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Ohio Geology

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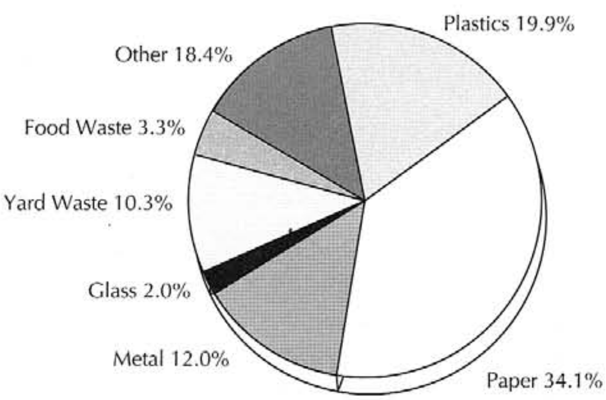
GEOLOGY AND THE WASTE STREAM

by Michael C. Hansen

The tremendous diversity of manufactured consumer products and foodstuffs that are integral to a prosperous society, or deemed necessary or desirable for our lifestyle, create an ever-increasing burden on the environment because of the waste generated in packaging or residue remaining after such items have been used or manufactured. According to the Division of Litter Prevention & Recycling of the Ohio Department of Natural Resources, Ohioans generate about 14 million tons of solid waste per year, which is about 1 ton per person, or 7 pounds per person per day.



Types of solid waste in the waste stream, by percent of volume. Data from U.S. Environmental Protection Agency, courtesy of ODNR, Division of Litter Prevention & Recycling.

In the simpler days of the last century, the common methods of disposal of these wastes were open burning, dumping in the nearest stream, or simply to "throw it over the hill." Increases in population, an ever-increasing amount of waste, and environmental awareness and legislation have made such practices not only objectionable but illegal.

The Summer and Fall 1992 issues of *Ohio Geology* focus on the importance of geology in the proper and safe disposal of waste materials in Ohio. Of the potential disposal sites for these materials—air, water, or Earth—the latter one is commonly the most desirable because the items are isolated from contaminating the other two. Disposal of waste in the Earth, either at near-surface depths or in deep horizons, requires detailed knowledge of the heterogeneous rocks or sediments that are perceived to eternally encapsulate these materials.

The primary methods of disposal of these wastes is in landfills for solid waste, deep injection wells for liquid waste, or incineration. The first two methods of disposal require numerous geologic considerations for safe isolation of the waste products. The accompanying article by Dennis N. Hull on solid waste and landfills provides detailed information on geologic considerations for this type of waste disposal. The fall issue will feature an article by Lawrence H. Wickstrom on liquid waste and injection wells.

Geology is a fundamental and critical factor in decisions on locations of landfills and injection wells. An increasing public fear of contamination, whether real or imagined, and the lack of geologically suitable sites has made it increasingly difficult to establish waste-disposal facilities in the state. To a degree, we are all NIMBY's (Not In My Back Yard). We all enjoy the consumer products that create the waste, and many people depend on the manufacture of these products for a livelihood, but no one wants the waste cached for eternity in their back yard. Unfortunately, there are no "free lunches"; that is, if we want the amenities we must deal with the residue. Proper understanding and investigation of site geology, along with technical design, can insure that the waste materials will remain safely entombed for millennia.

However, detailed geologic information is not always instantly available. Such information, commonly presented most effectively in the form of geologic maps, requires systematic, detailed field investigations which define and delineate rocks and sediments. This process is time consuming and may require several years from the beginning of field work to publication of the map.

Kentucky is the only state to have complete geologic map coverage, and many states lag far behind Ohio in availability of detailed geologic mapping. Although the expenditures for such mapping are sizable, the benefits far exceed the cost. In Kentucky, the benefit-to-cost ratio has been estimated to be 50:1.

Geologic mapping of the state of Ohio has been a fundamental goal of the Division of Geological Survey since its inception in 1837. Numerous maps have been published through the years, mostly on a county scale; however, limited staff and funding have prevented completion of detailed geologic mapping of the entire state.

The Division recently changed the focus of geologic mapping and has begun production of reconnaissance-quality bedrock geologic quadrangle maps that are made available on an open-file basis. Existing stratigraphic and drilling data, along with limited field checking and core drilling, are used in the preparation of these maps. It is our goal, by 1994, to complete reconnaissance bedrock geologic mapping in all 788 7.5-minute quadrangles in the state.

Many areas of Ohio, particularly in the western part of the state, will, for the first time, have geologic maps of the bedrock available. Consumers of geologic information, including those involved with waste disposal, will be able to make a preliminary geologic assessment of the bedrock in any area in the state for potential waste-disposal sites. Not only will the process be streamlined, but the possibility for such sites to be located in geologically unsuitable areas should be eliminated. Mapping of glacial and other unconsolidated sediments, which cover about two-thirds of the state, has been completed in northeastern Ohio and in scattered areas in other portions of the state. However, large areas of the state still lack detailed maps of unconsolidated sediments. Completion of this mapping is of critical importance to proper siting of landfills.

Recycle, Ohio!

OHIO Department of Natural Resources

George V. Voinovich, Governor • Mike DeWine, Lt. Governor • Frances S. Buchholzer, Director

FROM THE STATE GEOLOGIST . . . by Thomas M. Berg

GEOLOGY AND WASTE MANAGEMENT

Every activity we undertake results in some form of waste by-product. All living systems generate some form of waste that has been controlled before the time of humanity by natural recycling. Humanity's historically poor performance in emulating the balance of our planet and its natural recycling processes is well known. We humans have "trashed" vast areas of the land for thousands of years, and have evolved a disposable, "throwaway" mindset that is wasting unbelievable volumes of water, mineral, plant, and energy resources.

Progress is being made in changing human behavior regarding nonrenewable resources, waste, and recycling. As a child growing up in the 1940's and 1950's, I remember the occasional trip to the "city dump," where huge piles of glass, metal, paper, tires, yard waste, and garbage were tossed onto remote and uninhabited tracts—out of sight, out of mind. It was commonplace to see roadsides littered with all kinds of debris and accepted as our way of life. Contamination of ground water, non-point-source pollution of the environment, or the need to recycle were not common topics of conversation. The theoretically convenient "disposable" marketplace grew to untenable proportions in the 1960's and 1970's, and persists today. Now, many Americans have an elevated consciousness of the impact of our waste products on land, water, and air. But we still have a long, long way to go in educating ourselves about reducing the waste stream.

