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Santa Barbara Field Trip Guide

Figure 1. A satellite image of California with markings for Santa Barbara and major cities.

1. Introduction

Santa Barbara is a coastal city known for its beaches and temperate weather. Just 160 km north of Los Angeles and 525 km south of San Francisco (Figure 1), Santa Barbara sits at the northernmost extent of southern California. With the city framed by the Santa Ynez Mountain Range to the north and the Pacific Ocean to the south, the local geology of Santa Barbara is quite diverse.

Santa Barbara's terrestrial landscape is dominated by four major geographic features (Figure 2). The sandy beaches and coastal bluffs are a popular site to observe sedimentary structures such as wave cut terraces. Extending beyond the bluffs is the ~4-5 km wide coastal plain, covered in beautiful local chaparral flora. Rising above the plain is the front range of the Santa Ynez Mountains, with peaks reaching higher than 1,200 meters. Looking out ~35 km off the coast, the Channel Islands are home to unique terrestrial and marine ecosystems protected by the Channel Islands National Park.

Within the Santa Barbara region, there are a variety of geologic features including exposed stratigraphy, folds, and faults formed by the uplift and deformation of the Santa Barbara block. The objective of this field guide is to discuss these features by leading the reader through specific geologic sites and formations in the Santa Barbara region. In particular, this guide provides essential information regarding site access, mapping, and geologic history to explore how distinct geologic components interact with each other to form the current landscape of Santa Barbara.

Figure 2. This annotated image depicts three of Santa Barbara's major geographic features. Not pictured: Channel Islands. This image was taken from Henley Gate at UC Santa Barbara.

2. Geologic Background

The modern tectonics of California are dominated by a strike slip fault system, however California has many geologic features indicative of an ancient subduction zone that can be traced back to the Mesozoic era (252-66 Ma). This subduction zone along the western margin of California subducted the Farallon plate, an oceanic plate that once existed between the Pacific and North American plates. The subduction of the Farallon plate formed three major geological features in California (Figure 3):

1. The Franciscan Assemblage, an accretionary wedge along western California formed by the scraping and accreting of sediments from the subducting plate onto the overriding plate.
2. The Sierran volcanic arc along eastern California and formed by flux melting within the mantle wedge.
3. The Great Valley sequence, a forearc sedimentary basin bounded by the Franciscan Assemblage and Sierran arc.

Upon complete subduction of the Farallon plate ~30 Ma, the opposite motions of the Pacific and North American plates formed a transform boundary. This transform boundary is responsible for the present day strike slip fault system, the San Andreas fault.

The stratigraphy of present-day Santa Barbara (Figure 4) was deposited within primarily marine environments, with the exception of the terrestrial Sespe formation, in California's forearc basin between 51-27 Ma. Originally deposited in present-day Baja California, the tectonic activity of the San Andreas fault transported and uplifted the Santa Barbara block to the current geographical location of Santa Barbara. This uplift event started ~30 Ma and exposed the east-west oriented ranges of the Santa Ynez Mountains and Channel Islands. The progressive compression of the Santa Barbara block has caused coastal uplift of bluffs and exposure of local stratigraphy.

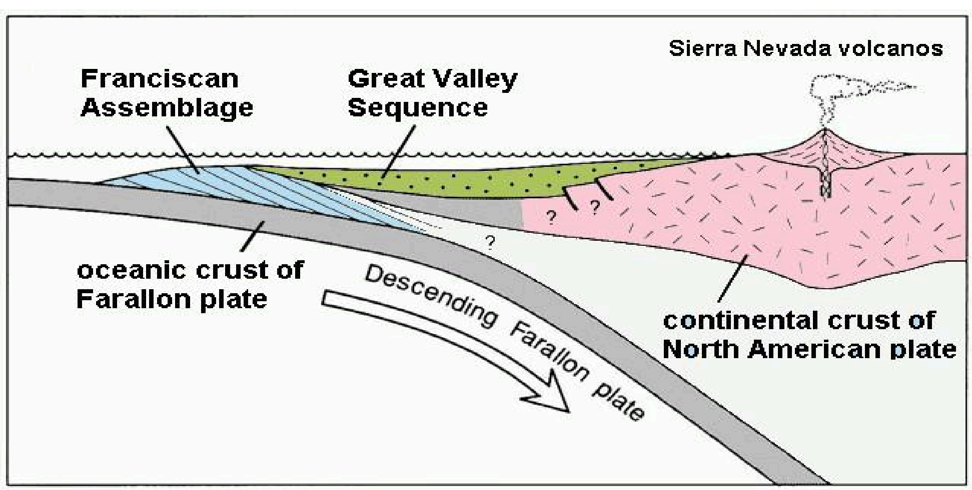

Figure 3. The figure depicts the formation of the Franciscan Assemblage, Great Valley Sequence, and Sierran arc by the subduction of the Farallon plate. Figure is by Irwin, 1990 modified by Mike Clark (CC BY-SA 3.0).

