Indiana Geology as it Influences Engineering Projects

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The modern philosophy of the science of geology is based on the theory that "the present is the key to the past." That is to say, the processes operating to modify the crust of the earth today have operated in much the same manner for countless ages. Thus by observing these processes and their incremental results, we may reconstruct the earth's history from similar but accumulated results. These accumulated results are the materials that surround us, the rocks and the soils, their shape and character. Their content and arrangement bear witness to the patterns of ancient lands and seas, mountains and valleys, deserts and frozen waste lands. No modern trained geologist doubts the plausibility of this thesis.

Conversely, in applying the science to utilitarian ends it may be pointed out that "the past is the key to the present." The past events, which have shaped the land and formed its underpinnings, are responsible for our present environmental and economic situations. In the field of engineering alone we can find this maxim illustrated over and over again. For example, what lies behind the fact that unbroken road alignments are readily obtainable in northern Indiana whereas in the southern part of the state tremendous cuts and fills are often required, adding to the expense of construction? Why does one rock bed in Indiana produce material suitable for aggregate whereas others of seemingly similar character yield material which is deleterious when put to the same use? Why do water supplies obtained from some wells seem limitless and consistent in purity while those of others are undependable and often need excessive treatment?

These and many another engineer's headache are intimately related to the past history of the earth. By delineating the areas of influence exerted by various periods of geologic time, similarity of conditions are found to be limited by areas and alternatives can be applied which might not be feasible or economical in another area. Moreover, many problems can be anticipated in advance and steps taken to minimize their effect.

Three broad processes are recognized today as altering the face of the earth. Their agents can be studied. Their results are to be seen at every turn.

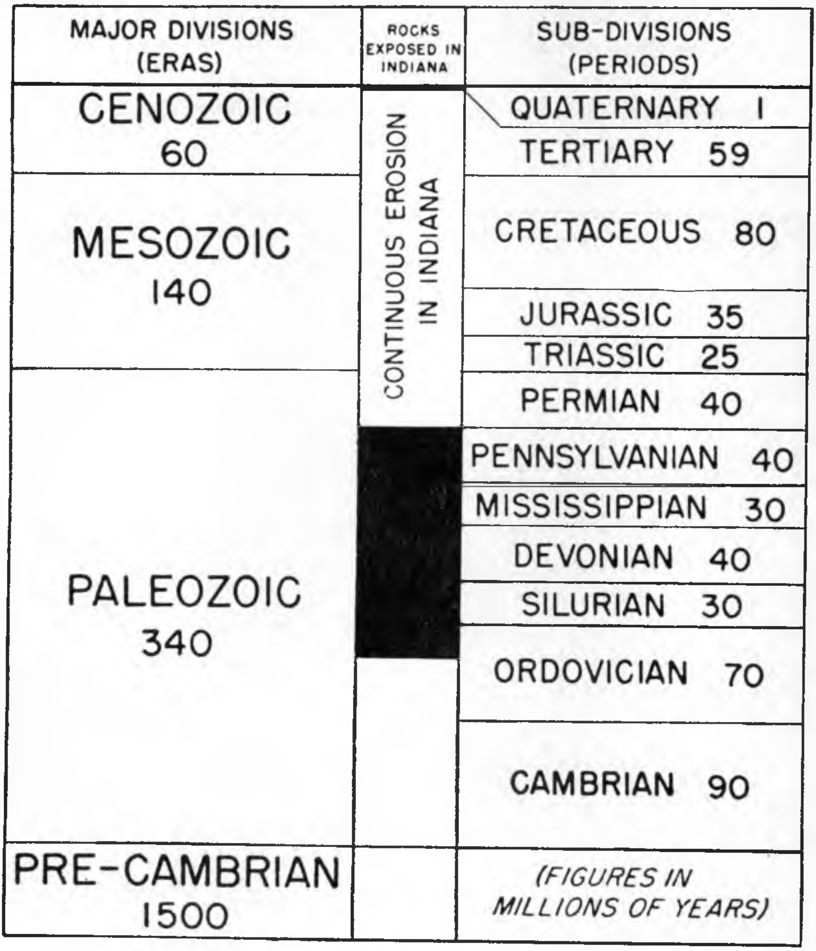
The first of these processes is gradation which is the great equalizer, i. e., the process by which the high areas are worn down and low areas are built up. This process is accomplished by such agents as water, air, and ice, all in a dynamic state. Each agent accomplishes in its own fashion the degradation of one area by erosion and the aggradation of another by the accumulation of the material previously eroded. Thus mountains and hills are worn down while flood plains and deltas are built up.

The other two processes tend to act in opposition to the net result of gradation. They tend to increase the irregularities or inequalities of the surface. One of these is volcanism, the process concerned with the movement of molten rock material. It produces volcanic cones and lava flows. The third process is called diastrophism which is a two dollar word for the movement of the solid parts of the earth with respect to each other. It produces folds and faults in rock, and it causes continents to rise and mountains to be brought forth. Needless to say, there is much to be learned of these processes.

