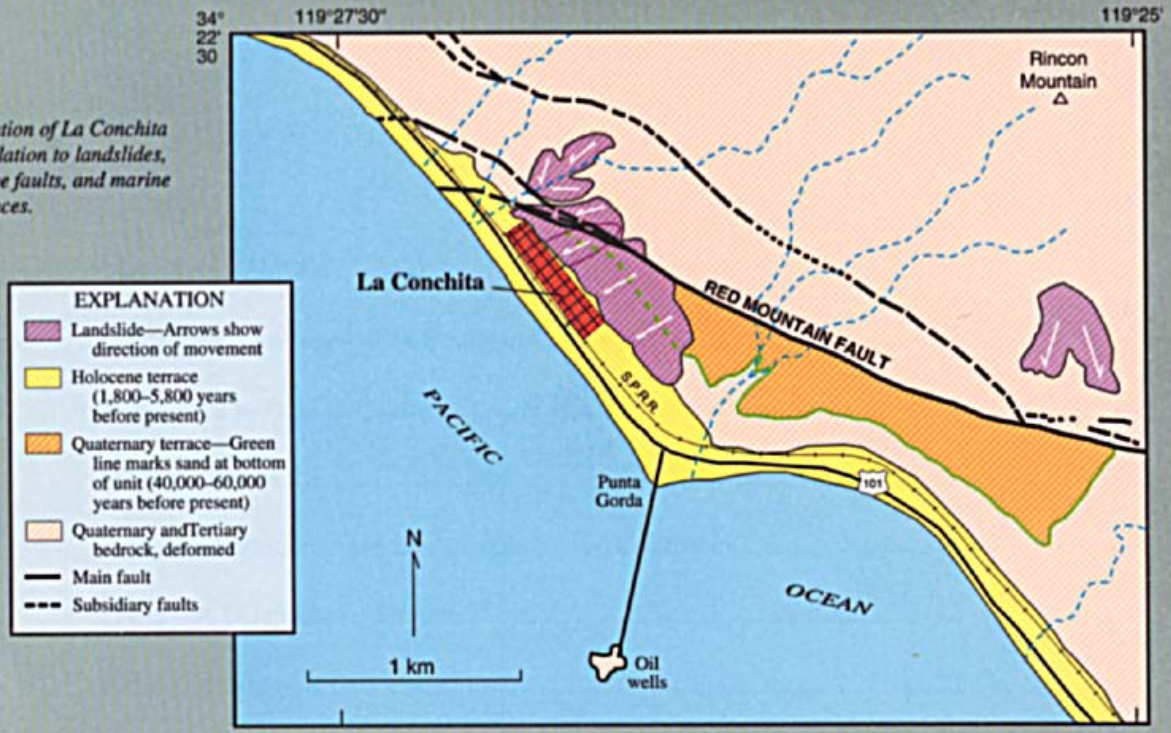
LANDSLIDES—An Example in Southern California

Landslides are major causes of property damage and loss of life throughout the world (Brabb, 1991). A graphic example of landslide risk occurred March 4, 1995, in the coastal community of La Conchita, California.

The community of La Conchita ("The Little Seashell") lies on a narrow strip of low land along the Pacific coast of Ventura County, Calif., wedged between U.S. Highway 101 and the Southern Pacific railroad on the ocean side, and the base of steep, wave-cut cliffs that form the base of Rincon Mountain on the landward side. The unique geologic and geographic settings of this area combine to make it picturesque and scientifically interesting—but also susceptible to several natural hazards.

Geologic mapping of the area by U.S. Geological Survey, California Division of Mines and Geology, and oil industry geologists over several decades has revealed the geologic history and identified the natural hazards to life and property in this area (Weber and others, 1973; Sarna-Wojcicki and others, 1987a). The mapping provides a basis for understanding the relationship between geologic processes and natural hazards.

The earth's crust in the western Transverse Ranges, where the community of La Conchita is located, is undergoing rapid deformation as the Pacific crustal plate moves northwest relative to the North American plate and meets the obstacle of a large, westerly bend in the San Andreas fault zone (the boundary between these plates; Wentworth and Yerkes, 1971; Morton and Yerkes, 1987). As a consequence, the earth's crust in this region is being compressed and thickened, and in places forced upward. Geologically young sediments once deposited on the deep ocean floor are now being squeezed like putty in a



Location of La Conchita in relation to landslides, active faults, and marine terraces.

vise and pushed up above sea level. In places north of the city of Ventura, the land is rising as much as 15 mm per year (Yerkes and others, 1987). At La Conchita, the rate is about 3 mm per year. These young sediments and rocks are poorly consolidated and very susceptible to erosion and downslope movement in the form of landslides and soil flows from the cliffs and mountain slopes above La Conchita, and floods, mudflows, and debris flows in the gullies north and south of the community.

Several large, old landslides were mapped in the 1970's in the cliffs directly behind La Conchita; some smaller, more recent landslides are nested within the older (see map, p. 2; Weber and others, 1973; Sarna-Wojcicki and others, 1987a). As a result of heavy rains in January and March of 1995, some of these landslides were reactivated, destroying nine homes near the base of the cliff (see photographs). The new slides now threaten to destroy additional homes. Highway 101 and the Southern Pacific railroad were closed down numerous times in this area by earlier landslides and debris flows before La Conchita was developed in the 1920's.

