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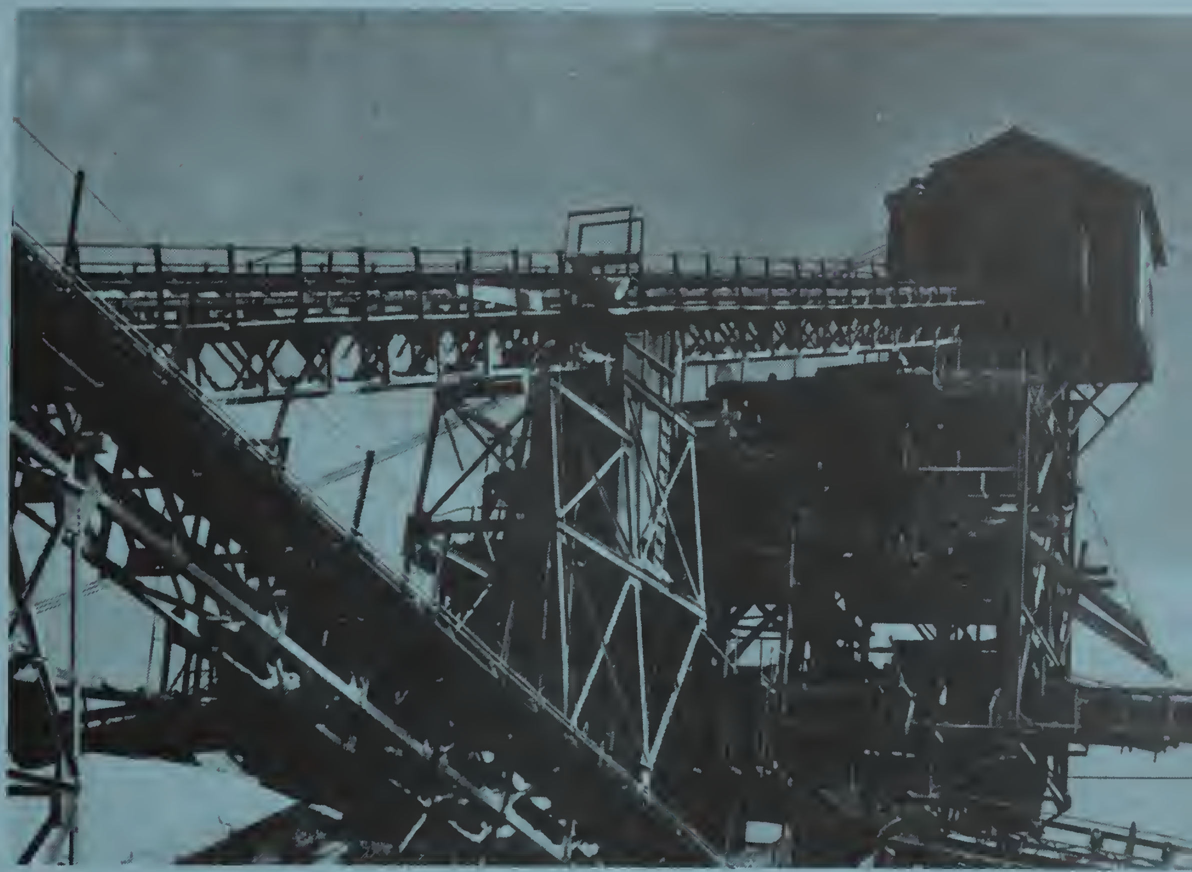

Geology of carbonate aggregate resources of Illinois

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STATE GEOLOGICAL SURVEY DIVISION
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ABSTRACT
Carbonate rocks ranging in age from Pennsylvanian through Ordovician provide the principal resources for crushed stone production in Illinois. In the northern third of Illinois, dolomite and calcareous dolomite of the Silurian and Ordovician Systems form the bedrock surface and are the basis of a large quarrying industry. One of the largest quarries in the United States wins stone from Silurian reefal dolomite at Thornton, near Chicago. In the southern two-thirds of Illinois, limestone and dolomitic limestone are won primarily from Mississippian and older Paleozoic carbonate rocks that crop out along the western and southern border areas near the Mississippi and Ohio Rivers. Rocks of Pennsylvanian age form the bedrock surface in much of the interior of the southern two-thirds of the state; these rocks contain relatively limited limestone resources, primarily in beds rarely more than 18 meters (60 ft) thick. Aggregate for skid-resistant asphalt pavement is produced from Devonian chert in extreme southern Illinois.

INTRODUCTION
Abundant resources of high-quality aggregate are available in many areas of Illinois. The dominant resources include sand and gravel in valley trains and outwash plains formed by Pleistocene continental glaciation, and crushed limestone and dolomite quarried from Silurian and Mississippian rocks.

Sources of high-quality Silurian crushed dolomite are especially abundant near the high-volume metropolitan Chicago market area. However, continued availability of these resources is threatened by urbanization. Elsewhere in Illinois, near-surface resources of crushed-stone aggregate commonly are of lower quality and are less abundant than in the Chicago area. Pennsylvanian rocks that have relatively few surface-minable limestone units form the bedrock surface in most of the southern two-thirds of Illinois. Limestone and dolomite units older than the Pennsylvanian are exposed mostly in the vicinity of the major river systems of the state near the western and southern borders. Pennsylvanian and older carbonate rocks exposed at the bedrock surface in the southern two-thirds of Illinois generally contain chert or other deleterious materials that make production of high-quality crushed-stone aggregate difficult.

Locations of limestone and dolomite quarries were compiled for this report from Bulletin 23 of the Illinois Department of Transportation (IDOT, 1977). Information on plant capacities and quality classes of aggregates also was compiled from this source. Many quarries in the state are operated with portable equipment on an as-needed basis. Since Bulletin 23 was compiled, some quarries have been abandoned and some new sites may have been opened. Thus, quarry sites included in this report should not be taken as absolutely indicative of the current structure of the carbonate aggregate industry in Illinois.

Aggregates are generally grouped into four quality classes on the basis of physical testing by the Illinois Department of Transportation (1979). Class A aggregate is acceptable for use in Portland cement concrete and all lower class applications. Class B aggregate is acceptable for use in top-quality bituminous pavements of interstate and primary roads and all lower class applications. Class C aggregate is suitable for base courses and seal coats in secondary quality bituminous pavements and all lower class applications. Class D aggregate is suitable only for use in fill and base courses and in water-based macadam gravel surfaces of secondary roads. Standards of the Illinois Department of Transportation have undergone some modifications, and mining conditions at some Illinois pits and quarries have changed since publication of Bulletin 23 (IDOT, 1977).

