GEOLOGY 25 - LECTURE 9

# National Parks along the San Andreas Fault:
# *Pinnacles NP & Point Reyes National Seashore*

Chapters 26, 28 & 29

## San Andreas Fault (SAF)

The westernmost geologic province in the North American Cordillera is called the **Coast Ranges province** that extends from north of Santa Barbara almost to the Oregon border.

The two parks within the Coast Range province that we'll visit are Pinnacles NP and Pt. Reyes National Seashore - the geologic feature that connects the two parks is the San Andreas fault.

- other national parks located along the tectonically active Pacific margin include Channel Islands NP, Redwoods NP, and Olympic NP in Washington

The **San Andreas fault (SAF)** extends for ~1300 km (800 mi) from the Imperial Valley in southeastern California northwest to the Coast Ranges where it trends slightly more northerly to the Bay Area. It skirts the north coast before bending seaward at Cape Mendocino. To the north of the SAF is the Cascadia subduction zone.

SAF is the major fault in a broader "**fault system**" that ranges from relatively simple linear segments in central Calif. to broad networks of subparallel faults in the south and north

- the SAF and its network of related faults is a **transform plate boundary**, where the plates of rock on either side slide laterally past one another, typically during earthquakes
- the Pacific plate to the west of the SAF moves toward the northwest relative to the North American plate to the east of the SAF

(At the plate scale, the SAF system is a transform plate boundary. At the smaller scale of a fault, the SAF is a type of fault called a strike-slip fault.)

SAF and associated faults are **strike-slip faults**

- strike-slip motion is lateral with the blocks on either side of the fault plane moving sideways adjacent to one another in response to tectonic **shear** stresses

Recall that compressional tectonic stress (like in the Rocky Mountains) results in the formation of thrust faults, whereas extensional tectonic stress (like in the Basin & Range) results in the formation of normal faults. In the Coast Ranges, tectonic shear stress produces strike-slip faults like the SAF.

**Earthquakes**: Big strike-slip faults like the San Andreas don't creep along at constant, slow rates. Instead, they remain locked for decades to centuries as tectonic shear stress accumulates. The rocks on either side of the fault hold together by the frictional strength of one massive block of rock against another massive block on the other side of the fault plane. But eventually the accumulated tectonic stress exceeds the frictional strength of the rocks and the fault ruptures abruptly. As the blocks of rock on either side of the fault grind past one another over a few violent seconds, waves of seismic energy are sent out in all directions from the point of rupture along the fault, resulting in the groundshaking of an earthquake. Offset along the part of the fault that ruptured may range from a few centimeters to several meters, depending on the size of the quake.

- given enough time, **total offset** along a big fault can range up to hundreds of km, occurring during tens of thousands of large earthquakes
- over its multi-million year history and tens of thousands of "Big Ones," the San Andreas fault has amassed a cumulative offset of over 300 km

In today's current configuration of the SAF plate boundary, the sliver of California to the west of the SAF (e.g., Baja, San Diego, L.A., San Luis Obispo, Santa Cruz, Pinnacles, Pt. Reyes) is continental rock attached to the gigantic, mostly oceanic Pacific plate. That sliver of continental rock is being dragged to the northwest as part of the oceanic Pacific plate.
- the rest of California occupies the western portion of the North American plate

## Pinnacles NP

Pinnacles NP was named a national park in 2013, upgraded from national monument status
- located east of the Salinas Valley and about 80 miles southeast of San Jose in the southern Gabilan Mountains, one of a series of parallel northwest-trending ranges and valleys that make up the Central Coast Range.
- notable for steep, rocky crags and pinnacles of rock, surrounded by chapparal vegetation that thrives in the arid climate – a mecca for rock-climbers (chapparal is composed of dense thickets of shrubs and bushes adapted to hot dry summers, mild wet winters, and wildfires.)
- elevations range from 824' to 3304', with much of the park consisting of rolling hills
- one of three current release sites in the United States for the California condor since 2003. The park currently manages 32 free-flying condors.

