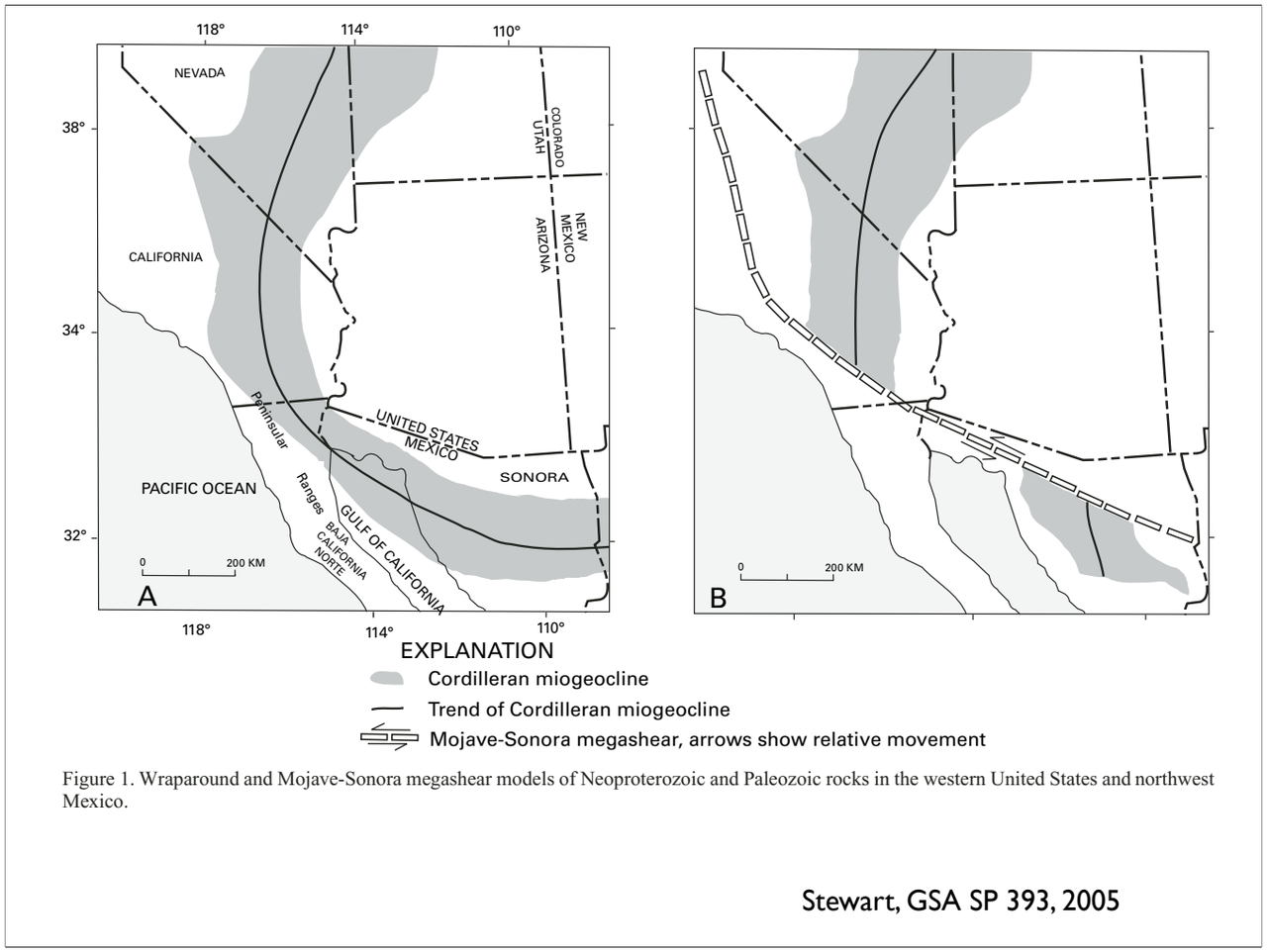
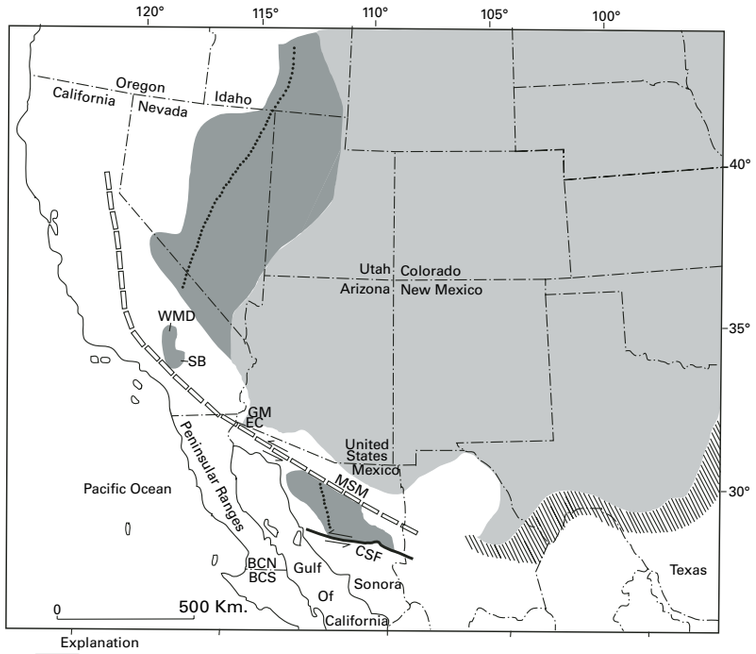


Figure 1. Wraparound and Mojave-Sonora megashear models of Neoproterozoic and Paleozoic rocks in the western United States and northwest Mexico.

Stewart, GSA SP 393, 2005

Miogeocline extends into CA on NNE-SSW trend but then vanishes—but very similar rocks show up in Caborca, Mexico. Which geometry is right?



Explanation

- Neoproterozoic and Paleozoic Cordilleran miogeocline
- Paleozoic continental cover strata
- Ouachita orogenic belt
- Trend of Cordilleran miogeocline
- Mojave-Sonora megashear. Position of megashear is not corrected palinspastically for post-Late Jurassic structural dislocations. See text for discussion of location of megashear. Arrows show relative motion.
- Central Sonora fault (CSF), arrows show relative motion

Symbols: BCN, Baja California Norte; BCS, Baja California Sur; EL, El Capitán; GM, Gila Mountains; SB, San Bernardino Mountains; WMD, western Mojave Desert

Stewart, GSA SP 393, 2005

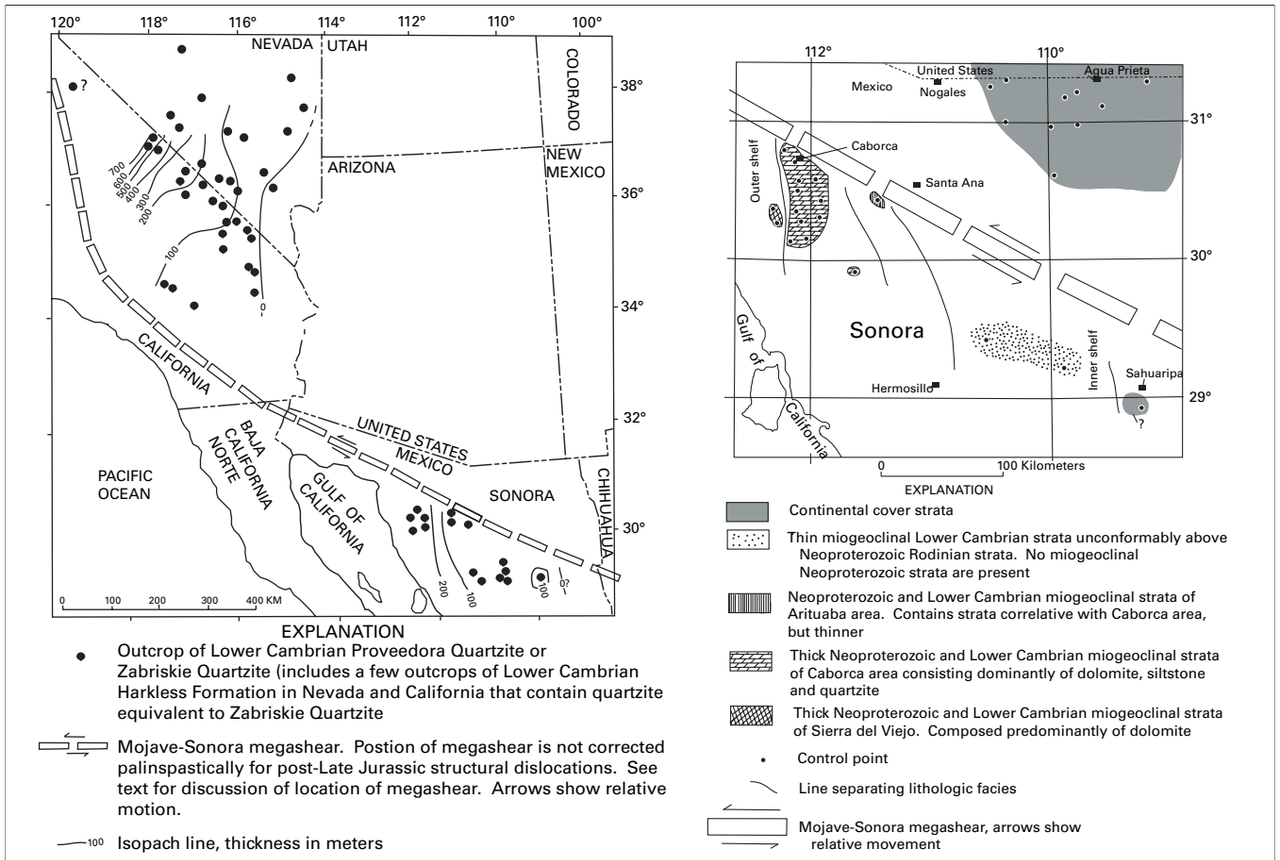
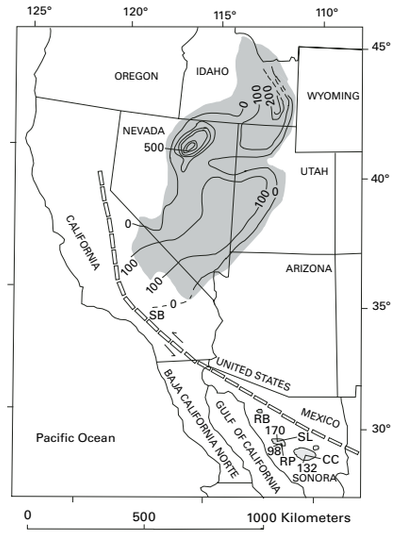


Figure 4. Distribution and thickness of Lower Cambrian Zabriskie Quartzite in California and Nevada and of the correlative Proveedora Quartzite in Sonora. Based on Stewart (1970) and Stewart et al. (1984).

