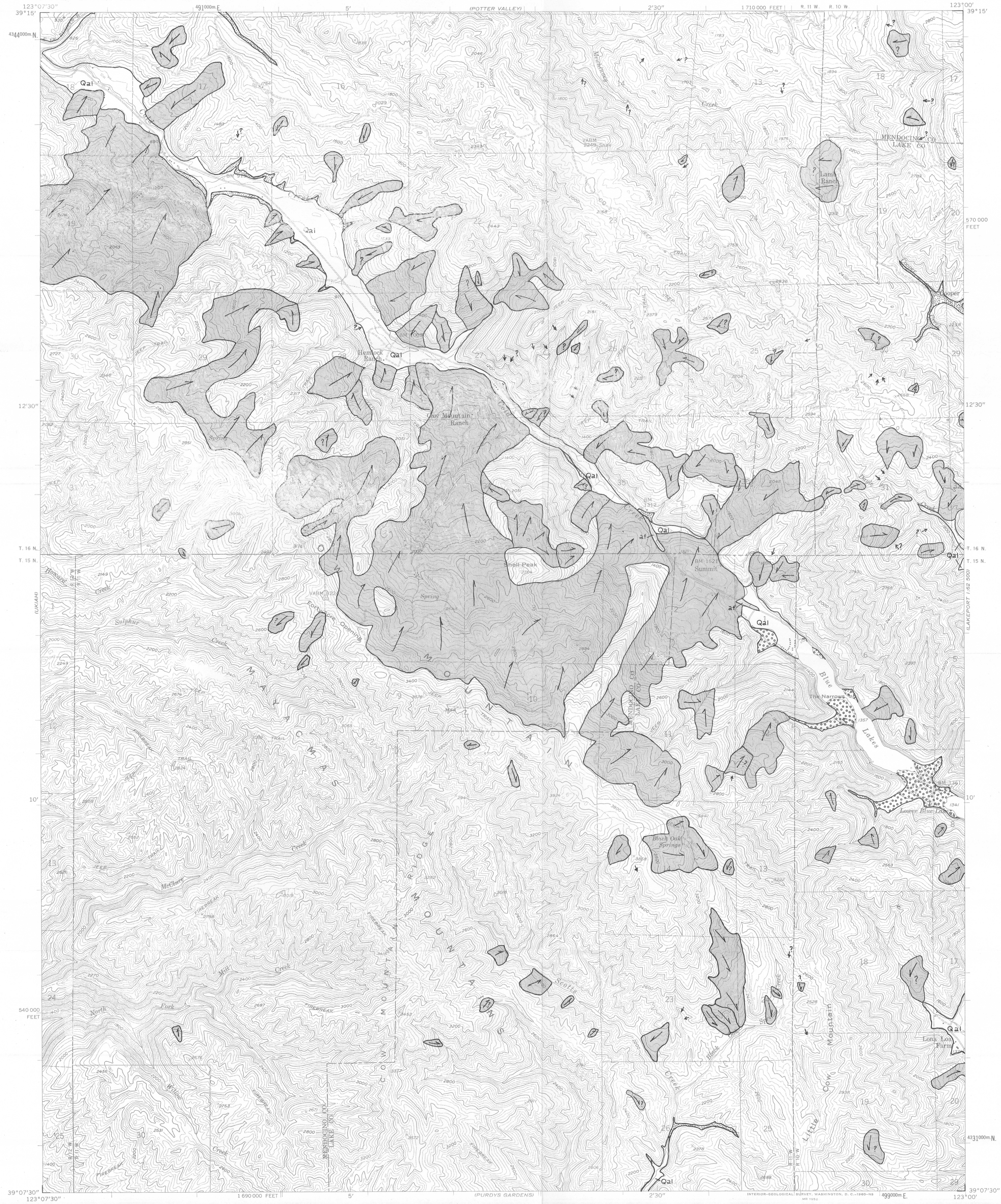
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY



Base by U.S.Geological Survey and
State of California, 1958

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL

QUADRANGLE LOCATION

INTRODUCTION

One aspect of the physical environment critical to sound land-use planning is the nature and distribution of surficial deposits. Because surficial deposits are common and well developed in the region, it is useful to know how and why they have formed, as well as what properties they possess. When maps of surficial deposits are used in combination with other types of environmental information, such as data on soils, bedrock geology, slopes, vegetation, climatic variation, seismic response, and hydrology, it will be easier to arrive at sound decisions regarding the physical aspects of land use.

