NCGS

NORTHERN CALIFORNIA GEOLOGICAL SOCIETY

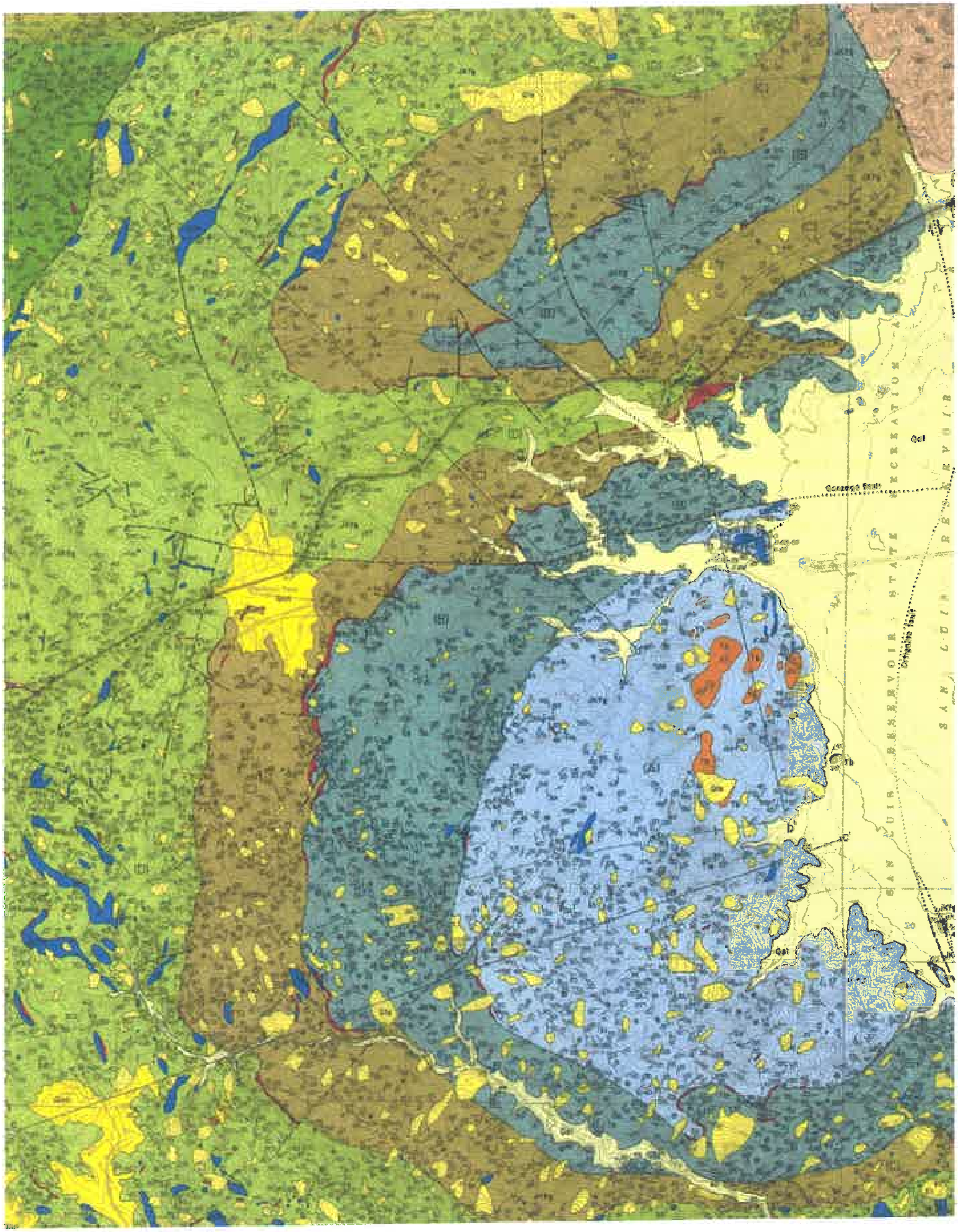
FIELD TRIP

FRANCISCAN METASEDIMENTARY SECTION AT PACHECO PASS

APRIL 12, 2003

LEAD BY

DR. GARY ERNST
STANFORD UNIVERSITY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NCGS / GES-052Q Field Trip
Pacheco Pass, Panoche Pass, The Pinnacles, and Hollister, Central California Coast Ranges, April 12, 2003

GENERAL INSTRUCTIONS

Excursion stops are described below. Here are brief notes on the geology as it flashes by on our way to Pacheco Pass. The trip mileage will start (near the toilets) in the parking lot of Casa di Fruta, ~13 mi east of Gilroy on CA Hwy 152. After a regional geo-introduction at the Casa di Fruta comfort stop, we will spend the first day in the Pacheco Pass area examining a section of an Upper Mesozoic subduction accretionary prism—the Franciscan Complex. That night we will camp at the state-operated Basalt Campground just downstream from the San Luis Reservoir. On Saturday, we will enjoy scenery and roadcuts southeast of the reservoir on our way to beautiful, off-the-beaten-track Panoche Pass, where we'll examine a serpentinite injected along the faulted boundary between Upper Mesozoic trench and forearc basin deposits; then we motor on down south to Pinnacles National Monument to study Miocene volcanic rocks, and finally back to Hollister and offset houses along the Calaveras-Sunol-Hayward strike-slip fault.

On this field trip we will see Mesozoic oceanic trench deposits + well-stratified forearc units, hydrated mantle material, a Miocene continental margin volcanic pile, and Neogene strike-slip topography and associated urban deformation. Home by 5:00 pm Sunday, I hope! The Saturday exposures are along a VERY busy highway. So, **after watching and listening for approaching vehicles, PUHLEEZE be extremely careful, do not stand in or cross the roadway, and do not EVER scatter rocks on the pavement!**

STANFORD-CASA DI FRUTA

Exit Stanford onto Page Mill Road westbound to I-280, drive south ~10 mi to CA Hwy 85, southbound on 85 ~21 miles to junction with U. S. Hwy 101, southbound ~23 mi through Gilroy, then east on CA Hwy 152 for 13.1 mi to the Casa di Fruita turnoff, stopping in the west-side parking lot near the toilets. We have driven through the Quaternary alluvium-covered Santa Clara Valley, the southern prolongation of the San Francisco Bay structure, and probably a right-lateral pull-apart basin between the Neogene Calaveras-Sunol-Hayward strike-slip system on the east, and the San Andreas plate-boundary zone on the west. After leaving Gilroy driving east on CA Hwy 152, as we leave the Santa Clara Valley and ascend the hills, we cross into chiefly massive Upper

Cretaceous sandstones and siltstones of the Great Valley Series forearc basin; the source of these strata was the more easterly Sierran volcanic-plutonic arc.