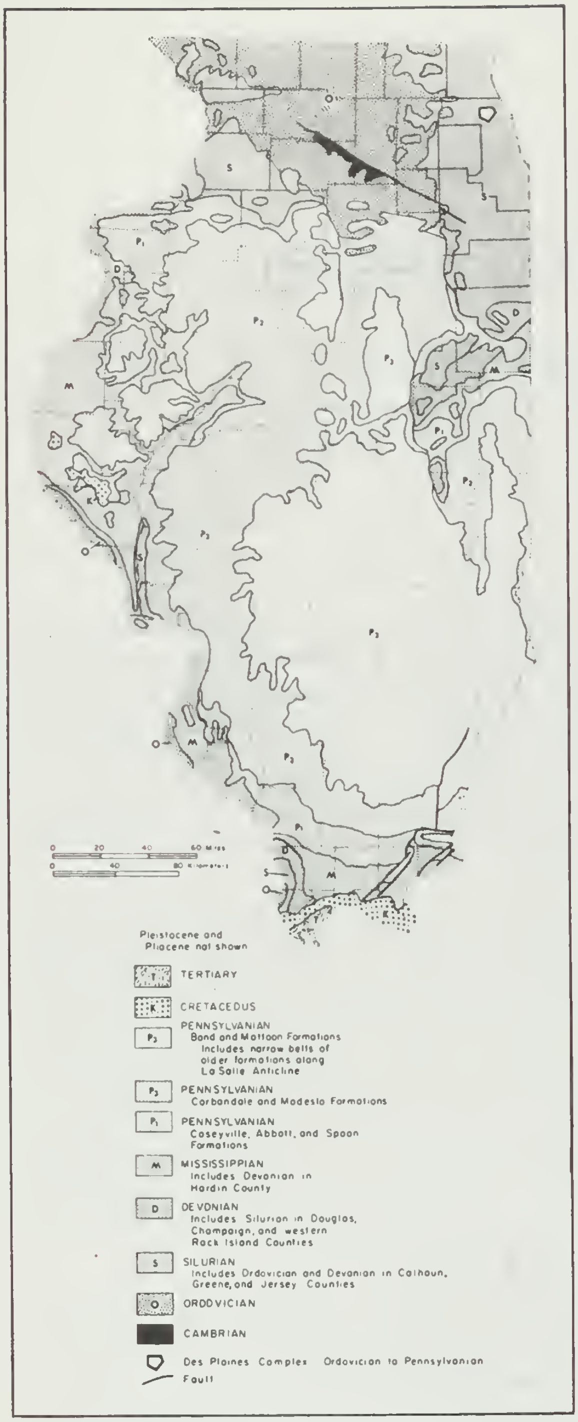

Figure 1. Simplified bedrock geologic map of Illinois (after Willman and Frye, 1970).

BEDROCK AGGREGATE RESOURCES

Bedrock geology of Illinois

Beneath the surficial deposits in the state the bedrock geology is dominated by the Illinois Basin. The Illinois (Eastern Interior) Basin is a structural basin that forms a spoon-shaped depression in most of the southern two-thirds of the state (fig. 1). The basin is bounded on the northwest by the Mississippi River Arch, on the north by the Wisconsin Arch, on the northeast by the Kankakee Arch, on the east by the Cincinnati Arch, on the southeast by the Nashville Dome, and on the south and southwest by the Ozark Dome and the Pascola Arch. Although it varied in size and shape through time, the Illinois Basin remained an area of active deposition throughout most of the Paleozoic Era. Rocks of most of the systems of the Paleozoic Erathem are present in the southern two-thirds of Illinois, but Pennsylvanian rocks form the bedrock surface over most of that part of the state.

Although numerous unconformities are present in the stratigraphic succession in Illinois, those that form the upper and lower boundaries of the Pennsylvanian System have had the greatest role in controlling the present-day configuration of the geology of Illinois. At the end of the Mississippian Period a major episode of erosion removed most of the post-Silurian rocks in northern Illinois. Rocks of the Pennsylvanian System overlap progressively older rocks around the northern margin of the Illinois Basin, and in La Salle County the Colchester Coal Member of the Carbondale Formation of the Pennsylvanian directly overlies the Ordovician St. Peter Sandstone.

Bedrock younger than Pennsylvanian is rare in Illinois. Triassic and Jurassic rocks are entirely absent, and Cretaceous rocks occur only in thin, limited outcrops in extreme southern Illinois and in westernmost Illinois (fig. 1). Rocks of the Tertiary System are found only in the southern tip of the state at the northern edge of the Mississippi Embayment.

Because of the configuration of the Illinois Basin and these extensive sub- and post-Pennsylvanian unconformities, outcrops of pre-Pennsylvanian rocks are confined largely to the northern third of Illinois and to the western and southern border regions along the valleys of the major river systems that bound the state. Thus, the bedrock geology restricts the areas where abundant resources of limestone and dolomite for the making of crushed stone are available at the bedrock surface.

Pennsylvanian System

Aside from limited outcrops of Cretaceous and Tertiary rocks, the youngest rocks exposed at the bedrock surface in most of Illinois are of Pennsylvanian age (fig. 1). In the deep part of the Illinois Basin in southeastern

Illinois near Fairfield in Wayne County, the Pennsylvanian stratigraphic section is up to 760 meters (2,500 ft) thick; the composite maximum thickness of all the 500 distinguishable Pennsylvanian units in Illinois may be more than 1,000 meters (3,300 ft) (Willman and others, 1975). Perhaps 90 to 95 percent of the Pennsylvanian rock units consists of sandstone, siltstone, shale, and coal; the remaining 5 to 10 percent consists of marine and nonmarine limestones, some of which are quite widespread (fig. 2).

Pennsylvanian limestone units quarried in Illinois rarely are more than 18 meters (60 ft) thick; several are less than 7 meters (20 ft) thick. Most of the Pennsylvanian limestone units contain shaly partings and interbedded shale that may make stone produced from these rocks unsuitable for some applications or complicate mining operations.

Some 41 quarries have been active recently in seven different Pennsylvanian limestone units (fig. 3). Most of these quarries are relatively small operations that have reported plant capacities of less than 1,350 T (1,500 t) per day. Of the 41 quarries, 16 produce from the Millersville and the stratigraphically equivalent Livingston Limestone Members of the Bond Formation. Another 13 quarries produce from the Shoal Creek Limestone Member at the base of the Bond Formation (fig. 2). Of the 29 recently active quarries in the Bond Formation, only five have produced Class A aggregate suitable for use in Portland cement concrete (IDOT, 1977); of these five, four produce from the Livingston and Millersville Members. All but one of these five quarries have plant capacities that exceed 2,700 T (3,000 t) per day; this means that in mining a limestone bed 6 to 12 meters (20 to 40 ft) thick, some 2.4 to 4.0 hectares (6 to 10 acres) of land must be stripped and reclaimed each year.

Of the 12 remaining recently active quarries that win stone in the Pennsylvanian from formations other than the Bond, one operates in the Greenup Limestone Member at the top of the Mattoon Formation, three from the Omega Limestone Member in the Mattoon Formation, five from the Lonsdale Member of the Modesto Formation, and three from the Seville Limestone Member of the Spoon Formation (figs. 2 and 3). No limestone is regularly quarried from the Carbondale Formation, although there have been some sales of stone from small surface coal mines where there is thick limestone overburden on coal seams in the Carbondale.

SERIES	Formation	Member
VIRGILIAN	Mattoon	Greenup Ls.
MISSOURIAN		Omega Ls.
	Bond	Millersville/Livingston Ls. Shoal Creek/LaSalle Ls.
DES MOINESIAN	Modesto	Lonsdale Ls.
	Carbondale	
	Spoon	Seville Ls.
ATOKAN	Abbott	
MORROWAN	Caseyville	

Figure 2. Classification of the Pennsylvanian System in Illinois showing relative positions of commercially important limestone units (after Willman and others, 1975).

Chesterian Series. Rocks of the Chesterian Series at the top of the Mississippian System underlie Pennsylvanian rocks only in southern and southwestern Illinois, generally south and east of a line connecting Alton and Kankakee (figs. 4 and 5). The series is exposed only around the margins of the Illinois Basin in southwestern and southern Illinois. Chesterian rocks consist predominantly of sandstone–shale formations that alternate with limestone–shale formations. The rather complex stratigraphy of this 425-meter (1,400-ft) thick series (fig. 4) consists of 20 formations. In general, Chesterian rocks are subject to fairly rapid facies changes and, although widespread, many of the units are lenticular and subject to large variations in thickness. Chesterian limestones presently quarried commonly provide high-quality aggregate resources, but facies changes and thickness variations limit the total resources in this series, and the geology of the state confines outcrops to areas that are far from major population centers.

Mississippian System

Mississippian and older rocks contain abundant limestone and dolomite resources in Illinois. Rocks of the Mississippian System commonly are exposed at the bedrock surface around the southern and western borders of the state and provide most of the carbonate aggregate resources throughout this area (fig. 1).

