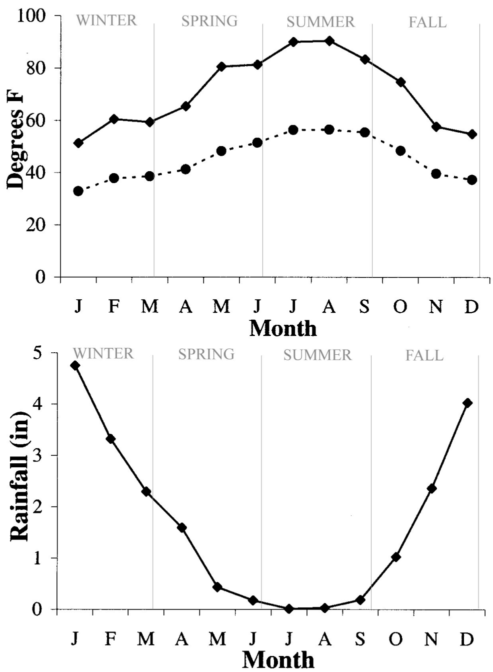
The Physical Environment

While humans can modify the landscape within a few generations, the physical forces of nature have just as large an impact on the shape of the land, but occur on much slower time scales. Geologic processes may mold the land over millions of years. Annual variations in rainfall and temperature influence which plants and animals become established or go extinct in the area on a time scale calculated in thousands of years. Therefore, understanding Cold Canyon's physical environment helps explain the diversity of life we see in in the reserve today.

Coast Range Climate

Northern California's climate is characterized by cool, wet winters followed by harsh, dry summers. Monthly changes in temperature and rainfall are therefore extreme and highly seasonal. This variation is caused by seasonal changes in weather patterns in the Pacific Ocean. During much of the year, a zone of high pressure running up the coast of California prevents the low-pressure storm systems that inundate the northwest coast from reaching much of Northern California. During the winter, this high pressure system breaks down, allowing the storm systems to move farther south. As a result, Cold Canyon receives precipitation primarily from November to March, much of it falling in the winter months. Accompanying the rain are cooler temperatures. During the winter, the thermometer often dips below freezing, especially during the night, and by day the temperature averages 50° F (10° C).

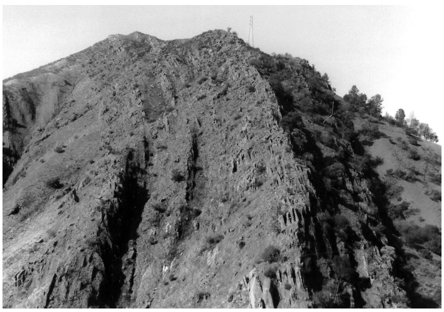


Minimum and maximum mean daily temperature and monthly rainfall over 12 years, taken at Markley Cove (1.5 miles west of Cold Canyon).

The situation is reversed in the summer, when daily temperatures can soar above 100° F (38° C) and less than 1% of the year's rain falls. In some respects, Cold Canyon is even harsher in the summer than other areas of the coast range. Nestled within the easternmost ridges of the North Coast Range, Cold Canyon receives somewhat less rain than hills to the west. These hills also prevent the drought-alleviating coastal fog from reaching Cold Canyon most of the summer. Furthermore, the canyon traps heat and the southern and western ridges shield the canyon from the cool delta breezes that blow in from the coast in the afternoons.

The Geology of Cold Canyon

Like the entire surface of the Earth, the landscape of Cold Canyon is constantly changing, albeit at a very slow rate. Geologic processes are continually reshaping the rocks and sediments that make up the landforms on the surface of the planet. Less than one million years ago, Cold Canyon was merely a shallow trough, not the deep canyon present today. Millions of years before that, the rock that would later form Cold Canyon was located far beneath the surface of the sea. The present landforms of Cold Canyon are the products of three slow but very active geologic processes: deposition of sediments, continental uplift, and erosion. Over many millions of years these geologic processes have created, uplifted, and eroded vast amounts of rock to create Cold Canyon. Evidence of all three processes can be seen today at the mouth of the canyon. Sedimentary layers bent skyward by uplift surround Monticello Dam, while nearby, Cold Creek erodes material from the canyon walls and deposits it on the banks of Putah Creek.



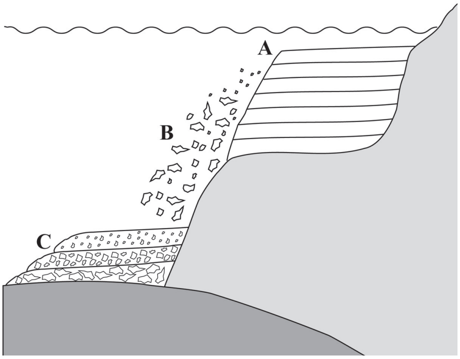
Near-vertical layers of sandstone in the ridge north of Monticello Dam.

