

## MAPPING OHIO'S KARST TERRAIN

by Dennis N. Hull

In southern Highland County, some landowners watch anxiously as lawns and farm lots slowly sag into the earth, causing birdfeeders, swing sets, clothesline posts, fence posts, and out-buildings to tilt out-of-plumb. In Columbus, city engineers struggle to contain the rapidly escalating cost of a multimillion-dollar tunneling project that is delayed by the unanticipated presence of an ancient buried valley and ancient caverns filled with sticky red clay. In north-central Ohio, rural residents from Bellevue to Castalia are frustrated by a maze of subterranean passageways that allow pesticides, fertilizers, herbicides, and animal wastes to move unabated from fields into underlying aquifers. Children might easily imagine that some rock-eating Stygian monster from *Star Wars* has been loosed upon the state to wreak such havoc. Geologists, however, quickly recognize that the common factor in all these problems is karst.

Karst is a landform that develops (p. 7) on or in limestone, dolomite, or gypsum by dissolution and that is characterized by the presence of features such as sinkholes, underground (or internal) drainage through solution-enlarged fractures (joints), and caves. Approximately 10 percent of Earth's continents, including about 20 percent of the conterminous United States, is underlain by karst-modified bedrock. The greatest concentration of karst terrain and karst features in the nation is in Florida, where 100 percent of the state is underlain by karst-forming carbonate bedrock.

Nearly one-third of Ohio is directly underlain by Ordovician, Silurian, and Devonian carbonate bedrock that has the potential to have developed some karst features during its existence. This potential is confirmed by the fact that solution-enlarged fractures are visible in the highwalls of most of the state's limestone and dolomite quarries. Even so, less than 2 percent of the Ohio landscape includes karst terrain. The percentage is low because most near-surface carbonate bedrock in Ohio is covered with a thick mantle of glacial deposits which greatly impede or preclude active karst-forming processes. In addition, the abrasive work of Ice Age glaciers is believed to have destroyed much of the karst terrain that had developed in Ohio prior to glaciation.

Karst, like landslides and coastal erosion, is a geologic hazard. Sudden collapse of an underground cavern or opening of a sinkhole can cause surface subsidence that can severely damage or destroy any overlying structure such as a building, bridge, or highway. Improperly backfilled sinkholes are prone to both gradual and sudden subsidence and similarly threaten overlying structures. Sewage, animal wastes, and agricultural, industrial, and ice-control chemicals entering sinkholes as surface drainage are conducted directly and quickly into the ground-water system, thereby pos-

ing a severe threat to potable water supplies. Because of such risks, many of the nation's state geological surveys and the U.S. Geological Survey are actively mapping and characterizing the nation's karst regions.

The Ohio Geological Survey recently released Digital Chart and Map Series (DCMS) 24, *Known and probable karst in Ohio*, a color, plot-on-demand, 1:500,000-scale digital map that depicts areas of probable karst and locations of documented karst features. Plotted on a county/township base, the map includes generalized bedrock-geology information for areas of probable karst.



Although DCMS 24 is the first statewide map showing known and probable karst areas of the state, reports on Ohio karst features have been published for more than a century. The first statewide survey of Ohio caves was conducted in 1924 by Ohio State University graduate student George W. White, working under the direction of State Geologist John A. Bownocker. White's cave survey included maps and descriptions of more than 20 of the state's major caves and was published in a 1926 Ohio Journal of Science article entitled "The limestone caves and caverns of Ohio." Following this investigation, White embarked on a distinguished career in geology that would span seven decades, earn him international recognition for his pioneering efforts in the field of glacial stratigraphy, and include an appointment as Ohio's seventh State Geologist (1946-47).

Following White's work in 1924, little if anything was done to document Ohio karst features on a statewide basis until 1952, when the Ohio Geological Survey and the Central Ohio Grotto of the National Speleological Society collaborated to establish a comprehensive survey of Ohio caves in-

*Large sinkhole developed in Peeble-Lilley Dolomites in eastern Oliver Township, Adams County. Note dog at center of depression. Photo by C. Scott Brockman, 1997.*



Thomas M. Berg, Division  
Chief and State Geologist

## Ohio Geology

A quarterly publication of the

Ohio Department of Natural Resources  
Division of Geological Survey  
4383 Fountain Square Drive  
Columbus, Ohio 43224-1362

614-265-6576  
614-447-1918 (FAX)

e-mail: [geo.survey@dnr.state.oh.us](mailto:geo.survey@dnr.state.oh.us)

World Wide Web: [http://www.dnr.state.oh.us/odnr/geo\\_survey/](http://www.dnr.state.oh.us/odnr/geo_survey/)

*Ohio Geology* is a free publication. To become a subscriber please contact the Division of Geological Survey at the above address, phone numbers, or e-mail.

Editor: Michael C. Hansen  
Layout/Design: Lisa Van Doren

Administration/State Geologist  
614-265-6988

Geologic Records Center  
614-265-6576 or 614-265-6585

Bedrock Geology Mapping Group  
614-265-6473

Cartography & Editing Group  
614-265-6593

Coal Geology Group  
614-265-6594

Environmental & Surficial  
Geology Group  
614-265-6599

Industrial Minerals Group  
614-265-6602

Lake Erie Geology Group  
419-626-4296  
419-626-8767 (FAX)

Petroleum Geology Group  
614-265-6598



Bob Taft, Governor  
Samuel W. Speck, Director

An Equal Opportunity Employer - M/F/H

# From The State Geologist...

Thomas M. Berg

## KNOW THE GROUND BENEATH YOUR HOME

The largest and most important investment that most Americans make is the purchase of their homes. Just going through all the paperwork connected with buying a home can be a frustrating, confusing, and laborious process. There are so many things to think about: the condition of the house, location of the lot with respect to neighbors, square footage, available storage space, interior décor, insurance, mortgage arrangements, and much more. I suspect that only a small minority of homebuyers gives much thought to what is *beneath* the house. What kind of geologic material is the foundation of the home placed in? How well drained are those materials? What is the position of the water table beneath the home? What is the support strength or bearing capacity of the geologic materials? Is the material susceptible to ground failure such as landslides? Is the material susceptible to liquefaction during an earthquake? Is there any potential for voids beneath the house? Are there abandoned underground mines? What is the potential for radon gas to enter the structure? What was the terrain prior to construction? What was the geomorphic and anthropogenic history of the terrain prior to development?

