Ohio Geology

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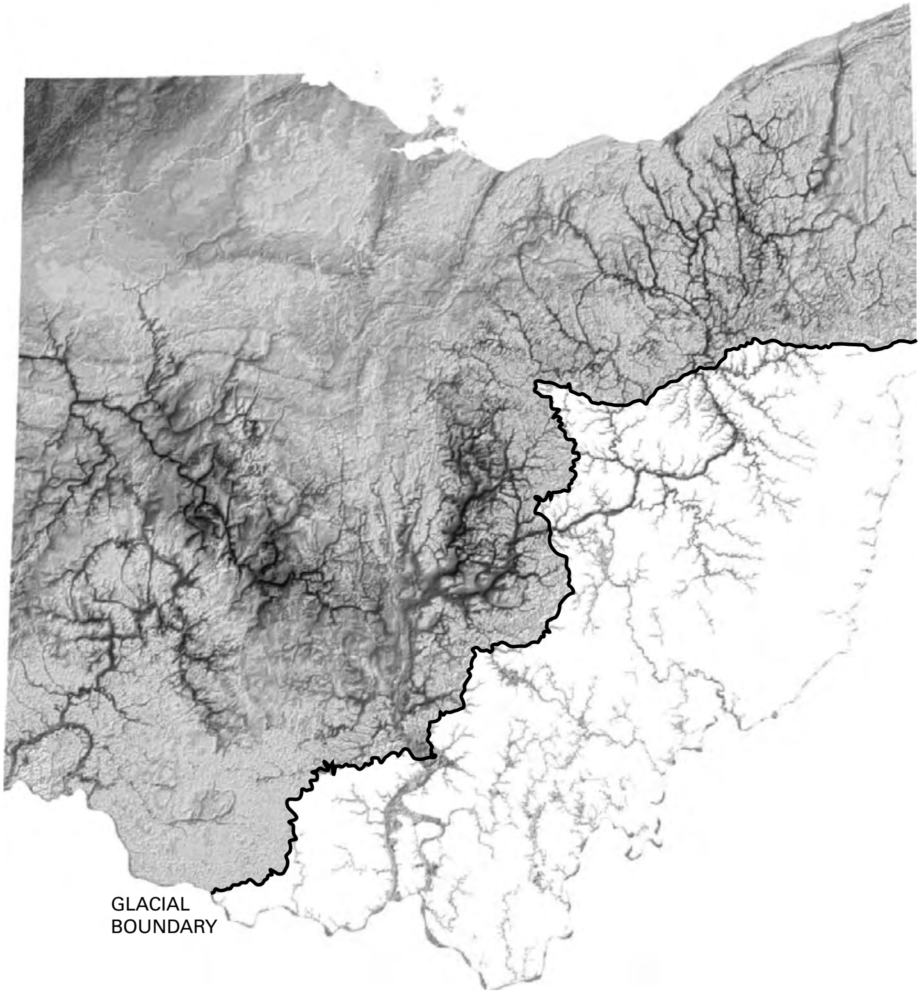
WHAT THE GLACIERS LEFT BEHIND—THE DRIFT-THICKNESS MAP OF OHIO

by E. Mac Swinford

A common question asked at the Division of Geological Survey is, how thick is the glacial drift (sediments left by a glacier) at a certain locality? Determining an answer to the question is simple: subtract the elevation of the top of bedrock (bottom of the drift) from the elevation of the corresponding land surface (top of the drift). However, to obtain the necessary elevation data, two maps are required: a bedrock-topography map and a land-surface elevation map. Calculating drift-thickness values for multiple locations quickly becomes tedious and time consuming. But now, thanks to a lengthy mapping and digital-data-conversion effort by the Division of Geological Survey, determining drift thickness at any locality, or at many localities, in Ohio is easy and fast.

The Division's most recent statewide digital mapping product, the *Shaded drift-thickness map of Ohio* by Donovan M. Powers, was produced using GIS technology to subtract digital bedrock-topography elevations (bottom of the drift) from digital land-surface elevations (top of the drift). This map depicts the thickness of glacially derived sediments and post-glacial stream or lake sediments overlying the buried-bedrock surface. Spectral hues on the color version of the map represent thickness intervals of these sediments from 0 to 726 feet.

Prior to the onset of continental glaciation in the Early Pleistocene, nearly two million years before present, the Ohio landscape was dominated by rolling hills and deeply incised valleys. An image of this ancient landscape is captured in the *Shaded bedrock-topography map of Ohio*, (see *Ohio Geology,* 2003, No. 1). Erosion and deposition by repeated advances and retreats of continental glaciers that crossed northern and western Ohio produced a low-relief land surface compared to the high-relief land surface of unglaciated southeastern Ohio. Comparing the shaded-elevation map to the bedrock-topography map reveals the dramatic impact of glaciation on the state's current landscape.



Shaded drift-thickness map of Ohio. *Note that darker shades represent areas of thicker drift.*

Drift thickness in western and northern Ohio is highly variable, a consequence of numerous geologic factors acting alone or in combination. In some areas, drift has been deposited on a relatively flat bedrock surface and variations in drift thickness are solely due to differences in the amount of glacial sediments deposited atop the bedrock as ground moraines, ridge moraines, eskers, and kames. In other areas, drift thickens where ancient preglacial valleys were filled with glacial sediment and today, are completely concealed under a land surface that is dominated by moraines and other glacial features. In still other areas, elevation of the modern land surface parallels elevation of the underlying buried-bedrock surface resulting in relatively uniform drift thickness.

