MANZANITA

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Serpentine: Of Rare Rocks and Botanical Varieties *by Allison Kidder*

Serpentine grassland, Missimer Snell Wildflower Preserve, Napa County, California in April 2021.

My old-ish bones creaked audibly as I lowered myself to lizard level, brought my hand lens to my eye, and balanced my feet and hands carefully on the green-waxy rocks around me. My aim was to see the rare *Calochortus tiburonensis*, the Tiburon mariposa lily, alongside a trail at Ring Mountain Preserve on the Tiburon Peninsula in southeastern Marin County. This surprisingly small—and at first glance humble—*Calochortus* flower only occurs in this one spot on our planet, in an incredibly diverse serpentine grassland that harbors a treasure trove of native plant species.

While most of the serpentine soils in North America occur in central and northern California (Central Coast ranges, Klamath Mountains, and Sierra Foothills), these unique soils are also found in Oregon and Washington in the west and along the folds of the Appalachian Mountain Range in the east. Serpentine soil habitats range from barren moonscapes to sparsely populated forests to technicolor grasslands, and individual plants and even entire plant communities have evolved to exist on them. Just one percent of California's land surface is composed of serpentine soil and rock, yet this soil and rock hosts more than twelve percent of plant species endemic to the California Floristic Province.

How come California has so much serpentine? Where are these unique areas located? And what fun plants can you find there? To answer these questions we will take a brief journey far back in time to explore how these rocks and soils developed and then embark on a serpentine wildflower/plant hunt around the state, from far Northern California in the Klamath and Siskiyou Mountains to the area near the City of San Luis Obispo. Thankfully, our own Regional Parks Botanic Garden grows many interesting plants found only on serpentine soils, and we will end our tour by swinging through the Garden's paths to highlight several of them.

First, a Little Geology

As a plant lover, do your eyes glaze over at the mere mention of rocks and soil? I hope to

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The nodding flower heads of Mt. Hamilton thistle (*Cirsium fontinale* var. *campylon*), Coyote Ridge, Santa Clara County, California.
Allison Kidder

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convince you that the study of serpentine rock and soil is well worth your time!

Technically, serpentine is a mineral. But colloquially the word *serpentine* refers to three things: the rock serpentinite, the soil type derived from weathered serpentinite, and the mineral itself. For our purposes we will specify whether we are referring to serpentinite rock or serpentine soil as needed.

Many of us know that serpentinite has been designated as California's state rock, but did you know that serpentinite has been found on Mars? And did you know that planetary scientists have found serpentine minerals in meteorites that have landed on Earth? Serpentinite might have provided the environmental conditions needed on early Earth and other planets for the spontaneous generation of amino acids necessary for the development of life. Also, the distribution of serpentinite and its associated rock types found around the world played a key role in the development of the revolutionary theories of continental drift, seafloor spreading, and plate tectonics developed in the 1960s and still actively researched today. These theories helped scientists discover the existence of the large subduction zone along the west coast of the United States that generated California's abundance of serpentinite and the large number of volcanoes in the west such as Mt. Shasta and Mt. Lassen.

One needs to dig into Earth's past to tell the story of how serpentine rock and soil developed. It begins when olivine and pyroxene minerals in peridotite, an igneous, ultramafic rock, are subjected to superheated water and high pressure within the Earth's upper mantle near tectonic plate boundaries and geologic faults, a process called serpentinization. Igneous rocks are solidified molten lava. Ultramafic rocks (like peridotite) dominate Earth's mantle and are high in the "mafic" minerals magnesium and iron, as well as other metallic elements; they are low in potassium and other elements. A rock is considered serpentinite if more than half of its minerals are serpentine.

Scientists estimate the metamorphic process of serpentinization consumes approximately 300 liters (79 US gallons) of water per cubic meter of rock that is transformed into serpentinite. That involves a lot of hydrogen and oxygen, and scientists speculate that the process may have fueled life on other planets, including Mars and Saturn's sixth-largest moon, the tiny Enceladus (whose diameter is only 314 miles). Serpentinization is also being used as a model by planetary scientists to help explain the development of planetesimals (very small planets, and a very fun word).

Waxy serpentinite, Missimer Snell Wildflower Preserve, Napa County, California.

Chris McCarron

Hand sample of peridotite.

Chris McCarron

Hand sample of serpentinite.

The three most typical sites of serpentinization are: divergent plate boundaries such as oceanic ridges where plates move away from each other and the resulting seafloor spreading forms new oceanic crust; convergent plate boundaries where plates collide and create mountain ranges like the Himalaya; and subduction zones where one tectonic plate dives beneath another, such as along the northwest coast of North America. Geologists have recently estimated that ultramafic rocks cover only about three percent of Earth's surface. This suggests that the chances of these rocks reaching the surface at these tectonically active sites is relatively slim.

As these harsh and active environments develop, the temperature, pressure, amount of available water, and mineral content vary widely. Peridotite can thus transform into several varieties of serpentinite that can be surprisingly variable in structure and appearance. Among these varieties are waxy-looking rocks with swirls of green and gray material, soft and smooth to the touch, that are higher in nickel, and dark brown or rust-colored rocks with sharp, jagged edges that are higher in iron. One notable type of serpentine mineral is chrysotile, a soft, fibrous type of asbestos. Though not especially common, it often forms veins within many types of serpentinite.

Over millions of years, geologic forces have uplifted a small amount of Earth's serpentinite to the surface, where exposure to the elements results in weathering and the development of serpentine soil—and some of our favorite botanizing areas. Many of the serpentine landscapes we see today formed at the bottom of the sea. In areas of seafloor spreading, oceanic peridotite has been pushed upward from Earth's mantle to the seafloor by convection currents carrying heat from the Earth's core toward the surface. The olivine and pyroxene in the peridotite react with seawater to form serpentine.

