Friends of Edgewood
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Geologic Mélange
at Edgewood Park and Natural Preserve

by Jonathan Starr
October 12, 2022

The Geology of Edgewood is Special

The underlying geology of Edgewood Park and Natural Preserve is a “geologic mélange,” more specifically a “geologic mélange involving the Franciscan Complex.” This means that within the preserve’s small area (less than one square mile), there are many different rock blocks of completely different types, compositions, and modes and times of formation. Somehow, they all ended up here side-by-side, and one-above-the-other.

Such close proximity of such a variety of different rock types is unusual!

For example, much of Oregon is covered by basalt and other volcanic rock, stretching for thousands of square miles.


Source: 2

Much of the states of Utah, Arizona, and Colorado is covered by colorful sandstone.


Source: 3

California’s long spine of the Sierra Nevada Mountains is largely grey granitic rock, which is igneous rock formed by magma that cooled underground, and later was uplifted to the surface by powerful geologic forces.


Source: 4

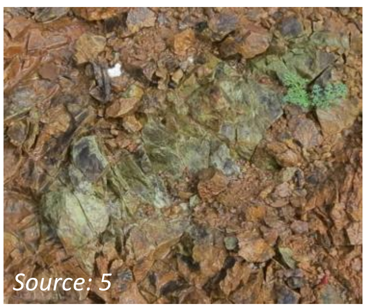
But, contrary to those vast expanses of uniform or similar rock-type elsewhere, in little Edgewood Natural Preserve there are sedimentary, bio-sedimentary, meta-volcanic, and metamorphic rocks, all mixed into a mélange.

How could this be?

This was a mystery until some new ideas came along in the 1960's. But before that story, here are some of the main rock types found in Edgewood.

Rock Stars at Edgewood Park and Natural Preserve

Serpentinite: The star of the show at Edgewood. Not common on the Earth's surface but plentiful in Edgewood. It forms from water mixing with mantle material. Near the top of the Sylvan Trail, dense woodland yields to sparser grassland underlain by serpentinite. Why the change in flora? Because soil containing degraded Serpentinite is toxic to many plants; only a few can tolerate it.



Greenstone: Usually reddish brown on the surface, due to oxidation of iron content. Originates as volcanic basalt flowing from fissures (called spreading centers) under the ocean, later subjected to heat, pressure, and water that change it to meta-volcanic greenstone. As the Live Oak Trail passes from sparse grassland to rich woodland, the rock type correspondingly transitions from the relatively toxic serpentinite to the more plant-friendly greenstone.

Greywacke: A sedimentary mixture of sand, mud, and gravel. It forms in near-shore marine environments from material eroded from coastal areas, delivered by streams or rainwater runoff or landslides, including ones underwater. It is present as underlay, outcrops, and/or rock islands in the wooded northern part of the preserve, in parts of the grasslands in the western corner of the preserve, and along the Clarkia Trail in the southern part of the preserve.

