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COAST RANGES

False facts are highly injurious to the progress of science, for they often endure long; but false views, if supported by some evidence do little harm, for everyone takes a salutary pleasure in their falseness.

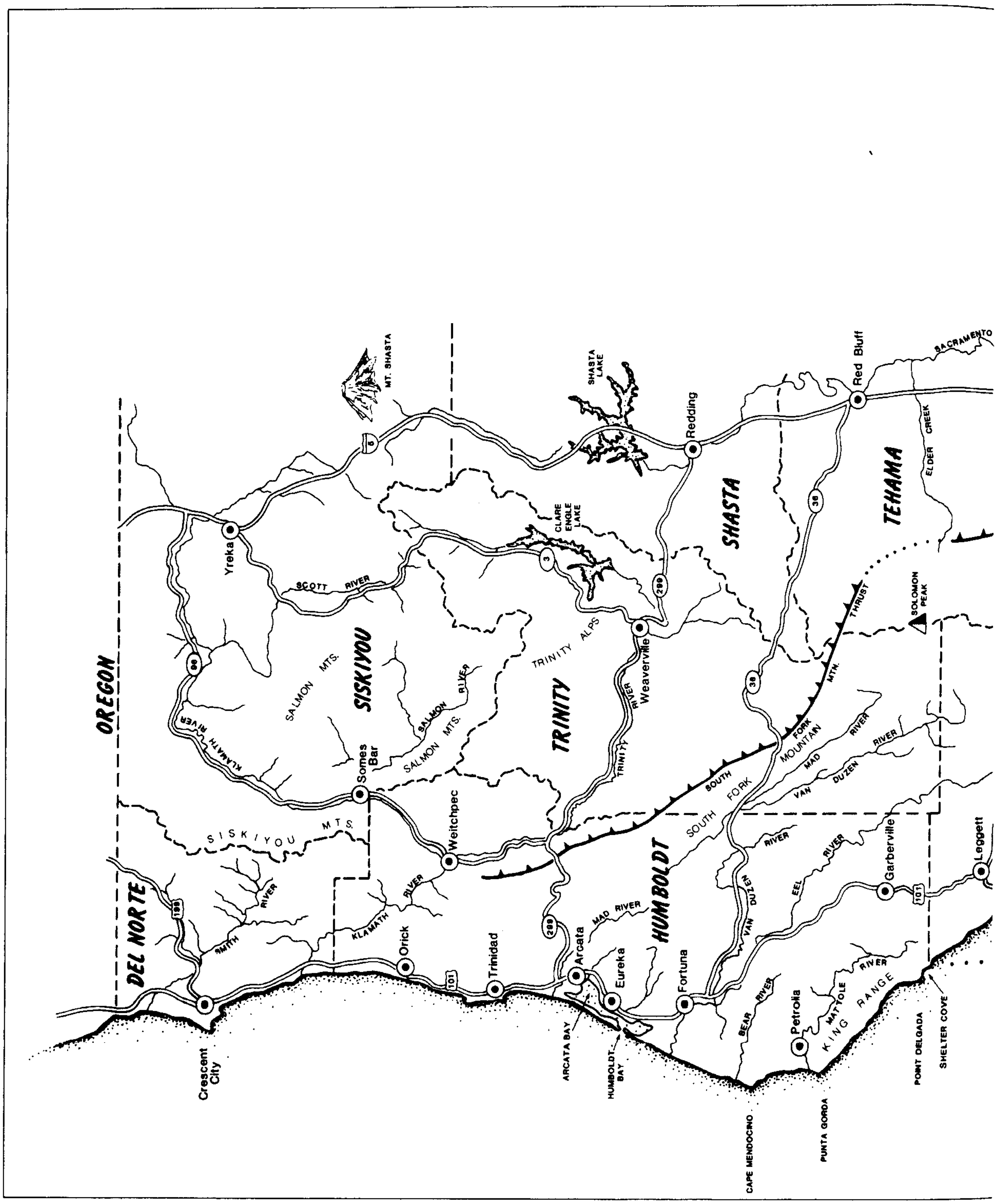
—Charles Darwin

Interpretations of Coast Range geology have been greatly affected by the theory of plate tectonics. As a result, much of the geologic history previously accepted for the province has now been substantially revised. In addition, studies of Coast Range rock relationships have contributed significantly to plate tectonic theory in general. Once mainly an enigma of local concern, the Coast Ranges are now a reference area of world importance.

