GUIDEBOOK NO. 9

CINCINNATI'S GEOLOGIC ENVIRONMENT: A TRIP FOR SECONDARY-SCHOOL SCIENCE TEACHERS

by

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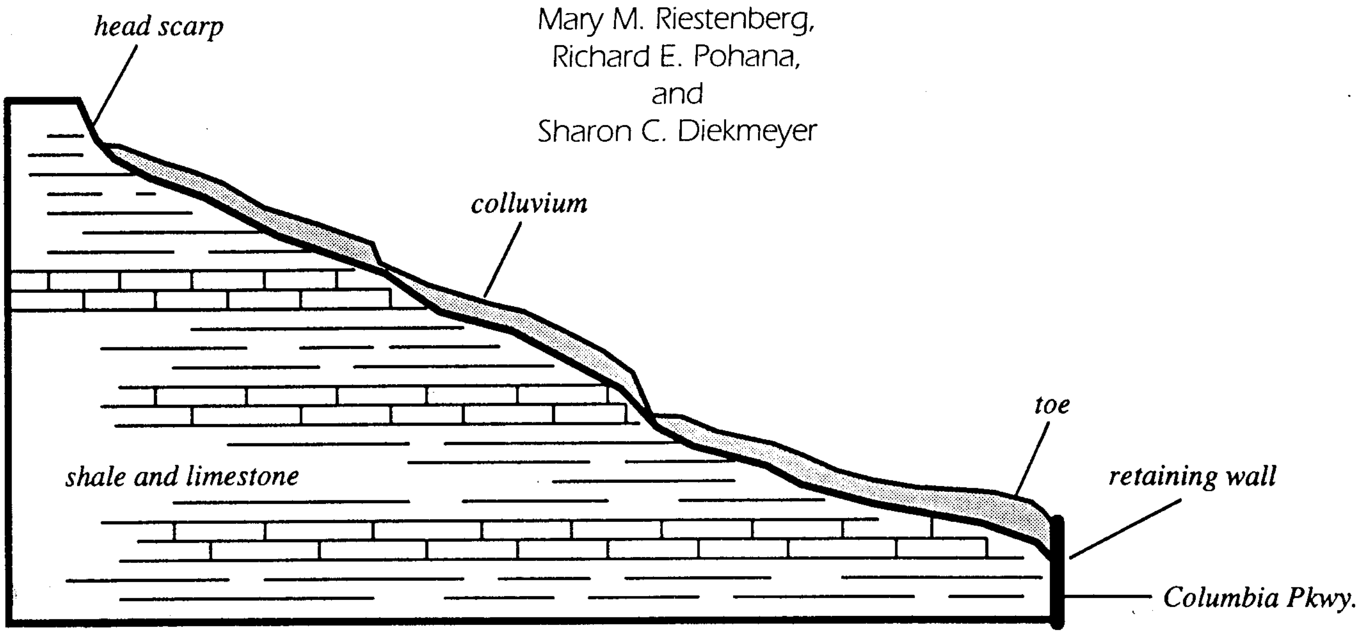

