DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

MISCELLANEOUS FIELD STUDIES
MAP MF-339

INTRODUCTION

The nine San Francisco Bay region counties lie within a geologically active, young, and dynamic part of the central and northern Coast Ranges of California. Significant movements of the earth's crust are occurring here at the present time, posing numerous problems to urbanization, including some of special concern. Geological processes such as fault movements, earthquakes, land subsidence, landsliding, slow downslope movement of bedrock and surficial materials, coastal and stream erosion, flooding, and sedimentation are all potentially hazardous. Because of these factors, an understanding of the operation of physical processes in the bay region is desirable for harmonious, efficient, and safe land-use planning, particularly now, with greatly expanded pressures for urban growth.

This map presents preliminary information about one aspect of the physical environment necessary to sound land-use planning--the nature and distribution of surficial deposits. Because surficial deposits are common and well developed in much of the bay region, it is useful to know how and why they have formed, as well as what properties they possess. When maps like this are used in combination with other types of information on topography, soils, bedrock geology, slopes, vegetation, climatic variation, seismic response, and hydrology, it should be easier to arrive at sound decisions regarding the physical aspects of land use. The U.S. Geological Survey is studying many of these factors in the bay region and hopes to provide the community with much of the required information as part of its San Francisco Bay Region Study in cooperation with the Department of Housing and Urban Development.

The representation of surficial deposits on this map reflects the way in which a geologist, working exclusively with aerial photographs, interpreted the origin of various elements of the present landscape. The deposits shown here have not been examined in the field. However, by viewing overlapping vertical aerial photographs through a stereoscope, the geologist sees a three-dimensional relief model of the ground surface and can study and interpret the origins of landforms with considerable ease. In fact, for mapping surficial deposits, particularly in reconnaissance-type studies, photointerpretation has advantages over both ground observations and laboratory studies of surficial materials. Of course, better information can be provided when all aspects of the study are integrated. These preliminary photointerpretation maps are only the first stage in a detailed study of surficial deposits in the bay region, but they should provide land-use planners with immediately useful information about the regional distribution of landslide and other surficial deposits.

This map indicates the dominant surficial processes that have probably been operative by showing the distribution of different types of surficial deposits. Processes such as weathering, erosion, sedimentation, and the slow as well as rapid downslope movement of earth materials have constantly reshaped the land surface in the past and will continue to in the future, although at varying rates. The processes are interrelated to varying degrees. For example, crustal uplift of the Coast Ranges will lead to increased erosion and downcutting by streams that in turn generally results in increased deposition of sediments in river valleys, lakes, and shoreline areas. Older flood plains and river deposits may be eroded, leaving elevated terrace deposits. In addition, downcutting by streams may cause adjacent slopes to become unstable, thereby increasing the possibility of slope failures.

Man's activities can alter natural physical processes in many ways. Simple acts such as overwatering a lawn or placing a septic tank drainfield in ground that is marginally stable may weaken the bedrock and surficial materials enough to induce landsliding. Relatively stable areas may be made unstable as a result of construction activities that involve cutting or oversteepening of natural slopes. Engineers, builders, conservationists, and others concerned with land use must evaluate the potential effects of all types of development, and maps that show the nature and distribution of surficial deposits should provide much of the basic information they need.

This map, then, shows the cumulative effects of various processes that have yielded surficial deposits up to the time the photographs used for photointerpretation were taken. It does not indicate directly what areas where processes will be most active, nor does it show the rate at which they will operate. However, knowledge of the history of geologic events is a key to understanding and predicting the evolution of an area, even where man's activities significantly change the character of the land. Almost all new landslides, for example, occur in areas with a history of landslide activity.

CHARACTERISTICS OF SURFICIAL DEPOSITS RELEVANT TO LAND-USE PLANNING

General background:

The physical properties and engineering characteristics of the mapped surficial deposits can be inferred from knowledge of the geologic processes that formed them. Thus, with the information provided by this map, preliminary evaluations of the significance of the materials and processes with regard to land-use decisions can be made.