In addition to the financial and legal concerns that face prospective homebuyers, all citizens should carefully investigate the ground beneath any house being considered for purchase. Also, it would be wise to contact your state geological survey to get answers to some of the questions above. Although the Ohio Geological Survey does not have the budget, human resources, or legal mandate to do site-specific investigations, we can provide general information on the geology of every part of the state. It might be a very worthwhile investment to hire a consulting geologist or geotechnical engineer to provide a precise evaluation of the ground.

One of the reasons for careful geologic evaluation of home sites is the continually increasing pressure to build more and more homes, sometimes in areas that are only marginally suitable geologically. On a recent commercial flight over southern Minnesota and parts of Wisconsin, I was amazed at how many homes have been built in areas of glacial lakes and bogs. It appeared that some homes were less than a stone's throw from existing bogs. Some homes in a part of Columbus, Ohio, have been built directly on ancient glacial-bog deposits that collapse with changes in water-table elevation. Homes are literally falling apart as they sink, and there is little that the owners can afford to do to remediate the situations.

In this issue of *Ohio Geology*, Assistant State Geologist Dennis Hull describes a new Ohio Geological Survey map that shows the general distribution of karst and probable karst in Ohio. "Karst" is the geologic phenomenon comprising sinkholes, caves, pinnacle weathering, and other features caused by the solution of limestone, dolomite, and gypsum.

Most seasoned geologists can tell horror stories about homes that have been built on top of karst features. I remember an incident in Pennsylvania when a man sat down in his living room to read the paper and suddenly heard a loud thud, followed by a rushing sound. When he opened his basement door, there was nothing left but a dark void with an underground river flowing through it. His basement had disappeared into a cavern. Karst is not as severe a geologic hazard in Ohio as it is in Pennsylvania and some other states, but it is a concern that prospective homeowners should be aware of. The new Ohio Geological Survey map helps identify areas of concern.

Geology plays a big role in everybody's life. Our drinking-water resources, our mineral resources, our energy resources, and our agricultural and environmental security all have their foundation in the geological sciences. Citizens need to become more aware of the role of geology in their lives today. And—very importantly—citizens should know the ground beneath their homes.

## Earth Science Week 1999

Governor Bob Taft has signed a resolution designating October 10-16, 1999, as Earth Science Week in Ohio. This is an opportunity for everyone involved in the earth sciences to call the attention of the public to the importance of geology and mineral resources to the state's economy, environment, and general well-being.

## POGO—Production of Oil and Gas in Ohio database

The Production of Oil and Gas in Ohio database, referred to as POGO, contains production data gathered from companies, individuals, and the Division of Oil and Gas. There are nearly 500,000 yearly records for more than 58,000 wells, including data from wells drilled as early as 1921 and extending through 1997. The database also contains more than 84,000 monthly production records. The database application is in Microsoft Access, and can be searched by county, township, section, lot, producing formation, operator, API number, and combinations of these attributes. The database will be updated yearly. Companies are encouraged to donate additional records for inclusion in the database.

The POGO database application is available on CD-ROM from the Geologic Records Center of the Survey (614-265-6576) for \$25.00 plus \$5.00 shipping and handling. Orders shipped to an Ohio address must include an additional \$1.44 sales tax. Technical questions about the database should be directed to Joe Wells, 614-265-1030; e-mail, [joseph.wells@dnr.state.oh.us](mailto:joseph.wells@dnr.state.oh.us).

continued from page 1

tended to include: (1) cave locations, (2) descriptions of caves, and (3) discussions of geological features associated with caves. P. M. Smith of the Central Ohio Grotto published a brief outline of these objectives in a 1953 Ohio Journal of Science article but never published any of the data collected by the cave survey. In 1974, Warren Luther of the Central Ohio Grotto compiled 22 years of Ohio Cave Survey data; however, this compilation also was never published. In 1978, responsibility for the Ohio Cave Survey was assumed by the Wittenberg University Speleological Society under the direction of Professor Horton H. Hobbs, III. Descriptions of caves in the Ohio Cave Survey have been published regularly since 1978 in the Wittenberg University Speleological Society's journal *Pholeos*.

The lack of statewide karst terrain information became a major issue in September 1993, when an Ohio Blue Ribbon Commission released its *Recommendations on siting criteria and development requirements for a regional low-level radioactive waste disposal facility in Ohio*. Ground-water flow is very rapid in the solution-enlarged bedrock fractures underlying karst terrain, thus any radioactive contaminants entering such fractures through sinkholes or other karst features would be dispersed quickly, thereby contaminating ground water over a broad area in short order. Knowing this, the Blue Ribbon Commission recommended that, "The [Ohio low-level radioactive-waste disposal] site shall not be located above a bedrock formation likely to cause [sic] karst features to develop on the site." The Ohio General Assembly subsequently enacted Section 3747.12 of the Ohio Revised Code, which states, "The disposal site shall not be located in areas of known or probable karst. As used in division (A)(13) of this section, 'karst' means a terrain with an assemblage of landforms such as sinkholes and caves that are due to solution weathering of predominantly carbonate bedrock."