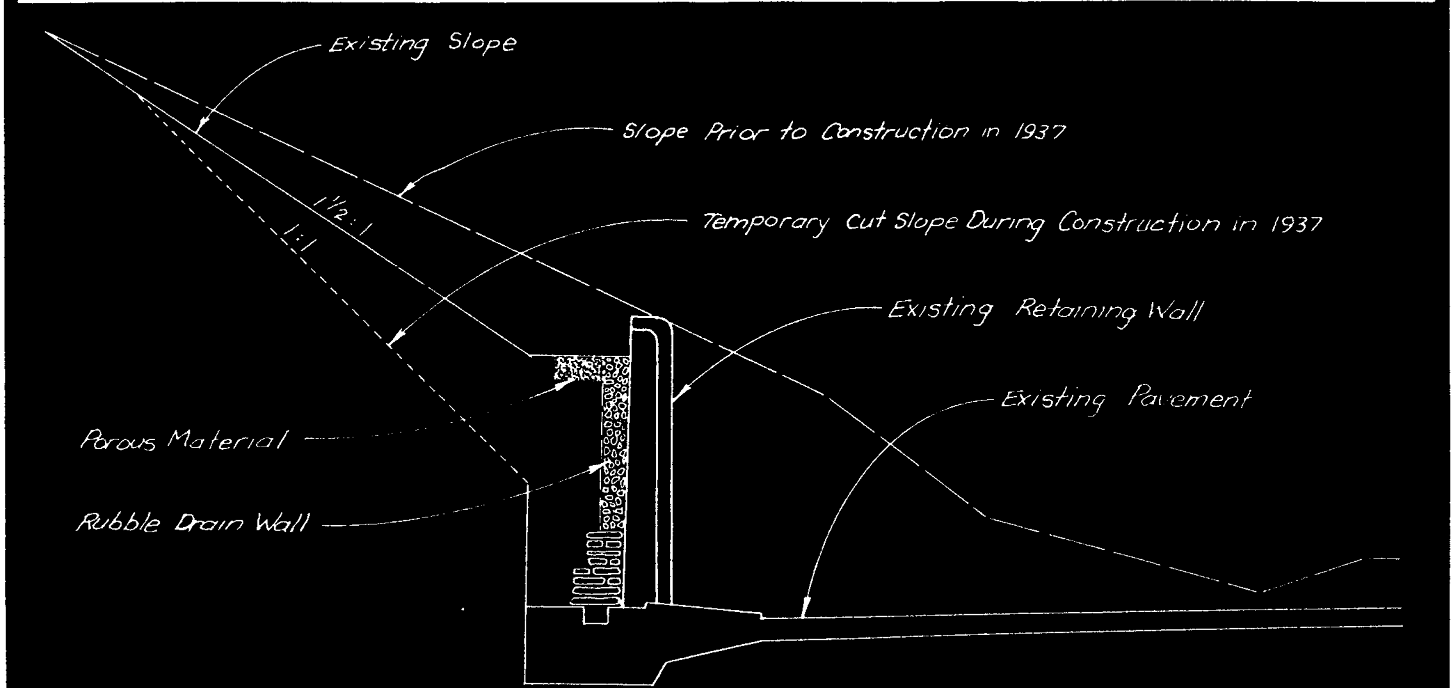

prepared for the 1992 Annual Meeting
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The field-trip stops are listed below. Geologic descriptions of the eight stops are provided in a series of five short papers that follow (two of the papers pertain to more than one stop each).

STOP #1. Columbia Parkway at Tusculum Avenue. Examine a pier wall constructed to stabilize the sliding hillside.

STOP #2. Alms Park overlook of Little Miami and Ohio River valleys. Observe the course of the pre-Illinoian Deep Stage River and physiographic setting of the Little Miami valley-fill aquifer.

STOP #3. McCullough Avenue at Columbia Parkway. Examine a pier wall constructed to stabilize the sliding hillside.

STOP #4. Lunken Airport. Discuss flow and occurrence of ground water, as well as subsurface stratigraphy of the Little Miami alluvial aquifer.

STOP #5. California Golf Course. Examine a Pleistocene depositional terrace.

STOP #6. River Downs. Inspect exposures of Pleistocene terrace sands and gravels.

STOP #7. Riedlin Road/Mason Road (Kentucky). Examine Upper Ordovician shale and limestone sequences, discuss paleontology and paleoenvironmental interpretations, and collect fossils.

STOP #8. Abandoned Delhi Pike at College of Mt. St. Joseph. Examine both thin and thick colluvium landslide complexes, the destructive effects of landsliding, and the relationship between vegetation and slope stability. If weather and time permit, we may take a short cross-country hike to examine landslides associated with undercutting of colluvium hillslopes along Rapid Run.

LANDSLIDES ALONG COLUMBIA PARKWAY (STOPS #1, 3)

by Richard E. Pohana

Although many people envision landsliding as a problem limited to steep mountain valleys, a study by the U.S. Geological Survey (Fleming and Taylor, 1980) concluded that Hamilton County, Ohio, probably has the highest annual per capita landslide damage costs in the country. The City of Cincinnati alone has about 25 miles of retaining walls (about 20 percent of which are in poor shape), spends about $500,000 per year on emergency landslide repairs, and has deferred about $15 million in repairs to roads and streets damaged by landslides (Smale, 1987). Of course, the total damage costs from landslides in some areas, such as the San Francisco Bay region, may be greater. Hamilton County's smaller population, however, means that the cost to each taxpayer is proportionally greater than in other areas. A recent economic study (Bernknopf and others, 1988) has shown that enforcement of rudimetary zoning and grading provisions throughout Hamilton County, taking into account only slope and bedrock type, would save more than twice the cost of enforcement.

Columbia Parkway (U.S. Route 50) is a limited access roadway connecting eastern Cincinnati, its suburbs, and eastern Hamilton County with downtown Cincinnati. The western terminus of Columbia Parkway is located on the edge of the central business district of downtown Cincinnati. The parkway extends 6.4 miles to the east, becoming Wooster Road at the Cincinnati-Fairfax corporation line.