Landslide deposits:

Landslides occur when the pull of gravity on earth materials overcomes their frictional resistance to downslope movement. Slope stability is affected by (1) type of earth materials--unconsolidated, soft sediments or surficial deposits will move downslope easier than consolidated, hard bedrock; (2) structural properties of earth materials--the orientation of the layering of some rocks and sediments relative to slope directions, as well as the extent and type of fracturing and crushing of the materials, will affect landslide potential; (3) steepness of slopes--landslides occur more readily on steeper slopes; (4) water--landsliding is generally more frequent in areas of seasonally high rainfall, because the addition of water to earth materials commonly decreases their resistance to sliding; water decreases internal friction between particles, decreases cohesive forces that bind clay minerals together, lubricates surfaces along which slippage may occur, adds weight to surficial deposits and bedrock, reacts with some clay minerals, causing volume changes in the material, and mixes with fine-grained unconsolidated materials to produce wet, unstable slurries; (5) ground shaking--strong shaking during earthquakes can jar and loosen bedrock and surficial materials, thus making them less stable; (6) type of vegetation--trees with deep penetrating roots tend to hold bedrock and surficial deposits together, thereby increasing ground stability; (7) proximity to areas undergoing active erosion--rapid undercutting and downcutting along stream courses and shorelines makes slopes in these areas particularly susceptible to landsliding.

All the natural factors that promote landsliding are present in the bay region. In addition, man has at times decreased the potential for slope failures by leveling slopes, building retaining walls at the base of slopes, planting trees or seeding forests, as well as practicing soil conservation. However, other of his activities have increased the potential for slope failures, including increasing slope angles for road or building construction; adding water to marginally stable slopes by watering lawns, improperly handling rain-water runoff and choosing poor sites for septic tank drainfields; adding to the weight of marginally stable slopes by building structures as well as by adding fill for foundations; and removing natural vegetation. Thus, slope failure, a natural phenomenon that has occurred throughout the bay region in the past, may be aggravated by improper land use.

The landslide deposits shown on the map may or may not be continuously or intermittently moving at the present time. The potential for continued movement varies greatly and depends on many factors, including the age of the deposits and their previous histories of activity. Some deposits may pose no problems for many types of development, while development on others may offer serious problems. Most landsliding takes place in areas where landsliding has occurred before, and old landslide deposits are commonly reactivated by either natural or artificial means. The materials that form landslide deposits may be so broken up and disturbed that landsliding may easily recur, especially if slope angles or moisture contents are changed. Landslide deposits are characterized by (1) small isolated ponds, lakes, and other closed depressions; (2) abundant natural springs; (3) abrupt and irregular changes in slope and drainage pattern; (4) hummocky irregular surfaces; (5) smaller landslide deposits that are commonly younger and form within older and larger landslide deposits; (6) steep, arcuate scarps at the upper edge of the deposit; (7) irregular soil and vegetation patterns; (8) disturbed vegetation; and (9) abundant flat areas that might appear suitable as construction sites. In general, fewer of these characteristics will be noted in the smaller deposits. Detailed ground studies, of course, are required for predicting the future behavior of landslide deposits under changing conditions.

Alluvial deposits:

The surfaces of these deposits generally are relatively flat or gently sloping, with finer grained sediments deposited on flood plains surrounding the active-stream channels. Excellent soils suitable for diverse agricultural activities are found on many older flood plains. These deposits may be water bearing, are commonly porous and permeable, and may compact slightly upon loading. In larger drainage basins, they may be excellent shallow sources of water and of construction aggregate. They are probably easy to excavate, with pebble- and cobble-rich layers locally abundant. The surface may be subject to flooding seasonally or less frequently; the active stream channel may alter its course gradually over a long period of time or rapidly during flooding. Migration of the channel can result in erosion, undercutting, and failure of stream banks if the bank edges slump or fall off into the stream channel.

