61st AEG Annual Meeting/13th IAEG Congress
San Francisco, California

Field Course #5: San Francisco Melanges and Bimrocks

aka: *A mélange: chunks of Franciscan geology in a matrix of tourist chatter*

Sunday September 16, 2018

Leader:

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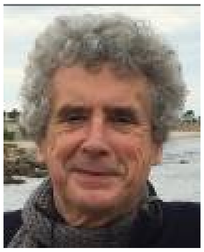
TRIP LEADER



Dr. Ed Medley is a geological engineer with about 40 years of international experience in geological and geotechnical engineering. His career includes chapters as a mineral exploration prospector, teacher, university lecturer, vagabond and bimrock researcher. He is a Principal Consultant with Terraphase Engineering. Inc. in Oakland, California where he practices Geological Engineering and performs failure investigations. He is licensed as an engineer and geologist in USA, Canada and the UK.

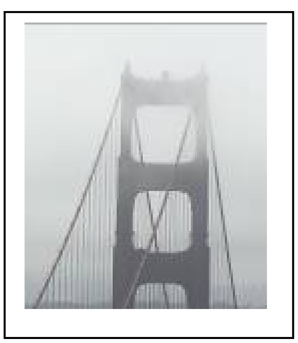
Please ask your questions loudly since I am **HARD OF HEARING** and other folk may want to hear your questions as well.

CO-LEADER

Dr. Julien Waeber has over 10 years of experience in geotechnical engineering and engineering geology, in North and Central America and Europe. He specializes in the assessment and mitigation of geologic hazards, construction support and characterization of weak and chaotic rock masses. Dr. Waeber has extensive experience with evaluation and design of dams, roadways, landfills, commercial development, pipelines, and natural and manmade slopes. He also has deep experience with the application of remote sensing technologies including continuous GPS, InSAR and LiDAR, particularly for landslide hazard assessment.

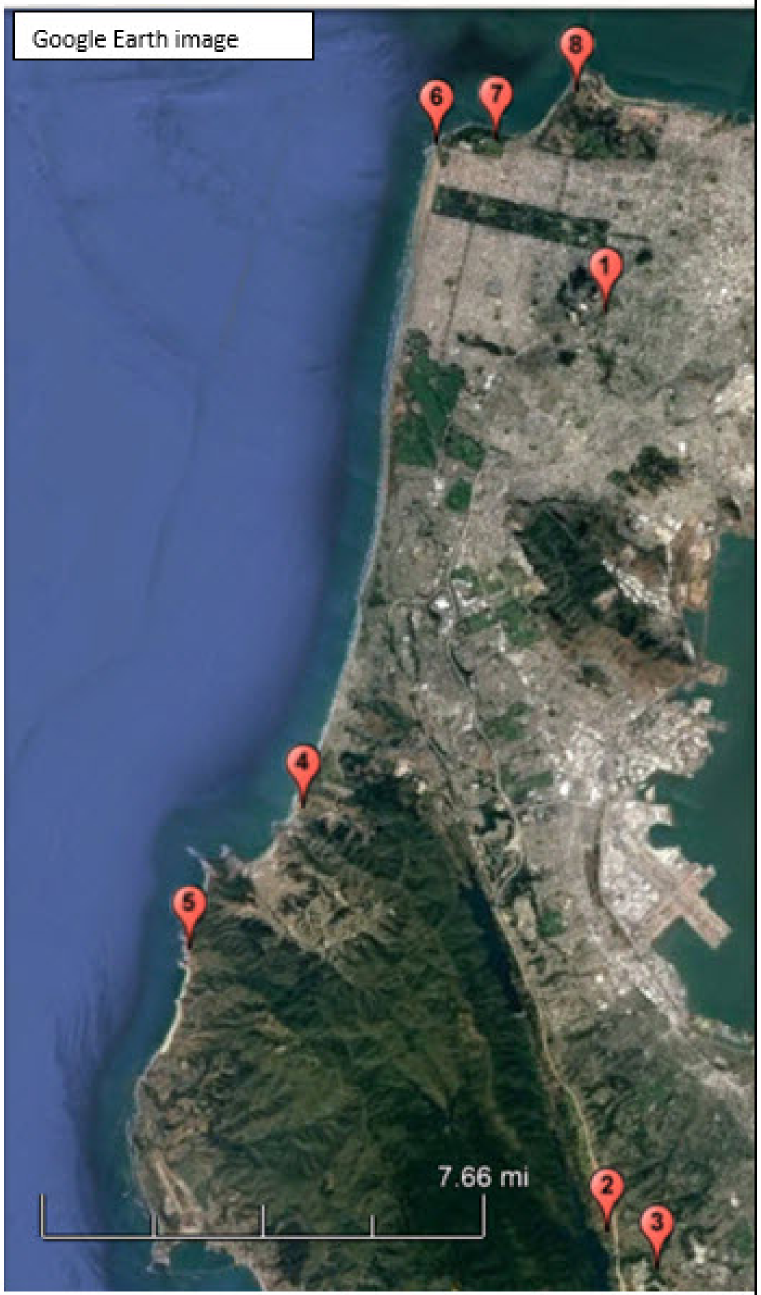
TRIP OVERVIEW

You shall enjoy today's field trip because you are going to see a lot of lovely sights and sites on the San Francisco Peninsula. The stuff you may learn about Franciscan Complex geology, melanges and bimrocks are an added benefit.



You will enjoy yourself more **IF** you brought along clothes to withstand the possible windy fog. You did bring something warm, did you not?? By the way, Mark Twain never said "The worst winter I ever spent was summer in San Francisco", although the quote is pithy enough to have come from him. No, that complaint was probably from someone visiting from Boca Raton. The fog is a result of cool ocean air condensing as it blows towards warmer climes inland.