CALIFORNIA COAST RANGES

General Geology. The uppermost Jurassic-Cretaceous Franciscan accretionary prism + its oceanic underpinnings constitutes the major basement complex flooring the California Coast Ranges (Bailey et al., 1964, 1970). It consists of incipiently to thoroughly recrystallized, tectonized equivalents of medium- to fine-grained detrital rocks, chiefly graywackes, micrograywackes, and dark shales. This erosional debris was derived largely from the coeval Late Mesozoic Sierran volcanic-plutonic arc, and was deposited in an offshore oceanic trench. Modest amounts of pillow basalt and pillow breccia (greenstone and blueschist, transformed from oceanic crust layer 2), radiolarian chert overlying basaltic flow tops (metachert, recrystallized oceanic crust layer 3), and faulted slices of serpentinized peridotite (mantle lithosphere) are interleaved with the dominantly metaclastic section. As evident from **Fig. 1**, the grade of relatively high-pressure/low-temperature (high P/T) Franciscan metamorphism in the exhumed belt in general increases eastward toward the interior of the continent (Blake et al., 1967). The ages of original Franciscan deposition and recrystallization young westward (Ernst, 1971). Rocks in the Diablo Range carry appreciable amounts of jadeitic pyroxene and quartz, an unusually high-pressure/low-temperature mineral assemblage, as documented both by theory and by phase-equilibrium experiments. The required low P-T gradients seem to be confined to subduction-zone environments. The thermal structure of a subduction zone + landward arc is illustrated diagrammatically in **Fig. 2**.

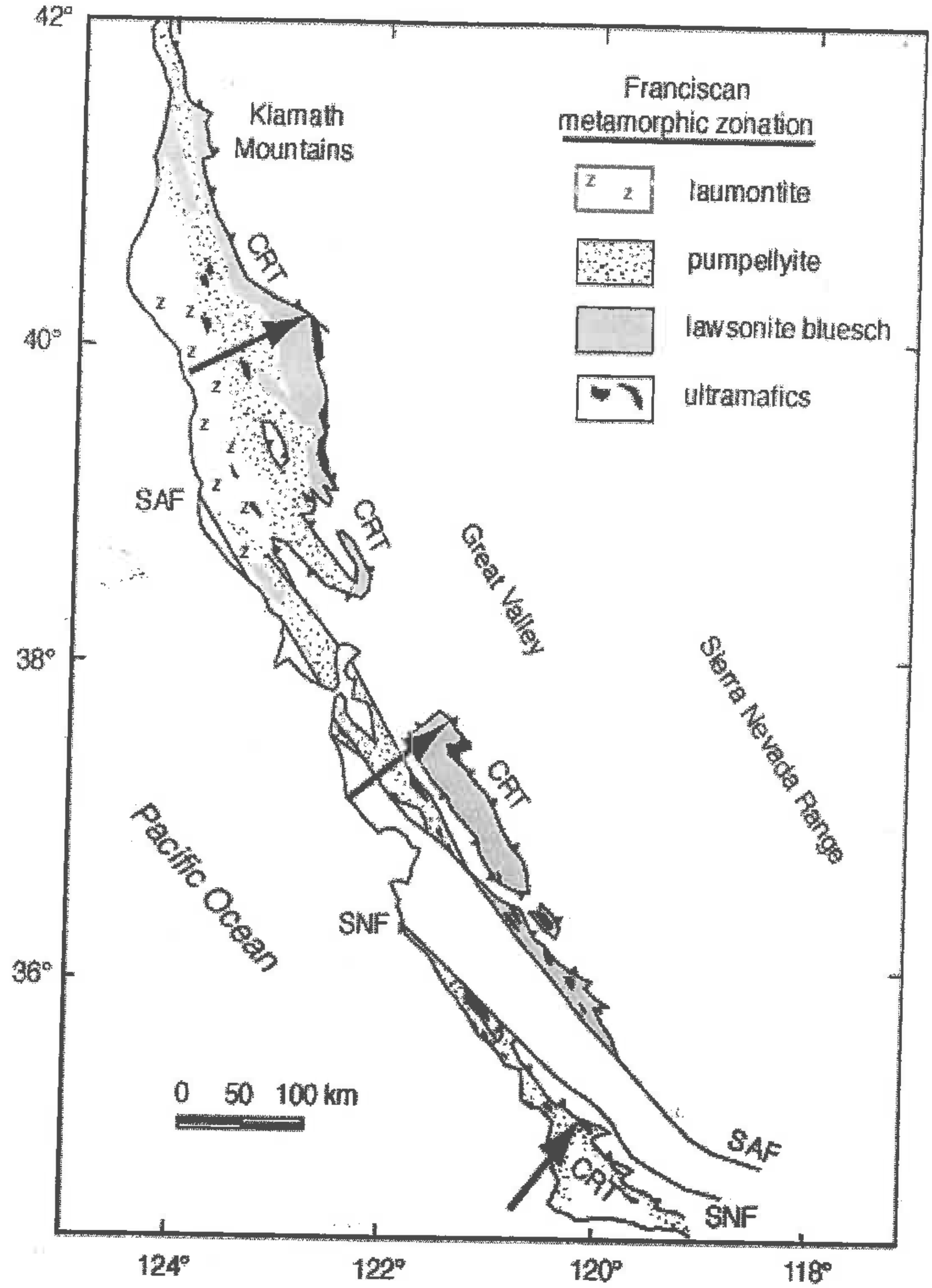

Fig. 1. Regional geology + metamorphism of the Franciscan Complex. Arrows show increasing pressure of recrystallization and subduction depth—now recovered. Ages of depositional packages decrease oceanward, but tops face landward. The San Andreas fault (SAF) transects the old Mesozoic margin. Neogene dextral slip has duplicated the landward volcanic/plutonic arc, medial forearc basin and oceanic trench. Franciscan and Great Valley units are juxtaposed along the Coast Range thrust (CRT).

