County index map of Pennsylvania showing location of Beaver County

Index to topographic quadrangle maps of the U.S. Geological Survey 7½-minute series, Beaver County

MAP SHOWING LANDSLIDES AND AREAS MOST SUSCEPTIBLE TO SLIDING IN BEAVER COUNTY, PENNSYLVANIA

By
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EXPLANATION

(See text for additional information)

RECENT LANDSLIDES—Well-defined, characterized by fresh scars, may still be active. Selected examples of slump (S), fill slump (FS), earthflow (E), debris slide (DS), mining-related slide (M). Arrow used to point out symbol. Number refers to locality, discussed in table 1

OLDER LANDSLIDES—Solid lines represent definite landslides, boundaries approximately located. Dashed lines represent indefinite landslides, fairly to poorly defined, boundaries inferred

AREAS MOST SUSCEPTIBLE TO LANDSLIDING—Underlain mostly by red mudstones of Conemaugh Group

STEEP SLOPES MOST SUSCEPTIBLE TO ROCKFALL—Bracket identifies steep, locally vertical, natural and manmade slopes and cliffs

SELECTED AREA SHOWN IN FIGURE 3

NOTE: This map and accompanying text contain data useable in the identification of areas involving slope stability, but these cannot be used as a substitute for detailed geological engineering investigations of specific sites.

INTRODUCTION

This map is one of a series of 1:50,000-scale county maps that identify areas with potential slope stability problems significant to regional development in the Greater Pittsburgh region. The interpretation of landslides on vertical black and white, aerial photography flown in 1975 at a scale of 1:24,000 was supplemented by field reconnaissance in the fall of 1975 and the spring of 1976. The map does not show all recent landslides, because many are too small to be discerned on the aerial photographs. Furthermore, many slopes undoubtedly include some older landslides, although the geomorphic evidence for the older landslides has been obliterated by erosion or modified by man.

The map is a guide to areas where detailed studies of slope stability would be most vital to the general public. In these areas, site examinations are necessary in order to determine the degree of difficulty that slope instability may pose to contemplated land use. The map is not intended to replace detailed geological and engineering studies of specific sites by competent technical personnel.

A discussion of the geology of Beaver County is found in Patterson (1963). Earlier geologic reports on 15-minute quadrangles in the county are those by Woolsey (1905; 1906), Munn (1911), DeWolf (1929), and Richardson (1936). Beaver County is an integral part of a recent 1:125,000-scale geologic map of the Greater Pittsburgh region (Wagner and others, 1975). Unfortunately, modern 1:24,000-scale geologic mapping does not exist for any 7.5-minute quadrangle in the county. For more information regarding landslides with recommendations and advice for the nontechnical reader, the user of this map is urged to refer to Briggs and others (1975). Landslides in adjacent areas are discussed by Pomeroy and Davies (1975), Pomeroy (1977b), and Fisher and others (1968). A lucid account of the geology of the Pittsburgh area is available (Wagner and others, 1970).

The soil survey of Beaver County (U.S. Soil Conservation Service, 1973a, b) was used as a source of data. J. L. Council, District Conservationist, Soil Conservation Service, and F. J. Lay, Executive Assistant, Beaver County Conservation District, provided the author with their knowledge of some landslides. Gerald Ferguson of the Beaver County Planning Commission granted me access to the Commission's landslide file. J. L. Craft, Pennsylvania Bureau of Topographic and Geologic Survey, discussed the Ambridge Heights slides area with the author. William Luxner, Soils Engineer-Geologist, Pennsylvania Department of Transportation, distributed the preliminary map (Pomeroy, 1977a) to office associates for purposes of editing. A map of the Beaver County part of the Aliquippa 7.5-minute quadrangle showing landslides and slopes most prone to sliding has been released (Pomeroy, 1977c). A study of surface subsidence in Beaver County is discussed by Bushnell and Briggs (1976). The report is cited here because subsidence can play a role in affecting slope stability.