Figure 5. Facies trends of Neoproterozoic and Lower Cambrian strata in Sonora. Based on data in Stewart et al. (2002).

Stewart, GSA SP 393, 2005

Right plot suggests that miogeocline trend in Caborca also cut off.



EXPLANATION

Ordovician miogeoclinal strata

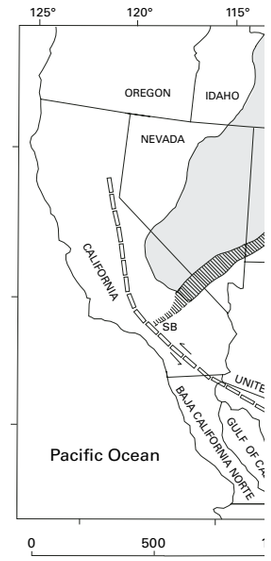
100 — Isopach of Middle Ordovician Eureka Quartzite and equivalent strata in western United States, thicknesses in meters. The Eureka and other Ordovician strata are absent in the Paleozoic in the Paleozoic succession of the San Bernardino Mountains (SBM)

98 Thickness in meters of Middle Ordovician Peña Blanca Quartzite in Sonora

Mojave-Sonora megashear. Position of megashear is not corrected palinspastically for post-Late Jurassic structural dislocations. See text for discussion of location of megashear. Arrows show relative motion.

Localities: CC, Cerro Cobachi; RB, Rancho Bizani; RP, Rancho Placeritos; SB, San Bernardino Mountains; SL, Sierra Lopez

Figure 7. Distribution and thickness of Ordovician miogeoclinal strata in the western United States and northwestern Mexico. Based on Ross (1977), Ross et al. (1991, 1992), Poole and Sandberg (1992a), Poole et al. (1995a), and Stewart and Poole (2002).



EXPLANATIO

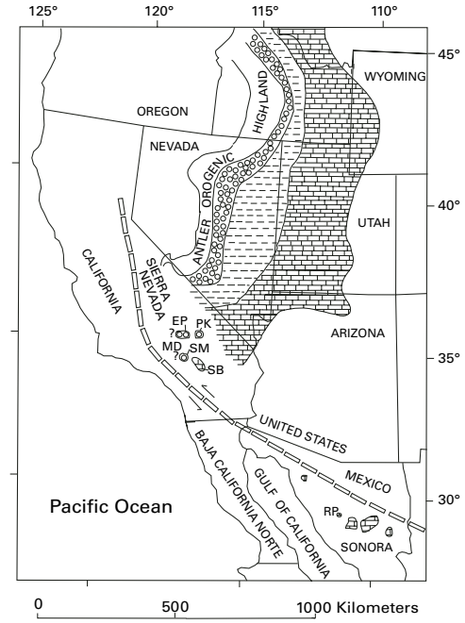
Zone of unconformable overlap of Devo Ordovician strata. Dashed where inferre

Silurian and Devonian miogeoclinal

Mojave-Sonora megashear. Position o palinspastically for post-Late Jurassic text for discussion of location of mega motion.

Localities: CCA, Cerro Carnero; RB, Rancho E SAV, Sierra Agua Verde; SB, San Bernardino

Figure 8. Distribution of Silurian and Devo the western United States and northweste et al. (1977), Poole and Sandberg (1977, and Poole (1992a, 1992b), Sheehan and Bo (1991), Poole et al. (1997, 1998, 2000a, 20 and Stewart and Poole (2002).



EXPLANATION

Mississippian limestone and sandy limestone

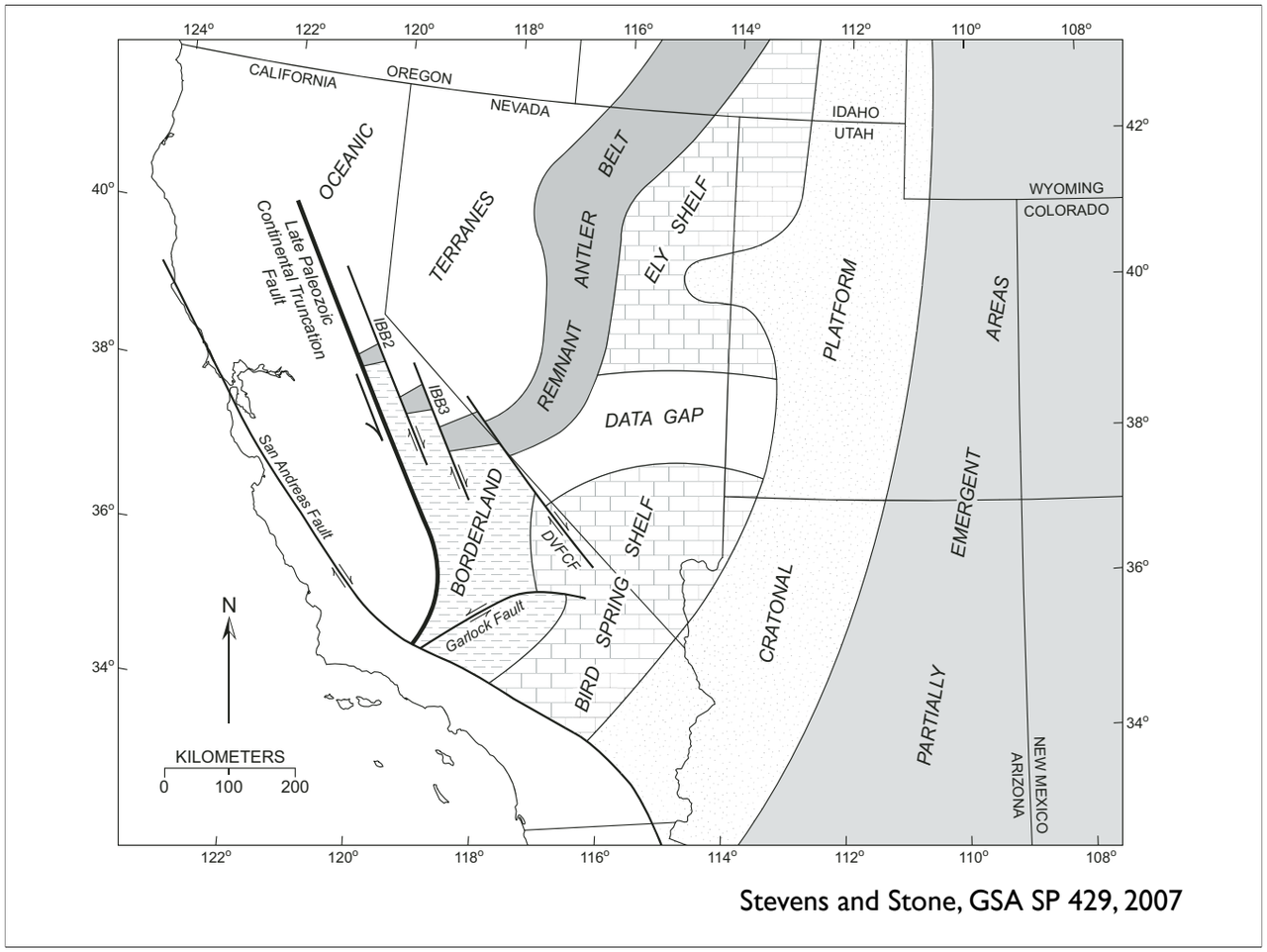
Mississippian fine-grained sandstone, siltstone, and mudstone

Mississippian conglomerate, medium- to coarse-grained sandstone, and siltstone

Mojave-Sonora megashear. Position of megashear is not corrected palinspastically for post-Late Jurassic structural dislocations. See text for discussion of location of megashear. Arrows show relative motion.