Each of the processes is fundamentally responsible for the development of one of the three major classes of rocks. Thus the sedimentary rocks are the result of gradational activity, the igneous or fire rocks are the result of volcanic activity and the metamorphic or changed rocks are closely associated with diastrophism. In Indiana the bedrock material is predominately sedimentary in origin.

Geologists have divided all of earth's long history into several great time units called eras and these in turn have been subdivided into lesser units called periods for ease of classification and study. Each unit of geologic time, large or small, is theoretically represented by rock material of some type or character. By studying the sequential arrangement of these materials, the details of earth's long history are revealed. Figure 1 is a simplified geologic time chart which also shows the geologic periods of importance to the present physical condition of Indiana. The latter are shown by the heavy black portion of the center column.

On our continent, bedrock of the first time division, called the pre-Cambrian, is to be found at or near the earth's surface in the so-called Canadian Shield Area of Canada, in the Piedmont area of the eastern



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)*

(Table drawn to scale for Paleozoic and later eras)

Fig. 1. Simplified Geologic Time Chart.

United States, in the cores of many of our western mountains, and exposed in certain valleys such as the Grand Canyon. One would have to penetrate several thousand feet of bedrock in Indiana before encountering rocks of this age. Thus, as a direct influence on our present environment in Indiana, we may wipe off the first billion years of earth history.

The next era, called the Paleozoic, has been quite influential however. It began about 550 million years ago. Rocks representing this era underlie the surface of Indiana everywhere. In some areas they form the residual surface soil while in others they lie buried beneath materials of more recent origin, as yet unconsolidated. The rocks consist essentially of layers of limestone, sandstone, shale and to a lesser degree, coal. Some of these beds are thick or massive while others are thin and interbedded.

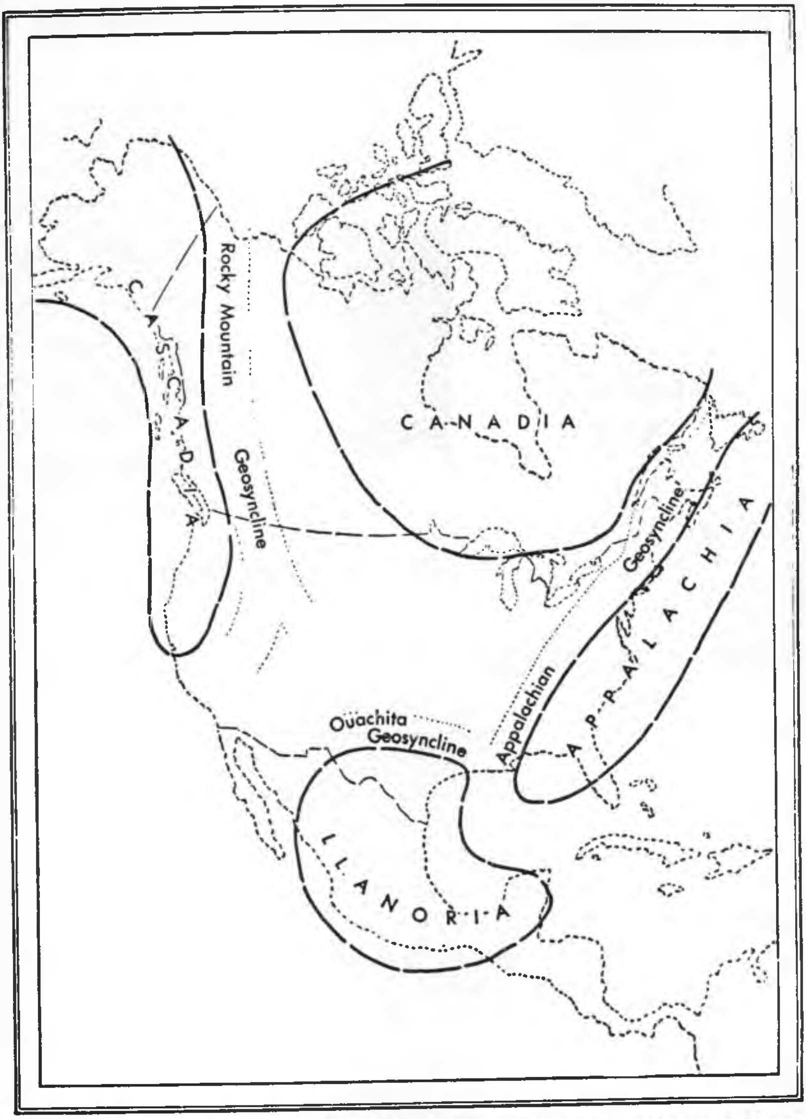


Fig. 2. Map showing generalized land areas and geosynclines of North America during Paleozoic Era.