STOPS FIGURE: NEXT PAGE



AEG/IAEG 2018: San Francisco Melanges and Bimrocks, Sept. 16, 2018

Trip Leaders: Ed Medley and Julien Waeber

Start/Finish: Hyatt Hotel, San Francisco

07:45 Meeting time for 08:00 Departure

1. **Twin Peaks**: San Francisco overview; chert and greenstone blocks

Drive-by: San Andreas fault from the "world's most beautiful freeway".

2. **Skyline Road (Hwy 35)**, ~ 1500 ft north of Crystal Springs Dam: sheared serpentinite and serpentinite melange; introduction to bimrocks

3. **Polhemus Rd Landslide,** at Ascension Rd**:** Effects of large blocks on slope stability; major landslide in melange in an urban area

Crystal Springs Village Shopping Center: coffee, snacks, W.C.

Drive-by on Hwy 280: Grazing blocks, W.C. in I-280 Rest Area

4. **Pacifica:** Rockaway Beach - Calera Quarry; Franciscan shale melange

LUNCH at Rockaway Beach, gift shops, cafes, beach, W.C.,

5. **South Portal End Devil's Slide:** weathered granite bimrock, W.C.

6. **Land's End/ Sutro Baths:** San Bruno Mountain Terrane sandstone, siltstone turbidites; chaotic rocks, broken formation; tunnel. Visit the Land's End Visitor center: gifts, snacks, W.C.

7. **El Camino del Mar north of Legion of Honor:** Golden Gate Bridge views.

8. **Golden Gate Bridge:** Serpentinite and melange landslides; Wander under/around/on the bridge. Be a tourist...

RETURN to Hyatt Hotel approx. 4:30 to 5 pm

INTRODUCTION

In California, hundreds of millions of years of plate tectonics has created an abundance of fault rocks, melanges and similar bedrock composed of complexly mixed, often lithologically heterogeneous, strong blocks embedded in a sheared, weaker matrix. Such rocks are ***bimrocks***[1] (block-in-matrix rocks). The most intractable bimrocks are melanges (from the French, *mélange*, or mixture) associated with tectonic subduction complexes. Melanges are of significance in California, because they constitute a large proportion of the Franciscan Complex, a regional scale jumble that makes up about a third of the bedrock in the central and northern Coast Ranges of northern California. The Franciscan is famous because it was the workshop that allowed greater understanding of convergent plate margin tectonics. Although the Franciscan is a famous locality for melanges, they and other bimrocks are found in many parts of the world, so the engineering problems associated with them are global in scope.

The goals of this one-day Field Trip - and associated conference Technical Sessions (15 and 23A) - is to introduce geopractitioners to the problems of bimrocks, as well as some rational approaches that have been developed to characterize such rocks. Also: we hope that geologists will be able to better communicate the significance of bimrocks to engineers. Trip participants are encouraged to ask these questions:

- Melanges? Bimrocks? So what? Who cares?
- What is a block? What is matrix?
- What is the strength of a bimrock?
- What should I measure?
- How can I produce dependable maps and cross sections in bimrocks?
- Bimrocks are so difficult to characterize: why bother describing them at all?

We cannot show you all there is to know about bimrocks today. So: a review paper on bimrocks is Attached to this Field Trip Guide (Medley and Zekkos, 2011).

[1] Medley (1994) coined the neutral word *bimrock* from Raymond's (1984) term" block-in-matrix rock". Formally, a bimrock is "a mixture of rocks, composed of geotechnically significant blocks within a bonded matrix of finer texture." The expression "*geotechnically significant blocks*" means that there is mechanical contrast between blocks and matrix, and the geometry and proportion of the blocks influence the rock mass properties at the scales of engineering interest, which range between centimeters for laboratory test specimens through tens of kilometers for tunnel lengths. For more info see the Medley and Zekkos (2011) and the bimrocks website (http://bimrocks.com).

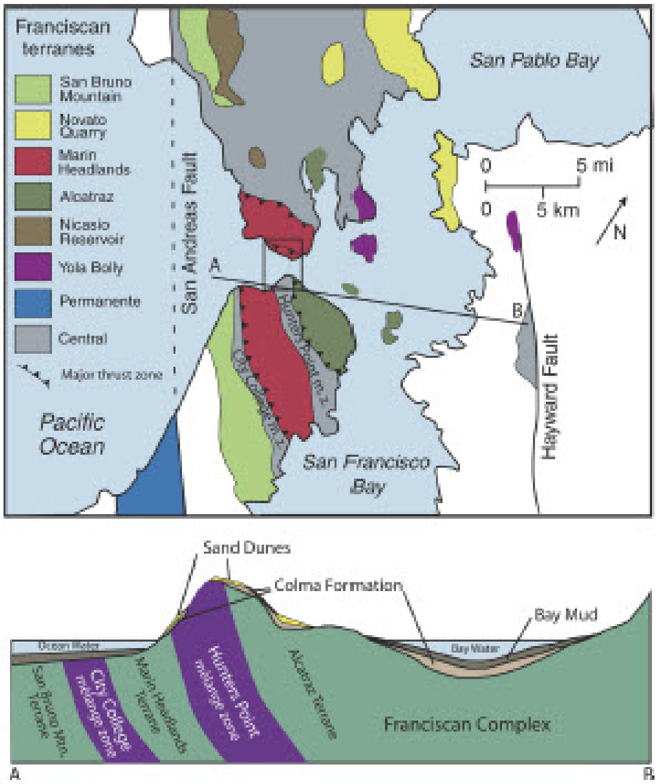


Figure 3.2. Top part of figure shows terranes of the Franciscan Complex in the San Francisco Bay area and dip direction of major thrust faults referred to in text. Cross section A-B for lower part of figure also is indicated (modified from Blake and others, 1984). Bottom part of figure is a schematic cross section through northern San Francisco Peninsula across bay to Oakland (not to scale).