Roads enter the park from the west through Soledad and from the east through Hollister, but the roads don't connect in the park. Most of the developed areas are on the east side of the park.
SAF passes by outside the park to the northeast, so the park is on the Pacific plate

***Rocks composing Pinnacles NP***

Pinnacles NP is dominantly composed of 23 m.y. old volcanic rocks that are mainly pyroclastic in origin. The pyroclastic debris has solidified to form resistant layers of **tuff** stacked one atop the other, separated by horizontal bedding planes.
- each of the layers of tuff represents a different eruptive event from the volcano that produced the pyroclastic debris
- movement along the SAF has tilted the volcanic layers over time

The Pinnacles volcanic field originated ~315 km (195 mi) to the south when it erupted 23 m.y. ago, and the volcano was located directly on the San Andreas fault.
- magma likely rose along the fault zone to the surface to form the volcano
- subsequent movement along the SAF split the volcanic field in half, one earthquake at a time, transporting the Pinnacles volcanics to the northwest and leaving the Neenach volcanic field near their original location (i.e., the Neenach volcanic rocks form the other half of the volcanic field. They are located near Gorman along Tejon Pass in southern California.)

- movement along the SAF strike-slip fault has carried the Pinnacles rocks northward at an average rate of about 0.6" (1.5 cm) per year. (most of the time is seismically quiet, interrupted every few hundred years by a sudden earthquake)

***Pinnacles Landforms***

Differential weathering and erosion along vertical joints and horizontal bedding planes created the strange landscape seen today
- the isolated pinnacles and crags of hard rock are resistant to breakdown in the arid climate, but weathering focuses along the joint planes and bedding planes, creating the rounded masses of rock that mark the landscape

"**talus caves**" form when steep, narrow canyons are filled with boulders, leaving passages between the intact rocks.
- rounded boulders likely shake loose as **rockfalls** during earthquakes
- the 'caves' are scoured by flash floods that episodically carve the passageways beneath the boulders
- most caves on Earth form by dissolution of rock by groundwater beneath the surface, but these talus caves form by the accumulation of talus blocks wedged within narrow canyon walls, with flash floods scouring the passageway beneath

***Moving north along the San Andreas fault through the Bay Area . . .***

Toward the Bay Area, the SAF splits into several subparallel strike-slip faults that each take up some of the strain along the SAF system. (e.g., San Gregorio fault, Hayward fault, Calaveras fault, Rodgers Creek fault)
- all of these faults are seismically active and have experienced earthquakes around magnitude 6 over the past few centuries
- the largest recent quakes were the 6.9 Loma Prieta event in 1989 and the estimated 7.9 quake that hit San Francisco in 1906 - both on the San Andreas
- we place the plate boundary on the largest fault, the SAF, but in reality the plate boundary is the broad zone of subparallel faults

## Point Reyes National Seashore

The SAF cuts obliquely across the San Francisco peninsula before moving offshore of the Golden Gate. From there, the SAF cuts northwest through Bolinas Bay, the Olema valley, narrow and elongate Tomales Bay, and Bodega Bay north along the coast.

Point Reyes National Seashore is tectonically separated from the mainland by the SAF and is thus on the Pacific plate – when you visit the park, you cross the SAF transform plate boundary.
- the bays form along the fault plane because the rocks along the fault have been ground up into weak gravels by countless earthquakes that occurred episodically over the past 20 million years. Water penetrates into the weakened rock along the fault plane, deepening it to form a narrow valley and permitting ocean water to submerge it to a few tens of meters of water depth.

This is the closest and easiest place to visit in the National Park system – about 2 hours from Davis. The coastline is classic Northern California – steep rocky sea cliffs with narrow sandy beaches lining the base, dramatic vistas, and abundant wildlife.
- it's commonly foggy and windy, but with a narrow annual temperature range

***Rocks of the Pt Reyes Peninsula***

The rocks beneath the grasslands of Marin County on the North American plate are Mesozoic oceanic rocks.
The rocks on the Pt Reyes side of the San Andreas fault are Mesozoic **granite** overlain by Cenozoic sedimentary rocks.
The granites of Pt. Reyes are identical in composition and age to those of the southern Sierra Nevada, about 310 miles (500 km) to the south. The Pt. Reyes granites are part of the Sierran batholith, but are located on the Pacific plate far to the west of the Sierra.
- the Pt Reyes granites were ripped off the southern Sierra Nevada as the young San Andreas fault cut through it about 20 m.y. ago. The granites were then displaced 310 miles to the northwest one earthquake at a time along the San Andreas fault over the past 20 million years.
- when you stand on granite at Pt Reyes, you are standing on the same granite as at Yosemite.

