GEOLOGIC FORMATIONS ON WHICH AND WITH WHICH INDIANA'S ROADS ARE BUILT

by

CHARLES F. DEISS

Indiana Department of Conservation

GEOLOGICAL SURVEY

Circular No. 1

1952

STATE OF INDIANA
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GEOLOGICAL SURVEY
Charles F. Deiss, State Geologist
Bloomington

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ILLUSTRATIONS

GEOLOGIC FORMATIONS ON WHICH AND WITH WHICH INDIANA'S ROADS ARE BUILT*

By Charles F. Deiss

INTRODUCTION

President Heckathorn, Members and Guests of the Indiana Mineral Aggregates Association:

The subject of this talk as given in your program might better have been "Sources of aggregates and types of highway subgrades in Indiana." You men, better than anyone else, know that our highways are built of aggregates cemented together with one kind or another of portland cement, bituminous materials, or resinous plastics. Often, however, you would like to know much more about the origin, extent, and mineral composition of your gravels and limestones. In fact, it is because you don't have dependable answers to those three questions that some of you suffer financial loss and frustration until you can find the answers, when the Highway Commission rejects the materials from one of your pits or quarries.

The engineers of the Highway Commission, likewise, know better than anyone else in Indiana the various types of subgrades and the characteristic behavior of each type on which our roads are built. But the engineers would like also to know much more about the origin, thickness, lateral extent, mineral composition, and interrelationships of the wide variety of subgrades encountered in our highway system.

To answer questions of this kind, engineers and aggregate producers, in this country and abroad, are turning increasingly to geology and mineralogy, because these sciences are proving to be the most economical and dependable methods of finding new deposits and of indicating the type and size of subgrades (terranes) that will be encountered by new highways that will cross untested areas. The greatly increased use of aggregates during the past 10 years is being intensified by the demand for aggregates to build the modern heavy duty roads of this decade. These demands already are beginning to exhaust some of our present deposits. New sources of aggregates, favorably located along the proposed routes of such new superhighways, will be expensive to find and to evaluate.

Since July 1947, the Indiana Geological Survey (Patton, 1949, pp. 1-47) has studied, sampled, and mapped every operating limestone quarry in Indiana (Pl. l), and also has examined nearly 3,100

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*Presented on request of the Engineer-Director of the Indiana Mineral Aggregates Association at its annual meeting in Indianapolis, March 13, 1952.

gravel pits, including the 620 that are currently operating (Pl. 2). In addition, the Geological Survey has made analyses of each type of limestone encountered in all of your quarries, and probably has more information about the composition of Indiana's gravels and sands than is known by any other state in the Union.

Being aware of this geologic information and of its practical usefulness to aggregate producers and users, your Engineer-Director, Ralph E. Simpson, invited me to discuss the geologic reasons that are responsible for the distribution and accessibility of our limestones and gravels, and also to indicate the differences in origin of the materials that make up the several kinds of subgrades which support our roads.

The first of these two subjects raises the questions: What is the distribution of limestone and gravel in Indiana, and why are they so distributed? In order to answer those two questions we need to learn how the limestones and grovels were formed, and to do that we must look at some of the geologic events that took place in this part of North America.