Narrow linear patterns of thick drift in western and central Ohio resulted from the infilling of deep valleys in the underlying limestone and dolomite bedrock. A large, northwest flowing drainage

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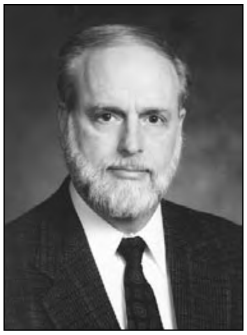

Thomas M. Berg, Division Chief and State Geologist

From The State Geologist...

Thomas M. Berg

SETTING FEDERAL SCIENCE PRIORITIES

As I watch the formulation of our federal budget, it is sometimes astonishing to see what science activities take a higher priority than others. At the last Geological Society of America national meeting, I acquired a brand new, colored, shaded-relief map of the Planet Mars. I have put it on display in one of our hallways; it is absolutely beautiful! Staff members of the Ohio Geological Survey are fascinated by this new image and have already plotted the location of the *Spirit* and *Opportunity* rovers of the recent Mars mission.

Exciting as this current space mission is, we must ask the question, "Why?" What is the immediate and essential benefit to American society and all humanity? How does determining the mineralogy of rocks or the presence of water on this forbidding planet compare with locating, managing, and protecting glacial aquifers in the central Great Lakes states? Sending the *Spirit* and *Opportunity* rovers to Mars cost over $800 million. Almost simultaneously, the Central Great Lakes Geologic Mapping Coalition (CGLGMC)—comprising the state geological surveys of Ohio, Indiana, Illinois, and Michigan, and the USGS—has only been able to persuade Congress to allocate $500,000 per year for five years (about three-tenths of one percent of the Mars mission) to map and characterize the glacial and related deposits of the four central Great Lakes states. The three-dimensional geologic framework of glacial deposits and the presence of ground water in those deposits in the four-state area are as much of an unknown (perhaps more so) as the surface of Mars.

In response to the question "Why explore Mars?" NASA's Space Science Chief Ed Weiler asserted: "The simple answer is we are going to Mars to search for life." Mr. Weiler further said: "We are following the water [on Mars] because on Earth we find out that where ever you find water, organic material and energy you find life. So the key for the search on Mars is following the water. That will lead us if there was past life or if there is present life." Chief Weiler movingly says: "We are going there not just to understand a science question but a basic human question that has been around since we started walking out of the caves finally and looking up into the sky—are we alone?"

As a scientist, and a geologist in particular, I too must gladly confess to being fascinated by images of a Martian landscape dominated by a volcano that is three times higher than Mount Everest and a canyon that is seven times deeper than the Grand Canyon. Even so, my sardonic vision is of a future withered and wrinkled person clutching an empty tin cup asking the question: "Why couldn't our decision-makers have invested adequately in producing the kinds of geologic maps required for identification and protection of our ground-water resources?" I truly hope that vision will not come to pass, and that our government leaders will see the necessity of putting a higher priority on the work of the CGLGMC. I urge our readers to learn more about the Coalition at <http://pubs.usgs.gov/circ/c1190/>.

Awards

Assistant State Geologist and Assistant Chief Dennis N. Hull, and retired Senior Geologist for the Division of Geological Survey, Dr. Michael C. Hansen, received career achievement awards at the winter banquet of the Ohio Section of the American Institute of Professional Geologists held on November 13, 2003. Dennis Hull received an award for Outstanding Service to the Public. He was recognized for providing accurate and timely geologic information in a professional manner to the public over the past 27 years and for his contributions to the increased understanding of Ohio's geology. The breadth of his work ranges from mapping surficial geology, sand and gravel resources, and landfill suitability to writing reports on carbonate rocks in Ohio for use as sulfur dioxide sorbents, karst features in Ohio, guides to geology along Interstates 70 and 75, and a variety of other topics. Dennis oversaw the development of the statewide mapping program, which has resulted in the remapping of Ohio's bedrock geology and bedrock topography and produced numerous surficial-geology maps. As supervisor over the Mapping and Economic Geology Branches of the Geological Survey, Dennis continues to perform a major role in guiding the