Localities: EP, El Paso Mountains; PK, Pilot Knob Valley; MD, Mojave Desert; RP, Rancho Placeritos; SB, San Bernardino Mountains; SM, Shadow Mountains

Stewart, GSA SP 393, 2005



Stevens and Stone, GSA SP 429, 2007

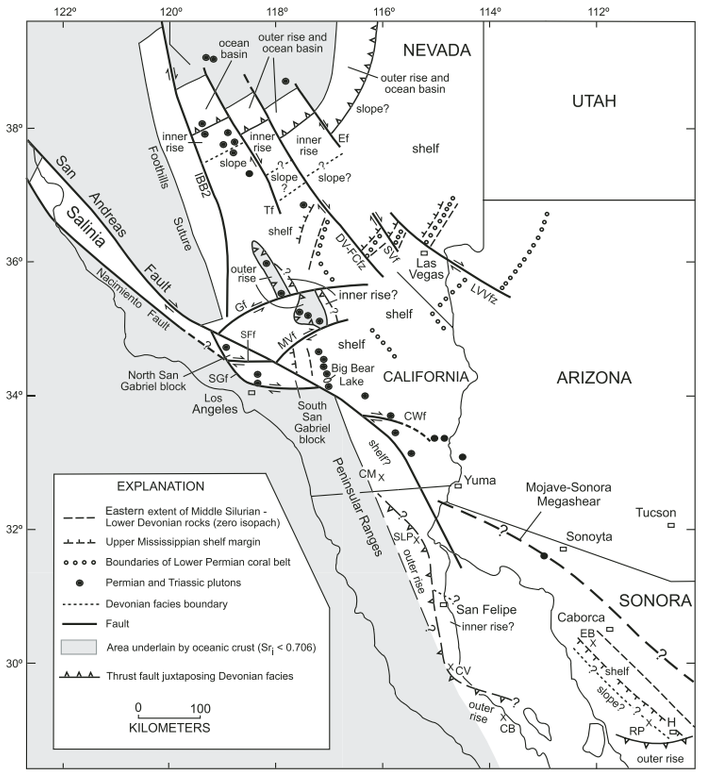


Figure 2. Index map showing Devonian facies belts, selected Paleozoic sedimentary boundaries on the continental shelf, areas interpreted to be underlain by oceanic crust, and major faults that have displaced facies belts and sedimentary boundaries. Note that in several areas rocks of the outer rise and ocean basin now are underlain by continental crust because of thrusting of those facies over the continental margin. In addition, outer-rise rocks not now exposed in the Saddlebag Lake area are inferred to underlie the ocean basin facies in that area. CB—Canal Ballenas area; CM—Coyote Mountains; CV—Cerro El Volcán; CWf—Clemens Well fault; DV-FCfz—Death Valley–Furnace Creek fault zone; EB—El Bisani; Ef—Excelsior fault; Gf—Garlock fault; H—Hermosillo; IBB2—Intrabatholithic break 2; LVVfz—Las Vegas Valley fault zone; MVf—Mojave Valley fault; RP—Rancho Placeritos; SFf—San Francisquito fault; SGf—San Gabriel fault; SLP—Sierra Las Pinta; SVf—Stewart Valley fault; Tf—Tinemaha fault.

Stevens et al., GSA SP 393, 2005

Today things are hacked up, but in the pieces between can divine the SSW trend possibly turning to SE in Mojave. Note the Permian-Tr plutons—will come back to those.

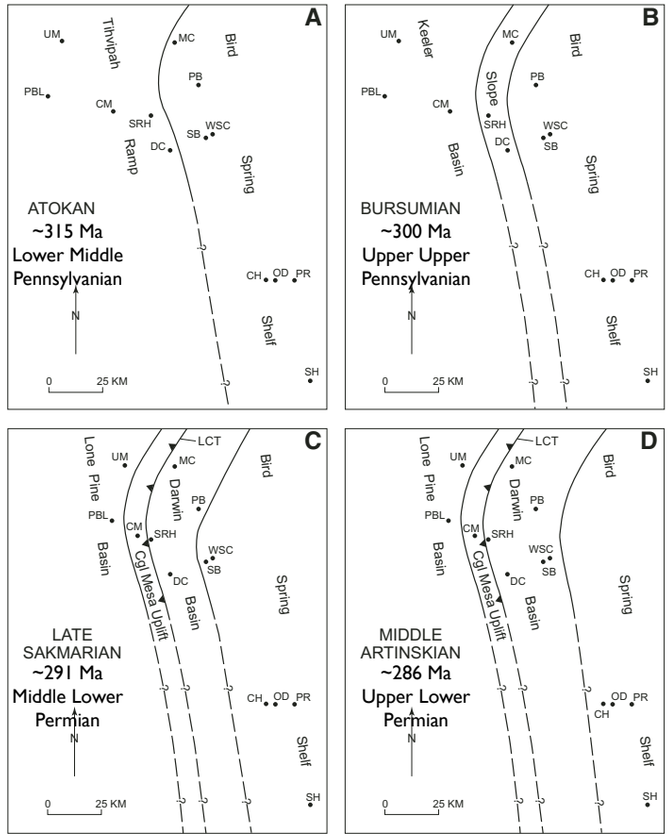
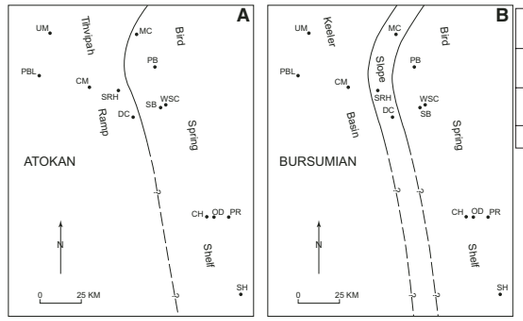


Figure 12. Paleogeographic maps illustrating evolution of the Bird Spring Shelf and adjacent basins during Pennsylvanian and Early Permian time. (A) Atokan. (B) Bursumian. (C) Late Sakmarian. (D) Middle Artinskian. Localities shown: CH—Cowhole Mountain; CM—Conglomerate Mesa; DC—Darwin Canyon; MC—Marble Canyon; OD—Old Dad Mountain; PB—Panamint Butte; PBL—Permian Bluff; PR—Providence Mountains; SB—Striped Butte; SH—Ship Mountains; SRH—Santa Rosa Hills; UM—Ubehebe Mine; WSC—Warm Spring Canyon. Palinspastic restorations are modified from Snow and Wernicke (2000). In addition, note that localities CM, PBL, and UM in (A) and (B) are in their

Stevens and Stone, GSA SP 429, 2007

Keeler basin (late Penn) inferred to be extensional from truncation event, then shortening in early Permian starved Keeler/Lone Pine basin. Darwin basin interpreted as a foredeep to Conglomerate Mesa uplift. Get very tight age controls indicating LCT moved 3 mm/yr over 10 m.y. Associates extension with left-lateral fault, LCT with Penn. deformation (Pinon orogeny?) in Nevada.



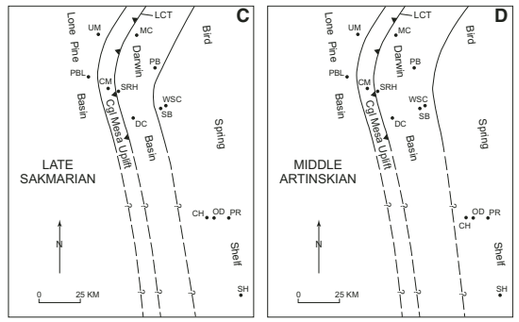
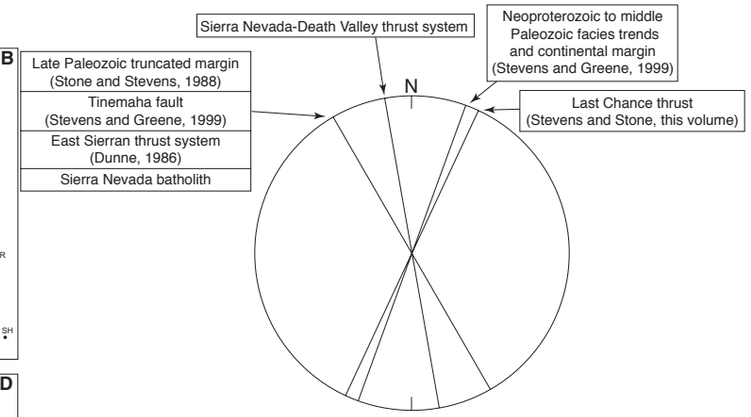


Figure 12. Paleogeographic maps illustrating evolution of the Bird Spring Shelf and adjacent basins during Pennsylvanian and Early Permian time. (A) Atokan. (B) Bursumian. (C) Late Sakmarian. (D) Middle Artinskian. Localities shown: CH—Cowhole Mountain; CM—Conglomerate Mesa; DC—Darwin Canyon; MC—Marble Canyon; OD—Old Dad Mountain; PB—Panamint Butte; PBL—Permian Bluff; PR—Providence Mountains; SB—Striped Butte; SH—Ship Mountains; SRH—Santa Rosa Hills; UM—Ubehebe Mine; WSC—Warm Spring Canyon. Palinspastic restorations are modified from Snow and Wernicke (2000). In addition, note that localities CM, PBL, and UM in (A) and (B) are in their inferred positions prior to eastward displacement in the upper plate of the Last Chance thrust (LCT) during Sakmarian time (Stevens and Stone, 2005).