GEOLOGIC HISTORY OF INDIANA

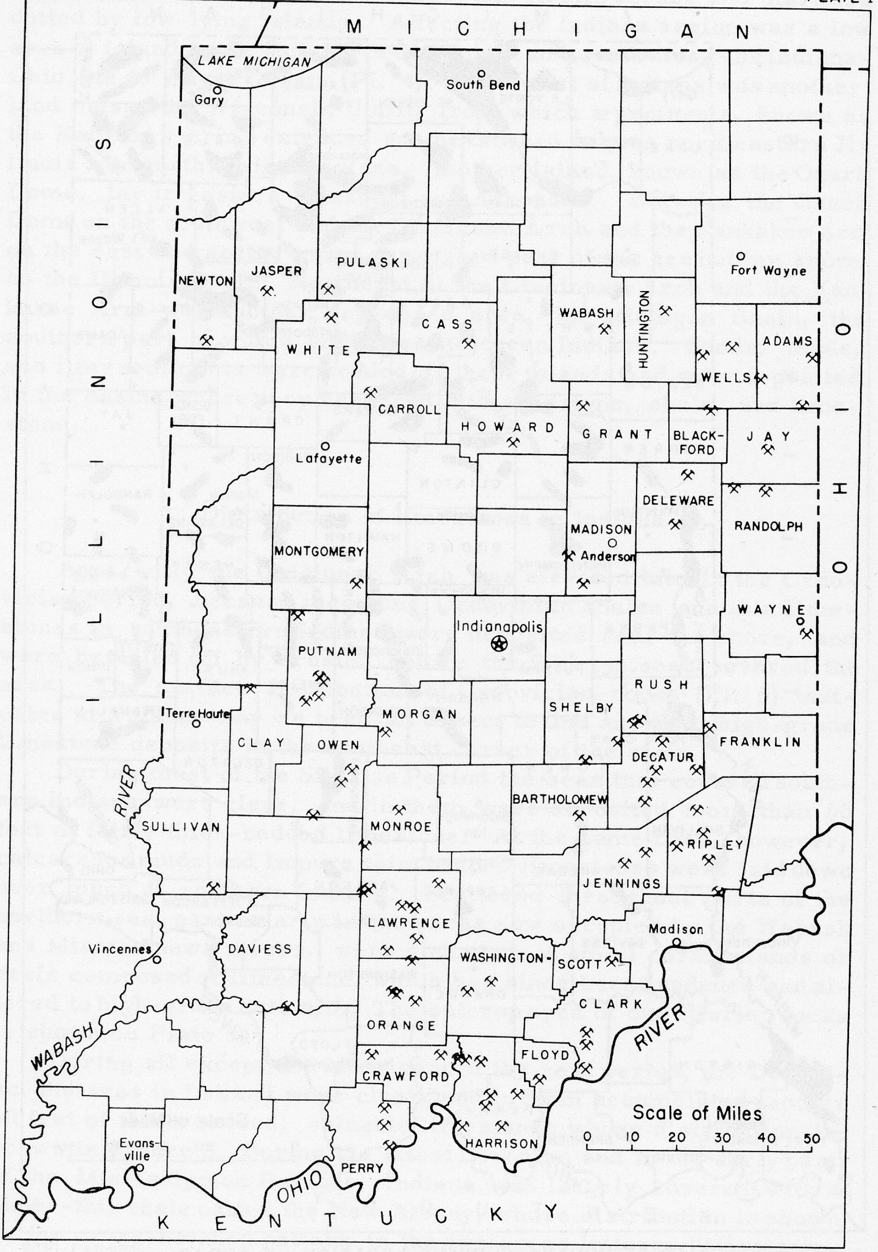
Periods of deposition and erosion

The geologic timetable (Pl. 3) is drawn to scale for the last 500,000,000 years of the earth's history. The length of the blue bar shows graphically that all of the bedrock exposed at the surface in Indiana was deposited between 240,000,000 and 400,000,000 years ago. The time table also shows that our bedrock belongs to five geologic periods which, from oldest to youngest, are the Ordovician, Silurian, Devonian, Mississippian, and Pennsylvanian. All of these periods belong to just one geologic era--the Paleozoic. Cambrian rocks are encountered in drilling deep oil wells but do not crop out at the surface anywhere in Indiana. You will note that we do not have any Mesozoic or Tertiary rocks. We do have as much as 550 feet of Quaternary or glacial deposits, but these are unconsolidated gravels, sands, and muds. This vast span of nearly 240, 000, 000 years during the Mesozoic and Tertiary was a time of- erosion in Indiana, and I shall refer to it again.

Ancient basins and land masses

The composition and distribution of our rocks indicate that in the Ordovician period, some 400,000,000 years ago, the central part of the country was covered intermittently by shallow seas that were

PLATE 1



MAP OF INDIANA SHOWING LOCATION OF QUARRIES THAT PRODUCE CRUSHED STONE

January 1, 1952

INDIANA DEPT. CONS., GEOL. SURVEY, CIRCULAR 1 PLATE 2

MAP OF INDIANA SHOWING LOCATION OF AREAS THAT PRODUCE GRAVEL AND SAND

January 1, 1952

connected with the Atlantic, Pacific, and Arctic oceans and that were dotted by low-lying islands. Affecting the Indiana region was a low arch or island in the vicinity of Cincinnati and north along the Indiana Ohio line to Wayne County (P1. 4). Northwest of Indiana was another land mass; the Wisconsin Uplift, from which a peninsula, known as the Kankakee Arm, extended southeastward across northeastern Illinois into northwestern Indiana. Another island, known as the Ozark Dome, lay in eastern Missouri and Arkansas. Between the Ozark Dome on the southwest and the Cincinnati Arch and the Kankakee Arm on the east and north, was a depressed part of the sea bottom known as the Illinois Basin. Northeast of the Cincinnati Arch and the Kankakee Arm was another depressed area, the Michigan Basin, the southern part of which underlies northern Indiana. Sands, muds, and limy sediments were eroded off these islands and were deposited in the basins where they hardened into sandstone, shale, and limestone.

Distribution of limestones in Indiana

Apparently the Cincinnati Arch was elevated late in the Ordovician period, because the young Ordovician shales and thin limestones in southeastern Indiana were deposited near the shore, and were bevelled off by erosion before the Silurian seas covered the area. The surface distribution of Ordovician rocks (Pl. 5) indicates at a glance why we need not expect to find any thick high-grade limestone deposits in the southeast corner of the state.

During most of the Silurian Period the seas that covered southern Indiana were clear, and in them were deposited more than 60 feet of fairly thick-bedded limestone. At the same time, however, calcareous muds and impure thin-bedded limestones were laid down over much of northern Indiana. Scattered throughout parts of the northern sea, particularly in the areas now occupied by the Wabash and Mississinewa rivers, were a number of small coral islands or reefs composed of limestone, which has since been hardened and altered to high-grade dolomite. The outcrop area of our Silurian rocks is shown on Plate 5.

During all except the latest part of the next period, the Devonian, the seas in Indiana were clear, and in them accumulated another 60 feet of thick-bedded, valuable limestones whose distribution is shown in Figure 3. During the latest Devonian and in the early part of the Mississippian Periods, Indiana was largely covered with a paper-thin shale called the New Albany, whose distribution is shown by the cross-hatched pattern in the two areas lettered “Mississippian-Devonian” on the map (Pl. 5).

The Lower Mississippian likewise was a time of mud deposition in Indiana. Throughout the western and southern parts of the area labelled "Lower Mississippian and Upper Devonian" in Figure 3, nearly 700 feet of muds and sands were laid down. These rocks and the underlying New Albany black shale do n of contain any commercial limestone and account for its absence in the north-south belt across the central part of southern Indiana (P1. 1).

In contrast, the Middle Mississippian seas were clear and in them were deposited 275 to 400 feet of high-grade, thick-bedded limestones which today are the most important sources of crushed stone in southern Indiana. Incidentally, the world famous Indiana building stone also is mined from one of these Middle Mississippian limestones. In late Mississippian time the islands surrounding the Illinois Basin were so elevated that they furnished muds and sands which were spread out over the limestones and formed the 400 to 1,000 feet of shales and sandstones that we call the Chester Series of formations.

After the Mississippian period the central part of North America rose above and sank below sea level at least 19 times. When the area was above sea level, great swamps developed and in them primitive trees grew rankly. When the land sank, ocean waters again flooded the Illinois Basin, drowned the trees and other vegetation, and deposited irregular beds of mud, dirty sand, and a few impure, thin, interbedded limestones. These Pennsylvanian rocks (Pl. 5) contain all our coals, much of our fireclays and shales, and part of our oil, but the thin limestones within them are quarried on a small scale at only two localities and are of little interest as sources of aggregates. Thus, the geology of the Pennsylvanian rocks indicates that new reserves of limestone suitable for highway aggregates will not be found along the west side of the state.

