KARST DENSITY MAP—AN INNOVATIVE APPROACH TO VISUALIZING KARST FEATURES

INTRODUCTION

Approximately 7 percent of Pennsylvania is underlain by carbonate bedrock in the form of limestone and dolomite. Most of the carbonate bedrock occurs in the valleys and lowlands of south-central and southeastern Pennsylvania, where over 2 million people live.

Carbonate rocks are unique in that they weather more readily than other types of rocks. The dissolution or dissolving away of the carbonate bedrock by water over long periods of time results in a landscape called karst topography. It is characterized by features such as sinkholes, surface depressions, and caves. The dissolution of the carbonate rock also develops the subsurface drainage network for water along widened cracks or fractures within the bedrock layers. The majority of water in karst areas does not occur as surface streams but is primarily in the subsurface as groundwater.

Sinkholes and surface depressions are subsidence features. The surface expression of these features is a result of water transporting residual material and soil through subsurface pathways established by the dissolution process. Both features are typically circular in shape and can vary in size. Sinkholes exhibit an actual break or hole on the land surface, whereas surface depressions are generally bowl-shaped hollows that do not show this land-surface break. Caves are formed as fractures widen by dissolution, creating large openings in the rocks.

Karst features often impact public safety and health. Subsidence and water-quality problems have been associated with karst topography for many years. Gradual subsidence or the sudden collapse of the land surface can cause serious damage to urban structures, utilities, and roadways. In addition, karst features serve as direct recharge zones to local and regional aquifers, making these areas highly vulnerable to groundwater contamination.

In 1985, the Pennsylvania Geological Survey began investigations to map karst features throughout the commonwealth. Results of these investigations were released as a series of county-based open-file reports (see "References"). For each county, karst surface features were located through an extensive review of aerial photographs (taken in the 1940s–70s) and a subsequent field survey. Identified features were then transferred to scale-stable, 7.5-minute topographic base maps. Additional karst features were compiled from municipal questionnaires and published and unpublished data sources. Although not karst features, small surface mines may be similar in appearance to karst subsidence features. This is most apparent where such a mine has been abandoned for a long period of time. For this reason, surface mines were identified and added to the open-file maps.

After completion of the open-file reports, karst features and surface mines were digitized as point data from the topographic base maps using GSMAP software from the U.S. Geological Survey. Points were positioned in the best-determined center of surface depressions, sinkholes, and surface mines, and at the entrance points of caves. Coordinates and feature types were saved in ASCII files, which were later converted to Microsoft Excel 2000 spreadsheet files. Shapefiles were created from the inventoried data, and point locations and feature attributes were spot-checked against the corresponding features on the original maps. Corrections to the data were made where applicable. The resultant data file served as the basis for the density layer calculations.

As a result of the inventory, 111,715 individual points were compiled for 14 counties (107 7.5-minute quadrangles). Karst features make up approximately 98.4 percent of the points in the database: 96 percent, surface depressions; 2.3 percent, sinkholes; and 0.1 percent, cave entrances. Approximately 1.6 percent of the data points were surface mines, which were not included in the density layer calculation.

DENSITY LAYER CALCULATION

To create the digital density surface, ESRI ArcView 3.2 software was used to divide the study area into 25- by 25-meter (82- by 82-foot) grid cells and to count the karst data points that fell within the area of a 250-meter (820-foot) search radius from the center of each cell. The number of points divided by the search area (approximately 0.2 square kilometer [0.08 square mile or 49 acres]) represents the karst density value of a cell. After the density value was calculated for the first cell, the search area was shifted to the next 25-square-meter grid cell, and the floating process was repeated until all of the cells were assigned a density value. This process smoothed the density data over the study area. Grid cells were then assigned a color using an ESRI ArcMap 8.3 "quantile" gradation of density values. On the map, red represents more than 150 karst features per square kilometer (nearly 400 per square mile). The darkest green color indicates that at least one karst feature falls within the 250-meter search radius of the cell.

DISCLAIMER

While this map is useful for planning and preliminary site studies, it is not a substitute for site-specific subsurface investigations.

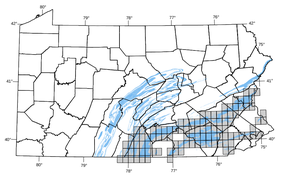
The occurrence of a sinkhole or surface depression depends on numerous factors, including rock type, geologic structure (e.g., fractures, joints, and faults), surface and subsurface hydrology, surficial materials (particularly in the glaciated areas of Northampton and Lehigh Counties), and land use. On the map, color shows the density of karst features over a given area. Although orange and red indicate areas where karst features are interpreted to be more abundant, it does not guarantee that new sinkholes will occur in these areas. Conversely, sinkholes can occur in areas where no karst features have been observed. The occurrence of sinkholes, therefore, is not restricted to the high-density areas delineated on the map.

On the map, a few karst density values are shown outside the mapped limits of carbonate bedrock. There are several possible reasons for this. Unconsolidated surficial material, such as colluvium or glacial sediment, can conceal the contact between noncarbonate and carbonate bedrock. In addition, due to the nature of the compilation of the 1980 "Geologic Map of Pennsylvania" on which the digital formation contacts were based, some limits of carbonate areas could be off by several hundred feet, and small areas of carbonate rocks may not be shown. Undetected faults may also account for karst density values occurring outside the areas of carbonate rocks.

A type of land use that affected the density and distribution of the karst data points used in constructing this map is urbanization. Urbanization can mask the surface expression of karst features, thereby impacting the interpretation of aerial photographs and the locating of features during subsequent field surveys. Thus some karst features, especially surface depressions, are commonly underrepresented in urban settings. Sinkholes may be skewed in distribution toward urban areas because of a greater likelihood of being recorded when they cause problems.

