# GEOLOGIC PERSPECTIVES--THE CINCINNATI EXAMPLE

Ву

ROBERT W. FLEMING U.S. Geological Survey Box 25046 Denver Federal Center Denver, Colorado 80225

## GEOLOGIC PERSPECTIVES -- THE CINCINNATI EXAMPLE

## BY ROBERT W. FLEMING

#### Introduction

Landslides are a common and longstanding problem in the Greater Cincinnati area. Reports of a resulting road closure, construction delay, or destruction of property occur altogether too frequently, and correction of slope-movement problems involves large expenditures of time and money. Estimates for correction of a major landslide that occurred in 1974 in connection with the construction of Interstate Highway 471 ranged upward from about \$8 million. During the period 1927-30, a landslide in Riverside, west of downtown Cincinnati, destroyed some 40 houses (Von Schlichten, 1935).

Although most slides appear to occur in the late winter or early spring, some happen during each month of the year. Not all slides along a valley wall on Hillside Avenue in Cincinnati have occurred on the steepest slopes. Stability problems are not restricted to the valley walls along the Ohio River and major tributaries but are common throughout much of the metropolitan area. For example, Yahne (1974) identified 49 active and incipient landslides in a 9-square-mile (23-km2) area immediately north of downtown Cincinnati. These seemingly unrelated facts make it difficult to grasp significant relationships among slope problems--and, taken as a whole, the slope-movement problems in the Greater Cincinnati area seem inordinately complex. Nevertheless, recognizing the apparent relation of slope movements to distinct and mappable geological units enables one to make some definitive statements about potentially hazardous areas. Many unfortunate experiences can be avoided if these areas are identified and described in a form that can be understood by public officials, contractors, and developers, as well as by the public in general. The purpose of this paper is to

illustrate the relationships between various types of slope movements and the geological conditions that prevail in those areas.

## Geology and landslides

Hamilton County, Ohio, occupies 414 square miles (1,072 km²) of extreme southwestern Ohio. The maximum relief in the county is 507 feet (155 m). The altitude varies from about 962 feet (293 m) at the Mt. Airy water tower, at the intersection of Colerain and North Bend Road in Cincinnati, to about 455 feet (139 m) at the mouth of the Miami River near the southwestern corner of Ohio (fig. 1). The topography is characterized by a rolling upland surface, hill slopes along the Ohio River and major tributaries, and flood plains and terraces of the rivers. The uplands are generally covered by glacial deposits, mostly till of Illinoian age. Bedrock, consisting of thin-bedded limestone and shale, underlies the glacial deposits at various depths in the upland areas and is exposed on some hill slopes where erosion has removed the glacial cover. The major river of the area, the Ohio, and its tributaries, Mill Creek, Little Miami River, Whitewater River, Miami River, and Licking River, contain flood plains and terraces of varying widths and heights. Materials in the terraces and flood plains vary from sand and gravel to laminated silts and clays.

The geology of the Greater Cincinnati area can best be described in two parts: (1) the bedrock of the area and the soils developed on bedrock, and (2) the glacial deposits of the area and the soils developed on them. Units related to both the bedrock and glacial deposits are unstable and, moreover, the modes of failure appear related to particular material types. Therefore, this report considers first the nature and distribution of the bedrock units, together with an analysis of the slope movements that are indigenous to them, and then presents a similar discussion of the glacial units.

## Bedrock

The Greater Cincinnati area is underlain by shales and limestones of Middle and Late Ordovician age. Geologic maps of the bedrock geology of four quadrangles (Madeira, Cincinnati East, Cincinnati West, and Addyston-Burlington) in Ohio have been published by the Division of the Geological Survey, Ohio Department of Natural Resources (Osborne, 1970, 1974; Ford, 1972, 1974). The U.S. Geological Survey is nearing completion of a program

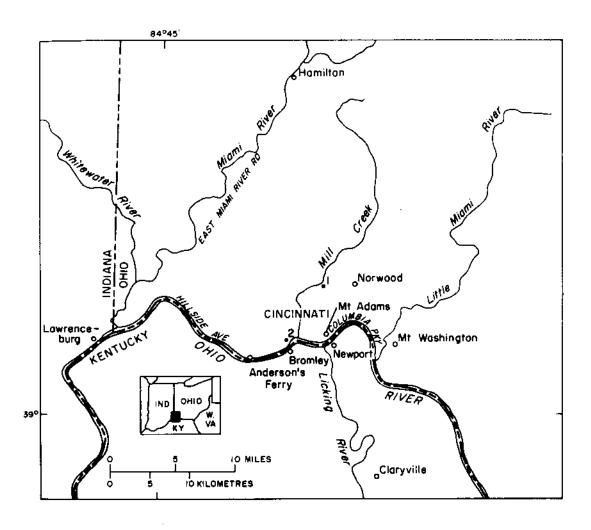


Figure 1.--Sketch map of Cincinnati area.

of geologic mapping of all the quadrangles in Kentucky, and, at the time of this writing, maps of most of the areas in Kentucky that are part of the Greater Cincinnati area have been published. See, for example, maps by Luft (1971, 1972) and Gibbons (1972).

The bedrock units dip northwestward at about 8 to 10 feet per mile (1.5-1.9 m/km) from the axis of the Cincinnati Arch, which is several miles east of the metropolitan area. Small, complex, deformational structures in stream valleys were observed by Hofmann (1966) and ascribed to erosional unloading and sliding, slumping, and flowing in conjunction with deposition of the beds in the general direction of the depositional dip. Neither the slight dip of beds nor the small complex structures have had any apparent influence on the modern landslide processes.

