Geology of sand and gravel aggregate resources of Illinois

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ABSTRACT

Most sand and gravel aggregate resources in Illinois—except for certain deposits of sand and chert gravel in western and extreme southern Illinois—are related to the waxing and waning of the continental glaciers that periodically reached into the state from Canada during the Pleistocene. Vast amounts of debris-laden meltwater issued from these glaciers, washing sand and gravel into outwash plains, fans, and deltas; valley trains; and ice-contact deposits such as kames and eskers. Some of this material was also modified and reworked by the processes of rivers, lakes, and winds. About 50 percent of the sand and gravel produced in Illinois is mined in a highly populated six-county area in the northeast corner of the state where the most extensive and highest quality sand and gravel deposits are concentrated. In sand and gravel pits to the south, the ratio of sand to gravel increases, the gravel tends to become finer, and poor-quality gravel particles become more abundant. Gravel products used in Portland cement concrete generally cannot be produced from pits in the southern half of Illinois, but high-quality sand is abundant—especially along the major river valleys.

INTRODUCTION

The state of Illinois has abundant resources of high-quality aggregate in many areas. The major sand and gravel resources are found in valley trains and outwash plains formed by Pleistocene continental glaciation.

High-quality Wisconsinan sand and gravel is especially abundant near the high-volume metropolitan Chicago market area; however, future availability of these resources is threatened by urbanization. Elsewhere in Illinois, sand and gravel is generally less abundant and of lower quality than in the Chicago area.

Locations of sand and gravel pits and information on plant capacities and quality classes of aggregates were compiled for this report from Bulletin 23 of the Illinois Department of Transportation (IDOT, 1977). Because many pits and quarries in the state are operated with portable equipment on an as-needed basis, some pits may have been abandoned and some new sites may have been opened since Bulletin 23 was compiled.

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 for 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. IDOT standards have been somewhat modified, and mining conditions at some Illinois pits have changed, since publication of Bulletin 23.

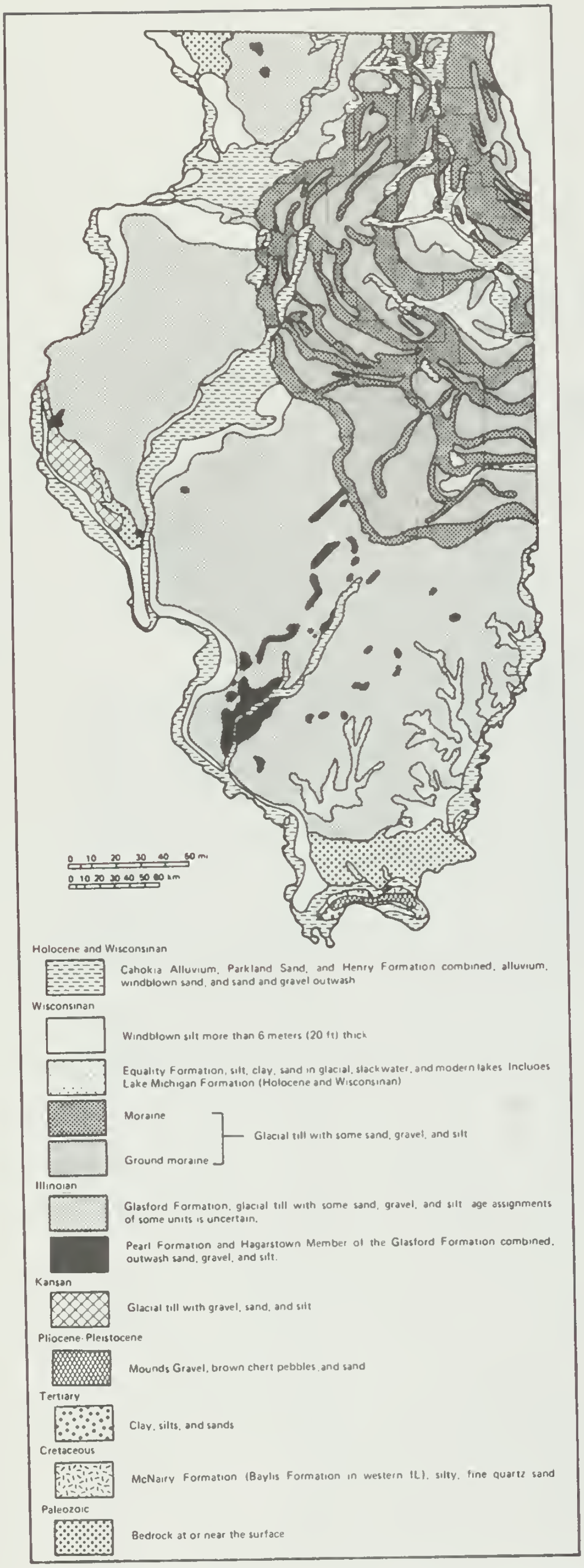

Figure 1. Simplified geologic map of surficial, unconsolidated materials (Quaternary and older) in Illinois (after Lineback, 1979, 1981).