Columbia Parkway was constructed in 1937 and 1938 and followed the alignment of pre-1937 Columbia Avenue. The latter was a two-lane roadway with a total width of 35 to 40 feet, measured from the ditch line on the uphill side to the top of the downhill slope. Columbia Avenue was constructed by cutting on the uphill side, and placing fill on the downhill side. The angle of the cut slope varied, but was generally about 1.5 horizontal to 1 vertical (1.5:1, or about 34 degrees), and the depth of cut ranged from 5 to 10 feet.

Columbia Parkway was created by widening Columbia Avenue, which was accomplished by cutting into the hillside on the northern, uphill side and constructing retaining walls. The cut section was about 20 feet wide, and the retaining-wall cuts were on a slope of approximately 1:1. The wall was constructed, and then backfilled at a slope of 1.5:1 to the intersection with the existing grade. The height of the wall ranged from 6 to 12 feet. Figure 2 shows the configuration of the pre-1937 ground line, the temporary cut for construction of the retaining wall, the retaining wall itself, and the ground slope behind the retaining wall.

The rebuilt roadway had a total width of 57 feet from the face of the retaining wall to the top of the downhill slope. Construction included a 44-foot-wide roadway, a 4-foot sidewalk along the north side, and a 9-foot berm along the south side, which included a second 4-foot-wide sidewalk.

GEOLOGY

The hillside above Columbia Parkway rises as much as 200 feet in a horizontal distance of 400 feet, which is a slope of 2:1 (about 27 degrees). Natural slopes beneath the parkway are generally about 3:1 (about 19 degrees). The hillside is underlain by Upper Ordovician shales and limestones of the Kope and Fairview Formations. The contact between the Kope and Fairview occurs at an elevation of about 700 feet above sea level, which is 75 to 100 feet above the parkway. The bedrock is covered with a clayey residual soil known as colluvium. Each of these is described below.

The Kope Formation is primarily shale, but thin limestone layers, typically 2 to 6 inches thick, constitute 20 to 30 percent of the Kope. Shale in the Kope Formation is not tightly cemented and is therefore susceptible to physical disintegration. The large amount of easily disintegrated shale results in accumulations of colluvium, which range from 3 to 50 feet thick, atop the Kope. Within the uppermost 50 feet of the Kope Formation is the 11-foot-thick Grand Avenue Member, which contains a higher percentage of limestone than does most of the Kope. Shale beds in the Grand Avenue Member are less than 2 feet thick, and limestone layers are as thick as 1 foot.

The Fairview Formation lies above the Kope Formation and has an average limestone-to-shale ratio ranging from 1:1 to 3:1. The limestone layers are typically thickly bedded and tabular. Many of the limestone layers are more than 4 inches thick, and some are 7 to 10 inches thick. Because of the higher percentage of limestone, the Fairview Formation supports steeper slopes and thinner soils than does the Kope Formation. Natural slopes developed on the Kope Formation can be as gentle as 6:1 (about 10 degrees), whereas slopes developed on the Fairview Formation can be steeper than 2.5:1 (about 22 degrees). Hence, there is in