GEOLOGY AND SOILS AND THEIR RELATION TO LANDSLIDING

Bedrock in Beaver County consists of flat-lying to subhorizontal cyclothemic sedimentary rocks of Pennsylvanian age and includes from oldest unit to youngest the Pottsville, Allegheny, Conemaugh, and Monongahela Groups (fig. 1, 2). Glacial deposits occur in the extreme northwest part of the county.

Most landslides observed in Beaver County occur in colluvial or residual clayey to clayey silt soil and weathered rock derived from mudstone, claystone, shale, and siltstone. Gilpin-Upshur soils (table 2) derived from the generally nonbedded red mudstones and shales of the Conemaugh Group are particularly prone to sliding. The most persistent red-bed sequence in the county is referred to as the "Pittsburgh red beds" of the Glenshaw Formation, Conemaugh Group (fig. 2), which probably averages 12 to 18 m in thickness over a large part of southern Beaver County. The "Pittsburgh red beds" also include greenish-gray, gray, purple, and tan mudstones, claystones, and shales.

Thinner red-bed sequences lower in the Conemaugh Group (fig. 2) occur in the Raccoon Creek area southwest of Aliquippa and in the hilly area northeast of Ambridge. Red beds above the Ames Limestone Member of the Glenshaw (fig. 2) have been identified along Raccoon Creek, newly developed areas south of Aliquippa, and in the southwestern part of the county.

The red beds weather very rapidly on exposure to air and water to a plastic red residual clay with low shear strength. A dried sample of the red clay immersed in water slakes or disintegrates quickly into a soft wet mass.

Red clay from ten recent slides in the county indicates a moderate to high plasticity index based on physical properties tests superimposed by S. F. Obermeier of the U.S. Geological Survey. X-ray diffraction analyses of one sample conducted by S. L. McNabb and interpreted by M. A. Hess, both of the USGS, indicate the clay consists of nearly equal amounts of the nonexpandable minerals illite and kaolinite and some expandable minerals, mainly vermiculite. A detailed analysis of the red claystone at the nearby western Allegheny County I-79 landslide locality to the southeast is reported by Hansel and Flint (1969). Physical, chemical, and clay mineralogical data of Vandergrift soils (table 2) from two locations in Beaver County are discussed by Ciolkosz and others (1976).

The red clayey materials derived from the Conemaugh Group have a high porosity (as much as 40 percent), but their permeability is relatively low, resulting in as little as 1 to 5 percent of the pore water draining by force of gravity (Subitzky, 1975). Proneness to sliding is increased when excessive pore-water pressure in the clay decreases its shear strength.

Nonred plastic soils derived from mudstone, claystone, and shale in the Allegheny and lower part of the Conemaugh Groups (table 2) occasionally demonstrate a moderate plasticity index and a medium to low shear strength based on a small number of samples. In particular, coal bed underclays in the Allegheny Group are highly plastic and possess the potential to slide. Bluish-gray clay in the lower part of the Conemaugh Group has served as a slip surface for several small slides.

An extrapolation of Soil Conservation Service figures for soil types and acreage in Beaver County reveals that the areal distribution of landslide-prone soils (based on a slope of at least 8 percent and a moderate to high shrink-swell ratio) amounts to approximately 20 percent of the total acreage.

FEATURES SHOWN ON THE MAP

RECENT LANDSLIDES

More than 90 percent of the recent landslides in Beaver County are small, generally less than 30 m in maximum dimension. Landslides having a maximum dimension of less than 9 m have not been plotted, because of the map scale; these are best designated as soil slips. Slumps, earthflows, debris slides (fig. 3A-C), and combinations of the three are usually thin-skinned, because they are generally less than 2.5 m thick. A few slides occurring in relatively thick colluvium along lower slopes involve heterogeneous unconsolidated material more than 15 m in thickness. Also, some slides occur in relatively thick manmade fill deposits of both mining and nonmining related origin. Over 250 recent slides have been identified in Beaver County.