The Coast Ranges stretch about 960 kilometers (600 miles) from the Oregon border to the Santa Ynez River and fall into two subprovinces: the ranges north of San Francisco Bay and those from the bay south to Santa Barbara County. This division is actually one of convenience rather than geologic distinction, for the ranges have more similarities than differences. The differences that do exist probably occur because the northern ranges lie east of the San Andreas fault zone, whereas most of the southern ranges are to the west. Moreover, the southern ranges are better known because of their oil and gas resources, easier accessibility, more intensive land development, and clearer rock exposures due to sparser vegetation from lower rainfall.

GEOGRAPHY

The province contains many elongate ranges and narrow valleys that are approximately parallel to the coast, although the coast usually shows a somewhat more northerly trend than do the ridges and valleys. Thus some valleys intersect the shore


OREGON
DEL NORTE
SISKIYOU
TRINITY
SHASTA
TEHAMA
HUMBOLDT
MT. SHASTA
SHASTA LAKE
CLARE ENGLE LAKE
SACRAMENTO
Red Bluff
Redding
Yreka
Weaverville
Somes Bar
Weitchpec
Orick
Trinidad
Arcata
Eureka
Fortuna
Crescent City
Petrolia
Garberville
Leggett
SCOTT RIVER
KLAMATH RIVER
SALMON MTS.
SALMON RIVER
TRINITY ALPS
TRINITY RIVER
SISKIYOU MTS.
SMITH RIVER
MAD RIVER
SOUTH FORK
SOUTH FORK MOUNTAIN THRUST
VAN DUZEN RIVER
EEL RIVER
BEAR RIVER
MATTOLE RIVER
KING RANGE
ELDER CREEK
SOLOMON PEAK
ARCATA BAY
HUMBOLDT BAY
CAPE MENDOCINO
PUNTA GORDA
POINT DELGADA
SHELTER COVE