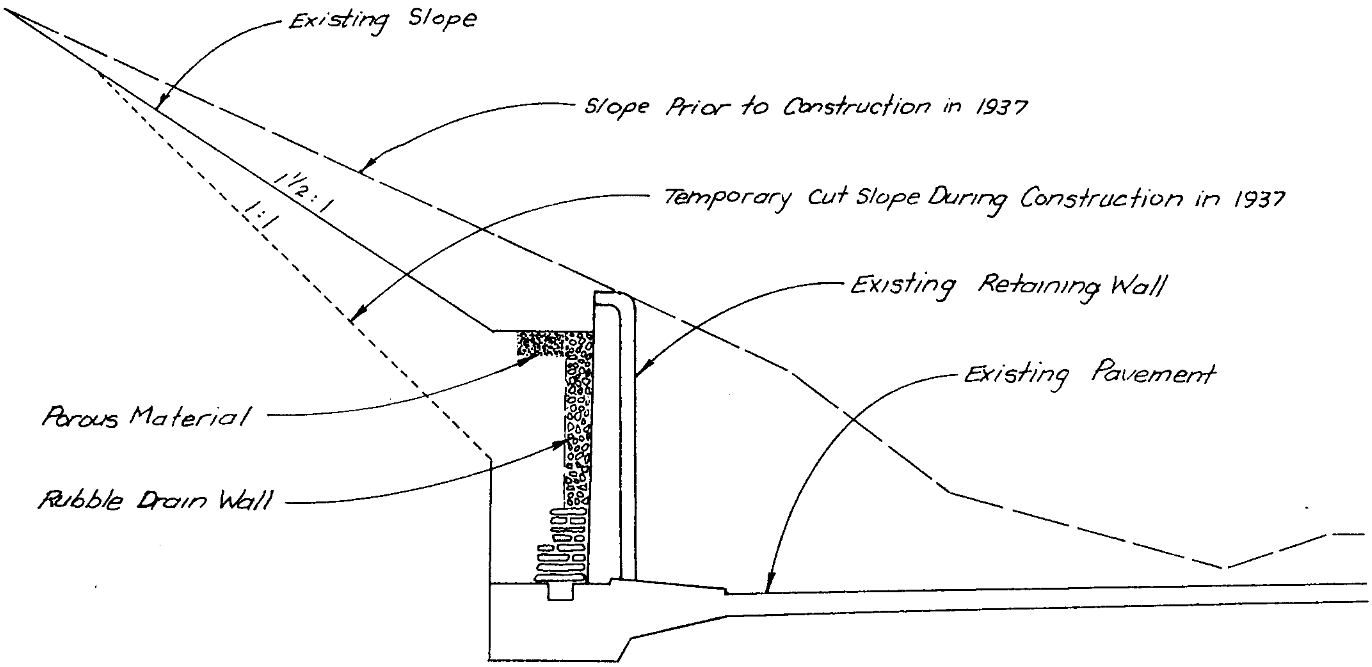

FIGURE 2.—Typical pre- and post-construction (1937) topography along the Columbia Parkway retaining wall.

many cases a noticeable change in topography at the Kope-Fairview contact. Colluvium thickness above the Fairview Formation ranges from zero to 6 feet.

Foundations for some of Cincinnati's early buildings were constructed with local limestone. Practically all of the commercial quarrying was done in the Fairview Formation, mostly in the upper Fairmont Member (also known as the Hill Quarry Beds). Steep slopes, terraces, and exposed bedrock suggest that limestone was quarried from the top of the hillside above Columbia Parkway. During quarrying, shale was often dumped over the slope across from the exposed quarry wall. In 1975, waste from 19th-century quarrying operations slid onto Columbia Parkway near Foster Avenue.

Colluvium in the Cincinnati area is weathered shale and limestone that has been transported downslope by soil creep. Colluvium derived from the Kope and Fairview Formations is typically a very stiff to hard, medium-plastic clay containing pieces of embedded shale and limestone. During dry periods, colluvium near the ground surface is dry and hard; however, it is softened and becomes plastic during rainy periods. Colluvium occurs along the entire length of Columbia Parkway and can be as much as 50 feet thick. When wet, Cincinnati colluvium is highly susceptible to landsliding. Landslide problems above the parkway are limited primarily to shallow, creeping movement that accumulates debris behind retaining walls. Deep-seated landslides below the roadway have severely damaged its pavement.

LANDSLIDES ABOVE COLUMBIA PARKWAY

Movement of colluvium on the hillside above Columbia Parkway has been a continuing problem, presumably, since its construction. In many cases, landslides have caused colluvium to slide over retaining walls and onto the parkway itself. Retaining wall maintenance is a yearly task in some places along Columbia Parkway. The slides block surface drainage behind retaining walls and cause trees to lean out over the roadway. During heavy rains, much material is washed over the wall and, in some cases, through the joints of the walls. Maintenance includes the cutting of trees leaning over the walls, as well as removal of soil and vegetation along the tops of the walls. Landslides above the wall occur in colluvium derived from the Kope Formation. Slip surfaces are probably located along the bedrock-colluvium interface. The slip surfaces are typically shallow, from 3 to 5 feet deep. The areas in which soil encroaches upon the retaining walls are slide blocks which have separated from the lower portions of much larger landslides, which extend much higher up the slope (fig. 3). The slide blocks eventually reach the foot of the slope, where they are removed by city maintenance crews or slide over the walls. The lower portion of the landslide remains dormant and marginally stable until another block separates, causing repeated landslides in the same location.

The original cause of landsliding along Columbia Parkway was road construction, which oversteepened the lower portions of the slope and removed lateral support for the colluvium. Other important factors are ground-water flow and precipitation, as well as continued oversteepening of the slope during maintenance. From time to time, large landslides occur above the retaining wall, bringing large amounts of debris over the wall and onto the parkway.

