Advanced Structural Geology, Fall 2022

Anatomy of the North American Cordillera

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Tectonics words

- Allocthon
- Miogeocline
- Craton
- Orogen/Orogeny
- Foreland
- Hinterland
- Accretionary mélange
- Rollback
- Taphrogeny

Others?

GSA GEOLOGIC TIME SCALE v. 5.0

https://www.geosociety.org/documents/gsa/timescale/timescl.pdf

CENOZOIC

Period		Epoch	Age	Picks (Ma)
QUATERNARY		HOLOCENE		0.012
		PLEISTOCENE*	CALABRIAN	1.8
			GELASIAN	2.58
TERTIARY	NEOGENE	PLIOCENE	PIACENZIAN	3.600
			ZANCLEAN	5.333
		MIOCENE	MESSINIAN	7.246
			TORTONIAN	11.63
			SERRAVALLIAN	13.82
			LANGHIAN	15.97
			BURDIGALIAN	20.44
			AQUITANIAN	23.03
	PALEOGENE	OLIGOCENE	CHATTIAN	27.82
			RUPELIAN	33.9
		EOCENE	PRIABONIAN	37.8
			BARTONIAN	41.2
			LUTETIAN	47.8
			YPRESIAN	56.0
		PALEOCENE	THANETIAN	59.2
			SELANDIAN	61.6
			DANIAN	66.0

MESOZOIC

Period	Epoch	Age	Picks (Ma)
			66.0
CRETACEOUS	LATE	MAASTRICHTIAN	72.1
		CAMPANIAN	83.6
		SANTONIAN	86.3
		CONIACIAN	89.8
		TURONIAN	93.9
		CENOMANIAN	100.5
	EARLY	ALBIAN	~113
		APTIAN	~125
		BARREMIAN	~129.4
		HAUTERIVIAN	~132.9
		VALANGINIAN	~139.8
		BERRIASIAN	~145.0
JURASSIC	LATE	TITHONIAN	~152.1
		KIMMERIDGIAN	~157.3
		OXFORDIAN	~163.5
	MIDDLE	CALLOVIAN	~166.1
		BATHONIAN	~168.3
		BAJOCIAN	~170.3
		AALENIAN	~174.1
	EARLY	TOARCIAN	~182.7
		PLIENSBACHIAN	~190.8
		SINEMURIAN	~199.3
		HETTANGIAN	~201.3
TRIASSIC	LATE	RHAETIAN	~208.5
		NORIAN	~227
		CARNIAN	~237
	MIDDLE	LADINIAN	~242
		ANISIAN	247.2
	EARLY	OLENEKIAN	251.2
		INDUAN	251.90

RAPID POLARITY CHANGES

PALEOZOIC

Period		Epoch	Age	Picks (Ma)
				251.90
PERMIAN		Lopingian	CHANGHSINGIAN	254.14
			WUCHIAPINGIAN	259.1
		Guadalupian	CAPITANIAN	265.1
			WORDIAN	268.8
			ROADIAN	272.95
		Cisuralian	KUNGURIAN	~283.5
			ARTINSKIAN	290.1
			SAKMARIAN	295.0
			ASSELIAN	298.9
CARBONIFEROUS	PENNSYLVANIAN	LATE	GZHELIAN	303.7
			KASIMOVIAN	307.0
		MIDDLE	MOSCOVIAN	315.2
		EARLY	BASHKIRIAN	323.2
	MISSISSIPPIAN	LATE	SERPUKHOVIAN	330.9
		MIDDLE	VISEAN	346.7
		EARLY	TOURNAISIAN	358.9
DEVONIAN		LATE	FAMENNIAN	~372.2
			FRASNIAN	~382.7
		MIDDLE	GIVETIAN	~387.7
			EIFELIAN	~393.3
		EARLY	EMSIAN	~407.6
			PRAGIAN	~410.8
			LOCHKOVIAN	~419.2
SILURIAN		PRIDOLI		~423.0
		LUDLOW	LUDFORDIAN	~425.6
			GORSTIAN	~427.4
		WENLOCK	HOMERIAN	~430.5
			SHEINWOODIAN	~433.4
		LLANDOVERY	TELYCHIAN	~438.5
			AERONIAN	~440.8
			RHUDDANIAN	~443.8
ORDOVICIAN		LATE	HIRNANTIAN	~445.2
			KATIAN	~453.0
			SANDBIAN	~458.4
		MIDDLE	DARRIWILIAN	~467.3
			DAPINGIAN	~470.0
		EARLY	FLOIAN	~477.7
			TREMADOCIAN	~485.4
CAMBRIAN		FURONGIAN	AGE 10	~489.5
			JIANGSHANIAN	~494
			PAIBIAN	~497
		Epoch 3	GUZHANGIAN	~500.5
			DRUMIAN	~504.5
			AGE 5	~509
		Epoch 2	AGE 4	~514
			AGE 3	~521
		TERRENEUVIAN	AGE 2	~529
			FORTUNIAN	541.0

PRECAMBRIAN

Eon	Era	Period	Bdy. Ages (Ma)
			541
PROTEROZOIC	NEOPROTEROZOIC	EDIACARAN	635
		CRYOGENIAN	720
		TONIAN	1000
	MESOPROTEROZOIC	STENIAN	1200
		ECTASIAN	1400
		CALYMMIAN	1600
	PALEOPROTEROZOIC	STATHERIAN	1800
		OROSIRIAN	2050
		RHYACIAN	2300
		SIDERIAN	2500
ARCHEAN	NEOARCHEAN		2800
	MESOARCHEAN		3200
	PALEOARCHEAN		3600
	EOARCHEAN		4000
HADEAN			

Cordilleran Overview

Well studied ; Dominantly a convergent margin (starts at 800 Ma)

- 1 continental plate interacting with numerous oceanic plates (Pacific and Farallon) + continental and oceanic (mostly island arc) fragments
- Terrane accretion is important (terranes are tectonic fragments with their own history distinct from surrounding rocks (island arcs, aseismic ridges, oceanic plateaus, small fragments of probable oceanic crust). Accretion means to add to margin during subduction
- Cenozoic interaction with intra-Pacific seafloor spreading systems fostered transform faulting along the Cordilleran continental margin and promoted incipient rupture of continental crust within the adjacent continental block.

Mostly from Moores and Twiss, Tectonics and Dickinson, 2004

Reading review questions

- How do they motivate their work? Why is it important?
- How did they do it (methods)?
- General result (bullet list of main outcomes)
- Questions you have

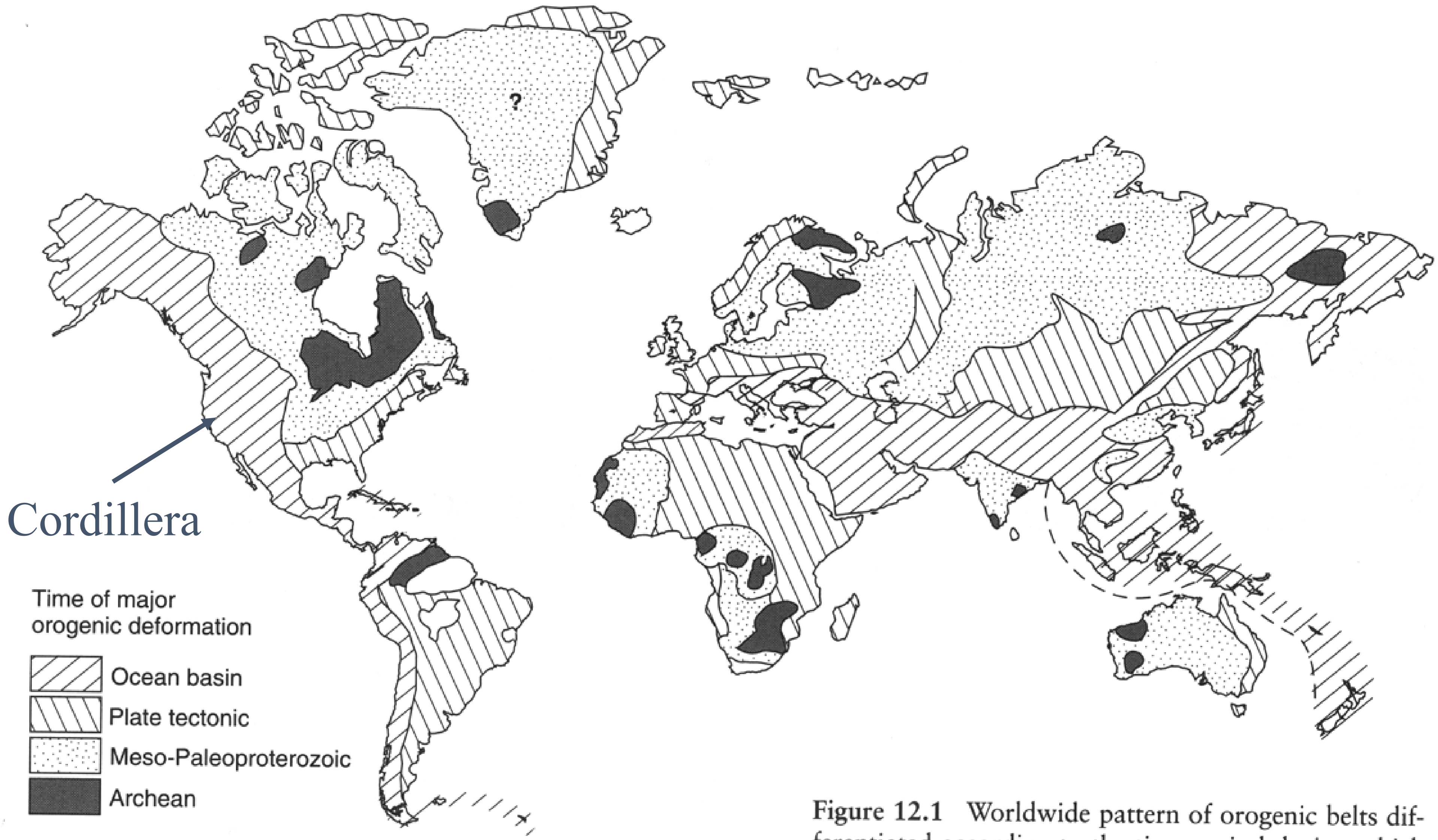


Figure 12.1 Worldwide pattern of orogenic belts differentiated according to the time period during which the deformation occurred. Belts are grouped according to their ages in ocean basin time (1–200 Ma), plate tectonic time (200–1000 Ma), Meso-Paleoproterozoic (1000–2500 Ma), and Archean (2500–3800 Ma). *(After B. C. Burchfiel, 1983)*

Moores and Twiss, Tectonics

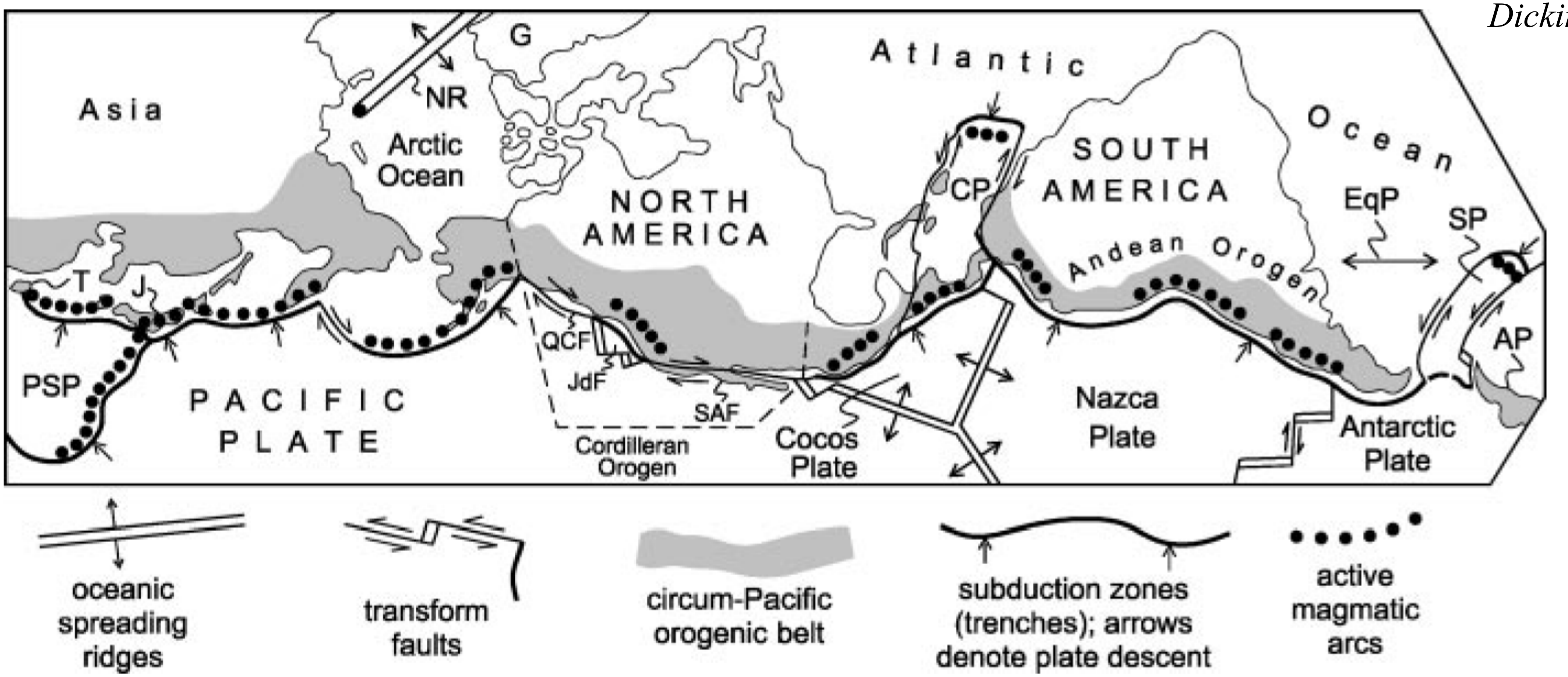
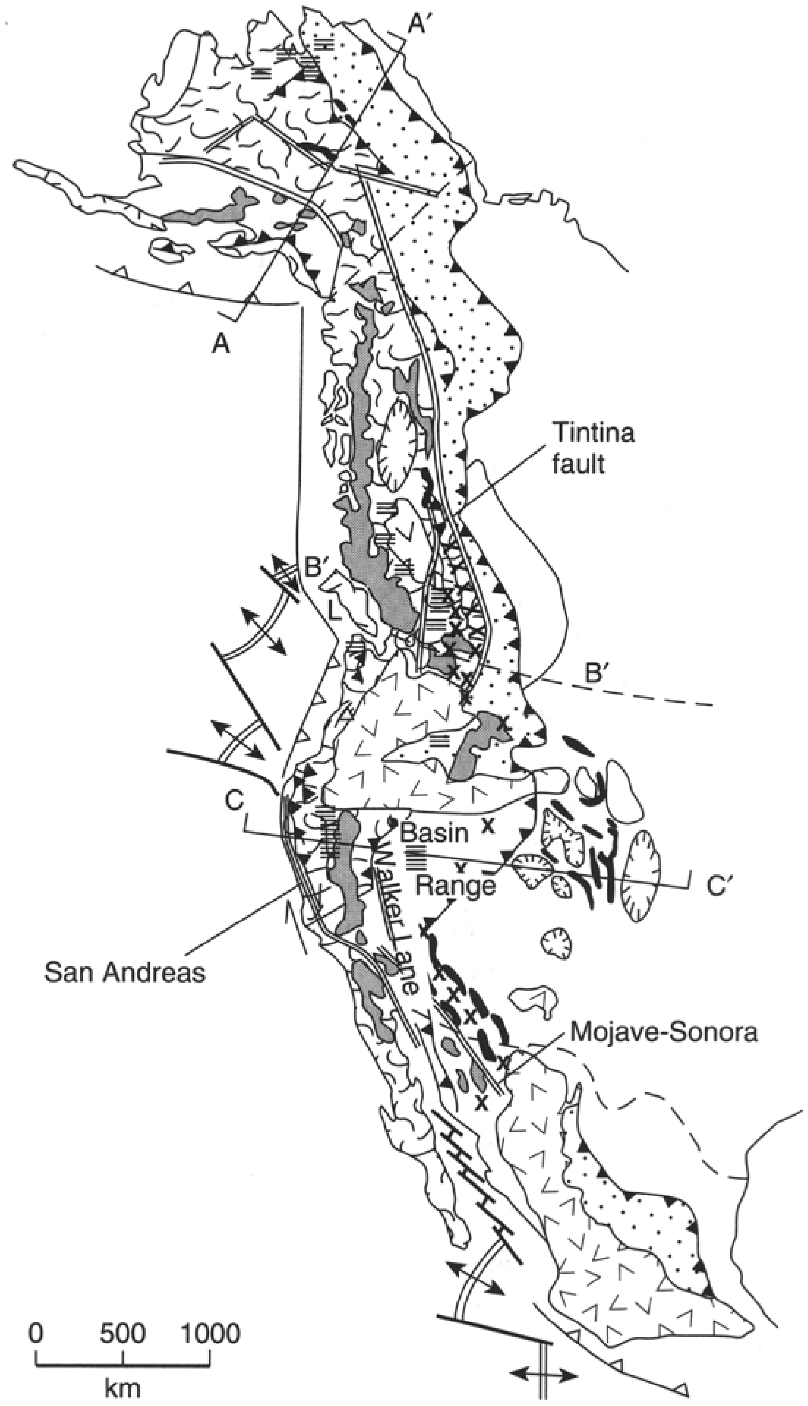


Figure 2 Position of the Cordilleran orogen of western North America along the Circum-Pacific orogenic belt (after Dickinson et al. 1986). Mercator projection with pole at 25° N Lat, 15° E Long (EqP is equatorial plane of projection). AP, Antarctic Peninsula; C, Cascades volcanic chain; CP, Caribbean plate; G, Greenland; J, Japan; JdF, Juan de Fuca plate; NR, Nansen Ridge (northern extremity of Atlantic spreading system); PSP, Philippine Sea plate; QCf, Queen Charlotte fault; SAf, San Andreas fault; SP, Scotia plate; T, Taiwan.

Moores and Twiss, Tectonics



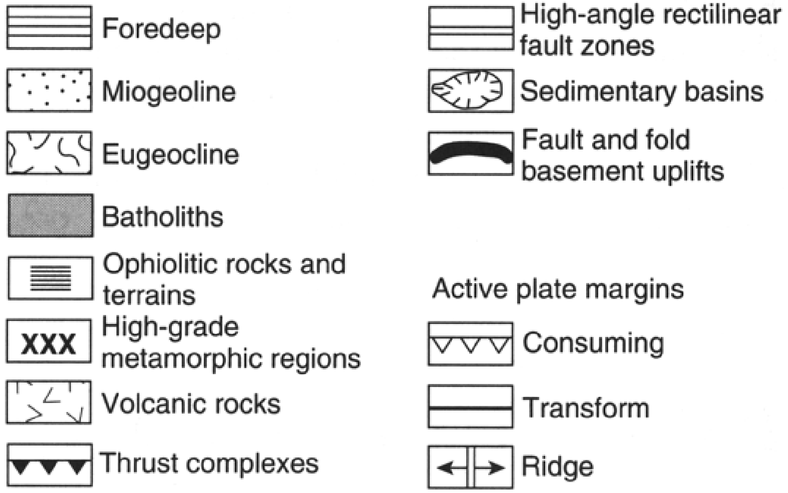


Figure 12.3 Map of U.S. Cordillera showing major tectonic features discussed in the text. Section lines A–A′ through C–C′, indicate locations of the cross sections shown in Figure 12.4. *(After King, 1977)*

- Noteworthy as an orogen for
  - Suspect terranes (far travelled allochthons; more as you go oceanward)
  - Strike-slip faulting (San Andreas System)
  - Voluminous magmatism
  - Plateau uplift
  - Normal faulting (Basin and Range)

