

Jurassic Intrusives of the Coyote Mountains, western Salton Trough, southern California and their relationship to the Nazas Arc of northern Mexico.

George J Morgan (georgemorgan@cox.net) and J R Morgan

Abstract

Zircon U/Pb dates from several granitic intrusives found in the Coyote Mountains (CMs) range from 164.1 to 138.9 Ma. The CMs magmatic activity is too early to be associated with the Cretaceous magmatic activity of the Peninsular Ranges Batholith (~128 to 92 Ma) (Hildebrand and Whalen, 2014b and references therein) but is in the age range of the magmatic activity associated with the Jurassic part of the Nazas Arc in northern Mexico (State of Sonora). The Nazas Arc in Sonora is comprised of two episodes of tectonic activity: an earlier episode from ~ 275 to 221 Ma and a second (Jurassic) episode from ~190 to 150 Ma. (González-León et al., 2017 and references therein).

The earliest normal faulting that represents a possibly detachment below the CMs is older than ~17 Ma: an age consistent with Early Miocene extensional tectonics of the Basin and Range in Sonora. Extensional tectonics and subsidence continue to affect the CMs until the start of right-lateral transtensional faulting and uplift associated with the reorganization of the San Andres Fault System at ~1.1 Ma (Steely et al., 2009). With extension of the Basin and Range in Sonora, followed by right-lateral transtensional faulting, the CMs left Sonora and arrive in the western Salton Trough, next to the Peninsular Ranges Batholith (Morgan and Morgan, 2018b).

