Ohio Geology

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ANCIENT METEORITES

by Michael C. Hansen, Ohio Geological Survey
and
Stig M. Bergström, Department of Geological Sciences, The Ohio State University

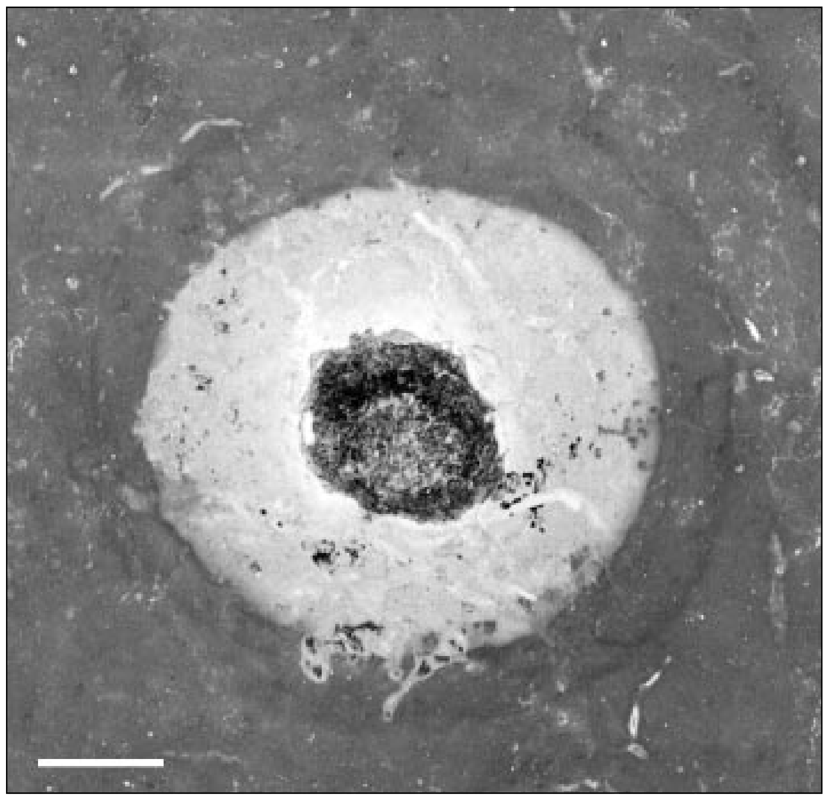
Perhaps it is a perversity of the human psyche, but we seem to have a fascination with disastrous events that have the potential to destroy life as we know it. The media are eager to exploit these primal fears, no matter how remote the probability.

Meteorites, asteroids, and comets have become the potential "destruction of the decade." Recent spectacular events such as the chain of cometary bodies known as Shoemaker-Levy crashing into Jupiter in 1994, the passage of the comet Hale-Bopp in early 1997, and claims of evidence of life preserved in Martian meteorites have captured the public's imagination.

Perhaps more mundane, but of no small scientific interest, are the meteorites occasionally found accidently in a field or collected after a fireball has streaked across the sky. Most of these finds are the result of comparatively recent events, certainly within a few tens, hundreds, or perhaps thousands of years. But what about the geologic past? We now recognize a large number of ancient meteorite craters on the Earth's surface, some of which contain meteoritic material, but, most certainly, large numbers of small meteorites must have fallen into the Paleozoic seas or delta swamps that covered Ohio and sank into the bottom muds. Estimates of the present rate of meteorite bombardment range from 100 to 1,000 metric tons of meteorites per day for the entire Earth, 1 percent of which are large enough to be recovered as macrometeorites. Shouldn't a meteorite occasionally be found in limestone or shale exposed in Ohio, or any other area for that matter?

However, the record of fossil meteorites (those with ancient terrestrial ages) is very meager, especially considering the amount of meteoritic material that has fallen in the last few hundred million years. An iron meteorite was reported in 1942 from Miocene sediments in Georgia; an iron meteorite was discovered in the 1950's during the drilling of an oil well in Eocene rocks in Texas; iron meteorites having terrestrial ages of 3.1 and 2.7 million years (my) were discovered in Alabama and Chile, respectively; relict chondrules (small, spherical, remelted mineral inclusions) of stony meteorites have been reported from bauxites of Mesozoic age in the Ural Mountains of Russia; and in 1996 a nickel-bearing meteorite fragment of Late Cretaceous age was recovered from a sediment core in the northwestern part of the North Pacific Ocean.

Remarkably, Sweden recently has produced a number of fossil meteorites from Ordovician limestones. The first specimen discovered was a 4-inch-diameter chondrite (stony meteorite containing chondrules) found in Middle Ordovician limestone (about 463 my) in 1952 in central Sweden but not reported until 1981. The nearly 30 years between its discovery and announcement was attributed to the fact that no one recognized it as being a meteorite until 1979. The specimen is in contact with the shell of a nautiloid cephalopod, which the meteorite's describers speculate may have been struck and killed by this extraterrestrial body. In 1988, another Swedish meteorite, named Österplana 1, was discovered in Lower Ordovician limestone about 5 million years older and 300 miles distant from the first specimen. This discovery prompted additional searching in the quarry where Österplana 1 was found. Twelve more meteorites have now been recovered from the Thorsberg limestone quarry near Österplana in the Kinnekulle region of southern Sweden.