Because of the factors mentioned above, the scale of compilation, and the conversion of areal features to point data, this map should not be used to predict the location of future sinkholes or to correlate numbers of karst features to specific formations.

LOCATION OF AREA*



*Gray indicates area of 7.5-minute quadrangles that show karst density data. Blue represents areas where carbonate rocks are at the surface.

DENSITY OF MAPPED KARST FEATURES IN SOUTH-CENTRAL AND SOUTHEASTERN PENNSYLVANIA

BY
WILLIAM E. KOCHANOV AND STUART O. REESE
2003

SCALE 1:300,000

5 0 5 10 15 20 25 30 KILOMETERS
5 0 5 10 15 MILES

Albers equal area conic projection
Standard parallels 40°N and 42°N, center 78°W

REFERENCES

Kochanov, W. E., 1987a, Sinkholes and karst-related features of Lehigh County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Open-File Report 87–01, scale 1:24,000, 6 maps plus 19-page text.

_____ 1987b, Sinkholes and karst-related features of Northampton County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Open-File Report 87–02, scale 1:24,000, 10 maps plus 24-page text.

_____ 1988a, Sinkholes and karst-related features of Berks County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Open-File Report 88–01, scale 1:24,000, 16 maps plus 13-page text.

_____ 1988b, Sinkholes and karst-related features of Lebanon County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Open-File Report 88–02, scale 1:24,000, 4 maps plus 11-page text.

_____ 1989a, Sinkholes and karst-related features of Cumberland County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Open-File Report 89–02, scale 1:24,000, 9 maps plus 16-page text.

_____ 1989b, Sinkholes and karst-related features of Dauphin County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Open-File Report 89–01, scale 1:24,000, 5 maps plus 8-page text.

_____ 1989c, Sinkholes and karst-related features of Franklin County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Open-File Report 89–03, scale 1:24,000, 20 maps plus 15-page text.

_____ 1990, Sinkholes and karst-related features of Lancaster County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Open-File Report 90–01, scale 1:24,000, 18 maps plus 12-page text.

Kochanov, W. E., Lichtinger, J. F., and Becker, Mona, 1993a, Sinkholes and karst-related features of Bucks County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Open-File Report 93–03, scale 1:24,000, 4 maps plus 9-page text.

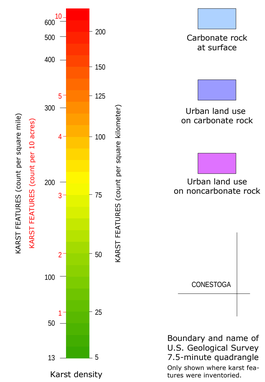
_____ 1993b, Sinkholes and karst-related features of Chester County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Open-File Report 93–01, scale 1:24,000, 10 maps plus 9-page text.

_____ 1993c, Sinkholes and karst-related features of Montgomery County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Open-File Report 93–02, scale 1:24,000, 5 maps plus 7-page text.

Kochanov, W. E., and Miller, Rachel, 1995a, Sinkholes and karst-related features of Adams County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Open-File Report 95–05, scale 1:24,000, 6 maps plus 9-page text.

_____ 1995b, Sinkholes and karst-related features of York County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Open-File Report 95–06, scale 1:24,000, 10 maps plus 9-page text.

EXPLANATION



MAP CREDITS

Karst

The karst features used for the density analysis are from open-file reports by W. E. Kochanov and others of the Pennsylvania Geological Survey, 1987–95 (see "References" for a complete list). Karst features were digitized by Survey interns and Kochanov, 1985–95, and coordinates and other attributes were imported into Microsoft Excel files by Kochanov, 1994–95.

Karst density analysis by S. O. Reese, Pennsylvania Geological Survey, 2003, based on shapefiles generated by Reese, 2002–03, from the Excel files. ESRI ArcView 3.2 software was used to do the analysis and to create the shapefiles.

Geology

Locations of carbonate rocks are slightly modified from *Geologic Map of Pennsylvania*, compiled by T. M. Berg and others (1980, Pennsylvania Geological Survey, 4th ser., Map 1, 2nd ed., scale 1:250,000, 3 sheets). The latter map was prepared as a data set by C. E. Miles, T. G. Whitfield, J. G. Kuchinski, and others (*Bedrock Geology of Pennsylvania*, 2001, Pennsylvania Geological Survey, 4th ser., scale 1:250,000).

Base Map

Urban areas are from the data set *Urban areas of Pennsylvania—PA Explorer CD-ROM edition* by Joe Bishop (1998, University Park, Gap Analysis Program, Environmental Resources Research Institute, Pennsylvania State University).

State and county lines are slightly modified from an unpublished municipality data set (Pennsylvania Department of Environmental Protection, 1998, 1:24,000-scale accuracy).

Quadrangle lines are from shapefiles created by M. E. Moore of the Pennsylvania Geological Survey (1990, unpublished), using ESRI Atlas GIS software.

River shorelines are from the data set *Major Rivers in Pennsylvania* by Environmental Resources Research Institute, Pennsylvania State University, in *Pennsylvania GIS Compendium* (1996, Pennsylvania Department of Environmental Protection, 1:24,000-scale accuracy). Data set derived from Pennsylvania Department of Transportation data.

Other

Map layout and design by S. O. Reese and C. E. O'Neil of the Pennsylvania Geological Survey, 2003. Cartography by S. O. Reese, 2002–03. Map editing by C. E. O'Neil, 2003.