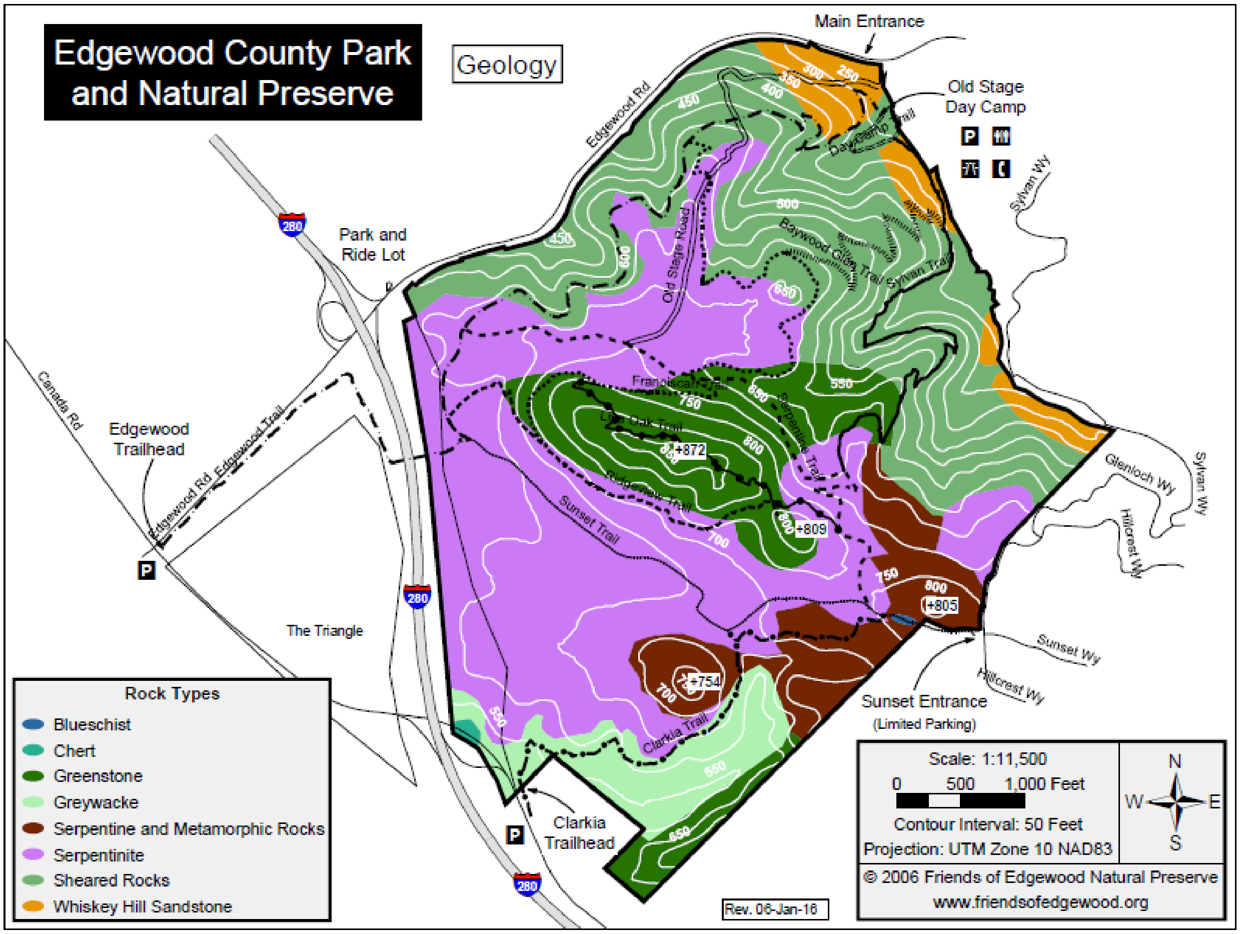
Whiskey Hill Sandstone: Not part of the Franciscan Complex, to which the other rocks here belong. Instead it formed from coarse-grained sediments in basins on top of the Franciscan Complex after the latter was already in place. It underlies a few northern parts of Edgewood, such as the Old Stage picnic areas, and is abundant at nearby Pulgas Ridge Open Space Preserve.

Radiolarian Chert: A bio-sedimentary glassy-looking rock, formed at the bottom of the deep ocean from the silicaceous skeletons of tiny plankton called Radiolaria. Common around the San Francisco Peninsula and forms prominent beds in the Marin Headlands. Appears as an outcrop in the southwestern part of Edgewood, and as scattered rock-islands and fragments in other parts of the preserve. Color varies: can be pink, maroon, orange, green, blackish, etc.

Blueschist: A metamorphic rock formed from certain minerals subjected to high pressures but low temperatures (by geologic standards) such as in subduction zones. Blueschist sometimes has other crystals, like garnets, embedded in it. In Edgewood, there is some ground-embedded blueschist near the Sunset entrance.

Note on Serpentinite-derived soils:
Why are they non-supportive or toxic to many plants?

1) They can have very low concentrations of essential plant nutrients like calcium, potassium, and phosphorus.
2) They can have very high concentrations of magnesium. While magnesium is an essential plant nutrient (e.g. it is a component of chlorophyll), in high concentrations magnesium can have deleterious effects.
    a. It impedes plant uptake of other nutrients, such as calcium.
    b. It makes soils dense and impermeable. When wet, they become sticky and expansive, putting pressure on roots and impeding them from penetrating or thriving.
3) They can have relatively high concentrations of certain heavy metals (e.g. nickel, chromium, cobalt, etc.) which can be toxic to many plants.



