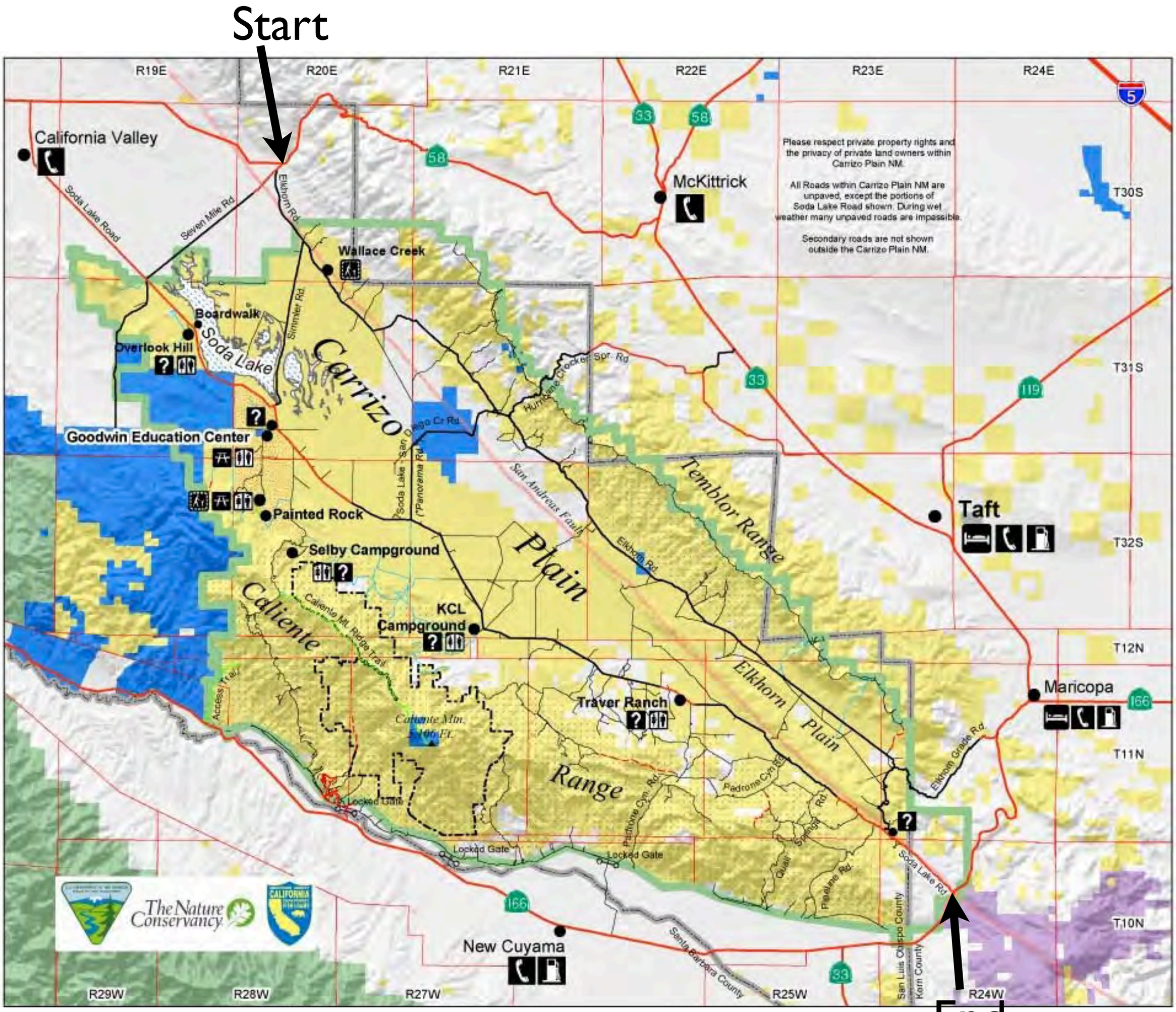
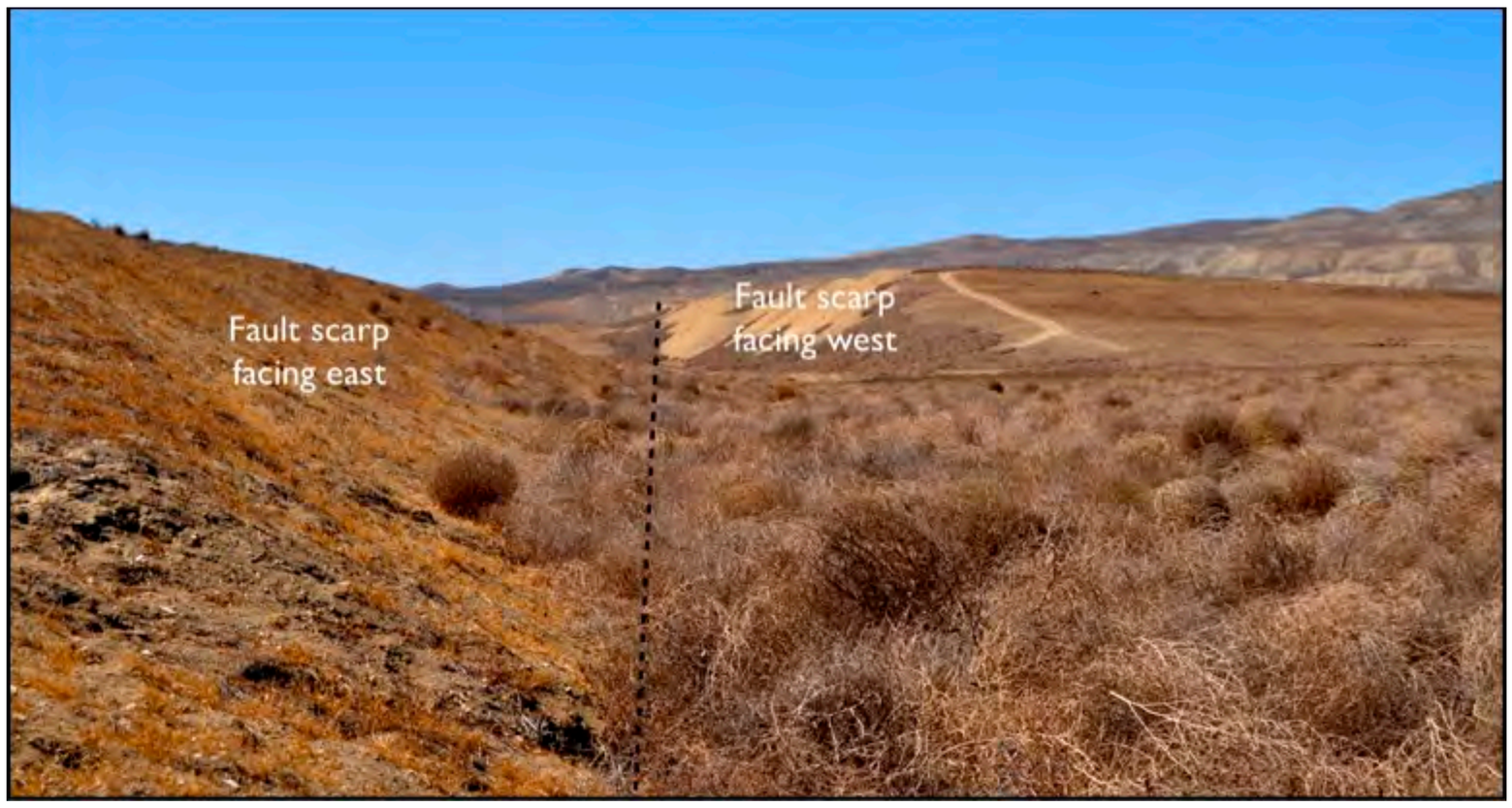
GEOLOGIC GUIDE TO ELKHORN ROAD CARRIZO PLAIN NATIONAL MONUMENT