Stony meteorite, Österplana 7, from Early Middle Ordovician limestone at the Thorsberg quarry near the village of Österplana, Sweden. The meteorite is the dark area in the center and is surrounded by a ring of light-colored limestone that resulted from chemical reactions between the meteorite and fluids in the limestone. Photo by Stiftelsen Paleo Geology Center, Lidköping, Sweden, courtesy of Andrew Sicree. Bar scale is 5 cm.

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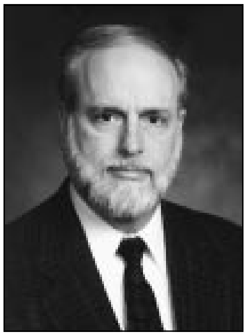

Thomas M. Berg, Division Chief and State Geologist

From The State Geologist...

Thomas M. Berg

STRATEGIC PLANNING AT GEOLOGICAL SURVEYS

When I began my working career at another state geological survey back in 1965, I clearly remember the level of planning that went into my first geologic-mapping assignment. It was pretty minimal and rather painless. I recall standing in front of a statewide geologic map together with a more senior geologist, examining a block of quadrangles in the middle of the state. We agreed that we would map the geology of a certain quadrangle, and started out. There was no analysis of societal need, and we did not prepare a written step-by-step plan or budget.

How things have changed! Over the years, as I moved into the administrative world, accountability, planning, and paperwork increased to mammoth proportions. This bureaucratic growth was spurred by the very justifiable public outcry for efficiency and fiscal responsibility in government. The burgeoning desk work was accompanied by numerous training courses in project management, planning, performance evaluation, managing professionals, employee development, problem-solving and decision-making, change management, dispute resolution, time management, and on and on. I built up a library of books on management principles, excellence, motivation, goal-setting, assertiveness, supervision, peak performance, delegation, conflict management, team-building, conducting meetings, etc., etc. One administrative system that was rigorously imposed was *management by objectives* (*MBO*), a seemingly rigid procedure whereby all time was accounted for and project or program goals and objectives were written in advance, accompanied by carefully constructed Gantt charts. Quarterly performance reviews were required. In theory, MBO was not bad, but it was difficult to apply to the geological sciences and to geological-survey work because of the many unknowns involved with geologic mapping, mineral-resource investigations, and geoenvironmental analyses. The discovery of a previously unknown fault or the abrupt lateral disappearance of a coal seam could easily add days or weeks to a project. It was not easy to apply MBO to geological-survey work. A sudden geologic event such as a landslide or an earthquake could easily throw a geologist's schedule out the window. It was difficult to convince geological-survey employees that planning by MBO was a continuum which had to be flexible and continually updated and revised.

At the 1997 National Meeting of the Association of American State Geologists (AASG), Director Gordon Eaton of the U. S. Geological Survey (USGS) explained how federal agencies must comply with the *Government Performance and Results Act* (*GPRA*), which is Public Law 103-62, passed by Congress in 1993. This law requires federal agencies (including the USGS) to develop a 5-year strategic plan with a complete mission statement and long-term goals and objectives. The plan must explain the approach to achieving the goals, along with a detailed schedule. GPRA further requires a description of key external factors that may affect the accomplishment of goals and objectives. In addition to the 5-year plan, an annual performance plan must be submitted, followed later by an annual program performance report. The performance report explains what was accomplished and how it was accomplished, what was not accomplished, and why each unmet objective was not attained. This seems to be a thoroughly "top-down" management system. It also seems as though it will require a huge investment in time, human resources, and fiscal resources just to comply with GPRA. I am looking forward to hearing more about GPRA and whether or not it can be successfully applied to a geological survey with all the unknowns of nature looming over it. Or will it turn out to be a glorified and greatly expanded MBO process that will leave no time for administrators at USGS to assure that good geoscience is being applied for the public good? Time will tell.

In Ohio state government, Governor Voinovich and his administrative team have implemented a very successful process of problem-solving and decision-making called *Quality Service through Partnership (QStP)*. The intent of QStP is to involve both management and nonmanagement employees in implementing systems of government that will provide service to citizens in the spirit of high-quality performance and teamwork espoused by W. Edwards Deming. All staff members at the Division of Geological Survey have been trained in QStP, and most have participated in problem-solving teams. In the Ohio Department of Natural Resources (ODNR), strategic planning is being carried out using all the principles of QStP. The planning is being applied to high-priority, natural-resource concerns that involve the many, diverse divisions within the Department. A distinct success for ODNR is the recent completion of a strategic plan for management of Ohio's Lake Erie coast. The strategic initiatives and action steps involve many divisions working together to provide quality service in managing the rich heritage of the Lake Erie coast.

