

Developing a Karst Map for West Virginia

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ABSTRACT

State regulatory agencies increasingly consider karst terrain when issuing Underground Injection Control permits, approving new horizontal oil and gas well permits, and allowing landfills to accept drill cuttings. These activities hold the potential for environmental damage, aquifer contamination, or serious accident through surface spills, poor casing jobs, or drilling into underground voids. New horizontal drilling legislation tasked the West Virginia Geological and Economic Survey (WVGES) with developing a map showing areas of potential karst in the state. Karst can occur in West Virginia where soluble rocks such as the Greenbrier and Helderberg limestones occur near or at the surface. These rocks occur predominantly in the eastern and southeastern parts of the state. Using a digitized map of the Geology of West Virginia at 1:250,000 scale, WVGES geologists created a map showing where thick carbonate units crop out, and overlaid locations of publicly-known caves as well as information from various karst related datasets pertaining to West Virginia. Where available, modern WVGES maps at a scale of 1:24,000 created with funding from the National Park Service and the US Geological Survey STATEMAP program were invaluable in developing the statewide karst map. This map serves as a guide to regulatory agencies to determine whether areas need further examination before industrial operations proceed. While useful in the regulation of drilling activities and associated waste disposal, the statewide karst map can be refined further with completion of 1:24,000 scale mapping of quadrangles with karst terrain, observation of surface karst features from LiDAR data, and hydrological studies.

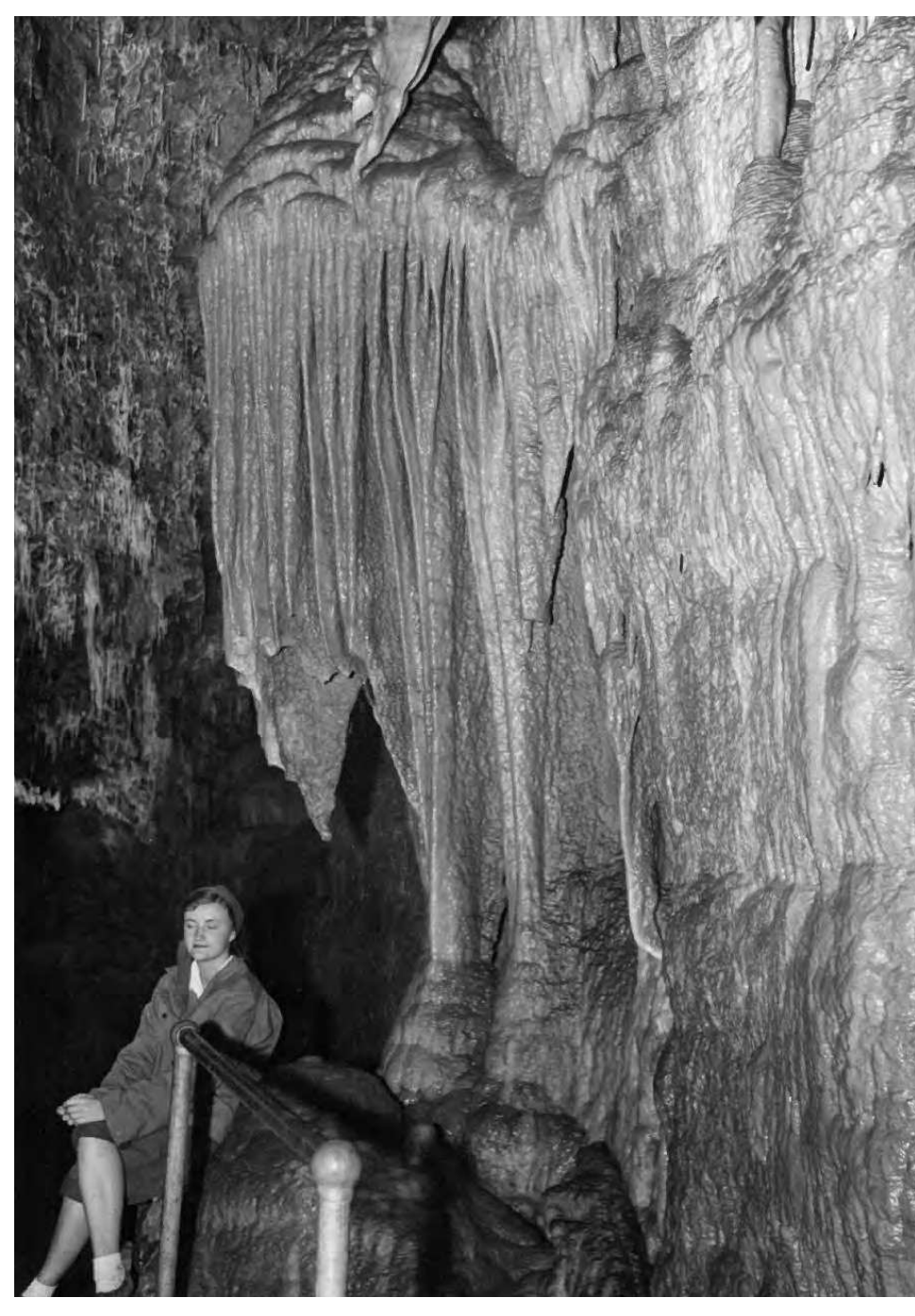
Generalized Stratigraphic Chart for West Virginia			
Era	System	Series/Stage	Western WV
PHANEROZOIC	PALEOZOIC	Permian	Dunkard Group
			Upper Monongahela Fm.
			Middle Allegheny Fm.
			Lower Kanawha Fm.
		Carboniferous	Pottsville Group
			Upper New River Fm.
			Middle Pennsylvanian Group
			Lower Mauch Chunk Group
		Devonian	Greenbrier Group
			Upper Ohio Sh.
PHANEROZOIC	PALEOZOIC	Silurian	Helderberg Group
			Upper Onondaga Ls.
			Middle Onondaga Ls.
			Lower Onondaga Ls.
		Ordovician	Black River Group
			Upper Wells Creek Fm.
			Middle Beekmantown Dol.
		Cambrian	Lower Rome Group
			Upper Tomstown Dol.
			Lower Tomstown Dol.