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 day landscape. The deposits shown here have not been examined in the field. By viewing overlapping vertical aerial photographs through a stereoscope, the geologist sees a three-dimensional relief model of the ground surface and can readily study and interpret the origins of landforms. 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. Preliminary photointerpretation maps such as this provide land-use planners with immediately useful information about the distribution of landslide and other surficial deposits.

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 by construction activities that involve cutting or oversteepening of natural slopes. For engineers, builders, conservationists, and others concerned with land use who evaluate the potential effects of all types of development, maps showing the nature and distribution of surficial deposits are especially useful.

This map, then, shows the cumulative effects of various processes that have yielded surficial deposits to the time the photographs used for photointerpretation were taken. It does not directly indicate areas where processes will be most active, nor does it show the rate at which they will operate. 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.

The landslides shown on this map are concentrated in a northwest-southeast-trending belt approximately defined by the subparallel ridge lines above the valley of Cold Creek. The rocks underlying the map area are greywacke, mudstone, and serpentine of the Franciscan assemblage of Jurassic and Cretaceous age. Franciscan rocks are greatly sheared, folded and faulted throughout the California Coast Ranges. Landslides are commonly localized where the more highly sheared or mudstone-rich Franciscan rocks are exposed. The fundamental geologic framework of the area mapped strongly determined the more recent geologic processes and their results. In particular, Pleistocene and Holocene climatic changes (Flint, 1971) and tectonic events (Sims and Rymer, 1974) have been largely responsible for the geomorphic responses in the Clear Lake region.

Factors relating to major episodes in the history of Clear Lake are discussed by Davis (1933, 1948), Anderson (1936), Brice (1953), Hodges (1966) and Hopkirk (1973). Central to Davis' arguments is the occurrence of a large landslide "several centuries ago" that blocked Cold Creek and completed the formation of Clear Lake. Anderson (1936) and Brice (1953) favored an hypothesis based on evidence that Clear Lake is contained in a fault-bounded basin. Hodges (1966) and Hopkirk (1973) strongly favor the hypothesis of Anderson and Brice modified slightly to make use of the evidence of Davis. To our knowledge, no one has carefully examined Davis' evidence and its implications on the geologic history of the Clear Lake region. The purpose of this map is to delineate landslides in the Cow Mountain 7½ minute quadrangle that bear on the geologic history of Clear Lake approximately 14 km to the southeast of upper Blue Lake.

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 evaluation 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 a function of (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, 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 makes slopes in these areas particularly susceptible to landsliding.

All the natural factors that promote landsliding are present in the Clear Lake region. Man has at times decreased the potential for slope failure by leveling slopes, building retaining walls at the base of slopes, planting trees or seeding forests, as well as practicing soil conservation. Other of his activities, however, have increased the potential for slope failures; increasing slope angle for road or building construction; adding water to marginally stable slopes by watering lawns, improperly handling rainwater runoff, and choosing poor sites for septic foundations; and removing natural vegetation. Thus slope failure, a natural phenomenon throughout the Clear Lake 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 the history of their activity. Some deposits may pose no problems for many types of development; others, serious problems. Most landsliding takes place in areas where landsliding has occurred before, and old landslide deposits may be so broken up and disturbed that landsliding may easily recur, especially where slope angle or moisture content are changed. Landslide deposits are characterized by (1) small isolated ponds, lakes, and other closed depressions; (2) abundant natural springs; (3) abrupt and irregular change in slope and drainage pattern; (4) hummocky irregular surface; (5) smaller landslide deposits, commonly younger, within older and larger landslide deposits; (6) steep, arcuate scarps at the upper edge; (7) irregular soil and vegetation patterns; (8) disturbed vegetation; and (9) numerous flat areas that might appear suitable for construction sites. In general, fewer of these characteristics are evident in the smaller deposits. Detailed ground studies are required for predicting the future behavior of landslide deposits under changing conditions.

Alluvial deposits:

The surfaces of alluvial deposits generally are relatively flat 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 probably are easy to excavate, as pebble- and cobble-rich layers are 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 the 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 (for road and building or other construction), 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, whereas others contain only alluvial sediments. As a result, porous and permeable gravel-rich layers may alternate with impermeable clay-rich layers making the deposits 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.

