PLATE TECTONICS AND CALIFORNIA GEOLOGY

So now that we have the basics down for Plate Tectonics – what it is, how it works, and how we know about it – so what? How does Plate Tectonics affect life in California, or anywhere else for that matter? To answer that let's look at California's current plate tectonic setting. As this map shows, we have a number of plate boundaries within or near the state. Notice at the northern part of California, we have a divergent plate boundary or an offshore seafloor spreading center where new oceanic crust forms and then is pushed away. Here, along the coast, that crust collides with and then sinks under northern California. That produces a convergent plate boundary where plate with an oceanic crust leading edge collides with a plate with continental crust on the edge. Result? Subduction, a trench, earthquakes, and inland, an active chain of volcanoes. This volcanic chain is known as the Cascades Mountains, and in California is expressed with the active volcanoes of Mt. Lassen and Mt. Shasta. (The most recent eruption in that area was the explosive eruption depicted in this image of Mt. Lassen on May 22, 1915.)
What happens to this seafloor spreading center off northern California? Like all such centers, it is offset at regular intervals by transform faults. If we move along the ridge north, we hit this transform boundary, that then connects to the continuation of the spreading centers a bit west. If we go back and follow the ridge south, we hit another transform. This one offsets the ridge eastward. Where? ALL THE WAY SOUTH to the Sea of Cortez (or Gulf of Mexico), where it connects with the seafloor spreading centers that are separating the Baja peninsula from the rest of Mexico. This long transform boundary that connects these two sections of ocean ridge is known as the San Andreas Fault System. Those of us who live along its path are familiar with its associated earthquake hazards. The Loma Prieta earthquake in 1989 was one of the most recent large earthquakes. The magnitude-6.9 earthquake caused significant shaking and damage from Santa Cruz to San Francisco as it released built up stress related to the transform plate motion.

Why is the transform so long? What made it this way? And why are these seafloor spreading centers so close to the continent and not in the middle of the ocean? This animation from the University of Santa Barbara shows what the Pacific Ocean likely looked like 80 million years ago, when the mid-ocean ridge seafloor spreading center, with all its offset transforms, was actually close to the middle of the ocean. Notice what has happened over the past 80 million years. As the Atlantic Ocean spread, North America was pushed westward. The western continental margin of North America was a large long subduction zone, with associated volcanoes and terrane accretion. But about 25 million years ago, the spreading center began to be overrun. It subducted under the North America continent, and the San Andreas Fault System began to form.

Pause now.

Subduction now over, the volcanism of the Sierra Nevada also ended. But what happened to that spreading center? We can image the crust under North America and see evidence of the old plate still subducting. And right above the spot where we suspect the spreading center would now be, we have an area of tension, where the continental crust is being pulled apart, similar to the breakup of Pangaea. The crustal stretching has created subparallel mountains and valleys, collectively known as the Basin and Range. Along the western-most edge, the Sierra Nevada Mountains are being pulled up out of the ground, causing high rates of erosion and exposure of deep granite rock bodies that are the now-frozen remnants of the magma chambers that used to feed the active subduction volcanoes. So walking in glacially carved Yosemite granite is actually walking along the remnants of old volcanic cores.

What else results from the stretching of the Basin and Range? In addition to exposing the eroded underbelly of ancient Sierran volcanism, the rifting activity is also producing a source of new volcanism to the area. The resulting volcanoes are completely different in character and cause to subduction-zone volcanoes, both by being more voluminous in their magma supply and more explosive in their eruptive style. Mammoth Mountain is one volcanic structure found in the middle of this region known collectively as Long Valley. In this region of rifting and thin crust, mantle rock is melting and rising beneath the surface, just like what happens at seafloor spreading divergent plate boundaries. Mantle melts combined with large amounts of crustal melt collect in a giant magma chamber just under surface. The Long Valley Caldera is a giant crater left behind after one of the largest volcanic eruptions to happen in North America emptied the magma chamber, and the surrounding crust collapsed. The last large eruption about 760,000 years ago left bits of ash and pumice strewn across most of the western United States. There is still an active magma chamber under the caldera, which releases carbon dioxide gases and hot water at numerous locations around the rim. It has been classified as one of the largest volcanic centers in North America. The most recent eruptions were those that produced Panum Crater and the Inyo Craters 500 to 600 years ago.

Pause now.

Let’s leave this unique volcanic region and return to the remnants of the ancient subduction zone volcanoes, now exposed as granite in the central and western Sierras, If you want to experience some of this granite closer to home, the San Andreas Fault has done a great job of moving rocks around in the state. As a result of the transform motion, sections of the southern Sierra Nevada granite were separated from their origination spot and carried northwards. We see them today as far north as Point Reyes. They also make up the rock of Montara Mountain and the rock of the Farallon Islands.

What about all the rest of the rock around us? Where did that come from? While some of the rock that makes up the Santa Cruz Mountains and the hills of San Francisco comes from recent deposition of coastal sediments during changing sea levels and ice ages, the majority of it consists of individual blocks or terranes that were accreted during the past periods of subduction. Prior to the collision of a mid-ocean ridge with the subduction zone 65 million years ago, there were hundreds of million years of active subduction. During that time ocean crust was carried into the subduction zones, and portions of what it carried were scraped off and attached to the edge of the continent, extending the continent westward in a papier mache style sequence of addition or accretion. Accreted material can include ocean sediment that got scraped off the top of the subducting plate, continental sediment that would have poured off the continental shelf into the trench, ocean seamounts or islands that would have gotten stuck in the trench and scraped off, sections of entire oceanic crust, and metamorphic rocks produced during collision and subduction.

As you can see, Plate Tectonics has had a huge impact on the past and present landscape of California. It produces many of our major geologic hazards and it has rafted in and combined the very landmasses that now make our state. Want to see it closer? Take a field trip to one of these nearby locations, where you can see the evidence and walk on the old surfaces yourself.

Pause now.

For more information and more detail, continue on to the next video in this series.

Plate Tectonics Video Series:
Part I: Earth's Layers and Isostasy
Part II: Plate Tectonics Basics
Part III: Plate Tectonics Global Impacts
Part IV: Plate Tectonics and Calif. Geology
Part V: Hotspots
Part VI: Paleomagnetism
Part VII: Hydrothermal Vents

Plate Tectonics and California Geology

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