Preglacial erosion and bedrock surface of Indiana

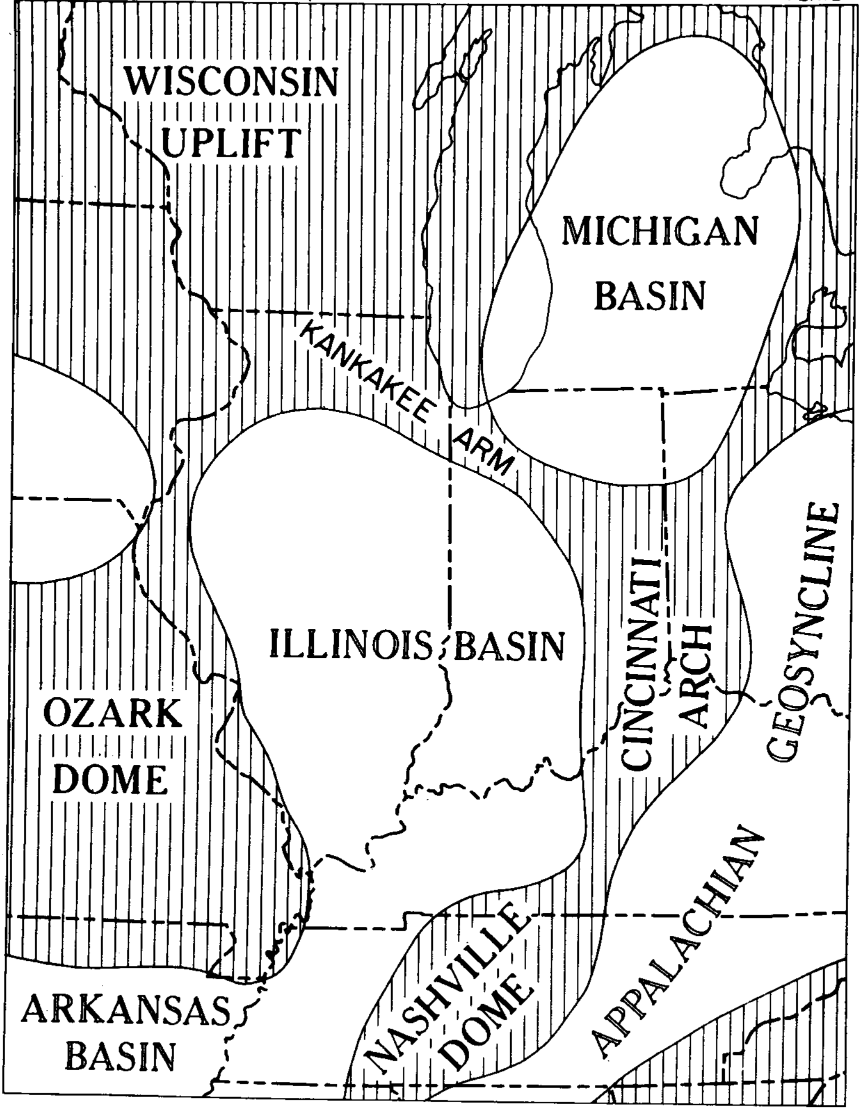
At the close of the Pennsylvanian, Indiana was raised above sea level and never again was covered extensively by ocean waters. This period of erosion, which lasted nearly 240,000,000 years, is represented graphically by the length of the segment of the column in Plate 3 labelled "continuous erosion in Indiana." Throughout this enormous time, the rocks that were formed in the shallow seas during the preceeding 160,000,000 years were exposed to the atmosphere and were carved into hills and valleys by the rivers and other streams that drained Indiana. Literally cubic miles of weathered and eroded rock debris was carried from Indiana to the Mississippi River, which in turn transported it to the Gulf of Mexico.

Records of water and oil wells, and especially the use of our seismograph in recent years, have given enough data to pl of the depths and courses of some of these ancient bedrock valleys that are now

MAJOR DIVISIONS (ERAS)	ROCKS EXPOSED IN INDIANA	SUB-DIVISIONS (PERIODS)
CENOZOIC 60	CONTINUOUS EROSION IN INDIANA	QUATERNARY 1
		TERTIARY 59
MESOZOIC 140		CRETACEOUS 80
		JURASSIC 35
		TRIASSIC 25
PALEOZOIC 340		PERMIAN 40
	■	PENNSYLVANIAN 40
	■	MISSISSIPPIAN 30
	■	DEVONIAN 40
	■	SILURIAN 30
	■	ORDOVICIAN 70
		CAMBRIAN 90
PRE-CAMBRIAN 1500		*(FIGURES IN MILLIONS OF YEARS)*

SIMPLIFIED GEOLOGIC TIME SCALE

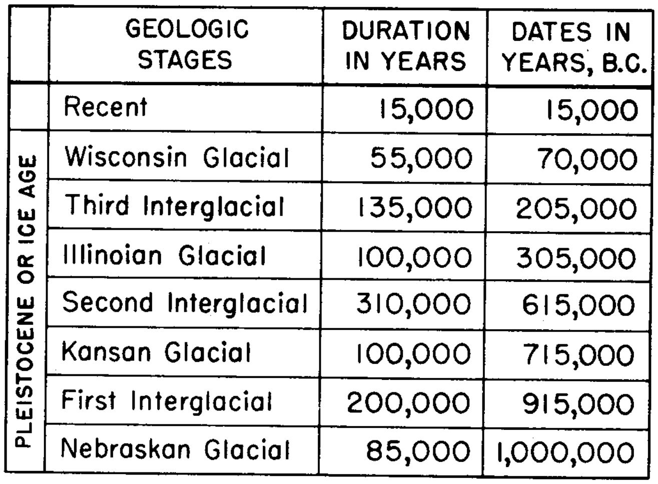
(Table drawn to scale for Paleozoic and later eras)



GENERALIZED MAP OF BASINS AND LANDS IN MIDWEST DURING EARLY PALEOZOIC buried beneath glacial drift (Pl. 6). If you will visualize Brown County filled and covered with drift that is 10 to 50 feet thick over the hills and more than 500 feet thick over the deeper valleys, you have a pretty good picture of what lies underneath the surface of more than three-fourths of central and northern Indiana. Herein lie the reason that in much of northern Indiana limestone is known in only a few places from 5 to 20 feet below the surface where the drift is thin, and the explanation for the fact that the limestone is absent elsewhere in the same county or township.