SAND AND GRAVEL AGGREGATE RESOURCES

Surficial geology of Illinois

During the Pleistocene, Illinois was repeatedly covered by thick continental glaciers that left extensive deposits of clay, silt, and sand and gravel in the form of terminal and ground moraines, outwash plains, valley trains, kames, eskers, and other landforms. Deposits of the Wisconsinan and Illinoian glacial advances are extensive in Illinois (fig. 1). Deposits of the Kansan glaciation (or possible older glaciation) are exposed only in extreme western Illinois.

Glacio-fluvial deposits related to the Wisconsinan Stage provide major resources of high-quality sand and gravel in the densely populated northeastern part of Illinois. Downstream from the terminal Wisconsinan moraines, valley-train deposits of Wisconsinan age and other glacio-fluvial deposits of Illinoian age are the principal sources of sand and gravel in Illinois.

The stratigraphy and nomenclature outlined in Pleistocene Stratigraphy of Illinois (Willman and Frye, 1970) and Handbook of Illinois Stratigraphy (Willman et al., 1975) are used in this report to group the sand and gravel resources and related deposits in the state that have similar ages, depositional histories, and physical characteristics. In this report, only the sand and gravel bearing units will be discussed, generally proceeding from the youngest to the oldest deposits.

Holocene and Wisconsinan deposits

Cahokia Alluvium. The Cahokia Alluvium consists of floodplain deposits and channel deposits of present rivers and streams (fig. 2). It is a low-lying deposit of poorly sorted silt, clay, clayey sand, and locally abundant wood fragments, shells, and gravel. Although often referred to as "recent alluvium," the Cahokia began to accumulate in many valleys as soon as they were free of glacial ice; it continues to accumulate, especially during flood events. In some major valleys, particularly in the Illinois, the alluvium of some large tributaries has formed broad fans that deflect the course of the river.

Some Cahokia Alluvium is present along all Illinois streams; however, only the more widespread deposits of larger streams can be shown in figure 2. The thickness of the Cahokia varies greatly: commonly 3 to 6 m (10 to 20 ft) in many valleys; 9 to 12 m (30 to 40 ft) along the Illinois River (central Illinois) and the Kaskaskia River (southwestern Illinois); and 15 to 18 m (50 to 60 ft) along the Mississippi River (especially in the southern half of Illinois).

The modern channel sands of the Cahokia Alluvium are dredged from the Mississippi, Ohio, and Wabash Rivers (fig. 2) for use as fine aggregate. Some gravel is recovered with the sand from the Ohio and Wabash. Ancient channel deposits in cut-off meanders in flood-

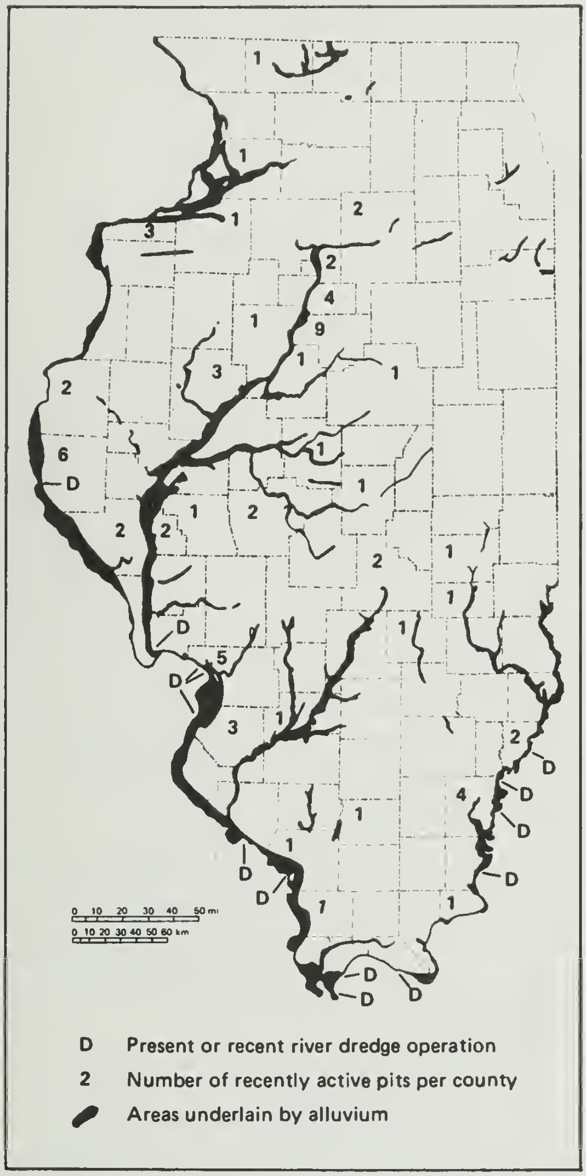

Figure 2. Distribution of the Cahokia Alluvium (Wisconsinan and Holocene) in Illinois (after Lineback, 1979).