Colluvial deposits and small alluvial fan deposits:

Colluvial deposits generally are easily eroded and excavated; they will probably compact under loading and may continue to move slowly downslope, particularly the steeper parts. They may be water-bearing, with small springs associated with some. Grading (road construction, etc.), particularly when it results in steeper slopes, may accelerate the rate of downslope movement and produce landslide deposits.

Small alluvial fan deposits range in character from sands and gravels deposited by streams to finer grained clay-rich accumulations deposited by mudflows. Some fans include abundant colluvial material, while others contain only alluvial sediments. As a result, porous and permeable gravel-rich layers may alternate with impermeable clay-rich layers; the deposits may be a good shallow source of water. Fan deposits are generally easy to excavate and not very resistant to erosion. Flooding and considerable erosion of the fans can be expected during periods of heavy rainfall. Natural slopes are normally stable, although stream undercutting can produce streambank failure, and some compaction or local subsidence of the fan surface may take place.

Alluvial terrace deposits:

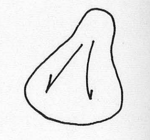
These deposits have many of the characteristics of alluvial deposits. However, because they are older and lie well above present stream level, they probably contain less water and may be more consolidated than alluvial deposits. The terrace deposits may be subject to slope failures, particularly where adjacent streams undercut the edges of the terrace. The lowest terrace deposit may still be subject to periodic flooding and sediment deposition, inasmuch as complete abandonment by the stream cannot be determined by photointerpretation.

Marshland deposits:

The soft, unconsolidated muds deposited along the margins of San Francisco Bay have some unique characteristics that pose serious problems to development and construction. These characteristics have been discussed at some length by several writers, and the reader is referred to the following for additional information:

(1) Goldman, H. B., ed., 1969, Geologic and engineering aspects of San Francisco Bay fill: California Div. Mines and Geology Spec. Rept. 97, 130 p.
(2) Mitchell, J. K., 1963, Engineering properties and problems of the San Francisco Bay mud: California Div. Mines and Geology Spec. Rept. 82, p. 25-32.
(3) Nichols, D. R., and Wright, N. A., 1971, Preliminary map of historic margins of marshland, San Francisco Bay, California: U.S. Geol. Survey open-file map, scale 1:125,000.
(4) Trask, P. D., and Rolston, J. W., 1951, Engineering geology of San Francisco Bay, California: Geol. Soc. America Bull., v. 62, no. 9, p. 1079-1110.

EXPLANATION



Landslide deposit larger than approximately 500 feet in longest dimension. Queried where identification uncertain. Arrows indicate general direction of downslope movement.

Landslide deposit approximately 200-500 feet in longest dimension. Queried where identification uncertain. Arrow indicates general direction of downslope movement and is positioned over location of deposit.

Debris composed of fresh and weathered rock fragments, sediment, colluvial material, and artificial fill, or any combinations thereof, that has been transported downslope by falling, sliding, rotational slumping, or flowing. Landslide deposits smaller than approximately 200 feet in longest dimension are not shown on the map. Complex landslide deposits, which result from combinations of different types of downslope movement, are perhaps the most common type of landslide deposit in the bay region. In particular, materials near the head of landslide deposits typically move in a different manner than materials at the toe. The landslide deposits shown on this map have not been classified according to either type of movement or type of material of which the deposit is composed. The deposits vary in appearance from clearly discernible, largely unweathered and uneroded topographic features to indistinct, highly weathered and eroded features recognizable only by their characteristic topographic configurations. The time of formation of the mapped landslide deposits ranges from possibly a few hundred thousand years ago to 1966. No landslide deposits that formed since 1966 are shown. The thickness of the landslide deposits may vary from about 10 feet to several hundred feet. The larger deposits are generally thickest; many small deposits may be very thin and may involve only surficial materials.