Stevens and Stone,
GSA SP 429, 2007



Stevens and Stone,
Earth Sci Rev., 2005

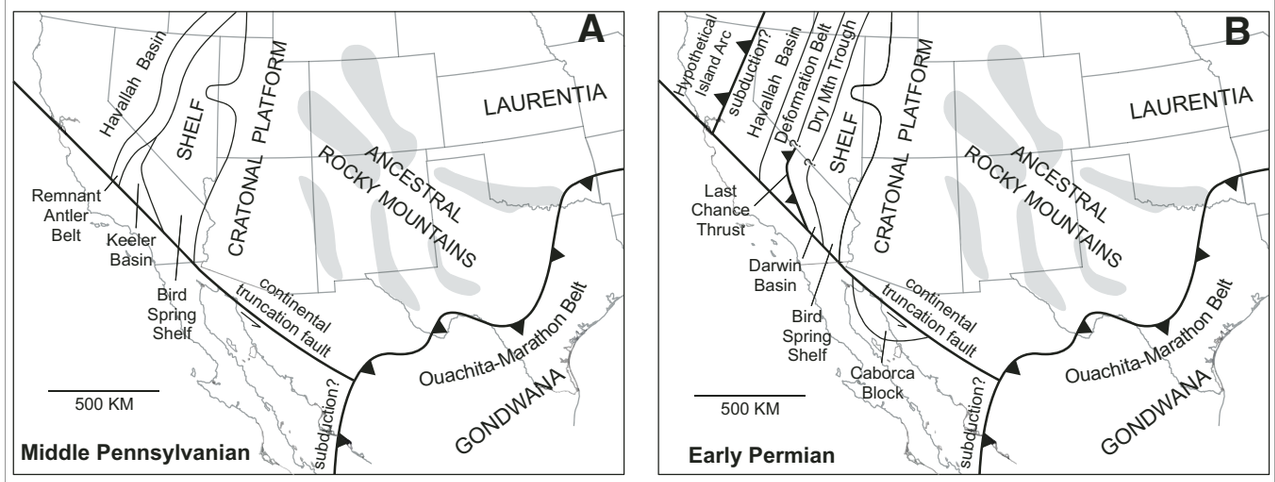
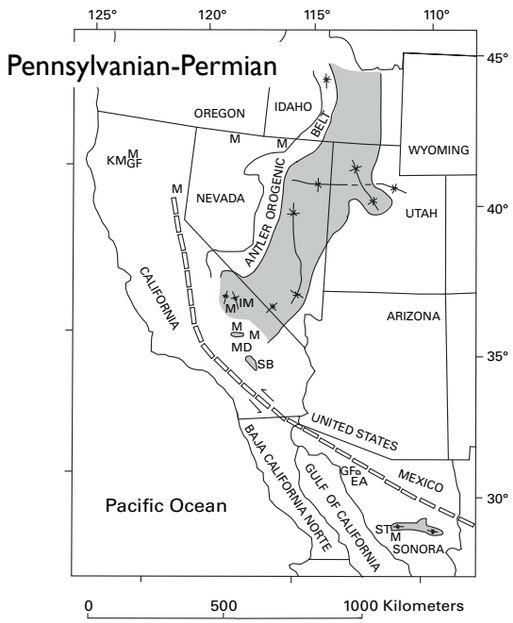


Figure 13. Maps showing major paleotectonic features related to the Bird Spring Shelf. (A) Middle Pennsylvanian. (B) Early Permian. Modified from Stevens et al. (1993), Dickinson (2000) and Trexler et al. (2004). Shaded areas are uplifts of the ancestral Rocky Mountains.

Stevens and Stone,
GSA SP 429, 2007

Deformation belt in B is Penn deformation in Nevada. There is also deformation like that in A that was left off.



EXPLANATION

Pennsylvanian and Permian miogeoclinal strata

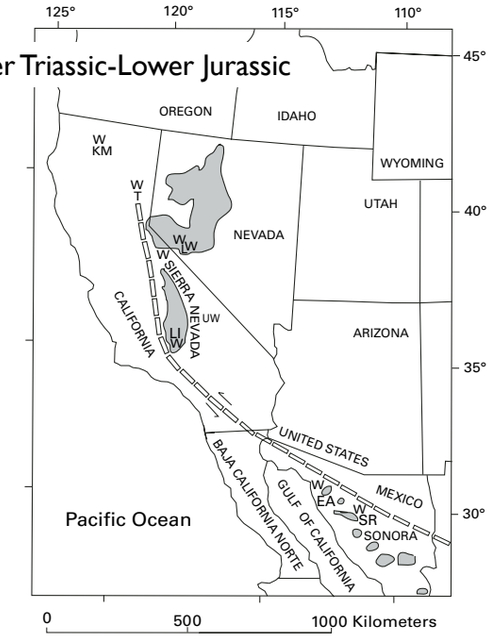
Sedimentary trough

M Fusulinids of McCloud fauna or McCloud-like faunas

GF Giant fusulinids

Mojave-Sonora megashear. Position of megashear is not corrected palinspastically for post-Late Jurassic structural dislocations. See text for discussion of location of megashear. Arrows show relative motion.

Localities: KM, Klamath Mountains; EA, El Antimonio; MD, Mojave Desert; SB, San Bernardino Mountains; ST, Sierra Santa Teresa; MI, Inyo Mountains



EXPLANATION

Outcrop of marine and some nonmarine Upper Triassic and Lower Jurassic strata

W Strata containing the Early Jurassic bivalve Weyla

Mojave-Sonora megashear. Position of megashear is not corrected palinspastically for post-Late Jurassic structural dislocations. See text for discussion of location of megashear. Arrows show relative motion.

Localities: EA, El Antimonio area; BM, Blue Mountains; KM, Klamath Mountains; LI, Lake Isabella; L, Luning Formation; SR, Sierra Santa Rosa; T, Taylorsville area; UW, Union Wash

But are younger units truncated and offset?? Can we look at latest Paleozoic to unravel?

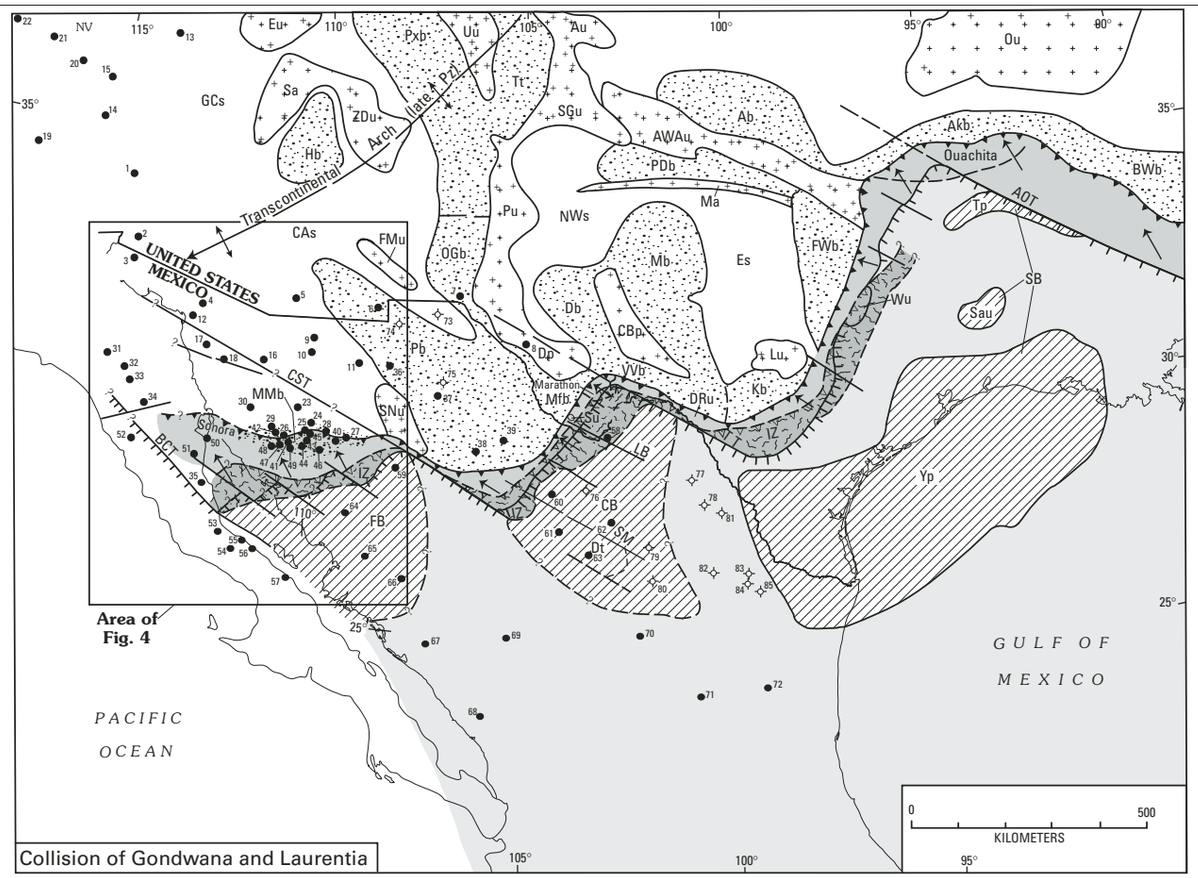
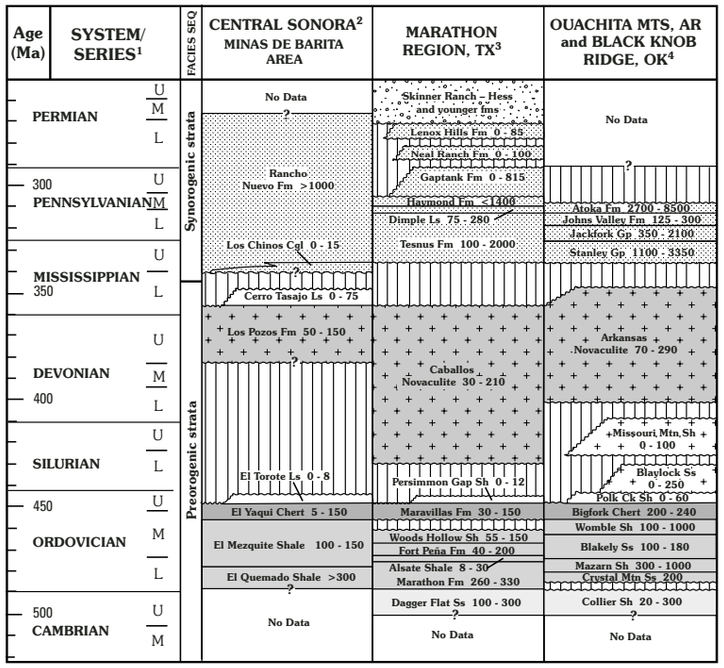


Figure 3. Regional map of southern Laurentia showing late Paleozoic geologic features and localities mentioned in text and described in Table 1, and location of Figure 4.

Poole et al., GSA SP 393, 2005

Is Caborca offset late Paleozoic?

