Field Trip to the Ancient Shorelines and the Calavera Hills Volcano

This field trip is to explore the remnant of an ancient volcano located in the Calavera Hills Nature Preserve in Carlsbad, California.

The nature preserve encompasses 256 acres of upland coastal sage scrub habitats. Rabbits, coyotes, raccoons, fence lizards, horned lizards, barn owls, road runners, hawks, tree frogs, garter snakes, rattlesnakes, and other wildlife inhabit the preserve. Lake Calaveras is a small man-made reservoir that is host to egrets, herons, ducks, coots, and other waterfowl.

To get there: Park on Tamarack Avenue or Strata Drive near the trailhead that leads to the dam. The drive to the parking area along Tamarack Avenue is approximately 2.1 miles (10-15 minutes drive) from MiraCosta's Oceanside campus. Follow College Avenue south and turn left on Taramack Ave. The maps below shows the location where to park (figs. 1-4).

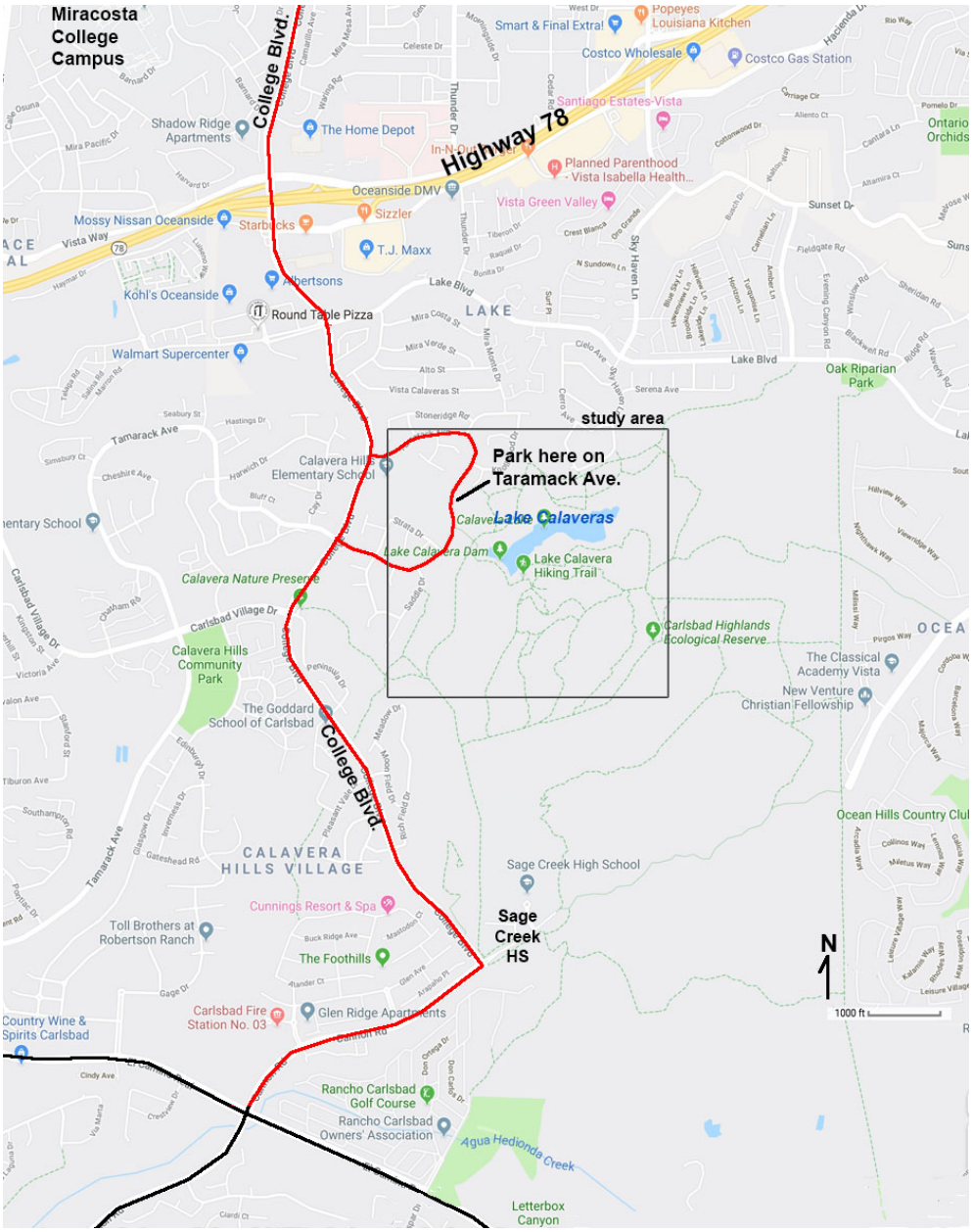


Figure 1. Map of the region around the field-trip study area showing directions to the Calavera Hills Trailhead.

