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U.S. Geological Survey. [Reports - Open file series]

Landslide susceptibility map of part of the Mars 7-1/2'
quadrangle , Allegheny County and vicinity, Pennsylvania.

By J.S. Pomeroy.

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OPEN FILE MAP

This map is preliminary and has not been edited for conformity with Geological Survey standards or nomenclature.

Landslide susceptibility map of part of the Mars 7-1/2-minute quadrangle, Allegheny County and vicinity, Pennsylvania

By J. S. Pomeroy

The purpose of this map is to identify areas with potential slope-stability problems significant to development. Essentially, it is a guide to areas of past landslide and present landslide susceptibility. The map is not designed to replace detailed studies of specific sites by competent technical personnel. Rather, it delineates areas where such detailed studies are most vital to the safety and welfare of the general public. In these areas, site examinations are necessary in order to seek firm evidence of the degree of difficulty that slope instability may pose to a contemplated land use, and so to define whether costs of hazard prevention are commensurate with the value of the contemplated use. Preparation of the map was sponsored by the Appalachian Regional Commission (ARC contract no. 74-31).

The map is based on an interpretation of large-scale (1:12,000) aerial photographs (series GS-VDGY) taken on April 14, 1973. About 2 days of field work during December 1973 supplemented the aerial photograph interpretations.

U. S. Geological Survey
OPEN FILE MAP 74-114
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1 Information from soil surveys by the Soil Conservation Service
2 (U.S. Dept. of Agriculture, 1973) was integrated with data from an
3 early geologic map (Munn, 1911) and other reports listed in the
4 references.

5 Large recent landslides are readily seen on aerial photographs.
6 The aerial photographs also are an excellent means of locating ancient
7 slump benches and the hummocky areas at the bases of slopes so indica-
8 tive of landslide-prone areas. In addition, arcuate scars at the heads
9 of slide areas are well displayed on aerial photographs. In contrast,
10 on topographic maps the contour interval and the configuration of the
11 contours alone are not sufficiently detailed to allow for the delinea-
12 tion of many landslide-prone areas.

13 Few landslides exist in the Mars quadrangle. The landslides shown
14 on the map were identified and plotted by direct field observations.

15 The rocks exposed in the Mars quadrangle are more or less flat-
16 lying shales, mudstones, sandstones, siltstones, and minor coal beds
17 and limestones of the Coneraugh Group of Pennsylvanian age. Of these,
18 weathered nonbedded red mudstone and related residual and colluvial soils
19 are particularly susceptible to landsliding. Most areas with moderate
20 to severe slope stability problems are underlain by the principal red
21 mudstone horizon, the "Pittsburgh redbeds," which ranges from 20 feet
22 (6.1 m) to 65 feet (19.8 m) thick north of the Ohio River (Winters,
23 1969.
24
25 -

1 It can be inferred that most slopes in the quadrangle are rela-
2 tively stable under natural conditions, but, as is shown on the map,
3 many slopes are sensitive and their natural equilibrium can be readily
4 upset. By far, the greatest number of landslides in the region occur
5 when a slope is oversteepened, overloaded, or otherwise modified by man
6 in the course of development of housing, roads, pipelines, and other
7 features. The largely prehistoric slump benches south of the Mars
8 quadrangle probably were formed under extremes of climate no longer
9 characteristic of the area. Relatively recent landslides on natural,
10 undisturbed slopes largely are caused by unusual conditions, such as
11 extremely heavy and prolonged rainfall.

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FACTORS AFFECTING LANDSLIDE SUSCEPTIBILITY

IN ALLEGHENY COUNTY, PENNSYLVANIA

(to accompany U.S. Geological Survey open-file

landslide-susceptibility maps of Allegheny County)

Significant factors bearing on landslide susceptibility include:

(1) rock types; (2) nature of rock layering; (3) rock fracturing;
(4) attitude of rock layers; (5) composition and thickness of soil
cover; (6) permeability of rocks and soils; and (7) steepness of
slopes.

1. Rock types.--Outcropping rocks are largely sandstone, silt-
stone, shale (or claystone), and limestone. Coal, though only a
relatively small part of the total rock volume, is widespread and
significant. Sandstone and limestone commonly are harder, more
resistant to weathering, than are siltstone and shale. This differ-
ential weathering explains why sandstone and limestone crop out on
many slopes as ledges and cliffs, whereas siltstone and shale are
rarely well exposed except in cut banks of streams, in other very
steep natural slopes, and in manmade exposures such as highway cuts.