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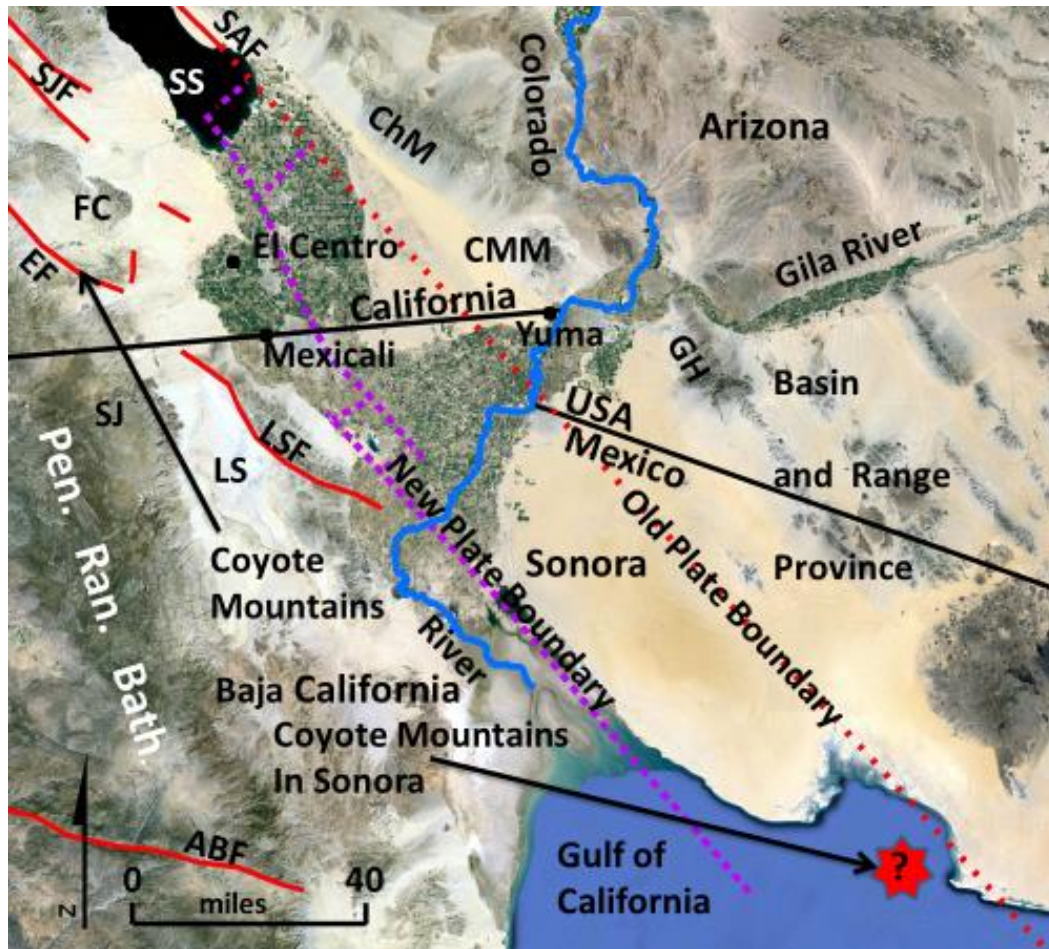