During the last several hundred thousand years, as this area was being uplifted above the ocean, the ocean itself was undergoing cyclic rises and falls in level that were climatically controlled. The ocean level fell during glacial periods, when ice was stored on land in glaciers, and rose during warm periods, when the glaciers melted and their water returned to the oceans. Over time, the uplift of the earth's crust in this region has been more rapid and continuous than the sea-level oscillations. As the land rose, the ocean carved notches into the rising Rincon Mountain during sea-level highstands. The notches show up as more-or-less flat topographic benches, called terraces, at different elevations on the mountain. The oldest terraces are high up on the mountain and have been much modified by erosion. The youngest, most recently emerged terrace is the low, flat bench on which La Conchita is built. Although a thin veneer of young alluvium and debris flows have covered the flat, beveled platform cut by the surf, the general shape of this terrace is still easily seen. Shells of clams and snails found in uplifted beach sands on this terrace yield radiocarbon ages of between about 1,800 and 5,800 years before the present (Lajoie and others, 1982).

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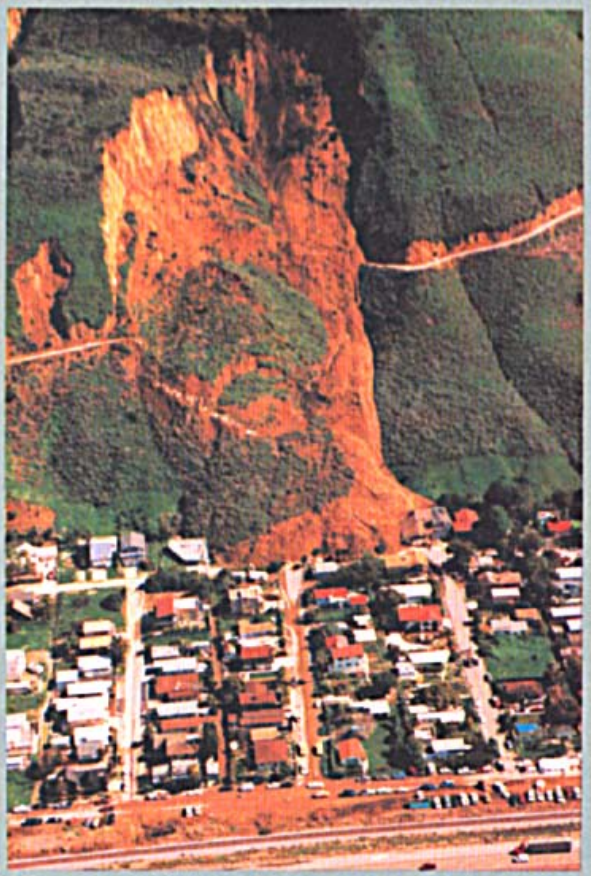

Oblique aerial view of the main landslide, showing houses engulfed along the toe of the slide. Light streaks forming a partial "V" on the face of the slide are broken remnants of the road that crosses the area diagonally from left to right. Small slide to left is one of four that broke out from topographic benches on the cliff face. Photograph on next page is at the right side of the toe of the slide. Aerial photograph, March 6, 1995, by AP/Wide World Photos.

Much of the community of La Conchita lies at elevations of between 6 and 12 m above mean sea level, elevations usually above the reach of high tides and winter storms. However, the community is vulnerable to the surf from exceptionally large storms and tsunamis, and these processes carved the steep cliffs behind the community, oversteepening the slopes and making them prone to landsliding.

Above the level of the cliffs, at an elevation of about 120 to 150 m, is another, broader bench that represents an older marine terrace. The base of this marine terrace (shown as a green line in map on p. 2) is again recognized by the presence of a beveled, wave-cut platform that was cut into the deformed marine sediments. A beach sand lies on top of this platform and contains many fossil mollusk shells. Ages obtained on these shells by amino-acid racemization and radiocarbon analyses indicate that this terrace is between about 40,000 and 60,000 years old (Lajoie and others, 1982). This terrace is also backed by old seacliffs and covered by younger alluvium and mudflows. The old sea cliffs are less steep and are partly buried, having been modified by erosion. The elevation of this terrace increases to the southeast to levels as high as 210 m, indicating that uplift is greater in that direction.

Deformed, clayey, relatively impermeable Quaternary bedrock that underlies the beveled marine terrace is overlain by well-sorted marine sand, which is in turn overlain by alluvium and mudflow deposits. This sequence of layers makes for an unstable combination that is particularly susceptible to landsliding when the permeable sediments are water saturated.

Faults just inland from La Conchita (see map, p. 2) appear to be active (Sarna-Wojcicki and others, 1979, 1987a; Yeats and others, 1987). Thus, there is a potential of ground shaking and ground rupture in the vicinity and at La Conchita. The faulted bedrock, marine terrace deposits, and old landslides above La Conchita represent a nexus of geologic circumstances that favor rapid downslope mass movements in the future. Ground rupture, ground shaking, and landslides can not only affect the houses in the community, but can also block the highway and railroad, and sever offshore and onshore oil pipelines, causing oil spills. Pacific Operators Offshore, Inc., which operates a crude-oil pipeline along the road above La Conchita, was forewarned of problems by the appearance of cracks in the road in late August 1994. The company took an elaborate series of precautions that averted a spill when the slide ruptured the pipeline.

The lessons of La Conchita underscore the importance of geologic studies as elements of land-use planning.

House on left was pushed onto the house at right by the slide. Photograph by Howard Wilshire.

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