Image Courtesy of Lost City 2003.

A serpentinite outcrop forms the south wall of the Atlantis Massif in the Lost City Hydrothermal Field. This image was taken by the remotely operated vehicle *Hercules* during an exploration of the area in 2003.

One unique example of undersea serpentinization is the hydrothermal vent known as the Lost City, which was discovered in December 2000 using a robotic submarine 2100 ft below the ocean's surface. This 30,000-year-old vent system is located about 30°N latitude immediately west of the aptly named Mid-Atlantic Ridge, a slow-spreading seafloor ridge that zippers north-south. The Lost City stands near the top of the southern cliffside of the Atlantis Massif, an underwater mountain that rises about 14,000 ft above the seafloor (equivalent to the height of Mt. Rainier). More than 70 percent of the Lost City's base rock is serpentinite and its carbonate chimneys soar up to 200 ft high. The peridotite's residual heat from coming directly from the mantle, plus the underwater serpentinization chemical reaction, can generate so much heat and gas (methane and hydrogen) that the near-freezing seawater is heated to about 190° Fahrenheit in the vent's chimneys. This supports what might be the most diverse array of microorganisms in an oceanic hydrothermal vent on our planet. Scientists speculate we will find more of these specialized habitats as we continue to explore unmapped seafloor.

A Tour of the Mines

Serpentinite can itself be altered further in fault zones by heat, pressure, and water to become rust-colored cinnabar, a rock type that is mined worldwide for mercury. Before mercury's deleterious environmental and health-related effects were known, cinnabar and mercury had their own rush at the same time as California's Gold Rush. Mercury was used to amalgamate (attach to) placer gold (small pieces of gold ore found in sediment) when the placer gold was washed in sluice boxes. The town of Placerville was incorporated and named in 1854 in honor of the placer gold that drew many people to the area when gold was struck there in 1848. Not surprisingly, California hosts the highest number of gold and mercury mines in the United States. The largest mercury mine was the New Almaden Quicksilver Mine south of San Jose. Named after a famous mercury mine in Almadén, Spain, New Almaden produced 46 million pounds of mercury between 1850 and 1875.

The cinnabar deposits in New Idria in San Benito County were discovered in the 1850s and shortly thereafter hosted a complex of mines. These mines became the second largest mercury producer in the country. The town of New Idria was abandoned in the 1970s because of the mines' closures and the persistent mercury contamination.

The ghost town still exists but is fenced off and is currently a US Environmental Protection Agency Superfund site. Cinnabar has historically been prized by many people around the world for its red pigment. It was used as face paint by California's Central Coast Ohlone, to color Chinese lacquerware and ancient Mayan burial chambers, and as a rouge cosmetic in ancient Rome.

Chromium, cobalt, and nickel (known in some circles as the "ultramafic triad") are valuable heavy metals found within both peridotite and serpentinite, and they have been mined worldwide. The first chromium mine in the United States was opened early in the 19th century in the Bare Hills district several miles north of Baltimore by Isaac Tyson, Jr., a Quaker businessman and metallurgist by training who made the astute observation that chromium was consistently associated with serpentinite. Among other uses, chromium is used to develop ferrochrome, an alloy of chromium and iron used in the production of stainless steel. This mine was the largest source of chromium in the world during the first half of the 19th century and served as the source of this metal for Pennsylvania's burgeoning steel industry. You can still visit the site of one of Tyson's first chromium mines, opened in the 1820s, at the 1,900-acre Soldier's Delight Serpentine Barrens. It is one of the largest and most biologically diverse serpentine areas within the Appalachian belt and noted for harboring dozens of rare and endangered plant species. Soldiers Delight Serpentine Barrens was named for the company of rangers in the service of King George II that regularly patrolled the area in the 18th century (the mine was closed in 1860).

Closer to home, chromium was mined in The Cedars, a 7,500-acre mass of serpentine barrens north of the Austin Creek Recreational Area and Armstrong Redwoods State Park in Sonoma County. A botanical and geological utopia (mis)named for the large number of Sargent cypress (*Hesperocyparis sargentii*), its rugged topography consists of deep canyons cut through peridotite and serpentinite by two branches of Austin Creek. Botanical explorations of The Cedars began in the late 1920s; but somewhat earlier geologists had their eyes set on the area's large deposits of chromite (a compound of iron oxide and chromium) and magnesite (also known as magnesium carbonate), first excavating the Layton

Chris McCarron

A lone Sargent cypress (*Hesperocyparis sargentii*) in The Cedars.

The Cedars is primarily peridotite, an ultramafic rock that has not yet undergone serpentinization. Here, Sargent cypress (*Hesperocyparis sargentii*) groves nestle in the canyons above Austin Creek.

Chris McCarron

The stream orchid (*Epipactis gigantea*; Orchidaceae) is a rhizomatous perennial that grows along streams and waterways throughout California. Normally sporting light green leaves with peach-colored flowers, this stream orchid in the Garden's serpentine bed is the unique burgundy-leaf form (*Epipactis gigantea* f. *rubrifolia*) endemic to the ultramafic rock and soil in The Cedars, Sonoma County, California.

chromium mine in 1916. The most productive years of the mine were in 1918 and 1944, when chromium was needed in the production of ammunition for World Wars I and II.

The creeks, seeps, grottos, and waterfalls found in The Cedars support lush vegetation that is rich in fun oddities and rarities like a beautiful, endemic, purple-leaved form of the stream orchid, commonly called burgundy-leaf stream orchid (*Epipactis gigantea* f. *rubrifolia*) and the large-flowered serpentine columbine (*Aquilegia eximia*). The Cedars also hosts the rare endemic cedars manzanita (*Arctostaphylos bakeri* subsp. *sublaevis*), an upright shrub with white flowers that bloom between February and April; this manzanita is found only in this single ultramafic rock outcrop.