Source: 8

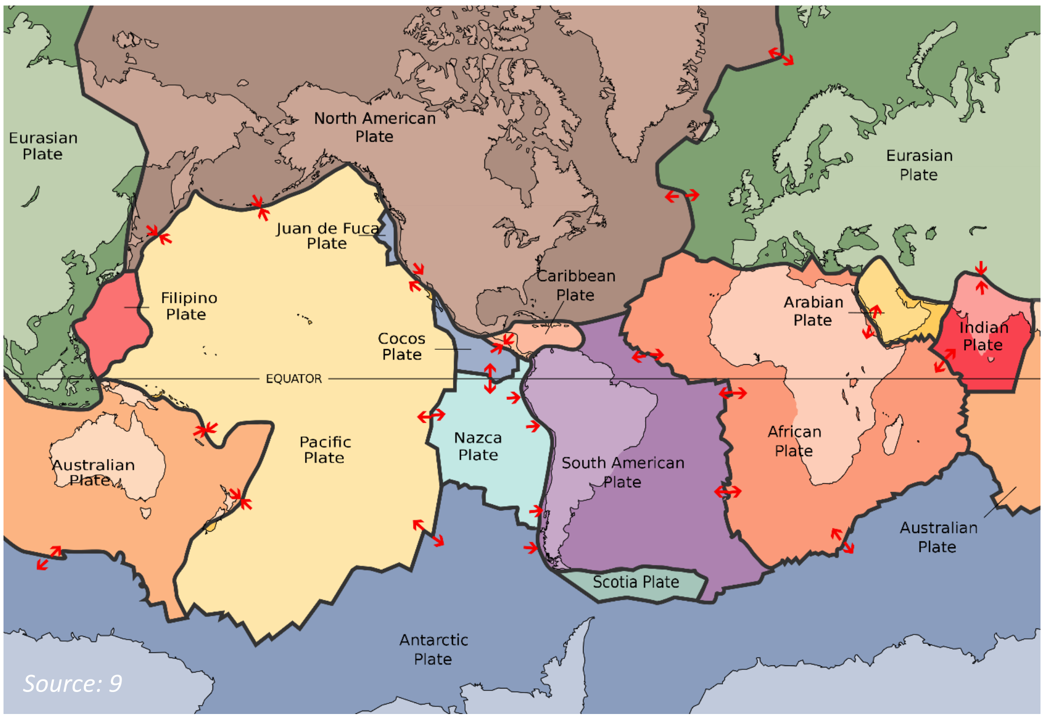
Above is a map of Edgewood Park and Natural Preserve showing the main rock types and trails. Note that:

1) Serpentinite underlies much of the grasslands.
2) Greenstone underlies much of the wooded central ridge cap.
3) The areas marked as "Sheared Rocks" have many different rock blocks broken into such small pieces that none can be said to dominate. Greywacke, including some outcrops and rock islands, is in the Sheared Rock area, including along the trails there. Much of the woodlands in the northern area of the preserve is in this area, as are portions of the grasslands on the west side of the preserve.
4) Chert is concentrated in a southwestern corner of the preserve, although it also appears as rock islands and smaller pieces in other parts of the preserve.
5) Blueschist is most readily seen near the Sunset entrance.

The map also shows how many different types of rock there are in this small preserve. There are near-shore sedimentary, deep-ocean bio-sedimentary, meta-volcanic, other metamorphic, and even mantle-derived rock blocks, all together here.

How could this happen? Plate Tectonics!

The overall answer is a theory first posed in the early 1900's, met with ridicule then, but later accepted in the 1960's and 1970's as evidence accumulated for it. The theory is called Plate Tectonics. It states that the crust of the Earth is divided into numerous plates, and they are in motion relative to each other. These plates, and their directions of motion, are illustrated here:



There are two types of plates: oceanic and continental. The oceanic plates are denser than the continental plates, and so ride lower in the underlying mantle layer.

Plates can move towards each other, away from each other, or parallel to each other in relatively opposite directions. There are several cases:

1) When two plates of the same type move towards each other, the crust crumples upward at the line of collision. See, for example, the Indian Plate and Eurasian Plate, where their collision is raising the Himalayan Mountains.
2) When two plates of different types move towards each other, the oceanic plate (being denser) subducts under the continental plate. That is, the leading edge of the oceanic plate dives underneath the continental plate, and continues moving towards, but underneath, the continental plate! See the Nazca Plate subducting under the South American plate.
3) An example of two plates moving parallel to each other is the relative motion of the Pacific Plate and the North American Plate, along the San Andreas Fault.

4) When two oceanic plates move away from each other, the fissure between them is called a "spreading-center." It allows magmatic mantle material to rise through the fissure and harden into new igneous crust along the back edge of each oceanic plate as they both recede away from the spreading-center. An example of this is the spreading-center where the Pacific Plate and the Nazca Plate are moving away from each other.

The Tectonic Plates in the vicinity of California today look like this:

As you can see, there are two tectonic zones of interest here:

1) The western part of California, where the oceanic Pacific Plate is moving northwestward relative to the continental North American Plate along the San Andreas Fault.