As shown in Figure 2, there were four major land areas during the Paleozoic era. One forms the present Canadial Shield Area (Canadia), one existed along the present western coastline of North America (Cascadia), a third occupied much of present Mexico and lower Texas (Llanoria), and the fourth existed along and off the present Atlantic coastline (Appalachia). Depressed troughs called geosynclines existed east of Cascadia (Rocky Mountain Geosyncline), north of Llanoria (Ouachita Geosyncline) and west of Appalachia (Appalachian Geosyncline). The interior portion of the continent was continually invaded by shallow seas and was covered much of the time. It was in these shallow seas that the sediments accumulated to form the bedrock of Indiana.

The first subdivision of the Paleozoic (Cambrian) lasted about 90 million years. Bedrock representing this period is not influential in our state as a surface material although it is encountered at depth.

During the second period of the Paleozoic, known as the Ordovician, shallow seas covered as much as 90% of the present continental boundaries of North America. In these seas were deposited limey oozes and mud which were derived from marine organisms and from debris carried into the sea from the adjacent land mass which lay to the east. This material later became indurated to form interbedded limestones and shales. Bedrock characteristic of this period is exposed in Switzerland, Ohio, Dearborn, Franklin, Ripley, Jefferson and Clark Counties in Indiana. (See Figure 3—Geologic Distribution of Paleozoic Bedrock in Indiana.)

Subsequent diastrophism caused uplifting and erosion of this material producing a topography which is readily recognizable on airphotos such as that shown in Figure 4 of a part of Switzerland County. Notice the irregular road alignment and odd shaped field patterns. The more familiar ground view as seen in Figure 5 illustrates the local relief which produces heavy ridges and valleys.

Landslides are a common problem wherever interbedded limestone and shale form the basis for the present surface soil. Roadways, of necessity have irregular alignments and often heavy grades, unless extensive cuts and fills are made. The latter practice is often an invitation to the development of a landslide situation. More commonly roads are confined to the valleys or the ridge tops. Surveying problems are numerous and sight distances short and interrupted.

During the third and fourth periods of the Paleozoic called the Silurian and Devonian, two more invasions of North America by shallow seas occurred. These were not as extensive as that of the previous period. In Indiana deposits from these seas overlie the

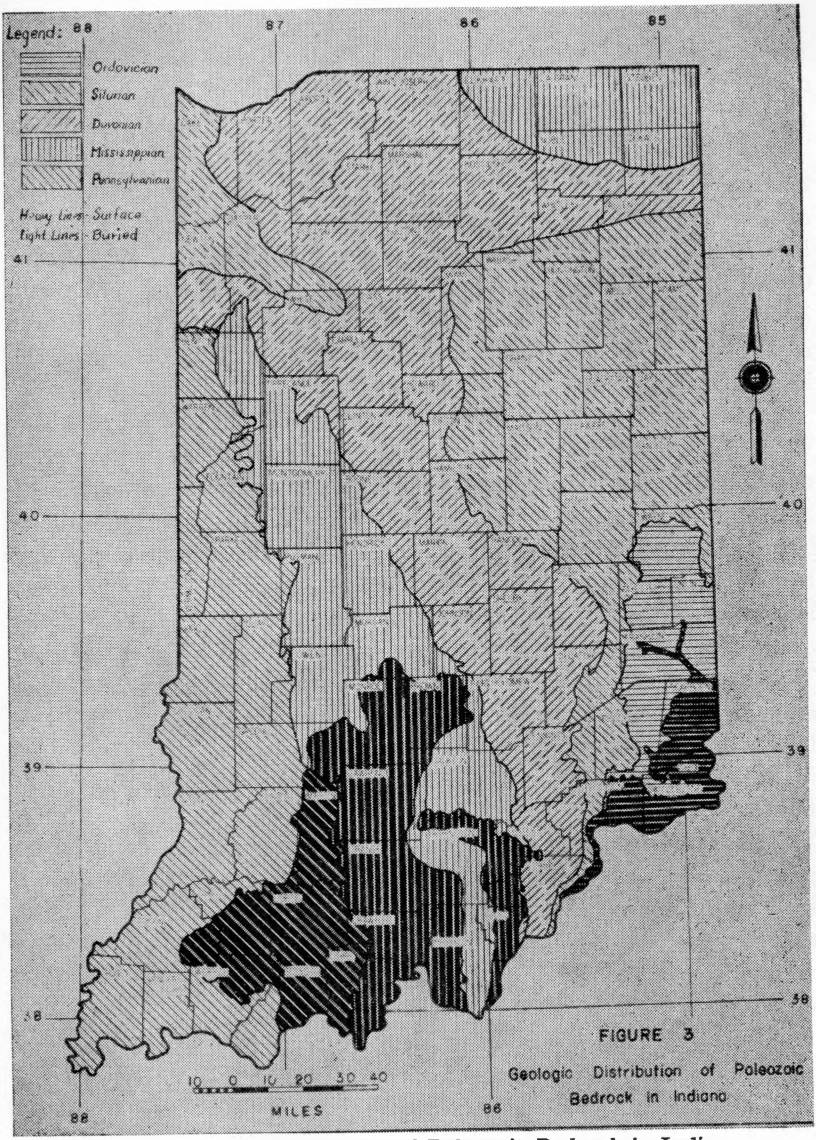


Fig. 3. Geologic Distribution of Paleozoic Bedrock in Indiana.

