Landslide susceptibility map of the Pittsburgh East 7-1/2-minute quadrangle, Allegheny County, 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. More than 1 week of field work during early 1974 supplemented the aerial photograph interpretations.

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Information from soil surveys by the Soil Conservation Service (U.S. Dept. of Agriculture, 1973) was integrated with data from an early geologic map (Johnson, 1928) and other reports listed in the references.

Large recent landslides are readily seen on aerial photographs. The aerial photographs also are an excellent means of locating ancient slump benches and the hummocky areas at the bases of slopes so indicative of landslide-prone areas. In addition, arcuate scars at the heads of slide areas are well displayed on aerial photographs. In contrast, on topographic maps the contour interval and the configuration of the contours alone are not sufficiently detailed to allow for the delineation of many landslide-prone areas.

The rocks exposed in the Pittsburgh East quadrangle are more or less flat-lying shales, mudstones, sandstones, siltstones, and minor coal beds and limestones of the Conemaugh and Monongahela Groups of Pennsylvanian age. Of these, weathered nonbedded red mudstone of the Conemaugh Group and related residual and colluvial soils are particularly susceptible to landsliding. Most areas with moderate to severe slope stability problems are underlain by the principal red mudstone horizon, the "Pittsburgh redbeds," which ranges from 20 feet (6.1 m) to 65 feet (19.8 m) thick north of the Ohio River (Winters, 1969). A lesser known redbed sequence ("Clarksburg") of red mudstone and related soils higher in the section has also been involved in landsliding in the quadrangle.

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In the overlying Monongahela Group thin complex zones of earth material of variable stratigraphic position derived from nonred interbedded shale, siltstone, and limestone are of lesser importance.

It can be inferred that most slopes in the quadrangle are relatively stable under natural conditions, but, as is shown on the map, many slopes are sensitive and their natural equilibrium can be readily upset. By far, the greatest number of landslides in the region occur when a slope is oversteepened, overloaded, or otherwise modified by man in the course of development of housing, roads, pipelines, and other features. The large prehistoric landslides probably were formed under extremes of climate no longer characteristic of the area. Relatively recent landslides on natural, undisturbed slopes largely are caused by unusual conditions, such as extremely heavy and prolonged rainfall.

The highest density of landslide activity occurs in the northwest corner of the quadrangle where widespread land modification has taken place in a thicker than average section of red mudstone (mostly "Clarksburg"). Indications of largely prehistoric landsliding are also in evidence.

Excellent examples of large fill slumps can be found along the sensitive slope west of Ninemile Run. Several slides shown on the map are documented by Ackenheil (1954).

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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, siltstone, 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 differential 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 ft (3m) thick, but in places layers exceed 30 ft (9.1m). For example, a 2-ft (0.6m) layer of limestone may rest on 7 ft (2.1m) of shale which in turn rests on a sandstone layer 10 ft (3m) thick. It is also common to find that a layer of shale as thin as 1 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.

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

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

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

4. Attitude of rock layering.--In Allegheny County, most rock layers dip at such small angles that their attitudes can best be measured in feet per mile rather than in degrees or in percent of grade. In some areas, layers dip more than 200 ft per mile (60.8 m per km) (about 2° or 4 percent grade), but most layers have gentler dips, and locally they are horizontal. In Allegheny County, rock attitude is most critical to landsliding on overdip slopes, where rock layers dip in the same general direction as the slopes but at lesser angles than the slopes.

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

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

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

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

Because water is a key agent in landslide susceptibility, permeability of rocks and soils, or the relative lack of it, is of particular importance.

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7. Steepness of slopes.--Allegheny County is a land of hills and ridges each of which is more or less the same height as its neighbor. Separating these hills are valleys through which streams and rivers flow at levels commonly 300 (91.2m) to 400 ft (121.6m) and locally more than 600 ft (182.4m) below adjacent ridge crests. The valley walls are relatively steep; slopes of 25 percent (about 14°) or greater occupy more than one-tenth of the area. This large incidence of steep natural slopes is a leading factor in the prevalence of landslides.

