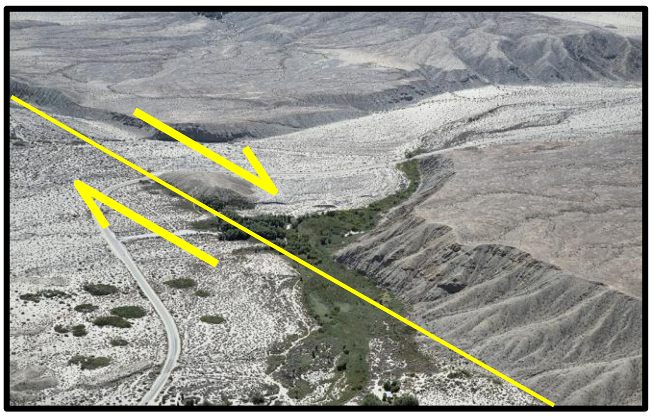
Fall 2019 Geo-Extravaganza!
Coachella Valley/Salton Trough
Mt. San Jacinto

San Diego Mesa College
Sat/Sun October 26th & 27th

Instructors: Don Barrie, Ray Rector, and Bulent Bas



<u>Saturday Oct. 26th:</u> After packing vehicles and finalizing carpools, we'll caravan as a group to the Coachella Valley Preserve (~ 2.5-3 hour drive), where we'll examine landscape features associated with the mighty San Andreas Fault. Next, we'll proceed to Whitewater Canyon to explore the Banning Fault, along with some interesting rock features, including the Pinto Gneiss—one of the oldest rock units in Southern California. After a quick dinner at a Mexican Restaurant in Desert Hot Springs, we'll camp for the night at Mission Creek Preserve.

<u>Sunday Oct. 27th:</u> We'll rise early (~ 7 am), eat a quick breakfast, pack up camp, and caravan over to the parking area for the Palm Springs Tramway. Then, we'll take a tram (cable car) ride up Mt. San Jacinto, one of the steepest mountain fronts in the continental U.S. As we ride up the mountain, we'll see an incredible cross section through several thousand feet of the Earth's crust. At the top, we'll be treated to spectacular views of the Colorado and Mojave Deserts. We'll end the field trip by 2 pm; plan to be back in San Diego by 5 pm.

As we explore the park this weekend, we'll learn about the region's long-term geologic evolution--a story that covers over 1.5 billion years of geologic time!

Figure 1: Coachella Valley vicinity & field trip map.
(map source: Google Maps)

Important Information:

- **Coachella Valley Preserve (STOP 2, SAT):** 29200 Thousand Palms Canyon Road, Thousand Palms, CA 92276 **Phone: (760) 343-2733**

- **Saturday Dinner Location (STOP 4 SAT):** Casa Blanca Mexican Restaurant, 66370 Pierson Blvd #3658, Desert Hot Springs, CA 92240; **Phone: (760) 251-5922**

- **Mission Creek Preserve (STOP 5, SAT; Camping): 60550 Mission Creek Rd, Desert Hot Springs, CA 92240;** Park at gate, then walk around to the opposite side of gate to find lock. Gate Code: 1602 (valid for Sat Oct 26th only); left-most combination lock; please lock gate behind you after you drive through.

Here are some rules to be aware of:

1. **We all travel together!** At all times as we're driving/walking from one spot to the next, please keep the person behind you and the person in front of you in view…if you have to, slow down to wait for the person behind you to catch up.

2. **No passing the instructor vehicles on the road.**

3. When in camp, on the road, and everywhere else (in other words, always!), **please be respectful to those around you**! Remember, you're representing Mesa College on this trip. It's important for us to maintain good relations with our neighbors so we can come back to Joshua Tree in the future.

*****One last thing…**BE CAREFUL OUT THERE**!*****

SATURDAY OCT 26TH

<u>DIRECTIONS TO STOP 1:</u> BATHROOM / MINIMART, TEMECULA, CA

- **I-163 North to I-15 North to Temecula**
- **Exit I-15 at I-79 South/Temecula Parkway (Exit 58)**
- **Turn right onto Temecula Parkway, then make a quick right onto Bedford Ct.**
  Mobile station/Circle K is on your left after you turn

<u>STOP 1 (approx. 1 hr with no traffic):</u> MOBILE STATION/CIRCLE K, 44520 Bedford Ct, Temecula, CA 92592; Circle K phone number: (951) 695-6841; there's also a mini-mart across the street which also has a restroom.

20 MIN STOP…PLEASE BE QUICK!!!

<u>DIRECTIONS TO STOP 2:</u> COACHELLA VALLEY PRESERVE

- **From the Mobile Station/Circle K, turn left onto Temecula Parkway, and get onto I-15 North**
- **In approx. 4.7 miles, merge onto I-215 North**
- **In approx. 30 mi, merge onto I-60 East**
- **In approx. 18 mi, merge onto I-10 East**
- **In approx. 37 mi, exit I-10 at Monterey Ave. (Exit 131); turn left onto Monterey Ave.**
- **In 0.7 mi, turn right onto Ramon Rd.**
- **In approx. 3.5 mi, turn left onto Thousand Palms Canyon Rd. and follow the road approx. 2 mi to the parking area**

STOP 2: COACHELLA VALLEY PRESERVE & THOUSAND PALMS OASIS

1. **Please summarize the current plate tectonic setting of California (Figure 2).**

- Northern CA (Oregon border to Cape Mendocino):
- Central/Southern CA (Cape Mendocino to Salton Trough):
- Southern/Baja CA (Salton Trough to Gulf of CA):

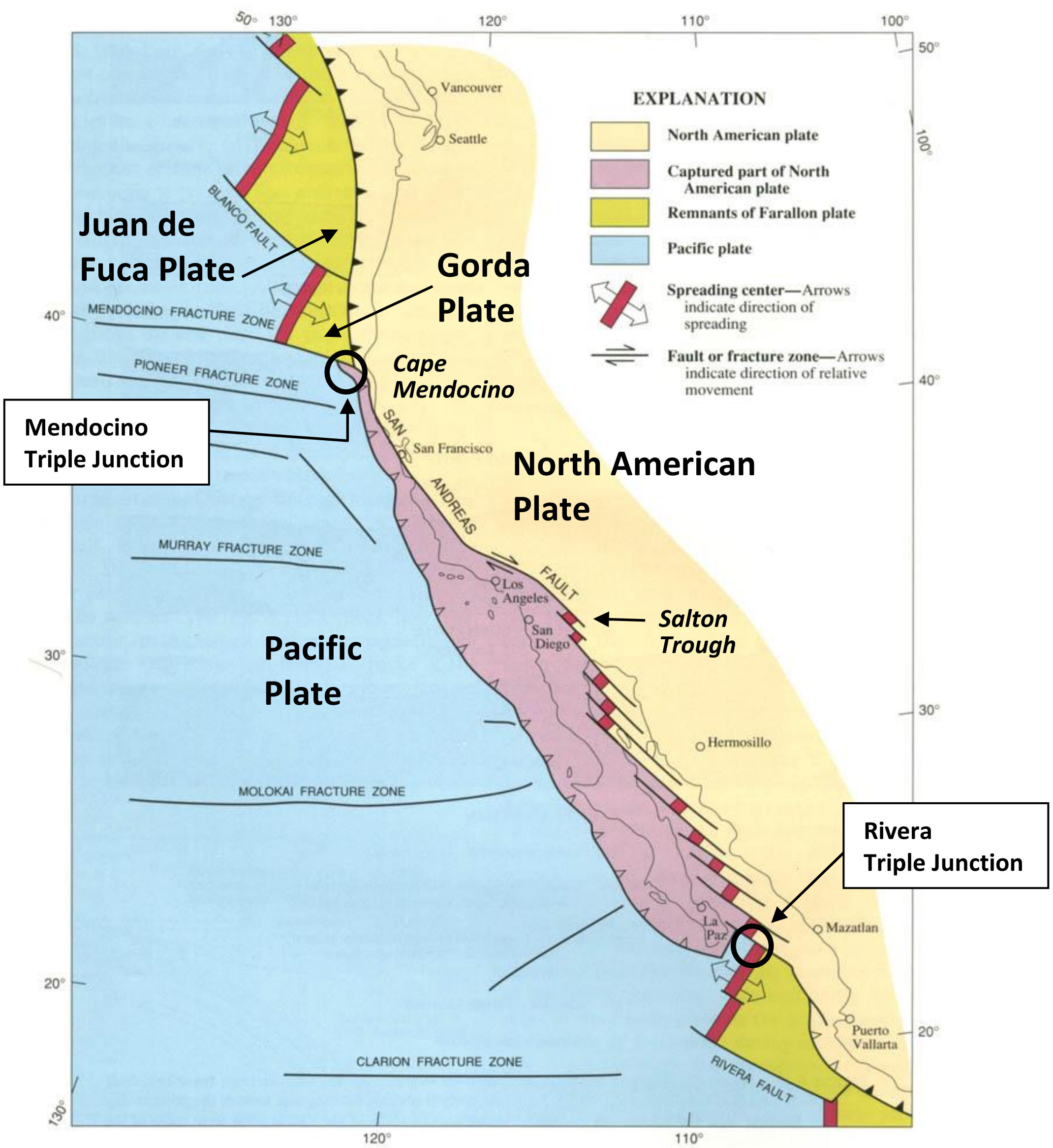


Figure 2: Plate tectonic setting of California.
(source: Geology Café, 2019)

At this location, we're also near the boundary between four of California's regional geomorphic provinces, including the low-elevation Colorado Desert (Salton Trough) to the southeast, the mountainous Transverse Ranges to the north, the Peninsular Ranges to the west, and the Mojave Desert to the east (Figure 3).

California's geomorphic provinces are geologic regions that display distinct landscapes and landforms. Earth scientists recognize eleven provinces in California. Each province displays various features based on geology (rock-type distribution), tectonics (vertical and horizontal movements of Earth's crust), topographic relief (slope), and climate (long-term weather patterns). This weekend, we'll focus mainly on geology and tectonics.