Ordovician beds to the west and north and form the bedrock material over a considerable part of the state. However, most of these rocks lie buried beneath unconsolidated material of a more recent age and generally they are not too important in engineering except where they are exposed very locally. The New Albany shale is a widely known example. Its tendency to readily disintegrate produces local cut problems.

Fig. 4. Airphoto of typical Ordovician L.S.-Sh. Area in Switzerland Co., Indiana.

It has been used for brick and tile manufacture, however. Elsewhere, limestone is a common representative. Although crushed limestone is often one of the better aggregate materials, the Silurian limestones have a record for deleterious character in Indiana. The rock is usually highly laminated and thus gives rise to inherent weakness in the individual aggregate pieces.

The Mississippian period is the term used to denote the fifth major subdivision of the Paleozoic. Again the continent was subjected to the advancements of an inland sea. Apparently the adjacent land masses did not stand as high as they had previously. Massive beds of limey ooze and prolific quantities of the calcareous remains of marine life make up thick sections of the Mississippian rocks; now limestone, often singularly free of clastic debris. Westward limestones are irregularly interbedded with sandstones and shales. In Indiana the massive limestone of this age has produced residual soil in Lawrence, Orange, Monroe, Harrison, and Washington counties.

A characteristic feature of many of these areas is the presence of sinkholes or swallowholes due to the collapsing of the roofs of limestone caverns which were formed by the solutioning action of ground water. Figure 6 is an airphoto of such a sinkhole studded plain in Lawrence County. Note the breaks in road alignment in order to

Fig. 5. Typical Ordovician L.S.-Sh. Topography in Dearborn County, Indiana.

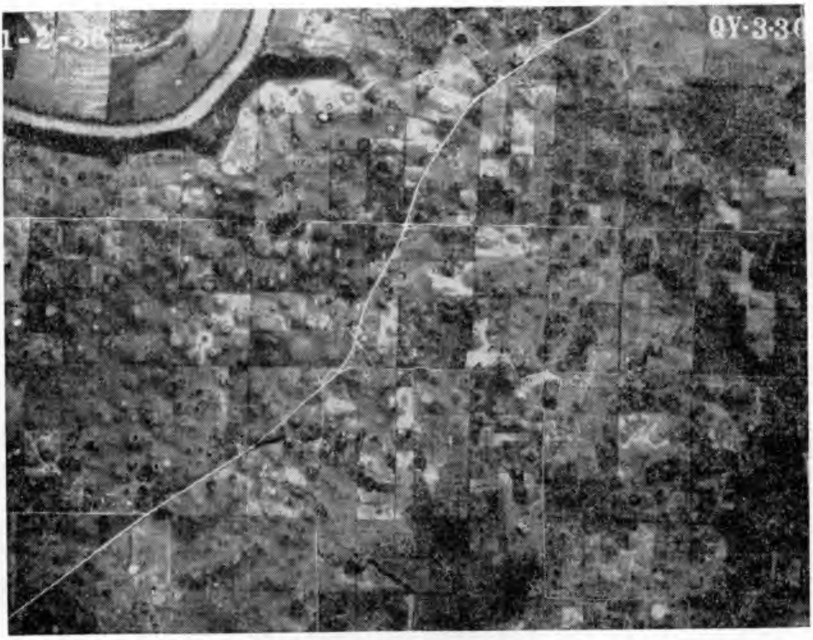


Fig. 6. Airphoto of typical Mississippian L.S., Lawrence County, Indiana.

Fig. 7. Typical karst topography in Mississippian Limestone, Orange County, Indiana.

Fig. 8. Highway excavation in Mississippian Bedrock (L.S.) near Bedford, Indiana.

Fig. 9. Airphoto of typical interbedded Mississippian L.S.-S.S.-Sh. area in Perry County, Indiana.

Fig. 10. Typical Mississippian L.S.-S.S.-Sh. Topography five miles west of the Junction of U.S. 150 and S.R. 37.

by-pass these depressions. A typical ground view is shown here in Figure 7. This sink became plugged due to construction and thus the pond was established. The soils on these rocks are commonly thin and excavations of rock are often required, as on S. R. 37 near Bedford, Indiana (Figure 8). Well water is generally high in calcium carbonate which produces hardness. In addition, water is often difficult to obtain and commonly requires acidification and iron reducing treatment. On the other hand, this area is the source of some of the finest building stone in the world. Many engineering problems arise from the movement of trucks bearing heavy loads of this dimension stone. Some horizons are quarried for use in the production of Portland cement, as fertilizer, and as aggregate. Gypsum beds in Martin County are now being mined.