El Paso Mtns (close to proposed truncation) has lower Mississippian conglomerate



[1]**System/Series boundaries:** Claoué-Long et al. (1992), Cooper (1999), Harland et al. (1990), Jin et al. (1997), Landing et al. (2000), Menning et al. (2000), Sandberg and Ziegler (1996), Sando (1985), Stone et al. (2000), Tucker et al. (1998).

[2]**Sonora:** Poole et al. (in progress).

[3]**Marathon:** Barrick and Noble (1995), Ellison and Powell (1989), Ethington et al. (1989), Finney (1986), McBride (1989), Noble (1990, 1994), Ross (1978, 1979, 1986), Ross and Ross (1995).

[4]**Ouachita:** Barrick and Haywa-Branch (1994), Ethington et al. (1989), Finney (1986), Hass (1951), Lowe (1989), Morris (1989).

Figure 5. Generalized stratigraphic sections characteristic of the Sonora, Marathon, and Ouachita segments of the Ouachita-Marathon-Sonora orogenic system. Thickness ranges in meters. Similar patterns represent correlative strata.

Poole et al., GSA SP 393, 2005

El Paso Mtns also have a pretty thick sequence of Ordovician-Cambrian deep water clastic seds and quite a bit of Devonian (including, apparently, a Devonian ash fall tuff—El Paso Mtn Geol Map)

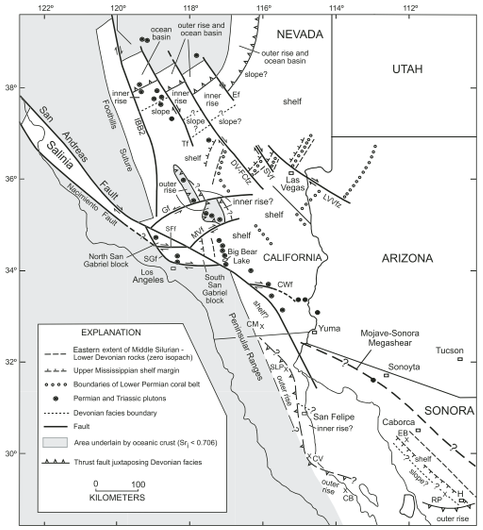


Figure 2. Index map showing Devonian facies belts, selected Paleozoic sedimentary boundaries on the continental shelf,

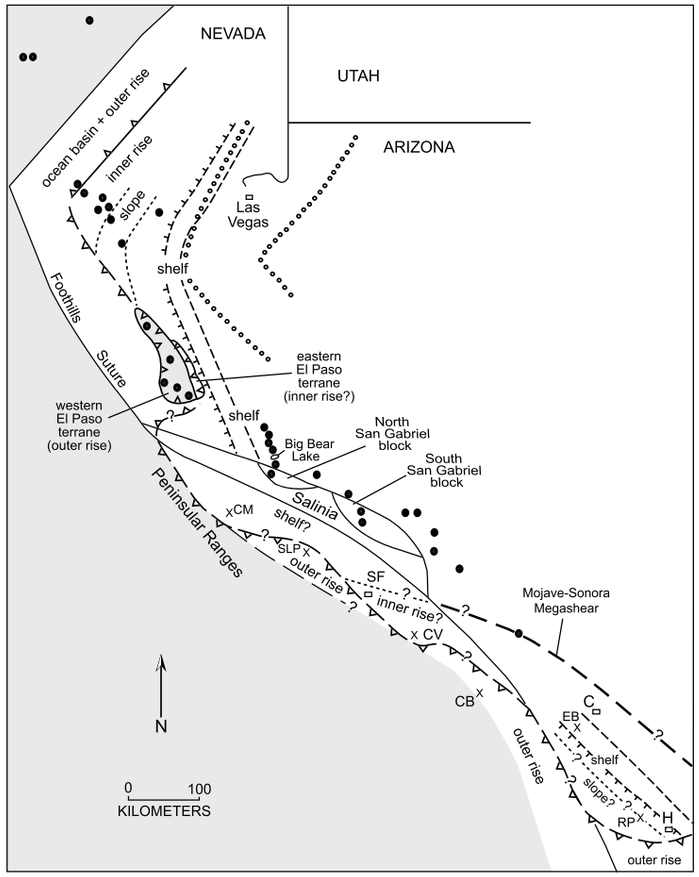


Figure 4. Paleogeographic reconstruction, step 2. Restoration of Cretaceous sinistral displacement of the Peninsular Ranges on the Nacimiento fault. See discussion in text. Abbreviations and symbols as in Figure 2.

Stevens et al., GSA SP 393, 2005

Recall the elements of the Permian here. If we restore for Cz and likely K faults, we get picture on right. Note in particular the distribution of Permian-Triassic plutons and how they cross the Devonian facies belts in NW.

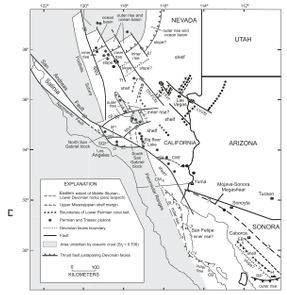


Figure 2. Index map showing Devonian facies belts, selected Paleozoic sedimentary boundaries on the continental shelf, [illegible]

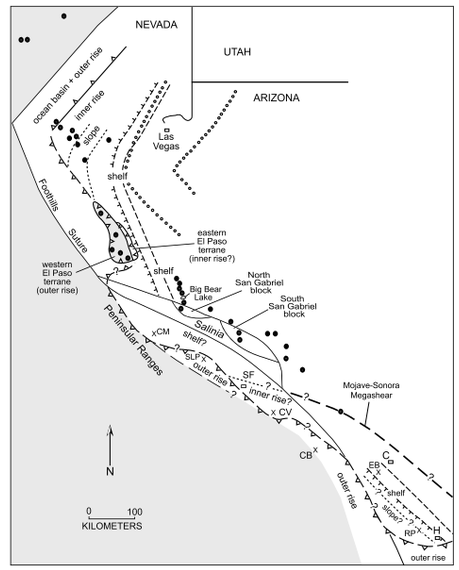


Figure 4. Paleogeographic reconstruction, step 2. Restoration of Cretaceous sinistral displacement of the Peninsular Ranges on the Nacimiento fault. See discussion in text. Abbreviations and symbols as in Figure 2.

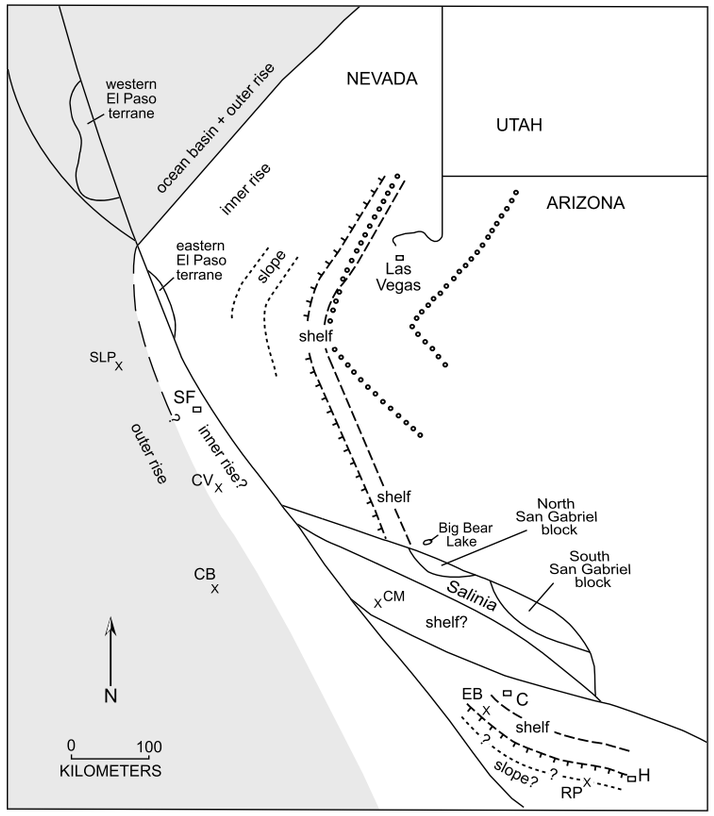
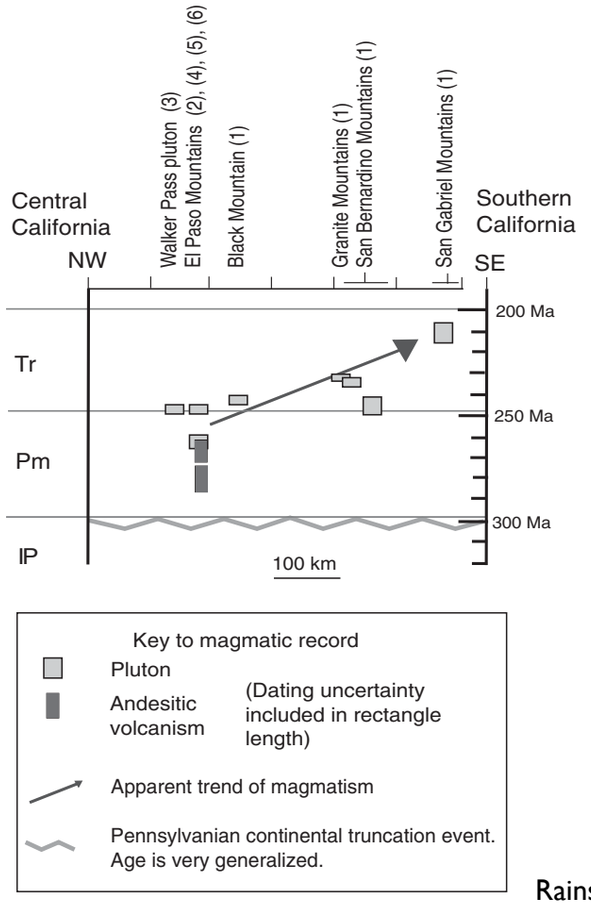


Figure 7. Paleogeographic reconstruction, step 4B. Restoration of sinistral displacement on a proposed Pennsylvanian continental truncation fault predating the Mojave-Sonora megashear. See discussion in text. Abbreviations and symbols as in Figure 2.