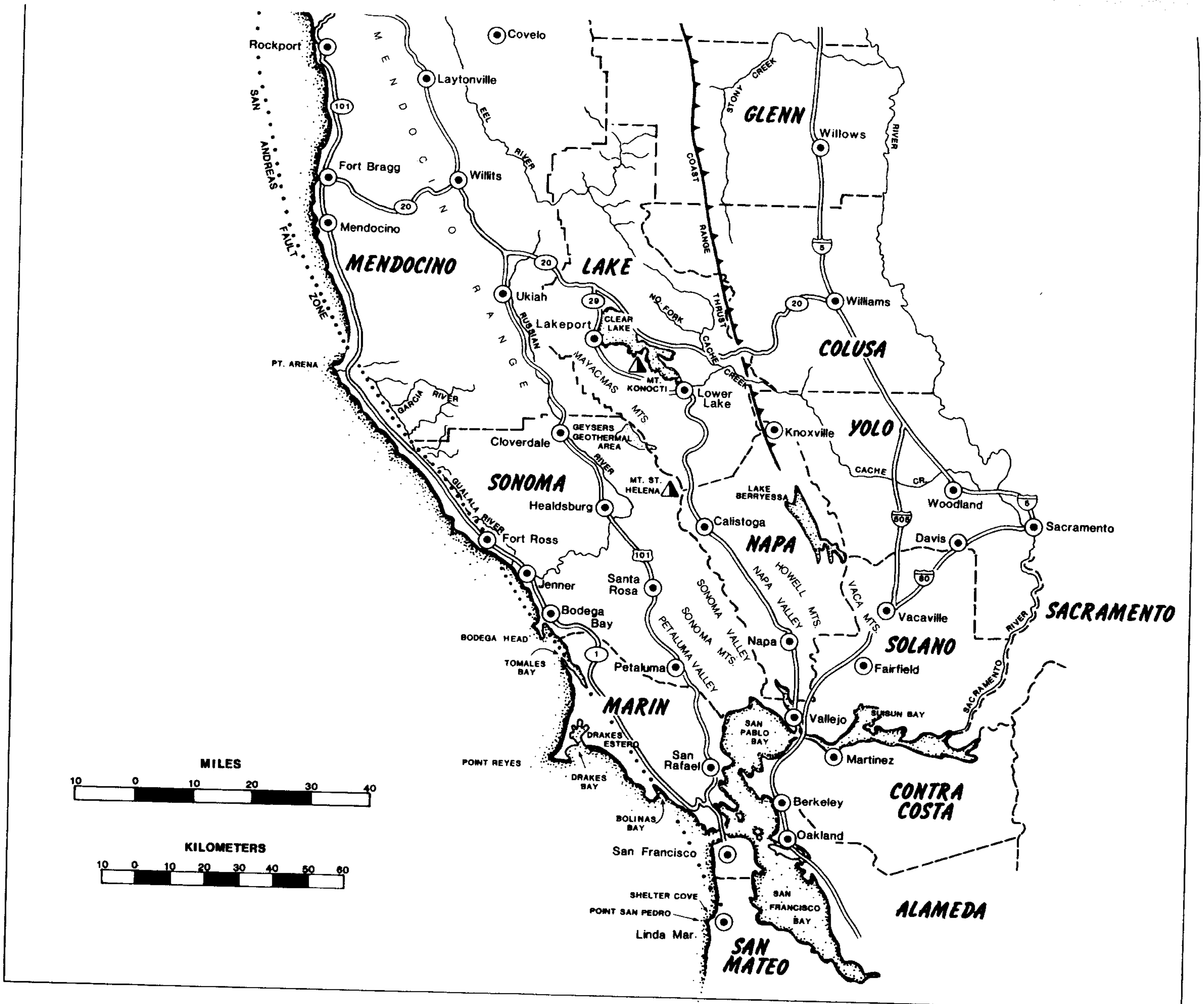


FIGURE 11-1 Place names, northern Coast Ranges.

