

The Geology of Calavera Hills, North San Diego County, California

John H. Turbeville
Professor of Geology and Oceanography
MiraCosta College, Oceanside, California
miracosta.edu/home/JTurbeville

Introduction The Calavera Hills area contains one of several volcanic plugs found throughout North San Diego County. The volcanic rocks here are generally intermediate in composition and form distinct flows along the flanks of the extinct volcano. None of the volcanic plugs have been radiometrically dated but they are thought to have formed in the Miocene. This is a time when our coastline was transitioning from a convergent plate boundary (subduction) to a transform plate motion. This transform motion eventually formed the San Andreas Fault. The volcanic processes here are thought to be similar in age and genesis to other volcanic events occurring up and down our coastline during Miocene time. At Calavera Hills, the age of the plug is estimated using relative age dating techniques. Several key field observations help us form hypotheses concerning the timing of geologic events at the site and the approximate age of the volcanic plug.

The hike will begin at the intersection of Tamarack Ave. (note: not Tamarack Ave N), and Strata Dr. in Carlsbad (Figure #1), which is 10.2 miles from Palomar College. There will be 4 stops at points of interest along the 1.5-mile loop. This trip has about 300' of vertical rise and moderately difficult hiking conditions.

Geologic Background Extensive subduction occurred on the western edge of North America from Early Mesozoic to Early Miocene time (approximately 200 to 19 million years ago MYA). Oceanic crust equaling the size of the entire Pacific Basin was subducted underneath the North American plate during this time. A transition from subduction (and plate convergence) to primarily a transform boundary occurred during Miocene time (from approximately 19 to 5 MYA). This transform boundary eventually became the San Andreas Fault (Atwater 1998). During the transition a spreading center was obliquely subducted along the convergent boundary. As the warm, buoyant spreading center was subducted the overlying continental crust was uplifted, fractured, and parts were significantly rotated. Some of rotational events were fairly large; one of them is believed to have formed the Transverse Ranges to the north of Los Angeles (Fritsche, 2001). This series of events left zones of weakness in the continental crust where magma could ascend to the surface to become lava. The volcanic plugs found in Northern San Diego County are thought to be a product of this tectonic transition from subduction to lateral motion.

The volcanic plug found at Calavera Hills (Figure #2) has been quarried creating excellent exposures. It is mapped as Miocene in age, however none of the plugs found in Northern San Diego County have been radiometrically dated. Relative dating observations have been used to determine the approximate age of the plug found at Calavera Hills. The volcanic rocks found here cut the Eocene Santiago Formation (Figure #3) (Tan 1996). This makes them younger than Eocene with a likely window of activity between late Oligocene and Miocene. This timing correlates very well with other similar regional volcanic activity that occurred along our coastline (to the north and south of us) during the same timeframe. One example of this is the

Conejo Volcanics found on the western side of the Santa Monica Mountains just north of Los Angeles (Weigand 2002). In addition, there is a great deal of volcanic ash found locally in sedimentary rocks of this age. It has not been determined which of the volcanic plugs (or all) located in this area produced the ash (Abbott 1999).