Figure 4. This figure is a topographic map of sedimentary units in the Santa Barbara region, created by draping Dibblee geologic maps over USGS topographic maps. See Figure 5 for associated rock unit colors and descriptions.

3. Stratigraphy of Santa Barbara

Santa Barbara's regional stratigraphy is composed of five major units that were deposited from 51-27 Ma during the Eocene and Oligocene epochs (Figure 5). Listed in order of deposition, these rocks were deposited in California's forearc basin as the Santa Barbara block was moved northward. The Sespe and Coldwater formations are described in further detail as they are highlighted throughout this guide.

The Juncal formation, the oldest of the units, is primarily composed of dark gray micaceous marine shale and has interbeds of tan sandstone. Overlying the Juncal is the Matilija formation, composed of thick bedded tan marine sandstone with thin partings of micaceous shale. Next is the Cozy Dell formation, a dark gray marine siltstone formation with gray and tan sandstone interbeds.

Following the Cozy Dell is the marine Coldwater formation, composed of highly resistant large blocky beds of golden tan and yellow sandstone. The clasts are fine to medium-grained, rounded, well-sorted, and primarily quartz and feldspars. Cross bedding and extensive jointing can be observed throughout.

The Sespe formation, overlying the Coldwater, is the youngest and most prominent unit in the Santa Barbara region. Characterized by its reddish brown color, the terrestrial Sespe formation contains major sandstone bedding and a 30 m basal conglomerate layer. The Sespe Conglomerate is composed of alternating beds of mudstone and conglomerate. Mudstone beds are reddish brown in color and are thin, ~20 cm in width. Conglomerate beds contain angular pebble to cobble sized clasts composed of various sedimentary and plutonic igneous rocks. Larger clasts are primarily chert, quartzite, and weathered gabbro, containing plagioclase and pyroxene.

Overlying sandstone beds are dark tan to gray with loosely compacted, reddish brown shale interbeds. The rounded clasts are fine grained, well-sorted, and composed of quartz and feldspars with minor biotite. Sedimentary structures such as rip up clasts and scour and fill are found intermittently at the base of sandstone beds. This guide will provide information on locations to observe the Sespe and Coldwater formations while further discussing the geologic features found.