The state geological surveys and the U.S. Geological Survey (USGS) play vital roles in the management of waste products. First, they must participate fully in educating citizens about the need to reduce waste, conserve mineral and fuel resources, and recycle as much as possible. Geologists are well aware of the limited space available in the Earth for permanent disposal of waste and have a professional responsibility to "lead the way" in reducing waste. Second, they must provide the geological information needed to make wise decisions about locating waste-disposal sites. Third, they have a responsibility to accurately assess the location, quantity, and quality of our mineral and fuel resources in order to maximize their availability for future generations.

In waste management, as in other Earth-related issues, the geological surveys serve as an essential bridge between the academic/research geoscience community and the consulting geological community. Consulting geologists carry out the detailed, site-specific analysis and characterization of potential waste sites. Academic geoscientists conduct the basic research needed to characterize the stability and reactivity of rock and soil materials used in waste disposal. They analyze the movement and reactions of waste fluids and gases within rock or soil bodies. The geological surveys provide regional, statewide, and national geologic information that helps consulting geologists, land-use planners, and zoning officials "zero in" on sites that appear geologically most suitable for waste disposal. The geological surveys must understand the research results coming from the academic arena and they must understand the required specific parameters for waste-disposal siting.

The Ohio Geological Survey furnishes basic bedrock and surficial geologic maps and accompanying reports that are needed for the proper location and development of waste-disposal sites. The Survey also maintains information on the subsurface geologic framework of the state from the near-surface environment down through the thick sequence of Paleozoic strata and well into crystalline "basement" rocks several miles beneath the land surface. This kind of information developed by the state surveys and the USGS is unique because no other agency has the ability or the interest to integrate and interpret the masses of geologic data used for regional, statewide, or national geologic assessments. No private organization could profitably undertake the broad scope of geological research conducted by a state geological survey or the USGS. What private firm would be willing to release its hard-earned information at no charge to the public? Tax-supported geological surveys benefit all citizens, not just a privileged few who can afford to pay for them.

State geological surveys are increasingly called upon to protect the public interest by providing unbiased and fully integrated geologic information needed for the safe, long-term disposal of waste. Snowballing requests for geologic information are becoming more and more difficult to answer in the current economic climate. Geology and the Division of Geological Survey play a critical role in the proper management of our waste stream. That role needs to be widely recognized and supported.

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RECYCLING AND SOLID WASTE MANAGEMENT: AN OHIO CHALLENGE

by Paul R. Baldridge, Acting Chief ODNR, Division of Litter Prevention & Recycling

Americans will discard approximately 180 million tons of municipal solid waste (MSW) this year. Ohio contributes about 7.6 percent of this amount, or 13.7 million tons, which is higher than the national average per capita share of MSW. In addition, Ohio will be a net importer of solid waste from out of state. More than 1.8 million tons will be shipped into Ohio's landfills and incinerators.

These statistics force Ohio to review solid-waste management in the state and develop plans to affect the quantity of solid waste generated and the methods of solid-waste management. The focus is on strategies to reduce waste generation, reuse products and materials, recycle materials, and buy products with recycled content. These strategies become components in a loop that creates a supply and demand for recycled materials and products and requires a change in habit and routine practices for the average Ohioan.

PAST PRACTICES

Some have suggested the solid-waste saga begins with the question, "Did Adam eat the apple core?" Because there were no solid-waste managers or litter enforcement officials present to ascertain the answer, a review of the more recent solid-waste-management story will prove to be more enlightening. Today, Americans are heavily reliant upon the use of landfills for waste disposal. Landfills receive 73 percent of our waste, whereas incinerators burn 14 percent. The remaining 13 percent is recycled.

Some industries have been recycling for decades. The steel industry has incorporated recovered steel into new steel production since the turn of the century. Steel production typically contains 25 percent recycled material for cars, cans, and appliances; structural components may be 100 percent recycled content. Steel is easily recovered from the waste stream. Magnets recovered 15,525 tons from the Columbus trash-burning power plant in 1991, resulting in avoided disposal costs of approximately $500,000.

Glass has been recycled and used to manufacture new containers for decades. There is no loss of quality in new containers made from recycled glass. The energy savings is significant when manufacturing new glass with recovered material. Recycling 1 ton of glass saves the equivalent of 9 gallons of fuel oil.

RECENT PRACTICES AND CURRENT TRENDS

More solid-waste demands are being placed upon fewer solid-waste facilities. In 1991, there were 107 solid-waste facilities in Ohio, a drop from 358 in 1971. The regulation of and sensitivity to the operation of landfills has forced closure of some facilities, delays in opening new ones, and even abandoned efforts in planning future ones. An assessment of current landfill capacity reveals 25 counties with five or more years of capacity, leaving 63 counties with less than five years of landfill capacity; approximately half of those have no capacity for MSW. However, in many states, the problem of decreasing landfill capacity is related more to public pressure than to a lack of safe locations.

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THE ROLE OF GEOLOGY IN THE MANAGEMENT OF OHIO'S SOLID WASTE

by Dennis N. Hull

A standard question nongeologists ask upon encountering a geologist in the field is, "Finding any gold?" Many people still think of geologists as "forty-niners"—eccentric loners on a quest for the mother lode. This image of geologists is beginning to fade, however, as geoscientists emerge across the nation as primary participants in determining how and where we will dispose of or otherwise process the burgeoning volumes of waste generated by our society. We Americans constitute just 5 percent of the world population but generate 40 percent of the world's waste in our consumption of 50 percent of the world's annual production of raw materials.

Increasing environmental awareness during the 1960's, 1970's, and 1980's has had some impact on virtually every aspect of our lives, yet it has not significantly reduced the rate at which we have grown more wasteful. Between 1960 and 1986, the amount of waste generated annually in the United States increased by 80 percent. By 1987, Americans were generating 220 million tons of collected residential and commercial waste each year, or about 1 ton of waste each year for every man, woman, and child in the nation.

Although environmental awareness has not substantially stemmed the escalating rate of waste production, it has certainly sensitized us to the dangers of improperly disposed waste. In this regard, environmental awareness has been so "successful" as to make the siting of any solid-waste facility virtually impossible without tremendous organized public resistance. Such public turmoil often finds geologists inextricably caught up in the fray, as they are usually the ones who have the unenviable task of explaining to an angry group of citizens the geologic justification for the placement of a landfill in their community as opposed to a site on the opposite side of the county. It becomes obvious that the geologist is more than a quaint prospector, and now assumes the role of diplomat, negotiator, and environmental-regulations expert in addition to the role of geologist.