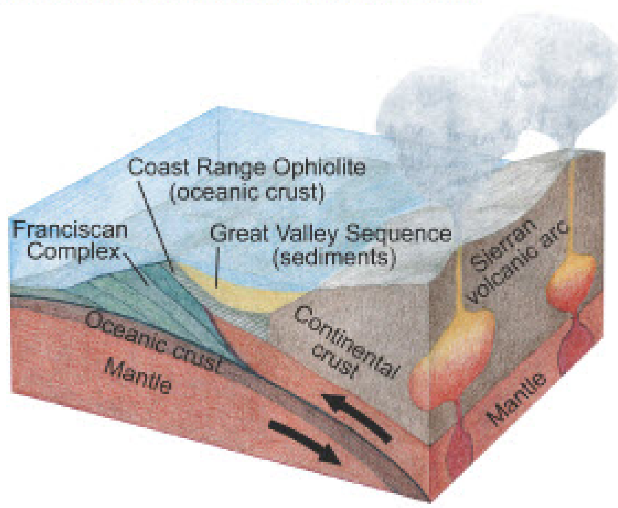


Figure 3.3. Cartoon of the subduction zone present on the West Coast 100 million years ago showing position of the accretionary wedge of the Franciscan Complex.

Simplified geology of the San Francisco Peninsula (Elder, 2001)

The trip starts in San Francisco. We drive to Twin Peaks upon which stands the tall red and white Sutro Tower, if we can see it. If we cannot, we will not be able to see the lovely views, but the rocks are lovely, so we are going to go there anyway. …

TOURIST CHATTER

San Francisco, named after St. Francis of Assisi, has some 870,000 people living in about 47 square miles. Many are in heavy debt: the median home price is about $1.76 million. Prices are as high or much higher, nearly everywhere we stop today.

STOP 1: TWIN PEAKS OVERLOOK
(Lat: 37.75241 Lon: -122.44752)

As can *hopefully* be seen from Twin Peaks: San Francisco is the type locality for the **Franciscan Complex**. At various times it has been called the Franciscan Formation, Franciscan Group, Franciscan Series, and Franciscan Assemblage. These historical names indicate increasing evolution in the understanding of the geological chaos of "the Franciscan" (which is how most folk get around the problem of not knowing what the second noun should be). The Franciscan Complex is world-famous because it is a showcase for subduction processes and complex tectonic shredding (Wakabayashi, 1999).

Simply, the Franciscan is a regional jumble of chunks of tectonic plates from various places, stirred together and separated by faults and shears zones. In places the shredding and shears are so pervasive that bands of **melange** form. Melanges (from the French, *mélange*, for "mixture", or "medley") are rock masses formed of mixtures of hard blocks of rock surrounded by weaker matrix. Block sizes range between mountains and gravel. The City's renowned hills are expressions of resistant blocks surrounded by weaker sheared zones of rock at a regional scale.

In San Francisco, there are several sub-parallel block-rich, hilly, bands (or "terranes") separated by block-poor shear zone melanges which trend across the city in NW-SE directions. Several of our last Stops are within the "**Marin Headlands**" terrane and the **Hunters Point Melange**, which exhibit a mosaic of sandstone blocks, blocks of interbedded sandstone and shales, sheared shales, chert/greenstone blocks and serpentinite melange.

The northern of the Twin Peaks is composed of chert, which is wildly contorted in places. The southern hill is a block of greenstone, which is metamorphosed basalt. Chert and greenstone are often found together in the San Francisco area.

Drive from Twin Peaks to I-280 via O'Shaunessy Blvd - see more contorted cherts
.
Take I-280 south - Past the Millbrae-Larkspur exit notice San Andreas lake on right.
Exit Black Mtn Road in Hillsborough, take right then southwards on Skyline Drive (Hwy 35) about a mile.

TOURIST CHATTER: SAN ANDREAS FAULT

The San Andreas fault passes through Daly City and into SF city watershed land. West of the I-280 freeway, three small reservoirs (on map: San Andreas (SAL) and Upper and Lower Crystal Springs (CSR)) lie on the fault trace. They are part of the city's main water supply, which originates at the Hetch Hetchy reservoir in the Sierra Nevada mountains.

The dams holding back these reservoirs held firm in 1906 and are not considered major hazards. Beyond them, the fault begins to take a slight leftward bend as it runs behind Black Mountain (BM) and through the notch directly beyond. The Loma Prieta (LP) peak gave its name to the 1989 earthquake because the greatest shaking occurred near the peak.

STOP 2: SKYLINE DRIVE, NORTH OF CRYSTAL SPRINGS DAM
(Lat: 37.53522 Lon: -122.36633)

At this long outcrop, note sheared serpentinite and serpentinite melange. Serpentinite is metamorphosed oceanic plate rich in Fe and Mg. In the subduction trench, the rock density decreases as its volume increases with hydration of water, and serpentinite bodies "float up" through subduction accretions as diapirs, shredding and incorporating adjacent material.

In the right light you will see the shining slickness of the blocks. Most are intact serpentinite, but some are greywacke sandstone, chert and greenstone blocks. You may be able to see why serpentinite is named after the smooth, scaly skin of snakes. Although pretty, serpentinite is prone to landslides when sheared; it hosts Naturally Occurring Asbestos; and, and is a source of chromium, cobalt and other metals. Serpentinite flora is also distinctively subdued and serpentinite terrains are often termed "barrens". Still, despite its troublesome nature, Serpentinite is the official California State rock.

