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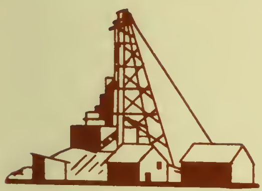
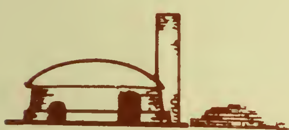


INDUSTRIAL MINERALS AND METALS OF ILLINOIS



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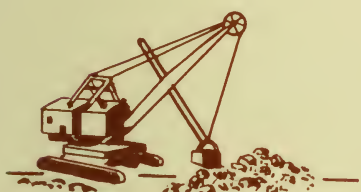

Illinois State Geological Survey

STATE of ILLINOIS

DEPARTMENT of
REGISTRATION and EDUCATION

1965

ILLINOIS STATE
GEOLOGICAL SURVEY
John C. Frye, Chief
URBANA, ILLINOIS

Printed by Authority of State of Illinois, Ch. 127, IRS, Par. 58.25.

(15M-4/65-8976) 10

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J. E. Lamar

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INDUSTRIAL MINERALS AND METALS OF ILLINOIS

J. E. Lamar

THE MINERAL resources of Illinois include many rocks and minerals of varied character and uses. From them are made an array of everyday products whose sources may not even be recognized by the consumer. The user of a glass bottle, for instance, rarely knows that it may have been made from Illinois silica sand, nor is the driver of an automobile generally aware that the Illinois concrete highway on which he is driving probably was constructed from a mixture of cement, sand and gravel, or crushed stone that may have come from Illinois pits or quarries.

The significance of these rocks and minerals to the economy of Illinois is great, although often unappreciated. Of the more than 600 million dollar value of all Illinois mineral production in 1963, almost 200 million was from industrial minerals. The diversity and widespread distribution of these mineral resources lend variety and balance to the mineral industry of the state, and their production, processing, and utilization afford direct and indirect employment to many people.

The term industrial minerals is used as a convenient group term for nonmetallic minerals that are not fuels. In Illinois they include limestone, dolomite, clay, shale, silica sand and other sands, fluorspar, tripoli (amorphous silica), ganister, novaculite, sandstone, feldspar-bearing sands, barite, gypsum, anhydrite, brines, greensand, oil shale, marl, peat, humus, and tufa. The metallic minerals of Illinois are galena (lead ore), sphalerite (zinc ore), pyrite, and marcasite.

This booklet briefly and nontechnically discusses the foregoing materials and some of the work the Illinois State Geological Survey does in gathering information about their occurrence, and character and in developing new uses.

The assistance of many Survey staff members and of many people in the Illinois mineral industry in the preparation of this booklet is acknowledged.

LIMESTONE

Limestone is a most versatile rock. Without it there would be no portland cement for making concrete roads and buildings, no lime for plastering and chemical use, no agricultural limestone for farms, and no crushed limestone for roads and driveways. A wide variety of industries, from steel making to glass manufacturing, use limestone in one way or another.

The early settlers of Illinois recognized the value of limestone and quarried stone blocks and slabs for making foundations, chimneys, and even houses. For mortar they used a mixture of sand and lime to hold the blocks together. The lime was made by heating limestone red hot in simple furnaces or kilns, the ruins of a few of which may still be seen.

Kinds of Limestone

Illinois has two principal varieties of limestone, referred to technically as limestone and dolomite. "Limestone" may be used as a general name for both varieties.

Limestone consists principally of crystalline particles of the mineral calcite (fig. 1). This mineral is glassy in appearance and is composed of calcium, carbon, and oxygen combined to form calcium carbonate—$CaCO_3$. Dolomite is largely made of crystalline particles of the mineral dolomite, which also has a glassy appearance and consists of calcium, magnesium, carbon, and oxygen—$CaMg(CO_3)_2$. The crystalline particles of limestone and dolomite vary in size. Some are coarse enough to be seen easily, others are so small that they can be distinguished only with a microscope.

Formation of Limestone and Dolomite

Almost all Illinois limestones were formed in seas that covered Illinois millions of years ago. The many different limestone formations in Illinois suggest that oceans covered all or part of the area several times. Numerous kinds of shell fish, corals, and other marine animals lived in these oceans and had shells and other hard parts made of calcium carbonate. Through countless generations, these animal remains accumulated on the ocean floor and gradually were compacted and cemented into limestone (fig. 2).

Other Illinois limestones, however, were formed by the hardening of muds composed mainly of calcium carbonate that accumulated on the floors of the ancient seas. Still other limestones were formed of a combination of animal remains and lime mud.

Figure 1 - Calcite crystals. Limestone is made up mainly of calcite crystals, but they are less perfectly formed and are crowded together.

The coral reefs of the South Pacific Ocean have their counterparts in Illinois. The ancient Illinois oceans contained extensive reefs that were built up just as the modern reefs have been. In northern Illinois, around Chicago for instance, a number of the ancient reefs are now the site of stone quarries. In southwestern Illinois such reefs are a source of petroleum.

The dolomites of Illinois probably were originally limestones, but, either while the limestones were still beneath the sea or after the sea had withdrawn, magnesium was exchanged for some of the calcium in the limestones. If the exchange took place under the sea, the sea water was the source of the magnesium. If it happened when the limestones were a part of the land, the magnesium was brought in by water circulating through the rock. Many of the marine animal fossils became difficult to recognize after the change, and the texture and general appearance of the rock also were altered. Some of it became noticeably porous.

Figure 2 - Limestone containing fossils. An Archimedes screw appears at lower left, lace-like bryozoa in the center, and fluted brachiopod shells at top and center.

Uses of Limestone and Dolomite

Some of the major uses for Illinois limestone and dolomite are mentioned below. Not every limestone or dolomite can be used for all purposes because for each use the stone must fulfill special requirements of a chemical or physical nature. For example, it must have high purity for lime, resistance to wear and weather for roads and buildings, and a pleasing appearance for decorative stone and marble.

Lime.—When limestone or dolomite is heated to a high temperature, it undergoes a change and carbon dioxide is liberated. The weight of the gas set free is equal to somewhat less than half the weight of the rock if the rock is pure. The solid product remaining after the gas has been driven off is known as lime. The heating process is called burning.

Besides being used in making mortar and plaster, lime is valuable in many other ways, especially in various chemical processes of modern industry. Plants at Chicago and Quincy make lime from Illinois limestone and dolomite.

Figure 3 - An Illinois dolomite quarry.

Cement.—Portland cement, sometimes called simply cement, is made at LaSalle, Oglesby, and Dixon in northern Illinois from limestone and a smaller, carefully measured amount of clay or shale. Cement also is made at Joppa in southern Illinois. The blend of materials is thoroughly ground and mixed, then heated at a high temperature in huge rotating horizontal furnaces, called kilns, until it forms a clinker. After it cools, the clinker is ground to a flourlike powder. This is basically the cement that binds together the mixture of sand and limestone (or dolomite), or of sand and gravel, to make the concrete from which roads, bridges, buildings, and other structures are made.

Aggregate.—The crushed stone used in making concrete is known as concrete aggregate. This is a major use for Illinois limestones and dolomites. Large amounts of stone aggregate also are used in bituminous roads, popularly called "blacktop" roads.

Agricultural Uses.—Agricultural limestone (agstone) is applied to farm land to neutralize soil acids and otherwise benefit the soil. Both limestone and dolomite are so used. Chickens are fed small limestone chips to provide calcium for the formation of egg shells. Pigs and cows get calcium from mineral supplements containing powdered pure limestone.

Figure 4 - An underground limestone mine.

Other Uses.—Illinois limestone or dolomite is used in steel making, as building stone and marble, as road stone, as ballast for the road beds of railroad tracks, for making refractory dolomite used in the steel industry, and for a variety of less commom uses.

Quarries

There are about 200 stone quarries in Illinois. Most of the larger quarries (fig. 3) are in the Chicago, Joliet, Kankakee, and East St. Louis areas, but one or more limestone or dolomite quarry occurs in many counties.

If all the stone taken from Illinois quarries in 1963 were removed from a hole 100 feet square, the hole would penetrate into the earth about 8 miles. It would take more than 350,000 railroad cars holding 100 tons each to haul away the stone. Limestone, dolomite, and their products added over 80 million dollars to the economy of the state in 1963, approximately 8 dollars for each person in Illinois.

Most Illinois limestone and dolomite is quarried from open pits, but in some places, as in the rocky bluffs along the Mississippi River, the stone is taken from underground mines (fig. 4).

There is also a dolomite mine in Chicago. At the quarries the first step is the removal of the earth overlying the stone. Next, in both pit and mine, the stone is blasted to free it from the parent deposit and break it into pieces. Mechanical shovels (fig. 3) load the stone into trucks that take it to the crushing plant where powerful crushers further break the stone into pieces. The pieces are sorted into various sizes by large screens. At some of the plants, the stone is ground into powder.

Location of Limestone Deposits

The geologic map of Illinois prepared by the Illinois State Geological Survey shows, with reasonable exactness, what bedrock formations would crop out at the surface if the overlying clay, sand, gravel, and earth were removed. Thick dolomite formations would be exposed in much of the northern fifth of the state, but would be rare elsewhere. Thick limestone formations would occur in an almost continuous zone, varying in width from 3 to 25 miles, along the Mississippi River from Rock Island to southern Illinois and then eastward across the extreme southern tip of the state. Limestone also would be seen along the Illinois River from Havana southward.