Map modified from maps.google.com, 2019

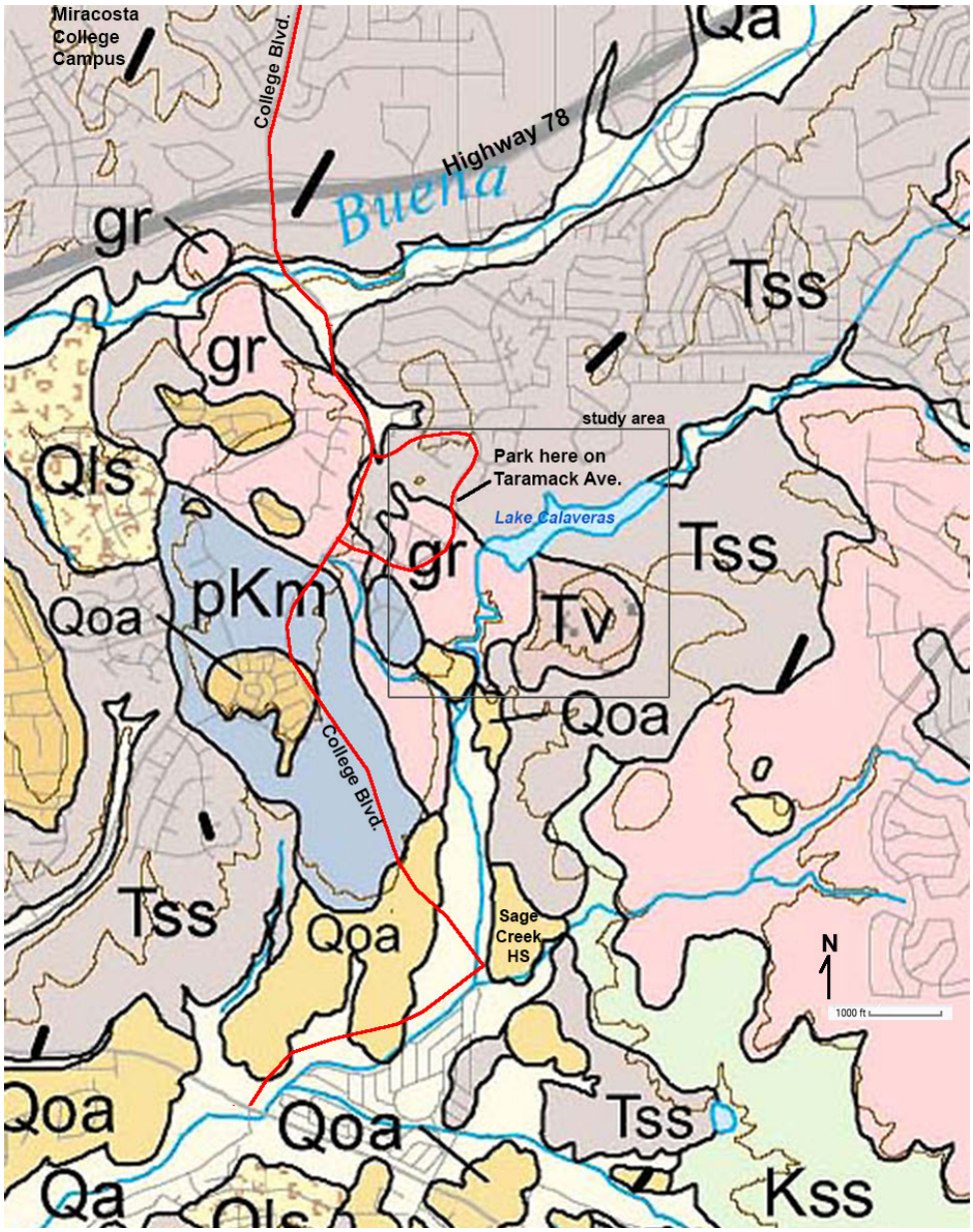


Figure 2. **Geologic map of the region around the Lake Calavera Hills volcano and Lake Calavera.**

Symbols for the geologic map

Qa - **young alluvial stream deposits**
Qoa - **older Quaternary alluvial deposits** preserved on upland surfaces along valleys
Qls - **landslide deposits** (active and/or older Quaternary landslide deposits)
Tv - **Tertiary volcanic rocks** — Calavera Hills volcano, volcanic stock (plug) and cone deposits.
Tss - **Tertiary sedimentary deposits** (sandstone and other fine-grained sedimentary rocks)
Kss - **Cretaceous sedimentary rocks** (sandstone, shale) that has yielded a variety of fossils.
gr - **granitic rocks** (mostly tonalite, a variety of felsic, quartz-rich plutonic rock, formed within the Peninsular Range volcanic arc during the Cretaceous Period, about 80-100 million years ago.)
pKm - **pre-Cretaceous metamorphic rocks**, mostly oceanic sedimentary and igneous rock formed in an oceanic setting prior to the formation of the Peninsular Range volcanic arc.

Map modified from: ***Geologic map of the Oceanside 30'x 60' Quadrangle, California.***" California Geological Survey, Regional Geologic Map No. 2, 1:100,000 scale.

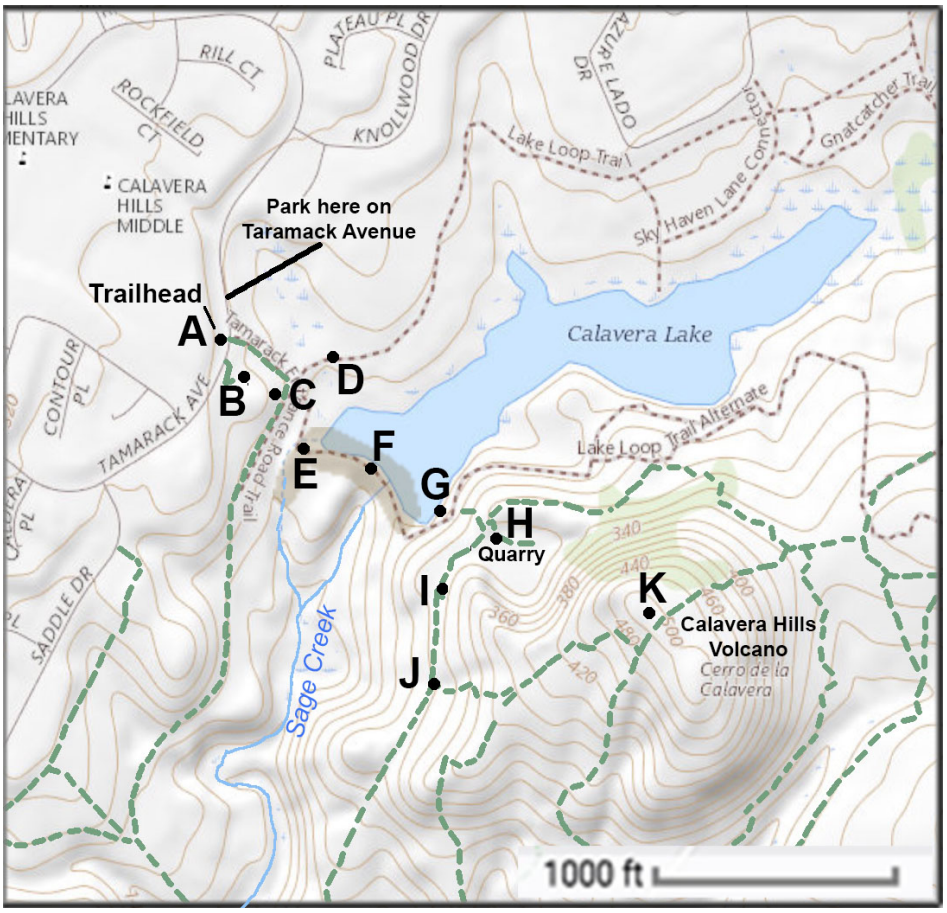


Figure 3. Map showing details and locations of the field-trip stops on the trail map and geologic map.

The trailhead is on Taramack Avenue. Dashed lines are hiking trails. Field trip stops are labeled dots A to K.