This guide is for a north to south road trip down Elkhorn Road, which lies mostly within Carrizo Plain National Monument at the western edge of the Temblor Range. The road is an unpaved but graded dirt road that is best attempted when the road surface is dry. It can be muddy when wet, and may be subject to local flooding during heavy rains.



Start at Highway 58 and 7 Mile Rd. Our guide will take you down Elkhorn Rd., 0.31 miles from the start, but if you continue on 7 Mile Rd another 0.85 miles from Hwy.58 you will find the San Andreas fault a little east of a small rise on your right, just before a slight bend in the road. At the rise, look north to see an east-facing fault scarp adjacent to the road, and further away a west-facing scarp. Look to the south and you will see a right-lateral offset on the small west sloping drainage channel. To continue, return to Elkhorn Rd.



View northward from 7 Mile Road showing east and west facing fault scarps along the trace of the San Andreas fault.

Looking south from the same point on 7 Mile Road showing a gully entering from the left, turning toward the viewer along the trace of the faut, and then turning to the west adjacent to the road. The high ground divering the channel is called a shutter ridge,

Starting south on Elkhorn Rd. (35.3185-119.856) the low hills closest to the road consist of late Pliocene-Pleistocene Paso Robles Formation, mostly clays, sands and gravels of an older phase of valley fill that has now been uplifted and folded. Here the bedding dips between 44-67 degrees toward Elkhorn Road. The hills in the middle distance are underlain by the marine Gould Shale Member of the Monterey Formation, of mid-Miocene age, and the marine Temblor Formation of early Miocene or Oligocene age. Both units show up in a steeply folded anticlinal structure, none of which is evident from the road.

Continuing south you will see some white colored, gullied badlands on the slopes of the Temblor Range. These are cut into the poorly consolidated Pliocene Morales Formation.

Pale colored badlands of the poorly consolidated Pliocene Morales Formation.

UNITS SEEN ALONG ELKHORN ROAD

Era	Period	Epoch	Start, million years ago
Cenozoic	Quaternary	Holocene	0.0042
			0.0082
			0.0117
		Pleistocene	0.129
			0.774
			1.8
			2.58
	Neogene	Pliocene	3.6
			5.333
		Miocene	7.246
			11.63
			13.82
			15.97
			20.44
			23.03
	Paleogene	Oligocene	28.1
			33.9
		Eocene	37.8
			41.2
			47.8
			56
		Paleocene	59.2
			61.6
			66

ALLUVIAL FILL OF VALLEY FLOOR

PASO ROBLES FORMATION
(Continental)

MORALES FORMATION
UNNAMED MARINE SANDSTONE
(Late Miocene Early Pliocene)

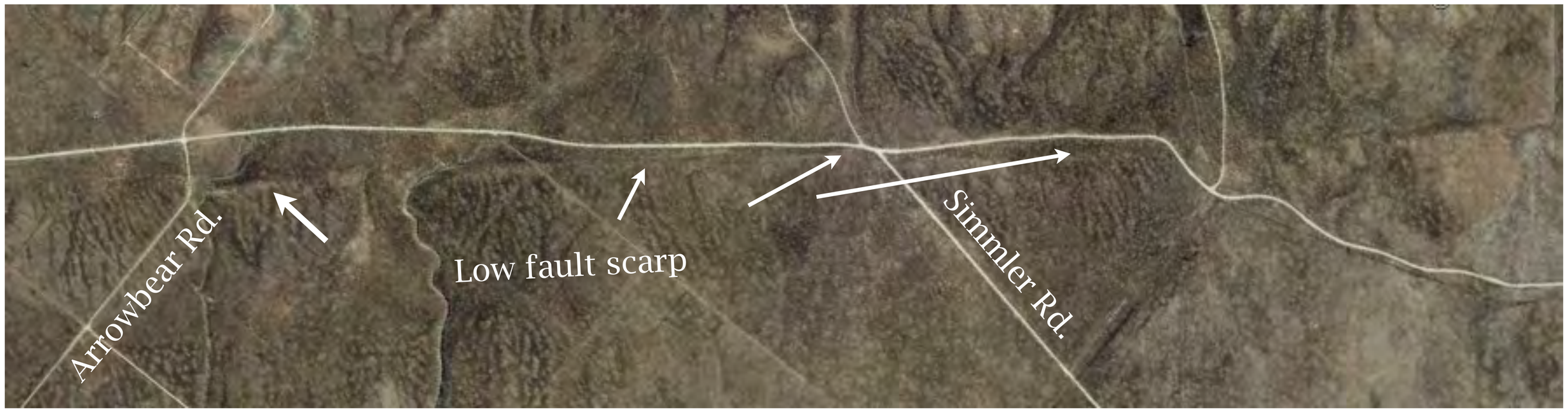
BITTERWATER CREEK SHALE
(Late Miocene marine)

SANTA MARGARITA FORMATION
(Late Miocene marine and alluvial

MONTEREY FORMATION
(Marine)

TEMBLOR FORMATION

Descriptions of each geological unit can be found at the end of this guide



Google Earth snapshot of Elkhorn Road between Arrowbear Rd. and a point just north of the Wallace Creek parking area.

At 1.85 miles from the start (35.29363-119.84945) you will see Arrowbear Rd on the right. Just after passing it a low gully crosses Elkhorn Road (35.29258-119.84814) and then turns and runs to the northwest along a low fault scarp of the San Andreas fault before turning to the west again. This is another drainage offset by the fault.