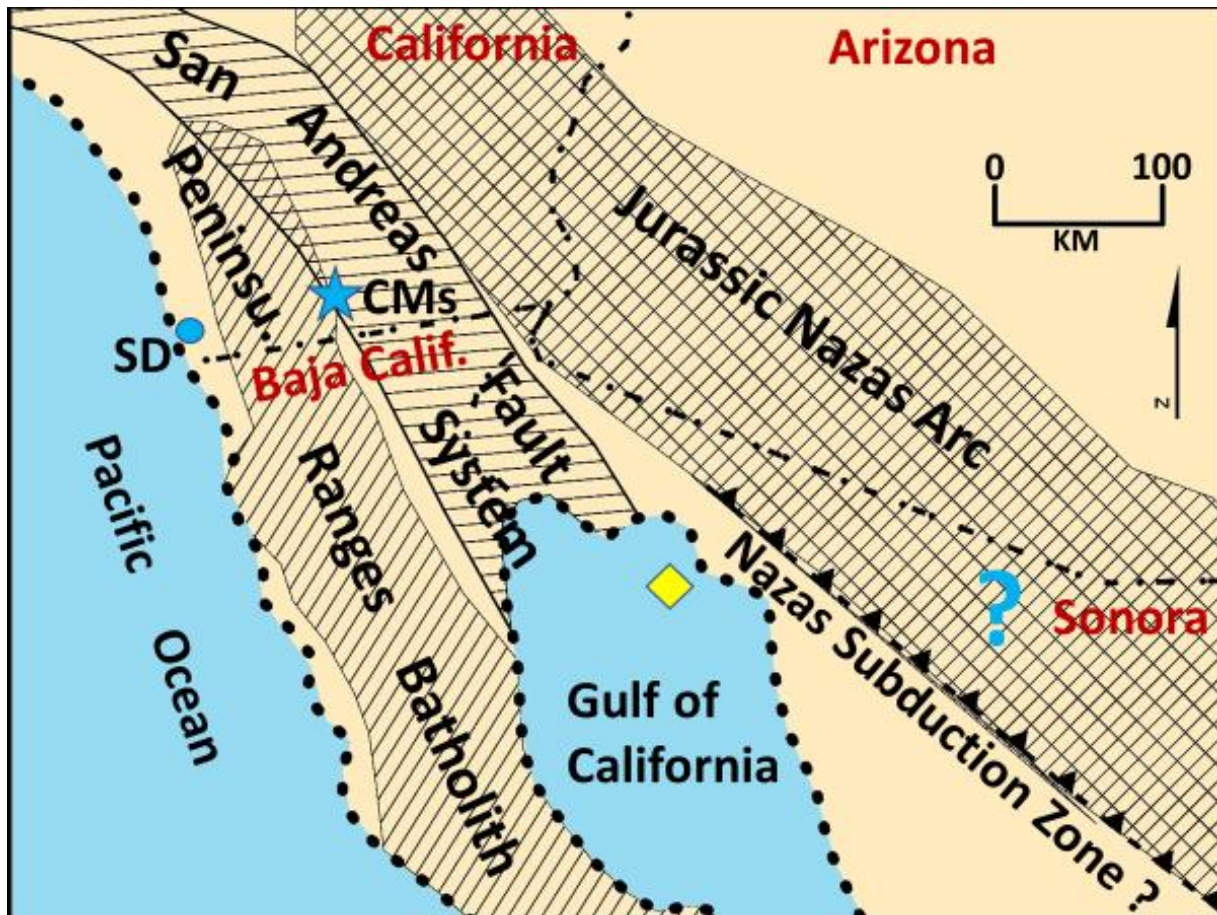
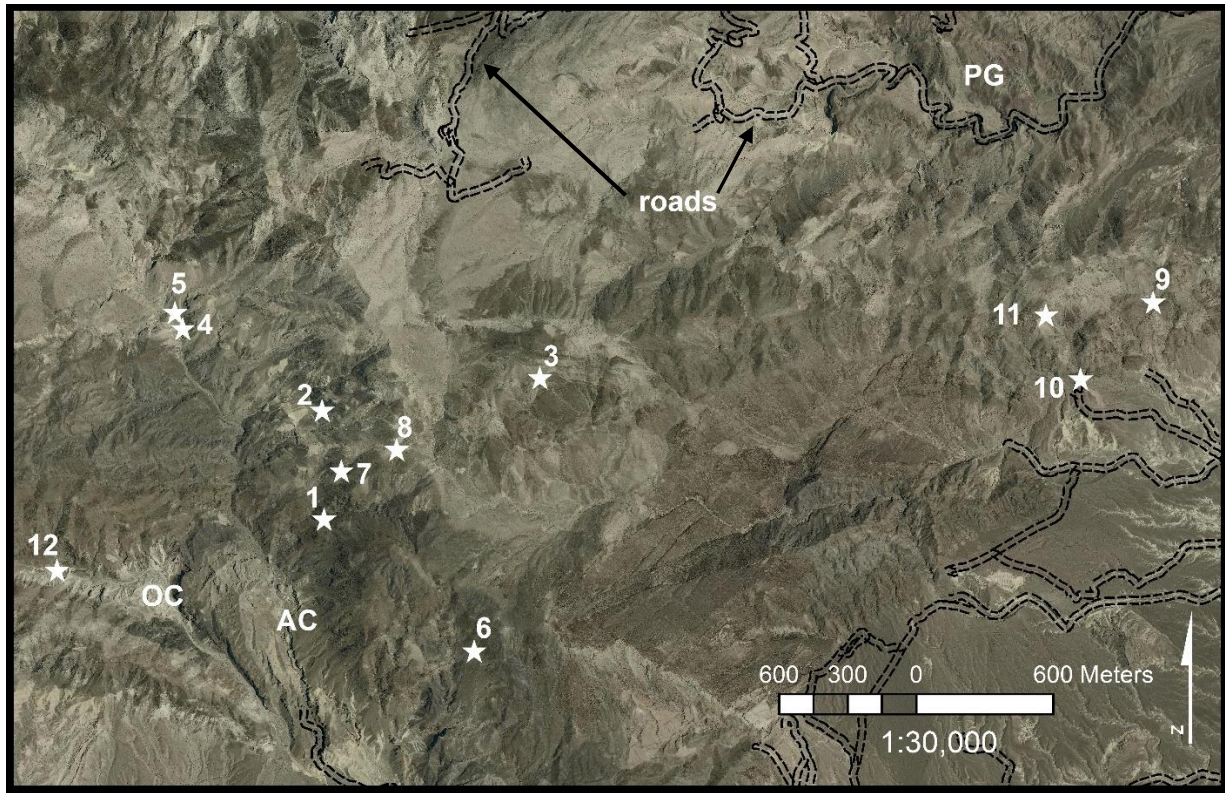