Cobalt is another metal mined in serpentine areas, mainly as a byproduct of mining for other elements, and is sourced mainly outside the United States, which imports the majority of the metal. Primary uses of cobalt are as an alloy in jet engines and in rechargeable electrodes in electric vehicles and other batteries. Scientists are currently trying to figure out how to recycle the cobalt entrenched deep inside these multilayered batteries.

Nickeliferous (another fun word) deposits in the United States are mostly found in peridotite within California and Oregon and, like cobalt, nickel is used in electric vehicle batteries and other industrial applications. California hosts the second largest number of nickel mines in the US (Alaska having the most), with the highest concentration in Del Norte County near Peridotite Canyon and the town of Gasquet. This area is well-known for botanical gems in a variety of serpentine habitats, from bogs and active springs filled with the California pitcher plant (*Darlingtonia californica*) to dry, open slopes sporting Kellogg's Lily (*Lilium kelloggii)*, a beautiful pink lily that thrives especially after a disturbance like fire.

Of about six types of asbestos, chrysotile is the only type mined from serpentinite. It is no longer mined in the United States but is still mined in many countries, with Russia and China being the top worldwide producers. The last American mine to close, in 2002, was in San Benito County, one of the most active asbestos mining areas in California. The mine was located in the rugged terrain of Clear Creek Management Area, a serpentine outcrop on San Benito Mountain that is a popular hiking and off-roading destination; it is near the ghost town of New Idria that once housed miners and their families. The polluted and hazardous remnants of several asbestos mines still scar the serpentine landscape, the result of short-fiber chrysotile asbestos mining for export to Japan.

This area was once designated a US Environmental Protection Agency Superfund site. However, despite the fact that the agency cleaned the open-pit mines and mine tailings and took the site off the EPA Superfund list in 1998, the threat of asbestos exposure is still very much present at Clear Creek. In a 2005 study, EPA employees and contractors donned respirators and full protective suits with special asbestos fiber-detecting cassettes to detect typical exposures of various recreational users of the area. Hikers revealed almost no fibers, while drivers of motorcycles, all-terrain vehicles, and sport utility vehicles all

The purple form of stream orchid (*Epipactis gigantea* f. *rubrifolia*) from The Cedars thrives alongside white-flowering Carolina bugbane (*Trautvetteria caroliniensis*; Ranunculaceae) in the bog portion of the Garden's serpentine bed on June 3, 2021. Somewhat rare in California, *T. caroliniensis* has large, maple-like leaves and flowers reminiscent of white starbursts. The Garden's specimen was collected by the previous Garden Supervisor, Joe Dahl, from a water course in the Klamath Mountains.

had levels greatly exceeding EPA guidelines, with the highest exposure being the folks driving through a dust cloud behind a leading vehicle. All the more reason to conserve the 13 sensitive plant species observed in the area, including the two CNPS List 1B plants, the San Benito evening primrose (*Camissonia benitensis*) and Indian Valley bush mallow (*Malacothamnus aboriginum*).

And Now Let's *Really* Get into the Plants!

It's not surprising that rare plants would be found on rare rocks. Serpentine areas are well known for jaw-dropping wildflower displays, but they are also known for high numbers of interesting rare plants. From far away, serpentine rock outcrops can look like barren moonscapes, but as we get closer our eyes begin to focus on the wide variety of plants eking out a living on rocky slopes, from the practically invisible and cryptic Brewer's jewelflower (*Streptanthus breweri*) to more colorful rarities, like the showy raillardella (*Raillardella pringlei*) found around Mt. Eddy and other serpentine areas in Trinity and Siskiyou counties.

Soil is developed when the rock below it degrades and weathers away. Rates of soil development are influenced by the type of parent rock, climate, vegetation, topography, and the types of organisms present, from microbes to earthworms. Soil can be eroded by rain and wind over time, faster on rocky outcrops and hilltops and more slowly on gentle slopes, eventually settling in largely flat alluvial plains and river valleys. Serpentinite develops into serpentine soil, and the resulting soil profile can be somewhat thick (as in some serpentine grasslands) or practically nonexistent (like on serpentine rock outcrops), depending on the amount of erosion that has occurred.

Serpentine soils are notoriously low in the nutrients important for plant growth, especially calcium but also nitrogen, phosphorus, and potassium. They have higher-than-normal levels of the metallic elements we have discussed above, resulting in their telltale low calcium-to-magnesium ratios. These soils are also typically shallow and have low water-holding capacity. All of these characteristics add up to habitats that are inimical to plant growth.

In 1951 the "father" of serpentine plant ecology, Arthur Kruckeberg, started the discussion about edaphic endemics (plants restricted to unique soils), specifically how plants tolerate serpentine soils. He observed that serpentine soil areas often serve as refugia for native plants that can tolerate low calcium, high magnesium, and low macronutrients. Further, he suggested that most plants living on serpentine soil don't actually require serpentine soil but instead are simply poor competitors on soils more conducive to plant growth. The Garden's own serpentine bed reflects this observation: although the rocks are serpentinite, the soil used to grow plants collected from serpentine habitats is not serpentine soil.

Showy raillardella (*Raillardella pringlei,* Asteraceae) is endemic to wet meadows in forest habitats on serpentine soils in the Klamath Mountains. Steve Matson photo.