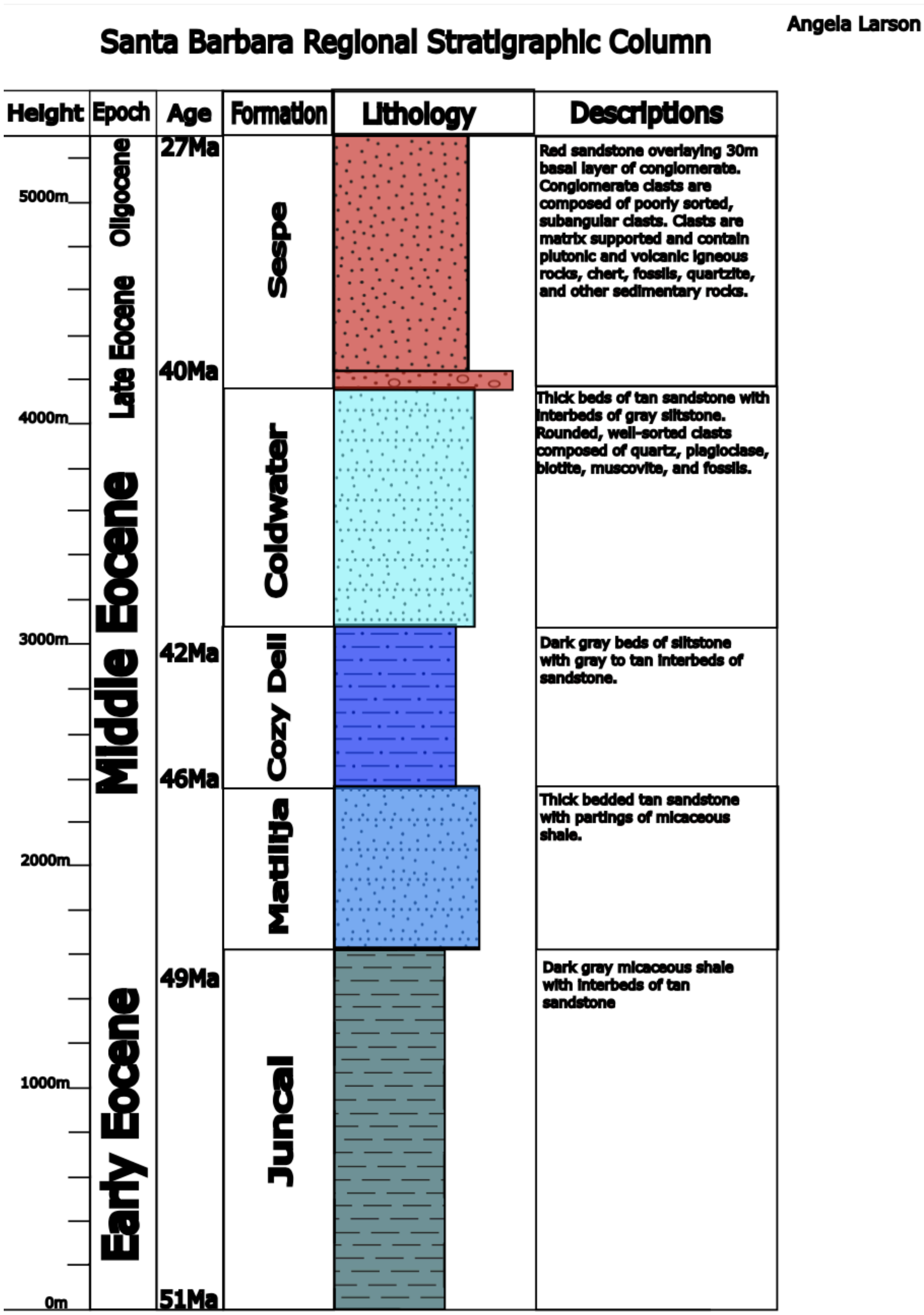

Figure 5. This regional stratigraphic column describes the five major sedimentary units in Santa Barbara. In the Lithology column, horizontal lines represent shale and dots represent sandstone. The rock unit color matches the topographic map in Figure 4.

Rattlesnake Canyon is a picturesque hiking trail at the base of the Santa Ynez Mountains that provides stunning views over Santa Barbara and the Channel Islands. The trail starts just north of Skofield Park on Las Canoas Rd, ~10 km from Downtown Santa Barbara.

The first 500 m of the hike is within the Sespe formation. Outcrops here are limited, however take notice of the red, crumbly soil and weathered pebbles from the basal conglomerate underfoot. Hike along the trail until reaching an offshoot on the right, then follow the offshoot until reaching Gibraltar Rd. At Gibraltar Rd, look uphill from the offshoot to observe the 0.1-1 m thick golden tan sandstone beds of the Coldwater formation. Look downhill from the offshoot to observe the contact between the Coldwater and Sespe formations, marked by the 0.15-1 m thick reddish brown basal conglomerate beds. The Sespe unit is younger than the Coldwater, yet it is physically underneath the Coldwater. This indicates that the rock units here are overturned. Additionally, the reverse grading in the Sespe Conglomerate beds and strike and dip measurements (Figure 6) are further evidence of the overturned orientation. Overturning occurs from tectonic movement, such as uplift and folding that causes the stratigraphy to become inverted.