THE WASTE STREAM AND THE NEED FOR COMPREHENSIVE WASTE MANAGEMENT

In order to understand the basics of solid-waste management, one must first have a general sense of the types of material which make up the waste stream. The U.S. Environmental Protection Agency reported that in 1990, on the average, municipal solid waste, by volume, was about 34 percent paper products, 10 percent yard waste, 12 percent metals, 2 percent glass, 3 percent food wastes, 20 percent plastics, and 19 percent miscellaneous other materials (wood, wallboard, concrete, rubber, etc.). Packaging alone represents about 50 percent of solid waste by volume or about 30 percent by weight. Although 80 percent of materials in the waste stream is technically recyclable or compostable, the nation in 1989 was burying 80 percent of its solid waste in landfills!

In Ohio, the combined effect of overdependence on landfills, escalating importation of out-of-state waste, and the lack of comprehensive solid-waste management planning led to a landfill capacity crisis in the late 1980's. By 1988, 35 of the state's 88 counties had less than five years of remaining landfill capacity; 28 counties had no solid-waste facilities. Clearly, Ohio had to develop and implement a comprehensive solid-waste-management program immediately if an environmental crisis was to be avoided. Ohio certainly would not want to be the focus of a national solid-waste embarrassment such as the one in which a barge carrying garbage from Islip, New York, sailed the length of the east coast and portions of the Caribbean in search of a facility which would receive and dispose of its cargo—only to be rejected at every port and forced to return to New York.

OHIO HOUSE BILL 592—FOUNDATION FOR SOLID-WASTE MANAGEMENT IN OHIO

On June 24, 1988, Ohio implemented House Bill (HB) 592, a new solid-waste-management law designed to reduce the amount of waste disposed in landfills through reuse, recycling, and waste minimization. The bill authorized the Ohio Environmental Protection Agency (OEPA) to develop and implement a statewide solid-waste-management plan and to coordinate the establishment of single- or multi-county solid-waste-management districts. Each of these districts in turn would be required to prepare and adopt a solid-waste-management plan which would comply with the provisions of HB 592 and the OEPA state plan.

On June 16, 1989, the OEPA, in concert with Ohio's 17-member Solid Waste Advisory Council, adopted a State Solid Waste Management Plan, which is to be evaluated and revised every three years. Major elements of the plan include:

1) revisions to existing criteria for siting of solid-waste-disposal facilities;
2) proposals to develop markets for recycled materials;
3) directives for state government and solid-waste-management districts to recycle, reuse, or reduce 25 percent of their waste within five years;
4) restrictions on landfill disposal of wastes for which other waste-management options are available;
5) proposals for waste-tire management and separation of residential hazardous waste from the solid-waste stream; and
6) discussions on landfill options for the disposition of ash from incinerated solid waste.

Thirty-two single-county and 16 multi-county districts have been formed, and each has or will submit a solid-waste-management plan that will be periodically evaluated and revised. For many districts, the development of a satisfactory solid-waste-management plan has been an extreme challenge. The myriad rules and regulations to be considered in the development of the plans require a broad range of technical expertise which is either not available from district staff or not affordable to acquire. The Solid Waste Program Development and Technical Assistance Section of the OEPA has been established to assist districts in the preparation of their solid-waste plans. Even so, the challenge of incorporating sound geologic and hydrologic principles into district plans has been a formidable task for many districts.

Although HB 592 will not eliminate the need for landfills, the recycling, reuse, and waste-minimization provisions of HB 592 will decrease significantly the amount of waste to be disposed in landfills. For example, HB 592's restriction on disposal of yard waste in 1993 could reduce the volume of the waste stream by 10 percent. Recycling and waste minimization could reduce the volume of the waste stream by another 25 to 35 percent. Incineration of waste, a very popular idea for waste disposal, can reduce the amount of waste to be disposed of in landfills even further; however, 20 percent of waste is noncombustible, and about 25 percent of combusted waste remains after incineration as bottom and fly ash, which typically must be disposed in a landfill.

Solid-waste districts in Ohio.

GEOLOGIC AND HYDROLOGIC CONSIDERATIONS IN SOLID-WASTE MANAGEMENT

Public concern relative to landfills commonly centers on legitimate questions about windblown trash, bird and vermin infestations, odor, dust, noise, aesthetics, traffic, and property devaluation. Ground-water contamination, however, is nearly always the foremost concern. Public acceptance, or at least tolerance, of a landfill is absolutely dependent on a competent demonstration that ground-water contamination will not occur or, if it does, that it will be promptly detected and completely corrected. Such a demonstration is possible only through an excellent design, construction, and operation plan that is in harmony with the geology and hydrology of the landfill site.

Generally speaking, landfills must be sited in areas where the buried waste can be effectively isolated from the ground-water system. Clay-rich materials, either on site or nearby, are required to provide daily and final cover over the waste and to prevent infiltration of rainwater into a landfill. Such materials also are required for construction of a recompacted "soil" or clay liner under a landfill to restrict the flow of ground water into the buried waste or the flow of leachate (a putrescent and toxic liquid formed by the dissolution of buried waste in water) away from the landfill. A synthetic liner (typically 60-mil high-density polyethylene) is placed above the recompacted soil liner to further assure isolation of the buried waste.

Effective isolation of buried waste also is dependent on the structural and functional integrity of a landfill. OEPA regulations require that landfills be located in areas that are geologically stable. Areas prone to mass (downslope) movement, differential compaction of soils, and subsidence (for example, karstic terrain) must be stabilized in order to be approved as landfill sites. Similarly, landfills cannot be sited over underground mines unless it can be demonstrated that there is no significant probability of surface subsidence, nor can they be sited within 200 feet of a geologic fault which has been active in the last 10,000 years. Sandstone and carbonate-rock (limestone and dolomite) quarries and sand and gravel pits are not acceptable as disposal sites because of the high permeability (rate at which a fluid will flow through a porous body) of such materials.