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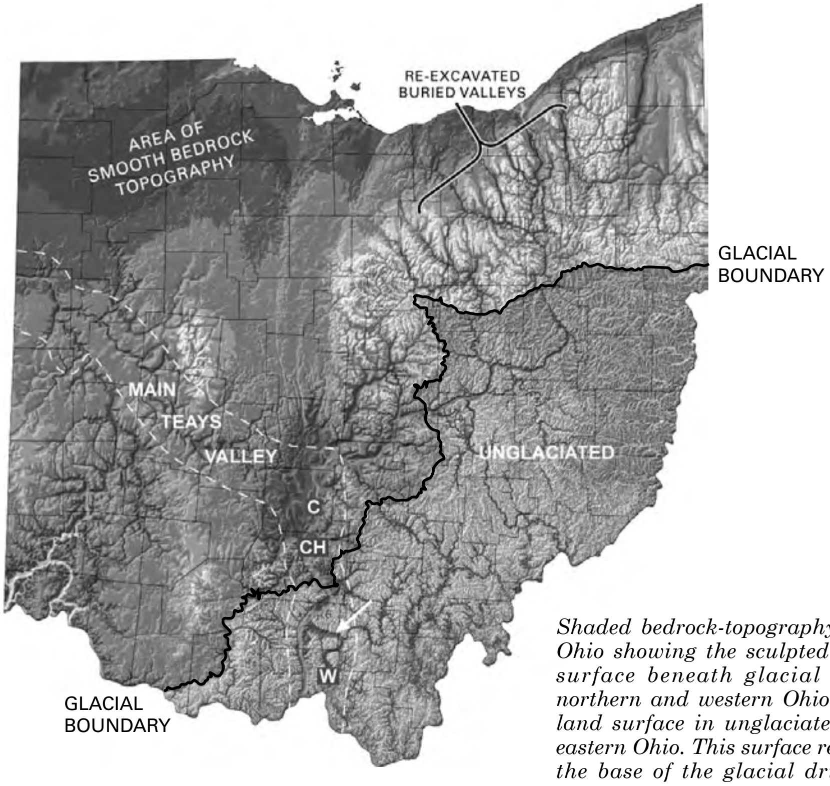
system, the Teays Valley system, existed prior to and during early glaciations (see *Ohio Geology*, Summer 1987). The Teays entered Ohio at Wheelersburg (Scioto County), where remnants of the Teays Valley, partially filled with sand and clay, are still evident on the modern land surface. The ancient valley dominates the terrain between Wheelersburg and Chillicothe (Ross County) where it is almost entirely buried by glacial sediment. From Chillicothe, the valley, partially or completely buried, continues north to Circleville (Pickaway County) and then northwest to Mercer County where it exits the state into Indiana. Water flow in the Teays Valley system was disrupted by early glaciations as southward-advancing glaciers blocked outlets of the north-flowing river system to create a series of huge lakes in the Teays River watershed. The water level of lakes forming in front of the glaciers rose and eventually breached a drainage divide near Manchester, Ohio, forming the modern Ohio River valley.

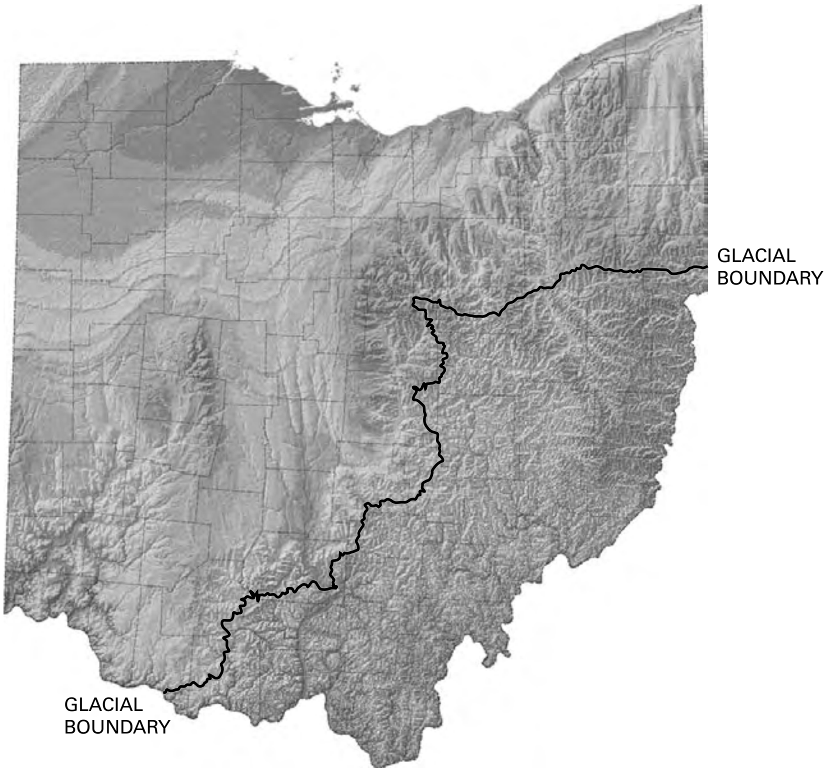
The thickest drift in the state, estimated to be over 720 feet thick, occurs in association with the Teays valley two miles east of Kiser Lake State Park near the boundary of Concord Township (section 33) and Johnson Township (sections 3 and 4), Champaign County. In this area, the deeply incised bedrock surface descends below an estimated 500 feet in elevation and is overlain by stacked glacial sediments associated with the Wisconsinan-age Farmersville Moraine and older ground moraines that ascend to 1,210 feet in elevation. It is the combination of a low bedrock-valley elevation and a high surface elevation that gives this area the unique distinction of having the thickest drift in the state.

In northeastern Ohio, narrow thick-drift areas south of Lake Erie also delineate the courses of preglacial bedrock valleys. These valleys were partially filled with thick deposits of till and glaciolacustrine (glacial lake) sediment and then re-excavated by later northward-flowing rivers such as the Cuyahoga River and portions of the East Branch of Rocky River. Glaciolacustrine deposits remaining on the steep valley sides can be over 250 feet thick and are notoriously landslide prone.