Organ Cave, Greenbrier County



Organ Cave, Greenbrier County



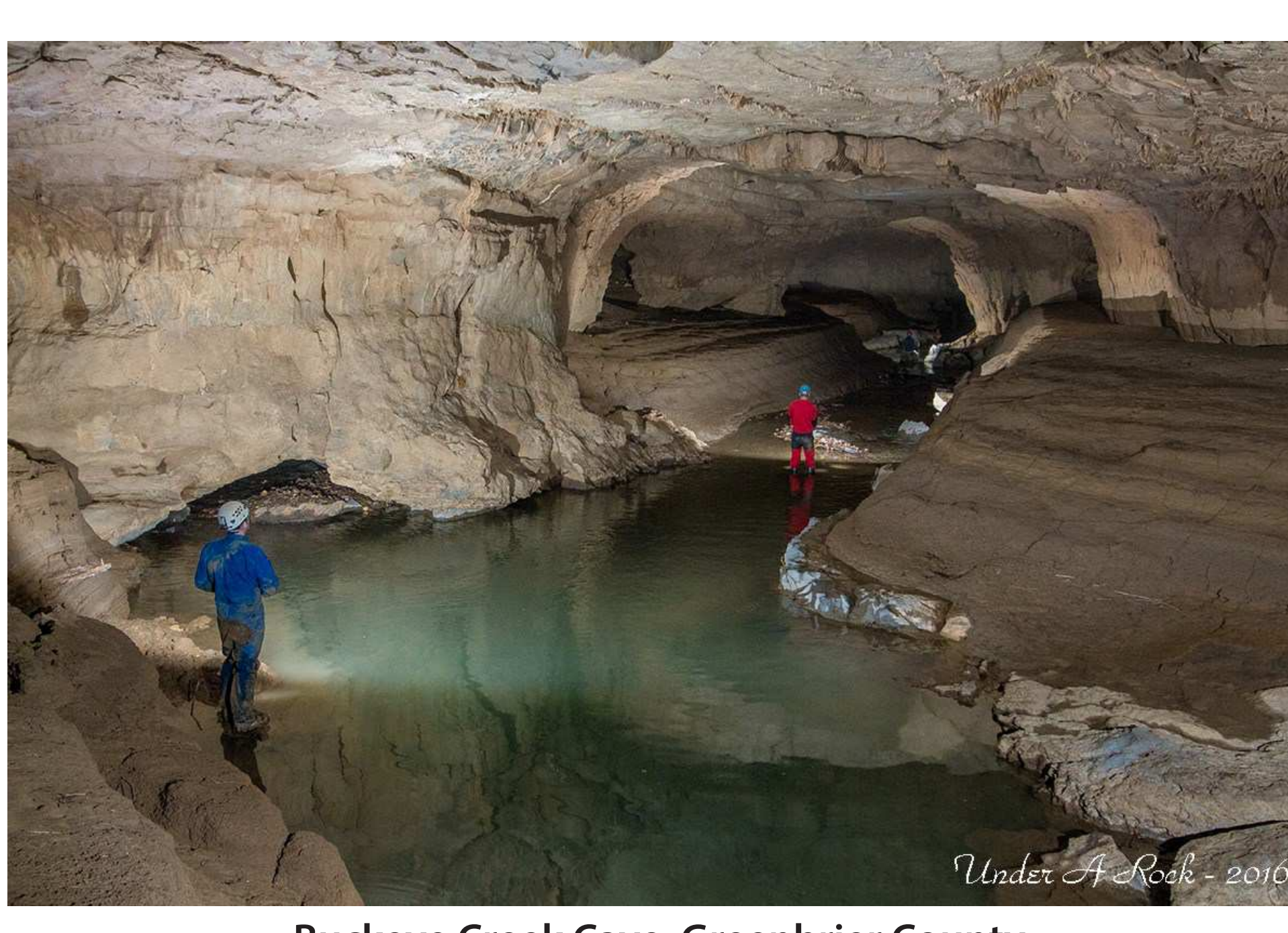
Smoke Hole Cavern, Grant County



Laurel Creek Cave, Monroe County



Maxwellton Sink, Greenbrier County