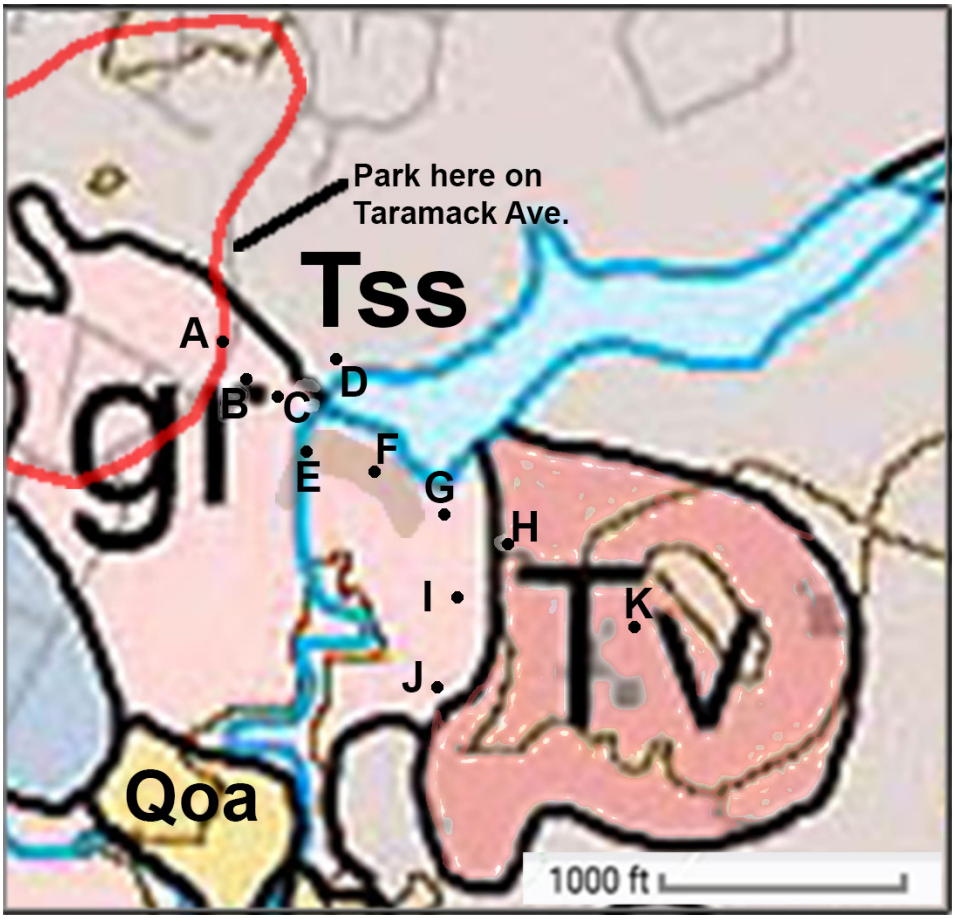


Figure 4. Geologic map detail showing location of field-trip stops. The colors represent the surface area expression of different rock units (described below under **Local Geology**).

Qoa = older Quaternary alluvial deposits (elevated stream terrace deposit).

Tss = Santiago Formation (Eocene) sedimentary rocks.

Tv = Volcanic Rocks (Miocene), Calavera Hills volcano.

gr = granitic rock (Cretaceous, tonalite)

Stop A. Meet at the **Calavera Hills Trailhead** on Taramack Avenue. Important things to discuss:

* Be prepared to walk about a mile to stop locations; climbing to the hilltop (stop K) is optional.
* Some of the trail is paved, some is unpaved, other parts are steep and rocky in short stretches.
* Sturdy shoes, water, and sunscreen are recommended. Stay on the designated trails.
* This park is part of a nature preserve. Therefore, please don't disturb or collect plants or animals.
* Rattlesnakes are rare, but may be encountered along trails. Do not go near or provoke them.
* Poison oak occurs in some locations — don't touch! "*Leaves of three, let it be!"*
* Do not leave anything of value in your vehicle (or put them out-of-sight).
* Mountain bikers use these trails, be courteous and assume they don't see you, let them pass.
* Dogs are discouraged on this field trip, pets must be on a short 6' leash.
* Take all trash out with you and deposit in recycle/trash bins. Absolutely no smoking or vaping.

Local Geology

On this field trip we will be observing 4 kinds of geologic materials that have different origins, from oldest to youngest as follows:

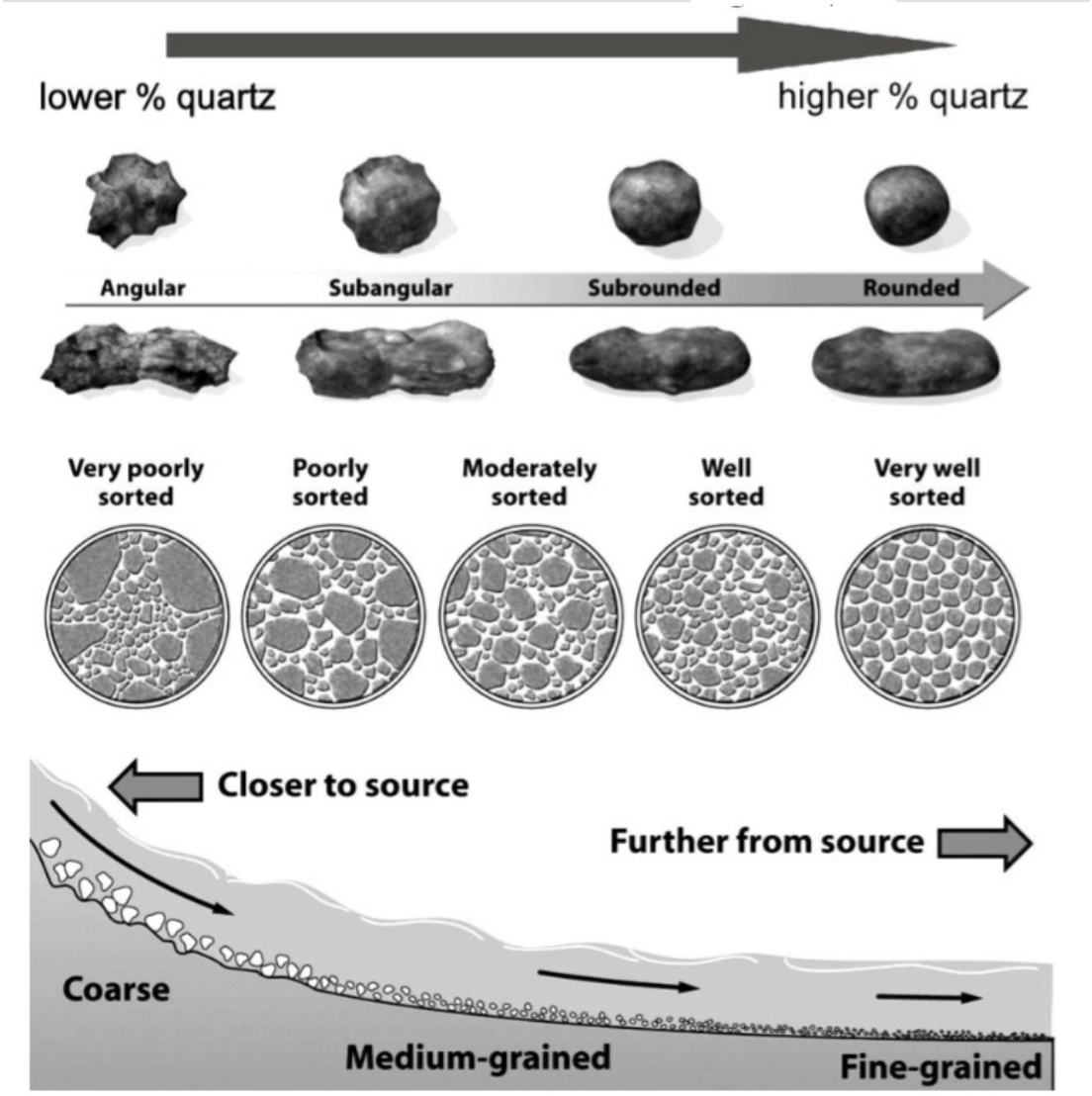
1) The **Green Valley Tonalite** is a crystalline, intrusive igneous rock (similar to **granite** in appearance and texture). Up close, you can see the medium to coarse-grained mineral crystals of **felspar** (white), **quartz** (clear to gray), **biotite** (black), and other dark mineral grains (**magnetite** and other ***mafic*** silicate minerals). The Green Valley Tonalite is a common bedrock exposed throughout the Peninsular Ranges in the San Diego County region. The tonalite is an intrusive igneous rock unit that was cooled slowly at depth, and was subsequently uplifted, and exposed by erosion. It is shown with the symbol **gr** on the local geologic map (**Figures 2 & 4**). The tonalite is associated with an ancient volcanic arc complex that existed along the western margin of the North America continent that was actively forming in this region during the Late **Cretaceous Period**, roughly 100 to 80 million years ago.