In the counties to the west of those named, the interbedded phase is predominant. Airphotos such as Figure 9 taken over Perry County show the dissected character of the topography. Typical ground views look much like Figure 10 which is about 5 miles west of the junction of U. S. 150 and S. R. 37. Notice the change in slope due to the interbedded character of resistant and non-resistant rock types. Engineering problems include plastic soils, variable subgrade support and landslides. Alignment is difficult due to local relief which can be great.

The Pennsylvanian period which began about 280 million years ago found the seas again invading large sections of the interior of the continent. However, in the eastern part of the country swamp land quite similar to sections of the present Everglades of Florida was widespread. These swamps gave rise to the accumulations of a series of organic deposits buried and interbedded by layers of sand, silt, and clay due to the fluctuating water level. Over a period of millions of years this organic material was gradually converted to coal. The sands, silts and clays have been lithified to sandstones and shales, some massive, others thin bedded. In Indiana this material creates the topography in much of Pike, Warrick, Dubois, Martin and Spencer counties. The material is very sensitive, and erosion is a tremendous problem in these areas. The white scars seen on Figure 11, an airphoto of part of Pike County, illustrate the extensive character of erosion. If improperly handled surface conditions rapidly degenerate as shown in Figure 12, a farm in Dubois County.

Highway engineering problems arise in cut-sections and fills. Landslides can be anticipated and embankments must be carefully prepared to minimize failure. The rock material is not suitable for aggregate and its interbedded nature is not conducive to good structural support.

Fig. 11. Airphoto of Pennsylvanian S.S.-Sh. area in Pike County, Indiana.

The porous and permeable character of sandstone does not work in the best interests of dams and water reservoirs.

In Indiana much of the coal is mined by stripping methods while in Illinois coal beds of similar age must be reached by shaft operations. Oil is also recovered from certain of these formations as well as the underlying Paleozoic rocks.

During the Paleozoic era and particularly at its close, the Paleozoic rocks were thrown into a series of sharp folds and faults in eastern North America forming the basis of the present Appalachian Mountain system. The diastrophic forces which brought these mountains forth also caused warping of bedrock as far west as Indiana and into Illinois. One great upwarped fold or anticline called the Cincinnati Arch has given the Paleozoic rocks a regional dip to the west across the southern part of Indiana. Locally this dip is difficult to observe but its general effect has been to expose the Paleozoic rocks of Indiana in successive layers across the state.

There followed the Pennsylvanian period a great length of time of which there is no direct record in the rocks of Indiana. We thus assume that the area was positive and undergoing erosion. This was the age of the reptiles (the dinosaurs, etc.). Thus for about the next 200

Fig. 12. Severe erosion of Pennsylvanian S.S.-Sh. topography in Dubois County, Indiana.

million years the state was not subjected to further deposition of major consequence. It may be assumed however that erosion was active and that much of the rugged terrain found in the southern part of the state is in large degree, a result of this activity.

About a million years ago the first of a series of glacial invasions occurred which covered a substantial portion of the northern part of North America. This episode is called the Pleistocene. Four major advances of ice have been interpreted but evidence of the last two only are positively identified in Indiana. These are known as the Illinoian and Wisconsin epochs. It should be emphasized that the periods between the successive advances were on the order of 125,000 years and that climates in these intervening periods must have been similar to our present climate and in some cases even tropical.

The oldest of the two ice invasions recognized in Indiana is the Illinoian. Its maximum extent is shown in Figure 13 by the dotted line. The most recent advance, the Wisconsin, is indicated by the broken dash-dot line. Each left a blanket of ice-transported debris mantling the older bedrock.

As the glacial fronts fluctuated they left behind characteristic ridges of material called moraines which represent stagnant ice margins. The many moraines found in Indiana are indicated on Figure 13 by the solid color areas.

Associated with all glacial activity are the results of melt water. These include the outwash plains fronting the moraines, the low serpentiferous ridges called eskers and the small conical shaped hills called kames. Good sources of aggregate are associated with some of these feaures. The finer material, rock flour, derived from bedrock and ground to powder by the moving ice was carried much farther, deposited,