In the central area of the state, limestones are present, but they are rarely over 25 and often less than 15 feet thick. Consequently, most of the larger quarries are in the northern, western, and southern parts of Illinois. The thinner limestones, nonetheless, are of much importance and are quarried at many places, chiefly to provide agricultural limestone, road stone, and limestone for making cement.

The Geological Survey locates and maps limestone and dolomite deposits and analyzes and tests samples to determine the best possible uses for the stone. Many reports have been published about the character and general use of the deposits in various parts of the state. Other reports deal with the use of limestone and dolomite for specific purposes such as cement making, building and decorative stone, rock wool, terrazzo chips, and lime.

METALLIC ORES AND FLUORSPAR

Lead and Zinc

Lead mining was one of the earliest industries of Illinois. The early settlers' need for bullets for procuring food and for defense of their lives and property made lead an important commodity, and

Figure 5 - Galena with cubic cleavage blocks in foreground.

the deposits of lead ore in the northwestern corner of Illinois were quickly exploited. The ore was the mineral galena (fig. 5), for which the city of Galena in Jo Daviess County is believed to have been named.

Galena is a dark, shiny mineral that breaks readily into cubes or combinations of cubes. It is composed of lead and sulfur (PbS). Galena itself is not suitable for use as a metal; the lead must first be separated from the sulfur.

The earliest method of recovering lead from galena was crude. A pile of logs, smaller pieces of wood, and ore was built on sloping ground. Just below it a pit was dug. When the wood was set on fire, the heat caused the lead and sulfur to separate, and the molten lead trickled down into the pit. The smelting process was later improved, and stone "furnaces" were built to house the operations.

Crevice Deposits and Residual Deposits.—Most of the lead ore mined in the early days of the northwestern Illinois mining district came from crevice deposits in the dolomite bedrock and from residual deposits at or near the surface of the ground. The crevices were vertical narrow joints or fissures. Ore was not continuously present along them but occurred from place to place in "pods" (figs. 6 and 7). Dimensions of the pods varied, but typical ones were about 3 feet wide, 5 feet high, and a few to a few hundred feet long. The galena, for the most part, occurred in a mixture of clay and weathered dolomite that filled, or partly filled, the crevices.

The residual deposits were found where the action of the weather for many thousands of years had dissolved the dolomite from the outcropping parts of a crevice deposit and left behind a residue of brown or red clay containing galena.

Some of the crevice and residual deposits worked by the early miners cropped out at the surface, but most of them were covered by earth. Other crevices were exposed in the bluffs of the Mississippi River and extended back into them for 1,000 feet or more.

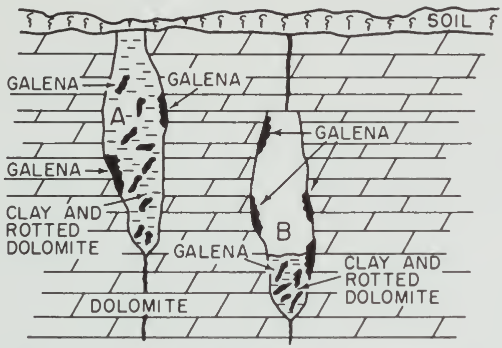

Figure 6 - Diagrammatic cross section of two crevice deposits. A reaches ground surface and is filled with clay; B is only partly clay filled. Galena coats parts of the walls and occurs as pieces scattered through the clay. Typical crevices are about 3 feet wide and 5 feet high.

When the richer deposits of ore in the crevices were worked out, some mines were deepened into the dolomite bedrock, but usually less rather than more galena was found.

As the amount of galena decreased, however, another mineral, which had been present before in only small amounts, was found in increasing quantities. This was sphalerite—a yellow, brown, or black mineral of resinous appearance that is composed of zinc and sulfur (ZnS). It does not look like a metallic ore.

At first the sphalerite was not used because there were no smelters in the area that could separate the zinc from the sulfur

Figure 7 - Crevice lead mine. Miner pries ore loose and pushes it into car at bottom of crevice. Shiny galena layer occurs above his head and another at level of his waist.

with which it was combined in the ore. Between 1850 and 1870, however, smelters were built in northwestern Illinois and southern Wisconsin and the ore was shipped there. Sphalerite is now the principal ore mineral produced in northwestern Illinois.

The sphalerite and galena of southern Illinois, described later, are similar to that found in northwestern Illinois.

Mining and Milling.—One large mine is producing zinc and lead near Galena at present. Smaller mines operate irregularly. The ore may occur as pockets, irregularly shaped rather flat masses, vertical or inclined veins (fig. 8), or small particles scattered through the dolomite. The principal ore bodies that have been worked in recent years have been of irregular shape, both horizontally and vertically, and usually have been between 50 and 200 feet wide and from a few to as much as 100 feet high. They lie at a depth of roughly 300 feet.

Blasting is required to loosen and break the ore. At the large mine the ore is brought to the surface by a hoist. In some relatively shallow mines an inclined tunnel has been driven to the ore body and the ore brought to the surface in trucks.

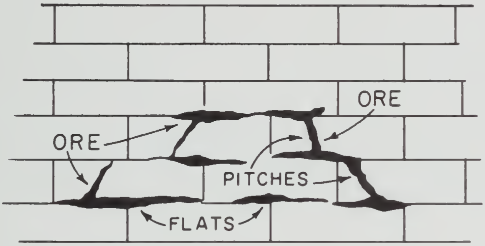

Figure 8 - Diagrammatic cross section of a zinc ore deposit showing flats and pitches. The deposit occurs in limestone and dolomite. Much of the ore is a mixture of dolomite, limestone, calcite, and sphalerite. Typical dimensions of such a deposit are about 30 feet high and 100 to 200 feet wide.

Because the ore consists of galena and sphalerite attached to and scattered through dolomite, it must be milled to free and separate the metals from the rock. Crushing, grinding, and other operations are involved. The dolomite is discarded and the galena and sphalerite concentrates are shipped away to be smelted. No smelters have operated in the Galena area for some time.

Aids to Prospecting.—Finding deposits of ore 300 feet underground is not easy. Inspection of the surface usually tells little. To find and outline a commercial ore deposit many holes often must be drilled to explore the unexposed rock strata. Because this is a costly process, every possible means is employed to drill the holes where ore is most likely to be found. This is where geologists are useful—geologists of the mining companies and of the Illinois Geological Survey. Three examples of how their investigations help to find ore are given here.

It was noted early in the development of the northwestern Illinois mining district that zinc ore deposits were most common along small downfolds in the bedrock, called synclines, that were a few hundred feet wide and a mile or so long. The synclines were associated with much larger synclines that extended for several miles. A map prepared by the Illinois Geological Survey shows the possible location and extent of many of these downfolds and has had much practical use in the selection of the most promising areas for test drilling to find ore.

The Survey also collects the records of borings made by companies and individuals in their search for ore. The records are on permanent file at the Survey offices and are valuable in several ways. Some indicate where no ore was found and where it is, therefore, useless to drill further; others show only traces of ore but suggest that more drilling in the vicinity might discover a deposit large enough to be mined profitably. Still other records are of borings that encountered rich ore in which mines have been developed.

The third aid to prospecting is the study of ore bodies and their minerals to determine how the deposits were formed. The ore bodies have been and are being studied in the mines. Ore specimens are carefully examined in the Survey laboratories. If geologists can learn how the known deposits were formed, it may be possible to direct exploration into promising new areas.

Fluorspar

In the southeastern tip of Illinois lie deposits of a mineral that contains the chemical element fluorine. This element is used in making the propellant that activates aerosol sprays, a plastic that resists chemicals and oil and is strong enough to be used for bearings, compounds that are said to help to prevent tooth decay, and many other useful chemicals.

The mineral is fluorite (fig. 9), commonly called fluorspar. It is composed of calcium fluoride (CaF_2), a compound of calcium and fluorine, and is a glassy mineral that is generally white or gray but may be purple, rose, yellow, blue, or green. In rare instances it is colorless.

Fluorspar mining in Hardin and Pope Counties began with lead mining. Galena was first discovered there in 1839 in a well being dug at the town of Rosiclare. Mining of galena began in the early 1840's, and somewhat later ore was being smelted by three furnaces, all of which have long since disappeared.

The veins that were worked for galena also contained fluorspar, but as there was little or no use for fluorspar in the 1840's

Figure 9 - Group of cubic fluorite crystals.

it was considered waste. In time, uses developed, however, and about 1870 it was mined and shipped in commercial quantities. Since then the tonnage and value of the fluorspar produced from the Rosiclare area have increased until fluorspar is the major product.

The fluorspar mining district north of the town of Cave in Rock in eastern Hardin County also was an early producer of galena. In that area the fluorspar-galena deposits are elongate and approximately flat. The first miners followed the ore bodies from outcrops by tunneling into the hillsides. In the late 1930's and early 1940's, many holes were drilled into the bedrock in search of new deposits. Ore was found that contained not only galena and fluorspar but also important amounts of sphalerite.