Over the past several decades, grassland ecologists have noted that exotic grass species, such as common wild oat (*Avena fatua*), soft brome (*Bromus hordeaceus*), slender wild oat (*Avena barbata*), and Italian ryegrass (*Festuca perennis*), have evolved the ability to exist on serpentine soils. Although these non-native grasses are mainly found along the edges of serpentine habitats, their presence "chases" native species into the even more unfavorable conditions on rocky outcrops, where the shallow soil and exposure to the sun and wind increase evapotranspiration, challenging native plants to obtain enough water and nutrients.

In some serpentine grasslands, such as Coyote Ridge in southeast San Jose, Santa Clara County, non-native grass species have been able to get a firm foothold because of nitrous oxide (N_2O) emissions from the cars streaming along Highway 101 immediately to the west. The non-native grasses were crowding out the abundant wildflowers as well as populations of California plantain (*Plantago erecta*), a diminutive annual plant that serves as the host plant for the federally threatened bay checkerspot butterfly (*Euphydryas editha bayensis*, in the family Nymphalidae). Land managers have learned that well-timed grazing by cows, who prefer to munch the nitrogen-filled exotic grasses, allows the native wildflowers and bunchgrasses to thrive.

Species benefitting from the hungry cows include Santa Clara Valley liveforever (*Dudleya abramsii* subsp. *setchellii*), a cryptic succulent whose

Metcalf Canyon jewelflower (*Streptanthus albidus* subsp. *albidus*) is found on serpentine soils on Coyote Ridge south of San Jose, Santa Clara County, California.

leaves match the color of the serpentine rocks its roots manage to nestle in; and Metcalf Canyon jewelflower (*Streptanthus albidus* subsp. *albidus*), an upright plant with tall spikes of ghost-like white flowers. *Streptanthus albidus* subsp. *albidus*, *S. albidus* subsp. *peramoenus*, and *S. breweri* have small but noticeable salmon-orange bumps at the ends of their strap-like leaves midway up the stem that appear when the plant develops its flowers. Butterfly expert Arthur Shapiro with the University of California at Davis believes these bumps are an example of protective egg mimicry by these *Streptanthus* plants. He theorizes that female California white butterflies (*Pontia sisymbrii*), thinking that these plants already have eggs laid on them when they do their egg-load assessment, will fly on past.

Serpentine refugia often lead to high levels of speciation because plants are reproductively isolated and thus prevented from exchanging genes. This can be due to distance (too far away from their own species to reproduce), different flowering time (plants living on harsh soils often flower earlier than plants on normal soils), evolved traits that allow plants to survive in the harsh conditions but also prevent them from being able to reproduce with other plants, or different pollinator behavior that drives plant survivorship and its ability to create seed-bearing fruit.

Strap-like basal leaves of many *Streptanthus* species, such as this most beautiful jewelflower (*Streptanthus albidus* subsp. *peramoenus*; Brassicaceae), have small orange-red callosities along leaf edges that mimic the eggs of spring white butterflies (*Pontia sisymbrii*), which lay orange or red eggs similar in size and shape. These butterflies may assess the egg-load on plants as they fly by, leaving these falsely-loaded *Streptanthus* plants in the clear.

For example, Milkwort jewelflower (*Streptanthus polygaloides*), a serpentine endemic found in the Sierra foothills, is one of several hyperaccumulators, or plants that have adapted to extreme serpentine soils by actively taking up heavy metals, especially nickel, in their roots and consolidating them in their foliage to levels more than 100 times the metal concentrations in the soil. Metals have also been found in this plant's flowers, nectar, and pollen, all at different concentrations and lower concentrations than in its leaves. Researchers have observed that *S. polygaloides* has slightly more pollinated flowers that successfully mature fruits when grown in soils with nickel versus without nickel, indicating that pollinators somehow prefer the nickel-laden pollen.

Plants endemic to serpentine areas are often considered neoendemics, or species that have evolved (relatively) recently, as opposed to paleoendemics, or species that were once widespread but have restricted their range over time. For example, species in the genus *Streptanthus* (Brassicaceae) and *Hesperolinon* (Linaceae), which have many edaphic (soil-influenced) endemics found throughout California, are considered neoendemics, whereas fossil evidence suggests coast redwoods (*Sequoia sempervirens*) used to flourish in many parts of the Northern Hemisphere but are now restricted to the coastal fog belt of California.

The genus *Hesperolinon* represents the western flaxes and is a terrific example of serpentine neoendemism. Most species evolved in this genus 1-2 million years ago during the Pleistocene epoch, a time of saber-toothed cats and mammoths and dramatically shifting climates and temperatures. One of these neoendemics, Sharsmith's western flax (*Hesperolinon sharsmithiae*), was discovered and described in 2006 by our own Garden volunteer and lecturer, Dick O'Donnell. This delicate annual has an airy form with small yellow flowers on the ends of delicately branched stems. Found in serpentine chaparral in Napa and Lake counties, it was named to honor the UC Berkeley botanist Helen Sharsmith for her extensive work on the genus.

Sargent Cypress (*Hesperocyparis sargentii*) and leather oak (*Quercus durata*) are of special interest because not only do they occur so reliably on serpentine soil that they are considered indicator species for serpentine, but they are serpentine endemic species that occur throughout

California's serpentine areas. The Garden's recent Student Interpretive Aide, Chris McCarron, is currently researching *Q. durata* to help resolve that conundrum. He has collected almost 200 samples of *Q. durata* throughout the state to examine how genetically diverse local populations are compared to statewide populations. He also is using a *Q. durata* sample from the Clear Creek Management Area to sequence the entire *Q. durata* genome, an effort that will serve as a valuable reference for future genetic work. There are two *Q. durata* in the Garden, a very large one right next to the Antioch dunes area and a good-sized one near the western bulb bed.