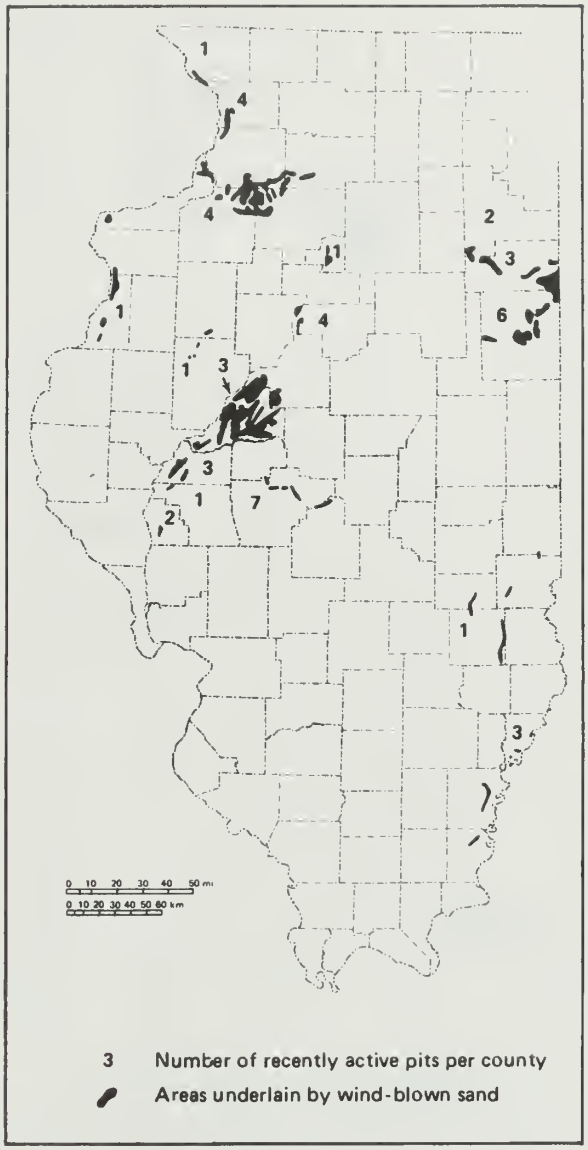

Figure 3. Distribution of the Parkland Sand (Wisconsinan and Holocene) in Illinois (after Lineback, 1979).

plain areas can sometimes be dredged and used as fine aggregate; however, floodplain deposits themselves are seldom usable. In the major river valleys and in some minor ones, the Cahokia Alluvium overlies deposits of the Mackinaw Member of the Henry Formation. In floodplain areas where the Cahokia is sufficiently thin it may be scraped away, and sand or sand and gravel recovered from the underlying Henry Formation. Typical pits of this type are located in the valleys of the Sangamon River (central Illinois) and the Mississippi River (southern half of Illinois).

Parkland Sand. The Parkland Sand consists of wind-blown sand, in dunes and sheetlike deposits (fig. 3), derived from valley-train deposits. These wind-blown deposits commonly overlie terraces of the Mackinaw Member of the Henry Formation and adjacent uplands of the main valleys. Although widespread throughout the northern part of Illinois, many deposits are too small or too thin to be shown in figure 3. Most dunes are 3 to 12 m (10 to 40 ft) high, but some accumulations of dunes and sheetlike deposits can be as thick as 30 m (100 ft). The sand generally becomes finer on the eastern sides of dune fields because of the prevailing westerly winds. Many of these dunes are covered only by thin soil and vegetation. Disruption of this cover may cause renewed dune migration. Raw and processed material from these deposits are used typically as blend sand, mason sand, molding sand, and fill sand. Studies at the Illinois State Geological Survey have shown that the

Figure 4. Distribution of the Wisconsinan age Batavia Member of the Henry Formation in Illinois (after Lineback, 1979).