Within the Division of Geological Survey, a 10-member QStP team has been empowered to develop a 5-year strategic plan. The group is called *Team 2002*, and includes a healthy mix of management and nonmanagement people. The Survey's 5-year plan will ultimately receive the input—and we hope—the consensus of all staff members of the Division. Although we are all oriented toward the geology of Ohio, we are diverse and entertain differing opinions. But we expect everyone to be heard, and are committed to working toward consensus. When the Geological Survey strategic plan is published, it will be distributed widely so that our customers will know what to expect of us. If you, our readers, wish to have input to the Survey's strategic plan, please contact me by writing, calling (614-265-6988), or sending me e-mail (thomas.berg@dnr.state.oh.us)

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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

World Wide Web: http://www.dnr.state.oh.us/odnr/geo_survey/

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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

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OHIO Department of Natural Resources

George V. Voinovich, Governor
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continued from page 1

A 10-foot-thick section of the Holen ("Orthoceratite") Limestone, of Early Middle Ordovician age, is extracted at the Thorsberg quarry and sawed into thin slabs that are used for windowsills and floor tile. Quarry workers discarded slabs with impurities, such as the meteorites, until Professor Maurits Lindström of the University of Stockholm alerted them to save such slabs. The 12 specimens were recovered between 1992 and 1996. Ten of the specimens were recovered from a 2-foot-thick bed of limestone and may represent a single meteorite fall. The other three specimens were recovered from two separate levels above this layer. Seven of the specimens, collected between 1993 and 1996, are from a quarried limestone volume of no more than about 127,000 cubic feet. Most of the specimens are now on display at the Stiftelsen Paleo Geology Center in Lidköping, Sweden.

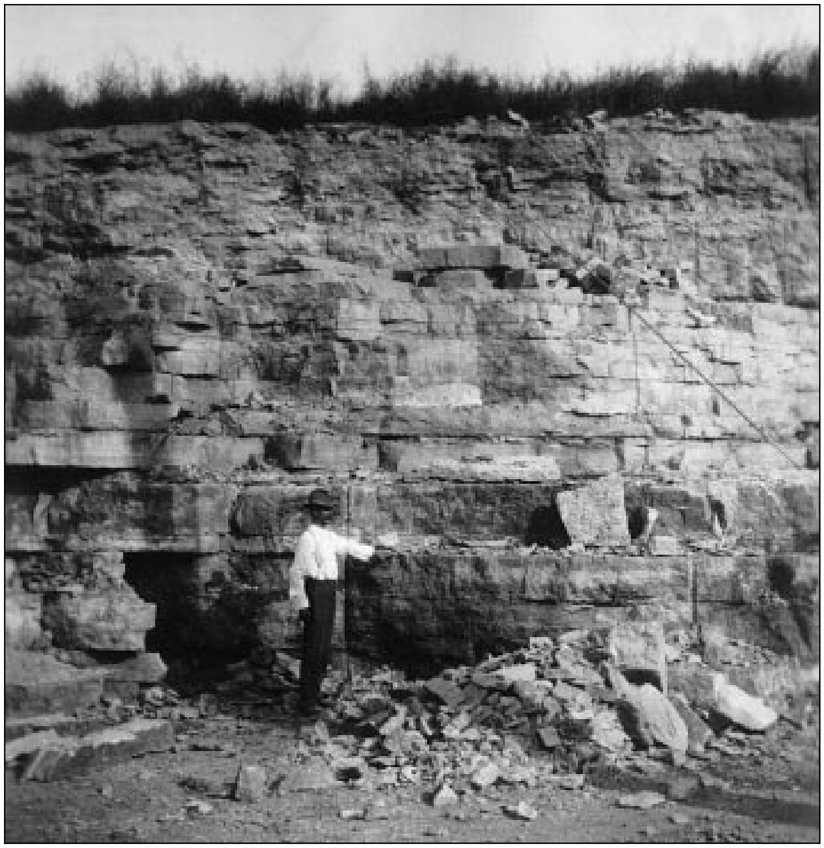
The Thorsberg quarry meteorites range in size from about 0.5 to 3.5 inches in diameter and have been almost completely replaced (pseudomorphosed) by calcite and barite. The dark, reddish-brown meteorite masses look like iron nodules surrounded by a zone of lighter colored limestone and would be mistaken by many people for common sedimentary features. However, they contain grains of chromite and have a high iridium content, among other confirming characteristics of extraterrestrial origin.

There is thus the intriguing possibility that meteorites might be found in limestones and shales across Ohio. That such specimens have not previously been reported is probably a matter of recognition rather than presence. Reddish or brownish iron-stained masses are not uncommon in many Ohio rocks and would easily be dismissed by geologists or quarry workers as weathered secondary iron minerals or an ironstone concretion. Some of these masses, however, may be meteorites.

In an attempt to recover fossil meteorites, a unique recovery system, The Meteorite Recovery Project, has recently been instituted by Pennsylvania State University. Andrew A. Sicree, curator of the Earth and Mineral Sciences Museum at Penn State, and David P. Gold, a Penn State geology professor, have contacted coal companies and other mineral producers, requesting them to watch for unusual iron fragments collected by powerful electromagnets used to separate "tramp" iron (machinery fragments and such) from the coal before it is crushed. The electromagnets are capable of recovering a peanut-sized iron fragment from beneath 2 feet of coal on a rapidly moving conveyor belt.