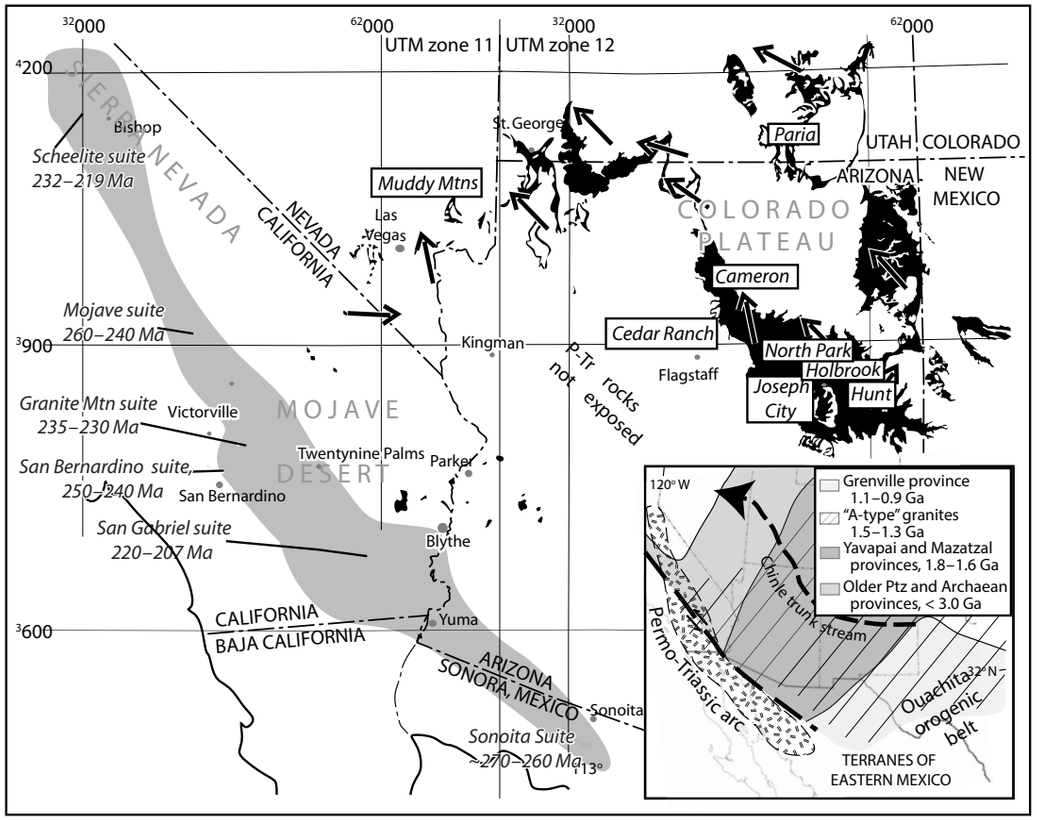
Stevens et al., GSA SP 393, 2005

Recovering the SW end of the miogeocline…



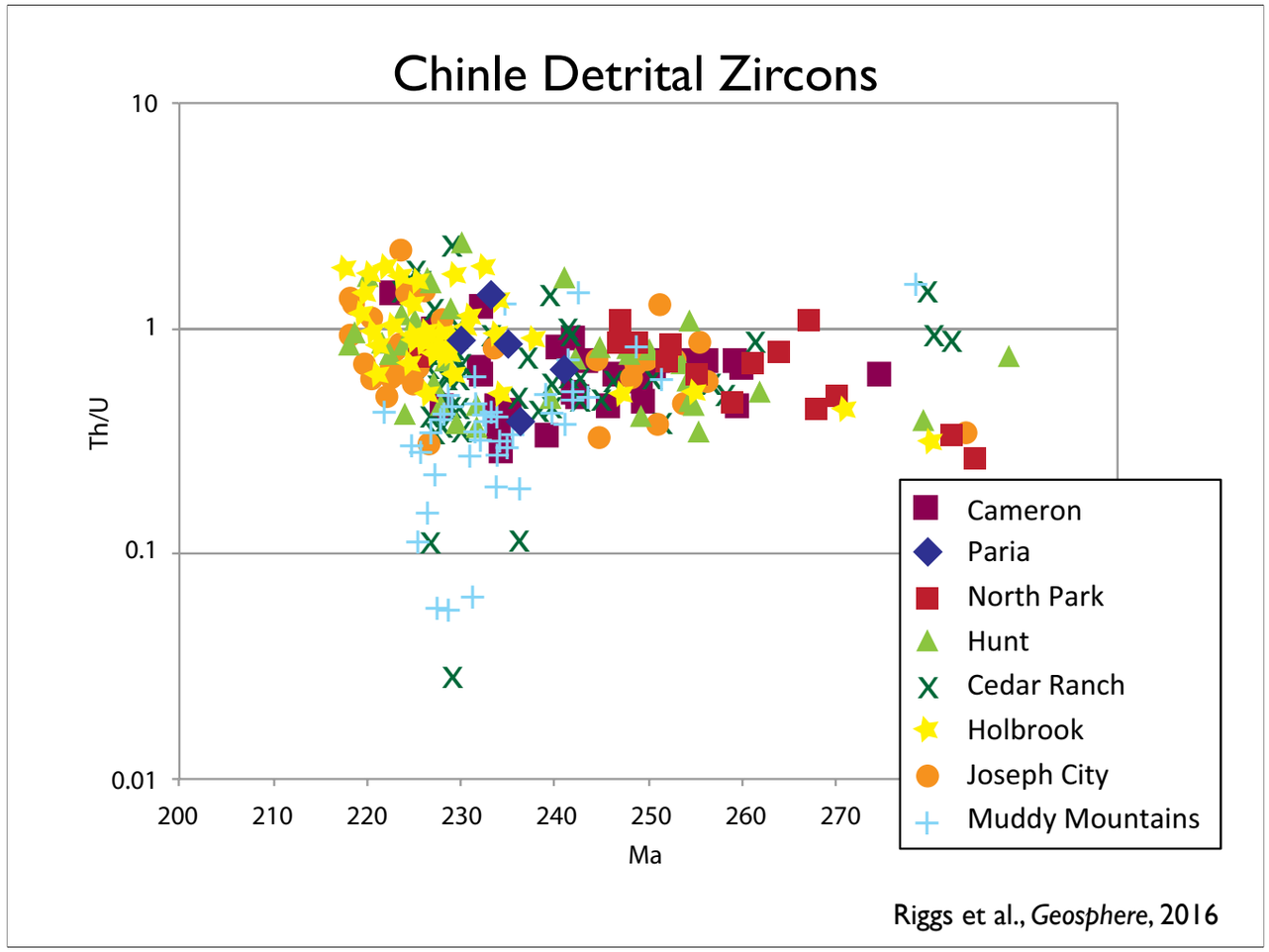
Rains et al., *Lithosphere*, 2012

Rather surprising apparent growth of the arc to the SE from El Pasos.