2) The **Santiago Formation** is a sedimentary rock formation of Eocene age, deposited about 40-45 million years ago. Locally, the rock formation locally crops out in the hillside in northern San Diego County. It is also called the Scripps Formation in some literature. The age of Santiago Formation is based on fossils and other data. The exact age of the Santiago Formation in this location is unclear, but by its physical characteristics it is considered equivalent in age to the Del Mar Formation and Torrey Pines Sandstone Formations exposed in the sea cliffs along the coast between Carlsbad and a Jolla, California. Locally the rock consists of a fine-to-coarse-grained sandstone, white-to-pale gray colored, and is a moderately to well-sorted arkosic sandstone (rich in feldspar grains). Fossils removed from locations nearby suggest that the formation was deposited in coastal settings: beach, nearshore, and lagoon or bay settings. The Santiago Formation is shown at **Tss** on the geologic maps (**Figures 2 and 4**).

3) **Volcanic rocks, undivided:** locally these consist of light-to-dark gray, black, to brownish colors. These are the rocks exposed in and around the Calavera Hills volcano (see Tv on the geologic maps; Figures 2 and 4). The volcanic rock locally is of **dacite** composition. Dacite is a fine-grained extrusive igneous rock intermediate in composition between **andesite** and **rhyolite** (**felsic** igneous rocks). The mineral grains in the rock are too small to see with the naked eye. Rare inclusions of the tonalite occur in the volcanic rock.

4) In addition, there are **unconsolidated sediments** exposed on the surface.. These deposits are weathering products derived the the breakdown of the bedrock in the area (**regolith** and **soil**). Some sediments were transported into the area along ancient streams and deposited locally (as alluvium). These deposits locally contain stream-rounded cobbles derived from distant sources.

Figure 5. How erosional processes influence the size, shape, and sorting of sediments.



As sediments are transported along streams, rolling and bouncing for miles along river bed as its moves down slope form sources in the mountains to the coast. Abrasion smooths the sharp edges of mineral grains or rock fragments. Stream current flow sort sediments into separate size fractions. Coarser sediments occur closer to source areas. Sorted sand and finer sediments have traveled longer distances along streams and by wave action along coastlines.

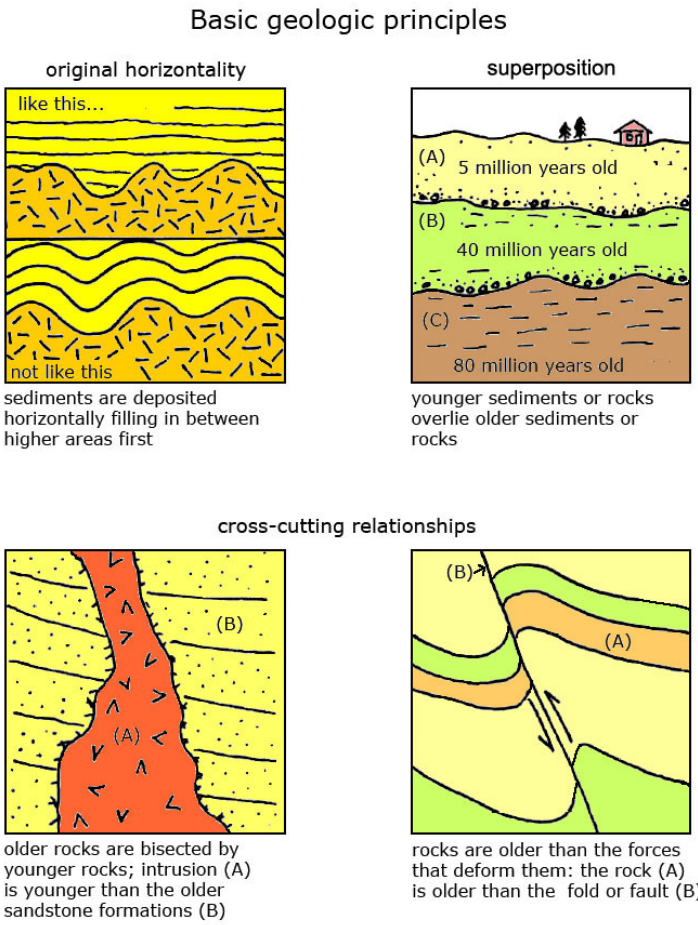


Figure 6. **Basic geologic principles** used for **relative dating**.

The **Law of Original Horizontality** basically shows that sediments are usually deposited horizontally, filling in low areas first.

The **Law of Superposition** shows that in a location where sediments or lava flows have formed and remain undisturbed, the oldest layers are on the bottom, the youngest layers are on top.

The **Law of Cross-Cutting Relationships** dictates that layers of rock are older than the forces that change them. For instance, a volcanic intrusion is younger than the rocks they cut through. Also, a fault or structural changes are younger than the rocks they cut through.

All three geologic principles can be observed in the Calavera Hills area.