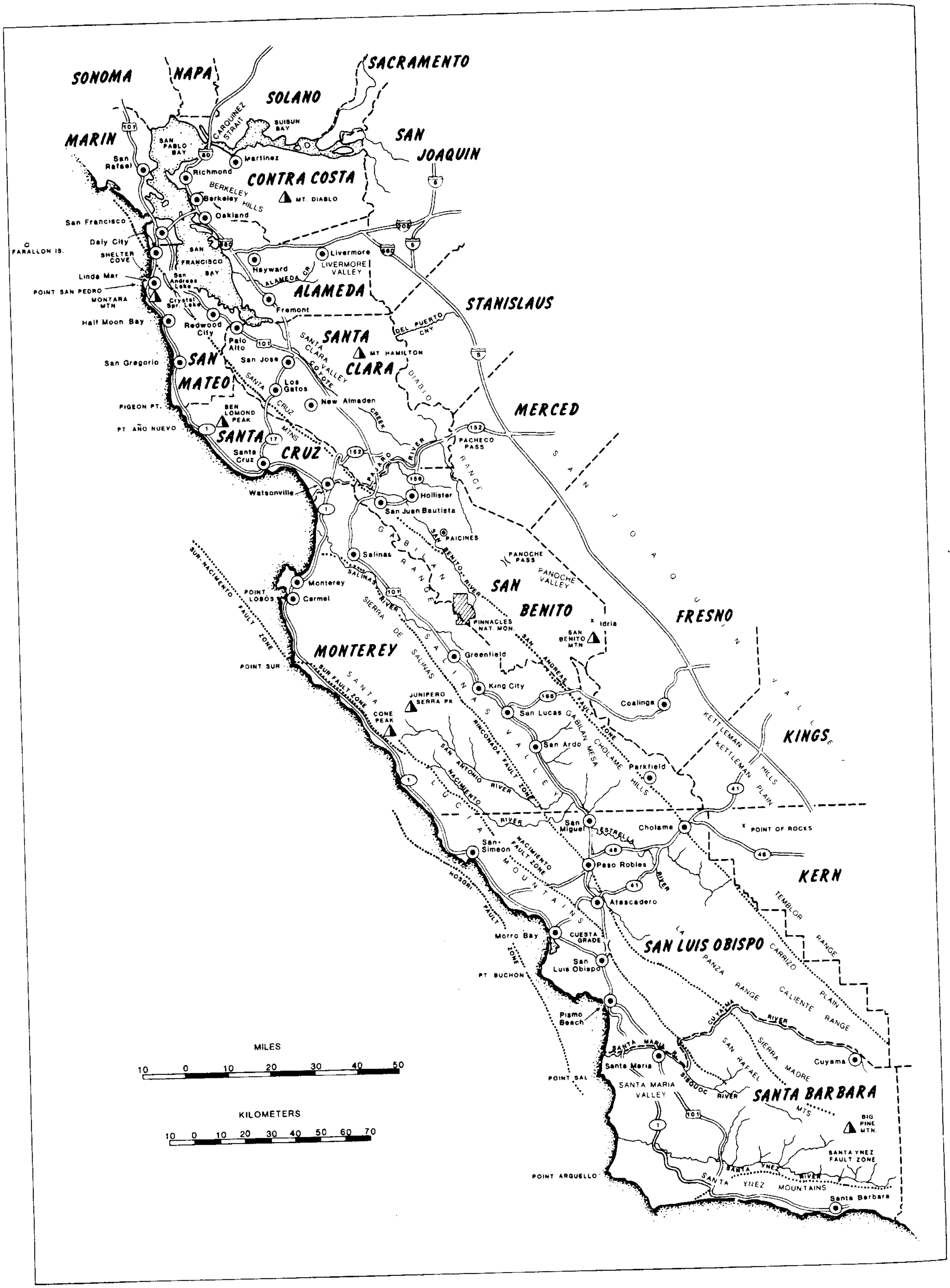


FIGURE 11-2 Place names, southern Coast Ranges.

at acute angles and some mountains terminate abruptly at the sea. Only minor streams enter the sea at right angles to the shore; most major streams flow many miles through inland valleys that roughly parallel the coast. Except at San Francisco Bay, where a pronounced gap separates the northern and southern Coast Ranges, travel in any direction in the province involves crossing range after range. Figures 11-1 and 11-2 show the locations of the main mountain units and valleys in the Coast Ranges.

Although elevations are moderate, relief is sometimes considerable. For example, within 1½ kilometers (1 mile) of the ocean are several peaks in the Santa Lucia Range that are more than 750 meters (2,500 feet) high; Cone Peak (1,572 meters or 5,155 feet) is only 6½ kilometers (4 miles) from the ocean. Travelers along the coastal highway from San Simeon to Monterey are almost always impressed with the precipitous seaward face of the Santa Lucia Range, for the road snakes along cliffs often 160 to 180 meters (500–600 feet) above the water. Highest elevation in the southern Coast Ranges is Big Pine Mountain (2,083 meters or 6,828 feet) in the San Rafael Mountains of Santa Barbara County. The northern Coast Ranges are higher, particularly in southern Trinity County where Solomon Peak rises to 2,312 meters (7,581 feet), the highest point anywhere in the California Coast Ranges.

DRAINAGE

Drainage is controlled primarily by structure. The large streams in the northern ranges, such as the lower parts of the Klamath, Mad, Eel, and Russian rivers, all follow the structural grain of faults or folds for much of their lengths. Of these, the Russian River has the most noteworthy drainage pattern. This river flows south in a normal way more than 64 kilometers (40 miles) to near Healdsburg where it abruptly turns west, crosses the Mendocino Range by a gorge up to 300 meters (1,000 feet) deep, and reaches the coast near Jenner. Because it appears simpler geologically for the river to continue south through the valley occupied by Santa Rosa and Petaluma and then into San Francisco Bay, geologists have long speculated about the origin of the river's lower course. Studies now indicate that the river established its initial channel on a more subdued Pliocene terrain. The river then flowed seaward across a blanket of sedimentary deposits, through which it subsequently cut downward into underlying Franciscan rocks. By the time the Santa Rosa-Petaluma lowland began sinking to its present elevation, the Russian River had already established the course that it retained even though the valley from Healdsburg to Santa Rosa and Petaluma continued to sink and the Coast Ranges continued to rise.