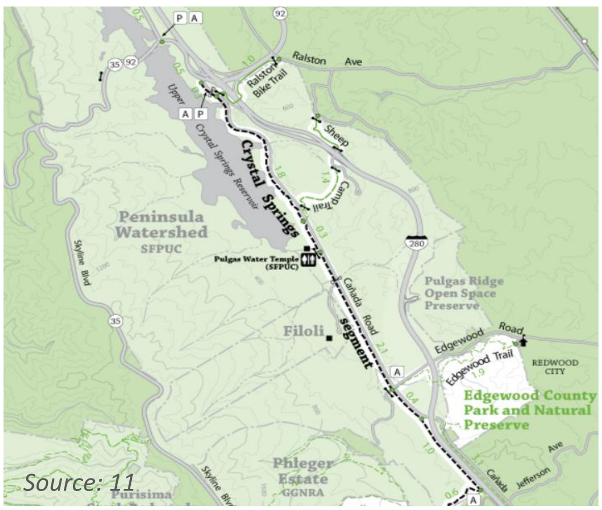
2) The west coast of Oregon, Washington, and southwestern Canada, where the oceanic Juan de Fuca Plate is moving eastward and subducting under the continental North American Plate.

It is actually the second zone, with the Juan de Fuca Plate, that is most related to the creation of the special and once-puzzling geologic mélange in Edgewood Natural Preserve!

How can that be? We shall see as we tell the story.

Edgewood and the San Andreas Fault

You can see the San Andreas Fault Zone from Edgewood Natural Preserve by looking west from the Ridgeview Trail on the open hillside of the central ridge. The elongated Crystal Springs Reservoir is lying in the trough of this fault zone.



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Source: 12

As you look across the San Andreas Fault Zone, and at the mountainsides beyond, you are looking at geologic blocks that did not originate there, and largely are made of different rock (like granite) than is found in Edgewood. That land/rock slowly moved there from its place of origin farther south, riding the northwestward relative motion of the Pacific Plate, at the average rate of about 2-3 inches per year. At that rate, Los Angeles would be a western suburb of San Francisco in about 10 million years!

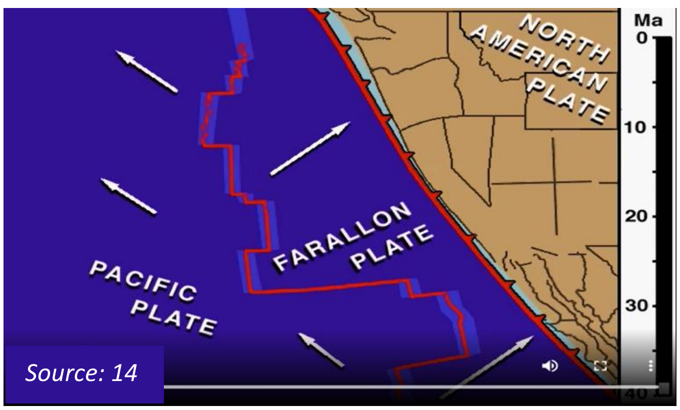
But the geologic mélange east of the fault zone, such as in Edgewood Natural Preserve, was already created before the San Andreas Fault got going in this area, which started about 15 million years ago. (For reference, the Age of Dinosaurs lasted from about 215 million years ago to about 66 million years ago. Anatomically modern humans arose about 0.2 million years ago.)

The Story of Edgewood: Forty Million Years Ago to Today

We begin the story of Edgewood's geologic mélange at about 40 million years ago.


Source: 13

Tectonically and geologically, things were different around this area then. Much of the land that is now the west coast of California did not exist. The western edge/coast of what is now the United States was at about what is now California's Central Valley.



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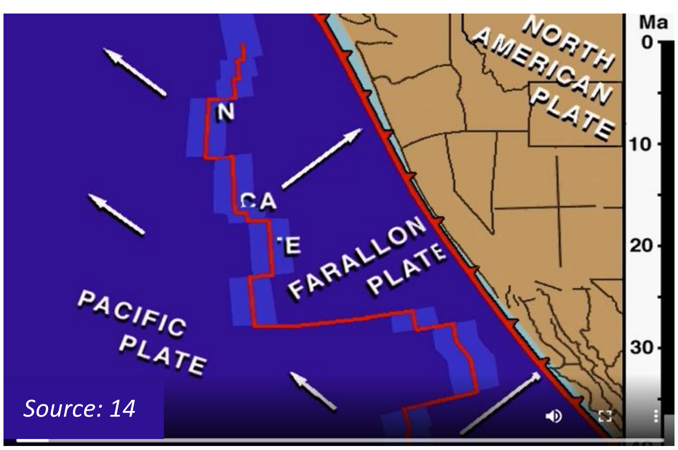
Unlike today, there was another large oceanic plate called the Farallon Plate positioned between the oceanic Pacific Plate and the continental North American Plate. There was a spreading-center between the Pacific Plate and the Farallon Plate as these two plates moved away from each other, allowing magma to rise up and create new rock on the edge of each plate. At the same time, the Farallon Plate was moving eastward relative to the North American Plate, and the eastern edge of the oceanic Farallon Plate was subducting under the western edge of the continental North American Plate.