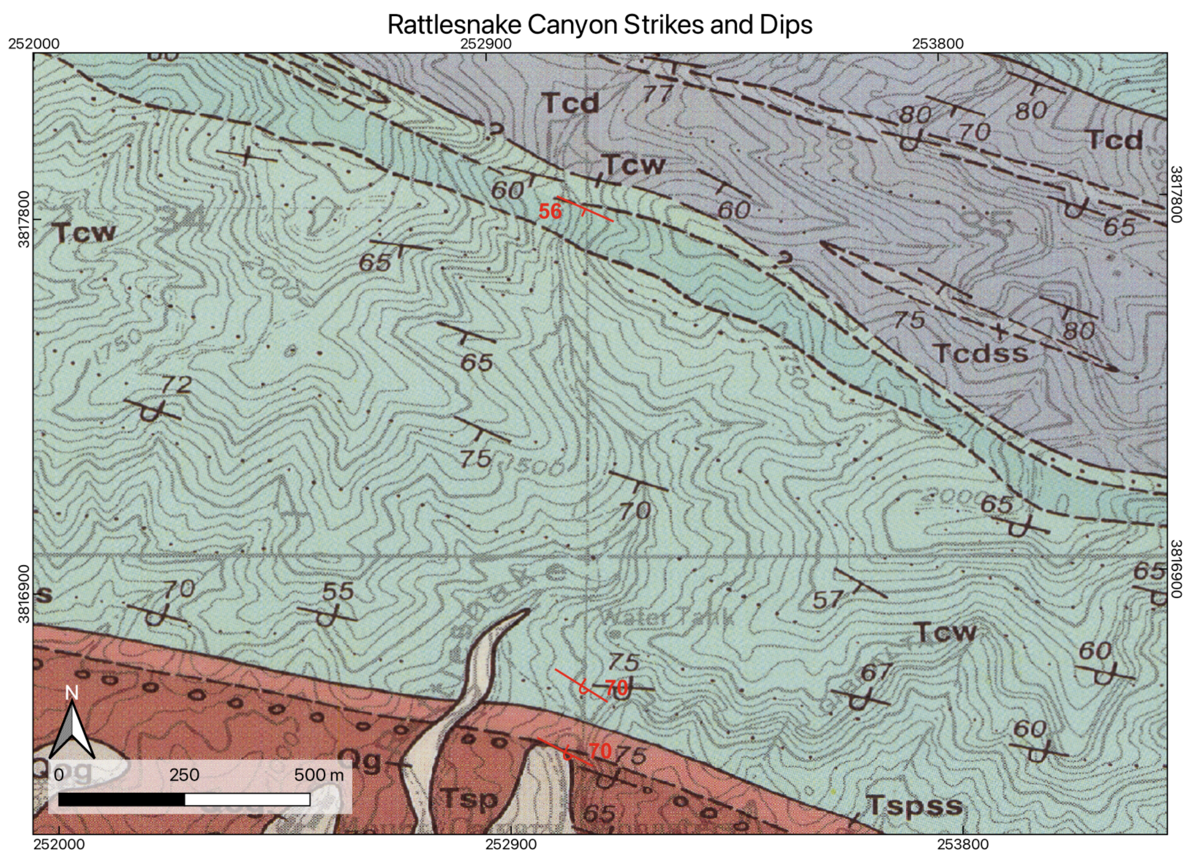

Figure 6. This map of the strikes and dips of Rattlesnake Canyon and Gibraltar Rd map the varying orientation of the Sespe Shale Sandstone and Coldwater Sandstone units.

A great location to further examine the Sespe formation is a ~220 m portion of San Marcos Rd (Figure 7), located at 34° 28' 08" N, 119° 48' 02" W. To access the transect, turn onto North San Marcos Rd from Cathedral Oaks Rd and drive 2.3 km. Park at the turnout and walk down to the transect on the east side of the road.

The alternating beds of reddish brown shale and sandstone described in Figure 8 are well exposed, despite slight vegetation coverage. This outcrop displays beds of ~1-20 meters thick, with sandstone trending slightly thicker than shale. Cross bedding in sandstone beds are observed throughout the transect, along with rip up clasts and scour and fill at the base of sandstone beds, indicating upright orientation. Additionally, strike and dip measurements confirm upright orientation.

The fluctuation between shale and sandstone is diagnostic of a meandering stream system. Rip up clasts and scour and fill are sedimentary structures often found in conjunction with a meandering stream system as they represent displacement of shale from the re-introduction of water flow.

Figure 7. This annotated satellite image is a map of the San Marcos Road transect. The transect is marked by the black line and is ~220 meters in length. This photo is from Google Earth.