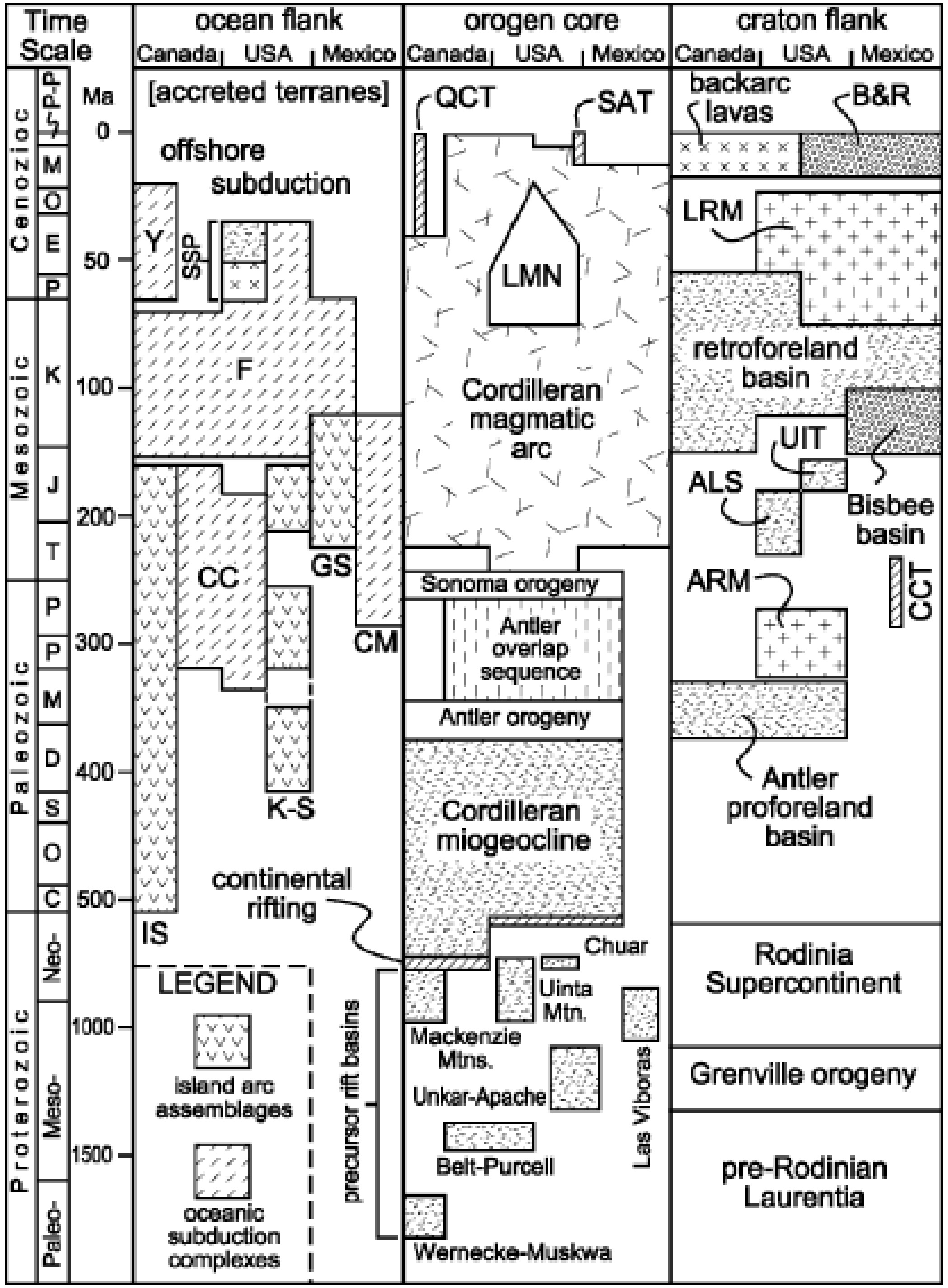
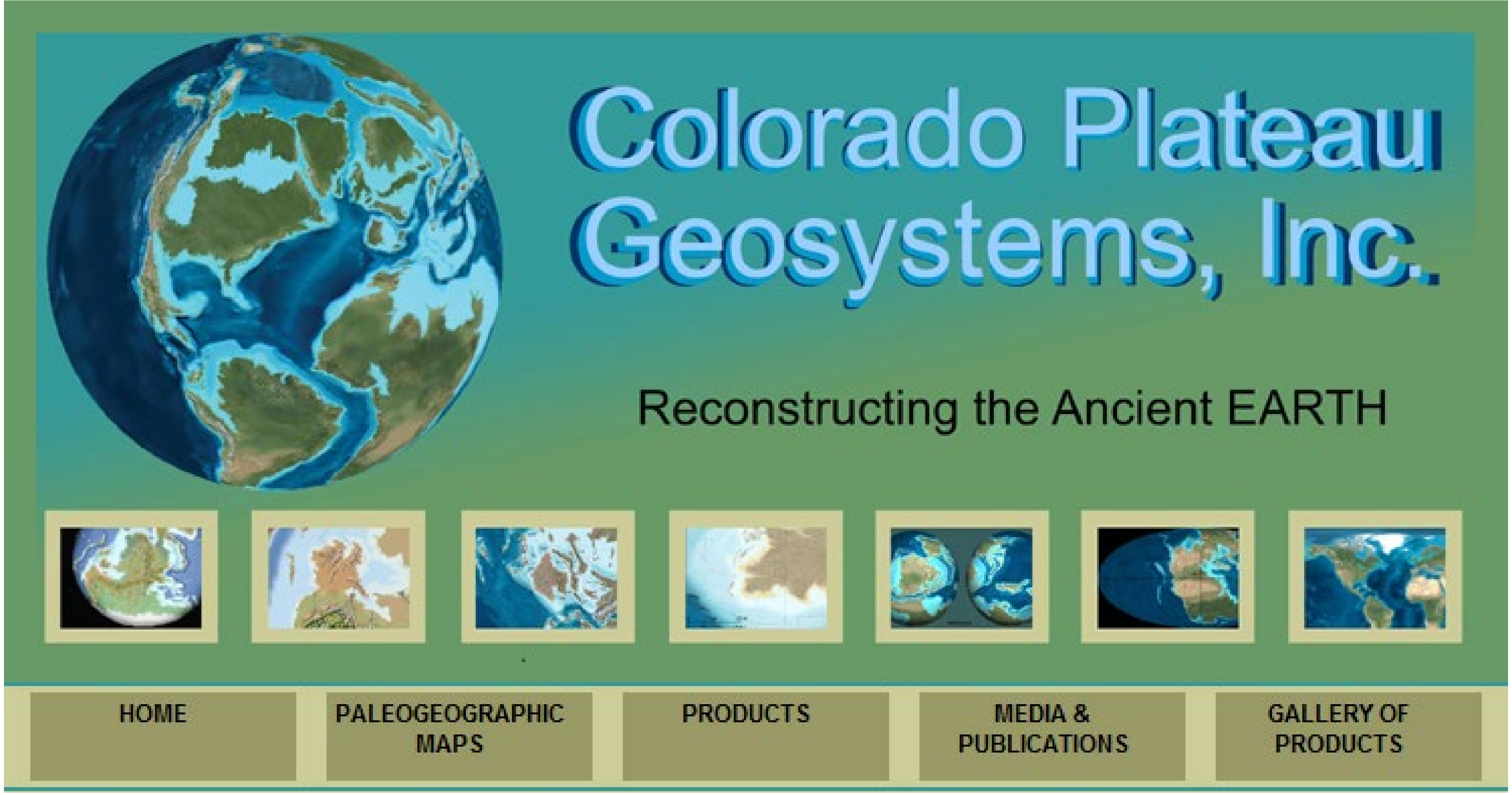


Figure 1 Schematic chronostratigraphic diagram of major Cordilleran rock assemblages (note changes in timescale at 100 Ma and 500 Ma). Canada includes the adjacent panhandle of southeastern Alaska, and Mexico includes the USA-Mexico border region south of the Colorado Plateau. Accreted island-arc assemblages: GS, Guerrero superterrane; IS, Insular superterrane; K-S, accreted arcs of Klamath Mountains and Sierra Nevada foothills. Subduction complexes: CC, Cache Creek; CM, central Mexico; F, Franciscan; Y, Yakutat. Transform faults (*diagonally ruled bars*): CCT, California-Coahuila; QCT, Queen Charlotte; SAT, San Andreas. Other features: ALS, Auld Lang Syne backarc basin; ARM, Ancestral Rocky Mountains province; B&R, Basin and Range taphrogen; LRM, Laramide Rocky Mountains province (LMN, Laramide magmatic null); SSP, accreted Siletzia and overlying forearc basin; UIT, Utah-Idaho trough.

Dickinson, 2004



Global Paleogeography
(see Plate Tectonics lecture)

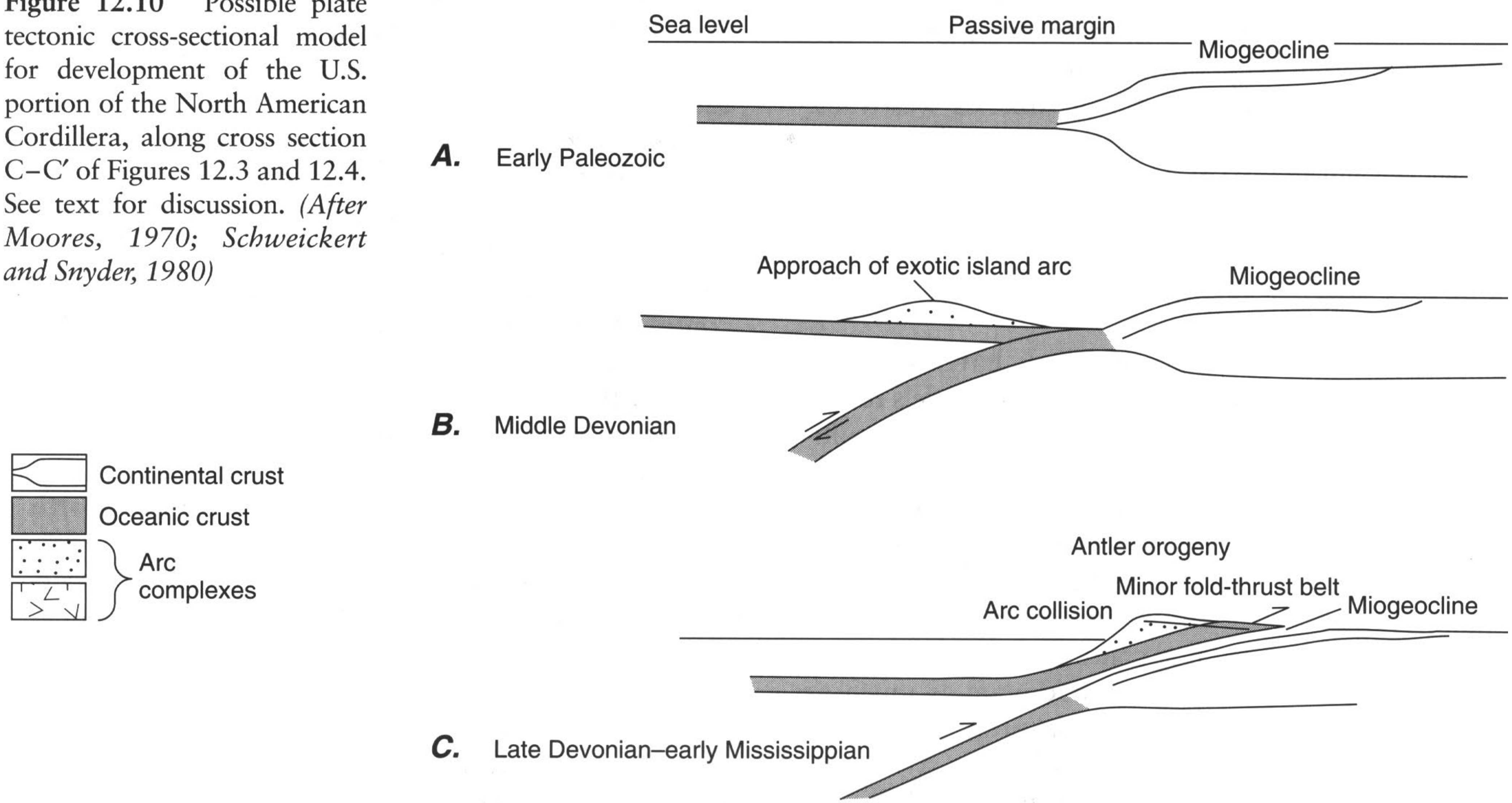
http://www.youtube.com/watch?v=Cm5giPd5Uro

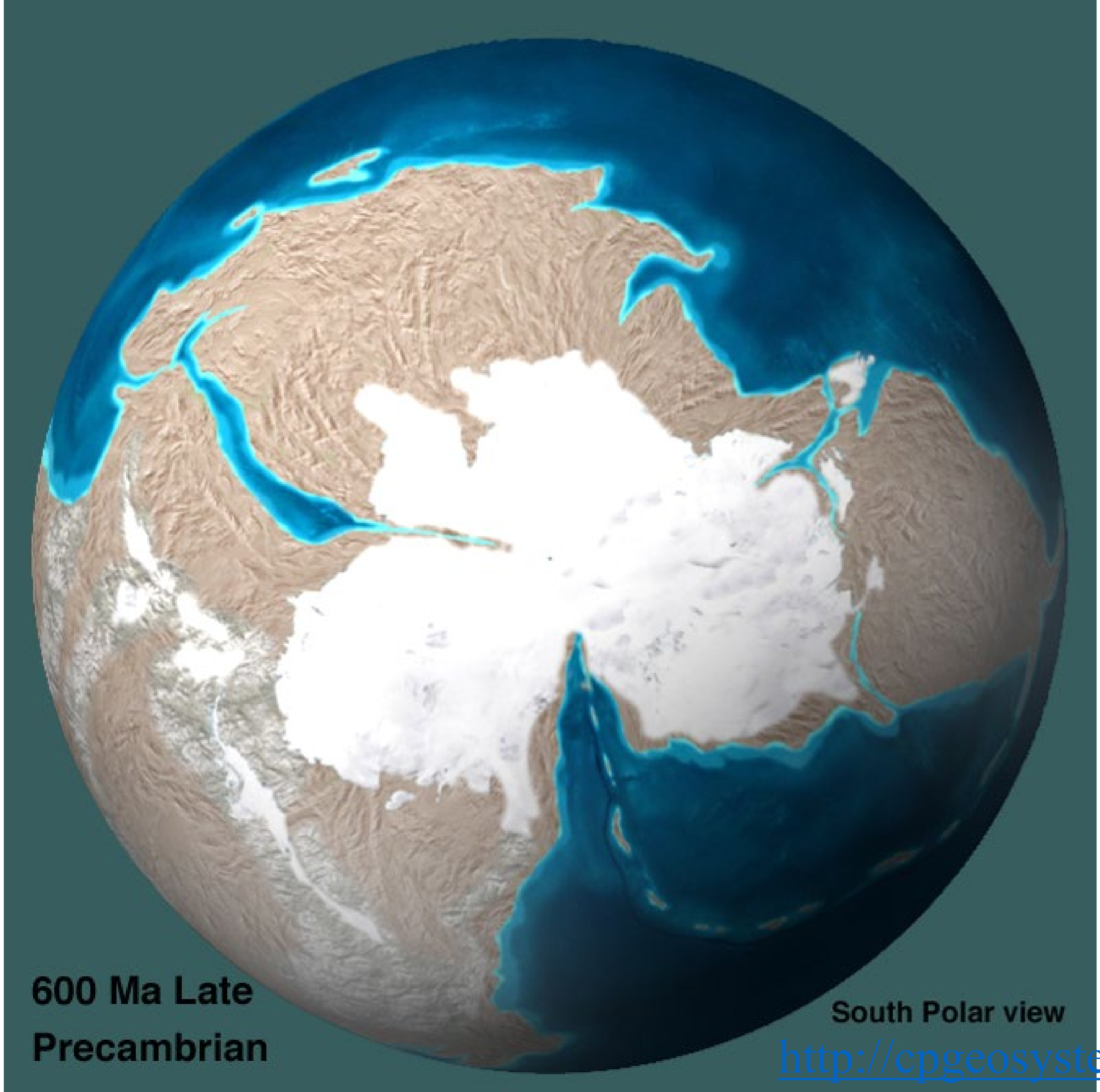
http://cpgeosystems.com

Plate Tectonic history (cross sections of margin)

Moores and Twiss, Tectonics

Figure 12.10 Possible plate tectonic cross-sectional model for development of the U.S. portion of the North American Cordillera, along cross section C–C′ of Figures 12.3 and 12.4. See text for discussion. *(After Moores, 1970; Schweickert and Snyder, 1980)*





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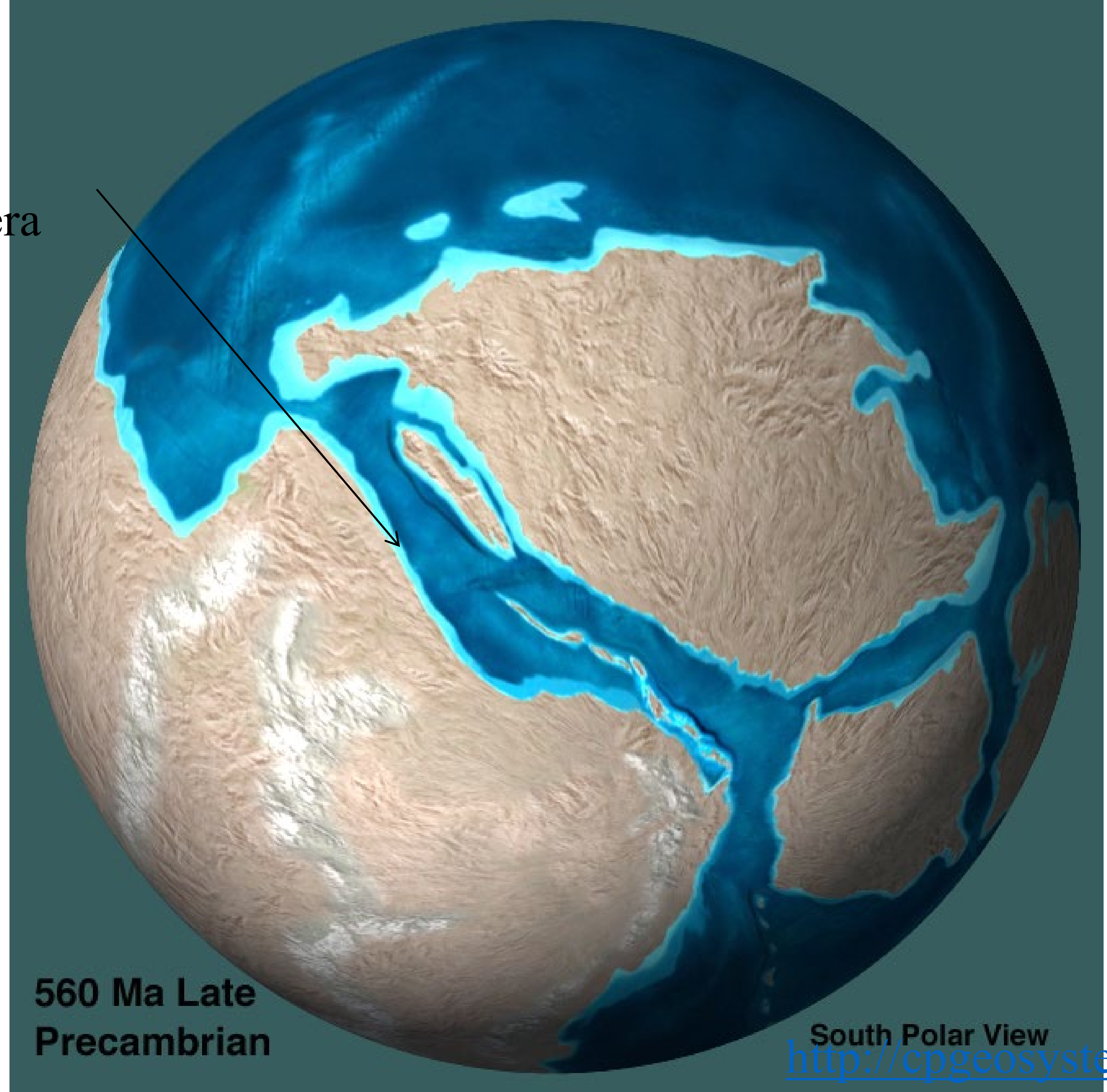

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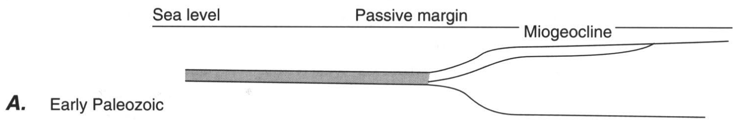
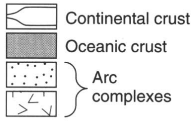
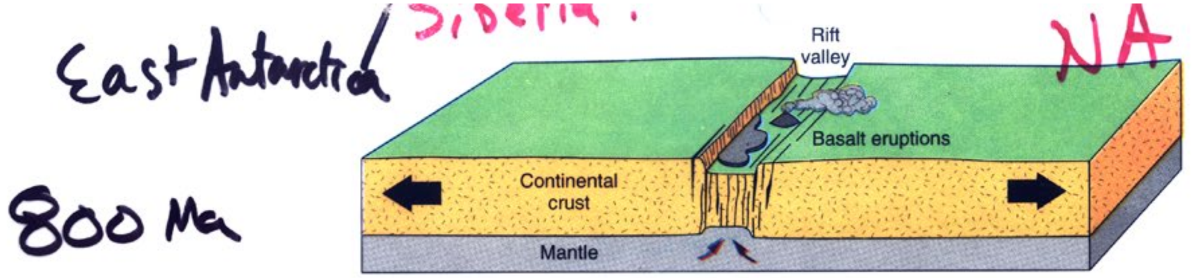
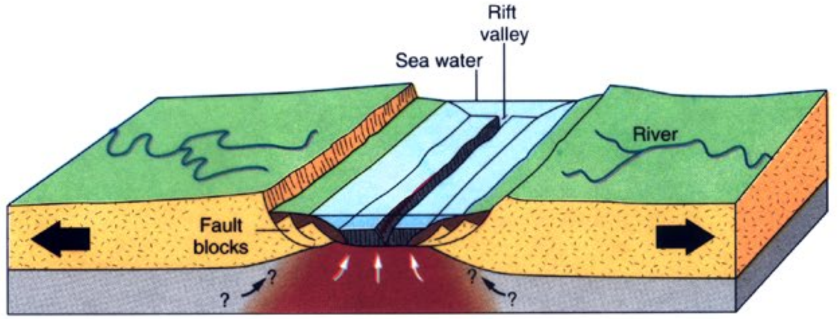


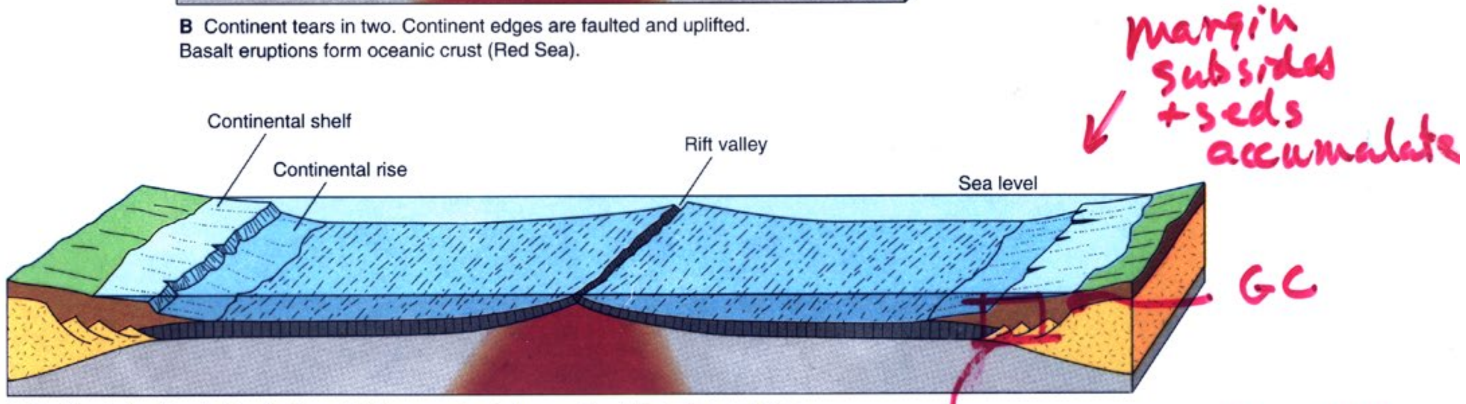




A Continent undergoes extension. The crust is thinned and a rift valley forms (East African Rift Valleys).



B Continent tears in two. Continent edges are faulted and uplifted. Basalt eruptions form oceanic crust (Red Sea).



C Continental sediments blanket the subsiding margins to form continental shelves and rises. The ocean widens and a mid–oceanic ridge develops (Atlantic Ocean).