Qal

Alluvial deposits

Irregularly stratified, poorly consolidated deposits of mud, silt, sand, and gravel deposited in stream and river beds and on adjoining flood plains. Alluvial deposits less than about 200 feet wide, common along smaller streams, generally have not been mapped; where colluvial deposits are adjacent to such narrow strips, the alluvial deposits have been included with them. Includes older and younger alluvial fan deposits that form broad, extensive, gently sloping surfaces composed of coalesced large alluvial fans that border upland areas. Deposition is continuing on the younger parts of these fan complexes as well in the major alluvial channels that cut across the fan surfaces. See Helley and Brabb (1971) for more detailed mapping of alluvial deposits in the western part of the map area.

Colluvial deposits and small alluvial fan deposits

Colluvial deposits: unstratified or poorly stratified, unconsolidated to poorly consolidated deposits composed of fresh and weathered rock fragments, organic material, sediments, or irregular mixtures of these materials that accumulate by the slow downslope movement or surficial material predominantly by the action of gravity, but assisted by running water that is not concentrated into channels. Colluvial deposits have been mapped only where they form a distinct apron near the base of slopes or where they fill and flatten canyon, ravine, and valley bottoms. Colluvial deposits are probably forming on almost every slope in the bay region, but only the thicker and more extensive accumulations that are recognizable on aerial photographs have been mapped. In some narrow stream valleys, colluvial deposits include alluvial deposits. Colluvial deposits may move downslope along the axes of ravines and may form fan-shaped deposits where they emerge onto more gently sloping valley floors.

Small alluvial fan deposits: irregularly stratified, unconsolidated to poorly consolidated, fan-shaped accumulations of water-laid sediment formed where narrow canyons emerge onto more gently sloping valley floors. The fan sediments are composed of mud, silt, clay, and gravel deposited by streams and thin water-rich mudflows. These deposits commonly grade upslope into colluvial deposits and may be interbedded with them.

Note: because of the difficulties in distinguishing small alluvial fan deposits from fan-shaped colluvial deposits by photointerpretation, the two units have not been distinguished on this map.

Alluvial terrace deposits
(boundaries dashed and queried where uncertain)

Irregularly stratified alluvial deposits of mud, silt, sand, and gravel that underlie horizontal to gently inclined flat surfaces that are adjacent to but above the present streambeds or valley floors. These deposits are generally not present sites of sedimentation, but represent older levels of stream deposition and erosion that have been abandoned as the stream continued to erode downward. Some areas may consist only of flat stream-cut surfaces eroded into bedrock without alluvial deposits on them; these areas cannot be easily distinguished from true terrace deposits by photointerpretation.

Qm

Marshland deposits

Stratified organic-rich fine-grained sediments deposited around the margins of San Francisco Bay. Primarily soft mud and silt, with some shell, peat, sand, and gravel layers. Generally form marshy or swampy areas at or near sea level; commonly inundated during high tides or floods where unprotected by artificial levees. Extensively converted to artificial salt evaporating ponds in this area. Grade shoreward into alluvial deposits, with shoreward boundary from Nichols and Wright (1971).

Qaf

Artificial fill

Highway, railroad and canal fills composed of rock and surficial deposits derived from nearby cuts or quarries; only large fill areas are shown on the map.

Bedrock
(queried where identification uncertain)

Igneous, metamorphic, and sedimentary rocks of various ages, physical properties, and engineering characteristics. Areas not shown on the map as covered with surficial deposits probably contain bedrock either exposed at the surface or mantled by a thin veneer of surficial deposits, most commonly colluvial material. The bedrock is commonly weathered to a considerable depth, so that there is a gradual change downward from highly weathered organic-rich soil to fresh bedrock. Thus, many of the small landslide deposits and some of the large landslide deposits that are shown on the map to lie within bedrock areas probably involve only material derived from weathered bedrock and other colluvial material.