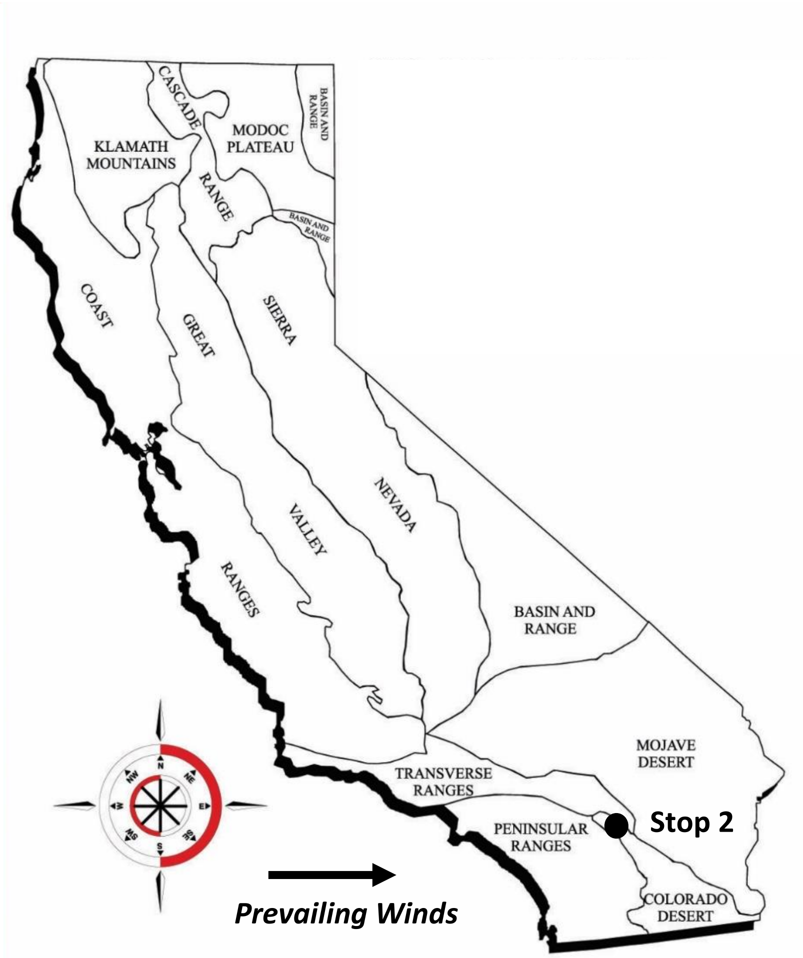


Figure 3: Geomorphic provinces of California.
(source: http://www.yamasun.net/CAMaps.html)

2. How do the Mojave and Colorado Deserts differ in terms of elevation?

3. Why are the Mojave and Colorado Deserts characterized by low rainfall?

San Andreas Fault Zone

Geologically speaking, we're currently along the transform boundary between the Pacific and North American plates, as marked by the San Andreas Fault (Figure 4). In this area, the San Andreas Fault trends more east-west than at other locations, and consists of two branches, including the Banning Fault to the south and the Mission Creek Fault to the north. We crossed the Banning Fault as we drove into the Coachella Valley Preserve.

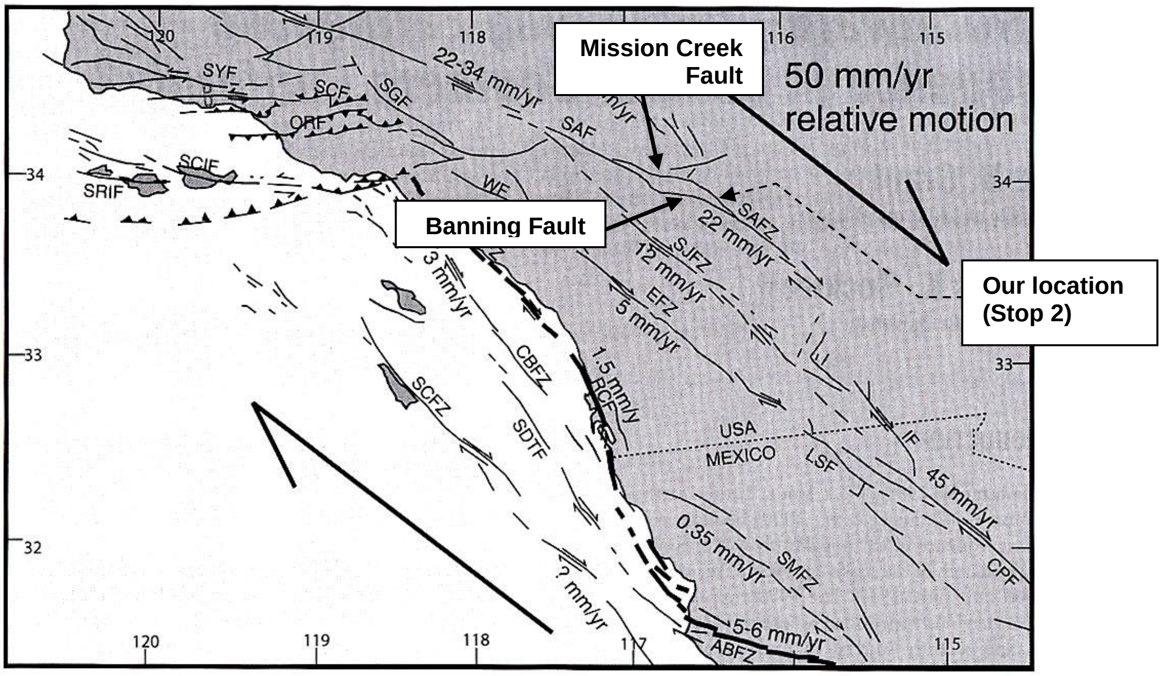


Figure 4: Fault map of southern California.
(Source: Grant and Rockwell, 2002)

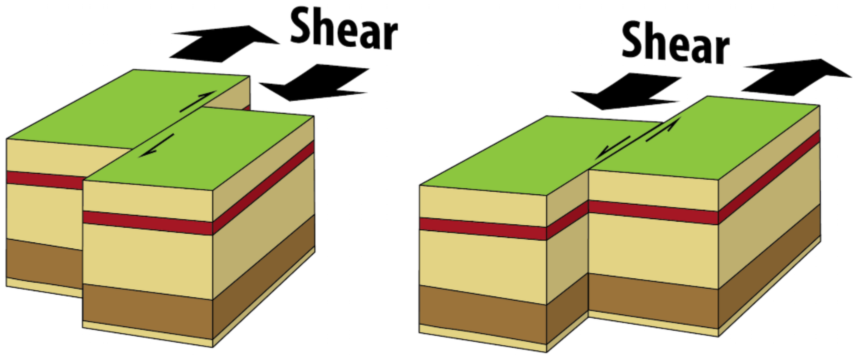
4. **Based on the fault slip-rate data in Figure 4, approximately what percentage of the total transform motion (~50 mm/yr) between the Pacific and North American plates is occurring along the southernmost San Andreas Fault Zone (SAFZ)? Circle correct answer below:**

About 75% ***About 50%*** ***A bit less than 50%***

5. **Does a long-term slip rate for the southern San Andreas Fault of 22 mm/year mean that the fault slips this much every year? Explain.**

Mission Creek & Banning Faults

Faults like the Mission Creek and Banning Faults are called strike-slip faults, which can either be right-lateral or left-lateral as shown in Figure 5. Strike-slip faults can typically be mapped at Earth's surface because landscape features like stream channels, hillside benches, and ridges, become aligned along the fault (Figure 6).



Right-lateral strike-slip fault

Left-lateral strike-slip fault

Figure 5: Strike-slip faults.
(source: https://openpress.usask.ca/app/uploads/sites/29/2018/02/strike_slip_faults.png)

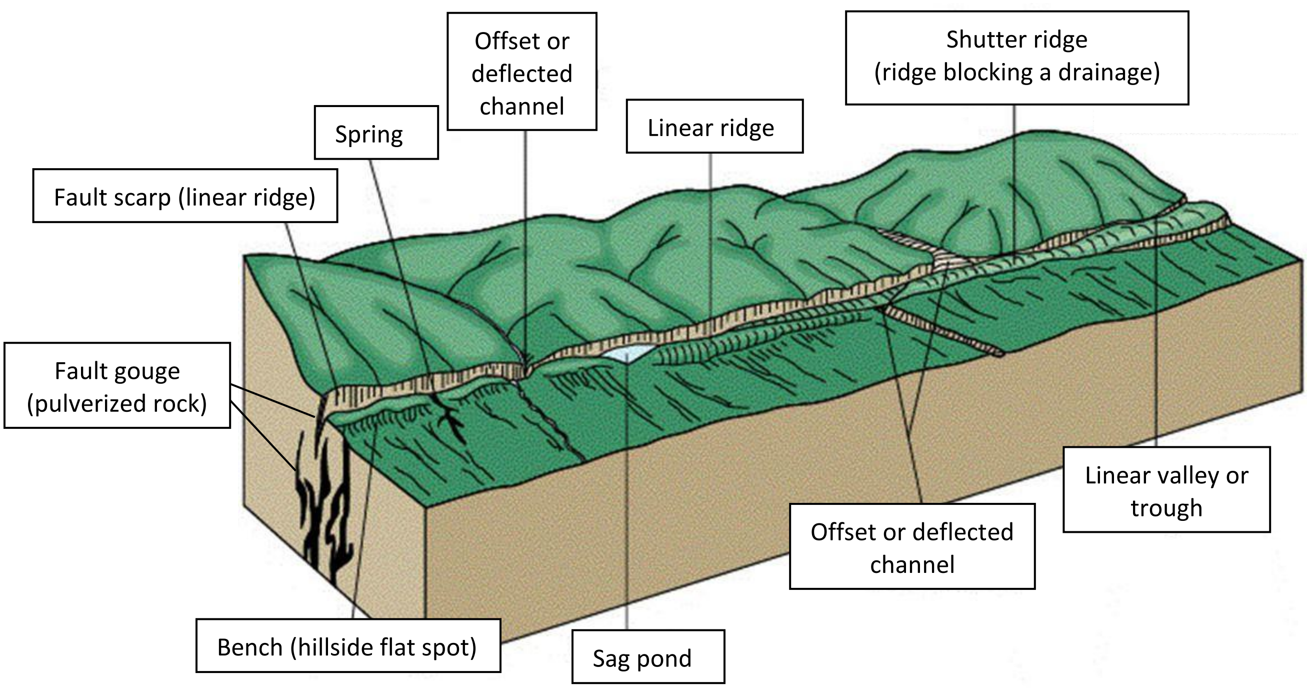


Figure 6: Fault-related landscape features.
(source: modified from https://images.slideplayer.com/17/5382569/slides/slide_13.jpg)

6. **As shown in Figure 4, above, the Pacific Plate is moving northwestward with respect to the North American Plate. Given this relative motion along the plate boundary, would you expect the Mission Creek and Banning Faults to be left-lateral or right-lateral strike-slip faults? Circle correct answer, below:**

Left-Lateral strike-slip ***Right-lateral strike-slip***

Indio Hills

As shown in Figure 7, strike-slip faults do interesting things where they bend, or "step over" from one fault to another. At a restraining bend along a right-lateral strike-slip fault, the fault bends toward the left as one moves along the length of the fault. Localized compressive stress develops along the restraining bend—producing tectonic uplift (hills/mountains). At a releasing bend, the fault bends toward the right as one moves along the fault. Localized extensional stress develops along a releasing bend—producing a depositional basin.