Vein Deposits.—In the Rosiclare district, the fluorspar and its accompanying minerals occur as steeply inclined veins a few inches to 25 feet or more wide (fig. 10), usually in limestone strata. The veins are not uniformly thick but widen or narrow from place to place both vertically and horizontally. They occur

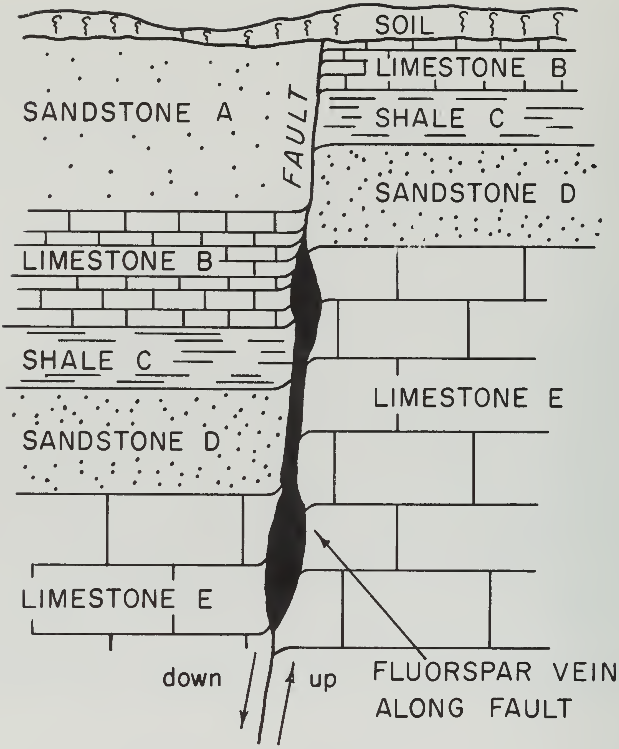

Figure 10 - Diagrammatic cross section of fluorspar vein along a fault. The strata on the left side of the fault have moved downward with reference to those on the right side.

along faults—planes along which the rocks of the earth's crust have broken and slipped. A fault may be a single plane of slippage but more often is a zone of broken and displaced rocks. In most of the faults that contain fluorspar, the slippage is vertical, or nearly so. Along one of the faults in the Rosiclare district, the rocks on one side of the fault have moved downward as much as 650 feet in relation to the rocks on the other side. Some faults are more than 10 miles long, and the depth to which they extend into the earth is unknown. Fluorspar has been mined from one of them at depths of 800 feet. Not all faults, nor all parts of any one fault, contain fluorspar.

Bedding Deposits.—In contrast to the vein deposits of the Rosiclare district, the bedding deposits of the Cave in Rock area are flat, or nearly flat, commonly 5 to 15 feet thick, and from a few to 200 feet wide (fig. 11). They may be as much as 2000 feet long, widening or narrowing and thickening or thinning throughout their extent. They are called bedding deposits because they lie along the beds or layers of the limestone in which they occur. Most of the ore bodies are associated with a fracture or a small fault.

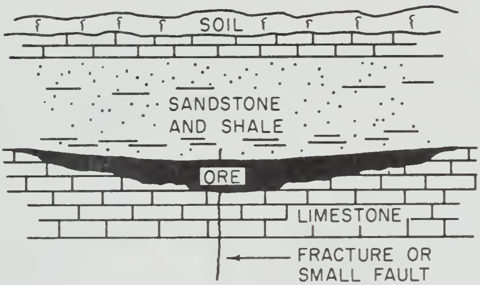

Figure 11 - Diagrammatic cross section of bedding deposit of fluorspar, lead, and zinc ore.

Grades and Uses of Fluorspar.—There are three principal grades of fluorspar—metallurgical, acid, and ceramic. The metallurgical spar is used as a flux in making steel and in metal foundries. Acid spar is used to make hydrofluoric acid, which plays a part in the preparation of uranium isotopes and in the production of a synthetic mineral essential in refining aluminum. The acid is also used in the production of high-octane gasoline and is the basis for a variety of important chemical compounds, among them refrigerants and insecticides. Ceramic grade fluorspar is used in making enamels, glazes, and certain kinds of glass.

Mining and Milling.—Fluorspar and its associated ores are mined in different ways in the Rosiclare and Cave in Rock districts because the types of deposits differ. However, in both areas most of the larger mines are entered by vertical shafts. In the mines, explosives are placed in holes drilled by machines and are then detonated to shoot down the ore (fig. 12). Mine cars, trucks, or conveyor belts carry the ore to the bottom of the mine shaft where hoists raise it to the mills at the surface. In the mills a variety of ore-classifying machines separate the galena,

Figure 12 - Machine loading fluorspar ore in mine near Cave in Rock.

sphalerite, and fluorspar from the waste mineral materials (chiefly limestone and calcite) with which they occur. Some fluorspar after the separation process is almost flour-fine. To increase its use, much of this spar is mixed with a binder and made into pellets or briquets one-half to one inch in size.

Geological and Chemical Studies.—Because much of the fluorspar produced in southern Illinois has come from veins along faults, geologists have mapped the faults of the area by investigating the distribution and nature of the various bedrock outcrops. The work was complicated by the mantle of earth and vegetation that covers the bedrock at many places. However, a geologic map was made that shows where the various rock formations—sandstone, limestone, and shale—lie beneath the surface and where the numerous faults crisscross the district.

The first geologic map of the fluorspar district was made in 1920 by the Illinois and U. S. Geological Surveys. New maps on a much larger scale have been made recently by the Illinois Survey to meet the needs of the modern fluorspar industry.

The Illinois Survey also has studied the ores and ore deposits of southern Illinois to determine how they were formed.

The records of many borings and pits sunk to find ore have been collected and filed at the Survey to guide future prospecting.

Survey chemists are finding new uses for Illinois fluorspar. Their research has produced new organic fluorine compounds that are being tested for use in agriculture, medicine, and industry. They also have worked out easier and cheaper methods of making certain fluorine compounds. Survey chemical engineers have helped to obtain needed information about the physical properties of the pellets made from fluorspar powder.

Origin of Illinois Ore Deposits

The ore deposits of northwestern and southern Illinois were formed so many millions of years ago that it is possible to propose only theories of their origin. Most geologists think that the minerals, dissolved in warm or hot water, came from deep in the earth. Perhaps the mineral-bearing water came from, or was associated with, rocks that were or had been molten (igneous rocks), but it may have had some other source. Why the ores occur where we now find them is not fully known. The cooling of the solutions and the lessening of pressure as the solutions rose toward the surface may have had a part in ore deposition. Faults and the nature of the rocks encountered by the depositing solutions also appear to have had an influence.

Illinois as a Mining State

Although Illinois is not usually thought of as a mining state, northwestern and southern Illinois together produced in 1963 nearly $5,000,000 worth of zinc, about $600,000 worth of lead, and $6,500,000 worth of fluorspar. The annual total value is about $12,000,000.

The southern Illinois fluorspar district has another distinction—for many years its mines have been the major domestic source of the nation's fluorspar.

SILICA SAND

About 450,000,000 years ago, a shallow ocean covered Illinois. Its waves and currents carried clean white sand and deposited it as curving beaches, sand bars, and dunes. This sand differed from many sands in that it was composed almost exclusively of grains of the mineral quartz instead of being a mixture of quartz and other minerals.

Quartz is composed of silica (SiO_2), and sands such as the ancient Illinois sand that are composed of quartz are known as silica sands. Quartz is very hard and will scratch glass and some steel. Perfect quartz crystals, which are rare, are longer than they are thick and end in pyramids. Probably not many grains of the ancient sand came from perfect crystals; they more likely resulted from the decaying and breaking down of rocks such as granite, which are mixtures of quartz grains and other mineral particles.

The quartz grains probably did not come directly from their source to Illinois. Instead, it is likely they first were deposited elsewhere and formed into sandstone. That sandstone was subsequently broken down by weathering agents and the grains transported to the ancient Illinois sea by streams.

As a result of the erosive action of the agents that transported them, many of the originally angular grains, particularly the coarser ones, were rounded and their surfaces dulled like that of frosted glass (fig. 13). Consequently, they appear white, although they actually are colorless.

Since the ancient sea deposited its silica sand, other seas have covered Illinois at various times and each has left deposits of sand, mud, or limy materials. The silica sand thus was buried by hundreds of feet of other sediments and became sandstone. This sandstone is called the St. Peter Sandstone. It is named from the St. Peter River, now the Minnesota River, in Minnesota where the sandstone was first described and named by geologists. The overlying deposits also were consolidated into rock.

St. Peter Sandstone is exposed at the surface at many places in northern Illinois and in one small area in the western part of the state. The sandstone exposed in northern Illinois generally varies from 125 to 300 feet thick. The fact that it crops out at the surface indicates that the materials that formerly covered it have been removed.