Although a few recent slides have been triggered by natural causes, such as unusually high amounts of rainfall, most have been man-generated in that they usually occur in the proximity of roads, construction sites, etc. Man's modification of sensitive slopes includes excavating at the base of a slope so that the slope becomes oversteepened, overloading a slope with fill causing instability, altering drainage conditions that affect not only the surface but ground water as well, and vibrations caused by increased heavy construction (blasting and pile driving). Any one of these actions can reduce the shearing strength of the earth material and cause slippage.

Soil creep is the imperceptible downslope movement of soil and rock material (fig. 3D) and is not considered a landslide process, but accelerated creep often precedes sliding. Creep is common on many slopes throughout the county where ground breakage is absent.

Most slides closely resemble the example shown in figure 3E. Although not shown in the diagram, springs and seeps, which occasionally develop cattail marshes due to the poorly drained hummocky surface, commonly characterize the toe of a recent slide. Obvious frontal movement typifies an active slide, as well as fresh scars not only at the head but throughout the entire landslide mass. At least half of the slides shown as recent were active at the time of the reconnaissance. Several slides became stabilized, at least temporarily, after movement occurred.

Slope failures related to strip mining constitute less than seven percent of the recent slides and are generally located north of the Ohio River, although several exist in the Bridgewater and lower Raccoon Creek areas. Almost all of these failures are spoil bank slumps. Reconnaissance indicates that movement has been generally restricted to the waste material itself and is largely independent of the underlying natural slope. The cause of failure might be one factor or a combination of factors, such as poorly controlled surface, subsurface runoff, and improperly compacted spoil material. A few slides occur where the highwall was cut into relatively thick colluvium and the unstable unconsolidated material began to move. Two examples showing recent movement emanating from older landslides include one that is 2 km east of Darlington and another in the extreme northeast part of the county.

Fill failures not related to mining are minimal, unlike the situation in adjacent Allegheny County (Pomeroy and Davies, 1975). A few fill slumps occur along Pa. 18 north of Beaver Falls.

Table 1 is a guide to selected landslide localities.

OLDER LANDSLIDES

About 3000 older landslides have been identified by reconnaissance methods in the present inventory in Beaver County. Approximately one-third of these slides have well-defined geomorphic features, such as hummocky ground, that indicate former movement. The remaining two-thirds may have similar but subdued characteristics and are fair to poorly defined (indefinite). The head scarp and hummocky lower slope of the latter slides are not always apparent due to erosion.

Figure 4 shows the characteristic topographic expression of older landslides. Generally, older landslides are found on hillsides that are concave both across slope and downslope. Instability is enhanced in these concave-shaped areas, because they obviously bear higher concentrations of ground water than adjacent slopes. In Washington County where there is a higher density of landsliding, the author has determined that 81 percent of the older slides are found on concave slope with the remainder on planar, convex, or a combination of slope forms. Colluvial material at the foot end of many older landslides exceeds 10 m in thickness.

Older landslides shown on the map are either individual slides or a series of coalesced slides that are mapped together as one unit. Some of the latter are up to 2.5 km in width and do not represent a single event in the history of the area, but they are part of a continuing process that has been occurring since Wisconsin Glaciation. The rate of sliding was no doubt greater immediately after Wisconsin time because of increased rainfall. Many mapped older landslides, however, probably represent slope movements that occurred within the past 50 to 100 years.

These older landslides, although presently stable, can be reactivated by increased moisture from unusually heavy rainfalls, by higher than normal precipitation during a period of several months or years, or by slope modification by man, such as excavation, loading, and changes in drainage conditions. A combination of factors may be involved.

AREAS MOST SUSCEPTIBLE TO SLIDING

It is important to note that landslides can occur anywhere in the geologic section if optimum conditions for movement are present, especially after man's modification of a slope. Slides can be anticipated in the future in the units shown on the generalized geologic map (fig. 1), in addition to the Quaternary deposits (not shown). However, the weathered material from some rock units has a greater potential for sliding than other material. Figure 2 shows the relative susceptibility to landsliding of the weathered material of the various rock units. It is apparent that the red clays derived from the weathering of the mudstones and claystones of the Conemaugh Group have the greatest potential for sliding, so these clays are shown in a stippled pattern on the map. The map shows the large member of recent and older landslides in terrain underlain by the Conemaugh Group.