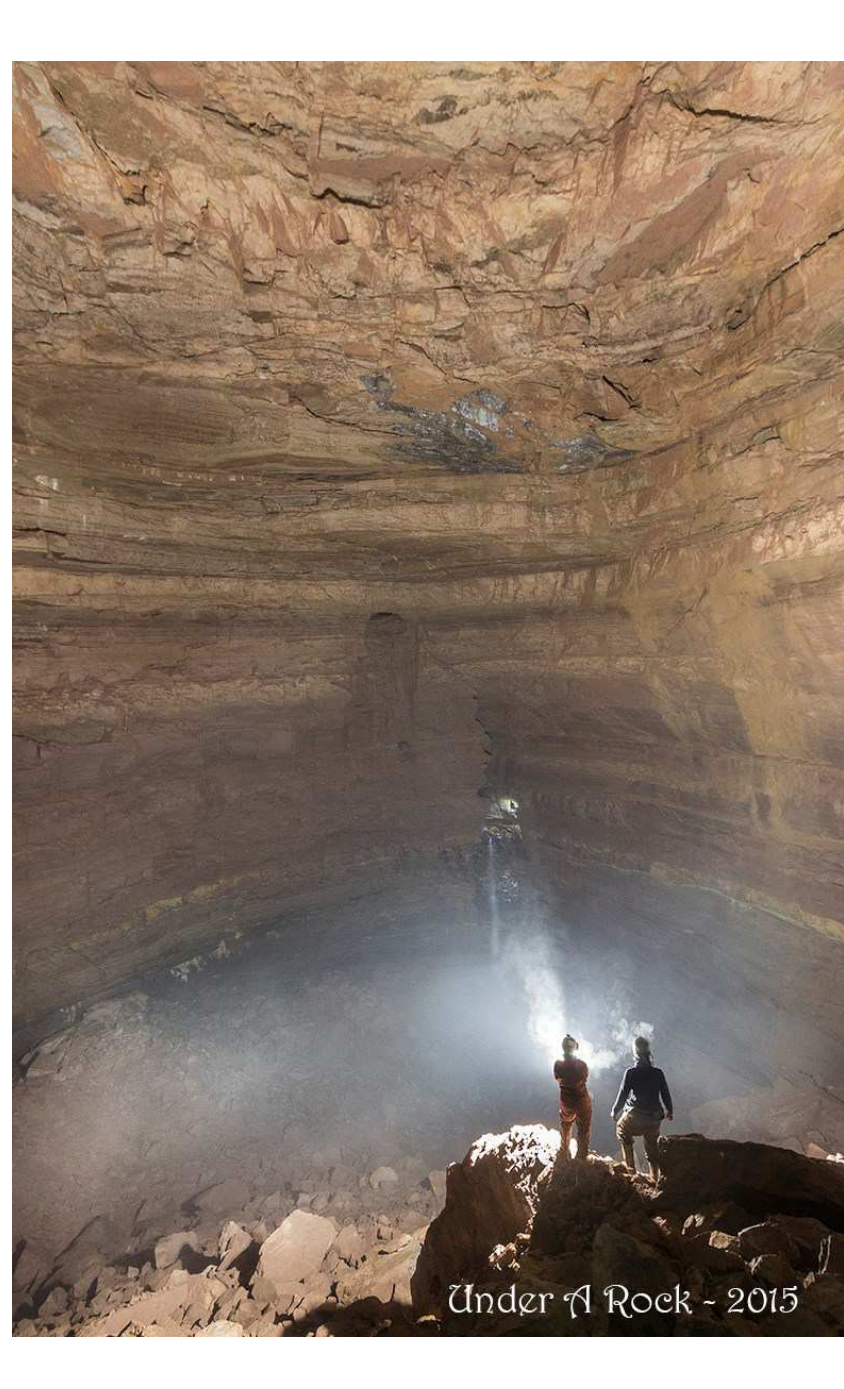
Buckeye Creek Cave, Greenbrier County



Culverson Creek, Greenbrier County



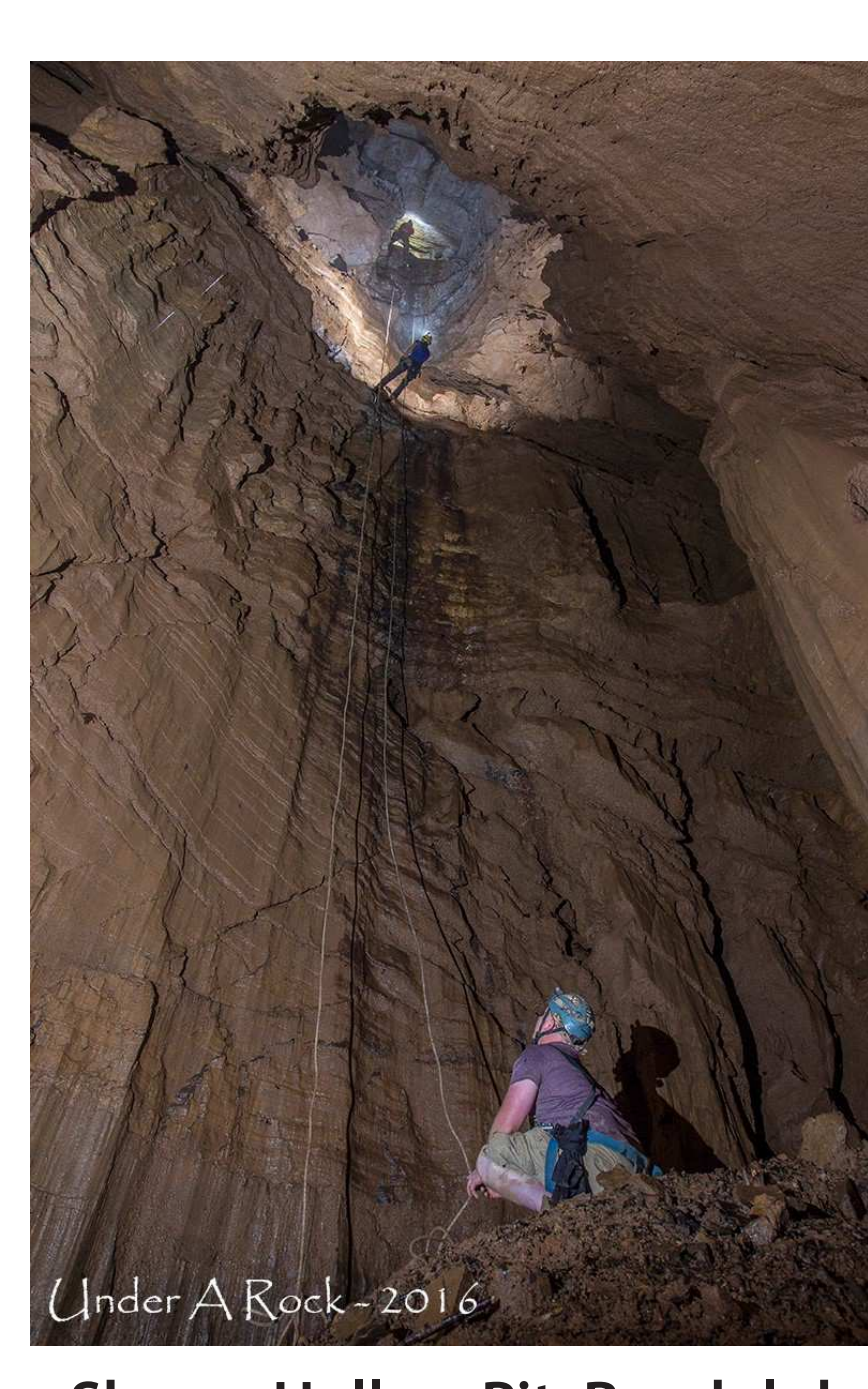
Dry Cave, Greenbrier County



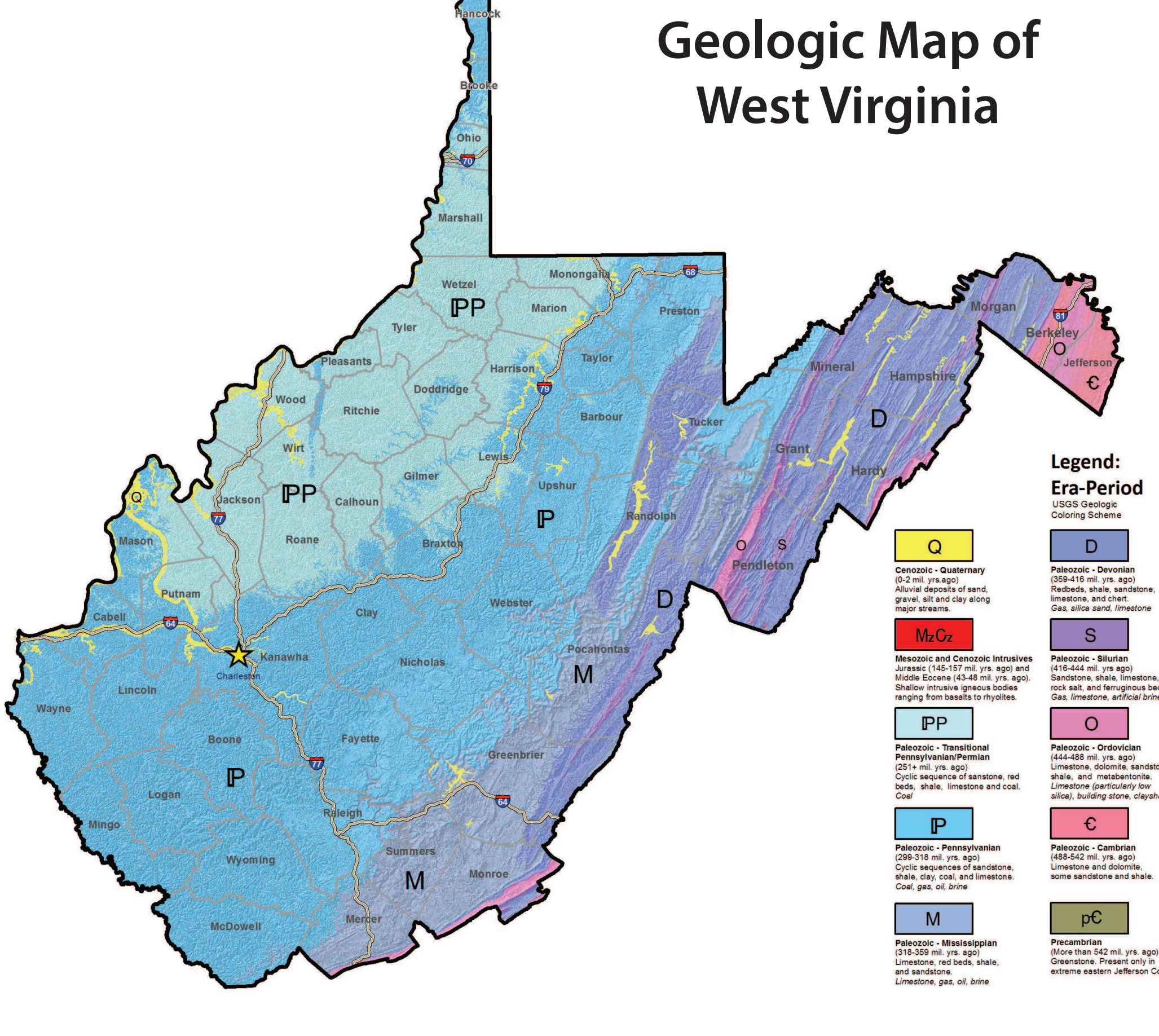