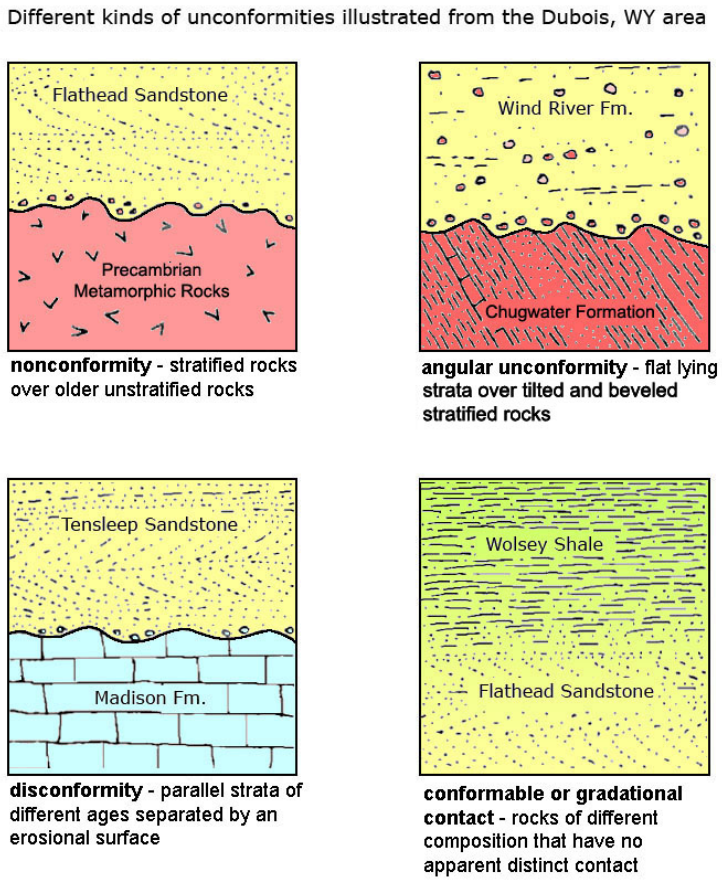


Figure 7. Different kinds of unconformities used for **relative dating**.

An **unconformity** is simply an ancient surface preserved in a succession of rocks, and may represent a "gap in time" when sediments or volcanic rocks were not deposited. Three types of unconformities can be seen in the Calavera Hills area.

A **non-conformity** exists between the Green Mountain Tonalite and overlying Santiago Formation.

Both an **angular unconformity** and a **disconformity** can be observed along the boundary between the Santiago Formation and the overlying volcanic deposits. They are likely the same **unconformable** surface, but taking different forms at different locations.

Stop B. Follow an unpaved side trail to overlook on the west side of the trailhead. Walk down the dirt path to a series of angular-shaped boulders of granitic rock near the steep drop off into the valley near the power lines. **Figure 7** shows a panoramic photo taken from the Stop B overlook that shows many of the locations and features to discuss on this field trip. Compare this photo to the maps (Figures 1-4).

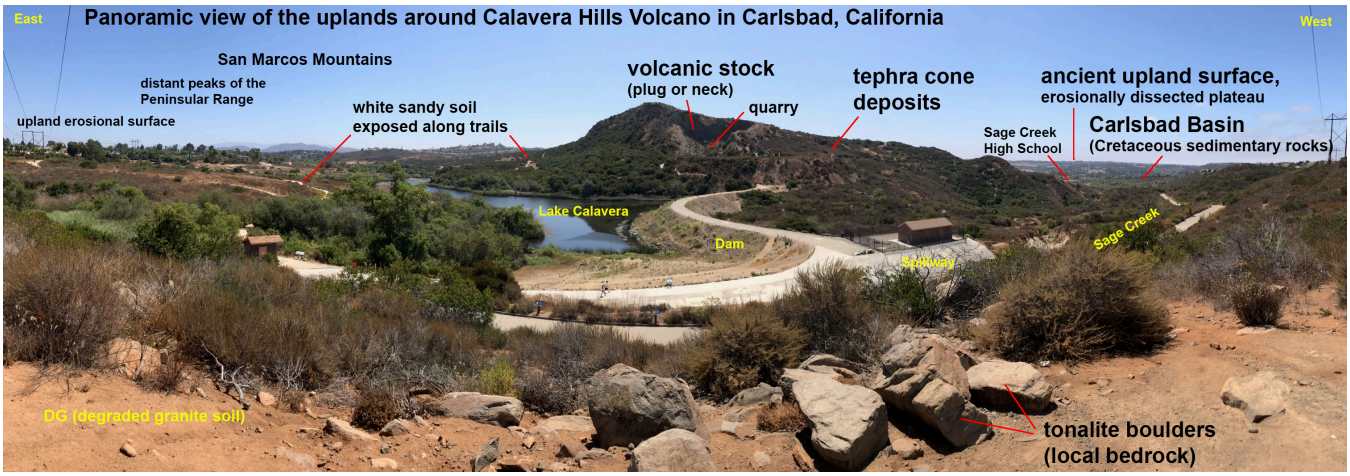


Figure 7. This photo is an east-to-west panoramic view (looking south) across the Calavera Lake Dam and **Calaveras Peak,** the highest point in Carlsbad, elevation **513 feet**. In contrast, the elevation of the top of Lake Calavera Dam is about 220 feet. The original name of the hill is **Cerro de la Calavera** (translated from Spanish, **Skull Hill**). How it got its name is unknown. The peak is also known as the **Calavera Hills volcano**, a remarkably small volcano compared with others in California.

From this location it is easy to see the volcano where is stands relative to a **regional upland surface**, a geographic feature called an **erosional dissected plateau**.

If you west look down the valley of Sage Creek from this location you can see a broader valley beyond Sage Creek High School (in the vicinity of the El Camino Real near Cannon Road). Sage Creek joins Agua Hedionda Creek which, in turn flows into Agua Hedionda Lagoon. When they excavated the foundation for homes and building in the area near the El Camino Real. Many rare and unusual fossil were recovered including shells of ammonites and teeth and bones of Ankylosaurs. According to the geologic map, what is the age and composition of the rock formation (hint: about 70 million years)?

Stop C. Follow the main trail down from the Trailhead to the intersection with the valley trail and turn right. Proceed to a sign describing the sun. This sign is the first of a series of signs describing the planets of the solar system spaced proportionally along the 1 mile trail from this location (the Sun) to Pluto - down the trail to Sage Creek High School. Across the trail from the Sun sign the local bedrock of **Green Mountain Tonalite** is partial exposed.

Granitic rocks break down when exposed to **weathering**, soft minerals dissolve or decay, but harder minerals like quartz and feldspars resist decay and become grains of sediment. Coarse-crystalline rocks like the local granite or tonalite becomes a coarse, sandy sediment called **grus**. If you go to a local business that sells rock, gravel, sand, and soil products, many of these places sell a product called **DG** (meaning ***degraded granite,*** *derived from grus*). (Note we can see grus (DG) forming in several location in and along the trails, such as in this area.) It is naturally forming here.

Stop D. Follow the Lake Loop Trail no the north side of Lake Calavera for several hundred feet until you reach a wooden fence area along the trail that give you a view of the lake and ***Cerro de la Calavera*** (the name for the hill on the south side of the lake). The hill is also known as the Calavera Hills volcano.

Figure 8. Close-up views of **grus** (DG) derived from the tonalite and sandy soil derived from of the Santiago Formation.

Figure 9. Outcrop exposure of dipping sedimentary layers of the Santiago formation on the west side of the Calavera Hills volcano.

Note the color and fine, sandy character of the soil on this outcrop.

Figure 10. Examples of **inclusions** preserved in the **tonalite**.

The inclusions are fragments of the older metamorphic rock (pre-Cretaceous age - pKm) that were incorporated into the magma body that cooled to form the tonalite.