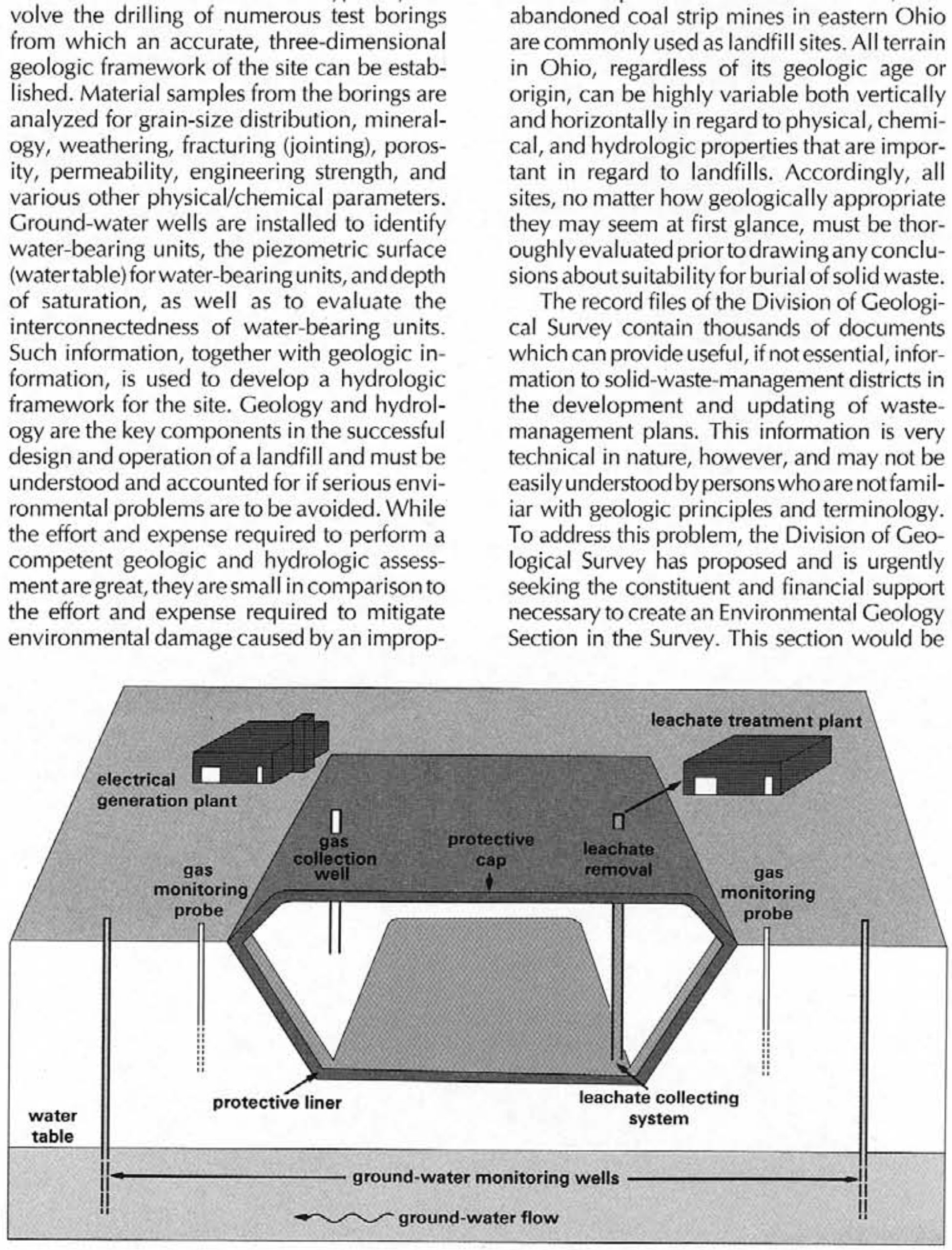
To further assure the hydrologic isolation of a landfill, OEPA regulations prohibit the burial of waste within l,000 feet of a pre-existing water well or developed spring unless (1) the landfill operator controls such water supplies or (2) the supplies are at least 500 feet hydrologically upgradient from the buried waste and the water is used for nondrinking purposes only. In addition, landfills cannot be located above federally designated sole-source aquifers or above unconsolidated (sand and/or gravel) aquifers having the potential to provide 100 or more gallons of water per minute to wells within 1,000 feet of the buried waste. Waste disposal on regulatory floodplains and areas within 200 feet of streams, lakes, or wetlands is prohibited. Landfills cannot be sited so near to public well fields that contaminants escaping from the landfill in ground water could be expected to intersect the wellhead(s) within five years. The bottom of the recompacted soil liner underlying a landfill and the uppermost aquifer must be separated by at least 15 feet of slowly permeable geologic materials. Sociological factors also are reflected in OEPA landfill regulations. For example, waste cannot be buried within 10,000 feet of an airport serving jet-turbine aircraft or 5,000 feet of an airport serving only piston-engined aircraft. Landfills cannot be sited in state or federal parks and recreation areas. Solid waste also cannot be buried within 300 feet of a property line or within 1,000 feet of a pre-existing residence.

In the site-selection process of locating a landfill, such regulatory criteria as those previously described are useful in the preliminary screening or reconnaissance phase of site selection. All areas which cannot meet these criteria are eliminated automatically from further consideration. Areas not excluded during this process become candidates for detailed geological and hydrological assessment.

Detailed site characterizations are time consuming and costly to perform but are absolutely essential in the preparation of an application for a permit to install and operate a landfill. Site characterizations typically involve the drilling of numerous test borings from which an accurate, three-dimensional geologic framework of the site can be established. Material samples from the borings are analyzed for grain-size distribution, mineralogy, weathering, fracturing (jointing), porosity, permeability, engineering strength, and various other physical/chemical parameters. Ground-water wells are installed to identify water-bearing units, the piezometric surface (water table) for water-bearing units, and depth of saturation, as well as to evaluate the interconnectedness of water-bearing units. Such information, together with geologic information, is used to develop a hydrologic framework for the site. Geology and hydrology are the key components in the successful design and operation of a landfill and must be understood and accounted for if serious environmental problems are to be avoided. While the effort and expense required to perform a competent geologic and hydrologic assessment are great, they are small in comparison to the effort and expense required to mitigate environmental damage caused by an improperly designed and/or operated landfill.

In Ohio, the western half and northeastern quarter of the state have been glaciated. Consequently, about 70 percent of Ohio is covered by a blanket of unconsolidated glacial and/or glacially derived sediments. Glaciated uplands mantled with thick deposits of clay-rich till and/or lacustrine (lake) clays are generally candidate areas for consideration as potential solid-waste disposal sites, if other siting criteria can be met. A fairly common former practice of using abandoned sand and gravel pits for burial of solid waste is no longer allowed because of the extreme risk of ground-water contamination. In unglaciated southeastern Ohio, upland areas underlain by thick sequences of Pennsylvanian-and Permian-age shale are commonly selected as sites for waste disposal. Underclays (clay units directly underlying coal seams) also are potentially good materials upon which to site a landfill, thus abandoned coal strip mines in eastern Ohio are commonly used as landfill sites. All terrain in Ohio, regardless of its geologic age or origin, can be highly variable both vertically and horizontally in regard to physical, chemical, and hydrologic properties that are important in regard to landfills. Accordingly, all sites, no matter how geologically appropriate they may seem at first glance, must be thoroughly evaluated prior to drawing any conclusions about suitability for burial of solid waste.