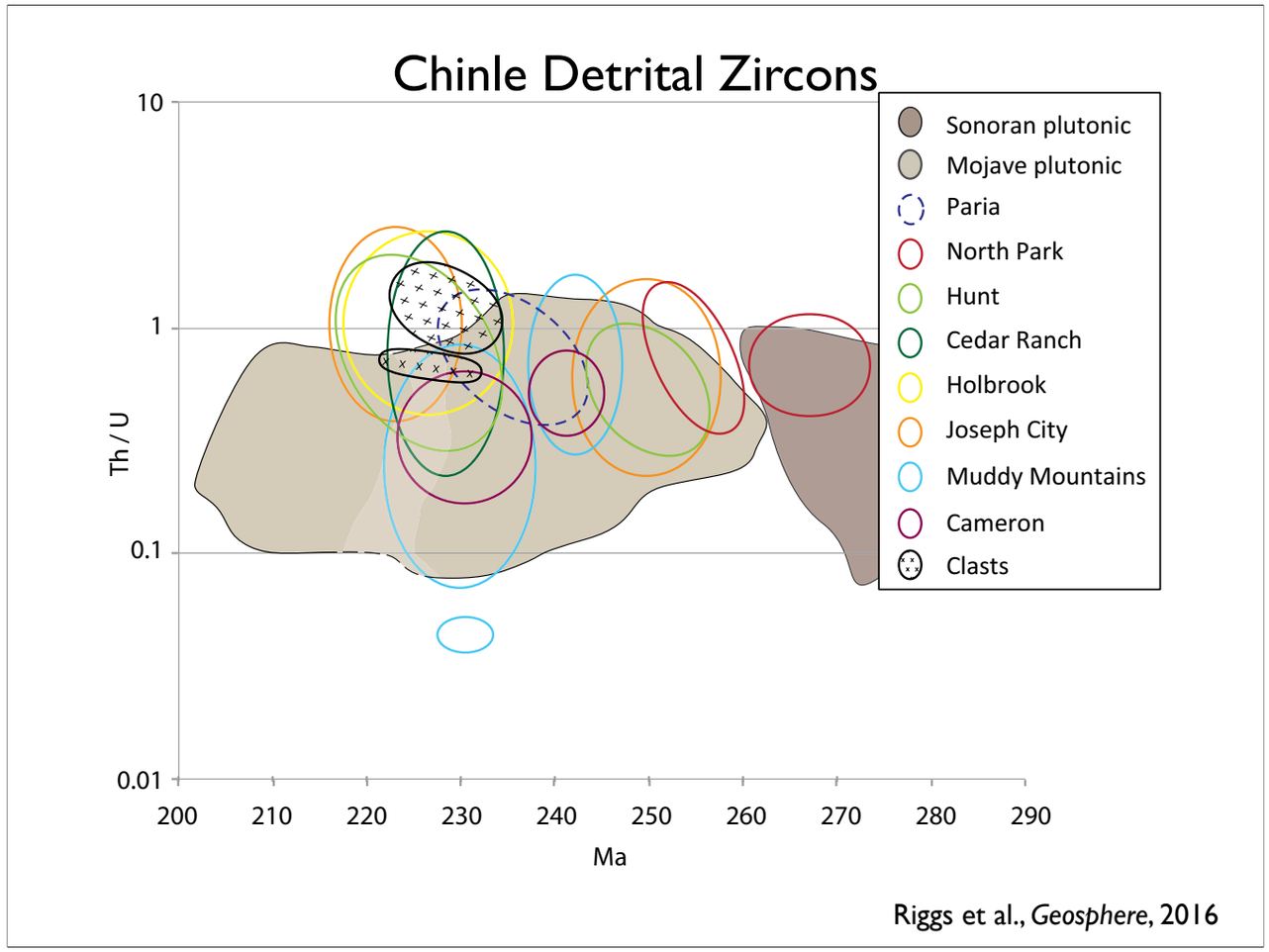


Riggs et al., *Geosphere*, 2016

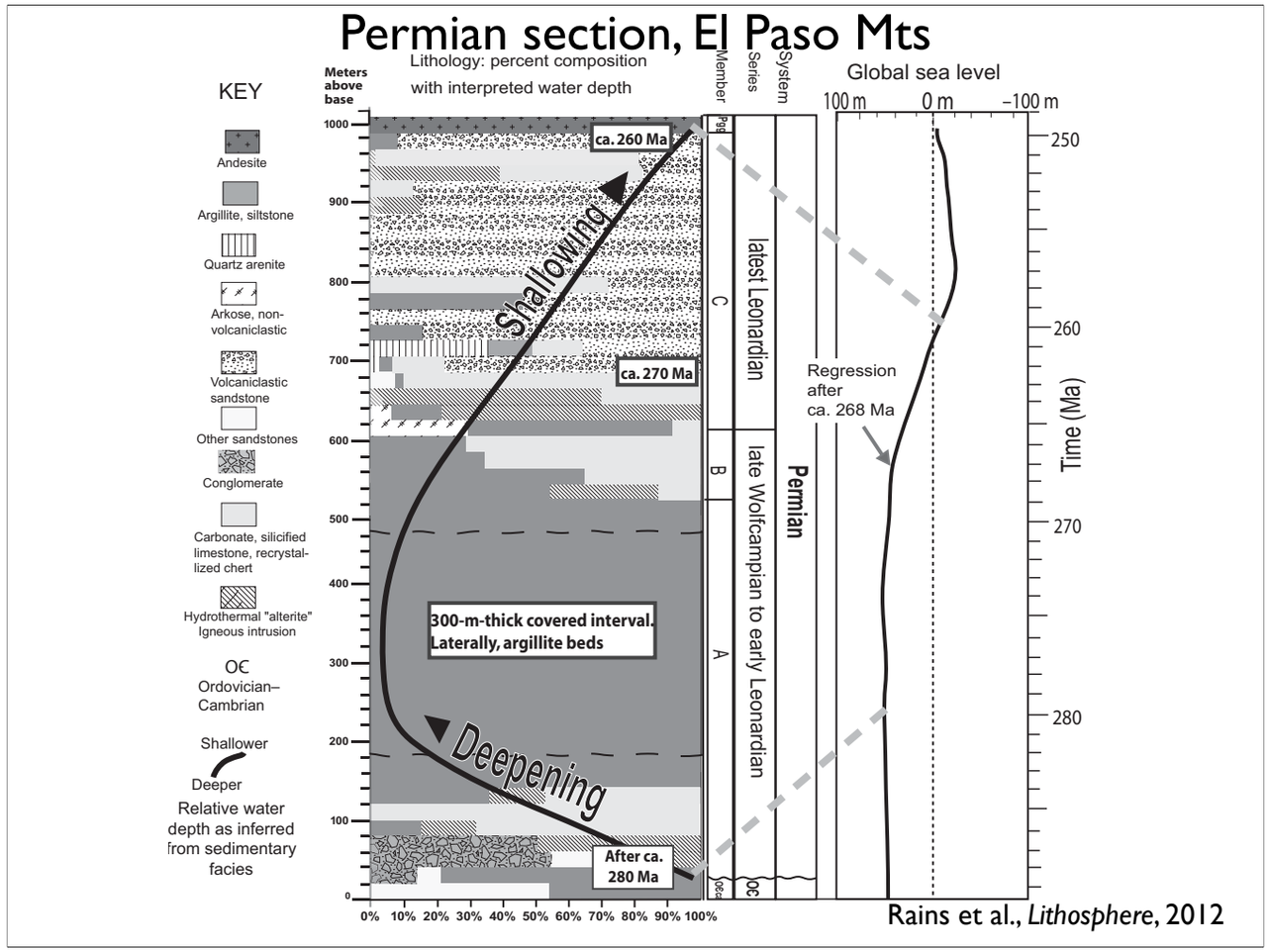
Note summary of ages of Permian into early Triassic on left. Oldest continental rocks receiving detritus from this arc is Chinle. Interestingly, these might not be quite as old as start of arc…



Subset of Permian-Triassic zircons. Suggests presence of arc even back to 280 Ma.

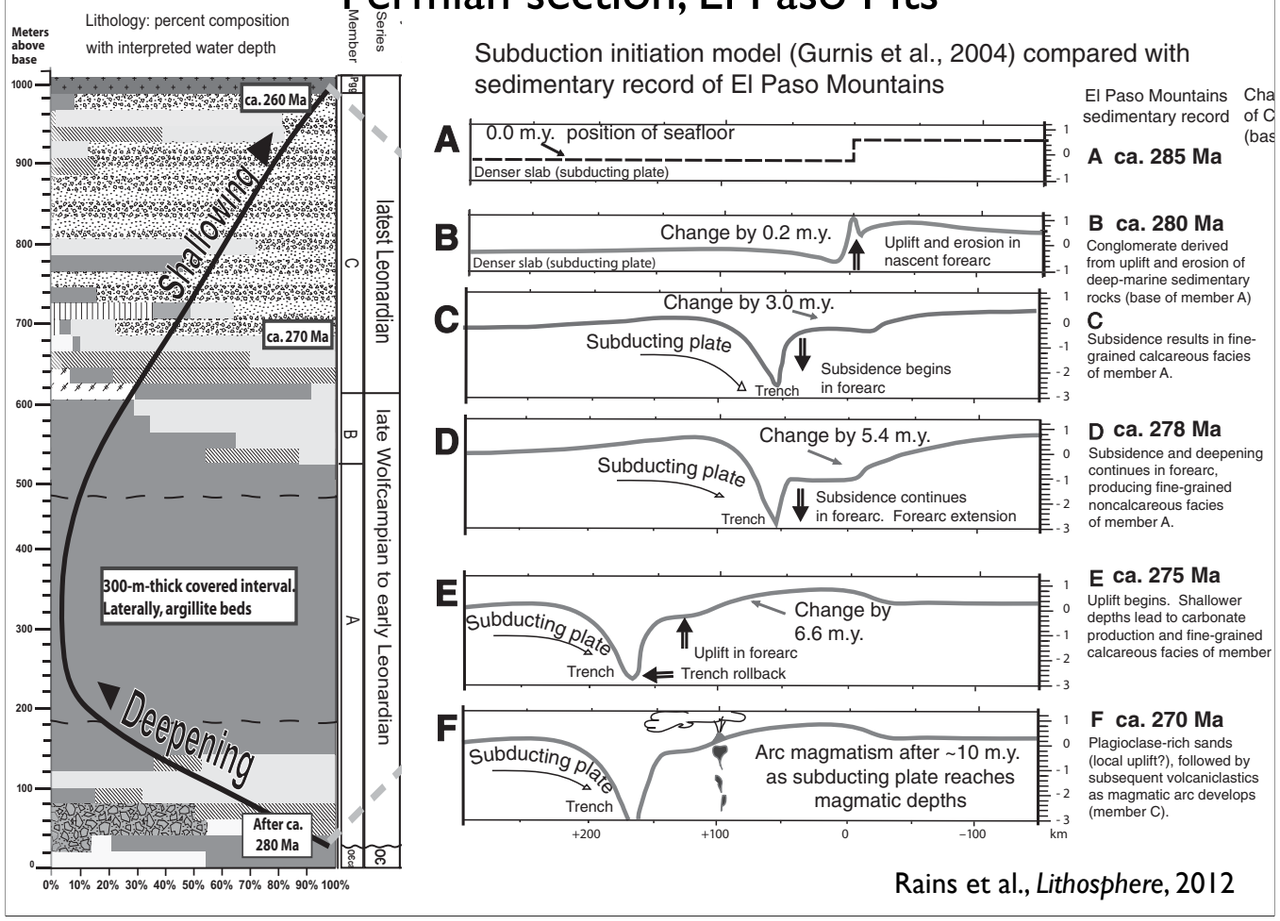


Lag in timing reflects, authors argue, presence of marine arc until c 230 Ma.



Facies changes in El Paso Mtns not global—what is this telling us about SW margin c. 280 Ma? (WOrth noting that this same deepening was inferred by Snow long ago as a fore deep in front of the Last Chance thrust system).

Permian section, El Paso Mts



Rains et al., *Lithosphere*, 2012

Interpreted as early phase of subduction initiation. We'll come back to the arc much later, but this would seem to help clinch truncation by Permian.