The uncovering was not a single, simple event but rather a series of events that took place at various times during the many years since the St. Peter sand was deposited. Among these was the up-bowing of the rocks of central northern Illinois into a broad arch. Streams then began to cut across the arched rock, slowly but persistently stripping away the top layers until the core of the arch was laid bare. Among the rocks thus exposed was the St. Peter Sandstone, which may be seen in northern Illinois in the valleys and tributaries of the Rock River near Dixon and Oregon and along the Illinois and Fox Rivers and some of their tributaries near Ottawa, Wedron, Millington, and Troy Grove. The St. Peter

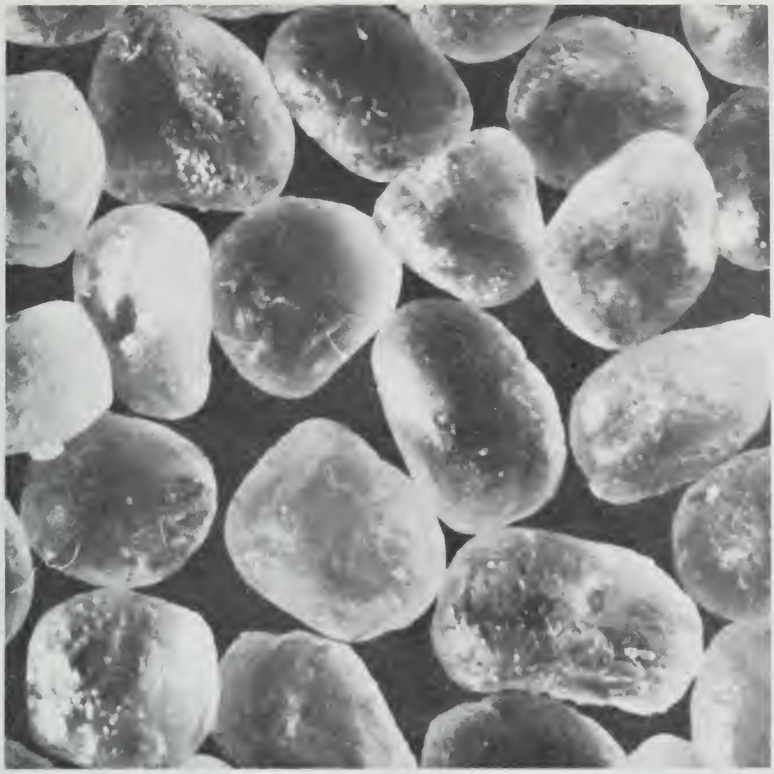

Figure 13 - Enlarged photograph of St. Peter sand showing the rounded and frosted character of the grains.

Sandstone at Starved Rock and Matthiessen state parks near LaSalle and along the highway between Dixon and Oregon is eroded into scenic bluffs and canyons.

Silica Sand Industry

The Illinois silica sand industry is based on the St. Peter Sandstone. It centers around Ottawa, Wedron, Troy Grove, and Utica in LaSalle County and in Oregon in Ogle County. Two principal grades of silica sand are produced—washed and crude. The value of the silica sand produced in Illinois in 1963 was about $9,000,000.

Washed Sand.—Although the St. Peter Sandstone is composed almost entirely of quartz grains, a small amount of clay is present. For some uses it is not necessary to remove the clay, for others its elimination is important and is achieved by washing the sand.

In the mining of silica sand that is to be washed, the sandstone is first blasted loose from the parent deposit to break it into sand or pieces of various sizes. Some of the larger pieces may require a second blasting to disintegrate them.

At some pits the material is loaded mechanically and transported to the washing plant. At others a powerful stream of water is directed against the broken sandstone (fig. 14) and the resulting mixture of sand and water flows to a collecting basin from which it is pumped through large pipes to the processing mill.

In both types of operation the sand is thoroughly washed at the plants. After it is washed, the sand is further processed to suit the needs of its users. Much of it is screened into different size grades.

Uses of Washed Silica Sand.—The washed silica sand produced in Illinois has many uses, some of which are briefly mentioned below. The suitability of the sand for some purposes depends in part on its having been screened to specified sizes.

The high purity of Illinois washed silica sand makes it suitable for making glass, which is more than half silica sand. Each year over a million tons is used for this purpose. The purity of the sand also is of importance for chemical and metallurgical uses such as the manufacture of sodium silicate and silicon carbide and in alloying.

The hardness of the sand makes it useful for grinding large sheets of plate glass to prepare them for polishing and also makes it an effective abrasive agent for sandblasting. Metal castings in foundries and the exteriors of buildings are cleaned by this process. Illinois produces thousands of tons of sand yearly for such abrasive purposes.

Because the coarser grains of the washed silica sand are rounded, strong, and available in uniform sizes, oil operators use thousands of tons of it annually in the hydraulic fracturing of oil-bearing strata. The sand is mixed with oil, other petroleum products, or water and is forced by powerful pumps into sandstone or limestone formations that contain oil. The great force thus exerted opens fractures in the rock strata and pushes the liquid and sand into them. When the pressure is relieved, the sand grains serve as props to hold the fractures open. The oil can then flow more easily into the wells and oil production is thus increased.

The washed sand, because it is clean and does not dissolve in water, is used to filter impurities from drinking water.

Figure 14 - Hydraulic mining of silica sand near Ottawa.

Its whiteness makes it a desirable constituent in plaster, mortar, and precast building panels.

Because it is round grained and withstands high temperatures without melting, large tonnages of the washed silica sand are used to make molds into which molten metal is poured to make various kinds of castings.

A special type of coarse silica sand from Illinois that is carefully prepared so that it is always of the same grain size is used throughout the world as a standard in laboratories that test cement and other commercial products.

Some silica sand is ground to a fine, white powder. The powder, called ground quartz, ground silica, silica flour, or potter's flint, has many uses. It is an ingredient in paints, potters

Figure 15 - Loading crude silica sand.

use it in making pottery and china, it goes into scouring powders, into molds used for precision types of metal castings, and into enamels.

Crude Silica Sand.—The crude silica sand produced from the St. Peter Sandstone generally is yellow or yellowish white and is not washed before it is used. It probably originally was white, but iron oxide, similar to the rust that forms on iron, now coats many of the sand grains and colors the small amount of clay in the sand. Thousands of tons of crude silica sand are mined annually (fig. 15). Because it is highly heat resistant, foundries buy much of it to make the molds used for castings, especially steel castings, and for automobile engine blocks, train wheels, and a variety of other metal products. Crude silica sand also is used around industrial furnaces to seal cracks and openings to prevent the loss of heat, in certain ceramic products, and for adjusting the silica content of the raw materials used for making portland cement.

Studies of the St. Peter Sandstone

The Illinois Geological Survey has made field studies and prepared maps showing where the St. Peter Sandstone is exposed in northern and western Illinois. Many samples have been screened and examined under a microscope to determine how the sand of different deposits, or different parts of the same deposit, varies in grain size and mineral composition. The possibility of using Illinois silica sand for making silica brick also has been investigated.

GRAVEL AND SAND

Some 225,000 years ago, most of what is now Illinois was buried under the ice of the Illinoian glacier. Two earlier glaciers had covered large parts of Illinois, and another, known as the Wisconsinan glacier, came into the state later, about 50,000 to 70,000 years ago (fig. 16).

The relatively small glaciers in the United States today, such as those in the northern Rocky Mountains, are concentrated in valleys and are called valley glaciers. The glaciers that covered Illinois were parts of huge ice sheets that extended over much of the North American continent and are called continental glaciers. They spread over most of Canada, then pushed southward to bury New England and a great area in the north-central part of the United States north of the Ohio and Missouri Rivers.

Formation of Gravel and Sand Deposits

As the glacial ice edged slowly southward from Canada, it froze fast to and picked up soil and loose pieces of rock, with enormous force tore away huge chunks of bedrock, and mixed and ground these materials together (fig. 17).

Into Illinois the glacier carried rock materials from Canada, Wisconsin, Minnesota, and Michigan; other rock fragments were picked up in Illinois as the ice front advanced. When the glacier melted, it left behind its load of rock flour and rock fragments, much of it as a gray clay containing pebbles, cobbles, and boulders. Geologists call such deposits glacial till.

The ice in the continental glaciers usually crept forward, sometimes slowly, sometimes more rapidly. Whether the front of a glacier moved forward or back depended on the balance between the rate of forward motion of the ice and the rate of melting. When the ice advanced faster than it melted, the front of the glacier moved forward.

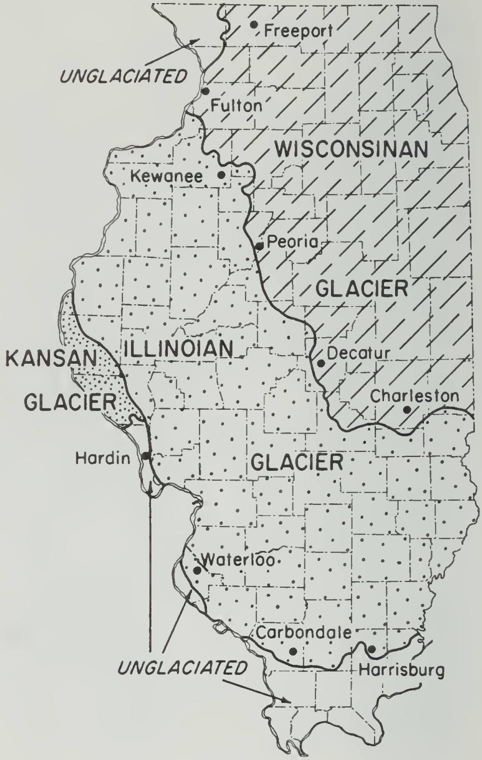

Figure 16 - Extent of the exposed deposits of the Wisconsinan, Illinoian, and Kansan glaciers in Illinois, and the unglaciated areas of the state.

Figure 17 - Striated boulder. Scratches and flattened surfaces were caused by abrasion by other rocks while boulder was embedded in glacial ice.

When the glacial ice melted faster than it moved forward, the front of the glacier receded. When the rates of melting and advance were about equal, the front of the glacier stood still or moved back and forth in a narrow zone.