Play the hand gap picture game: Take 3 "slit-camera" pictures through the gap between your hands held up before you. Imagine that the strips are boreholes. What we see: "interbedded clay and serpentinite blocks?" **NO!**. One of the largest problems is not recognizing the fabric of blocks in matrix. Block-in-matrix rock is commonly found in geology as weathered rocks, fault rocks, etc., which is why the term *bimrock* is useful - it has no genetic implication.

Observe blocks of different sizes, with sheared serpentinite matrix. There are a few large blocks and many small ones in this outcrop. The block size distribution follows a negative power law (fractal) and is scale independent (self-similar block size distributions).

What is block? What is matrix? It depends on the scale of interest and hence, the *characteristic dimension* $\mathbf{L_c}$. Blocks are defined as being between $0.05L_c$ and $0.75L_c$. Here, the height of the slope would be L_c (i.e. ~10m). with blocks ranging between 0.5 m and 7.5 m. A lab sample taken from the outcrop will have a different L_c, say the diameter of a triaxial specimen (0.15 m), and so the with block sizes will range accordingly. What is a block at lab scale may not be a block at outcrop scale.

The engineering significance of melanges and other bimrocks comes from the block/matrix contrasts, forcing failures around blocks. The number, or volume, of blocks makes the difference mechanically - where enough blocks increase the bimrock strength by tortuosity of failure surfaces. The condition of the boundary between blocks and matrix can have the opposite effect, where "unwelded" boundaries can lead to a decrease in cohesion (i.e. welded Lahars vs unwelded Laterites).

There are simple relationships between **volumetric block proportion** (**VBP**) and strength. Although easy enough to measure VBP at lab scales, there is great difficulty in estimating volumetric block proportions at site scales.

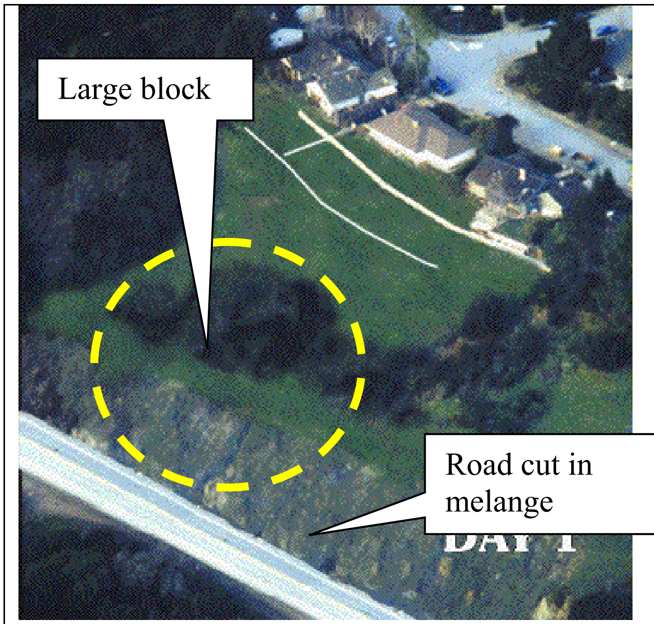
Could we estimate VBP with **linear** block proportions from borings? Stereology says we can, but in geopractice we rarely can drill enough borings to produce sufficient block-boring intersection lengths (chords) to produce representative Linear Block Proportions. So: must consider the **uncertainty** in assuming that our LBPs=VBPs. A rule of thumb is to drill ten times the length of the largest characteristic block to generate enough LBP data to justify the assumption. There is a simple chart useful for estimating uncertainty in Medley (1997) but Medley himself nowadays urges caution in its use. It is long past time to update the chart and findings of Medley (1997).

Continue South to Polhemus Rd and turn right, We are in rural San Mateo County. Note blocks in hillside and road cuts, Go to intersection with Ascension Drive. Park in big dirt area on west side road just past the intersection.

STOP 3: POLHEMUS ROAD LANDSLIDE
(Lat: 37.52842 Lon: -122.34602)

A few hundred feet south of the slide is a large block, apparently of greenstone, protruding from the hill. Its presence suggests the role of large blocks in buttressing slopes.

During the 1996/1997 winter, a landslide damaged houses at the top of slope. The slide initially piled up at the slope base, buttressed by a large block covered with oak trees (no longer there). In melange terrain, blocks stabilize soils around them and encourage vegetation development. Shale matrix ground being more mobile allows less chance for trees to develop. Eventually, the slide moved out over Polhemus road, a major rural traffic route to Hwy 280.



Polhemus Rd. landslide **before** failure (USGS photo)

Polhemus Rd. landslide **after** failure (USGS photo)

FROM USGS website http://elnino.usgs.gov/landslides-sfbay/photos.html - stills from animation depicts the movement of a deep-seated "slump" type landslide in San Mateo County. Beginning a few days after the 1997 New Year's storm, the slump opened a large fissure on the uphill scarp and created a bulge at the downhill toe. As movement continued at an average rate of a few feet per day, the uphill side dropped further, broke through a retaining wall, and created a deep depression. At the same time the toe slipped out across the road. Over 250,000 tons of rock and soil moved in this landslide. Animation: https://archive.usgs.gov/archive/sites/walrus.wr.usgs.gov/elnino/landslides-sfbay/images/LS.gif

Under the road is an 8-foot diameter concrete pipe from the Hetch Hetchy reservoir in the Sierra Nevada Mountains; it provides water to San Francisco and it was vital that it not be damaged.