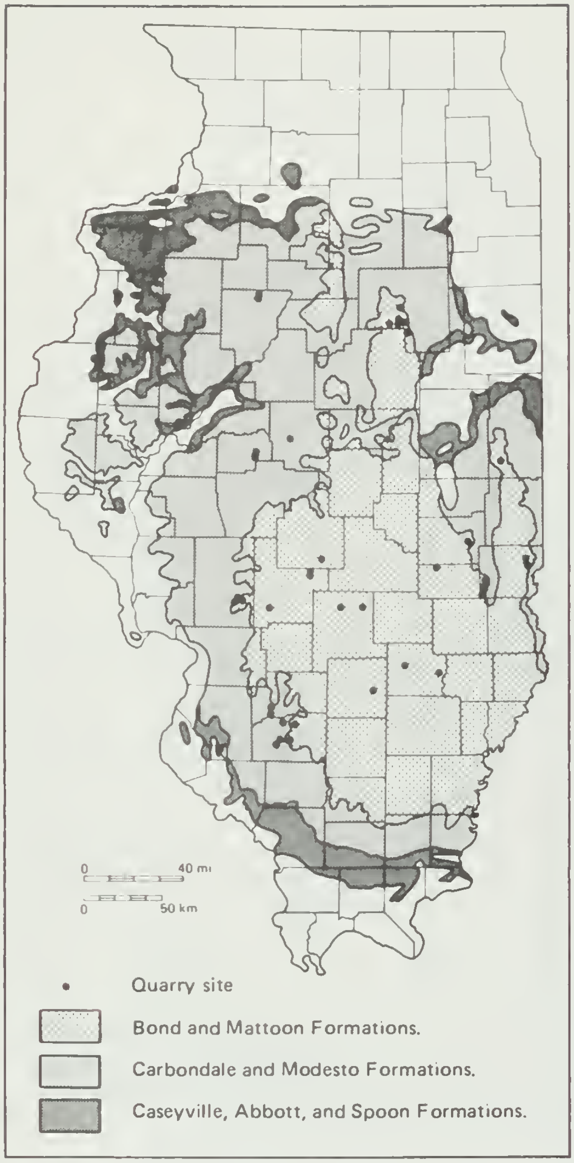

Figure 3. Geologic map of Pennsylvanian rocks exposed at the bedrock surface in Illinois (after Willman and Frye, 1970).

SERIES	STAGE	G-WEST	G-EAST	FORMATION	MEMBER		
CHESTERIAN	ELVIRAN			Grove Church Sh			
				Kinkaid Ls	Goreville Ls Cove Hill Sh Negli Creek Ls		
				Degonia Ss			
				Clore	Ford Station Ls Tygett Ss Cora Ls		
				Palestine Ss			
				Menard Ls	Allard Ls. Scottsburg Ls Walche Ls		
				Waltersburg			
				Vienna Ls			
				Tar Springs Ss			
	HOM-BERGIAN	Okaw		Glen Dean Ls			
				Hardinsburg Ss			
			Gol-conda	Haney Ls			
				Fraileys Sh	Big Clifty Ss		
	GASPERIAN			Beech Creek Ls			
			West Baden	Cypress Ss			
		Point Creek		Ridenhower	Reelsville Ls Sample Ss Beaver Bend Ls		
				Bethel Ss			
			Cedar Bluff	Downeys Bluff Ls			
				Yankeetown Ss			
				Renault Ls	Shetlerville Popcorn Ss Bed Levias Ls		
VALMEYERAN	GENEVIEVIAN			Aux Vases Ss	Rosiclare Ss		
				Ste Genevieve Ls	Joppa Karnak Ls Spar Mtn Ss Fredonia Ls		
				St Louis Ls			
				Salem Ls	Rocher Chalfin Fults Kidd		
				Ullin Ls	Harrodsburg Ls Ramp Creek Ls		
				NORTH and WEST		SOUTH and EAST	
				FORMATION	MEMBER	FORMATION	FORMATION
				Sonora		Fort Payne	
				Warsaw Sh.			
				Keokuk Ls	Montrose Chert	Borden Sts Bilyeu M	Springville Sh Slate Pond M
				Burlington Ls			
				Fern Glen			
				Meppen Ls			
KINDERHOOKIAN		North Hill		Starrs Cove Ls		Chouteau Ls	
				Prospect Hill Sts			
				McCraney Ls			
		New Albany	New Albany	Hannibal Sh	Nutwood Sh	Hannibal Sh	
				"Glen Park"			

Figure 4. Classification of the Mississippian System in Illinois (after Willman and others, 1975).

Only four limestone units in the Chesterian outcrop area are of sufficient thickness and quality to be worked for aggregate. Because of the general dip of the rocks into the Illinois Basin, facies changes, and progressive overlap of Pennsylvanian rocks onto Chesterian rocks toward the north, successively older limestone units in the Chesterian are exploited toward the northwest along the outcrop belt. In the southern part of the belt (fig. 5) at least two quarries operate in the Kinkaid Limestone, the youngest limestone of the Chesterian Series. In the central part of the outcrop belt near Chester, Illinois, an underground mine is operated in the Glen Dean Limestone, about 110 meters (360 ft) stratigraphically below the Kinkaid (fig. 5). The mine produces aggregate from the middle 6 meters (20 ft) of the Glen Dean. Just north of Chester at Roots, a currently inactive quarry won stone from the "Marigold Oolite" in the Haney Limestone (fig. 5) (Bradbury, 1963). To the north of Roots, a modest-size quarry has been operated in an especially limestone-rich facies of the Fraileys Shale that immediately underlies the Haney (fig. 5); this quarry is the only one of the five quarries that has not produced Class A aggregate (IDOT, 1977).

Upper and Middle Valmeyeran Formations. The Valmeyeran Series in Illinois corresponds to the Osagian and Meramecian Series of the Mississippian System as recognized by the U.S. Geological Survey and by some surrounding states. The principal carbonate units among Upper and Middle Valmeyeran formations are the Levias Member of the Renault Formation (uppermost

Valmeyeran), and the Ste. Genevieve, St. Louis, Salem, and Ullin Limestones (fig. 4).

Levias Member. In Hardin County in southeastern Illinois, several of the fluorspar mines in the area have supplied low-quality road stone, probably crushed from waste rock. Since the mines produce from ore zones in the Levias Member of the Renault and in the Ste. Genevieve, the Levias may be considered a source of aggregate. Also, a newly opened quarry near Shetlerville produces primarily from the Renault (figs. 4 and 6).

Ste. Genevieve Limestone. Elsewhere in Hardin County, four quarries produce Class A aggregate primarily from the Ste. Genevieve (fig. 6). In Hardin County, the Ste. Genevieve Limestone reaches a maximum thickness of about 55 meters (180 ft); to the north and west the upper members of the Ste. Genevieve become progressively more sandy and shaly and in southwestern Illinois grade laterally into a sandstone facies in the lower part of the overlying Aux Vases Sandstone. The lower part of the Ste. Genevieve commonly grades into the underlying St. Louis Limestone (except in the westernmost outcrop areas where the base of the Ste. Genevieve is marked by a conglomeratic bed and rests unconformably on the St. Louis). The Ste. Genevieve is thickest in south-central Illinois and the Aux Vases is thickest in southwestern Illinois. Both units are eroded toward the north, and the Ste. Genevieve and Aux Vases are absent in most areas where overlying Chesterian rocks also are absent (see fig. 5) (Willman and others, 1975).

St. Louis Limestone. The St. Louis Limestone also provides a significant resource for aggregate production (fig. 4). In southernmost Illinois, uppermost St. Louis Limestone commonly is quarried together with an overlying portion of the Ste. Genevieve. To the northwest, where the Ste. Genevieve is thin or absent, the St. Louis may be quarried alone or in combination with a portion of the underlying Salem Limestone. In southeastern Illinois, in Pope and Hardin Counties, the St. Louis reaches a maximum thickness of 116 meters (380 ft), but the unit thins north-westward to a thickness of about 30 meters (100 ft) in outcrops near the Monroe-Randolph county line.