The record files of the Division of Geological Survey contain thousands of documents which can provide useful, if not essential, information to solid-waste-management districts in the development and updating of waste-management plans. This information is very technical in nature, however, and may not be easily understood by persons who are not familiar with geologic principles and terminology. To address this problem, the Division of Geological Survey has proposed and is urgently seeking the constituent and financial support necessary to create an Environmental Geology Section in the Survey. This section would be



Cross section of a landfill. Diagram courtesy of Tony Furgiuele, Waste Management of North America, Inc.

responsible for investigating and reporting on all aspects of Ohio geology relevant to environmental and engineering geology. Among other advantages, it would enable the Survey to develop and dispense highly accurate information relative to solid-waste management in a format that is readily understood and used by nongeologists. The personnel of this section also would be available to respond to requests from solid-waste planners for geologic data or professional opinions.

While management of our nation's waste remains one of the most controversial and divisive of environmental and sociological issues facing American communities today, the conflict has not been entirely undesirable. Vast numbers of people, who once never thought for a moment about where their trash went after it was collected, are becoming actively involved in waste-management decisions affecting their communities. And geologists, still stereotypically viewed by many as thick-spectacled, humorless professors in tweed jackets or lonely, grizzled prospectors, are now emerging more and more as scientists with a major and essential role to play in the preservation of the environmental integrity of the nation.

ACKNOWLEDGMENTS

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continued from page 2

More than 35 percent of the volume of solid waste in U.S. landfills is paper. This category includes all paper and corrugated products. The chart on page 1 shows the volume of the types of solid waste in the national waste stream.

Recycling in Ohio has been on the increase for several years. In a 1990 survey, the Division of Litter Prevention & Recycling of the Ohio Department of Natural Resources found 533 Ohio businesses, municipalities, and counties collecting 23 kinds of recyclables from the public at 869 locations in 85 counties. There also has been strong community interest in curbside recycling. In 1990, there were approximately 143 communities, with curbside recycling-collection programs serving 525,000 households.

The Division of Litter Prevention & Recycling has assisted and encouraged recycling and litter prevention in the state through grant funding since 1981. More than $80,000,000 has been awarded to communities throughout the state. The Division's "Recycle, Ohio!" program encourages recycling at all levels. Although emphasis on recycling at the national and state level is increasing, litter prevention, containment, and enforcement are still valuable initiatives in implementing a comprehensive waste-management and recycling program.

DIRECTIONS FOR THE FUTURE

Even the most adept soothsayers are reluctant to comment about the future of recycling and solid-waste management in Ohio and the nation. The competing forces of economic growth and conservation ethics will meet numerous times on the playing field, influencing future decisions in this area. Several important factors will impact Ohio and the U.S. over the next decade.

First, research and technology related to packaging and manufacturing of virgin and recycled content products can impact consumers and investors. Technological enhancements which substantially increase the production of recycled content goods will someday create an abundant supply of cost-competitive products.

Second, on the demand side, "buy recycled" programs to stimulate markets and research will increase. These programs will establish an equilibrium, where price-per-item is competitive with virgin products. These programs also will educate consumers on the high quality of products manufactured with recyclables and destroy the myths which imply products with recycled content are of inferior quality.

Third, waste-reduction practices are essential, but will, like recycling, require a change in habits and behavior. People and cultures become accustomed to policies, practices, and extravagances that are difficult to change. The trade-off between sacrifice and convenience will most likely go through an adjustment towards the former.

Fourth, policy-makers will soon realize that recycling costs money. These costs, though, represent an investment in the future. The economics of recycling will improve but, more importantly, the conservation of resources and extended landfill life will become increasingly important.

Finally, and perhaps more importantly, legislation has a direct influence over all the above factors and more. The national and state agendas are not clearly defined in many areas of recycling and solid-waste management. Arguments continue to be sharpened and impacts assessed for future programs and policies.

In conclusion, recycling and solid-waste management have evolved into sciences of technology and foundation blocks of public policy. The State of Ohio has a strong commitment to recycling. Communities across the state are also actively supporting recycling programs. While states and communities use different approaches to managing their solid waste and implementing recycling programs, they all have common goals: REDUCE, REUSE, RECYCLE.

For more information on recycling in Ohio, contact the Division of Litter Prevention & Recycling at 614-265-6333.

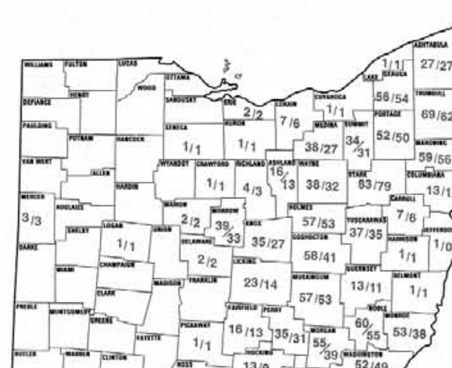
1991 OHIO OIL AND GAS DEVELOPMENTS

by Michael P. McCormac
ODNR, Division of Oil & Gas

Overall permitting activity for oil and gas wells continued to decline in 1991, extending the downturn that began in 1985. The Division of Oil & Gas issued 3,001 permits in 1991, a decline of 12.3 percent from 1990. This total includes permits issued to drill new wells, revised locations, and permits to convert, deepen, plug back, plug and abandon, reissue, and reopen. Breaking a recent trend, August replaced December as the most active permitting month; November was the slowest month. The Division issued 1,378 permits to drill for oil and gas, an 18.9 percent decline from 1990. These permits included 1,246 new permits and 132 reissue permits.

Considering the drop in the number of permits issued, it was no surprise that drilling declined 13 percent. The Division estimates that 1,141 oil and gas wells were drilled during 1991, a decrease of 176 wells from 1990. This total is the lowest since 1969, when 1,109 wells were drilled. Wells were drilled in 46 of Ohio's 88 counties, an increase of six counties from 1990. Although the majority of Ohio wells were drilled by rotary tools (882), cable-tool rigs drilled 110 wells (11 percent) and operated in 21 counties. Cable-tool depths ranged from 207 to 4,336 feet. The average depth per well drilled by cable tool was 2,148 feet; rotary-drilled wells averaged 4,438 feet.

Ohio oil and gas owners/operators submitted 992 well-completion reports, representing 87 percent of the wells drilled in 1991. These reports showed that 854 wells were productive and 138 were dry holes, an 86 percent completion rate. Average well depth was 4,188 feet, a decrease of 164 feet per well from 1990. Total depth of the deepest well drilled was 8,425 feet, in Columbiana County. Thirty additional reports were received for other types of drilling operations.



New wells drilled for oil and gas in Ohio in 1991, by county.