The slide developed over the years. The County of San Mateo was sued too because road maintenance and clearing of slope debris allegedly “undermined” the slope stability. The litigation settled when a contractor bought the land and paid off claimants so he could repair the slide and develop the land.

A tie-back wall with soldier piles to 40+ feet deep was installed. In the process of building the wall, the contractor encountered “unexpected’ blocks, particularly one very large, strong greenstone block. A Differing Site Condition construction claim was submitted to the City of Can Francisco, but the claim was eventually denied. The block should have been expected. See paper by Kim et al (2004) for a stability analysis of the slide.

Continue South on Polhemus Rd. to Crystal Springs Village

SERVICE STOP: CRYSTAL SPRINGS VILLAGE

Stop here for sandwiches, drinks, coffee, W.C.

Take 280 North:. Near 280/92 intersection notice blocks popping out of ground like grazing sheep, typical of melange terrain. Take Hwy 35 exit; head north to Sharp Park Road to Pacifica. Take Hwy 1 southbound and make right turn to Rockaway Beach. Park in one of the parking lots. Walk paved footpath north into the quarry.

STOP 4: ROCKAWAY BEACH- PACIFICA QUARRY.
(Lat: 37.61427 Lon: -122.49396)

In 1776, an ancestor of this now-abandoned quarry yielded limestone to the Spanish to whitewash the Presidio in San Francisco. The quarry later produced cement.

The excavated slopes show one of the best exposures of classic shale matrix melange in the San Francisco Bay area (*Prof. John Wakabayashi, pers. comm.)* Most of the blocks are limestone; a few are greenstone and chert. The limestone is formally known as the Calera Limestone, which is the largest and most stratigraphically extensive oceanic limestone in the Franciscan. The type locality is this quarry. The limestone has a tropical provenance. The masses here define this part of the Franciscan as the *Permanente terrane*, an original piece of tectonic crust that has been shredded and widely dispersed within the Franciscan. There are several limestone quarries in the surviving fragments.

Play the hand gap picture game again!: Imagine strips are boreholes. This is a good place to take hands-slightly-apart "slit" pictures to imagine drilled borings or scanlines and how these would depict apparent "interbedded" shale and limestone "beds". What we see: "interbedded shale and limestone/chert/greenstone? **NO!** (Think about the geological improbability of "layers" of limestone and greenstone juxtaposed). Again: one of the largest problems is geopractitioners not recognizing the fabric of blocks-in-matrix rocks.

Observe the range in block sizes and that the blocks are evidently much more competent than the surrounding weak, sheared matrix. Blocks in shale matrix Franciscan are often sandstone but range from limestone to highly metamorphosed “exotics”. Block sizes here range from gravel size to at least the size of the quarry slope. You may see finely broken, shiny shale matrix, typical of “*argille scagliose*” (scaly clay). Here, the matrix has raveled and failed in many places and is gullied by surface drainage. There are thick layers of mine waste (like colluvium). These are *bimsoils* at the scale of a few feet.

It is also evident in the quarry slopes how impossible it would be to accurately characterize the blocks in the rockmass on the basis of a few borings, or even many borings. Besides the engineering geology implications for slope stability, there are economic quarry resource implications too.

EAT LUNCH AT ROCKWAY BEACH.

Picnic on the Beach, or visit the small shops and a couple of cafes, like Pacific Java Cafe on Dundoo St. There are some benches under trees, and W.C.s in the 450 Dundoo St shopping plaza.

After lunch:

Drive South on Hwy 1 (right)). Observe the blocks in shale matrix in the road cuts. Also, the isolated hilly bumps between the road and the ocean are large blocks in the Franciscan.

Continue south into the San Pedro Mountain at the south end of Pacifica. The north face of the hill is the expression of the Pilarcito fault, a splay of the San Andreas fault.

The road winds through Tertiary interbedded sandstones and shales. You will see a new highway with bridges and a tunnel that was constructed recently. The tunnel by-passes Devil’s Slide, which plagued coast side motorists for years because its periodic lurching lead to frequent months-long road closures.

Go through the tunnel. Slow down at the South end of the tunnel. Immediately after exiting the tunnel, pull into the parking lots on the right side.

STOP 5: SOUTH PORTALS OF DEVIL'S SLIDE TUNNEL (Tom Lantos Tunnel) (Lat: 37.57234 Lon: -122.51662)

The Devil's Slide, on the abandoned section of Highway 1 here, has a long, very pricey history, having destroyed previous roads and a railway since the 1890's. Failure occurs as kinematically unstable blocks of steeply dipping, faulted and sheared rocks which daylight on the very steep slopes continually destabilized by the ocean. The twin-bore 4100 feet long by-pass tunnel was constructe, with difficulty, between 2005 and 2011.

Granite of the Salinian Block outcrops at the south portal of the tunnel. The granite has been transported from the southern Sierra Nevada Mountains by the San Andreas fault. It is deeply weathered: observe (to the south) the old WWII battery structure, which is almost undermined. Some previously good exposures have been masked by construction. Above the portal are many prominent pinnacles of partly weathered granite protruding from well-weathered granite.

The outcrops adjacent the parking lot reveal mostly decomposed granite with a few weathered corestones. While there is little contrast in the strengths of the core stones and the gruss here, it is easy to imagine that the rock mass contains fresher corestones, such as the pinnacles above the portal. So: the weathered granite is in places a bimrock.

Excavation of the tunnel, using NATM, was reportedly delayed considerably by unexpected abruptly changeable ground conditions, particularly through the three major fault zones encountered, as well as in disrupted sedimentary series in the northern third.