North of this point, foraminiferal-oolitic calcarenites assigned to an upper portion of the Salem grade laterally into fine-grained limestone, dolomite, and evaporites assigned to a lower part of the St. Louis. As a result, the St. Louis has a thickness of 60 meters (200 ft) in the Alton-East St. Louis area. Still farther to the northwest, west of the Illinois River, the St. Louis is truncated by the sub-Pennsylvanian erosion surface and occurs only in a few large outliers (fig. 6). In the subsurface, the St. Louis consists mainly of cherty, fine-grained,

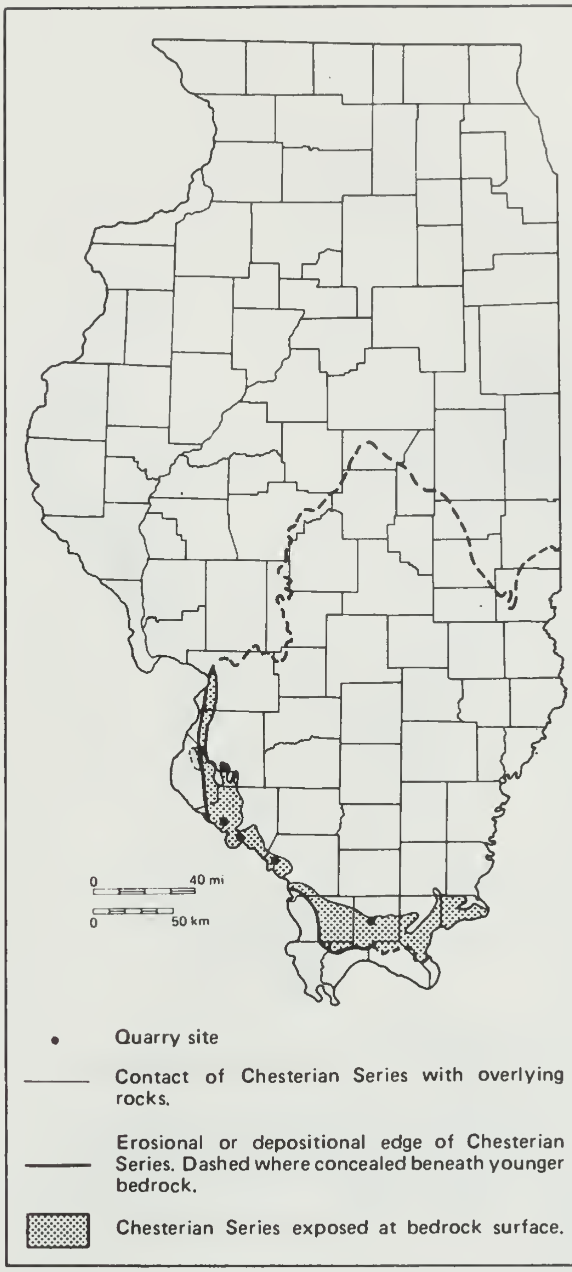

Figure 5. Geologic map of Chesterian Series (Mississippian) rocks showing bedrock outcrops and subsurface distribution in Illinois (after Willman and others, 1975).

dense limestone; some interbedded, coarsely fossiliferous limestone; some lenses and beds of dolomite; minor shale; and beds of gypsum or anhydrite that may reach 9 meters (30 ft) in total thickness. Near the outcrop zones along the major river valleys, and in the outliers of western Illinois (fig. 6), the evaporite beds have dissolved, but layers of moderately to strongly cemented limestone breccia probably indicate their former presence (Willman and others, 1975).

In southeastern Illinois, in Hardin County, a fairly sizable quarry in the St. Louis that produced Class A aggregate has been abandoned because of excessive overburden, increased chert, fault complications, and

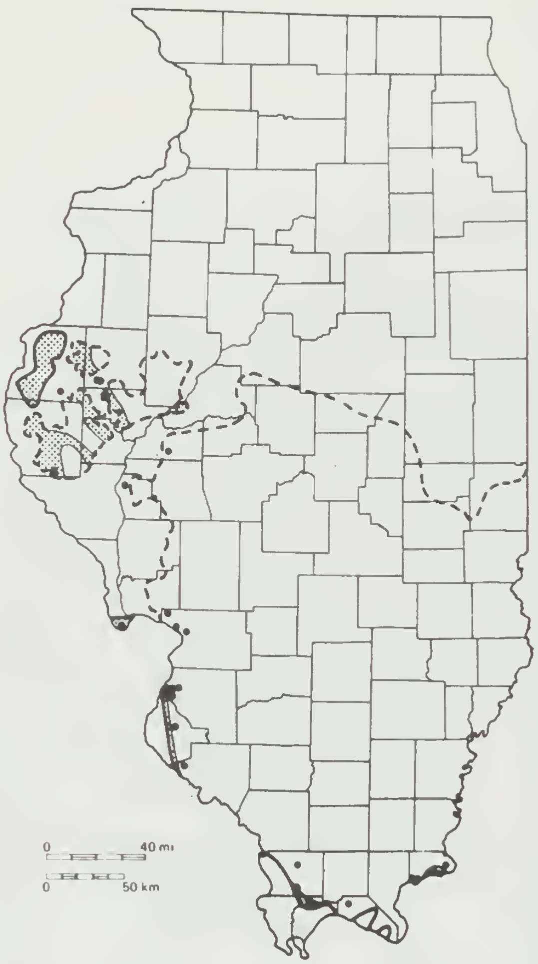

Figure 6. Geologic map of upper and middle Valmeyeran (Mississippian) rocks showing bedrock outcrops and subsurface distribution in Illinois (after Willman and others, 1975). Map shows only distribution of St. Louis Limestone.

excessive waterflow. In western Illinois (from the East St. Louis area northward to the Macomb area) eight quarries in five counties have produced stone from the St. Louis; however, only the two in the Alton-East St. Louis area produce Class A stone (fig. 6). The others produce stone of Class C or D quality, suitable only for use in secondary bituminous pavements, oil and chip seal coats, water-bound macadam gravel surfaces, and base courses (IDOT, 1979).

Salem Limestone. Beneath the St. Louis Limestone in southwestern Illinois, the Rocher Member of the Salem Limestone (fig. 4) crops out in Randolph County and is mined underground to produce Class A aggregate (fig. 6). Nearby, a currently inactive underground mine in the Rocher Member produced limestone for use in making soda ash by the Solvay process. The Rocher commonly consists of chemically pure, medium- to coarse-grained, fossil-fragmental limestones. In southwestern Illinois, Baxter (1960) subdivided a 60-meter (200-ft) thickness of the Salem into four members: the Rocher, Chalfin, Fults, and Kidd, from top to bottom. Lineback (1972) restricted the Kidd Member to an upper portion of the original Kidd, assigned the lower beds to the Ullin Limestone, and demonstrated (by electric log cross sections) that calcarenites assigned to the upper Salem in the Illinois Basin grade laterally into fine-grained facies of the lower part of the St. Louis of the type area. In some places in the outliers of western Illinois (fig. 6), a fine-grained, algal-bedded, and brecciated St. Louis lithology completely replaces the biocalcarenites of the Salem. Where this occurs, the St. Louis Limestone is considered to directly overlie the shales of the Warsaw Formation that elsewhere underlie the Salem lithology (fig. 4). In extreme western Illinois, the St. Louis and Salem Limestones have a combined thickness that rarely exceeds 23 meters (75 ft). However, five recently active quarries in four counties have produced aggregate from these rocks (fig. 6). None of these quarries produces aggregate of better than Class C quality.

Ullin Limestone. In extreme southern Illinois, the Ullin Limestone underlies the Salem Limestone (fig. 6). In the deep part of the Illinois Basin, near McLeansboro in Hamilton County, the Ullin is up to 244 meters (800 ft) thick, but the unit thins rapidly northward and westward against the Borden Siltstone delta facies. To the south and east, the Ullin thins rapidly against, and probably partly grades into, the very cherty, siliceous, fine-grained, deep-water limestones of the Fort Payne Formation (Willman and others, 1975).