The plastic nonred underclays in the Allegheny Group are especially susceptible to a loss of shearing strength after being wetted. Though most sliding in the Allegheny Group seems to occur immediately beneath the Upper Freeport coal, the appearance of frequent sliding is probably merely a function of the greater areal extent of that particular part of the sequence, as opposed to the extent of an underclay, claystone, or mudstone lower in the group. Areas particularly prone to sliding in the Allegheny Group, as shown by the stippled pattern on the map, occur along the Ohio River west of Midland, Brady Run, and the Beaver River southwest and south respectively of Beaver Falls, and the lower part of Raccoon Creek.

Large unstable colluvial deposits located along Raccoon Creek are not necessarily related to red-bed bottoms. Slides have developed on colluvial slopes west and southeast of Independence and in Center Township at the point of maximum curvature of the stream, where the slope receives the greatest impact from the water.

Stress release following the removal of support by stream erosion along major valley walls has produced extensive parallel joints that can result in the rotational slumping of bedrock. Some of the larger older slides along the Ohio River and lower Raccoon Creek no doubt owe their origins to this factor.

It can be assumed that in any given year most slides will occur within the most susceptible zone (see map). This assumption is based on a recent updating of the preliminary map compilation with assistance from the Pennsylvania Department of Transportation (PennDOT) office at Pittsburgh. Three of four new slides reported by PennDOT occurred within the most susceptible or "stippled zone" shown on the map. Of more than 250 recent slides documented on the map, approximately 75 percent are located within the Conemaugh Group, though it must be considered that rocks of the Conemaugh Group cover twice as much area in the county than rocks of the Allegheny Group. A composite inventory of all slides (recent and older) shows greater than 2.3 times as many slides per km² occurring along slopes on the Conemaugh Group compared to those on slopes on the Allegheny Group.

ROCKFALLS

Widely differing physical characteristics of individual lithologies cause geologic-engineering problems in areas underlain by cyclic sedimentary rocks. The rockfall problem is a prime example. Rockfalls (fig. 3F) are produced by weathering and erosion that affect mudstone and shale more readily than sandstone, siltstone, and limestone, thus causing unsupported ledges of the more resistant rock to break away by falling. Jointing is a significant factor. A rockfall, involving 115 m³ of material, crushed a bus and killed 22 people on December 22, 1942, along the west side of the Ohio River south of Aliquippa, 1 km north of the Ambridge bridge (Ackenheil, 1954).

The map shows the more extensive steeper slope localities where the rockfall hazard is especially serious.

SUMMARY

More than 3,000 recent and older landslides have been identified in Beaver County. Movement on slopes is related to specific rock sequences, primarily red clay-rich lithologies in the Conemaugh Group and to a lesser extent nonred clay-rich lithologies in the Allegheny Group. Slopes where sliding is most likely to occur also have been identified on the map. Downslope movement of soil and weathered rock is a continuing and natural process and can be accelerated by man. Proper engineering and judicious control of land use in sensitive areas can be used to control the threat of landslides.

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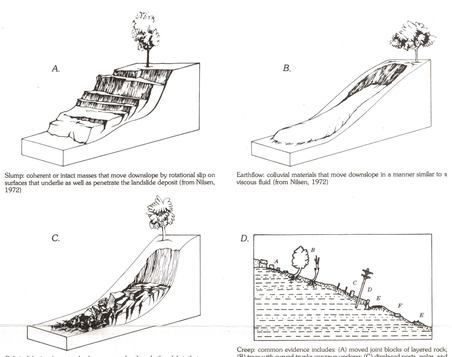
TABLE 1.—GUIDE TO SELECTED LANDSLIDE LOCALITIES