When such a more or less stationary front existed, an enormous amount of clay, silt, sand, pebbles, and boulders was deposited in a belt only a few miles wide along the front of the glacier, creating a line of hills and ridges that extended for many miles. Such belts, called end moraines, can be seen today in many parts of Illinois.

The building of end moraines often was accompanied by the release of great quantities of water (meltwater) from the melting ice. The water, laden with rock debris, flowed from the front of the glacier in many streams.

As the meltwater flowed away from the glacier it sorted its load, although the sorting was rarely perfect. The heavy boulders and pebbles usually were dropped first, then the sand, next the silt, and finally the clay. In general, the farther the deposits were from the glacier the finer they were. The major streams frequently carried pebbles 50 to 100 miles from the glacier and it was many more miles before all the sand was dropped. They carried some of the fine silt and clay as far as the Gulf of Mexico.

Sometimes the floods of glacial water were greater and flowed faster than usual and so were able to carry coarse rock materials farther. As a result, gravel was laid down on top of earlier sand deposits. Later there may have been further sand deposition.

The debris-laden meltwater that flowed into valleys often deposited in them a considerable filling of sand and gravel. Some valleys were filled to a depth of as much as 100 feet. Such deposits are called valley fills or valley trains. Modern streams have cut their courses into many of these fills and even worn away large parts of them. Remnants of valley train deposits are now large terraces or benches along streams, many of them well above the present stream channels.

Where many small streams flowed from the glacier, they deposited sand and gravel as a large apron in front of the glacier. Such deposits are called outwash plains and many of them extend for miles.

Two other types of sand and gravel deposits made by glacial meltwaters also are significant. One was formed where water issued from the front of a glacier or poured into holes or crevasses in the ice. The sand and gravel in the water formed a deposit that now appears as a rounded hill associated with a terminal moraine and is called a kame. The second type of deposit was laid down in beds of streams flowing under, through, or on the glaciers and was left as a more or less continuous ridge of sand and gravel when the ice melted. Such a deposit is called an esker. Some eskers in Illinois are about a quarter of a mile wide and several miles long. Typical are the Kaneville Esker northwest of Aurora, the Adeline Esker south of Freeport, and the Exeter Esker west of Jacksonville.

The deposits of both the Illinoian and Wisconsinan glaciers are widely distributed throughout the state. Melting of the Illinoian glacier caused comparatively little flooding; consequently, extensive gravel deposits were formed in only a few places. The ice of the Wisconsinan glacier, however, melted rapidly and produced great floods laden with sand and gravel. Thus, most major gravel deposits in Illinois are related to the Wisconsinan glacier.

Wind sweeping across the sand and gravel deposits blew the sand into hills or sand dunes near such places as Havana, Prophetstown, Kankakee, and Watseka. Even today the wind shifts sand of long-forgotten glacial floods.

Studies of Glacial Deposits

The foregoing discussion of glaciers and their deposits is greatly simplified. For some time geologists of the Illinois Geological Survey have been mapping the moraines, valley trains, outwash plains, and other glacial deposits of the state. Because the Illinoian and Wisconsinan glaciers advanced and retreated several times, they built many moraines. The Survey has made a map (fig. 18) that shows the complexity of the moraines left by the Wisconsinan glacier. They are roughly concentric, indicating that the general shape of the glacier front remained about the same.

Principal Commercial Sources of Sand and Gravel

The sand and gravel industry is widely distributed throughout Illinois. The principal commercial sources of sand and gravel are valley trains and outwash plains. The Fox, Rock, Illinois, Mississippi, and Wabash Rivers and many smaller streams have terraces in their valleys that are parts of valley trains. In these deposits are some of the largest sand- and gravel-producing operations in the state.

Composition

An examination of glacial gravel deposits in Illinois reveals pebbles and larger pieces of many kinds of rock. Some are gray, others white, pink, brown, or black. They commonly include limestone, dolomite, granite, and many rocks with less common names such as quartzite, schist, and basalt. The limestone and dolomite were picked up by the glaciers from outcrops in northern Illinois, Wisconsin, and Michigan. Some of the granite pebbles resemble outcrops in Wisconsin; others look like granite that crops out in Canada. The quartzite probably came from Wisconsin, and black shale fragments found in some gravel deposits came from the floor of Lake Michigan or from western Michigan. Occasionally pieces of metallic copper are found that probably had their source in the Lake Superior copper-bearing area.

In addition to the sand associated with gravel deposits, extensive deposits of sand alone are found at many places in Illinois. Most of the sand grains are pieces of minerals that were constituents of rocks until weathering, the grinding action of the glaciers, and other erosive agencies broke the rocks into sand. The principal mineral in glacial sand is quartz, but many others occur in lesser amounts, including calcite, dolomite, feldspar, pyroxene, tourmaline, garnet, magnetite, and hornblende. Most of these are foreign to Illinois, although the calcite and dolomite may be native.

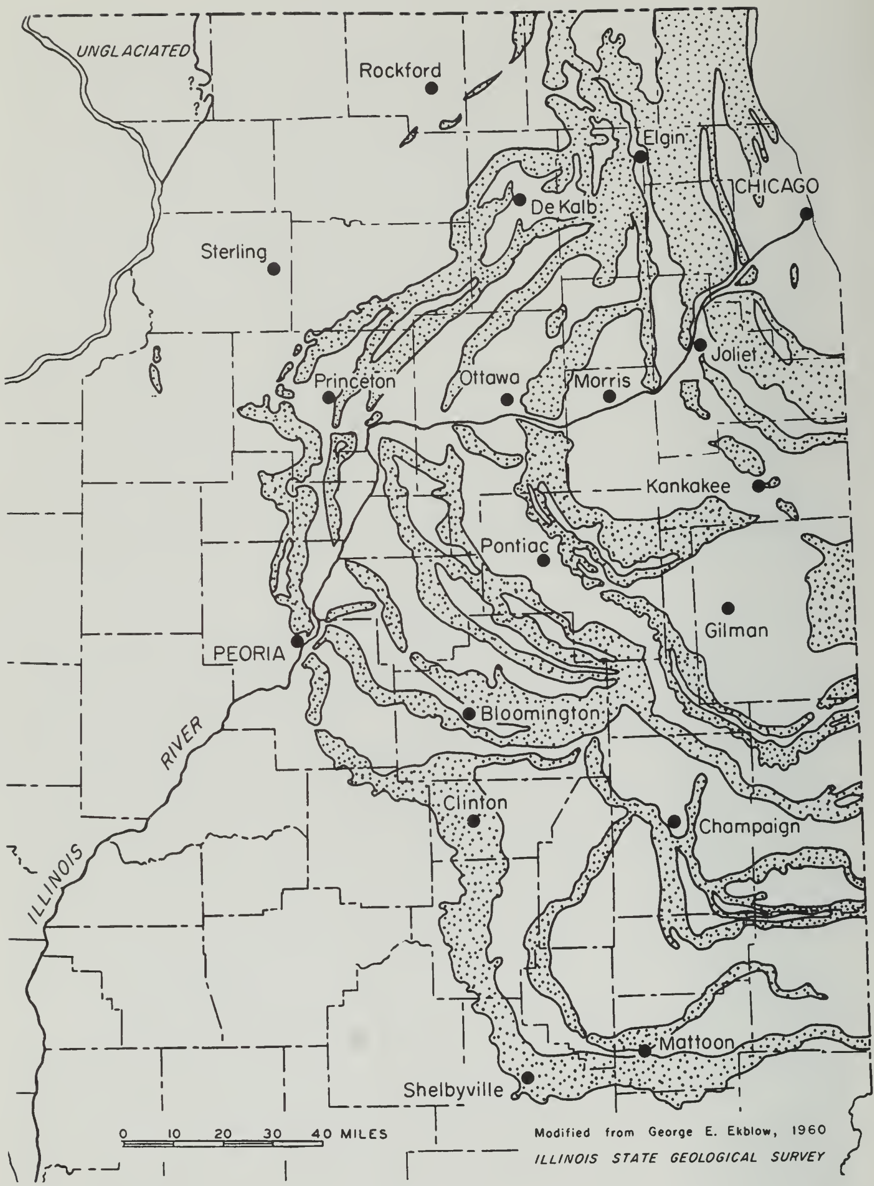

Figure 18 - Moraines left by Wisconsinan glacier.

Figure 19 - Gravel dredge, with plant for processing the gravel in background.

Uses of Sand and Gravel

In 1963 more than 27 million tons of sand and gravel, directly or indirectly of glacial origin, was sold by Illinois producers for almost 25 million dollars. The sand alone would have filled a child's sand box, with an area of 8 square miles, to a depth of 1 foot. The gravel would have covered an even larger area.

The gravel was used in making concrete for roads and buildings, for surfacing roads, for ballast for railroad tracks, and for other purposes. The sand found its way into plaster, mortar, concrete, and a variety of other products and uses. Some of it was produced for use as molding sand.

Production of Sand and Gravel

The production of sand and gravel from its deposits may be a relatively simple operation or one of considerable complexity. Gravel for surfacing a road may be dug from a conveniently located pit and loaded mechanically into trucks that haul it to the road. A large sand- and gravel-producing operation, however, may include not only mechanical equipment to load and transport the material but also a processing plant where it can be washed if necessary and screened to various sizes.

In a "dry pit" operation, mechanical cranes or shovels pick up the gravel and sand and load it into trucks, railroad cars, or conveyor belts to be transferred to the processing plant. There clay and dirt may be washed out and the sand and gravel is sized by screens. Conveyor belts carry sand and gravel to the various processing operations and to storage bins or piles on the ground.