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

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

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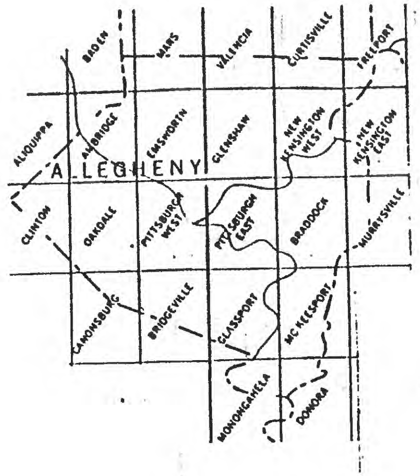
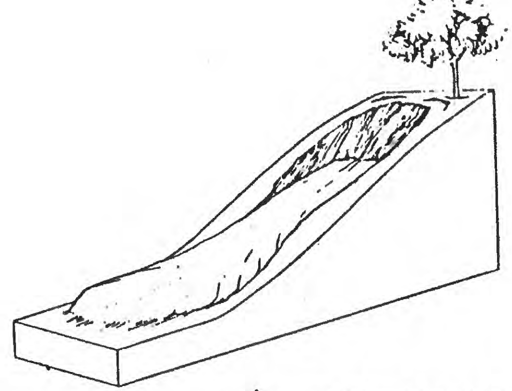
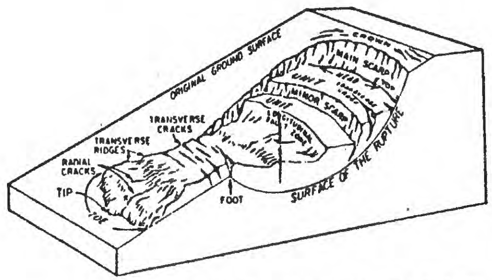


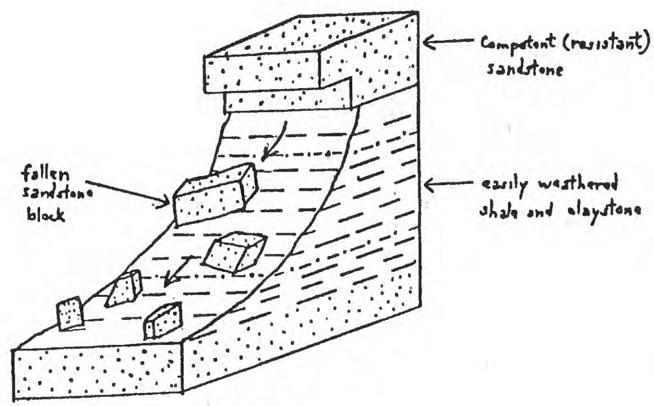
Index to 7½' quadrangle maps of Allegheny County, Pennsylvania



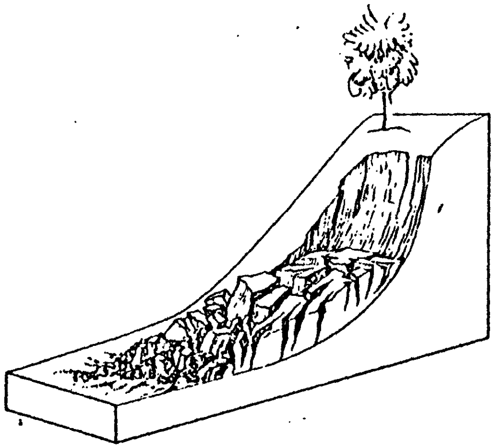
Earthflow: colluvial materials that move downslope in a manner similar to a viscous fluid.



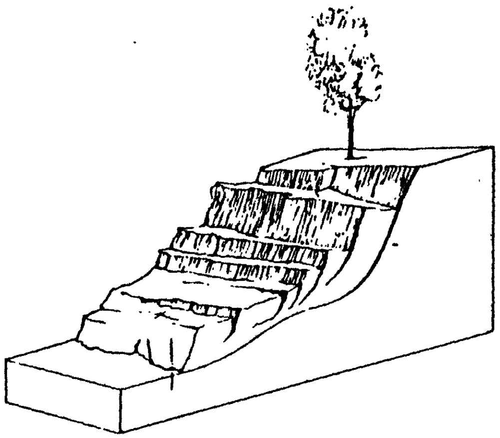
Nomenclature of parts of a landslide (from Eckel, 1958):



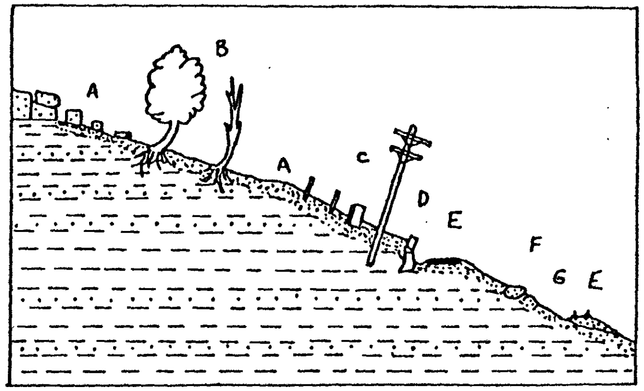
ROCKFALL



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.