Pleistocene events

The last 1,000,000 years of geologic history are called the Quaternary Period, of which the Pleistocene or ice age consumed all but 15, 000 years, and the Recent age is that time since the last glacier melted and disappeared from North America (Fig. 1). Although Indiana may have been covered by ice during all four glacial periods, we can recognize only two periods within Indiana. The older and wider spread deposits were made by the Illinoian glacier, from 305,000 to 205,000 years ago. The youngest or last glacial period is called the Wisconsin, and during this period Indiana experienced two glaciers, the last of which melted between 25,000 and 15,000 years ago. Note that the time between the Illinoian and early Wisconsin Stages (Fig. 1) was 135, 000 years, a longer time than that of either



	GEOLOGIC STAGES	DURATION IN YEARS	DATES IN YEARS, B.C.
	Recent	15,000	15,000
PLEISTOCENE OR ICE AGE	Wisconsin Glacial	55,000	70,000
	Third Interglacial	135,000	205,000
	Illinoian Glacial	100,000	305,000
	Second Interglacial	310,000	615,000
	Kansan Glacial	100,000	715,000
	First Interglacial	200,000	915,000
	Nebraskan Glacial	85,000	1,000,000

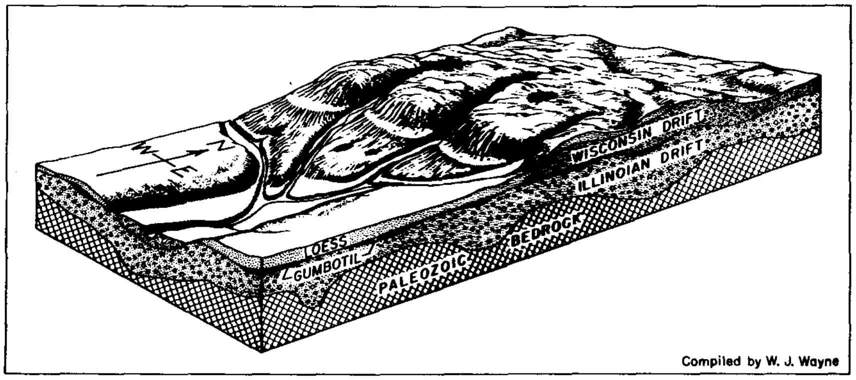
Figure 1. *Pleistocene time table for North America*

glacial stage.

Glacial ice piled up first in central Canada, from whence it spread outward in all directions. Much of this ice moved southward across Wisconsin, Michigan, and Ohio into Indiana. As it crossed southern Canada, the glacier picked up enormous tonnages of granitic and metamorphic rocks, transported them southward, and finally dropped them haphazardly when the ice melted. Incidentally, Indiana's gold and diamonds have the same origin. The southern extent of the Illinoian and Wisconsin glaciers in Indiana are shown by heavy broken lines on the maps (Pl. 5 and Fig. 3).

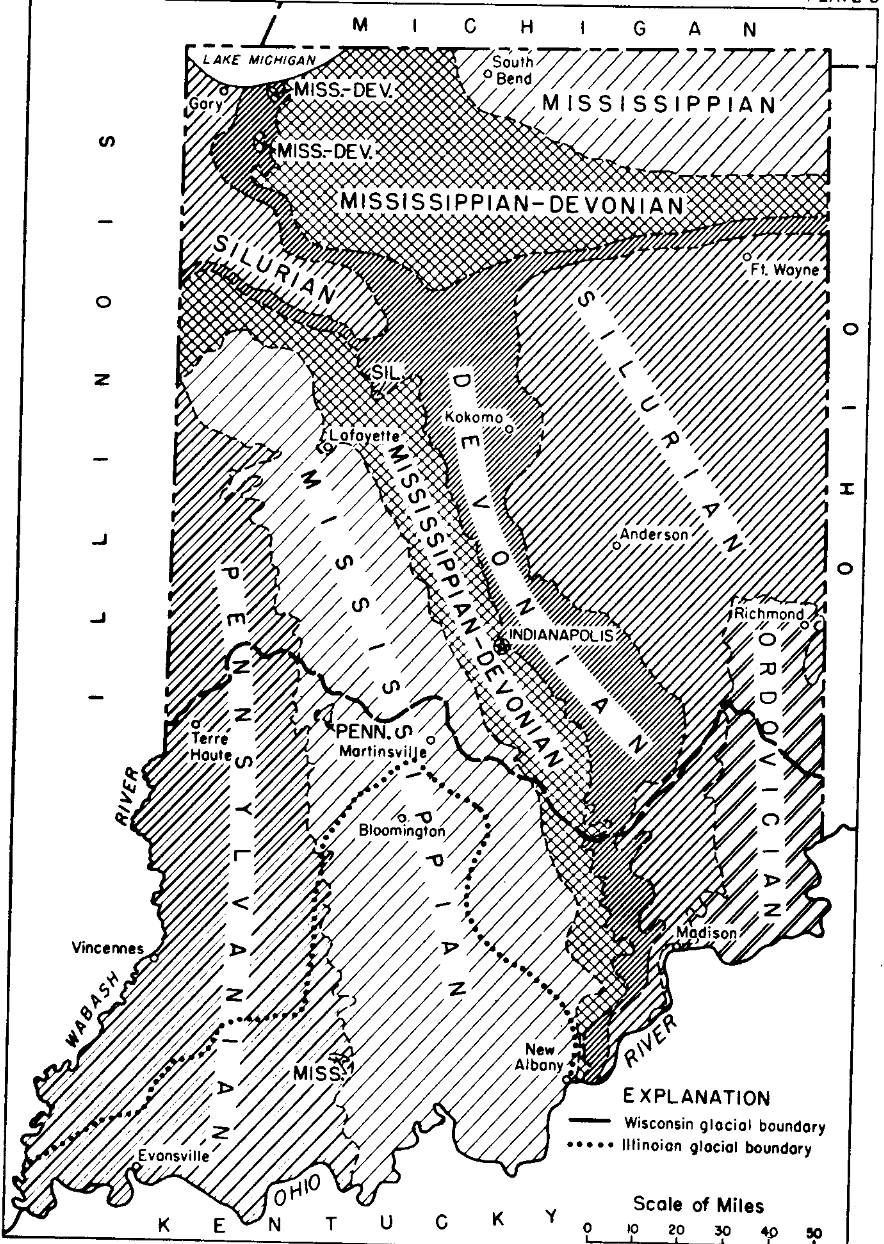
The simplified block diagram (Fig. 2) illustrates the relationships of these major glacial deposits in Indiana, and shows that the older Illinoian drift extended farther south than the younger Wisconsin drift; that a mature, black gumbotil soil was developed on the old drift; that the debris carried into Indiana by the Wisconsin glacier forms the youngest glacial deposits in the state; and finally that windblown dust, called loess, was dropped upon all the older deposits.