A "wet pit" operation produces sand and gravel from an artificial pond or lake. In some operations the sand and gravel is mined by a dredge that floats on the water (fig. 19). In some pits, a stream of water is directed from the dredge against the bank of gravel to wash the gravel into the lake. A large metal pipe at the front of the dredge slants down into the water and sucks up the sand and gravel from the underwater part of the deposit. The gravel, sand, and water is then pumped through a pipe at the rear of the dredge to the processing plant on the shore.

In some types of wet pit operations a large scoop or bucket operated from a crane on the shore, or by cables fastened to the shore, is used to dig sand and gravel from beneath the water.

Dredges are used to pump up sand and gravel from the beds of Illinois rivers, especially the Mississippi, Ohio, and Wabash.

The sand and gravel resources of many parts of the state have been mapped and studied by the Illinois Geological Survey, and work of this kind is continuing.

SILICA (TRIPOLI) AND OTHER MINERAL MATERIALS OF EXTREME SOUTHERN ILLINOIS

The hills of extreme southern Illinois contain several mineral materials that are entirely or largely restricted, in important quantities, to that part of the state. Some of them, such as silica and novaculite, come directly from bedrock deposits of great age; others, such as some of the sands and gravels, are of more recent origin.

Silica (Tripoli)

A mineral material unique in Illinois is the amorphous silica, or tripoli, mined in the hills of southern Illinois about 20 miles north of Cairo.

Most of the silica mines are found at the heads of valleys or in tree-covered hill slopes along the less traveled roads. An arched opening (fig. 20) with a road leading into it may be all that is visible of the mine from the outside. Inside are many rooms, some 30 feet high, separated by rounded pillars about 20 feet thick that have been left to support the arched mine roof.

Most of the silica in the mines is white, and this is the part that is mined. A silica deposit is made up of layers—some of white, powdery rock material, others that look chalky but are firm or hard.

Figure 20 - Entrance to a silica mine.

In the mines the silica is blasted loose from the natural deposit and loaded into trucks that take it to the processing mills at Elco and Tamms, where it is crushed and then transferred to huge grinding mills that pulverize it to a very fine powder. Air currents of different velocities separate the powder into various grades of fineness, and the finished silica goes into large paper bags for shipment.

Origin of Silica.—Some of the history of the formation of silica deposits is not fully known, but it seems probable that their original character was quite different from what it is today. Investigations by Survey geologists suggest that the parent rock formation was limestone and chert. The limestone was composed of the mineral calcite, but scattered through it were myriads of small particles of quartz. Interlayered with it were bands and beds of chert that contained varying amounts of calcite.

As the rocks above them were worn away by the ceaseless erosion of streams and rivers, these original deposits were uncovered. Rain and snow-water then worked down into the limestone and chert deposits through cracks and crevices and dissolved the calcite in the rock. The quartz remained because it is much less soluble than the calcite. After many thousands of years all the calcite had been removed, leaving behind a "skeleton" of quartz—the silica deposits of today.

Uses of Silica.—The silica mined and milled in southern Illinois has many uses. A superfine grade, known as white rouge, is used to polish optical lenses. Other grades are used in scouring compounds, metal polishes, paints, electrical resistors, high-temperature pipe coverings, fiberglass manufacture, plastics, silicone rubber, wood filler, caulking compounds, ceramic products, floor tile, billiard cue chalk, as foundry parting or facing, concrete admixture, in the manufacture of buffing compounds that are used to polish metal objects, and for other purposes. Industry uses many thousands of tons of silica each year.

Chert and Chert Gravel

Deposits of chert, chert gravel, and ganister also are among the variety of mineral materials found in extreme southern Illinois. Chert consists principally of minutely crystalline particles of quartz. Some chert is popularly called flint. In southern Illinois chert occurs in two principal kinds of deposits, those composed of solid ledges and those consisting of gravel. The term novaculite is used in southern Illinois for those solid deposits that are white, comparatively thick, and free of other interlayered materials. No novaculite is mined at present, but it is said to have been sold in past years for making sodium silicate and silica brick.

The chert gravels of southern Illinois are of three kinds—novaculite gravel, Elco gravel, and "Lafayette" Gravel. The novaculite and Elco gravels consist of fragments of chert plus lesser amounts of fine silica particles and clay. The chert fragments of the novaculite gravel are angular, but the Elco gravel includes both angular and rounded fragments. These gravels are white, yellow, brown, or reddish brown, the novaculite gravel usually being the more highly colored. Deposits in Union and Alexander Counties have been used for road surfacing and other purposes. Deposits of chert gravel also occur in Hardin and Saline Counties, and some stream valleys in southern and western Illinois also contain such gravel.

"Lafayette" Gravel consists principally of brown chert pebbles. Most of the pebbles are rounded and have a smooth, semi-polished surface. The sand and clay occurring with the gravel are brown or dark red. In some places there are deposits of coarse, red quartz sand. The gravel is most abundant in the four southernmost counties of the state, and deposits may be as much as 65 feet thick. It is used principally as a road-surfacing material.

Ganister

Ganister occurs in the hills of Alexander and Union Counties and is a loosely consolidated, granular material consisting of irregular particles up to about an inch in diameter or of masses of material readily disintegrated into such particles. The particles are composed mainly of fine crystalline quartz. Ganister is white, cream, light yellow, or red and occurs in deposits up to 25 feet or more thick. Relatively small tonnages of the light colored ganister are now used, principally in making refractories, but ganister is said to have been more widely used in that field in the past. It is produced from underground mines. Some red ganister, or ganister like material, mined from open pits has been used for road surfacing.

Studies of Southern Illinois Materials

Survey geologists have mapped the chert- and silica-bearing formations of Alexander and Union Counties and also many of the various kinds of gravel deposits. Samples have been tested to determine their chemical composition and the size of the particles composing them. Laboratory studies by ceramists indicate that novaculite and novaculite gravel, when suitably processed, can be used for making silica brick, which withstands great heat. Ganister and the gravels of southern Illinois offer a variety of raw materials awaiting increased industrial use.

Sands of Extreme Southern Illinois

In southern Illinois deposits of sand laid down in an arm of the ocean that once extended northward into Illinois from the Gulf of Mexico are found in Alexander, Union, Pulaski, Pope, and Massac Counties. The deposits are commonly a light color—white, cream, yellow, or gray.

The grains of the sand are almost all quartz and generally are angular. Some of the sands are of almost powder-like fineness, others are fine or medium grained. Many of the sands contain flakes of white mica, a glistening, silvery-looking mineral often mistaken for silver or platinum. Unlike these metals, however, mica is comparatively light in weight and is not metallic. Also present in some sands are small flakes of the mineral graphite.

The southern Illinois sands have not been widely used, but some of them have been employed in making concrete. They also may have possibilities for molding and core sand.

As a result of work by Survey geologists, the location and properties of many of the southern Illinois sand deposits are known.

CLAY AND SHALE

Man has used clay in various ways for many hundreds of years. From it he made, and still makes, bricks to build his dwellings, pottery utensils of many kinds, and other useful products.

Everyone knows what clay is, yet it is a substance difficult to define. All clays are earth materials, most of them plastic or sticky when wet but firm when dry. If heated sufficiently (fired) they become hard.

Clays are composed of various minerals. Of these, the so-called clay minerals—complex substances composed mostly of alumina, silica, and water—generally are the most important. They impart the property of plasticity and also cause clays to become hard when fired.

Most clays are what geologists call unindurated (unhardened) rocks. Clay that has been indurated and occurs in layered deposits is commonly called shale. The layers may be from a fraction of an inch to several inches thick. Most Illinois shales are not plastic when dug from freshly exposed deposits, but they become plastic when crushed and kneaded with water. The clays and shales of Illinois are the basis of a huge and important industry.

Early Uses in Illinois

Clays and shales are useful because they can be made plastic by adding water, formed into desired shapes, and fired to a rock like hardness. As a result, various kinds of bricks, drain tile, pottery, and other useful products are made from them. In its early years, Illinois had many widely distributed potteries that used clay from nearby deposits to make a variety of jugs, crocks, and bowls that served in place of many present-day glass or metal articles.

Drain tile has been of major importance in the development of the state. Early settlers found many low lying, swampy areas and tracts of land that drained poorly after heavy rains. Ditches were dug to carry away the water from some areas, but others were drained by means of drain tile—pieces of fired clay pipe several inches in diameter and about a foot long that were laid end to end in trenches below plough depth and then covered with earth. Water seeped into the tile, which discharged it into ditches. Tile factories, built throughout Illinois near clay or shale deposits, did an active business. Gradually, however, as more and more farm land was drained the demand slackened and many tile factories went out of business. Although there are fewer factories, much drain tile is still manufactured in Illinois.

Many of the early tile plants also made bricks to be used for making foundations, buildings, sidewalks, and other structures. The bricks were made by hand-operated equipment. Some of the old hand-molded bricks may still be seen in older buildings. Now the brick-making process is highly mechanized and even though there are fewer plants they produce more bricks.

Clay and Shale Deposits

Illinois shales are a part of the bedrock—that is, they are associated with indurated rocks such as sandstone and limestone. Most clays are surficial rocks occurring in deposits near the surface, where they lie above the bedrock. Exceptions are certain clays found in extreme southern Illinois and the underclays, also called fireclays, that occur beneath coal seams and are part of the bedrock.