SUGGESTIONS FOR MAP USERS

Planning departments and developers:

The density of landslide deposits is a crude measure of the importance of slope failure as an erosional process and, therefore, a measure of the overall slope stability of an area. However, this map cannot be used to determine the probability of future landsliding, primarily because geologic and climatic changes during the past few hundred thousand years have altered slope stability and because the map does not provide detailed information regarding the composition and type of movement of individual landslide deposits. Therefore, the map should not be used as a substitute for detailed site investigations by engineering geologists and soils engineers; areas susceptible to landslide activity should be carefully studied before any development.

Geologists and engineers:

This map has been prepared to provide a regional context for interpreting detailed site investigations and should be used in conjunction with slope maps, bedrock geology maps, soils maps, and other available information. It is not intended as a substitute for site investigations, and its limitations should be clear. Comments regarding its usefulness and accuracy would be appreciated.

Home buyers:

Areas with relatively low densities of landslide deposits probably have good slope stability compared with areas with high densities of landslide deposits. However, landslide deposits less than 200 feet long have not been mapped, and the scale of this map is such that individual buildings cannot be precisely located. In fact, areas mapped as landslide deposits are not necessarily less stable than adjacent areas. The map, therefore, should not be used as a substitute for a report by an engineering geologist or soils engineer, because detailed site investigations are necessary for judgments about the slope stability of individual areas. In addition, other types of surficial deposits may pose construction problems and require investigation.

FACTORS AFFECTING MAP ACCURACY

Date of photography:

Modifications of the landscape that have occurred since the date the aerial photographs were taken are not shown on this map. Thus, landslide deposits and large artificial fills that postdate the photography are not delineated, although some of the topographic base maps were photorevised in 1968 and do show the extent of urbanization to that date.

Urbanization:

Surficial geologic features can be obscured in urbanized areas by (1) modification of the natural landscape by grading (leveling, cutting, filling, or terracing), and (2) man-made structures that cover the natural land surface. Less than 10% percent of the area included in this map has been extensively urbanized.

Forest cover:

Surficial deposits may be difficult to recognize in forested areas, so that such areas may be mapped less accurately than grass-covered areas. Many landslide deposits may be impossible to recognize on slopes covered with dense stands of tall trees. Less than 15 percent of the area included in this map is densely forested.

Quality of photography: The accuracy of the map varies directly with the clarity and contrast of the aerial photographs used. Accordingly, haze, cloud cover, or poor sun angles make photointerpretation more difficult; also, the steepness of the topography and the location and extent of shaded areas affect the usefulness of individual photographs. In general, however, the photographs used to prepare this map are of excellent quality.

Scale of maps and photography: Landslide and other surficial deposits less than about 200 feet long are not shown because they are too small to be clearly identified on the photographs or clearly portrayed on the topographic base map. In addition, no attempt has been made to show the numerous small areas covered by artificial fill along highways, railroads and airstrips, in cementeries, in populated and farming areas, or near quarries and mines, even though some are more than 200 feet in longest dimension.

Problems in interpretation: Mapping of surficial deposits by photointerpretation alone presents a number of difficult problems, some of which can be resolved only through field checking. Problems that are especially difficult include: (1) distinguishing terrace-shaped slump-type landslide deposits from alluvial terrace deposits where both are located adjacent to stream courses; (2) recognizing bedrock cropping out beneath surficial deposits, especially where a creek or stream has cut down through the overlying surficial deposits to expose bedrock along the streambed; (3) determining boundaries between adjacent surficial deposits that laterally grade into or interfinger with one another without leaving any easily discernible topographic boundaries, e.g., the downstream gradation of alluvial terrace deposits into alluvial deposits; (4) recognizing landslide deposit boundaries--whereas the upslope boundary is commonly defined by an easily recognized scarp, the toe or downslope boundary is seldom well defined and is difficult to locate exactly; (5) recognizing stable masses of bedrock within landslide deposits, especially where the bedrock may appear only as a large block within the surrounding landslide deposit; and (6) distinguishing between irregular or hummocky topography caused either by variations in the erosional resistance of bedrock or by the erosion of landslide deposits.