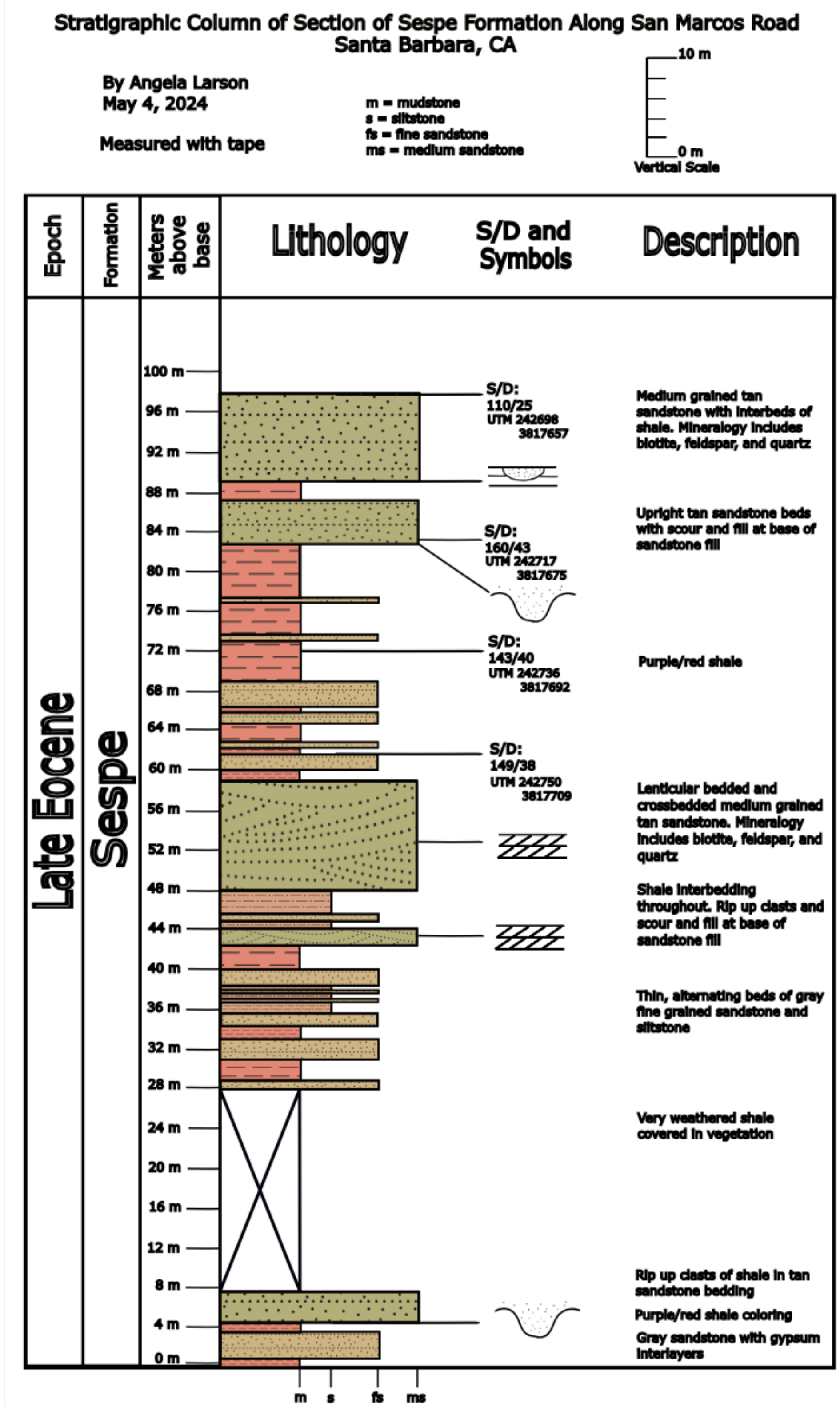

Figure 8. The stratigraphic column of the Sespe Shale Sandstone unit along San Marcos Rd displays the variable bedding thickness and sedimentary features throughout. The "X" in the column denotes stratigraphy concealed by vegetation.

4. Geologic Structure of Santa Barbara

The Santa Barbara region has undergone significant tectonic deformation due to the rotation and compression of the Santa Barbara block along western California. The transform motion of the San Andreas fault is largely responsible for the rotation and compression of Santa Barbara against the Nacimiento and Salinian blocks. This has resulted in the uplift of various geologic features such as the exposed folds and coastal bluffs found in this region.

The Ellwood bluffs are a great location to observe angular unconformities and wave cut terraces. To reach the bluffs, park on Santa Barbara Shores Dr off of Hollister Ave. Take the trail at the end of the street and continue straight until reaching the edge of the bluffs. Look west to view the angular unconformity imaged in Figure 9.

Angular unconformities can be interpreted as wave cut terraces, a coastal sedimentary feature formed by wave erosion and deposition of loose sediment such as sand, soil, and shells on the beveled surface. These terraces are then exposed through uplift and sea level retreat, making them particularly useful for calculating uplift rates. This is done by measuring the height of the terrace and adjusting for paleo-sea level height, then dividing by the age. For Ellwood Mesa, the uplift rate is 1.2 mm/yr, however these rates vary from 0.96-1.36 mm/yr across Santa Barbara's coastlines. The progressive compression of the Santa Barbara block is the cause of variable bluff uplift rates.