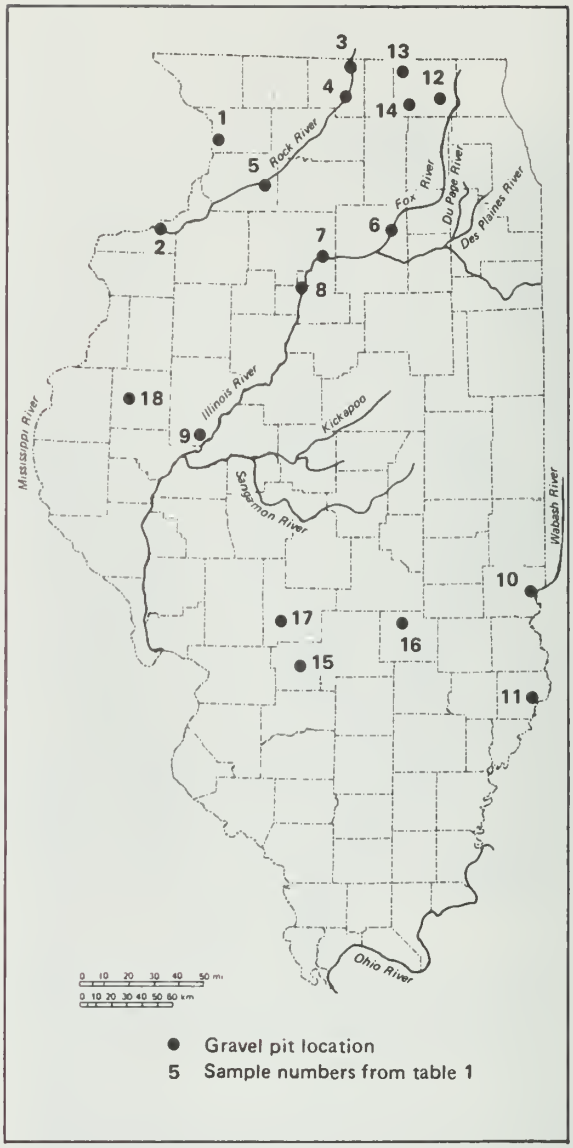

Figure 5. Locations of gravel pits from which samples in table 1 were obtained.

sand is also a potential source of feldspar and quartz used in the manufacture of ceramics and glass (Ehrlinger and Masters, 1974).

Wisconsinan outwash sand and gravel and lake deposits
Henry Formation. The Henry Formation includes all types of outwash sand and gravel deposits of Wisconsinan age in Illinois. Many of these deposits are too small to be illustrated in figure 1, and are combined on the map with other related deposits. Where outwash sands and gravels are overlain by, or intertongue with, their associated tills, they are mapped with the till deposits. The formation is divided into three members: the Batavia Member consists of outwash plains, the Mackinaw Member of valley trains, and the Wasco Member of ice-contact deposits.

These members all contain abundant sand, suitable in quality and particle size for processing into various types of fine-aggregate construction products. The gravel in these members is not as abundant or as widely distributed as the sand, but gravel of sufficient quantity and of Class A quality (IDOT, 1979) can be found in all three members. Gravel is most abundant in northeastern Illinois, tending to decrease in size, abundance, and quality to the south.

Batavia Member. Outwash plains of the Batavia Member of the Henry Formation (fig. 4) are upland deposits located along the fronts of moraines in discontinuous, sheetlike deposits. Batavia deposits generally occur high on the land surface. In northeastern Illinois they may be more than 60 m (200 ft) thick, and may extend far

Table 1. Summary pebble count data of samples collected from selected Illinois gravel deposits.*

	Sample no.	Rock Types					
		Carbonate	Other sedi-mentary	Chert	Igneous	Meta-morphic	Miscel-laneous
WISCONSINAN STAGE							
Henry Formation (outwash)							
Mackinaw Member (valley trains)							
Mississippi	1	1	7	7	65	12	8
	2	6	8	4	66	13	3
Rock	3	78	4	8	10	–	–
	4	72	–	10	14	3	1
	5	68	1	22	6	3	–
Fox	6	88	–	4	8	–	–
Illinois	7	79	4	9	5	3	–
	8	64	6	15	6	5	4
	9	43	8	18	15	10	6
Wabash	10	60	8	8	8	16	–
	11	42	2	20	22	12	2
Batavia Member (outwash plains)	12	87	1	2	8	2	–
	13	84	1	2	9	4	–
	14	90	1	1	6	2	–
ILLINOIAN STAGE							
Glasford Formation							
Hagarstown Member (crevasse deposits)	15	29	21	41	4	4	1
	16	48	20	26	4	2	–
	17	–	18	53	10	10	9
Pearl Formation (outwash)	18	2	8	68	5	5	12

* Data sources: samples 1, 3, 4, 5, 6, 7, 8, 10, 11, 15, 16, 17, and 18 are taken from an unpublished ISGS collection of pebble counts, sample 2 is from Anderson (1967), sample 9 is from a current research project, and samples 12, 13, and 14 are from Anderson and Block (1962). All samples represent material in about the 3/8- to 1/2-inch size range. All are spot or channel samples, except number 9, which is from an uncrushed production sample.

below the water table. The Batavia Member generally grades downslope into valley-train deposits of the Mackinaw Member of the Henry Formation. In Boone, Kane, and McHenry Counties, prominent outwash plains grade outward into valley trains in the broad valleys of the Fox and Kishwaukee Rivers and Piscasaw Creek (fig. 4). In comparison with valley trains, outwash plains are more variable in particle size and thickness. Some gravel deposits can be characterized by the relative abundances of boulders, cobbles, and pebbles (Masters, 1978). Commonly, more than 80 percent of the particles in the gravel are dolomite (table 1, samples 12, 13, and 14; fig. 5).

In northeastern Illinois, boulder gravels of the Batavia Member generally are poorly sorted, indicating deposition in a high-energy, near-ice environment where debris-laden meltwater could not sort out fine material. In most cases deposition occurred from the east, and the east sides of outwash plains generally contain the coarsest gravel (Cobb and Fraser, 1981). Many of these outwash plains are so coarse grained that they contain more gravel than sand. Where over-ridden by glacial ice, outwash plains are generally pitted, contain complex deformation features, and grade into ice-contact deposits of the Wasco Member.

