

COASTAL LANDSLIDES IN SOUTHERN CALIFORNIA

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COASTAL LANDSLIDES IN SOUTHERN CALIFORNIA

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Sea Grant Publication

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INTRODUCTION

The Southern California shoreline, some of the most beautiful in the world, extends more than 300 miles from Point Conception to the Mexican border. About 180 miles of this coast contain cliffs ranging in height from a few feet to over 300 feet. Population pressure and urban sprawl have produced increasing development of the sea-cliff areas far from the city itself. It is estimated that within the next two decades a "megalopolis" will extend from San Diego to Santa Barbara, much of which will be within the coastal zone. The bluffs above the sea cliffs are considered ideal residential and commercial locations, due to the mild climate, ocean views, and recreational opportunities. Unfortunately, parts of the cliffed portion of the coastal zone are unstable. As a result, over 200 landslides resulting in property damage have occurred. Many more pre-historic and ancient slides have been mapped by geologists. Governmental bodies, builders, and, particularly, consumers of the final product should be aware of the geologic hazards attendant with sea-cliff development, and the existing technology for minimizing the risk.

Geologists generally agree that most coastal landslides are young, having occurred within the past 5,000 years when the sea was slowly rising and near its present level. Erosion and formation of sea cliffs could only be initiated when waves could attack the more rugged terrain landward of the flat continental shelf.

Changes in the elevation of the land relative to sea level have produced land forms that make the coastal zone inviting for development.

Figure 1. The Point Fermin landslide at the southern tip of the Palos Verdes Peninsula. The slide disrupts the nearly flat surface of a marine terrace in the right half of the picture. One can also barely discern the foundations of removed structures adjacent to the disrupted asphalt street across the slide. (Photo by John S. Shelton)

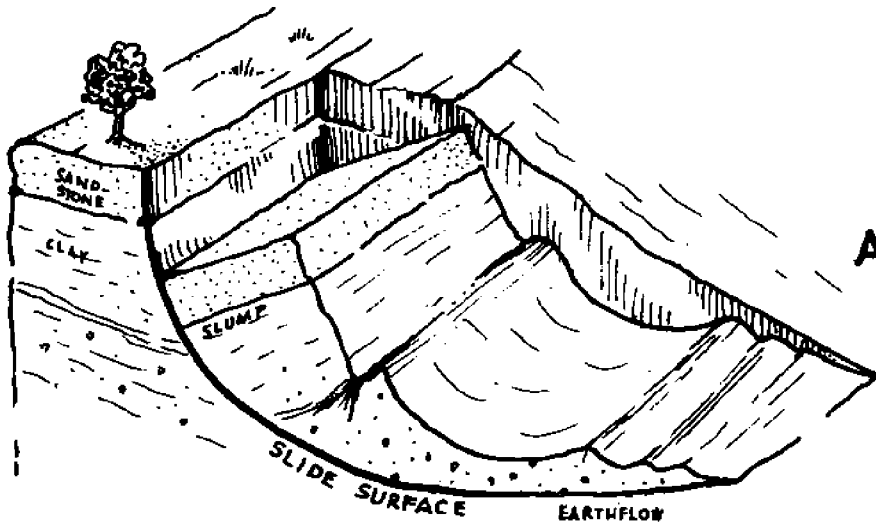


Nearly flat surfaces, formed by the erosive action of waves and surf, have risen to be identified as fossil beaches by geologists. These surfaces, known as marine terraces, form gentle slopes toward the sea above many of the sea cliffs (Figure 1).

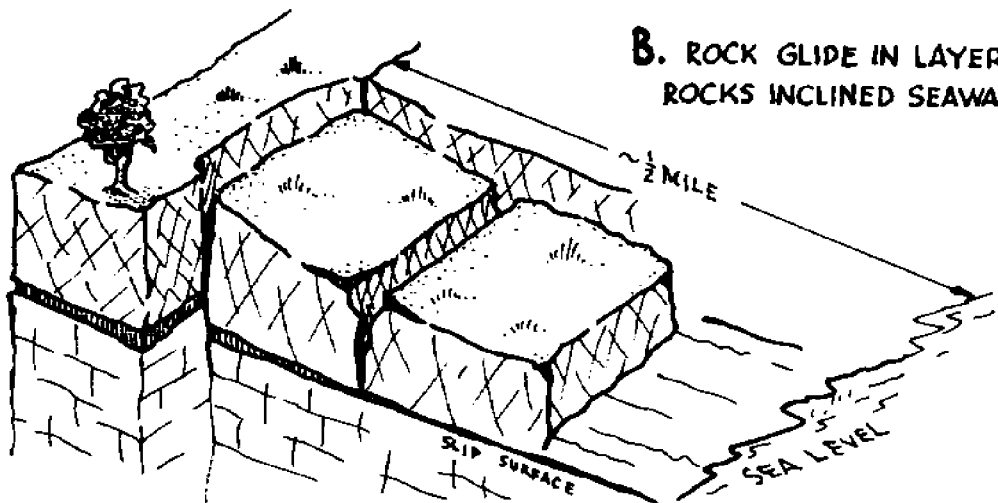
TYPES AND CAUSES OF LANDSLIDES

Most large earth movements or landslides may be classified according to their shape and the earth materials composing the slide mass. Spoon-shaped slides with a curved slide plane are known as slumps (Figure 2-a). These are most common in homogeneous earth materials such as soil and badly broken rock. Block glides, on the other hand, involve translation of large bodies of rock along weak layers that are plane surfaces inclined out of the cliff toward the sea (Figures 1 and 2-b). Both types of slides are common along California's sea cliffs, and some reach enormous dimensions. In addition to the downward and outward sliding of earth materials, rock and soil falls are quite common. Falls, although they occur rapidly, generally affect only a relatively few square yards of area. These result in a slow deterioration of the cliff face, rather than a sudden catastrophic failure of large areas, as may be produced by slump and block glide type failures (Figure 2-c).