In northwestern Ohio, repeated scouring of the relatively soft bedrock surface by glacial ice flowing southwestward from the Erie Basin smoothed the bedrock surface, destroyed most preex-



*Shaded bedrock-topography map of Ohio showing the sculpted bedrock surface beneath glacial drift in northern and western Ohio and the land surface in unglaciated southeastern Ohio. This surface represents the base of the glacial drift when calculating drift thickness. Note the surface expression of the Teays Valley system south of the glacial boundary (arrow), the location of the main Teays Valley (white dashed line), the area of ice-scoured smooth bedrock topography in northwestern Ohio, and the re-excavated buried valleys in northeastern Ohio. (*W *= Wheelersburg,* C *= Circleville,* CH *= Chillicothe). Modified from Division of Geological Survey, map SG-3, 2003.*



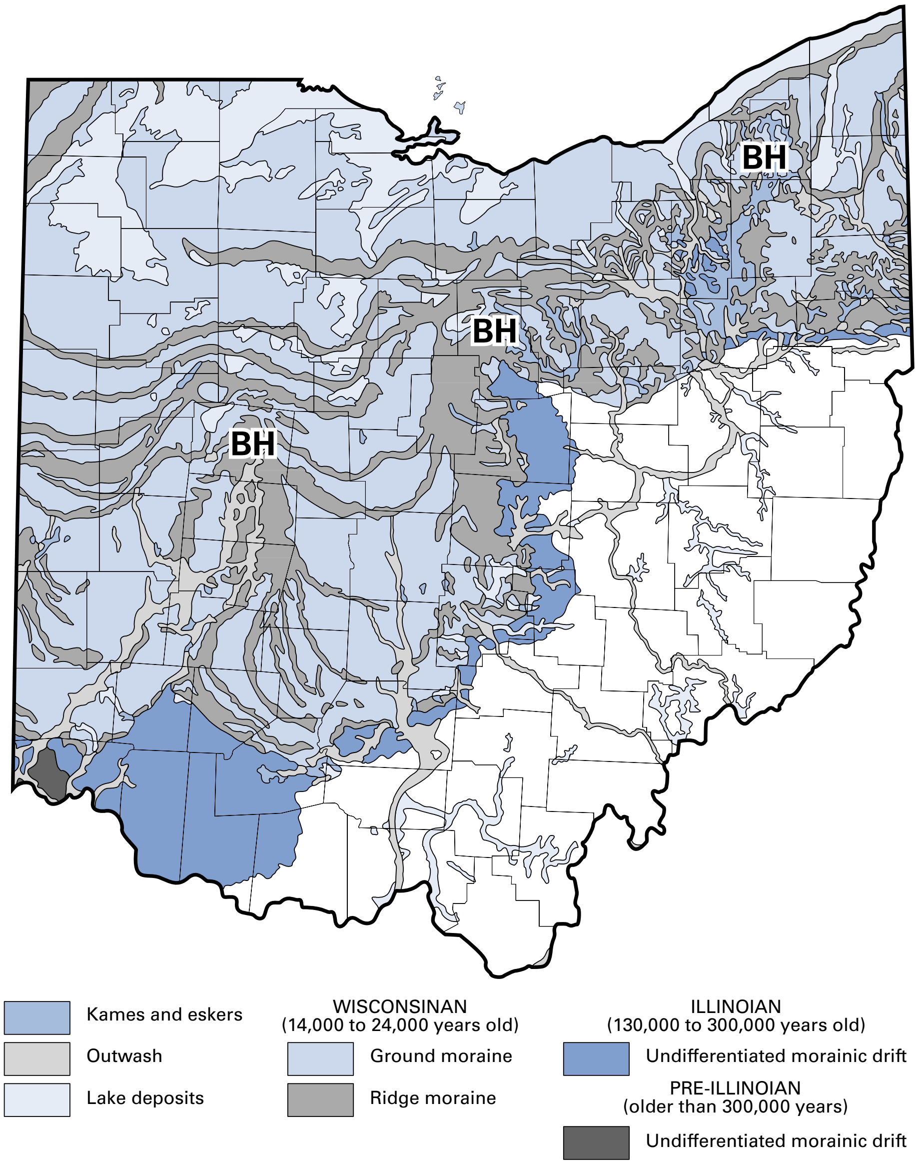
Shaded-elevation map of the land surface of Ohio with glacial boundary. This surface represents the top of the drift when calculating drift thickness. Note the smooth landscape of glaciated northern and western Ohio compared to the high-relief landscape of unglaciated southeastern Ohio. Modified from Powers, Laine, and Pavey, 2002.

isting drainage systems, and deposited additional drift. The upper surface of the drift has been leveled off by wave action of a post-glacial, high-level ancestral Lake Erie. Drift thickness in this area is generally less than 50 feet and varies less than other parts of the state. However, in the extreme northwest corner of Ohio, in Williams County and portions of Defiance County, drift ranges from 160 to 330 feet thick because of numerous moraines that formed along the northwestern edge of the Erie Lobe.