Several landslides occurred on the slopes above Columbia Parkway during the spring of 1992, requiring the city to close the road and remove about 950 cubic yards of debris at a cost of $19,000. Areas in which sliding occurred are between Bains and Kemper, just east of Kemper Lane, and just west of the intersection of William Howard Taft Road. During March 1981, accumulated landslide debris behind the retaining wall across from Audubon Avenue created a public hazard. Trees were reportedly resting on power lines, and were in danger of falling onto the parkway. Some mud was washed over the wall. City records do not indicate the amount of soil removed or the cost involved. In 1975, a large landslide, involving as much as 10,000 cubic yards of soil, occurred about 800 feet west of Audubon. The weight of the slide mass caused about 160 feet of retaining wall to fail. Apparently, most of the slide

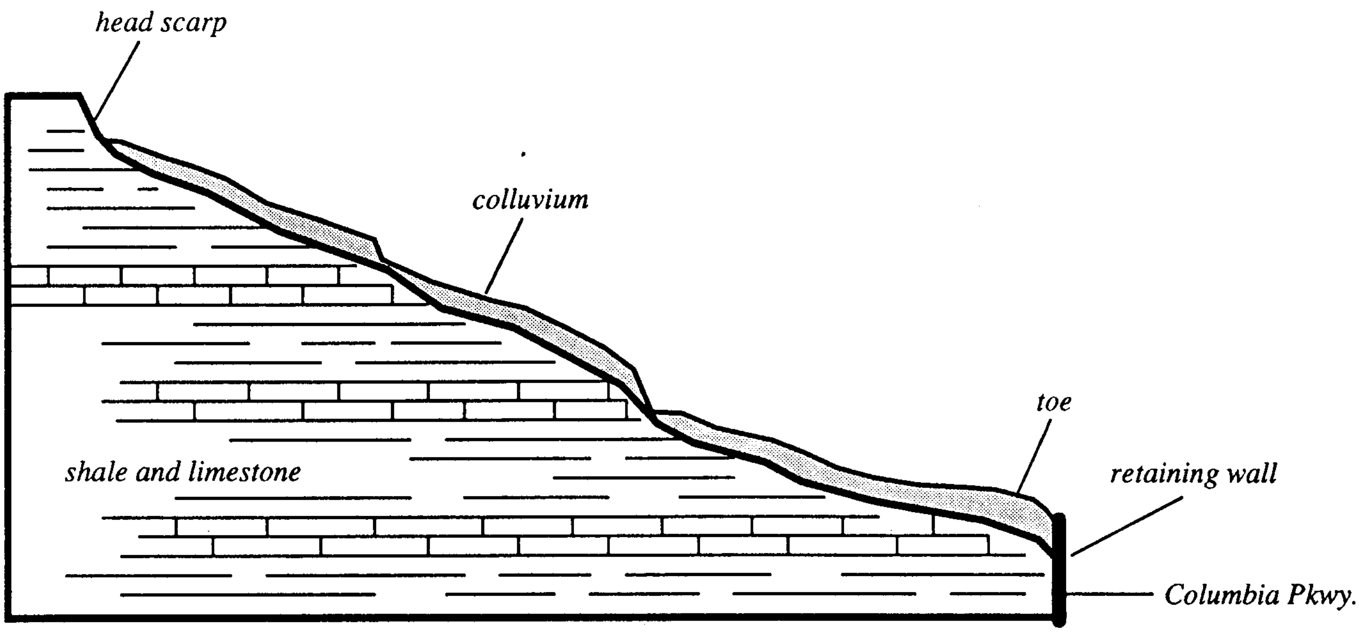

FIGURE 3.—Cross section through a typical thin colluvium landslide along the Ohio River valley. Bedrock is predominantly shale with limestone interbeds, and the landslide slip surface coincides with the bedrock-colluvium contact.

material was shale and clay dumped along the slope during 19th-century quarrying operations. Cost of removal was $31,000. Also in 1975, six landslides occurred along the hillside east of Kemper Lane. About 5,000 cubic yards of soil was removed from behind the retaining wall, at a cost of $19,000. A review of files revealed that in 1973 a large amount of soil slid over the retaining wall, blocking the westbound lane of Columbia Parkway in several places. Sliding was caused by heavy rains that occurred between February and May 1973. The costs to remove the debris along the parkway were:

Bains to Kemper	$8,325
Kemper to Taft	$1,930
East of Torrence Pkwy.	$2,352
At Wortman	$4,754

Landslides above Columbia Parkway will continue to occur, and the rate of sliding at any given time will be related to rainfall. The conditions most conducive to landsliding will be heavy rain storms during early spring, after the spring thaw but before trees had leafed out.