Approximately 11 percent (106) of all wells completed were classified as exploratory wells. Twenty-nine were completed and 77 were dry holes, representing a 27.4 percent success rate. The Cambrian-Ordovician Rose Run and Cambrian Trempealeau accounted for 74 percent of all exploratory drilling. Of the exploratory wells drilled to these zones, 72 percent (56) were categorized as deeper pool wildcats or wildcats. Only 12 of these wells were productive.

1991 DRILLING OPERATIONS BY TYPE OF WELL

Type of hole	*Drilled*	*Converted*	*Total footage*
Productive wells	854	0	3,512,136
Dry holes	138		642,720
Reopened wells	11		0
Lost holes	8		7,084
Gas storage wells	0	2	0
Conventional brine-injection wells	0	4	0
Enhanced-recovery wells	7	5	3,802
Solution-mining wells	4	0	10,323
TOTAL	1,022	11	4,176,065

COMPLETION ZONES

Completion zones ranged from several shallow Pennsylvanian sandstones to the Precambrian basement rock. Washington County again had the most diverse drilling activity. Wells in this county were drilled to six different geologic zones ranging from the Pennsylvanian Cow Run sandstone to the Silurian "Clinton" sandstone.

The number of new wells that were dry in their permitted formation but plugged back to produce a shallower zone declined by 50 percent to 37 wells. Correspondingly, only 25 wells were plugged back from the Rose Run sandstone to the "Clinton" sandstone, a decline of 35 wells from 1990. Seventeen existing wells were plugged back to shallower producing zones, and eight existing wells were drilled to a deeper producing formation.

"Clinton" sandstone

The Silurian "Clinton" sandstone continued to be the most actively drilled zone since 1965. Sixty-five percent (647) of the total wells were completed in this zone. This is the lowest number of "Clinton" wells drilled since 1965. "Clinton" sandstone wells had a 98.6 percent completion rate and averaged 4,442 feet in depth, a decrease of 34 feet per well from 1990. "Clinton" wells were drilled in 29 counties. The top five counties for "Clinton" drilling were Stark (76), Trumbull (62), Geauga (54), Mahoning (51), and Portage (46).

Rose Run sandstone

Drilling to the Cambrian-Ordovician Rose Run sandstone exceeded the 100-well mark for the second consecutive year. Ninety-nine completion reports had been received by the reporting deadline; that number is expected to increase to 120 wells. Although 73 percent of Ohio's estimated 800 Rose Run wells have been drilled since 1981, the dramatic upturn in activity began in 1987. Since then, 498 Rose Run wells have been drilled.

In 1991, Rose Run wells were drilled in 11 counties by 35 operators. Holmes County led the activity with 43 wells, followed by Coshocton (20) and Muskingum (12) Counties. Since 1987, 76 percent of Rose Run dry holes have been plugged back to produce from the "Clinton" sandstone. In 1991, however, only 46 percent of Rose Run dry holes were plugged back to the "Clinton."

Trempealeau dolomite

Seventy-four wells were drilled to the Cambrian Trempealeau dolomite in 1991. Morrow County continued to be the most active county for Trempealeau drilling with 32 wells. Trempealeau drilling occurred in 14 counties, an increase of four from 1990. Wayne County was second with 13 wells, followed by Knox, Licking, and Medina Counties, all with four wells each. Forty-two percent of all Trempealeau wells were completed as productive.

Devonian shale

Drilling interest in the Devonian Ohio Shale declined 27 percent in 1991; only 70 wells were drilled, compared to 96 in 1990. Monroe County led Ohio Shale drilling with 36 wells, followed by Noble County with 28 wells. Sixty-three percent of these wells were dual-completed in the Berea Sandstone. The only dry hole was a shallow test in Delaware County.

Berea Sandstone

The Mississippian Berea Sandstone ranked fifth among producing formations; 69 wells were drilled in 17 counties. Morgan County again had the most Berea wells (13). In addition, 44 wells were dual-completed in the Berea Sandstone and Ohio Shale in the following counties: Noble (24), Monroe (19), and Washington (1).

TEN MOST ACTIVE COUNTIES

Stark County led the 1991 top-10 list for the second straight year with 83 new wells drilled. This is the third time in the last four years that the first-ranked county had fewer than 100 wells drilled (the exception was Monroe County in 1989). Prior to 1988, the last time fewer than 100 wells were drilled in the top-ranked county was in 1961.

Top-10 counties are distributed throughout eastern Ohio (see table below). Seven of 10 counties retained top-10 status from 1990; Ashtabula, Washington, and Wayne Counties dropped from the 1991 list. The new additions and the last time they were ranked in the top 10 are: Geauga (1988), Morgan (1984), and Muskingum (1985).

TEN MOST ACTIVE COUNTIES IN 1991

1991 rank	*County*	*1990 rank*	*Wells drilled*	*Permits issued*	*Footage drilled*
1	Stark	1	83	84	383,889
2	Trumbull	9	69	77	295,323
3	Noble	6	60	66	206,229
4	Mahoning	5	59	74	278,651
5	Coshocton	4	58	66	220,980
6	Holmes	3	57	72	304,816
6	Muskingum	19	57	69	231,608
8	Geauga	18	56	62	205,947
9	Morgan	20	55	57	131,439
10	Monroe	10	53	70	89,428

DIRECTIONAL DRILLING

Applications for directional-drilling permits increased for the third year. A directionally drilled well is commonly drilled vertically to a predesignated depth, then deviated at an angle designed to encounter the producing formation. Before 1989, the division issued fewer than three directional-drilling permits per year; issuances increased to seven in 1989, doubled to 14 in 1990, and nearly tripled to 41 in 1991. With the exception of two, all of the directional-drilling permits issued targeted the "Clinton" sandstone and were for wells in northeastern Ohio. In 1991, 11 directional-drilling permits were issued to drill under Berlin Reservoir, which was leased from the U.S. Bureau of Land Management.

Although directional drilling is normally employed to access areas where surface conditions are restricted, in 1991 the technology was applied to subsurface geological conditions. Two permits were issued to plug back to directionally drill into the Trempealeau dolomite. In both cases, the original vertical well was dry and after a geologic evaluation of the formation, the decision was made to plug back and attempt to directionally drill into a productive Trempealeau prospect.

PRODUCTION

Ohio's total reported crude oil production was 9,158,332 barrels. This production volume is the lowest recorded since 1974, and a 8.5 percent decrease from 1990. Through 1991, Ohio wells have produced 1,010,688,716 barrels of oil.