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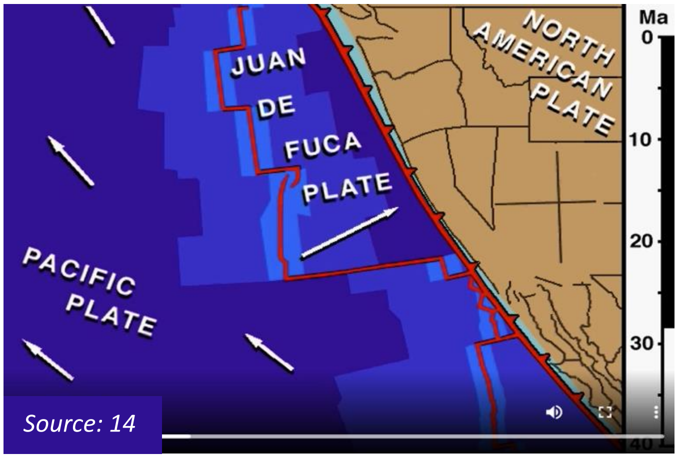
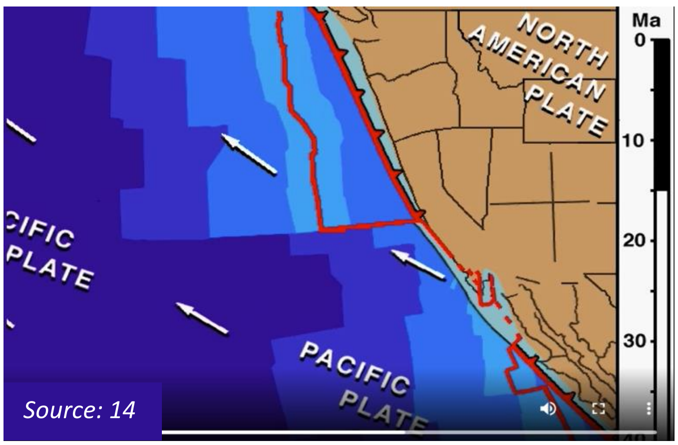
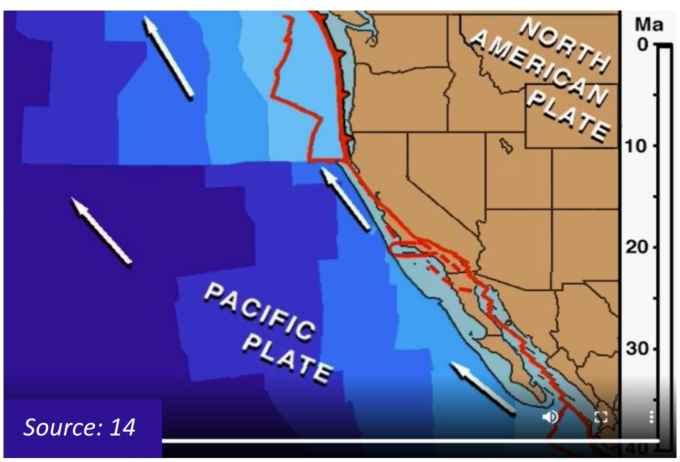
Checking a few million years later, we can see that not only is the Farallon Plate moving eastward, and subducting under the North American Plate, but also the spreading center between the Farallon and Pacific Plates is moving eastward, too! The extant Farallon Plate is effectively shrinking (west to east) and so the Pacific Plate and the North American Plate are getting closer together.



By about 30 million years ago, a portion of the Farallon Plate has completely subducted under the North American Plate in the area of what is now Southern California. Even that part of the spreading center between the Farallon Plate and the Pacific Plate also is subducting under the North American Plate. So, what remains of the Farallon Plate is now in two pieces, the northern one being called the Juan de Fuca Plate.



