SAN FRANCISCO BAY — 400 THOUSAND YEARS AGO

San Francisco Bay first formed 400,000 years ago during an Ice Age

During the many glacial periods (Ice Ages) of the past 2 million years, glaciers grew larger in the Sierra Nevada—the only location in California where ice could be found. Melt water flooded out of the Sierra Nevada with a large amount of eroded rock flour and sand. During ice ages, water is trapped on land in glaciers, so sea level drops as much as 100 meters (~300 feet), which exposes the flat, shallow, currently flooded **continental shelf**. The raging rivers that flowed out of the Sierra carried their heavy loads of sand to the new shoreline (offshore of today's) and dumped their load in large sand deltas. Strong winds blew the sands onshore across flat areas creating huge sand dune provinces.

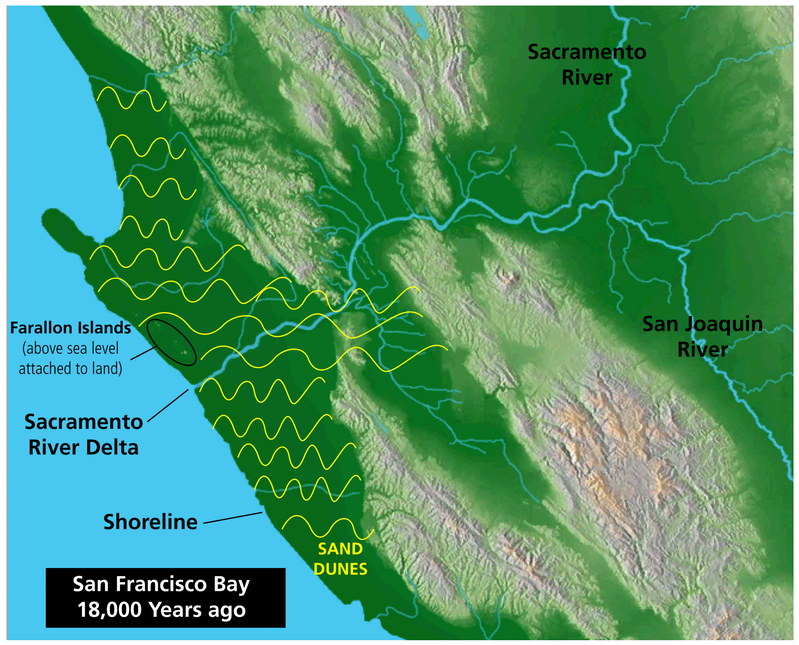
Prior to 400,000 years ago, the East Bay Hills prevented the Sacramento River from finding an exit to the Pacific through the San Francisco region. Instead, the river flowed south along the eastern edge of the hills, where it eventually joined the San Joaquin River and reached the ocean through the Monterey Bay Area. But 400,000 years ago, the San Andreas Fault cut off the main river path through the Monterey Bay Area, and the erosive power of the ice-age-flooded Sacramento River finally cut through the East Bay Hills in an area we know today as the Carquinez Strait. This strait is narrow because the rocks are so hard—the river and tides cannot easily erode the rocks horizontally, so as water is pushed at great speeds through this Strait today, the area is eroded deeper and deeper.

During Ice Ages, there is no bay. The Sacramento River carves a channel through the Golden Gate and towards the ocean, where it dumps its load out near today's Farallon Islands. Tons of sand are blown inland and cover all the low-lying areas, including the flat continental shelf, the northern tip of the San Francisco Peninsula, and any coastal lowland areas, like Ocean Beach. When sea level rises, after each ice age ends, the shelf floods and the river delta is pushed inland towards Sacramento. The tops of some of the older hills become islands, such as Alcatraz and Angel Island. The sand dunes still exist, but most of them are under water—or still active at the tip of the San Francisco Peninsula.

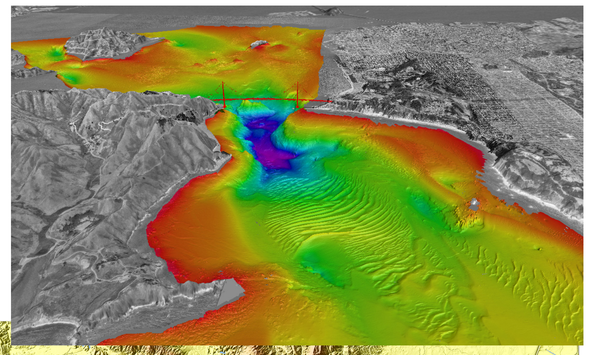
According to California geologists, for the past 400,000 years, there has been a continual tug-of-war between Monterey Bay and San Francisco Bay as the best exit for drainage of the central valley. It has shifted multiple times between the two, and while San Francisco Bay is the exit of choice today, it is likely only temporary, awaiting the next ice age or accumulated motions of the San Andreas Fault.