Figure 1. Location map of the Salton Trough and the Coyote Mountains in California, Arizona, Baja California and Sonora, Mexico. The Salton Trough, an northern extension of the Gulf of California, is bounded by the San Andreas Fault and Old Plate Boundary to the east and, for the most part, by the Peninsular Ranges Batholith to the west. **ABF** - Agua Blanca Fault, **ChM** - Chocolate Mountains, **CMM** - Cargo Muchacho Mountains, **EF** - Elsinore Fault, **FC** - Fish Creek Mountains, **GM** - Gila Mountains, **LA** - Laguna Salada, **LSF** - Laguna Salada Fault, **Pen. Ran. Bath.** - Peninsular Ranges Batholith, **SAF** - San Andreas Fault, **SJ** - Sierra de Juarez, **SJF** - San Jacinto Fault, **SS** - Salton Sea. Red star with query is the paleogeographic location of the Coyote Mountains at 5.5 Ma by Winker and Kidwell (1996) in Sonora, Mexico. We agree the paleogeographic location for the CMs was somewhere in Sonora, Mexico. NASA photograph.

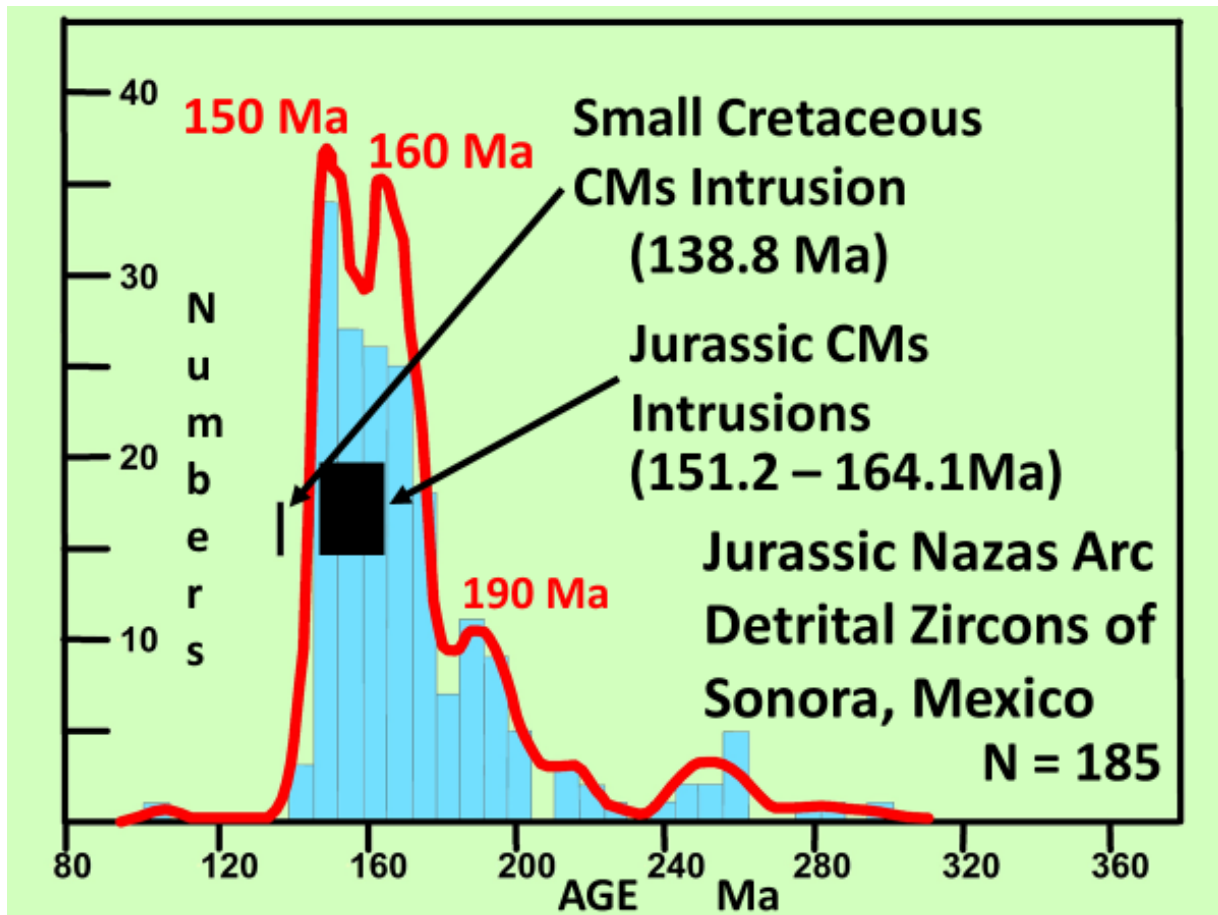


2. Simplified sketch map, modified from Titley and Zurcher (2008) showing a part of the Jurassic Nazas Arc with subduction zone (?), San Andreas Fault System, Peninsular Ranges Batholith, Coyote Mountains (CMs) and San Diego (SD). Blue Star is the present location of the CMs. Yellow Diamond is Winker and Kidwell's (1996) location of the CMs at 5.5 (?) Ma. Blue Question Mark is a possible location for the CMs in Sonora, Mexico.

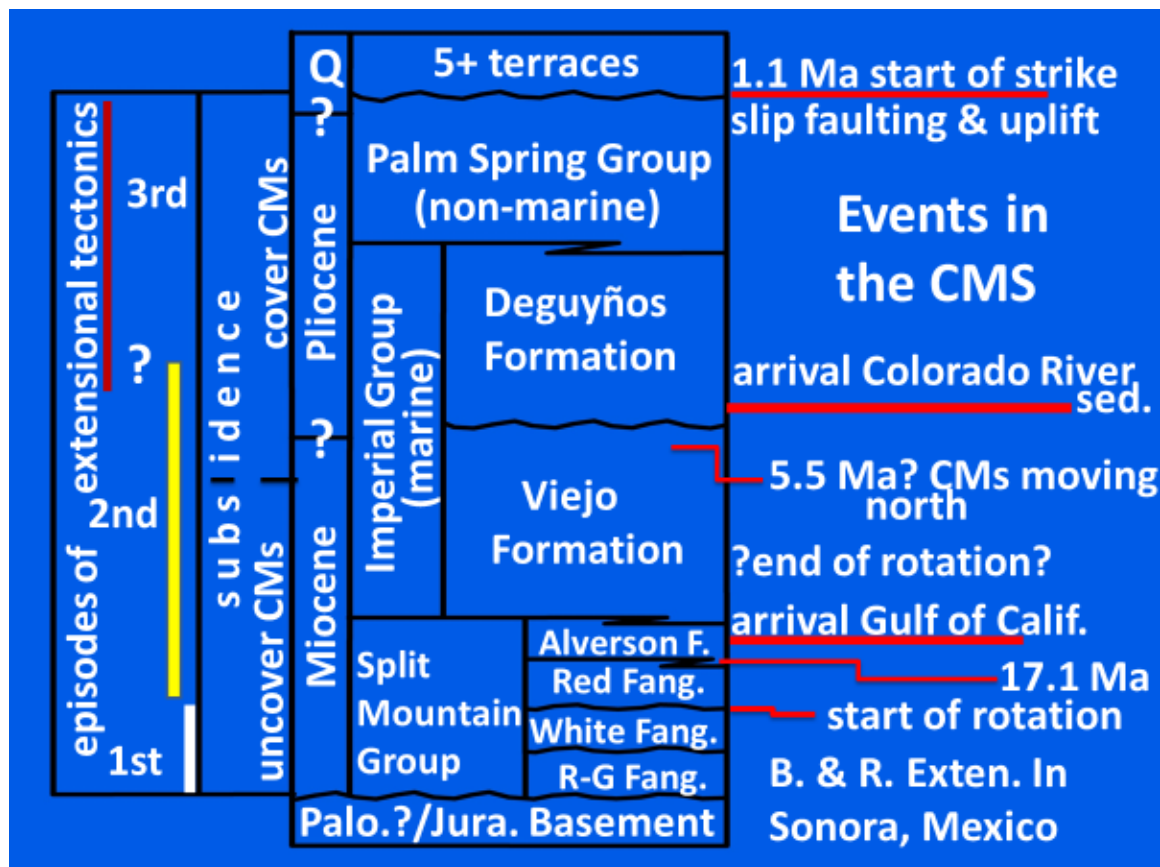


4. View on the southern CMs showing the locations of the zircon-dated granitic intrusions with roads. Most of the dated granitics are associated with Morton's green metamorphic unit. **AC** – Alverson Canyon. **OC** – Ocotillo Canyon. **PG** – Painted Gorge.

