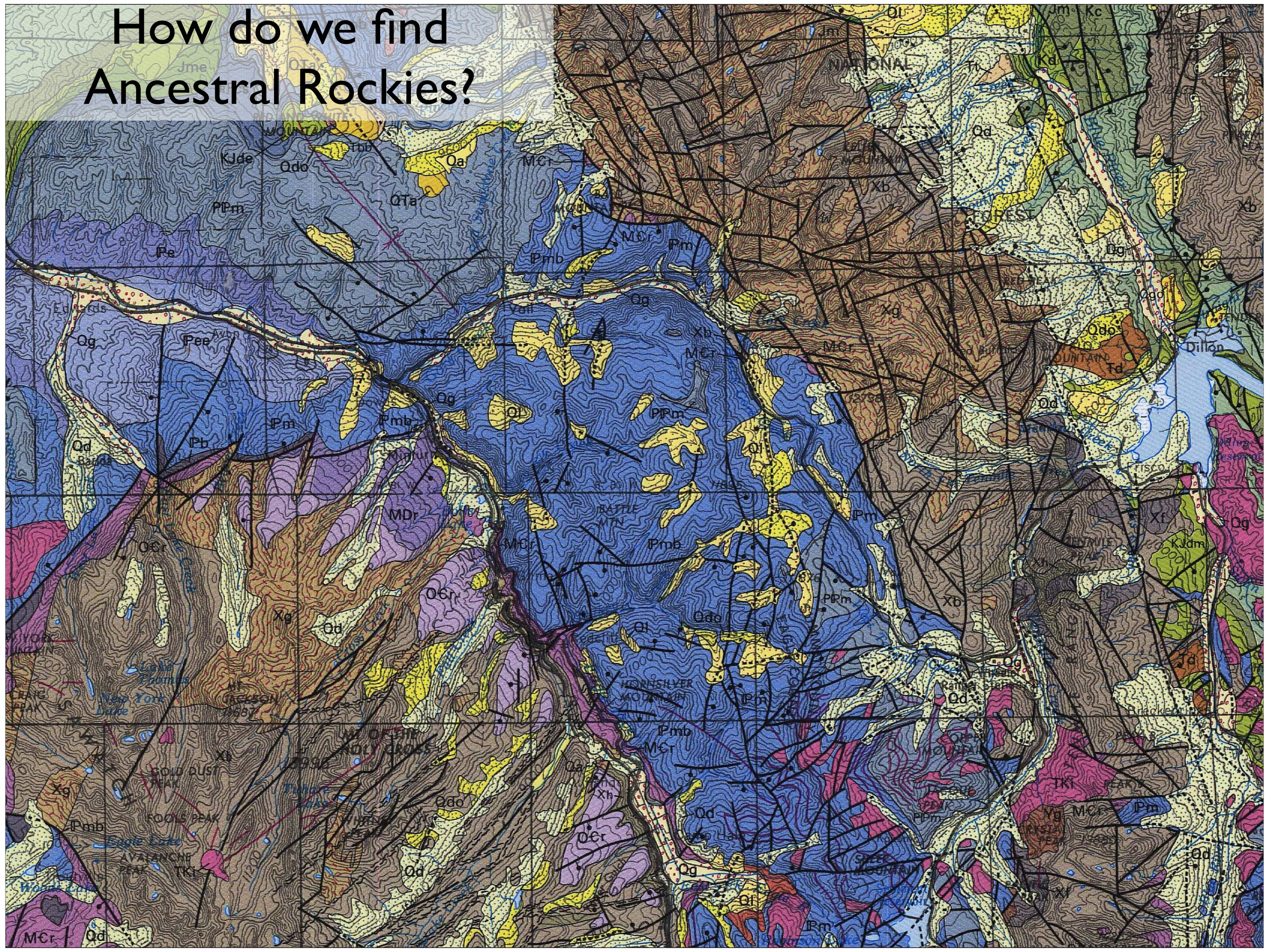
Ancestral Rockies

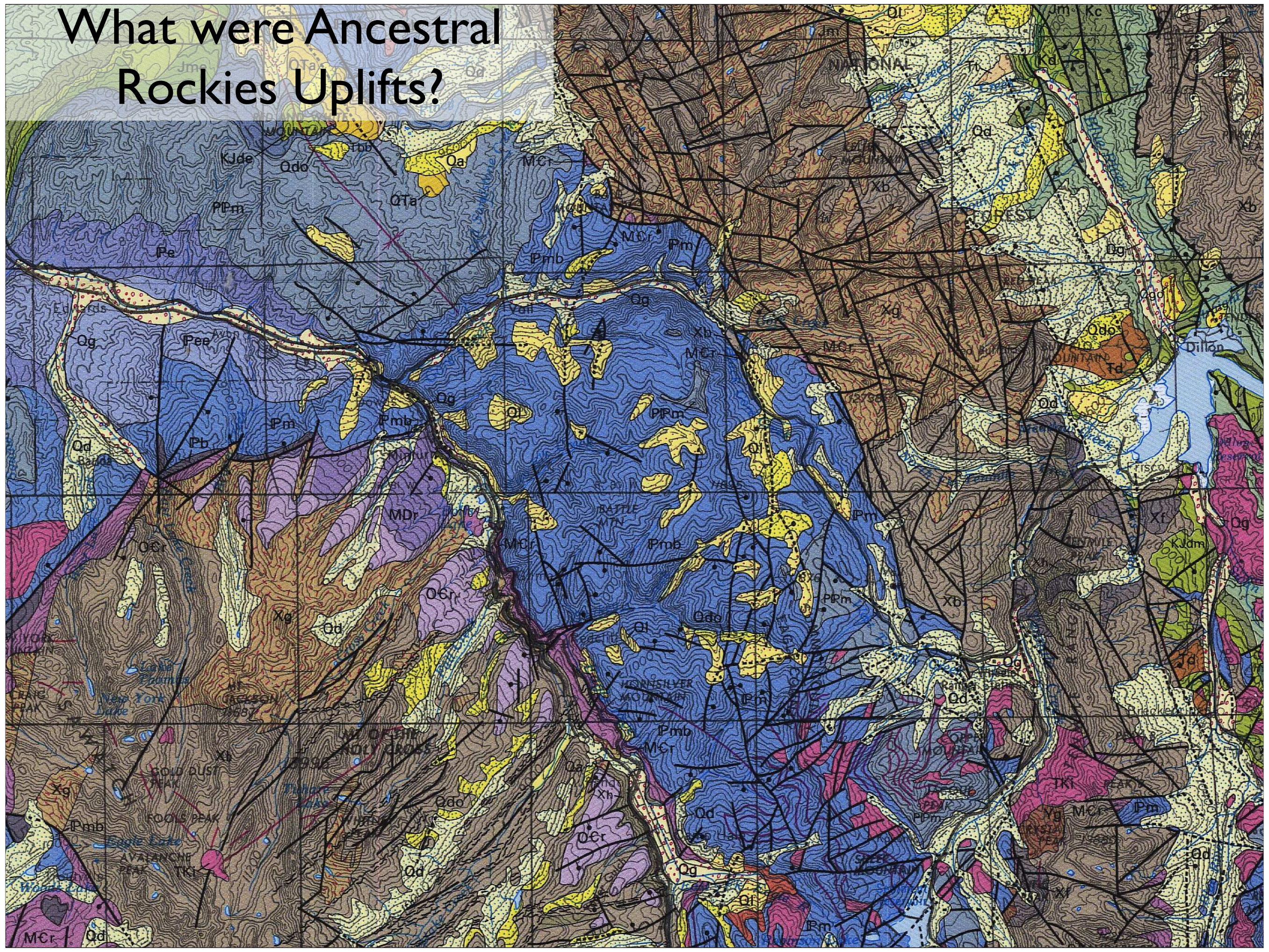
Pull out geologic map and ask about it.

How do we find Ancestral Rockies?

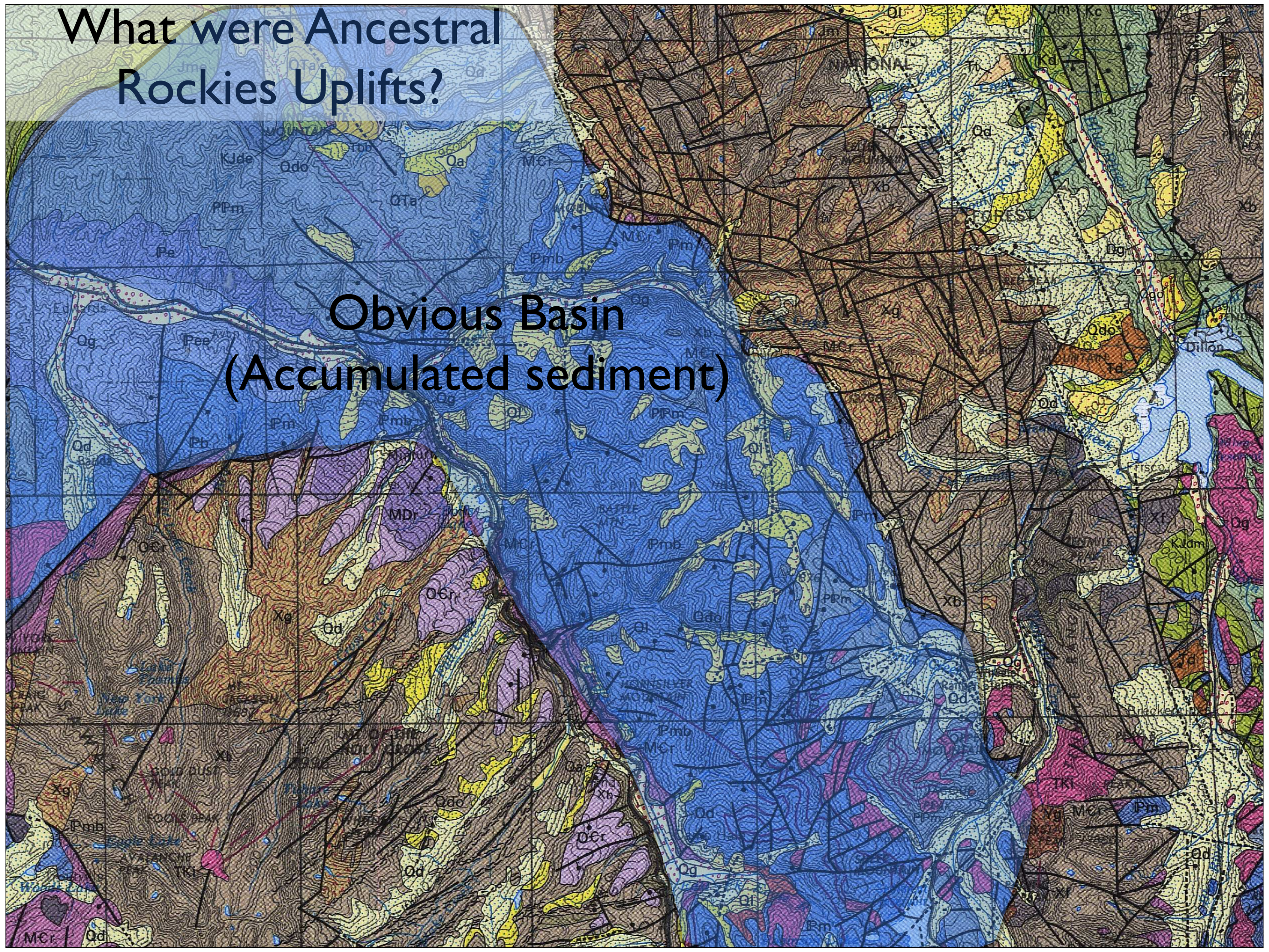


This is a prelude to pulling out maps and looking at them

What were Ancestral Rockies Uplifts?

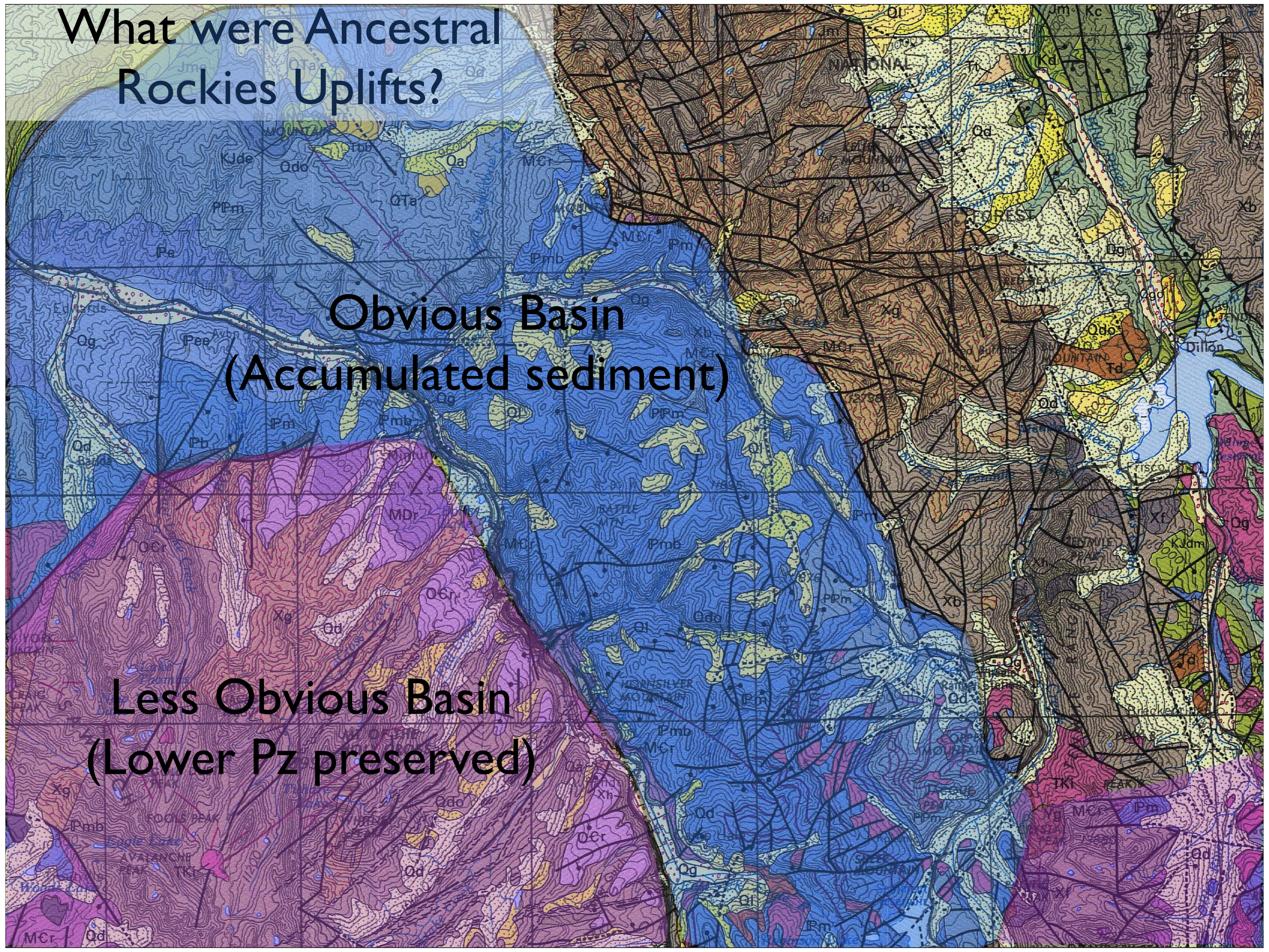


What were Ancestral Rockies Uplifts?



Obvious Basin
(Accumulated sediment)

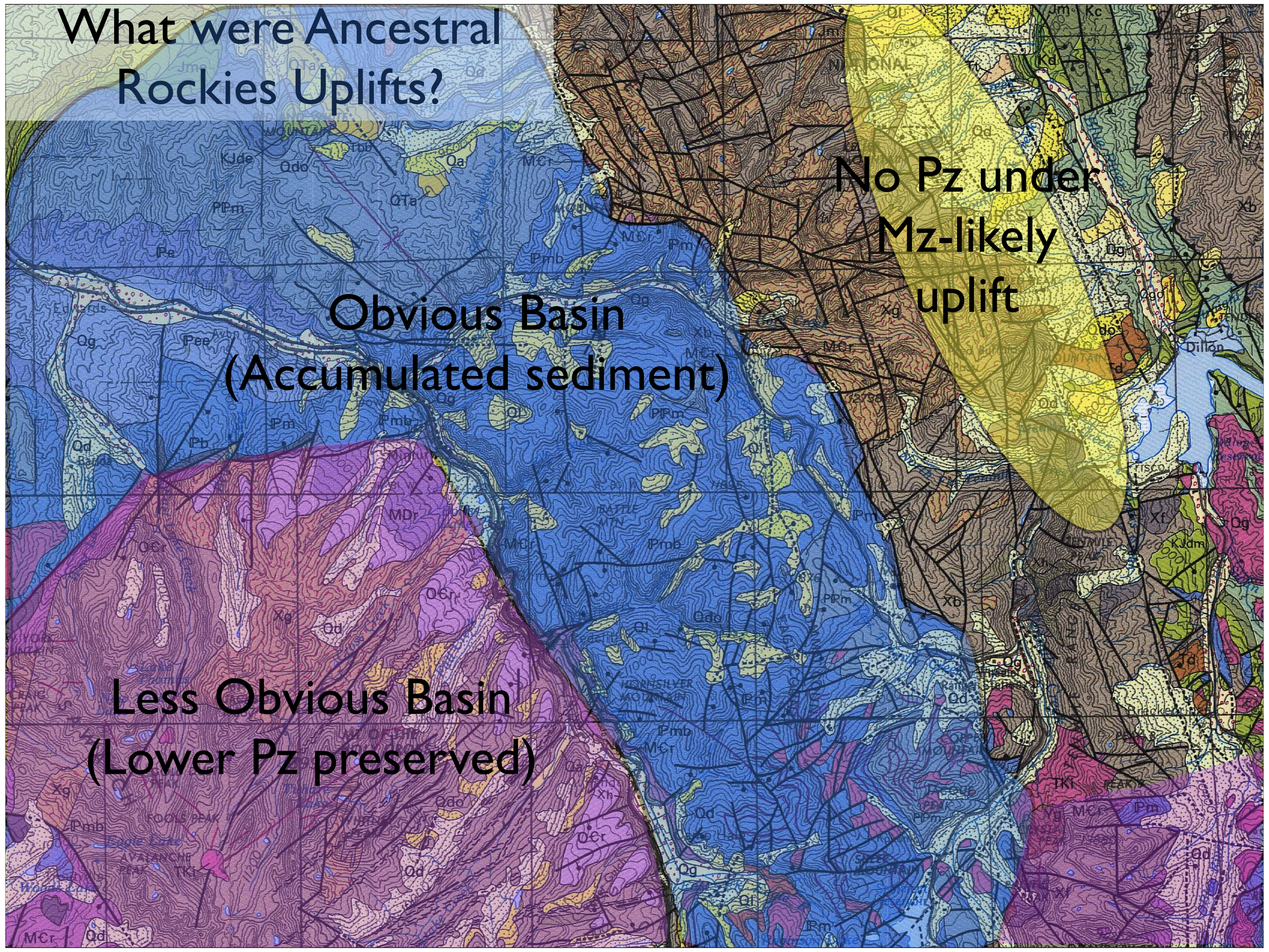
What were Ancestral Rockies Uplifts?



Obvious Basin
(Accumulated sediment)

Less Obvious Basin
(Lower Pz preserved)

What were Ancestral Rockies Uplifts?

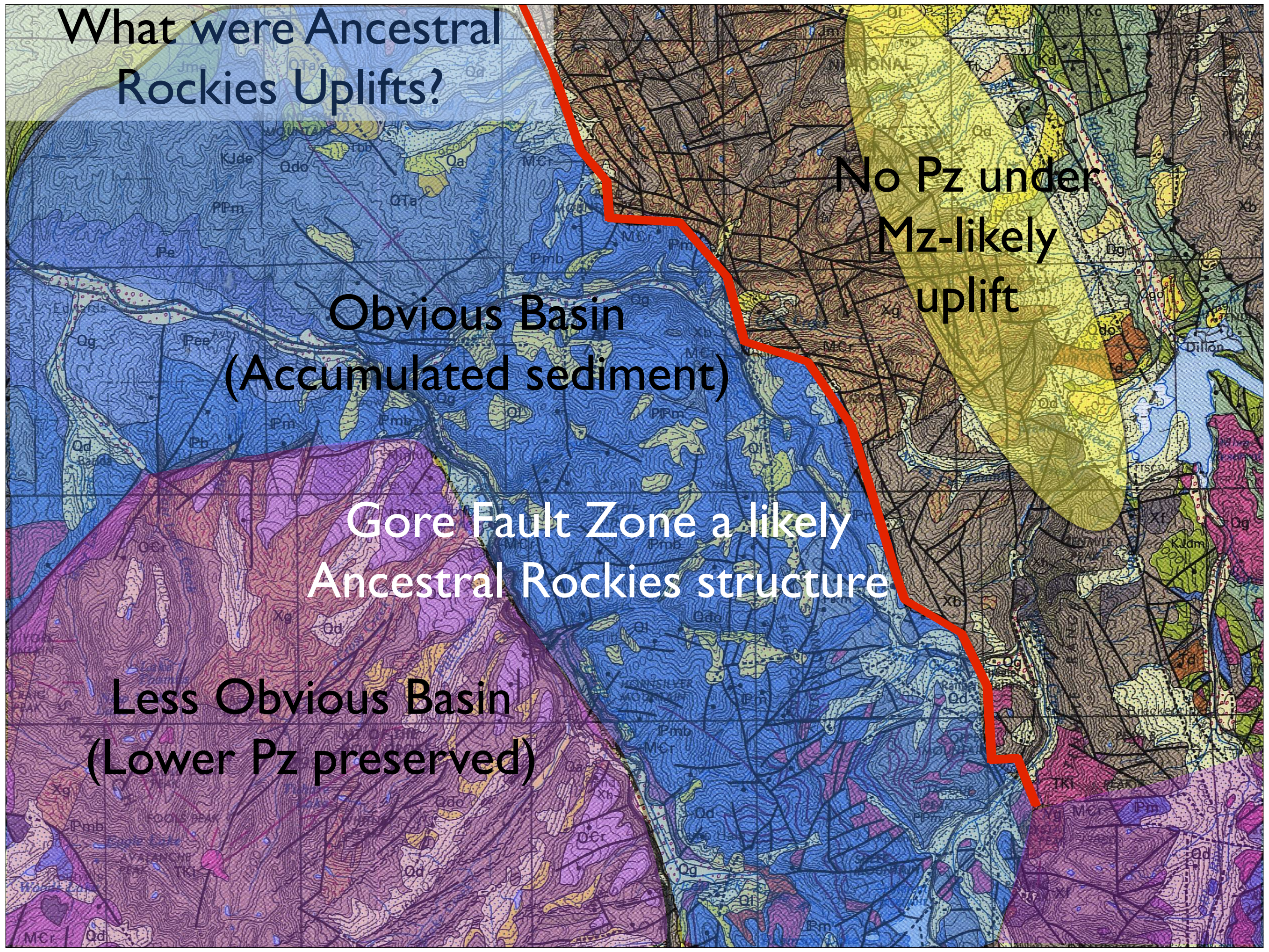


No Pz under Mz-likely uplift

Obvious Basin
(Accumulated sediment)

Less Obvious Basin
(Lower Pz preserved)

What were Ancestral Rockies Uplifts?