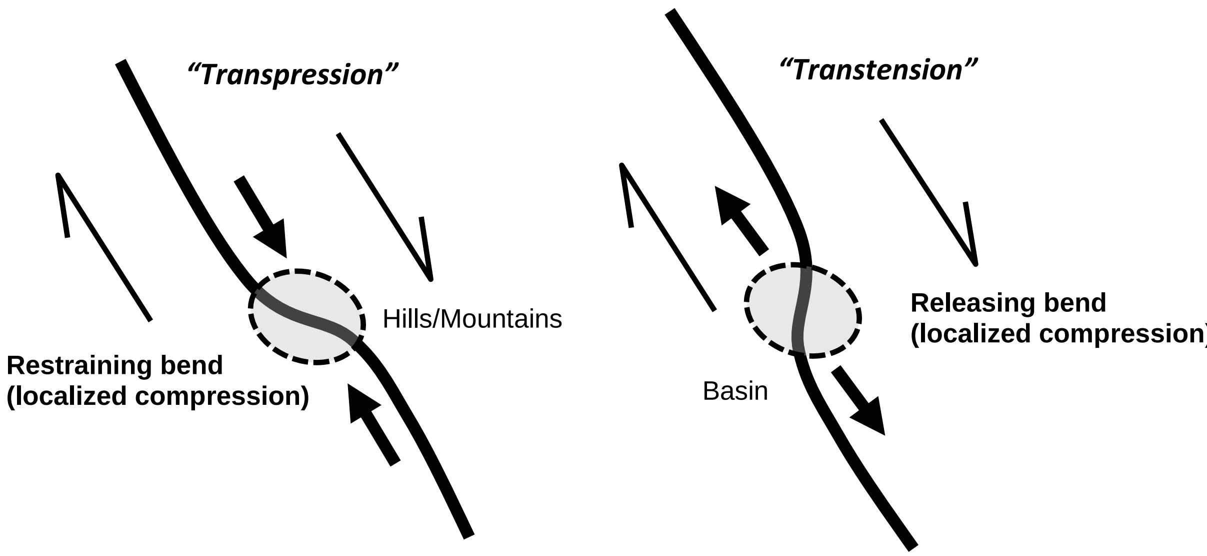


Figure 7: Releasing and restraining bends along a right-lateral strike-slip fault.

As shown in Figure 8, the upland area in this region is called the Indio Hills. Together with the Mecca Hills and Durmid Hill to the southeast, the Indio Hills have developed along a slight bend in the San Andreas Fault. In these three areas, transform plate motion, together with crustal compression ("transpression") have pushed up low mountains.

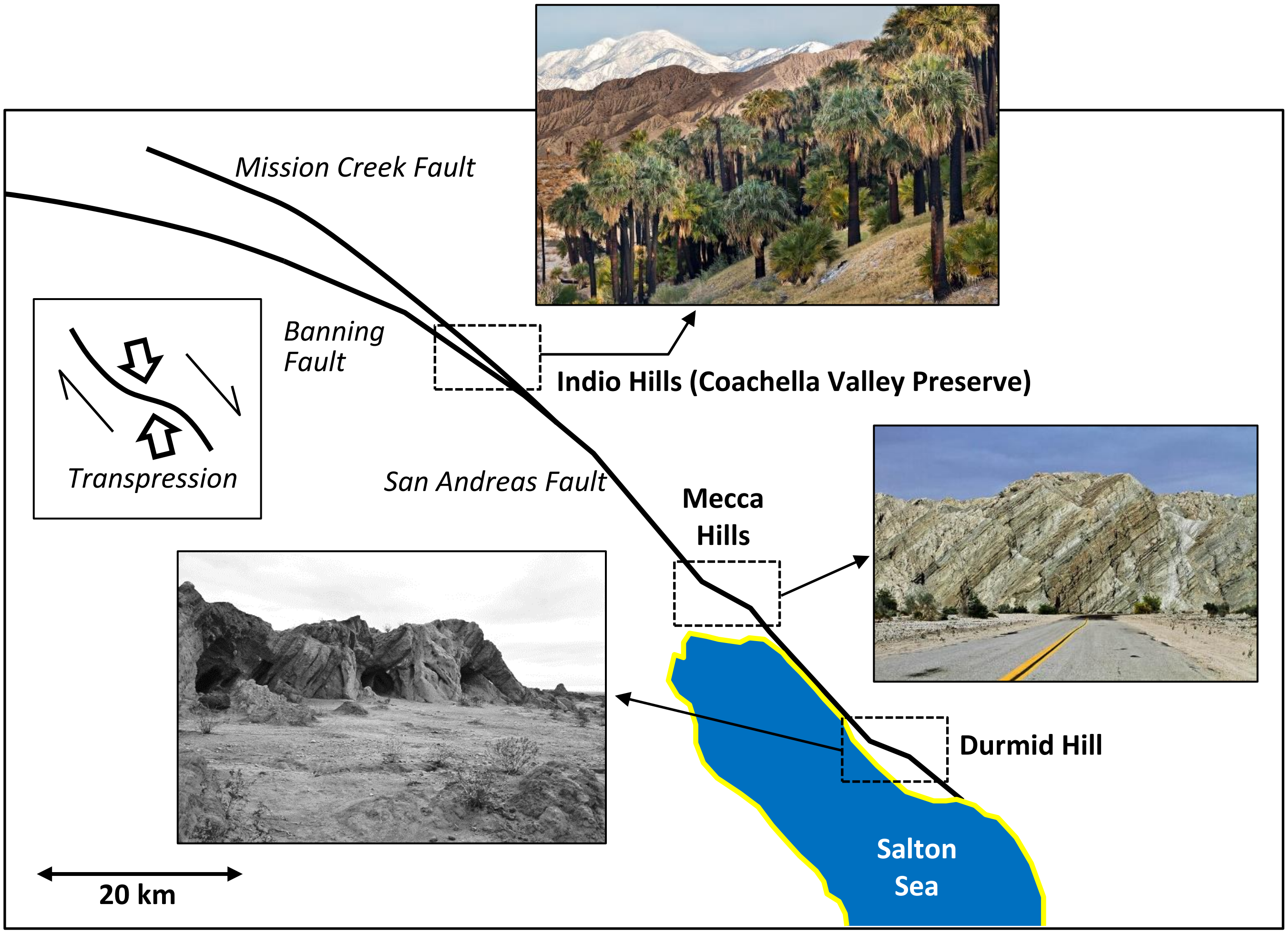


Figure 8: Transpressive structures along the southern San Andreas Fault.

Springs and Palm Oases

Here at Coachella Valley Preserve, Palm trees are growing almost directly atop the fault. This is because the sheared, pulverized rock along the fault retards the flow of groundwater, forcing it up to the surface along the fault to create a series of springs, which provide water for the desert palm, *Washingtonia filifera.* This process is illustrated in Figure 9.

Palm Alignments and Fault Mapping

In this area, the alignment of Palm trees along the Mission Creek Fault is so dramatic that geologists can use this alignment to map the location of the fault.

7. Figure 10 is a Google Earth image of this area. Draw a bold line along the surface trace of the Mission Creek Fault across the entire image. Make your line as straight as possible. Include relative slip arrows on both sides of the fault.

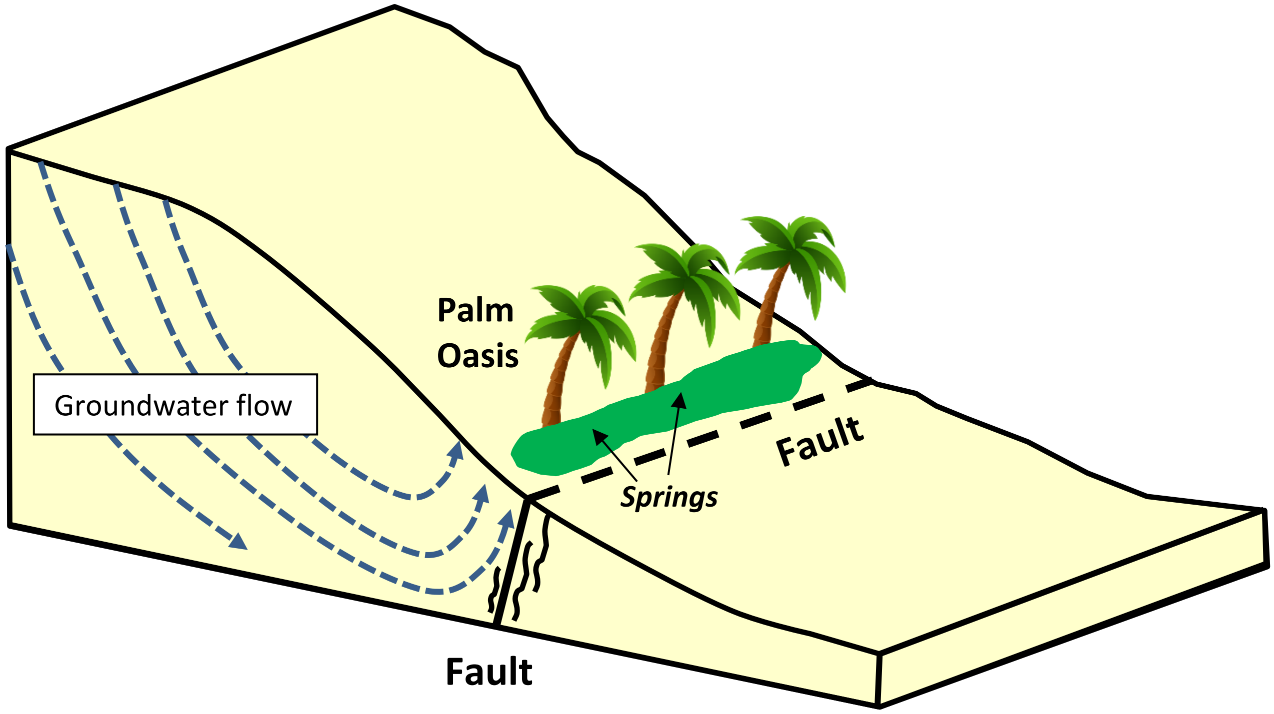


Figure 9: Development of a groundwater barrier along a fault.

As shown in Figure 11, large, surface-rupturing earthquakes generally occur along the San Andreas Fault about every 150 years, on average; however, research at various locations along the southern San Andreas Fault, including here at Thousand Palms, indicates that this section of the fault hasn't ruptured since approximately 1676-1726 (Fumal, Rymer, and Seitz 2002; Rockwell, Meltzner, and Haakar 2018).

At our current location (Thousand Palms), the Mission Creek Fault has experienced four and possibly five surface-rupturing earthquakes in the past 1,200 years (Fumal, Rymer, and Seitz (2002).

Other research conducted at Biskra Palms Oasis, a few kilometers southeast of our location, indicates that the Mission Creek Fault exhibits a long-term slip rate of 14-17 mm/yr (Behr et. al 2010).