Monster Caverns, Pocahontas County



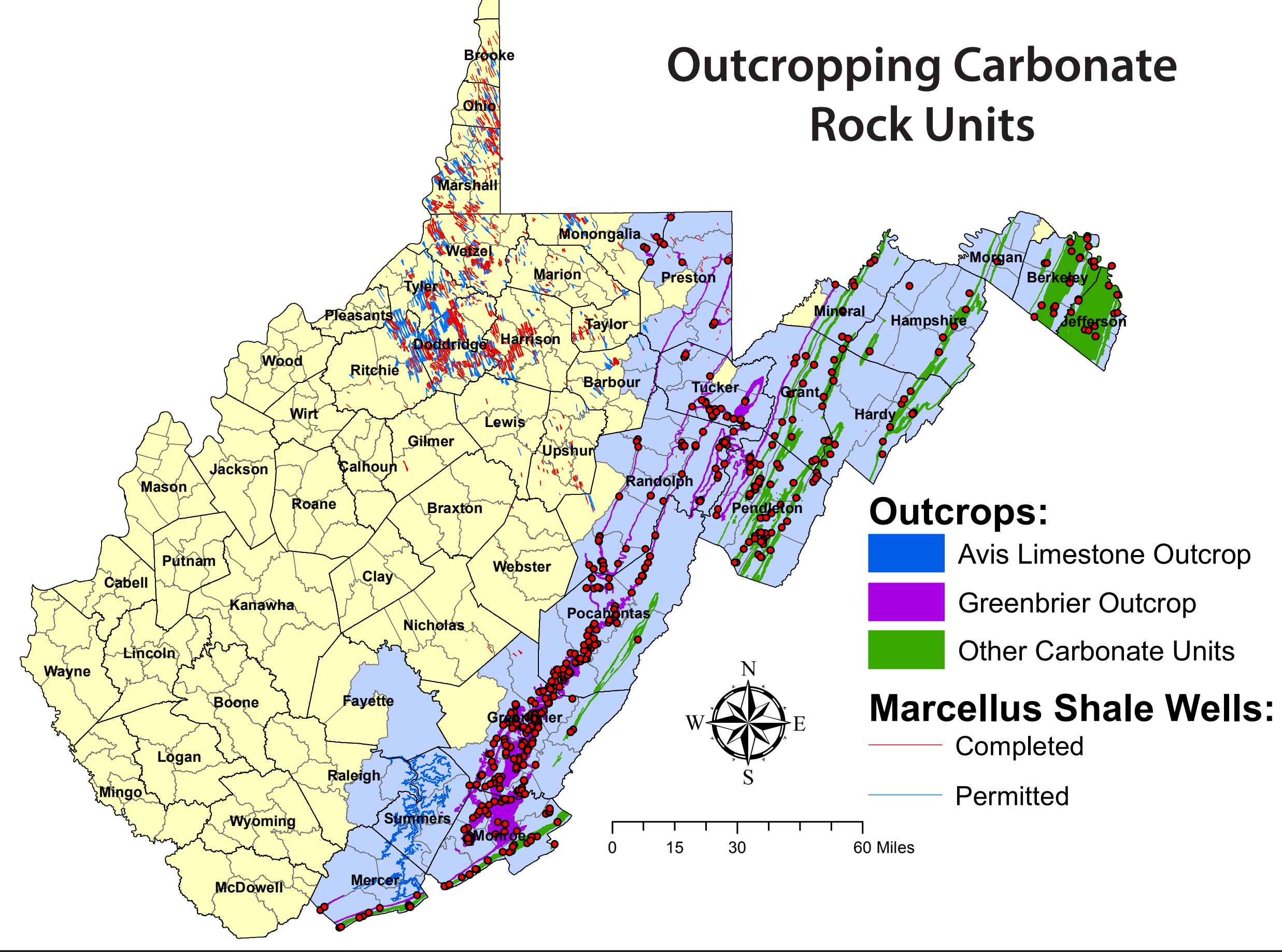
Sites Cave, Pendleton County



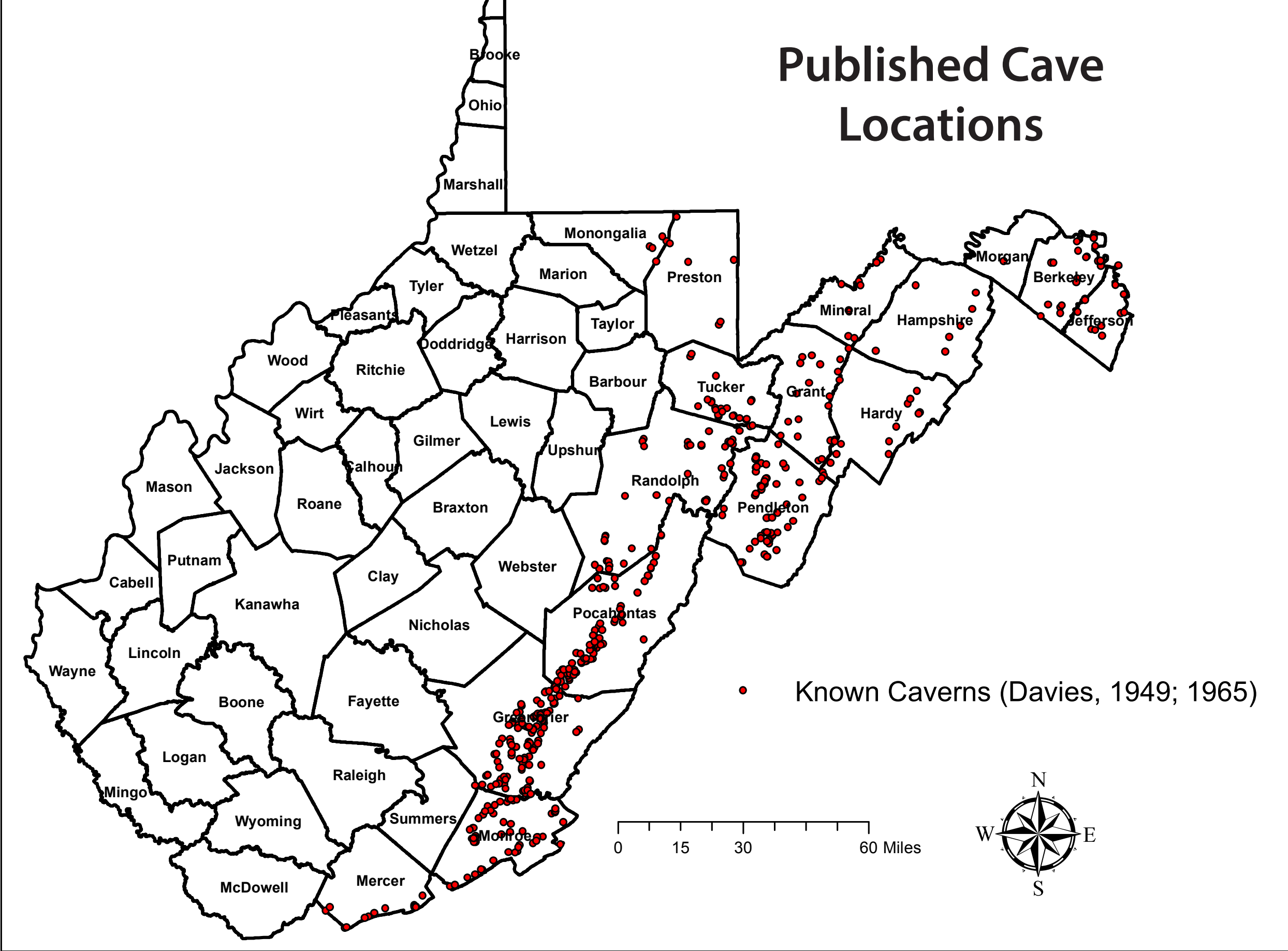
Shreve Hollow Pit, Randolph County



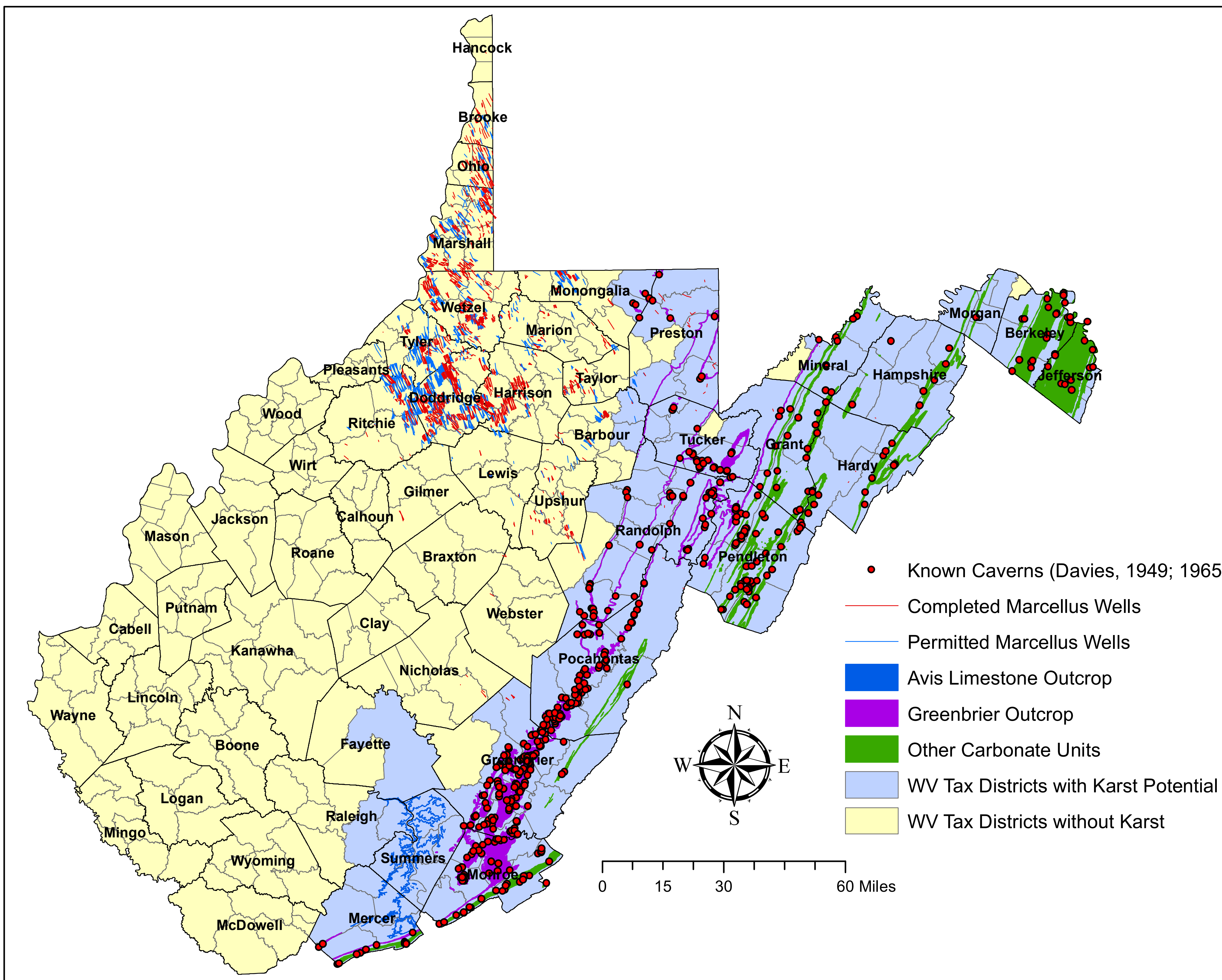
Outcrops of carbonate rock units is used as a first approximation to karst potential. Karst-forming carbonates occur in generally narrow bands in the Valley and Ridge Province within eastern West Virginia.