Because much of western Ohio is underlain by carbonate strata susceptible to the development of karst, the Research and Technology Committee of the Ohio Low-Level Radioactive Waste Disposal Facility Development Authority determined that karst terrain should be considered an exclusionary criterion in the statewide screening process to identify areas of the state that obviously would be unsuitable for disposal of low-level radioactive waste and that should receive no further consideration in a site-selection process. The Committee then asked the Division of Geological Survey to prepare a proposal for preparation of a 1:500,000-scale map of known and probable karst that could be used in the statewide screening process for a low-level radioactive-waste disposal facility.

A proposal for a six-month-long karst mapping project was submitted to the Committee and approved in April 1997. Karst mapping began immediately thereafter, and a 1:500,000-scale digital map of Ohio showing locations of known karst features and areas of probable karst was completed on schedule in October 1997. However, the map was never delivered to the Ohio Low-Level Radioactive Waste Facility Development Authority, as that agency closed its doors on August 31, 1997, following a decision by the Midwest Low-Level Radioactive Waste Compact to cease all facility development operations in Ohio.

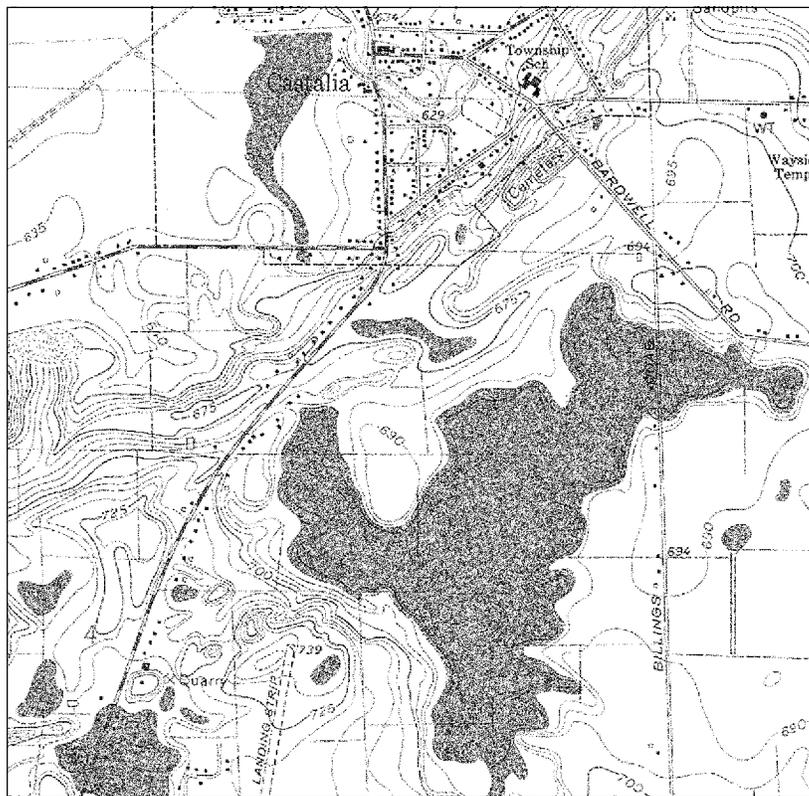
In recognition that karst is a significant geologic hazard in Ohio, and that many Ohioans have

an interest in knowing the location of the state's principal karst regions, the Division decided at the conclusion of the six-month project to produce a new state map of known and probable karst for public release. Accordingly, the digital cartographic files of the locations of known and probable karst were merged with digital bedrock-geology maps to produce the new open-file map, DCMS 24, *Known and probable karst in Ohio*. This new map, prepared by Richard R. Pavey, Dennis N. Hull, C. Scott Brockman, Gregory A. Schumacher, David A. Stith, E. Mac Swinford, Terry L. Sole, Kim E. Vorbau, Kevin D. Kallini, Emily E. Evans, Ernie R. Slucher, and Robert G. Van Horn, is designed to provide an overview of Ohio karst and is not intended for site-specific investigations. The five most significant Ohio karst regions appearing on the new map are described below.

#### BELLEVUE-CASTALIA KARST PLAIN

The Bellevue-Castalia Karst Plain occupies portions of northeastern Seneca County, northwestern Huron County, southeastern Sandusky County, and western Erie County. Adjacent karst terrain in portions of Ottawa County, including the Marblehead Peninsula, Catawba Island, and the Bass Islands, is related in geologic origin to the Bellevue-Castalia Karst Plain.

Sinkholes within sinkholes is one way to describe the Bellevue-Castalia Karst Plain. Huge, irregularly shaped, closed depressions up to 270 acres in size and commonly enclosing smaller, circular-closed depressions 5 to 80 feet in diameter pockmark



A portion of the Castalia, Ohio, 7.5-minute quadrangle showing an area in Margaretta Township, Erie County, where a number of large sinkholes enclose smaller sinkholes. The large sinkhole south of the city encompasses 270 acres and is considered by the Ohio Geological Survey to be the state's largest sinkhole. This and other sinkholes in the area are developed in Columbus Limestone and Bass Islands Dolomite strata that have collapsed into large solution cavities in underlying Salina Group strata.

the land between the village of Flat Rock in north-eastern Seneca County and Castalia in western Erie County. The area is believed to contain more sinkholes than any of Ohio's other karst terrains. Surface drainage on the plain is very limited, and many of the streams which are present disappear into sinkholes, which are referred to as swallow holes.