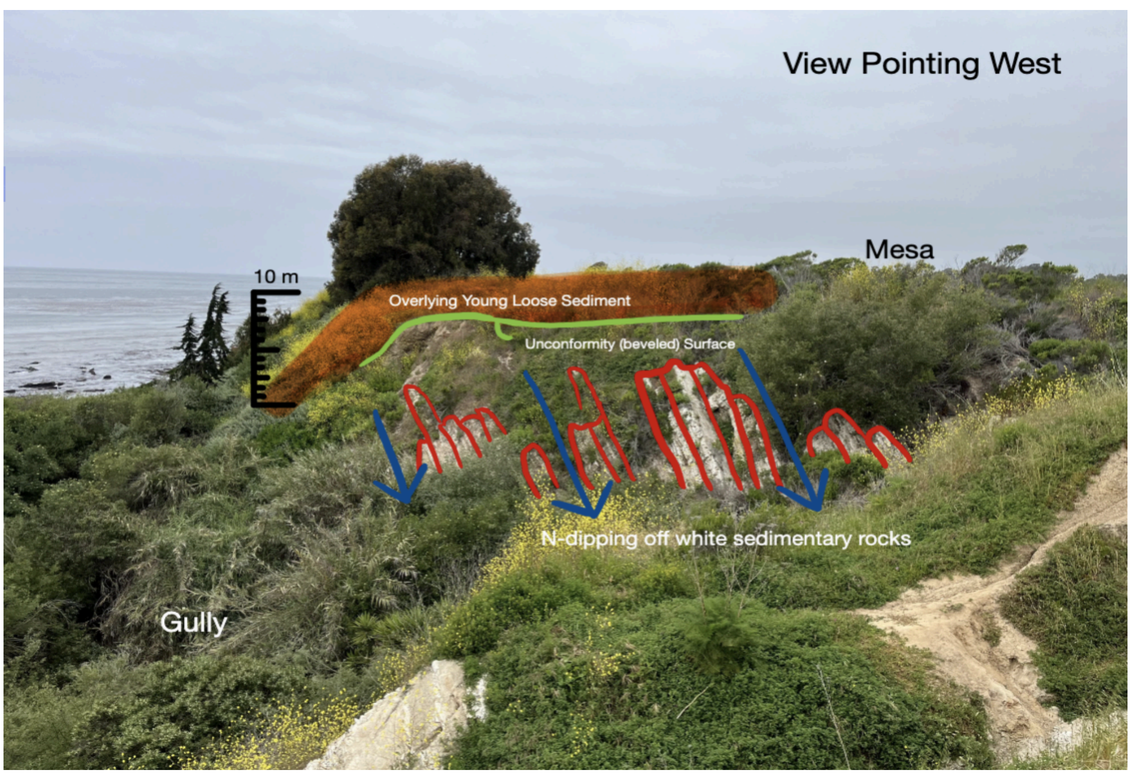

Figure 9. A wave cut terrace, interpreted by an angular unconformity, at the Ellwood bluffs shows the north-dipping Monterey formation truncated by overlying sediment.

The deformation of the Monterey formation is well exposed in the bluffs at Ellwood Beach. This formation, the youngest of the Santa Barbara units, was deposited in a transform basin and is composed of diatomaceous shale. The Monterey formation is responsible for the natural oil seeps that occur in the Santa Barbara basin. The natural oil formed by mass die off events of silica rich phytoplankton called diatoms that became buried organic matter in sediments and converted to oil through increased pressure and temperature.

To reach Ellwood Beach, travel west along the trail from the wave cut terrace until reaching a downward sloping offshoot on the left. Take the offshoot down to the beach, then walk ~0.8 km until reaching a series of weathered wooden posts along the bluffs at 34° 25’ 25” N, 119° 54' 17” W. Follow along the bluffs and notice the exposed synclines and anticlines (Figure 10). At 34° 25’ 27” N, 119° 54' 21” W, a large upright anticline is exposed with a subangular fold hinge that trends 273° and plunges 22° (Figure 11). The plunge line is best observed through the alignment of exposed bedding in the intertidal zone of the beach. The folds observed here are a result of ductile deformation caused by the compression of the Santa Barbara block.

Figure 10. The red strike and dip measurements taken along Ellwood Beach overlie satellite and Dibblee geologic maps to indicate structure orientation and folding. The black fold axes overlie the satellite map to display the syncline or anticline nature of the fold.