Moores and Twiss, Tectonics

Rodinia

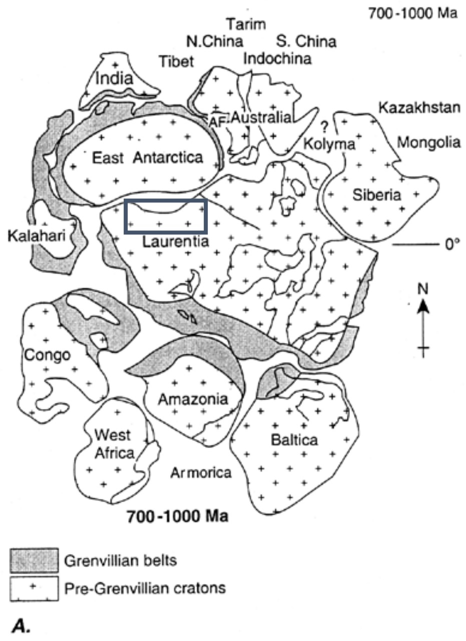
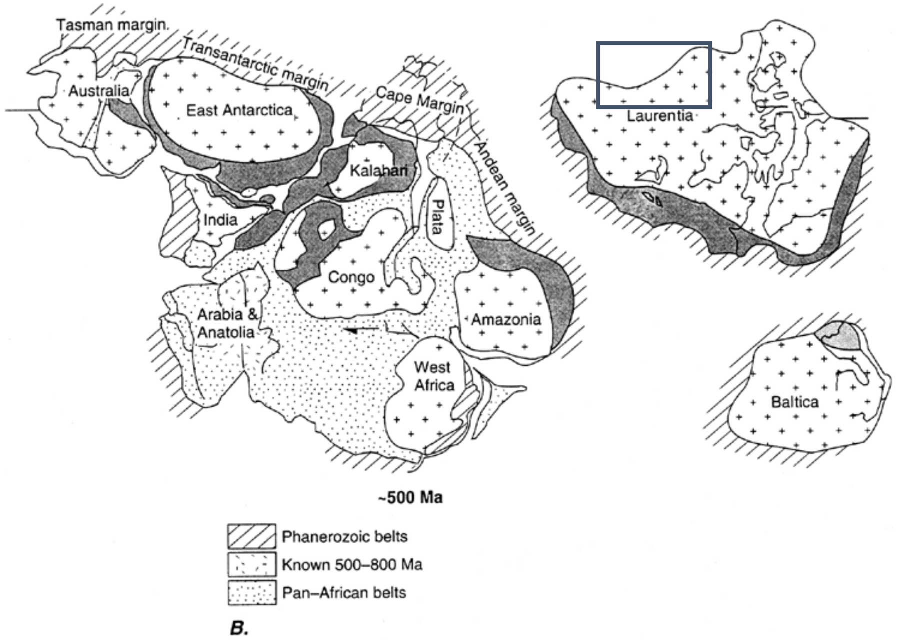


Figure 12.33 Possible late Precambrian continental configurations. *A.* Possible prebreakup configurations of Precambrian cratonic region in supercontinent Rodinia; areas of Grenvillian (800–1500 Ma) orogenic belts. *B.* Possible configuration of Gondwanaland formed by breakup and rearrangement of fragments shown in *(A)*. *(After Hoffman, 1991)*



Grand Canyon record: 1.8 Ga to

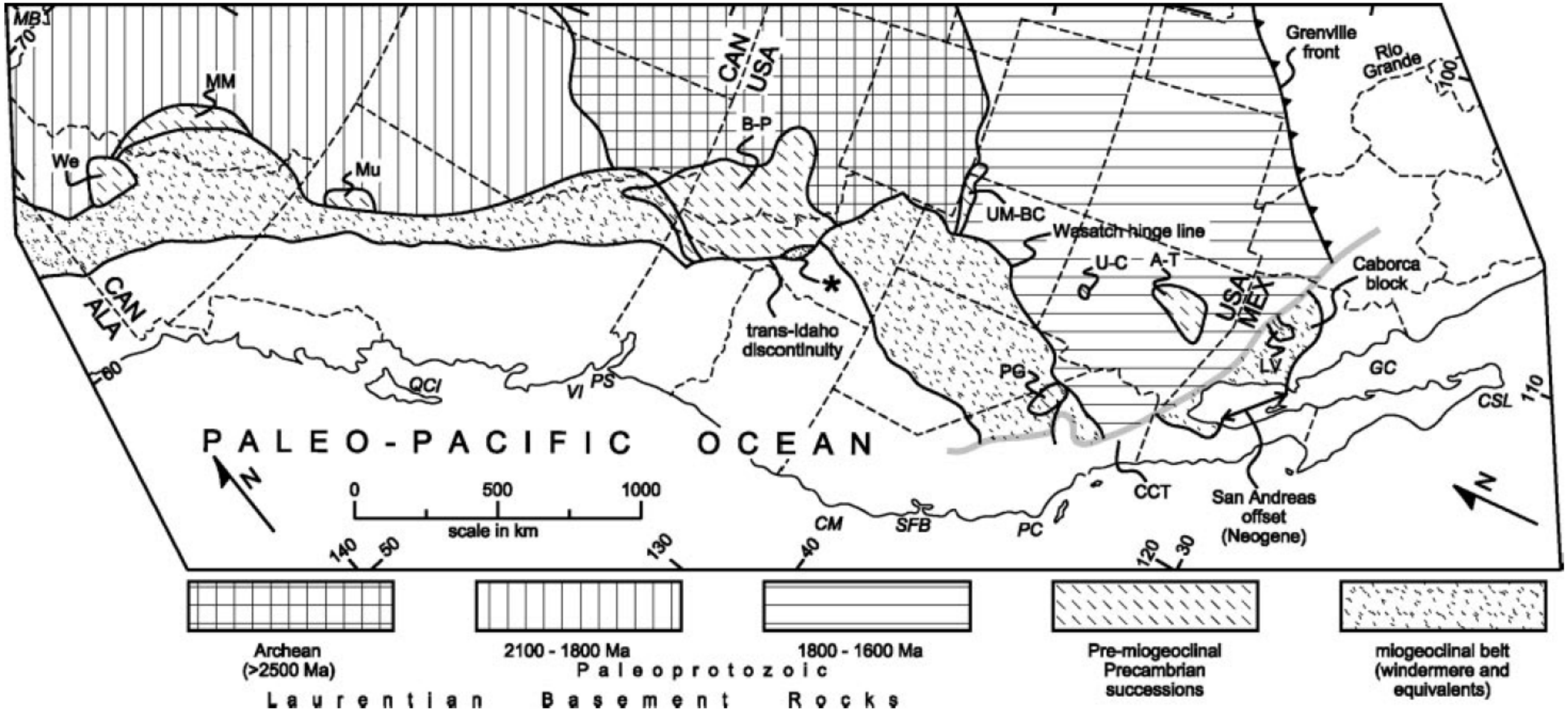
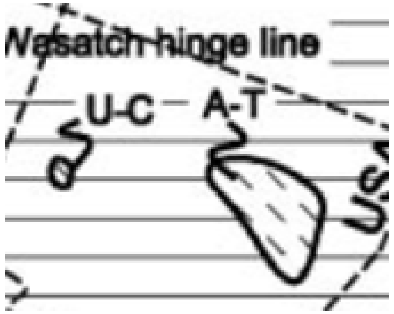


Figure 5 Neoproterozoic-Early Paleozoic Cordilleran miogeocline and premiogeoclinal sedimentary basins along the trend of the North American Cordillera (rock assemblages now present west of the miogeoclinal belt were added to the continental block after mid-Late Devonian time). Asterisk (*) denotes miogeoclinal strata along trans-Idaho discontinuity (Lund et al. 2003). Grenville front is margin of Mesoproterozoic Grenville orogen along which Rodinia was assembled. CCT is Permian-Triassic California-Coahuila transform (Dickinson 2000), which offset the Cordilleran miogeoclinal assemblage of the Caborca block by overprinting an older paleotransform system that delimited the early Paleozoic southwest margin of Laurentia (Dickinson & Lawton 2001a). See text for ages of premiogeoclinal successions. (A-T, Apache-Troy; B-P, Belt-Purcell; LV, Las Víboras; MM, Mackenzie Mountains; Mu, Muskwa; PG, Pahrump Group; U-C, Unkar-Chuar; UM-BC, Uinta Mountain—Big Cottonwood; We, Wernecke). Coastal locales (*italics*): CM, Cape Mendocino; CSL, Cabo San Lucas; GC, Gulf of California; MB, Mackenzie Bay of Arctic Ocean; PC, Point Conception; PS, Puget Sound; QCI, Queen Charlotte Islands; SFB, San Francisco Bay; VI, Vancouver Island.

Dickinson, 2004



Troy Quartzite
Arnett Creek

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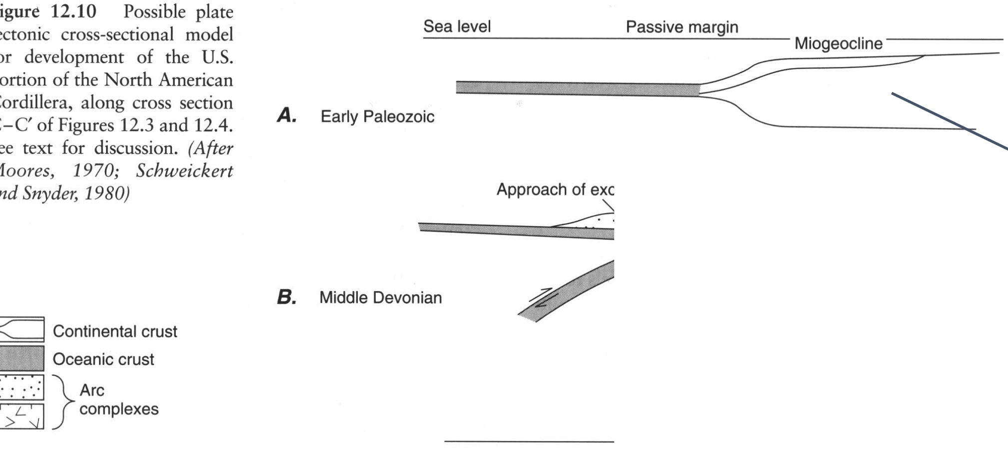

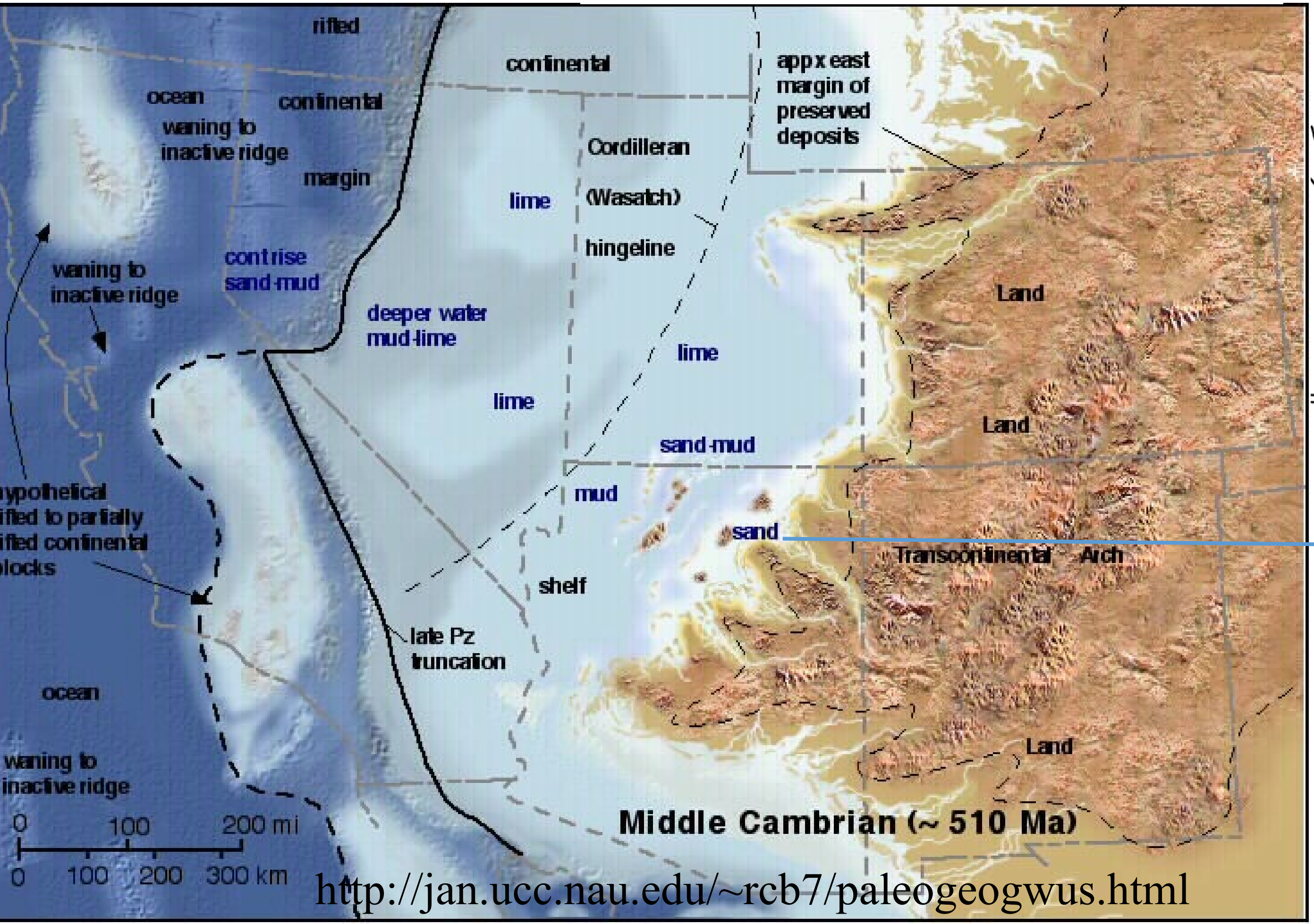

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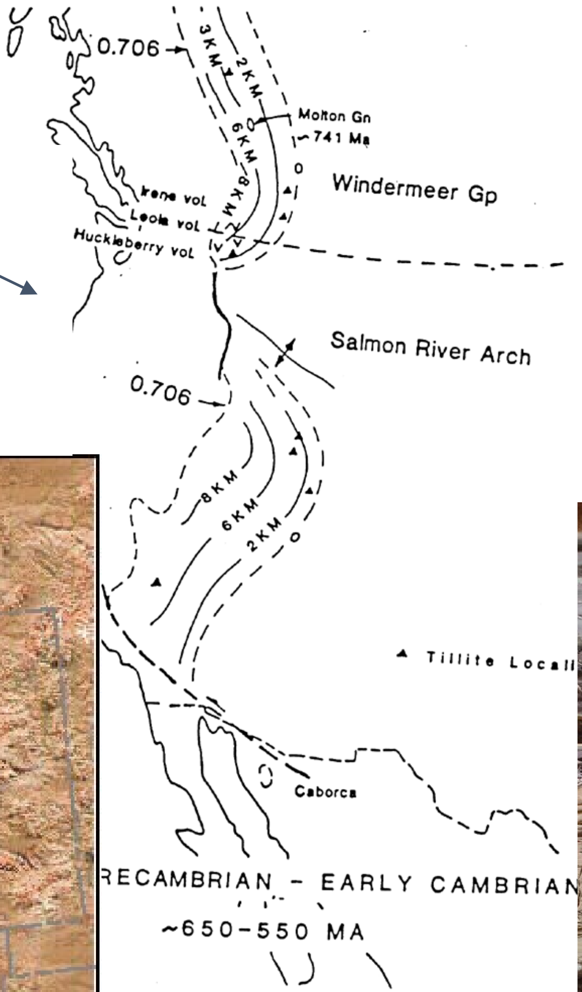
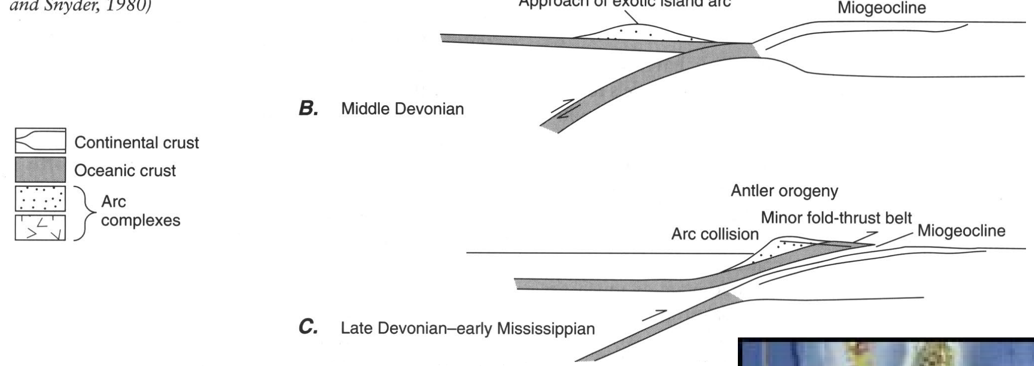
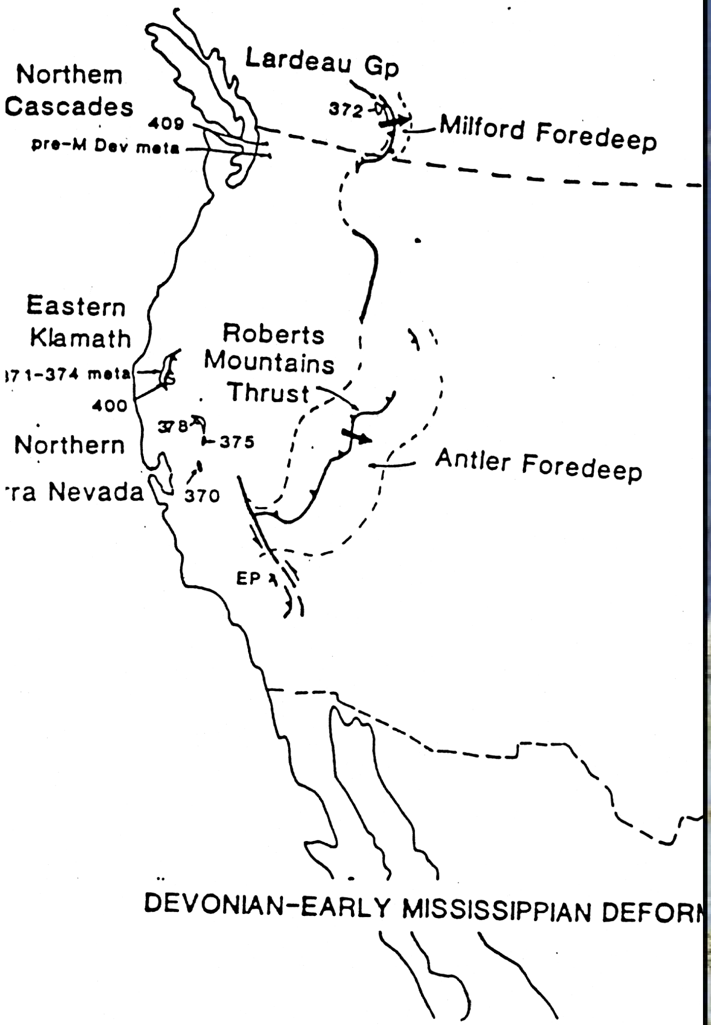
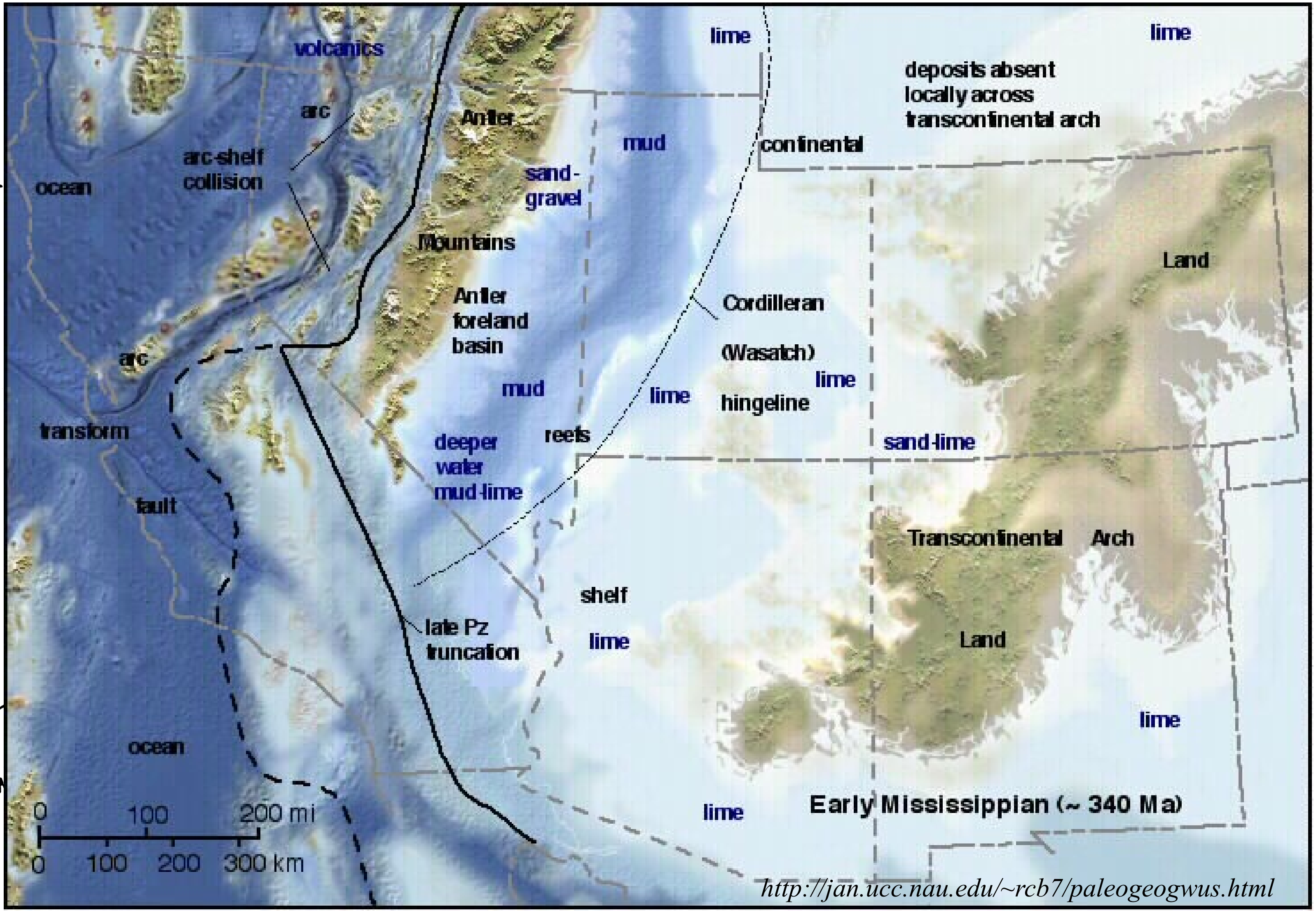


Tapeats over schist, Great Unconformity, Grand Canyon

and Snyder, 1980)