Many interesting serpentine endemics have disjunct populations, where a grouping of a species is located in a separate geographic region than its main population. One example in the San Francisco Bay area is Tiburon paintbrush (*Castilleja affinis* subsp. *neglecta*). The main population of this hemiparasitic perennial is located on the Tiburon Peninsula, where you can view it at the Ring Mountain and Old St. Hilary's preserves (see Glenn Keator's article about the special plants found on the Tiburon Peninsula on page 14). Surprisingly, a population of this plant is also found on Coyote Ridge, southeast of San Jose.

Another example of a geographically separated serpentine endemic is the state- and federally-listed endangered species, Presidio clarkia (*Clarkia franciscana*). This graceful, pink-flowering member of the primrose family (Onagraceae) lives only in the East Bay Regional Park District's Skyline Serpentine Prairie in the Oakland Hills and in a serpentine prairie in the Presidio in San Francisco. Echoing the management strategy on Coyote Ridge, EBRPD manages the Oakland population using carefully timed mowing to reduce non-native grasses, including annual barley (*Hordeum murinum*) and Italian ryegrass (*Festuca perennis*). How did the plants in populations of *Castilleja affinis* subsp. *neglecta* and *Clarkia franciscana* come to exist so far apart, and further, become limited to only these relatively small serpentine habitats?

Seeps, creeks, and bogs in serpentine areas promise fun botanical finds, such as the serpentine columbine (*Aquilegia eximia*) found in grottos in The Cedars. While not a strict serpentine endemic, the carnivorous California pitcher plant (*Darlingtonia californica*) is often found in areas where cold, fresh water flows over serpentine soil and rock. This bog habitat is acidic and deficient in plant-available nitrogen, so the plant obtains its nitrogen from the insects that get trapped in its oversized, hooded leaves. The Garden currently grows *D. californica* in a pot near the upper part of the serpentine bed and in a rock-garden seep near the new crevice garden.

Mt. Hamilton thistle (*Cirsium fontinale* var. *campylon*) is another serpentine endemic that likes keeping its feet wet. Found in seeps and draws in serpentine grasslands mostly in Santa Clara County in the northeastern foothills of the Santa Cruz Mountains, this perennial thistle is several feet tall and quite grand upon close inspection. It is deeply lobed with distinctive wavy leaves, and the tips of the spiky phyllaries on its perpetually nodding flower heads are often tinted a deep maroon that nicely emphasizes its white-to-pink-colored pappus.

The Garden grows many other serpentine endemics, from bulbs to shrubs to grasses. In the Garden's western bulb bed is San Luis Obispo mariposa lily (*Calochortus obispoensis*), a bright and showy mariposa lily that is found only on serpentine areas around San Luis Obispo. It has marigold-yellow petals with maroon-red tips and long, scraggly, saffron-like trichomes covering each pointed petal. The flower resembles a cat's ear, much like other hairy mariposa lilies such as the

Serpentine reed grass (*Calamagrostis ophiditis*) lives on serpentine soils in Northern California.

Tiburon mariposa lily (*Calochortus tiburonensis*), pussy ears (*C. tolmiei*), and cat's ear (*C. elegans*) in Northern California.

Calamagrostis ophiditis is an attractive grass growing in the upper part of the Garden's serpentine bed and is one of the few serpentine endemics in the grass family (Poaceae). The species growing in the Garden was collected from Carson Ridge in Marin County and can also be found on the Tiburon Peninsula, on and around Mt. Tamalpais, and in Sonoma, Mendocino, and Napa counties. The grass-like serpentine sedge (*Carex serpenticola*) is a nice, tiny sedge found in Del Norte County and southwest Oregon and is growing at the edge of the bog in the Garden's serpentine bed.

Bart O'Brien

Siskiyou Mountains willow herb (*Epilobium rigidum*) in the Garden's serpentine bed.

Oregon bleeding heart (*Dicentra formosa* subsp. *oregana*) grows in the Garden's serpentine bed and is distinguished by its creamy-yellow flowers with rose tips.

After many trials and tribulations, the Garden is successfully growing two specimens of the Siskiyou Mountains willow herb (*Epilobium rigidum*), which thrives in serpentine rock outcrops and is also found in Del Norte County and southwest Oregon. This uncommon plant has pink, showy flowers characteristic of the primrose family (Onagraceae) that are especially striking against its bluish-green leaves. Back in October 2016, the previous Garden Supervisor, Joe Dahl, and longtime Garden instructor Glenn Keator collected cuttings and seed of this beauty near the town of Gasquet; and according to Kiamara Ludwig, former Garden Student Interpretive Aide and expert propagator, the two plants growing in the Garden's serpentine bed took much cajoling—including using various seed treatments, lighting changes, plant growth hormones, and more—to get them to their present healthy and flowery state.

Oregon bleeding heart (*Dicentra formosa* subsp. *oregana*) is thriving in the lower part of the Garden's serpentine bed and will stop you in your tracks. This plant is from rocky serpentine slopes on Ship Mountain in Del Norte County and is a noted variety of *Dicentra formosa* with its unique bluish leaves; hanging, heart-shaped flowers; and petals that range from cream to pale yellow with distinctive rosy tips. Notoriously difficult to grow, this plant was planted directly into the serpentine bed, and our Regional Parks Botanic Garden is the only garden in California to successfully grow it.

Serpentine soils are obviously important in California's cultural and biological heritage. Besides being California's state rock, serpentinite is the product of a wild transformation of primordial materials in Earth's deepest core into a unique and rare rock found worldwide. Fans of rocks say it's the rocks that are rare and the plants are just along for the ride. Plant fans might disagree. Regardless of who's right, we are privileged to be able to witness the unique natural history and extreme beauty of the rich flora thriving in these special serpentine habitats throughout our beautiful state of California.