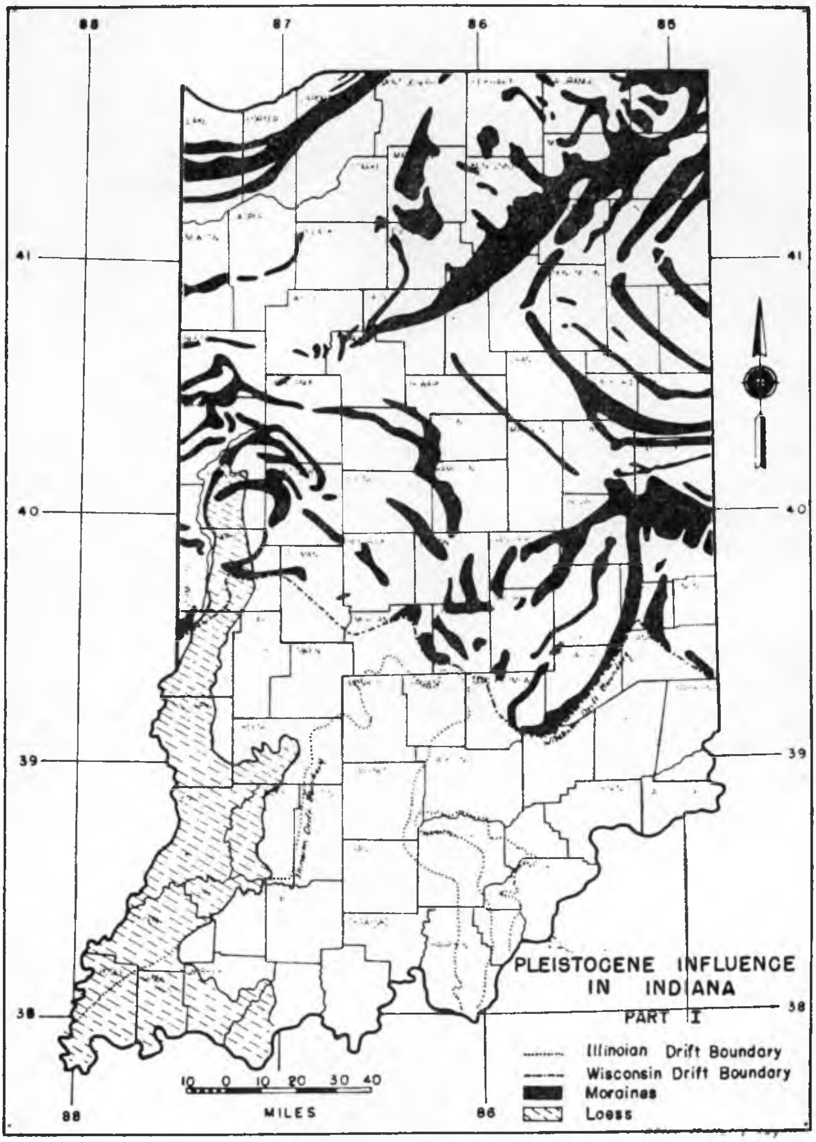


Fig. 13. Pleistocene Influence in Indiana. Part I.

Fig. 14. Terrace and alluvial deposits at Lafayette, Indiana.

and later reworked by the wind to form blankets of loess. Extensive parts of southwestern Indiana are blanketed with this material.

Often the granular material was deposited in the swollen river valleys of that day. Many of these deposits have since been partly removed leaving remnants in the form of terraces along present river valleys. Purdue University stands on one such terrace (Figure 14).

The Illinoian drift with its deeply developed soil profile is readily recognized on airphotos such as Figure 15. It is often a source of trouble in road cuts due to its poor internal drainage characteristics. A ready prey to the agents of erosion, it must be handled carefully by

Fig. 15. Airphoto of Illinoian Drift area in Decatur County, Indiana.

farmer and engineer. Figure 16 shows a series of check dams built to retard erosion in this old drift. Illinoian drift areas often produce droughty soils conditions, and granular materials are difficult to obtain in these areas.

By contrast the Wisconsin drift areas are readily recognized on airphotos by their mottled character. Figure 17 is a Wisconsin till plain in Tipton County, Indiana. They generally have a high ground water table which must be lowered by ditching practices. Note the spoil banks across some of the fields.

The mottled character displayed on the airphoto is due to a difference in soil color which also conforms to the slight rises and depressions. The higher areas are light while the lower areas are dark.

Because of soil variations in the young drift, problems of pavement pumping and poor internal drainage are common. However, granular materials are more readily available in these areas, than in those of Illinoian till. Occasionally belts of boulders are encountered nearly paving the surface. Foundations of any type built on Wisconsin drift are complicated by the rapid changes in material composition. Each site must be studied on its own merits. The magnitude of some

Fig. 16. Check dams to retard erosion in Illinoian Drift area of Decatur County, Indiana.