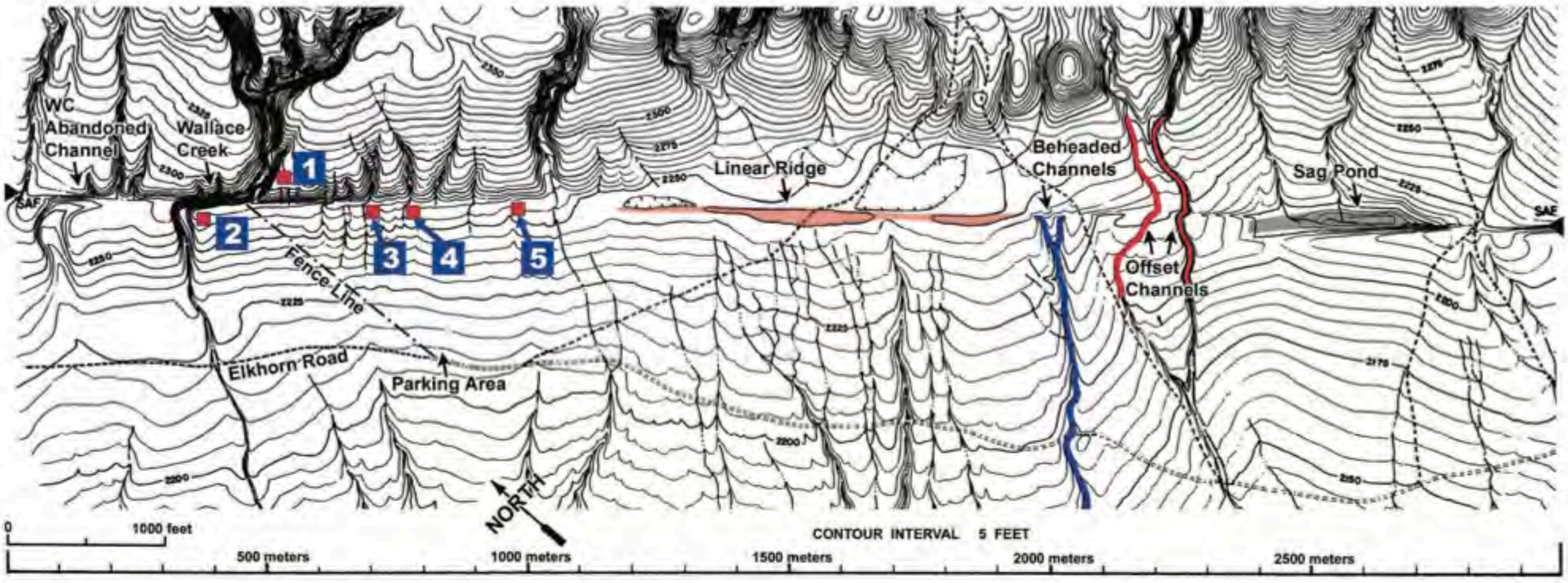
Continue on Elkhorn Road to the junction with Simmler Road (2.71 miles from the start 35.28356-119.84003) This appears as San Diego Creek Rd on some maps. The low fault scarp seen at Arrowbear Road now crosses from the west side to the east side of the road at the Simmler/Elkhorn intersection. The slopes immediately to the east of the road are underlain by Paso Robles Formation. Simmler Road descends toward Soda Lake on alluvial fans of Recent Alluvium.

Continuing to the southeast, the road runs along the fault until it takes jog to the right and passes under a high tension power line. The fault now forms a low scarp about 1,000 ft. to the east. Continue to the parking area for the Wallace Creek exhibit on the San Andreas fault. (35.26730-119.82713). There is a trail up to an interpretive sign at the offset drainage "Wallace Creek". Many past earthquakes have now offset the stream by 0.1 mile. This is regarded as one of the best places to view past movement between the North American and Pacific Plates.

Interpretive pamphlets are usually available at the parking lot, There is a small trail along the base of the fault scarp to the southeast of the offset stream. Here you can see small gullies that were offset 10-20 feet by the great 1857 earthquake, which was the last earthquake to occur on this section of the fault. The fault scarp is formed in Paso Robles Formation material. A screen shot of a portion of the pamphlet is shown on the next page with information about offsets generated in the 1857 earthquake.

Please note that the area between the parking lot and the fault is Endangered Species Habitat, so please use the trails when returning to your car as you may crush the burrows of these rare animals.

(Left) The famous Wallace Creek offset. The creek channel enters from lower right, turns 90 degrees at the shutter ridge , and then turns again to the west. The total offset is about 430 feet, and represents the cumulative offset of the last 10,000 years. The last earthquake as in 1857, when the fault moved 30 feet horizontally and 3 feet vertically.
(Below) Taken from the pamphlet that is usually available at the trailhead. Points 1 and 2 are at each end of the Wallace Creek offset, and Points 2, 4, and 5 are offsets from the 1857 Fort Tejon earthquake

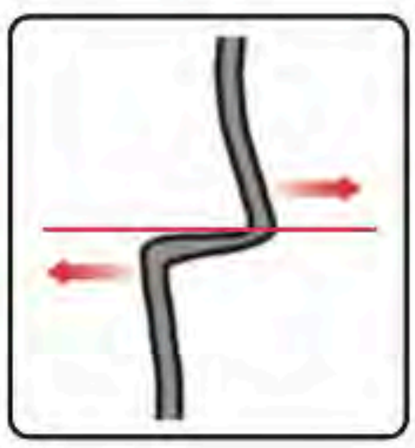


3 and 4 More clues to the past

Post 3. Look northeast (upstream). Follow the course of the small creek down to the fault where you are standing. Now look southwest (downstream), and see if you can find it. You might not see it at first. Where did the channel go?

From **Post 3**, walk northwest 30 feet (9 m) along the fault. Look again for the downstream channel. It is not as obvious as the upstream channel, but it is still a visible gully. Like Wallace Creek, this channel has been **offset** by motion along the San Andreas fault.

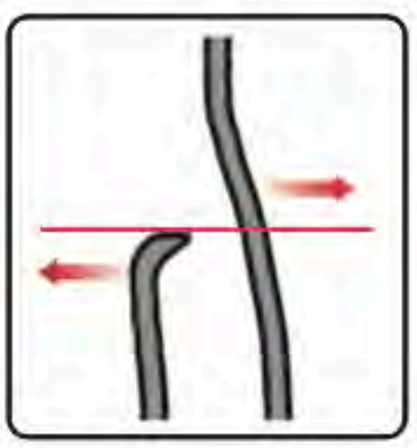
Now do the same at **Post 4**. If you can find the offset channel, you are doing the work of a geologist!



5 A channel with no source

Post 5. Look southwest (downstream). There is another channel here, although it is very subtle and may be difficult to recognize. Where did it come from? Look northeast (upstream)—there is no source for this channel, nothing to flow into it! There is only an "escarpment"—a steeply sloping hill. The downstream landform is called a **beheaded channel**.

A stream once flowed downstream into this channel, but motion across the fault has separated it from its original source. Where is that source now? The original upstream portion of this channel must lie somewhere to the southeast—this is because the upstream portion has been carried in that direction by plate motion.