Outwash plains and related sand and gravel deposits in northeastern Illinois contain the largest concentrations of coarse-grained deposits in Illinois. They have supplied large tonnages of construction aggregates to the Chicago metropolitan area since early in this century

(Burchard, 1907). In 1978, 53 percent of the sand and gravel produced for construction aggregate in Illinois came from the six counties in the northeastern corner of the state where the Batavia and other members of the Henry Formation are thickest (Samson, 1981). However, production from this area is likely to decline drastically because the expanding demand for land for urban development is limiting the expansion of existing pits and the opening of new pits.

Deposits of outwash sand and gravel underlie large areas of Whiteside, Lee, Henry, and Bureau Counties in northwestern Illinois (fig. 4). These deposits commonly consist mostly of sand in the uppermost 12 m (40 ft), but may contain abundant gravel at depths from 12 to 30 m (40 to 100 ft). Layers of clay and till are often interbedded with this outwash and most of the deposits occur below groundwater level. Because of the resulting extraction problems and the distance of the deposits from major, high-volume markets, these outwash plains are not as extensively mined as those in the northeast.

In central and east-central Illinois, most outwash plains lie in narrow bands along the convex outer side of Wisconsinan moraines (figs. 1 and 4). These deposits are often relatively thin and are composed of poorly sorted sand and fine gravel. However, some well-sorted deposits about 10 m (30 ft) thick with some medium to coarse gravel occur where morainal re-entrants and subglacial channels are present (Anderson, 1960; Hester and Anderson, 1969). These deposits generally contain too many deleterious gravel particles to meet Class A (IDOT, 1979) specifications, but they are suitable for lower quality aggregate.

Wasco Member. The outwash of the Wasco Member (fig. 6) includes ice-contact sand and gravel in kames and eskers, and is most abundant in northeastern Illinois. These deposits are generally recognized by their characteristic topographic expressions and extreme lateral and vertical variability of grain size, sorting, bedding, and deformational features, such as folds and faults. Although present in all Illinois counties covered by Wisconsinan ice sheets, the areal extent of most Wasco deposits is too small to be shown in figure 6. The Wasco Member provides locally important sand and gravel resources, but because all are relatively small, the member contributes relatively little to the total aggregate resources of the state.

Mackinaw Member. Valley trains of the Mackinaw Member (fig. 7) generally are lowland deposits of glacial outwash sand and gravel deposited in alluvial terrace systems in valleys that extend away from glacial fronts. Valley-train deposits are generally more evenly bedded and less variable than outwash plains or kames and eskers. Characteristics of valley trains include: (1) coarsening upstream, especially in northern Illinois, (2) extension of deposits to depths of 30 m (100 ft) or more below local floodplains in buried valleys, (3) increasing terrace elevations upstream, and (4) extension of deposits down major valleys beyond the margin of Wisconsinan glaciation to the southern tip of the state. The upstream portions of valley trains often contain more than one set of terraces that can be distinguished by their different elevations, loess cover, soil development, grain-size distributions, or perhaps by rock lithologies in the gravel. Fewer valley-train terraces are found downstream; in the southern half of the state they may be completely buried by modern deposits of Cahokia Alluvium (fig. 2).

Several different glacial lobes supplied gravel to the valley trains of the Mackinaw Member. Each lobe traversed somewhat different bedrock terrain, picking up rock types unique to each area: the Mississippi River valley train was largely supplied by the Lake Superior Lobe; the Rock, Fox, and Illinois River valley trains were largely supplied by the Lake Michigan and Green Bay Lobes; and the Wabash River valley train was supplied by both the Lake Michigan Lobe and the Erie Lobe. Differences between the igneous and metamorphic rock assemblages in the Mackinaw between the Mississippi and Wabash River valley trains are the most distinct. In northwestern Illinois, the Mississippi River valley train, down to the mouth of the Rock River, consists almost entirely of igneous and metamorphic rock types (table 1, fig. 5). At the Rock River, sedimentary rock types become more abundant because of contributions from the Rock River valley train and erosion of material from the surrounding terrain. The Rock, Fox, and Illinois River valley trains contain about 80 percent middle to early Paleozoic dolomite particles (table 1, fig. 5) near their upstream ends, but this composition is progressively diluted downstream, primarily with other sedimentary rocks, including chert. For instance, in the Illinois River valley-train samples (samples 7, 8, and 9, table 1), carbonate rocks decrease from 70 to 40 percent, and other sedimentary rocks increase from 4 to 8 percent and chert increases from 9 to 21 percent. In general, only Class B or lower quality coarse aggregate is produced from downstream valley-train gravel pits; this indicates that the downstream addition of deleterious gravel lowers the overall quality of the material for use as construction aggregate.