LOCALITY NUMBER	GEOLOGIC UNIT	LOCATION	COMMENTS
1	Kittanning Formation. Middle Kittanning coal underclay(?)	Pa. 351 west of Koppel	20-m-wide slump below highway; hummocky material indicative of earlier slide.
2	Quaternary terrace gravel overlying lower part of Glenshaw Formation	Baden, department complex	Seepage at gravel-bedrock interface probably triggered slide; inadequate storm water disposal has contributed to surcharging the slope.
3	Casselman Formation, largely red beds	Ambridge Heights, behind Ridge Road	Backyard fill failure involved in debris slide that triggered slide farther downslope.
4	Glenshaw Formation, red beds ("Pittsburgh")	Ambridge Heights, south of location 3	Active slides (in extensive older landslide area) have caused condemnation of two houses. Drainage from location 3 may be contributing factor to recent sliding.
5	Glenshaw Formation (lower part)	Aliquippa, Valley Terrace Apartments	Modified cut slope behind parking lot; 12–15-m-wide colluvial slump. Slide problems in area due to inadequate drainage controls (J. L. Craft, oral commun., 1976).
6	Casselman Formation	Hopewell Township, Schell Circle vacant lot	Rupture of water line from storage tank at hilltop undermined house foundation, house carried downslope, driveway of house to west slid.
7	Casselman Formation, red beds	Hopewell Township, subdivision	Small slides in backyard fills; reel soil abundant in area.
8	Glenshaw and Casselman Formations, red beds ("Pittsburgh")	Pa. 60 south of Aliquippa intersection	Minor slumping along 2.2 km stretch to south. Weathered Ames Limestone Member has slumped locally.
9	Glenshaw Formation, red beds ("Pittsburgh")	Road west of Bocktown	Progressive deterioration (slumping) of wide area (300 m wide) both above and below road.
10	Glenshaw Formation, red beds and nonred beds	Independence–Bocktown Road	Recurring slide problems above east side of creek; previous slumping north and south of most recent sliding. Larger of two slides is 30 m wide.
11	Glenshaw Formation, red beds and nonred beds	Secondary road west of Independence	Slumping of small section of finale nonred shale above road; slumping of weathered red mudstone (and fill) below road.
12	Glenshaw and Freeport Formations	Closed road above west bank of Raccoon Creek	600-m-long zone of active slumping. Debris slides near transmission line northeast of slump zone and above sharp bend in creek.
13	Glenshaw Formation, red beds and nonred beds	Pa. 60 3 km northwest of Aliquippa intersection	Classic example of recent slide (characterized by conspicuous head scarp and slanted trees in frontal area) occupying center of older landslide. Reprofiling of highway below slide is probably indicative of fill failure during construction.
14	Freeport and Kittanning Formations	Road along west side of Raccoon Creek	20-m-wide slide buttressed at head (one of many south- and facing slides along this road). Seeps may account for instability of slope due to gentle southeast dip; also impact of water along stream bend has weakened toeof slope.
15	Glenshaw Formation, red beds ("Pittsburgh")	East side of Raccoon Creek, south of bridge	Very recent landslide possibly caused by new farm road. An 18 m road section has been carried downslope by several meters. Series of transverse scarps above road is fresher than head scarp.
16	Glenshaw Formation, red beds ("Pittsburgh")	Raccoon Creek State Park	Slumping is very common along lower slopes of Traverse Creek and tributary drainages; road maintenance problems occur.
17	Glenshaw Formation, red beds ("Pittsburgh")	Hanshaville U.S. 30	60- to 75-m-long and 25-m-wide slide having undrained depressions at front of flow; excavation for quarrying operation triggered toe of older slide.
18	Freeport Formation Upper Freeport coal underclay(?)	Shippingport Road	Mine waste deposited over colluvial slope; slide is approximately 45 m wide, 30 m long, and has a well-defined head scarp.
19	Glenshaw Formation	Shippingport area, secondary road	Failure of previous road due to extensive slumping of outer lane fill, which necessitated cutting road back into bedrock. Present road is secure.
20	Glenshaw Formation, red beds ("Pittsburgh")	McCleary Road	Relatively moderate slope of 15 percent grade that has active slumping, extensive series of scarps from toe to head scarp.
21	Glenshaw Formation, red beds ("Pittsburgh")	Traverse Creek, east side	"Natural cause" earthflow (rainfall); no slope modification by man.
22	Freeport and Kittanning Formations	Little Blue Run impoundment area	Very wide 350 m zone of colluvium where some fill failed during or shortly after road construction. USSCS (1973b) showed this area as "slumped" on pre-construction aerial photographs.
23	Freeport and Kittanning Formations	Road along Little Beaver Creek north of Glasgow	60-m-wide zone of active slumping has affected road. Recent slide is part of older, more extensive slide.
24	Freeport and Kittanning Formations	Pa. 68 west of Midland	Active slide area that, according to local source, has been caused by heavy blasting and pile driving. Entire slope (2.5 km wide) west of here is a hummocky older landslide deposit.
25	Kittanning Formation	Pa. 68 at Midland–Shippingport Bridge	Three colluvial slumps (all showing rotational movement); heavy construction in immediate area may have triggered off slides.
26	Freeport and Kittanning Formations	Pa. 68, Industry	Relatively fresh heads scarp along abandoned road. Deterioration of drainage system along abandoned road could have caused recent sliding. Part of older, more extensive slide.
27	Glenshaw Formation, red beds and nonred beds	Pa. 60, east side	Drainage culvert have shifted on red claystone soil; slope slumping in small areas above vertical bedrock cut.
28	Freeport, Kittanning, and Clarion Formations	Pa. 51, east side slightly north of Brady Run Park entrance	Approximately 200-m-long by 120-m-wide slide. Head of slide at abandoned road. One of the largest recent slides in Beaver County.
29	Kittanning and Clarion Formations	Abandoned road between Beaver Falls and Patterson Heights	Small slides occur below an abandoned road 1 km east of location 28.