By about 15 million years ago, the Juan de Fuca Plate has gotten even smaller, and its southern border has moved northward, as that plate has subducted under the North American Plate. Correspondingly, the direct interface between the Pacific Plate and the North American Plate has gotten longer. Since, as we have seen, the Pacific Plate and the North American Plate were (and still are) moving roughly parallel to each other, but in opposite directions, the San Andreas Fault came into being.



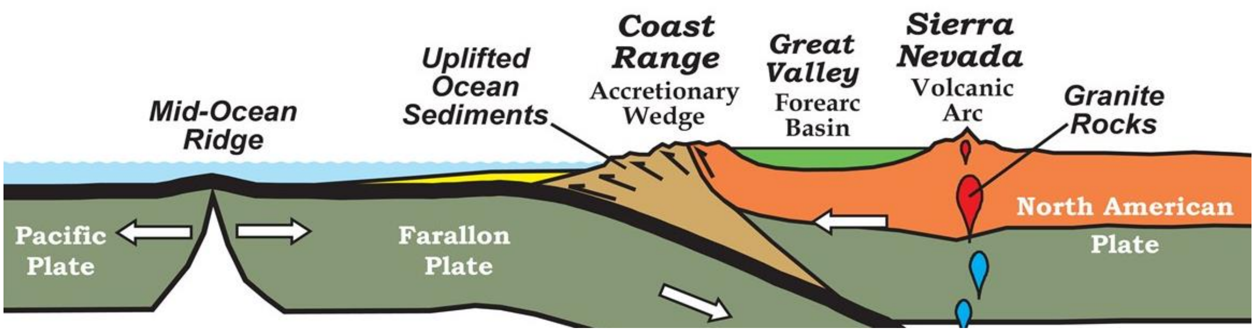
This process continued, producing the state of things today. The northern remnant of the Farallon Plate, called the Juan de Fuca Plate, is even smaller, and its southernmost edge is near the California-Oregon border. The San Andreas Fault now runs nearly the full length of California.

Notice that as the process progressed, more land was added to the west coast of the North American Plate, creating much of the land that is now the western portion of California, including the Bay Area, and including Edgewood Natural Preserve.

The Creation of the Franciscan Complex

As the Farallon Plate slowly ground eastward, silt, sand, skeletons of plankton, and other sediment accumulated on its surface and hardened into rock. Where this oceanic plate subducted under the continental North American Plate, this material, including greywacke, chert, and other sedimentary rocks, was scraped off the Farallon Plate and plastered into "accretionary wedges", creating new land extending the western edge of the North American continent. Fragments of the Farallon Plate itself, including basalt, greenstone, serpentinite, and other igneous, metamorphic, and mantle-derived rocks, also mixed into the accretionary wedges. Within the subduction zone, the special temperature, pressure, chemical, and hydrologic conditions produced blueschist and other metamorphic rocks, which reached the surface in the general tumble.

The resulting collection of all those different rocks is called the Franciscan Complex, which underlies much of northwest coastal California east of the San Andreas Fault. That includes much of the San Francisco Peninsula, including Edgewood Natural Preserve. Areas where many blocks of these different rock types lie mixed together are called geologic mélanges.



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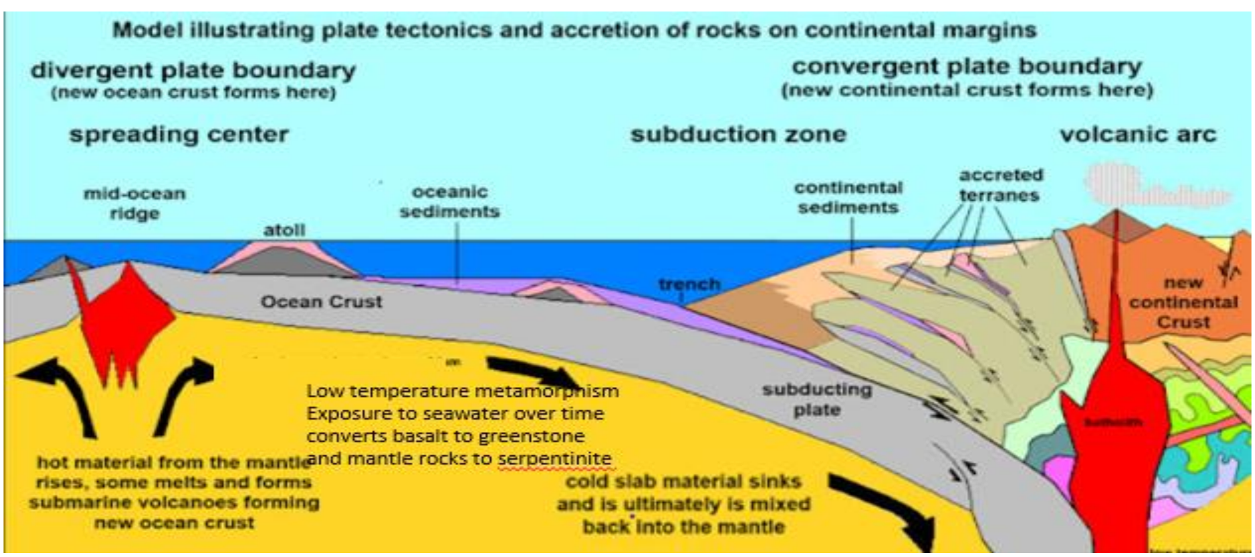