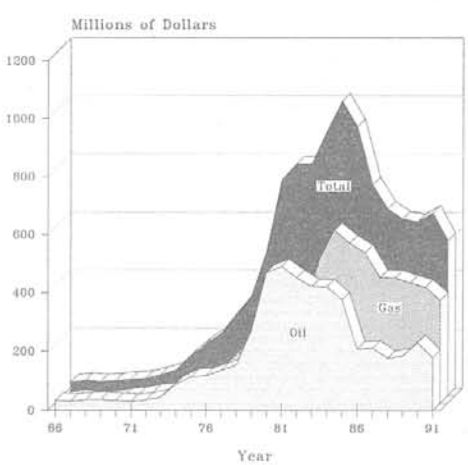
In 1991, Ohio wells produced 147,651,188 MCF of natural gas, a decrease of 4.6 percent from 1990. Gas production figures include an estimated 1,461,893 MCF of natural gas used on the lease. Through 1991, Ohio wells have cumulatively produced 6,547,181,125 MCF of natural gas.

MARKET VALUE

The market value of Ohio crude oil decreased 22.3 percent in 1991 to $179,594,619. The average price per barrel was $19.61, a 15 percent decrease from the 1990 average of $23.10 per barrel.

Ohio natural gas production was valued at $348,341,267, a decrease of 11.3 percent from 1990. The average price paid per MCF was $2.38 in 1991, a drop of 16 cents per MCF from 1990.

Ohio's combined oil and gas market value decreased by 15.5 percent in 1991. The total dollar value was $527,935,886, the lowest market value since 1979.



Dollar value of oil and gas produced in Ohio, 1966-1991.

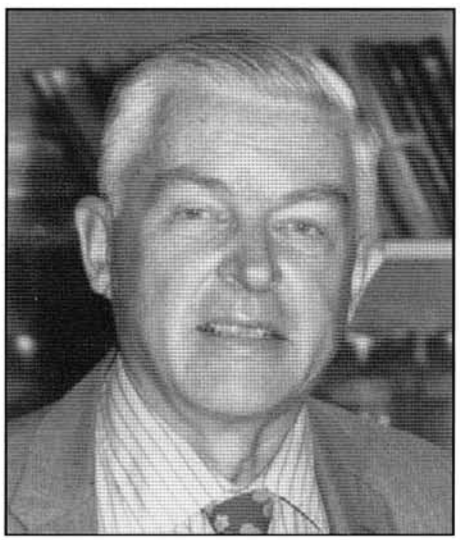
SUMMARY

Oil-and-gas-well permitting and drilling activity continued to decline in 1991. Oil prices returned to previous levels after the Middle East war. Gas prices also dropped due in part to a warmer than usual winter. Bright spots included an increase in directional drilling and deep-well exploration activity.

The "Clinton" sandstone continued to be the producers' mainstay, accounting for 65 percent of the wells drilled in 1991. Interest in the Rose Run sandstone remained strong—drilling to this formation exceeded the 100-well mark for the second straight year. Trempealeau exploration expanded to 14 counties.

Even though the total number of wells declined, drilling occurred in 46 counties, which was an increase of six from 1990. Top-10 counties were distributed throughout eastern Ohio.

Overall, Ohio now has 64,830 active wells and 3,483 well owners. In 1991, these wells produced over 9 million barrels of oil and nearly 148 million MCF of natural gas. The market value of Ohio's 1991 oil and gas production exceeded $527 million.



RICHARD P. GOLDTHWAIT, 1911-1992

With great regret, we report the passing of one of Ohio's great geologists, Richard P. Goldthwait, on July 7, 1992, at the age of 81. Dr. Goldthwait died of a cerebral hemorrhage near his summer home in his native New Hampshire while collecting a water sample.

Richard P. Goldthwait was born June 6, 1911, in Hanover, New Hampshire, where his father was professor of geology at Dartmouth College. After receiving a bachelor's degree in geology at Dartmouth in 1933, he went to Harvard University, where he received master's (1937) and doctoral (1939) degrees in geology. After completing his Ph.D., Dr. Goldthwait served as an assistant professor of geology at Brown University until 1943.

Dr. Goldthwait came to Ohio in 1944 while serving as a materials engineer with the U.S. Army Air Force at Wright Field in Dayton. In 1946, the late George W. White recruited Dr. Goldthwait for the faculty of The Ohio State University, where he remained until his retirement in 1977. During his long tenure at Ohio State, Dr. Goldthwait served as chairman of the Department of Geology and Mineralogy (1965-1969), the first director of the Institute of Polar Studies (1960-1965), and Acting Dean of the College of Mathematical and Physical Sciences.

Soon after his arrival at Ohio State, Dr. Goldthwait began investigating the glacial geology of Ohio, a subject that would occupy his talents to the end. In 1947 he began investigations on the glacial geology of Ohio for the Division of Water; portions of bulletins on the water resources of Greene and Franklin Counties were authored by Dr. Goldthwait. In 1950, he began the first of six summers in the field for the Division of Geological Survey and began to publish the first of more than 30 papers on the glacial geology of the state. Dr. Goldthwait was among the first to use carbon-14 dating to unravel the time stratigraphy of glacial deposits. Numerous students at Ohio State did theses and dissertations on Ohio glacial geology under the guidance of Dr. Goldthwait. His lifelong contributions to the knowledge of the geology of Ohio were formally recognized by the Survey in 1989 when he received the Mather Medal.

Dr. Goldthwait's final, and perhaps most significant, contribution to the glacial geology of Ohio is a map of the Quaternary deposits of the state, to be published by the Division of Geological Survey. This map will replace the 1961 U.S. Geological Survey map that he coauthored with George W. White and Jane L. Forsyth. The compilation of this new map occupied much of Dr. Goldthwait's time during his retirement years.

In addition to his Ohio contributions, Dr. Goldthwait was a leading researcher in glacial geology in both polar areas and in other geographic regions. He published more than 100 professional papers and was the writer/editor of five books. Among the many awards Dr. Goldthwait received for his accomplishments were selection as one of "Ten Outstanding Men of the Year" by the *Columbus Dispatch* (1962), Antarctica Medal of the U.S. Congress (1968), Mount Goldthwait named for him in Antarctica (1969), library of the Institute of Polar Studies (now Byrd Polar Institute) named "Goldthwait Polar Library" (1976), Outstanding Quaternary Scientist award from the Geological Society of America (1981), and a distinguished career award from the Geological Society of America (1986).

Dr. Goldthwait was a member of many professional organizations and was active in the leadership of several of them. He served as president of the Ohio Academy of Science in 1958-1959, and his presidential address, "Scenes in Ohio during the last Ice Age," was published in the *Ohio Journal of Science* in 1959. This paper is still one of the most useful summaries of the Wisconsinan glaciation in Ohio.