This map shows the outcrop of these carbonate units based on the state geologic map as well as field observations by geologists who have conducted detailed geologic mapping in the state. Also shown are locations and pathways of completed horizontal wells in the state. In general the karst region overlaps very little with the oil and gas producing fairway. The principal exceptions are in Preston County in the northern part of the state adjacent to Pennsylvania and Maryland.



The only public source for cave locations in West Virginia is West Virginia Geological and Economic Survey Volume 19A by William E. Davies, "Caverns of West Virginia." Despite the fact that Davies' locations were somewhat generalized, the vast majority fall within the bands of carbonate outcrop. Cave locations in other parts of the state are generally isolated, very small, in some cases "shelter" caves, or formed in sandstone, and not part of a karst terrain. Thin marine limestones occur in the coal measures, but where these units crop out in the northern part of the state, isolated caves are few in number and small in size.

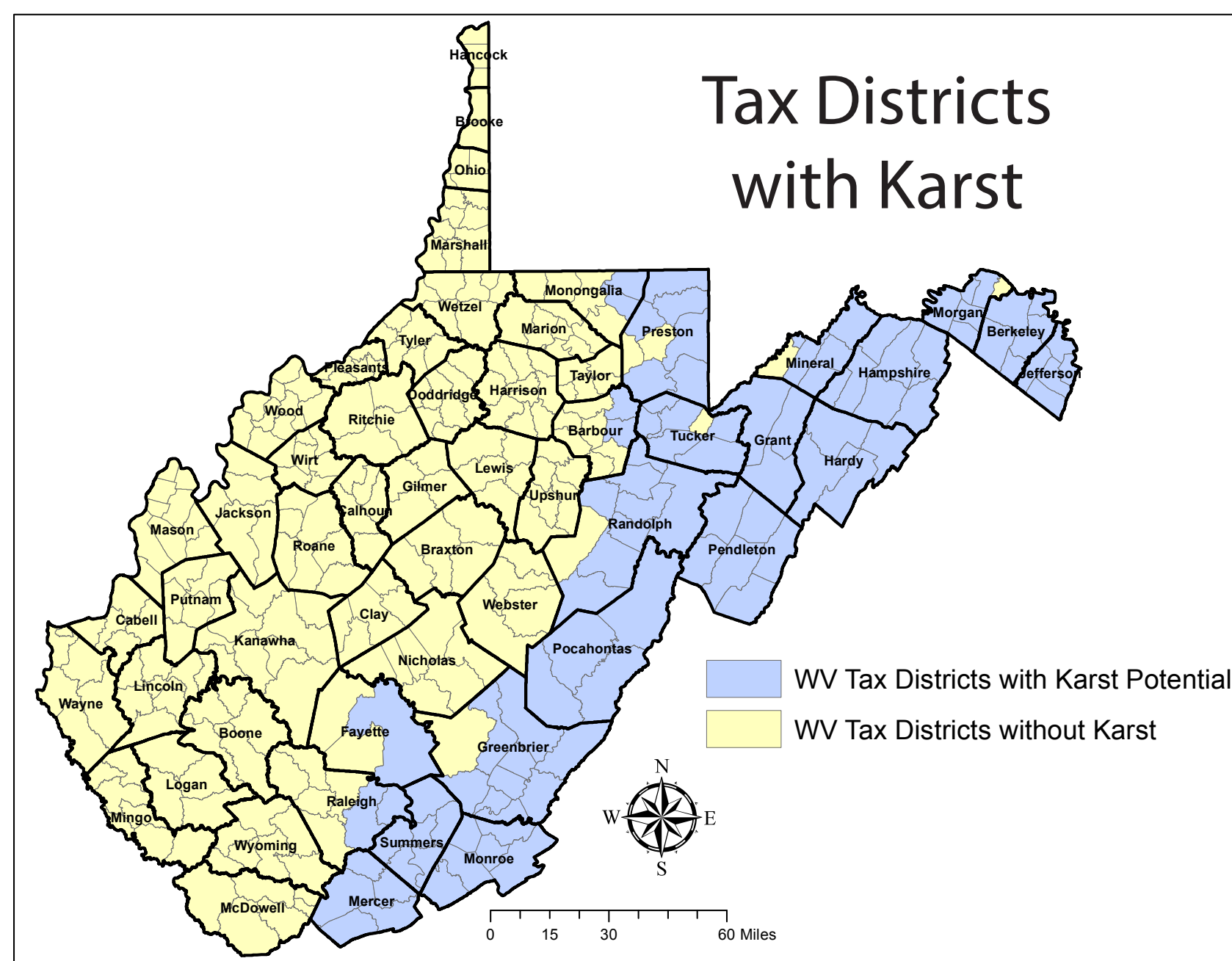


We used the outcrop of limestones units, published cave locations, and information provided by the community of cavers to determine the occurrence of karst within county tax districts, a readily-available government unit in West Virginia.