Because the Wisconsin glaciers gave most of our gravels and because these glaciers covered three-fourths of Indiana, let us look at them a little more carefully. Wisconsin ice moped over Indiana in two separate invasions. In the older invasion, known as the Tazewell Substage (Wayne and Thornbury, 1951, pp. 10-16), the glacier had the form of three giant ice lobes (Pl. 7). the Erie lobe on the east, the Saginaw lobe on the north, and the Lake Michigan lobe on the northwest (Moore, 1949, p. 442). The Erie lobe covered eastern Indiana and deposited the Shelbyville, Champaign, Bloomington, and other moraines. At the same time, the Lake Michigan lobe of ice moved south from the Lake Michigan Basin, covered the western part of Indiana, and merged with the southwest edge of the Erie lobe



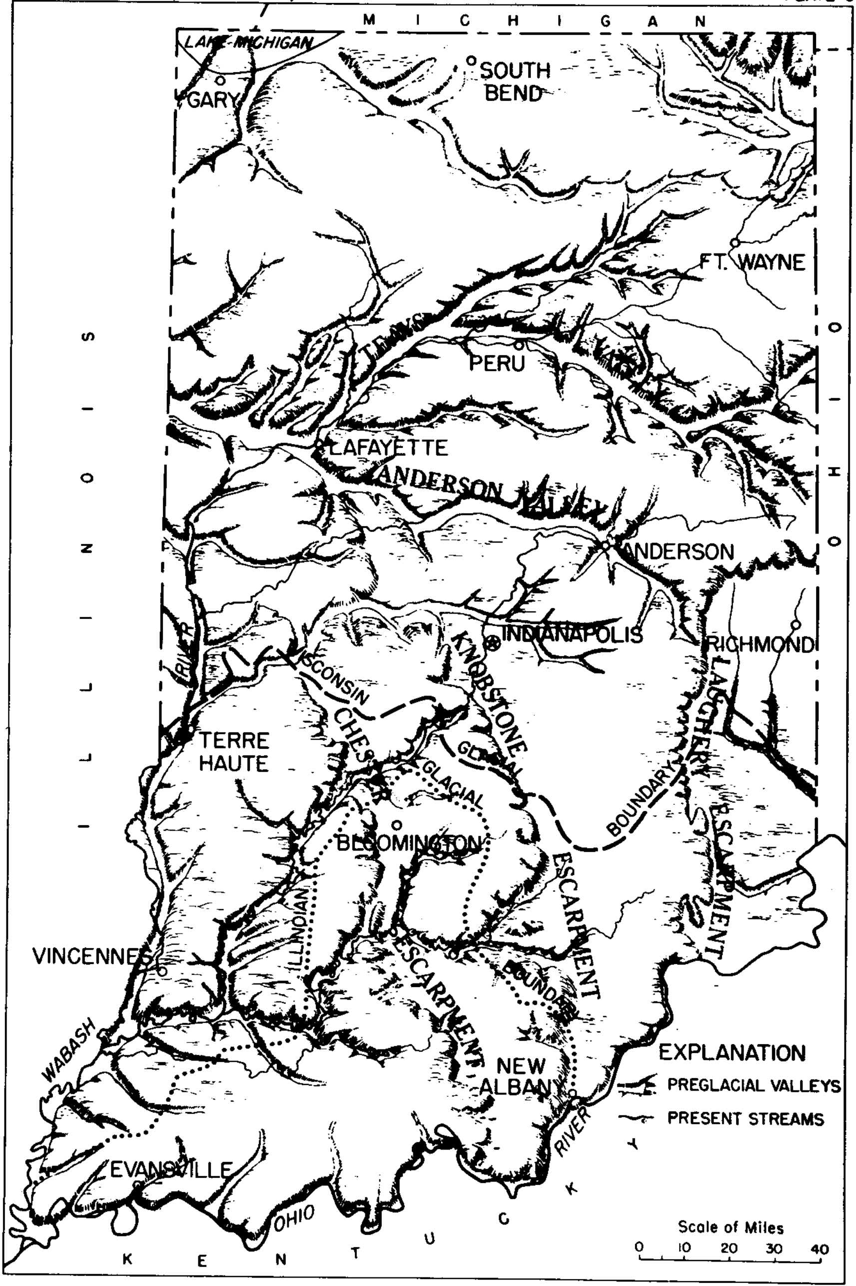
Compiled by W. J. Wayne

Figure 2. *Diagram showing relationships of Illinoian and Wisconsin deposits in Indiana*



GENERALIZED BEDROCK MAP OF INDIANA

Compiled by J. B. Patton
1952



MAP OF INDIANA SHOWING PREGLACIAL DRAINAGE AND PRINCIPAL RIDGES

Compiled by W. J. Wayne
1952

from Martinsville northward to Wabash. The third or Saginaw lobe of this early Wisconsin glacier moved due south from Saginaw, Michigan, but covered only the north-central part of Indiana between the Erie and Lake Michigan lobes. The ice in these lobes remained over Indiana 25,000 years or more and then melted beyond the boundaries of the state.

About 40,000 years ago, the Erie and Lake Michigan lobes again advanced into Indiana; but during this younger glaciation, known as the Cary Substage (Wayne and Thornbury, 1951, pp. 10; 16-19), the Erie lobe terminated in Wabash County and covered only the northeastern part of the state, and the Saginaw lobe did not get into Indiana. Upon melting and retreating, this latest Erie lobe deposited the Mississinewa moraine and those to the east around Fort Wayne. The Lake Michigan lobe of the Gary Substage glacier extended only 25 to 30 miles south of Chicago, where it deposited the Valparaiso moraine. Final meltwaters of this ice lobe gave birth to Lake Michigan and to the sand dunes that are still forming in northern Indiana.