Drive north on Hwy 1 to Skyline Boulevard (Hwy 35) and continue through Daly City past Lake Merced to the Great Hwy at the stoplights. Turn left and see if you can beat all the red lights along the Great Highway. As you proceed up the hill you will see on the left the recently renovated Cliff House perched above the cliffs. On the right side of the road, at base of the slope, was the shaft for access to the Richmond Transport tunnel which was under construction at the time of the Sea Cliff Incident in December 1995 (described later in a drive-by, if we have time).

The road becomes Point Lobos Ave, after the bend; a shortly after Louis' Restaurant (perched at the top of the slope) there is a parking lot on the left-hand side. The newish building is the Land's End Visitor Center, which houses a café, shop, and W.C.s. We shall be walking down toward the shore.

The steps are many and steep. If you do not feel like the exertion., stay in the parking lot area and enjoy the views or walk down to the Cliff House.

STOP 6: CLIFF HOUSE-SUTRO BATHS/LAND'S END
(Lat: 37.78001 Lon: -122.51153)

TOURIST CHATTER

This area is part of the Golden Gate National Recreation Area. The structure below is the remains of the Sutro Baths, a public bathing place. Pictures of the Baths in its heyday can be seen in the Visitor's Center. The baths are named after a famous San Francisco financier, Adolph Sutro. His home used to be on the hill opposite the Visitor Center. The Cliff House was a well-known bawdy house. There have been several of them: at least two burned down. A railway line brought visitors to Ocean Beach and to a fun fair that used to be located just south of the Cliff.

The Cliff House is on a large headland block within the San Bruno terrane within the Franciscan. Across the open space to the north is another headland formed by a block-rich mass of chaotic and intact shale/sandstone sequences. The blocks and gray shale are clearly visible. The intervening space is occupied by block-poor rock which is weak enough to have been preferentially eroded by the ocean. It is also slide-prone.

The interbedded sandstones and shales here are turbidites. They are mechanically complex but straight forward to characterize from mapping and borings. Core of these rocks is a series of alternating sandstone and shale bands can rightly be called "interlayered sandstones and shales". But in places the bedding becomes contorted and a "broken formation" is evident with pieces of sandstones forming isolated blocks. In other words – a bimrock. Although there are both sandstones and shale present is would <u>not</u> be correct to describe them as "interlayered sandstone and shale" even though sandstone blocks and shale matrix intersections in drill core look like inter-layered sandstone and shale. Actual turbidites lack the tiny blocks of sandstone in shale matrix of broken formation/melanges.

There is a coastal trail from here to the Golden Gate Bridge. Access to the beach is also possible but there are over 300 steps to climb and we don't have the time.

Just north of the Land's End area there are great exposures of Franciscan melange in the cliffs. The beaches are formed of cobbles of varied lithologies, colors and textures. You may see many rocks in the water near the shoreline: These are relict blocks originally in the melange that are remaining after the matrix was eroded. Such relict blocks are typical of melange all along the coast, especially in Marin and Sonoma Counties north of San Francisco\; and the Big Sur coastline on Monterey and San Luis Obispo counties to the south.

To the north of us are splendid views of the Golden Gate Bridge and across the strait the cliffs of the Marin Headlands. The headland below is of green, red and tan colors and is formed of red chert, green greenstone (metamorphosed basalt) and sandstone in gray shale matrix.

This area was mapped by engineering geologists as part of an investigation of ground conditions for the Richmond Transport tunnel which passes nearby underneath us. Medley reviewed the drill core from the exploration as a part of his PhD research.