Equality Formation. The Equality Formation consists of silt, clay, and sand deposited in glacial and slackwater lakes (fig. 1). Except for ancient and modern (Lake Michigan Formation) beach ridges in the vicinity of Lake Michigan, none of these deposits is known to contain sand or gravel in sufficient concentrations to be used in construction aggregates. Sand has been excavated in the past for fill and certain fine aggregate

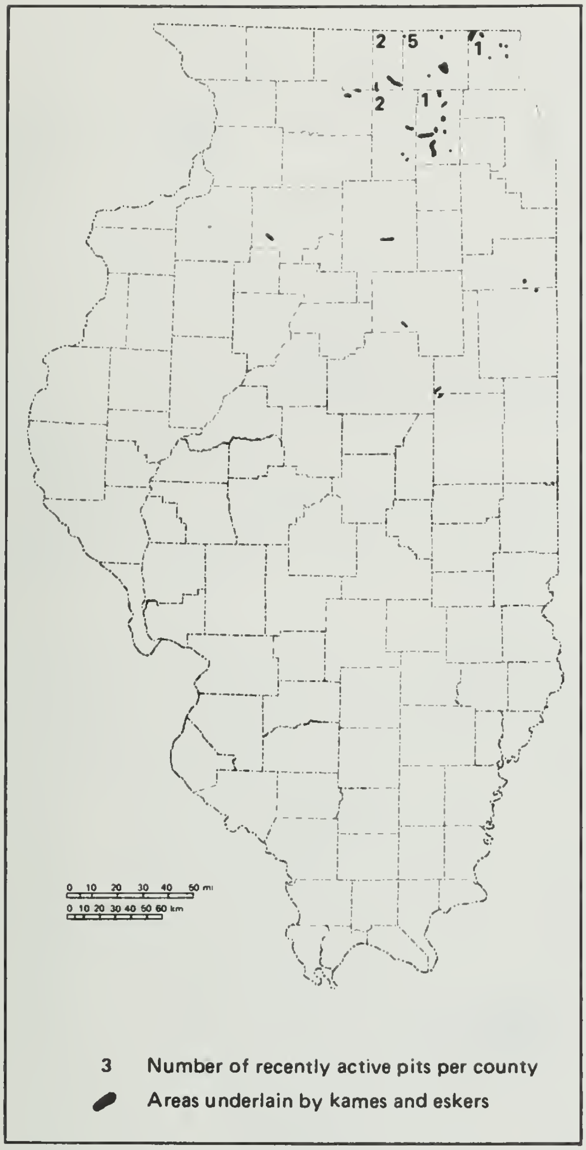

Figure 6. Distribution of the Wisconsinan age Wasco Member of the Henry Formation in Illinois (after Lineback, 1979).

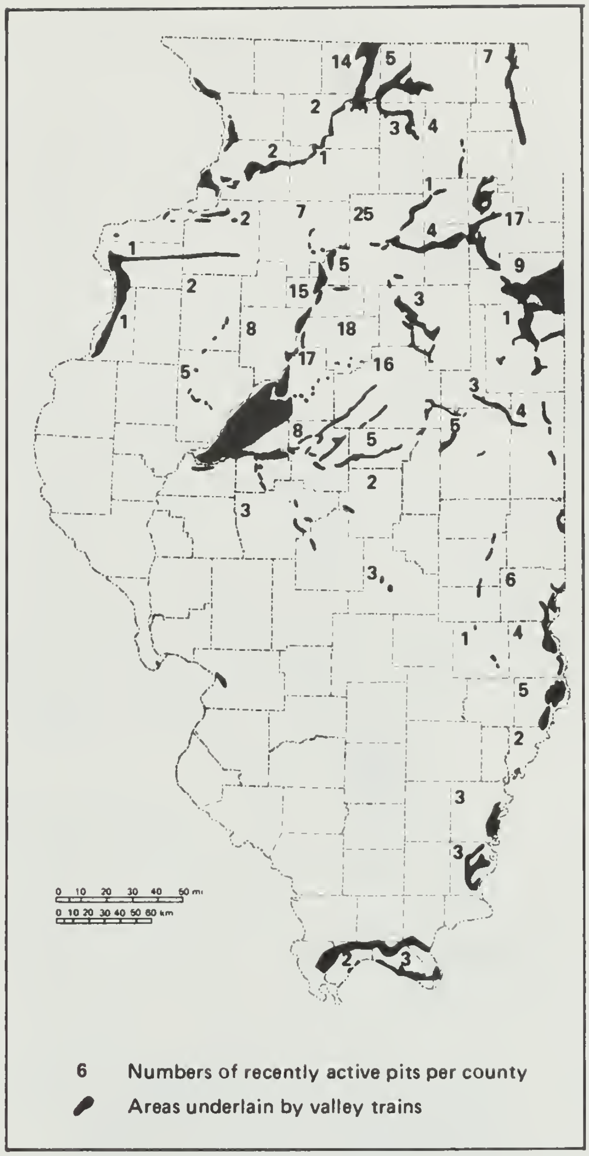

Figure 7. Distribution of the Wisconsinan age Mackinaw Member of the Henry Formation in Illinois (after Lineback, 1979).

uses from the beach ridges, but these deposits have essentially been depleted, covered by urban development, or absorbed into local and state parks or nature preserves.