Sicree and Gold estimate that about 3.5 ounces of magnetic macrometeorites should be expected in every 16,000 tons of coal recovered. They assume that if only 5 percent of these were strongly magnetic, then each million tons of coal should yield about 10.5 ounces of meteorites.

Sicree and Gold point out that many fossil meteorites may not look like classic examples, as they may be heavily corroded or have a secondary covering of pyrite or other minerals. The Division of Geological Survey has attempted to assist the Meteorite Recovery Project by including a letter and flyer with copies of the 1995 *Report on Ohio mineral industries*, sent to Ohio mineral producers in the fall of 1996. So far, no meteorites have been recovered by this project. Mineral producers who find suspected meteorites should contact Andrew Sicree, The Meteorite Recovery Project, Penn State University Earth & Mineral Sciences Museum, 122 Steidle Building, University Park, PA 16802, telephone: 814-865-6427.



Typical quarry exposure of Paleozoic carbonate rock in Ohio. Silurian-age Springfield and Cedarville Dolomites in the Mills Brothers quarry, southwest of Springfield, Clark County, Ohio. Such exposures could potentially yield fossil meteorites. Photo by J. A. Bownocker, 1909.

ACKNOWLEDGMENTS

We thank Andrew A. Sicree of Pennsylvania State University for his assistance with this article.

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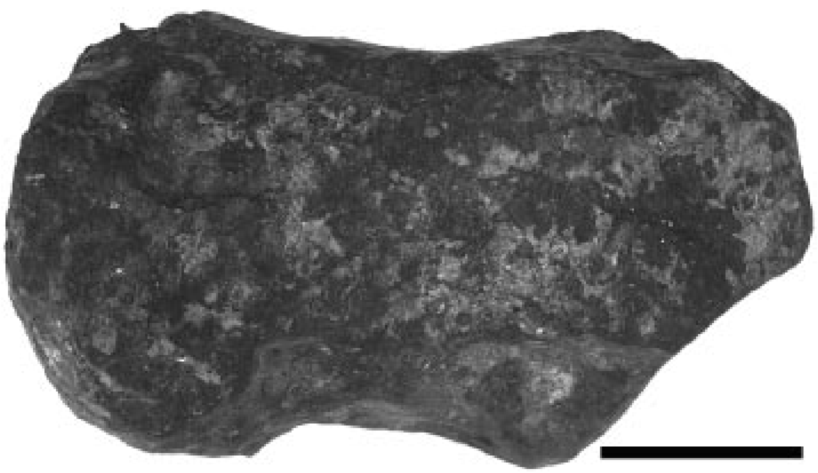
AUGLAIZE COUNTY METEORITE

Meteorites are thought to fall with equal frequency on the surface of the Earth; therefore, any area should be as likely to produce a specimen as any other area. Obviously, most of these objects fall into the oceans that cover three-quarters of the Earth's surface. A densely populated and intensely cultivated area such as Ohio should produce a number of specimens, but only seven have previously been reported from the state (see *Ohio Geology*, Summer 1983). Two of these, the New Concord meteorites in Muskingum and Guernsey Counties in 1860 and the Pricetown meteorite in Highland County in 1893, were recovered after their fall was witnessed. The remaining five specimens were discovered as surface finds in Hamilton, Montgomery, Clark, Preble, and Wayne Counties. Only one of these was found in this century.

We learned recently that a portion of an Ohio meteorite was being offered on the commercial market. This specimen was discovered in Auglaize County in 1975 but remained in the owner's possession for more than 20 years. The meteorite weighed 13.07 pounds when found by a farmer in his field near Kossuth, Auglaize County. Little additional information is available about the discovery of the specimen. A portion of the specimen is being studied at the University of California, Los Angeles. John Martin, Director of the Oklahoma Meteorite Laboratory in Stillwater, originally obtained the specimen from its discoverer and prepared it for scientific study.



View of the 13-pound Kossuth meteorite found in 1975 in Auglaize County. This iron meteorite is classified as a IVA octahedrite. The rusted surface shows shallow surface pits, termed regmaglypts. It is the first meteorite known to be recovered from Ohio since 1941. Photo by John Martin, Oklahoma Meteorite Laboratory. Bar scale is 4 cm.

The Kossuth meteorite is an iron meteorite, of a type termed an octahedrite, in which the nickel-iron alloys of kamacite and taenite form an octahedron. It retains its general surface features of atmospheric sculpturing in the form of shallow pits, known as regmaglypts, created by frictional heating during its fiery passage. The surface of the specimen is dark to reddish brown and shows oxidation (rusting). It is apparent that the meteorite fell within the last few hundred years or it would have been significantly altered or perhaps destroyed by the weathering process in the moist climate of Ohio.