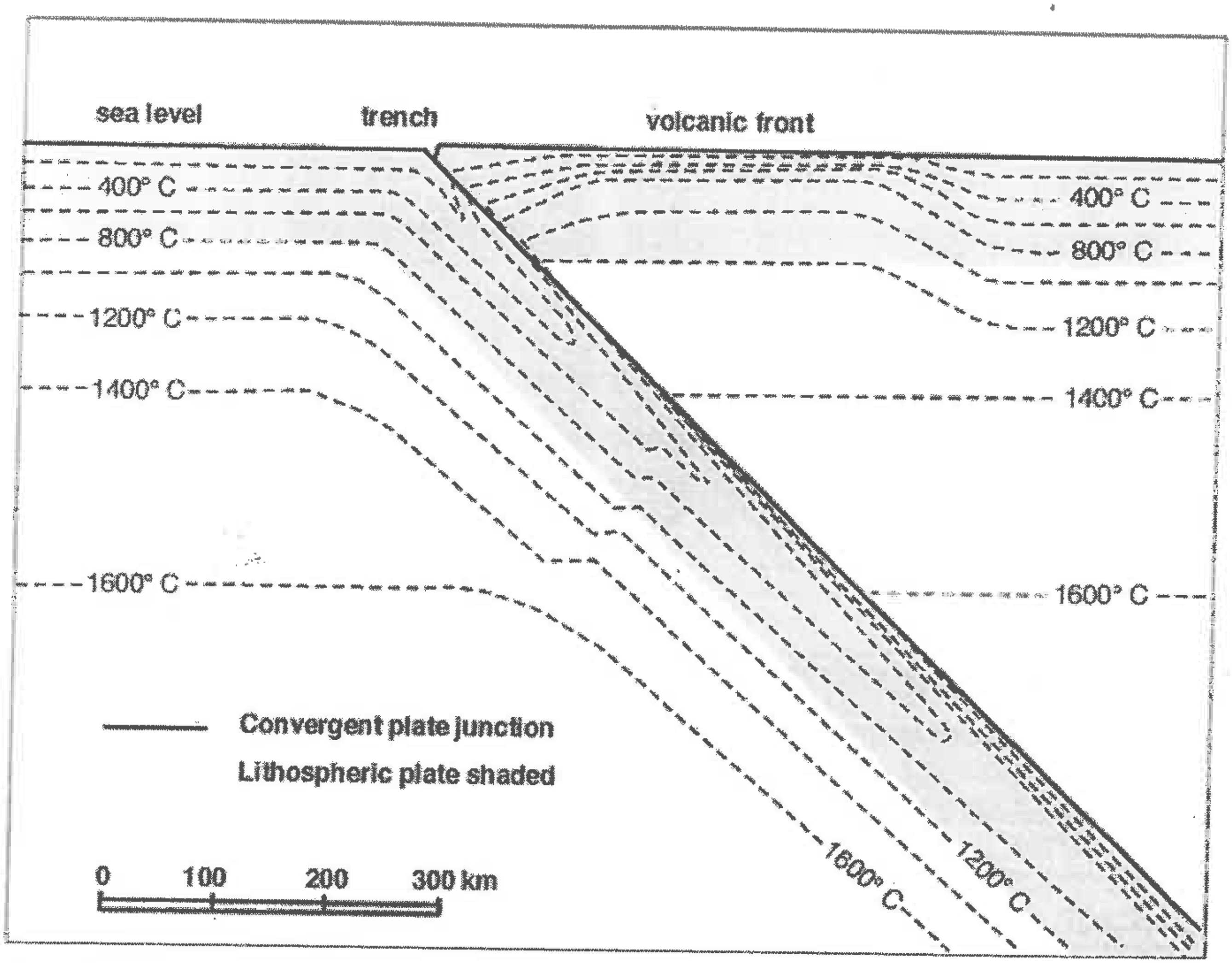

Fig. 2. Computed thermal structure of a subduction zone such as the Mesozoic Franciscan convergent plate junction.

PACHECO PASS

Geologic mapping in the central Diablo Range at Pacheco Pass (Ernst et al., 1970; Ernst, 1993) allowed the documentation of syn-metamorphic, imbricate, subhorizontal bedding-plane thrusts within an apparently conformable Franciscan stratigraphic sequence (Maruyama et al., 1985). The terrane consists dominantly of jadeitic metagraywackes and finer grained metaclastic rocks as clear from **Fig. 3**. At the base of each tectonic unit, an obscure décollement was identified by the presence of small, discontinuous lenses of mafic blueschist and invariably-overlying metachert; upon a substrate of oceanic crust, fine-grained turbidites and an upward coarsening detrital sequence was deposited prior to relatively high P/T subduction-zone metamorphism.

Evidently, as oceanic crust-capped lithosphere approached the Late Mesozoic margin of California, distal—then progressively more proximal—turbiditic sediments were laid down on the approaching paleo-Pacific plate (*e. g.,* Matsuda and Isozaki, 1991). This assemblage was then carried down the eastward-inclined Franciscan subduction zone, and portions of the sedimentary section + the very uppermost part of the oceanic crust (layers 2 and 3) were sliced off and included in the growing accretionary prism. Decoupled from its denser lithospheric underpinnings, the complex buoyantly returned to upper crustal levels as the rest of the dense oceanic plate sank into the upper mantle. The metaclastic rocks exhibit growth of the high-pressure mineral jadeitic pyroxene from preexisting albite; spatially associated mafic lenses contain glaucophane (the blue sodic amphibole) ± sodic pyroxene. Only the lowest thrust unit in the northwestern corner of the mapped area is made up principally of metagraywackes that completely lack jadeitic pyroxene, and the interlayered mafic metavolcanics appear to be less intensely metamorphosed as well; still, the rocks contain some lawsonite ± metamorphic aragonite (orthorhombic $CaCO_3$).

Stop #1. 8.0 mi from Casa de Fruta onramp, park in pullout.