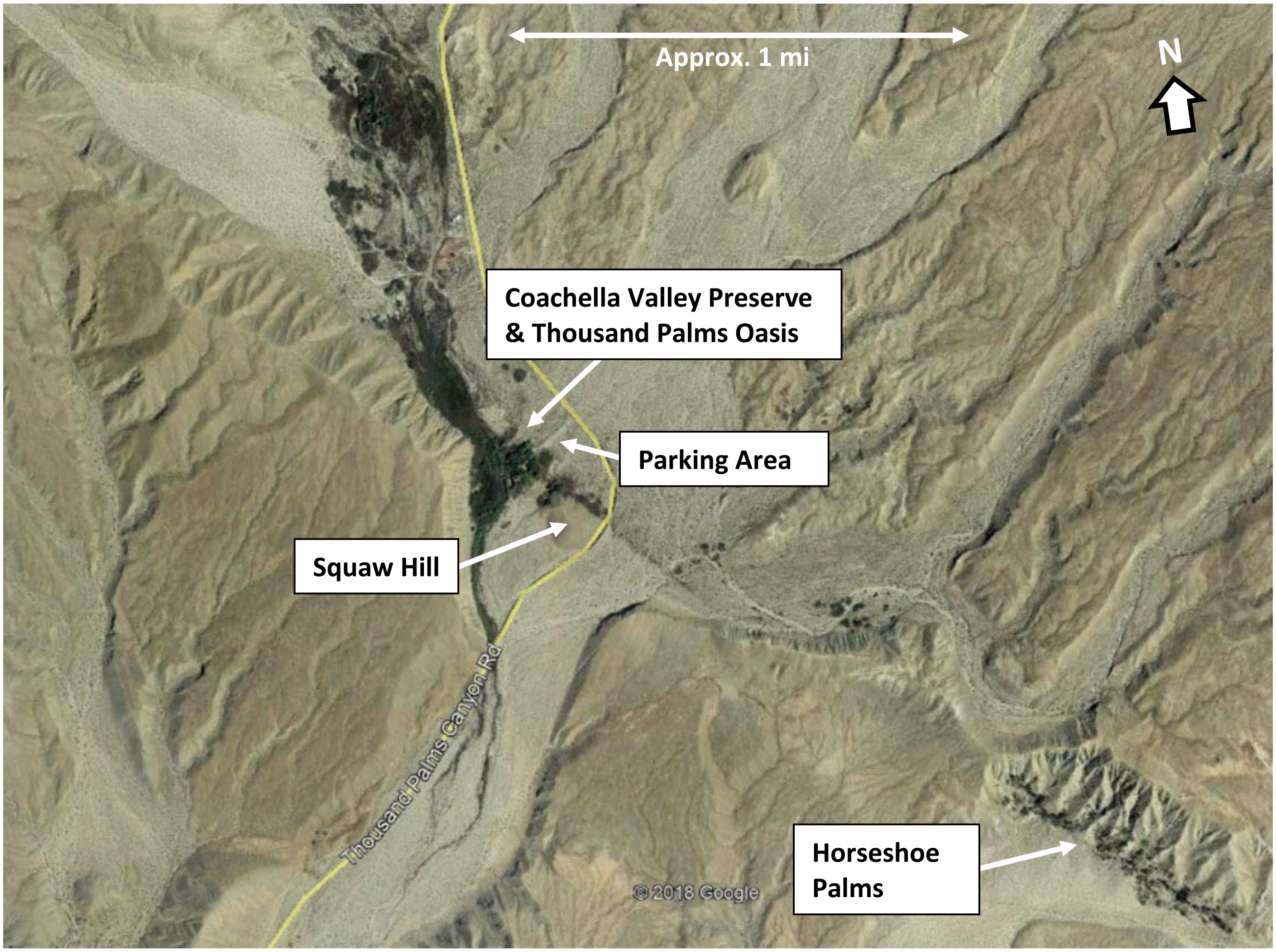


Figure 10: Surface trace of Mission Creek Fault.
(Image source: Google Earth)

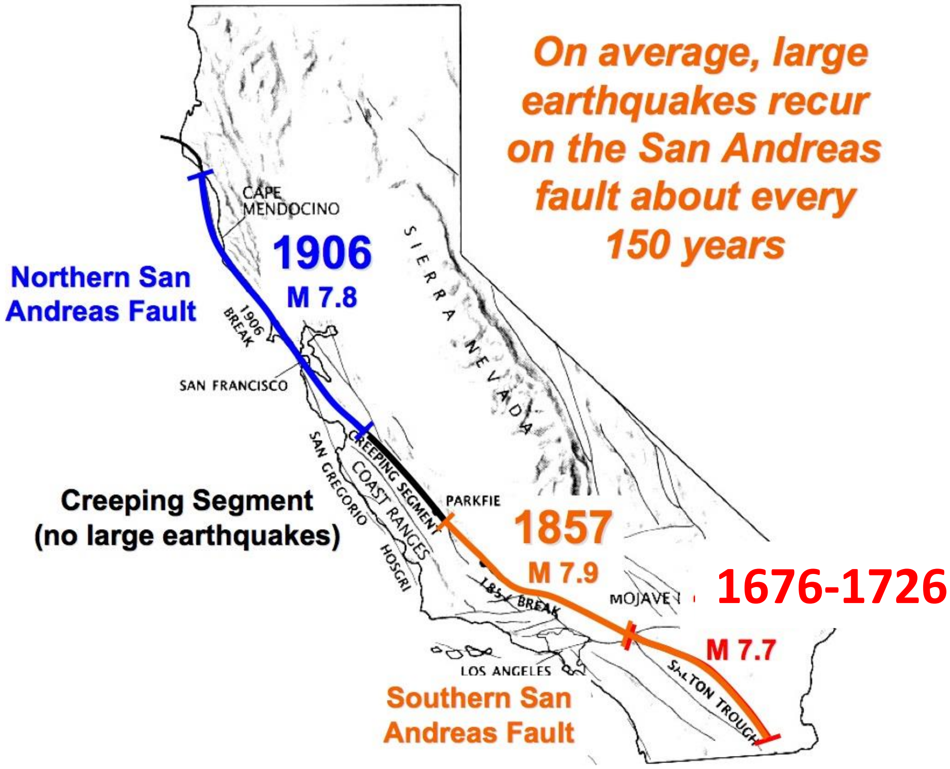


Figure 11: Record of large earthquakes along the San Andreas Fault.
(Source: Blankenheim, 2015)

8. **For calculation purposes, assume that the Mission Creek Fault (Salton Trough section) hasn't experienced a surface-rupturing earthquake since 1726 and that the long-term slip rate of this fault is 15 mm (0.015 m) per year.**

   How much displacement might be expected to occur along the Mission Creek Fault during a large earthquake in 2019 if all of the 1726-2019 "slip deficit" is recovered in a single earthquake?

$$\frac{0.015\text{ m}}{\cancel{\text{yr.}}} \times 293\ \cancel{\text{yr}} = \qquad\qquad \text{meters...WOW!}$$

9. **Use your displacement value from Question 8, together with the graph below (Figure 12) to estimate the magnitude of the next large earthquake along the Mission Creek Fault. Here's how to do this:**

Find your displacement value in meters (answer to Question 6) on the horizontal axis (Average Displacement) of the graph in Figure 10. Then, draw a vertical line from this value to where it touches the bold, sloping line on the graph. Then, draw a horizontal line to the left, to where it intersects the horizontal (Magnitude) axis of the graph.

Estimated Moment Magnitude (Mw) of next large earthquake

on the Mission Creek Fault: ___________________

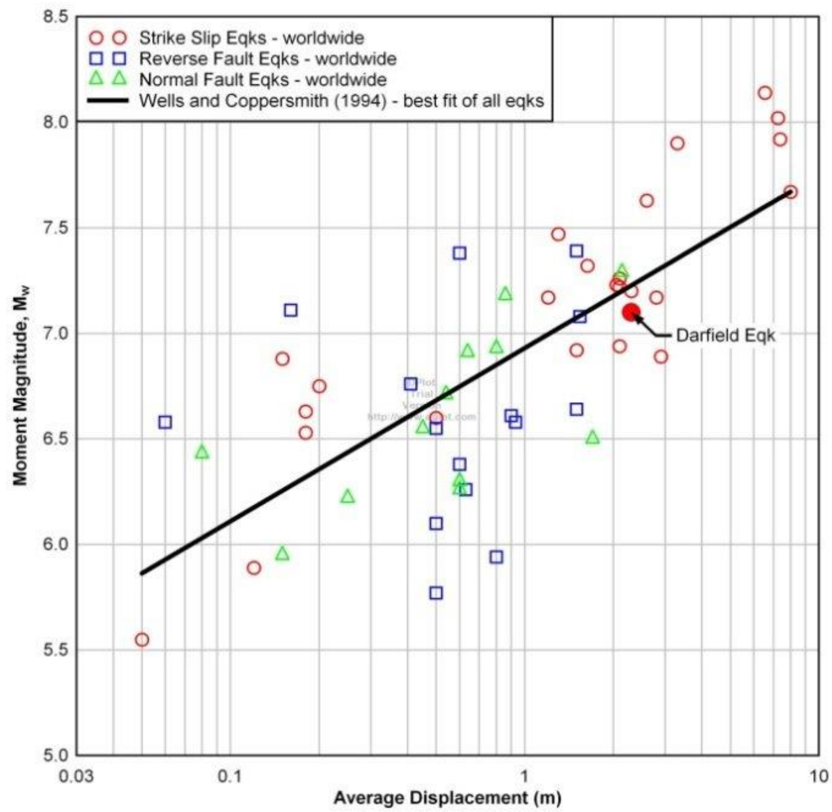


Figure 12: Relationship between earthquake magnitude and average fault displacement.

(Source: https://www.google.com/url?sa=i&source=images&cd=&ved=2ahUKEwjJx62h_5_lAhUTvZ4KHUf-CcUQjRx6BAgBEAQ&url=https%3A%2F%2Fwww.researchgate.net%2Ffigure%2FComparisons-of-average-left-and-maximum-right-surface-rupture-displacements-for-the_fig3_245025536&psig=AOvVaw0jTBNOARs3HeQAsM3wO1SB&ust=1571288314349761)

Horseshoe Palms Overlook

From our ridgetop location, we can look down to the southeast to see a well-developed alignment of Palm Trees below us, called Horseshoe Palms. The Mission Creek Fault runs along the alignment. Using the map below as a reference (Figure 13), notice that the drainage channel has been offset and deflected along the fault.

Interestingly, the offset part of channel has been abandoned: water no longer flows down the offset portion. Downstream of where the current channel crosses the fault, it flows southwest, effectively straightening out the deflection (Figure 13).