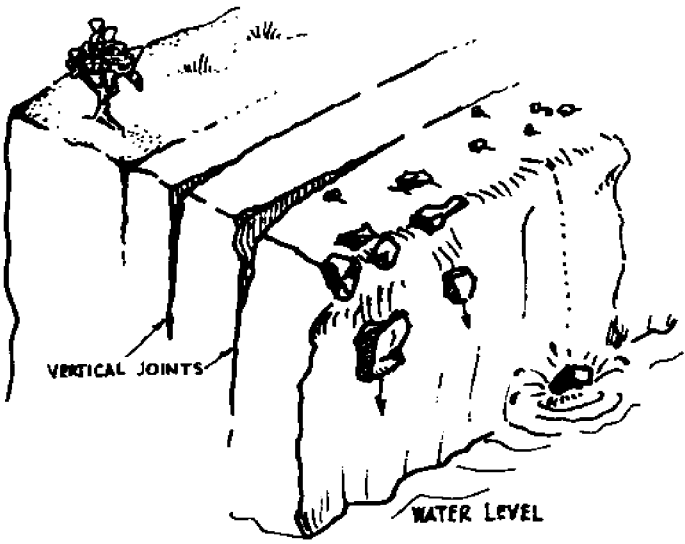
A steep slope that has been standing for some time, perhaps centuries, doesn't just suddenly collapse. Conditions must change, whereby the driving force causing failure (gravity) exceeds the forces resisting movement. The changes leading to failure may be man-made or natural; in many cases these are predictable. Although the



A. SLUMP IN RELATIVELY UNIFORM MATERIAL. NOTE CURVED SLIDE SURFACE.



B. ROCK GLIDE IN LAYERED ROCKS INCLINED SEAWARD.



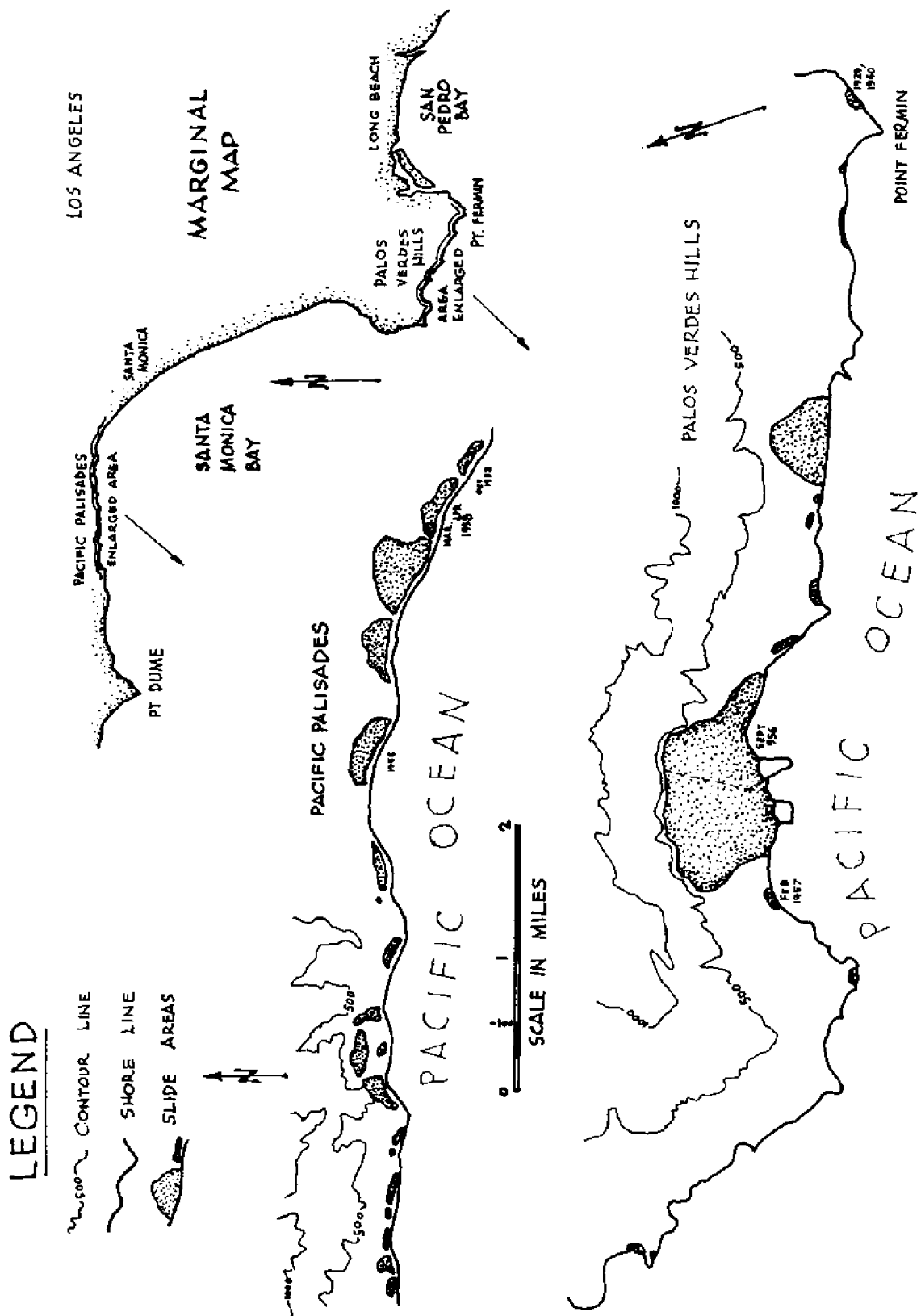
C. EXAMPLE OF A ROCKFALL

factors contributing to a landslide may be complex, they generally fall into two categories: (1) an increase in stresses on the rock due to oversteepening by erosion, regional tilting, or earthquakes; and (2) a reduction of the strength of earth materials by weathering or by changes in moisture content. Commonly, the introduction of water underground due to excessive precipitation, cesspools, or broken water mains is responsible for triggering a slide. Oversteepening of the cliffs by wave action may also be the culprit. In any event, studies suggest that slopes simply do not fail; instead, changes occur over long periods of time in the strength properties or stresses on the rock that ultimately lead to slippage.