Directly to the west, four or five large greenstone knobs occur as tectonized lenses defining a rough stratigraphy. They probably represent the remnants of feebly recrystallized oceanic crust—perhaps a seamount. These blocks are sheared into and surrounded by metagraywacke and metashale—the latter behaving rather like toothpaste during the penecontemporaneous deformation and metamorphism that took place in the Franciscan subduction zone. The metasedimentary and metavolcanic rocks here contain differing proportions of quartz, chlorite, white mica, stilpnomelane, lawsonite, sodic pyroxene, and aragonite (partly replaced by calcite) in veins. Sodic amphibole and pumpellyite stringers occur in a few of the vaguely pillowed metabasalts. In addition, several generations of carbonate layers and veins transect the greenstones. Boulders of metaconglomerate occur down in the streambed to the south, but the metaconglomerate layer itself crops out capping the bluff about 100 m to the SE across the valley (upstream).

Stop #2.

As we continue driving on eastward and uphill, note the coherent but folded stratigraphy in the Franciscan metaclastic units and, on the left at 1.3 mi (NO STOP), serpentinite emplaced along a NS –trending fault. A distance of 3.3 mi from Stop 1, on the right at Pacheco Pass is the Old Hwy 152 junction; turn right and go 0.9 mi farther. On the right is a somewhat weathered (OK, really weathered) outcrop of relatively coarse-grained jadeitic pyroxene-bearing metagraywacke, in which fibrous sprays and prismatic clusters of pyroxene (+ quartz) have been caught in the act of replacing detrital grains of plagioclase. In addition to approximately 40% sodic pyroxene ± albite, the rock consists mostly of white mica, sodic amphibole, stilpnomelane and quartz. This is about as coarse as the jadeitic pyroxene gets. Even so, the texture here is hard to see with the hand lense, but is schematically illustrated in **Fig. 4**.