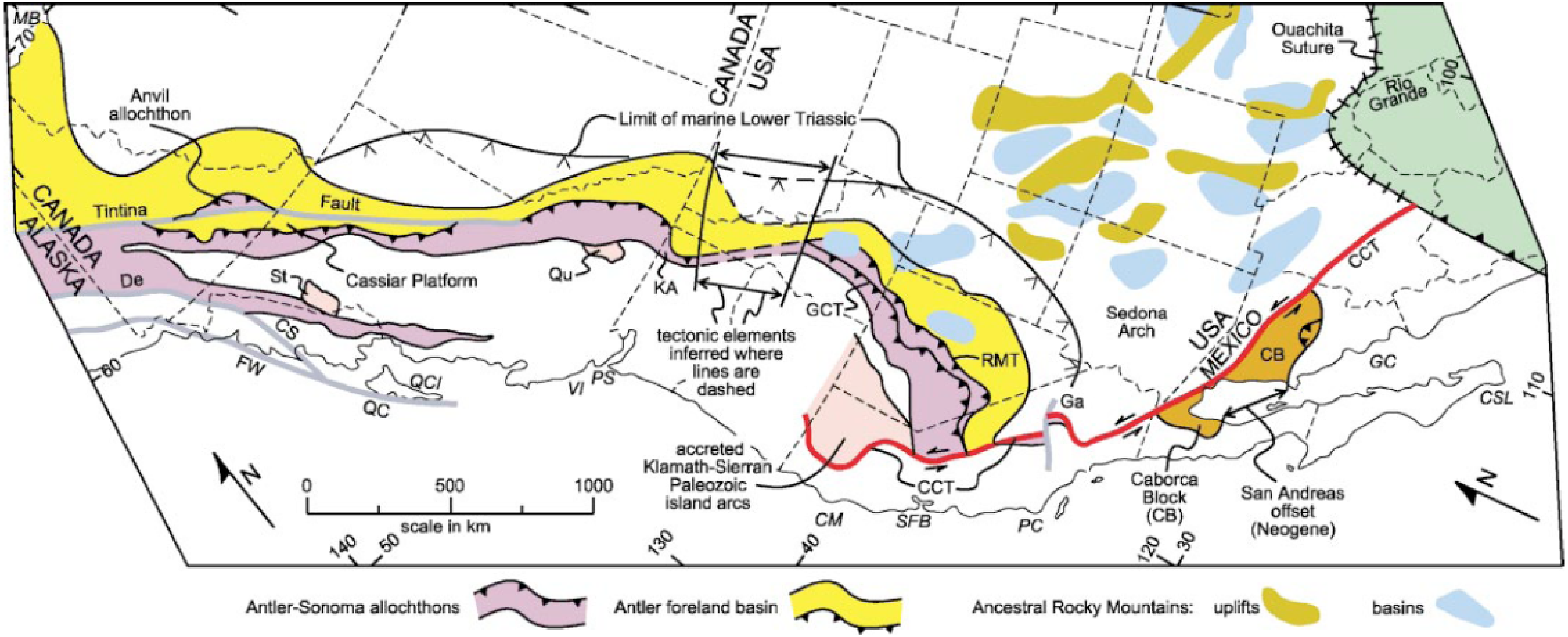
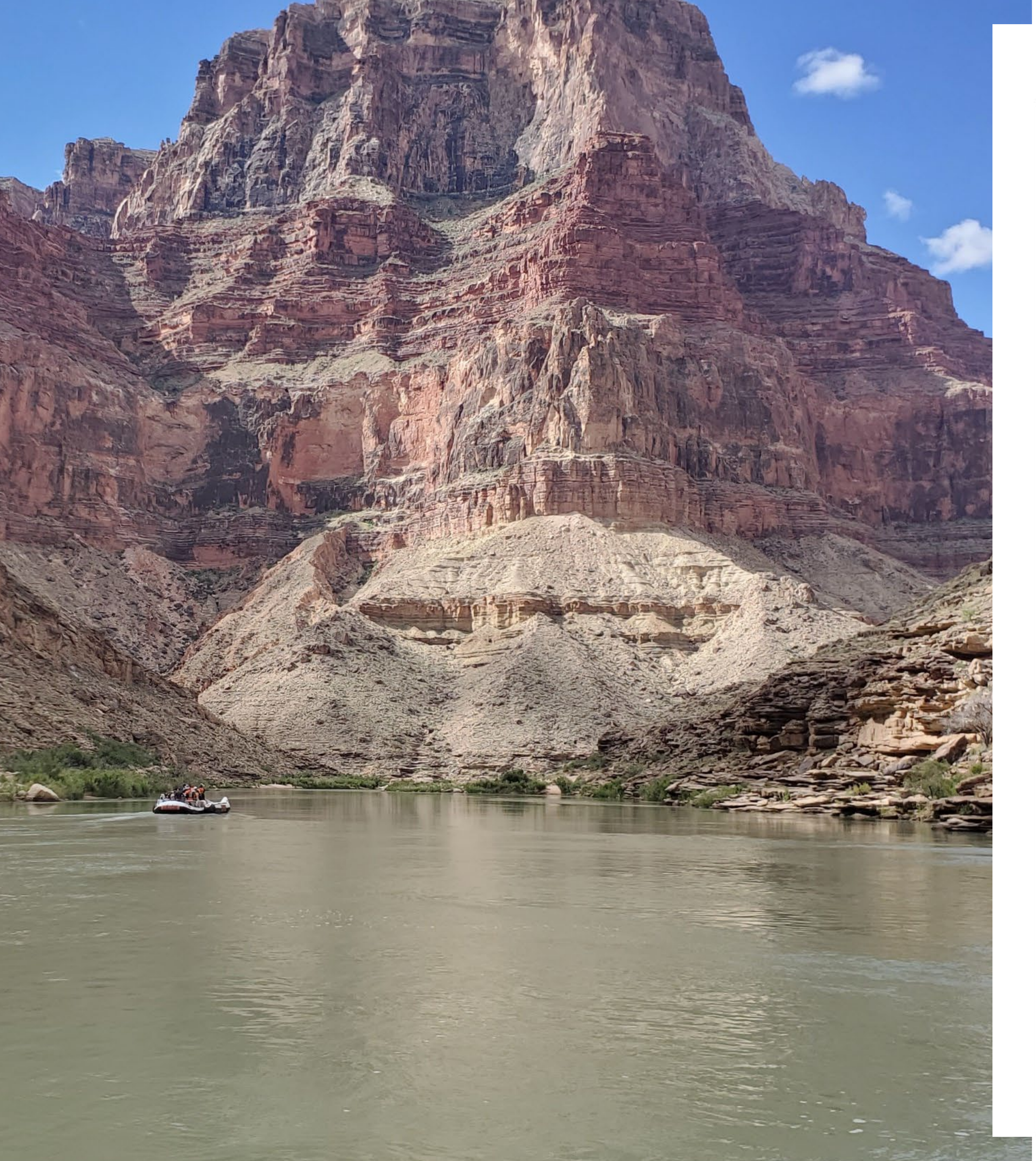
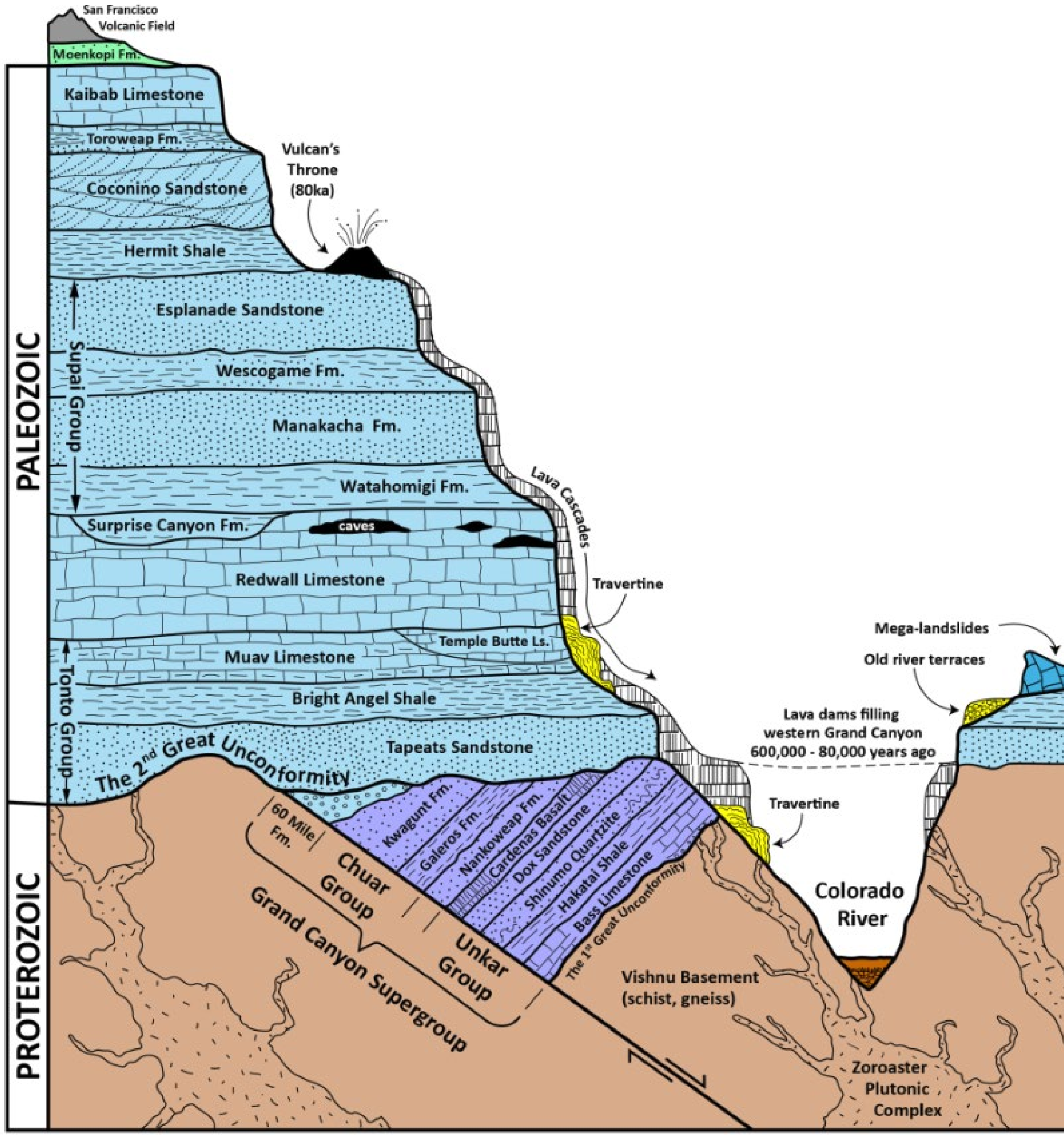


Figure 6 Geotectonic features of the Antler orogen (Late Devonian–Early Mississippian), the Ancestral Rocky Mountains province (Pennsylvanian–Early Permian), and the Sonoma orogen (Late Permian–Early Triassic) of the North American Cordillera (allochthons of Antler and Sonoma age are combined, but note the uncertain continuity of tectonic trends along the trans-Idaho discontinuity of Figure 5). See text for discussion of Kootenay structural arc (KA) and remnants of Paleozoic arc assemblages in Quesnellia (Qu) and Stikinia (St). Key active faults: RMT, Devonian-Mississippian Roberts Mountains thrust; GCT, Permian-Triassic Golconda thrust; CCT, Permian-Triassic California-Coahuila transform. Gondwanan Mexico restored (after Dickinson & Lawton 2001a) to position before mid-Mesozoic opening of the Gulf of Mexico. Tintina and De-CS-FW-QC fault systems are Cenozoic structures. See Figure 5 for geographic legend.

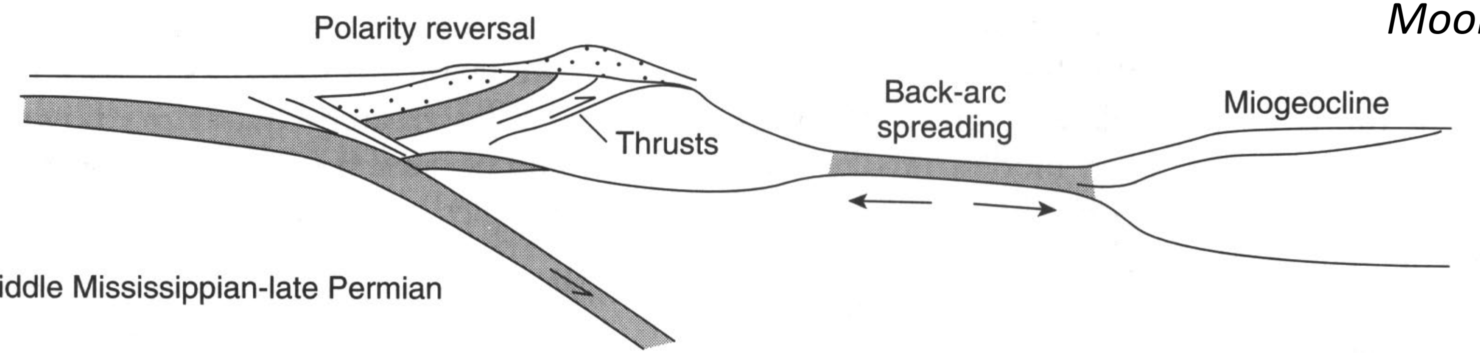
Dickinson, 2004

https://azgs.arizona.edu/photo/grand-canyon-stratigraphy

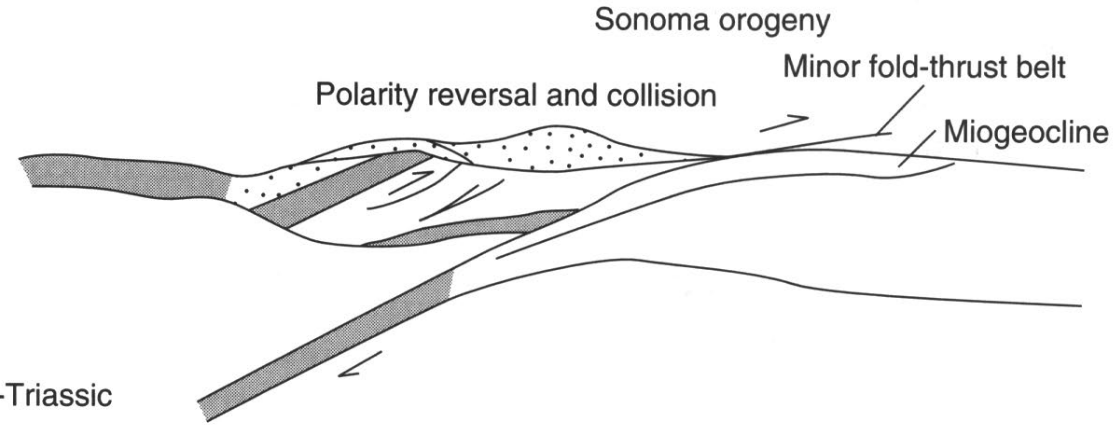




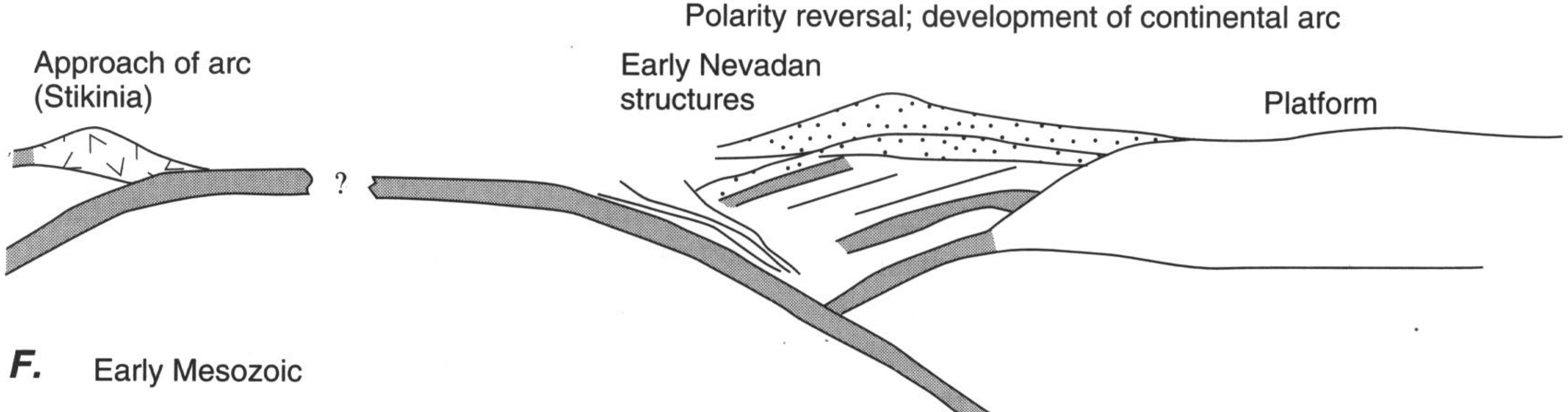
Moores and Twiss, Tectonics



D. Middle Mississippian-late Permian



E. Permian-Triassic



F. Early Mesozoic

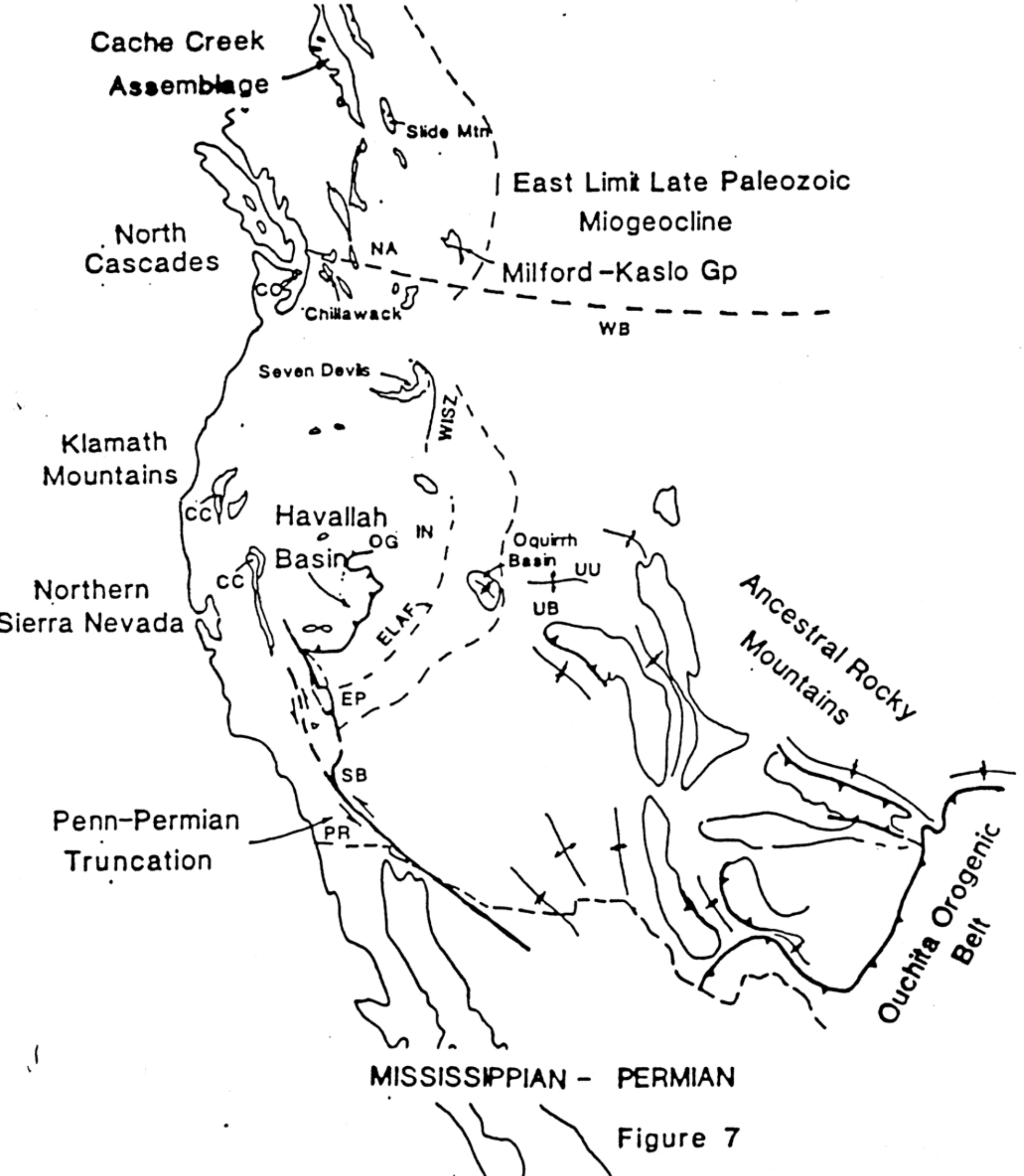
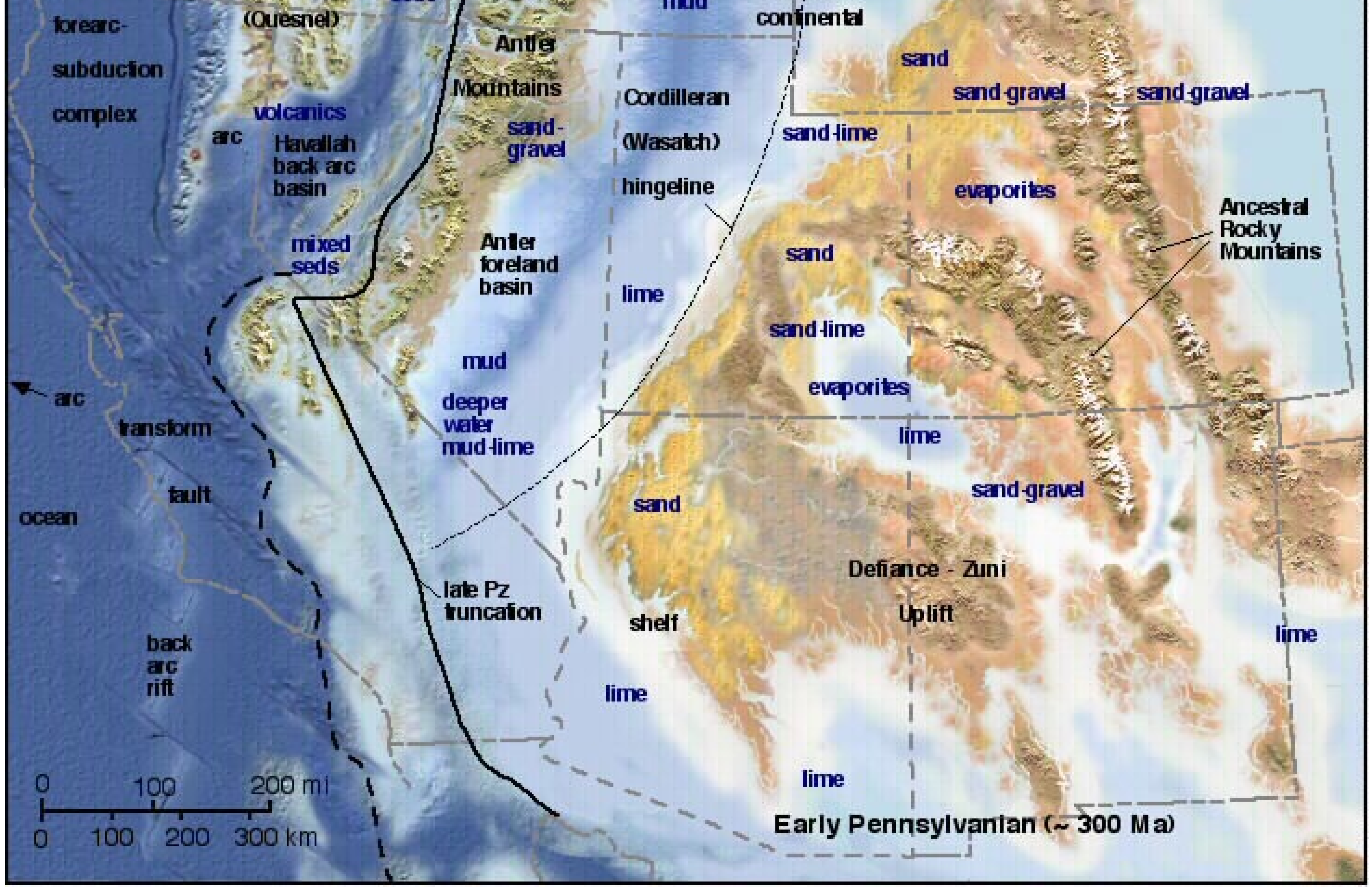