Stratigraphically, the Bellevue-Castalia Karst Plain consists of up to 175 feet of Devonian carbonate rocks (Delaware Limestone, Columbus Limestone, Lucas Dolomite, and Amherstburg Dolomite) overlying Silurian dolomite, anhydrite, and gypsum of the Bass Islands Dolomite and Salina Group. The geologic history of karst development in the Bellevue-Castalia area, and the Marblehead Peninsula-Lake Erie islands area to the north, is still debated. Newberry (1874) noted that the Bass Islands appear to have been uplifted and shattered. Kraus (1905), Cottingham (1919), Verber and Stansbery (1953), and other workers noted that floors and ceilings of Bass Islands caves match like adjacent pieces of a jigsaw puzzle, indicating that the floors subsided by the removal of underlying strata. In his 1926 article on Ohio caves, White noted this floor-ceiling relationship in Seneca Caverns (formerly Good's Cave) near Flat Rock.

Kraus (1905) was the first to propose that karst in the Bellevue-Castalia and Lake Erie islands region was due to collapse of overlying carbonate strata into voids created by the dissolution and removal of underlying gypsum beds. According to Verber and Stansbery (1953), ground water is introduced into Salina Group anhydrite ( $\text{CaSO}_4$ ) through pores and fractures in the overlying carbonates. The anhydrite chemically reacts with the water to form gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ), undergoing a 33 to 62 percent increase in volume in the process. This swelling lifts overlying strata, thereby opening fractures and creating massive passageways for conduction of greater volumes of ground water through the Bass Islands Dolomite and into underlying Salina Group strata. Gypsum, being readily soluble in water, is dissolved, creating huge voids. Overlying carbonates then collapse or break down, leaving surface depressions similar to those resulting from roof failure of an underground mine. Separation along collapse fractures in overlying carbonates imparts the gross structure and matched floors and ceilings of caves in the Bellevue-Castalia Karst Plain and Marblehead Peninsula-Lake Erie islands. Post-collapse karstification, however, has modified some of these fracture caves to an extent that the matching relationship between cave floors and ceilings is no longer discernible.

#### DISSECTED NIAGARA ESCARPMENT

The dissected Niagara Escarpment of southwestern Ohio includes the largest single area of karst terrain in the state and the greatest number of surveyed caves. The karst terrain of the escarpment also is estimated to include the second-largest number of sinkholes in the state.

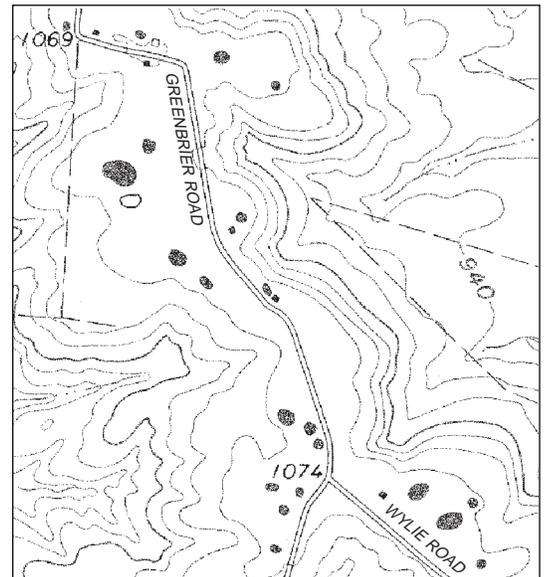
The Niagara Escarpment in Ohio, north-central Kentucky, and southeastern Indiana is an erosionally resistant ring of heavily dissected, ledge-forming, carbonate-rock-dominated, Niagaran Series strata of Silurian age. The outcrop pattern of the Niagara Escarpment in Ohio is due to the Cincinnati Arch, which plunges to the north-northeast and dips eastward into the Appalachian Basin and westward into the Illinois Basin. The effect of this structure is the creation of a subtle, dissected ridge

or cuesta, which has a relatively steep, undercut face and a gentle dip slope descending perpendicular and away from the face.

Stratigraphically, the Niagara Escarpment consists of the Peebles Dolomite, Lilley Formation, Bisher Formation, Estill Shale, and Noland Formation in Adams, Highland, and Clinton Counties and the Cedarville Dolomite, Springfield Dolomite, Euphemia Dolomite, Massie Shale, Laurel Shale, Osgood Shale, and Dayton Formation in Greene, Clark, Miami, Montgomery, and Preble Counties. The Peebles-Lilley-Bisher sequence and Cedarville-Springfield-Euphemia sequence constitute the Lockport Group.

Most karst features along the Niagara Escarpment in southwestern Ohio are developed in Lockport Group strata. More than 100 sinkholes and caves developed in the Lockport have been documented in the field, and more than 1,000 probable sinkholes in the Lockport have been identified on aerial photographs, soils maps, and topographic maps. As with most karst terrain, sinkholes developed on the Niagara Escarpment commonly show linear orientations aligned with prevailing joint trends. The greatest concentration of sinkholes on the escarpment are south of the Wisconsin glacial border in southern Highland and Adams Counties, where highly dissected ridges capped by Silurian carbonate rocks rise 150 to 200 feet above surrounding drainage. Illinoian till in these areas is thin to absent, and soils are completely leached with respect to calcium and calcium-magnesium carbonate. Such geologic settings are ideal for active karst processes, as downward percolating, naturally acidic rain water is not buffered until it has dissolved some of the underlying carbonate bedrock. Many sinkholes in the area can be observed growing in size and depth each year. Seven Caves, formerly known as Rocky Fork Caves, and individually known by 10 or more individual cave names, are the best known commercial caves of the Niagara Escarpment in Ohio. Other significant karst features of the Niagara Escarpment include small caves in escarpment reentrants created by the valleys of the Great Miami

**The Bellevue-Castalia area is believed to contain more sinkholes than any of Ohio's other karst terrains.**



*Enlargement of a portion of the Belfast, Ohio, 7.5-minute quadrangle showing sinkholes developed in Peebles Dolomite in northern Scott Township, Adams County.*

and Stillwater Rivers in Miami County.