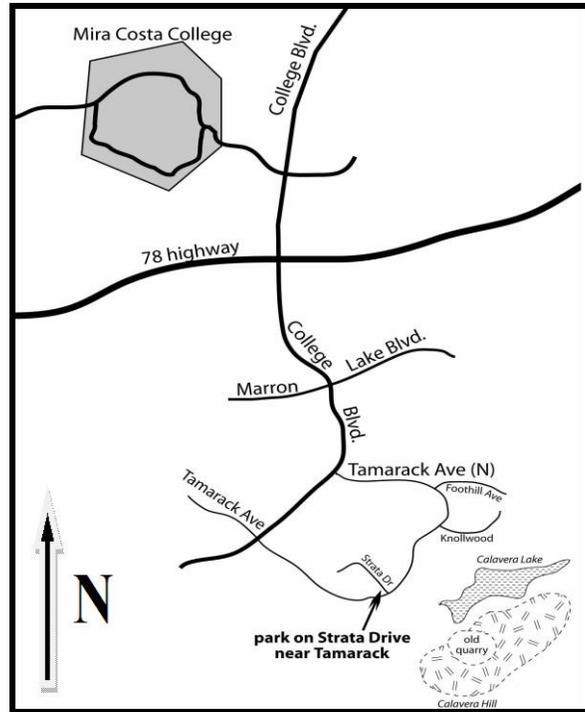


Figure #1: The Calavera Hills area. *The meeting point is at the intersection of Tamarack Ave. (not Tamarack Ave N) and Strata Dr. This location is about 10.2 miles from Palomar College.*



Figure #2: The volcanic plug at Calavera Hills. Quarrying of the rock in the neck has created excellent exposures.