Allison Kidder became a Garden docent in 2017 and serves on the Manzanita *editorial committee. She is fond of California natural history and obtained a PhD from UC Berkeley researching the ecophysiology of California's coastal scrub and grassland ecosystems.*

Photos by the author except as noted.

Walker Ridge: The Fight to Preserve What is Precious *by Nick Jensen*

Editor's Note: When Steve Edwards, former Garden Director, edited The Four Seasons*, he devoted the entire 2011 issue to "Glorious Walker Ridge," describing the beauty and botanical significance of the area and the case against a proposed wind-energy development. Here, ten years later, CNPS Conservation Program Director Nick Jensen revisits the topic and provides an update on the status of this unique treasure of botanical richness.*

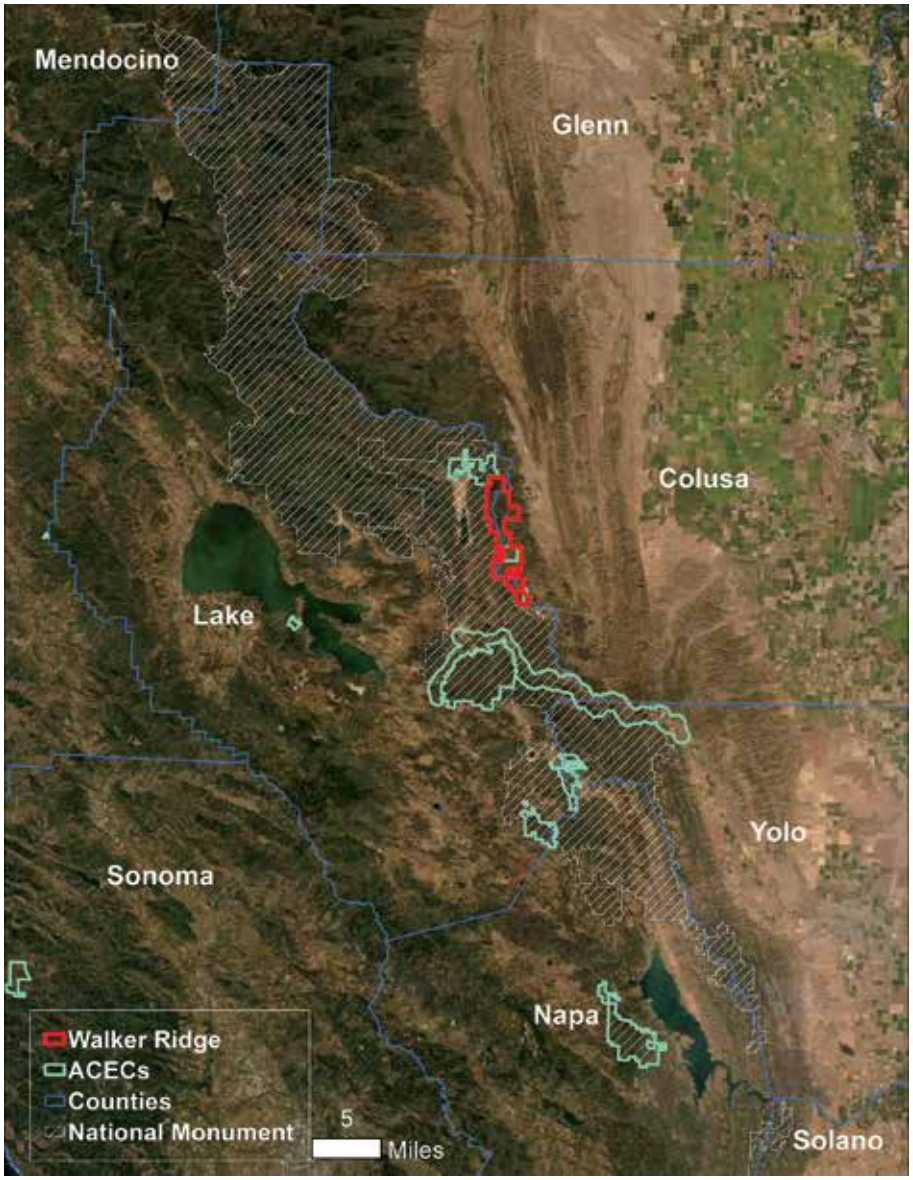
(See also Breaking News on the back page.)

Walker Ridge is a portal into the rugged habitats of California's Coast Ranges 90 miles north of San Francisco and 10 miles east of Clearlake. Immediately adjacent to Bear Valley, the area is a mecca of botanical richness within the global biodiversity hotspot that is the California Floristic Province. Shaped by wildfire, geologic history, human activity, and ecological processes, Walker Ridge should be a top priority for careful management and loving preservation. Yet even after decades of dedicated conservation battles the ridge remains imminently threatened. In this article, I focus on what makes Walker Ridge special, report on the continued threat of industrial-scale renewable energy development, and conclude with optimism about how future actions may ensure its long-term conservation.

A place like no other

Walker Ridge is located on the border between Lake and Colusa Counties, just north of Highway 20. It abuts the recently created Berryessa Snow Mountain National Monument (BSMNM) and is eminently worthy of inclusion in this specially managed area. The ridge is managed by the Bureau of Land Management and boasts easy recreation access via Walker Ridge Road to practically anyone. Whereas many adjacent areas require either four-wheel-drive vehicles or hiking on rugged trails, Walker Ridge is accessible to all.

The ridge looms over Bear Valley, where many people, in years with ample precipitation, flock to experience wildflower displays that rival those of North Table Mountain or the Carrizo Plain. The area's vast fields of California poppies (*Eschscholzia californica*), lupine (*Lupinus* spp.), and adobe lily (*Fritillaria pluriflora*) are cherished by thousands of visitors. Walker Ridge rises for more than 2000 ft, offering views of the surrounding landscape and region that are beyond compare. Along with this gain in elevation, countless drainages, ridges, and topographical features influence habitat diversity; this results in the area hosting more than 450 plant taxa (species, subspecies, and varieties).