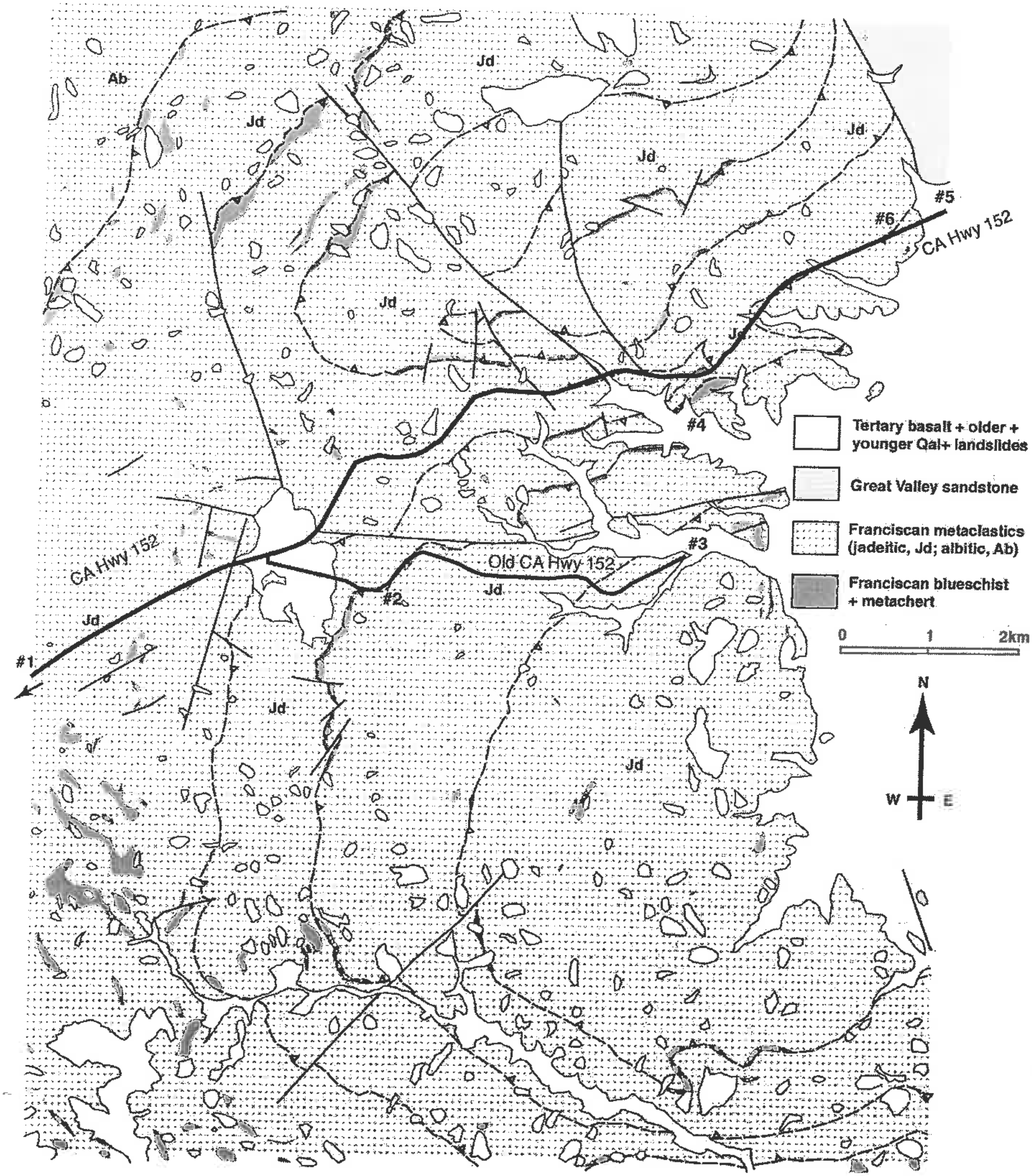

Fig. 3. Geology of the Pacheco Pass quadrangle

Growth of jadeitic pyroxene + quartz
from detrital albite

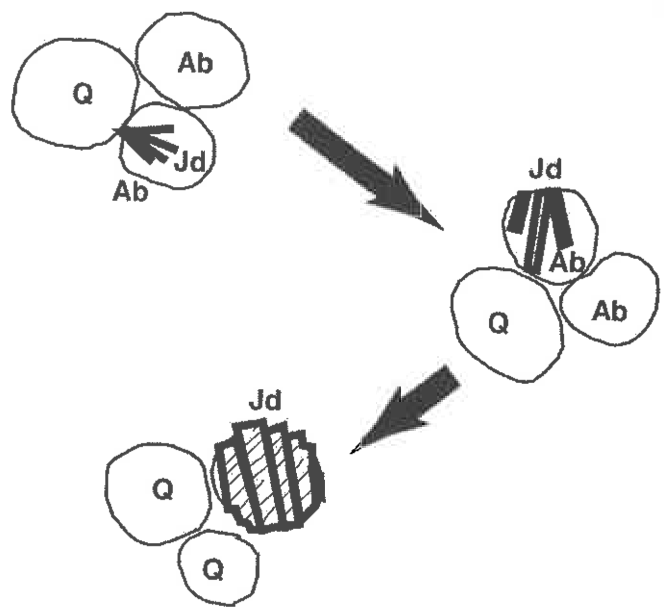

Fig. 4. Diagrammatic progressive conversion of $NaAlSi_3O_8$ to $NaAlSi_2O_6 + SiO_2$

Stop #3. 2.2 mi farther east on the Old Hwy 152, drive into the Dinosaur Point parking lot.

An Ichthyosaur snout apparently was recovered from a chert bed ~50 mi NNW of here in Hospital Canyon, but don't expect a T rex here; even radiolaria are not well preserved in the thoroughly recrystallized Pacheco Pass metasiliceous units. Directly NE of the Dinosaur Point parking lot, glaucophanized metagabbro is intrusive into jadeitic metagraywacke; the metagabbro contains igneous relict plagioclase and Ti-rich augite as well as the newly crystallized high-pressure/low-temperature minerals sodic pyroxene, lawsonite and aragonite. Clearly, the mafic magma was injected into the turbiditic clastic sedimentary prism prior to subduction-zone metamorphism and subsequent exhumation. **LUNCH STOP.**

Stop #4. Leave the parking lot, drive back up the road to junction with CA Hwy 152 and turn east, driving 3.3 mi ENE from junction and park in pullout.

We will walk east along the edge of the roadway—**lookout!**—passing subhorizontal fine-grained but folded (note nearly horizontal fold axes) metagraywackes, meta-micrograywackes, and a slightly faulted lens of greenstone-blueschist. Then climb up above the roadway cut to view cinnamon-colored siliceous shale overlying chert, in turn overlying greenstone. At the very east end of this exposure, a fold nose is defined where the beds cross the highway (fold axis plunges east at ~10°). The relatively high-pressure, low-temperature mineral assemblages in metagraywackes and mafic metavolcanic rocks are the same as in outcrops that we visited earlier today. Coexisting white mica and glaucophane from a blueschist lense directly beneath the metachert horizon just south of the roadway yielded K/Ar radiometric ages of mineral formation of 115 ± 3 and 122 ± 3 Ma respectively (Suppe and Armstrong, 1972).

Stop #5. Continuing on eastward by car at 2.5 mi (NO STOP)

CA Hwy crosses the Ortigalita fault; this is the so-called Coast Range thrust, a high-angle reverse—later normal—fault. Beyond it, we now drive through exposures of steeply east-dipping, feebly recrystallized conglomeratic sandstones ± siltstones of the Upper Cretaceous Great Valley Series. This detrital material was derived from the Sierran arc located yet farther east, as indicated by measured paleocurrent vectors, and lithologies of the clasts. We continue eastward 2.3 mi beyond the fault to the turnoff for Romero Visitor Center. Here we have a brief comfort stop and consideration of the California Water Project.

Stop #6. Leave Romero Visitor Center and, taking care as you turn left, drive westward for 2.7 mi on CA Hwy 152 across the Ortigalita fault, stopping at the first outcrop after the fault valley (pull 'way off the roadway!).

When this outcrop was fresh, I was able to determine sedimentary tops from graded bedding, but most rocks are now so degraded that relationships now seem to be equivocal. Most of this section is right-side-up, although some beds are slightly overturned. Ptygmatic folding of quartz veins reflects penetrative synmetamorphic deformation about subhorizontal fold axes. Greenish, micaceous, sandy layers appear to represent an ashy (tuffaceous) detrital component. As elsewhere in the Pacheco Pass map area, the metagraywacke mineral assemblage is indicative of high-pressure/low-temperature subduction-zone metamorphism.

End of First Day.

We bid goodbye to our friends, who return to the Bay Area. The GES-052Q group drives westward up to the pass, and turns around at the Old Hwy 152 intersection (after admiring the Franciscan section one last time) and heads east for the Basalt Campground (turnoff on the right, roughly 12 miles east of the summit).

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Beginning of Second Day.

From the Basalt Campground, we drive east for ~3 mi along CA Hwy 152 to the intersection with I-5 and turn south through the San Joaquin Valley, proceeding nearly parallel with the California Aqueduct. After ~25 mi, we turn west, then south on the Mercy Hot Springs Road (San Benito County Road J-1), traveling through the east-tilted Great Valley section and, turning westward, over Panoche Pass well within the Franciscan terrane.

PANOCHE PASS

Franciscan field relations combined with petrologic analysis in the Panoche Pass area (Ernst, 1965), southern Diablo Range, require relatively high P/T recrystallization, and the presence of low-angle faults, as shown in **Fig. 5**. For a long time, I puzzled over the obscure relationship between lower pressure albite-bearing metagraywackes ± blueschist blocks, and localized regions of higher pressure jadeitic pyroxene-bearing metagraywackes ± blueschist blocks. Large tracts of the terrane consist chiefly of metaclastic rocks that contain albitic plagioclase but totally lack jadeitic pyroxene, whereas in a few areas, the metagraywackes are typified by neoblastic jadeitic pyroxene (+ quartz) growing from relict albite. My initial interpretation was that metamorphic isograds separated essentially continuous sections of metaclastic rock ± associated metamafic boudins (*i. e.,* gradation in P-T conditions). More recent field observations combined with petrographic re-examination of mylonitic rock types suggest that the boundaries are actually low-angle, post-metamorphic faults, rather than isograds (*i. e.*, discontinuity in P-T conditions).

Stop #7.