In extreme southwestern Illinois where it is well exposed, the Ullin consists of up to 90 meters (300 ft) of medium- to coarse-grained, light gray, fossiliferous limestone that contains more than 97 weight percent calcium carbonate and has a reflectance value of more than 70 percent (Goodwin and Baxter, 1981). Two large quarries a few kilometers north of Cairo, Illinois, in Union and Pulaski Counties, produce Class A or Class B stone from the Ullin (fig. 6). Until fairly recently, the Ullin was exploited as a dimension stone in a quarry near Anna in central Union County.

Lower Valmeyeran Formations. For purposes of this report, the lower part of the Valmeyeran Series includes the Keokuk, Burlington, and Meppen Limestones (fig. 4). The Burlington and Keokuk Limestones consist predominantly of medium- to coarse-grained, fossil-fragmental limestones containing minor to significant amounts of bedded and nodular chert and minor amounts of interbedded dolomite. These carbonates accumulated on a shallow bank that rimmed the northern and western sides of the Illinois Basin depression in Illinois during Early Valmeyeran time.

In western Illinois, the combined thickness of the Burlington and Keokuk Limestones reaches more than 60 meters (200 ft); the units pinch out rapidly to the south and east at the shelf edge and are overlapped by siltstone deposited in the Borden Delta (fig. 7). Clastic deposition in the Borden Delta ultimately swamped carbonate deposition on the Burlington-Keokuk shelf.

The Keokuk Limestone at the top of the lower Valmeyeran carbonate sequence is overlain by up to 21 meters (70 ft) of soft, greenish-gray, cherty, calcareous shale and siltstone assigned to the Warsaw Formation (Lineback, 1981) (fig. 4). The contact of the top of the Keokuk with the base of the Warsaw is gradational. Nodular and bedded chert are locally abundant in some places in the Burlington and Keokuk Limestones. A zone of especially abundant chert up to 8 meters (30 ft) thick at the base of the Keokuk is known as the Montrose Chert Member; a middle portion of the Burlington also has abundant chert.

In conformity with usage in Iowa, the Burlington in Illinois has been divided into three members: from bottom to top, the Dolbee Creek, Haight Creek, and Cedar Fork Members (Cloos and Baxter, 1981). In the Quincy area, the Dolbee Creek Member of the Burlington contains a zone of chemically pure limestone that is mined underground to produce mineral filler and specialty products of extremely high whiteness (Goodwin and Baxter, 1981).

The large number of quarries in the Burlington and Keokuk Limestones in western Illinois is more a function of the abundance of these units at the bedrock surface than of their quality as an aggregate resource (fig. 7). Of the 42 quarries in western Illinois in the Burlington-Keokuk, only four produce aggregate of Class A quality and only five more produce aggregate of Class B quality suitable for use in primary bituminous pavement. In most areas the rocks contain too much deleterious chert to make Class A stone (IDOT, 1977). Because the two units commonly contain abundant porous and weakly cemented fossil fragments, aggregates produced from the Burlington and Keokuk generally perform poorly in sodium sulfate soundness and Los Angeles abrasion tests (IDOT, 1979; Harvey et al., 1974).

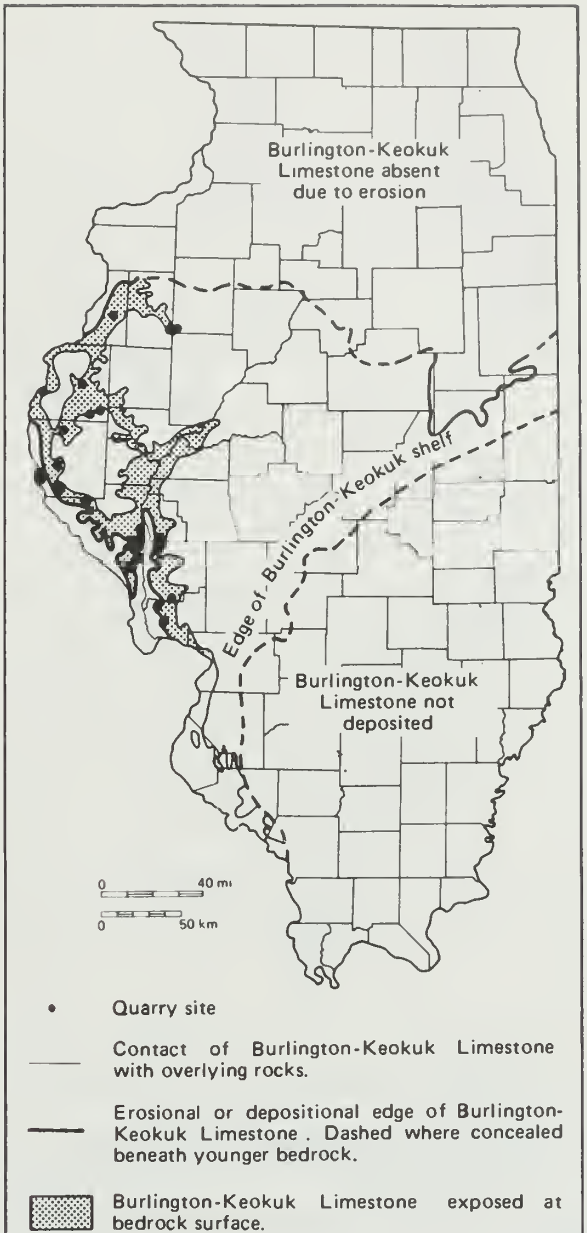

Figure 7. Geologic map of lower Valmeyeran (Mississippian) rocks showing bedrock outcrops and subsurface distribution in Illinois (after Willman and others, 1975). Map shows only distribution of Burlington-Keokuk Limestone.

Kinderhookian Limestones. In southern Calhoun and Jersey Counties near the confluence of the Illinois and Mississippi Rivers, the Chouteau Limestone of Kinderhookian age underlies the thin Meppen Limestone of Valmeyeran age (fig. 7) and reaches a thickness of more than 21 meters (70 ft). In two quarries in Jersey County the Chouteau has been benched and to some extent quarried along with the Burlington and Meppen. To the south and east the Meppen is absent, and the Chouteau thins rapidly and is overlain by the Borden Siltstone or the Springville Shale, a deep-water, distal equivalent to the Borden (fig. 7). To the north and west on much of the Burlington-Keokuk shelf, the Chouteau is absent because of pre-Burlington erosion.

In a portion of extreme western Illinois, limestone and shale units of the North Hill Group are unconformably overlain by the Burlington (figs. 4 and 7).