MASS MOVEMENT BELOW THE PARKWAY

The entire hillside below Columbia Parkway is actively creeping downslope. When the rate of movement within a given area differs sufficiently from the adjacent area, scarps, cracks, and other landslide features develop and the area is referred to as a landslide. Sidewalks and curbs may be offset, and buried utility lines may rupture due to the effects of landsliding. Deep-seated active and inactive landslides occur on the hillside below Columbia Parkway and are almost continuous from Bains to Torrence Parkway. The landslides are elongated, with their long dimension running perpendicular to the hillsides. The head scarps of the landslides occur within 6 to 10 feet of the roadway, in some places cutting through several feet of roadway if not through the roadway entirely. Within the pavement, the head scarps are easily distinguished by extensive cracking, settlement, and warping of the pavement. Head scarps on the downhill side of the pavement are not as easily distinguished because of vegetation and the effects of weathering. The slip surfaces of the landslides presumably occur along the soil-rock interface, which is typically more than 15 feet deep. The toes of landslides occur along the north side of the Conrail tracks and in some instances extend downhill as far as Eastern Avenue.

Maintaining the integrity of the eastbound lanes of Columbia Parkway has been a long-term problem. The rate of movement, as determined by the amount of vertical displacement within the pavement, is on the order of several inches per year. In order to insure a smooth ride, asphalt overlays must be placed at least twice a year in areas most affected by landsliding. As is the case for landslides above the parkway, the rate of sliding at any given time is directly related to precipitation.

IMPROVING COLUMBIA PARKWAY

Columbia Parkway is currently being widened and improved between Bains and Beechmont Avenue. The improvement is being performed in three sections: Bains to Torrence Parkway, Torrence to Tusculum, and Tusculum to Beechmont.

In 1976, the section of Columbia Parkway between Torrence Parkway and Delta was widened by adding approximately 8 feet onto the south side of the roadway. Retaining walls consisting of 36-inch-diameter concrete piers, socketed into bedrock, were required in several places. Sections of the roadway between Torrence and Delta that are not supported by a pier wall are affected by soil creep. This movement has caused up to 5 inches of settlement along the southern curb line and opening of joints in the eastbound lane. The City of Cincinnati will improve this section in the fall of 1992 by rehabilitating and resurfacing the existing pavement, installing pier walls, and underpinning sections of the existing barrier walls.

In October 1990, the State of Ohio began construction on the improvement of Columbia Parkway from Tusculum to

Beechmont Avenue. This project was completed in the spring of 1992. In October 1991, the State began construction on the improvement of Columbia Parkway from Bains to Torrence; this project is expected to be completed by the spring of 1993. The Tusculum to Beechmont and the Bains to Torrence projects involve widening the existing traffic lanes, rehabilitation and resurfacing of the existing pavement, resurfacing and strengthening or replacement of uphill retaining walls, and other safety upgrades. The existing reinforced concrete retaining walls along the uphill side of Columbia Parkway between Tusculum and Beechmont were resurfaced with 8 inches of reinforced concrete. The top of the wall was raised slightly and a safety barrier was incorporated into the wall along the roadway. The retaining walls were also strengthened using tiebacks to prevent the kind of sudden wall failures that have occurred in the past. All existing uphill retaining walls between Bains and Kemper will be strengthened, refaced, and tied back with grouted rock anchors. Existing uphill walls between Kemper Lane and Torrence Court will also be strengthened or replaced. Several new walls will be built in areas where there are none.

Because of continuing sliding beneath the parkway and the need to further widen the roadway, the downhill side of the pavement along 5.2 miles of Columbia Parkway will be stabilized using 3.2 miles of drilled pier walls. A pier wall is an earth-retaining structure consisting of a row of individually drilled piers socketed into stable bedrock. The piers are constructed so that they penetrate the unstable soils and develop resistance to the lateral loads in the underlying bedrock. In many cases, the depth to bedrock is such that tiebacks with grouted rock anchors are necessary to support