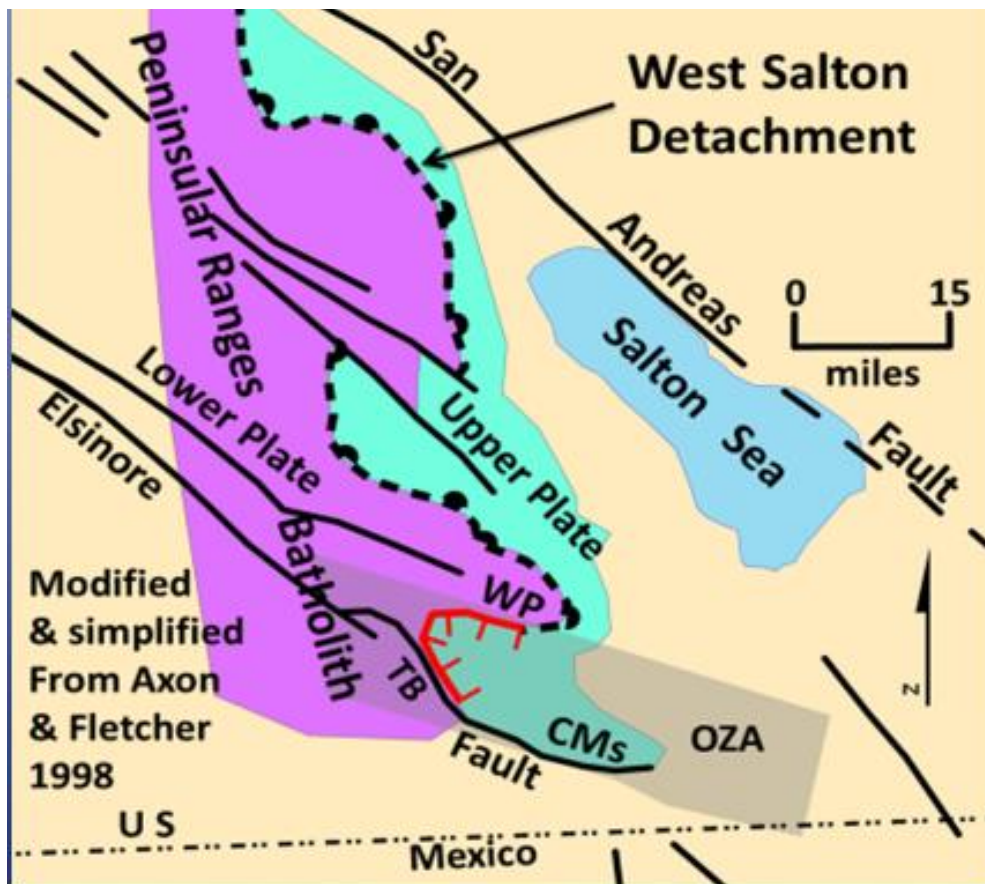
Number	Zircon Age-Dates
1	164.1 ± 2.8 Ma
2	163.9 ± 2.8 Ma
3	163.8 ± 3.0 Ma
4	163.2 ± 2.4 Ma
5	162.4 ± 2.2 Ma
6	162.2 ± 3.5 Ma
7	161.9 ± 2.4 Ma
8	161.4 ± 2.6 Ma
9	160.2 ± 2.0 Ma
10	153.6 ± 1.4 Ma
11	151.2 ± 1.3 Ma
12	138.8 ± 0.96 Ma