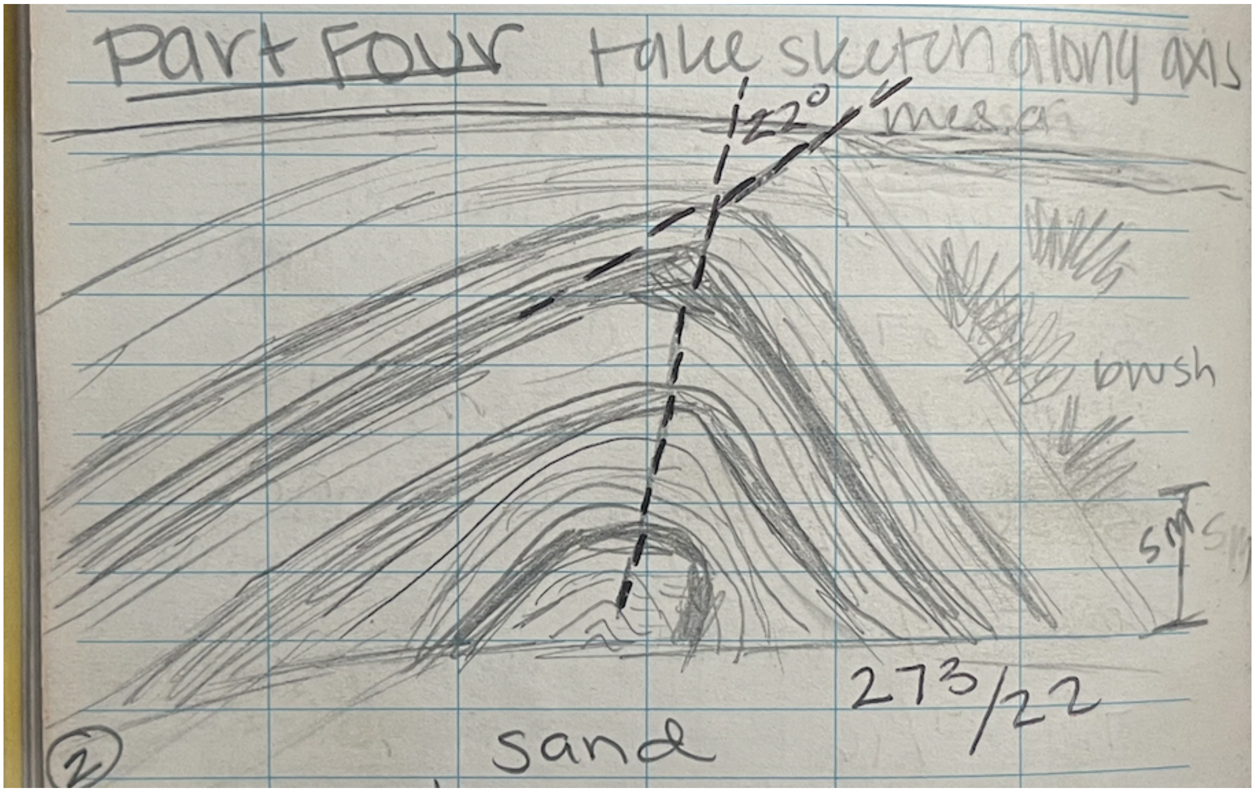

Figure 11. This drawing is of the large anticline at Ellwood Beach. The subangular fold hinge trends 273° and plunges 22°.

Another prominent fold in Santa Barbara is the syncline along East Camino Cielo Rd. To access the syncline, follow along East Camino Cielo Rd until reaching 34° 30' 52" N, 119° 48' 03" W, then park at the turnout in the road. The mapped cross section in Figure 12 starts ~0.3 km downhill from the turnout, spanning ~3.5 km of East Camino Cielo Rd.

Figure 12 is a geologic map of the syncline containing three formations: the golden tan and highly resistant sandstone of the Coldwater (Tcw), the reddish brown conglomerate with mudstone interbeds of the Sespe Conglomerate (Tsc), and the reddish brown alternating sandstone and shale beds of the Sespe Shale Sandstone (Tss). Refer back to section 3 on the stratigraphy of Santa Barbara for detailed rock descriptions.

The majority of the bedding along this transect dips east and north, however the orientation of the units begin dipping to the west at 34° 31' 06" N, 119° 47' 36" W. As shown in Figure 12, these units dip towards each other, indicating that a syncline is present. Additionally, the bedding reflects across the observed fold axis, providing further evidence of a fold (Figure 13). The folds in this area, much like at Ellwood Beach, are caused by ductile deformation of the Santa Barbara block. The compression of sedimentary features by the movement of the San Andreas fault provides the unique geologic environment of Santa Barbara.