10. Using a measured slip rate of 15 mm (0.015 m)/year and a drainage offset distance of 1,069 meters, determine the age of the initial channel offset (i.e., when the fault first offset the channel).

channel offset → 1,069 ~~m~~

fault slip rate → 0.015 ~~m~~/yr

$$\frac{1{,}069 \text{ m}}{0.015 \frac{\text{m}}{\text{yr}}} = \qquad \text{years}$$

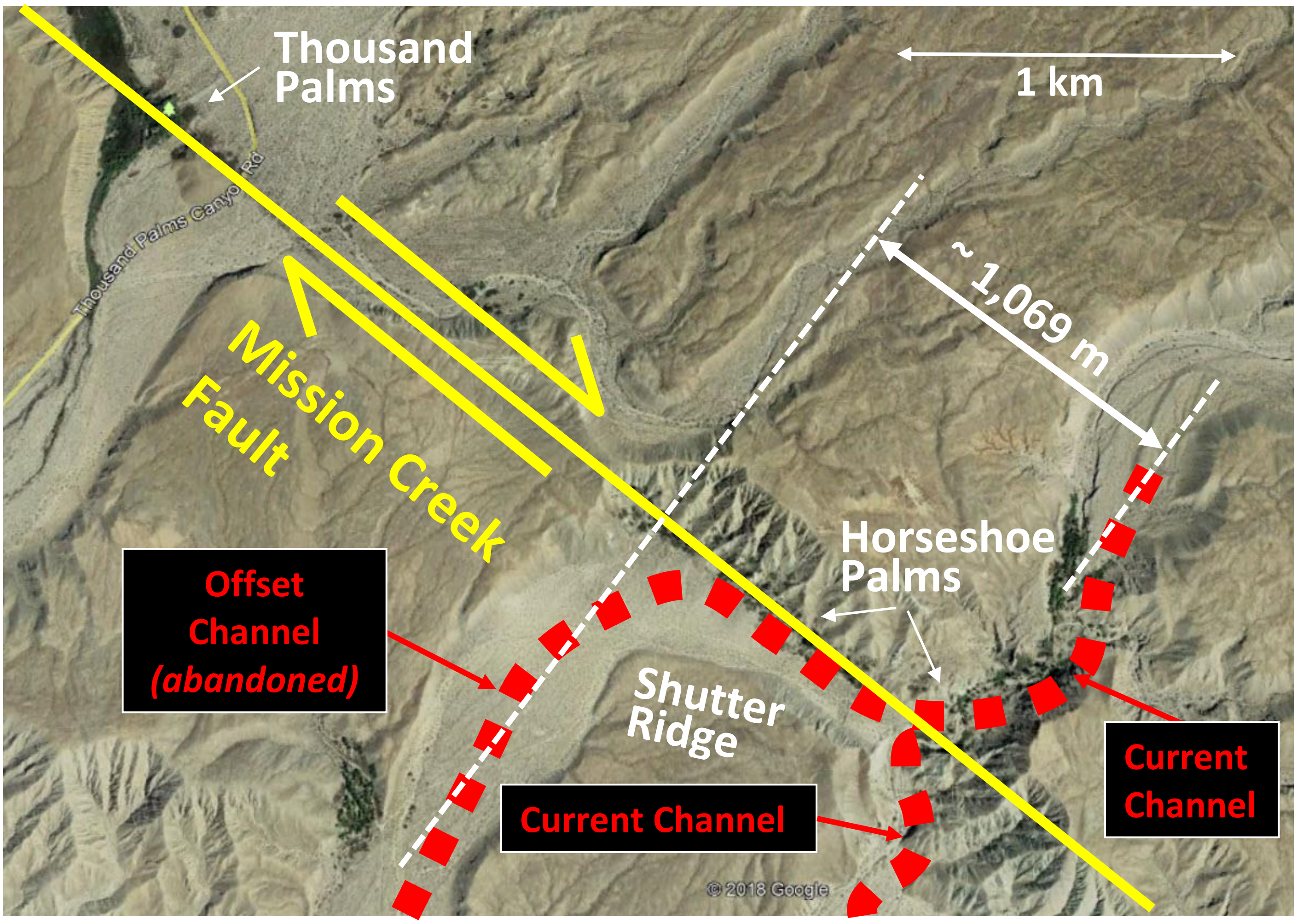


Figure 13: Offset, abandoned drainage channel along Mission Creek Fault.
(map source: Google Earth)

DIRECTIONS TO STOP 3: WHITEWATER CANYON

- **Head southeast on Thousand Palms Canyon Road (the same road you drove in on)**
- **In 2 miles, turn right onto Ramon Rd.**
- **In 3.5 miles, turn left onto Monterey Ave.**
- **In 0.6 miles, turn right and merge onto I-10 West.**
- **In 16.5 miles, take Exit 115 toward Whitewater.**
- **In 0.2 miles, turn right onto Tipton Rd.**
- **In 1.5 miles, meet at the intersection of Tipton Rd. and Whitewater Canyon Rd.**
- **From the Tipton/Whitewater Rd. intersection, we'll proceed ~ 1.5 miles up-canyon, to the hamlet of Bonnie Bell.**

STOP 3: WHITEWATER CANYON (BONNIE BELL)

Here at Bonnie Bell, the line of Palm Trees indicates the approximate location of the Banning Fault, the southern branch of the San Andreas Fault (Figure 14). Geologic studies of offset alluvial fans cut by the fault indicate that the long-term slip rate of the Banning Fault is approx. 4-5 mm/yr (Gold et al. 2015) – lower than that of the Mission Creek Fault, which exhibits a long-term slip rate of approx. 14-17 mm/yr (Behr et. al 2010).

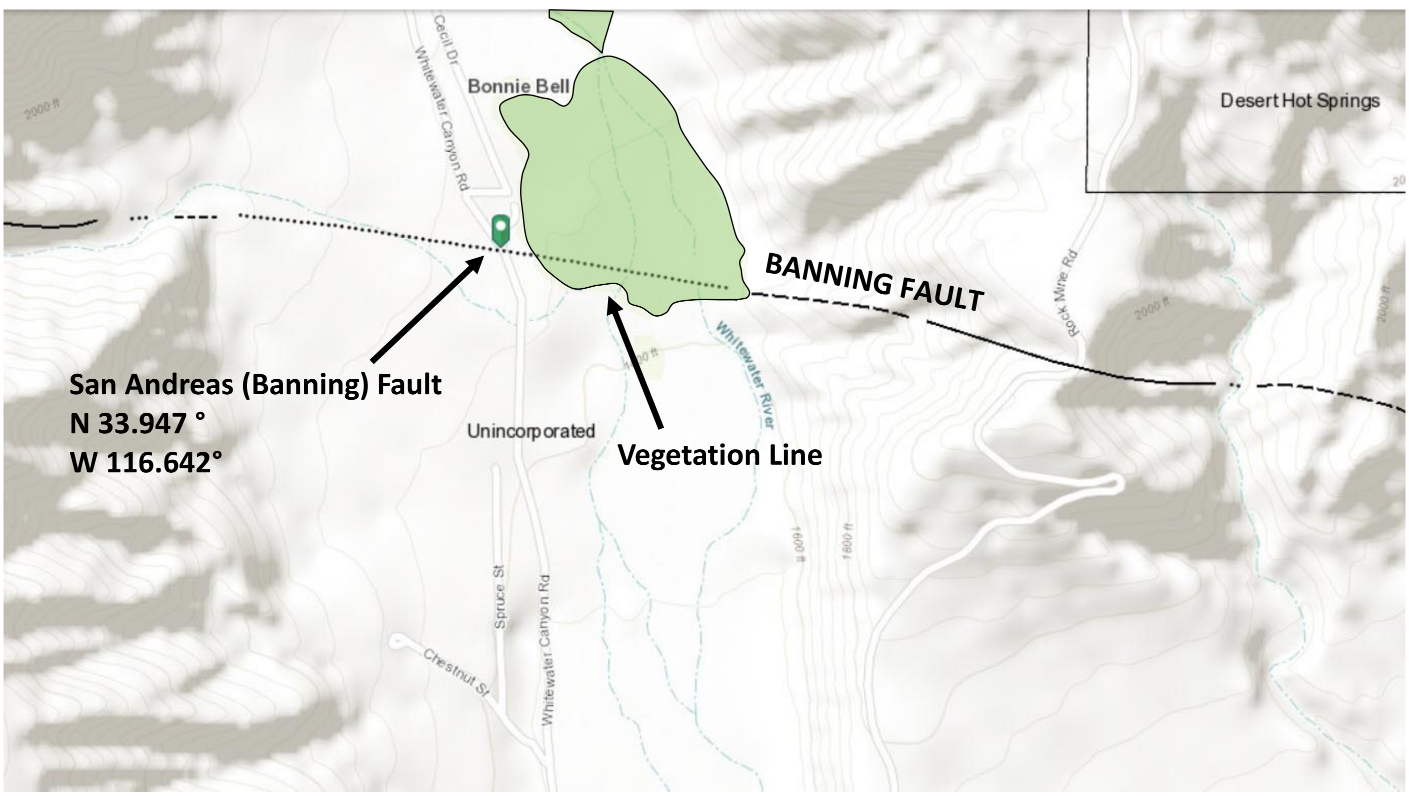


Figure 14: Banning Fault Location, Whitewater Canyon Rd
(map source: CA Geologic Survey)

1. **Briefly explain why the line of Palm Trees occurs along the Banning Fault here at Bonnie Bell.**

As shown in Figure 15, two different rock units are brought into direct contact along the Banning Fault, including Precambrian (older than 541 million years old) metamorphic rocks (purple unit labeled gn) and the Quaternary-age (older than 11,700 years old; less than 2.6 million years old) Cabazon "fanglomerate" (Qcf) – a conglomerate deposited in an alluvial fan environment.

2. **Was the Cabazon Fanglomerate deposited in its current location? Explain. *Hint: which direction does the conglomerate, located south of the Banning Fault, move, as you imagine going backward to an earlier period in geologic time?).***