Table 2.—Major landslide-prone soils, Beaver County (In decreasing order of abundance)

SOIL NAME	STRATIGRAPHIC INTERVAL	LITHOLOGY OF PARENT MATERIAL
GILPIN-UPSHUR	CONEMAUGH	LARGELY RED MUDSTONE AND SHALE
WHARTON	CONEMAUGH, ALLEGHENY	NONRED SHALE AND MUDSTONE
GUERNSEY-VANDERGRIFT	CONEMAUGH	RED AND NONRED MUDSTONE AND SHALE, LIMESTONE
ERNEST	CONEMAUGH, ALLEGHENY	NONRED MUDSTONE, SHALE, AND SILTSTONE
CAVODE	ALLEGHENY, CONEMAUGH	NONRED SHALE AND MUDSTONE
GUERNSEY	MONONGAHELA	NONRED SHALE AND MUDSTONE, LIMESTONE
VANDERGRIFT-GILPIN	CONEMAUGH	LARGELY RED MUDSTONE AND SHALE

NOTE: Soils shown above are highly plastic and have a moderate to high shrinkage-swell potential



Slump: coherent or intact masses that move downslope by rotational slip on surfaces that underlie as well as penetrate the landslide deposit (from Nilsen, 1972)

Earthflow: colluvial materials that move downslope in a manner similar to a viscous fluid (from Nilsen, 1972)

Debris slide: incoherent or broken masses of rock and other debris that move downslope by sliding on a surface that underlies the deposit (from Nilsen, 1972)

Creep: common evidence includes: (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 (from Sharpe, 1938)