Formational names and boundaries of bedrock units have been revised several times during the past 20 years, and recent publications continue to differ slightly as to nomenclature. The stratigraphy of the bedrock units is discussed in Caster, Dalvé, and Pope (1955), Weiss and Norman (1960), Weiss and Sweet (1964), Peck (1966), Ford (1967), and Gray (1972).

Figure 2 presents generalized geologic columns, based on lithology, for the Greater Cincinnati area as adopted by the U.S. Geological Survey for mapping in Kentucky and by the Division of the Geological Survey, Ohio Department of Natural Resources, for Ohio. Interfingering of formations, thickness changes, and local warping of beds make it impossible to specify elevations of the formational contacts in the entire area. These are best obtained from the published maps and projected, if necessary, into unmapped areas.

The bedrock units appear relatively stable in most slopes. There are a few minor instances of rockfalls associated with steeper slopes and abandoned limestone quarries in the Fairview Formation. In one more serious incident, a large mass of Bellevue Limestone was observed to have moved laterally, apparently on the Miamitown Shale, a distance of several inches, posing a potential threat to property downslope (R. H. Durrell, oral commun., 1973). However, if this were the extent of the slope stability problem in the Greater Cincinnati area there would be no cause for the present concern.

| Sys-<br>tem | Se-<br>ries                    | KENTUCKY<br>(U.S. Geol. Survey)   | OHIO<br>(Ohio Dept. Natural Resources)  |
|-------------|--------------------------------|---|---|
| ORDOVICIAN  | Upper Ordovician               | Bull Fork Formation<br>85+ (26+)<br>50% shale   | Undifferentiated<br>0-135+ (0-41+)<br>% shale varies                                  |
|             |                                | Grant Lake Limestone (Bellevue<br>tongue) 0% shale 2-33 (2-10)<br>Miamitown Shale of<br>Ford (1967) | Bellevue Limestone<br>0-25 (0-8) 0% shale<br>Miamitown Shale<br>0-35 (0-11) 90% shale |
|             |                                | Fairview Formation<br>∿100 (∿30)<br>45-60% shale  | Fairview Formation<br>∿70-100 (∿21-30)<br>60-75% shale                                |
|             |                                | Kope Formation<br>200+ (61+)<br>80-85% shale  | Kope Formation<br>200+ (61+)<br>70-80% shale  |
|             | Middle and<br>Upper Ordovician | Point Pleasant Formation<br>∿100 (∿30)<br>30-50% shale  | Not exposed   |

Figure 2.--Generalized geologic columns for the Greater Cincinnati area in Kentucky and Ohio, showing thickness in feet (metres) and percentage of shale for each unit.

The stability problems, in general, involve not the intact, unweathered bedrock but rather the colluvium derived from the bedrock by weathering. Most of the shales in the bedrock sequence, particularly those in the Kope Formation, are not tightly cemented and slake readily to their constituent grains. Certain hill slopes are covered by a layer of bedrock-derived colluvium that may vary in thickness from a few inches to at least 30 feet (9 m). Figure 3a is a view of a near-vertical cut in the Kope Formation. The interbeds of shale and limestone in this cut are apparently stable. Other similarly cut slopes in the same material, such as at the Newport Shopping Center, Newport, Ky. (fig. 1), have stood for several years without landslide problems. The shale interbeds, however, slake and form a pile of debris at the foot of the cut slope. Figure 3b is a closeup view of a block of previously unweathered shale that has been exposed for only a short time and has already begun to disintegrate.

There have been no published studies of the engineering characteristics of the shales in the area. Observations of the slaking behavior suggest that the shales in the Kope Formation are more susceptible to physical disintegration than shales in other formations in the area. This may be more apparent than real, however, simply because the Kope contains a greater proportion of shale and because it occupies the lower part of most slopes and can collect debris transported by water or creep from upslope.

The overlying Fairview Formation supports a steeper slope than does the Kope Formation, and the soil cover is noticeably thinner. Natural slopes on the Kope Formation may be as low as 9° or 10°, while those on the Fairview Formation may exceed 20°. There is commonly a noticeable topographic break at or near the interformational contact. Whether the steeper slope and thinner soil are a result of (a) cementation in the shale, as suggested by Von Schlichten (1935), or (b) transport of slaked debris off the Fairview Formation by water or creep, or (c) a difference in clay mineralogy (Bassarab and Huff, 1968) is not known. The presence of more limestone in the Fairview Formation could, in itself, account for the steeper slope. Whatever the reason, landslides related to bedrock in the Greater Cincinnati area are almost exclusively contained in the colluvial cover overlying the Kope Formation. In the relatively unpopulated part of northwestern Hamilton County, where the Miamitown Shale reaches its maximum thickness, smaller but similar problems occur on that unit.





Figure 3.--Photographs of the Kope Formation along Hillside Avenue near Anderson's Ferry.

- a. Excavation into Kope Formation showing its rocklike character. Note accumulated debris at foot of excavation and slide in colluvial material uphill from ready-mixed concrete truck.
- b. Closeup view of a block of shale that is slaking after short exposure. Largest dimension of shale block is about 2 feet (0.6 m) across.