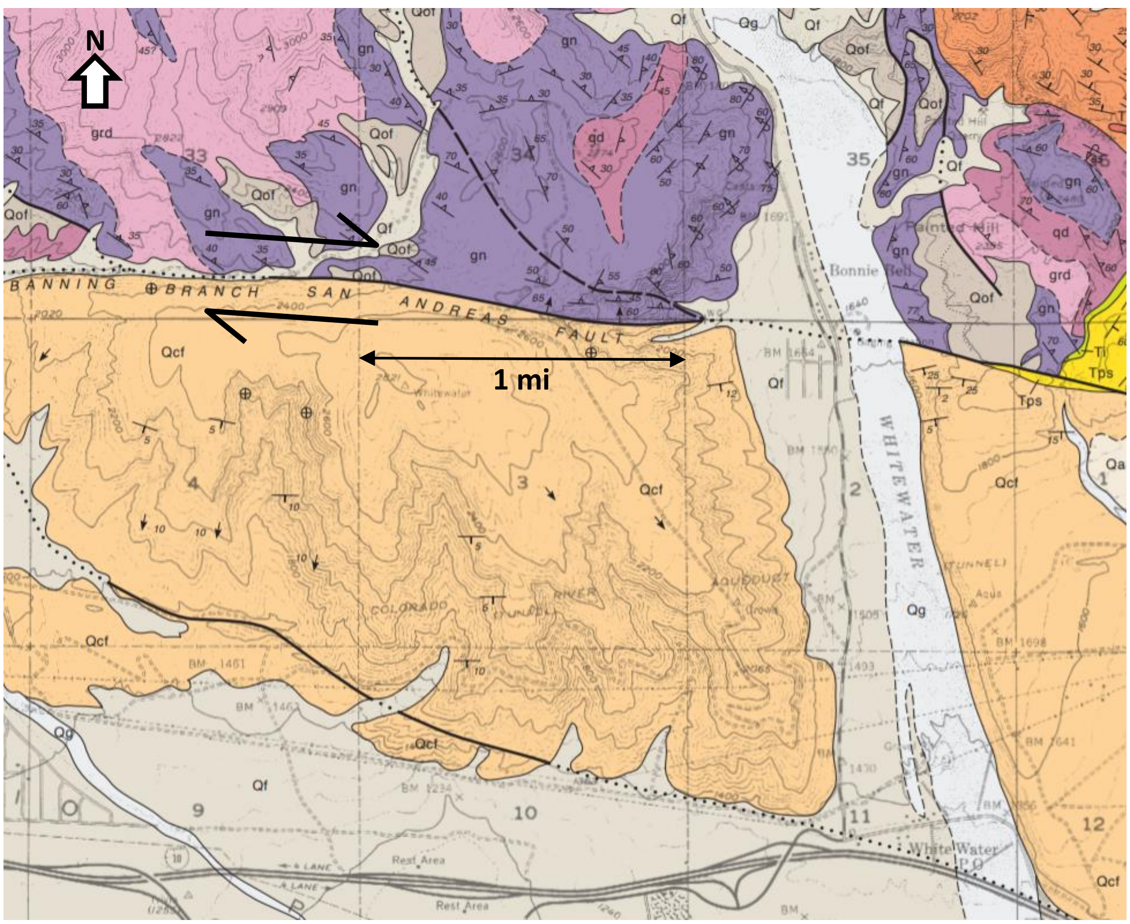


Figure 15: Banning Fault in vicinity of Whitewater Canyon
(source: Dibble Digital Geologic Map Collection)

Pinto Gneiss/Chuckwalla Complex

Time permitting, we'll head a bit further up-canyon to see exposures of Precambrian metamorphic rock north of the Banning Fault. This ancient metamorphic rock unit is widespread in this area, where it's locally called the Pinto Gneiss (Joshua Tree region) and the Chuckwalla Complex (Mecca Hills). This rock unit is one of the oldest in California; its metamorphic age has been measured at ~ 1.7 billion years old (Barth et. al 2004).

Amazingly, the Pinto Gneiss/Chuckwalla Complex has been part of four supercontinents (Condie 2016, Veevers 2004), as shown here:

Supercontinent	Assembly (m.y. ago)	Break-up (m.y. ago)
Pangea	450-320	185-present
Greater Gondwana/Pannotia	650-540	joined Pangea ~ 320 m.y. ago
Rodinia	1,000-850	780-600
Nuna (Columbia)	1,650-1,580	1,450-1,380

DIRECTIONS TO STOP 4: Casa Blanca Mexican Restaurant, 66370 Pierson Blvd #3658, Desert Hot Springs, CA 92240; Phone: (760) 251-5922

- **Head southeast (down-canyon) on Whitewater Canyon Road.**
- **In approx. 2.5 miles, turn right onto Tipton Rd.**
- **In approx. 0.4 miles, merge onto I-10 East**
- **In approx. 2.1 miles, take Exit 117, Hwy 62, toward 29 Palms/Yucca Valley**
- **In approx. 4 miles, turn right onto Pierson Blvd.**
- **In approx. 5 miles, the restaurant will be on your left (just past Cactus Dr.)**

DIRECTIONS TO STOP 5 (CAMPING SPOT): MISSION CREEK PRESERVE, 60550 Mission Creek Rd, Desert Hot Springs, CA 92240

- **Head west on Pierson Blvd.**
- **In approx. 5 miles, turn right onto Hwy 62 East.**
- **In approx. 1.6 miles, turn left onto Mission Creek Road.**
- **Follow Mission Creek Road for several miles, until you come to a locked gate.**
- **Gate Code: 1602 (valid for Sat Oct 26th only); if the gate is locked, exit your car, walk around the gate and find the left-most combination lock; please lock gate behind you after you drive through.**
- **After driving through the gate, proceed approx. 1 mile to the camping spot (look for trees).**

*****END OF SATURDAY FIELD TRIP*****

SUNDAY OCT. 27TH

<u>DIRECTIONS TO STOP 1:</u> PALM SPRING AERIAL TRAMWAY, 1 Tram Way, Palm Springs, CA 92262

- **Head down-canyon, back to Hwy. 62**
- **In approx. 3 miles, turn right onto Hwy. 62 West**
- **In approx. 5 miles, follow signs to I-10 East/Palm Springs/Indio**
- **Merge onto I-10 East**
- **In approx. 4 miles, exit at Exit 120, North Indian Canyon Dr.**
- **Turn right onto Indian Canyon Dr.**
- **In several miles, turn right onto West San Rafael Dr.**
- **Follow West San Rafael Dr. several miles to the Aerial Tramway Parking Lot**

<u>STOP 1 (TRAMWAY PARKING AREA)</u>

From the parking lot, we'll walk as a group to the tram station, where we'll board the tram and take a ride up to the top of Mt. San Jacinto. Please stay with the group! Professor Rector will discuss the plate tectonic history and emplacement of the Peninsular Ranges Batholith (PRB) and the rocks we'll see exposed along the tram route.

1. Talking Points:

- **The ______ consists of a complex "collage" of igneous and metamorphic rock that stretches from near the southern tip of Baja peninsula, northwestward to Palm Springs (Figures 16, 19).**

- **The PRB developed along the western edge of North America during subduction of the ________________ plate beneath the North American plate (Figures 17, 18).**

- **The PRB consists of many crystallized magma chambers, called __________________, created as a result of both ocean-__________________ and ocean-_________________ subduction (Figure 18).**

- **Within batholiths, plutons are emplaced by three mechanisms, including: (1) ______________, (2) ___________________, and (3) diapirism.**

- **Approximately 28 m.y. ago, the _______________ plate was completely subducted in the southern CA region, and for the first time, the Pacific plate and the _____________________ plate were brought into direct contact (Figure 17).**

- **Following destruction of the Farallon plate, a ________________ plate boundary developed between the Pacific and North American plates (Figure 17).**

- **Within the last ~ 6-8 million years, the Pacific-North American plate boundary "jumped" eastward. This allowed Baja, CA to tear away from mainland Mexico, creating the Gulf of ________________, and the southern __________________ fault (Figure 17).**

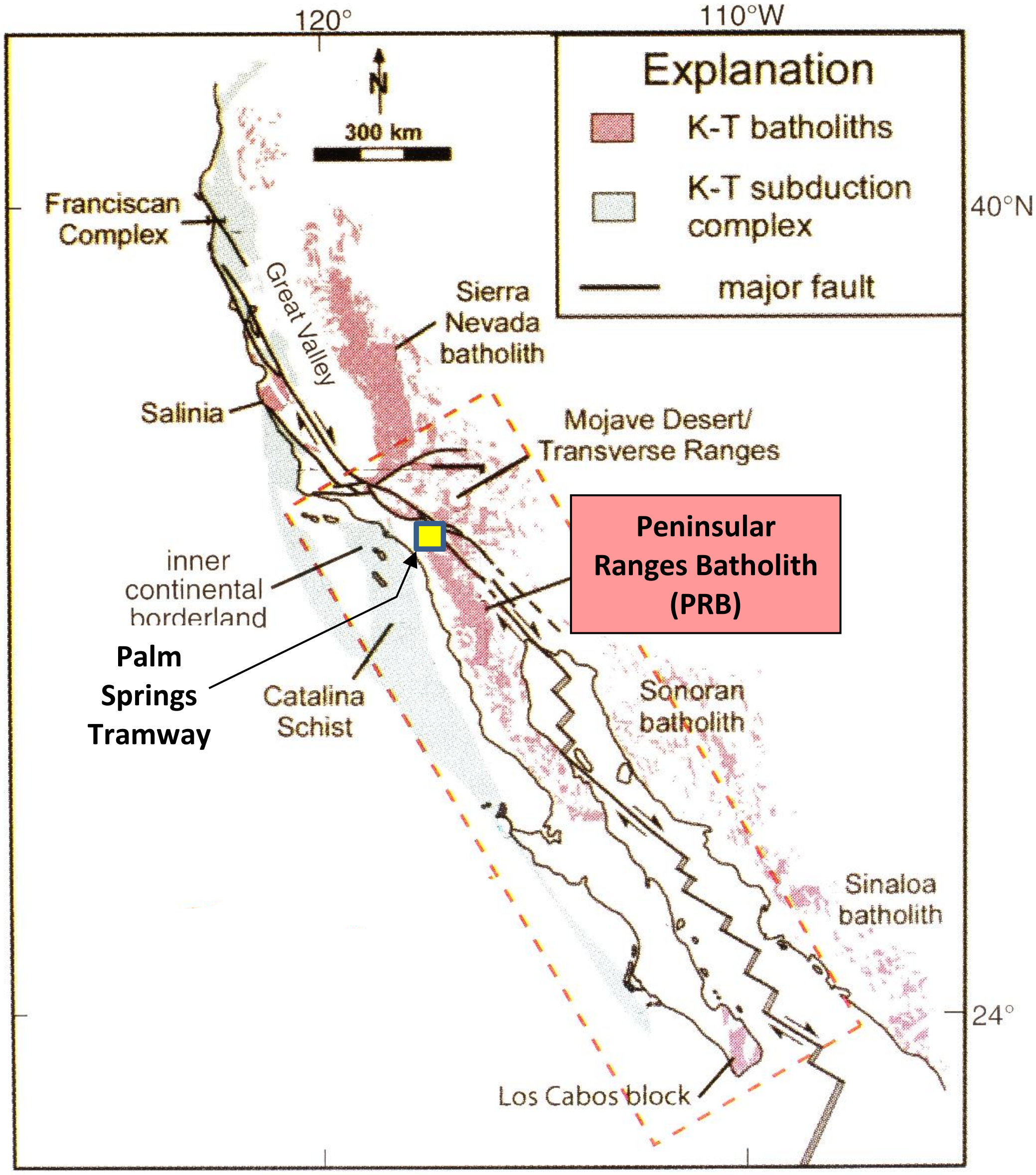


Figure 16: Peninsular Ranges Batholith (PRB).
(Source: modified from Langenheim, Jachens, and Aiken 2014)