Figure 7



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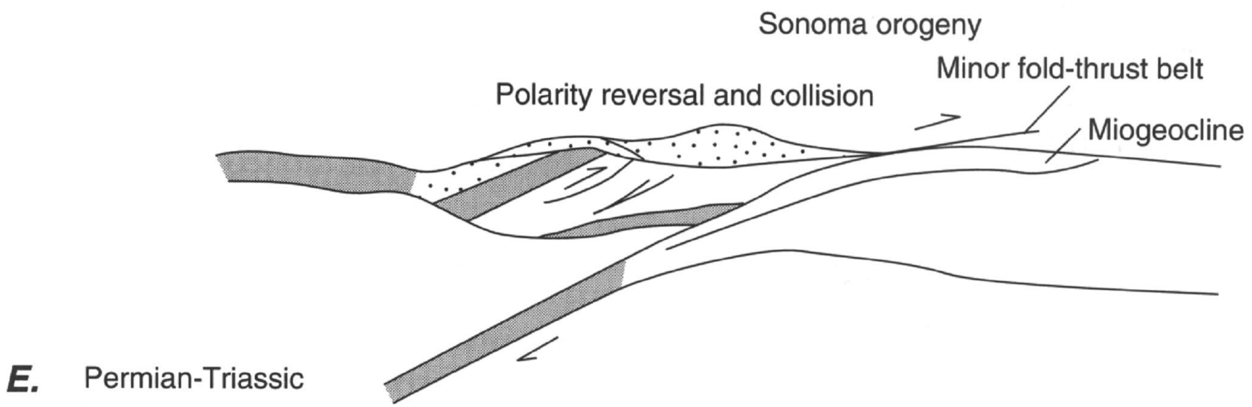
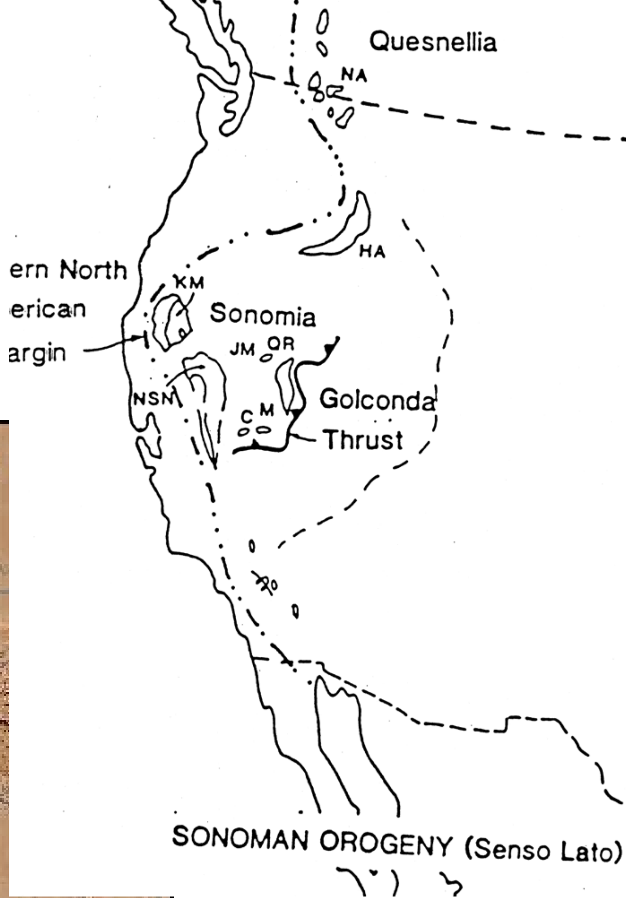

Sonoma orogeny
Polarity reversal and collision
Minor fold-thrust belt
Miogeocline
E. Permian-Triassic


Quesnellia
NA
HA
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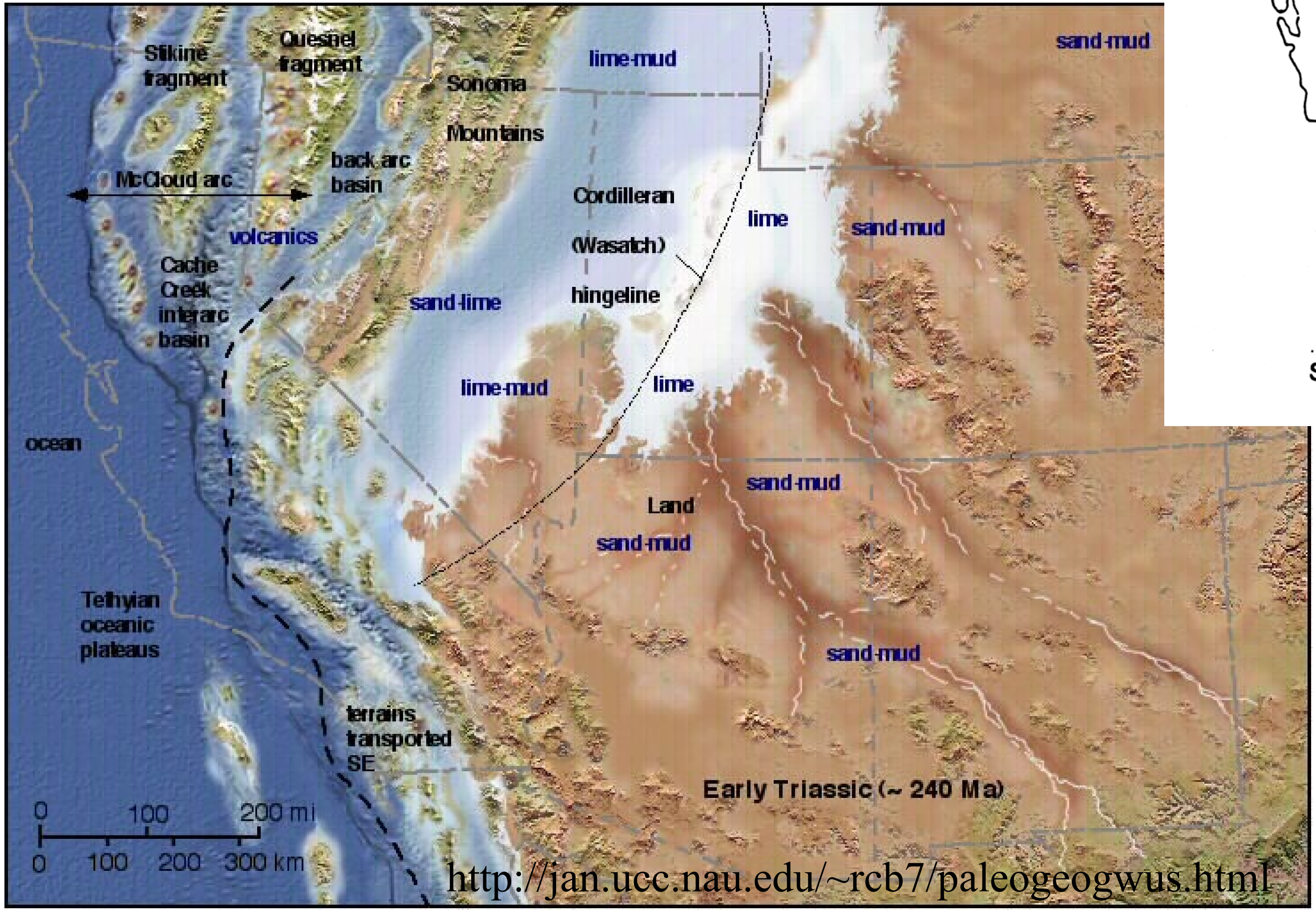
JM
OR
NSM
CM
Golconda
Thrust
SONOMAN OROGENY (Senso Lato)


Stikine fragment
Quesnel fragment
Sonoma
Mountains
lime-mud
sand-mud
McCloud arc
back arc basin
Cordilleran
(Wasatch)
hingeline
lime
sand-mud
volcanics
Cache Creek interarc basin
sand-lime
lime-mud
lime
ocean
sand-mud
Land
sand-mud
Tethyian oceanic plateaus
sand-mud
terrains transported SE
Early Triassic (~ 240 Ma)
0 100 200 mi
0 100 200 300 km
http://jan.ucc.nau.edu/~rcb7/paleogeogwus.html

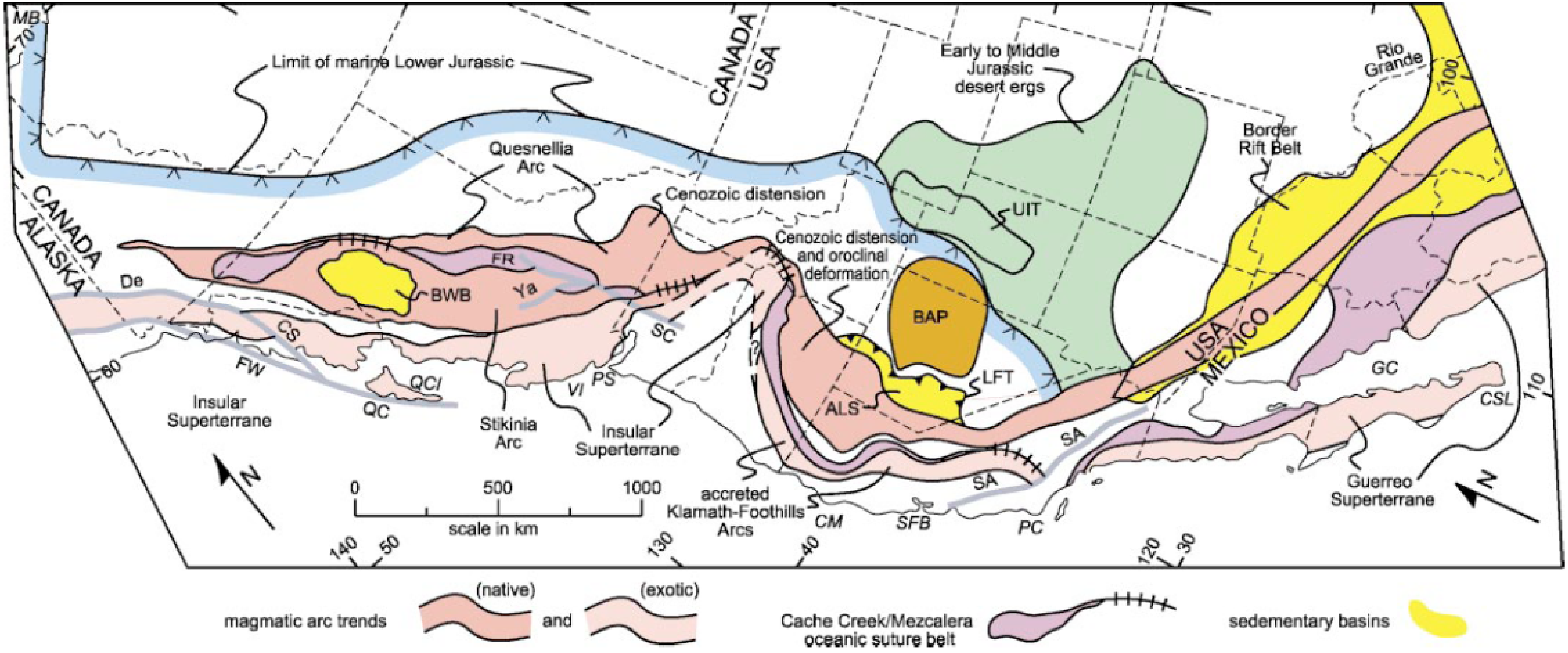
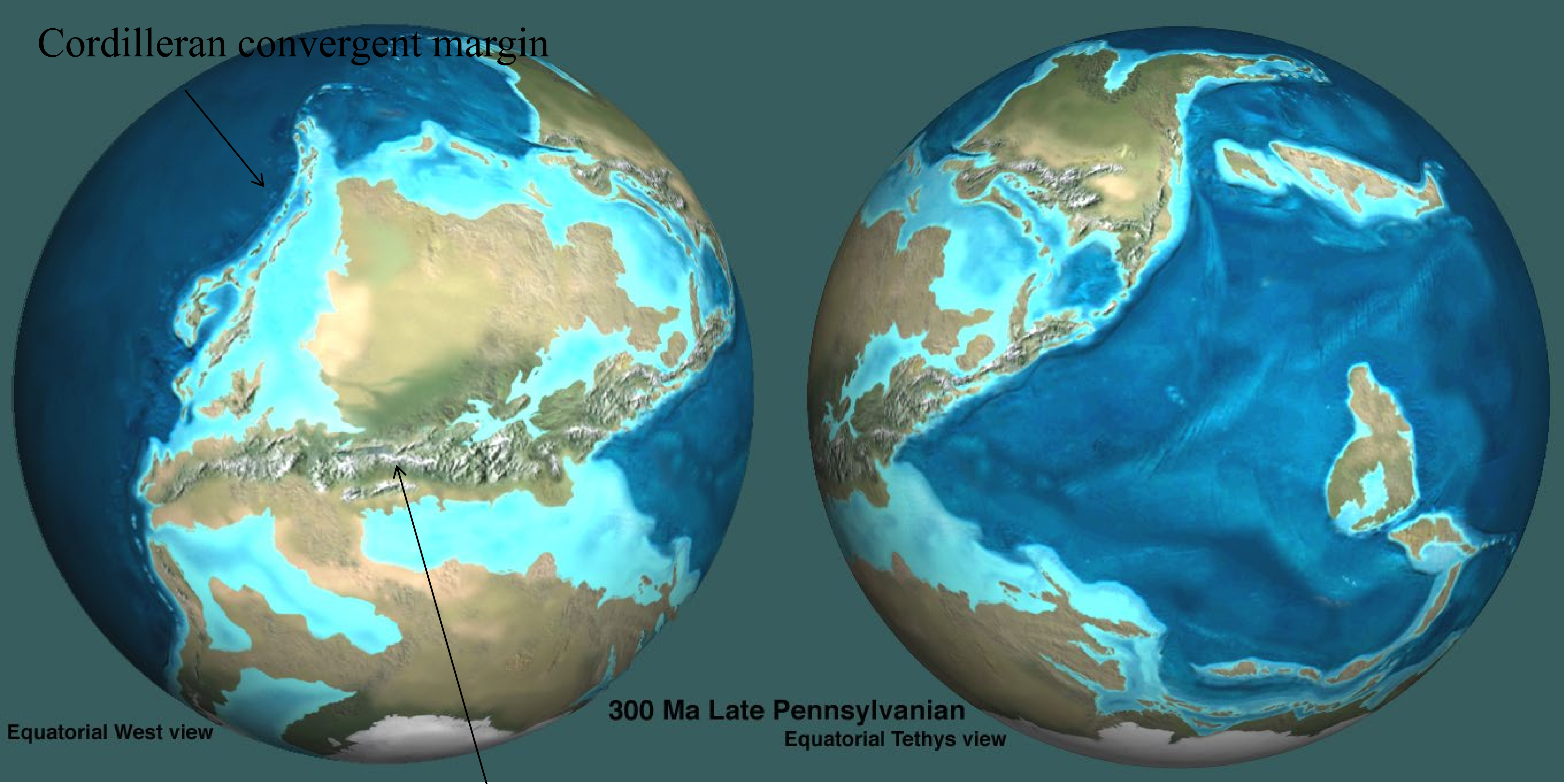
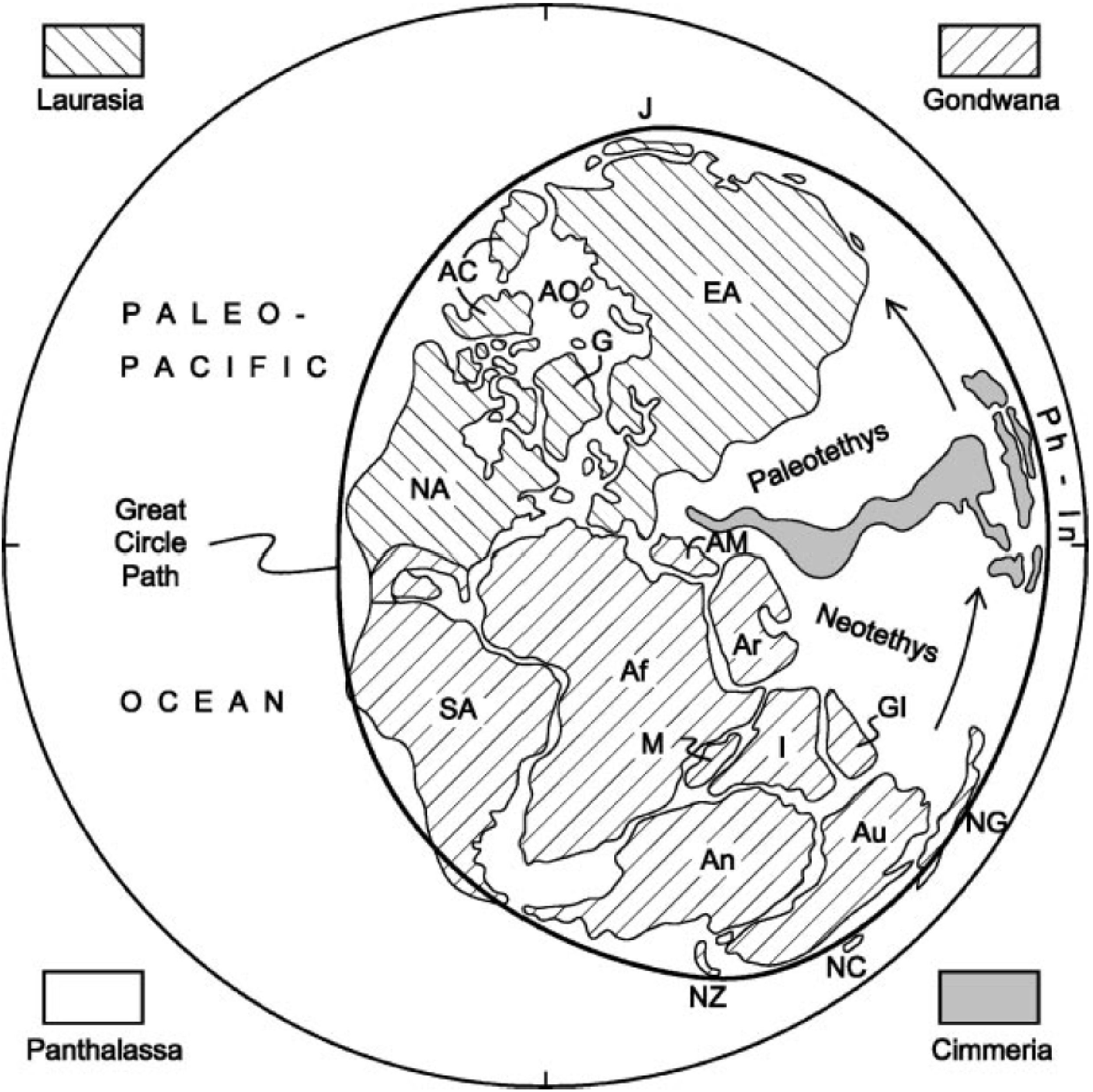


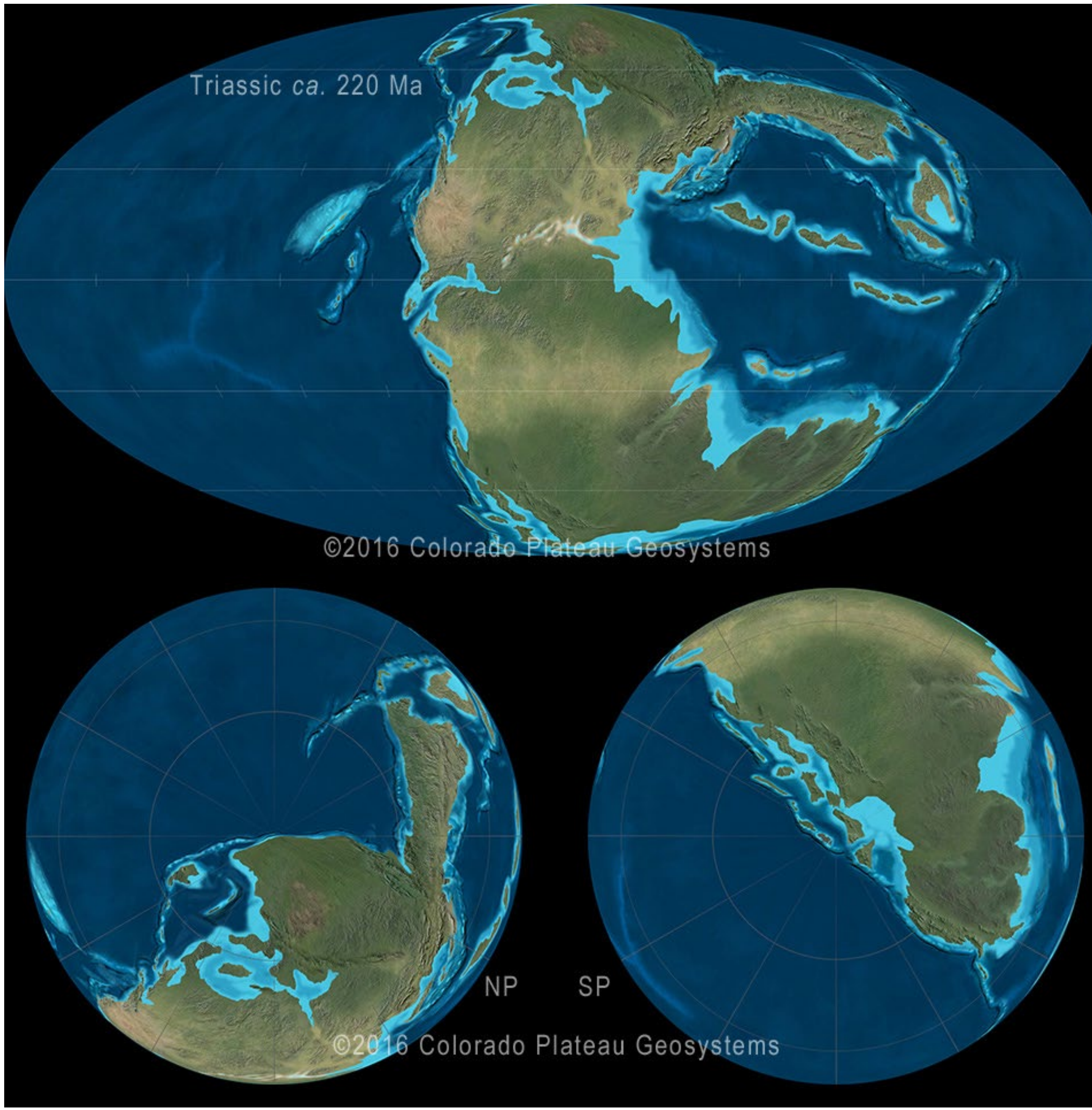
Figure 7 Mid-Early Triassic (~247.5 Ma) to mid-Early Cretaceous (~120 Ma) geotectonic features of the Cordilleran arc-trench system, including intraoceanic arc structures accreted to the Cordilleran continental margin between Middle Jurassic and Early Cretaceous time. Selected geologic features: ALS, Late Triassic to Early Jurassic Auld Lang Syne backarc basin; LFT, Middle Jurassic Luning-Fencemaker backarc thrust system; BAP, zone of diffuse Middle to Late Jurassic backarc plutonism (Nevada-Utah); UIT, Middle to Late Jurassic Utah-Idaho backarc trough; BWB, Late Jurassic to Early Cretaceous Bowser successor basin (superimposed on accreted Stikinia arc). Border rift belt (Late Jurassic to Early Cretaceous) includes Bisbee basin and Chihuahua trough. Cenozoic faults (*gray*): De-CS, Denali-Chatham Strait; FR, Fraser River; FW, Fairweather; QC, Queen Charlotte; RL, Ross Lake; SA, San Andreas; SC, Straight Creek; Ya, Yalakom. See Figure 5 for geographic legend.