The Final Map

For the WV Department of Environmental Protection to implement the new legislation, they needed some way to determine from our map when a proposed well would potentially intersect underground voids. We considered applying a buffer to the outcrop and designating the enclosed area as a karst region. However, it is not obvious what distance should be used to create the buffer. The potential for underground voids depends on local geology such as structure and topography. In conjunction with geologists at WVDEP we decided to define karst regions to be those county tax districts with karst.

Permit applications that lie within these tax districts will require closer study to see whether the proposed drilling will intersect karst. WVDEP regulations specify what additional precautions must be taken during well drilling operations to protect from environmental damage.



Acknowledgements

The authors would like to thank John Bocan, Wayne Perkins, and Sarah Gooding for help in creating this poster. We would also like to thank members of the West Virginia Speleological Survey for information and advice helpful in creating the West Virginia Karst Map, and Ryan R. Maurer for allowing us to use photographs "Under a Rock".

THE PROBLEM

Technological advances in oil and gas well drilling have led to development of unconventional reservoirs including the Utica and Marcellus shales in the Appalachian basin. The potential exists for these technologies—including horizontal drilling and hydraulic fracturing—to be applied to conventional oil and gas reservoirs in the region.

Karst presents a special concern because surface spills associated with drilling could contaminate shallow aquifers and spread underground very quickly. In addition, drilling into underground voids unexpectedly could represent an environmental hazard.

In response to public concerns over the environmental and social issues associated with new drilling, the West Virginia legislature passed a comprehensive "horizontal well law" late in 2011, followed by legislation regulating the disposal of well cuttings in landfills. Both pieces of legislation pay specific attention to karst and charge the WV Geological Survey with mapping karst regions in the state.

Principal karst-forming carbonate rocks in West Virginia (shown in blue) are within the Mississippian Greenbrier Group; Devonian Silurian Helderberg Group and Tonoloway Limestone; and Cambrian and Ordovician Tomstown Dolomite, Elbrook Formation, Conococheague Formation, Beekmantown Group, Saint Paul Group, and Black River Group. Based on recent geologic mapping in southern West Virginia the Mississippian Avis Limestone, also known as the Little Stone Gap, can be added to this list.

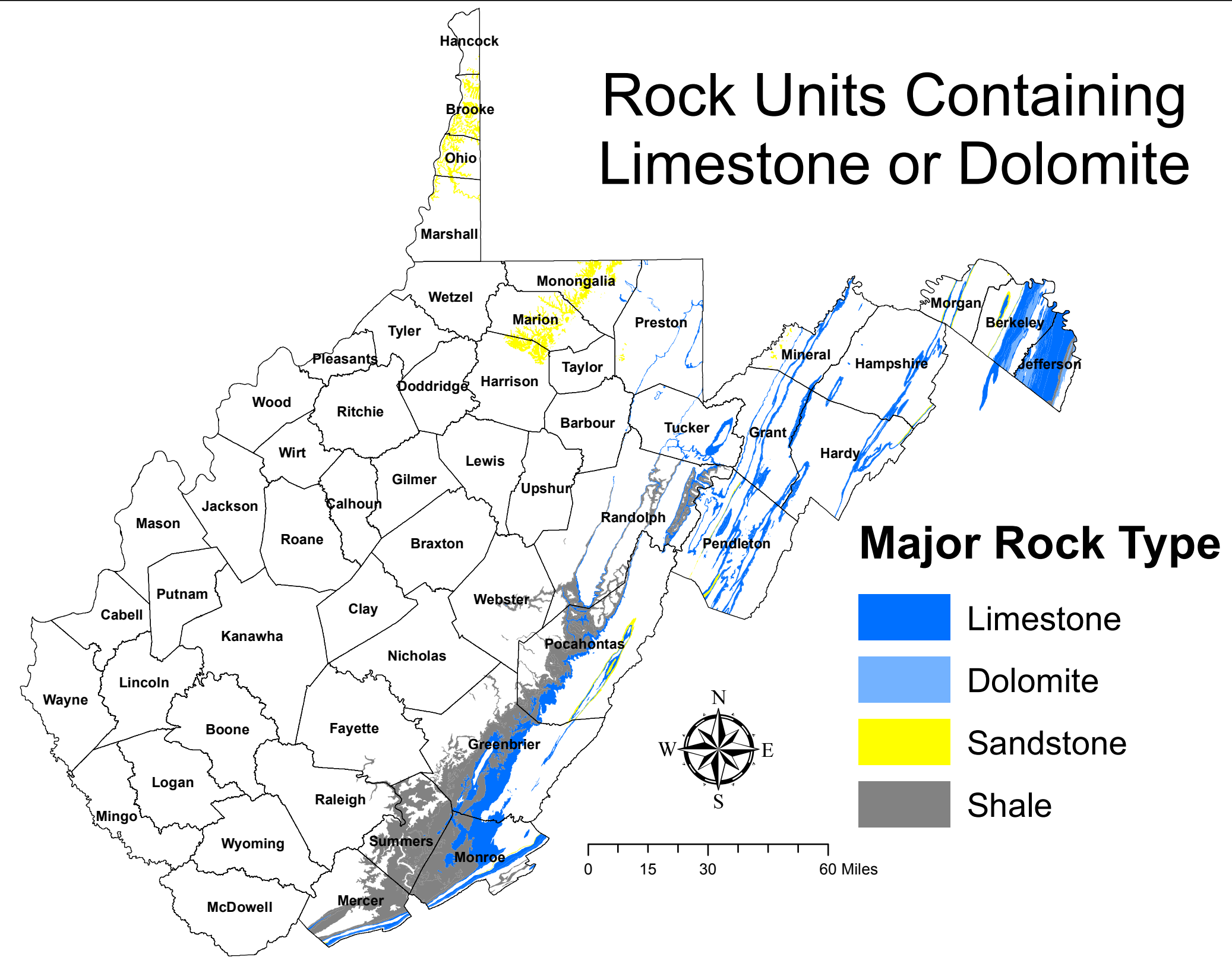
U.S. Geological Survey: Karst in the United States: A Digital Map Compilation and Database

By David J. Weary and Daniel H. Doctor; U.S. Geological Survey Open-File Report 2014-1156