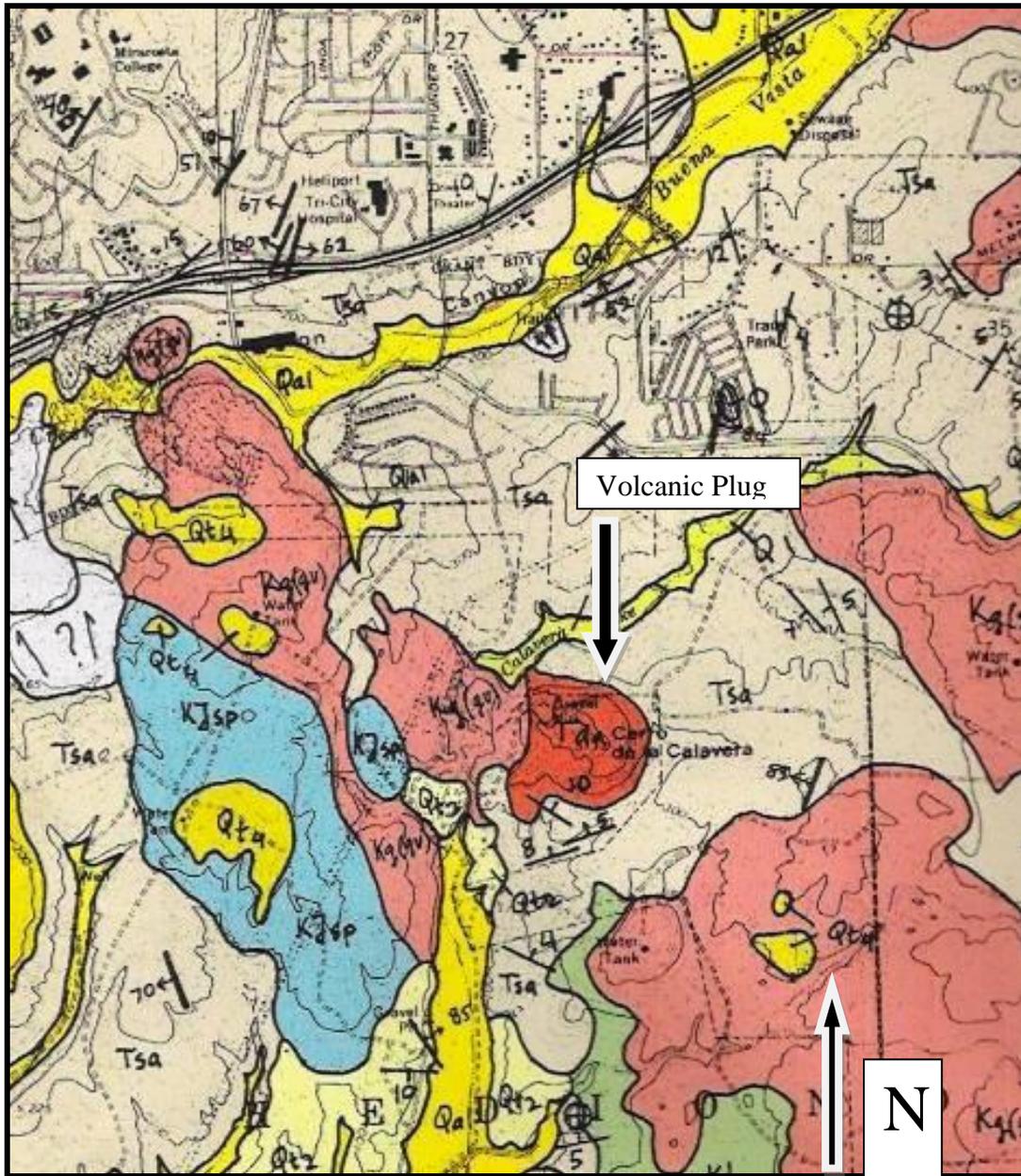


Figure #3: Geologic map of the Calavera Hills area. The Cretaceous Green Valley Formation (gv) is shown in redish-pink, Eocene Santiago Formation (Tsa) is shown in tan, and the Miocene Dacite Volcanic Plug (Tda) is red and in the middle of the figure (Tda 6). Figure courtesy of U.S.G.S, open File Report 96-02.

Local Geology

On this fieldtrip, we will observe three rock units ranging from Cretaceous to Miocene in age. Each unit is described below in order of decreasing age.

Green Valley Tonalite (Cretaceous)(Larson 1948): The first rock unit we will see is part of the Peninsular Ranges. It is an intrusive igneous unit that was cooled slowly at depth and subsequently uplifted, eroded and exposed. It is mapped as a tonalite, which is very similar to a granodiorite, see Figure #4. This unit has a phaneritic texture (medium to coarse-grained), which means you can see the grains with the naked eye (Figure #5).

Santiago Formation (Eocene)(Tan 1986, 1987) In the Calavera Hills area, the Santiago Formation is very soft and for this reason there are only a few outcrops in the area. The local extent of the formation is primarily based upon the light colored material it generates from weathering (Figure #6). The Santiago Formation was deposited in a beach setting. The sandstone is fine to medium grained, poorly cemented, poorly bedded, and is interbedded with siltstone and claystone that is locally prone to significant slumping. The Santiago Formation is not to be confused with the Santiago Peak Volcanics that are much older.

This formation was renamed from the Scripps Formation locally in the mid-1980s (Tan 1986, 1987). It is found regionally from Orange County to Northern San Diego County where it begins to interfinger to the south of Leucadia with the Torrey Sandstone

Volcanic Plug (Miocene): This rock unit is “mouse gray” in color and has an aphanitic texture, which means that you cannot see the grains with the naked eye. The rocks shown in Figure #7 are from the volcanic neck and are dacitic in composition. A dacite is between a rhyolite and an andesite in composition, see Figure #4.