Appalachian collisional orogen

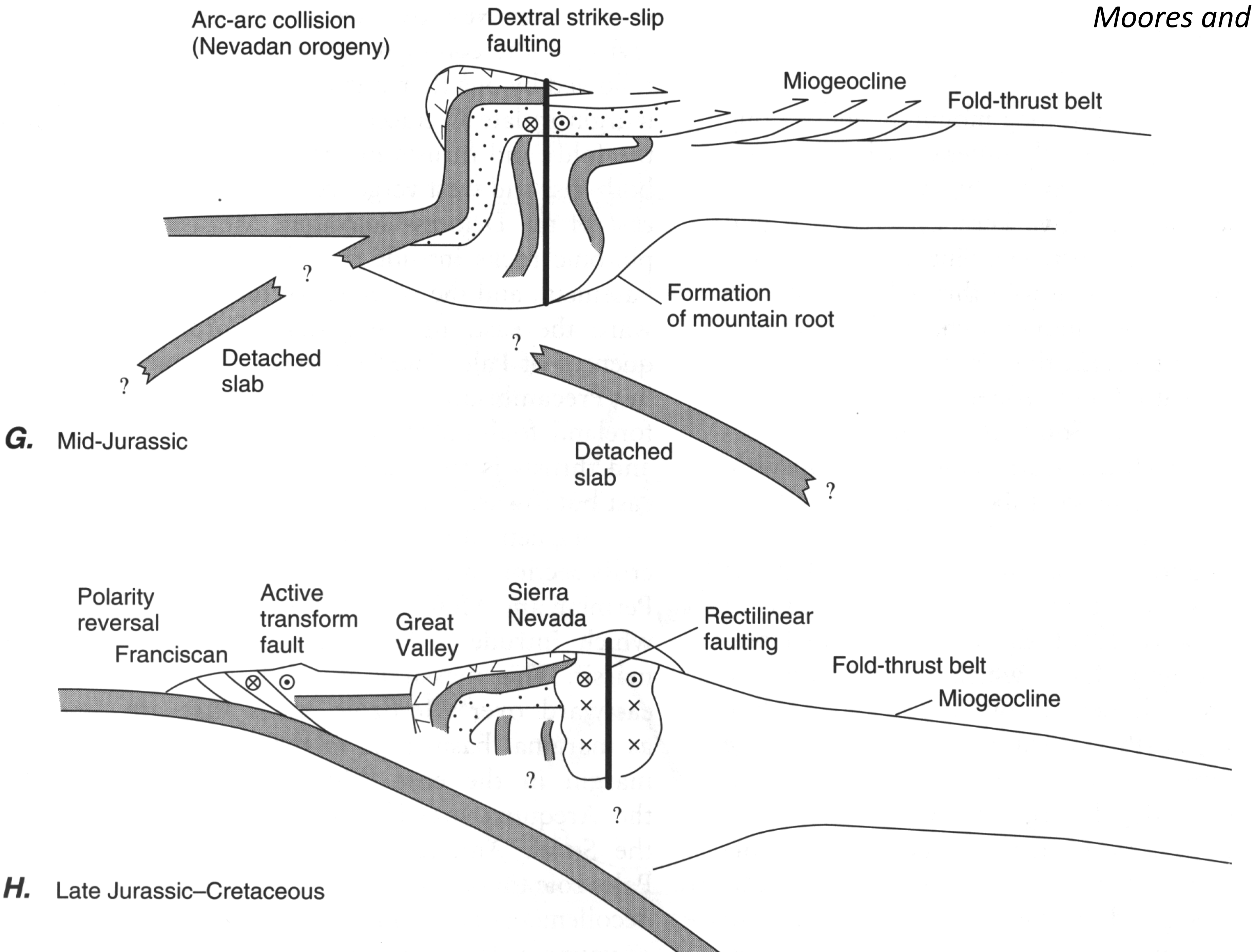
http://cpgeosystems.com

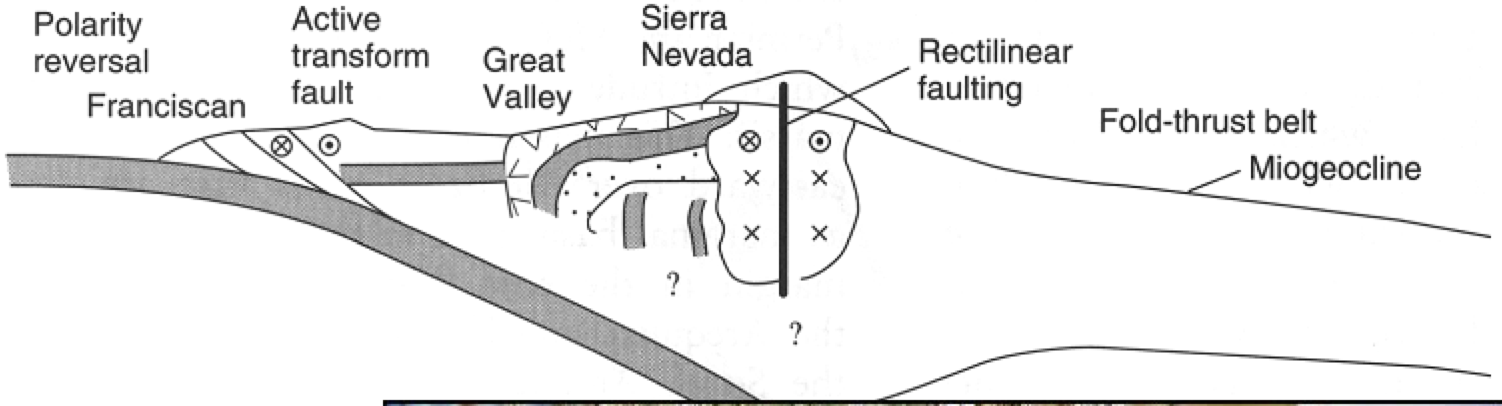




Dickinson, 2004

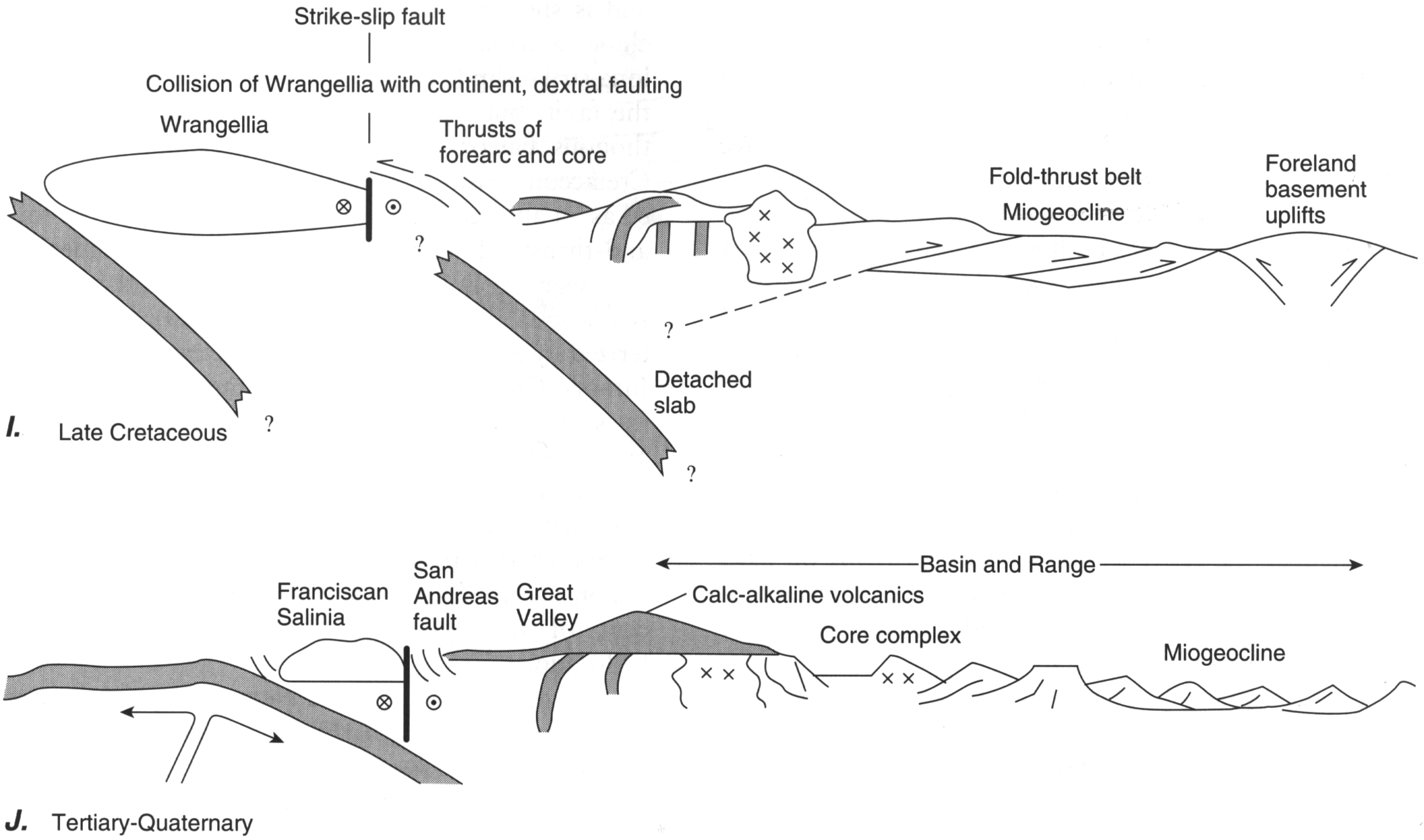
Moores and Twiss, Tectonics

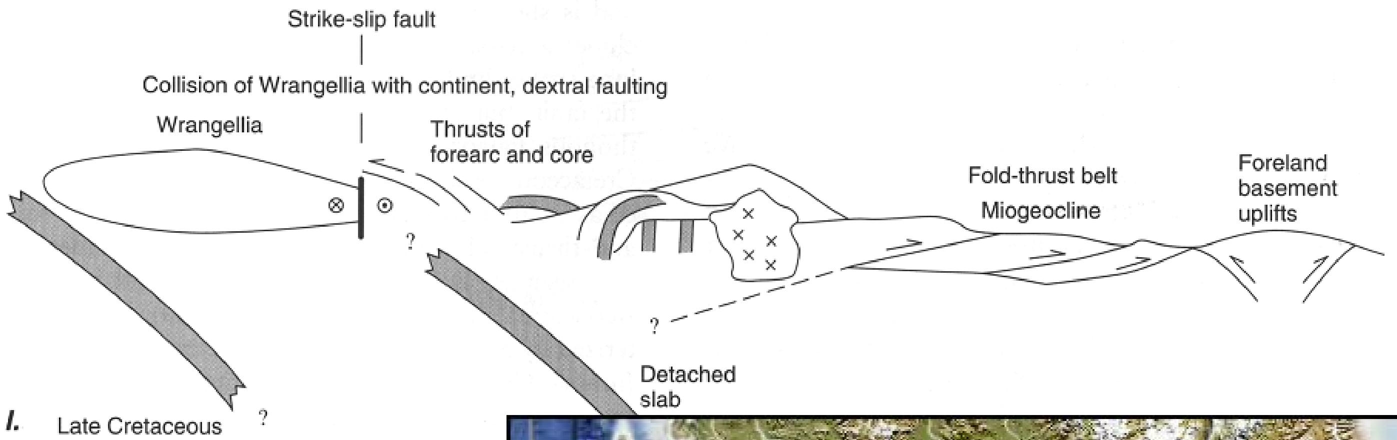


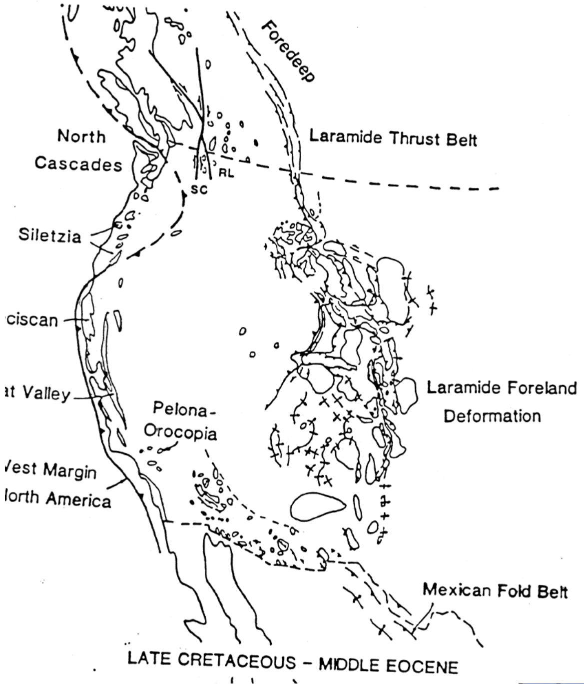


H. Late Jurassic–Cretaceous

Moores and Twiss, Tectonics







http://jan.ucc.nau.edu/~rcb7/paleogeogwus.html

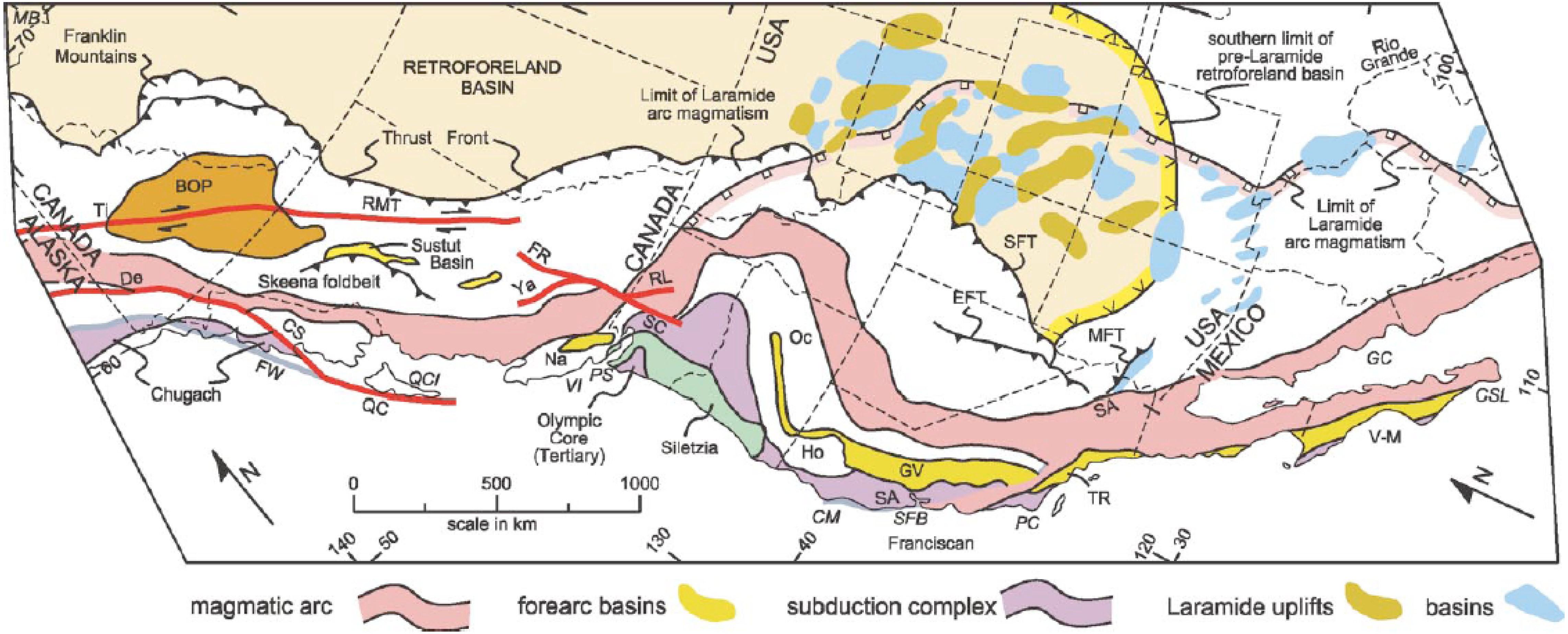
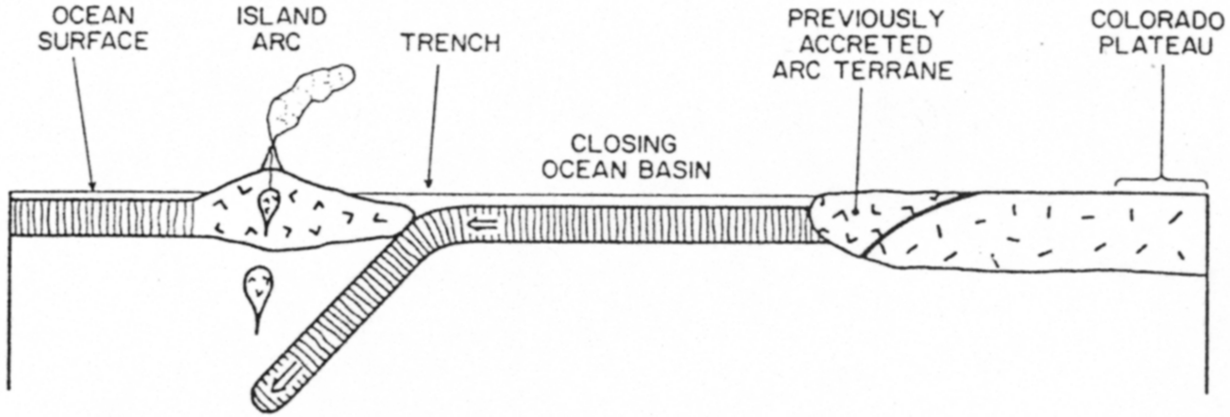
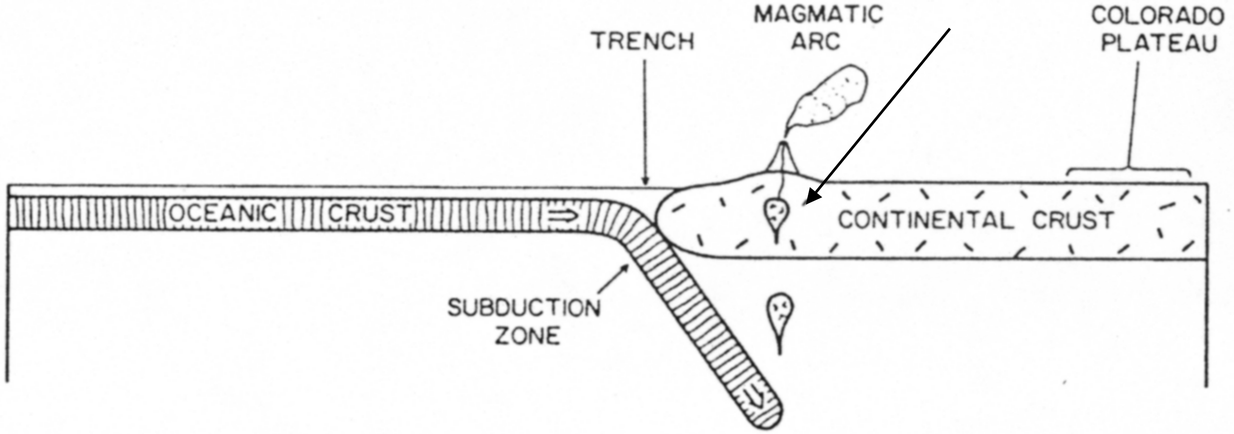


Figure 9 Mid-Early Cretaceous (~120 Ma) to mid-Cenozoic (Eocene/Oligocene boundary) geotectonic features of the Cordilleran arc-trench system, including the Laramide province of intracontinental deformation. The main batholith belt is delineated as the magmatic arc, but subsidiary arc magmatism spread inland for varying distances (BOP, Omineca zone of backarc mid-Cretaceous plutonism). Active Paleogene strike-slip faults (*red lines*): De-CS, Denali-Chatham Strait; FR, Fraser River; QC, Queen Charlotte; RL, Ross Lake; SC, Straight Creek; Ti-RMT, Tintina–Rocky Mountain Trench; Ya, Yalakom. Younger Neogene strike-slip faults (*gray lines*): FW, Fairweather; SA, San Andreas. Key active fold-thrust belts: EFT, Eureka; MFT, Maria; SFT, Sevier. Key forearc basin segments: GV, Great Valley (California); Ho, Hornbrook; Oc, Ochoco; Na, Nanaimo; TR, Transverse Ranges; V-M, Vizcaino-Magdalena. See Figure 5 for geographic legend.

