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HISTORIC ROCK QUARRIES AND MODERN LANDSLIDES IN PRICE HILL, CINCINNATI

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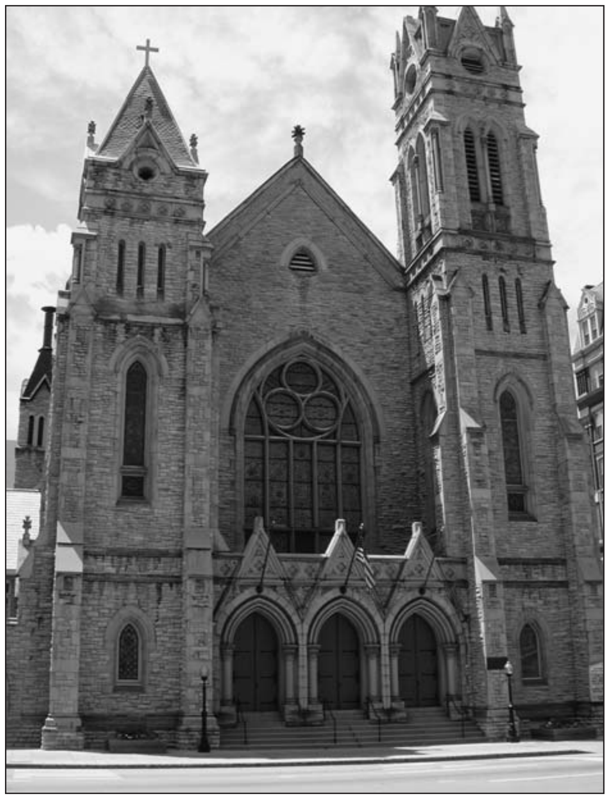
A chisel, hammer, and a strong back were all that was necessary to work the rock quarries that peppered the greater Cincinnati landscape at the close of the 19th century. Numerous small rock quarries existed on the hillsides of Cincinnati in the 1800s and early 1900s when one of the nation's most rapidly growing cities had a tremendous need for the local building stone. Now these historic quarries can be directly associated with modern-day landslide problems.

Local sources of limestone for construction of buildings and city infrastructure were as vital for a growing economy in the 1800s as they are today, and perhaps more so. Early in Cincinnati's history, numerous small limestone quarries sprang up across the region near local population centers where there was a need for building stone. Concrete had not yet come into widespread use as a building material, so dimension stone (stone that is quarried or cut to a required dimension) was the main building material for foundations, basement walls, and facings on buildings. The limited ability to transport heavy stone products great distances in those days demanded that quarries be developed in close proximity to end-use markets. This is in contrast to modern quarries, where railroad, truck, and boat transportation of quarried stone allow a few large quarries to serve markets that may be a considerable distance away. Some modern uses of stone include aggregate (i.e., crushed stone) used in construction projects for road and foundation base, and dimension stone for walls and building facades. Today's builders are highly dependent on limestone resources, much as the early inhabitants of Cincinnati depended upon the local stone resources.

The preferred building stone in 19th-century Cincinnati was Ordovician-age limestone of the Fairview Formation—a 70- to 120-foot-thick interval of interbedded limestone and shale. The upper 75 feet of the Fairview is dominated by planar beds of limestone, commonly four to seven inches thick, and ideal for use as dimension stone. The strong local demand for this stone is readily apparent today, as evidenced by its widespread use in numerous pre-1920-era residential foundations, retaining walls, and buildings throughout Cincinnati.



The Covenant First Presbyterian Church, built in 1875 and located at the corner of Eighth Street and Elm Street in downtown Cincinnati (Mill Creek Valley), was constructed of limestone taken from the Neff quarry located on the Cincinnati Bible College property in Price Hill, a suburb of Cincinnati about 2 miles west of the church. Photo by Agnello, 2002.

Numerous local quarries mining this interval were in operation and dotted the hillsides of Cincinnati to supply the stone. In 1916, Nevin M. Fenneman, a well-known geology professor at the University of Cincinnati, stated that the Fairview Formation could be readily identified in the field because of the numerous quarries developed in it. Fenneman also remarked that the stone had little use outside the localities where it was quarried, and that the interbedded shale was discarded downslope as mine spoil. Today, these long-abandoned quarries with their associated shale-waste piles have contributed to past and ongoing landsliding and only marginally stable landscapes.