The southern ranges also contain drainages strongly controlled by faults and synclinal folds. The best example of a structurally controlled stream is the Salinas River, which lies in a synclinal trough for most of its course. Some faulting is involved in the lower valley, but even there folding seems to be the dominant structural control. Before joining the Salinas River, the San Antonio and Nacimiento rivers also follow linear systems of folds and faults.

Conversely, streams such as the Pajaro, Alameda Creek, and Santa Maria-Cuyama drain broad inland valleys and then follow gorges before emptying into the sea. Alameda Creek drains the Livermore Valley via Niles Canyon, a narrow gorge across the Diablo Range, and empties into southern San Francisco Bay. The Pajaro occupies a deep gorge between the Santa Cruz and Gabilan chains and, with its tributary the

San Benito River, drains the southern Santa Clara Valley. The Santa Maria River and a primary tributary, the Cuyama, have cut a zigzag course across the trend of the southern ranges, separating the Sierra Madre and San Rafael Mountains from the ranges of southern San Luis Obispo County. The upper Cuyama drains a broad structural depression between the Caliente Range and the Sierra Madre. The Sisquoc River, another principal tributary of the Santa Maria, follows the trend of faults and folds within the San Rafael Mountains.

Why the Pajaro and Santa Maria rivers behave as they do is not fully known, but there are several possibilities. Both rivers may be antecedent, with their present courses determined before folding and faulting outlined modern Coast Range structure; they may have been superimposed on sedimentary rocks that previously covered older Coast Range basement; streams eroding headward may have breached mountain barriers and captured upland drainages; or some combination of these events may have occurred. As with the Russian River, a complex explanation is likely, probably involving both antecedency and superimposition. In the case of Alameda Creek and Niles Canyon, it is clearer that the stream is antecedent because uplift is still in progress. First-order surveys through Niles Canyon, covering a 53-year period, show that the Diablo Range is being uplifted at a rate of about 1.5 to 2.0 millimeters (0.06–0.08 inch) per year with respect to the lowland on the east side of San Francisco Bay.

The discharge of southern Coast Range rivers, although important to the area, is no match for the discharge of the rivers draining the rainy north coast region. The largest of these northern rivers is the Klamath which, on average, accounts for about 18 percent of the total runoff from California, but the Klamath and its tributary the Trinity are mainly Klamath Mountain province streams; only a small part of their drainage basins lies within the Coast Ranges. On the other hand, the Mad, Van Duzen, and Eel Rivers are mainly Coast Range streams and all carry spectacular volumes of water during floods and substantial flows under normal conditions (Figure 11-3).

The Eel River is of special interest because it holds the record for the greatest average annual suspended load for any stream of its drainage area or larger in the United States; it exceeds both the Colorado and Mississippi in this respect! In tons of sediment per square mile of drainage basin, the Eel yields 4 times as much as the Colorado and 15 times as much as the Mississippi. One part of the Eel basin produced 1,079 metric tons of sediment per square kilometer (3,080 tons per square mile) per year. These very high rates are due to a combination of factors, including very high annual rainfall, soft, easily eroded sedimentary rocks in the basin, a multiplicity of landslides, and timber-harvesting practices.

ROCKS

Since the 1914 work of A. C. Lawson, it has been recognized that the Coast Ranges have two dissimilar core complexes (basement rocks) in contact along major longitudinal faults—a Franciscan subduction complex with oceanic crustal rocks and a granitic-metamorphic complex that includes the Sur Series and its equivalents. Present distribution of these rocks raises many questions that have not yet been answered satisfactorily.