### BELLEFONTAINE OUTLIER

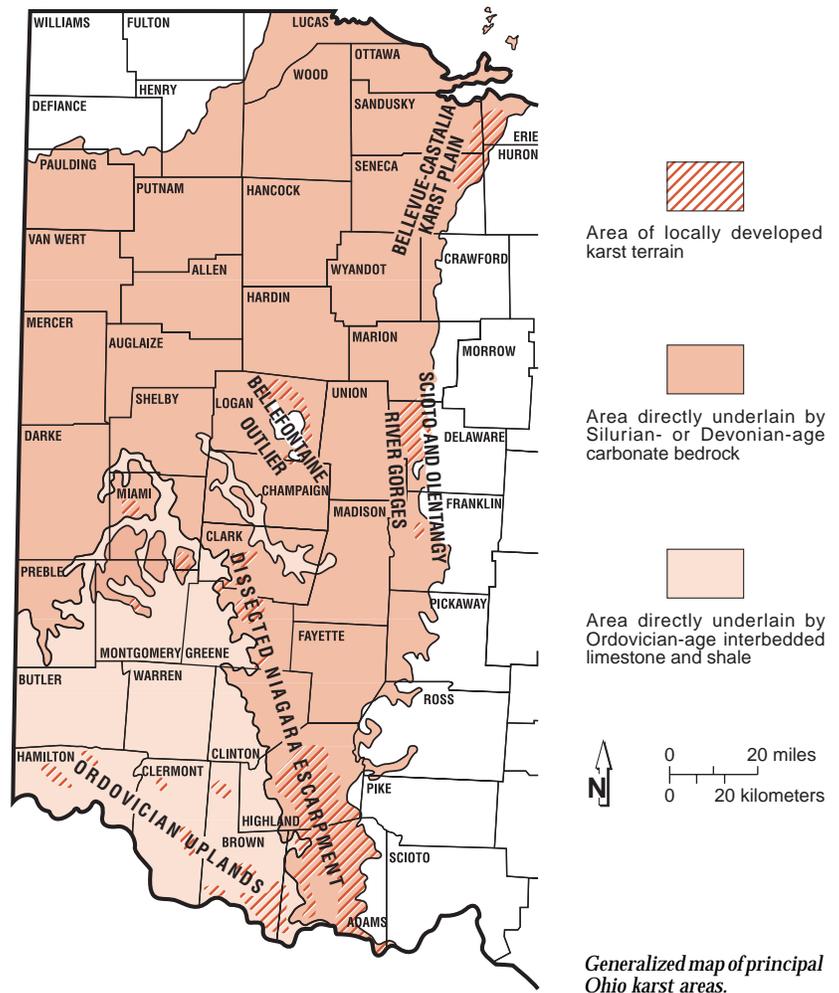
The Bellefontaine Outlier in Logan and northern Champaign Counties is an erosionally resistant "island" of Devonian carbonates capped by Ohio Shale and surrounded by a "sea" of Silurian strata. Though completely glaciated, the outlier was such an impediment to Ice Age glaciers that it repeatedly separated advancing ice sheets into two glacial lobes—the Miami Lobe on the west and the Scioto Lobe on the east. The outlier is the location of Campbell Hill—the highest point in the state at an elevation of 1,549 feet above mean sea level (see *Ohio Geology*, Winter 1991).

Although it is not known for having an especially well-developed karst terrain, the outlier is the location of Ohio's largest known cave, Ohio Caverns. The greatest sinkhole concentrations are in McArthur and Rushcreek Townships of Logan County, where the density of sinkholes in some areas approaches 30 per square mile. Sinkholes here typically occur in upland areas of Devonian Lucas Dolomite or Columbus Limestone that are 30 to 50 or more feet above surrounding drainage and are covered by less than 20 feet of glacial drift and/or Ohio Shale.

Some areas of the outlier, such as the carbonate uplands near East Liberty, would seem to be especially well-suited for development of karst terrain, yet contain surprisingly few sinkholes. Recent excavations for highway construction provide an explanation for the sparseness of surface karst features in the area. These excavations into bedrock revealed extensive networks of solution cavities that are partially or completely filled by glacial sediments. Wisconsinan-age glacial ice advancing over the outlier approximately 20,000 years ago buried a well-developed interglacial karst terrain under a layer of thick drift, filling most sinkholes and solution cavities with till (a mixture of clay, silt, sand, and boulders) and effectively stopping, at least temporarily, karst development. In areas of thinner drift, erosion and infiltrating ground water have exhumed and unplugged some sinkholes, allowing active karst processes to resume. Presumably, karst action in this area will continue to accelerate over the coming centuries as the till cover and plugs are leached and/or removed by erosion, and naturally acidic rainwater is able to penetrate underlying carbonate rocks. It should be noted that plugs of drift and terra rossa residuum (red, clayey material formed in place through weathering by selective removal of nonclay-mineral constituents from clay-bearing limestone and dolomite) in some sinkholes and caverns contain radiometrically datable materials and paleontological specimens that provide important clues as to the age of the karst features. For example, a charcoal layer within sediment filling the sinkhole at Indian Trails Cavern in Wyandot County has been radiometrically dated to 11,700 years before present and confirms that karst processes were active at that site prior to that date (see *Ohio Geology*, Spring 1992). A sinkhole near Fort Wayne, Indiana, recently has been reported to contain fossils of Pliocene vertebrates, confirming that karst processes have been active at that site prior to 1.64 million years before present.