The shale-rich bedrock and clayey glacial deposits of Hamilton County and the City of Cincinnati are highly conducive to landslides (See *Ohio Geology,* Spring 1986). The Ordovician-age Kope Formation underlies the broad, steep slopes around Cincinnati and weathers to form a clay-rich colluvium (unconsolidated material derived from weathered/eroded bedrock, transported downslope by water and the force of gravity, and commonly accumulating

continued from page 1

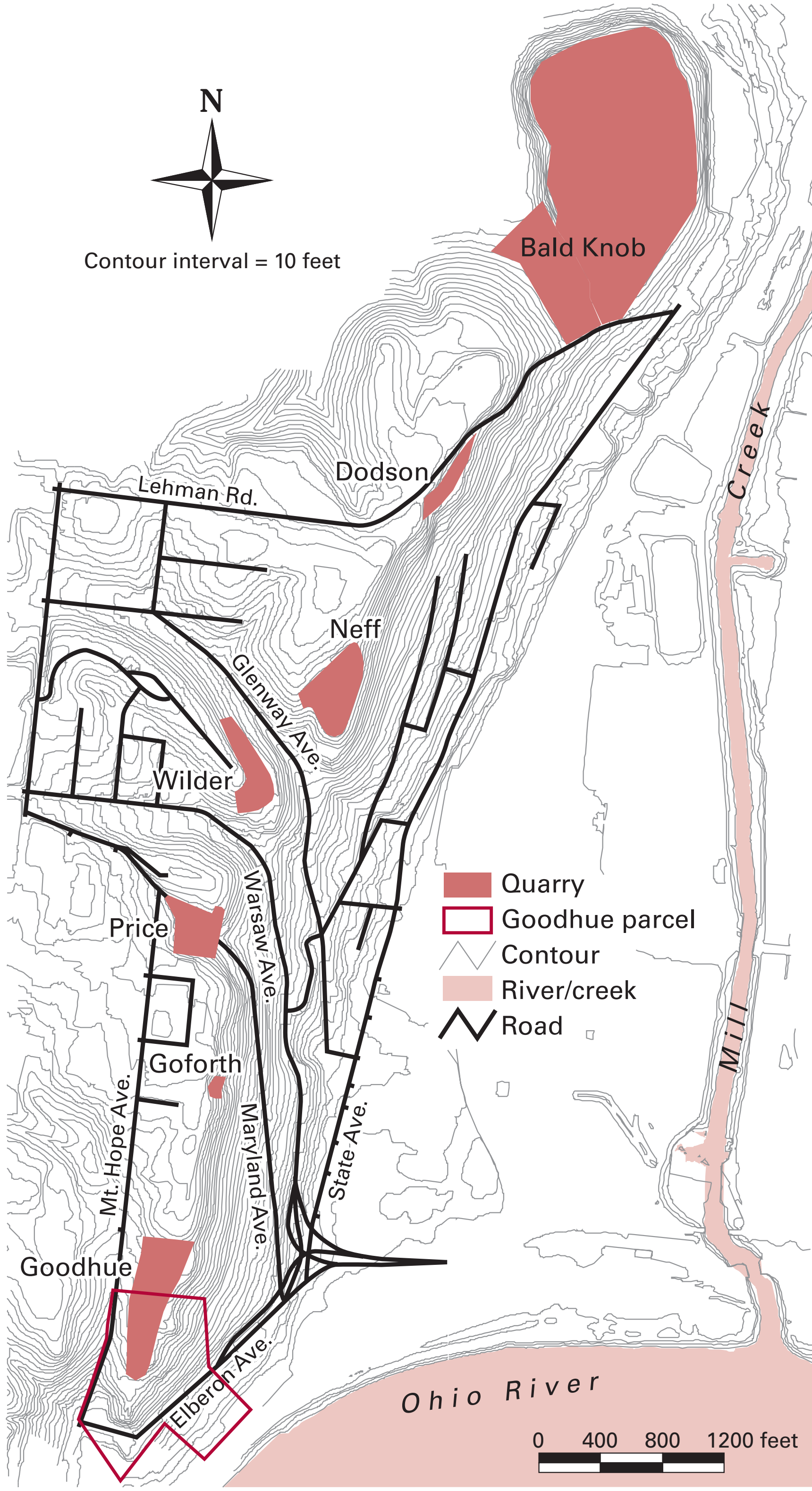
at the base of slopes) that is unstable and prone to landslides. The interface between unweathered bedrock and overlying colluvium is typically the zone of slippage; however, slip surfaces in deep landslides can be entirely located in colluvium. Landslide movement in colluvium is most common during spring and winter when high levels of precipitation dramatically increase the weight of the colluvium, and hydrostatic pressure builds up within the colluvium and at the bedrock-colluvium interface.