In western Ohio, draping linear features of thick drift, called ridge moraines, formed along the temporarily stationary ice-front as glacial sediment was released from the ice. These bands of thick drift define the lateral dimensions of glacial ice lobes, particularly those of the last Wisconsinan ice sheet. Many ridge moraines in western and northeastern Ohio have a draped appearance because south-flowing ice, impeded by bedrock highlands, moved more easily along major lowlands. This caused moraines to stack up on the north side or on top of the bedrock highlands, but spread down into adjacent lowlands. The numerous resistant bedrock highlands in northeastern Ohio caused ridge moraines to be especially arcuate and stacked close together.

Southeastern Ohio is unglaciated and devoid of ice-deposited sediment (glacial till). Many southeastern Ohio valleys, however, carried huge volumes of glacial meltwater away from the ice front and toward the Ohio River. In the process, many of these valleys were at times made deeper by the erosive force of fast-flowing meltwater streams, and at other times were partially filled with outwash deposits of silt, sand, and gravel. Some valleys in unglaciated Ohio contain thick deposits of clay and silt that accumulated on the bottoms of lakes that formed when glacial ice blocked the flow of rivers or when rapidly accumulating meltwater sediments blocked the mouths of smaller tributaries and streams.

Overall, the drift-thickness map reveals the immense, ground-moraine dominated areas of Ohio covered with less than 50 feet of glacial drift. Ice-deposited Wisconsinan-age ridge moraines generally contain drift between 50 to 160 feet thick. Limited areas of unusually thick drift between 160 to 726 feet are largely the result of deep bedrock valleys filled with drift except for extreme northwest Ohio where thick morainic deposits dominate the landscape.



*Glacial map of Ohio showing the distribution of the glacial sediments and their relative ages. Note glaciated northern and western Ohio, unglaciated southeastern Ohio, and the position of the glacial lobes and the Lake Erie Basin. Bedrock highlands (*BH*) impeded the southward advance of glacial ice causing moraines to form a lobate configuration. Modified from Pavey and others, 1999.*

CONSTRUCTION OF THE MAP

Two digital layers are required to generate the drift-thickness map: the surface-elevation layer and the bedrock-topography layer. The land-surface topography, is based largely on digital data derived from the U.S. Geological Survey's National Elevation Dataset (30 meter grid spacing). These data have been modified extensively by the Division of Geological Survey to replace the anomalous level-one grid areas in the National Elevation Dataset.

The bedrock-topography layer is one of the products resulting from a multi-year effort by the Division of Geological Survey to map the bedrock geology of Ohio. Elevation contours and more than 162,000 data points from the 788 bedrock-topography maps were digitized and compiled for the glaciated portions of the state and for the valleys beyond the glacial boundary. The bedrock-topography contours were digitally converted in the ARC GIS environment into a continuous grid model (60 meter grid spacing). Uncolored areas of southeastern Ohio represent extensive portions of unglaciated Ohio where the land surface and the bedrock surface are essentially the same.

A grid of the digitized bedrock-topography contours was subtracted from a grid of the land-surface Digital Elevation Model to derive a third grid (60 meter grid spacing) representing the thickness of the drift. This grid surface was shaded from the northwest, slightly above the horizon, to produce the appearance of a three-dimensional surface.

The *Shaded drift-thickness map of Ohio* is a fascinating and detailed statewide depiction of the thickness of Ohio's glacial sediments. Anyone interested in geology or the natural history of Ohio would be interested in obtaining this map. Professional geologists and engineers that have a need to know drift thickness would find this map useful as an initial data source.

A page-size version of the *Shaded drift-thickness map of Ohio* is available for viewing or downloading from the Ohio Division of Geological Survey Website (map in .pdf format). Copies of the detailed, wall-size version of the map may be ordered for $15 plus $4.00 handling (add $1.50 for mailing tube if map is to be sent rolled) and $1.02 tax (Ohio addresses only at 6.75%). Orders can be placed with the ODNR, Division of Geological Survey, 4383 Fountain Square Drive, Columbus, OH 43224-1362, telephone: 614-265-6576.

FURTHER READING

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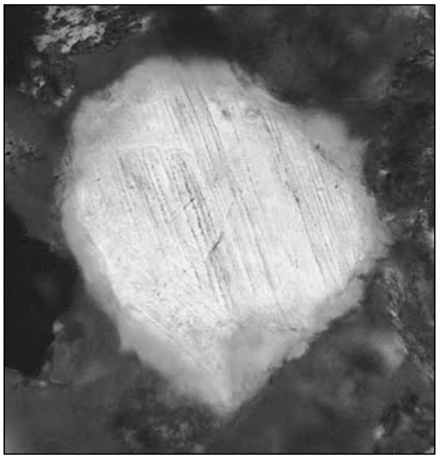
THE THRILL OF DISCOVERY—PDFS HOLD THE KEY

"I found them! I found them!" Dick Carlton excitedly proclaimed as he rushed into my office one dreary February morning in 1997. What did you find I asked? "PDFs, lots of them in the breccia sample collected at 1,439 feet in the central uplift core [DGS 3274]." We rushed down the hall to the microscope waiting in the petrography laboratory. I sat down and, for the first time, gazed at PDFs in the tiny, gray-to-straw-colored quartz grains. Dick explained that planar deformation features, or PDFs for short, are very thin lines or lamellae of amorphous silica aligned along crystallographic planes of quartz. Under the microscope, they appear as dark, closely spaced, parallel lines cutting across each quartz grain. PDFs commonly form multiple sets of parallel lines. Each set crisscrosses other sets of PDFs. Dick said, "It looks like there are at least two or three sets in most grains, and you know, PDFs are only found in the fractured and deformed rocks adjacent to or within craters formed by the impact of a meteorite or comet." At that moment, I realized that Dick had found unequivocal evidence that a meteorite or comet impact played the major role in the origin of the Serpent Mound Disturbance (SMD).