The Kossuth meteorite is the first documented Ohio find since discovery of the New Westville (Preble County) iron meteorite in 1941 and only the second Ohio specimen in this century. This rate of discovery suggests the rarity of meteorites, although it is probably not a true indicator of their abundance. It is likely that many specimens are not recognized as something sufficiently different from a terrestrial rock to warrant examination by an expert. However, specimens of presumed meteorites are brought to the Survey offices, as well as to museums and geology departments in the state, on a regular basis. At the Survey, we probably average about 10 specimens annually. Most of the presumed meteorites are "meteorwrongs," that is they are terrestrial rocks or industrial by-products such as slag. A few of the specimens have had sufficient similarity to a meteorite that we have sent them to the Smithsonian Institution for chemical and mineralogical analysis. These specimens have turned out to be highly weathered terrestrial iron.

METEORITE CHARACTERISTICS

Meteorites are planetary fragments, most of which originate in the asteroid belt between the orbits of Mars and Jupiter, that are captured by Earth's gravity and fall to the surface. These fragments are termed meteoroids (asteroids, if they are large) while in space, meteors during their flaming atmospheric passage, and meteorites when they have landed on Earth's surface.

Meteorites are distinctive rocks, unlike any rocks of terrestrial origin. However, there are many terrestrial rocks that have a superficial resemblance to meteorites and are commonly mistaken for them. Included in this category, especially in Ohio, are spherical carbonate concretions (see *Ohio Geology*, Fall 1994) that are common in some Upper Paleozoic rocks; ironstone and pyrite nodules common in some Mississippian and Pennsylvanian rocks; sandstones in which certain zones are impregnated with iron cements deposited by ground water (case hardening); unusual-appearing glacial erratics, especially igneous and metamorphic rocks of Canadian origin; and industrial by-products such as slag, clinkers, cinders, certain ore concentrates and alloys, and pig iron from furnaces of the last century.

There are three major groups of meteorites based on their composition. The most common type is stony meteorites, which are composed of silicate minerals and contain scattered grains of metallic iron and, commonly, small spherical mineral inclusions called chondrules. Stony meteorites account for about 90 percent of recovered specimens. Stony meteorites may be any shape or size but are commonly blocky to rounded. When fresh, their surface is dark owing to a fusion crust formed by frictional heating during atmospheric passage. This crust quickly weathers to a rusty-brown color.

Iron meteorites account for about 8 percent of recovered specimens but are the most easily recognized. They are strongly magnetic and extremely heavy when compared to terrestrial rocks of similar size. They are black when fresh and weather to a rusty brown. A polished edge, when etched with acid, will reveal interlacing bands of iron, called Widmanstätten patterns—a feature not seen in terrestrial iron.

Stony-iron meteorites are the least common variety and consist of nearly equal proportions of iron and silicate minerals. One type of stony-iron meteorite is a pallasite—an iron matrix surrounding crystals of greenish, glassy olivine.

Although geologists are familiar with most "meteorwrongs," many people do not have such familarity with a multitude of rock types. There are a few characteristics that will enable most people to easily determine if an unusual rock might be a meteorite. First, meteorites are extremely heavy when compared to most terrestrial rocks (such as limestone or sandstone) of similar size. Second, almost all meteorites are strongly to weakly magnetic because of their iron content. Iron and stony-iron meteorites are strongly magnetic, whereas stony meteorites are moderately to weakly magnetic. This characteristic can easily be tested using a simple household magnet.

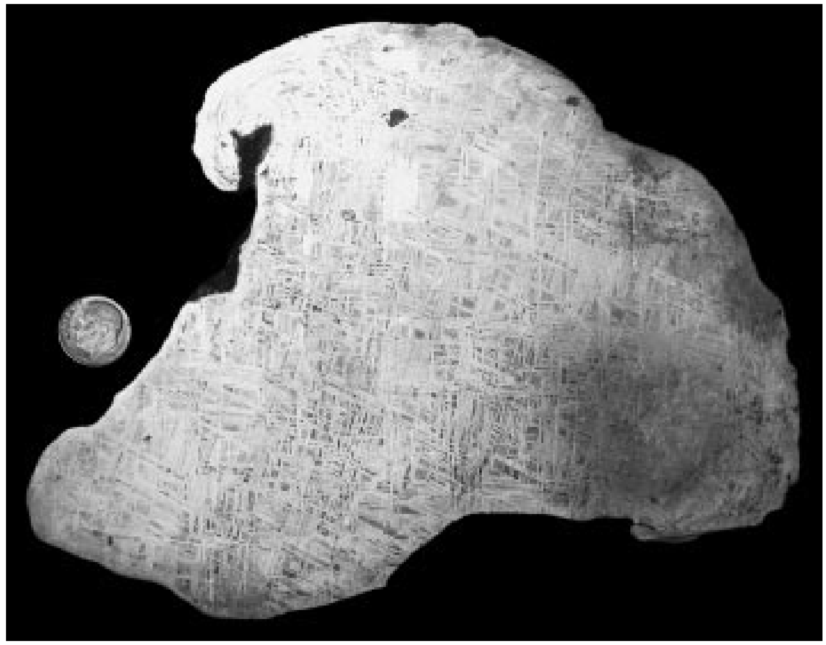
Meteorites may be of almost any size and shape, but some of them show a definite streamlined shape acquired during atmospheric passage or a pitted surface resembling thumbprints in clay. These pits (regmaglypts) were formed when certain minerals were vaporized, leaving a pit, when the meteorite was heated by the atmosphere. A freshly fallen meteorite will exhibit a black fusion crust. Within a short time this crust begins to rust, giving a brownish appearance to the surface. The interior of a meteorite is gray to silvery metallic when a broken, sawed, or filed-off corner is examined.