Another type of landslide-prone deposit in this area is clay- and silt-rich lacustrine sediment deposited at the bottoms of Ice Age lakes. Landslides in lacustrine sediment can develop on relatively low-slope gradients, which is in sharp contrast to landslides on steeper colluvial slopes. These ancient lake sediments are common along the courses of major stream valleys in which water at one time flowed predominantly from the south to the north in the vicinity of Cincinnati and were dammed up by the southward advancing glaciers, effectively ponding water in front of them and forming lakes. Silt and clay deposited on the bottoms of these lakes occur in almost any topographic setting, from the base of hillsides to flat-lying upland areas, and are notoriously unstable.

An engineering-geology study of a 168-acre hillslope in Price Hill, a western suburban area of Cincinnati, located 3 miles from the central business district and on the west side of the Mill Creek Valley, was undertaken by the author to determine the cause of chronic landsliding in this area. The majority of landslides in the study area were found to be associated with historic quarry operations along with other historic human activities (such as the construction of roads and houses) that destabilized the hillside.

The quarries identified in the study area probably operated from the early 1800s to 1920 with the exception of Bald Knob, which was worked until the early 1930s. Bald Knob, it is interesting to note, was stripped of four million cubic yards of limestone and shale for use as fill material for Union Terminal (now home of the Cincinnati Museum of Natural History) and the associated rail yard. More than 240 acres of the Mill Creek Valley were infilled an average of 16 feet (some areas were filled in up to 58 feet) to elevate rail lines and the terminal above flood level.

Most of Cincinnati's hillside quarries were significantly smaller than the Bald Knob quarry and probably were worked by a handful of men using picks, hammers, and chisels to produce valuable dimension-stone products. The quarries typically were excavated at the tops of hills or along the colluvium-mantled midslopes of hillsides using the contour-strip-mining method. The shale between limestone layers was generally treated as

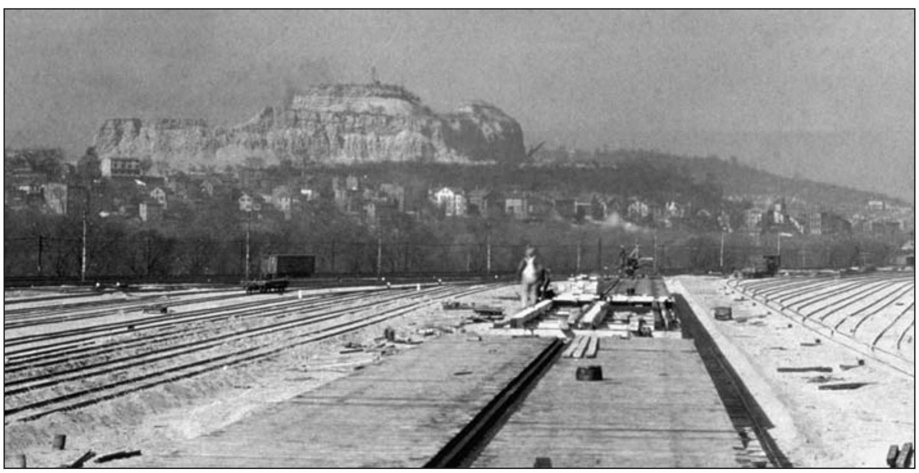


Seven Price Hill rock quarries identified by the author and worked between 1800 and 1930. Note that the Goodhue parcel boundaries extend to the Ohio River, possibly facilitating transportation of limestone. Prior to the study, only two quarries (Bald Knob and Neff) were well known.

mine spoil and dumped onto the hillside slopes below the quarry. The spoil added weight to the colluvial "soil" wedge (natural slope deposit developed over bedrock by solifluction, and varying in thickness from 2 to 70 feet), unnaturally oversteepened the slope below the quarry operation, and made the slopes more susceptible to movement. Detailed geologic mapping by the author determined that landsliding caused by spoil is common downslope of most of the historic quarries in the mapping area. It should be noted that other human activity such as grading for road and house construction also set the stage for landsliding below the quarries.