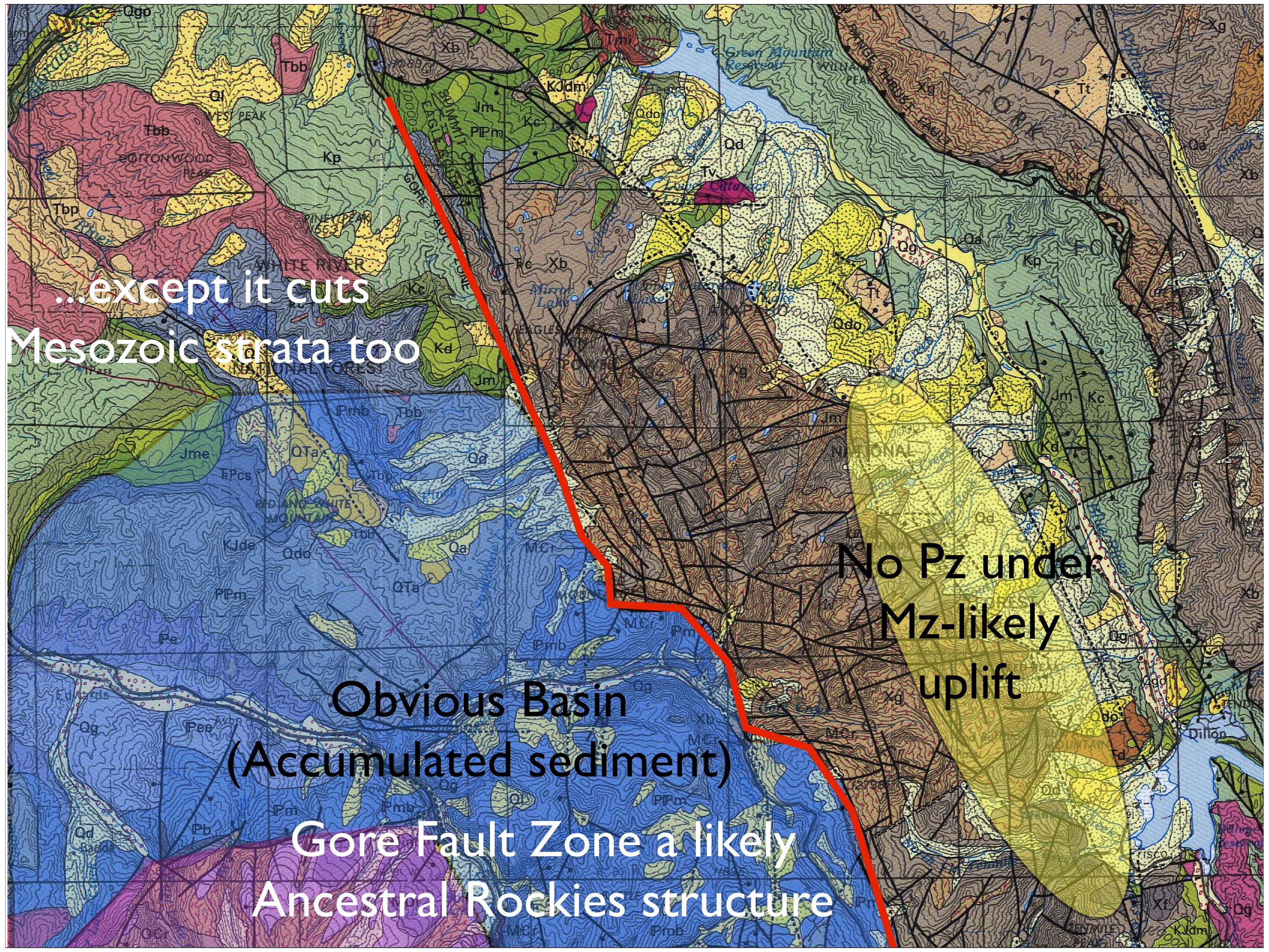


No Pz under Mz-likely uplift

Obvious Basin (Accumulated sediment)

Gore Fault Zone a likely Ancestral Rockies structure

Less Obvious Basin (Lower Pz preserved)



...except it cuts
Mesozoic strata too

No Pz under
Mz-likely
uplift

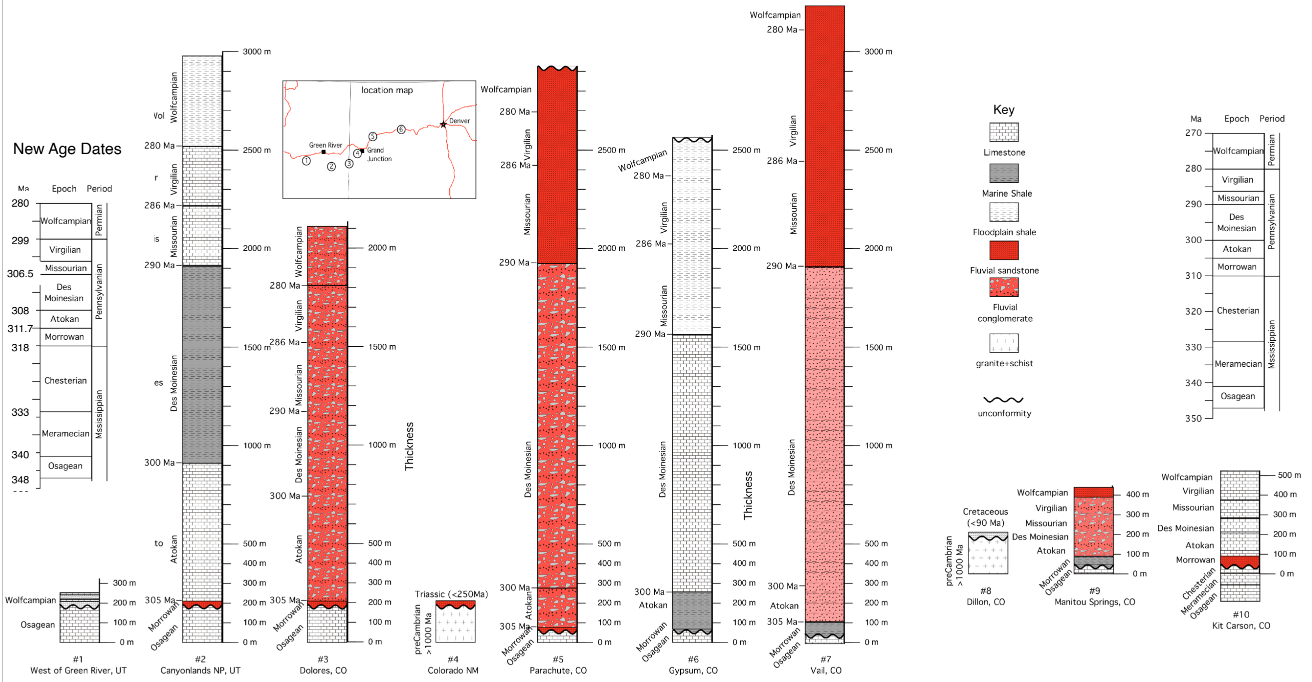
Obvious Basin
(Accumulated sediment)

Gore Fault Zone a likely
Ancestral Rockies structure

A lead in to, where can we see unreactivated Ancestral Rockies structures?

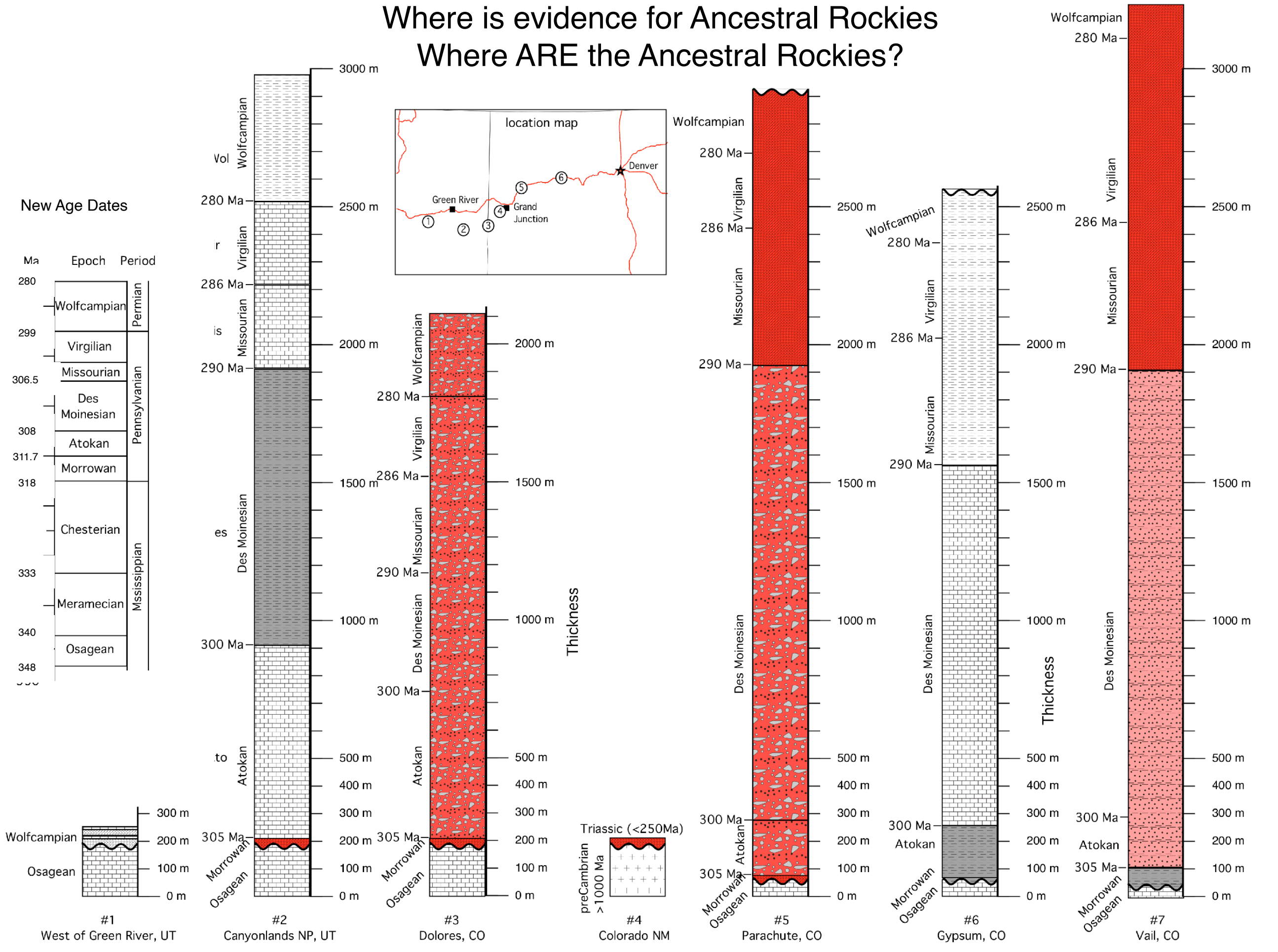

I70 west of Vail

Where is evidence for Ancestral Rockies
Where ARE the Ancestral Rockies?

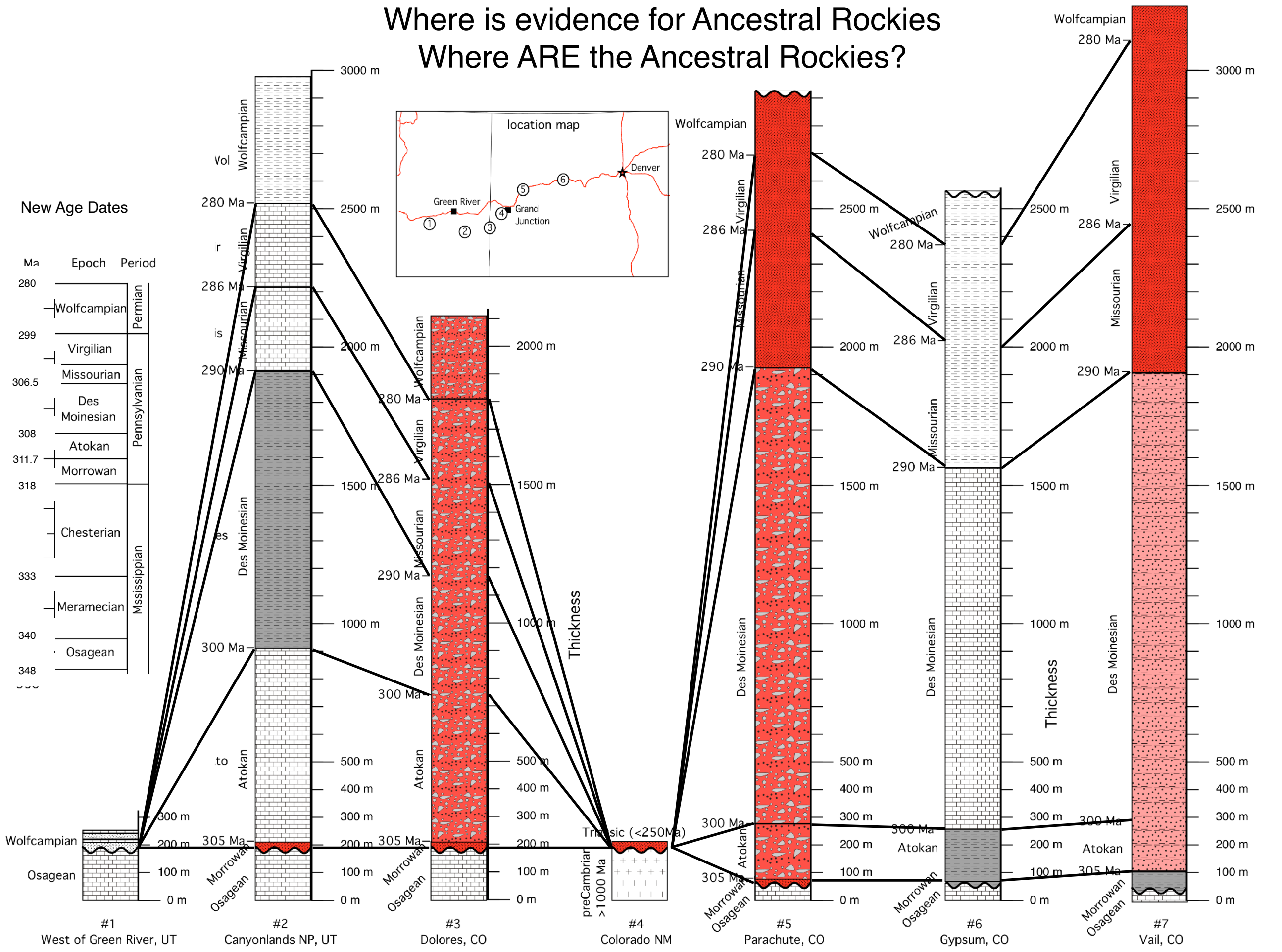


Might note that the timescale on right shown here is out of date (it was one Kluth used). Penn-Perm now put at 299 Ma, Mis-Penn 323 Ma by GSA, 318 by stratigraphy.org

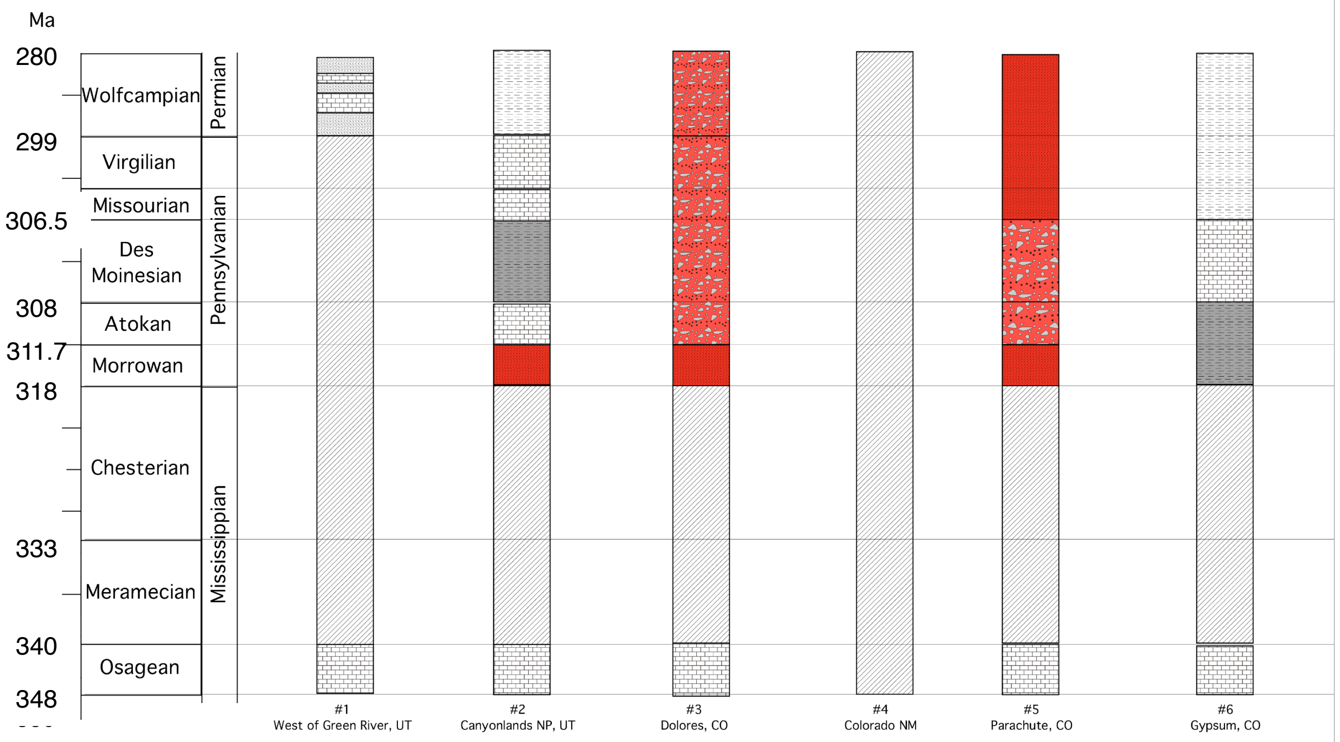
Where is evidence for Ancestral Rockies
Where ARE the Ancestral Rockies?



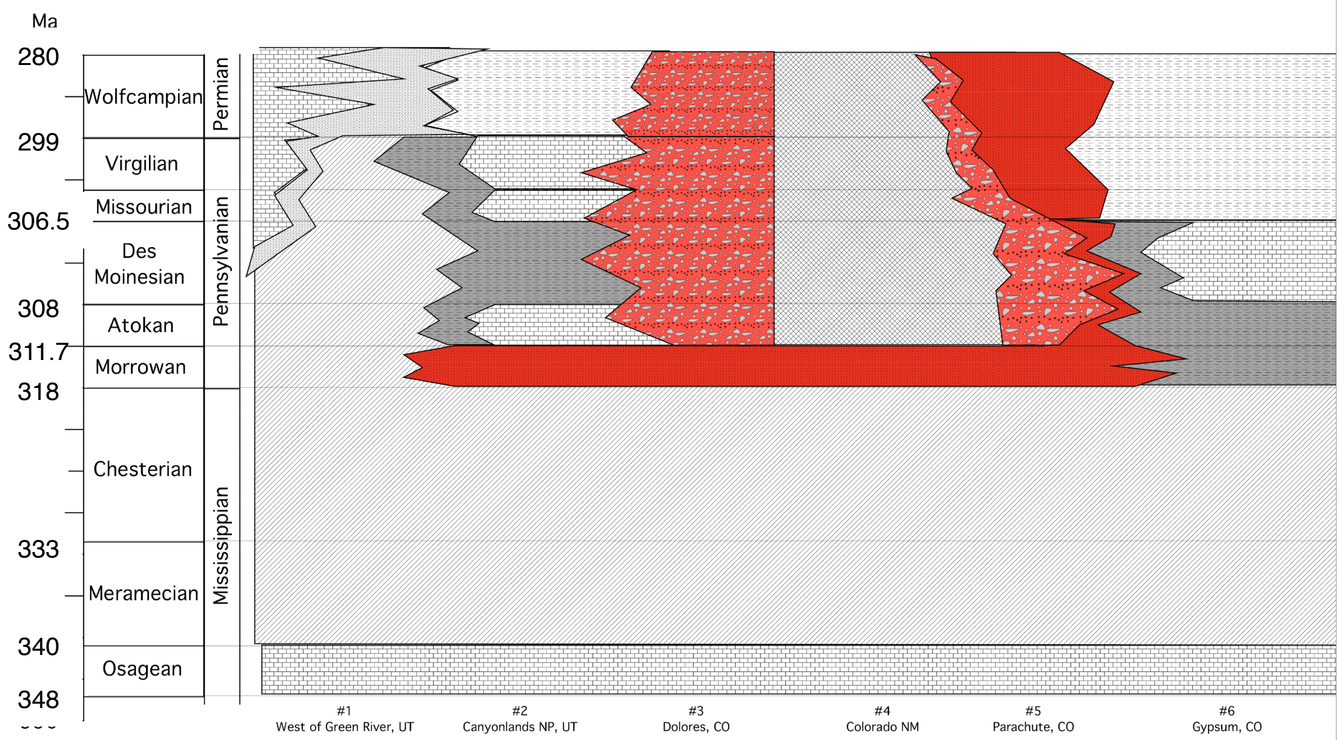
Where is evidence for Ancestral Rockies
Where ARE the Ancestral Rockies?

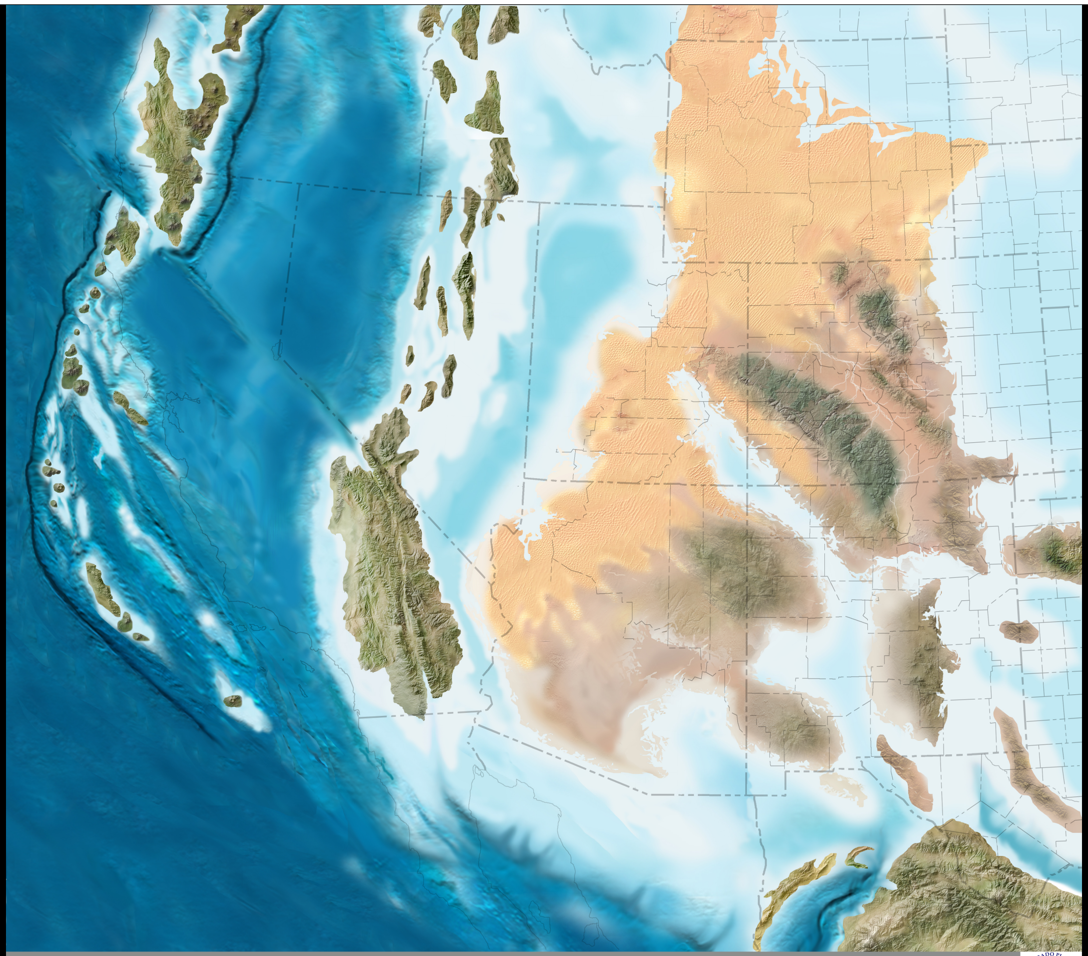


New Age Dates

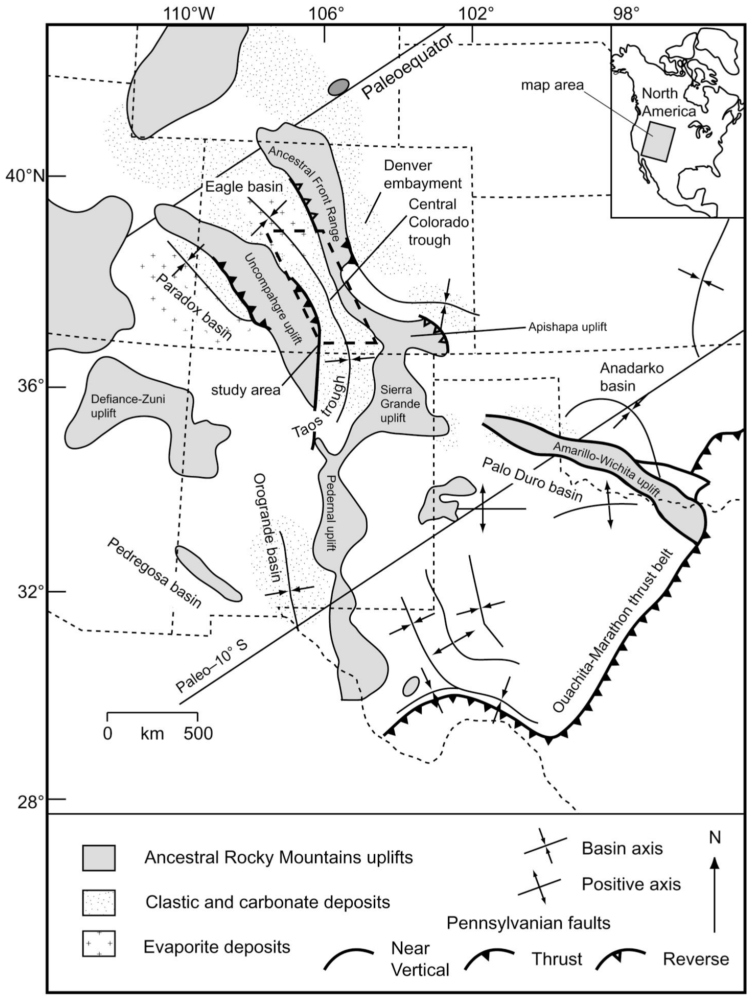


New Age Dates



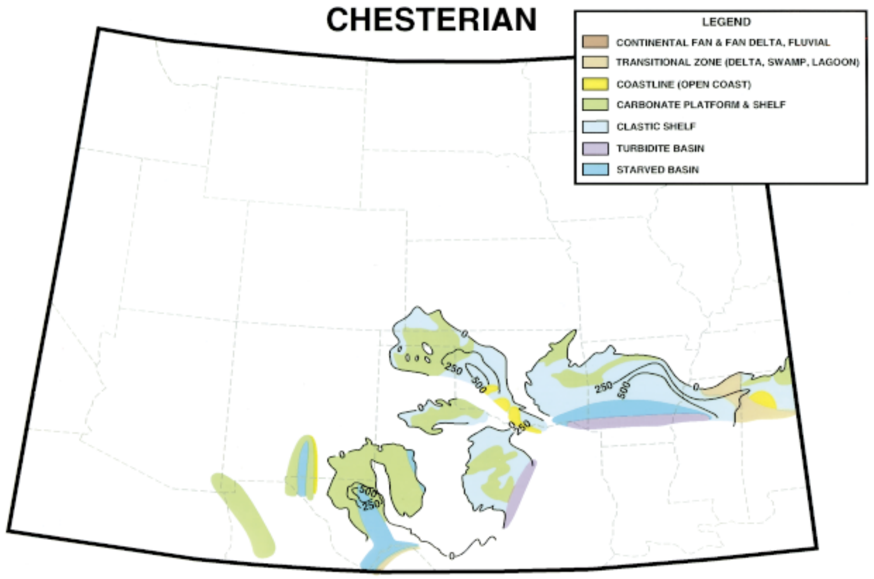


Late Pennsylvanian
300 Ma (299-301 Ma)