Make a note of your odometer reading. As you continue on Elkhorn Road, you cross alluvial fans that descend gently to the salt pans of the Soda Lake complex. These are ephemeral alkali lakes that form salt pans when they dry out. Rainfall, on entering the Carrizo Plain, has no outlet, and collects on the lowest part of the valley floor with all of the salts released by chemical weathering of the surrounding rocks. The white salt cover of the lake bed forms when the salt is drawn from the underling clay sediments. The two largest lakes are separated by a clay dune, a linear mound of dusty material blown off the lake floor and deposited on a ridge downwind of the salt pan, Other smaller lakes lie between other, smaller clay dunes which define their linear shapes. Simmler Road crosses the valley on a clay dune. (see Google Earth image below)

Continue south past Wallace Creek along Elkhorn Road for about 1.5 miles. Look to your left at the low scarp of the San Andreas fault, about 0.2 miles away ('A' in the photo on the next page). The opposite side of the fault was uplifted, and so southwest flowing streams have cut down into the fault scarp. The road continues quasi-parallel and south of the fault. The higher ground east of the fault is on uplifted Paso Robles Formation, the lower ground between the ridge and road is formed of alluvial fans of modern alluvium.

At 2.6 miles past Wallace Creek (35.23953-119.79775, 'B' in the photo on the next page), the road turns sharply to the left. The 'real' Elkhorn Road goes to the left, but some maps mislabel the 'straight ahead' road as Elkhorn Road. Go left, not straight. At 0.23 miles past the bend the road crosses the San Andreas fault which has been buried under young alluvial fan material and does not show up as a recognizable feature ("C" in the photo on the next page).

Google Earth photo showing positions of Wallace Creek (A), the left turn on Elkhorn Road (B), the road crossing of the San Andreas fault (C), and the gap (D) discussed below.

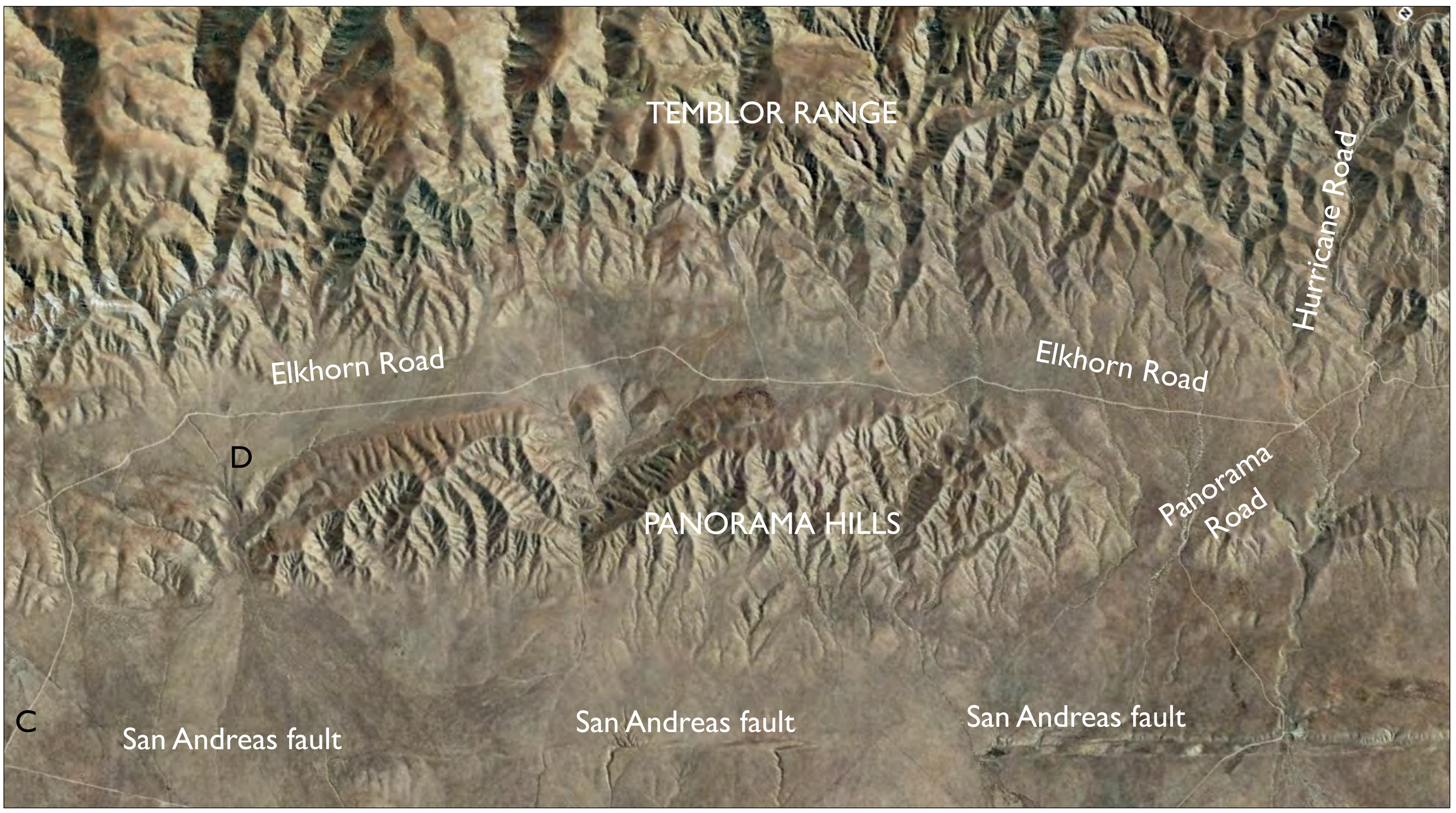
After crossing the San Andreas fault, the road passes a cattle guard at 35.2411 -119.7912, and climbs into some low hills of the Paso Robles Formation and the northwest end of the Panorama Hills. The road then turns back to the southeast in a valley between the Panorama Hills and the Temblor Range. At 0.6 miles past the turn a gully crosses the road and descends to a gap in the Panorama Hills ('D' in the photo above) . The gap was eroded by ephemeral runoff, but also has Paso Robles Formation on the north side and Morales Formation on the south side (35.24452-119.77170). The older Morales Formation underlies the Paso Robles Formation, the latter being removed by erosion on the south side of the gap.