### SCIOTO AND OLENTANGY RIVER GORGES

The uplands adjacent to the gorges of the Sci-



oto and Olentangy Rivers in northern Franklin and southern Delaware Counties include areas of well-developed, active karst terrain. These uplands also are among the most rapidly developing areas of the state, which means karst should be a consideration in site assessments for commercial and residential construction projects.

The Scioto River in this area has been incised to a depth of 50 to 100 feet into underlying bedrock, creating a shallow gorge. The floor, walls, and adjacent uplands of the gorge consist of the Delaware and Columbus Limestones mantled by up to 20 feet of Wisconsinan till. The combination of moderate relief, carbonate bedrock, and thin-to-absent glacial cover represents ideal conditions for the formation of karst terrain. Sinkhole concentrations up to one sinkhole per acre are not uncommon in Concord, Scioto, and Radnor Townships of Delaware County. The sinkholes range in diameter from about 10 to 100 feet and commonly are aligned linearly along major joint systems. In one area of Radnor Township, surface drainage during intense rain storms collects in swallow holes on the uplands and erupts as a fountain from a sinkhole several hundred feet removed and at a lower elevation.

The Olentangy River is approximately 5 miles east of the Scioto River in southern Delaware County and occupies a gorge that is narrower and up to 50 feet deeper than the Scioto River gorge. The floor and the lower half of the walls along the Olentangy Gorge are composed of the Delaware and Columbus Limestones; the upper half of the walls is com-

posed of the Ohio and Olentangy Shales mantled by a thin veneer of glacial drift. Karst terrain has developed along portions of the gorge in a manner similar to karst terrain along the Scioto River. A commercial cave, Olentangy Indian Caverns, is located in karst terrain developed in the wall of the Olentangy River Gorge.

#### ORDOVICIAN UPLANDS

The Ordovician Uplands of southwestern Ohio are the location of surprisingly well-developed karst terrain. White, in his 1926 Ohio cave survey, said, "The Ordovician limestones of the State are too thin-bedded and argillaceous to permit the formation of caves." Although it is true that there may be few surface karst openings in the Ordovician strata of Ohio large enough for a person to enter (that is, a cave), karst processes are extremely active on the Ordovician Uplands south of the Wisconsin border. Twenty-one documented sinkholes have been mapped in the Ordovician of Adams County, 27 in Brown County, 3 in Clermont County, and 4 in Hamilton County. Many more probable sinks were identified on aerial photographs and topographic maps.

The carbonate-rich members of the Grant Lake Formation (Bellevue and Mount Auburn Members), Grant Lake Limestone (Bellevue and Straight Creek Members), and the upper portion of the Arnheim formation are the Ordovician units most prone to karstification; however, the shale-rich (70 percent shale, 30 percent limestone) Waynesville Formation also has a surprising amount of karst development in southeastern Brown and southwestern Adams Counties, just north of the Ohio River. The mechanics of sinkhole development in this predominantly shale unit is uncertain. Perhaps the dissolution of limestone beds in the Waynesville along interconnected fractures has been sufficient

to allow clayey-silty residue from the limestone and the interbedded shale to be flushed down and away, so that sinkholes can develop without becoming clogged. Alternatively, perhaps some sinkhole development in the Waynesville Formation of this region is the result of dissolution within the underlying, carbonate-rich Grant Lake Limestone.

The Division of Geological Survey is grateful to the Ohio Low Level Radioactive Waste Facility Development Authority for funding the mapping investigations that led to development of DCMS 24. While the map may not be needed for siting of an Ohio low-level radioactive-waste disposal facility in the foreseeable future, DCMS 24 will serve planning agencies, geotechnical consultants, transportation officials, environmental regulators, and interested citizens for many years in their efforts to mitigate karst-related property losses in Ohio. Copies of the map may be obtained from the Division's Geologic Records Center (614-265-6576) for \$8.00 plus \$0.46 sales tax for Ohio orders and \$2.50 handling for all mailed orders; an additional \$1.50 must be included for a mailing tube if a rolled copy is desired.

#### FURTHER READING

- Cottingham, K. C., 1919, The origin of the caves at Put-in-Bay, Ohio: *Ohio Journal of Science*, v. 20, p. 38-42.
- Kraus, E. H., 1905, On the origin of the caves of the island of Put-in-Bay, Lake Erie: *American Geologist*, v. 35, p. 167-171.
- Newberry, J. S., 1874, Report on the geology of Erie County and the islands: *Ohio Geological Survey*, v. 2, pt. 1, *Geology*, p. 183-205.
- Smith, P. M., 1953, The Ohio cave survey: *Ohio Journal of Science*, v. 53, p. 325-326.
- Verber, J. L., and Stansbery, D. H., 1953, Caves in the Lake Erie islands: *Ohio Journal of Science*, v. 53, p. 358-362.
- White, G. W., 1926, The limestone caves and caverns of Ohio: *Ohio Journal of Science*, v. 26, p. 73-116.

---

***The risks to property and health from living on karst can be greatly reduced by using common sense and maintaining a sense of respect for both the power and vulnerability of the environment.***

---

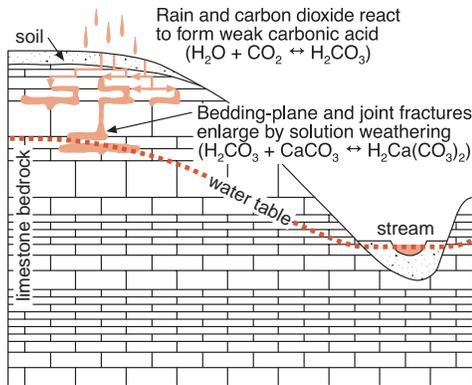
## Should I be concerned if my home is located in a karst area?