Some presumed meteorites may require chemical testing in order to confirm their identification. In particular, some irregular-shaped, rusted pieces of terrestrial iron may resemble meteorites. A diagnostic test on these specimens is the presence of nickel, which is absent in terrestrial iron except for some specialty stainless steels. Such testing is carried out at a number of educational and research institutions at no charge to the individual submitting the specimen. The Division of Geological Survey will do preliminary screening of presumed meteorites and, if appropriate, forward specimens to the proper expert for confirmation.

SEARCHING FOR METEORITES

Because meteorites land with statistically equal frequency on the Earth's surface, they are no more likely to be found in one area or another. However, surface finds are more likely to be discovered in agricultural areas where freshly plowed fields make such specimens more visible. In Ohio, the majority of agriculture is carried out in the glaciated two-thirds of the state. A complication in locating meteorites in these glaciated areas is the large number of glacial erratics that litter the fields, making it difficult to spot the odd rock. The Pleistocene glaciers may have concentrated meteorites in some areas where the glacier was forced to override a topographic high. In Antarctica, it has been discovered that such impediments cause meteorites imbedded in the ice to rise to the surface of the glacier along glide planes and thus be concentrated in certain areas. The Bellefontaine outlier in Logan County may have acted in this fashion, although no meteorites have been found so far in this area.

The greatest likelihood of finding a meteorite is after a witnessed fall in which the most probable landing area can be determined. However, there is considerable confusion about the landing area by observers of fireballs (bolides) because of the lack of knowledge about the velocities and altitudes associated with meteors. The common misconception is



Sliced iron meteorite from South Africa that has been etched to show the distinctive Widmanstätten pattern of interlocking crystals. Such structures are unknown from specimens of terrestrial iron. Photo courtesy of Orton Geological Museum.

that a fireball struck the ground just beyond a distant row of trees or buildings, whereas in reality the meteorite may have landed hundreds of miles downrange from its apparent landing point.

Meteoroids enter Earth's upper atmosphere at cosmic velocities of about 10 to 26 miles per second. At an altitude of about 60 miles, the atmosphere is sufficiently dense to initiate frictional heating to more than 3,000°F. At this point, the meteoroid begins to glow brightly and becomes a meteor as the surface material of the body vaporizes. An object only a foot or two in diameter may create a glowing plasma ball that is hundreds of feet in diameter, thus creating a bright fireball that is visible over a wide, sometimes multistate, geographic area.

Meteoroids up to about a ton in weight are sufficiently slowed by the density of the atmosphere at altitudes of several miles (retardation point) that they lose their cosmic velocity and descend to Earth only under gravitational acceleration. They quickly achieve terminal velocities of only 200 to 400 miles per hour and land on the surface at comparatively low speeds.

When meteoroids reach the retardation point, they lose their incandescence; larger bodies commonly fragment into a number of pieces, which fall to Earth in an elliptical dispersion pattern. The dispersion ellipse may have a long dimension of several miles, and meteorites may be recovered from anywhere within the strewn field. The largest meteorites are found at the far end of the ellipse because these fragments lose their cosmic velocity at a lower altitude owing to their larger mass.

Sonic booms and a variety of complex sounds commonly accompany the fragmentation of a meteorite and may be heard over an area of a few tens of miles from the retardation point. Witnesses to the actual fall of meteorites have described whistling or hissing sounds as the rocks fall to Earth.

Observers who witness the extinguishing of a fireball directly overhead (zenith) and hear sonic booms or other sounds are likely to be close to the

Fragment of the New Concord meteorite that fell on May 1, 1860. More than 30 fragments, having a collective weight of 500 pounds, were recovered from a strewn field on the Muskingum-Guernsey County border that measured 3 x 10 miles. This fragment of the stony meteorite clearly shows the dark, unweathered fusion crust and thumbprintlike regmaglypts. Photo courtesy of Orton Geological Museum, The Ohio State University.

impact point of meteorites. Observers who see fireballs streak across the sky and disappear over the horizon are many miles away from the impact point, although most are convinced that they saw the fireball strike the ground just beyond the trees in the distance. Many presumed meteorites are brought in for identification after the observer walks the ground on the other side of the tree line and finds a rock that looks unusual to them and they assume it to be the fallen meteorite.

The chances of recovery of meteorites from a witnessed fall are slim, but the odds are increased when the probable landing area can be defined through the reports of multiple observers. If each observer notes the direction of travel of the fireball and its altitude above the horizon (a closed fist at arm's length represents about 10°), multiple observations can determine the path of the fireball. Observations that note that the fireball "burned out" directly overhead and sounds were heard begin to define the probable dispersion ellipse.