Dick's major discovery of PDFs was first published for a scientific audience in *Earth and Planetary Science Letters* in 1998 and was reported again in 2003 as part of Ohio Division of Geological Survey, Report of Investigations 146, *Subsurface geology of the Serpent Mound disturbance, Adams, Highland, and Pike Counties, Ohio.* Renewed interest in the geology of the SMD began in the fall of 1991 when oil- and gas-consultant Arie Janssens suggested that the Ohio Department of Natural Resources, Division of Geological Survey organize a consortium of interested geologists from government, academia, and industry to investigate the geology and origin of the SMD. A consortium was created and, after a series of meetings, tentative plans were proposed to drill a core hole through the faulted and fractured sedimentary rocks of the SMD into the Precambrian igneous and metamorphic basement rocks below, conduct geophysical studies including seismic lines over the central uplift of the SMD, and acquire existing seismic data and two core holes drilled by John L. Carroll Exploration in 1979. In 1992, Paragon Geophysical Corporation acquired and donated a seismic profile that crossed the central uplift and joined a seismic profile of the eastern portion of the SMD donated by Columbia National Resources in 1989. Unfortunately, limited funding did not allow new core drilling into the SMD. In 1993, Michael Hansen of the Ohio Division of Geological Survey successfully completed negotiations for the transfer of 5,022 feet of core from Carroll's Eichorn, Illinois core repository to the Ohio Division of Geological Survey core repository in Columbus. In 1995, Doyle Watts and his student Belgasum El-Saiti were granted funding from the Royal Society of London to investigate the origin of the SMD by logging the two rock cores drilled by John L. Carroll Mineral Exploration, reprocessing and interpreting the available seismic profiles, and conducting additional geophysical and paleomagnetic studies. In 1997, Ohio Division of Geological Survey staff geologists Mark Baranoski, Richard Carlton, and Gregory Schumacher were contracted to organize, measure, and describe the Carroll cores and three cores drilled in the northern part of the SMD by Cominco American Corporation; select samples for mineralogical, paleomagnetic, and thin-section analysis; and assume a major role in the writing of an Ohio Division of Geological Survey Report of Investigations.


Quartz grain showing two sets of PDFs. The sample containing this grain was collected at 1,439 feet in core DGS 3274.

Several years in the writing, RI 146 is the first study to examine the highly fractured, faulted, and brecciated sedimentary rocks buried within the SMD to a depth of nearly 3,000 feet. The report begins with an overview of our current knowledge of the geology of the SMD and describes the objectives of this study. The authors provide a comprehensive review of previous studies examining the surface and subsurface geology of the SMD and note that August F. Foerste is the first geologist to map the complex geology of the SMD (See *Ohio Geology*, 2003, No. 2). The report then describes the depositional and stratigraphic framework and structural setting of southern Ohio prior to the formation of the SMD. The body of the report provides detailed megascopic, microscopic, and geochemical descriptions of the rocks present in the Carroll and Cominco American cores and includes general discussions of the data from available oil and gas cuttings and from geophysical logs in the SMD region. Later chapters discuss the reprocessing and interpretation of the donated seismic reflection profiles, the results of new regional gravity, magnetic, and paleomagnetic investigations surveys conducted by Watts and El-Saiti. The RI concludes with a discussion of the origin of the SMD and presents a model describing the sequence of major structural events occurring during its formation. RI 146 contains 26 figures including many photographs illustrating the highly complex fracturing, faulting, and brecciation observed in the cores. There are five tables that summarize data examined, previous studies describing the geology of the SMD, and major brecciated intervals in each of the John L. Carroll cores. Three plates provide lithologic and structural information on the geologic units involved in the SMD and seismic reflection data. Four appendices include: a glossary of terms, an overview of the lithostratigraphy of southern Ohio, a core description checklist, and sample descriptions of thin section blanks. The report may be ordered from the Geologic Records Center of the Survey, 4383 Fountain Square Dr., B-2, Columbus, OH 43224-1362; telephone: 614-265-6576; fax: 614-447-1918; e-mail: geo.survey@dnr.state.oh.us. Price is $20.00 plus $4.00 postage and handling and sales tax of 6.75% for all non-tax exempt Ohio orders. Visa and MasterCard are accepted.

FURTHER READING

Carlton, R.W., Koeberl, Christian, Baranoski, M.T., and Schumacher, G.A., 1998, Discovery of microscopic evidence for shock metamorphism at the Serpent Mound structure, south-central Ohio: confirmation of an origin by impact: Earth and Planetary Science Letters, v. 162, p. 177-185.