After another ~20 mi, we will stop at a tectonic contact between the Franciscan Complex metasedimentary rocks on the east, and Upper Cretaceous sandstones of the Great Valley forearc section on the west. At this locality, serpentinite (representing hydrated—thus buoyant—mantle material) has been emplaced along this high angle reverse fault. As shown by Coleman (1961), these serpentinites characteristically contain tectonic blocks of mafic blueschist. Some are present in the Tres Pinos streambed just south of the road. Most of the graywacke terrane in the Panoche Pass area contains lawsonite but lacks any jadeitic pyroxene or aragonite; however, at this stop, these high-pressure/low-temperature minerals are present in the metaclastic rocks.

After leaving the Franciscan Complex, we continue on to the NW ~10 mi, and turn south on CA Hwy 25 (The Airline Highway) at Paicines. Now we travel along the San Andreas topographic slot. The fault zone here is more than a mile wide, with lots of offset ridges and sags—really chopped up topography, due to differential slip on different subparallel strands of the San Andreas. It juxtaposes Cretaceous granites of the Salinian block on the west against the Franciscan-cored Diablo Range on the east. The Salinian block (volcanic/plutonic arc) has moved northwestward approximately 300 mi since 28-29 Ma subsequent to the collision of the East Pacific Rise spreading center with the western edge of the North American lithospheric plate, and the Franciscan (trench complex). We turn right (south) into Pinnacles National Monument, and drive SW, then NW to the Chalone Creek picnic area.

Stop #8.

The Pinnacles Formation is an andesitic-dacitic-rhyolitic pile of lava flows, flow breccias, tuffs, and tuffaceous clastic sediments. These rocks were deposited at 24 Ma. Approximately 200 mi to the SE, the Neenach Volcanics constitute a very similar 22-24 Ma pile lying on the east side of the San Andreas fault. Hence, the post-Early Miocene right-lateral slip was ~200 mi (Dickinson, 1997), as illustrated in **Fig. 6**. We will hike a short distance up the High Peaks Trail, examining flow-banded rhyolite, a feldspar porphyry dike, perlite (hydrated obsidian exhibiting conchoidal fractures), pumice tuff, pumice breccia, and andesitic flows. No collecting, please! This volcanic section may represent Franciscan graywackes that partly melted when the East Pacific Rise collided with the North American continental margin, but that is another story. Back down hill to the Chalone Creek picnic area and LUNCH.

After our field banquet, we return to Hollister, via CA Hwy 25, again noticing the hummocky topography of the San Andreas fault zone. We are zigzagging along and across the profound tectonic boundary between the North American and Pacific lithospheric plates, so no sleeping! It is, of course, a series of subparallel, anastomosing fault strands, in aggregate more than a mile wide here. This is a constantly creeping section of the San Andreas, so there are numerous small earthquakes, but few big shakes (it says here). At the south end of the main part of Hollister, take Nash Road west to San Benito Street, right turn and northbound to Sixth Street. Turn left and stop at Dunne Park.

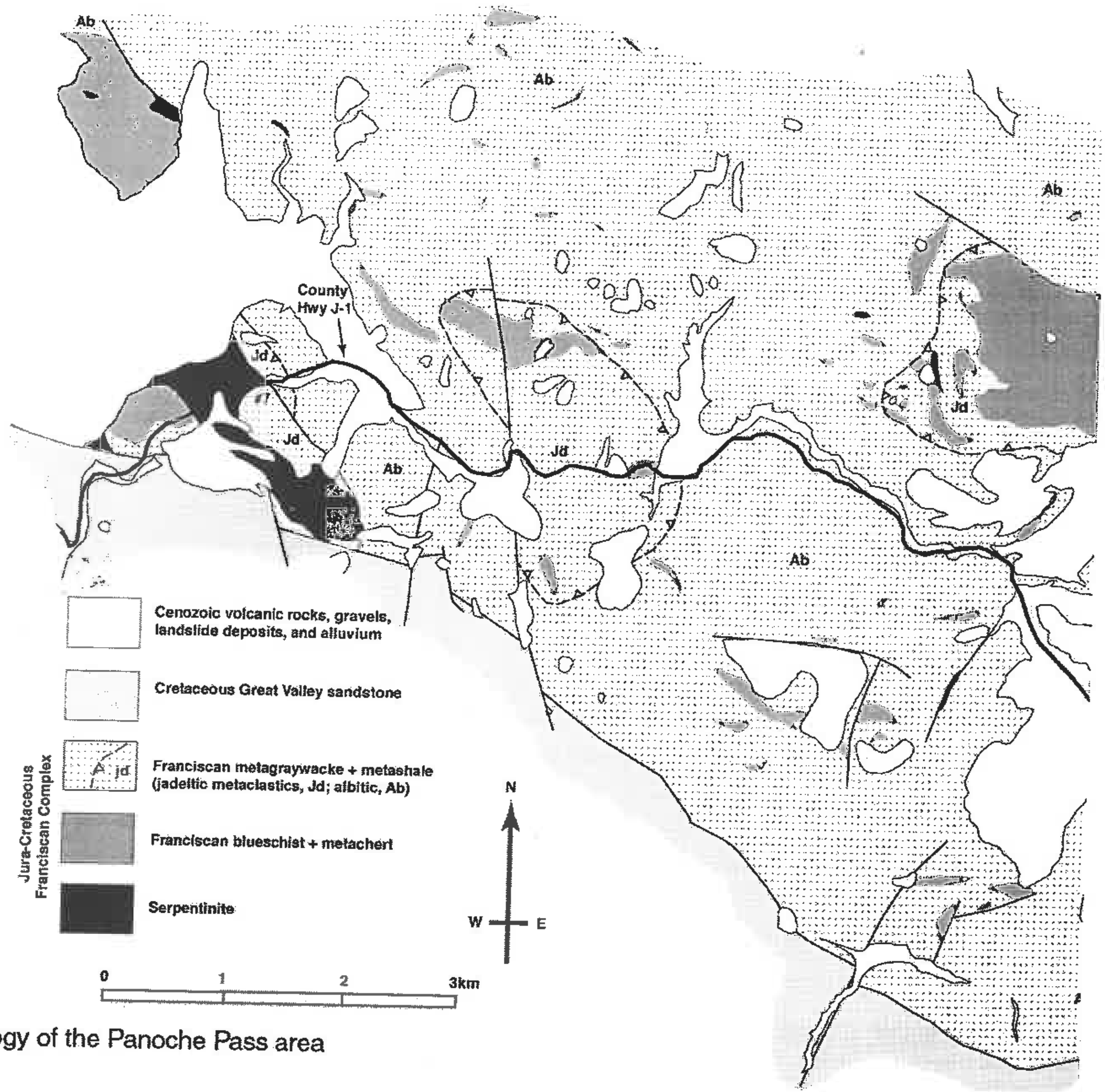
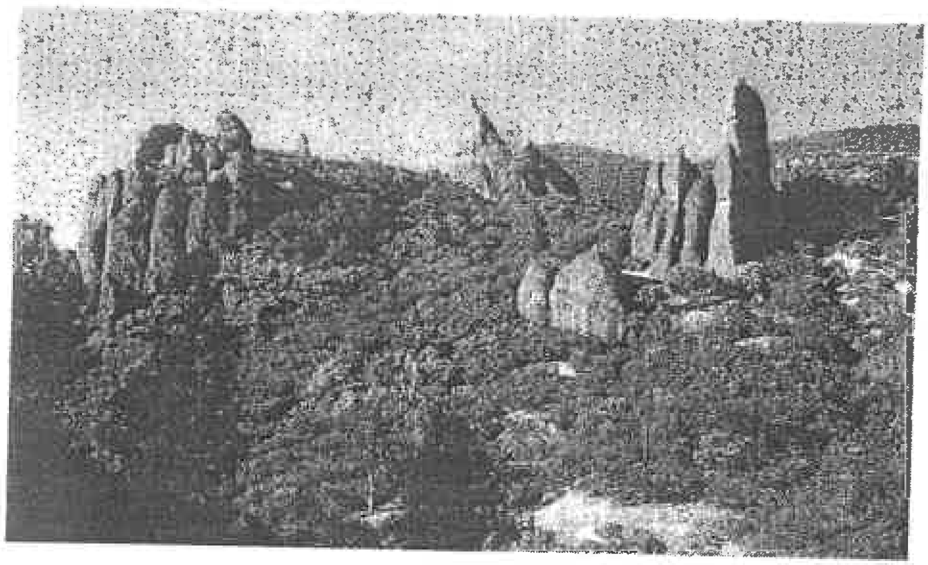