Glacial origin of gravel and sand deposits. --The block diagrams (PI. 8 illustrate how the material dumped at the front of the glacier formed a ridge after the ice melted: This kind of ridge is called a terminal or end moraine. Temporary halts in the retreat of the glacier produced recessional moraines, all of which may have sand and gravel in them, and certainly form a variety of subgrades on which roads must be built. As the glaciers melted, great volumes of water were released. In some places the water was temporarily ponded to orm lakes; in other places it drained away in great streams or moving sheets that formed outwash plains in front of the glacier (Pl. 8). In places streams cut tunnels in the lower surface of the ice, and these tunnels became choked and filled with stratified sand and gravel - dropped by the streams as their velocities were reduced, thus producing glacial deposits known as eskers.

During maximum time of melting, torrents of water drained away from the glacial fronts. and collected into giant rivers that literally roared across Indiana to join the Ohio and Mississippi. These short-lived but -gigantic streams cut steep-walled, broad valleys, called sluiceways, which were soon filled irregularly with sands, gravels, and muds derived from debris that had been frozen in the glacier. Plate 9 shows the moraines, outwash plains, sluiceways, and a few eskers in Indiana. Most of the 3, 100 gravel deposits that we have mapped fall within these four glacial features. Equally importantly, gravel and sand become finer grained as one moves down the sluiceways away from the ice fronts. Thus, a knowledge of glacial geology is the important key to (1) why the gravel deposits are where we find them, (2) why some deposits contain more shale than others, and (3) where we can look most profitably when we are compelled to seek new deposits.

Clearly, the glaciers destroyed and covered beyond use most of the limestone deposits in more than two-thirds of the state, but over much of the same general area the glaciers gave us our other aggregate-gravel. The outstanding exception is in the northwestern part of the state, where the Michigan lobe passed over the black Devonian shales and Mississippian siltstones in the Lake Michigan Basin (Pl. 5) and thus put much useless shale into the gravels instead of hard usable rocks.

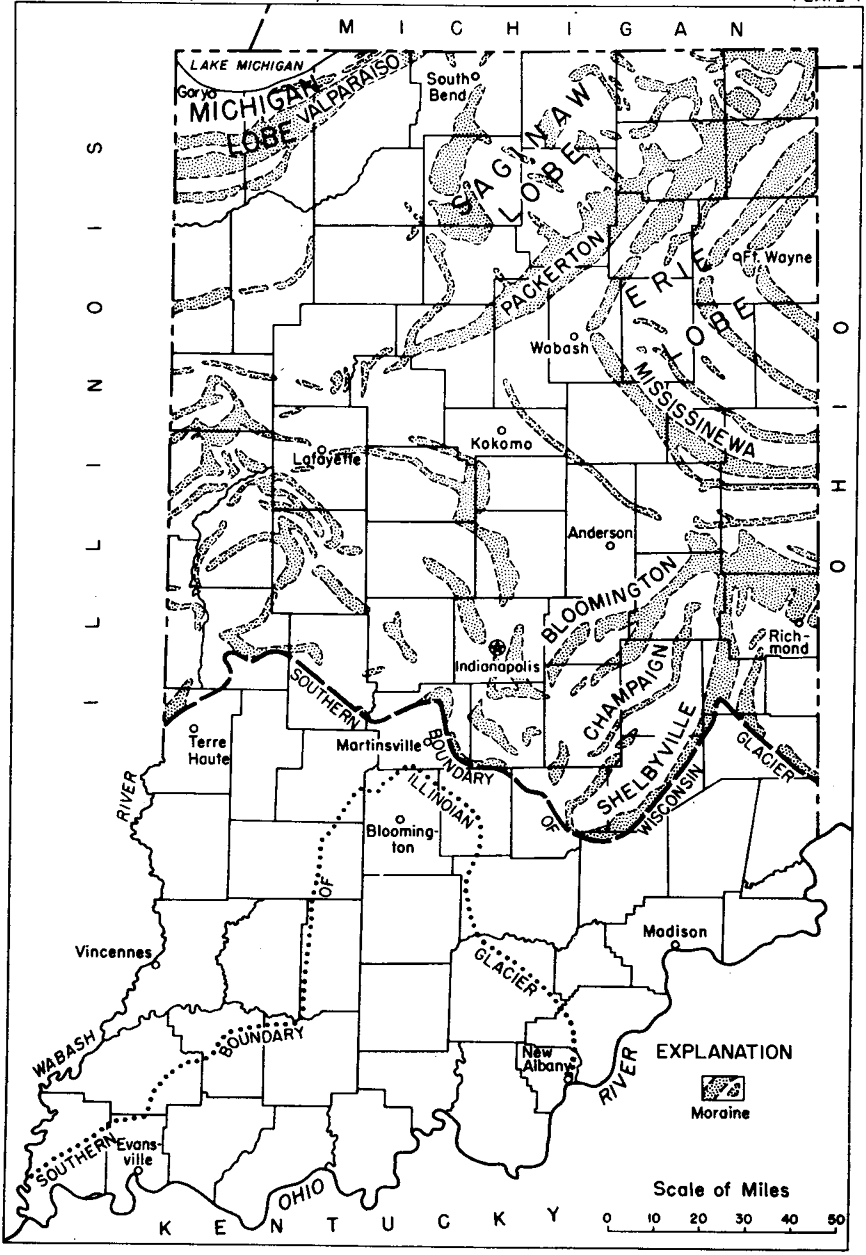
DISTRIBUTION OF POTENTIAL QUARRY SITES

From the foregoing summary of early geologic history in Indiana, five dependable conclusions are obvious and have direct hearing on the location of new quarry sites. (1) The Ordovician rocks crop out only in the southeast corner of the state, are thin limestones separated by useless shales, and will not yield desirable new quarry sites. (2)In the unglaciated area of south-central Indiana and inmost of the southeastern and southwestern parts of the state covered by Illinoian drift, bedrock is close enough to the surface to permit economical stripping and quarrying. (3) Between the outer edge of Wisconsin drift and the edge of the youngest (Cary) drift (Fig. 3), the larger streams have cut through the drift into bedrock and thereby permit quarrying without excessive stripping. Thus in much of southern Indiana, as noted by Patton (1951, p. 261), “potential quarry sites are numerous, and the quarry operator may select a location upon the basis of convenience, geographic advantage, stripping conditions and character of the limestone.” (4) But in central Indiana, the glacial drift is thin only in the valleys of major streams and at a few places in the till plains. New quarries, therefore, will have to be opened only where the limestone is available, and new quarry sites probably will not be found where they would be most desirable. (5) Limestone is absent and, therefore, quarry sites are not possible in three broad belts: the first belt includes the upper two tiers of counties across northern Indiana (Pl. 1), the second is a narrow belt from Louisville, Kentucky (Fig. 3) slightly northwest across the central part of Indiana, and the third is the wide belt underlain by Pennsylvanian rocks (Pl. 5) along the western part of the state.