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Jenkins, O. P., ed., 1951, Geologic guidebook of the San Francisco Bay Counties: California Div. Mines Bull. 154, 392 p.

Radbruch, D. H., and Wentworth, C. M., 1971, Estimated relative abundance of landslides in the San Francisco Bay region, California: U.S. Geol. Survey open-file map, scale 1:500,000.

Rogers, T. H., compiler, 1966, Geologic map of California, Olaf P. Jenkins Edition--San Jose sheet: California Div. Mines and Geology, scale 1:250,000.

Schlocker, J., compiler, 1971, Generalized geologic map of the San Francisco Bay region: U.S. Geol. Survey open-file map, scale 1:500,000.

Geology of the San Jose, Mount Hamilton, and Mount Boardman 15-minute quadrangles

Crittenden, M. D., Jr., 1951, Geology of the San Jose-Mt. Hamilton area, California: California Div. Mines Bull. 157, 74 p.

Helley, E. J., and Brabb, E. E., 1971, Geologic map of late Cenozoic deposits, Santa Clara County, California: U.S. Geol. Survey open-file map, scale 1:62,500.

Maddock, M. E., 1964, Geology of the Mt. Boardman quadrangle, Santa Clara and Stanislaus Counties, California: California Div. Mines and Geology Map Sheet 3, scale 1:62,500.

Nichols, D. R., and Wright, N. A., 1971, Preliminary map of historic margins of marshland, San Francisco Bay, California: U.S. Geol. Survey open-file map, scale 1:125,000.

Radbruch, D. H., 1967, Approximate location of fault traces and historic ruptures within the Hayward fault zone between San Pablo and Warm Springs, California: U.S. Geol. Survey Misc. Geol. Inv. Map I-522, scale 1:62,500.

Robbins, S. L., 1971, Gravity and magnetic data in the vicinity of the Calaveras, Hayward, and Silver Creek faults near San Jose, California: U.S. Geol. Survey Prof. Paper 750-B, p. B128-B139.

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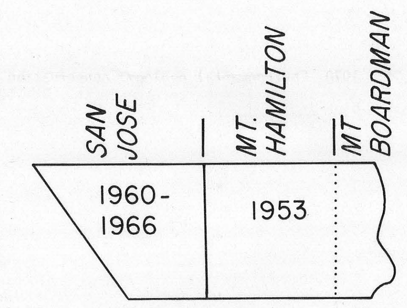
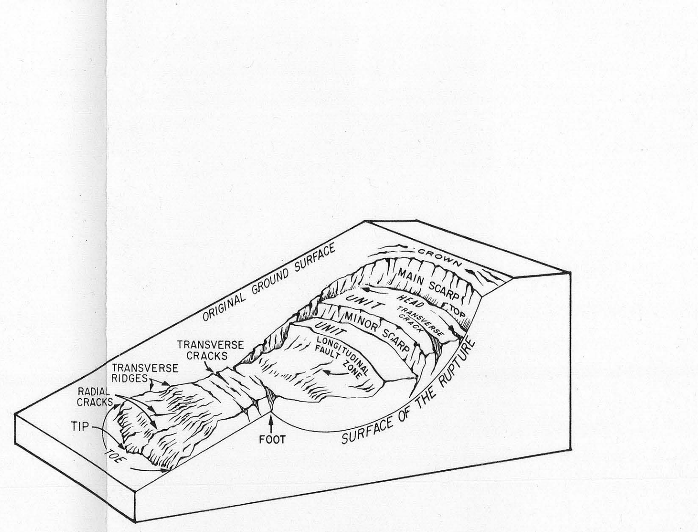
SOURCE MATERIALS