Two questions of great significance to anyone building a structure near the top of a sea cliff are: (1) what is the general stability of the cliffed area in question--will a destructive landslide occur; and (2) what is the rate at which the cliff edge is retreating due to surface erosion and undercutting by waves? Basically, are the geologic conditions such that the property will be free from geologic hazards for the lifetime of the project? These questions can best be answered for a given site by a qualified engineering geologist and soils engineer.

A recent study by the junior author is instructive in terms of the general stability of 38 miles of cliffed shoreline from the Palos Verdes Hills southward to Dana Point. About 15 percent of the coastline within this area has suffered landslides; however, over 90 percent of the cliffs are undergoing mass movement, consisting mostly of rockfalls and downhill creep of material. The landslides occur predominantly

Figure 3. Landslides (darkened areas) from Emery (1960) and Roth (1959)

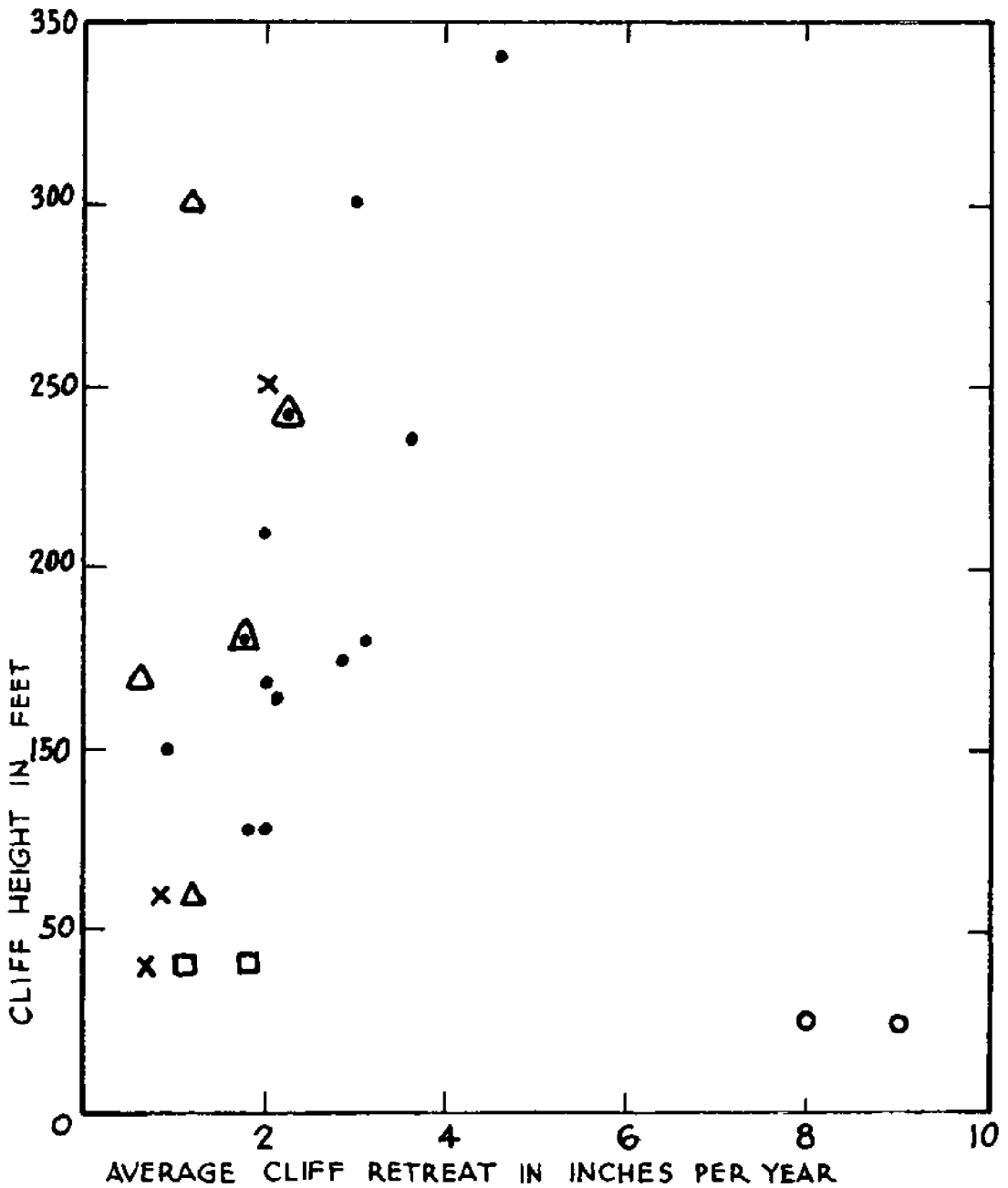


along the eastern portion of the Palos Verdes Hills. Between Abalone Cove and Cabrillo Beach in Palos Verdes, 53 percent of the shoreline has undergone some form of landsliding, and the remainder has experienced rockfalls (Figure 3). Almost all the slides occur in predictable areas where shale beds are inclined seaward out of the sea cliff as in Figure 2-b. The remainder of the slides occur in areas of inherently weak rocks that are subject to sliding wherever moderate or steep slopes occur. It is axiomatic in the field of engineering geology to suspect unstable terrain where ancient or active landslides occur, or where earth materials known to be slide-prone in other localities are present.

The rate of cliff-edge retreat due to erosion is quite difficult to evaluate, but an attempt was made in this study. A bedrock terrace cut by wave action exists at a depth of 30 feet off much of the southern California coastline. This terrace is believed to have been formed 6,000 to 8,000 years ago. Assuming the cliffs were at the location of the terrace 6,000 to 8,000 years ago, and have been eroded back to their present position, rates of erosion can be calculated. Rates as high as 9 inches per year were calculated for cliffs composed of soft sedimentary deposits, to as low as 0.2 inches per year in hard volcanic rocks. Two inches a year seems a reasonable average over a long period of time for the rocks exposed in the sea cliffs from Palos Verdes to Dana Point.