Illinoian outwash sand and gravel

Pearl Formation and Hagarstown Member of the Glasford Formation. The Pearl Formation consists of all types of Illinoian outwash sand and gravel deposits in Illinois. No members have been defined because different types of Illinoian outwash are difficult to identify and map because of deeper weathering, more subtle land forms, and thicker overburden. Although assigned to the Glasford Formation, the Hagarstown Member, which also contains abundant sand and gravel, will be discussed along with the Pearl Formation. The larger outcrop areas of both units are illustrated in figure 8. Table 1 indicates that these units generally are lower in carbonate rocks and higher in deleterious rocks (such as chert and other sedimentary rocks) than are Wisconsinan gravels. Where outwash sands and gravels are overlain by, or intertongue with, their associated tills, they are mapped along with the till deposits (Glasford Formation, fig. 1).

The Pearl Formation occurs in terraces of valley-train deposits along valleys near the margin of the Illinoian till sheet. Similar deposits may also be buried by Wisconsinan valley-train deposits. In the lower half of the Illinois River valley, for example, older gravel deposits may be preserved at depth, or Wisconsinan meltwaters may have reworked the gravels, incorporating older and younger material. This possible mixing, at least in part, would account for the increase in chert and other deleterious particles down the valley. The Pearl also occurs in outwash plains, kames, and eskers,

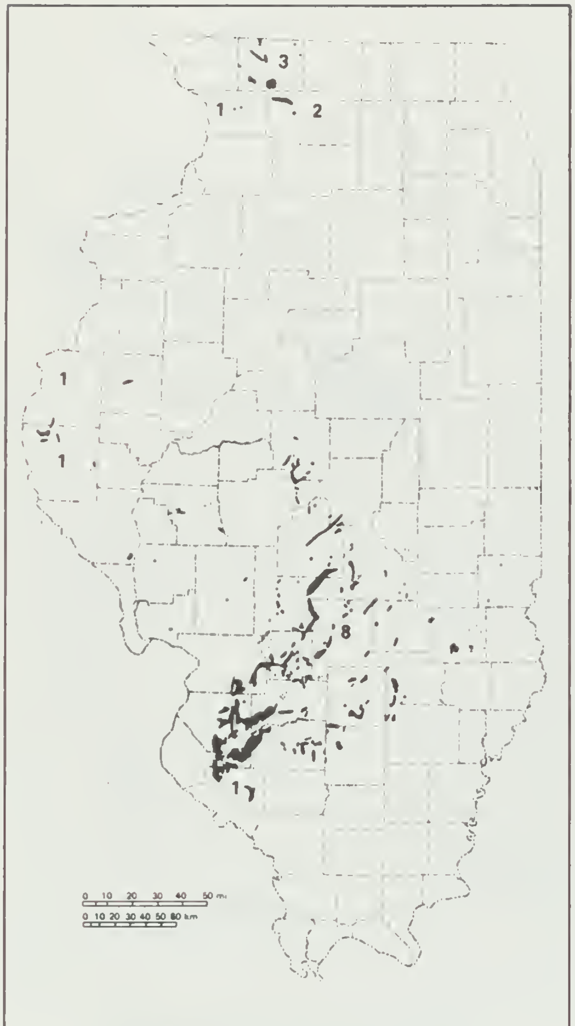

Figure 8. Distribution of the Illinoian age Pearl Formation and Hagarstown Member of the Glasford Formation in Illinois (after Lineback, 1979).

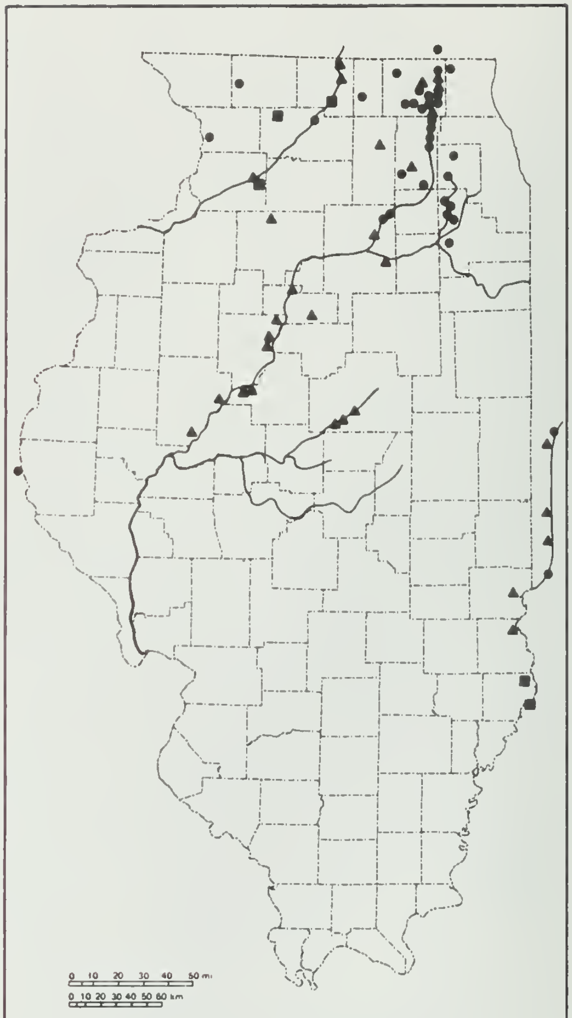

Figure 9. Pit locations and summary of relative freeze-thaw expansion values of test beams made with gravel from pits in and near Illinois that have recently produced Class A quality (IDOT, 1979) coarse aggregate.

but it is not as extensive, thick, or coarse grained as many Henry Formation deposits of similar origin.