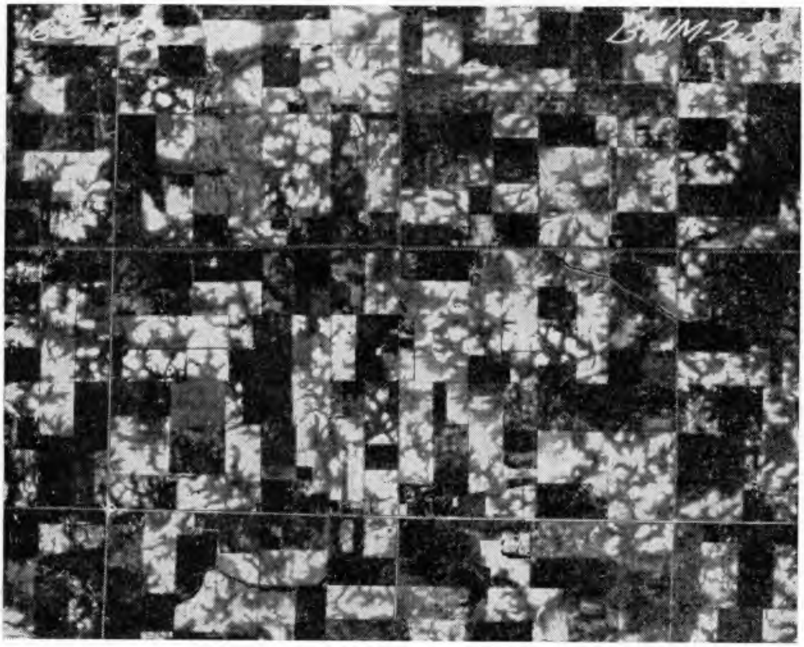


Fig. 17. Airphoto of Wisconsin Drift Area in Tipton County, Indiana.

Fig. 18. Ditch practice required to drain Wisconsin Drift area in White County, Indiana.

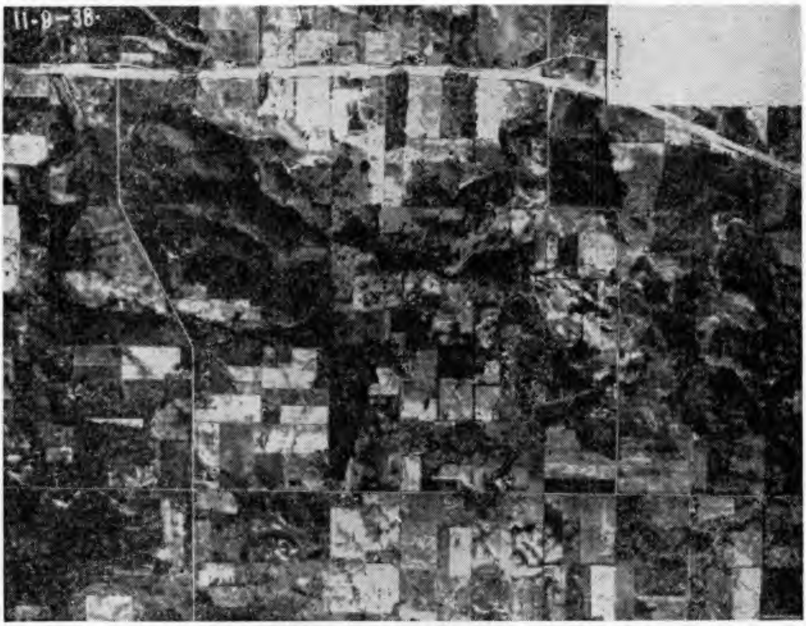


Fig. 19. Airphoto of moraine area in northern Indiana.

Fig. 20. Gravel pit in a kame in northern Indiana.

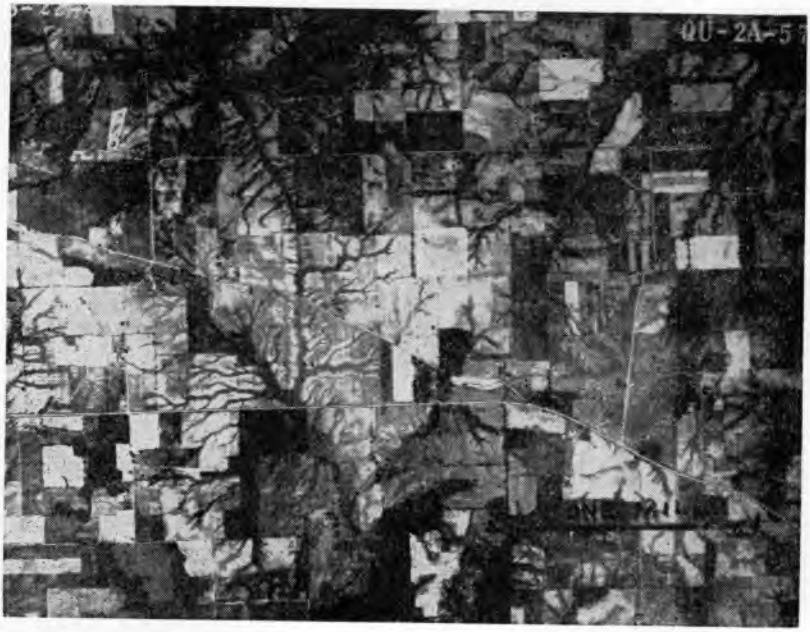


Fig. 21. Airphoto of loess covered area in Posey County, Indiana.