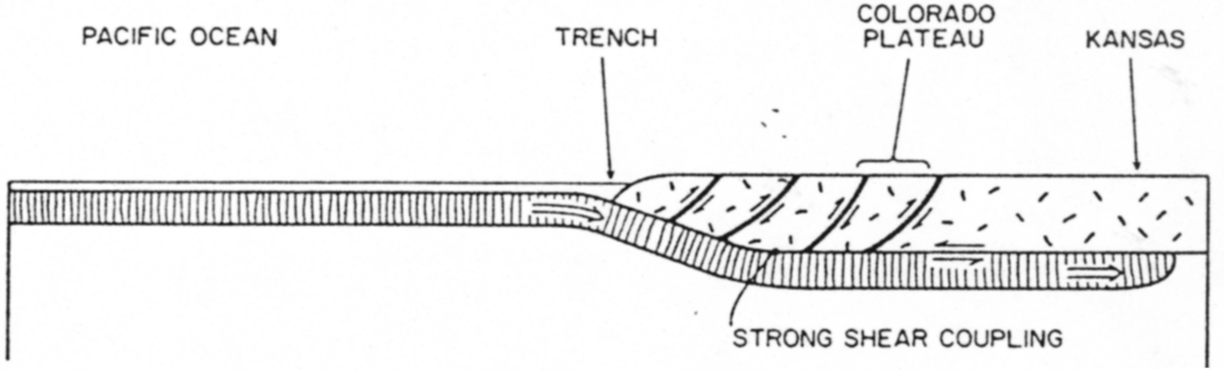


Proterozoic to early Mesozoic convergent margin

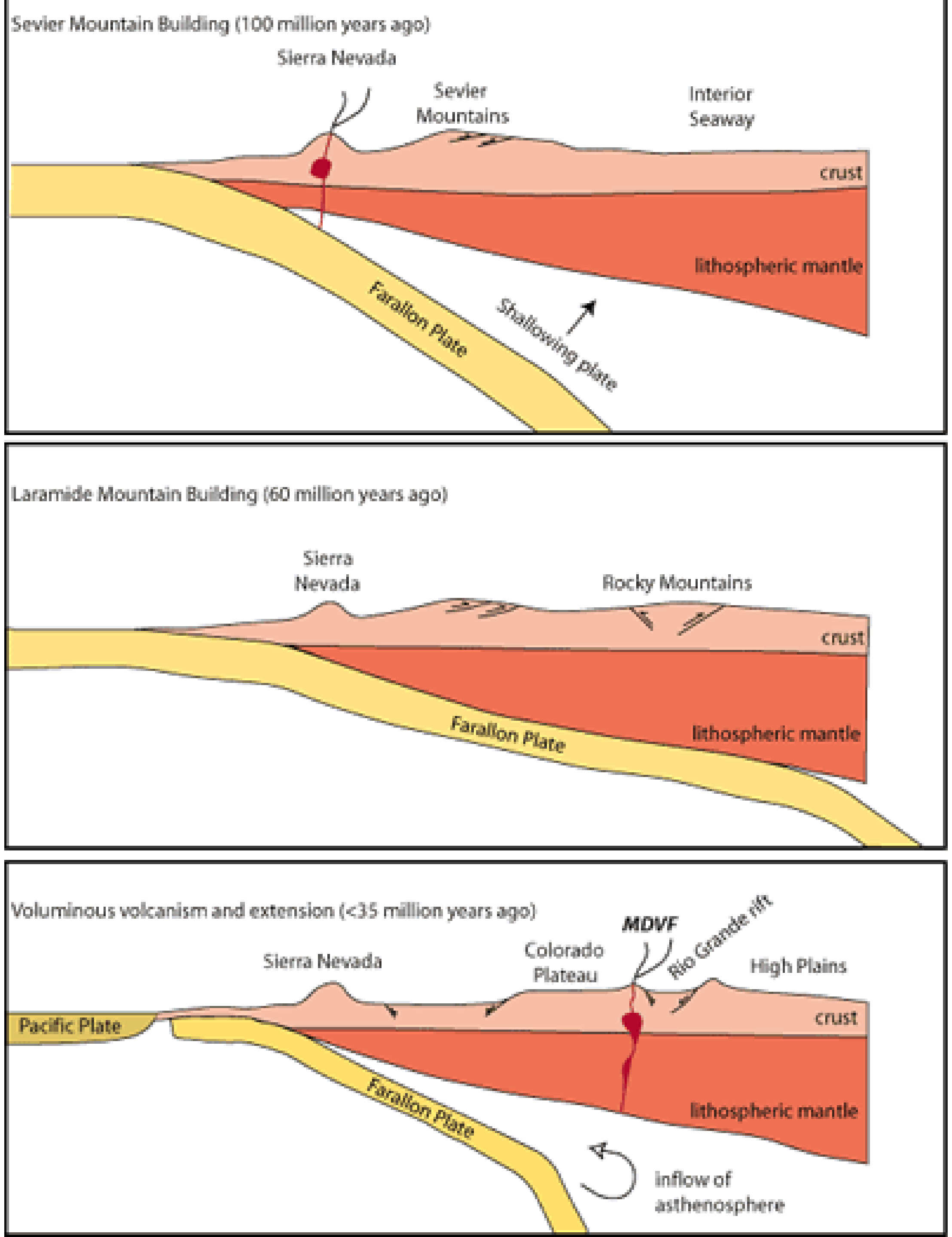
Sierra Nevadas



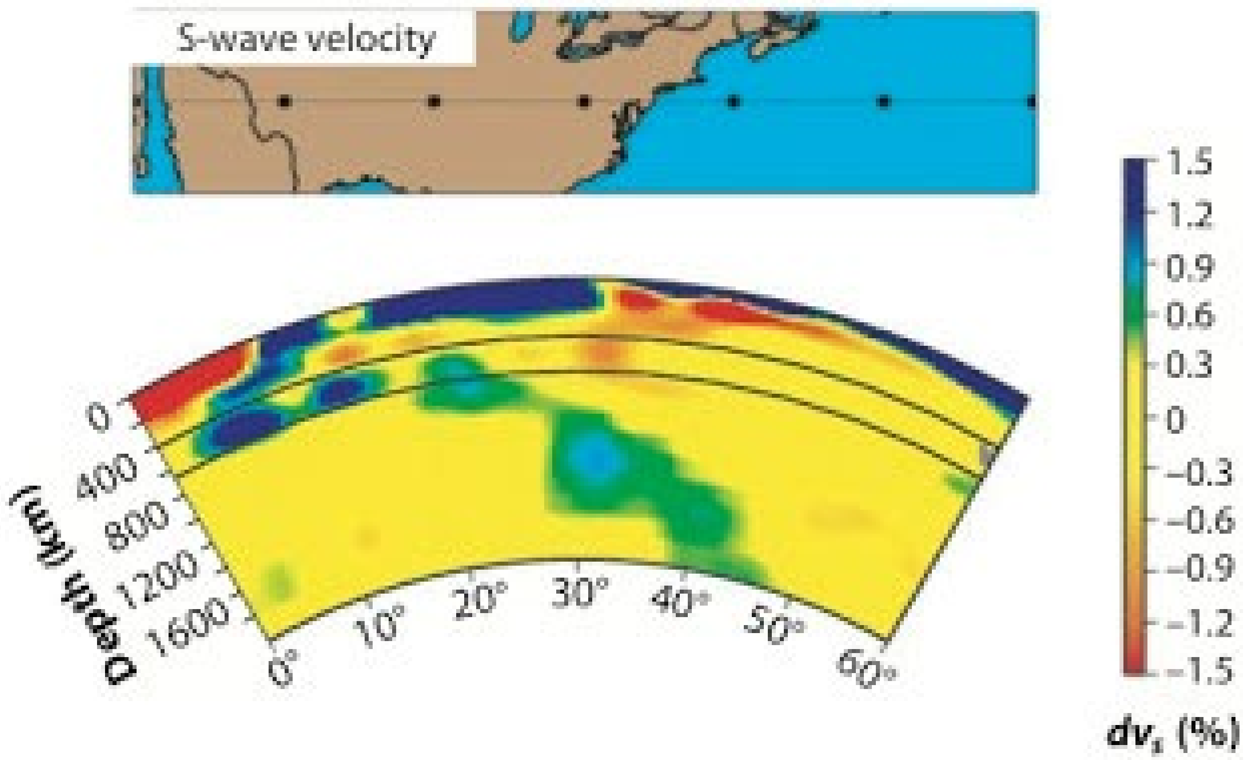
Mesozoic convergent margin (“classic”)



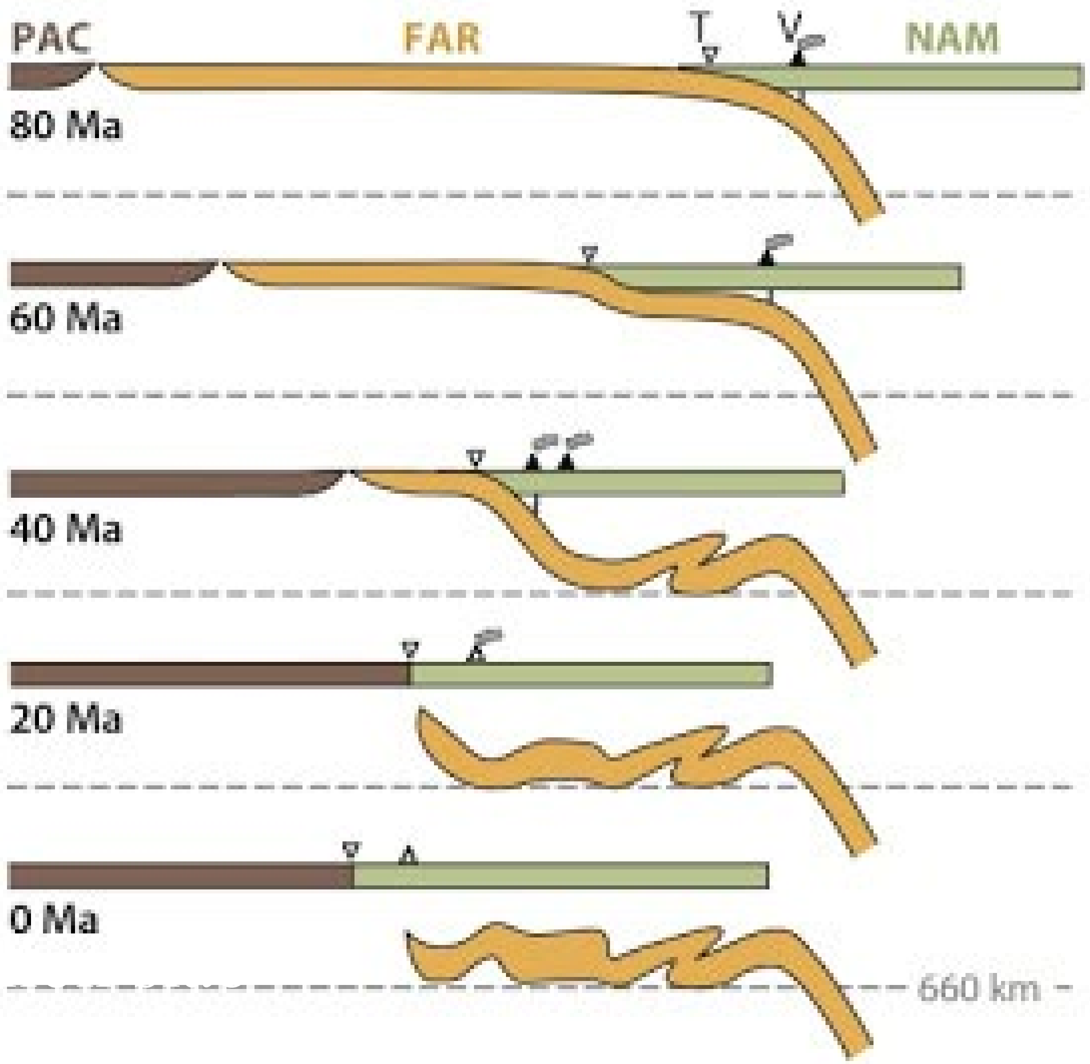
Shallow subduction in the Laramide (early Cenozoic)



https://geoinfo.nmt.edu/tour/federal/monuments/gila_cliff_dwellings/home.html



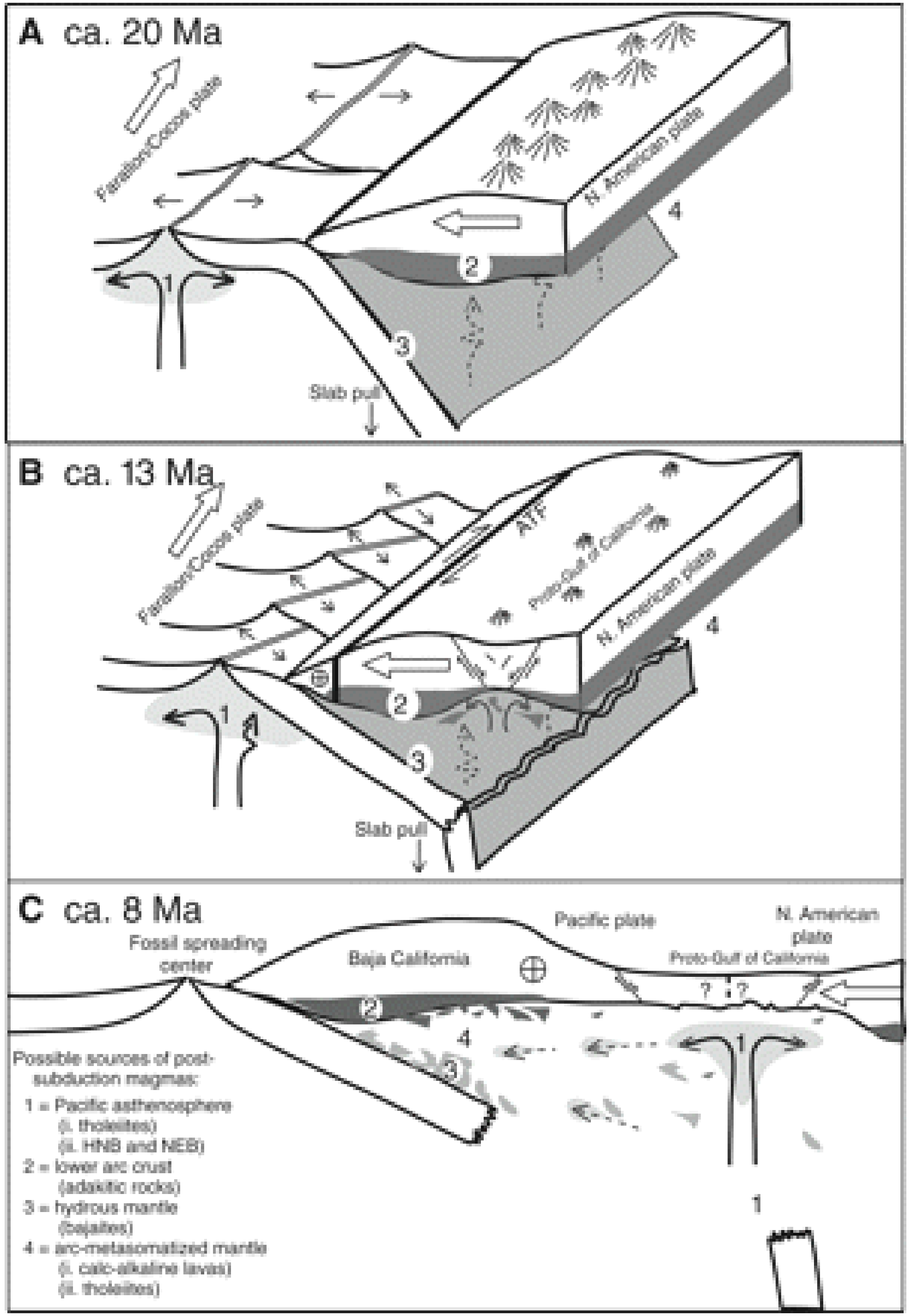
Data

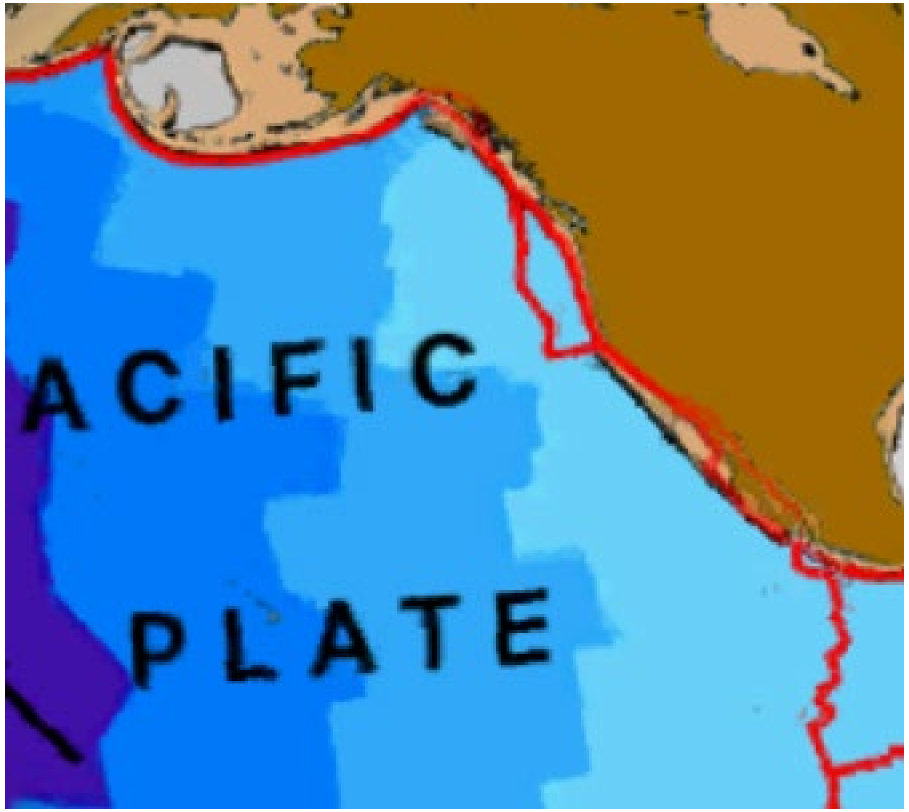


Model

http://www.geopoem.com/2013/04/tectonic-congestion-on-road-from.html
http://www.sciencedirect.com/science/article/pii/S0012821X02009858

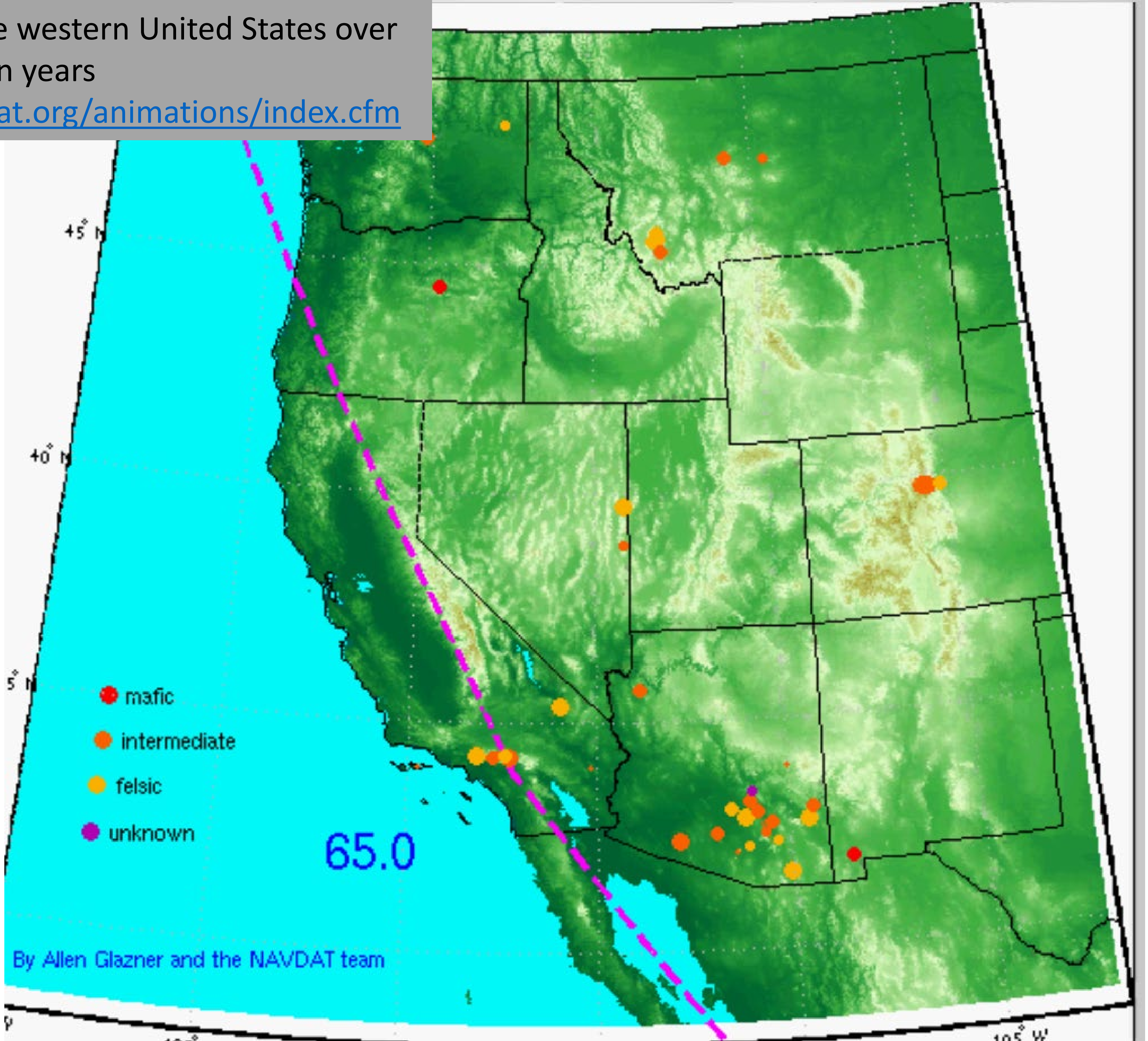
Baja California





http://bulletin.geoscienceworld.org/content/120/3-4/451/F6.expansion

Magmatism in the western United States over the past 65 million years
http://www.navdat.org/animations/index.cfm