2. Rock layering.--The rocks form layers commonly $1^{(0.3m)}$ to $10\text{ ft } (3m)$
thick, but in places layers exceed $30\text{ ft. } (9.1m)$ For example, a $2\text{-ft } (0.6m)$ layer
of limestone may rest on $7\text{ ft. } (2.1m)$ of shale which in turn rests on a sand-
stone layer $10\text{ ft. } (3m)$ thick. It is also common to find that a layer of
shale as thin as $1\text{ inch } (.02m)$ lies between two layers of sandstone each many
feet thick. If a shale layer is decomposed to some depth by weathering,
then overlying hard rock is less firmly supported and tends to move
down slope in response to gravity.

1 Some rock layers are continuous over a number of miles, but most
2 sandstone layers, for example, probably grade laterally into another
3 rock type, perhaps siltstone, in shorter distances, and some conspicu-
4 ous lateral changes are seen within a single outcrop.

5- 3. Rock fractures.--Two types of rock fracture occur: faults,
6 fractures along which rocks on one side are offset from rocks on the
7 other side; and joints, fractures, some tight, some open, along which
8 little or no evidence of movement can be seen. Faults are relatively
9 rare in Allegheny County. The harder rock layers, sandstone and lime-
10- stone, are well jointed in outcrop, with joints commonly open and one
11 to several feet apart. Joints also occur in siltstone and shale layers
12 but the joints are chiefly tight rather than open. Most joints are
13 more or less perpendicular to the plane of layering.

14 Joints contribute to landslide susceptibility, for if rock layers
15- were not jointed, their tendency to fail when underlying rocks are
16 removed would be less. Joints are also an important factor in rock
17 permeability.

18 4. Attitude of rock layering.--In Allegheny County, most rock
19 layers dip at such small angles that their attitudes can best be meas-
20- ured in feet per mile rather than in degrees or in percent of grade.
21 In some areas, layers dip more than 200 ft per mile ^(60.3m per km) (about 2° or 4 per-
22 cent grade), but most layers have gentler dips, and locally they are
23 horizontal. In Allegheny County, rock attitude is most critical to
24 landsliding on overdip slopes, where rock layers dip in the same general
25- direction as the slopes but at lesser angles than the slopes.

1 5. Soil cover.--Soils are composed chiefly of fine-grained mineral
2 constituents derived from rock decomposition during weathering. How-
3 ever, soil means different things to different people. For example,
4 to a soil scientist, soil supports plant life and has undergone near-
5- surface zonation resulting from the interaction of climate and living
6 matter, conditioned by slope and relief. An agricultural soil rarely
7 is more than 6 ft ^(1.8m) deep and may rest on and be developed from a parent
8 material that is itself decomposed rock. In contrast, to an engineer,
9 soil includes all unconsolidated material above hard bedrock, and so
10- includes the parent material of many agricultural soils. Only where
11 depth to bedrock is relatively shallow will there be virtual agreement
12 between a soil scientist and an engineer as to thickness and composi-
13 tion of a soil. For present purposes, soil is used in the engineering
14 sense; it applies not only to material resulting from rock weathering
15- in place, but also to masses of fragmented and decomposed rock particles
16 that have been transported and redeposited elsewhere. Examples of
17 transported soils are colluvium and alluvial terrace deposits, both
18 of which can be subject to landsliding.

19 In Allegheny County, soils of the hill tops are relatively thin,
20- less than 6 ft ^(1.8m) thick in many areas. Soils of hill slopes are absent
21 where bedrock crops out, are relatively thin on many upper slopes, and
22 are made up of more than 20 ft ^(6m) of colluvium near and at the base of
23 many slopes. Valley-bottom soils generally have nearly level surfaces
24 and so are not a significant factor in most landsliding; they may
25- exceed 100 ft ^(30.4m) in thickness.

