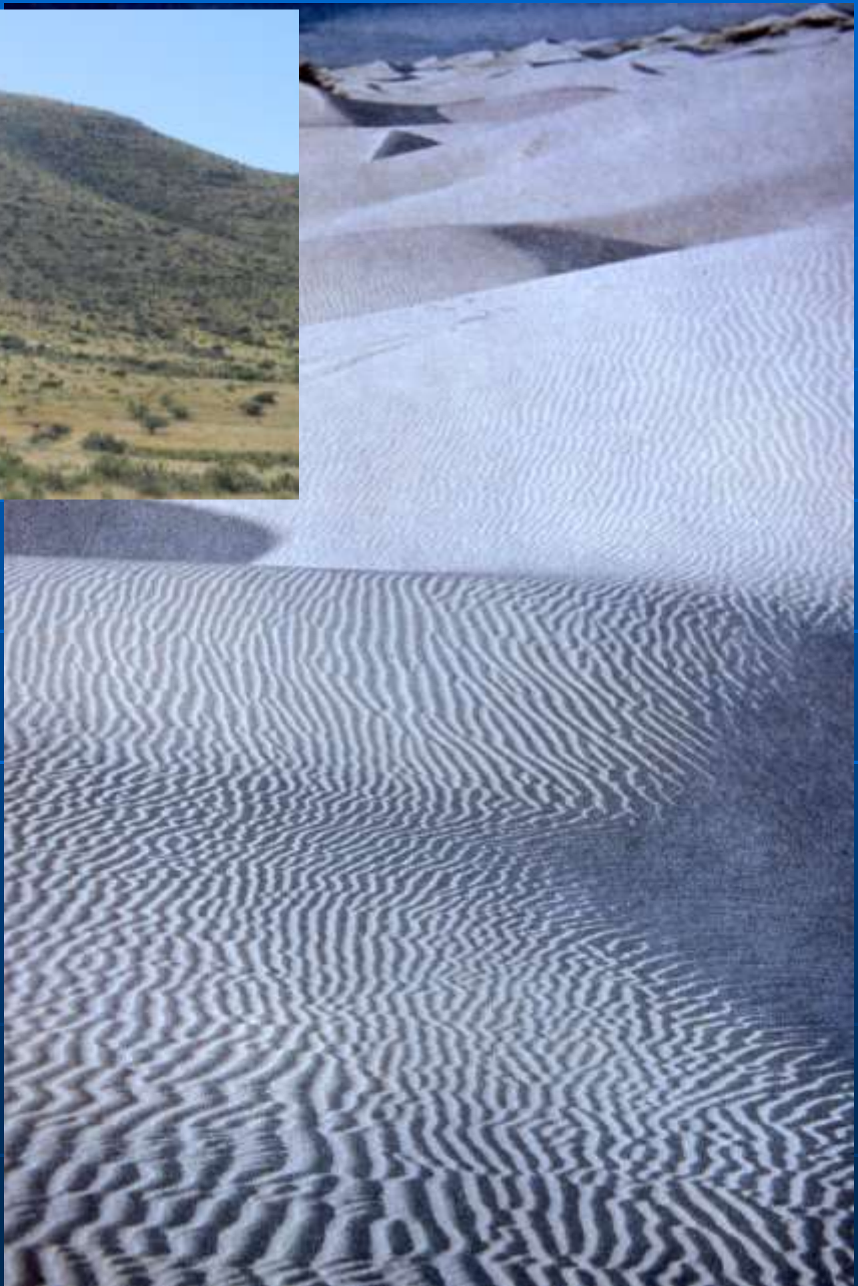


FIGURE 10-80 **Mammal-like reptiles.** The scene depicts three carnivorous forms (*Cynognathus*) about to attack a plant-eating therapsid reptile (*Kannemeyeria*). (*Courtesy of*