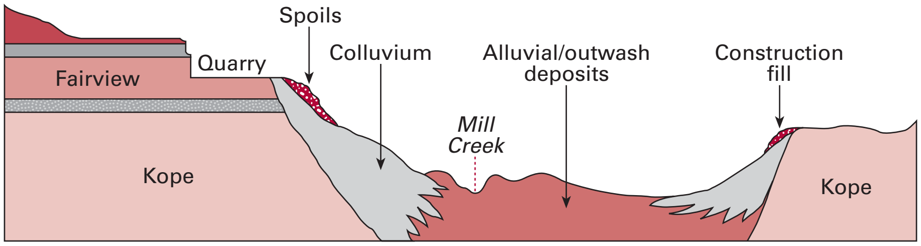
Fenneman noted in 1916 that 20 rock quarries existed on the upper portion of the hillslope in the Mill Creek Valley in the vicinity of downtown Cincinnati. While Fenneman did not report the exact locations of these quarries, evidence for rock quarries in the field consists of thick deposits of unconsolidated material (i.e., quarry spoil) on hillsides downslope from unnaturally squared-off topography (i.e., benches), and vertical rock exposures of the upper Fairview Formation. Unnaturally thick surficial deposits at the top of hillsides where the colluvial cover typically is thin are sometimes recognized in the field by the presence of extensive piering and walls that have been built to hold back the material. Retaining walls at the southern end of the study area in the vicinity of the Goodhue rock quarry surround a substantial portion of the upper hillside and quarry. The Goodhue rock quarry terminates at the northern end in an abrupt 30-foot-high vertical limestone and shale exposure, marking the last working face of the quarry. Examination of historical records indicates that two large tracts of ground encompassing the quarry operation extended down to the Ohio River, and were owned by D. F. Goodhue and G. W. Goodhue. The Goodhues may have utilized the Ohio River to transport rock. The Goodhue's business interests are listed under the categories: "freestone," "stoneyards," and "real estate" in the *Williams Cincinnati Directory* from 1867 to 1880 (comparable to our telephone directory today).

Elberon Avenue, located at the southern end of the study area, was constructed in the early 1890s to connect Mt. Hope and Maryland Avenues. At the time, Elberon Avenue crossed over the Goodhue parcels and below the Goodhue rock quarry on a hillside that was "loaded" with quarry spoils and thus predisposed to landsliding. Funds for construction of Elberon Avenue were provided by a $100,000 county bond, however, an additional $75,000 was needed to complete the road because of a landslide that developed in mine spoil and colluvium during construction of the road. In April-May of 1963, a landslide described by the Cincinnati City Engineer (*Cincinnati Enquirer* 1963) as "an act of God" encompassed an area 300 feet parallel to Elberon Avenue and extended more than 200 feet upslope to the base of the former quarry. Newspaper reports stated that landslide debris rose above and topped the Elberon Avenue retaining wall at a rate of between 2 to 12 inches per hour. The landslide blocked three of four lanes of traffic on Elberon Avenue, and required clean-up crews to remove 400 to 500 cubic yards of landslide debris per day. The landslide damaged a home at the southern end of the former rock

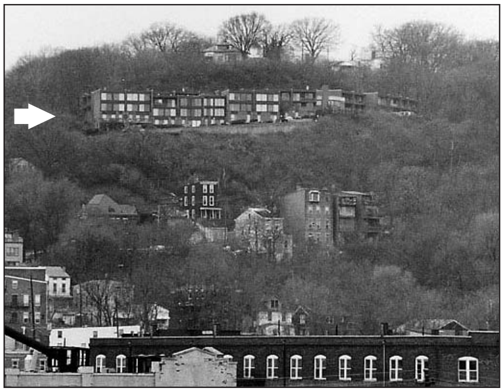


1930 photo showing construction of rail facilities at Cincinnati's Union Terminal. Bald Knob is located in the middle background of the photo. This photo illustrates the extent to which mining and stripping of bedrock for fill material had impacted Bald Knob prior to and during the Union Terminal project. Photo from the University of Cincinnati archives.

