Mount Tamalpais State Park

Franciscan Mélange

Features/Process:
Geology of a tectonic mélange with red cherts and blue schist

The term terrane (different from terrain) refers to a large, fault-bounded “packet” of rocks having a geologic makeup and history distinctly different from surrounding areas. Several different terranes have been recognized in the Mt. Tamalpais area, but most of the park is underlain by mélange. The Franciscan mélange (French for “mixture”) is composed largely of shale and sandstone that has been crushed and ground to the consistency of soil. Enclosed within the soil-like matrix are isolated blocks of hard rock from different terranes that vary from smaller than a soda can to larger than a house. This composition of hard blocks within an easily eroded matrix produces distinctive landscapes unique to the mélange. The presence of mélange on the fog-shrouded hillsides of Mount Tamalpais State Park leads to ghostly settings, where lonely rocky knobs protrude from grassy slopes like monuments in an ancient graveyard.

What you can see:
Mount Tamalpais is part of the California Coast Ranges geomorphic province, a region of fascinating geology produced by the interaction of slowly moving tectonic plates (giant pieces of the earth's crust) over millions of years. Visitors may encounter a "suite" of rock types at the park.

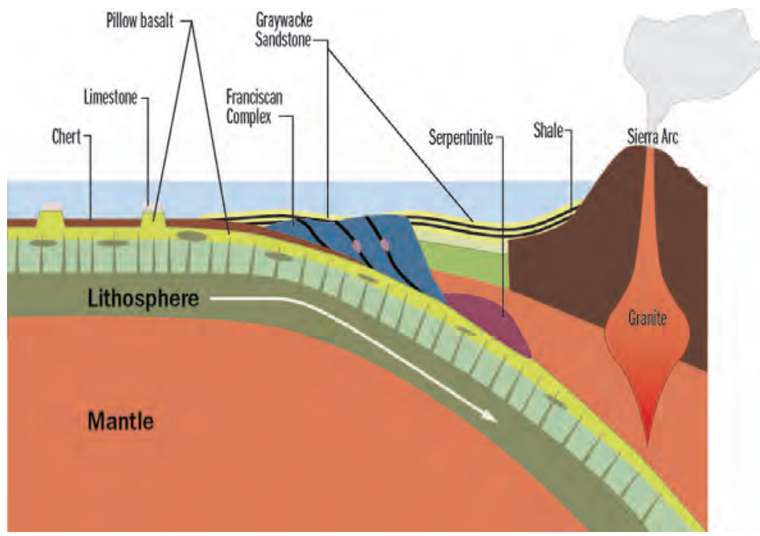
Radiolarian Chert

Chert has played a particularly important part in deciphering the age and origins of the Franciscan Complex because it is one of the few rock types in the rock unit where fossils have been preserved. Chert is created from the silica skeletons of billions of tiny plankton called radiolaria, which accumulate on the seafloor. Radiolarian skeletons come in a myriad of shapes that scientists have been able to categorize by age and ocean environment. Studies of radiolaria found in chert from the Marin Headlands, south of the park, and blocks in the mélange suggest that the chert was deposited between 200 and 100 million years ago (Early Jurassic to Late Cretaceous time), and in tropical to subtropical environments far to the south of their current location.

Most Franciscan chert has a red color produced by minute amounts of oxidized iron in the rock. However, green, black, and gray varieties are also common, reflecting different minerals and oxygen levels present when the rocks formed. The resistant chert beds are frequently separated by paper thin layers of soft shale creating thinly bedded sequences referred to as ribbon chert. Red ribbon chert forms some of the more interesting rock outcroppings in the mélange at the park, including those where the bedding has been folded and contorted into stunning designs.

Why it's important:

The Franciscan Complex has perplexed geologists from around the world, and has served as an important proving ground for modern plate tectonic theories. It provides an excellent above-ground laboratory of what happens in subduction zones beneath the oceanic crust and continental crust.



Adopted from Bob Lillie, 2005.

The story that geologists have derived from the rocks begins roughly 200 million years ago, with creation of new oceanic crust (seafloor) from volcanic eruptions of basalt along a mid-ocean rift (spreading center) in the Pacific. Once new seafloor formed and moved away from the rift, sediments slowly blanketed the basalt. Chert was deposited in the open ocean, and then layers of sand and mud (graywacke and shale) were added as the seafloor plate moved from the spreading center (rift). When the dense oceanic crust collided with the thick continental North American plate, it was forced under the crust, down into the hot plastic mantle along a subduction zone. Basalt and sedimentary rocks scraped from the surface of the subducting oceanic crust were churned in with continental fragments and sediments caught up in the chaos of the subduction zone. Portions of this mixture were pushed out of the subduction zone to be accreted (attached) to the North American plate in a succession of tectonic terranes that collectively form the Franciscan Complex.

Large Landslides

The dynamic geologic environment that helped build the beauty of Mount Tamalpais has also endowed the area with ongoing hazards from landslides and earthquakes. Rocks weakened by tectonic shearing, combined with the mountainous terrain and soakings by storms from the Pacific, provide ideal conditions for unstable slopes. This is particularly true along the coast where vigorous, relentless ocean waves constantly cut away at the base of the hills. Highway One crosses many enormous landslides some thousands of feet wide. Most of these are ancient features that may remain dormant and unnoticed over long periods. However, events such as earthquakes or unusually wet winters can sometimes reactivate movement over all or parts of the old landslides. Sliding can occur as slow creep that rumples and deflects roadway pavement, or as abrupt failures with more severe consequences. A dramatic example of this occurred within the park, south of Lone Tree Creek in 1990, when movement of a known landslide progressed from inches per month to feet per month between January and May. This deep-seated landslide dropped some 600 feet of roadway and closed the highway for nearly two years.

Transition from Subduction to Transform Boundary

The process of subduction and accretion that created the Franciscan Complex continued in the Mount Tamalpais area up until about 27 million years ago, when plate movements and conditions along the continental margin underwent a huge change. Instead of colliding, the Pacific and North American plates began to move past each other, the Pacific Plate moving north along what would become the now-famous San Andreas Fault.

Final Thoughts

The spectacular vistas, unique landforms, and geologic hazards of Mount Tamalpais all reflect the amazing tectonic events of the past, as well as the ongoing plate motions that continue to reshape the California Coast Ranges.

Written by Marc Delattre, California Geological Survey
Photos: Mike Fuller

Geological Gems of California State Parks, Special Report 230 – Fuller, M., Brown, S., Wills, C. and Short, W., editors, 2015 Geological Gems of California, California Geological Survey under Interagency Agreement C01718011 with California State Parks.