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Origins of Edgewood's Rock Stars

So, what about the individual stories of the individual "rock stars" making up the geologic mélange at Edgewood Natural Preserve?

Greywacke formed from accumulations of near shore sediments from erosion off the coast, outflow from streams, landslides, and underwater flows of sediment-laden water called "turbidity currents." These cemented and hardened into rock lying on top of the oceanic Farallon Plate, which subsequently was scraped off and accumulated into the accretionary wedges as the Farallon Plate subducted under the North American Plate.

Radiolarian Chert formed far offshore in the cold deep ocean where the skeletons of tiny radiolarian plankton rained down onto the ocean floor, atop the Farallon Plate, forming a silicaceous ooze that hardened into Radiolarian Chert. This, too, was conveyed to, and accumulated in, the accretionary wedges of the subduction zone.

Greenstone typically started as igneous basalt formed from upwelling lava/magma at the spreading center between the Farallon Plate and the Pacific Plate, and added to the receding edges of both plates. Metamorphosing conditions of temperature, pressure, and water-exposure within the Farallon Plate and in the subduction zone transformed the basalt to greenstone. Fragments of this portion of the plate accumulated in the general jumble of rocks in the subduction zone.

Blueschist forms from particular accumulations of minerals subjected to high pressure and low temperature (by geologic standards), such as occur in subduction zones. Slow churn of all the accumulating rocks brought some blueschist to the surface.

Serpentinite probably forms from water mixing with mantle material at spreading centers, at the bottom of oceanic plates, and in subduction zones. It is a slippery rock that some believe was squeezed up, like toothpaste, to the surface by the pressures of the subduction zone. Or, perhaps like blueschist, it might rise through the general slow tumbling of all of the types of rocks accumulated in the subduction zone.

Whiskey Hill Sandstone was not conveyed by the Farallon Plate to the accretionary wedges or subduction zone. Instead, it formed later, from coarse grained sediments accumulated in basins on top of the already-emplaced Franciscan Complex of the other rocks described above. Its presence adds to the mélange of different rock types.

All in One Place at Edgewood

So now we have these many different rocks, of different character, composition, and method and time of origin, all in one place. Most of them were delivered to the western coast of what is now California by the movement and subduction of the Farallon Plate. There they were plastered onto the coast in accretionary wedges, and/or formed in the subduction zone itself. The result is the remarkable presence of such different rock types all adjacent to each other, together in one geologic mélange, in beautiful Edgewood Park and Natural Preserve.

Something to ponder as you enjoy a view such as this one of the serpentine grasslands, with 1) a chert "rock island" (with its localized shrubs thriving in chert-derived soil, which is less toxic than the surrounding serpentinite soil); and with 2) the abrupt transition to dense woodland demarking the edge of the greenstone ridge cap.

The chert is whitish, not its original color, via removal of iron by metamorphic and hydrothermal processes (per geologist Paul Heiple).