Map showing the location of Walker Ridge in red outline. The area in white with diagonal lines is Berryessa Snow Mountain National Monument. Existing Areas of Critical Environmental Concern (ACECs) appear in teal. County names are in white.

Map sources: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

Aspiring botanists quickly learn the importance of geologic substrates in promoting plant diversity, and these substrates play a vital role on Walker Ridge. The southern portion of the ridge is primarily influenced by sedimentary geology.

Broadly speaking, these substrates host the more common oak-woodland and chaparral (shrub-dominated) habitats. To the north, Walker Ridge's habitats are influenced by serpentinite, California's state rock. When serpentinite and associated rock types weather, they produce soil with chemical and physical properties that present a challenge for many plant species. These substrates are often high in elements like magnesium and certain heavy metals that negatively affect some species, while they are low in elements like calcium and nitrogen that are essential for plant growth. They are also home to special species, some of which have developed a diverse suite of strategies to tolerate these challenging conditions. Some of the plants that call serpentine habitats home are considered endemic and are rarely found off of these substrates. It is this suite of plants that sets Walker Ridge, and other areas with extensive serpentine habitat, apart. To date, more than 30 plants included in the California Native Plant Society's Inventory of Rare, Threatened, or Endangered Plants have been documented from Walker Ridge. This magnitude of rare plant diversity can be found in few (if any) other places in California.

In the variety of habitats offered by Walker Ridge, you will find rare plants like Hall's harmonia (*Harmonia hallii*) and Jepson's navarretia (*Navarretia jepsonii*), as well as many more common species. The ridge is home to one of the world's most extensive stands of McNab Cypress (*Hesperocyparis macnabiana*). The cypress is flanked by myriad versions of chaparral, some dominated by chamise (*Adenostoma fasciculatum*) and others by manzanita (*Arctostaphylos* spp.) or wild lilac (*Ceanothus* spp.). The area's serpentine habitats range from barrens with little vegetation save for hardy, rare, serpentine endemics like Snow Mountain buckwheat (*Eriogonum nervulosum*) to meadows boasting kaleidoscopes of colorful wildflowers. This level of habitat heterogeneity is a primary driver of Walker Ridge's botanical diversity.

A final factor that surely contributes to Walker Ridge's diversity is simply its location in California. The North Coast Ranges are known for their botanical diversity, and the ridge happens to be in an opportune location where species from other ecological regions likely converge. This is evident when you travel to Walker Ridge. Its proximity to the Sacramento Valley, coastal areas, higher elevations of the North Coast Range, and the San Francisco Bay Region surely contributes to the unique character of this botanical melting pot.

A beautiful display of wildflowers following a wildfire.

Glen Holstein

A botanical hotspot under threat

Conservationists have been known to fight hard to save places with one or just a few rare plant species. With more than 30 rare species and such high habitat and botanical diversity at stake it is hard to believe that organizations like CNPS have had to fight a nearly continuous, two-decade battle to save Walker Ridge. A place like this should be treasured; and it should be deemed off limits to industrial development, much like our national parks are. We should think of Walker Ridge as the Yosemite of rare plants! Meanwhile, there is a special poignancy to the fact that the development proposals we have been fighting against are aimed to provide something we as a society truly need, renewable energy. Walker Ridge has been the site of no fewer than five proposed commercial-scale wind development projects dating back to the early 2000s.

The latest of such developers, Colusa Wind LLC, a subsidiary of the Canadian company Algonquin, proposes to install 40 wind turbines, each 400 ft tall, over nearly 8,000 acres of habitat. The road leading up the ridge would be bulldozed to as much as 50 feet wide to accommodate construction activities, fences would be erected, and more than 2,000 acres of habitat would be destroyed. Indirect impacts would be far more extensive. Rare plant populations would be eliminated, and birds and bats would be killed by the spinning blades of the turbines. This type of development is not consistent with the conservation of rare species, nor with recreational use or ensuring that wildlife have intact habitat and corridors for migration. This is why CNPS and many other organizations and

Serpentine habitat and Western wallflower (*Erysimum capitatum*). Photo courtesy of Tuleyome.

individuals advocate that renewable energy be sited where impacts to sensitive habitat and species can be avoided. Our society needs to curb its reliance on fossil fuels to solve the problem of climate change, but it seems irresponsible to try to solve that problem by exacerbating another problem, the loss of biodiversity. Perhaps the most frustrating piece of the equation is that Walker Ridge does not possess wind resources of the quality typical of other sites developed for commercial wind energy. It seems criminal to want to squander what is truly rare, unique, and special for a mediocre source of renewable energy. We should focus first on developing wind and solar energy in places where environmental impacts are negligible, like rooftops, parking lots, abandoned agricultural fields, and disturbed lands.

Solutions and optimism

Responding to the persistent threat of development, CNPS petitioned BLM in 2005 and 2011 to designate Walker Ridge as an Area of Critical Environmental

A wonderful display of wildflowers including red ribbons (*Clarkia concinna*), Ithuriel's spear (*Triteleia laxa*), and woolly sunflower (*Eriophyllum lanatum*). Photo courtesy of Tuleyome.

Concern (ACEC) with the possibility of future development removed. To date, BLM has not responded to CNPS's proposals. During the same time frame, BLM has reviewed multiple proposals to develop wind energy on Walker Ridge. Thankfully, each of these proposals has failed. The establishment of Berryessa Snow Mountain National Monument (BSMNM) in 2015 opened the door for a different future for Walker Ridge. In that bright future we can envision Walker Ridge as both an ACEC and part of BSMNM. Until then, we have drawn a line in the serpentine and will continue the fight to preserve what truly is special and rare.