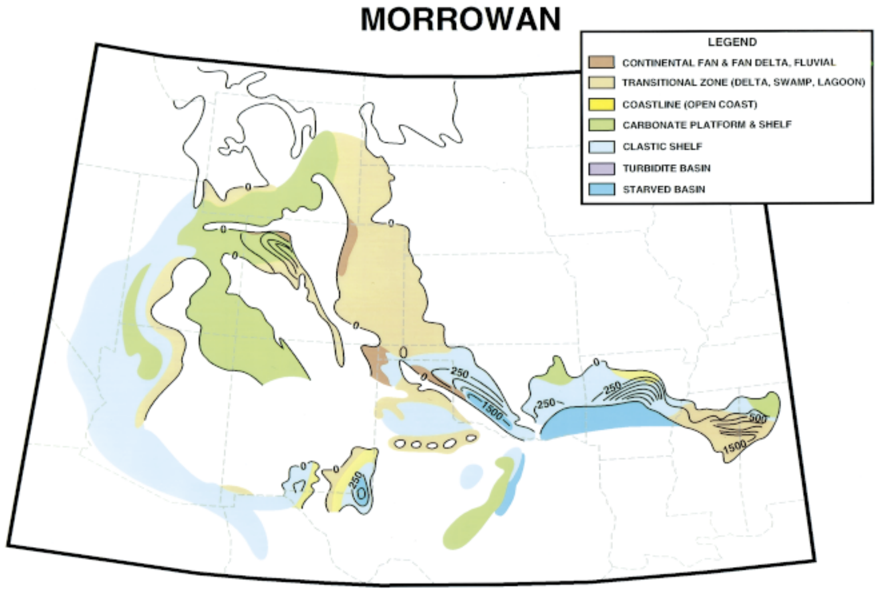
Hoy and Ridgway 2002

334-320 Ma



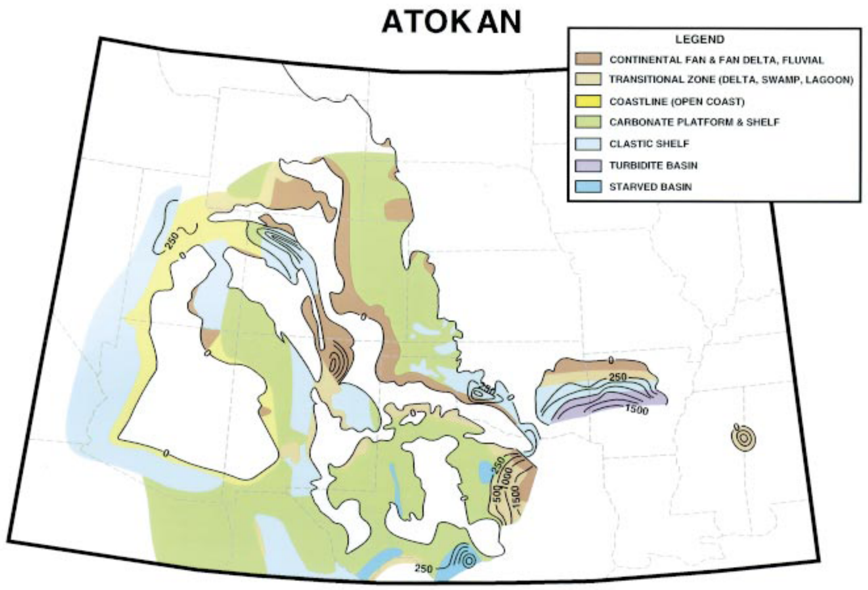
Ye et al., AAPG Bull, 1996

320-313 Ma



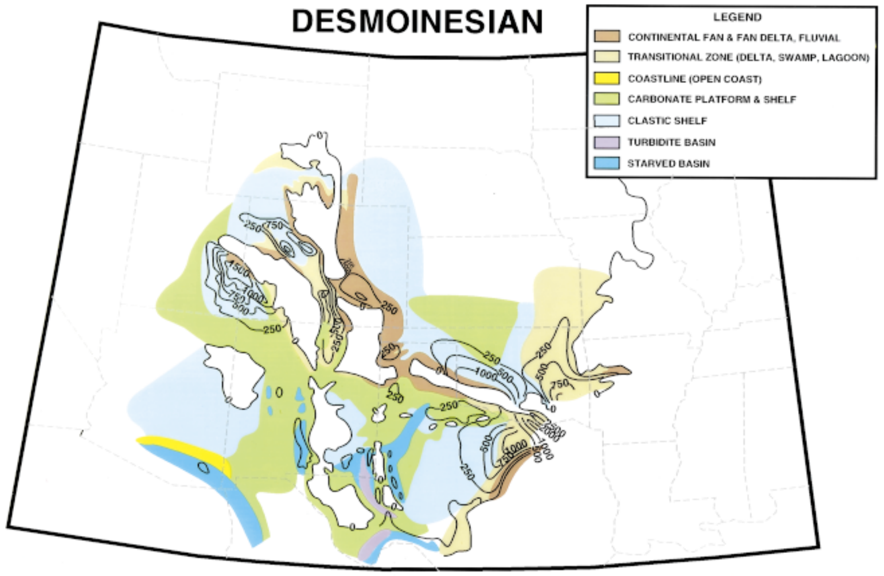
Ye et al., AAPG Bull, 1996

313-308 Ma



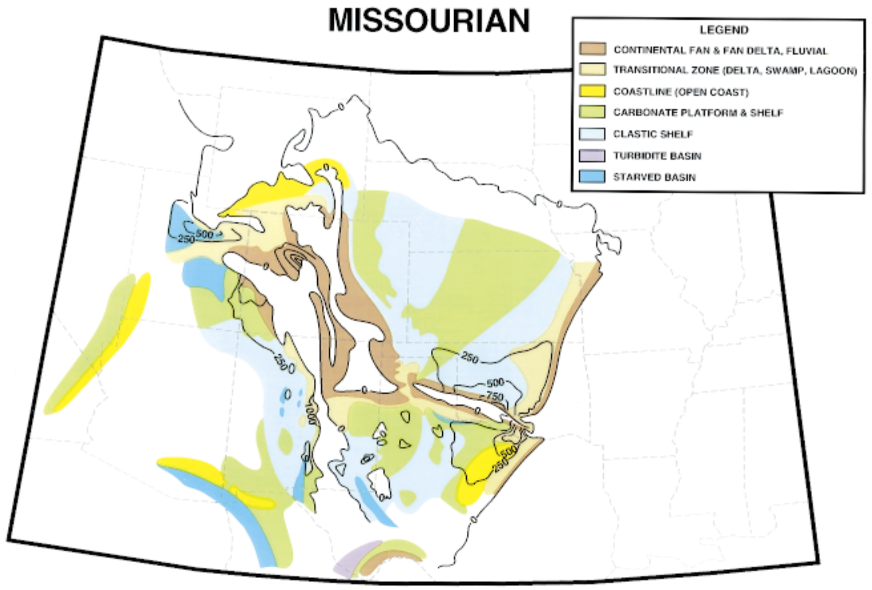
Ye et al., AAPG Bull, 1996

308-305 Ma



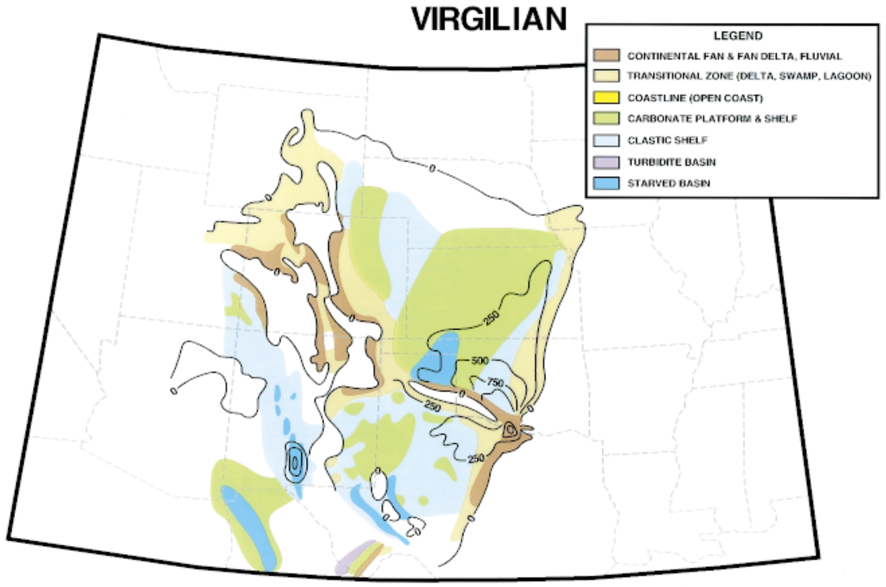
Ye et al., AAPG Bull, 1996

305-303 Ma



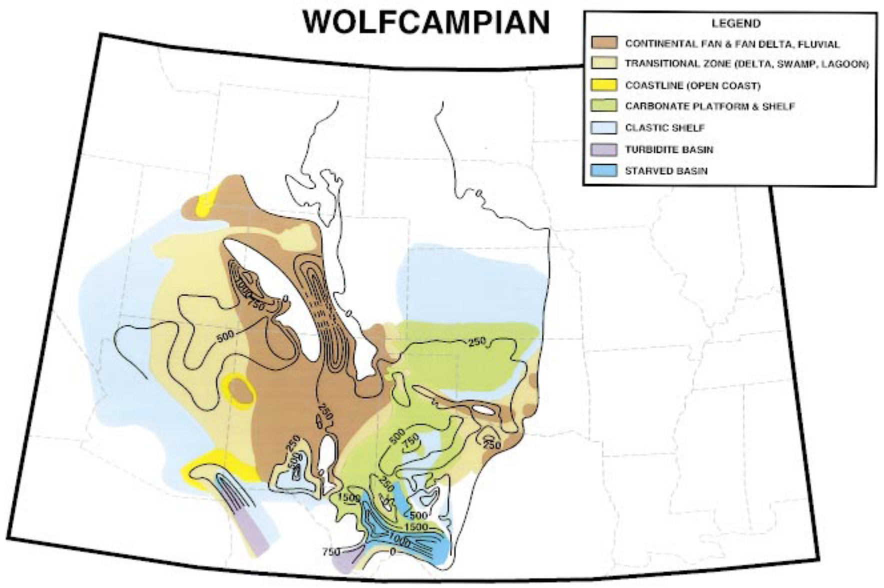
Ye et al., AAPG Bull, 1996

303-296 Ma



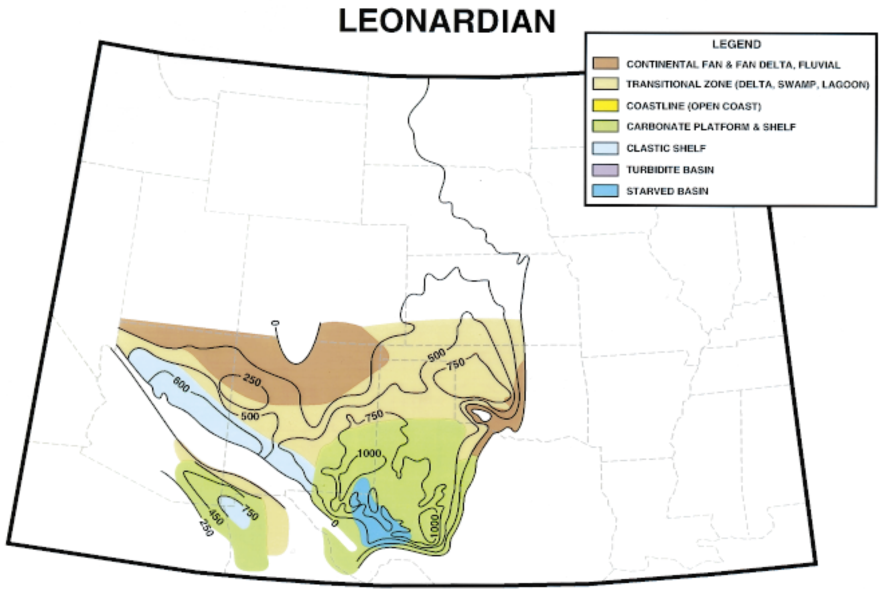
Ye et al., AAPG Bull, 1996

296-280 Ma (Permian)