If you think you have found a meteorite, first apply the criteria noted above, especially magnetic susceptibility and specific gravity (weight). If the specimen appears to be a genuine meteorite, have it examined by an expert. The Division of Geological Survey serves as an intermediary. Specimens are examined at no charge and, if the specimen appears to be a meteorite, it will be sent to a scientific institution for further testing by meteorite researchers. The specimen remains the property of the submitter and will be returned with a letter indicating the identification.

—*Michael C. Hansen*

FURTHER READING

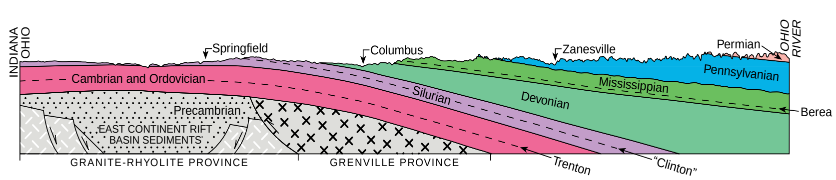
Norton, O. R., 1994, Rocks from space: Missoula, Montana, Mountain Press Publishing Company, 449 p.

Availability of limestone and dolomite for sulfur sorbent use

The Division of Geological Survey recently published Information Circular No. 59, *Limestone and dolomite availability in the Ohio River Valley for sulfur sorbent use, with observations on obtaining reliable chemical analyses*. This publication was produced by the Ohio Valley Mineral Consortium, a group consisting of the six state geological surveys bordering the Ohio River—Illinois, Indiana, Kentucky, Ohio, Pennsylvania, and West Virginia. The consortium, assisted by the aggregate and crushed-stone associations of the region, compiled information on the availability of high-purity limestone and dolomite and the reliability of chemical analyses of carbonate rocks for potential use in SO_2 emission control at coal-fired power plants.

This 16-page report contains maps depicting the distribution of high-purity carbonate rocks in the region, tables showing the status of geologic mapping and carbonate chemical analyses at the state geological surveys, and several photographs of power plants and mineral operations. Information Circular No. 59 was authored by David A. Stith and Thomas M. Berg of the Ohio Survey, Curtis H. Ault and Norman C. Hester of the Indiana Survey, Garland R. Dever, Jr., of the Kentucky Survey, John M. Masters of the Illinois Survey, Samuel W. Berkheiser, Jr., of the Pennsylvania Survey, and Claudette M. Simard of the West Virginia Survey. It is available from the Division of Geological Survey for $2.00 plus $2.00 mailing. Copies sent to Ohio addresses must add $0.12 state sales tax.

New page-size bedrock map of Ohio available



Cross section from new page-size map.

The Division of Geological Survey has produced a new version of the color page-size geologic map of Ohio. The map shows the distribution of geologic systems in the state on a county base map. The most significant addition to the map is a new east-west cross section of the state that depicts the East Continent Rift Basin in Precambrian rocks of western Ohio. This rift basin has been known only since the 1980's and its full extent delineated only recently. The map is available for $0.10.

New Survey logo

After a number of months of consideration, the Division of Geological Survey has a new logo. Division Chief Thomas M. Berg convened a committee to establish criteria for a new logo and to evaluate designs submitted by 62 students from the Columbus College of Art and Design. The choice was difficult because of the number of outstanding submissions. The committee, consisting of Thomas M. Berg, Jonathan A. Fuller, Michael C. Hansen, Edward V. Kuehnle (Chairman), Glenn E. Larsen, James M. Miller, and Lisa Van Doren, finally chose a design by Karen Griffith, a junior from Bucyrus who is majoring in advertising and graphic design. She was awarded a cash prize for her efforts.

The new logo portrays a stylized State of Ohio outline that has a sedimentary sequence superimposed over the bedrock-geology map of the state. The new logo is adaptable to both color and black-and-white graphics at a variety of scales.

O.D.N.R GEOLOGICAL SURVEY

Thomas M. Berg congratulates Karen Griffith on her winning design of the new Division logo.

Field workshop on fractures in till

Several Ohio earth science and consulting organizations are sponsoring an intensive hands-on workshop this summer entitled "Field Workshop on Joints and Fractures in Ohio Tills: Site Investigation Techniques and Field Hydraulic Measurements." This one-day field demonstration will be held Thursday, August 28, 1997, from 8:00 a.m. to 4:15 p.m. at The Ohio State University Molly Caren Agricultural Center near London, Ohio (site of the annual Farm Science Review).

The workshop will concentrate on identifying fractures (joints) in till and testing their hydraulic properties. Both direct and indirect methods will be used to document the fractures. The demonstration will include (1) coring and core description techniques: Bowser-Morner, Inc., will core vertical and angled holes on site with both a traditional auger and a new rotosonic unit; (2) test-pit examination: a large, walk-in, 12-foot-deep pit, engineered with multiple benches, will be constructed to view joints in three dimensions; and (3) azimuthal resistivity survey and gamma logging: the Indiana Geological Survey will demonstrate these geophysical techniques which characterize site-specific fracture patterns. There will also be demonstrations and evaluations of a variety of in situ hydraulic conductivity tests run on the fractured tills.