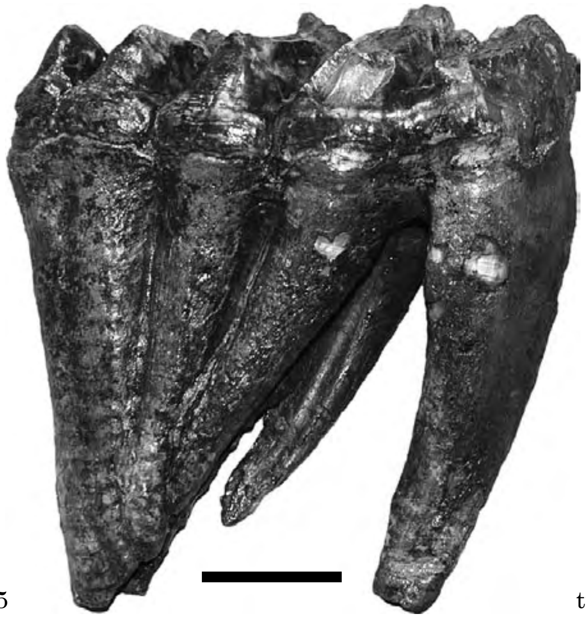
—*Gregory A. Schumacher*

MASTODON MOLAR DISCOVERED IN FAIRFIELD COUNTY

On a chilly Sunday morning in late December 2003, Fairfield County resident Gary Graham, was walking along the rippling waters of a local stream when he noticed a large dark object glistening just inches below the surface. Slowly and carefully, Gary removed the brownish gray sand and gravel surrounding the object to reveal a huge tooth approximately 8 inches long, 4 inches wide, and 8 inches high. Initially, it reminded him of a human molar with two rows of projecting cone-like cusps separated by v-shaped furrows. However, a human molar has only four cusps, not the ten present on this tooth. Each cusp was encased in shiny black enamel that ended at the top of carrot-like roots that were 5 to 6 inches long. Some cusps had areas of enamel that were worn away.

Later that morning, Gary returned home and told his family about his discovery. Their first reaction was that he was joking until he showed them the specimen. "What type of animal would have a tooth that big?" they asked. "I would say a prehistoric mastodon," he replied.

The next morning, Gary's daughter Jamey, an intern with the Ohio Department of Natural Resources, Division of Wildlife, showed the tooth to Wildlife employees, Tim Daniel and Vicki Ervin. They realized the tooth was from a prehistoric animal and suggested that maybe one of the geologists from the Division of Geological Survey might be able to identify the tooth. A short time later, Jamey and Tim met with Survey geologists, Scott Brockman, Rick Pavey, and Greg Schumacher, who quickly confirmed Gary's theory that the huge tooth once belonged to a mastodon. They went on to explain that rapid drying could damage or destroy the tooth and suggested to Jamey that her father contact Dale Gnidovec, collections manager and curator of the Orton Geological Museum of The Ohio State University, for assistance in properly preserving the specimen.



The well-preserved Graham mastodon molar. The gum line, represented by a thin white line, separates the carrot-like roots from the shiny black enamel covering the upper surface of the tooth. Scale bar is 5 cm.

Tuesday morning, Gary and Jamey met with Dale at the Orton Museum. He explained that mastodons were elephant-like creatures that roamed Fairfield County thousands of years ago during the Ice Age. Adult mastodons stood about 9 feet high at the shoulder and probably weighed in the neighborhood of 4 tons. Four stout legs supported their massive head and body. Two curving tusks and a long trunk protruded from the base of their head.

Dale continued, the worn areas on this ancient molar are the consequence of the mastodon's diet of tough twigs and branches of spruce and other conifers. In addition, the mastodon probably grazed on softer aquatic vegetation that flourished in the many lakes and bogs that dotted Ohio's periglacial landscape.

Mastodons died out about 9,500 years ago. Scientists are not sure what caused their extinction. Some suggest that mastodons were unable to adapt to changing food sources as the conifer forests of the frigid Ice Age gave way to the deciduous forests of the present-day climate. Others theorize that efficient Paleo-Indian hunters may have hunted Pleistocene mastodons, their distantly related mammoth cousins, and other large mammals to extinction.

Dale concluded his comments by explaining that mastodon or mammoth remains are rare fossils in Fairfield County. He referred to a copy of Jane Forsyth's 1963 article "Ice Age Census" published in the *Ohio Conservation Bulletin* for the mastodon or mammoth remains found in Fairfield County. Jane listed two: a single mastodon or mammoth tusk found southeast of Lancaster in 1928 and a single mammoth molar discovered in the city limits of Lancaster in 1960.

Gary and Jamey asked Dale if he would be willing to properly preserve the tooth. He agreed and indicated that the specimen would have to be slowly dried over the course of a couple of weeks before it would be ready for a coating of protective sealant.

In mid-January 2004, Dale and employees of the Ohio Division of Geological Survey traveled to Fairfield County to photograph Gary with his discovery and to examine the discovery site—a meandering stream cut into a broad and level flood plain. Survey geologists examined the strata exposed at the discovery site and noticed a thin layer of dark brown to black clay containing black wood fragments. Over the clay layer was 2 or 3 feet of rusty brown sand and gravel that was capped by the sandy soils of the modern flood plain. They speculated that the molar likely came from the clay layer because of its dark coloration—otherwise the tooth would have been a rusty brown color like the overlying sand and gravel.