The Hagarstown Member (Jacobs and Lineback, 1969) occurs mainly as low ridges in the Illinoian till plain and is known as "ridged drift." In many places the ridges and hills gradually rise 15 to 30 m (50 to 100 ft) above the till plain. The base of the outwash varies from the surface of the till plain to deeply entrenched valleys in the till. Most of the ridges are parallel to the direction of Illinoian ice movement and were deposited by meltwater streams flowing in ice-walled channels during stagnation of the Illinoian ice sheet. The ridges consist of poorly to well sorted sand and gravel, gravelly till, and some silt and clay. They are sometimes more than 30 m (100 ft) thick, but these thick areas usually consist mostly of sand. Coarse gravel is rare. Large masses of sand and gravel commonly are cemented by calcite (and sometimes limonite) into conglomerates. The Hagarstown deposits are the major upland sources of sand and gravel aggregate within the Illinoian till plain. This aggregate, in proper size gradations, is generally satisfactory for most uses (except for Portland cement concrete).

Pliocene-Pleistocene to Cretaceous Age deposits

Mounds Gravel. The Pliocene-Pleistocene Mounds Gravel consists of deeply weathered, subrounded chert pebbles in a matrix of red, clayey sand. Chert pebbles have a glossy, medium to dark olive-brown patina, but may be of various colors and textures when broken open. The gravel is cemented locally with hematite and limonite. Broad lenses and beds of red, clayey sand without gravel are common in some places. The Mounds Gravel is widespread in southernmost Illinois (fig. 1); it ranges in thickness from 3 to 6 m (10 to 20 ft) in most areas, but in some places may reach 15 m (50 ft). Willman and Frye (1970) interpret the Mounds as terraced fluvial deposits derived primarily from the Tennessee River drainage basin. Chert gravel from the Mounds commonly was used in the past as aggregate in concrete, but today is used mainly for fill and for surfacing gravel roads.

Older Tertiary units underlie the Mounds Gravel toward the western end of the outcrop belt (fig. 1). The Wilcox Formation is occasionally exposed and excavated for fill sand.

McNairy Formation. The McNairy Formation is a Gulfian (late Cretaceous) fluvial-deltaic sand deposited in the northernmost part of the Mississippi Embayment in southernmost Illinois. The McNairy generally consists of slightly micaceous, fine-grained, white to light-gray, loosely consolidated to unconsolidated quartz sand and very clayey, gray to black lignitic silts. Clean sands are most common in upper and lower parts of the section. In some places the McNairy is 150 m (500 ft) thick, but commonly it is 15 to 60 m (50 to 200 ft) thick, because of the erosion of the top and onlap of the deposit onto the irregular Paleozoic rock surface (Kolata, Treworgy, and Masters, 1981). In Illinois, the sand of the McNairy has been used only as fill material, but it can be used as blend sand or as a silica sand for various industrial uses. The McNairy has been mined in Tennessee and Kentucky and used in glass making and as a foundry and abrasive sand (McGrain, 1968). Another Cretaceous deposit of fine- to medium-quartz sand and clayey sand occurs in western Illinois (fig. 1), but has limited economic potential.

Freeze-thaw testing of gravel aggregates

The Illinois Department of Transportation is reevaluating coarse aggregate products currently being used in Portland cement concrete. Their work has concentrated on freeze-thaw expansion testing of concrete beams (ASTM C-666, 1979) formed using the various sources of coarse aggregate (Traylor, 1981). The data shown in figure 9, when considered along with the geologic history of the sample sites, indicate that: (1) in general, only Wisconsinan outwash plains, kames, eskers, and valley trains contain gravel of a quality suitable for use in Portland cement concrete; (2) gravels with the lowest freeze-thaw expansion values tend to be concentrated in the youngest, coarse-grained outwash plains located in northeastern Illinois; and (3) valley-train gravels tend to have higher expansion values with increasing distance from the Wisconsinan glacial front.

SUMMARY

Sand and gravel deposits are abundant in Illinois, but gravel suitable for use in Portland cement concrete is generally limited to Wisconsinan outwash deposits, and is most abundant in northeastern Illinois. Additional sand and gravel deposits containing material suitable for uses with lower quality specifications can be found in Wisconsinan deposits toward the margin of the ice sheet; the more distal portions of valley trains; in Illinoian deposits, especially the Hagarstown; and in the Pliocene-Pleistocene age Mounds Gravel.

Sand suitable for use as fine aggregate in Portland cement concrete is abundant in the same deposits as is gravel of that quality. In addition, such high-quality sand can also be produced with proper processing from sand deposits within all other discussed Pleistocene units. Sand of the Gulfian (late Cretaceous) McNairy Formation of southernmost Illinois may also meet certain fine-aggregate and industrial sand needs in the future.

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