Figure 4 is a plot of cliff retreat versus cliff height. It is interesting to note that fast recession rates are associated with low cliffs composed of soft rocks and deposits, whereas high cliffs composed of resistant rock

Figure 4. Maximum average cliff retreat based on 30 foot submerged terrace contrasted with sea cliff height.



- QUATERNARY TERRACE
- SANDSTONE
- SHALE
- x BRECCIA (SAN ONOFRE BRECCIA)
- △ IGNEOUS ROCKS (BASALT AND ANDESITE)
- ◀ SHALE AND IGNEOUS ROCKS

retreat slowly. With the exception of those places where landslide conditions occur, the conclusion can be drawn that high cliffs exist because they are composed of tough rocks that are capable of supporting steep slopes.

SOME EXAMPLES

Portuguese Bend was developed in the 1940's and 1950's on the terraced land of the south shore of the Palos Verdes Hills (Figure 3). In 1956, a large area of the development began to slide seaward, resulting in distress to many homes on the slide mass. By late 1956, it was realized a large-scale mass movement was taking place that eventually encompassed over 300 acres and destroyed more than 150 homes. Figures 5 and 6 are photos of the same area of Portuguese Bend, one taken in March, 1958, during early stages of the slide, and the other taken in November, 1959, when destruction was almost complete. The location of the slide plane is clearly defined by the buckle in the pier of the beach club. The seaward end of the pier is in stable ground, with the shoreward end on the slide mass. Since 1959, all structures below the highway have been destroyed, the terrain broken into chaotic blocks separated by wide, deep fissures. Although the slide is complex, it is essentially a block glide moving seaward on a plane inclined only 6 degrees from the horizontal. There has been more than 140 feet of horizontal motion since the slide began. Ironically, this area had been mapped prior to development as a slide area by geologists of the United States Geological Survey. The survey published a report and geologic map on the Palos Verdes Hills in the early 1940's that clearly

Figure 5. Lower portion of the Portuguese Bend landslide as of March 5, 1958, with Inspiration Point at right center and Portuguese Point at the extreme right of the photo. Signs of distress are the buckle in the pier that marks the slide plane and fissuring of the ground between the highway and Inspiration Point. In fact, many homes suffered severe distress at this stage and were rendered uninhabitable. Compare with Figure 6. (Photo by John S. Shelton)

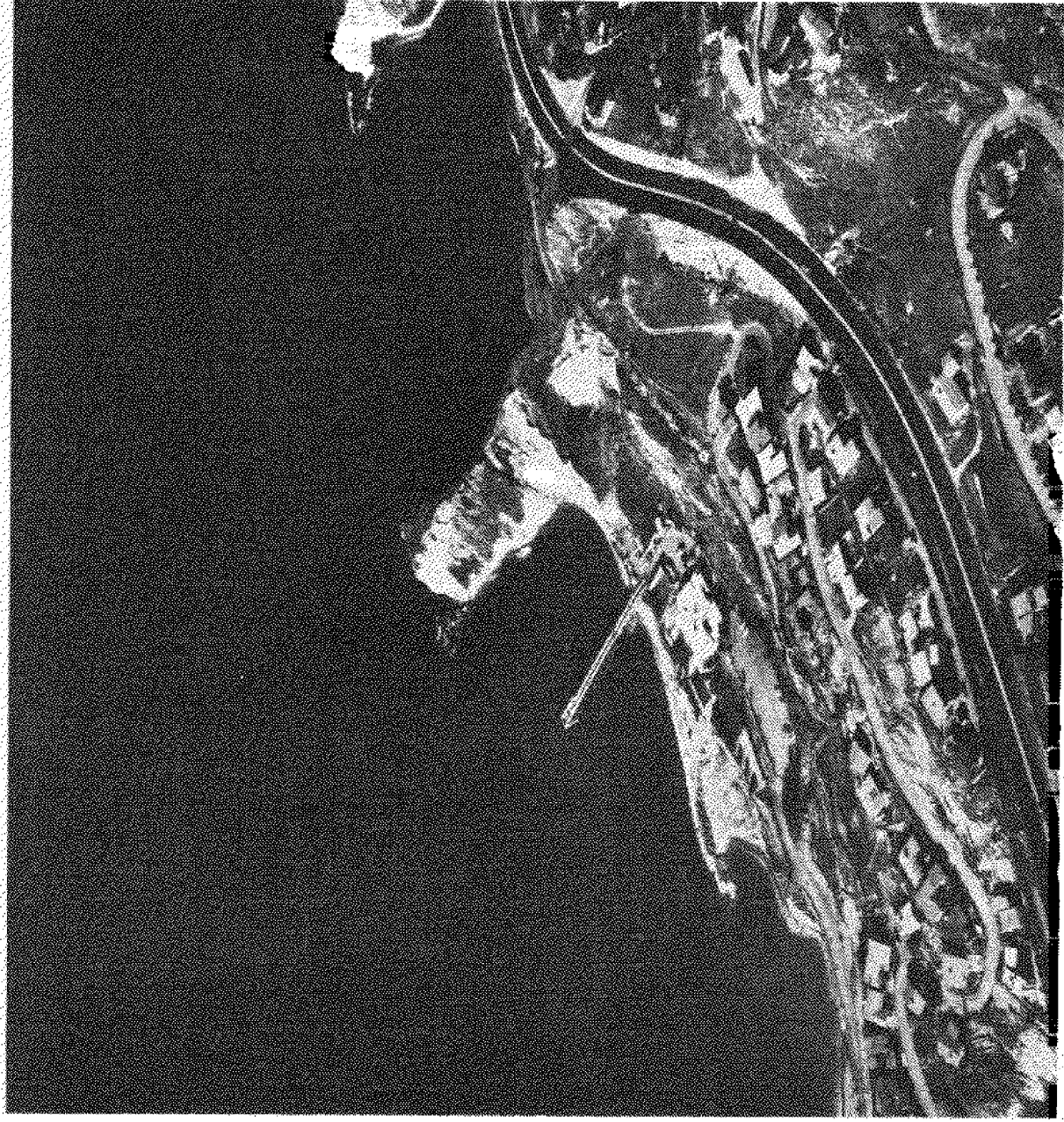


Figure 6. Lower portion of the Portuguese Bend landslide taken November 24, 1959. Inspiration Point is in the upper middle part of the photo. Note the break in the pier that marks the slide plane, the disrupted and fissured ground, and the wavy center divider on the highway. The slide is still moving, as of 1972, at an average rate of about .25 inches per day. The center divider has been removed and the area covered by asphalt. (Photo by John S. Shelton)