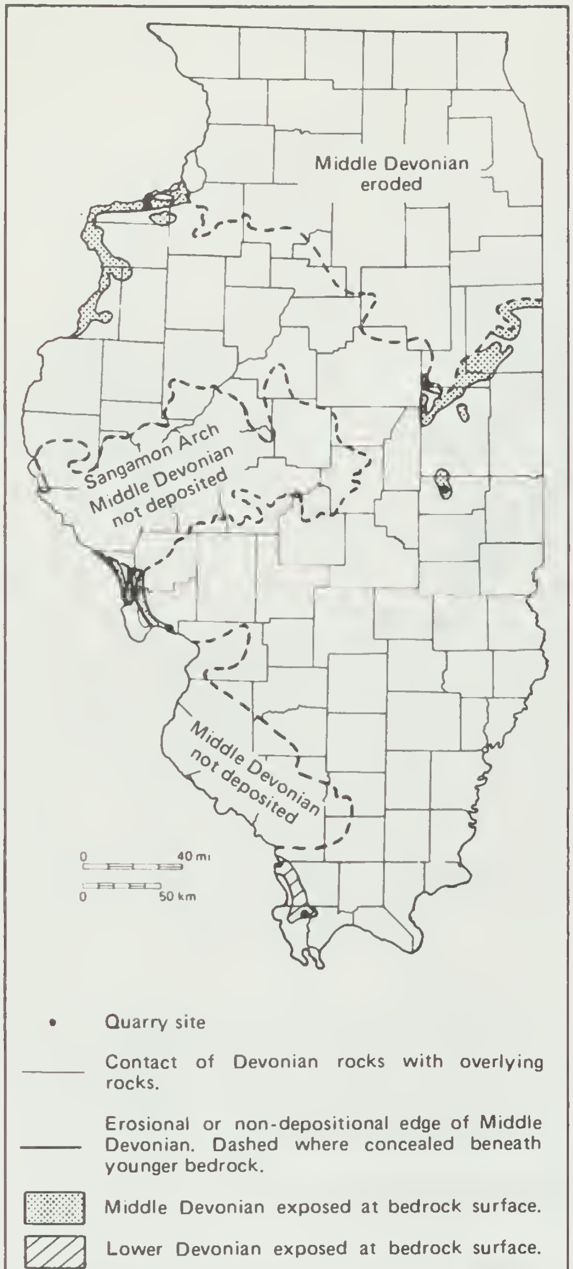

Figure 8. Geologic map of Middle and Lower Devonian rocks showing bedrock outcrops and subsurface distribution in Illinois (after Willman and others, 1975).

The uppermost unit, the Starrs Cave Limestone, is present only in the subsurface in westernmost Hancock County. To the west and south, the Burlington overlies the Prospect Hill Siltstone (the middle unit of the North Hill Group) until it, too, is eliminated by pre-Burlington erosion. The lowermost unit of the North Hill, the McCraney Limestone, reaches a maximum thickness of almost 18 meters (58 ft) in southeastern Adams County, but the McCraney, too, is eliminated by pre-Burlington erosion to the south and east. Outside this limited zone in western Illinois, the Burlington or the underlying Meppen unconformably overlies shales and siltstones of the Hannibal Shale of the Kinderhookian Series (fig. 4).

Fossils indicate that the McCraney Limestone is equivalent in age to the upper part of the Hannibal Shale and the lower part of the Chouteau Limestone, and that the Prospect Hill Siltstone and overlying Starrs Cave Limestone are equivalent in age to the upper part of the Chouteau.

Devonian System

Very few outcrops of Devonian rocks occur at the bedrock surface in Illinois. All the Devonian outcrops appear at the bedrock surface as a result of structural complications (fig. 8). Devonian limestones are exposed in Rock Island County by erosion on the Mississippi River Arch; in Douglas County on the crest of the Tuscola Anticline in the La Salle Anticlinal Belt; in Jersey County on the edge of the Cap au Grēs Faulted Flexure on the Lincoln Fold; in Alexander County near the Ste. Genevieve Fault Zone on the Harrison Creek Anticline. Although not quarried, Devonian rocks also are exposed at the apex of Hicks Dome in southeastern Illinois.

Upper Devonian rocks in Illinois consist of shale, siltstone, and minor limestone units assigned to the lower part of the New Albany Group. Beneath the New Albany, the Middle Devonian consists mostly of brown dolomite and sandy limestone up to 49 meters (160 ft) thick in the Rock Island area of northern Illinois and up to 120 meters (400 ft) thick in the deep part of the Illinois Basin in southeastern Illinois (Willman and others, 1975). Middle Devonian rocks were not deposited on the Sangamon Arch in west-central Illinois (Whiting and Stevenson, 1965) (fig. 8).

To the north of the Sangamon Arch, in Rock Island County, two quarries win stone from the upper Middle Devonian Cedar Valley Limestone and the lower Middle Devonian Wapsipinicon Limestone. The most prominent and thickest members of the Wapsipinicon contain gray to brown, fine-grained limestone or dolomite, whereas the much thinner Cedar Valley consists of medium-to coarse-grained, highly fossiliferous limestone. In the subsurface in Hancock County, southwest of Rock Island County, some beds of gypsum and anhydrite are present in the upper part of the Wapsipinicon. In outcrops in Rock Island County, these evaporites are represented by zones of brecciated limestone and dolomite.

The Tuscola Anticline in Douglas County in east-central Illinois is one of many anticlinal structures forming the La Salle Anticlinal Belt that extends from the Illinois River in La Salle County southeastward to the oil fields of southeastern Illinois (Treworgy, 1981). The Tuscola Arch is unusual because it is one of the few structures in the southern part of the belt that brings rocks as old as the Devonian to the bedrock surface (fig. 1). Much of the deformation of the La Salle Anticlinal Belt is post-Mississippian in age, but on the basis of thinning and relative amounts of deformation of Pennsylvanian rocks, less than half the folding is post-Pennsylvanian in age (Clegg, 1965). The quarry operated here (fig. 8) wins stone from the Middle Devonian Grand Tower Limestone that occurs south of the Sangamon Arch and is equivalent to the Wapsipinicon Limestone.

On the north side of the Cap au Grès Faulted Flexure, on the Lincoln Fold, in the bluffs of the Mississippi River just east of the confluence of the Illinois River, about 4.5 meters (15 ft) of thin-bedded, gray-brown dolomite and sandy limestone of the Middle Devonian Cedar Valley Formation overlie Silurian-age dolomite of the Joliet Formation (fig. 8). The name Lingle Formation commonly is applied to carbonate rocks of Cedar Valley age south of the Sangamon Arch, but the lithology of the outcrops in Jersey County is so similar to that of the Cedar Valley north of the Arch that the name Cedar Valley continues to be used for these special, limited outcrops (Willman and others, 1975).

The quarry at Grafton that contains these outcrops is no longer active because of excessive overburden. When active, it produced Class A quality aggregate; this stone came almost entirely from the underlying thick, dense, reef-type dolomite in the Silurian Joliet Formation rather than from the impure Devonian Cedar Valley at the top of the quarry. Of the other three quarries in Middle Devonian carbonates, one of the two in Rock Island County and the one at Tuscola in Douglas County produce Class A aggregate.

In extreme southern Illinois in northern Alexander County on the Harrison Creek Anticline, a small quarry has recently been reopened in the Clear Creek and Grassy Knob Formations of the Lower Devonian Series (fig. 8). These two units consist primarily of dense, bedded, and tightly packed nodular chert. In places, the chert is highly brecciated, apparently where relict, interstitial limestone was dissolved away from the chert. The quarry operator markets this chert aggregate as a skid-resistant, non-polishing aggregate material suitable for pavements in dangerous areas such as bridge decks and intersections. Although accepted by the Illinois Department of Transportation, reserves and production capacity of the operator are limited.

Silurian System

Rocks of the Silurian System crop out almost exclusively in the northern third of Illinois on the east and west sides of the Wisconsin Arch (fig. 9). Although Silurian rocks commonly are present elsewhere in Illinois, erosion only rarely has reached deep enough to expose them at the bedrock surface. Exceptions to this general rule include the bedrock exposures in Calhoun and Jersey Counties adjacent to the Cap au Grès Faulted Flexure on the Lincoln Fold, and on the northeast flank of the Pascola Arch in southwestern Illinois (fig. 9).