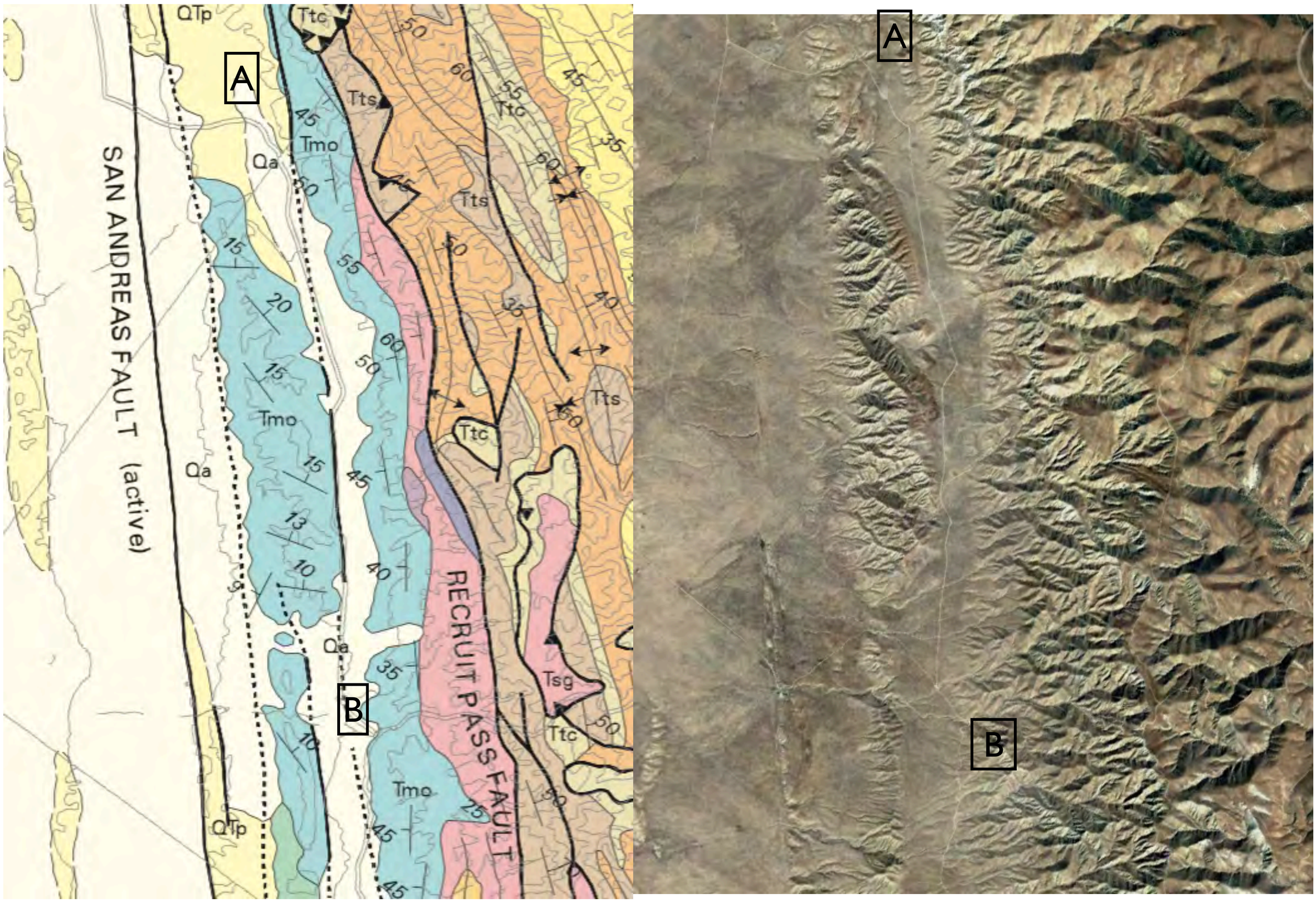
The Temblor Range seen from the 'dogleg' on Elkhorn Road. Most of the oucrops exposed on the hillside are of the Gould Shale member of the Monterey Formation. The photo was taken during a wildflower superbloom in 2017. The road here is on private property, so please respect fences and do not trespass,

Looking north from the Panorama Hills toward Elkhorn Rd. and the lower slopes of the Temblor Range.

The low slopes on both sides of the valley are underlain by the Morales Formation. The bushes are *Ephedra*, common name “Mormon Tea”

The Temblor Range on the east side of the road is dominated by Morales Formation at the base of the slope, overlain by Santa Margarita Formation. A southwest dipping reverse fault separates the Santa Margarita Formation from older Gould Shale Member of the Monterey Formation, which is higher on the slope, and is highly folded and faulted and containing faulted slivers of the older Temblor Formation. A road enters from the west at 35.19889-119.72129. This is Panorama Rd., which connects to Soda Lake Road. **This road is not advisable when wet or it has recently rained, and it can stay wet for weeks. Be very careful as there is no tow service. Many people have beeb stranded on Panorama Road in the winter.** Continue to the junction with Hurricane Road (35.19818-119.71454., **Note your odometer reading,**





(Above) Geologic map (left) and screen shot (right) from Google Earth of Elkhorn Road's pass through the Panorama Hills in the north ('A') to the junction with Hurricane Road in the south ('B'). The blue 'Tmo' on the geological map is Pliocene Morales Formation, an old valley alluvial fill, pink is shallow marine Santa Margarita Formation of late Miocene age, seen as paler shaded and more highly gullied than other units in the aerial view. The units shown as brown and tan on the map and lettered Tt- are Miocene marine deposits of the Temblor Formation, and show up as brown colored surfaces on the right side of the photograph. The Santa Margarita and Temblor Formations are in contact along the Recruit Pass fault, a compressive reverse fault with uplift on the east side. Shales of the Monterey Formation lie further to the east and along the crest of the Temblor Range.

Eroded slopes of the Temblor Formation on the upper slopes of the Hurricane Road grade. The photo was taken during a wildflower superbloom in 2017. BLM recommends 4-wheel drive for this road.

If you want up-close views of geological formations in the Temblor Range, take Hurricane Road to the top of the ridge. (Note that it is quite steep and single track, 4-wheel drive recommended). For the first 0.46 miles up Hurricanr Road from the junction with Elkhorn Road, the Paso Robles Formation is exposed, tilted at about 45 degrees toward the southwest. From 0.46 miles to 1.1 miles Santa Margarita Formation is exposed, consisting of Miocene age alluvial fan and shallow marine sediments. Pebbles in the sediment are dominated by granitic rocks probably derived from west of the San Andreas fault, and now offset far to the northwest by displacement along the fault. Beyond 1.1 miles to the top of the ridge the bedrock is early Miocene to Oligocene Temblor Formation, here dominated by sandstones. At 1.1 miles the contact between the contact between the Santa Margarita and Temblor Formations is the southwest dipping Recruit Pass fault. Here the Temblor Formation is crumpled into folds and faults by compression. (This is likely due to low strength rocks of the Franciscan Formation deep below the Temblor Range). The compression shortened the Temblors from east to west, but thickened the depth of the rocks, resulting in the buoyant uplift of the range. At the crest of the hill a small patch of Santa Margarita Formation lies above a thrust fault.

Continue past Hurricane Road on Elkhorn Road. The road here lies on recent alluvium, with Morales Formation forming slopes on both sides of the valley. Several washes cross the road at 1.05, 1.65, 1.81 miles past Hurricane Road. At the first wash at 1.05 miles, the high point in the Panorama Hills seen on the downstream side of the gully is Panorama Point (35.17934-119.71069). The hill is underlain by an “Unnamed Marine Sandstone”, or alternatively “Panorama Hills Formation” which is poorly consolidated sandy and silty marine sediment of late Miocene or early Pliocene age, with an unconformable contact with the overlying Morales Formation.

A wash crossing Elkhorn Road containing granite pebbles from the Santa Margarita Formation and older units. The Temblor Range is in the background. (35.18579-119.70627)

At 2.5 miles past Hurricane Road (35.1741 -119.6859), Elkhorn Rd. dips through a relatively deep gully. The Panorama Hills fault parallels the strike of the hills on the east side of the road. The hills on the west are dominated by Panorama Hills Formation, and in the east by the Santa Margarita Formation. South of the gully, the Morales Formation pinches out along the fault and is no longer present. The Santa Margarita Formation is full of granitic and schist pebbles, and is of Miocene age. U.S.G.S. Geologist Tom Dibblee suggested that this material is derived from the Salinian Block and the west side of the San Andreas fault. The source terrane might now lie in the Big Sur region of the Santa Lucia Mountains.