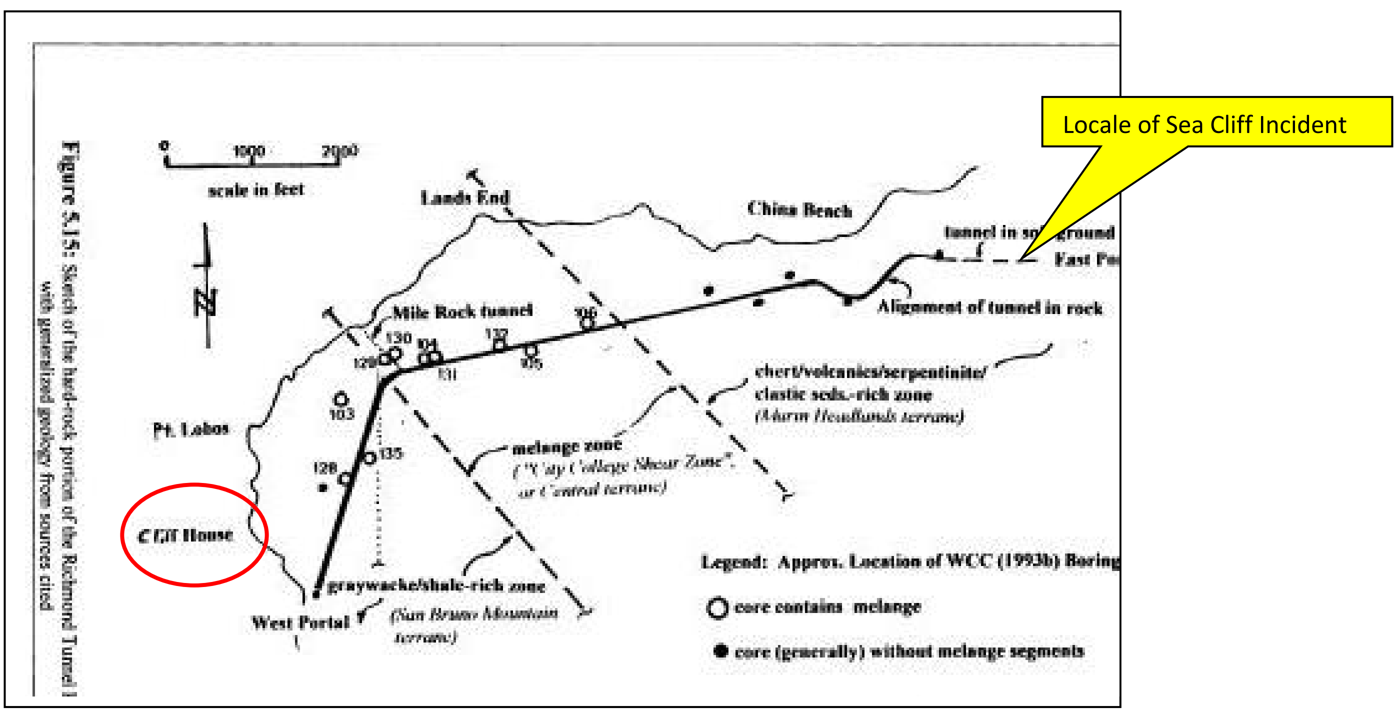


Figure 5.15: Sketch of the hard-rock portion of the Richmond Tunnel
with generalized geology from sources cited

Drilled Core from Richmond Transport Tunnel exploration boring B103 (Medley, 1994)

Much of the tunnel traversed melange, as pictured here. Light gray is (mainly) greywacke sandstone blocks and the dark gray is shale matrix.

Based on work had performed on block size distributions in the Franciscan, Medley estimated the size of the largest reasonable **possible** block that the tunnel could encounter. (The tunnel had barely started when Medley wrote his dissertation).

A rule of thumb is that the largest block is 0.75 the length of the characteristic dimension L_c scaling the problem at hand. At the scale of the entire tunnel length through the melange**,** L_c is $\sqrt{A}$, where A was the area between the tunnel and the coastline. On this basis a block of about 600m length could have been encountered. The tunnel did intersect several hundred feet of unexpected hard sandstone.

Head West on Point Lobos Ave. (becomes Geary Blvd), and turn Left on 34th Ave. Continue along Legion of Honor Drive to Camino del Mar, North of the Legion of Honor.

STOP 7: CAMINO del MAR, NORTH OF LEGION OF HONOR
(Lat: 37.78587 Lon: -122.49646)

At this spot you can take a picture of the Golden Gate Bridge without trees obscuring part of the view. Note the green and gray-colored cliffs near the Bridge: those are landslides in sheared serpentinite and shale matrix melange

TOURIST CHATTER

The Legion of Honor museum is formally called the California Palace of the Legion of Honor, a ¾ scale model of the Parisian original. The museum was a gift of the Spreckels family, sugar magnates. There are statues by Rodin in the courtyard, and a Holocaust Memorial near the fountain and parking lot in front of the Legion of Honor. It houses intermittent exhibitions of fine art and a permanent collection of several thousand pieces.

North of the Legion is the road El Camino del Mar. The community in the distance, perched above the cliffs, is Sea Cliff, an affluent and architecturally distinctive area, famous for being Where the Movie Stars Live (such as the late Robin Williams and Sharon Stone).

Drive along El Camino del Mar through Sea Cliff. Continue on El Camino del Mar as it changes name to Lincoln Blvd in the Presidio. Pass entrance to Baker Beach and continue to just before the left turn into Merchant St. Park in one of the three parking lots. There is one on Merchant St too (at Battery Boutelle) but it is likely to be jammed with cars and traffic. The best one is the dirt lot in the trees east of Battery Godfrey. The Batteries are an abandoned concrete gun emplacement that were active in the early 1900's.

A tunnel below the Bridge Toll Plaza provides a boring pedestrian access to the main Visitor Area for the Golden Gate Bridge but there is a more interesting route via a footpath along the cliff side.

STOP 8: GOLDEN GATE BRIDGE VISITOR AREA AND THEREABOUTS - MOSTLY A TOURIST FROLIC
(Lat: 37.80321 Lon: -122.47673)

During the late Pleistocene, sea level was up to 400 feet lower than currently. The Golden Gate was a valley through which the Sacramento River flowed toward an earlier shoreline some 25 to 30 miles to the west (Steinpress, 1998). Sea level changes resulted in Quaternary estuarine, alluvial, near –shore and aeolian deposits. Several deep paleo-valleys in the Franciscan bedrock were filled with soil deposits.

The irregularly graded footpath along the cliff edge seaward of Battery Godfrey and Battery Boutelle is a good place to see landslides in serpentinite and melange.

The footpath to the Visitor Area is narrow, and likely to be busy with bikers. Take care.

From the footpath, you can clearly see the additional structural steelwork installed as a part of the seismic retrofit for the bridge.

This is a good place to look at the Bridge, which is suspension structure. Serpentinite supports the foundations of the bridge. The road deck hangs from vertical cables attached to the curved ("catenary") cables supported by the two towers. The cables are in tension (pulling away from the towers) so the towers are in compression, bearing down on the foundations.

It is because of the large bearing forces that a controversy broke out between in 1934 between two eminent geologists (Vantine, 2000) Professor Andrew Lawson of University of California at Berkeley and Professor Bailey Willis of Stanford University (a rival school, south of San Francisco). Based on geological mapping, Professor Willis interpreted a vulnerable adverse-dipping fault contact between the serpentinite and a graywacke sequence. A single exploration boring proved serpentinite was continuous. However, serious deficiencies were recently identified in the seismic capacity of the Bridge, and it is the remediation of those which has been the focus of much recently-completed construction.

From the time it was erected in the 1930's, the Bridge has been continually painted in a hue known as Universal Orange. One cannot think of the Bridge being any other color! But generations of lead-based paint have had to be removed. You shall have a chance to see a number of informative signs detailing the vital statistics at the Bridge Visitor Area.