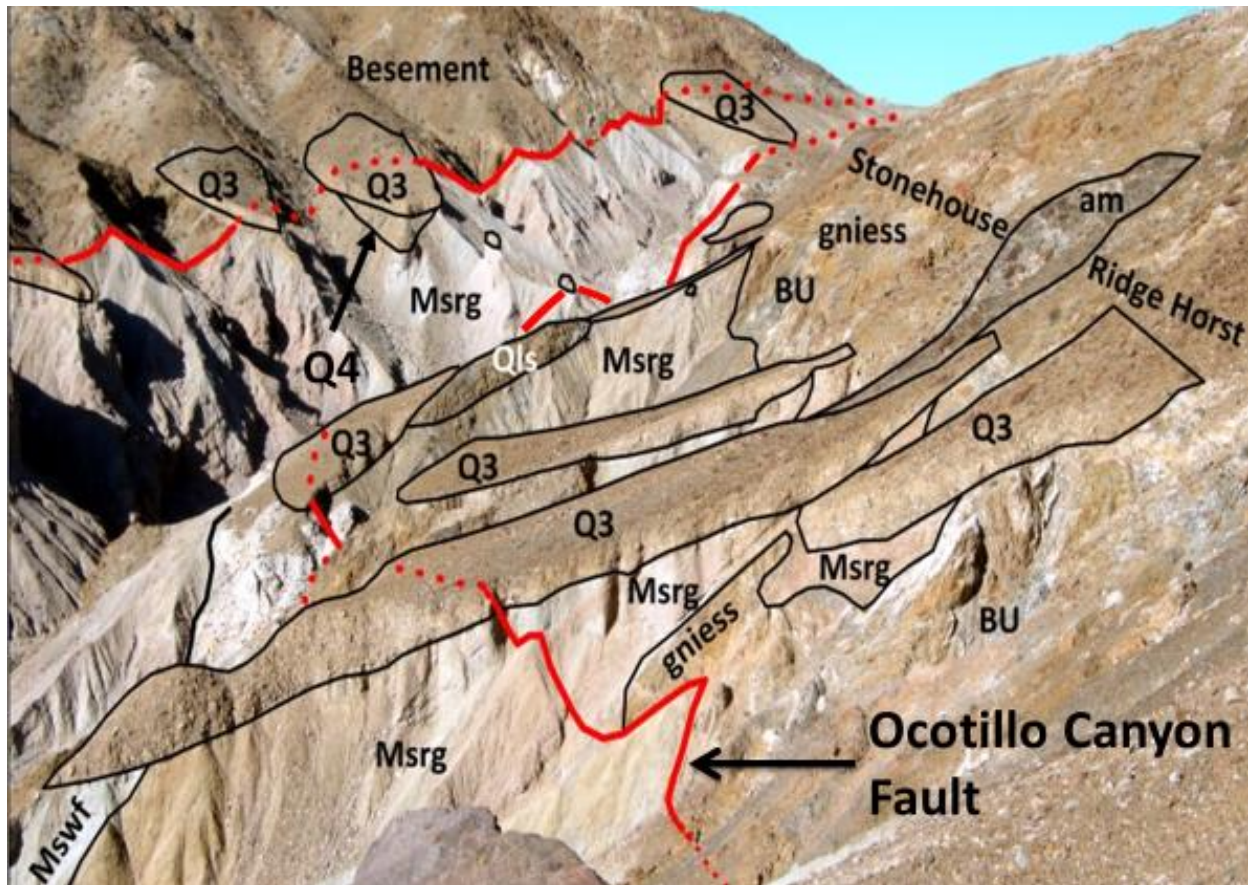
5. Figure modified from González-León et al. (2017). González-León et al.'s data shows the second (Jurassic) episode of magmatic activity of the Nazas Arc, which is inferred from detrital zircons of the Jurassic Sierra de Santa Rosa, Basomari, Lilt Formations (original data from González- León et al., 2009) combined with detrital zircons from the Cucurpe Formation (data from Mauel et al., 2011). The black rectangle represents the Jurassic intrusives found in the CMs. The thin, black, vertical bar to the left represents the single, small, Early Cretaceous intrusive found in the CMS. We have yet to find any granitic intrusives that are the age of the Peninsular Ranges Batholith (~128-92 Ma, Hildebrand and Whalen, 2014b) in the CMs.



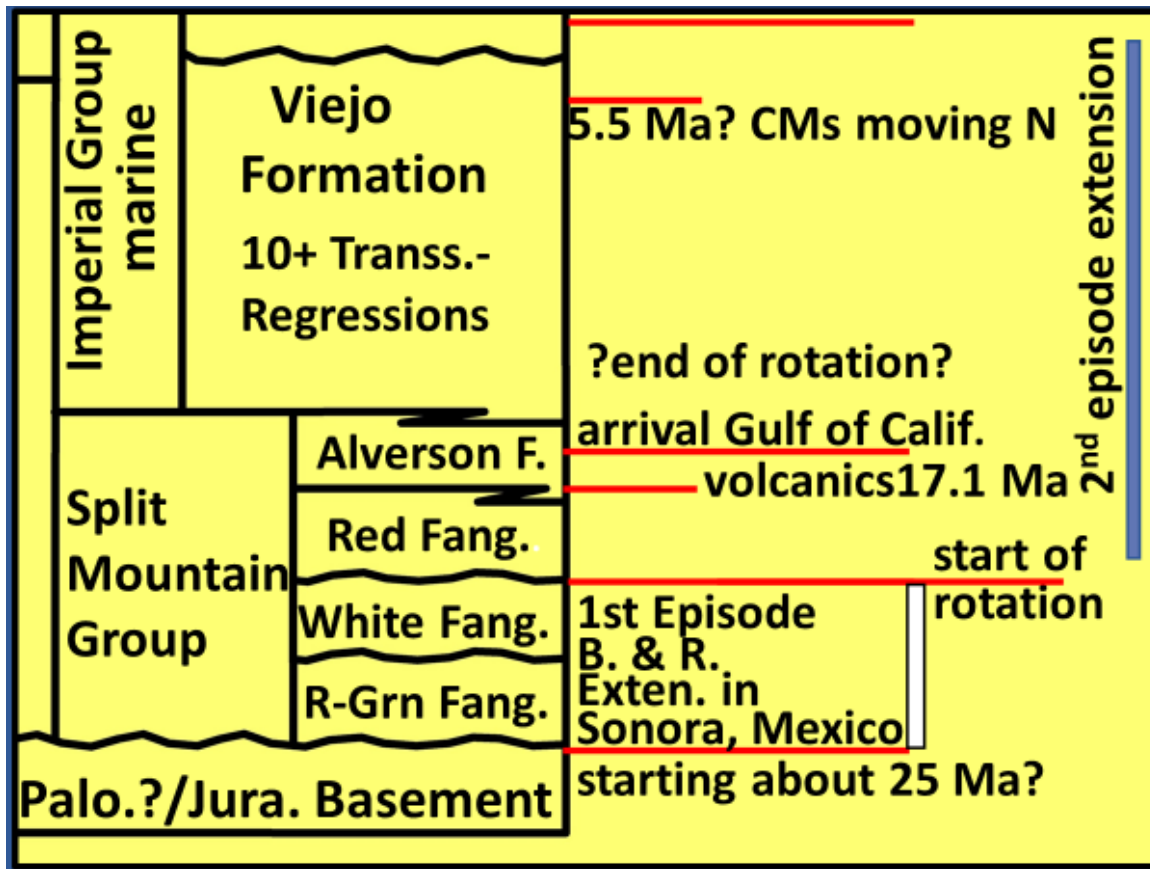
6. Three extensional tectonic episodes found in the CMs are shown in relational to group and formational units, their relationship to each other and to events that have taken place in the CMs (Morgan and Morgan, 2017a). The white “?” mark between the second and third extensional episode questions the timing of the end of the second and the start of the third. These two episodes may be one continuous episode. The white “?” mark between the epochs is questioning where the corresponding age boundaries are in the sedimentary units. The 90 degrees of clockwise rotation in the CMs started at the end of the first episode of extension and ended during the deposition of the Viejo Formation (Morgan and Morgan, 2018b). **B & R** – Basin and Range. **F** – Formation. **Fang.** – Fanglomerate. **Q** – Quaternary.