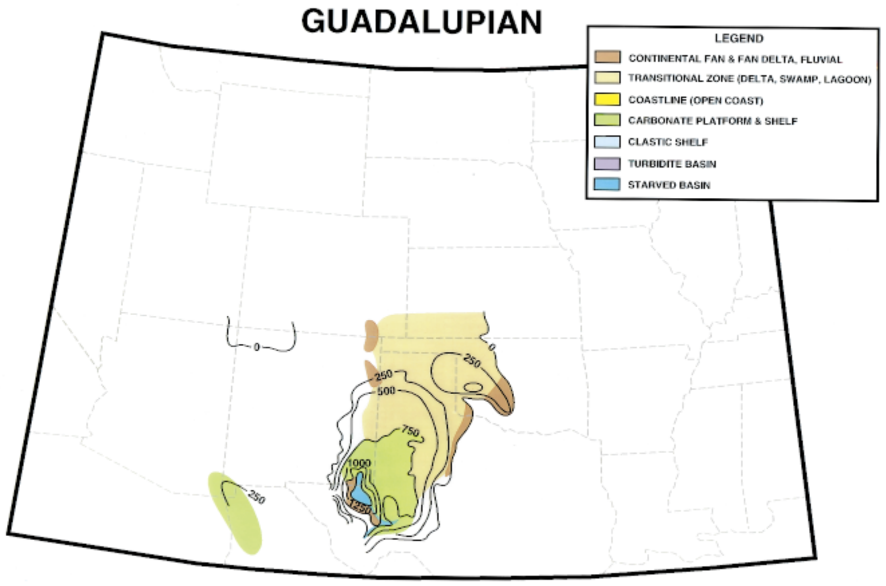
Ye et al., AAPG Bull, 1996

280-273 Ma

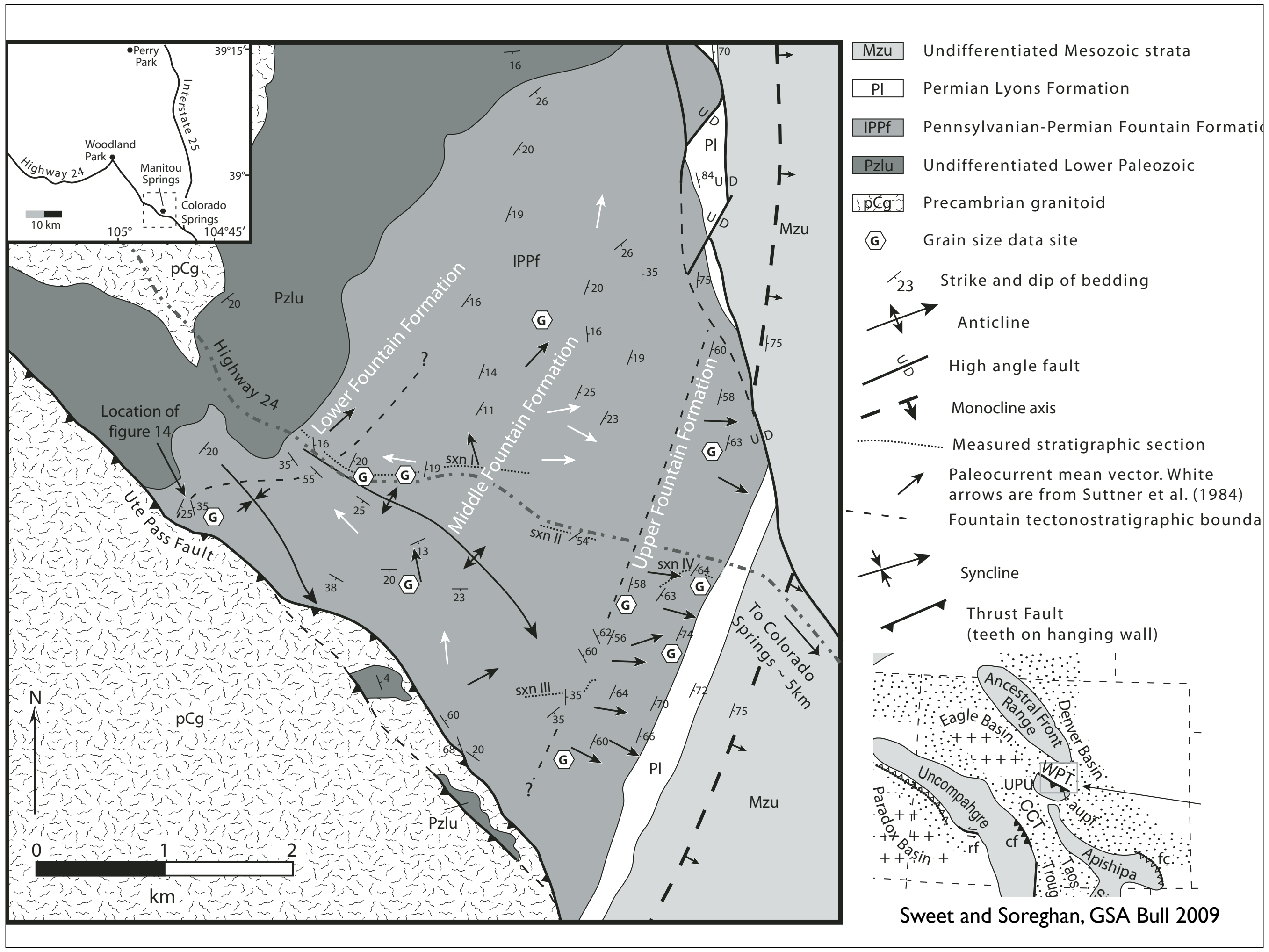


Ye et al., AAPG Bull, 1996

273-261 Ma

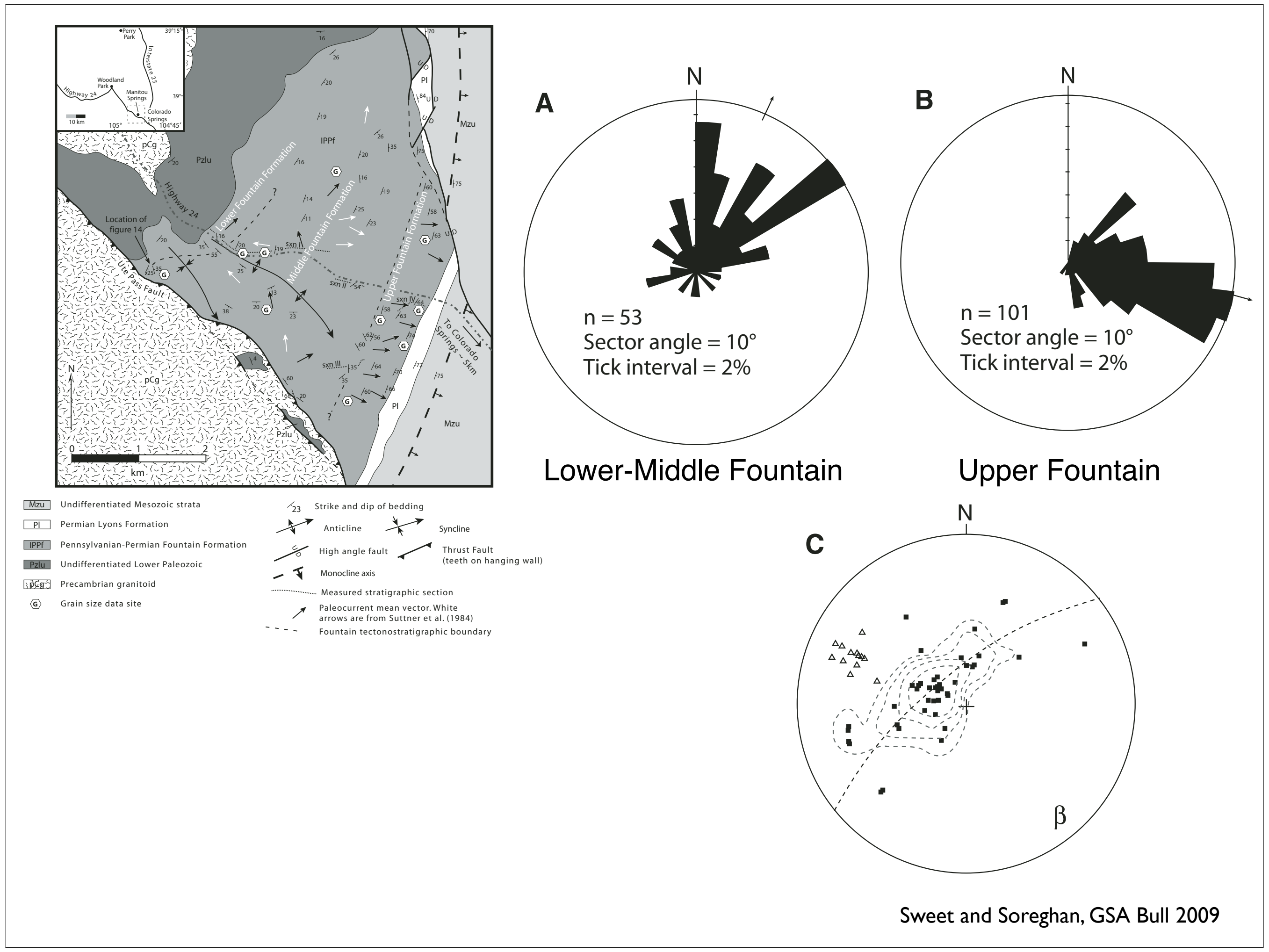


Ye et al., AAPG Bull, 1996



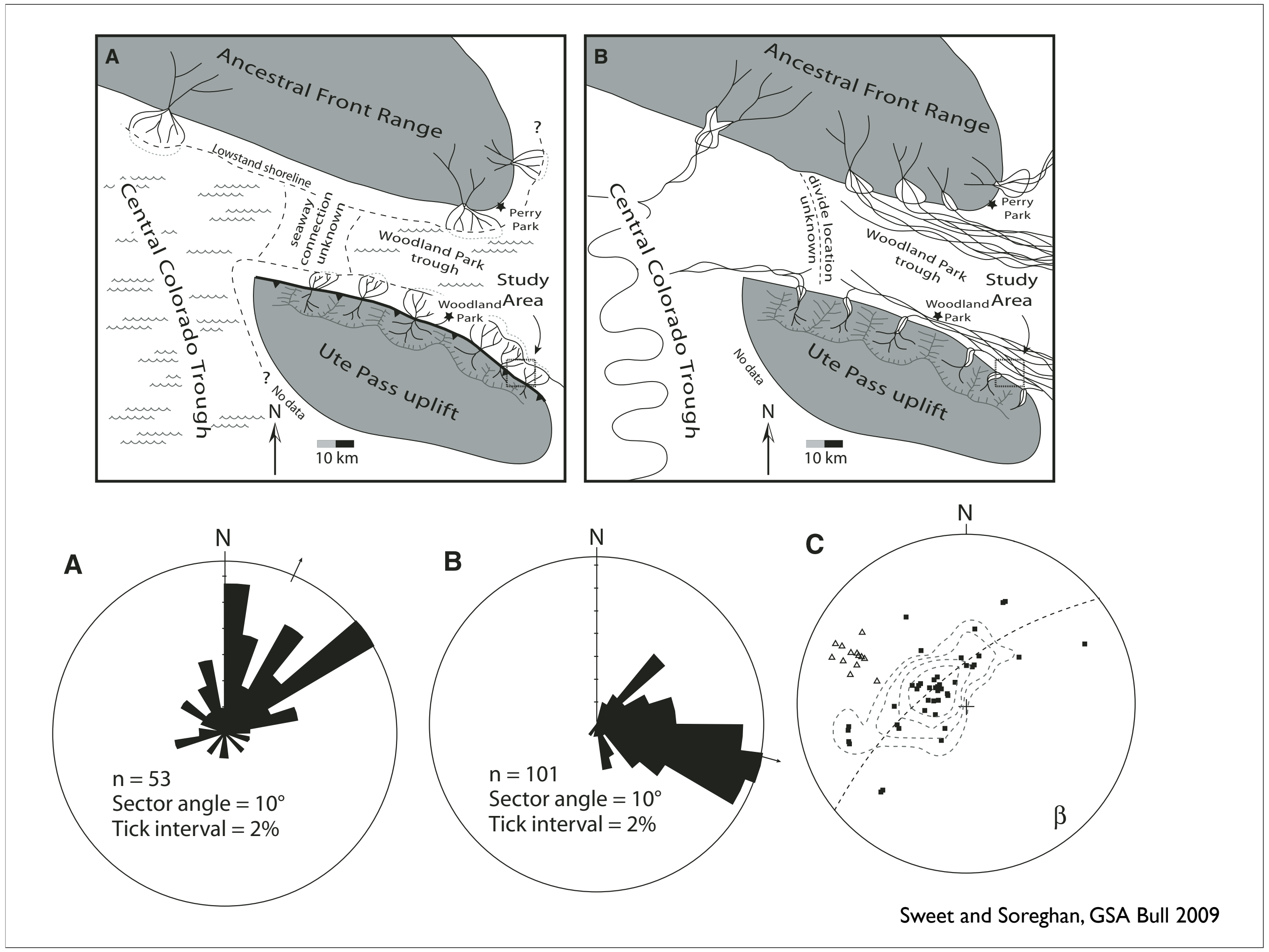
Sweet and Soreghan, GSA Bull 2009

So maybe can look at strat record more closely



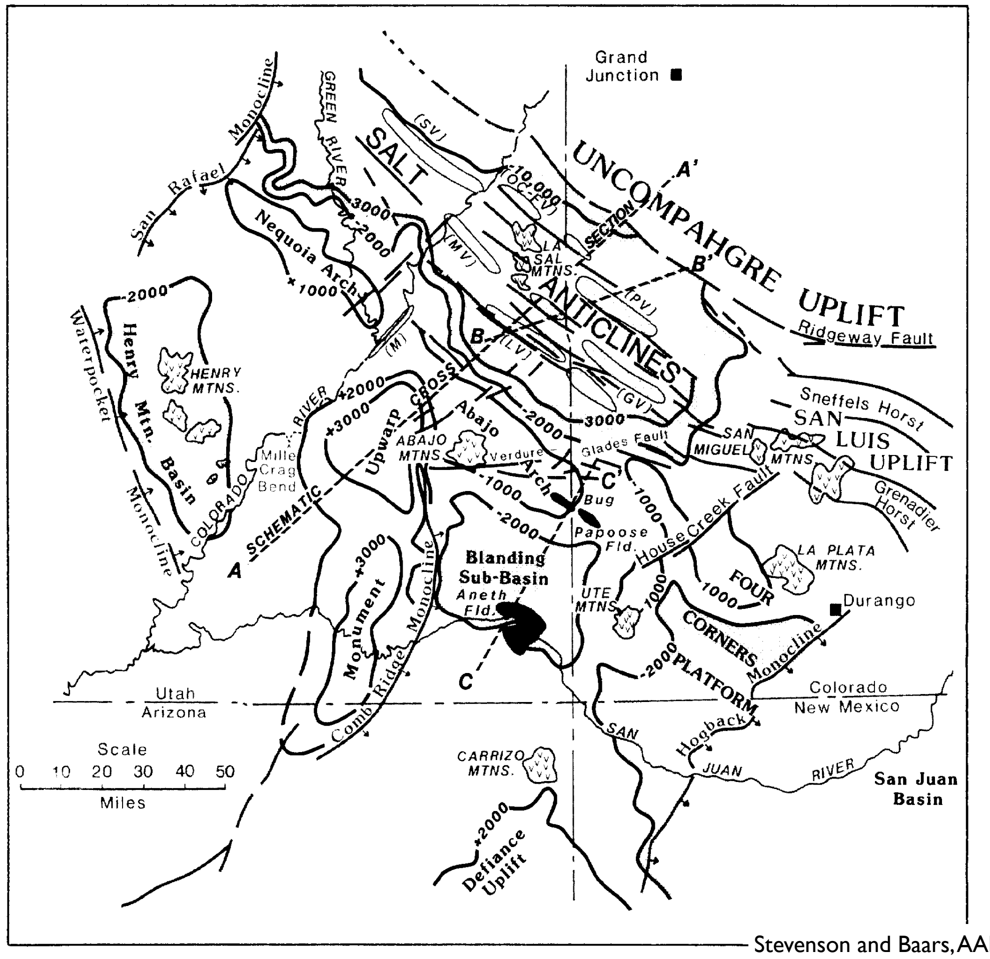
Sweet and Soreghan, GSA Bull 2009

Transport changes during Fountain deposition. (c) shows bedding in black squares from lower-middle Fountain near fold indicating folding was done before upper Fountain deposited.

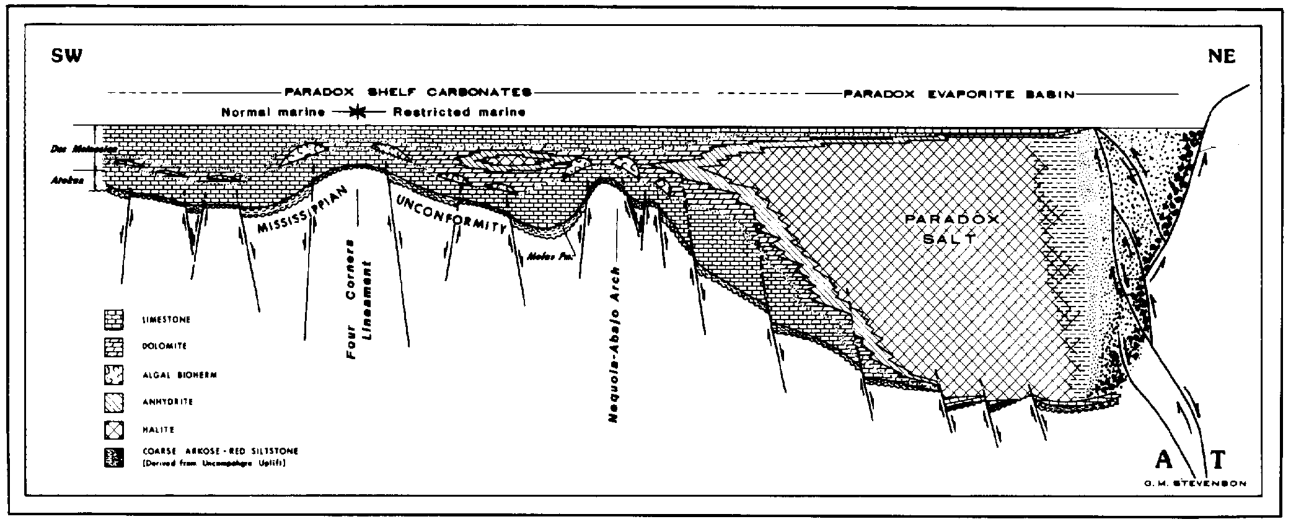


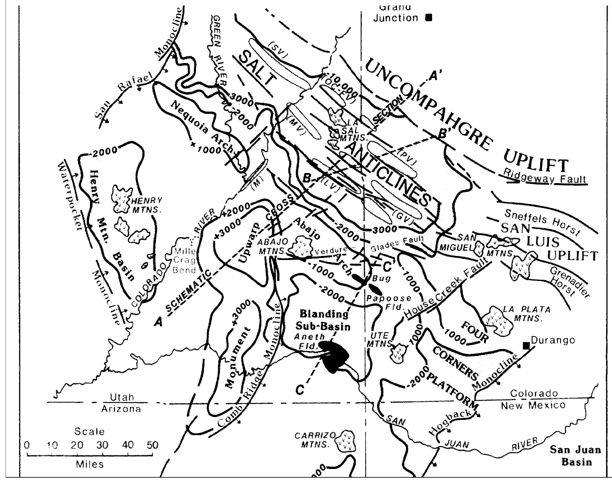
Sweet and Soreghan, GSA Bull 2009

From this conclude that faulting on Ute Pass fault was active early and then shutdown, allowing more of an axial transport.



Stevenson and Baars, AAPG Mem 41, 1986

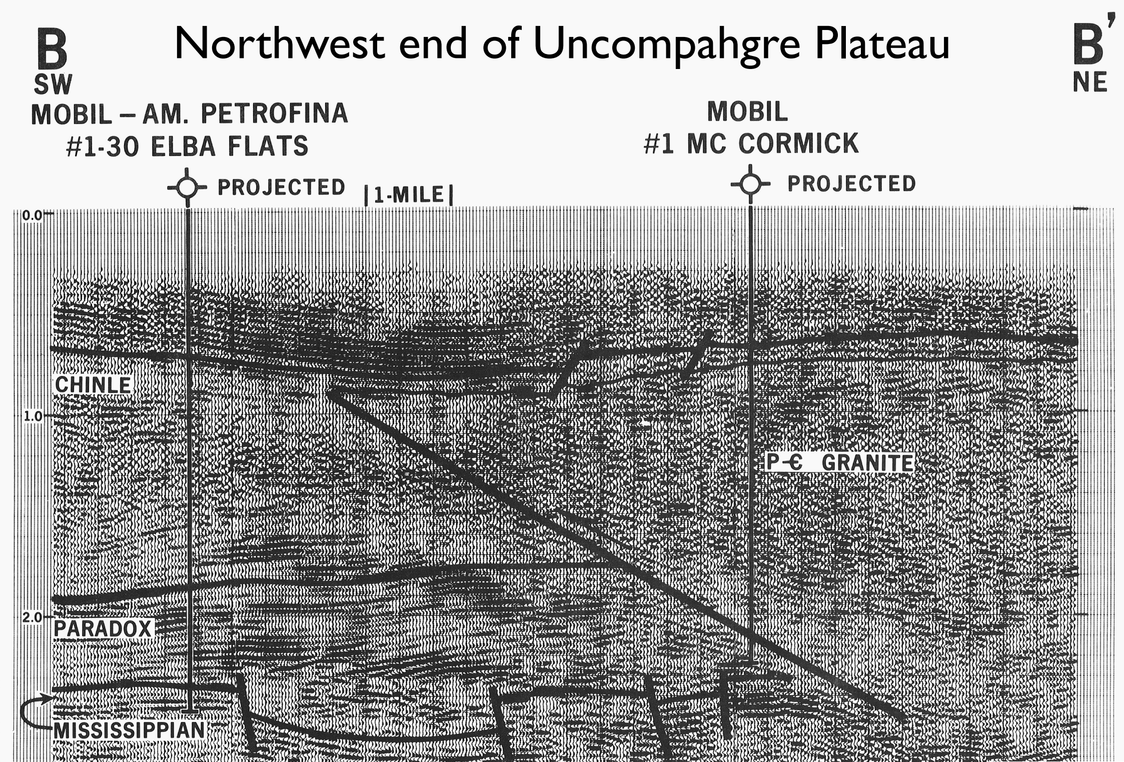


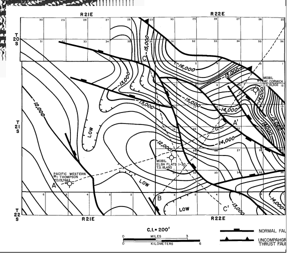


Inferred lots of normal faults and strike-slip faults

Stevenson and Baars, AAPG Mem 41, 1986

Northwest end of Uncompahgre Plateau





Frahme and Vaughn, RMAG 1983

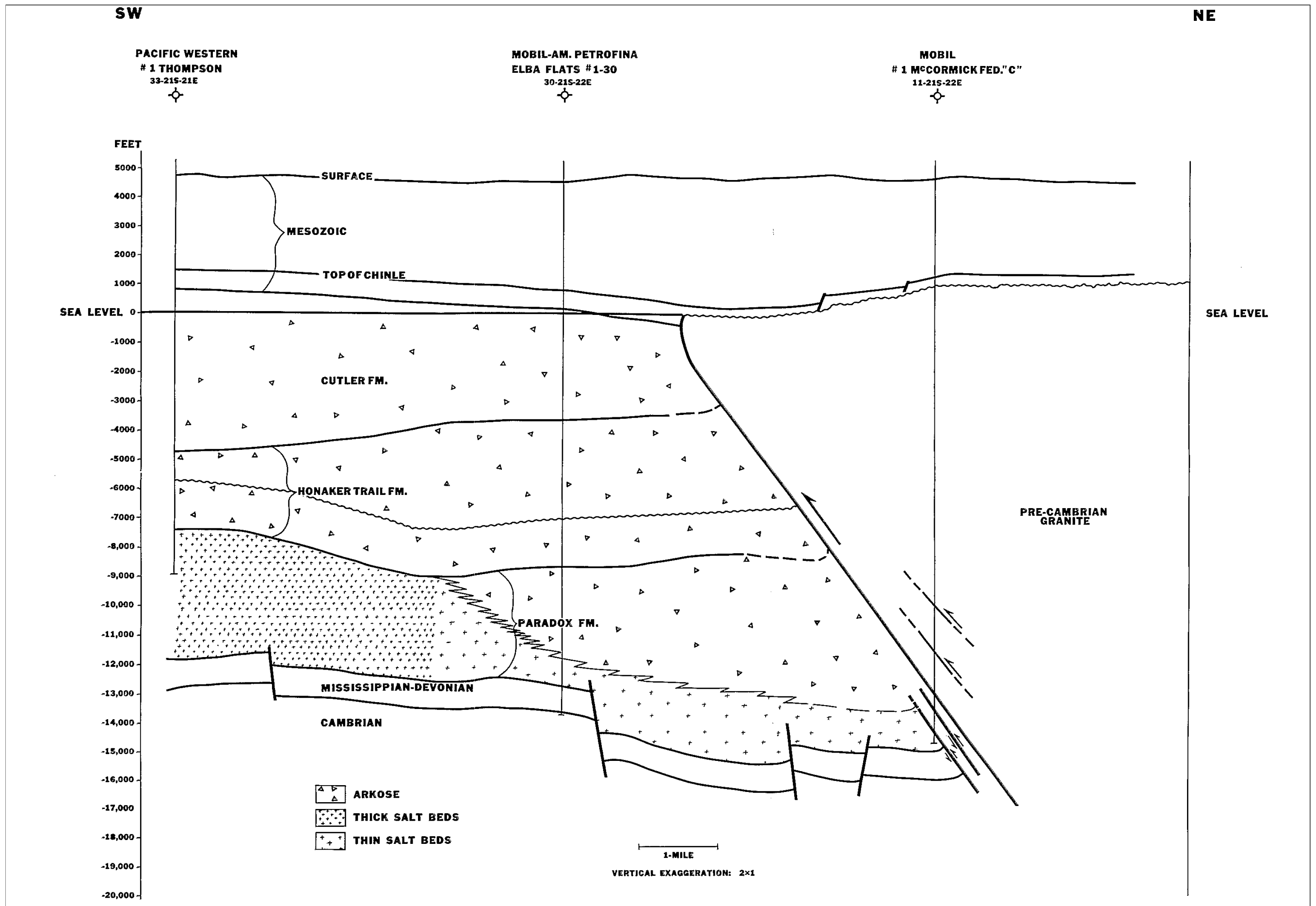
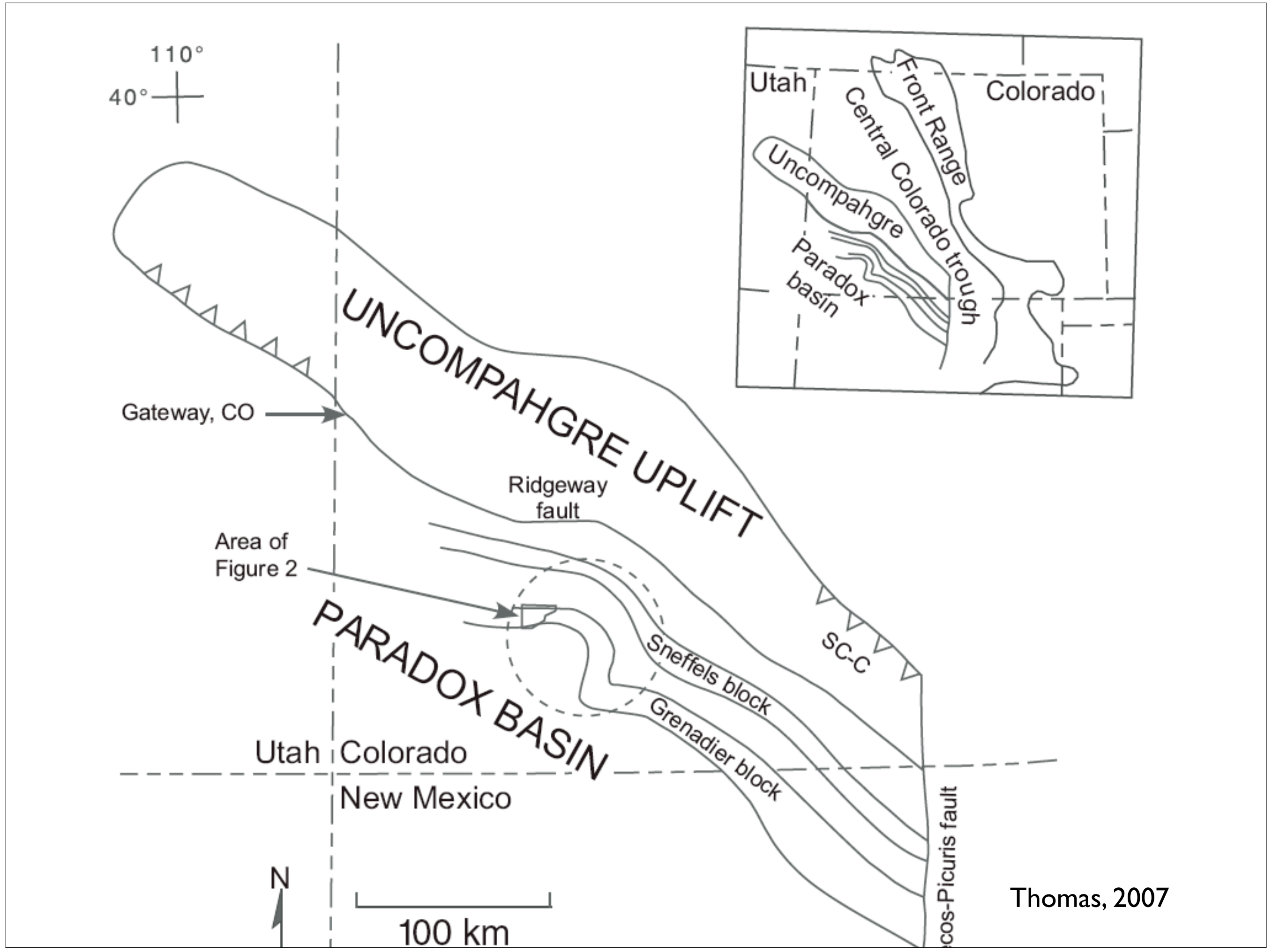


Figure 9. Generalized cross-section model of the northern Uncompahgre front.

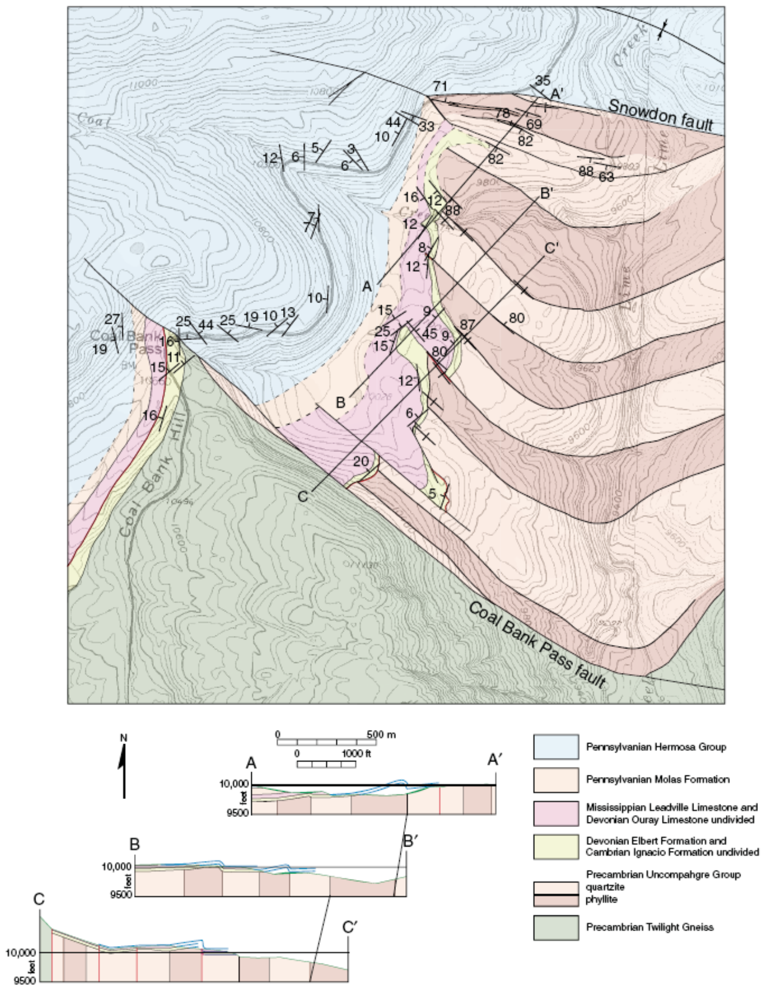
Frahme and Vaughn, RMAG 1983

Possible strike-slip along this fault (or partitioned slip) quite possible.



Thomas, 2007

If NE-SW shortening, then an E-W segment should have sinistral faulting as well…



Thomas, 2007

Lot of subtlety here. First up, Thomas notes the cores of the anticlines in the lower Pz are the upright phyllite. Phyllite extends above the planar unconformity of the qtzts. “Each of three anticlines plunges and flattens northeastward along strike of the underlying quartzite–phyllite, and the plunging noses of the anticlines define a sinistral, en echelon alignment, which trends northward between the Coal Bank Pass and Snowdon faults”–so source of sinistral interpretation. Also this is NE–SW shortening. Snowdon Fault has vertical throw decreasing to WNW, but considered strike-slip, termination in anticline in Hermosa Group provides date. So the throw on these makes them look right-lateral but the argument here is they are sinistral.