What is special about South San Francisco Bay?

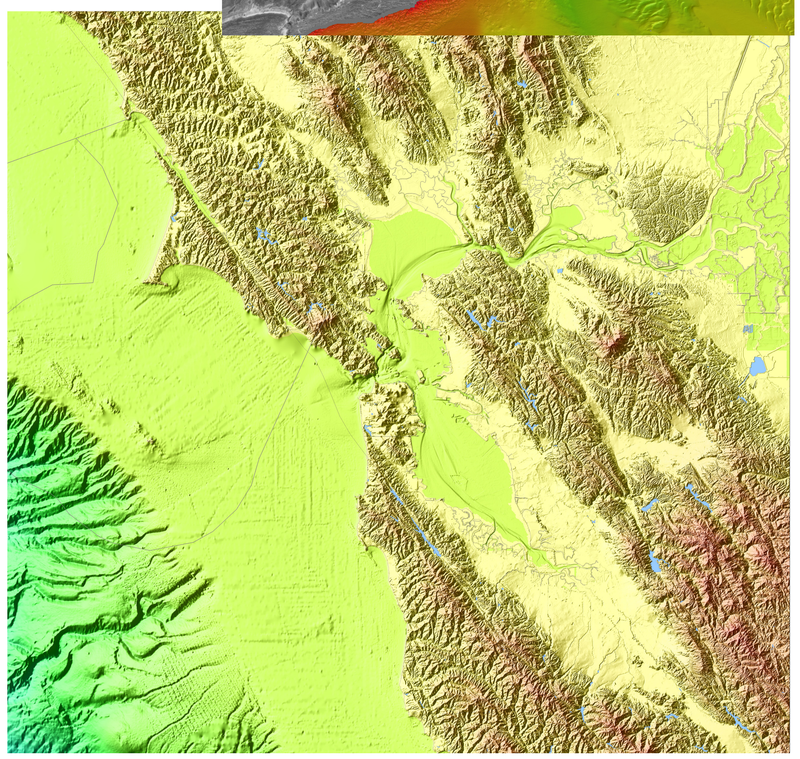
While uplift has occurred for many millions of years along the California coast ranges north and south of San Francisco (due to some residual compression with the Pacific Plate), the area around South San Francisco Bay has been an anomaly. Notice the shallow fault-bounded region of South San Francisco Bay. This area was created by the activity of the San Andreas and Hayward Faults that bound it. There is uplift on the eastern side of the Hayward Fault (creating the East Bay Hills) and western side of the San Andreas Fault (creating the Santa Cruz mountains). Between those two faults, the land has dropped down. (Imagine three blocks held against each other. If you pull the outside blocks upward, the center block sinks down.) This low-lying basin fills with water during interglacial periods and forms the boundaries of South San Francisco Bay. Because there are no significant river inputs to South San Francisco Bay, the water there is almost as salty as seawater.



San Francisco at the end of the last Ice Age. Green represents land that was above water during the ice age (but is under water today). The green offshore area is also known as the continental shelf. Blue areas are covered by ocean. Yellow squiggly lines represent the region covered by sand dunes. Notice how the dunes cover the entire offshore shelf and the flat portions of the San Francisco Peninsula. These dunes are underwater today.



Sidescan sonar image of the entrance to San Francisco Bay, looking west through the Golden Gate Bridge. San Francisco is to the right (south) of the bridge. Notice the deep channel carved under the bridge by tidal currents today (and by the Sacramento River during the past Ice Ages). It is 351 feet deep at its deepest point. In contrast, San Francisco Bay (inside the bridge) has an average depth of 22 feet. Note also the underwater sand dunes formed in the foreground by the tidal currents. USGS.



Combined bathymetry and topography image of San Francisco Bay Area. Notice the SUBMARINE CANYONS offshore, on the steep CONTINENTAL SLOPE (green). Notice the 4-km-deep abyssal plains (blue) at the base of the slope (where an apron of sediment known as the CONTINENTAL RISE fans outwards). Notice the shallow, flat CONTINENTAL SHELF (yellow) off the coastline. The edge of the shelf (where it meets the slope) is called the BREAK and represents where sea level was during the last Ice Age. During the last Ice Age, most of this yellow zone (including what is currently San Francisco Bay), was covered by sand. Notice the narrow opening (Carquinez Strait) in the East Bay Hills. This area was excavated by the river for the first time 400,000 years ago, providing a new output for the Sacramento and San Joaquin Rivers and the start of San Francisco Bay and estuary.

Sand dunes at Ocean Beach. Dunes like these covered most of the land of San Francisco before a city was built over them. Katryn Wiese ©

Oblique satellite view of San Francisco Bay with three times vertical exaggeration. The view angle is 20 degrees below the horizontal. Active faults (slipped during the past 10,000 years) are shown in red. This image drapes Landsat TM satellite imagery over Digital Elevation Models. USGS.