Dr. Goldthwait will be missed for his encyclopedic knowledge of Ohio's Pleistocene and personally missed by his friends and colleagues. He is survived by his wife, Katherine, three daughters, and one son.

—Michael C. Hansen

KENNETH E. CASTER, 1908-1992

Dr. Kenneth E. Caster, professor emeritus of geology at the University of Cincinnati, died on May 18 at the age of 84. Although his studies of paleontology and stratigraphy were global in scope, he authored a number of papers on Ordovician rocks and fossils from the Cincinnati area and was very active in the promotion of paleontology in this region. Dr. Caster was one of the founders of the Cincinnati Dry Dredgers, an amateur fossil-collecting club that celebrated its 50th anniversary in 1992. Perhaps his best known work on Ohio geology was his 1955 (with Elizabeth A. Dalvé and John K. Pope) *Elementary guide to the fossils and strata of the Ordovician in the vicinity of Cincinnati, Ohio*, published by the Cincinnati Museum of Natural History.

Dr. Caster received his bachelor's, master's, and doctoral (1932) degrees from Cornell University. He was an instructor in geology at Cornell until he became a member of the geology faculty at the University of Cincinnati in 1936. He remained active in teaching at the university until his retirement in 1979. His donated collection of historical books and papers are housed in the Caster Library in Braunstein Hall.

In addition to his research, Dr. Caster trained many students during his long tenure at the University of Cincinnati. A number of theses and dissertations on Ohio geology and paleontology were carried out under his direction. After his retirement, he established the Kenneth E. Caster Fund, which supports graduate students in paleontology. Throughout his career he was an active and influential force in the field of paleontology. He was one of the early supporters of the theory of continental drift and plate tectonics, at a time when these ideas generated much controversy among geologists.

Dr. Caster was a member and officer of many professional organizations, including a former president of the Ohio Academy of Science, and received numerous awards for his professional accomplishments. He served as visiting professor at several domestic institutions and at universities in Brazil, Colombia, Tasmania, and Germany. He and his wife, Anneliese, who survives, enjoyed literature, theater, and music. Dr. Caster was one of the leaders of the geological profession during his long and productive career. He will be missed not only for this leadership but also as a friend and mentor to a generation of geologists.

— Michael C. Hansen and David L. Meyer

SURVEY GEOLOGISTS HONORED BY THE OHIO ACADEMY OF SCIENCE

Survey geologists Gregory A. Schumacher, E. Mac Swinford, and Douglas L. Shrake received the 1991 "Paper of the Year" award from the Ohio Academy of Science for their paper "Lithostratigraphy of the Grant Lake Limestone and Grant Lake Formation (Upper Ordovician) in southwestern Ohio," which was published in the *Ohio Journal of Science*. Mac Swinford accepted the award certificate at the Annual Meeting of the Ohio Academy of Science on May 2 at the University of Akron.

This paper was a product of the Survey's statewide mapping program and was written to revise the stratigraphic nomenclature of the Grant Lake Limestone, provide documentation of the lithologic variability of the unit between Maysville, Kentucky, and Cincinnati, Ohio, and to correlate the Grant Lake into the subsurface of southwestern Ohio. This award is an affirmation of the high-quality and significant work being performed by Survey staff as part of the statewide mapping program.

BUILDING STONES OF CLEVELAND

The Division of Geological Survey recently published Guidebook No. 5, *Guide to the building stones of downtown Cleveland: a walking tour.* This 33-page publication, which includes 33 photographs and maps and three tables, was authored by geologists Joseph T. Hannibal of the Cleveland Museum of Natural History and Mark T. Schmidt of Woodward-Clyde Consultants.

Twenty different buildings or monuments are described within a four-block area around Public Square. Each description includes a brief history of the structure, the type of rock used and its age and source, and photographs of the building. Such Cleveland landmarks as the Terminal Tower, the Soldiers' and Sailors' Monument, the Old Stone Church, the Cleveland Public Library, City Hall, and the BP America Building are part of the walking tour. Numerous other buildings and bridges in downtown Cleveland are described in a section on "Additional sites." A glossary of technical terms used in the discussions and a detailed map of downtown Cleveland enhance the usefulness of the guide.

Guidebook No. 5, *Guide to the building stones of downtown Cleveland: a walking tour*, is available from the Division of Geological Survey for $4.96, which includes tax and mailing.

1992 MATHER MEDAL DINNER

The Mather Medal of the Division of Geological Survey will be awarded to Ralph J. Bernhagen, former State Geologist of Ohio, and Richard M. DeLong, retired Survey geologist, at a banquet in conjunction with the Bownocker Lectures of the Department of Geological Sciences of The Ohio State University on Thursday, November 5, 1992. Dr. William R. Dickinson of the University of Arizona will be the Bownocker Lecturer, speaking on "The meaning of orogeny and taphrogeny in a plate tectonics world." The banquet will begin at 5:45 p.m. at the Fawcett Center for Tomorrow on the OSU campus. Cost of the banquet is $16.00; deadline for reservations is October 21. For reservation forms or more information, please contact Mac Swinford, ODNR Division of Geological Survey, 4383 Fountain Square Drive, Columbus, OH 43224-1362 (telephone: 614-265-6473).

QUARTERLY MINERAL SALES, JANUARY -- FEBUARY -- MARCH 1992

complied by Sherry L. Weisgarber

Commodity	Tonnage sold this quarter[1]	Number of mines reporting sales[1]	Value of tonnage sold[1] (dollars)
Coal	7,648,692	130	$202,305,725
Limestone/dolomite[2]	5,897,498	95[3]	23,430,766
Sand and gravel[2]	4,235,651	194[3]	13,722,610
Salt	621,454	5[4]	13,362,436
Sandstone/conglomerate[2]	186,200	16[3]	3,478,466
Clay[2]	368,442	17[3]	1,148,202
Shale[2]	359,978	20[3]	575,198
Gypsum[2]	51,996	1	493,962
Peat	2,948	2[3]	48,375

[1] These figures are preliminary and subject to change.

[2] *Tonnage sold* and *Value of tonnage sold* include material used for captive purposes. *Number of mines reporting sales* includes mines producing material for captive use only.

[3] Includes some mines which are producing multiple commodities.

[4] Includes solution mining.

SURVEY STAFF CHANGES

COMINGS

Danielle A. Foye, Geology Technician, Lake Erie Geology Section.

Scudder D. Mackey, Section Head, Lake Erie Geology Section.

GOINGS

Suzan E. Jervey, Head, Publications Center, to Office of Public Information and Education.

Barbara M. Cain, Executive Secretary, to Division of Litter Prevention and Recycling.

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

OHIO DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL SURVEY

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