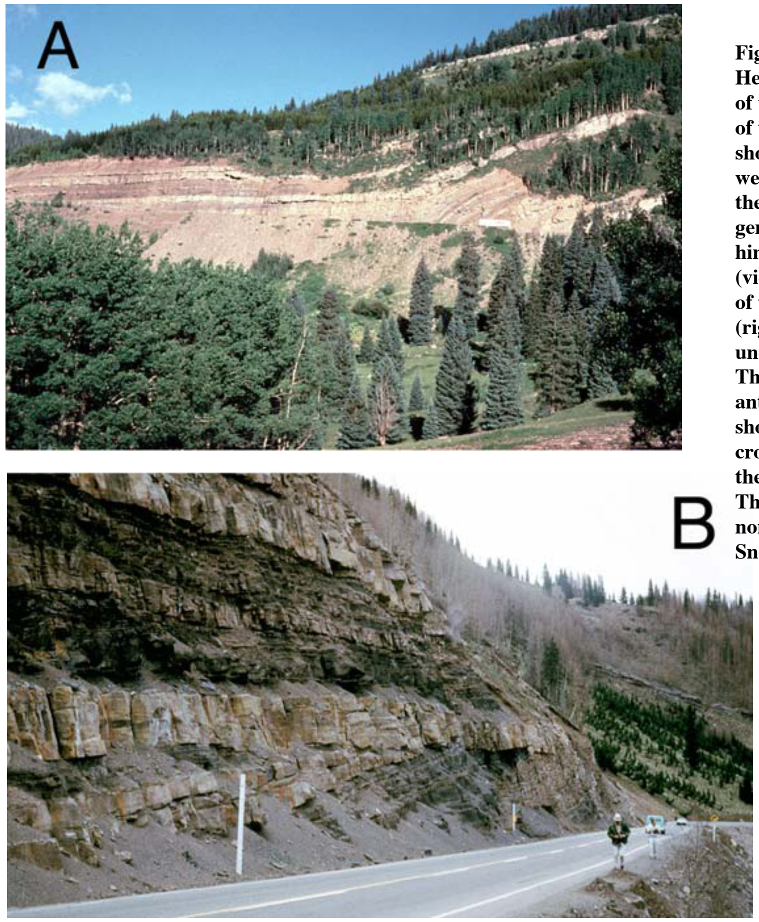
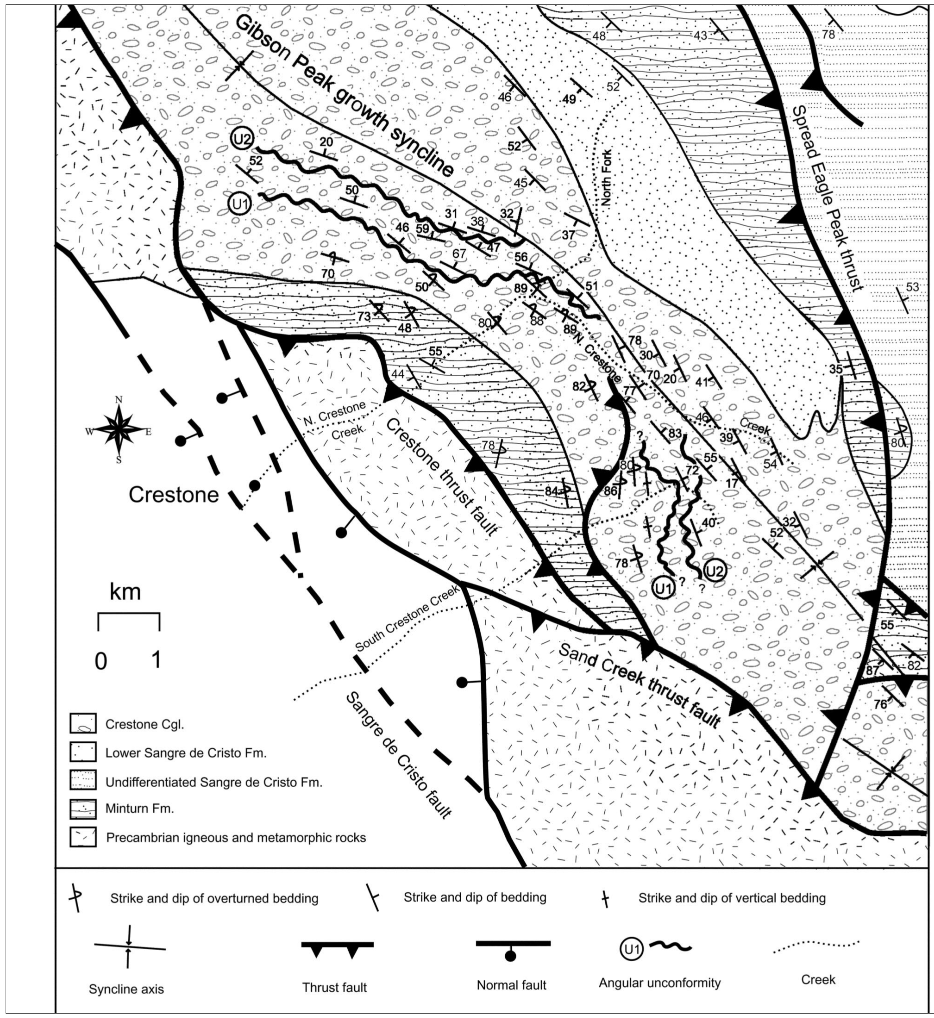
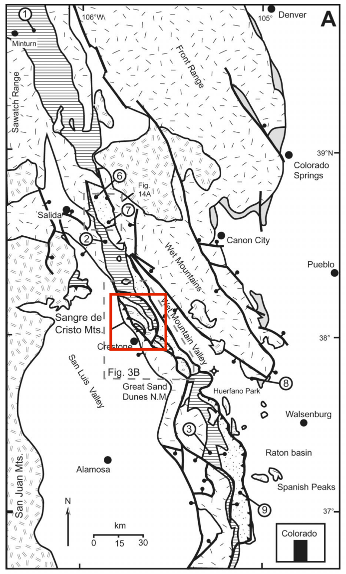


Figure 9. Photographs of angular unconformity in Hermosa beds exposed along U.S. Highway 550 south of the Snowdon fault. Orientations of the views are shown in Figure 2, and the location is shown in Figure 5. (A) Steep south limb of anticline at west end of the Snowdon fault; the angular unconformity is exposed beneath more gently dipping beds south (left in view) of the abrupt hinge on the south limb of the anticline (view to west). The crest of the anticline and the trace of the Snowdon fault are out of the view to the north (right in view). (B) Angular unconformity exposed in highway cut (view to north). The hinge and steep up-turn of the south limb of the anticline are hidden behind the shoulder of the highway cut. The Snowdon fault crosses the highway approximately at the position of the most distant car on the highway. The north-dipping beds in the distance are in the north limb of the anticline on the north side of the Snowdon fault.

Thomas, 2007

These are the “positive flower structure” (anticline) at the north end of the Snowdon Fault.





Hoy and Ridgway, GSA Bull, 2002

“Growth syncline” indicates the syncline was growing as the sediments were being deposited. Thrust fault dying into

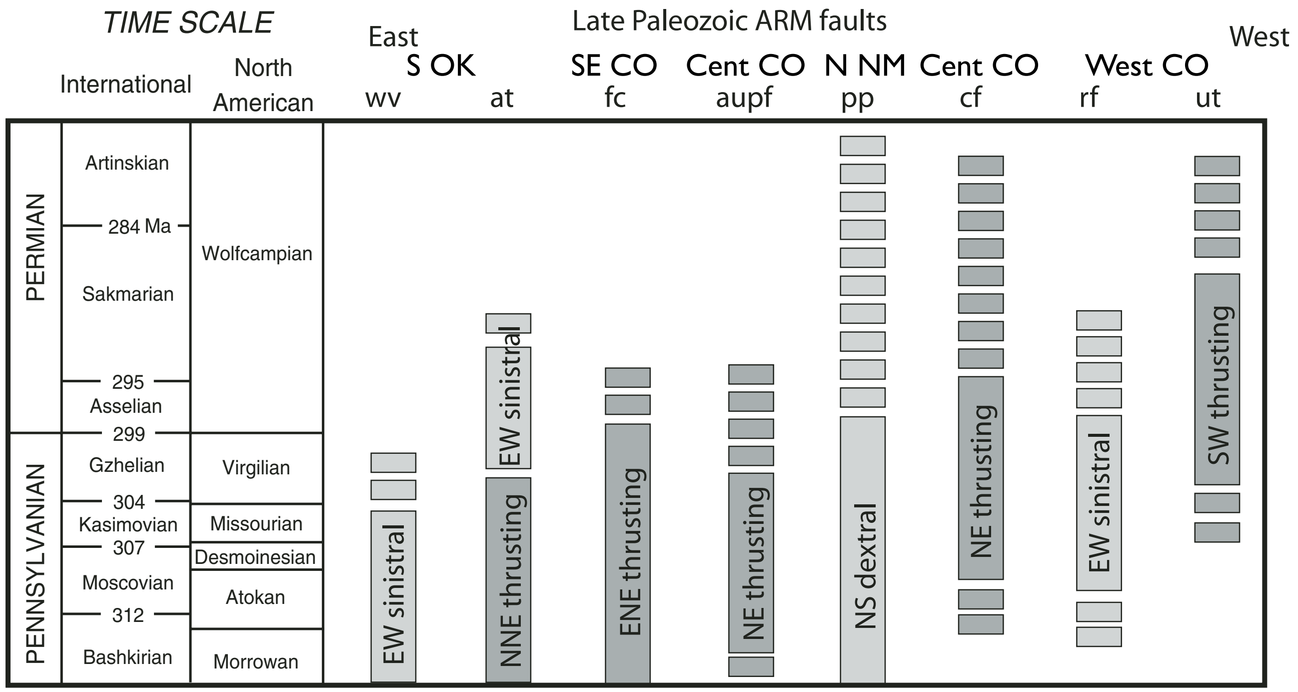
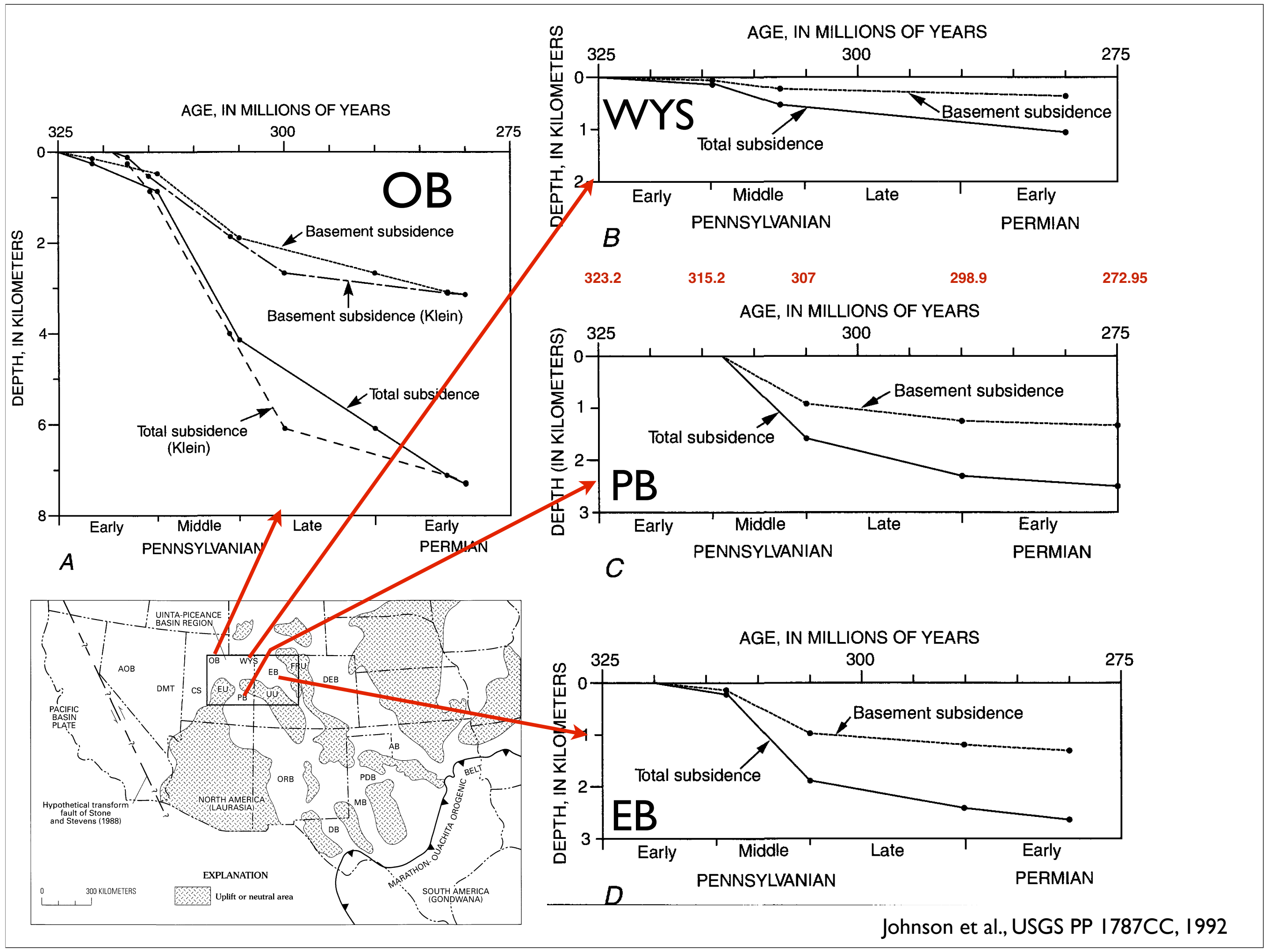


Figure 17. Inferred timing and kinematics of faults with a documented ancestral Rocky Mountains history. Light gray represents predominantly strike-slip motion, whereas dark gray indicates predominantly reverse motion. Dashed bars indicate range of time faulting is thought to have initiated (bottom of figure) or ceased (top of figure). Abbreviations: ut—Uncompahgre thrust (slip-sense from Frahme and Vaughn, 1983); rf—Ridgeway fault (slip-sense from Stevenson and Baars, 1986; Thomas, 2007); pp—Picuris-Pecos fault (slip-sense from Cather et al., 2006; Wawrzyniec et al., 2007); ct—Crestone thrust (slip-sense from Hoy and Ridgway, 2002); aupf—ancestral Ute Pass fault (slip-sense data herein); fc—Freezeout Creek fault (slip-sense from Maher, 1953; McKee, 1975); at—Anadarko thrust (slip-sense from Brewer et al., 1983); wv—Washita Valley fault (slip-sense from Tanner, 1967). Time scale is from Gradstein et al. (2004).

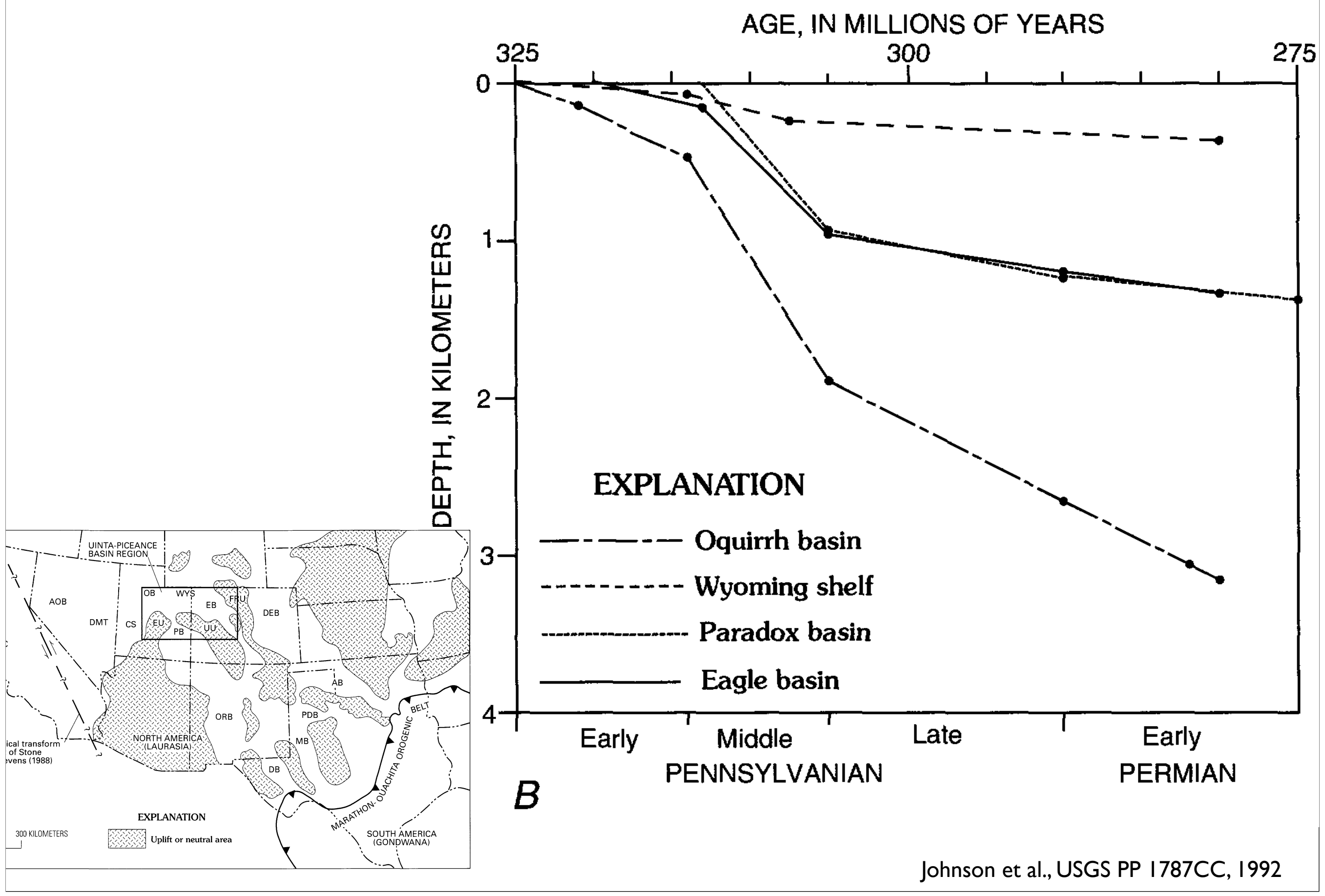
Sweet and Soreghan, GSA Bull 2009



Johnson et al., USGS PP 1787CC, 1992

Note that this is with an older timescale, too.
Early Penn now 323.2–315.2
Middle 315.2–307
Late 307–298.9
Early Permian 298.9–272.95(?)

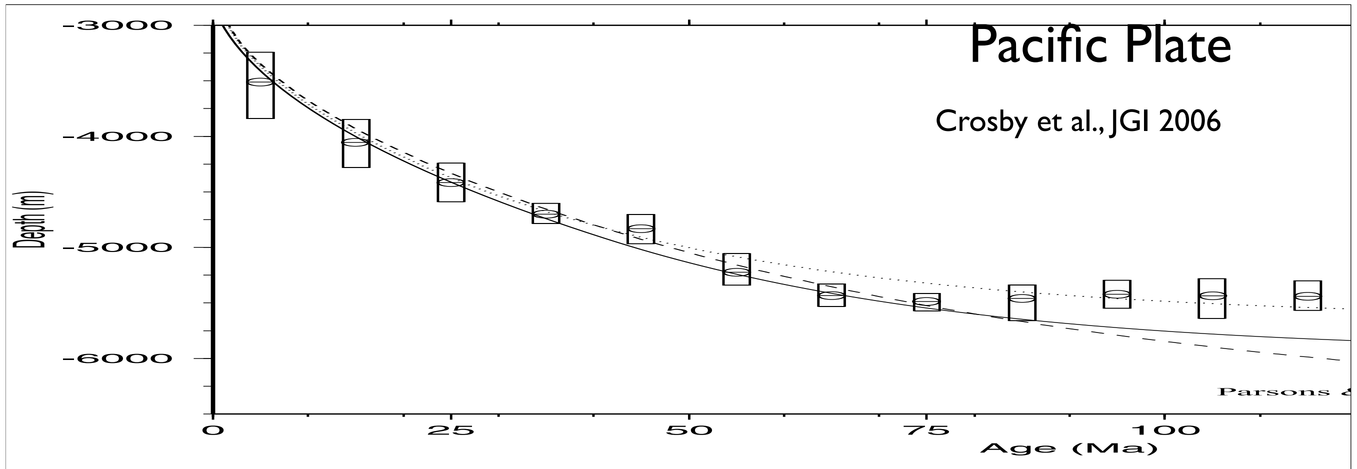
Tectonic Subsidence

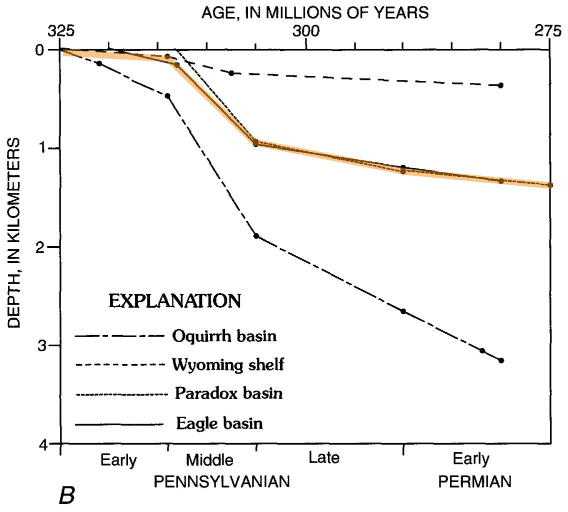


Johnson et al., USGS PP 1787CC, 1992

Pacific Plate

Crosby et al., JGI 2006





Johnson et al., USGS PP 1787CC, 1992

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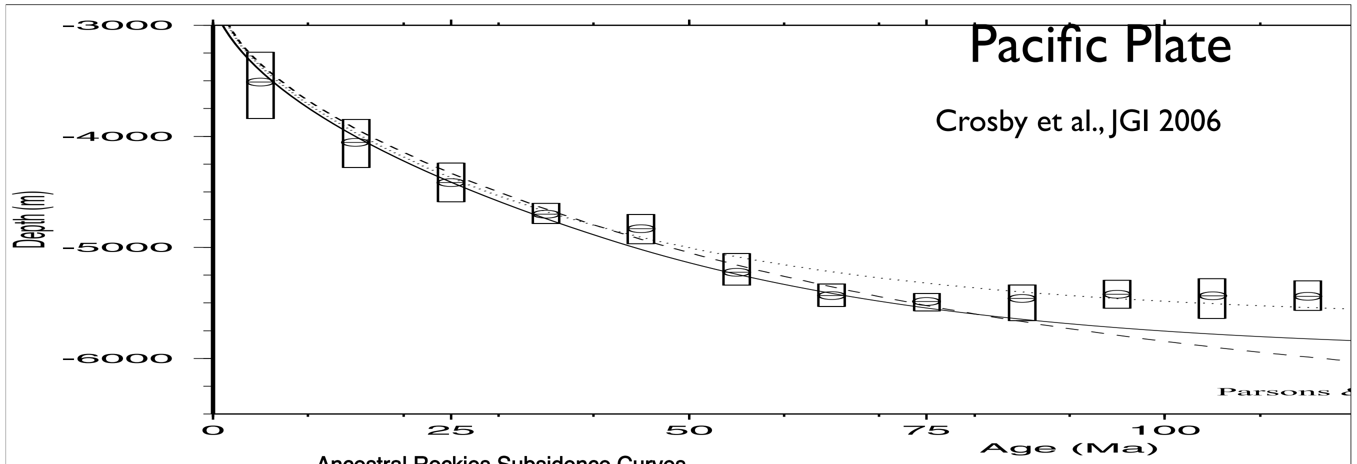
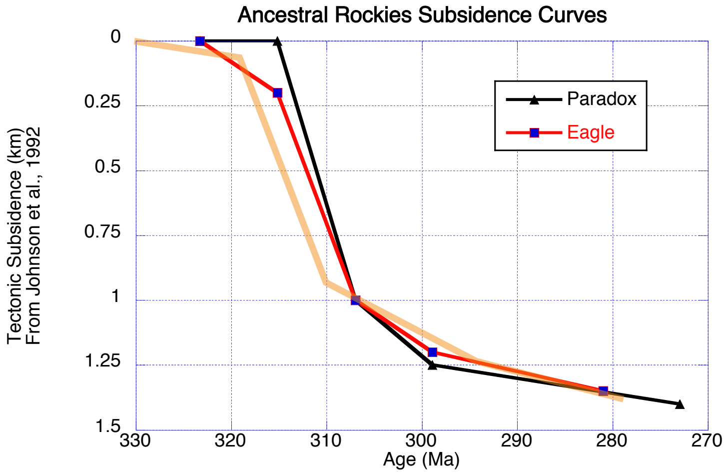
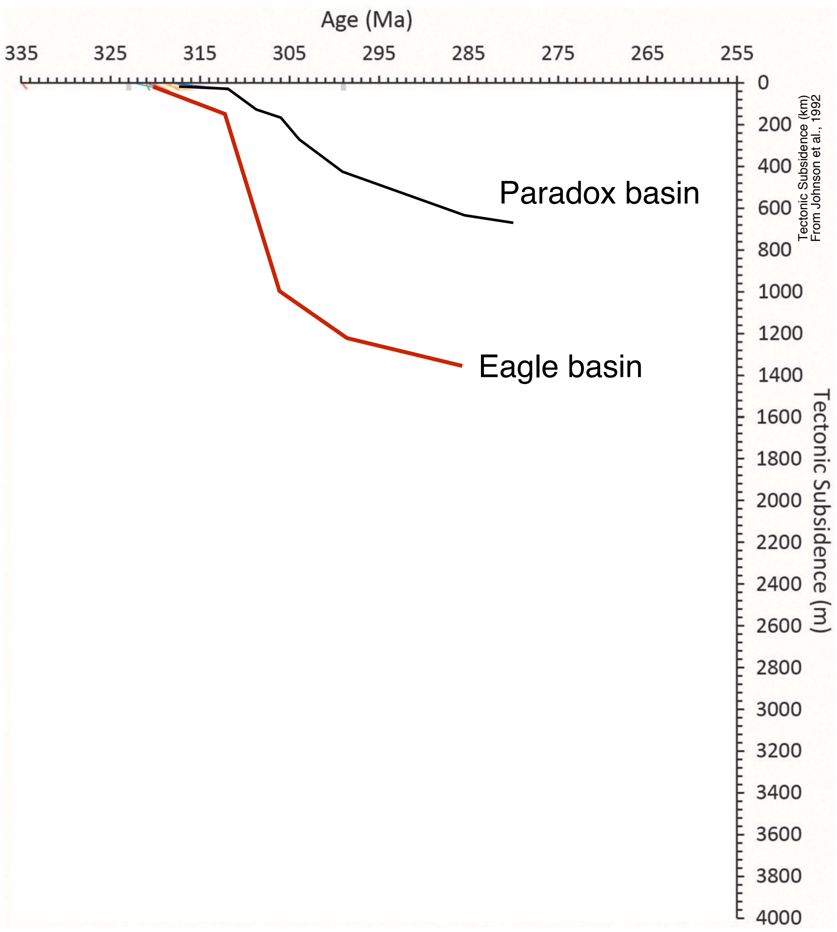
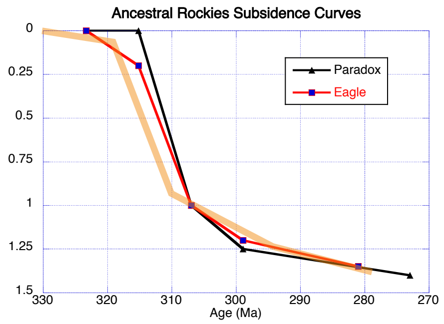