Sediment deposition on the banks of Putah Creek east of Cold Canyon.

Sediment Deposition and Bedrock Formation

Millions of years ago, off the western coast of the ancient continent, the land that would later become Cold Canyon was being deposited as river delta sediment. As rivers flow into the sea, they lose velocity, and thus lose their ability to carry sediment. Larger, heavier particles carried by the river, such as sand, are deposited close to shore, while finer-grained particles, such as silt and clay, are carried farther offshore by the diminishing current. Some sediment is carried all the way to the continental shelf, the edge of the continent where it falls away steeply into the sea. Here, sediments accumulate on the steep slope, and over time become unstable. These sediments can then slide under their own weight, similar to a landslide or avalanche. These "undersea landslides" are called turbidites and can occur quite regularly. As the muddy turbidite slides down the continental slope, the larger, heavier particles, such as sand, are the first to settle onto the slope, followed by lighter, finer particles, such as silt and clay. In the end, the muddy sediments have been sifted into layers, with silts and clays generally overlaying sands. This layering can occur at two scales: beds of silt over 200 feet in depth may overlay similar-sized sandy deposits, and within a single bed (several inches thick), sediment grain size changes from sandy material at the bottom to silty material at the top. Geologists use these small-scale changes in particle size to determine the original position of different layers relative to each other.

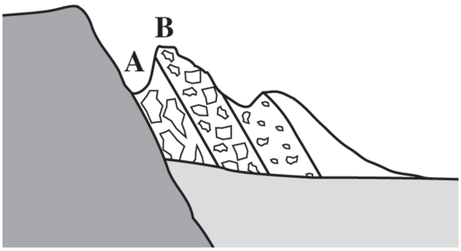
Over several million years, as new depositional layers are built upon old layers, the weight of the upper layers creates great pressure on the lower layers, causing a transformation from muddy sediment to solid rock. The coarse sediments form sandstones, while the finer particles form mudstones or shales. These types of rocks can be seen today in Cold Canyon. The canyon walls, including the rock outcrops on both ridges, are predominantly sandstone. The bedrock underlying the canyon bottom is shale. These bedrock layers have been given names and approximate ages. Pleasants Ridge, the eastern ridge of Cold Canyon, is part of the Sites Formation and was deposited 88 million years ago. Blue Ridge, the western ridge, is part of the 91 million-year-old Venado Formation, and the shale canyon bottom is part of the Yolo Formation, which was deposited 90 million years ago.



A. Sediment deposition in a delta. B. An undersea landslide on the steep edge of the delta. C. Sediment is deposited into layers of different grain size, with finer layers on top.

Continental Uplift

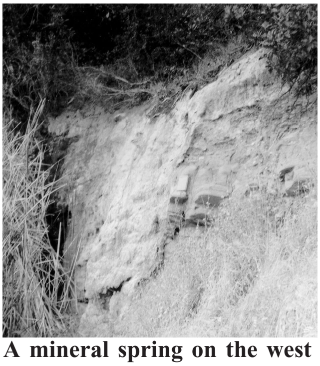
As deposition was occurring millions of years ago, the entire continent was slowly rising. The entire surface of the planet is covered by a number of massive plates, rafts of solid rock afloat on a layer of molten rock. These plates are in constant motion, jostling and grinding against each other. For example, the San Andreas fault, which runs through much of California and causes many earthquakes, is the boundary between two plates which are sliding past each other. Another type of plate boundary, a convergent boundary, occurs when two plates are moving toward one another. When the plates collide, the denser oceanic plate typically dives beneath the other and into the interior of the Earth. The lighter continental plate rides on top and is slowly uplifted as a result.



Continental uplift has changed the orientation of the sediment layers, and erosion has cut valleys into less resistant layers (A) and leaving behind more resistant layers (B) as ridges.

California's Coast Range was formed by the actions of a convergent plate boundary. A collision of the oceanic plate with the continental plate forced the coastal sediments up above sea level. Further pressures from this collision bowed these horizontal sedimentary layers into a near vertical orientation. This vertical layering is visible around Monticello Dam, near the mouth of Cold Canyon. After uplift, the motion along the plate boundary changed from convergence to lateral sliding, as attested by the motion of the San Andreas Fault today.

The Cold Canyon region may still be tectonically active. To the north of Putah Creek, a number of mineral springs lie scattered on a line extending southward towards Cold Canyon. The presence of certain minerals and the linear pattern of springs on the landscape indicate the pres-



A mineral spring on the west face of Cold Canyon.

ence of a fault in this area. A similar spring is located within Cold Canyon. Although the evidence is not conclusive, the presence of this spring suggests that an active fault runs through the canyon, and within a quarter mile of Monticello Dam.