On the east side of the Bridge is a plaza, which contains touristy sights, a snack bar, toilets and a good gift shop. The premier attraction is the Bridge itself, as well as a statue of Joseph Strauss, the designer. Much of the design was performed by two unheralded and visionary engineers, Charles Ellis and Leon Moissieff, who performed calculations for the bridge using slide rules, pencil and paper. There is a display with a section of cable used in the construction of the Bridge, but your patience will be challenged while you wait to take a picture of the cable section in which no other tourist appears.

We suggest that you walk on the Bridge by accessing the sidewalk north of the Gift Shop. You should walk to **the first tower**<u>**, which will take about 15 minutes**</u>. It is only when you get near the tower that you have unobstructed views of San Francisco and the Bay since there is a high chain link fence attached to the handrails up to that point. The fence is not to deter jumpers but to protect workers and visitors to Fort Point below. There are suggestions for a jumper-proof fence but there is debate surrounding the proposals.

Give yourself 20 minutes to walk back along the Bridge from the tower to meet the bus.

Next stop HYATT HOTEL. Thanks for coming!!!

STOP 8+ 1 (AN EXTRA): FORT POINT (BELOW THE BRIDGE)

The Military bastion at **Fort Point** is one of several installations that were actively occupied and used for coastal defense between the 1840's and the 1940's. The Fort is open, and you should have a reconnaissance to appreciate this windy promontory, which was probably quiet before the 1933 construction of the Golden Gate Bridge brought the incessant rumble of traffic.

Access is limited around the Fort and has been since the 9/11 terrorist attack. There is a steep footpath between the Fort and the Visitor Area for the Bridge. The access road to the Fort is open to traffic (which is why we can park here). You will have to give way to runners, who you may see pat a metal plate on the chain link fence at the far end of the road way against the fort wall. The plate is "**Hoppers' Hands**" (and one for dog paws below it), which recognizes the lives lost every year by suicides jumping from the Bridge. Ken Hopper is a Bridge Ironworker who counsels people intending to jump. He and his volunteer colleagues have saved many lives. Nevertheless, since the Bridge opened in 1937, more than 1600 have died by jumping. Suicide nets have been suggested for years but only now are there plans to install them

Along the access road are exposures of sheared serpentinite, several landslides, and abundant seeps. The serpentinite has a block-in-matrix (bimrock) fabric evident here and there by blocks of intact serpentinite surrounded by sheared matrix. The bimrock fabric is also present in the steep cliff of serpentinite that ends close to the south wall of the Fort. Note the curved boundaries of blocks.

REFERENCES

Elder, W; 2001 "Geology of the Golden Gate Headlands", Field Trip No. 3., "Geology and Natural History of the San Francisco Bay Area- A field trip Guidebook, 2001 Fall Field Conference National Assoc Geoscience teachers, far western Section; US Geology Survey Bulletin 2188.

Konigsmark, T., 1998: "Geologic Trips - San Francisco and the Bay Area", Published by Geo Press, Gualala, CA.

Kim, C, C. Snell and E. Medley, 2004; "Shear Strength of Franciscan Complex Mélange as Calculated from Back-Analysis of a Landslide," Proceedings 5th International Conference on Case Histories in Geotechnical Engineering, New York, NY, April 2004.

Medley, E.W., 1994, "The engineering characterization of melanges and similar block-in-matrix rocks (bimrocks)" [Ph.D. thesis]: Berkeley, Department of Civil Engineering, University of California, 387 p.

Medley, E.W., 1997, Uncertainty in estimates of block volumetric proportion in melange bimrocks: Proceedings of the International Symposium of the International Association of Engineering Geologists, Athens, Greece, June 23–27: Rotterdam, A.A. Balkema, p. 267–272.

Medley, E.W., and Zekkos, D., 2011, "Geopractitioner approaches to working with antisocial mélanges", *in* Wakabayashi, J., and Dilek, Y., eds., Mélanges: Processes of Formation and Societal Significance: Geological Society of America Special Paper 480, p. 261–277.

Raymond, L.A., 1984, "Classification of mélanges", in Raymond, L.A., ed., Melanges: Their Nature, Origin, and Significance: Geological Society of America Special Paper 228, p. 7–20.

Steinpress, 1998, "Transformation of the Presidio of San Francisco, Hydrology and Environmental Restoration: Field Trip Guidebook", Chapter 4, California Groundwater Resources Association, San Francisco Branch.

Vantine, R.; 2000, Field Trip : “Northern San Andreas Fault System and Sonoma County Slope Instability”, in Alvarez, 2000, AEG/GRA 2000 Field Trip Guidebook “From the Pacific Ocean to the Sierra Nevada: Taming Shaky Ground.”

Wahrhaftig, C. 1979, “A Streetcar to Subduction and Other Plate Tectonic Trips by Public Transport in San Francisco”, published in periodically Revised Editions by the American Geophysical Union.

NOTE: Dr John Wakabayashi will lead an updated version of Wahrhaftig’s Field Trip for conference attendees on Wednesday Sept.19 2018.

Wakabayashi, J., 1999; “Franciscan Complex, San Francisco Bay Area: A Record of Subduction Complex Processes”, in Wagner, 1999, “Geologic Field Trips in Northern California” for Centennial Meeting of GSA; publ. California Division Mines and Geology, Special Publication 119.

Williams, J., 2001; Field Trip No. 5: “Elements of Engineering Geology on the San Francisco Peninsula- Challenges When Dynamic Geology and Society’s Transportation Web Intersect”; in Geology and Natural History of the San Francisco Bay Area- A field trip Guidebook, 2001 Fall Field Conference National Assoc Geoscience teachers, far western Section; US Geology Survey Bulletin 2188.