Karst, like coastal erosion, landslides, radon, mine subsidence, and earthquakes, is a geologic hazard that Ohioans must live with. As with any geologic hazard, however, the risks to property and health from living on karst can be greatly reduced by using common sense and maintaining a sense of respect for both the power and vulnerability of the environment. Here are a few key points to consider when living on karst.

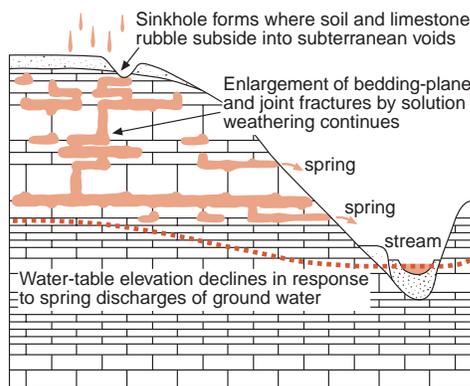
- Herbicides, insecticides, and fertilizers entering sinkholes are conducted rapidly into the ground-water system with little or no soil filtration. In order to protect ground-water resources from contamination, farmers, lawn-care providers, and residential property owners should not apply agricultural or horticultural chemicals within 100 feet of sinkholes.
- Septic systems, animal feedlots, manure lagoons, and other potential sources of bacterial contamination should not be located near sinkholes.
- Buffer or filter strips of grass, or other noncrop vegetation that does not require fertilization, should be planted around sinkholes to reduce the amount of coarse-grained sediment and other contamination being carried into them.
- Sinkholes should never be used to dispose of trash, appliances, furniture, automobiles, tires, used motor oil, fuels, chemicals, paints, solvents or other waste products. Homeowners acquiring property that has waste-filled sinkholes should consider removing this litter. Local public health departments and county extension offices should be contacted for information on removing litter from sinkholes and possible sources of financial assistance for sinkhole clean-up.
- Sinkholes are part of the natural drainage system of an area, and ill-considered backfilling or sealing can result in serious flooding of adjacent land. Structures built on top of improperly backfilled sinkholes are highly vulnerable to catastrophic foundation failure when plugging methods fail. For these reasons, stabilization, sealing, or backfilling of sinkholes should always be performed under the oversight of an engineering geologist or foundation engineer who is experienced in sinkhole repair.

## TYPICAL DEVELOPMENT OF KARST IN OHIO

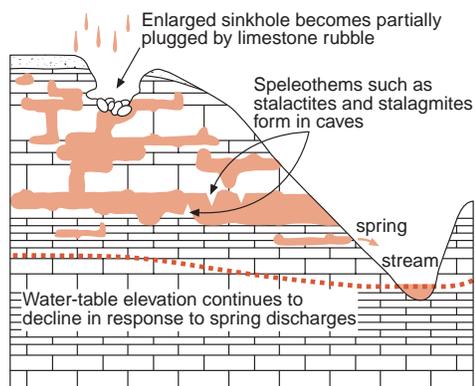
Karst develops on or in water-soluble rock such as limestone, dolomite, and gypsum and is characterized by the presence of sinkholes, caves, and underground drainage. The term "karst" is derived from the Slovenian region of northwestern Yugoslavia along the Adriatic Sea, where karst is well developed and was first described scientifically. The particular style and rate of karst development is dependent on many factors, including physical and chemical properties of the rock, structural orientation of the rock, temperature, vegetation, and the amount of rainfall. Rainfall and water-soluble rock are the most critical factors in Ohio karst formation.



Rainwater falling through the air reacts with atmospheric carbon dioxide to form carbonic acid ( $H_2O + CO_2 \leftrightarrow H_2CO_3$ ). Upon entering the soil, rainwater reacts with carbon dioxide released from decaying vegetation to form additional carbonic acid. As part of the ground-water environment, carbonic-acid-charged water continues to move downward under the force of gravity into underlying limestone bedrock. The water moves laterally along horizontal fractures (bedding planes) and downward along vertical fractures (joints) until it reaches a depth where all fractures and pore spaces within the rock are filled with water (the water table). As the water moves along fractures, both above and below the water table, small amounts of limestone are dissolved by the carbonic acid ( $H_2CO_3 + CaCO_3 \leftrightarrow H_2Ca(CO_3)_2$ ). Additional limestone is mechanically abraded and removed by the movement of the water.



With the passing of time, bedrock fractures become greatly enlarged by the dissolution and abrasion process. Sinkholes (dolines) begin to form on the surface where enlarged vertical fractures allow soil and rock debris to collapse into the earth. Surface drainage is diverted directly into the ground-water environment where sinkholes intersect drainageways, thereby accelerating the rate of fracture enlargement through mechanical abrasion. The water table is lowered as ground water escapes to the surface through springs. The terrain created by the presence of numerous sinkholes and other solution features is called karst.



Over the course of many centuries, sinkholes continue to enlarge and coalesce with other sinkholes as underground voids collapse and ongoing abrasion and/or dissolution continue to remove bedrock. Horizontal and vertical fractures become enlarged to the extent that they can be classified as a cave (an underground passage large enough for a person to enter). The water table continues to drop in elevation as internal drainage networks within the cave system become more integrated and efficient in collecting and discharging ground water. Ground water saturated with calcium carbonate (calcite) and dripping from cave ceilings and walls or flowing along the cave floor evaporates, causing calcite to be deposited as cave formations (speleothems) such as stalactites, stalagmites, flowstone, and travertine.