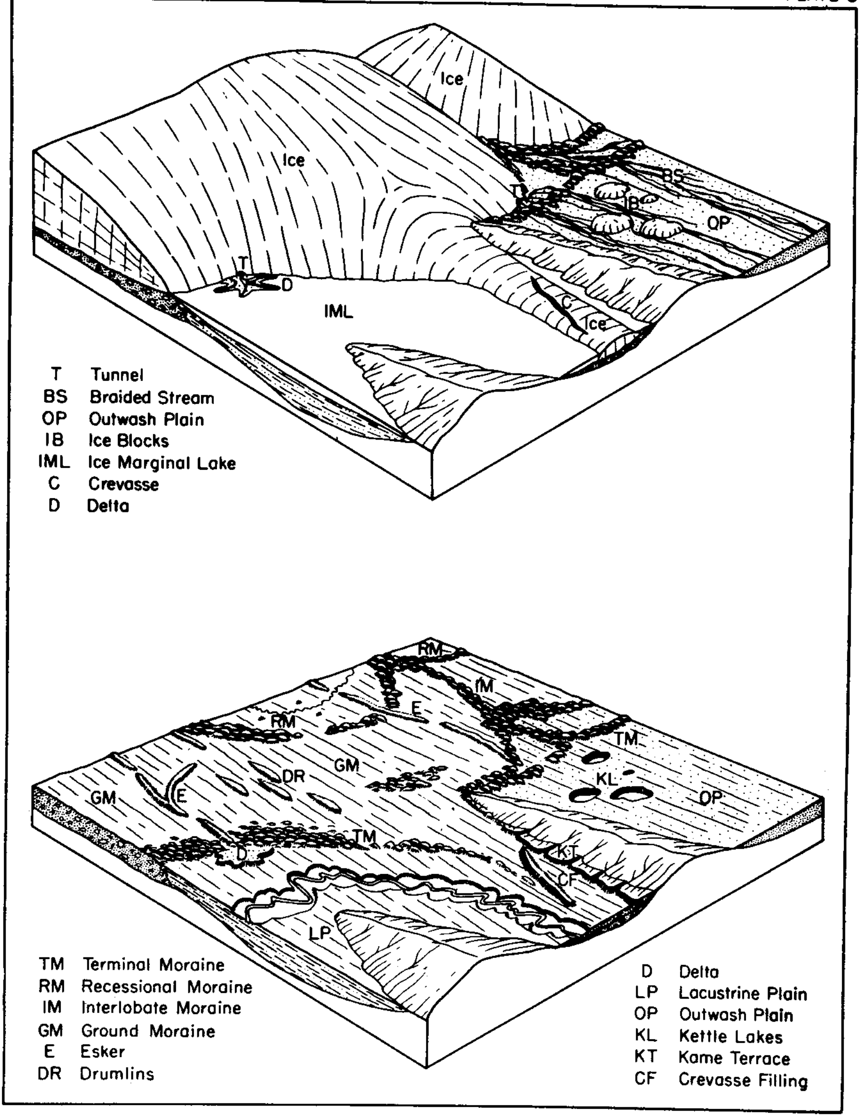
TYPES OF HIGHWAY SUBGRADES IN INDIANA

Without attempting to make a complete list, one can state that at least 19 types of subgrades support Indiana’s highways. These types are:

1. Solid, thick-bedded limestone.



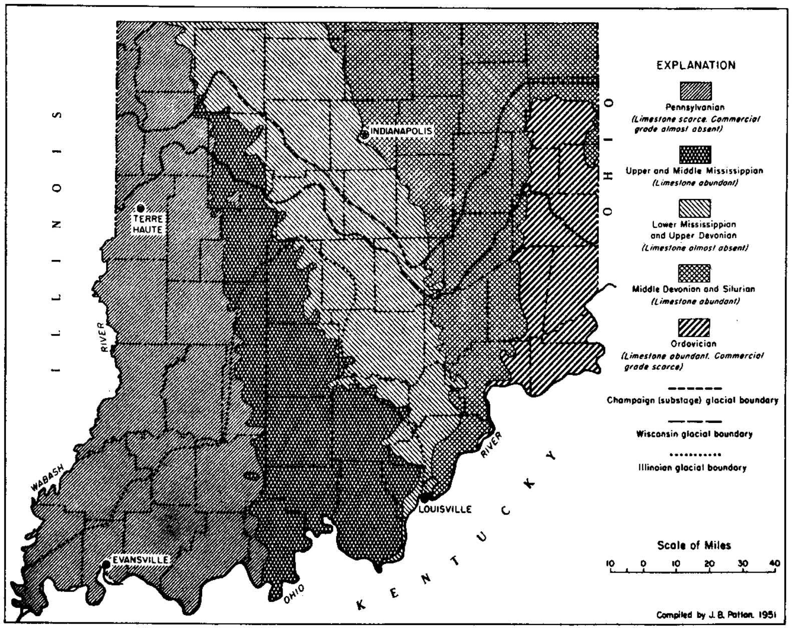
MAP OF INDIANA SHOWING WISCONSIN GLACIAL LOBES AND MORAINES



DIAGRAMS ILLUSTRATING
ORIGIN OF GLACIAL DEPOSITS

Compiled by W. D. Thornbury
for use in textbook on Principles of Geomorphology

2. Hard, thick-bedded sandstone.
3. Interbedded platy limestones and shales.
4. Shale and some interbedded thin sandstones.
5. Postglacial sand dunes in the Lake Michigan area.
6. Ancient dunes on Wisconsin and Illinoian glacial drift.
7. Moraines composed of till (unsorted clay-like particles and boulders) only.
8. Terminal and ground moraines composed of interbedded till and gravel.
9. Gravel and sand in sluiceways.
10. Illinoian till veneered on preglacial bedrock slopes.
11. Lake clays resting on outwash gravels and sands.
12. Till plains.
13. Kames and eskers on or within moraines.
14. Bogs and marshes in filled Wisconsin lakes.
15. Bogs and marshes in clayey till plains.
16. Gumbotil soil on Illinoian glacial drift.
17. Wind-blown dust (loess) which may blanket any older deposit.
18. Residual clay soils derived from leached and weathered limestone.
19. Recent floodplains (river muds).