Fig. 5. Geology of the Panoche Pass area



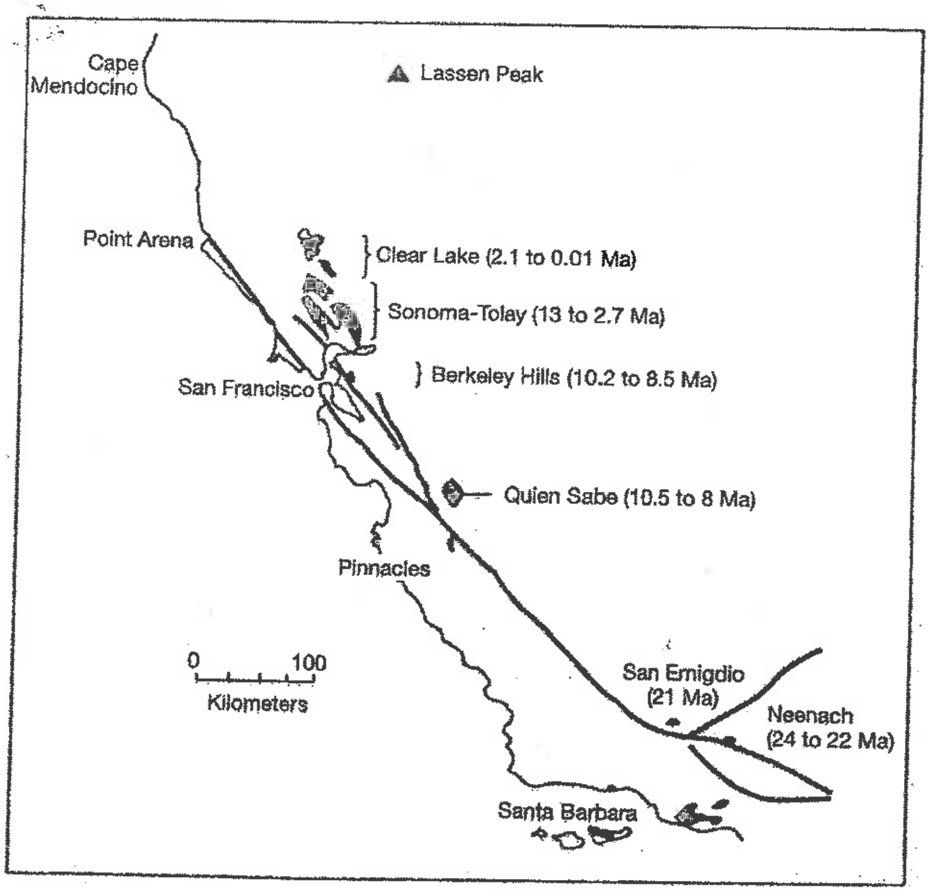


Fig. 6. Pinnacles and Neenach volcanic piles indicating ~200 km post-Early Miocene right-lateral slip on the San Andreas fault system.