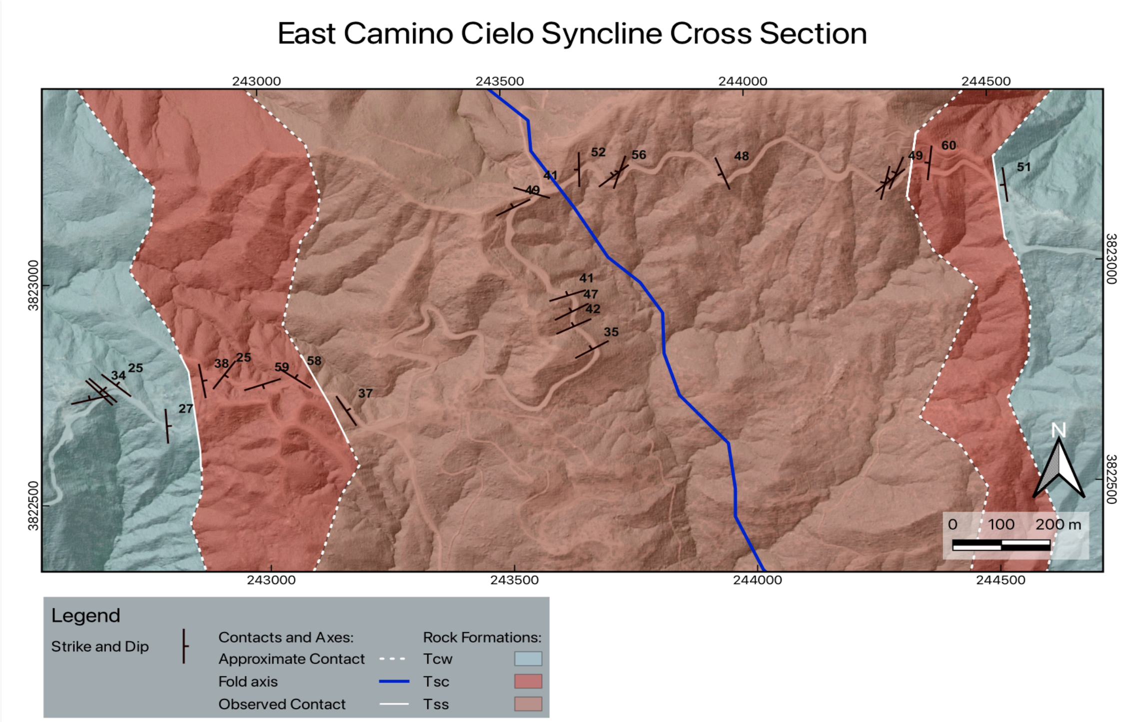

Figure 12. This geologic map of the East Camino Cielo syncline displays the contacts between the Coldwater (Tcw), Sespe Conglomerate (Tsc), and Sespe Shale Sandstone (Tss) and the syncline fold axis, denoted by the change in dip direction of the black strike and dip symbols.

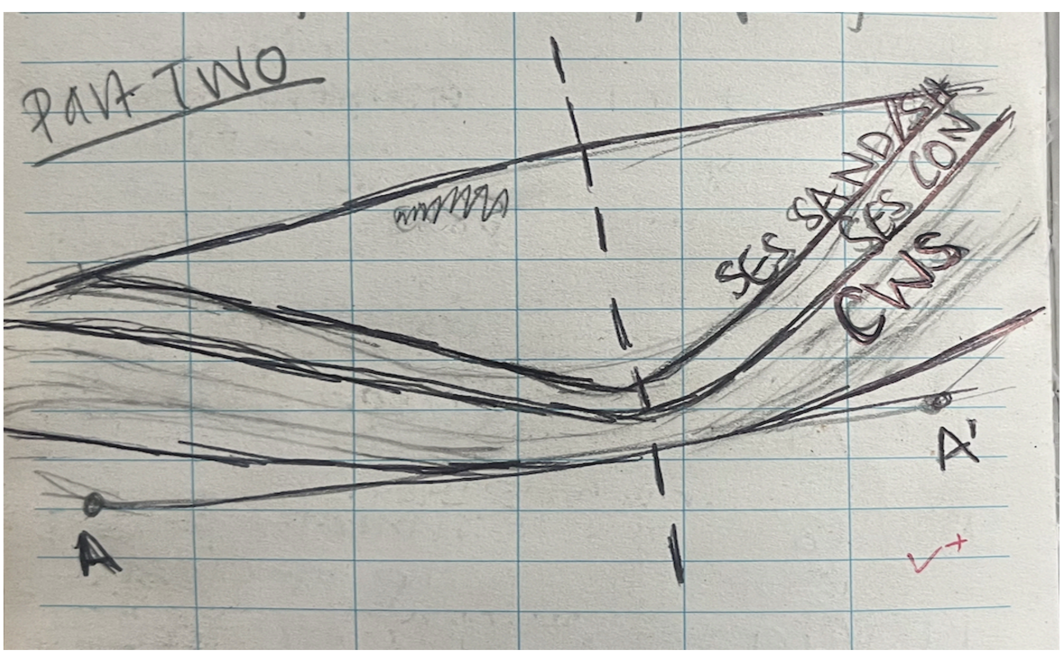

Figure 13. This drawing of the East Camino Cielo syncline depicts the shape of the syncline while also displaying the mirrored stratigraphy of the sedimentary units.