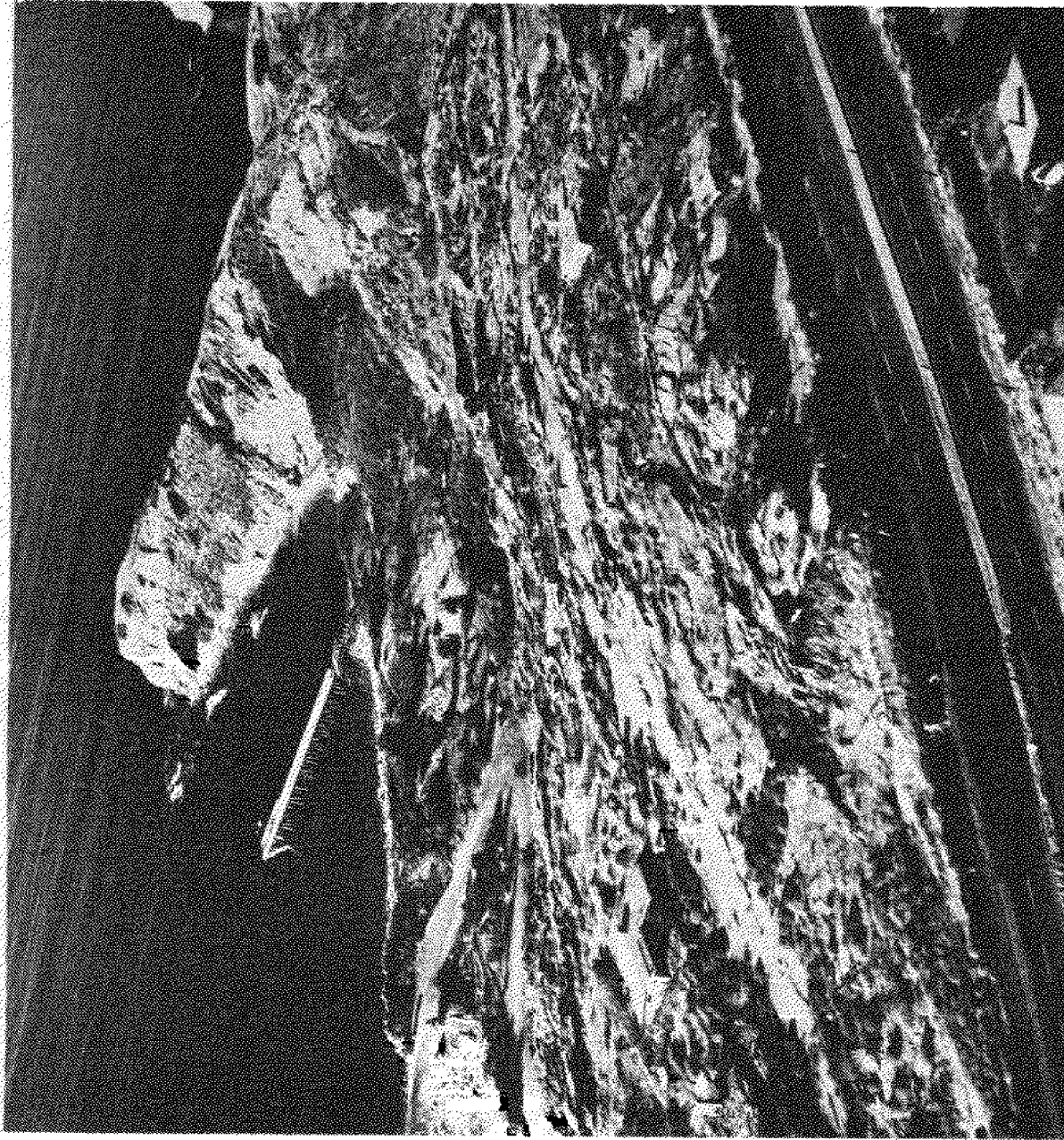
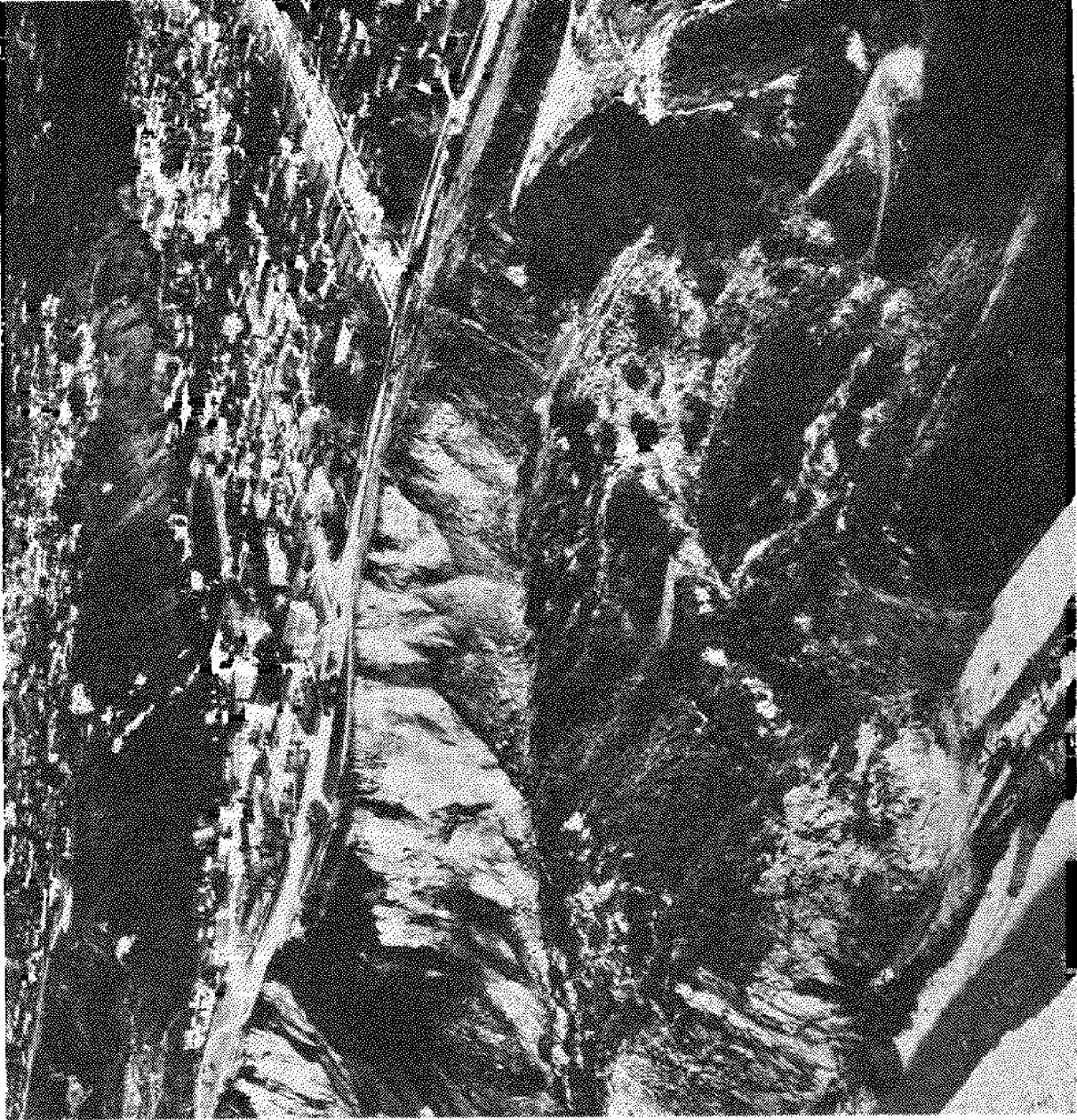