Updated timescale
(GSA v5, 2018)

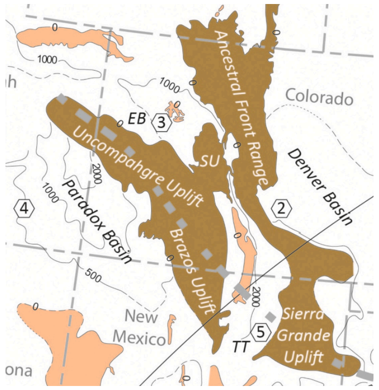
Johnson et al., USGS PP 1787CC, 1992





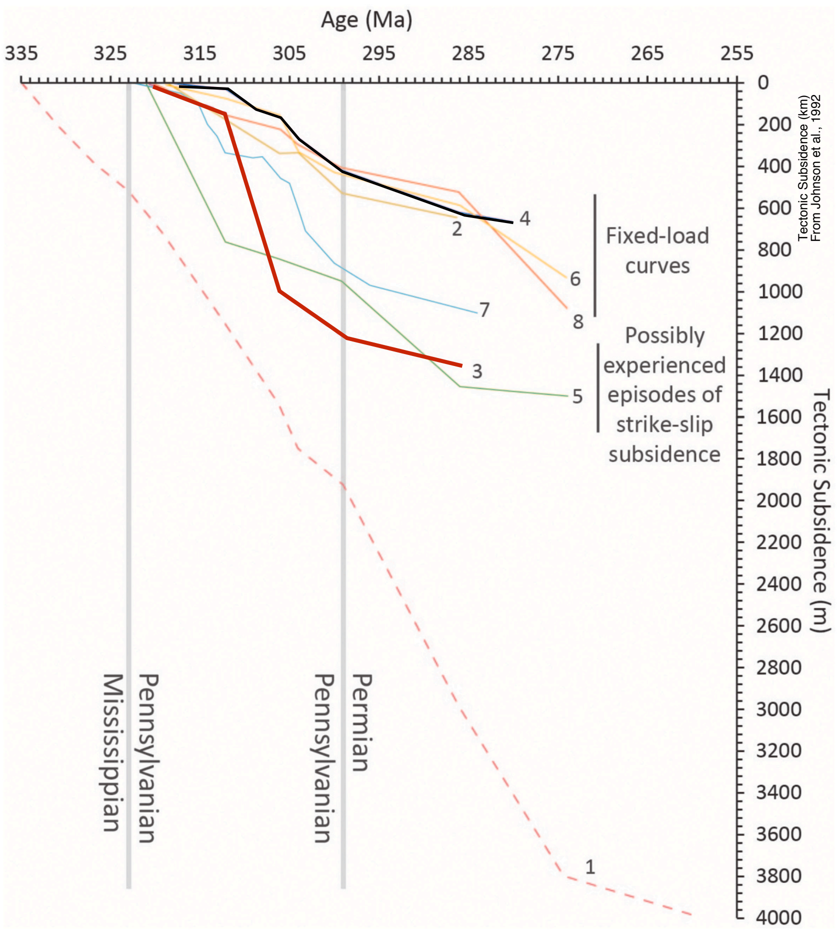
Updated timescale (GSA v5, 2018)

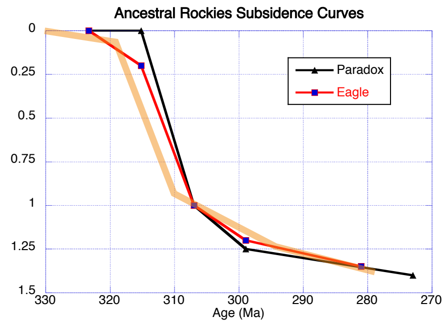
Johnson et al., USGS PP 1787CC, 1992



Sweet et al., P^3, 2021

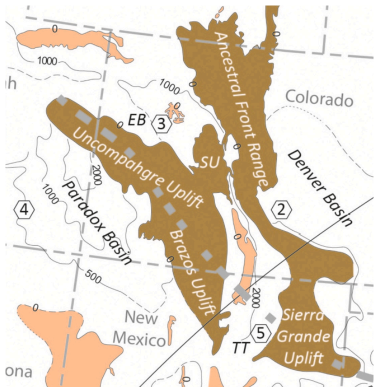
1 Anadarko, **2 South Denver, 3 Eagle, 4 Paradox, 5 Taos Trough**, 6 Midland, 7 Orogrande, 8 Pedregosa





Updated timescale (GSA v5, 2018)

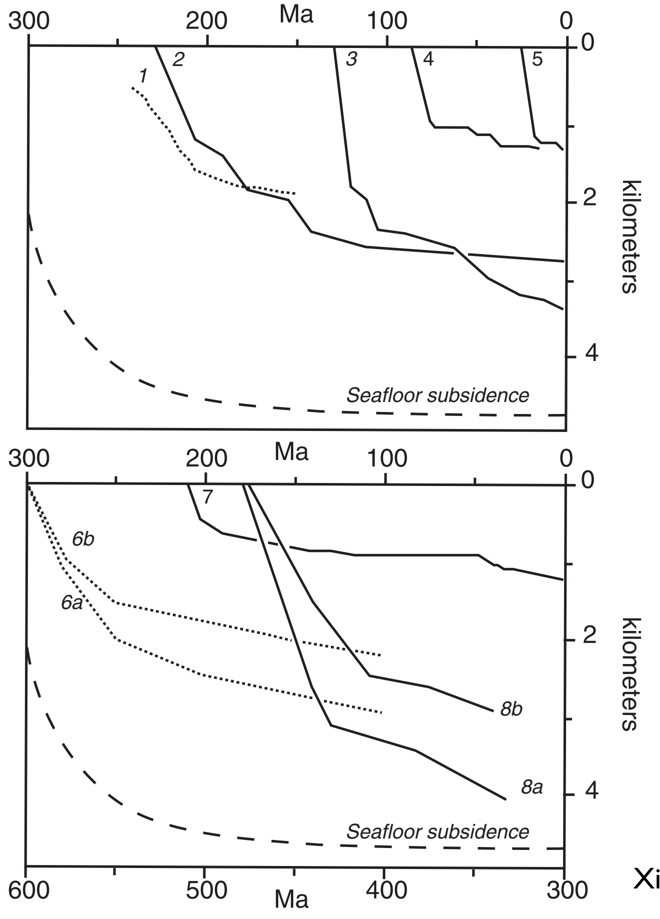
Johnson et al., USGS PP 1787CC, 1992



Sweet et al., P^3, 2021

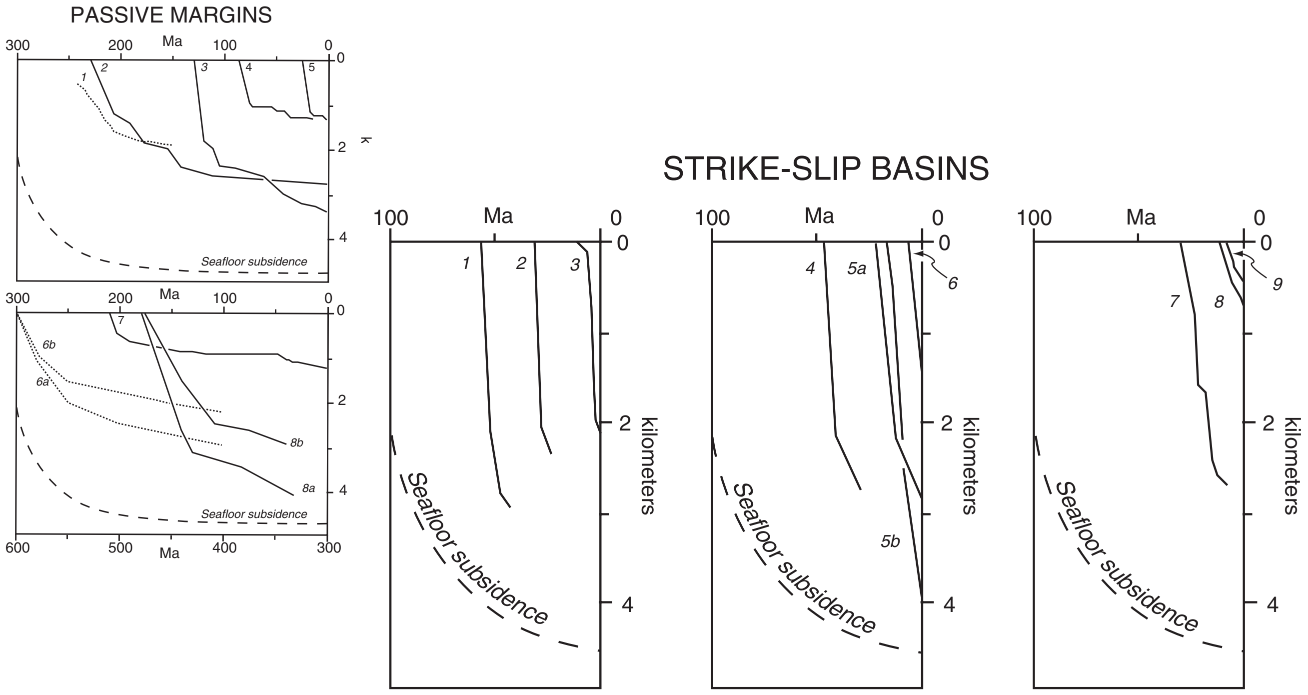
1 Anadarko, **2 South Denver, 3 Eagle, 4 Paradox, 5 Taos Trough**, 6 Midland, 7 Orogrande, 8 Pedregosa. Difference in Paradox probably location of section used. “Fixed load curves” refer to foresees where the load just grows in place without propagating outward.

PASSIVE MARGINS



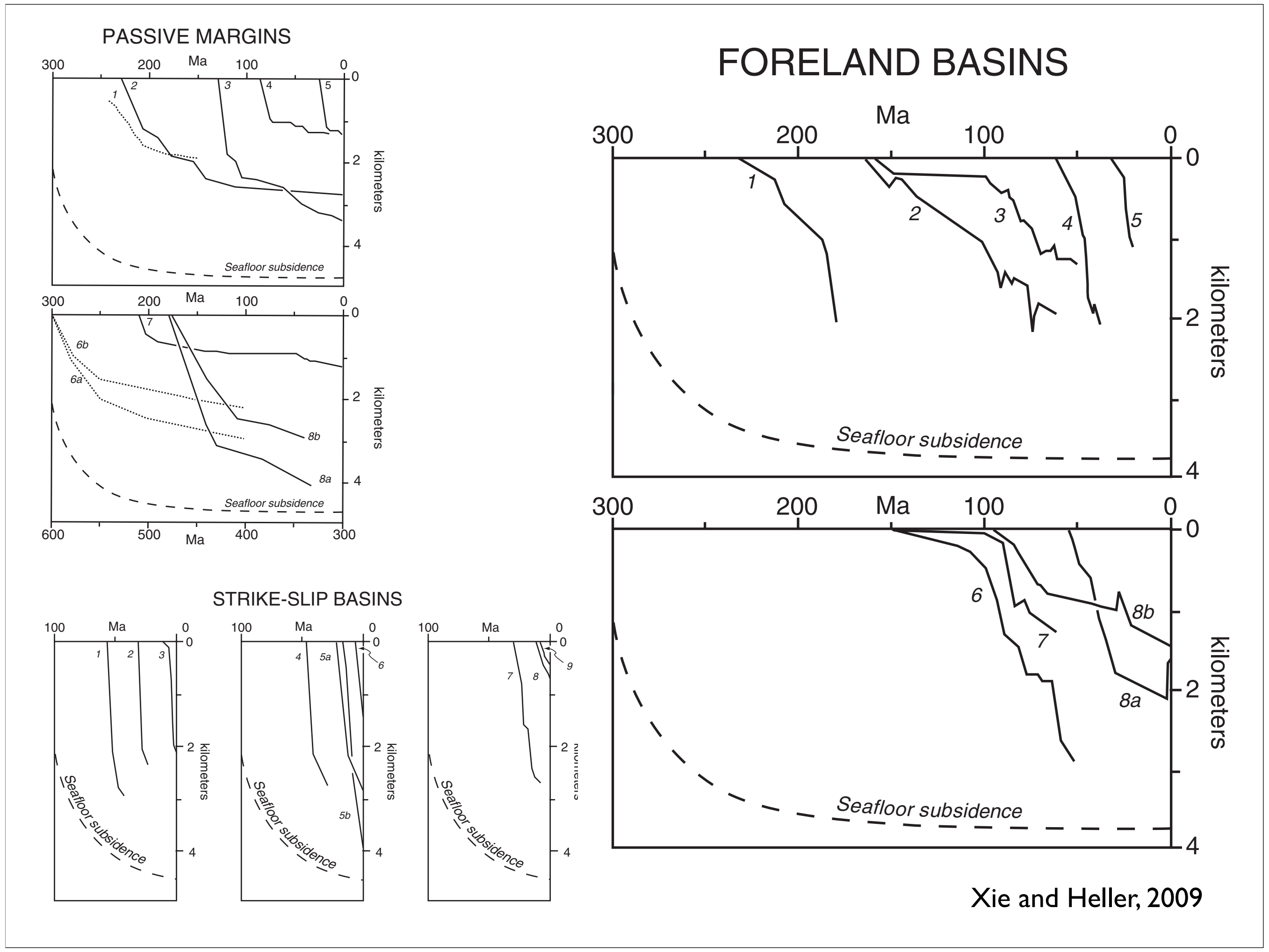
Xie and Heller, 2009

Figure 2. Tectonic subsidence curves for passive margin settings. Locations shown on Figure 1. Solid curves correspond to time scale at top of graph and dotted lines to time scale at bottom of graph. Thermal decay curve (dashed) for subsidence of cooling seafloor (Stein and Stein, 1992), minus (i.e., shallowed) 500 m, is shown for comparison. 1—Paleozoic Miogeocline, southern Canadian Rocky Mountains (Bond and Kominz, 1984); 2—Moroccan Basin (Ellouz et al., 2003); 3—Campos Basin (Mohriak et al., 1987); 4—Gippsland Basin (Falvey and Mutter, 1981; P. Yin, 1985, per– sonal commun.); 5—Gulf of Lion (Benedicto et al., 1996); 6—U.S. Cordilleran Miogeocline (Bissell, 1974; Armin and Mayer, 1983; Devlin et al., 1986; Devlin and Bond, 1988); 7—Lusitanian Basin (Stapel et al., 1996); 8—U.S. Atlantic margin (Steckler and Watts, 1978; Swift et al., 1987).



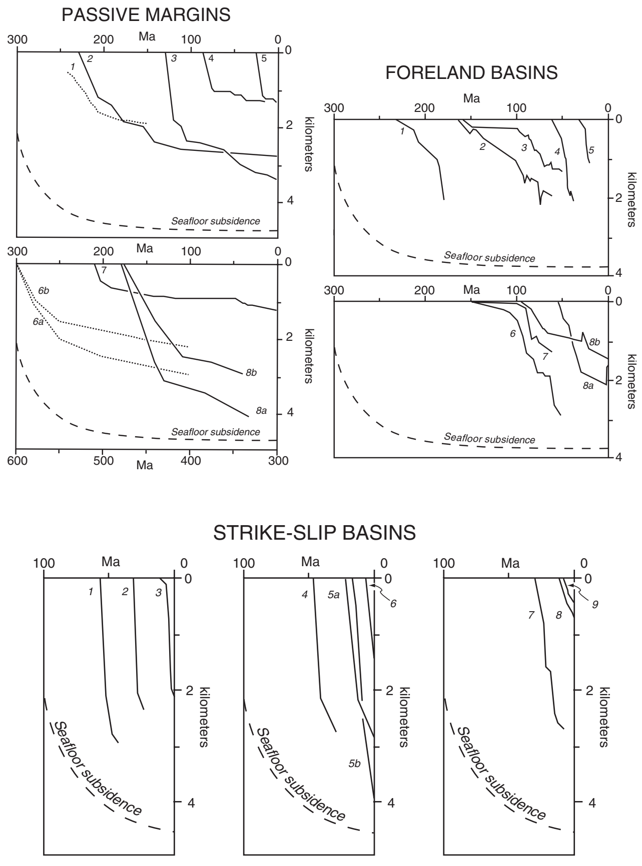
Xie and Heller, 2009

Figure 3. Tectonic subsidence curves for strike-slip basins. Locations shown in Figure 1. Thermal decay curve (dashed) for subsidence of cooling seafloor (Stein and Stein, 1992), minus 500 m, is shown for comparison. 1—Chuck- anut Basin (Johnson, 1984, 1985); 2—Ridge Basin (Crowell and Link, 1982; Karner and Dewey, 1986); 3—Death Valley (Hunt and Mabey, 1966); 4—Salinian block (Graham, 1976); 5—Los Angeles Basin (Rumelhart and Ingersoll, 1997); 6—Gulf of California (Curray and Moore, 1984); 7—Cuyama Basin (Dickinson et al., 1987); 8—Bozhang Depression (Hu et al., 2001); 9—Salton Trough (Kerr et al., 1979).



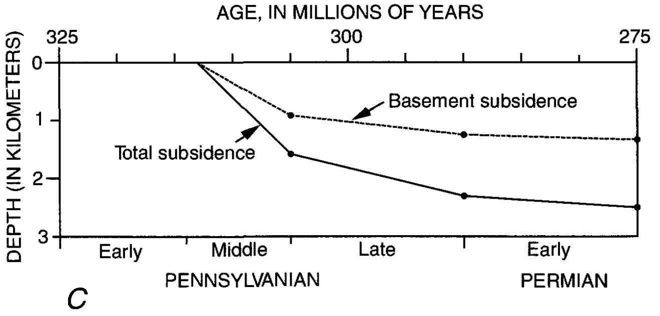
Xie and Heller, 2009

Figure 6. Tectonic subsidence of foreland basins. Locations shown in Figure 1. Thermal decay curve (dashed) for subsidence of cooling seafloor (Stein and Stein, 1992), minus 1500 m, is shown for comparison. 1—Eastern Avalonia, Anglo-Brabant fold belts (van Grootel et al., 1997); 2—Southern Alberta Basin (Gillespie and Heller, 1995); 3—San Rafael Swell, Utah (Heller et al., 1986); 4—Pyrenean foreland basin, Gombrèn (Vergés et al., 1998); 5—Swiss Molasse basin (Burkhard and Sommaruga, 1998) modified from total subsidence using water:sediment density contrast); 6—Hoback Basin, Wyoming (Cross, 1986); 7—Green River Basin, Wyoming (Cross, 1986; Heller et al., 1986); 8—Magallanes Basin (Biddle et al., 1986).