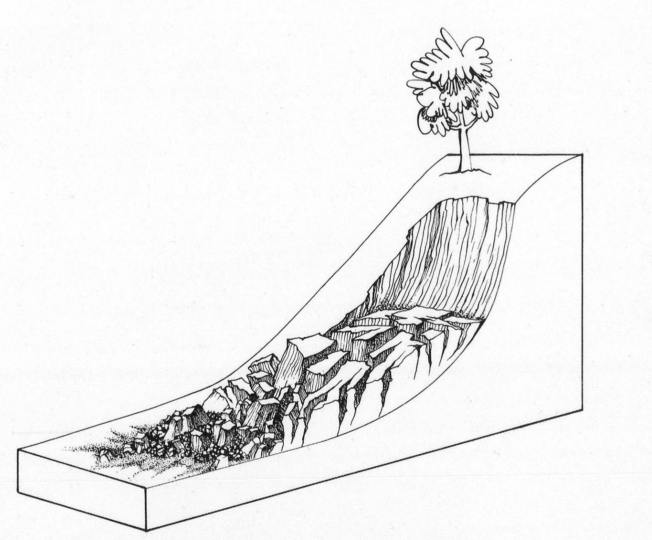
Vertical aerial photographs at scales from 1:20,000 to 1:30,000 (see diagram at left for area of coverage) were used principally to prepare this map. For the Mount Hamilton and Mount Boardman quadrangles, the photographs used are from the series GS-YF, taken in July 1953 for the U.S. Geological Survey at a scale of 1:23,600, and include photograph numbers 3-2 to 3-15, 3-27 to 3-34, 3-52 to 3-65, 3-78 to 3-92, 3-123 to 3-138, 4-03 to 4-17, 4-22 to 4-35, and 6-38 to 6-52. For the San Jose quadrangle, the following series of photographs were used: (1) series BUT, scale 1:20,000, taken in May 1966, including photograph numbers 2GG-167 to 2GG-169, 4GG-14 to 4GG-18, 5GG-21 to 5GG-26, and 5GG-29 to 5GG-32; (2) series CIV, scale 1:20,000, taken in July 1963, including photograph numbers 1DD-177 to 1DD-182, 2DD-13 to 2DD-16, and 2DD-57 to 2DD-58; (3) series CIV, scale 1:20,000, taken in September 1963, including photograph numbers 6DD-25 to 6DD-39, 6DD-55 to 6DD-65, 6DD-95 to 6DD-100, and 6DD-115 to 6DD-122; (4) series CIV, scale 1:20,000, taken in October 1963, including photograph numbers 7DD-11 to 7DD-23, and 7DD-30 to 7DD-38; (5) series GS-VACY, scale 1:30,000, taken in August 1960, including photograph numbers 2-18 to 2-23, 2-29 to 2-33, 2-71 to 2-74, 2-95 to 2-98, 2-152 to 2-156, and 2-196 to 2-199. In addition, vertical aerial photographs taken in April and May 1970, scale 1:80,000, were used as a supplement to the larger scale photographs; these photographs are from the series GS-VCMI, and include numbers 1-139 to 1-143, 1-159 to 1-162, 1-191 to 1-194, 2-46, 2-61 to 2-64, 2-71 to 2-72, 2-83 to 2-87, and 3-153.

APPENDIX

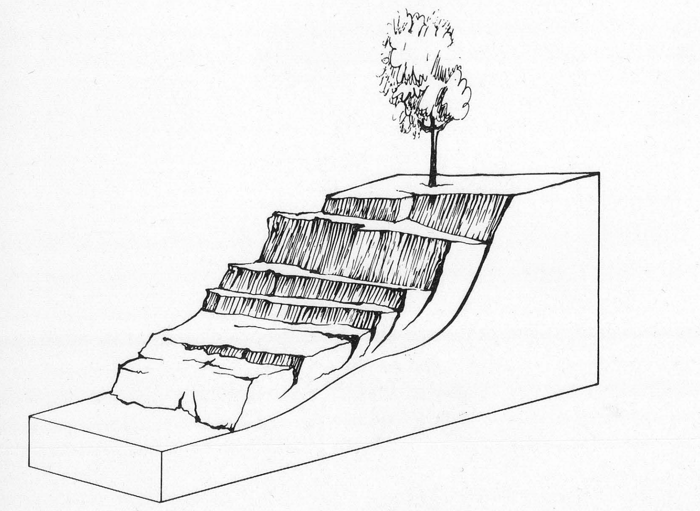
These illustrations show the nomenclature used to describe landslide deposits and four common types of landslide deposits found in the San Francisco Bay region:



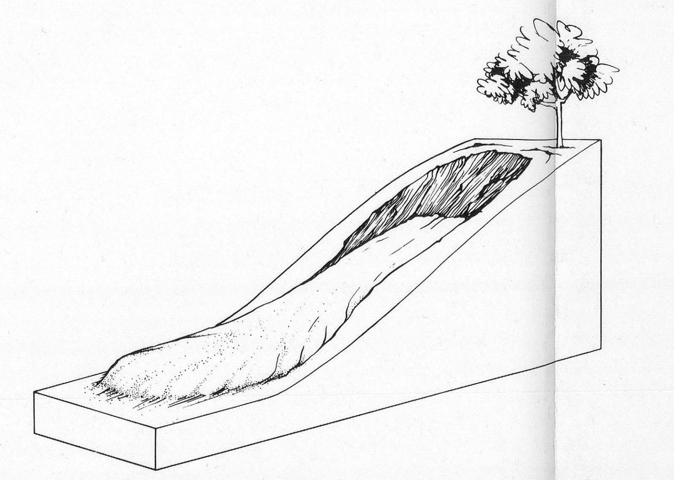
Nomenclature of parts of a landslide (from Eckel, 1958).



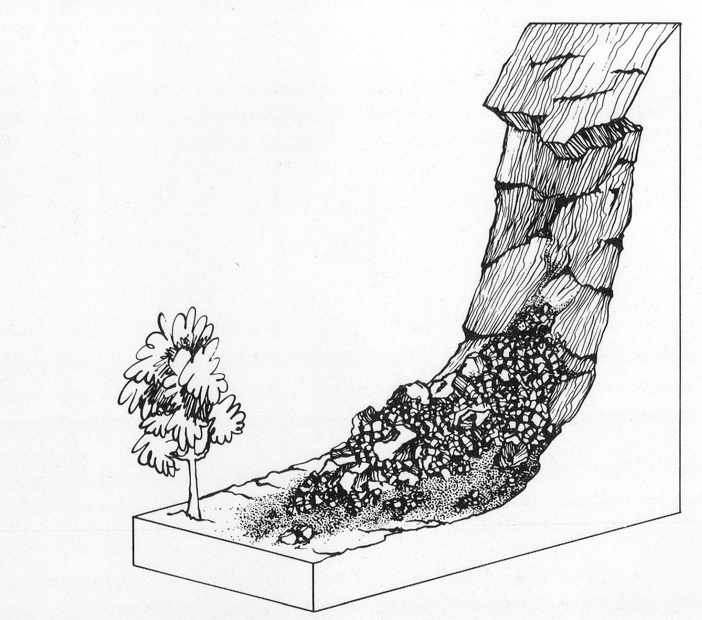
Debris slide: incoherent or broken masses of rock and other debris that move downslope by sliding on a surface that underlies the deposit.



Slump: coherent or intact masses that move downslope by rotational slip on surfaces that underlie as well as penetrate the landslide deposit.



Earthflow: soil and other colluvial materials that move downslope in a manner similar to a viscous fluid.



Rockfall: rock masses that move primarily by falling through the air.

PRELIMINARY PHOTOINTERPRETATION MAP OF LANDSLIDE AND OTHER SURFICIAL DEPOSITS OF THE MOUNT HAMILTON QUADRANGLE AND PARTS OF THE MOUNT BOARDMAN AND SAN JOSE QUADRANGLES, ALAMEDA AND SANTA CLARA COUNTIES, CALIFORNIA

by
Tor H. Nilsen
1972