Figure 7. Pacific Palisades landslide the day after it occurred, April 4, 1958. Note the slide to the north that had taken place only a month earlier. Because the slide was so large, the highway had to be relocated around the toe. An ancient slide is to be seen at the low terrace in the lower-right portion of the picture. (Photo by John S. Shelton)



showed Portuguese Bend as an old landslide. Although nature tends to heal landslide scars quickly, a competent geologist can interpret certain terrain features as indicative of ancient landsliding. Such slides, even though no movement has occurred for tens or even hundreds of years, are likely to reactivate. Renewed movement of ancient landslides often results from the addition of water underground.

The Point Fermin slide (Figure 1) became active in 1929 and the photo shows the total displacement after 30 years. Many homes, and a quarter-mile section of road, were destroyed. Failure was caused by underground water weakening shale layers sloping toward the cliff face. Total movement on the slide has been about 200 feet, and recurrent movement takes place during heavy rains.

The Pacific Palisades are a cliffed segment of the coastal zone north of Santa Monica. The palisades themselves present a scalloped appearance from ancient and active slumps and rock-falls. On April 4, 1958, a slide involving 90,000 cubic yards of material plunged down on the Pacific Coast Highway (Figure 7). The movement took place so suddenly that an engineer was killed and several pieces of equipment were buried. The real irony, however, is that the men and equipment had just finished removing the last of the debris from a slide which had taken place a month earlier just to the west. Rather than risk another slide during removal, it was decided to build the highway around the toe of the slump.

In the Pacific Palisades alone, no less than fifty active slides are known. They vary

from small, surface slumps to gross failures as pictured in Figure 7. An insidious type of cliff retreat is that shown in the Figures 8-10. The palisades here have been gradually deteriorating by rock and debris falls over recorded history. The lesson to be learned is that longevity is no guarantee that deterioration or slippage won't occur. It is significant that within the last two decades, the greatest landslide activity occurred during or shortly after heavy rains.

REDUCING THE RISK

The personal tragedies resulting from damaging earth movements are hard to measure by dollar losses alone. "To be forewarned is to be forearmed." There is a wealth of information available to the potential home buyer or builder through agencies on all levels of government. Geological and soils engineering reports concerning the stability of a site are required by many county and local governments before a building permit can be obtained. Any person considering a residence or construction within the cliffed portion of the coastal zone would benefit greatly in the long run by following a few simple suggestions.

1. Find out what the local grading ordinances and code requirements are for construction on hillside or sea-cliff areas. This information is usually obtainable through the local Department of Building and Safety or Engineer's Office. These agencies also distribute lists of Registered Engineering Geologists and Licensed Engineers.