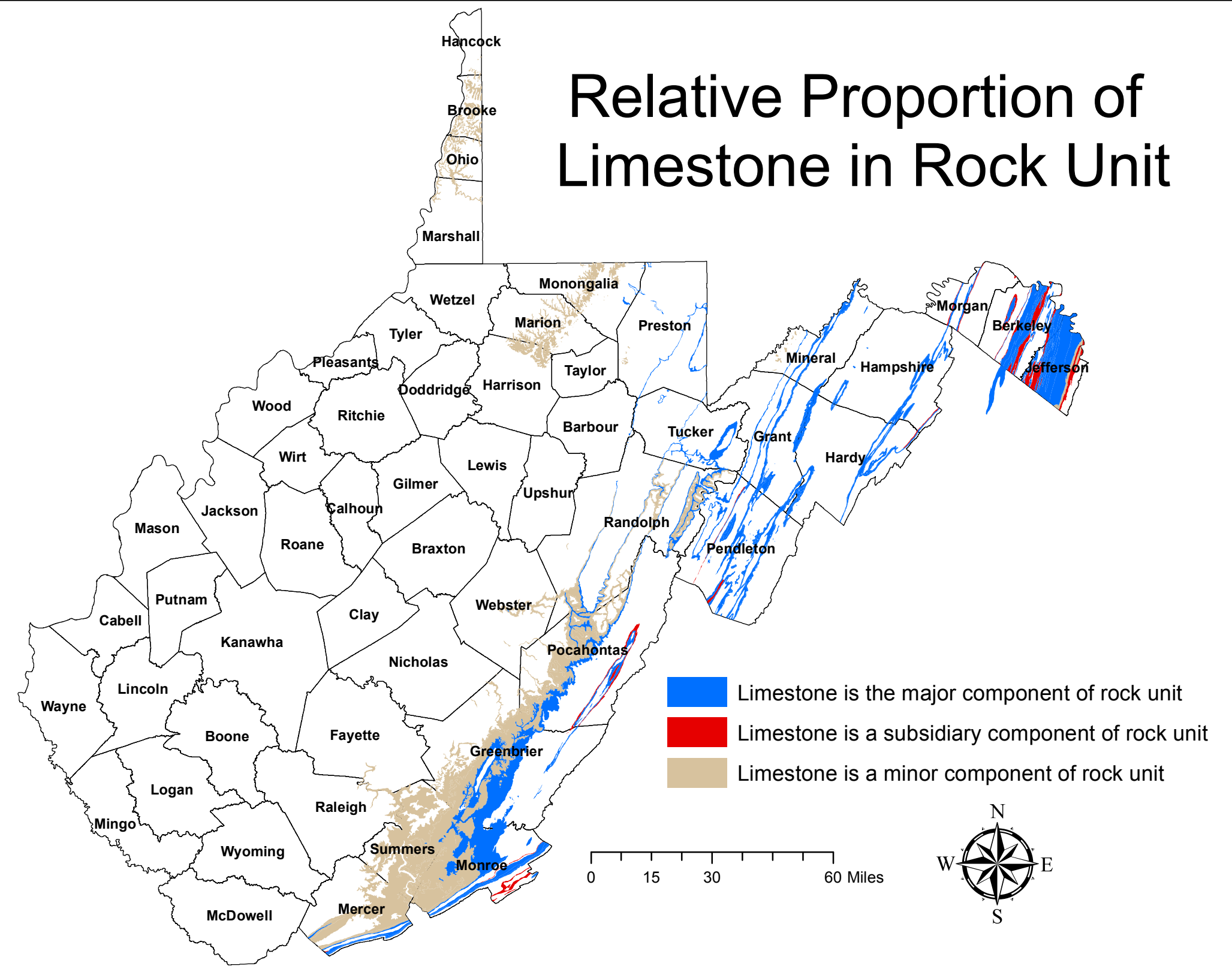
In 2014 the U.S. Geological Survey released an open file report showing karst or the potential for karst across the U.S. The map and accompanying database were generated from state geologic maps and included areas of soluble rocks, primarily rock units with significant proportions of carbonate or evaporitic minerals.

Many of the areas of karst potential corresponded with ones on our own maps of carbonate outcrop. However, relatively thin carbonate units occur in Carboniferous units in the northern part of the state. Geologic mapping confirmed the existence of generally very small, scattered caves and we did not include these areas in our map of karst.

Although we did not include some of the units in our final map, this publication was very useful to us as a check on our previous assumptions that karst in West Virginia was largely found within a northeast to southeast band of counties.



The USGS map and database included all rock units with some portion of carbonate, whether they are principally limestone, dolostone, sandstone or shale. This map shows the major lithology of each unit.



This map is another representation of the same data, in this instance showing the relative importance of carbonate within each unit mapped by the USGS as having the potential for karst.

WEST VIRGINIA CODE

§22-6A-3a. Karst terrain; rulemaking.

(a) Because drilling horizontal wells in naturally occurring karst terrain may require precautions not necessary in other parts of the state, the secretary (of the WV Department of Environmental Protection) may require additional safeguards to protect this geological formation. When drilling horizontal wells in naturally occurring karst terrain, such additional safeguards may include changing proposed well locations to avoid damage to water resources, special casing programs, and additional or special review of drilling procedures.

(b) In order to carry out the purposes of this section, the secretary, in consultation with the state geologist, shall propose emergency and legislative rules in accordance with the provisions of chapter twenty-ninea of this code to establish designated geographic regions of the state where the provisions of this section are applicable and to establish standards for drilling horizontal wells in naturally occurring karst terrain. For horizontal wells drilled into naturally occurring karst terrain in such designated geographic regions, the rules shall, at a minimum:

- (1) Require operators to perform certain predrilling testing to identify the location of caves and other voids, faults and relevant features in the strata and the location of surface features prevalent in naturally occurring karst terrain such as sink holes; and
- (2) Provide any other requirements deemed necessary by the secretary to protect the unique characteristics of naturally occurring karst terrain, which requirements may include baseline water testing within an established distance from a drilling site.

§22-15-8

(g) . . . a commercial solid waste facility that is not located in a county that is, in whole or in part, within a karst region as determined by the West Virginia Geological and Economic Survey may lawfully receive drill cuttings and drilling waste generated from horizontal well sites . . .

What's Next?

Our ability to draw accurate maps of karst potential depend on availability of 1:24,000 geologic maps in conjunction with observations collected during field mapping. A focus of our mapping has been karst, but we need to complete mapping quadrangles with significant carbonate outcrops in southeastern West Virginia.

This area is shown by the rectangle.

As a result of severe flooding in this part of the state in 2016, the Federal Emergency Management Agency has acquired LiDAR covering most of this area under the 3DEP program. Once processed and available we can use this information to supplement our geologic maps in providing advice to the WV DEP and others.

Finally, pending availability of funding, we plan to cooperate with the US Geological Survey in hydrogeological studies of karst areas in southeastern WV.

Mapping Status Summary All 1:24,000 Scale Geologic Mapping March 2017