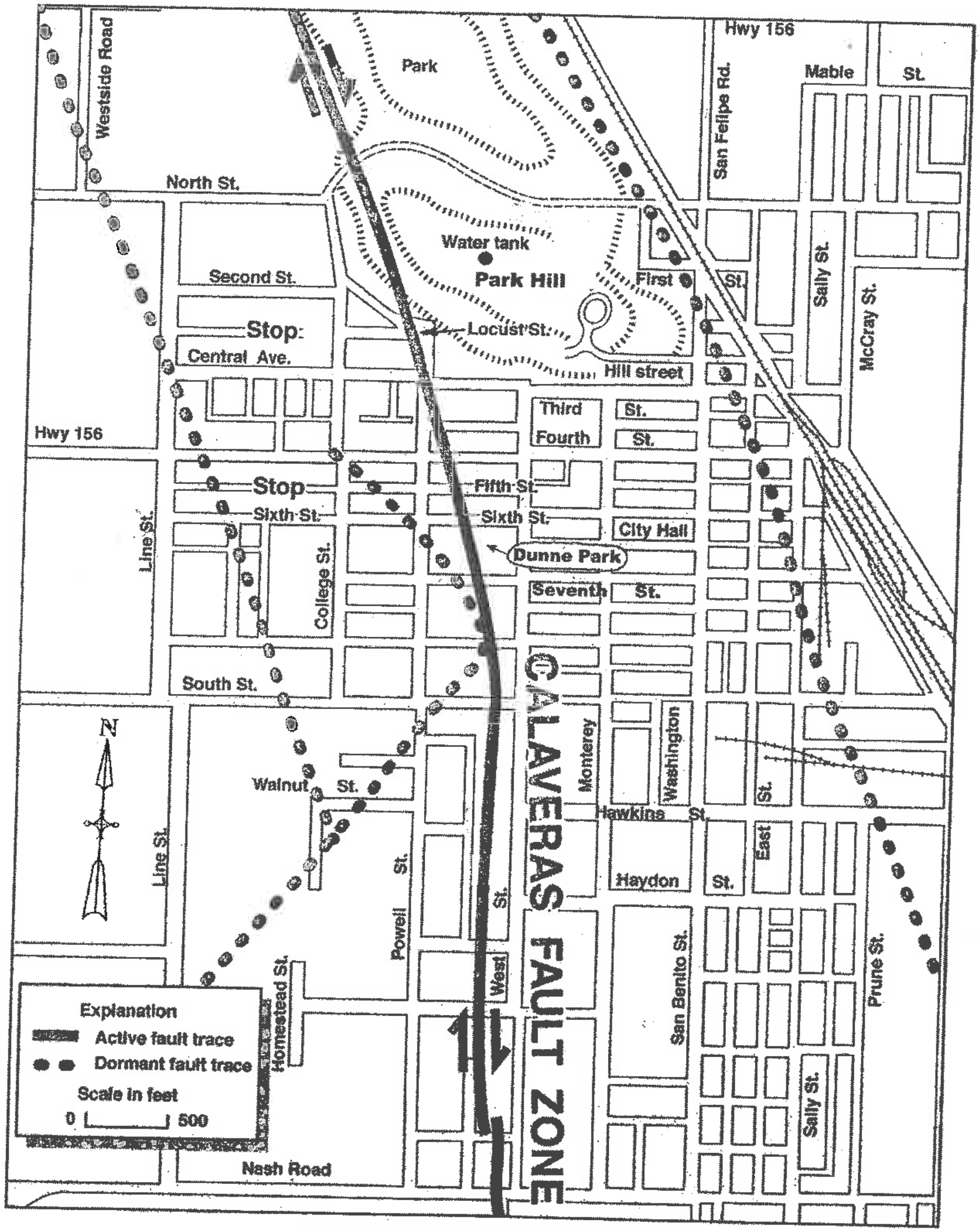


Fig. 7. Downtown Hollister

Stop #9.

Now we walk along the strand of the Calaveras-Sunol-Hayward fault, checking surface expression (offset curbs, sidewalks, tilted porches and garages) of the right-lateral creep. A map of the town is shown as **Fig.** 7. No finger pointing and loud laughing—people do live here, you know.

Returning to the vehicles, we go north a couple of blocks to CA Hwy-156 (Fourth Street) and turn left for San Juan Bautista. Continue northwest for 11 miles, and turn north on the main drag in San Juan Bautista, heading for the Mission.

Stop #10.

San Juan Bautista Mission is constructed on a flat alluvial bench, bounded on the east by an approximately 10 meter high escarpment that marks the San Andreas fault. The Mission was shaken to the ground in 1800, barely a year after the initial construction. Since then it has been rebuilt, again as an unreinforced masonry structure. My oldest grandchild was baptized here. How appropriate!

Now we go back to the Farm.

REFERENCES CITED

Bailey, E. H., Irwin, W. P., and Jones, D. L., 1964, Franciscan and related rocks, and their significance in the geology of western California: California Division of Mines and Geology Bulletin 183, 171p.

Bailey, E. H., Blake, M. C., Jr., and Jones, D. L., 1970, On-land Mesozoic oceanic crust in California Coast Ranges: U. S. Geological Survey Professional Paper 700-C, p. 70-81.

Blake, M. C., Jr., Irwin, W. P., and Coleman, R. G., 1967, Upside-down metamorphic zonation, blueschist facies, along a regional thrust in California and Oregon: U. S. Geological Survey Professional Paper 575-C, p. 1-9.

Coleman, R. G., 1961, jadeite deposits of the Clear Creek area New Idria district, San Benito County, California: Journal of Petrology, v. 2, p.209-247.

Dickinson, W. R., 1997, Tectonic implications of Cenozoic volcanism in coastal California: Geological Society of America Bulletin, v.109, p. 936-954.

Ernst, W. G., 1965, Mineral parageneses in Franciscan metamorphic rocks, Panoche Pass, California: Geological Society of America Bulletin, v.76, p. 879-914.

Ernst, W.G., 1971, Metamorphic zonations on presumably subducted lithospheric plates from Japan, California, and the Alps: Contributions to Mineralogy and Petrology, v.34, p. 43-59.

Ernst, W.G., 1993, Geology of the Pacheco Pass quadrangle, central California Coast Ranges: Geological Society of America Maps and Charts Series MCH078, scale 1:24,000, accompanying text 12 p.

Ernst, W.G., Seki, Y., Onuki, H., and Gilbert, M. C., 1970, Comparative Study of Low-grade Metamorphism in the California Coast Ranges and the Outer Metamorphic Belt of Japan: Geological Society of America Memoir 124, 276 p.

Maruyama, S., Liou, J. G., and Sasakura, Y., 1985, Low-temperature recrystallization of Franciscan graywackes from Pacheco Pass, California: Mineralogical Magazine, v. 49, p. 345-355.

Matsuda, T., and Isozaki, Y., 1991, Well-documented travel history of Mesozoic pelagic chert in Japan: From remote ocean to subduction zone: Tectonics, v. 10, p. 475-499.

Suppe, J., and Armstrong, R. L., 1972, Potassium-argon dating of Franciscan metamorphic rocks: American Journal of Science, v. 272, p. 217-233.