2. When buying property or a home, make execution of the contract contingent upon a

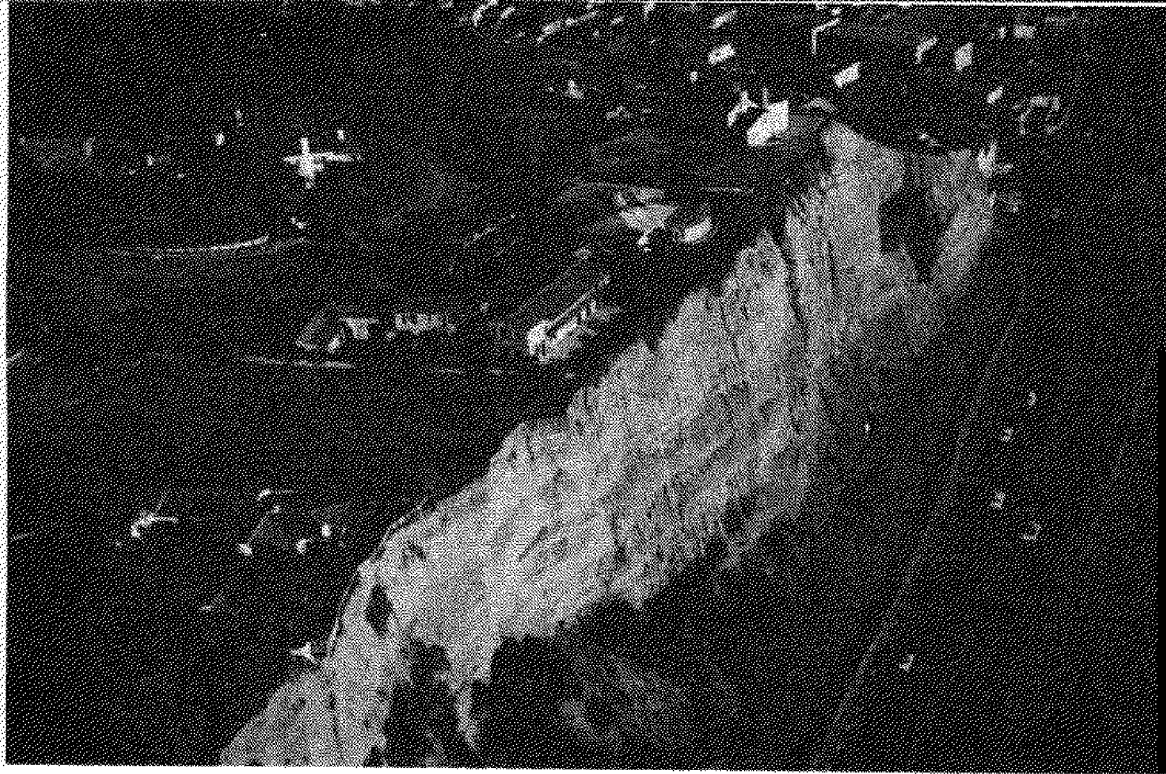


Figure 8. Portion of the Huntington (Pacific) Palisades looking east prior to 1968. Cliffs are composed of poorly consolidated sands and gravels and are 160 feet high.

Figure 9. Closeup of cliff face shown in Figure 8 below dwelling valued in excess of \$100,000. Note vertical cracks (joints) that have become enlarged due to poor surface drainage and precipitation.

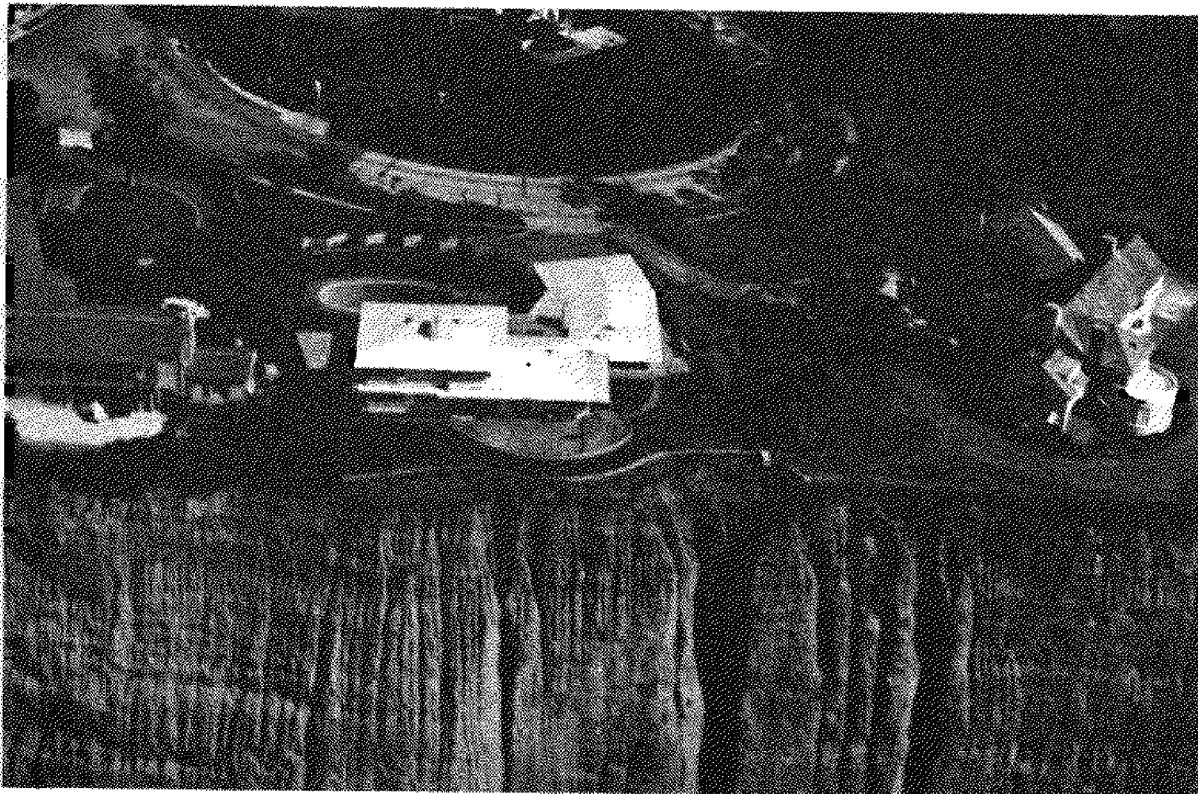
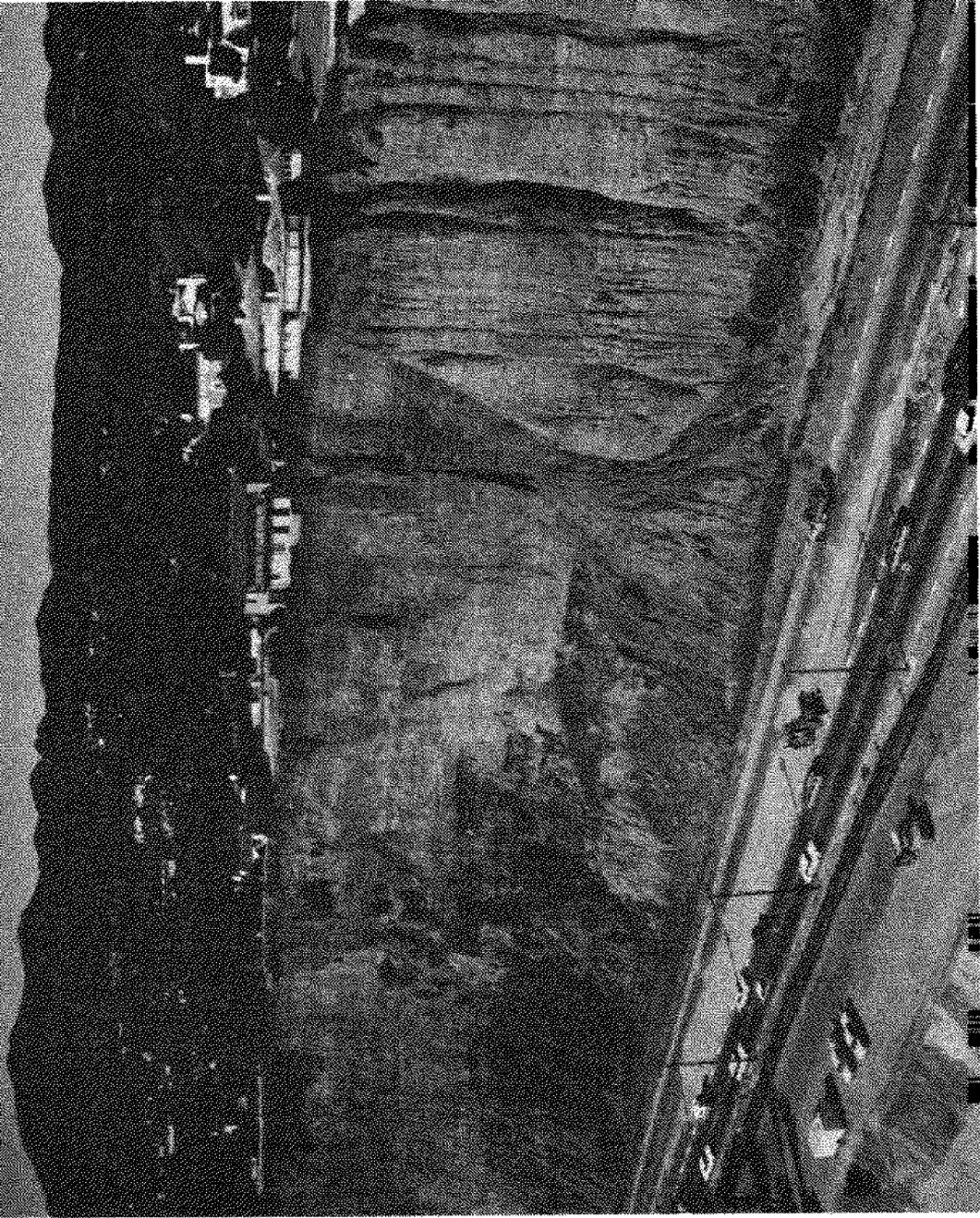