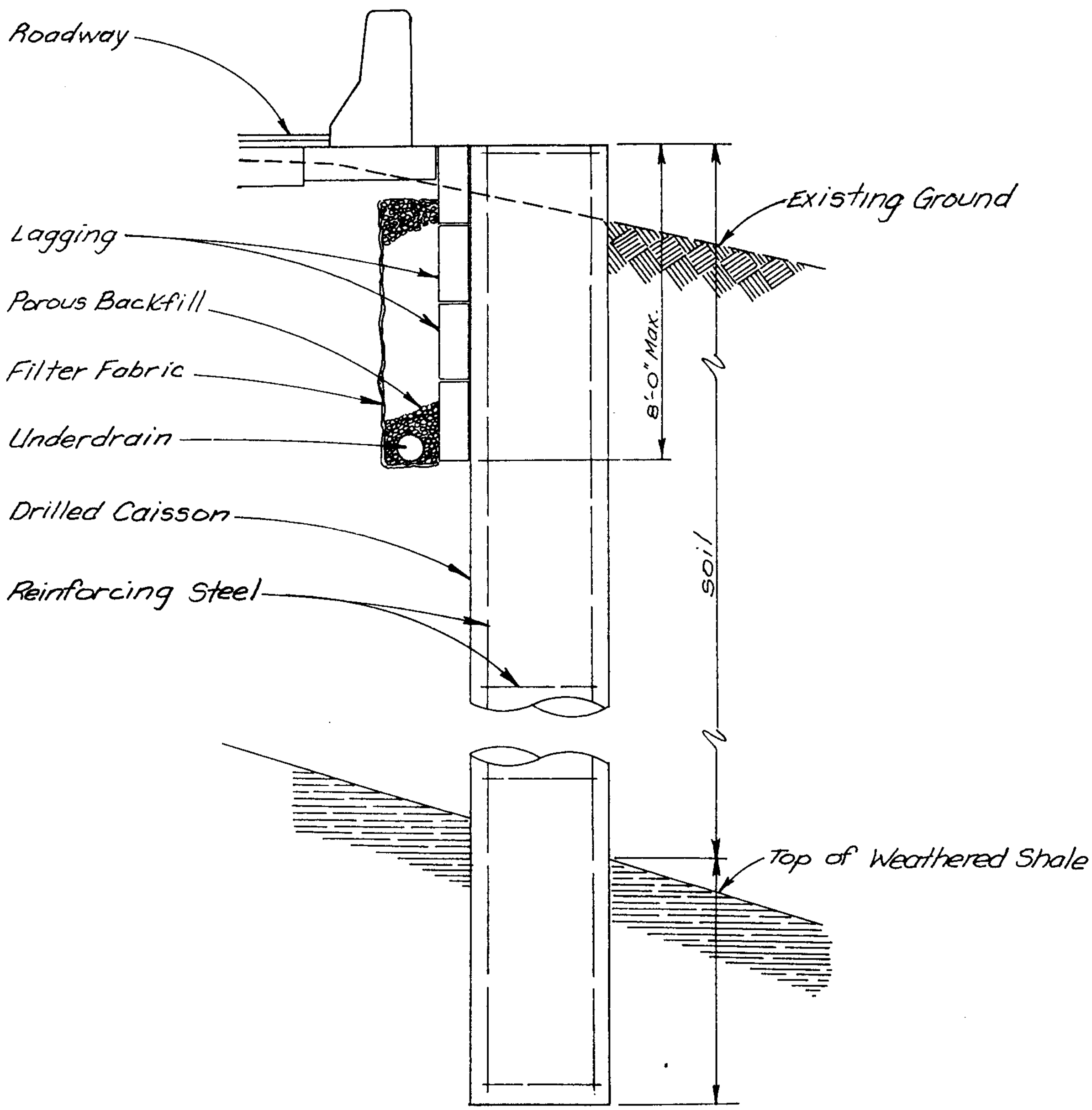

FIGURE 4.—Design of a typical cantilevered pier wall used to support potentially unstable slopes in the Cincinnati area. Pier walls are constructed by drilling large diameter holes into bedrock, which are in turn filled with reinforced concrete. When completed, each pier acts as a lever to prevent the colluvium from moving downslope.