Sources and Attributions for Photos and Graphics

1. County of San Mateo, Parks, Edgewood Park & Natural Preserve
https://parks.smcgov.org/edgewood-park-natural-preserve
2. Oregon State Archives, Mt. Jefferson from Cove Palisades State Park (Photo No. jefDB1418)
https://sos.oregon.gov/archives/records/county/Pages/scenic-images.aspx
3. Utah State Parks, Dead Horse Point State Park
https://stateparks.utah.gov/parks/dead-horse/
4. U.S. National Park Service, Yosemite National Park, Glacier Point
https://www.nps.gov/yose/planyourvisit/glacierpoint.htm
5. Friends of Edgewood, Education Center, Land and Water section
https://friendsofedgewood.org/land-and-water
6. Photos by author Jonathan Starr: Greywacke sample at Bill and Jean Lane Education Center, Edgewood County Park and Natural Preserve; Whiskey Hill Sandstone along Sylvan Way on east side of Edgewood; Chert layers in southwest corner of Edgewood.
7. Courtesy of Andrew Alden, Oakland Geology website, Oakland blueschist archive.
https://oaklandgeology.com
8. Friends of Edgewood (Docent Manual); www.friendsofedgewood.org
9. U.S. Geological Survey, Plate Tectonics Map, Scott Nash, Public Domain via Wikimedia Commons
http://commons.wikimedia.org/wiki/File:Plates_tect2_en.svg
10. U.S. Geological Survey, Understanding Plate Motions, Figure 25
http://pubs.usgs.gov/gip/dynamic/understanding.html, Modified by author Jonathan Starr
11. County of San Mateo, Parks, Crystal Springs Segment
https://www.smcgov.org/parks/crystal-springs-segment
12. Crystal Springs Reservoir aerial view
https://commons.wikimedia.org/wiki/File:Crystal_Springs_Reservoir_aerial_view,_February_2018.JPG
Author: Pi.1415926535
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13. Scotese, C.R., and Scotese, J.D., 2006. Plate Tectonic Evolution of North America, PALEOMAP Project, Evanston, IL , https://youtu.be/2yKNhbY3Nbk
14. Courtesy of Tanya Atwater, Emeritus Prof. of Tectonics, U. of California at Santa Barbara
https://animations.geol.ucsb.edu/2_infopgs/IP4WNATect/bNEPacWNoAm.html
15. U.S. National Park Service, Geology, Convergent Plate Boundaries - Subduction Zones
https://www.nps.gov/subjects/geology/plate-tectonics-subduction-zones.htm
Per NPS: graphic "modified from 'The Geology of our National Parks, Monuments and Seashores,' by Robert J. Lillie, New York, W. W. Norton & Company, 298 pp., 2005, www.amazon.com/dp/0134905172."
16. Courtesy of Phil Stoffer, Assoc. Prof., MiraCosta College
http://geologylearn.blogspot.com/2017/01/continental-accretion-and-plate.html

Suggested Resources

- **Geology of the San Francisco Bay Area**; Author: Doris Sloan, Adj. Professor of Earth & Planetary Sciences, U. of California, Berkeley; Photographer: John Karachewski, geologist, California Environmental Protection Agency; Copyright 2006 by Regents of the U. of California, U. of California Press, Ltd. ISBN-10: 0520241266, ISBN-13: 978-0520241268
- **Wollaston Medal Lecture, 2022**, Prof. Tanya Atwater (source 14, above): A personal memoir by an early advocate of the theory of plate tectonics, and pioneer in its application to California and the west coast of the USA. https://www.youtube.com/watch?v=zr8L1-5vaq4

Edgewood Park and Natural Preserve is the only natural preserve in the San Mateo County Park system. This special status is due to Edgewood's extraordinary biodiversity, many native plant communities, and more than a dozen rare, threatened, or endangered species. Edgewood's 467 acres are a wonderful place to experience and learn about nature. Interactive exhibits at the Bill and Jean Lane Education Center near the preserve's main entrance encourage discovery and stewardship of the area's unique habitats. Edgewood is located at 10 Old Stage Coach Road, Redwood City, CA.

Friends of Edgewood was founded in 1993 by a group of conservation-minded citizens dedicated to protecting Edgewood's important native California landscape. Friends of Edgewood continues that legacy by engaging in land and wildlife stewardship, nature education, and interpretive programs that support Edgewood Park and Natural Preserve. Our mission is to protect Edgewood's extraordinary biodiversity and foster lasting connections with Edgewood and the larger natural world.

For more information, visit www.friendsofedgewood.org.

About the Author: Jonathan Starr

Jonathan Starr is an engineer by profession. Though not a geologist by trade, he has been fascinated with geology (and paleontology) for most of his life. He has taken several college-level courses; been on numerous field trips, guided outings, fossil digs, and hikes; attended many lectures and seminars; watched many documentaries; read many books, articles, and on-line content; and talked geology and paleontology with whoever else had the interest!

Jonathan completed the Friends of Edgewood Docent-Training Class of 2013. He has led hikes, and prepared other educational documents for fellow docents and others on such topics as woodpeckers, wildflowers, fence lizards, lace lichen, etc. – all for the pleasure of sharing his interests with others!

Much appreciation for very helpful geologic information and explanations from professional geologist Paul Heiple, who for many years has been a very active member of Friends of Edgewood and a docent-trainer.