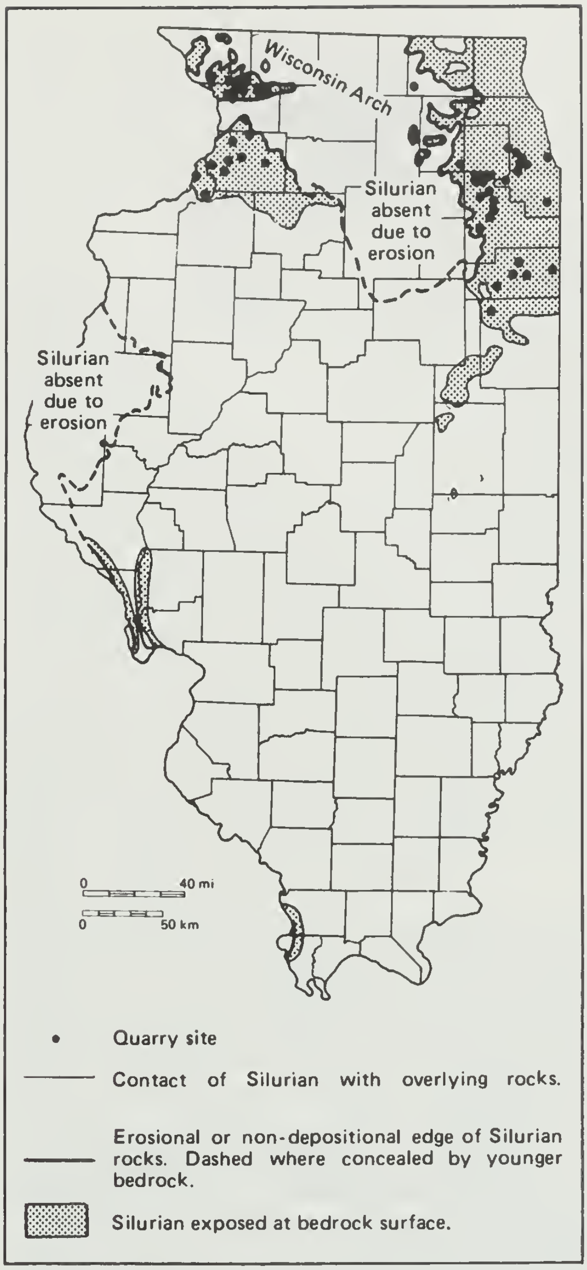

Figure 9. Geologic map of Silurian rocks showing bedrock outcrops and subsurface distribution in Illinois (after Willman and others, 1975).

In the subsurface in southwestern Illinois east of East St. Louis the Silurian contains abundant reefal accumulations of coral, algal, and stromatoporoid fossil debris that in some places are as much as 300 meters (1,000 ft) thick. These reefs consist of fairly high purity limestone (90 to 95 percent $CaCO_3$), but the interreef rocks commonly consist of impure, cherty, argillaceous limestone that is mottled red and green. South of the reef area in southern and southeastern Illinois, the

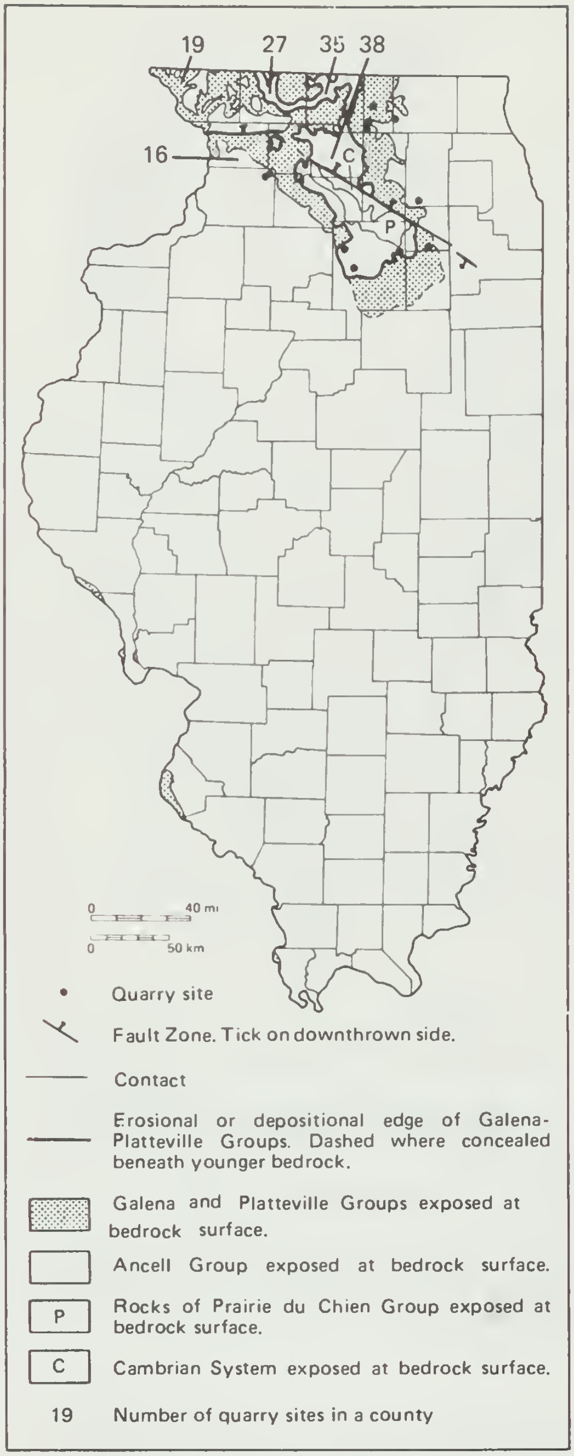

Figure 10. Geologic map of Ordovician and uppermost Cambrian rocks showing bedrock outcrops and subsurface distribution (after Willman and others, 1975).

Silurian rocks contain no reefs and consist mostly of slightly argillaceous and arenaceous fine-grained limestone that probably was deposited in fairly deep water (Willman and others, 1975).

In the northern third of Illinois the Silurian rocks contain numerous reefs that apparently formed in shallow water fringing the Wisconsin Arch area (fig. 9). These reefs are not as thick as those in southern Illinois, but have been uniformly altered to dense, vuggy, pure dolomite. Interreef rocks in northern Illinois consist mostly of silty or argillaceous, cherty dolomite and dolomitic siltstone or shale. Reef structures apparently are confined to the Racine Formation in northern Illinois and to the age-equivalent Moccasin Springs Formation in southern Illinois, the youngest units in the Niagaran Series in Illinois (Willman and others, 1975).

In northwestern Illinois individual reef structures are rather rare, apparently because the reefs grew together to form a nearly continuous unit through many areas. Rocks older than the Racine in the Silurian System in northern Illinois generally consist of slightly argillaceous and cherty, thin- to medium-bedded dolomite units; their total thickness generally does not exceed that of the reef-bearing Racine Formation, about 90 meters (300 ft).

The outcrop pattern of the Silurian System has provided Illinois with an abundance of high-quality crushed-stone resources in the high-volume Chicago market area. In 1980, 27 percent of the reported crushed-stone production in Illinois came from Cook County alone, and almost 40 percent came from Cook, Du Page, Kane, and Will Counties in the Chicago metropolitan area (fig. 9). Of the 60 recently active quarry sites in the Silurian rocks of Illinois, 20 produce Class A aggregate (14 of those 20 are in the Chicago metropolitan area). Most of the largest quarry operations in Illinois are in the Chicago area. Seven of the 14 producers of Class A stone in the Chicago area have plant capacities of more than 3,600 T (4,000 t) per day; two have capacities exceeding 12,700 T (14,000 t) per day (IDOT, 1977).

Ordovician and Cambrian Systems

Along the crest of the Wisconsin Arch where overlying Silurian rocks have been eroded, Ordovician rocks of the Galena and Platteville Groups are exposed at the bedrock surface (fig. 10). On the eastern and western limbs of the Wisconsin Arch, where Silurian rocks are preserved as erosional outliers, deep bedrock erosion has exposed Ordovician rocks in the valleys surrounding the uplands capped by the Silurian.

In Jo Daviess and Carroll Counties in extreme northwestern Illinois, the Silurian outliers and the underlying Ordovician rocks have been protected from even deeper erosion in this unglaciated, driftless area: they have been down-dropped on the north side of the east-west trending Plum River Fault Zone and the Upton Cave Syncline that parallels this fault on the north side (Treworgy, 1981).