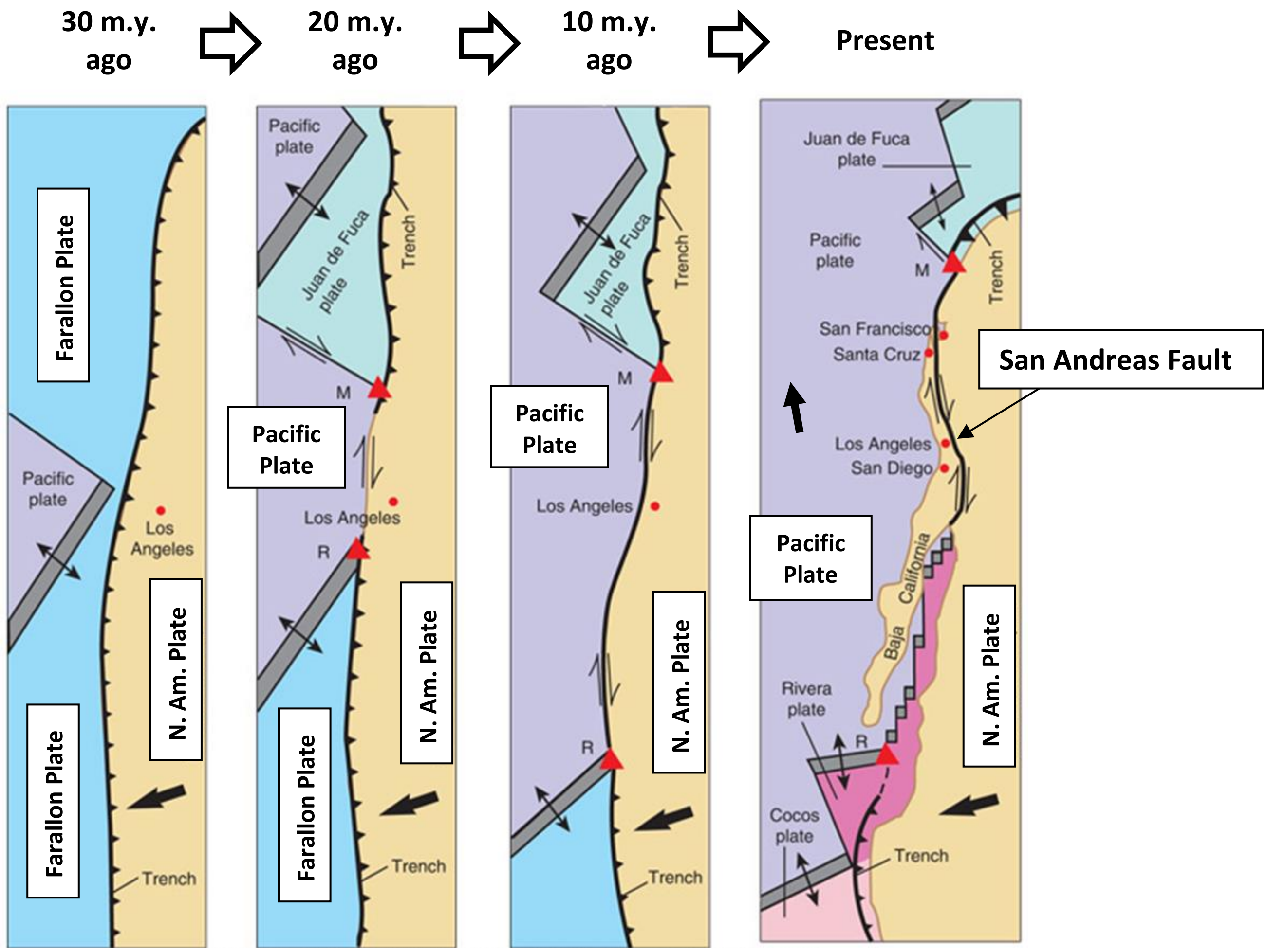


Figure 17: Evolution of the Farallon-Pacific-North American plate boundary.
(source: http://geophile.net/Lessons/Earthquakes/EarthquakesND_08.html)

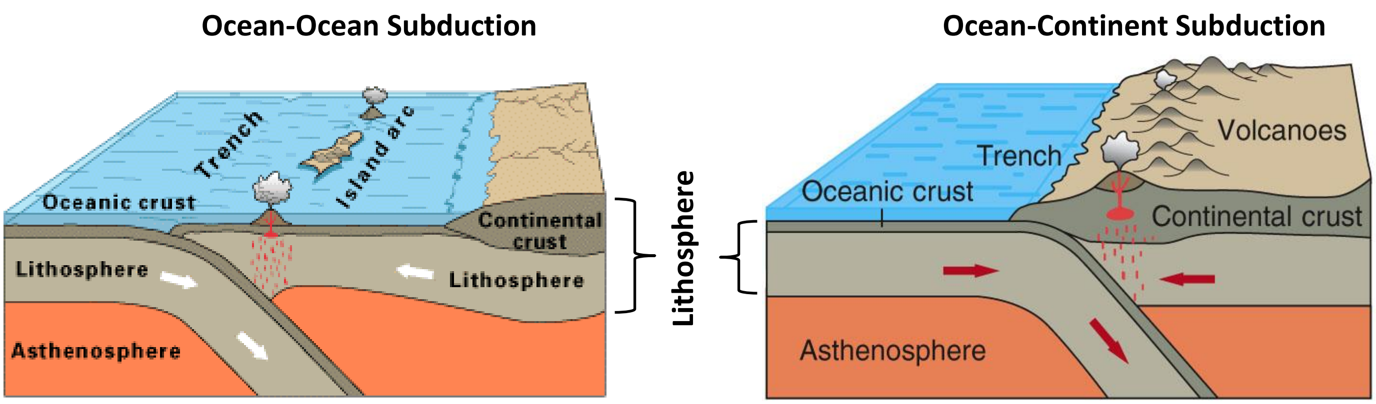


Figure 18: Ocean-ocean vs. ocean-continent subduction systems.
(source: USGS)

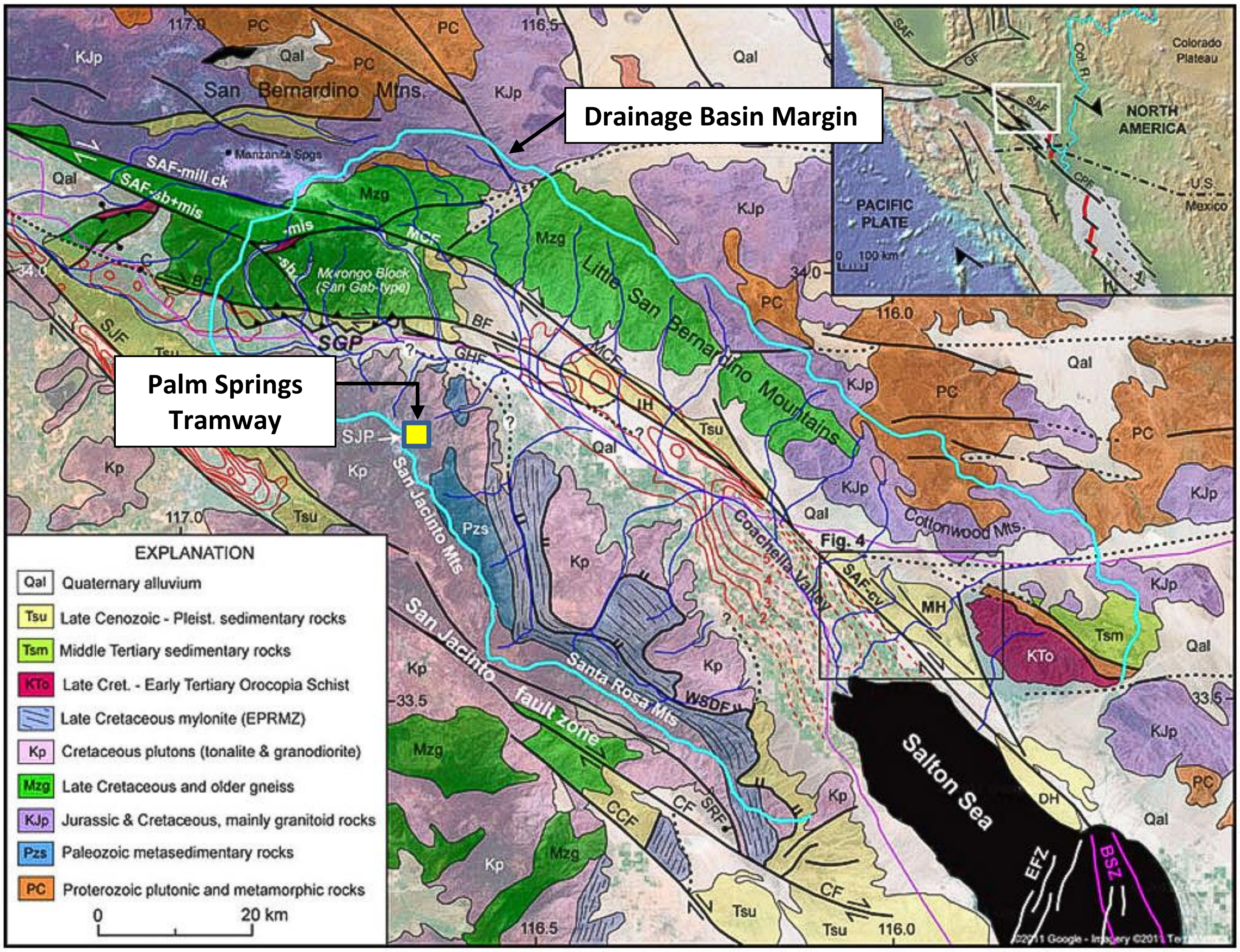


Figure 19: Geologic map of Coachella Valley and vicinity.
(from Dorsey, https://pages.uoregon.edu/rdorsey/CoachellaValley.html)

STOP 2 (MT. SAN JACINTO, MOUNTAIN STATION, 8516')

2. **Which lithospheric plate are we currently on? Hint: we're just south of the San Andreas Fault Zone and just west of Palm Springs (Figures 19 and 20).**

3. **What major tectonic feature stretches out in front of us, to the east (Figure 20)? *Hint: it's a deep depression that represents the landward continuation of the Gulf of California*.**

Now, look at the simplified Salton Trough fault map below (Figure 20). Does the “step-over” between the right-lateral Imperial and San Andreas Faults represent a restraining or releasing step-over? *Hint: review Figures 20 and 21 and think about our discussion from yesterday.*

4. The step-over between the Imperial and San Andreas Faults is a *restraining / releasing* bend (circle correct answer).