After some discussion, the geologists suggested a theory describing how the tooth may have been preserved in the dark clay layer. Along the margins of a glacier, especially as the ice retreated, many lakes were formed in low spots across the landscape or by the melting of isolated, stagnant ice blocks. Over time, aquatic plants slowly colonized these lakes. With the passing of each growing season, plant remains accumulated on the lake bottoms and become buried with other sediments washed into the lakes. Rotting plants quickly depleted oxygen levels in the lake sediments below the level required for survival of oxygen-dependent bacteria and fungi. Many types of bacteria and fungi acquire the necessary nutrients for survival through the decomposition of plant and animal remains. Decomposition of plant material will occur in anoxic environments with little or no oxygen, but at rates much slower than in oxygen-rich environments. So, in the oxygen-starved lake sediments, plant remains accumulate faster than anoxic processes can break them down. Slowly, after thousands of growing seasons, anoxic sediments fill the lakes with mucky silts and clays containing abundant plant and animal fossils.

Mastodons frequently waded into such lakes to feast on the lush aquatic vegetation. Occasionally, their feet became mired in the black, mucky silts and clays on the lake bottom. Most mastodons escaped this trap, but some unfortunate animals drowned, died of starvation, or fell victim to predators: such as saber tooth cats or Paleo-Indian hunters. Their remains sank into the oxygen-depleted muck—a perfect environment for the preservation of teeth and bones. It is no coincidence that many of the best-preserved remains of Ice-Age animals are found in black lake sediments filling old glacial lakes (See *Ohio Geology,* Winter 1990 and Winter 1992).

Gary Graham displaying the mastodon molar he discovered in 2003.

In the case of this molar, the decomposition process began anew when it was eroded from the black lake clay layer and was deposited in the oxygen-rich, sand-and-gravel sediments of the modern stream. Over time, stream transport, abrasion, and decay would have destroyed this beautiful specimen. Gary and Dale short-circuited the decomposition process, saving the molar for the enjoyment of Ohio's citizens.

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—Gregory A. Schumacher
and Gary R. Graham

AWARDS *continued from page 2*

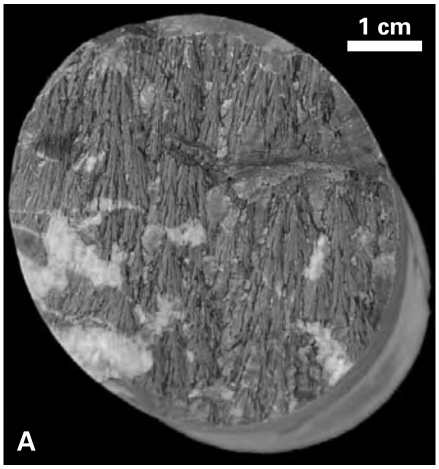
Division's geologic mapping, petroleum geology, and map production and sales efforts that benefit the public in need of geologic information.

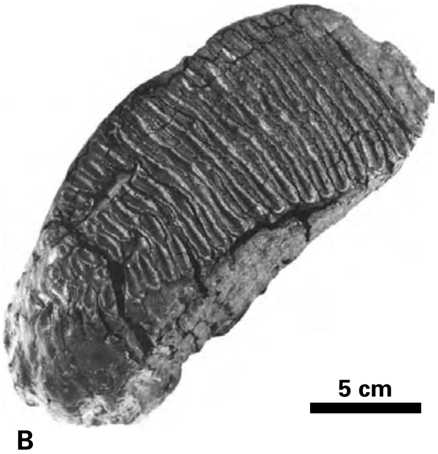
Dr. Michael Hansen received an award for Outstanding Service to the Profession and was recognized for his 30 plus years of public service at the Division of Geological Survey and his contributions to the study of the geology of Ohio. Mike founded *Ohio Geology* and compiled it for 20 years, writing articles on a wide range of geologic topics including fossils, mineral resources, meteorite impacts, coal and coal mine dogs, mastodons, gold and diamonds in Ohio, landslides, the history of the Ohio Geological Survey, and much more. He has written popular Educational Leaflets on the Ice Age in Ohio, earthquakes in Ohio, and guides to the geology along I-77 and Route 23 and numerous scientific papers. As the Division's public relations officer, Mike patiently answered thousands of questions from the general public on a spectrum of geologic topics. He worked hard to establish OhioSeis, the Ohio Seismic Network, and he continues to monitor and study earthquakes in Ohio.

Congratulations to Dennis and Mike for the deserved recognition of their career achievements and legacies of dedicated public service.

TEST YOUR KNOWLEDGE

Test your knowledge is an interactive feature that challenges readers to identify some aspect of Ohio's geology. Below are three photos to identify.





We will post *Test your knowledge* answers on our website at <http://www.dnr.state.oh.us/odnr/geo_survey/> about six to eight weeks after the mailing of this issue of *Ohio Geology*. Complete answers and information on where to learn more will be provided in the next issue of *Ohio Geology*.

Did you know . . . ?

Did you know . . . Ohio had six earthquakes in 2003, but worldwide, there are about 25,000 earthquakes per year or about 50 per day? The year 2003 was one of the deadliest for earthquakes since 1990 with 43,819 earthquake-related deaths confirmed by the United Nations Office for Coordination of Humanitarian Affairs. (Source: U.S. Geological Survey)

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