At the southern end of the Wisconsin Arch in Ogle, Lee, and De Kalb Counties, uplift along the southwest side of the Sandwich Fault Zone and the parallel Ashton Arch has allowed erosion to expose rocks of the Croixan Series (Upper Cambrian) at the bedrock surface (Willman and Kolata, 1978) (fig. 10). These are the oldest rocks exposed at the bedrock surface in Illinois. In southern Illinois the Galena and Platteville Groups are exposed in the bluffs of the Mississippi River in western Calhoun County on the western flank of the Lincoln Fold; on the crest of the Valmeyer Anticline at Valmeyer in Monroe County; and on the northeast limb of the Pascola Arch in northwest Alexander County (fig. 10).

Galena Group. In northern Illinois, rocks of the Galena Group consist mostly of fine- to medium-grained, buff to brown dolomite, argillaceous dolomite, and some fine- and coarse-grained limestone. Units at the bottom of the Galena Group tend to be more argillaceous and impure than those nearer the top; however, the uppermost unit of the Galena (the Dubuque Formation) grades upward from almost pure dolomite at the base to very argillaceous, thin-bedded dolomite at the top. The Dubuque is unconformably overlain by shales of the Ordovician Maquoketa Group.

Beneath the Dubuque, the Wise Lake Formation in northern Illinois consists of about 23 meters (75 ft) of pure, massive, light-brown, vesicular to vuggy dolomite. Although the Wise Lake generally is regarded as the source of the best aggregate in the area, the unit commonly has been eroded away except in areas where it is overlain by thick overburden. However, the Galena Group (particularly the Wise Lake) is a target for underground mining in northeastern Illinois, especially where accessible by inclines through the Maquoketa Shale from the floors of deep quarries in the Silurian.

The Dunleith Formation beneath the Wise Lake consists of gray to light brown, medium- to thin-bedded, slightly argillaceous, somewhat cherty dolomite. In extreme northern Illinois, the lower 8 to 12 meters (25 to 40 ft) of the unit consist of gray, fine-grained limestone containing a few shaly beds. Overall, the Dunleith is uniformly 36 to 41 meters (120 to 135 ft) thick in northern Illinois. Because it is the thickest unit in the Galena Group, the Dunleith generally forms the bedrock surface over large areas. Older units are exposed only along major stream valleys where local relief is thicker than the Dunleith. Units of Dunleith age and older in the Galena Group change southward from dolomite to limestone. At Valmeyer in Monroe County (fig. 10) the pure limestone of the Moredock Member of the Dunleith is mined underground to produce mineral fillers (Goodwin and Baxter, 1981).

The Galena Group is unusual among the stratigraphic units in Illinois because it is thickest in northern Illinois and becomes thinner to the south. Most of this thinning is caused by an erosional unconformity at the top of the Galena Group. Rocks younger than the Moredock Member of the Dunleith in the Galena Group in southern Illinois have been removed by post-Galena, pre-Maquoketa erosion so that shales of the Maquoketa Group unconformably overlie the Dunleith (Willman and others, 1975; Templeton and Willman, 1963).

Platteville Group. In northern Illinois, rocks of the Platteville Group consist mostly of blue-gray, somewhat cherty, fine-grained, dolomite-mottled limestone and argillaceous, somewhat cherty dolomite. Over much of the northern Illinois outcrop area the Platteville formations are dominantly dolomitic; in areas near Dixon in Lee County, and Oglesby in La Salle County, they are limestone or dolomite-mottled limestone. Platteville rocks generally are finer grained, thinner bedded, and grayer than rocks of the overlying Galena Group, but the Pecatonica Formation at the base of the Platteville Group and the Nachusa Formation near the top can easily be mistaken for parts of the Galena Group.

In the northern outcrop area the Platteville Group ranges from somewhat less than 30 meters (100 ft) to a little more than 46 meters (150 ft) thick from northwest to southeast along the general trend of the Wisconsin Arch (fig. 10). The unit continues to thicken gradually toward the south and is more than 183 meters (600 ft) thick in extreme southeastern Illinois.

St. Peter Sandstone. The St. Peter Sandstone of the Ancell Group underlying the Platteville Group is exposed by deep erosion in the vicinity of the Sandwich Fault Zone (fig. 10). Although primarily exploited as a glass and industrial sand, small amounts of the St. Peter occasionally are used as fine aggregate or mineral filler.

Canadian Series and Cambrian System. Ordovician rocks older than the Ancell Group are exposed at the bedrock surface only in the vicinity of the Sandwich Fault Zone of northern Illinois (fig. 10). Here the Shakopee and Oneota Dolomites of the Prairie du Chien Group of the Canadian Series and the Eminence Formation at the top of the Croixan Series of the Cambrian System are exposed in six quarries in La Salle, Ogle, and Lee Counties in northern Illinois.

The Shakopee consists of argillaceous to pure, very fine-grained dolomite and some thin beds of medium-grained, cross-bedded sandstone, medium-grained dolomite, green to light gray shale, and buff siltstone. Oolitic, sandy chert occurs in discontinuous bands and nodules. Algal stromatolite domes and mats ranging from a few centimeters up to 3 meters (10 ft) thick are common.

The Oneota Dolomite consists of fine- to coarse-grained, light gray to brownish-gray, cherty dolomite that contains minor amounts of sand and, at its base, thin shaly beds. The Arsenal Member is the lower part of the Oneota and is especially cherty; the chert occurs in layers, lenses, nodules, and irregular bodies that have a distinctive branching habit.

The Cambrian Eminence Formation consists of light-gray to brown or pink, sandy, fine- to medium-grained dolomite that contains oolitic chert and thin beds of sandstone. The unit is finer grained and sandier than the overlying Ordovician Oneota Dolomite (Willman and others, 1975). In the northern Illinois outcrop area, the Eminence Formation is less than 15 meters (50 ft) thick. Overlying Ordovician rocks of the Canadian Series have a composite thickness in the outcrop area of less than 60 meters (200 ft); the thickness varies by as much as 15 to 30 meters (50 to 100 ft) because of relief on a pre-Champlainian (Middle Ordovician) erosion surface on the top of the Shakopee (Willman and others, 1975).

In just 12 counties in the northern third of Illinois (fig. 10), 163 active quarries win stone from the Ordovician rocks. Of these, 18 produce Class A aggregate. Only 19 of the 163 quarry sites have reported plant capacities greater than 3,200 T (3,500 t) per day (IDOT, 1977). Many of the sites are small quarries operated with portable equipment on an as-needed basis. Nineteen of the 163 sites are operated by county highway departments.

South of the 12-county northern area, only one quarry, on the west flank of the Lincoln Fold in Calhoun County, produces aggregate from Platteville Group rocks exposed in the bluffs of the Mississippi River. Of the six quarries operated in rocks of the Canadian Series or the Croixan Series, none produces aggregate of a quality better than Class C, according to the standards of the Illinois Department of Transportation (IDOT, 1977).

Of the 368 recently active quarry sites in Illinois, 223 (almost 61 percent) are located in the 17 northernmost counties of the state (figs. 9 and 10). Those 223 quarry sites produced 55.6 percent of all the crushed stone reported to the U.S. Bureau of Mines in 1980 from Illinois; that aggregate was produced from carbonate rocks in just two systems, the Silurian and Ordovcian.

SUMMARY

Of the 102 counties in Illinois, 62 have recently active quarry sites that produced crushed stone for aggregate or mineral-filler uses (IDOT, 1977). Most of these 62 counties have quarries that produce stone from only a single formation or group of formations within a single stratigraphic system; however, five counties have sufficient topographic relief or structural complications to permit quarrying from more than one system.

More than 55 percent of all the crushed stone produced in Illinois in 1980 came from 223 quarry sites in Silurian and Ordovician carbonate rocks in the northernmost 17 counties in the state. Almost 40 percent came from just four counties in the Chicago metropolitan area. In the southern two-thirds of Illinois, crushed stone is produced primarily from carbonate rocks older than Pennsylvanian that outcrop adjacent to the major river systems in the state. Pennsylvanian rocks form the bedrock surface in most of the southern two-thirds of Illinois, but limestone units are rare in the Pennsylvanian and provide only limited resources for production of crushed stone.

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