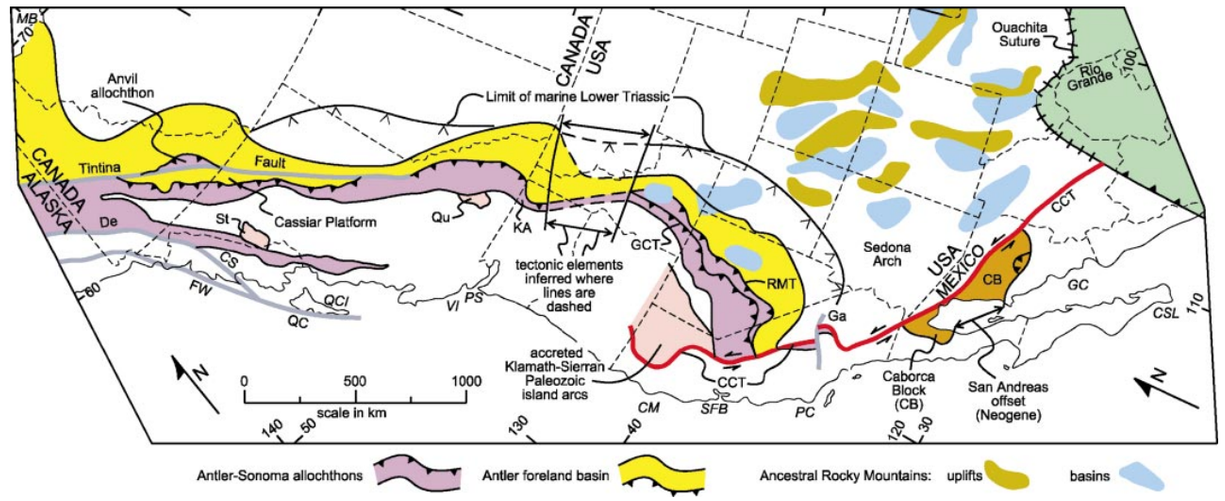
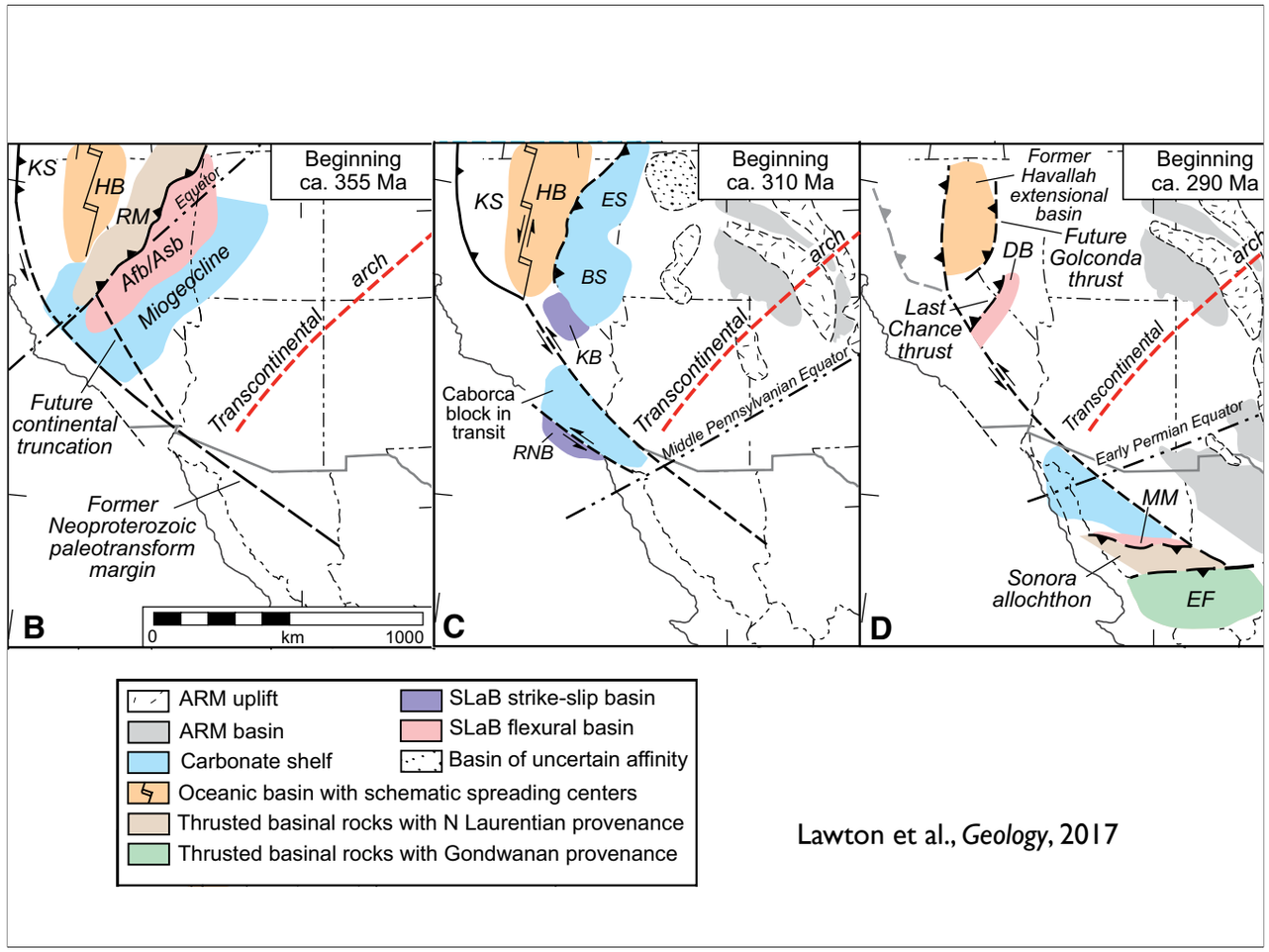


Figure 6 Geotectonic features of the Antler orogen (Late Devonian–Early Mississippian), the Ancestral Rocky Mountains province (Pennsylvanian–Early Permian), and the Sonoma orogen (Late Permian–Early Triassic) of the North American Cordillera (allochthons of Antler and Sonoma age are combined, but note 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, *Earth Plan Sci Rev.*, 2004

Standing back, how does all this fit in?



Lawton et al., *Geology*, 2017

Standing back, how does all this fit in? And does this make sense with the Ancestral Rockies? [Wonder how this might look on a proper palinspastic base]

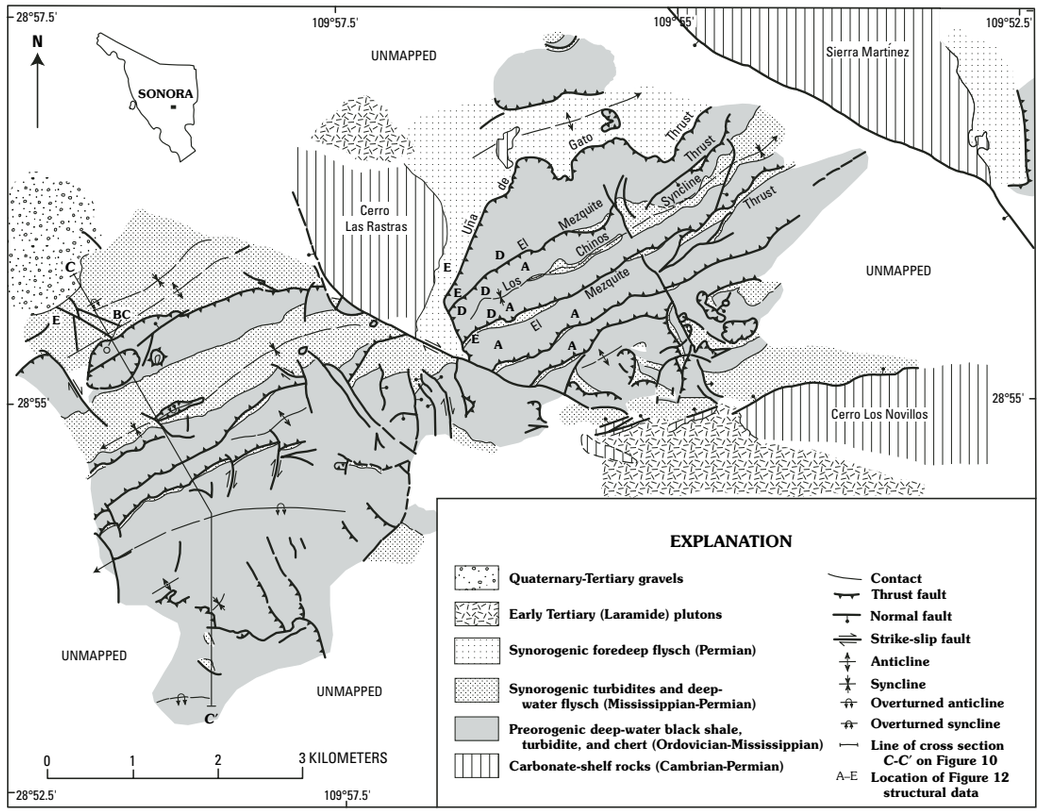


Figure 11. Simplified geologic map of the Minas de Barita area, central Sonora, showing distribution of allochthonous Paleozoic preorogenic and synorogenic rocks, autochthonous to parautochthonous carbonate-shelf Paleozoic rocks and foredeep Permian flysch, major faults and folds, and location of fold-orientation studies of Figure 12. Localities A–E on map denote areas of structural measurements for stereo plots A-E on Figure 12. Outline of map shown on Figure 4.

Poole et al., GSA SP 393, 2005

Note that we have both the deep water facies and the shallow shelf rocks in close quarters, like the situation in eastern NV