Stop E. Lake Calaveras Dam (Spillway Overlook Area)

This stop is to simply look at the construction of the dam and the spillway. The dam was originally constructed in 1942 to be used as a source of drinking water for Carlsbad. After the city was incorporated, the city started getting its drinking water from the Colorado River, and this reservoir was largely forgotten by the late 1960s. Since then, massive regional development has taken place, and the lake and dam now serve other purposes (flood control and wildlife habitat). Some attempts were made to remove the dam, but this was later rejected for environmental reasons.

Stop F. Middle of the Dam

Note the large blocks of volcanic rock used in construction of the dam and along the trail on the dam.

From near the middle of the dam you can look down stream along the canyon of **Sage Creek.** Along the sides of the stream valley you can see **step-like benches** and small hilly features that are remnant of ancient **elevated stream terraces**. These ancient stream terraces locally preserve old **alluvial flood plain deposits** (show as **Qoa** on the geologic map; **Figure 2**). In many places around this region old river terraces are preserved on hillsides along many of the major river drainages. Many of these **Qoa** deposits preserve rounded stream cobbles that were carried into the valley from sources a

long way away (possibly even from Mexico before the formation of the San Andreas Fault system and Baja California separated from Mexico, creating the Gulf of California).

Stop G. Trail from the dam to the rock quarry on Calavera Peak.

Follow the trail to the left on the south side of the lake. Be careful as you walk, this is a rocky trail that wind uphill into the quarry. Along this trail pay special attention as to how the appearance and composition of the soil changes as you walk along the trail from the dam to the quarry (Stop H).

What soils can tell us about the geology history of an area?

Geoscientists look at soils for a variety of reasons. Soils can tell us much about the bedrock geology and climate history of an area. Also, in many areas there is little or no exposed bedrock to easily examine. The tree different kinds of bedrock described in Local Geology (above).

Based on what you observe in the soil, what rock formations probably exists in the bedrock along this lower and upper sections of trail between the dam the quarry (Stop H)?

Figure 11. View of the dacite rock quarry in the Calavera Hills volcano (showing locations of Stops H, I, and J. Stop K is located on the peak (of *Cerro de la Calavera*) above the quarry on the left.

Stop H. Volcanic Plug and Rock Quarry

At this stop you have arrived at the center of the **rock quarry** in the **Calavera Hills volcano**.

Around you can see the gray rock walls of rocks that has an abundance of vertical cracks resulting in **columnar jointing**. Columnar joints form in pools of cooling lava as the shrinks in volume at the lava solidifies. Stresses in a relatively homogeneous body of cooling lava result in a hexagonal or polygonal pattern of cracks (similar to cracks that form in drying mud puddles).

The volcano is an eroded remnant of an original volcanic cone. The actual age of the volcano is disputed, but estimates suggest that the **relative age** is late Tertiary Period (or Neogene Period). The USGS map gives it an age of the **Miocene Epoch** (between 23 and 5.3 million years). The absolute age of the Calaveras Hills volcano is somewhat disputed. The volcano probably formed in the time frame of other volcanic features in the region including the **Scripps Dike** (or **Dike Rock**) in La Jolla that has

been **absolute age** dated to being 13.89 million years (middle Miocene age) (source: Day and others, 2019). Volcanic rocks of middle Miocene age are known from seafloor sample collected San Diego Trough region offshore. Near Temecula, California (about 25 miles to the northeast), volcanic rock know as the **Santa Rosa Basalt** has been dated to an age of about 8.7 million years (Hawkings, 1970).

The **volcanic tephra cone** and **lava flows** rest **unconformably** on an ancient erosional surface that predates the volcano. This ancient surface is still visible as the **erosionally dissected plateau** that exists throughout the region in eastern San Diego County. It can be easily seen throughout the vicinity of the Calavera Hills volcano (see **Figure 7**). This surface probably correlates to the **Perris surface** that underlies the Santa Rosa volcanics that erupted about 8.3 million years ago (Woski and Howard, 1987).

Dacite volcanic plug crosscutting Santiago Formation at Stop H.

Along the trail on the west side of the quarry it is easy to see an uplifted block of the Eocene-age **Santiago Formation** in contact with the the border of the Miocene-age **dacite volcanic plug** of the volcano. There is a reddish-colored zone along the boundary where heat from the volcanic material partially baked (local contact metamorphism) the sedimentary rocks of the Santiago Formation. The steep orientation of the sedimentary layers exposed in the cut suggest that layers were forced up as the volcano formed. These deformed layers also suggest faulting may have occurred in the area before and/or during the formation of the volcano. It is likely the molten material that formed the volcano had migrated to the surface along fault or fracture zone that extended deep into the crust in this region.

Looking back north across the dam from this location, can you discern the possible location of a fault that may run across the valley (Hint: look at the locations of Stops A, B, and C.). Where might there be a fault (not that not all faults are active; there may actually be no fault in this location). What alternative explanation might explain the relationship of the tonalite and Santiago Formation on the opposite side of the valley?

Figure 12. Dacite (an extrusive igneous [volcanic] rock. These samples are from the nearby Morro Hills volcanic field near Falbrook, CA. These samples are nearly identical to the volcanic rock (dacite) exposed in the Calavera Hills volcano.

Stop I. Spheroidal-weathering features preserved in the tonalite.

Continue down the trail on the west side of the quarry. As you walk, notice the changes in the appearance of the soil along the trail. Along the way you may see exposures of the old bedrock that display usually ring-like circles in blocks of deeply weathered blocks of the tonalite. This is a result of **spheroidal weathering**. It is caused by the repeated process of wetting and drying as water soaks into fractures in the granite, gradually causing the granitic bedrock to break down (forming DG).

Figure 13. Spheroidal weathering an fracture in the tonalite exposed along the trail.

In this location note the relationship of some of the white fractures that cross the spheroidal weathering circular lines. Based on **basic geologic principles [Figure 6]**, which formed first?

How might you interpret the geologic history of this rock (relative to the formation of the volcano)?

Stop J. An abandoned mine.

Figure 14. An abandoned mine along the boundary between the tonalite (below) and a fine-grained lava flow (above). The picture on the left show the entrance of the mine below the base of the lava flow (picture from field guide by John Turbeville. The picture on the right was taken after the mine was seal off in 2018. The mine audit was was dug probably in the early 19th century by prospectors searching for precious mineral. It is unclear if they recovered anything significant.

Based on the Law of Superposition, what does this boundary tell us about the age-relationships between the lava flow and the tonalite? What might explain why there is no Santiago Formation exposed in this location?

Stop K. Top of the Calavera Hills Volcano

Stop K is onthe peak of **Cerro de la Calavera** (the historic name of the Calavera Hills volcano).