1 Most soils contain a large proportion of silt and clay, some soils
2 are composed entirely of clay, and others are relatively coarse grained,
3 containing large proportions of sand and rock fragments. The composi-
4 tion of a soil reflects the composition of the rock from which the soil
5- was derived, for a sandstone will weather to a sandy soil, a shale to a
6 clayey soil, and hard blocky rocks may weather to a rocky soil. Because
7 soils result from weathering of rock particles, they commonly are finer
8 grained near the surface than they are at depth. Most soils are loose
9 to moderately cohesive. They will not stand long on steep slopes, and
10- are subject to landsliding if affected by undercutting, overloading, or
11 other processes. Clayey soils when dry commonly are friable and rela-
12 tively low in weight per unit volume. When wetted, clay soils retain
13 water and so become heavier, become plastic, and depending on their
14 mineral composition may become very slippery.

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1 6. Permeability of rocks and soils.--Permeability as used here is
2 the capacity of bedrock and soil to transmit water. Sandstone in Alle-
3 gheny County commonly is moderately permeable; water may pass around
4 grains of sand and through intergrain voids in many of these rocks. In
5- addition, sandstone layers may have closely spaced joints that facili-
6 tate passage of water. Although limestone is fine grained and is
7 inherently more or less impermeable, most limestone layers are permeable
8 because they are closely jointed, and these joints commonly are enlarged
9 by solution and removal of minerals by moving ground water. In contrast,
10- siltstone and shale are fine grained, inherently less permeable than
11 most coarser grained rocks, and joints in siltstone and shale layers
12 commonly are relatively tight. Thus, sandstone and limestone layers
13 in southwestern Pennsylvania are more likely avenues for movement of
14 ground water than are siltstone and shale layers. Similarly, most
15- sandy and rocky soils are appreciably more permeable than are soils
16 composed largely or entirely of clay. Saturation of rocks and soils by
17 water is most likely to be complete in zones where permeable materials
18 overlie relatively impermeable materials. This saturation, coupled
19 with lateral movement of water in these zones, enhances lubrication,
20- and so potential instability.

21 Because water is a key agent in landslide susceptibility, perme-
22 ability of rocks and soils, or the relative lack of it, is of particular
23 importance.
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1 7. Steepness of slopes.--Allegheny County is a land of hills and
2 ridges each of which is more or less the same height as its neighbor.
3 Separating these hills are valleys through which streams and rivers
4 flow at levels commonly 300_Λ to 400 ft_Λ and locally more than 600 ft (182.4m)
5 below adjacent ridge crests. The valley walls are relatively steep;
6 slopes of 25 percent (about 14°) or greater occupy more than one-tenth
7 of the area. This large incidence of steep natural slopes is a leading
8 factor in the prevalence of landslides.

9 Relative importance of factors.--All of the above factors are
10 interrelated. At a given place one factor may be the chief control of
11 landslide susceptibility, whereas at another place the same factor may
12 be less important than others. For example, where a major stream is
13 undercutting its bank, oversteepening will occur and slope failure
14 ultimately will ensue, whether the bank material is rock or soil; where
15 a thick soil cover becomes saturated with water, failure may occur even
16 on relatively gentle slopes. Some reverse-dip slopes, contrary to what
17 might be expected, can be consistent landslide hazards because of
18 natural or manmade steepness or excessive rock fracturing; some over-
19 dip slopes, on the other hand may be less susceptible to landsliding
20 because only one type of rock is present.

1 Credits.--This text is abstracted with minor changes from Briggs
2 (1974). The following illustrations are adapted with minor modifications
3 from Nilsen (1972), Eckel (1958), and from the pioneering text by
4 Sharpe (1938). They illustrate nomenclature of landslides, types of
5- landslides found in Allegheny County, and features of creep, which is
6 a widespread feature of Allegheny County slopes.

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3 landslides in the area of Pittsburgh, Pennsylvania: Univ. Pittsburgh
4 Ph.D dissert., 121 p.

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6 in Allegheny County, Pennsylvania: U.S. Geol. Survey Misc. Field
7 Studies Map MF-543.

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

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11 the Pittsburgh area: Pennsylvania Geol. Survey, 4th ser., Gen. Geol.
12 Rept. G-59.

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16 rangles, Santa Clara County, California: U.S. Geol. Survey Misc.
17 Field Studies Map MF-416, 2 sheets.