Middle Permian – deserts, beaches

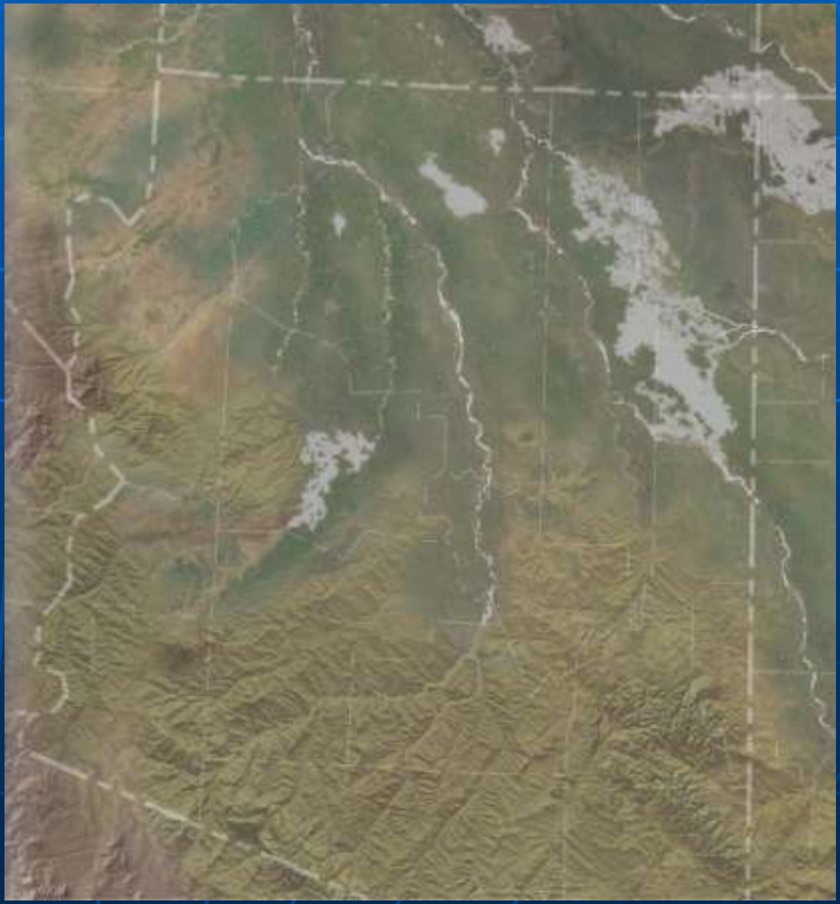
Permian – Gunnison Hills



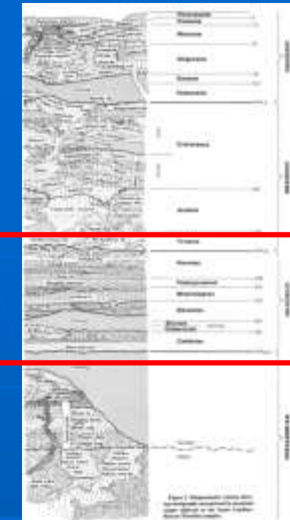
End of Permian – land areas

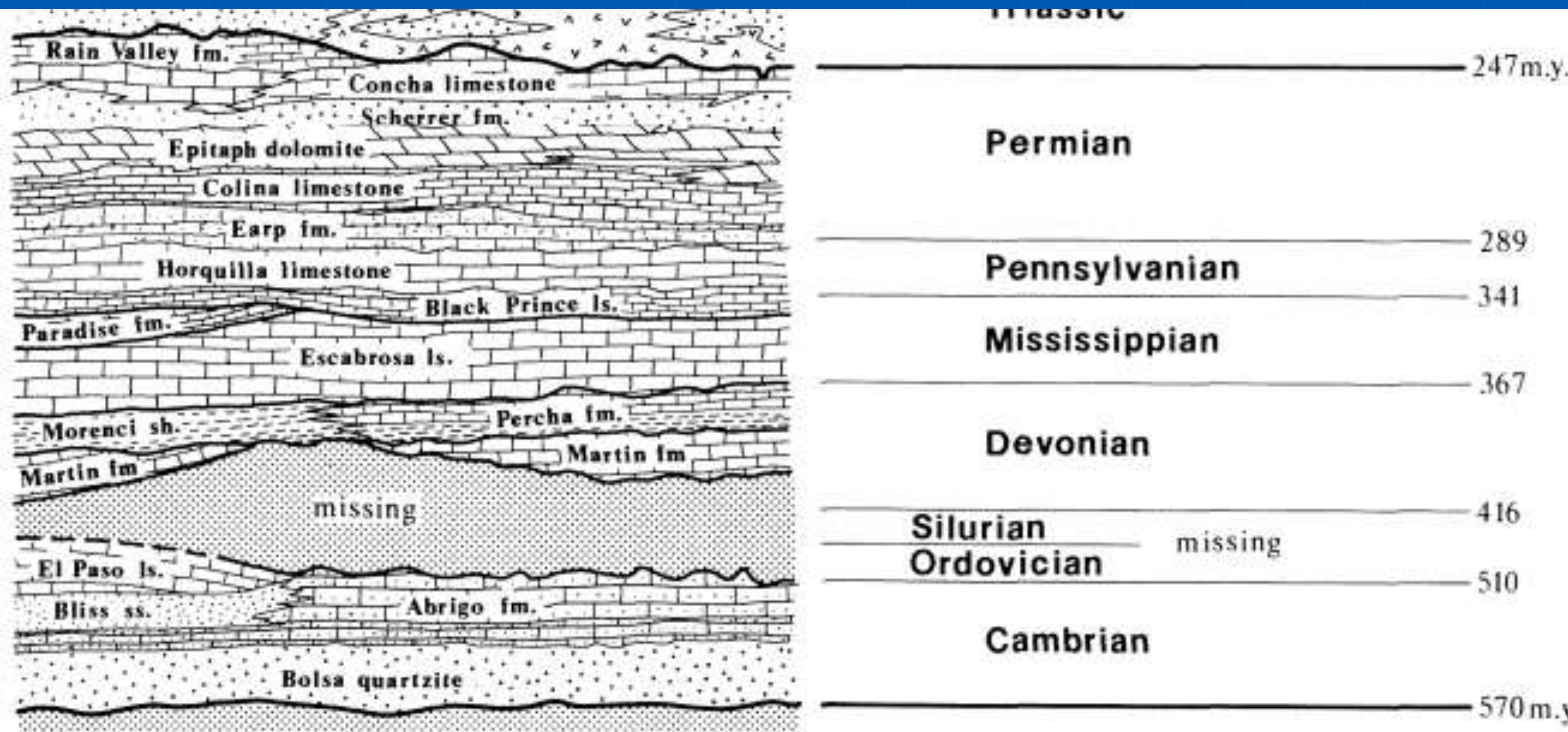
FIGURE 11–1 Paleogeographic reconstruction of the world about 180 million years ago, when the break-up of Pangea was beginning. (After Scotese, C. R. and McKerrow, W. S. 1990. Paleogeography and Biogeography, *Geol. Soc. London Mem.* 12:1–21.)

Pangea continent begins to break up



Paleozoic Formations in the Tucson area





Glaciation through Geologic time

- Depends on plate tectonics through geologic history
- Continental collisions = ice ages
- Big environmental changes through geologic time
- Warm periods vs. ice ages ~ every 250 million years