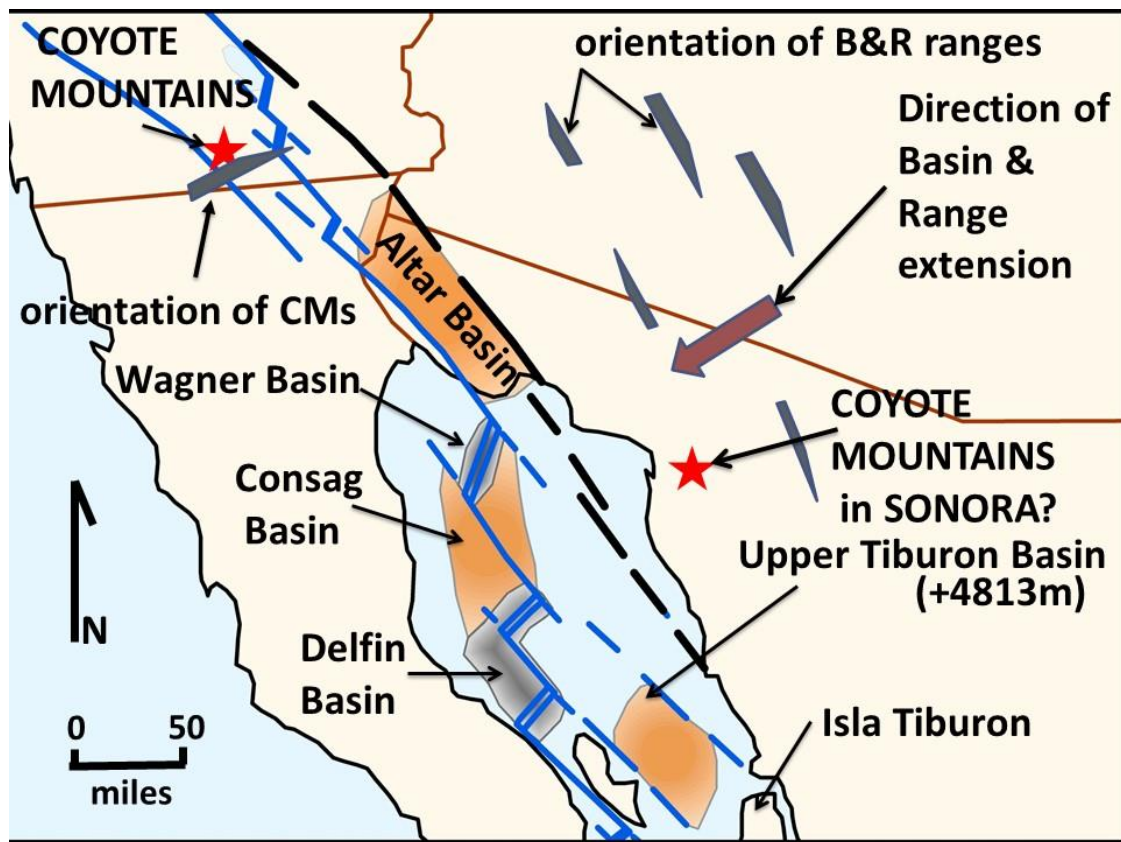
7. Sketch map of the upper and lower plates of the West Salton Detachment. In this area the western trace of the West Salton Detachment is the western edge of the Salton Trough. **OZA** – Ocotillo Zone of Accommodation (gray area). In later mapping (Axen et al., 2006) the West Salton Detachment was extended from Whale Peck (**WP**) to the Terra Blanca Mountains (**TB**). This implies that the OZA should be thinned to the Elsinore Fault. Pridmore and Frost (1992), Axen and Fletcher (1998) and Morgan and Morgan (2017a) all believe that the CMs are on the upper plate of a detachment. All the normal faults we have mapped in the CMs are possibly rooted to this detachment (Morgan and Morgan, 2017a). The lower plate and the upper plate are structurally tied together. If the lower plate is moved east in a reconstruction, the upper plate has to follow. With the removal of the extension of the Basin and Range Province in Sonora, the Peninsular Ranges Batholith would be next to the Sonoran Block along a geosuture (?). This geosuture may have been a part of the Nazas Arc Subduction Zone(?) (?). We believe the Peninsular Ranges Batholith Block would under-thrust the Sonoran Block.