18 Sharpe, C.F.S., 1938, Landslides and related phenomena; a study of
19 mass-movements of soil and rock: New York, Columbia Univ. Press,
20- 136 p. [repr. 1960, Paterson, New Jersey, Pageant Books].

21 Winters, D.M., 1972, Pittsburgh red beds--stratigraphy and slope
22 stability in Allegheny County, Pennsylvania: Univ. Pittsburgh M.S.
23 dissert., 49 p.
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LANDSLIDE MAPS

EXPLANATION

Additional information is contained in a leaflet accompanying this map.



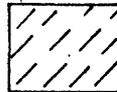
RECENT LANDSLIDES

Dominantly earth slumps and earth flows; historically recorded or characterized by fresh scars. Small landslides enclosed by triangles.



PREHISTORIC LANDSLIDES

Dominantly earth slumps and earth flows characterized by hummocky topography and slump benches; relatively stable in natural state but can be reactivated by excavation, loading and changes in ground and surface water conditions. Includes some probable recent landslides not covered by records examined.



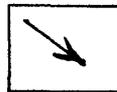
SLOPES WITH CONSPICUOUS SOIL CREEP

Clayey soils, generally less than 5 ft. thick, commonly underlain by weathered shale; characterized by shallow, slow but distinct, down-slope movement that can be greatly accelerated by overloading from fills or structures.



OUTCROP AREA OF THICK "RED BEDS" AND ASSOCIATED ROCKS

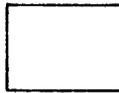
Rock weathers rapidly on exposure; weathered rock and related soil commonly result in soil creep and landslides; cuts and fills in "red beds" generally not stable.



DEBRIS SLIDES

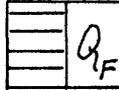
Slides in steep narrow valleys; primarily rock, soil and vegetation debris.

HIGHLY SENSITIVE TO DISTURBANCE BY MAN



RELATIVELY STABLE GROUND

Most slopes have little susceptibility to landsliding unless extensively modified by man; slight soil creep common on undisturbed slopes.



MAN-MADE FILL

Heterogeneous soil and rock material; variable susceptibility to slope failure depending on nature of materials, foundation conditions, design and construction. Fills in older urbanized areas mapped only where associated with recent landslides. Fills too small to be shown by pattern identified by letter "F".



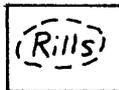
STEEP SLOPES SUSCEPTIBLE TO ROCKFALL

Dominantly thick-bedded sandstone and limestone; 1 to over 10 ft. thick; subordinate flaggy sandy shale and interbedded shale; in steep natural and cut slopes and cliffs, 15 to over 150 ft. high.



GROUND WITH HIGHLY VARIABLE SLOPE CONDITIONS

On the ticked side of the dashed line, ground has been widely disturbed by past and present cut-and-fill operations related to residential and commercial development and/or surface mining of coal. Thin complex zones of soil and weathered rock mantle the area. These conditions combine to make uncertain the classification of slopes on the basis of conspicuous or relatively minor soil creep.