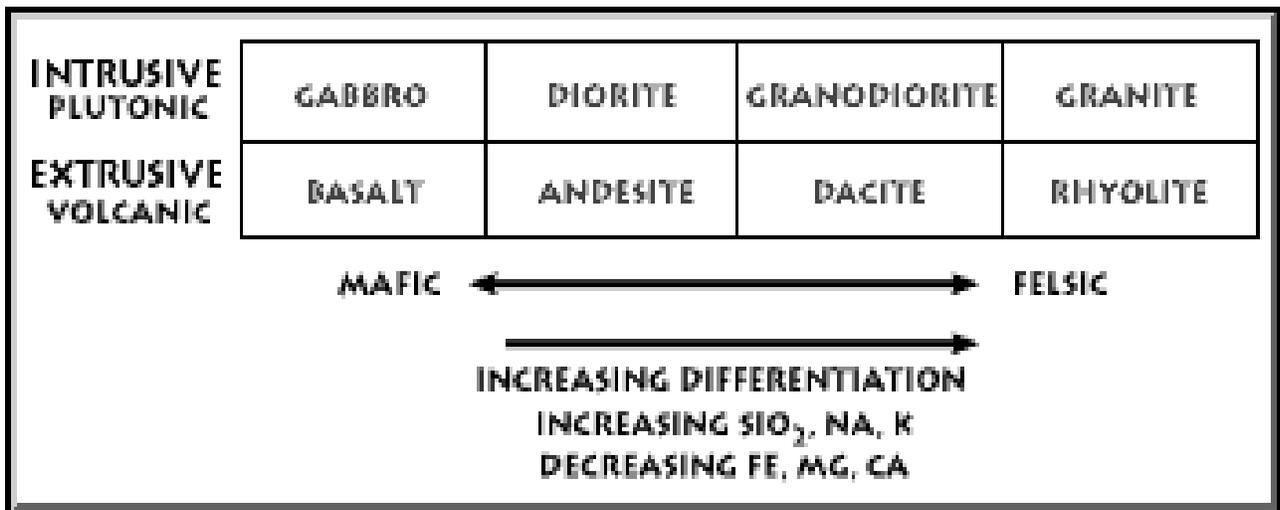


Figure #4: General classification of igneous rocks. Figure reproduced courtesy of U.S.G.S.



Figure #5: *The Cretaceous Green Valley Tonalite as exposed at Stop #1. Note the medium to coarse-grained (phaneritic) texture.*



Figure #6: *The Eocene Santiago Formation is tan, soft and friable in the Calavera Hills area.*



Figure #7: The Miocene Dacitic Volcanic Plug material found at Calavera Hills. Note the fine-grained texture and “mouse gray” color.

Fieldtrip Log The hike will begin at the intersection of Tamarack Ave. and Strata Dr. in Carlsbad (33 degrees 10’ 13” N and 117 degrees 17’ 20” W) and form about a 1.5-mile loop. There will be 4 stops at points of interest along the way (Figure #8). This trip has about 300 feet of vertical rise and has moderately difficult hiking conditions.

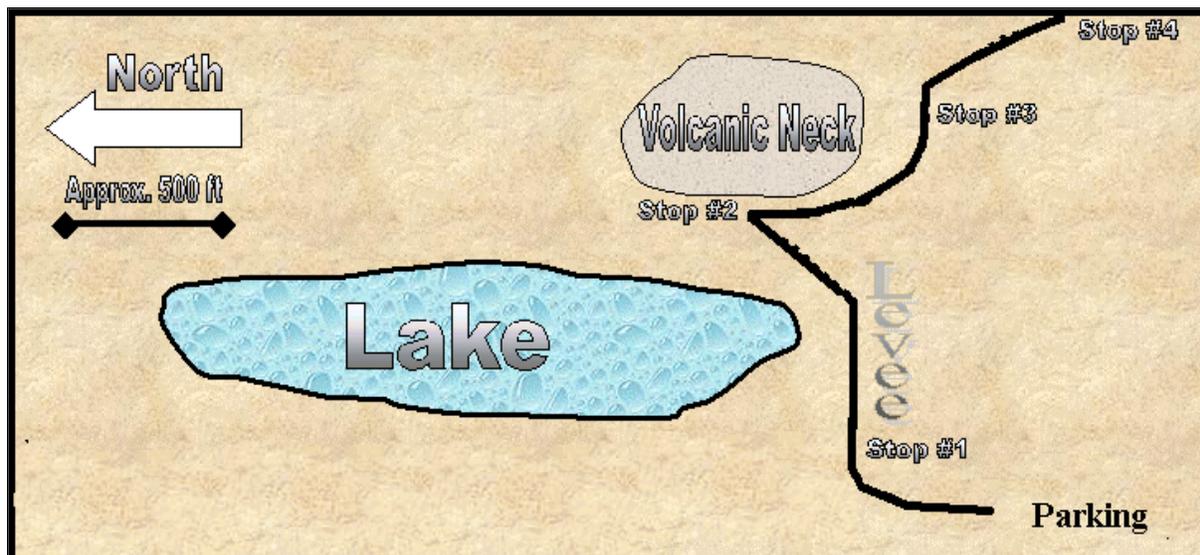


Figure #8: The fieldtrip stops relative to the lake, volcanic plug and parking area at Calavera Hills.