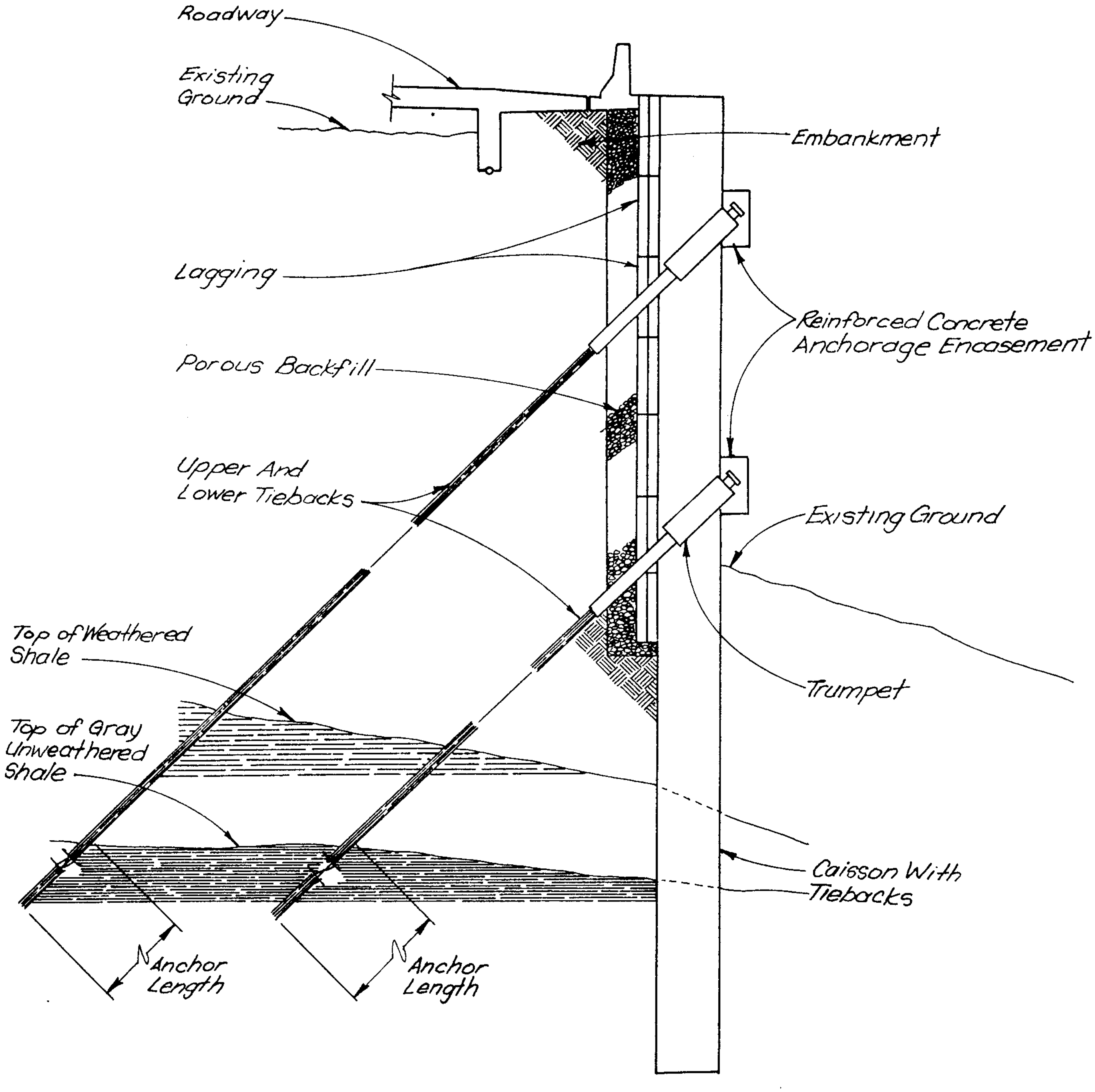

FIGURE 5.—Design of a typical tied-back pier wall. Tied-back pier walls are similar to cantilevered pier walls, but resistance to sliding is increased by adding steel tiebacks anchored in stable shale bedrock.

the tops of the piers. Figures 4 and 5 show typical details of a cantilevered and tied-back drilled pier. The diameter of the piers on Columbia Parkway projects ranges from 30 to 48 inches, and the length ranges from 15 to 55 feet. The bedrock sockets range from 5 to 18 feet deep, and the total number of individual piers to be installed is 2,526. Estimated cost of the project is $25 million, or about $5 million per mile. While these projects will stabilize the parkway, they will neither eliminate landsliding below the pier walls nor reduce the occurrence of landslides above the parkway.

As we travel east along Columbia Parkway, observe the barren areas along the uphill side of the roadway, where soil has slid over the wall. Along the downhill side of the roadway, pier-wall construction should still be in progress. It may be possible to pull off the road to inspect and discuss the construction of pier walls (Stop #1). If not, we will stop at McCollough Avenue off Eastern Avenue to inspect an existing pier wall (Stop #3).