Figure 10. Same area shown in preceding figures after failure (rockfall) along joints shown in closeup of Figure 9. The fall took place in the upper part of the cliff and resulted in the loss of about 15 feet of property at the top.



favorable engineering geological report. Some sites are so difficult that building costs become prohibitive, and some lots with beautiful views are actually unbuildable because of geological hazards. Just because a structure has been standing for 20 years doesn't mean that it is free from hazardous conditions. Most reputable realtors will readily agree to this condition. The cost is nominal, and usually borne by the seller. Remember, even though a site may be hazard-free, local unstable conditions affect property values, and should be considered in the purchase.

3. Before construction, obtain a full-scale engineering geology and soils engineering report. This aids the architect in siting the structure and greatly reduces the risk of property loss. Such reports represent a fraction of one percent of the project cost, and in many cases, save more than the fee.

4. Follow the grading ordinance and consultant's recommendations on lot drainage. Poor surface drainage can cause severe sloughing and speed recession of the edge of sea cliffs.

5. Irrigate judiciously, remembering that excess soil moisture eventually percolates downward, building up pressures that reduce the strength of foundation materials.

More information about landslides may be obtained from the following publications and agencies:

1. Ecket, Edwin B. (1958) Landslides and engineering practice; National Academy of Science-National Research Council Publication 544.

2. Emery, K. O. (1960) The sea off Southern California; John Wiley and Sons, Inc., pp. 20 and 311-313.
3. Krynine, D. P., and Judd, William R. (1957) Principles of Engineering Geology and Geotechnics; McGraw-Hill Book Company, Inc., New York, Chapter 17 on Landslides and Crustal Displacements.
4. Lung, Richard, and Proctor, R., eds. (1966) Engineering Geology in Southern California; Association of Engineering Geologists Special Publication, Los Angeles Section.
5. McGill, John T. (1959) Preliminary map of landslides in the Pacific Palisades area, City of Los Angeles, California; U.S. Geological Survey Miscellaneous Geologic Investigation Map 1-284.
6. Nichols, D. R., and Campbell, Catherine (1969) Environmental planning and geology; Proceedings of Symposium on Engineering Geology in the Urban Environment, U.S. Government Printing Office Stock 2300-1195, \$2.75.
7. Ploessel, M. R. (1972) Sea Cliffs of Southern California, Malaga Cove to Palos Verdes; University of Southern California, unpublished master's thesis, 110 pp.
8. Roth, E. R. (1959) Landslides between Santa Monica and Point Dume; University of Southern California unpublished master's thesis, 184 pp.

Government publications may be obtained from the U. S. Government Printing Office, Public Documents Department, Washington, D.C., 20402. In many cases, these documents exist in the local library. References 1-4 should be available in a large public library or local college or university library. References 7 and 8 are available at the Doheny Library, University of Southern California. In addition, many unpublished landslide maps are available for inspection at the offices of the U. S. Geological Survey, Room 7638, Federal Building, 300 N. Los Angeles Street, Los Angeles, California.