Stop #1 (33 degrees 10' 13" N and 117 degrees 17' 14" W)

Stop #1 provides excellent exposures of the Cretaceous Green Valley Tonalite (Figures #5 and #9). The overall color of this rock is intermediate and the crystals can be seen easily with the naked eye. Using a hand lens on a fresh surface you will notice it consists of three minerals. The primary mineral is grayish-brown and has two distinct cleavage planes. You may note some striations on the cleaved faces. Most of us are used to seeing a lighter variety of this mineral in hand specimen. This is a dark variety of plagioclase feldspar. There are also smaller amounts of amphibole and quartz in this rock.



Figure #9: Stop #1 is in a ditch just before we reach the dam. There are excellent exposures of the Green Valley Tonalite in this area. Note the fresh outcrop in the bottom of the ditch. The side of the ditch in the background is the same material but heavily weathered. The cracked tonalite blocks in this weathered area represent the early stages of spheroidal weathering.

On the way to Stop #2 we pass (to your right) some large intrusive igneous outcrops that exhibit spheroidal weathering. These are intrusive igneous rocks of the Green Valley Tonalite.

Stop #2 (33 degrees 10' 8" N and 117 degrees 17' 5" W)

Stop #2 is midway up the hill and at the base of the Calavera Hills Volcanic Plug (Figure #10). The rocks that comprise the "volcanic neck" are very resistant to weathering relative to the surrounding material. So the volcanic neck is what remains of the volcano after the surrounding sediment and pyroclastic material have been stripped away. It is composed of a fine-grained (aphanitic), "mouse gray" rock that is dacitic in composition (Figure #7).

There are near vertical, long, linear features near the middle and top of the ridge. This is called columnar jointing. The columns form due to stress as the lava cools from the base upward and from the top downward. They form distinct six-sided (mostly) columns.



Figure #10: *Stop #2 and the volcanic neck.*

Along the road on the way to Stop #3 we see two points of interest. The first is an exposure of Eocene Santiago Formation that is seen being crosscut by the Miocene Dacite Volcanic Plug (Figure #11). The second is a series of volcanic flows going over the top of the tan and coarser-grained Green Valley Tonalite. The tonalite seen in the road cut is deeply weathered, crumbly, and much lighter in color than fresh tonalite. This is mostly due to the weathering of the plagioclase feldspar to light-colored clay minerals.



Figure #11: *The Miocene Dacite Volcanic Plug (left) is seen crosscutting the tan Eocene Santiago Formation (right) enroute from stop #2 to stop #3.*

Stop #3 (33 degrees 10' 3" N and 117 degrees 17' 7" W)

Notice the small opening in the middle of the picture (Figure #12). This is called an "adit", which is an exploratory excavation for valuable minerals. Geologists commonly look for mineralization and ore deposits at the contact between two rock units. The picture below shows the gray fine-grained lava flow going over the top of the coarser-grained tonalite here. The rocks to the right of the "adit" opening are not in place. The Principle of Superposition is tricky in igneous rocks but what might their superposition suggest about their relative age?



Figure #12: *This is the entrance to the adit. Note the gray fine-grained lava flow going over the top of the tan and coarser-grained Green Valley Tonalite here.*

Stop #4 (33 degrees 10' N and 117 degrees 17' 9" W)

Here we see an inclusion of the coarse-grained Cretaceous Green Valley Tonalite enclosed within a matrix of the gray fine-grained volcanic plug material (Figure #13). The surfaces of the fine-grained volcanics are "mouse gray" where fresh and orange-brown where weathered. What does the inclusion data tell us about the relative age of the rocks?



Figure #13: *An inclusion of the coarse-grained Green Valley Tonalite enclosed in a matrix of gray fine-grained volcanic material.*

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