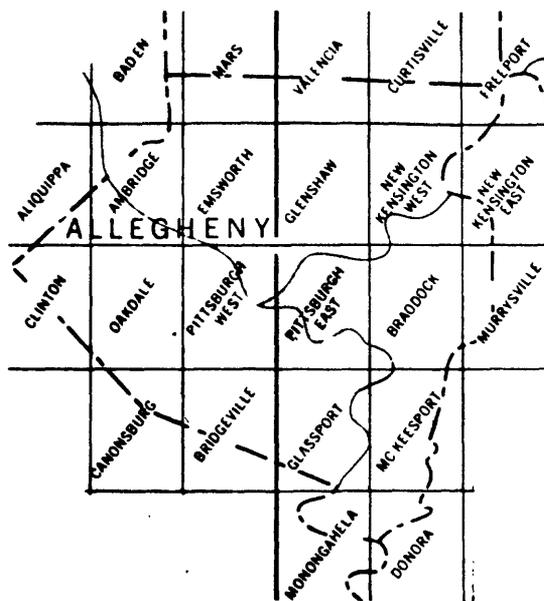


AREA OF RILLS

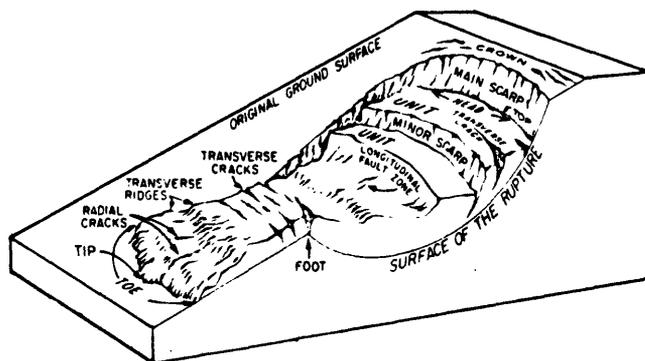
Numerous rills or gullies in rounded hills of highly erodable claystone and siltstone. The erosion undercuts most slopes, rapidly leading to small slides. Rills are more numerous near summit of hills.

NOTE

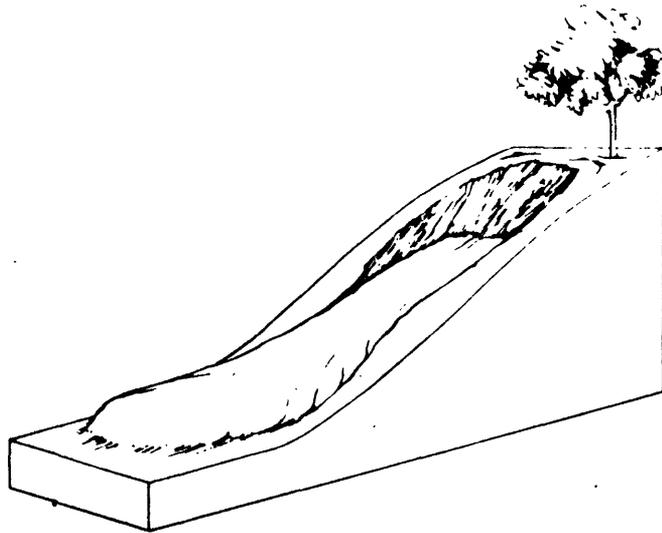
Variations in slope sensitivity may occur at any specific point within a unit. Boundaries largely are inferred and information given is intended as a general guide and should not be construed as applicable to all localities within the area shown. This map cannot be used as a substitute for detailed engineering investigations of specific sites.



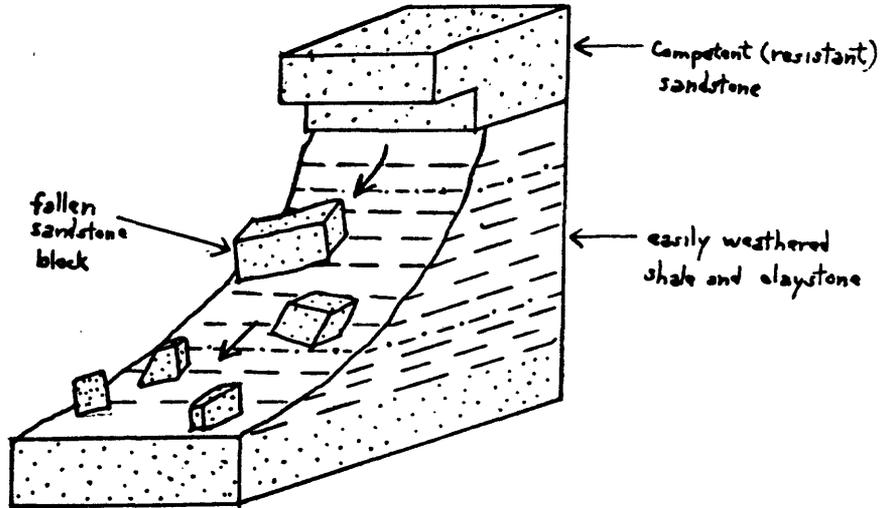
Index to 7½' quadrangle maps
of Allegheny County, Pennsylvania