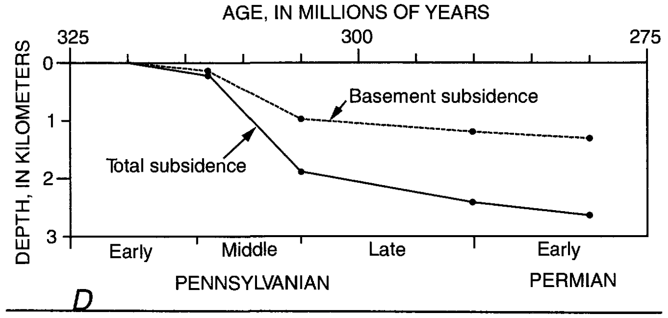


Xie and Heller, 2009

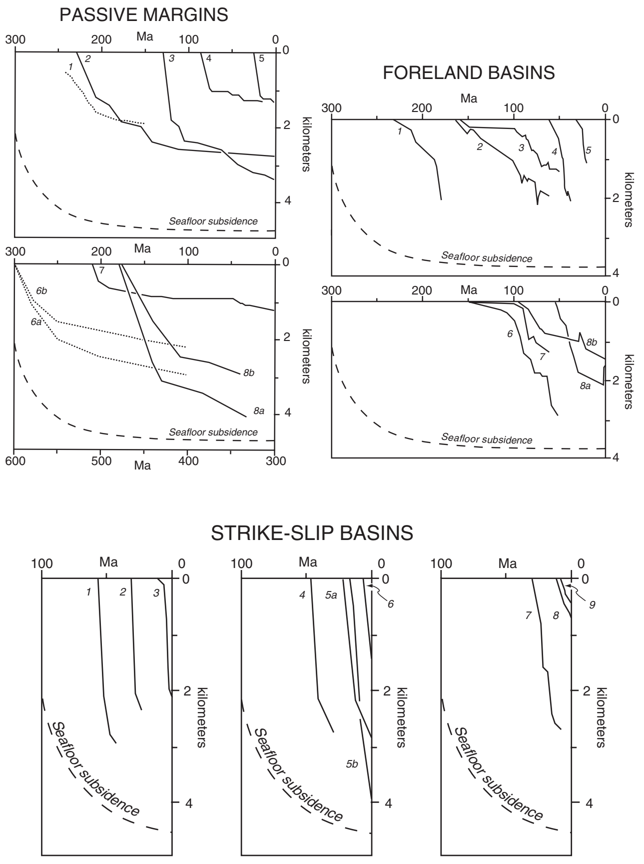
Paradox Basin



Eagle Basin

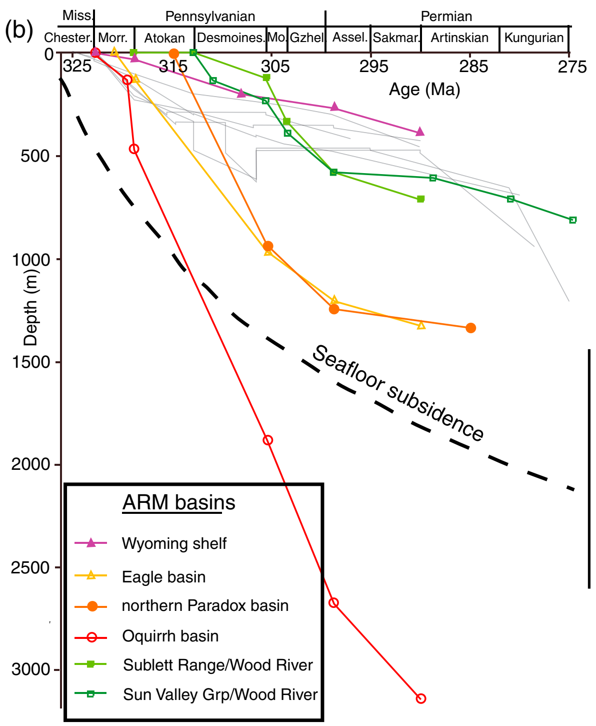


Johnson et al., USGS Bull 1787CC, 1992



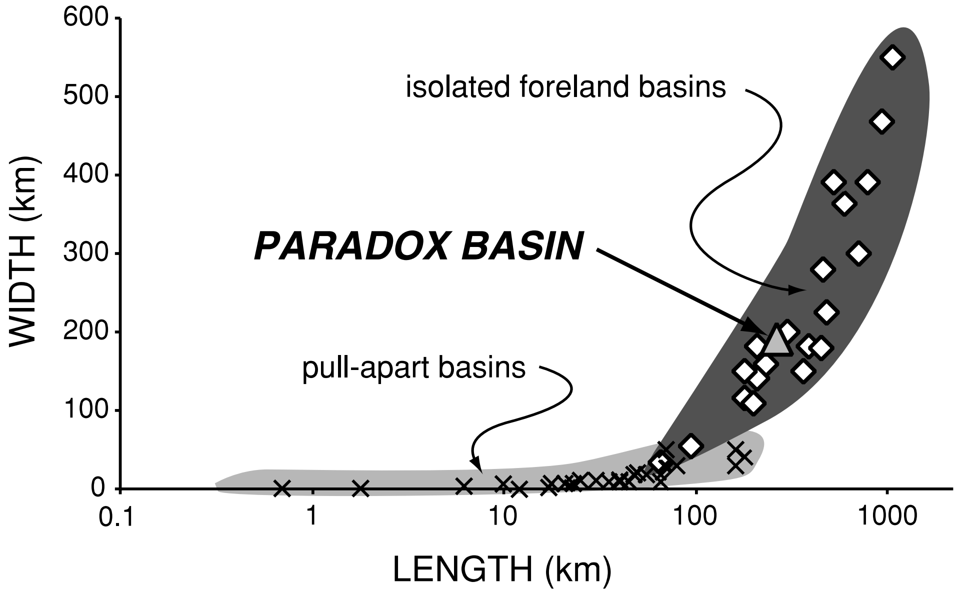
Xie and Heller, 2009

Paradox Basin



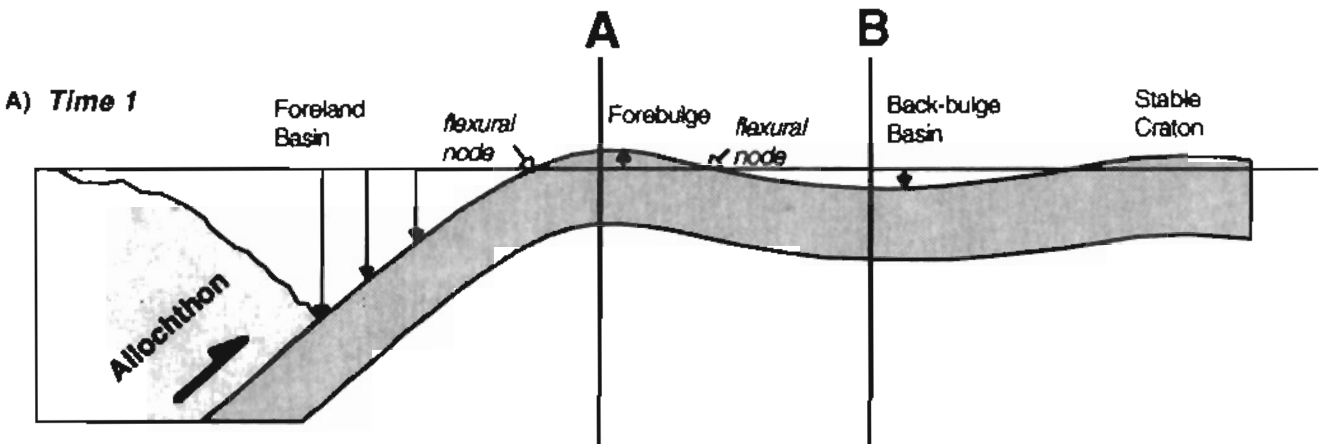
Sturmer et al., *Tectonics*, 2018

SO how does more recent subsidence curves look like? Let's delve into the foreland basin profiles a bit—there are other criteria to consider…



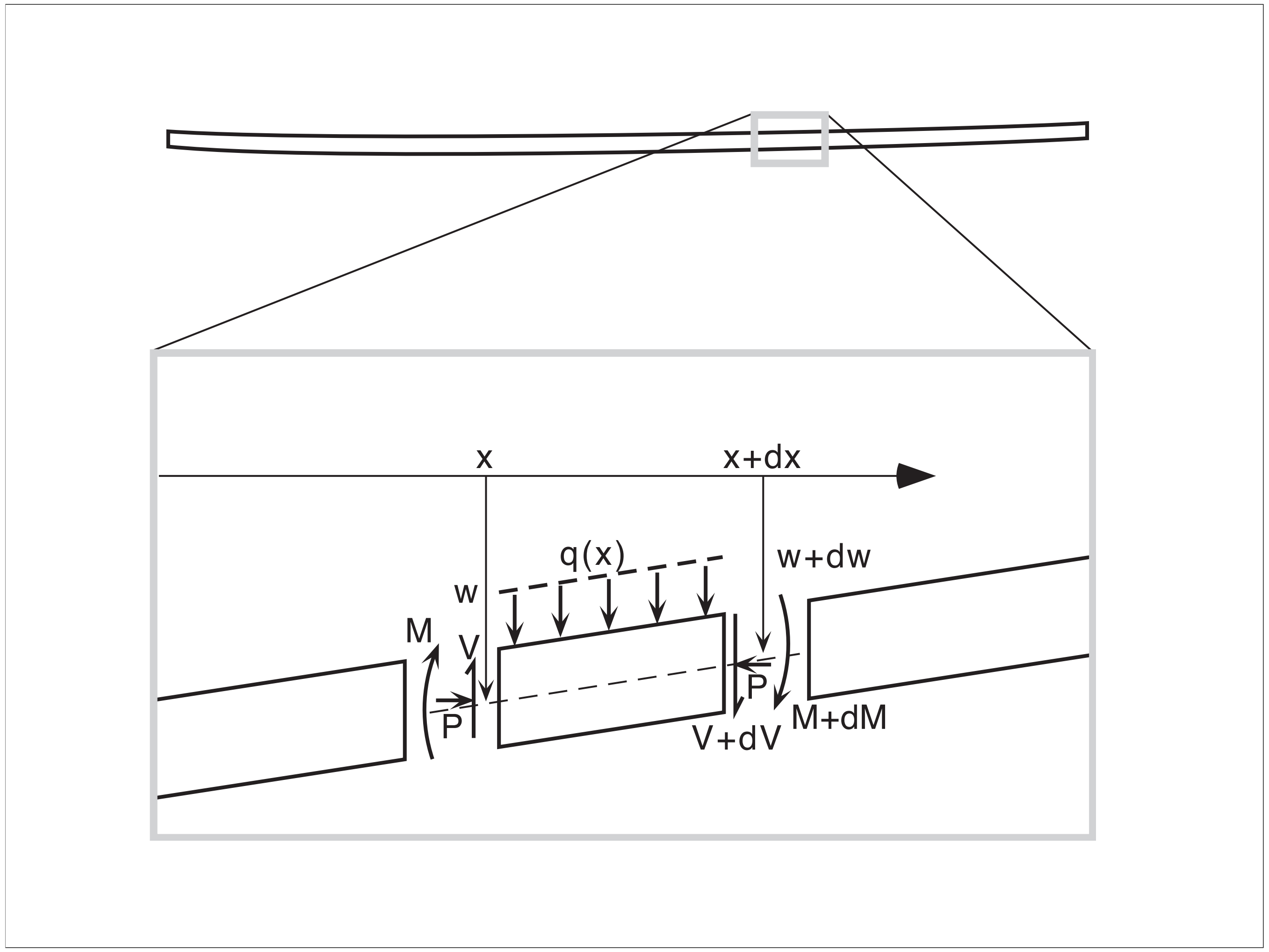
Barbeau, 2003

Pull-apart are strike-slip basins on previous figures.

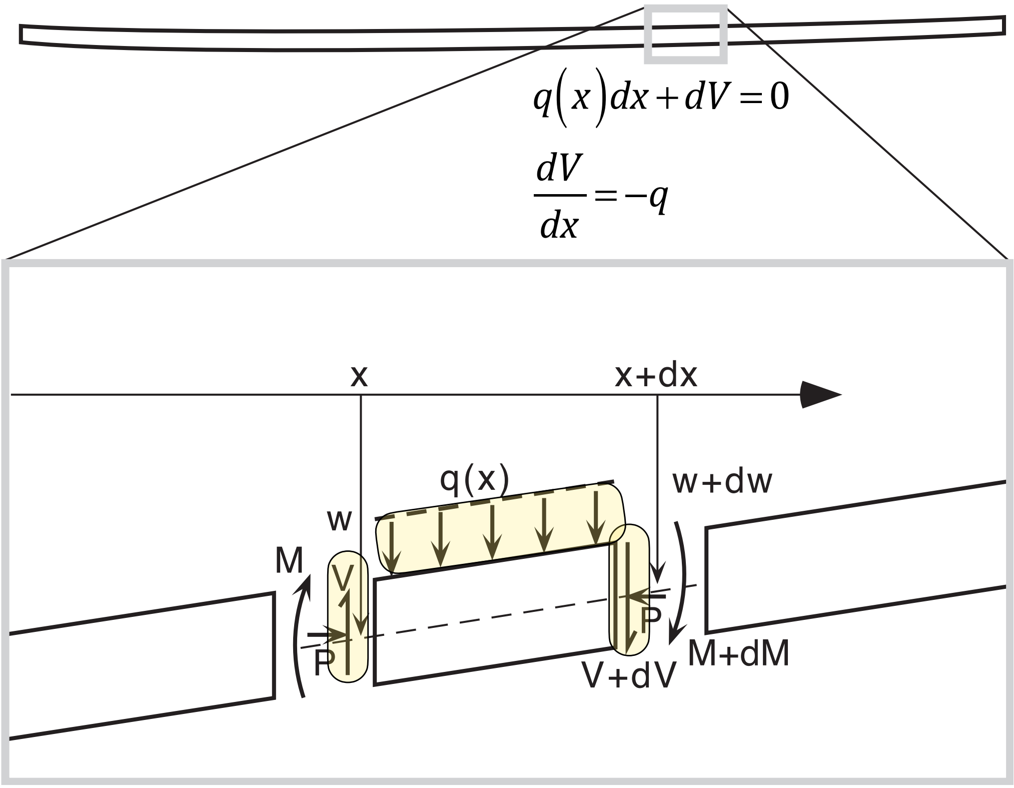


Giles and Dickinson, 1995

Might be worth discussing “allochthon” vs “autochthon”



Some assumptions at the start. One is that the plate’s thickness isn’t varying.



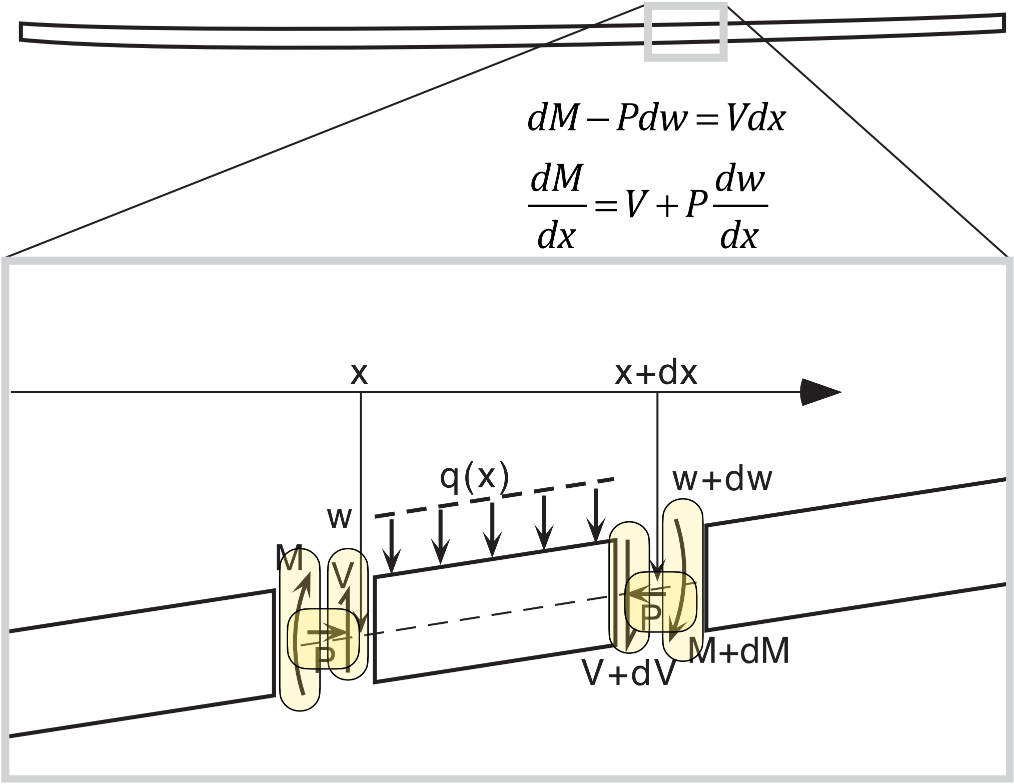
$$q(x)\,dx + dV = 0$$

$$\frac{dV}{dx} = -q$$

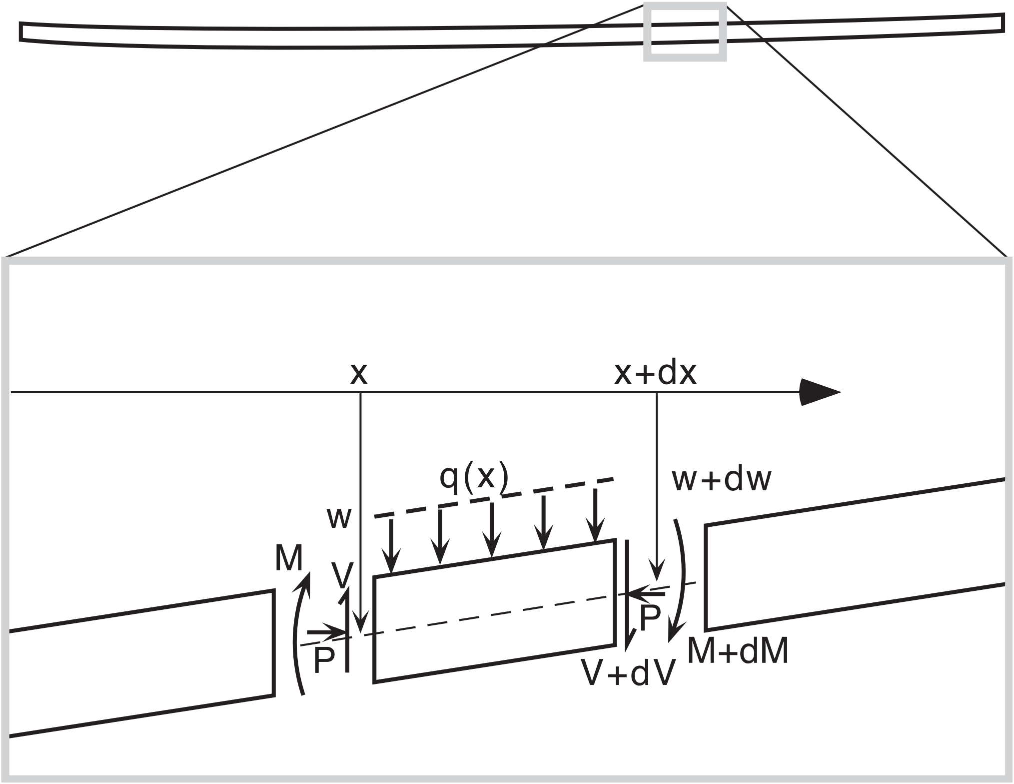
$$\frac{dV}{dx} = -q$$

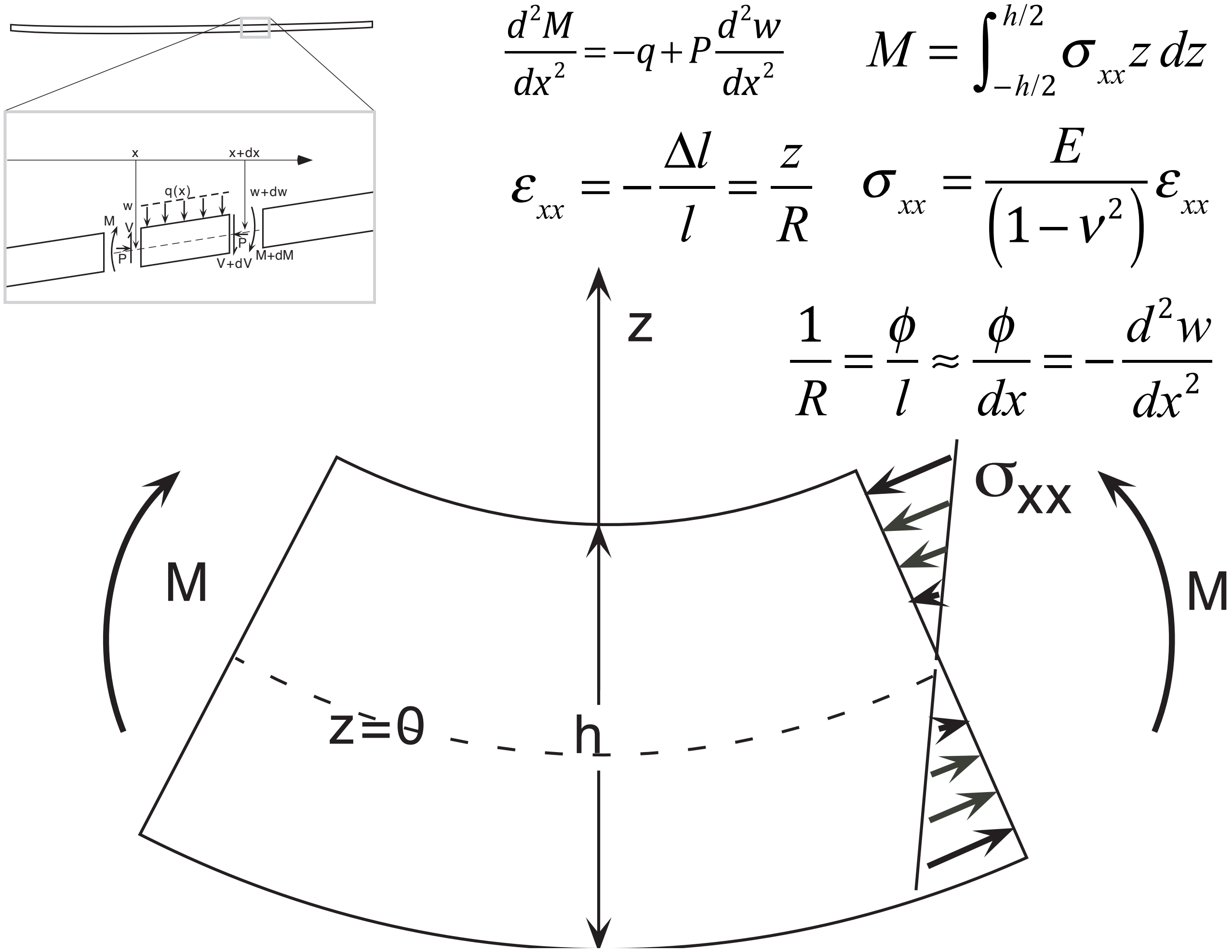
$$dM - Pdw = Vdx$$

$$\frac{dM}{dx} = V + P\frac{dw}{dx}$$



$$\frac{dV}{dx} = -q \qquad \frac{dM}{dx} = V + P\frac{dw}{dx} \quad \Rightarrow \quad \frac{d^2M}{dx^2} = -q + P\frac{d^2w}{dx^2}$$





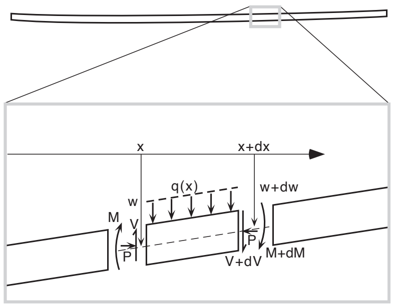
$$\frac{d^2M}{dx^2} = -q + P\frac{d^2w}{dx^2}$$

$$M = \int_{-h/2}^{h/2} \sigma_{xx} z\,dz$$

$$\varepsilon_{xx} = -\frac{\Delta l}{l} = \frac{z}{R}$$

$$\sigma_{xx} = \frac{E}{\left(1-\nu^2\right)}\varepsilon_{xx}$$

$$\frac{1}{R} = \frac{\phi}{l} \approx \frac{\phi}{dx} = -\frac{d^2w}{dx^2}$$



$$\frac{d^2M}{dx^2} = -q + P\frac{d^2w}{dx^2}$$

$$M = \int_{-h/2}^{h/2} \sigma_{xx} z \, dz$$

$$\varepsilon_{xx} = -\frac{\Delta l}{l} = \frac{z}{R}$$

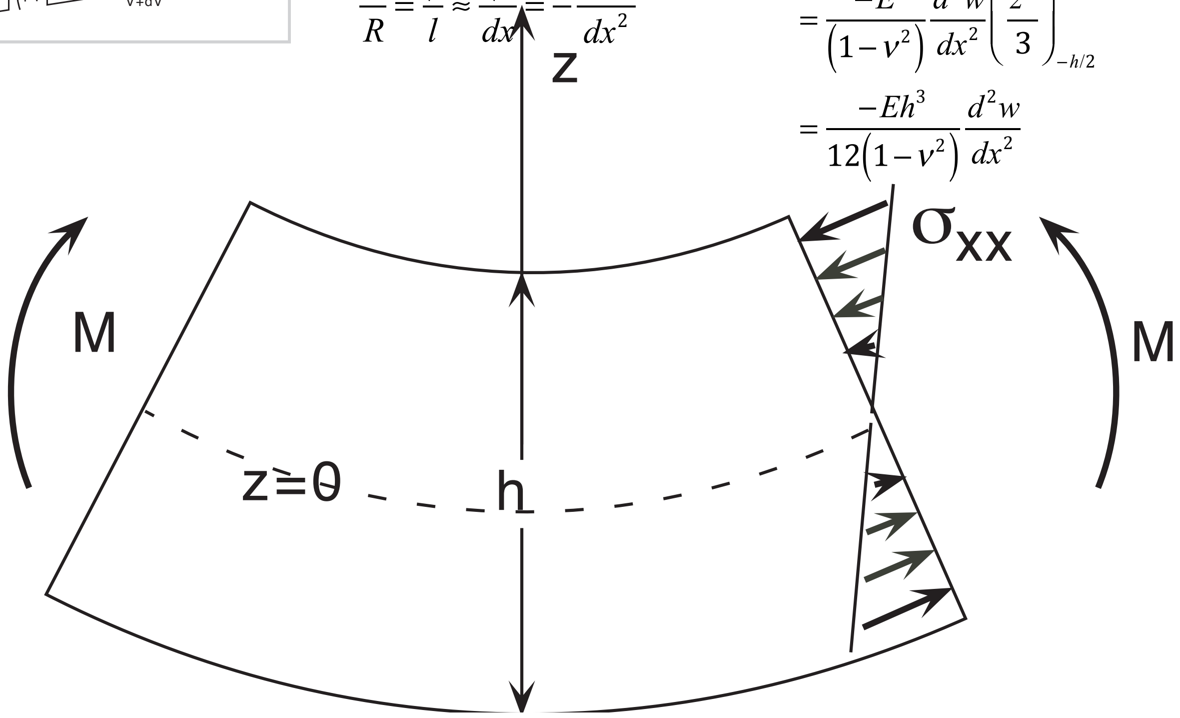
$$\sigma_{xx} = \frac{E}{\left(1-\nu^2\right)}\varepsilon_{xx}$$