Nick Jensen is Conservation Program Director at the California Native Plant Society (CNPS). He earned his BS degree in Environmental Horticulture at UC Davis and recently completed his PhD in botany at Rancho Santa Ana Botanic Garden/Claremont Graduate University. As a graduate student Nick produced the first Flora of Tejon Ranch and studied evolutionary patterns in perennial Streptanthus *(jewelflowers).*

Steve Edwards

One of Walker Ridge's many rare plants, Snow Mountain buckwheat (*Eriogonum nervulosum*).

Two Wildflower Hotspots on the Tiburon Peninsula *by Glenn Keator*

View from Ring Mountain.

Despite being heavily populated, the Tiburon Peninsula in Marin County offers pockets of fascinating habitat, particularly on its serpentine outcrops. One interesting area surrounds the historical Old St. Hilary's Church, which sits on a hill overlooking Tiburon. This area consists mostly of native bunch grassland featuring purple needle grass (*Stipa pulchra*) and squirreltail grass (*Elymus elymoides*). At the base of the church's stone steps there's a year-round seep worth looking at in late spring to early summer.

But first the grassland. There, two plants particularly stand out. One is the rare, endemic, Tiburon jewel-flower (*Streptanthus niger*), currently considered a variety of *S. glandulosa*. This tiny, inches-high annual takes sharp eyes to find and features a few crimped flowers with sepals so dark they appear black, though they are actually dark purple. Try looking for it on the main trail through St. Hilary's, north of the chapel, or on the Heathcliff Fire Road near the end of Heathcliff Drive at the north edge of the preserve. Then there's the yellow mariposa tulip (*Calochortus luteus*), blooming around the same time—late

spring—with its cheerful, bright-yellow, tulip-shaped flowers stenciled inside with dark brown spots or thin lines. What's especially interesting is that while this is a common species both on and off serpentine, at the west end of the peninsula it's entirely missing.

Where the seep emerges from a spring, there are large patches of Bolander's sneezeweed (*Helenium bolanderi*), a wet grower uncommon in the Bay Area. With it, varying in numbers from year to year, is the lovely leopard lily (*Lilium pardalinum*), unusual here for growing in nearly full sun. And to top it off, you may find a good stand of long-rayed brodiaea (*Triteleia peduncularis*), noted for the very long stalks of its flowers arranged in open umbels. The flowers are trumpet-shaped, white flecked with purple outside, and with a bright yellow ovary inside.

Which brings us to Ring Mountain on the western end of the peninsula. Although some housing developments have climbed part way up the mountain, most of it is open preserve. A loop trail to the top takes you through a combination of non-serpentine and serpentine soils. Many of the common wildflowers bloom in April or even earlier, but the best time to visit for the more unusual flora is late May to early June.

A couple of vernal streams spill down the mountain, providing a home for California wax-myrtle (*Morella californica*), the rather uncommon long-rayed brodiaea mentioned above, the fountain variety of death camas (*Toxicoscordion fontanum*), and yellow monkeyflower (*Erythranthe guttata*). There are also thick groves of wind-pruned bays and stalwart coast live oaks with an understory of common wood fern (*Dryopteris arguta*) and sword fern (*Polystichum munitum*). The rolling grasslands feature a wide variety of common spring flowers, but also the less-common Oakland star-tulip (*Calochortus umbellatus*) and Ithuriel's spear (*Triteleia laxa*). The serpentine areas support the tiny delicate and rare Marin western flax (*Hesperolinon congestum*), along with the common sandwort (*Minuartia douglasii*) and, on areas with less vegetation, the low-growing pitted onion (*Allium lacunosum*) with tight umbels of white flowers. Temporarily wet areas are also noteworthy for the native foxtail grass, meadow barley (*Hordeum brachyantherum*).

But of all the flowers sought, the most unique is the Tiburon mariposa lily, *Calochortus tiburonensis*, found in only a few areas of serpentine outcrops close to the top of the mountain and, it seems, nowhere else in the world! It was not discovered until late in the twentieth century, partly because it blooms late and partly because its dull colors don't stand out. Each shallowly bowl-shaped flower is pale green, but intricately flecked with dark maroon splotches and lines and dense with shaggy hairs. No other species in our area looks anything like it, and it seems its closest relatives are in drylands of Southern California! Look for it in the rocky, serpentine area several hundred yards before the end of the Phyllis Ellman trail in the Ring Mountain Preserve.

Tiburon jewel-flower (*Streptanthus niger*).

Tiburon mariposa lily (*Calochortus tiburonensis*).

Glenn Keator is a popular instructor of botany and a field-trip leader in the Bay Area. He teaches the docent training course at the Regional Parks Botanic Garden and is the author of several books on California native plants.

Photos by the author.

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BREAKING NEWS! As we were going to press, Congressman John Garamendi (D-CA 3rd District) released draft legislation to add the Lake County portion of Walker Ridge to the Berryessa Snow Mountain National Monument! Please visit the CNPS website (CNPS/NEWS&STORIES) for more details. CNPS encourages all concerned to contact Congressman Garamendi and thank him for taking this important step towards long-term conservation of Walker Ridge.

THE BOTANIC GARDEN IS FULLY OPEN TO THE PUBLIC!

The Garden is now open seven days a week for its summer hours, 8:30 AM to 5:30 PM.

Both Anza View and Wildcat Canyon Gates are open.

The Garden's FREE e-newsletter, newly named ***The Botanic Garden Monthly***, is a terrific source of information about the Garden—its plants, features, and natural history—and about Friends classes and events. Please consider subscribing!
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