FIGURE 11-3 Mouth of the Eel River just south of Eureka, Humboldt County. The town at the right edge of the photo is Loleta. This major north coast river carries about 3 percent of the total river discharge of California. (Photo by David Swanlund, courtesy Humboldt County Department of Public Works)

Franciscan Basement

The Franciscan subduction complex has been variously labeled a *series*, a *formation*, or an *assemblage*. Some portions are called a *melange*, a tectonic unit produced by fragmenting and mixing several rock types, presumably in a subduction zone. Lithologically, the Franciscan is dominated by greenish-gray graywackes (sandstones), generally in beds 0.3 to 3 meters (1–10 feet) thick. These graywackes were derived from rapid erosion of a volcanic highland and deposited in deep marine basins, usually by turbidity currents or submarine mudflows. The graywackes are composed mainly of quartz and plagioclase feldspar, with a chlorite mica matrix that confers the dark-greenish color. These rocks have immense volume and constitute 90 percent of the Franciscan. It is estimated that they average 7,600 meters (25,000 feet) in thickness and are exposed over 190,000 square kilometers (75,000 square miles) on both land and the sea floor. This gives an approximate volume of 1,500,000 cubic kilometers (350,000 cubic miles)—enough to cover all of California to a depth of 3,000 meters (10,000 feet) or all 48 contiguous states to a depth of 180 meters (600 feet).

The graywackes are interbedded with lesser amounts of dark shale and even occasional limestone. Sometimes, associated are thick accumulations of reddish radiolarian cherts, which are thought to represent organic deposition in marine waters possibly at least 3,000 meters (10,000 feet) deep. One limestone, the Calera, occurs discontinuously along the east side of the San Andreas fault from San Francisco to near Hollister. Another is the red Laytonville limestone found north of San Francisco Bay almost to Eureka; it has fewer and smaller outcrops than the Calera. Previously both limestones were thought to be chemical precipitates, because of their fine grain and lack of obvious fossils. Studies have shown, however, that these rocks contain siliceous radiolarians and planktonic calcareous foraminifers, with bulk composition resembling some modern deep-sea oozes. Furthermore, the dark color and bituminous character of some parts of the Calera show that deposition occurred in stagnant basins. Within this array of sedimentary rocks are some altered submarine volcanics, now mostly greenstones, and other metamorphic rocks such as the distinctive blue glaucophane schist and the more common green chlorite schist.

All these Franciscan rocks have been intruded by ultrabasic igneous rocks, now serpentinized peridotite (serpentinite). Sometimes the serpentinites have been injected as normal molten intrusives, but in other instances they occur in sill-like sheets that lack the thermal alteration of the enclosing rocks characteristic in most sills. In still other cases, these plastic serpentinites have squeezed up through the overlying rocks as plugs or diapirs. The prevailing view is that these serpentinized peridotites are altered masses derived from the upper mantle and transferred tectonically to the earth's surface.

Although the Franciscan is more than 15,000 meters (50,000 feet) thick, no recognizable top or bottom has yet been observed. This is surprising, because many rocks in adjacent provinces are much older. This curious record—like a book missing its first and last pages—has prompted the suggestion that the Franciscan sediments were deposited in a deep oceanic trench directly on mantle material or on a thin oceanic crust overlying the mantle. Supporting this contention is the presence of ophiolites in the Franciscan, which are distinctive assemblages of ultramafic rocks thought to represent typical oceanic crust. A complete ophiolite sequence includes: (top) pillow lavas often containing pockets of radiolarian chert; a mass of basaltic dikes and sills (the sheeted complex); gabbro and diorite; and (bottom) an ultramafic complex of serpentinites and dunites.

Fragments of ophiolite sequences occur in the Franciscan melanges, but in a number of places Great Valley beds of late Jurassic age rest in depositional contact on radiolarian cherts and typical Coast Range ophiolites of middle Jurassic age. Some of the best examples of ophiolite sequences occur at Point Sal in Santa Barbara County, in Del Puerto Canyon in the northern Diablo Range, and along the South Fork of Elder Creek in western Tehama County in the northern Coast Range. Many other partial sequences occur in the Coast Ranges, and other fine examples (previously mentioned) occur in the Sierra Nevada and Klamath Mountains.

Ophiolite sequences occur at many other places in the world; they are always associated with eugeoclinal sedimentary rocks similar to the Franciscan. Ophiolites are interpreted as masses of oceanic crust because of

1. Their lithologic similarity to samples dredged from oceanic fracture zones.
2. Their bulk chemical composition.
3. Their close association with pillow lavas and radiolarian cherts, indicating deep-sea volcanic extrusion.
4. Similarity of seismic characteristics measured in both ophiolites and ocean crust.