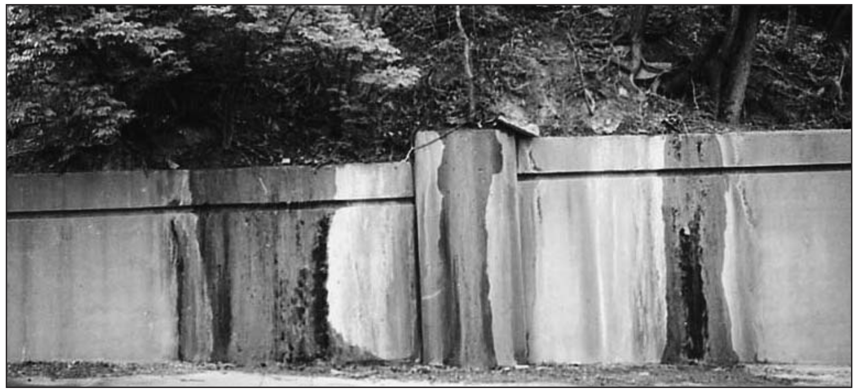
Railroad cars dumping rock stripped from Bald Knob and used as fill material on the Union Terminal project. More than 240 acres of natural wetlands adjacent to Mill Creek were lost in construction of the terminal. Photo from the University of Cincinnati archives.



Schematic cross section of the Mill Creek Valley illustrating the shale-rich Kope Formation (200-plus feet thick), colluvial wedges that commonly develop on Kope Formation hillsides, a quarry in the Fairview Formation, and mine spoils and construction fill loading the landslide-prone colluvial wedges. Added weight of mine spoils and construction fill destabilize the hillside and are prone to landsliding. Agnello 2005.



The West View condominium complex (indicated by arrow) on the west wall of the Mill Creek Valley is located on the former site of the Wilder quarry. It is easy to picture a working quarry here instead of the condominium building. In fact, the last working face of the former quarry is exposed behind the building. A large landslide has developed in mine spoil on the vegetated hillslope below the former rock quarry. Photo by Agnello, 2002.



Landslide toe resting on and overtopping the concrete retaining wall on Elberon Avenue located just west of Maryland Avenue. Note the water seeping out at the bottom of the landslide, and the earth and rock resting on top of the concrete wall. Photo by Agnello, 2002.

quarry and eventually led to the home being condemned. The toe (bottom) of the landslide can still be seen, and is located just behind and on top of the Elberon retaining wall.

In the relatively short time span of about 150 years, humans have reshaped the hillsides in the Price Hill area of Cincinnati through quarrying, oversteepening, and overloading the hillslopes with discarded mine spoil, which has initiated subsequent landsliding of the marginally stable preexisting colluvium. Human activity has disturbed the natural geologic processes that shaped the hillsides of the area over the course of thousands of years, and have created conditions conducive to landslide development**.** Detailed mapping of the locations of old quarries (and other historic activity) can help explain the cause of persistent landslides in areas downslope of the operations and provide engineers and professionals vital information to allow efficient mitigation or avoidance of problematic areas. Rock quarries are not unique to Price Hill, and perhaps landslide risk identified through this study can be applied to similar geologic terrain in other areas of southwestern Ohio, northern Kentucky, and southeastern Indiana.

FURTHER READING

Agnello, T.J., 2002, Land use and landsliding in Price Hill, Cincinnati, Ohio: Unpublished M.S. Thesis, University of Cincinnati, 169 p.

Fenneman, N.M., 1916, Geology of Cincinnati and vicinity: Ohio Geological Survey Bulletin 19, 207 p.

Hansen, M.C., 1986, When the hills came tumbling down—Landslides in Ohio: Ohio Division of Geological Survey, Ohio Geology, Spring, p. 1-7.

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