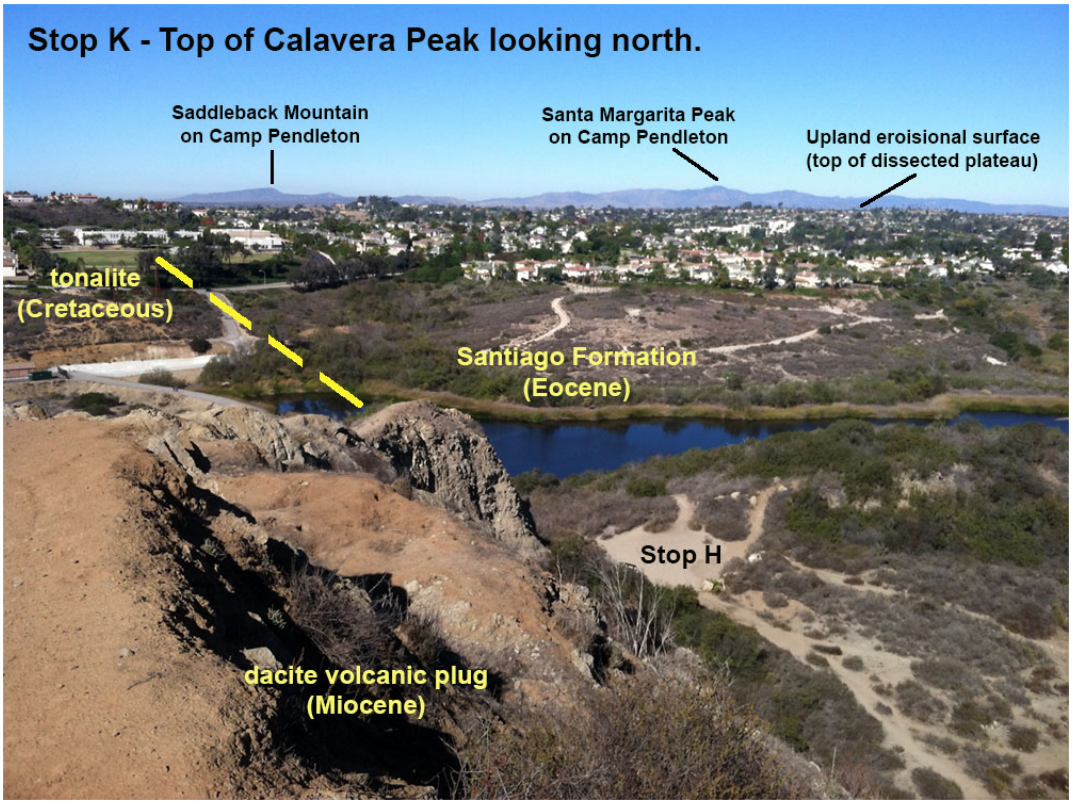


Figure 15. View looking north from the top of the Calavera Hills volcano. The upland surface of the erosionally-dissected plateau is clearly visible. The high peaks of mountains on Camp Pendleton are in the distance.

Other similar volcanic areas in western San Diego County.

San Diego County is host to a variety of volcanic rocks. The core of the Peninsular Ranges is made up of intrusive igneous crystalline rocks and volcanic rocks of Mesozoic age. These rocks include the tonalite expose in the Calavera Hills Preserve and the nearby San Marcos Mountains and the distant ridge of Mount Palomar. These rocks are much older and different than younger intrusive and volcanic rocks exposed in several locations around western San Diego County. Three well-known localities of Miocene age volcanic rocks include Dike Rock (on the beach about 1,500 feet north of the Scripps Pier in La Jolla, CA.

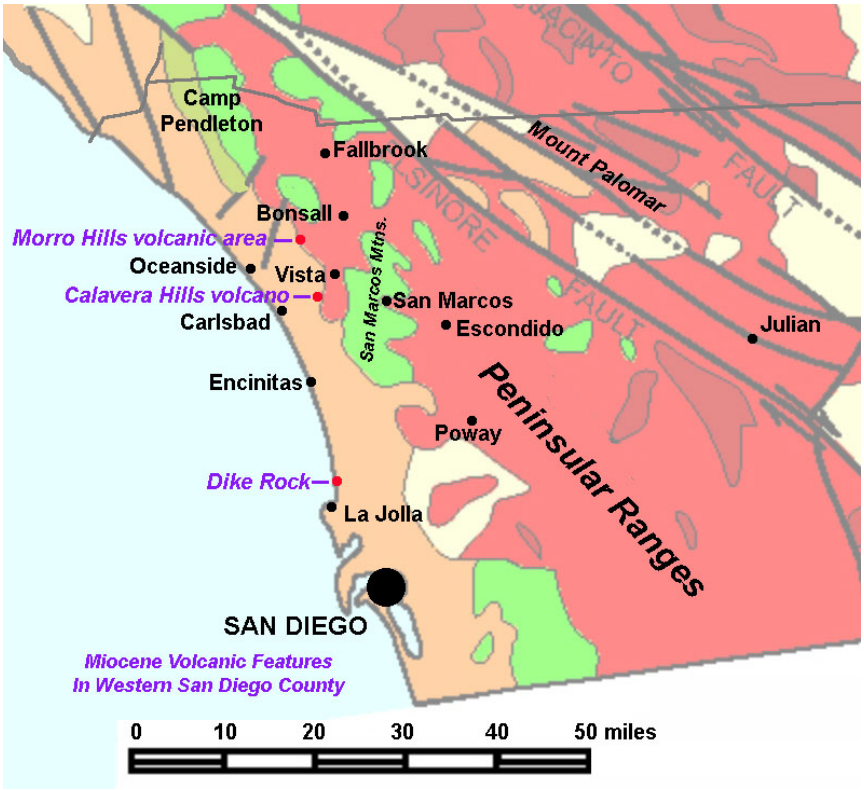


Figure 16. Map showing the location of three known volcanic areas of Middle-to-Late Miocene age in western San Diego County: Dike Rock, Calavera Hills volcano, and the Morro Hills volcanic area. Other smaller igneous bodies (dikes and sills) in the San Marcos Mountains region of similar composition, but undermined ages.

Figure 17. **Dike Rock** is a volcanic dike exposed by wave erosion along the beach about 1,500 feet north of the Scripps Pier in La Jolla. The dike strikes in a northeast direction. Rubble eroded from the dike creates one of the largest tide pool areas along the San Diego coastline.

The Morro Hills Volcanic Area

The Morro Hills are located about 9 miles north of the Calavera Hills volcano (Figure X). This area contains 7 separate igneous bodies (plugs and lava flow and tephra materials) that are composed of dacite, similar to the Calavera Hills volcanic rocks. The volcanic rock also rest unconformably on top of marine sandstone and siltstone bed of the Eocene Santiago Formation. The Santiago Formation rests unconformably on a surface of Cretaceous age crystalline intrusive igneous rocks (granodiorite, a rock similar to the Green Valley Tonalite in the Calavera Hills area.