7. Looking west at the northern part of Ocotillo Canyon (first canyon west of Alverson Canyon). The normal Ocotillo Fault is the northern boundary of a half-graben that formed during the first episode of extension tectonics, while the CMs were in Sonora, Mexico (Morgan and Morgan, 2018a). The Ocotillo Canyon Fault does not cut the volcanics of the 17.1 Ma Alverson Formation. The only extensional tectonics taking place before 17.1 Ma in southwestern North America was in the Basin and Range Province. A southern and younger fault truncated and removes the southern part of the half-graben. Both faults can be seen converging to the west as they narrow the graben. Normal faults of the second extensional episode cut the Ocotillo Canyon Fault and the corresponding Stonehouse Ridge Horst (Morgan and Morgan, 2018b). **am** – amphibolite. **BU** – buttress unconformity. **Q3** – Quaternary Terrace 3. **Q4** – Quaternary Terrace 4. **Qls** – Quaternary landslide. **Msrg** – Miocene Red-Green Fanglomerate and **Mswf** – Miocene White Fanglomerate; both a part of the Split Mountain Group (SMG).



9. At about 25 Ma Basin and Range extension started in Sonora, Mexico (Nourse et al., 1994). During this extension the Red-Green (**R-Gen**) and White Fanglomerates of the SMG were syn-extensionally deposited in the CMs. The Red Fanglomerate and the volcanics of the Alverson Formation of the SMG are syn-extensionally related to the second episode found in the CMs. The Red Fanglomerate interfingers with the Alverson Formation (Mendenhall, 1910; Christensen, 1957). The Viejo Formation interfingers with the Alverson (Woodring, 1931; Morgan and Morgan, 2014, 2016). This second episode appears to be related to the continuing Basin and Range extension and the arrival (~17.1 Ma) of the Gulf of California (Viejo Formation). The continuing rotation of the CMs is recorded at two paleomagnetic (Mace, 1981) sites located in the volcanics of the Alverson Formation on the stable (?) Stonehouse Ridge Horst (34° and 70° of clockwise rotation). Rotation ends sometime during the deposition of the Viejo Formation. **B & R** – Basin and Range.



10. Map showing the present-day northern part of the Gulf of California. Helenes et al. (2009) suggest that the proto (young) gulf of California filled basins produced during the Miocene extension associated with the Basin and Range Province in Sonora. Brown areas (Upper Tiburon, Consag and Altar Basins) are some of the older marine basins associated with this Basin and Range extension and subsidence. The Old Plate Boundary is also associated with this Miocene extension. McDowell et al. (1997) observed that the Basin and Range extension in Sonora continued and was “coeval with initial evolution” of the right-lateral transtensional tectonics that produced the Gulf of California. Our second episode of extension in the CMs corresponds to McDowell’s observation (Morgan and Morgan, 2017a). The Basin and Range extension has to move the CMs west of the New Plate Boundary before 5.5 Ma when the new boundary is established. The right-lateral transtensional faulting then can move the CMs to the western edge of the Salton Trough, east of the Peninsular Ranges Batholith.

Inferences:

Jurassic granitic intrusions in the CMs are associated with the Jurassic Nazas Arc and not the Cretaceous Peninsular Ranges Batholith.

Early to Mid-Miocene extension, before 17.1 Ma, of the Basin and Range Province moved the CMs and the Peninsular Ranges Batholith west.

Before extension, the Peninsular Ranges Batholith was suture to Sonora, possibly along the Nazas Arc Subduction Zone(?). During collision with the Cretaceous Peninsular Ranges Batholith the Sonoran Block was thrust up and over the Peninsular Ranges Batholith.

Extensional tectonics and subsidence may have continued until ~1.1 Ma in the CMs.

Extensional tectonics moved the CMs west of the New Plate Boundary before 5.5 Ma. Then right-lateral transtensional faulting associated with the San Andreas System moved the CMs northwest to their present location in the western Salton Trough.

The Peninsular Ranges Batholith moved in unison with the CMs.

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