As you drive further to the southeast, the Panorama Hills merge into the Temblor Range. At a wash at 35.15582-119.66743 the road turns south. Before the road resumes its southeasterly direction you will pass some steep slopes and gullied hills on the left, where the “Unnamed Marine Sandstone” is replaced by a gray silty clay of similar age, dipping toward the road.

Elkhorn Road now moves away from the Temblor Range into the open country of the Elkhorn Plain. The Carrizo Plain can be seen beyond a low ridge, created by uplift along the northeast side of the San Andreas fault. A small hill to the west standing above the gently sloping alluvium of the Plain that is underlain by the “Unnamed Marine Sandstone”. Cross a wash at 35.13880-119.65786. The hills where this wash emerges from the Temblor Range are of coarse sands and gravels of the Santa Margarita Formation. The wash contains a lot of granitic pebbles, derived from the older sediments to the east, and probably derived from granitic terrane that lay west of the San Andreas fault and then transported to the northwest along the San Andreas fault by the motion of the Pacific Plate.

To the west all the hills between Elkhorn Road and the Carrizo Plain are underlain by Paso Robles Formation. At this point you can see the back side of the ‘Dragon’s Back’ ridge, an eroded badland (arrows in photo above) . Caliente Mountain is the cloud capped distant peak. This ridge is best seen from the Traver Ranch area of the Carrizo Plain (photo below).

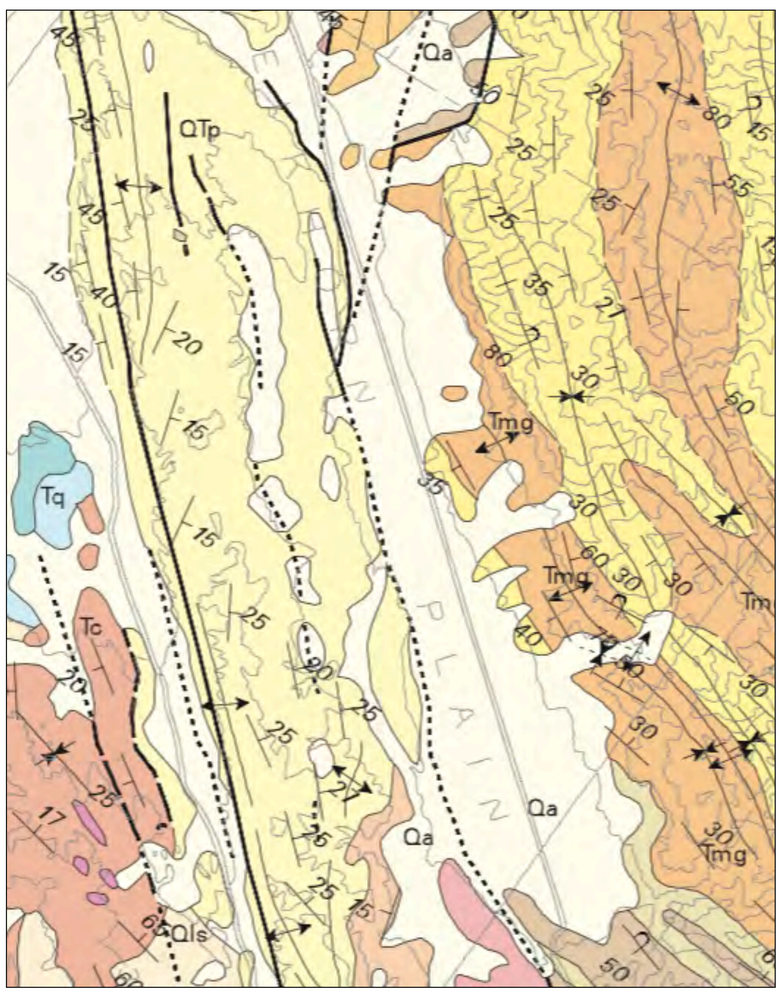
Continue about 2.5 miles (35.1186 -119.6222) until you see the exposed white clays of hills immediately east of the road (see photos next page). These are composed of the Bitterwater Creek Shale of late Miocene age. It is composed of marine siliceous siltstone and diatomaceous mudstone.

At 35.1015 -119.5989 you pass low hills composed of Bitterwater Creek Shale. These are seen on both sides of the road until 35.0877 -119.5759. The road now becomes very straight in a southeast direction. The Paso Robles Formation to the west is cut by a number of NW-SE trending compressive reverse faults, all fault offsets being downward on the east side and upward on the west side. The steep hills to the east predominated by diatomaceous and siliceous marine shales of the Miocene Monterey Formation.