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

FIGURE 3—Diagrammatic representation of mass movement phenomena

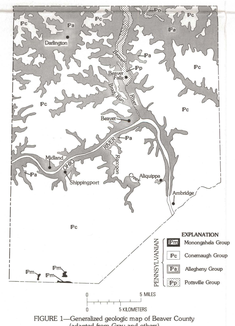
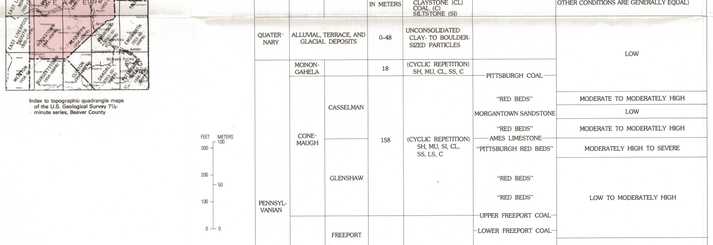


FIGURE 1—Generalized geologic map of Beaver County (adapted from Gray and others)



SYSTEM	GROUP	FORMATION	APPROXIMATE THICKNESS, IN METERS	LITHOLOGY SHALE (SH) SANDSTONE (SS) MUDSTONE (MU) LIMESTONE (LS) CLAYSTONE (CL) COAL (C) SILTSTONE (SI)	KEY BEDS, MEMBERS, AND SEQUENCES	RELATIVE SUSCEPTIBILITY OF DERIVATIVE SOILS AND WEATHERED ROCK TO LANDSLIDING (ASSUMING SLOPES ARE STEEPER THAN 15 PERCENT AND OTHER CONDITIONS ARE GENERALLY EQUAL)
QUATERNARY	ALLUVIAL, TERRACE, AND GLACIAL DEPOSITS		0–48	UNCONSOLIDATED CLAY- TO BOULDER-SIZED PARTICLES		LOW
PENNSYLVANIAN	MONONGAHELA		18	(CYCLIC REPETITION) SH, MU, CL, SS, C	PITTSBURGH COAL	
	CONEMAUGH	CASSELMAN	158	(CYCLIC REPETITION) SH, MU, SI, CL, SS, LS, C	"RED BEDS"	MODERATE TO MODERATELY HIGH
					MORGANTOWN SANDSTONE	LOW
		GLENSHAW			"RED BEDS"	MODERATE TO MODERATELY HIGH
					AMES LIMESTONE	
					"PITTSBURGH RED BEDS"	MODERATELY HIGH TO SEVERE
					"RED BEDS"	LOW TO MODERATELY HIGH
					"RED BEDS"	
					UPPER FREEPORT COAL	
					LOWER FREEPORT COAL	
	ALLEGHENY	FREEPORT	91	(CYCLIC REPETITION) SS, SH, MU, CL, SI, LS, C	UPPER KITTANNING COAL MIDDLE KITTANNING COAL LOWER KITTANNING COAL	LOW TO MODERATE
		KITTANNING				
		VANPORT				
		CLARION			CLARION COAL	
	POTTSVILLE	HOMEWOOD	60	SS, SH, C		LOW
		MERCER				
		CONNOQUENESSING				

FIGURE 2—GENERALIZED STRATIGRAPHIC SECTION OF BEAVER COUNTY (MODIFIED FROM PATTERSON, 1963) AND RELATIVE SUSCEPTIBILITY OF WEATHERED MATERIAL TO LANDSLIDING

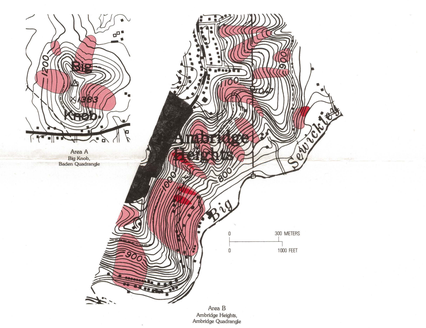


FIGURE 4—Selected areas at 1:12,000 scale showing relation of older landslides (light red) to topography. Dark red shows areas of recent landsliding. Dashed line indicates inferred position of Ames Limestone Member of Glenshaw Formation (Munn, 1911). Outcrops are obscured by wide area of unstable colluvium derived in part from red mudstone and claystone

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