### Price increase

In order to maintain our printing fund, the Division of Geological Survey reluctantly has increased the cost of all Division publications. The price of U.S. Geological Survey topographic maps has not increased. A new *List of Publications* is available that reflects the new prices; to request a copy, please contact the Geologic Records Center, 4383 Fountain Square Drive, Columbus, OH 43224-1362; telephone 614-265-6576; e-mail [geo.survey@dnr.state.oh.us](mailto:geo.survey@dnr.state.oh.us). The cost for a mailing tube is now \$1.50. Handling charges also have increased:

Total cost of order	Handling charge
\$10.00 and under	\$2.50
\$10.01 - \$20.00	\$4.00
\$20.01 - \$50.00	\$6.50
\$50.01 - \$100.00	\$11.00
\$100.01 and over	\$13.00

## NEW PUBLICATIONS

In addition to the karst map featured in this issue of *Ohio Geology*, the Division of Geological Survey has released a number of other new publications. All the publications described below may be ordered from the Geologic Records Center of the Survey; credit-card orders may be placed by calling 614-265-6576. Sales tax of 5.75% applies to all Ohio orders, and handling charges apply to all mailed orders (see p. 7); if rolled copies of maps or charts are desired, \$1.50 per order must be included for a mailing tube.

**Quaternary geology of Ohio.** Division of Geological Survey Map 2, compiled by Richard R. Pavey, Richard P. Goldthwait, C. Scott Brockman, Dennis N. Hull, E. Mac Swinford, and Robert G. Van Horn. Scale 1:500,000 (1 inch equals about 8 miles), 1999, \$10.00. This map consolidates the improved understanding of the Quaternary history, geomorphology, and deposits of Ohio that have resulted from efforts by numerous workers since publication of the Glacial map of Ohio by the U.S. Geological Survey in 1961.

**Geology of the Dunkard Group (Upper Pennsylvanian-Lower Permian) in Ohio, West Virginia, and Pennsylvania.** Division of Geological Survey Bulletin 73, by Wayne D. Martin. 49 p., 30 figures, 2 tables, 1998, \$12.00. This summary of Dr. Martin's 50 years of investigation of the Dunkard Group discusses previous studies, information on lithofacies, clastic-rock composition, and depositional environments.

**Generalized correlation chart of bedrock units in Ohio.** Division of Geological Survey Open-File Report 98-2, compiled by Glenn E. Larsen. 36- x 44-inch color chart, 1998, \$8.00. This plot-on-demand chart shows the regional correlation and relationships of most surface-rock units identified on the 7.5-minute-scale reconnaissance bedrock-geology maps on open file at the Ohio Division of Geological Survey and the generally accepted subsurface terminology. The chart is divided into 14 columns representing 14 geologic/geographic regions of the state. A list of references is included.

**Sampling the layer cake that isn't: stratigraphy and paleontology of the type-Cincinnatian.** Division of Geological Survey Guidebook 13, edited by Richard Arnold Davis and Roger J. Cuffey. 194 p., 107 figures, tables, 2 appendixes, 1998, \$16.00. The 18 papers by 15 authors in this book discuss the geology of Upper Ordovician rocks at numerous sites in southwestern Ohio, southeastern Indiana, and northern Kentucky. An

extensive locality listing and bibliography are included.

**Geology along the towpath: stones of the Ohio & Erie and Miami & Erie Canals.** Division of Geological Survey Guidebook 14, by Joseph T. Hannibal. 60 p., 78 figures, 4 tables, glossary, 1998, \$4.00. This guidebook provides an overview of Ohio's two major canals, lock construction, and the types and sources of stone used for the locks and other canal structures. The 16 stops (nine on the Ohio & Erie Canal and seven on the Miami & Erie Canal) include maps, photos, and detailed descriptions of the stone of numerous locks.

**Earthquakes in Ohio.** Educational Leaflet No. 9, by Michael C. Hansen. Revised 1999, free. Portions of the text have been revised to reflect new developments in earthquake research and implementation of earthquake programs. Many of the illustrations have been updated or modified, and the earthquake epicenter map of Ohio has been revised and includes border-region seismic events.

**Bathymetry of Lake Erie and Lake St. Clair.** Map, National Geophysical Data Center Report MGG-14, 1998, \$1.00. This 11- by 17-inch mini poster (map scale: 1 inch equals about 15 miles) shows the depth of the lakes in meters using color as well as contour lines. This map is not intended to be used for navigational purposes.

**Ecoregions of Indiana and Ohio.** U.S. Geological Survey poster, by Alan J. Woods, James M. Omernik, C. Scott Brockman, Timothy D. Gerber, William D. Hosteter, and Sandra H. Azevedo. 35 x 44 inches, two-sided, 1998, \$4.00. The main map shows 36 ecoregions of Indiana and Ohio at a scale of 1 inch equals about 24 miles. The sheet includes descriptions and photographs of each of the 36 ecoregions and a summary table of the physiography, geology, soils, climate, potential natural vegetation, and land use and land cover for the 36 regions.

## State nature preserve directory available

The Division of Natural Areas and Preserves has issued a directory of the state's 111 nature preserves, many of which exhibit outstanding geological features. The guide provides comprehensive information on each of the preserves, including photographs, drawings, and location maps. The directory is available from the Division of Natural Areas and Preserves, 1889 Fountain Square Court, Columbus, OH 43224-1331 for \$14.18 plus \$3.00 shipping. Orders shipped to an Ohio address must add \$0.82 sales tax.

**Ohio Geology**

Ohio Department of Natural Resources  
Division of Geological Survey  
4383 Fountain Square Drive  
Columbus, Ohio 43224-1362

Bulk Rate  
U.S. Postage  
PAID  
Columbus, OH  
Permit No. 5767



recycled paper