Weathering and Erosion

Cold Canyon formed as a result of weathering and erosion of the different bedrock layers by wind and water. Weathering is the breakdown of rock into small particles and can occur through chemical or physical mechanisms. Erosion is the transport of these particles by running water or landslides. Running water will typically seek the path of least resistance, cutting through softer, finer-grained rock layers, while avoiding more resistant layers. This is evidenced by the fact that the floor of Cold Canyon lies in the midst of the Yolo Formation, which is a fine-grained mudstone layer, while the canyon walls consist of more resistant Sites and Venado Formation sandstone layers.

The erosion that created Cold Canyon continues today both on a small scale, through the chemical breakdown of rock by air and rain, and on a larger scale by physical mechanisms such as landslides. Landslides are common on the steep walls of Cold Canyon. In the 1980's, two different slides covered the main trail. In 1995, a large landslide came down the eastern wall, toppling trees and piling soil and rocks along the streambank. The evidence of this slide can easily be seen along the trail, near the mouth of the canyon where the trail comes closest to the creek.

However, these landslides were tiny compared to a massive slide that must have occurred in Cold Canyon many thousands of years ago. This slide formed the entire western slope of the canyon, and exposed the rock outcrops topping Blue Ridge. To best appreciate the size of this slide, hike up the western trail. Near the top of the trail, you will be able to look at rock outcrops on the ridgetop extending to your left and right. The large cliff on the left is the bedrock of the Venado Formation that was exposed by the massive landslide. In fact, the slope you are standing on, which runs south underneath the cliff and along the rest of the canyon, is the top of the huge mound of earth that slumped several hundred feet in that landslide!

Remains of the 1995 landslide near the reserve entrance.

This rock outcrop is actually the scarp of a huge landslide!

More gradual erosive processes are also currently taking place. The creek actively erodes its channel, especially during winter floods, and Cold Canyon gets slightly deeper every year. The rounded boulders in the creek bed, smoothed by the scouring action of sediments transported by the stream, attest to this on-going erosion.

A Geologic Puzzle in Cold Canyon

Geologists dedicate their work to interpreting the processes that formed the landscape features that we see today. This task can be particularly daunting, as most geologic formations are completely covered by other rock formations, soil, and plants. The landscape of Cold Canyon can be a particular challenge – the many landslides that have occurred in the canyon have hidden much of the underlying bedrock that might yield clues to ancient geologic events. Fortunately, geologists have found enough outcrops in Cold Canyon and other neighboring areas to provide the general geologic history described above.

Fining-upward beds near the creek crossing.

Sometimes, however, the incomplete information available creates a geologic puzzle. One such puzzle exists in Cold Canyon. This puzzle concerns the orientation of a particular bedrock outcrop. Recall that the bedrock layers were created long ago by the filtering action of water. Within a particular bed of sediment, coarse material settled first, followed by finer and finer layers. For example, the sandstone outcrop near the trail's creek crossing reveals that rock layers composed of coarse-grained particles lie underneath finer-grained layers. At this outcrop at least, the rock layers still lie in relatively the same way they were laid (and "fine-upwards").

Overturned beds.

It is thus rather surprising to discover a very different pattern in an outcrop just several hundred meters north of the outcrop at the creek crossing. This second outcrop occurs on the west side of the creek near an old landslide scar. Checking the gradation in particle size in the layers of this outcrop reveals that the coarser layers occur above the finer beds. The entire outcrop is upside-down! How could these layers of rock become overturned? This, in essence, is the geologic puzzle of Cold Canyon.

An answer to this puzzle is not easy to obtain, because the clues that would help solve the mystery are buried deep beneath the western canyon wall. However, there are at least two plausible explanations for the existence of these overturned beds. A relatively simple explanation supposes that some of the bedrock layers, moved in the huge landslide that shaped the western canyon wall, were overturned as they came crashing down the hill side. A second, more elaborate explanation alludes to the existence of a large fault in the canyon. In this scenario, the Venado Formation was split into two sections by a fault, and then one section was thrust above the other by continental uplift. This thrust may have caused certain layers caught near the edge of the fault to become overturned.

One clue supporting the second explanation is the existence of the mineral spring, less than 660 feet (200 m) from the location of the overturned beds. Because mineral springs tend to follow fault lines, and are less likely to occur within the jumble of landslide debris, the existence of the spring suggests that a fault line lies very close to the overturned beds.

Gathering clues like the presence of the spring is the key to understanding the geologic processes that shaped Cold Canyon. Hence, the present landscape can be used to explain the actions of the past. At the same time, an improved understanding of the link between past events and present geologic features can help geologists predict what might happen in Cold Canyon in the future. For example, if additional observations help connect the mineral spring in Cold Canyon with those in areas to the north and lead geologists to determine that an active fault runs through Cold Canyon, we might conclude that the bedrock along this fault is particularly unstable. We would therefore predict that any earthquakes in the region could be centered along this fault line.