(Above) White hills of weathered Bitterwater Creek Shale

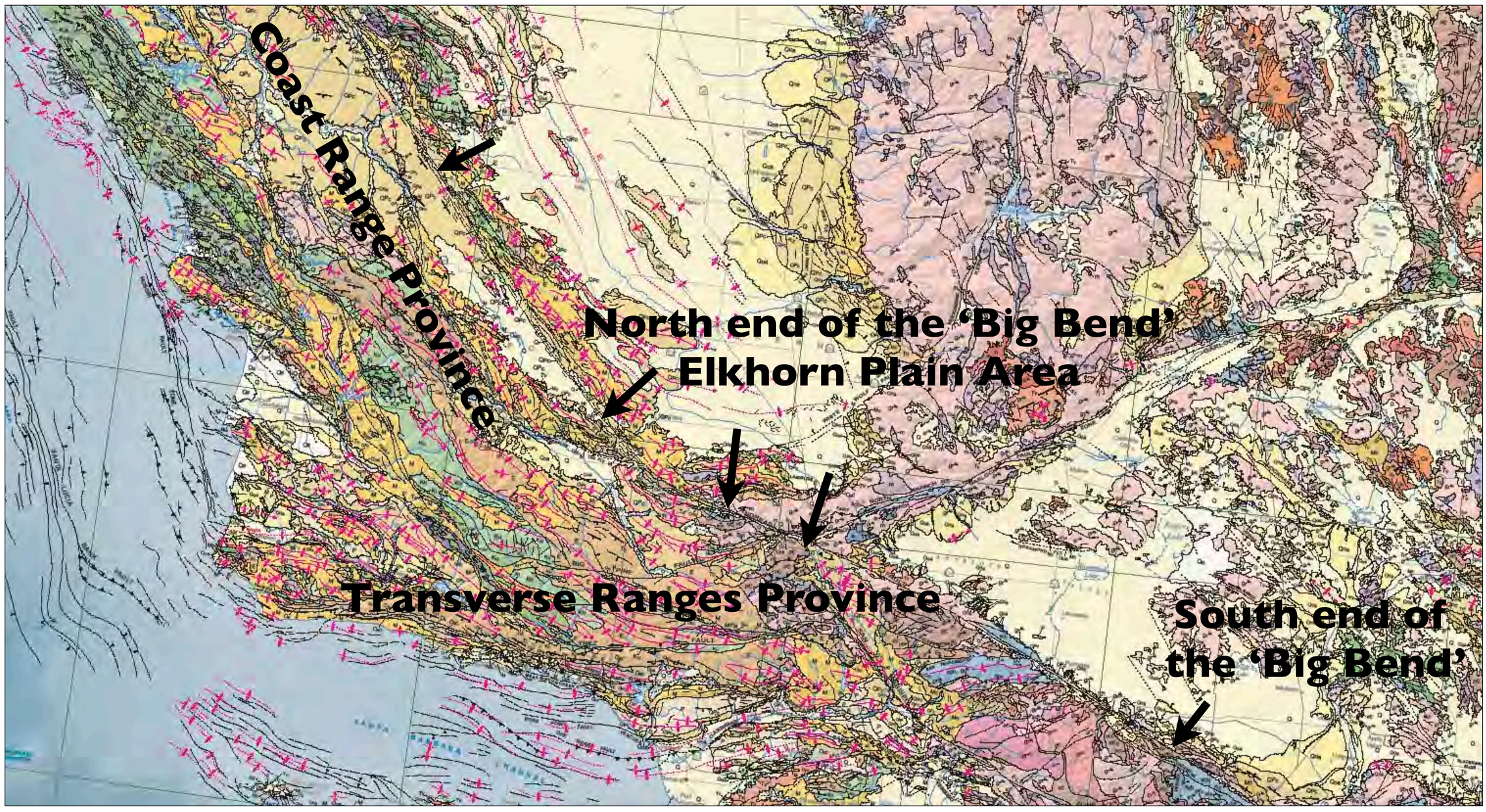
Continuing on, the road now enters the broad valley of the Elkhorn Plain. The hills on the east side are mainly of the Gould Shale Member of the Monterey Formation, a diatomaceous marine shale.

(Above) View south along Elkhorn Road. Hills of folded and faulted Paso Robles Formation lie between the Elkhorn Plain and Soda Lake Road.
(Right) Geologic map of the Elkhorn Plain showing yellow and tan shaded rocks of the Monterey Formation on the east side, and pale yellow Paso Robles Formation on the west side.



(Left) Gould Shale Member of the Monterey Formation, looking north from 35.0962-119.54960.

After the white clay hills, Elkhorn Road continues southward for about 6-7 miles on a very straight path. The long valley is closed off by hills at the southeastern end (35.02883-119.48262). At this point the road bends right, turning south and climbing on folded Temblor Formation shales and sandstones. The Temblor Formation is early Miocene and possibly Oligocene shallow marine strata. Much of this sequence has been folded into west dipping overturned beds. This is the point where the compressive features of the Transverse Ranges become evident, as the 'big bend' on the San Andreas fault has resulted in compression at right angles to the trace of the fault.



What is the 'Big Bend' in the San Andreas fault? The San Andreas fault 'should be' a long straight fault parallel to the N-W direction in which the Pacific Plate is sliding past the North American Plate. It is exactly that in the Coast Ranges and in southern California. However westward expansion of the crust in Nevada and Utah has pushed northern and central California westward, kinking the San Andreas fault into a more east-west direction in the 'Big Bend'. This causes the two plates to jam into each other, folding rocks into the east-west mountain ranges of what geologists call 'the Transverse Range Province'.

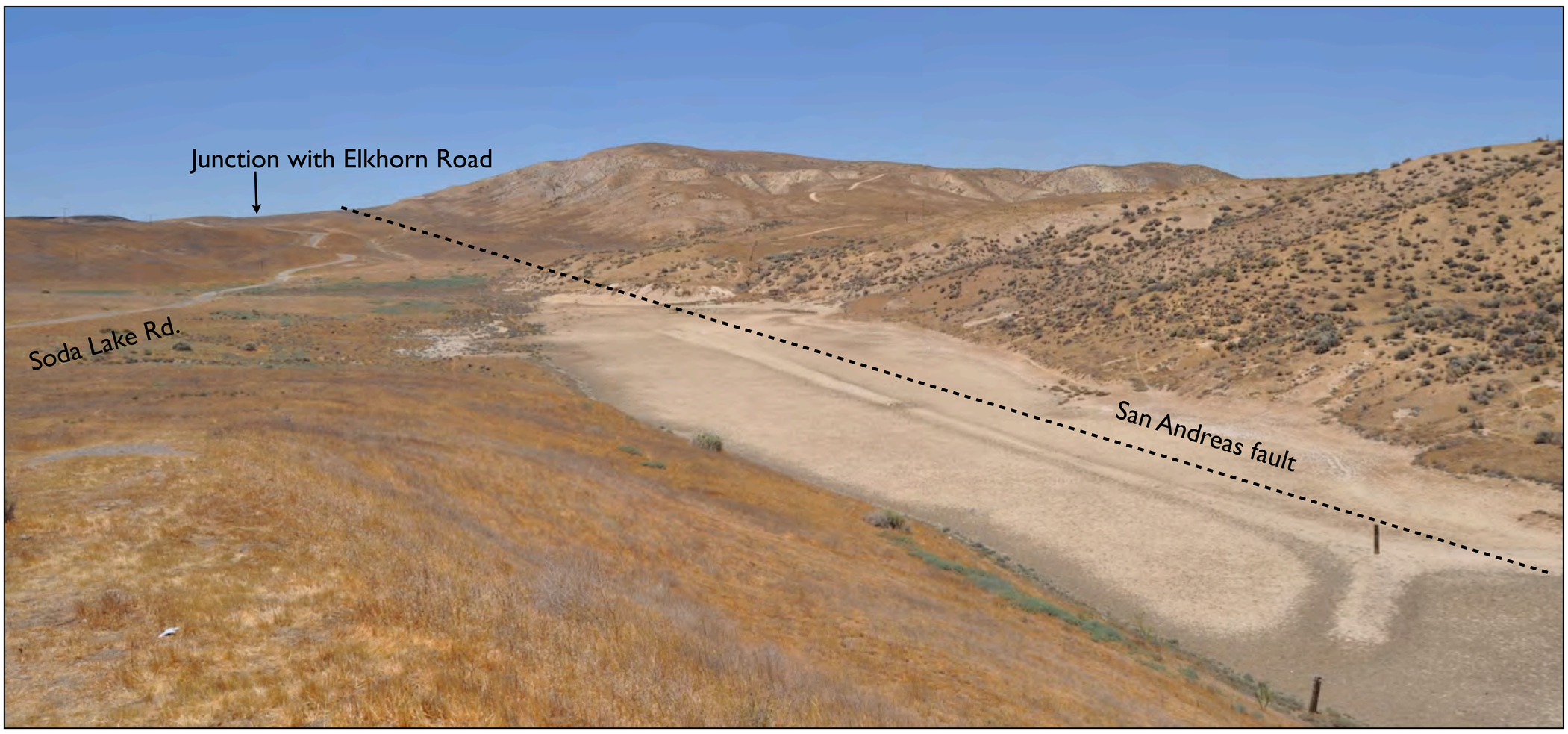
At about 1/4 mile after the road starts climbing out of the valley you will reach the intersection of Elkhorn Road and Elkhorn Grade Road (35.0252 -119.4826). Turn west (right) to return to reach Soda Lake Road and continue with the guide, turn left to go to Maricopa. Our guide continues to the right on Elkhorn Grade Road.