The surficial clays are of two principal kinds—till and loess. Till is a deposit left by glaciers. It is a gray, blue-gray, or brown clay containing varying amounts of sand, pebbles, cobbles, and even boulders. Till is found at many places in the state and is used for brick making, especially in the Chicago area.

Loess is a wind-deposited silty clay or clayey silt and is found in many parts of Illinois. It is thickest on or near the bluffs of the Mississippi, Illinois, and Ohio Rivers. It generally is brown and stands in steep faces in roadcuts and other excavations. It once was widely used for making brick and tile.

Of major importance in making clay products in Illinois are the bedrock shales and the clays associated with the coal-bearing rocks that underlie much of the state. The shales, and the clays to a lesser extent, are dug at many places for making structural clay products such as bricks, structural tile, and drain tile. They also are used to make lightweight aggregate for concrete. The underclays of some of the older coal seams are used to make buff-colored brick, stoneware, and a highly heat-resistant brick (firebrick) that is used in industrial furnaces or in other operations involving high temperatures. Some fireclay, ground as fine as flour, is added to molding sand to make it coherent enough to form into molds for metal casting. Sewer pipe and flue lining also are made from underclays.

Clays unlike those found elsewhere in the state occur in extreme southern Illinois. One of these has the property of removing color from oils and was so used at one time by petroleum refineries. Another, kaolin, was extensively used during World War I for making crucibles.

Clay Minerals

The uses of clay and shale are determined to a large degree by the properties of their clay minerals and to a lesser degree by the impurities present. A clay or shale containing the clay mineral illite, and other similar but less important clay minerals, commonly becomes red when fired and gets hard at a relatively low temperature. It therefore is used to make red bricks, drain tile, building tile, and other structural clay products.

Another clay mineral, kaolinite, generally burns to a light color and is difficult to fuse. Therefore, clays composed wholly or mainly of kaolinite can be used for making buff or light-colored bricks and for the manufacture of highly heat-resistant (refractory) bricks.

The clay mineral in the southern Illinois clay that was used to decolorize oil is montmorillonite. This clay is now used in sweeping compounds, as an oil absorbent, as animal litter, and for other purposes.

Studies of Clay and Shale

In view of the significant relationship between the clay minerals and the utilization of the clays and shales in which they occur, the Illinois Geological Survey has investigated extensively the clay minerals in the clay and shale deposits of Illinois. Many samples were studied by means of powerful microscopes, X-ray, and chemical analysis. Most of the surface clays and shales proved to be composed principally of illite or related minerals. The kaolin clay of extreme southern Illinois contains the mineral kaolinite. The older underclays also contain kaolinite, but many of them also contain smaller amounts of illite.

The Survey also has tested many clays to determine their burning properties and color when fired, and hence their potential uses. The bonding capabilities of other clays have been measured to find out whether they can be used as a bonding material for molding sand. The bloating properties of Illinois clays and shales from many deposits have been studied to determine which are suitable for making lightweight aggregate for the manufacture of concrete.

The object of these studies has been to discover the location, character, and possible uses of the state's clay and shale resources. Special studies are continuing in several parts of the state. Illinois is well endowed with clays and shales that can be used for a variety of purposes and has resources to fill future as well as present needs.

How Bricks Are Made

Conversion of Illinois clays and shales into useful products is an interesting process and is exemplified by the making of building bricks. Mechanical shovels dig the clay or shale and load it into trucks or small railroad cars that take it to the brick plant. There, machines grind the raw material and mix water with it until it has the consistency of stiff mud.

Next, a machine, which operates somewhat like a meat grinder, extrudes a brick-sized column of clay. As the column moves forward, it is automatically cut into bricks by wires. The bricks are then dried in large heated rooms.

Figure 21 - Beehive brick kiln.

From the driers, the bricks go to huge ovens (kilns) and are heated until they are hard and have attained the desired color. This is known as firing or burning the bricks. Temperatures employed are rarely lower than 1800° F.

Three kinds of kilns are used in Illinois for burning bricks—beehive, tunnel, and scove. A beehive kiln (fig. 21) has a round base and a dome-shaped top and somewhat resembles an oversized beehive. Unfired bricks are stacked in the kiln and the doors are sealed with burned bricks and clay. Fires are started in hearths or fire boxes in the wall of the kiln and the heat is circulated into and through the kiln. It usually takes several days to fire the bricks adequately and let the kiln cool so that the bricks can be removed.

Tunnel kilns, made from heat-resistant bricks, are actually tunnels big enough for a man to stand in. The unburned bricks are loaded on flat steel cars on top of a layer of refractory blocks that protect the steel from the heat. The cars enter the kiln and heating begins. As they move through the kiln, they carry the bricks through a firing area, then through a cooling zone, and finally out into the air.

In some brickyards in the Chicago area, dried unburned bricks are carefully stacked by machines into piles about 17 feet high, 35 feet wide, and 115 feet long, which are known as scoves or scove kilns. A layer of burned bricks that is plastered with clay covers the sides of the scove. A jet of flame is directed through small tunnels at the base of the scove, and the heat fires the bricks.

During 1963, more than 325,000,000 bricks were produced by Illinois brick plants. In the same year, the value of all the clay and clay products produced in Illinois was nearly $54,000,000. Besides brick and drain tile, the products of the clay and shale industry of Illinois include refractory brick, building block and tile, fire-proofing, sewer pipe, flue liners, stoneware, lightweight bloated burned clay aggregate for concrete, and a variety of unburned clays for special purposes, including bonding clay, refractory fireclays, absorbent for use on garage floors, and litter for animal cages.

PEAT

After the retreat of the last of the great ice sheets from Illinois, numerous ponds and lakes were left in northern Illinois, especially in the eastern section. Some of them were soon drained by natural processes, but others remained. In the shallow water along their shores grew various plants, chiefly reeds and sedges and, locally, a variety of moss. As the plants died, their partially decomposed remains were preserved beneath the water. Ultimately, the ponds and lakes were overgrown and more or less completely filled by the plants and their remains, giving rise to peat (fig. 22) bogs.

Some peat bogs have been drained and are now used as farm land. Others remain and a few of them are the source of peat or humus for horticultural purposes. Producing operations are located in northeastern Illinois and in Whiteside County in northwestern Illinois.

OTHER MINERAL RESOURCES

In the future, new uses will be made of the Illinois industrial minerals already discussed. In addition, other mineral resources of the state that are not now being used may be the bases of new mineral industries. Some of these minerals are at present too costly to mine because the deposits are deeply buried or are

Figure 22 - Peat from Kane County showing its fibrous nature and remains of plants.

not sufficiently rich to be worked at a profit. Others are not convenient to markets, and still others have no present commercial use. In years to come, however, changes may occur that will make it practical to mine, process, and use some of these resources. Furthermore, some other mineral deposits that are now being utilized in a limited way may have greater future use. The Illinois Geological Survey continues to study the location, character, and composition of many such mineral materials and is alert for the development of new uses. Some of the materials are discussed briefly below.

Gypsum and Anhydrite

Gypsum is a mineral that consists of calcium sulfate plus two molecules of water ($CaSO_4 \cdot 2H_2O$). By suitably heating it, the amount of water can be reduced, and a product called calcined gypsum (plaster of paris) results. This material changes back to gypsum if mixed with an appropriate quantity of water. The ability of calcined gypsum to "set" when water is added makes it important in the manufacture of a variety of plasters and related products, especially building materials. Gypsum also is used in cement making and in agriculture.

Anhydrite ($CaSO_4$) is like gypsum except that it contains no water and hence cannot be made into plaster of paris. Its uses are limited in the United States.

Wells that were drilled for oil, water, or coal have encountered gypsum and/or anhydrite in some parts of south-central Illinois, but the gypsum and anhydrite are not known to crop out at the surface. A study of diamond drill cores and well cuttings on file at the Survey showed that the shallowest gypsum and anhydrite reported occurred at a depth of 470 feet in Madison County. The greatest continuous thickness of gypsum found was 2 feet; but in one well, over 6 feet of strata was penetrated that averaged almost 75 percent gypsum. It is possible that thicker deposits of gypsum might be found if drilling were done especially in search of it.

Feldspar-Bearing Sands

Feldspar is the name applied to a group of minerals that are mainly silicates of potassium, sodium, and calcium. Various kinds of feldspar are used industrially in making glass, enamels, pottery, and other products. All the feldspar now used in Illinois is shipped into the state. The discovery by the Illinois Survey that some Illinois sands contain considerable feldspar led Survey geologists and chemists to find where deposits highest in feldspar occur, what kinds of feldspar they contain, and whether it could be separated from the sand in which it occurs. Beach sands, river sands, dune sands, and sands from other kinds of deposits were studied.

It was found that many sands contain more than 15 percent feldspar and some as much as 25 percent. Means of separating the feldspar from the sand are believed to exist, but problems relating to the purity of the separated spar remain to be solved.

Brines

No salt is now produced in Illinois, but at one time the state was a major salt producer. Salt works were in operation near Equality, Central City, Murphysboro, St. John, Danville, and possibly other places. The salt was obtained by evaporating salt water (brine) that came from natural springs or from wells. The Equality area was a particularly important producer of salt in the 1800's. Discovery elsewhere in the Middle West of deposits of rock salt and brines that contained more salt than those of Illinois is said to have been responsible for the discontinuance of salt making in the state.