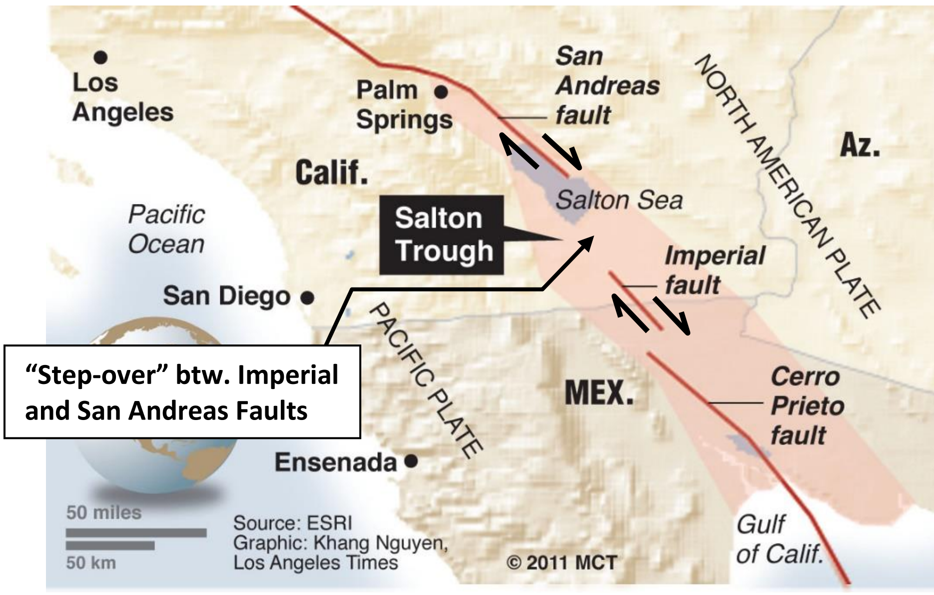


Figure 20: Simplified Salton Trough fault map.

(Source: [California Seismic Safety Commission, http://baylorlariat.com/wp-content/uploads/2013/03/20110325_QUAKE_SANANDREAS.jpg](http://baylorlariat.com/wp-content/uploads/2013/03/20110325_QUAKE_SANANDREAS.jpg))

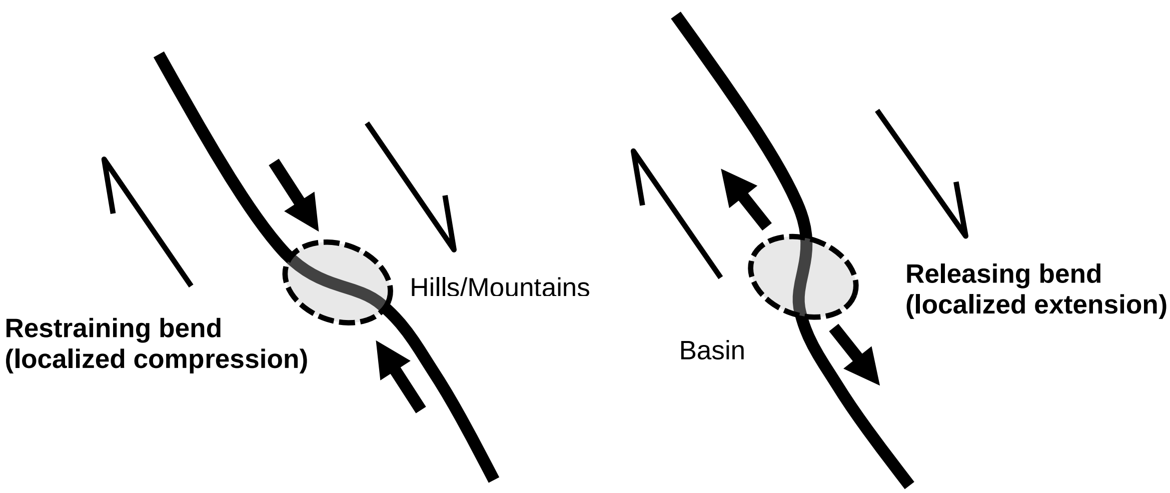


Figure 21: Releasing and restraining bends along a right-lateral strike-slip fault.

As shown in Figure 22, the San Andreas Fault Zone (including the Mission Creek and Banning Faults) bends toward the west just west of the Indio Hills/Coachella Valley Preserve, where we were yesterday. This portion of the San Andreas Fault is the beginning of the "Big Bend."

The Transverse Ranges include, from east to west, the San Bernardino, San Gabriel, and Santa Yanez Mountains in the eastern, central, and western segments, respectively. Notice that the Transverse Ranges, unlike most California mountain ranges, are oriented east-west instead of northwest-southeast.

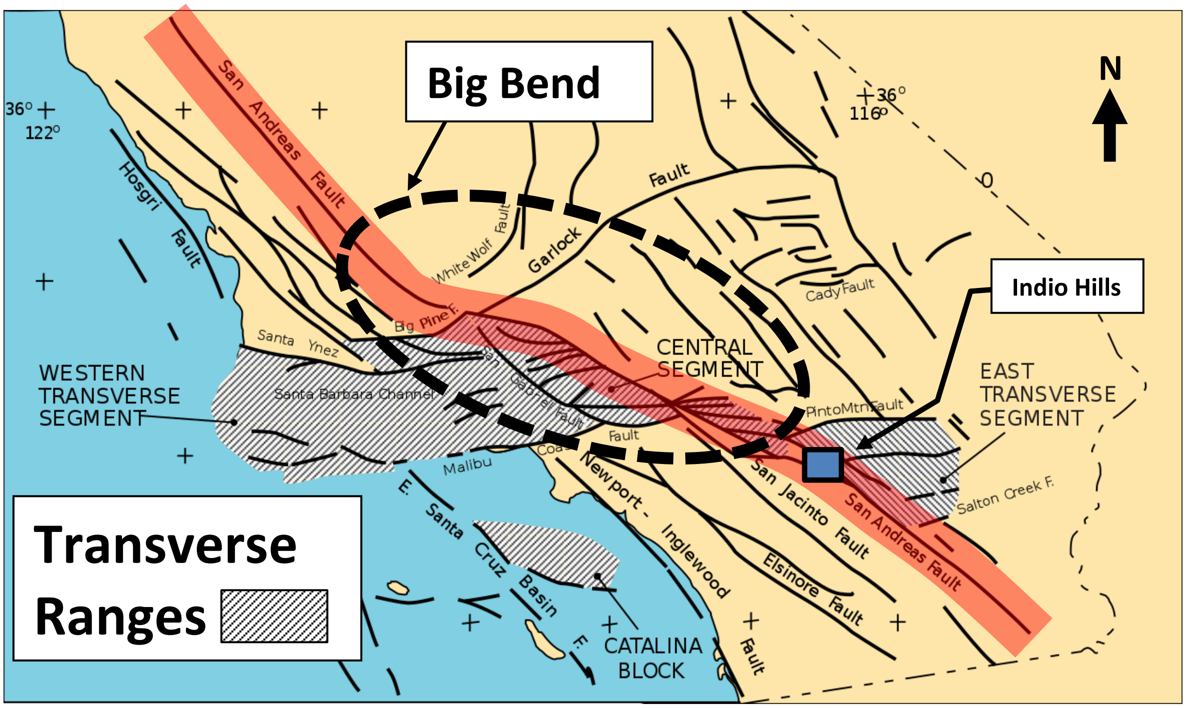


Figure 22: Transverse Ranges and Big Bend region, San Andreas Fault.
(Source: Wikipedia, https://en.wikipedia.org/wiki/Transverse_Ranges#/media/File:SoCal_Transverse_Ranges.svg)

5. Study Figure 22. Which statement below represents most accurately the tectonic setting of the Transverse Ranges (circle correct answer)?

- **The transverse ranges developed along "right-hand" releasing bend in the right-lateral strike-slip San Andreas Fault (transtension)**
- **The transverse ranges developed along a "left-hand" restraining bend in the right-lateral strike-slip San Andreas Fault (transpression)**
- **The transverse ranges developed along a straight section of the San Andreas Fault, with no bend.**

6. **Briefly describe the igneous rock exposed atop Mt. San Jacinto:**

- **Mineralogy:**
- **Texture (circle all that apply):**
  - **Aphanitic (fine-grained)**
  - **Phaneritic (coarse-grained)**
  - **Porphyritic (two crystal size populations)**
- **Color index (percentage of dark minerals):**
- **Rock name (Figure 23):**

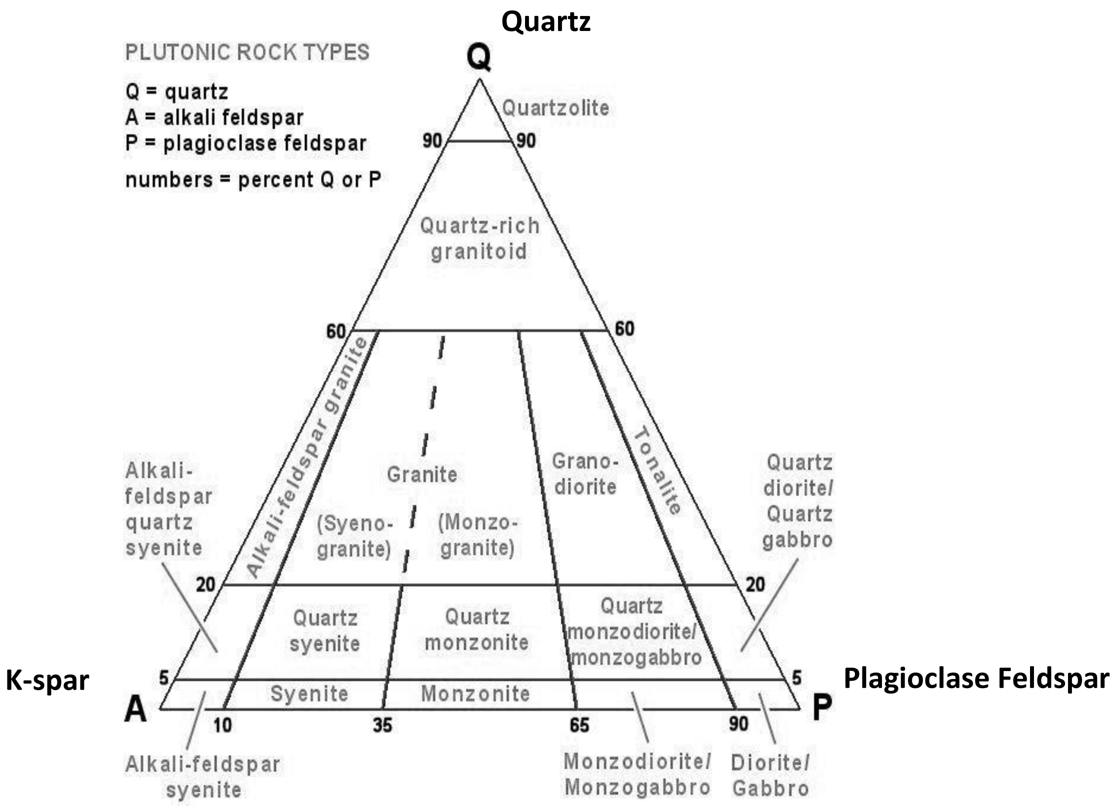


Figure 23: Intrusive igneous rock classification.

(source: https://www.thoughtco.com/thmb/gTdgM5httOEk3n6X1yzf-5KISQ8=/600x565/filters:no_upscale():max_bytes(150000):strip_icc()/600QAPplutonic-56a367bb5f9b58b7d0d1c834.jpg)

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Post-trip Reflection: Please write a 2-3 paragraph (1-page) summary reflection about this weekend's field experience. How does what you learned on this trip relate to what you've learned in lecture or lab this semester? What aspects of this trip did you enjoy the most? Please turn in this field trip guide to your instructor. Thanks for coming!