Cost for the workshop is $40 ($25 for students). The number of participants is limited to 75. For additional information and registration materials contact Scott Brockman at the Ohio Geological Survey, telephone: 614-265-7054, e-mail: scott.brockman@dnr.state.oh.us.

The workshop is sponsored by the Ohio Academy of Science, the Association of Ohio Pedologists, Bowser-Morner, Inc., and Bennett & Williams Environmental Consultants, Inc. Other agencies and organizations that will be represented are the Ohio Department of Natural Resources, The Ohio State University and the Ohio Agricultural Research and Development Center, Indiana University, and the U.S. Department of Agriculture Agricultural Research Service and Natural Resources Conservation Service.

FOSSILS OF OHIO A BIG SELLER

Readers of *Ohio Geology* should have received the Fall 1996 issue during May 1997. This long-held issue, announcing the availability of Bulletin 70, *Fossils of Ohio*, was sent as soon as the reprinted volumes of the fossil book arrived. Sales have been brisk and many complimentary comments have been received.

Fossils of Ohio may still be purchased for $18.00 plus $1.03 tax (if mailed to an Ohio address) and $3.00 mailing from the Division of Geological Survey, 4383 Fountain Square Drive, Columbus, OH 43224-1362. Credit-card orders may be placed by calling 614-265-6576.

HANDS-ON EARTH SCIENCE

by Sherry L. Weisgarber
(614)265-6588

DO ROCKS LAST FOREVER?—PART 2

The Winter 1997 issue of *Ohio Geology* discussed weathering, the destructive processes that change the character of rock at or near the Earth's surface. The two main types of weathering are mechanical and chemical. Processes of mechanical weathering (or physical disintegration) break up rock into smaller pieces but do not change the chemical composition. The most common mechanical weathering processes are frost action and abrasion. The processes of chemical weathering (or rock decomposition) transform rocks and minerals exposed to water and atmospheric gases into new chemical compounds (different rocks and minerals), some of which can be dissolved away. The physical removal of weathered rock by water, ice, or wind is called erosion. In nature, mechanical and chemical weathering typically occur together.

Two experiments that illustrate the effects of mechanical and chemical weathering are presented below. Two more experiments were featured in the Winter 1997 issue of *Ohio Geology*.

SHAKE IT UP (MECHANICAL WEATHERING)

What you need: 15 rough, jagged stones that are all about the same size, three containers with lids (like coffee cans), three clear jars, a pen, paper, masking tape.

What to do: (1) Separate the stones into three piles of five. Put each pile on a sheet of paper. (2) Label each pile A, B, or C. Label each can and jar A, B, or C. (3) Fill Can A halfway with water and put in the stones from Pile A. Do the same with Can B and Pile B and Can C and Pile C. Let the stones stand in the water overnight. (4) The next day, hold Can A in both hands and shake it hard 100 times. (5) Remove the stones from Can A with your hands and pour the water into Jar A. Observe the stones and the water. (6) Give Can B 1,000 shakes (you can rest between shakes). Remove these stones and pour the water into Jar B. Observe the stones and the water. (7) Do not shake Can C. Remove the stones and pour the water into Jar C. Observe the stones and the water. (8) Compare the three piles of stones and the three jars of water.

What to think about: How do the piles of stones differ? Why? Which pile acted as the control? Why? How do the jars of water differ? How does this show what happens to stones that are knocked about in a fast-moving river?

What should have happened: The stones that were shaken should have more rounded edges than the stones that weren't shaken, and the stones in Can B should have rounder edges than the ones in Can A. Both jars should have some sediment in the bottom, but Jar B should have more sediment because more shakes would have broken off more bits of rock. The same thing happens to rocks that are carried along in rivers or are tumbled about by waves.

STEEL WOOL AND WATER (CHEMICAL WEATHERING)

What you need: Three shallow dishes, three pieces of steel wool, salt, water, gloves.

What to do: (1) Place each piece of steel wool in a shallow dish (wear gloves because steel wool can give splinters). (2) Pour equal amounts of water over two of the pieces of steel wool. Leave the third piece dry. (3) Sprinkle one of these wet pieces with plenty of salt. (4) Observe and compare the pieces every day for a week.

What to think about: What happened to each piece of steel wool? Which piece changed the most? Why do you think the steel wool changed? Which piece of steel wool acted as the control? What does this experiment have to do with weathering?

What should have happened: When iron gets wet, the water acts as an agent to speed up oxidation (oxidation occurs when oxygen combines with another substance). In this case, oxygen in the water combined with the iron in the steel wool to form an iron oxide, or rust. Rust is a weaker material than the original metal and erodes quickly. When salt is added to the water, it speeds up the oxidation of iron. So, the steel wool in the salt water should have changed the most. The same thing happens to rocks that contain iron as happens to cars during northern winters when salt is put on the roads.

SOURCE: *Ranger Rick's Nature Scope: Geology: the Active Earth*, National Wildlife Federation, 1988.

Ohio Geology

Ohio Department of Natural Resources
Division of Geological Survey
4383 Fountain Square Drive
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