***Coastal Landforms & Shoreline Processes***

The Point Reyes peninsula (and many other parts of the Northern California coastline) are elevated above the shoreline due to small amounts of compressional tectonic stress combined with shear stress along the San Andreas fault.
- this tectonic uplift along the coastline raises the land surface so that it is constantly attacked by waves, forming **sea cliffs**.
- the California coastline of beaches and sea cliffs (like those at Pt. Reyes) formed from a balance between strike-slip faulting (causing slight uplift) and **coastal erosion** (wearing the rocks away).
- the steepness of sea cliffs is maintained by landslides, triggered as waves attack the base of the cliffs during high tide, undercutting the cliff face
- the landslide debris on the beach is broken down by the constant motion of waves and tides, creating sand for the beaches

Many elevated, rocky coastlines, like those at Pt. Reyes, consist of headlands that protrude out into the water alternating with sandy pocket beaches
- this is a temporary arrangement because waves tend to focus their energy on the headlands, breaking them down over time and redistributing the erosional debris onto the beaches
- so the headlands are sites of erosion by wave attack, whereas the beaches are sites of deposition
- as waves attack the sides of headlands, they may break down the rock to form a **sea arch**
- if the narrow bridge above the sea arch collapses, it leaves an isolated erosional remnant of the headland out in the surf zone called a **sea stack**. Once formed, a sea stack protects the adjacent seacliff from waves by absorbing the energy. The position of sea stacks in the surf mark the former position of the sea cliff.

Rainwater drains off the peninsula into Drake's Estero, an **estuary** where fresh water and saltwater mix. (Tomales Bay and Bolinas Lagoon are estuaries as well.)

- the finger-like shape of Drake's Estero (estuary in Spanish) reflects its origin as a network of former stream valleys. Then how did it become an estuary?

At the end of the **Last Glacial Maximum** about 20 thousand years ago, sea level was about 120 meters lower than today and the shoreline was about 50 km west of its present location. The exposed continental shelf was covered with woodlands and grasslands, and animals roamed the region. (This lower sea level occurred because water from the oceans had evaporated during the glacial phases and fallen out over the continental ice sheets as snow then was converted to glacial ice.)

- during the Last Glacial Maximum when sea level was lower and the shoreline was far seaward, the Pt Reyes peninsula was a hilly part of the mainland about 50 km inland. Streams drained the hills before flowing across the exposed continental shelf to the distant shoreline. *(It may be useful to review the Pleistocene Ice Ages and the Last Glacial Maximum from the Yosemite notes.)*

As the glacial ice melted over the last 20,000 years, sea level rose about 120 meters, with the shoreline transgressing over the exposed continental shelf. When the shoreline reached the Pt Reyes area, the stream network was flooded with seawater to create the estuary of Drake's Estero.

- this rise in sea level and landward migration of the shoreline is called the **post-glacial marine transgression** and has been occurring over the last 20,000 years globally.
- around 6000 years ago, the shoreline stabilized near its current position and the Pt Reyes peninsula began to look as it does today.
- the post-glacial marine transgression is responsible for the marine flooding of river valleys, bays and lagoons throughout the peninsula, the erosional development of the sea cliffs and headlands, and the sediment accumulation on ocean beaches and coastal dunes. This means that today's landscape of Point Reyes National Seashore was created only over the last few thousand years as sea level stabilized near its current position.

The main point here is that even a temperate coastal setting like Pt Reyes felt the effects of the Ice Ages, specifically during the interglacial warming of the past 18 thousand years.

**Websites for those of you not using the textbook**

National Park Service – Pinnacles NP geology fieldnotes
https://www.nps.gov/pinn/learn/nature/geology.htm#:~:text=Geological%20Origins&text=The%20Pinnacles%20Rocks%20are%20remnants,Plate%20carried%20the%20Pinnacles%20northward.

Wikipedia – Pinnacles NP
http://en.wikipedia.org/wiki/Pinnacles_National_Park

NPS – Point Reyes NS geologic activity
http://www.nps.gov/pore/naturescience/geologicactivity.htm

Wikipedia – Point Reyes NS
http://en.wikipedia.org/wiki/Point_Reyes_National_Seashore