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 found 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, the downstream gradation of alluvial terrace deposits into alluvial deposits; (4) recognizing landslide deposits 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; (6) distinguishing between irregular or hummocky topography caused either by variations in the erosional resistance of bedrock or by the erosion of landslide deposits; and (7) recognizing any surficial deposit in areas of dense vegetation, as the southwest corner of the mapped area.

SOURCE MATERIALS

The following series of photographs were used: series GS-VQV taken in 1957 with an approximate scale of 1:53,000 including photograph numbers 2-46 to 48 and 2-77 to 78; and series GS-CVM taken in 1958 with an approximate scale of 1:21,000 including photograph numbers 5V-103 to 109, 5V-134 to 139, 10V-181 to 186, and 10V-215 to 219.

SELECTED REFERENCES

Anderson, C.A., 1936, Volcanic history of the Clear Lake area, California: Geol. Soc. America Bull., v. 47, p. 629-664.

Bailey, E.H., ed., 1966, Geology of northern California: California Div. Mines and Geology Bull. 190, 508 p.

Brice, J.C., 1953, Geology of Lower Lake Quadrangle, California: California Div. Mines Bull. 166, 72 p.

Davis, W.M., 1933, The lakes of California: California Jour. Mines and Geology, v. 29, p. 175-236.

______ 1948, The lakes of California: California Jour. Mines and Geology, v. 44, p. 201-242.

Eckel, E.B., ed., 1958, Landslides and engineering practice: Highway Research Board Spec. Rept. 29, NAS-NRC 544, 232 p.

Flawn, P.T., 1970, Environmental geology; conservation land-use planning, and resources management: New York, Harper & Row, 313 p.

Flint, R.F., 1971, Glacial and Quaternary Geology: New York, John Wiley and Sons, Inc., 892 p.

Hodges, C.A., 1966, Geomorphic history of Clear Lake, California: Ph.D. thesis, Stanford Univ., Stanford, Calif., 171 p.

Hopkirk, J.D., 1973, Endemism in fishes of the Clear Lake region of central California: California Univ. Pubs. Zoology, v. 96, 135 p.

Leighton, F.B., 1966, Landslides and hillside development, in Engineering geology in southern California: Assoc. Eng. Geologists, Los Angeles Sec., Spec. Pub., p. 149-193.

Sharpe, C.F.S., 1960, Landslides and related phenomena: Paterson, N.J., Pageant Books, 137 p.

Sims, J.D. and Rymer, M.J., 1974, Gaseous springs in Clear Lake, California and the structural control of the lake basin: Geol. Soc. America Abstracts with Programs, v. 6, no. 3, p. 254.

Terzaghi, Karl, 1950, Mechanism of landslides, in Paige, S.M., chm., Application of geology to engineering practice (Berkey volume): New York, Geol. Soc. America, p. 83-123.

Weaver, C.E., 1949, Geology of Coast Ranges immediately north of San Francisco Bay region, California: Geol. Soc. America Mem. 35, 242 p.

Zaruba, Quido, and Mencl. Vojtech, 1969, Landslides and their control: Amsterdam, Elsevier Pub. Co., 205 p.

Landslide deposits

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

Landslide deposit larger than approximately 200 feet in longest dimension. Queried where identification uncertain. Arrows indicate general direction of downslope movement. Many of the larger landslides, in particular, slides shown in Cold Creek drainage, are complex landslides made up of many smaller landslide deposits; individual components not mapped separately

Debris composed of fresh and weathered rock fragments, sediments, 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 resulting from combinations of different types of downslope movement, are perhaps the most common type of landslide deposit in the Clear Lake 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 type of movement or type of material. 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 1958. No landslide deposits that formed since 1958 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

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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 within them

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 of 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 this region, but only the thicker and more extensive accumulations 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 form fan-shaped deposits where they emerge onto more gently sloping valley floors

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

Bedrock

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. Many of the small landslide deposits and some of the large landslide deposits shown on the map to lie within bedrock areas probably involve only material derived from weathered bedrock and other colluvial material

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Artificial fill

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

For sale by U. S. Geological Survey, price $.50

PRELIMINARY PHOTOINTERPRETATION MAP OF LANDSLIDES AND OTHER SURFICIAL DEPOSITS IN THE COW MOUNTAIN 7 1/2-MINUTE QUADRANGLE, LAKE AND MENDOCINO COUNTIES, CALIFORNIA

BY

MICHAEL J. RYMER AND JOHN D. SIMS

1975

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