At about 0.6 miles past the intersection (35.0241 -119.4842), the road crosses the NW-SE trending Recruit Pass fault, which has a southwest dipping fault plane and is buried under recent alluvium at this location. On the southwest side of the fault, upper Miocene Santa

Margarita Formation lies against Temblor Formation on the northeast side of the fault. The Santa Margarita Formation here consists of both shallow marine and continental beds, marking a shoreline's shifting position, and the beds dip to the southwest. It is overlain by the Bitterwater Shale and, above that, the Paso Robles Formation.

Continuing southward you will pass cattle corrals to the right at 35.0157-119.4868. The Paso Robles Formation underlies the road from a point about 0.5 miles from the corrals (35.0087 -119.4874) to the road's junction with Soda Lake Road. The poorly consolidated sediments of the Paso Robles Formation have been recently uplifted along the east side of the San Andreas fault, resulting in deep gullying from runoff. The road skirts a deeply incised, east-directed drainage at 35.00537-119.49165 exposes Paso Robles Formation, and marks the axis of an anticlinal fold in the Paso Robles Formation.

34.9944 -119.4859 The road crosses the San Andreas fault, just before Soda Lake Road. Junction. Note the sag pond southwest of the intersection (photo below).



Looking north from the sag pond toward the Elkhorn Road/Soda Lake Road junction. The hills on the skyline are underlain by Paso Robles Formation. The sag pond formed when folding along the fault zone formed a closed drainage.

If you continue to the southeast on Soda Lake Road, you will be driving along the trace the San Andreas fault. Highway 33/166 is about 3 miles from the junction with Elkhorn Road, and you will pass another sag pond at about 2 miles from the junction.

If you turn to the northwest at the Elkhorn Road/Soda Lake Road junction, Soda Lake Road will return you to Highway 58. There is a separate geological road guide for Soda Lake Road.

DESCRIPTIONS OF GEOLOGIC FORMATIONS

TEMBLOR FORMATION

The Temblor Formation lies below the Monterey Formation, and most extensively exposed as sandstone-dominated marine deposits at the southern end of the Elkhorn Plain. It extends to the east beneath the Central Valley, and is thought to be the source of the oil in the 1998 Belleview No.1 well blowout. It represents in age the Zemorrian and Saucesian microfossil stages of Oligocene and early Miocene age, around 25 million years ago. The rocks were laid down at a time compression associated with subduction was replaced by transform plate motion on the incipient San Andreas fault system. The marine basin was being constricted from the open ocean by an uplift of rocks in the area of today's Diablo Range.

MONTEREY FORMATION

The Monterey Formation is a widespread geological unit encompassing a wide variety of rocks and environments, but nearly all of them are represented by fine grained deposits formed under deep marine conditions. The formation is commonly rich in diatomaceous sediments, representing a highly productive plankton population near the surface that contributed a rain of tiny siliceous tests onto the sea floor. It appears that deep water conditions were anaerobic, probably due to density layering within the water body. This resulted in preservation of much of the organic matter contributed to the seafloor by the deceased diatoms, and this organic matter was transformed into the oil and gas that is currently extracted from the western San Joaquin Valley. In the Temblor Range the dominant subunit of the Monterey Formation is the Gould Shale Member, which is as much as 2,000-3,000 feet thick at the southern end of the Temblor Range. It is a cream to light brown-colored fissile, siliceous shale. The unit's age centers on the mid-Miocene Relizian stage, dated as 15.5-16.5 million years ago.

SANTA MARGARITA FORMATION

The Santa Margarita Formation is named from the creek of the same name in San Luis Obispo County, and also on the Pacific Plate. The application of the name to rocks on the North America plate where there may have been no direct connection to depositional basins in the type area is a little problematic but well established in the literature. In the Temblor Range it reaches a maximum thickness of 2,500 feet, is dominated by sandstone, conglomerate and breccias containing pebbles of granitic and metasedimentary rocks from a source area to the southwest, possibly represented today by rocks in the Big Sur area following offset along the San Andreas fault. Lying both conformably above, and in some areas interfingering with the Monterey formation, it represents a shallowing of the marine basin.

BITTERWATER CREEK SHALE

The Bitterwater Shale lies above the Santa Margarita Formation, but is finer grained, and dominated by indistinctly bedded siltstone and diatomaceous mudstone. Diatoms are of the Mohnian faunal stage of late Miocene age (7.5-13.5 Ma in age). It reaches 2,000 feet in thickness. In some areas this marks the top of the marine sedimentary sequence, and it is unconformably overlain by the continental Paso Robles Formation. It also grades laterally into a unit once named the 'Panorama Hills Formation' by U.S.G.S. Geologist Tom Dibblee, although as the name is not formarly recognized, it is mapped currently as Unnamed Marine Sandstone.

UNNAMED MARINE SANDSTONE

Originally named the Panorama Hills Formation by U.S.G.S. Geologist Tom Dibblee, which has not been formally recognized as a formation name. the unit consists of weakly indurated light brown sandstone and gray clay, of either Pliocene or of latest Miocene age. The unit grades laterally into the Bitterwater Creek Shale. Marine fossils recovered from the unit suggest very shallow water depths and are of youngest Miocene age.

MORALES FORMATION

This unit consists of Pliocene, and possibly earliest Pleistocene, continental beds in the Cuyama Valley, Caliente Range, and Carrizo Plain areas. It is dominated by light gray, crumbly sandstone and conglomerate, and gray to red siltstones. Pebbles in the conglomerates appear to have been derived from older conglomerates. The Morales Formation has been identified on the east side of the San Andreas fault in the Panorama Hills, east of Soda Lake, where it is 2,500 ft. thick and unconformably overlies conglomerates assigned to the Santa Margarita Formation.

PASO ROBLES FORMATION

The formation consists of sediments washed into the valley in Pliocene or early Pliocene times. They are distinguished from modern alluvium by being partly consolidated, and also by being deformed into folds by tectonic movements along the San Andreas fault. The name has been applied to all sediments of this type that resemble extensive deposits in the Paso Robles area.

This Guide has been produced by Dr. David Chipping and the Friends of the Carrizo Plain.
Visit the Friends website at 'carrizo.org'
Geologic Maps are taken from U.S. Geological Open File Report 99-014, Regional Geologic Map of San Andreas and Related Faults in Carrizo Plain, Temblor, Caliente and La Panza Ranges and Vicinity, California; A Digital Database. Compiled by T.W. Dibblee