Compiled by J. B. Patton. 1951

Figure 3. *Generalized bedrock map of southern Indiana showing geologic distribution of limestones*

You will note that each of these 19 types is a distinct, recognizable, geologic phenomenon, such as bedrock, glacial lake clays, moraines, outwash plains, sand dunes, and Recent floodplains. Each type also is susceptible to precise mapping and to mineral analysis; each rests on or lies beneath its adjacent geologic type; and each constitutes a subgrade that, under certain conditions of moisture and topographic position, has its own peculiar behavior characteristics.

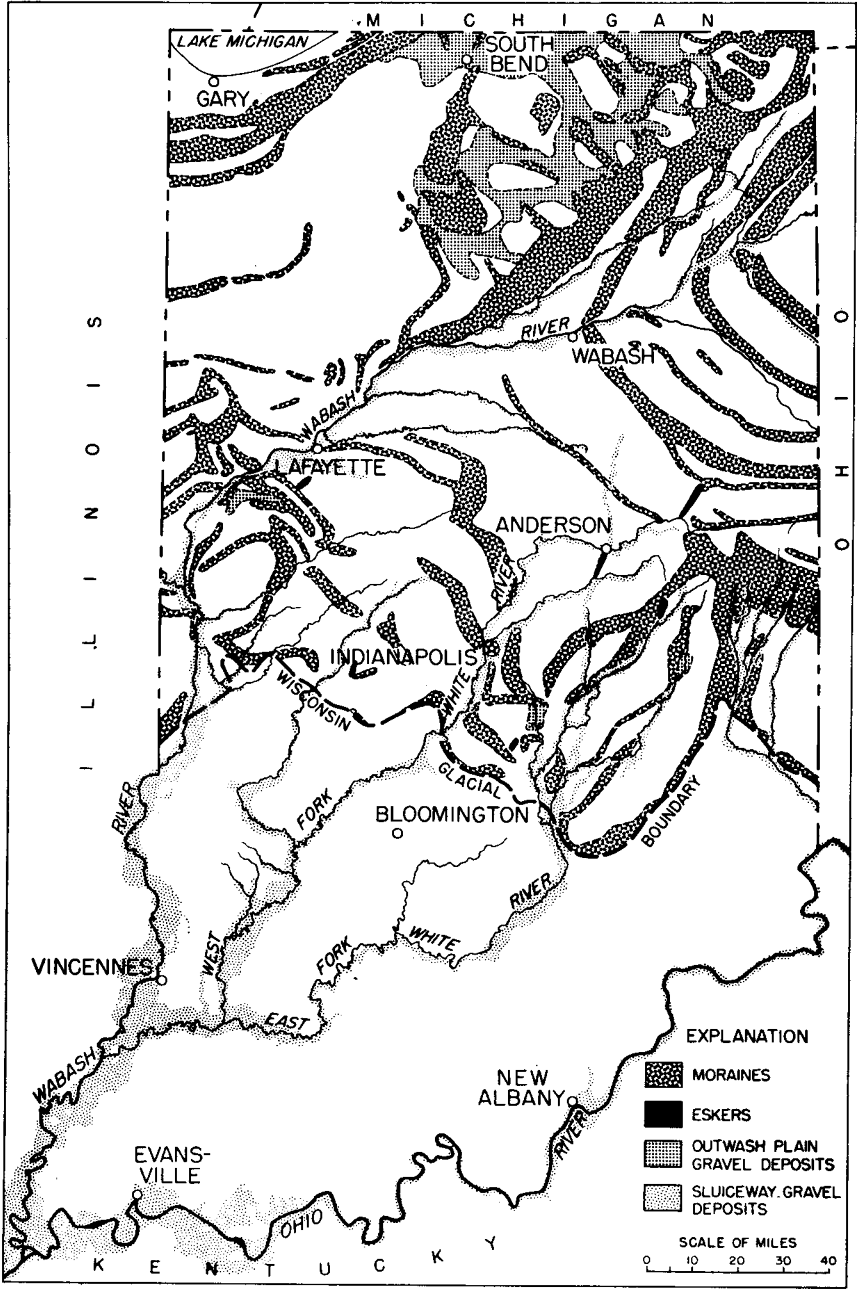
The problem of highway subgrades is made more complex by the fact that the minerals or rock particles in many of these 19 types are affected along the zone where they are in contact with their neighbors. For example, a slippery lake clay or an old weathered till resting on a steep limestone hillside behaves quite differently than does the same clay or till out on a flat underlain by gravel and sand. Likewise a till plain of Wisconsin glacial muds resting on Illinoian gumbotil presents a very different drainage problem than does similar Wisconsin muds underlain by sluiceway gravels.

As previously stated, the solution of specific problems concerning the behavior of subgrades is the province of highway engineers. The determination of the extent, thickness, inter-relationships, and mineral composition of subgrade materials is the province of geologists. The fact is becoming clear that dependable, quantitative geologic and mineralogic information is useful to engineers in solving subgrade problems, if in no other way than by helping to avoid undesirable subgrades wherever possible at the time new highways are planned and long before their construction is begun.

CONCLUSIONS

In closing, I should emphasize that much detailed geologic work remains to be done before we shall know the quantitative answers to such problems. Nevertheless, the geologic information that is now available in Indiana and that will be available within the next 2 years is fundamental to (1) finding new deposits, (2) saving money for aggregate producers who might otherwise explore useless areas or invest in deposits of marginal value, and (3) indicating the type, size, composition, and relationships of subgrades that will be crossed by new highways.

Thank you for the privilege of speaking to you and for your most courteous attention to the ideas that have been presented.



Compiled by J. B. Patton
1952

MAP OF INDIANA SHOWING PRINCIPAL MORAINES, SLUICEWAYS, OUTWASH PLAINS, AND ESKERS

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