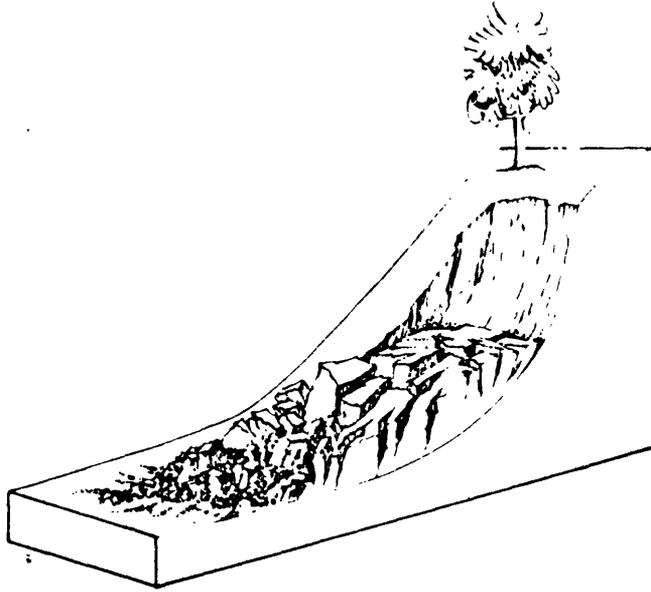
Nomenclature of parts of a landslide (from Eckel, 1958):



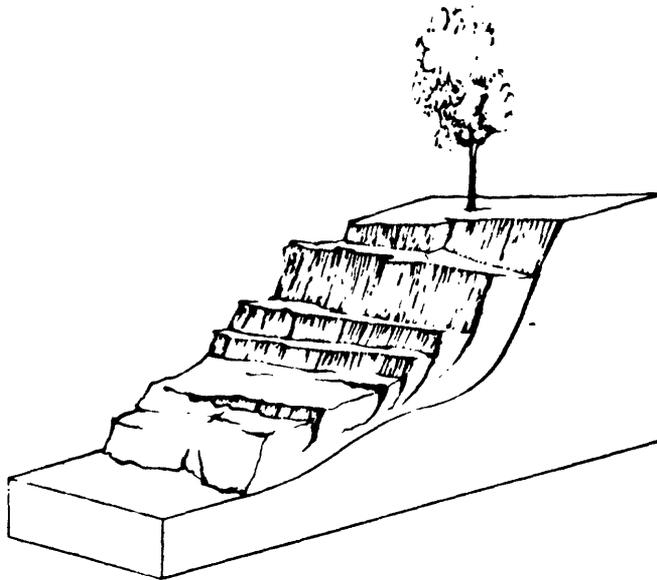
Earthflow: colluvial materials that move downslope in a manner similar to a viscous fluid.



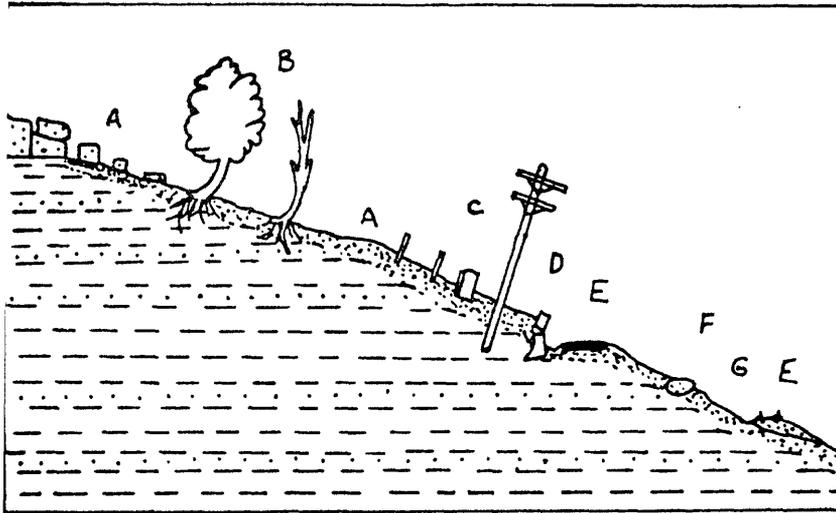
ROCKFALL



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.



Creep: Common evidences - (A) Moved joint blocks of layered rock; (B) trees with curved trunks concave upslope; (C) displaced posts, poles, and monuments; (D) broken or displaced retaining walls and foundations; (E) roads and railroads moved out of alignment; (F) turf rolls downslope from creeping boulders; (G) stone-line at approximate base of creeping soil.