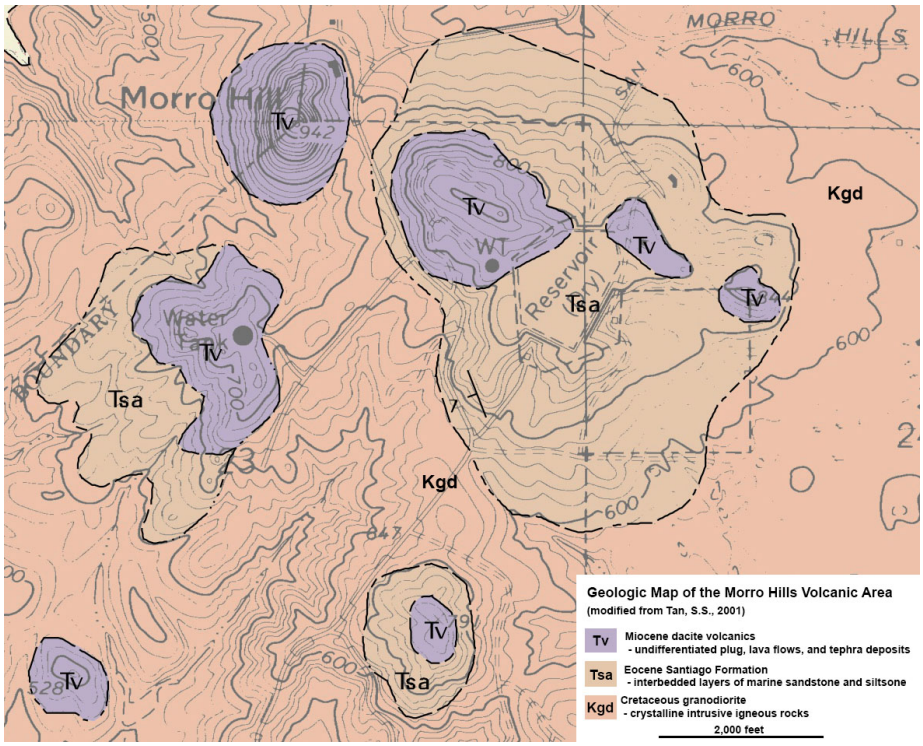


Figure 18. The geologic map of the Morro Hills volcanic area shows seven small volcanic plugs (necks or stocks). These intrusive bodies (**Tv**) cut through and rest unconformably on top of an eroded surface on Tertiary sandstone (**Tsa** - equivalent to the Santiago formation in the Calavera Hills volcano area). The Santiago Formation rests unconformably on Cretaceous-age granodiorite (similar in age to the tonalite in the Calavera Hills locality.

Figure 19. Morro Hill is one of the largest volcanic plugs in the Morro Hills volcanic area. The bedrock in the nearly symmetrically shaped dome consist of dacite (samples shown in Figure 12).

Special thanks to Dr. John Turbeville and Dr. Keith Meldahl (Miracosta College) for discussions and assistance in compiling information for this report.

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Calaveras Hills Volcano Field Trip Questions

Stop A. What are the two "biological risk" factors to be acutely aware of in this field trip area?

1) _____

2) _____

Stop B.

3) What is the composition of the **bedrock** in this location?

_____.

Describe characteristics of the unconsolidated sediment (soil or regolith) on the surface in this location. Circle the best choices:

4) What is the dominant composition of rock fragments in the soil? _____

5) Composition of sediment: _____ % Quartz
_____ % Feldspar
_____ % Biotite and mafic minerals
_____ % other (rock fragments or other unidentifiable material)

6) Dominant fragment shapes: ***Angular*** ***Subangular*** ***Subrounded*** ***Rounded***

7) Sorting: ***Very poorly sorted*** **|** ***Poorly sorted*** **|** ***Moderately sorted*** **|** ***Well Sorted*** **|** ***Very well sorted***

8) Based on what you can observe from this location, what is roughly the elevation of this **upland surface**? (Hint: look at the contour lines on Figure 3.)

_____ feet.

9) Based on what you observe here, what would say is older, the **volcano** or the original **upland surface**?

_____.

Stop C.

Locate a clear patch of **DG** on or along the trail. Describe its grain characteristics of composition, particle shape, particle size, and sorting of some local DG (look closely at a sample of mostly **coarse-grained sand**).

10) What is **DG**? _____

11) What is **DG** used for? What characteristics make DG so useful?

_____

_____

12) What is the dominant composition of bedrock and rock fragments in the soil in this location?

_____

13) Composition of sediment: _____ % Quartz
_____ % Feldspar
_____ % Biotite and mafic minerals
_____ % other (rock fragments or other unidentifiable material)

14) Dominant fragment shapes: ***Angular*** ***Subangular*** ***Subrounded*** ***Rounded***

15) Sorting: ***Very poorly sorted*** **|** ***Poorly sorted*** **|** ***Moderately sorted*** **|** ***Well Sorted*** **|** ***Very well sorted***

16) What would you say is the source of the sediments? Where did they come from?

_____

17) What gives DG its color? (Hint: think of a rusty car!)
_____

_____
(We will see a variety of **weathering features** along this field trip.)

Stop D.

How would you describe the sediment you see on the trail here? Locate a clean sample of the sand on the trail exposed along the trail. Describe its grain characteristics of composition, particle shape, and sorting.

18) Composition of sediment: _____ % Quartz
_____ % Feldspar
_____ % Biotite and mafic minerals
_____ % other (rock fragments or other unidentifiable material)

19) Dominant fragment shapes: ***Angular*** ***Subangular*** ***Subrounded*** ***Rounded***

20) Sorting: ***Very poorly sorted*** **|** ***Poorly sorted*** **|** ***Moderately sorted*** **|** ***Well Sorted*** **|** ***Very well sorted***

21) Where might you expect to finds similar sediments being deposited today? (circle one)

Beach or nearshore sand bar **River or stream deposit?** **Hillside slope deposit?**

22) What would you say is the source of the sediments? Where did they come from?

_____

Hint: which of the three geologic formations described in under **Local Geology.**

Stop E:

23) Can you think of any reasons why Calaveras Reservoir and dam is still maintained?

_____

_____

_____

Stop F:

24) What type of rocks were used to construct the dam. Where did it come from?

_____

_____

Stop G:

25) Based on what you observe in the soil, what rock formations probably exists in the bedrock along this lower section of trail to the Quarry?

_____

26) Based on what you observe in the soil, what rock formations probably exists in the bedrock along this upper section of trail to the Quarry?

_____

Stop H:

27) Look around the scenery of across the valley. Where might there be a fault? (Note: not all faults are active; there may actually be no observable fault in this location).

_____

_____

28) What alternative explanation might explain the relationship of the tonalite and Santiago Formation on the opposite side of the valley?

_____

_____

29) Name and describe the volcanic features you can observe exposed in the quarry.

_____

_____

Stop I:

30: How would you interpret the geologic history of this rock (relative to the formation of the volcano)?

_____

_____

_____

Stop J:

31. Based on the Law of Superposition, what does this boundary tell us about the age-relationships between the lava flow and the tonalite?

_____

_____

_____

32. What might explain why there is no Santiago Formation exposed in this location?

_____

_____

_____

Stop K: The hike to the top of the Calavera Hills volcano provides exceptional views of the regional landscape. It is possible to see the eroded tops of the columnar joints exposed on the top of volcano.