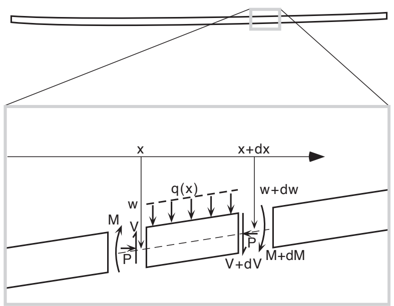
$$\frac{1}{R} = \frac{\phi}{l} \approx \frac{\phi}{dx} = -\frac{d^2w}{dx^2}$$

$$M = \frac{-E}{\left(1-\nu^2\right)}\frac{d^2w}{dx^2}\int_{-h/2}^{h/2} z^2 \, dz$$

$$= \frac{-E}{\left(1-\nu^2\right)}\frac{d^2w}{dx^2}\left(\frac{z^3}{3}\right)_{-h/2}^{h/2}$$

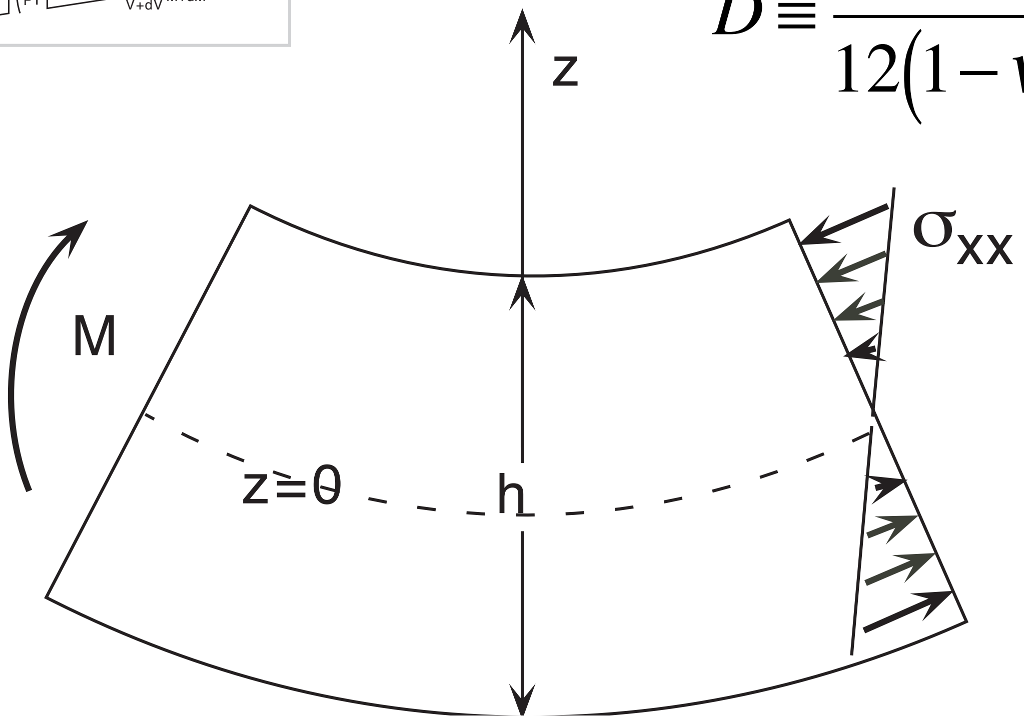
$$= \frac{-Eh^3}{12\left(1-\nu^2\right)}\frac{d^2w}{dx^2}$$

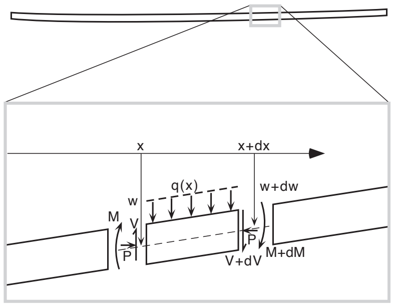


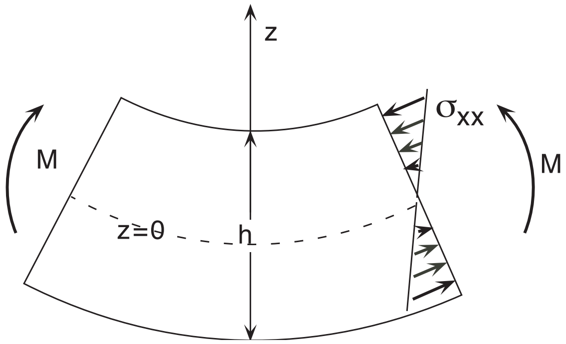


$$D\frac{d^4w}{dx^4} = q(x) - P\frac{d^2w}{dx^2}$$

$$D \equiv \frac{Eh^3}{12\left(1-\nu^2\right)}$$

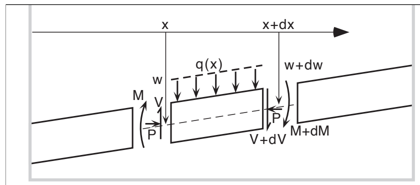


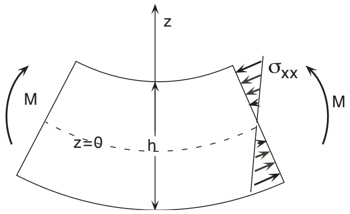




$$D\frac{d^4w}{dx^4}+P\frac{d^2w}{dx^2}+\left(\rho_a-\rho_f\right)gw=q_a(x)$$

$$q_a(x)=\rho_c g e_0 \sin 2\pi\frac{x}{\lambda}$$





$$D\frac{d^4w}{dx^4}+P\frac{d^2w}{dx^2}+\left(\rho_a-\rho_f\right)gw=q_a(x)$$

$$q_a(x)=\rho_c g e_0\sin 2\pi\frac{x}{\lambda}$$

$$w(x)=w_0\sin 2\pi\frac{x}{\lambda}$$

$$w_0=\frac{e_0}{\frac{D}{g\rho_c}\left(\frac{2\pi}{\lambda}\right)^4+\frac{\rho_a}{\rho_c}-1}$$

This sinusoidal solution lets you examine extreme cases: big lambda is isostasy, small is rigidity.

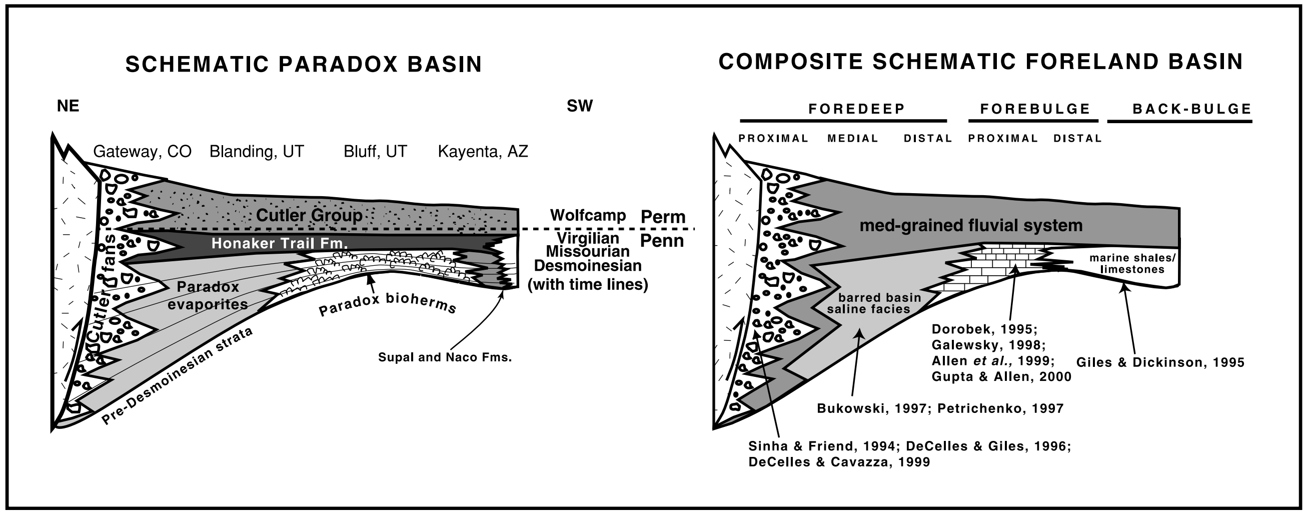
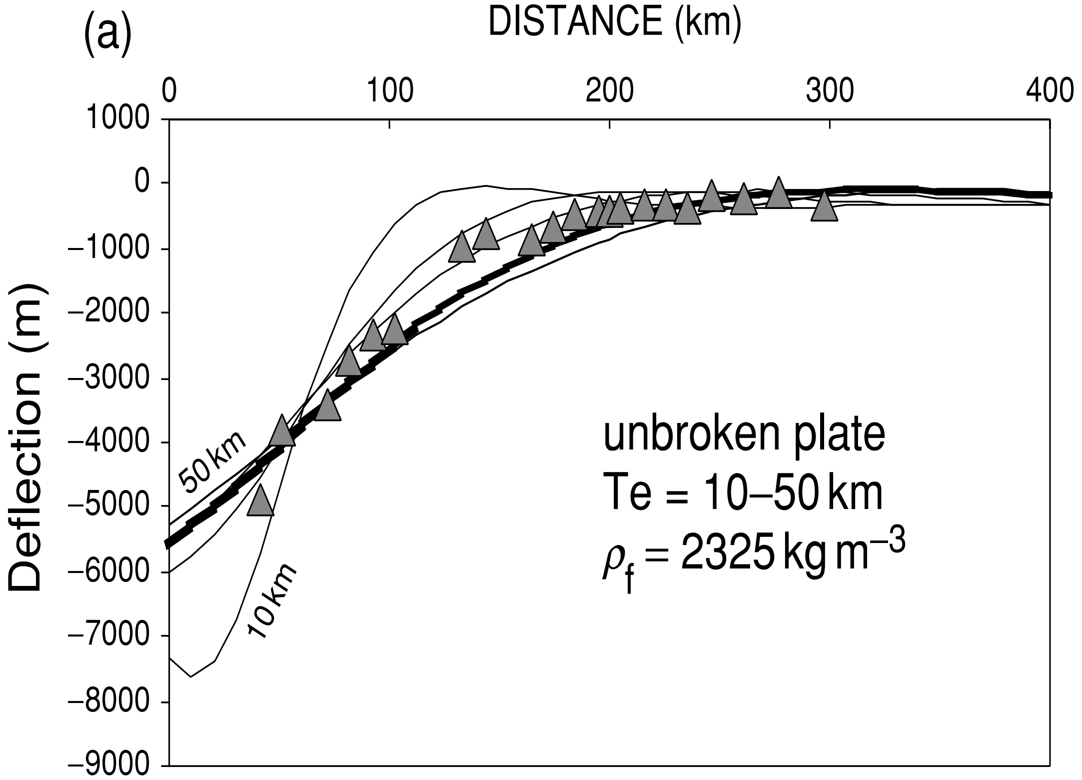
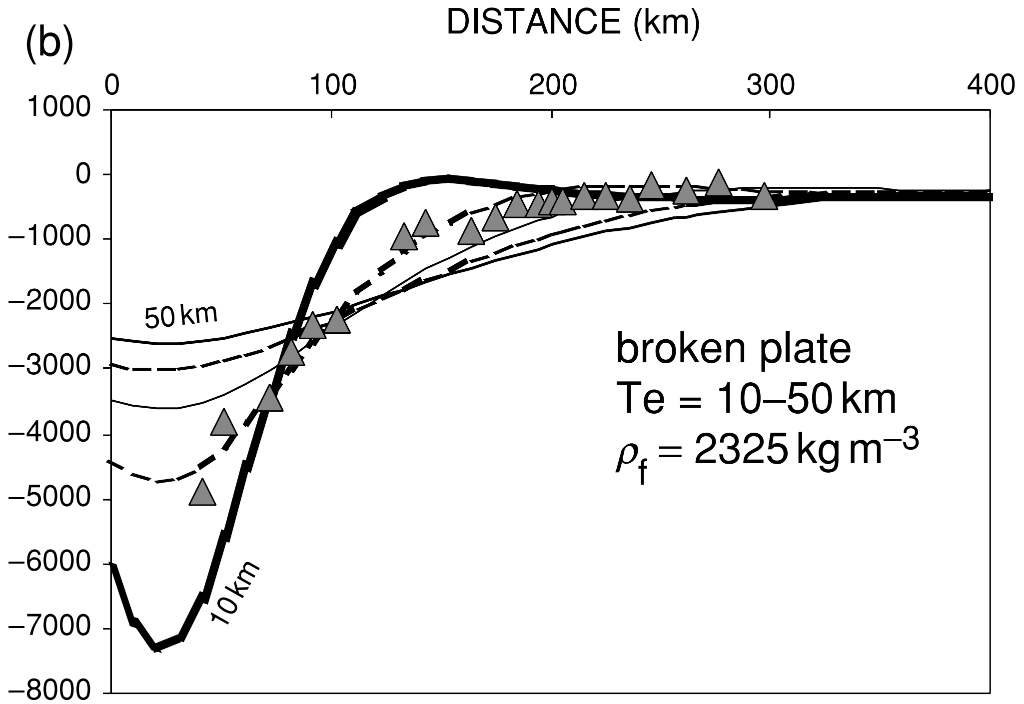


Fig. 7. (a) Schematic facies architecture of the Paradox Basin. (b) Schematic facies architecture of a composite restricted-marine isolated flexural basin. Facies recognized in other foreland basins are cited by reference.

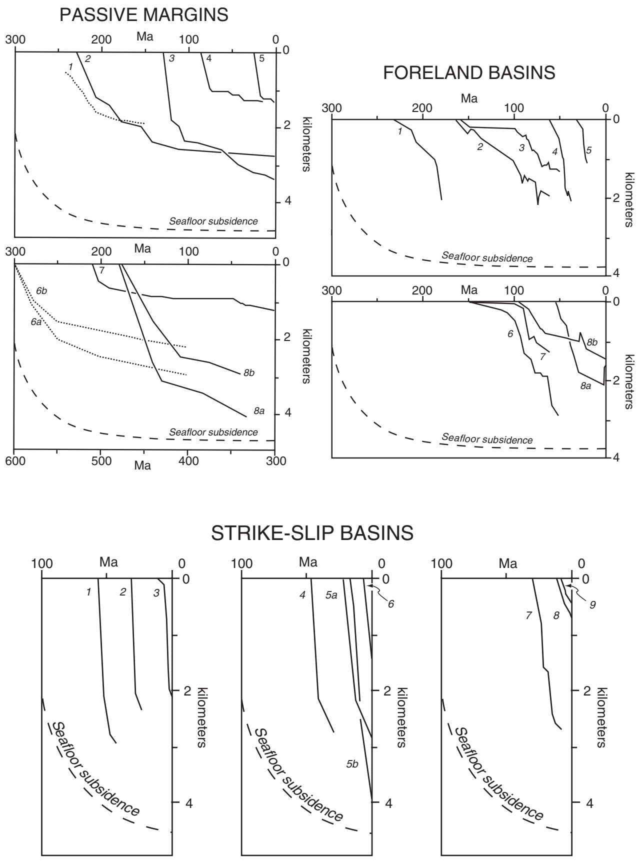
Barbeau, 2003



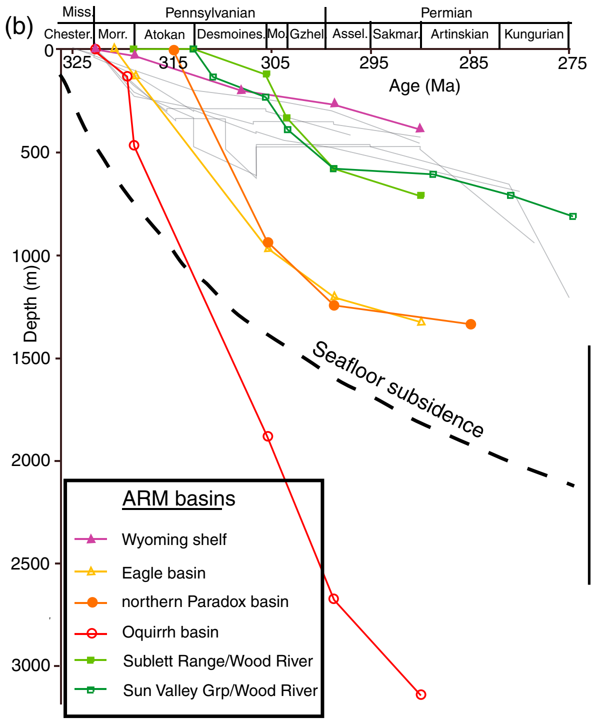
Barbeau, 2003



Barbeau, 2003

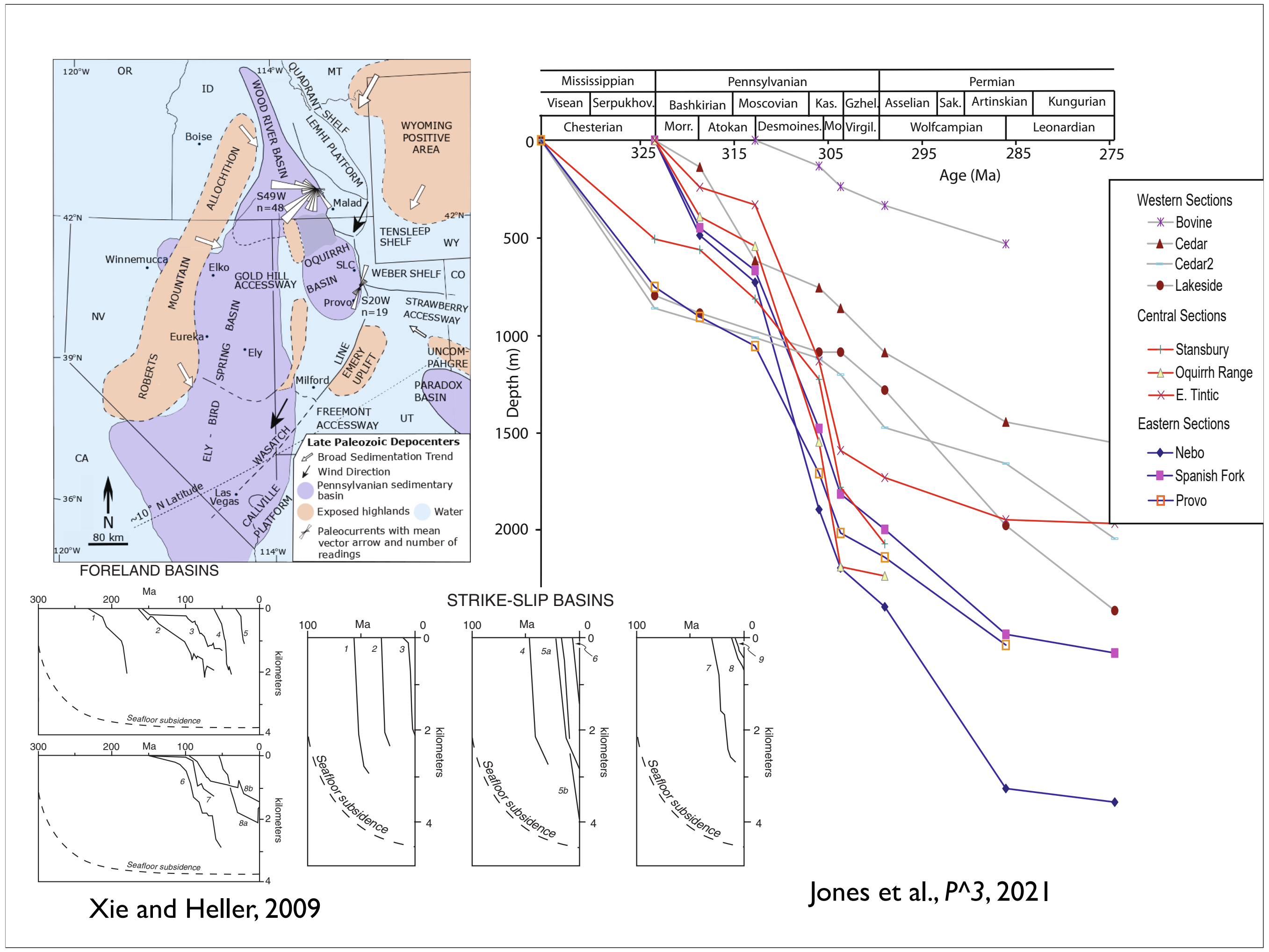


Xie and Heller, 2009



Sturmer et al., *Tectonics*, 2018

So a lot of aspects of the Paradox and Eagle basins are like foreland basins…but let's take a moment to look at the Oquirrh basin as this will start to connect us back to the west, where we will have to back up a bit next time…

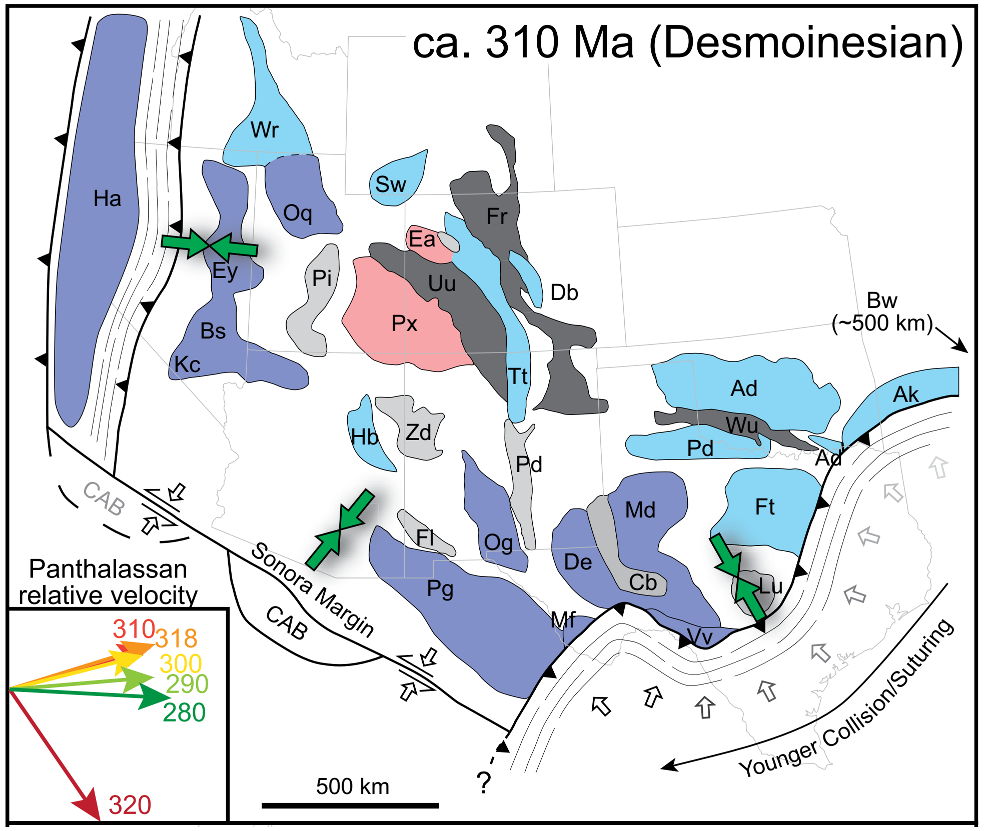


Xie and Heller, 2009

Jones et al., *P^3*, 2021

Note that subsidence is *way* stronger than thermal subsidence. Authors argue that Penn subsidence in central and east but Permian stronger in west..so maybe straddling two things? Some of the steep subsidence resembles strike-slip patterns as well…something to keep in mind [authors suggest that the Orogrande, Eagle and Taos Trough exhibit this as well—would go back to that earlier plot]

A three-sided orogen?



Leary et al., *Geology*, 2017

This points out some of the directions we will look at. We have the final collision to for Pangea to the SE, some thrusting to the west, and a more cryptic margin to the south