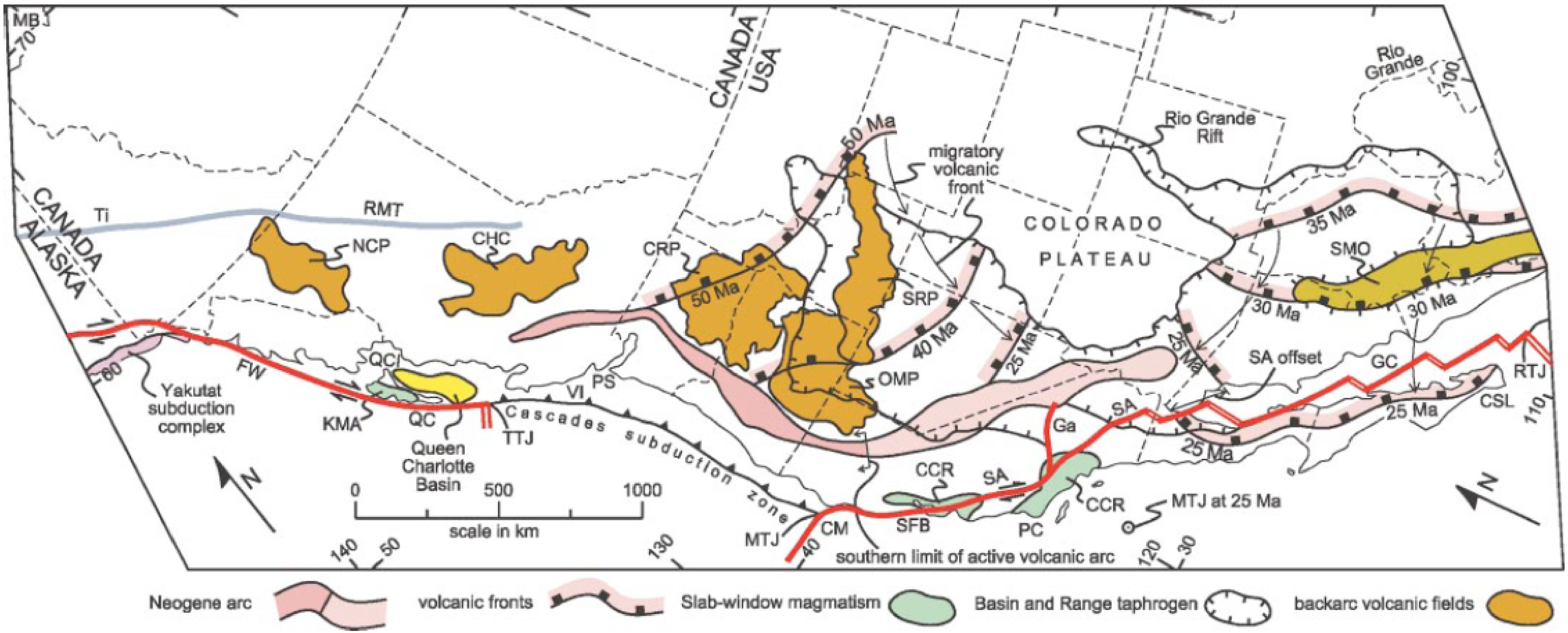


Figure 10 Post-Eocene geotectonic features of the North American Cordillera, including the Basin and Range taphrogen (SMO, Paleogene magmatic arc remnant in the Sierra Madre Occidental). Active Neogene strike-slip faults (*red lines*): FW, Fairweather; Ga, Garlock; QC, Queen Charlotte; SA, San Andreas. Offshore triple plate junctions: MTJ, Mendocino (FFT); RTJ, Rivera (RTF); TTJ, Tofino (RTF). Slab-window magmatism (near the coastal transform systems): CCR, California Coast Ranges (28–0 Ma); KMA, Queen Charlotte Islands (46–17 Ma). Backarc lava fields (erupted inland from main Cordilleran arc trend): CHC, Chilcotin (14–6 Ma); CRP, Columbia River Plateau (17–8 Ma); NCP, Northern Cordilleran Province (8–0 Ma); OMP, Oregon-Modoc Plateau (17–7 Ma); SRP, Snake River Plain (16–0 Ma). See Figure 5 for geographic legend.

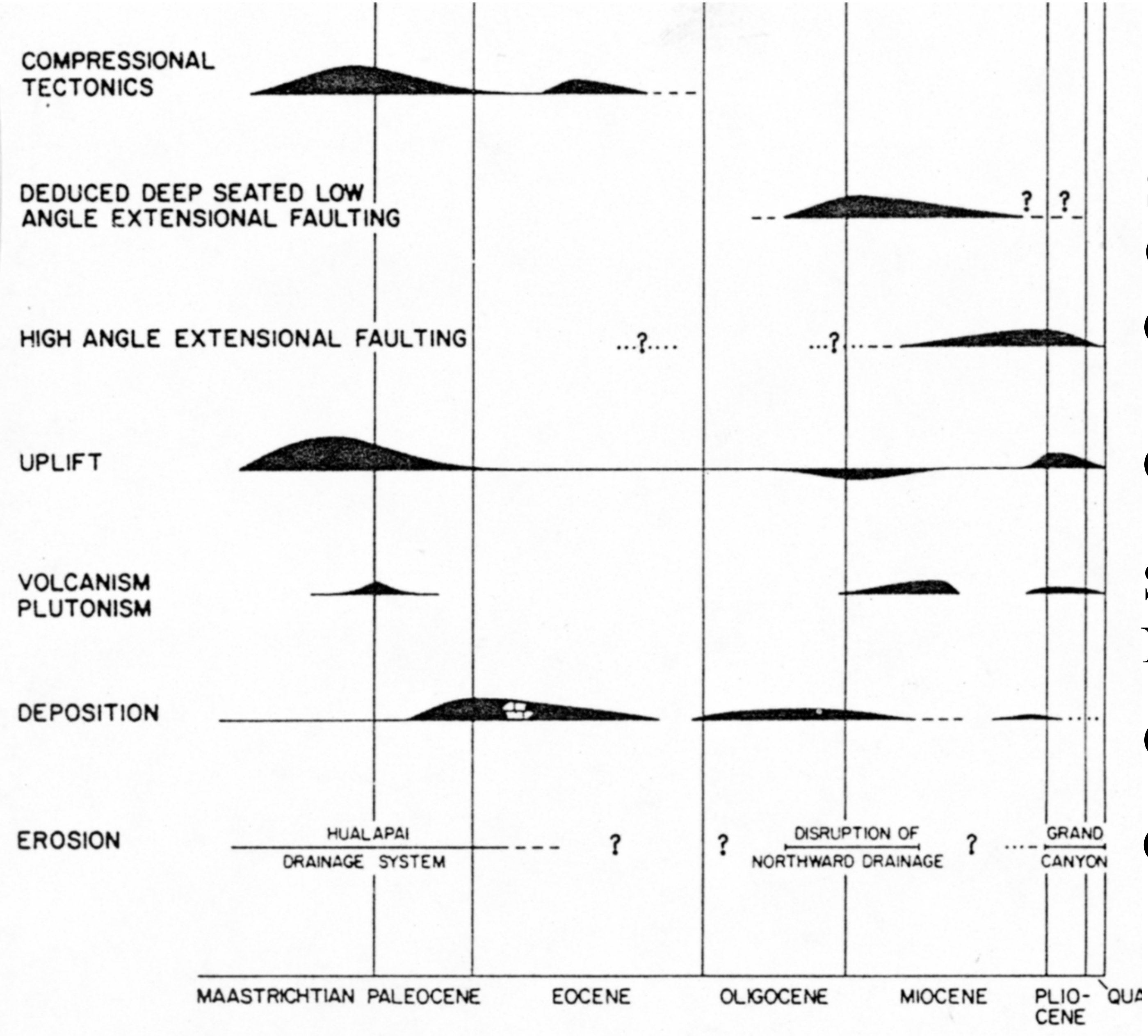


Figure 20. Temporal relationships between tectonics, sedimentation, and erosion in the Grand Canyon region, Arizona, during Laramide and post-Laramide time

Monoclines

South Mountains
Catalinas, etc.

Central AZ basins

Colorado Plateau

Superstitions
N. AZ Volcanics

Central AZ basins

Colorado Plateau

Laramide + Monoclines + reactivation in late Cenozoic as Normal faults

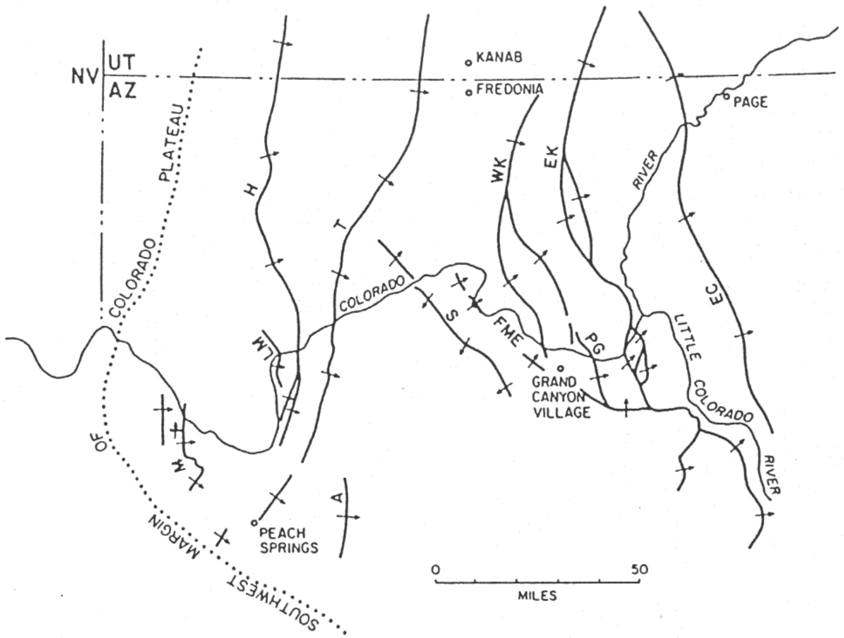


Figure 3. Locations of the Laramide monoclines in the Grand Canyon region, Arizona. From west to east: M - Meriwhitica; LM - Lone Mountain; H - Hurricane; T - Toroweap; A - Aubrey; S - Supai; FME - Fossil-Monument-Ermita; WK - West Kaibab; PG - Phantom-Grandview; EK - East Kaibab; EC - Echo Cliffs

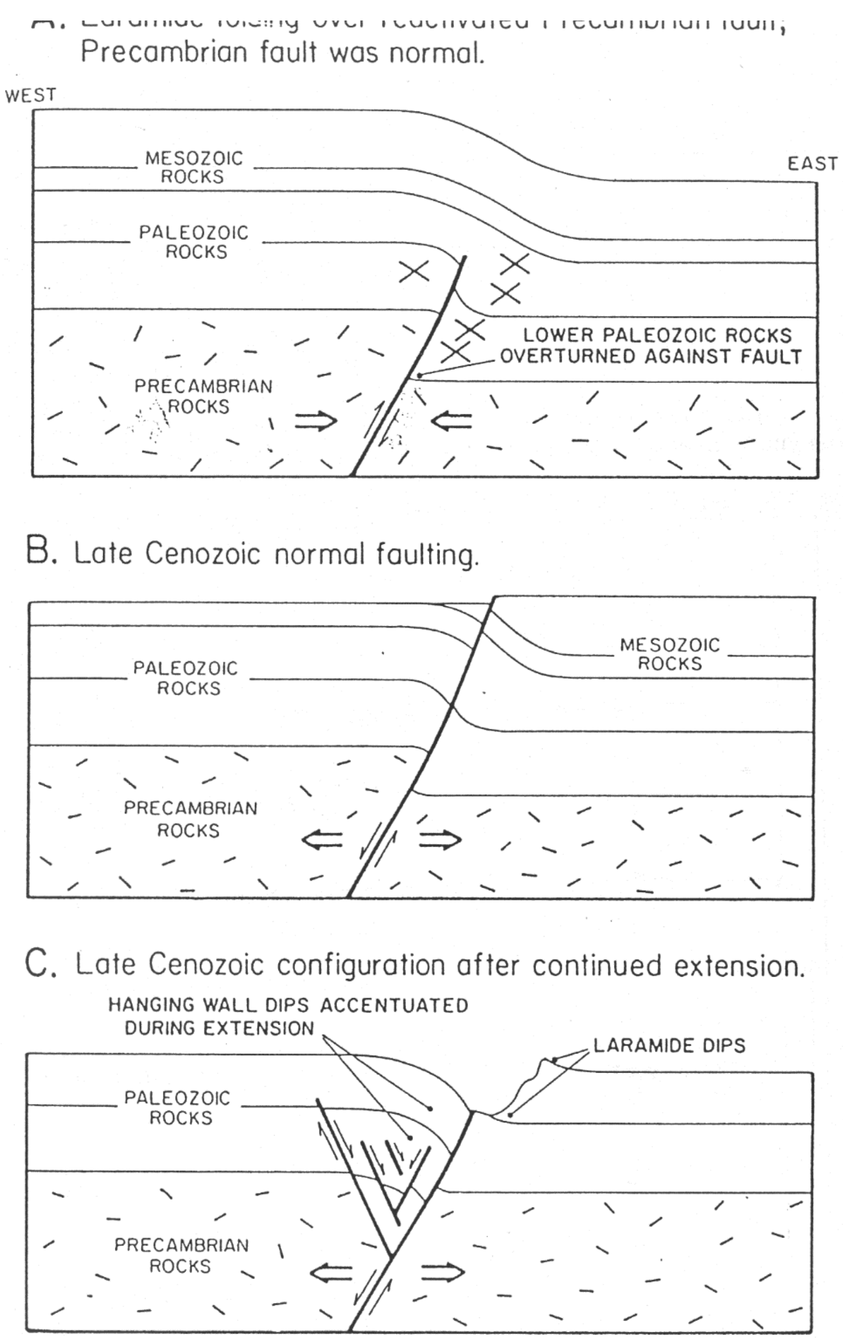
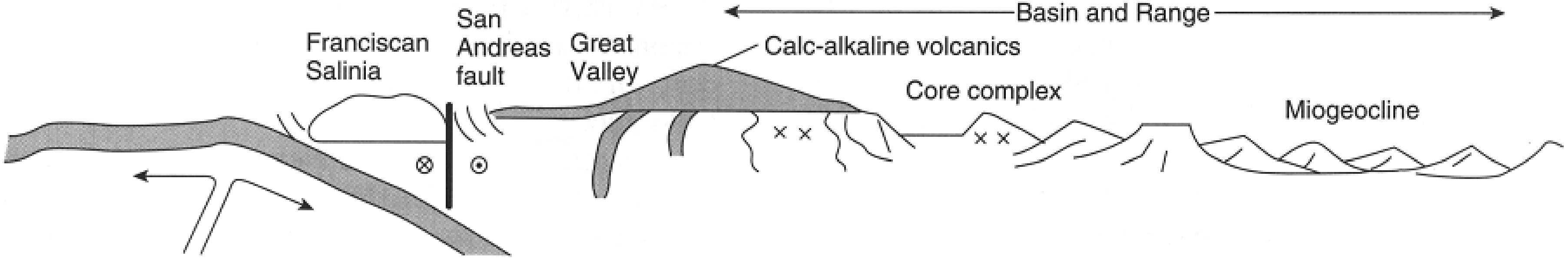


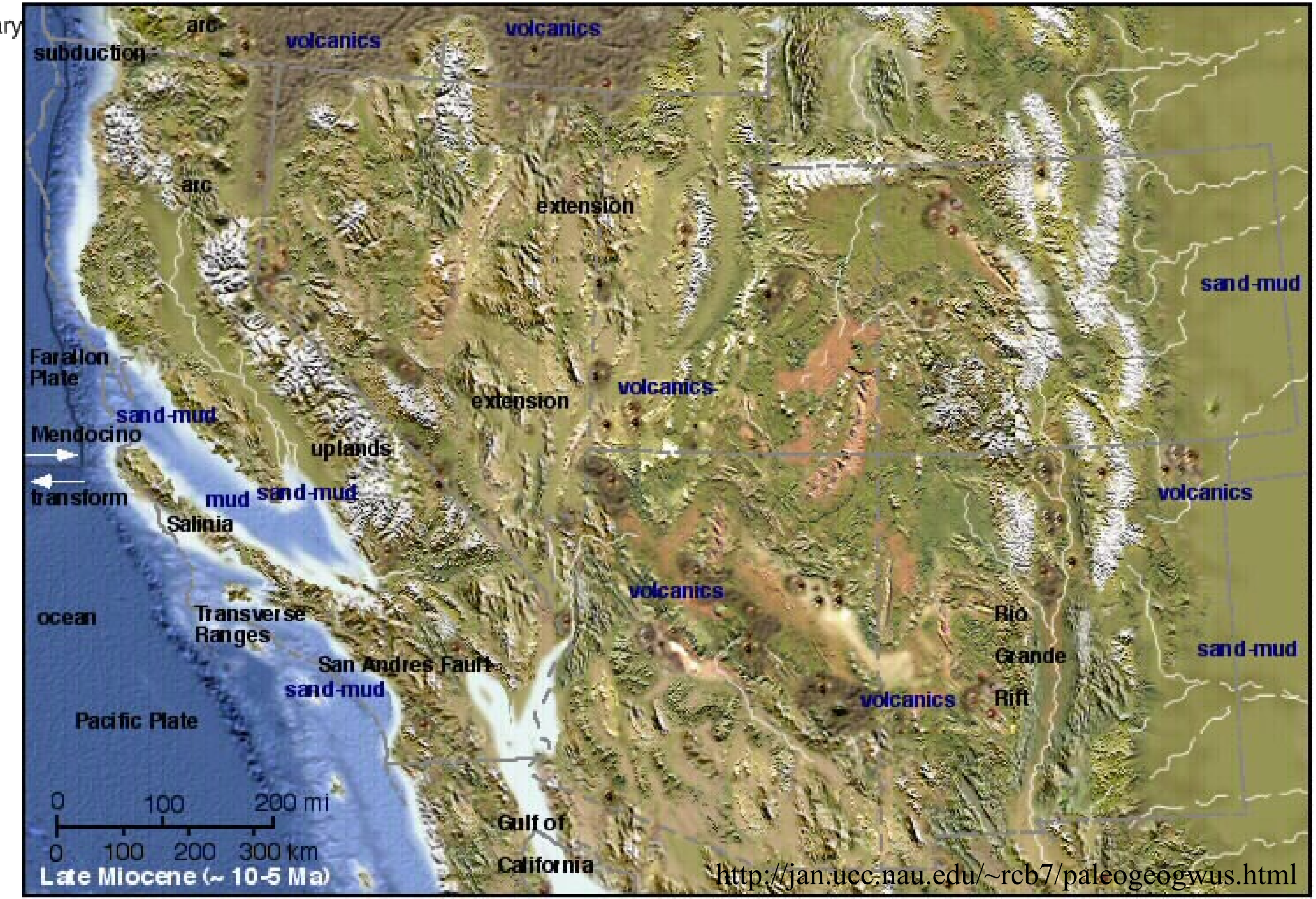
Figure 4. Stages in the development of a typical north-trending monocline-fault zone, Grand Canyon region, Arizona

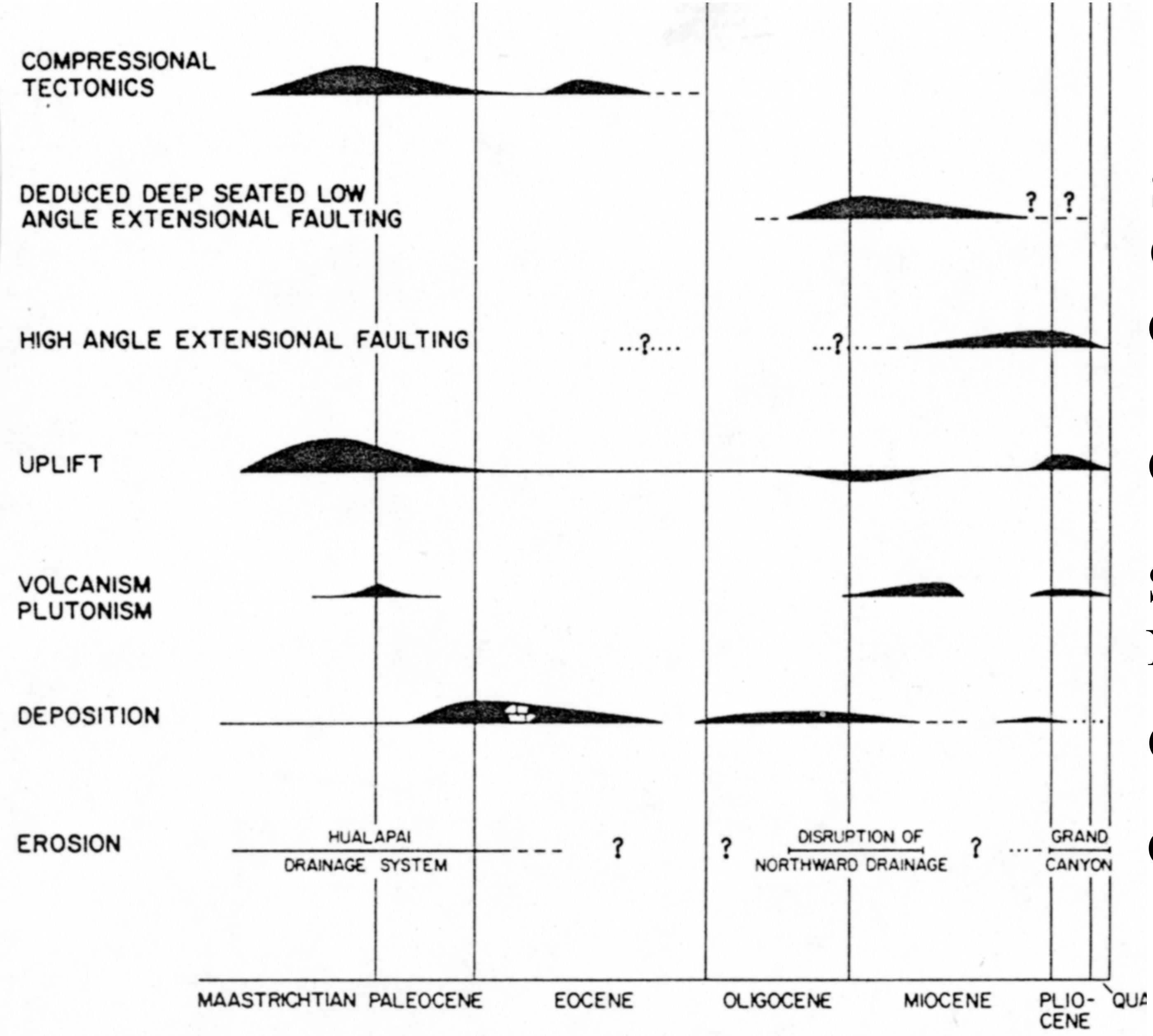
NE AZ monoclines

East Kaibab view to the South



J. Tertiary-Quaternary





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Monoclines

South Mountains
Catalinas, etc.

Central AZ basins

Colorado Plateau

Superstitions
N. AZ Volcanics

Central AZ basins

Colorado Plateau

End of the semester….

Your Name:____________________________

Essay 2: Draw a present-day E-W tectonic cross section across the Cordillera from coastal California to Denver. Identify each of the main tectonic belts and write a short paragraph or bullet list summarizing the most important features of each (maybe turn this page sideways).

Your Name: ____________

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