No salt beds crop out in Illinois, nor are any known to have been encountered in the many wells that have been drilled for coal, oil, or water. However, most oil well drilling encounters brines containing various amounts and kinds of salts, including the common table salt, sodium chloride.

For reasons relating to the production of oil, Survey geologists and chemists have collected and analyzed many samples of Illinois oil field brines, and data are therefore available on their salt content. No commercial use is being made of the brines as sources of salt.

Oil Shale

Illinois has a large oil-producing industry that obtains oil from wells. The state also contains beds of shale that yield oil when the shale is heated.

In order to estimate the present and future importance of the oil shale resources, the Survey collected and tested more than 100 shale samples from 41 Illinois counties. A few samples contained more than 25 gallons of oil per ton of shale, but most contained less than 15 gallons per ton. A study of the crude oil distilled from selected shale samples showed it to be somewhat different from the oil that comes from wells. It could, nevertheless, be made to yield gasoline, fuel oil, and other products if suitably processed.

The shale strata generally the richest in oil are found above coal seams, are black, and are sometimes called slate by coal miners. They are rarely more than 3 feet thick, but they extend over large areas.

Sandstone

Sandstone has a long history of use in Illinois. Pioneers built foundations for their houses and barns and curbs around their wells from it. Slabs of sandstone were once a popular material for sidewalks, some of which are still in use. Churches and other sizable buildings have been constructed from it, and at one time an Illinois sandstone was used to make grindstones. Except for the St. Peter Sandstone, which was discussed under "Silica Sand," the use of sandstone has decreased, although comparatively small quantities are still used as building stone.

Most Illinois sandstones may be thought of as a mass of sand whose grains are more or less firmly cemented together by clay, iron oxide, and quartz, either singly or in combination, or, less commonly, by calcite. The grains are particles of various minerals, but most of them are quartz.

Sandstones are especially common in the hill country of extreme southern Illinois. The Survey's investigations in this area revealed that if they are suitably processed some of the sandstones may have possibilities for commercial use. Sandstones in other parts of the state also have been studied, with similar conclusions.

Barite

Barite (barium sulfate, $BaSO_4$) is a deceptive mineral—it is much heavier than it looks. Barite found in Illinois is generally white or light colored, and, although some of it looks rather like white limestone, it is more than half again as heavy as limestone. Barite's unusual weight is responsible for one of its major uses—as a constituent of drilling muds for the oil industry. These muds are a mixture of clay, water, and a weighting material such as barite. They are used in various ways in the drilling of oil wells by rotary drills. Barite also is an important raw material for the manufacture of chemicals.

Barite is found in Hardin and Pope Counties, the site of the fluorspar industry. According to studies made by Survey geologists, the barite occurs both as veins and beds associated with fluorspar, but its distribution is irregular and the deposits are of limited size. A barite mine is said to have been worked years ago, and more recently comparatively small tonnages have been taken from open pits. Future exploration in southern Illinois may reveal deposits of barite that will be profitable to mine.

Greensand

In some parts of Illinois occur sands or sandstone that contain numerous grains of the green mineral glauconite. If the sands are not discolored by iron compounds or other substances, they too have a greenish color and, therefore, are called greensands. Glauconite varies in composition but contains potassium, magnesium, iron, aluminum, silicon, and water. Greensand is said to be used in relatively small amounts as a soil conditioner and as a water-softening agent.

Greensand is known to occur in the general vicinity of Olmsted in southern Illinois. Near Oregon in northern Illinois an old quarry exposed 10 feet of greenish brown sandstone that contains glauconite. Samples from southern Illinois and from the sandstone at Oregon contained more than 6 percent potassium oxide.

Marl

In some of the lakes and ponds left by the glaciers lived numerous small mollusks with calcium carbonate shells. As the animals died, their shells formed a deposit on the bottom of the lakes and ponds. Certain plants, especially algae, may have added a mudlike precipitate of calcium carbonate to the deposits, and varying amounts of clay washed from the shores mixed with both these materials. The resultant deposit is called marl. Some marl deposits have peat mixed with them, and peat also overlies some marl deposits.

Only comparatively small amounts of marl are known to have been dug in Illinois. One deposit containing many shells and shell fragments, some of it associated with peat, was worked in southeastern Livingston County as a source of agricultural liming material. Other deposits have been reported at other places in northeastern Illinois. The available information indicates that the marl deposits are likely to be principally of local importance.

Tufa and Travertine

The tufa (fig. 23) and travertine occurring as surficial deposits in Illinois were formed by springs. The deposits usually occur at or near the outcrop of a layer of porous water-bearing earth material, such as gravel, sandstone, or fissured limestone, that is underlain by a nonporous clay or shale formation. Water moving down through the porous layer cannot sink through the clay or shale and so is forced to move laterally. Where valleys have cut into the layers of gravel or rock, the water emerges as springs.

If the material through which the water has passed is limestone, or gravel containing limestone as most Illinois gravels do, some of the limestone is likely to have dissolved in the water. When the water issues as a spring, conditions may be such as to cause precipitation of the dissolved limestone as tufa or, more rarely, travertine.

Tufa is generally highly porous and more or less impure, whereas travertine is harder and less porous.

The middle or lower slopes of bluffs are common sites for spring-deposited tufa or travertine. Deposits have been seen in various parts of Illinois, but are not known to have been worked, except in Calhoun County where small quantities of tufa were produced for use as agricultural limestone. It is thought that the tufa and travertine deposits of Illinois are relatively small, but they may be of local importance.

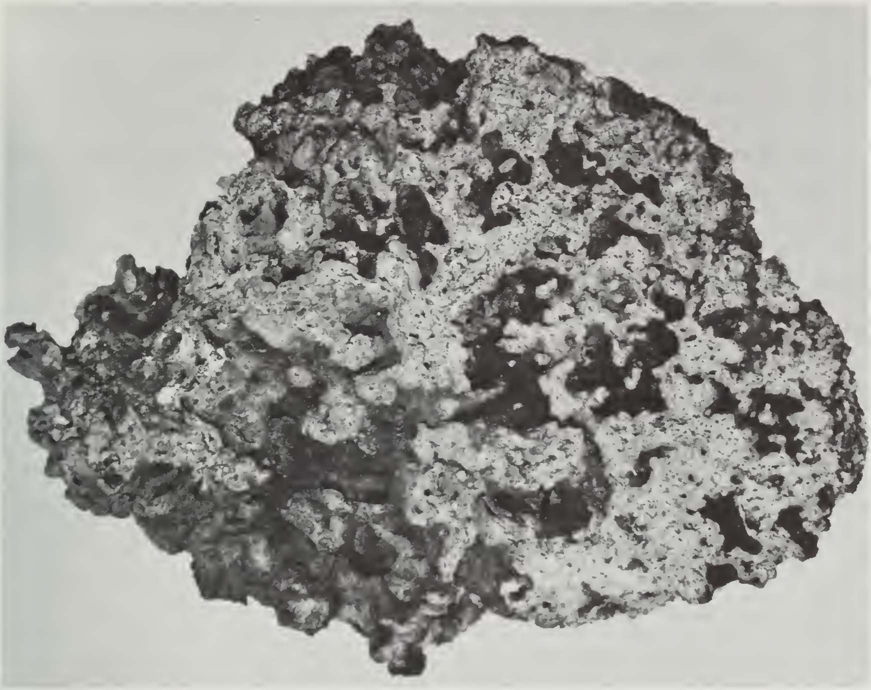

Figure 23 - Calcareous tufa from Pike County. In addition to the large visible pores there are numerous tiny ones.

Pyrite and Marcasite

The mineral pyrite consists of iron and sulfur as the compound iron sulfide (FeS_2) and, because of its shiny, brassy yellow color, is sometimes called fool's gold. Marcasite has the same composition as pyrite, but its crystals have a different shape and it is often lighter colored. Both minerals occur in various parts of the state; they are particularly prevalent in some coal seams, and when so occurring are in some cases called coal brasses or "sulfur."

Pyrite and marcasite are used commercially as raw materials for making sulfuric acid, although sulfur itself is more extensively used for that purpose. At one time coal brasses recovered during coal-cleaning operations at a northwestern Illinois coal mine were sold for acid making. A large quantity of coal brasses probably could be recovered from such operations at Illinois coal mines.

Uranium

Uranium has been sought in Illinois by many people in recent years. The Geological Survey also carried out a wide search for uranium and particular attention was paid to certain clays and other rocks in Hardin County and certain black shales in other parts of the state.

About 200 samples from Hardin County and 175 samples of the shales were tested by the Survey. No deposits were found that are known to be of the required richness and quantity.

Iron Ore

About the middle of the 19th century two furnaces in Hardin County in extreme southern Illinois for a time produced iron from local limonite ores. The ore is said to have occurred as pellets, chunks, and masses scattered through soil and clay and apparently was of irregular distribution. Little can be seen of the deposits today. Their extent is not known, but they are believed to be of limited size.

The Illinois State Geological Survey carries on a continuous program of research on the industrial minerals and metals of Illinois and their uses.

In addition to the investigations mentioned in this booklet, many others have been made or are in progress. Such studies are necessarily a continuing activity if the full potentialities of Illinois mineral resources are to be realized, for industry continually demands new raw materials and changes its requirements for those now used.

The Survey has issued numerous reports that deal with the resources discussed here and mimeographed lists of these are available upon request.

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Illinois State Geological Survey
Educational Series 8