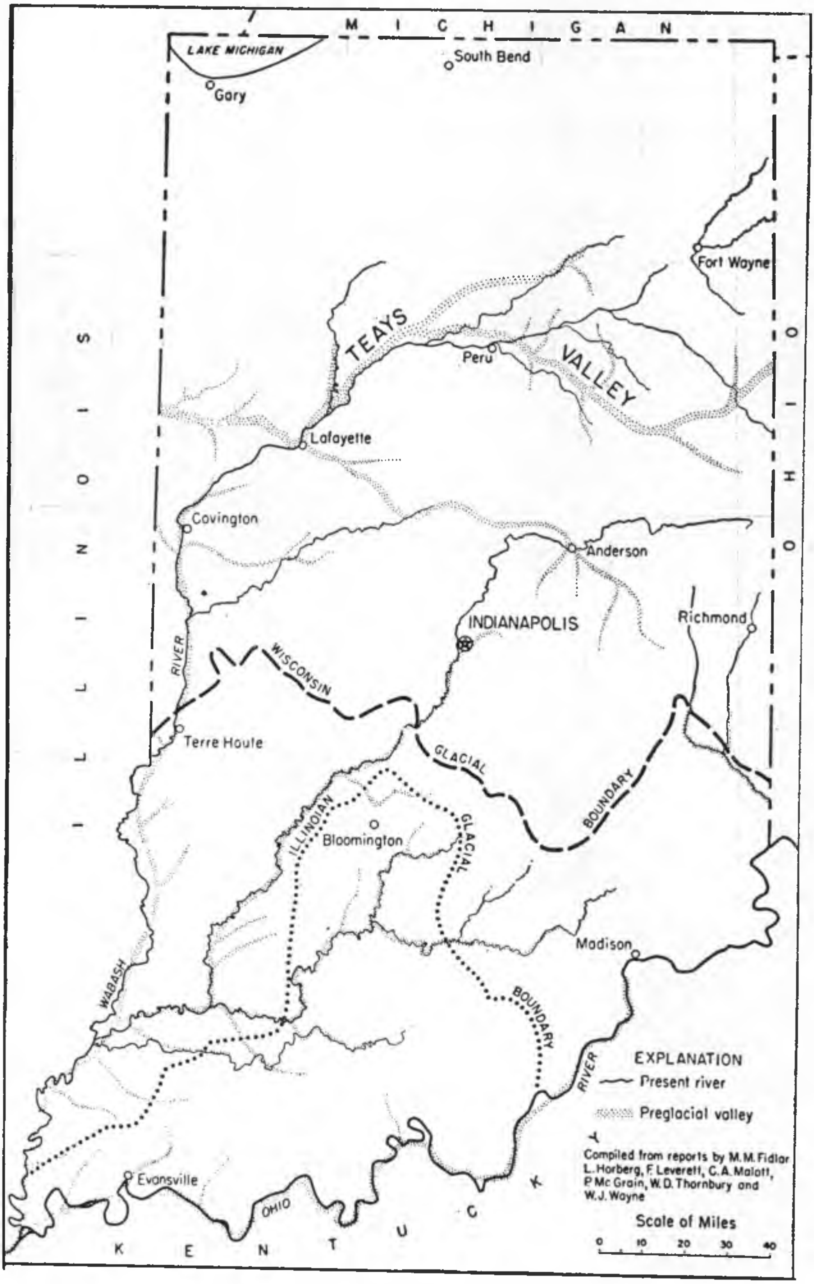
Fig. 22. Road cut in loess is similar to those in southern Indiana.

ditches required to adequately drain such areas is shown in Figure 18. Natural conditions offer few obstructions to long sights in surveying and good road alignment is easily maintained.

The moraines offer a contrast in topography to the till plains. A typical moraine area in northern Indiana is shown in Figure 19. The irregularity of the field pattern and road network attests to their hilly nature. Granular materials are generally no problem in the moraine areas. Figure 20 is an example of a gravel pit in a moraine associated kame in northern Indiana. Material from such pits is often of very high quality although limited in areal extent.

As previously noted, the southwestern part of the state has a cover of windblown silt (loess). In Posey County, for example, an aerial view such as Figure 21 is common. The hills are softly rounded while the drainage pattern is almost comb shaped. This soil is rich agriculturally. The soil drains well when undisturbed, but this feature is destroyed when it is reworked into fills or embankments. Loess also has a high shrinkage factor. Because of its natural tendency to stand in vertical banks, road cuts are usually left vertical rather than back sloping them (Figure 22).

The glaciers disrupted the previously existing drainage systems, burying many of them completely. Some of these buried valleys are as much as 400 feet deep and contain gravel floors which are excellent



Compiled from reports by M. M. Fidlar, L. Horberg, F. Leverett, C. A. Malott, P. Mc Grain, W. D. Thornbury and W. J. Wayne

Fig. 23. Preglacial drainage of Indiana.

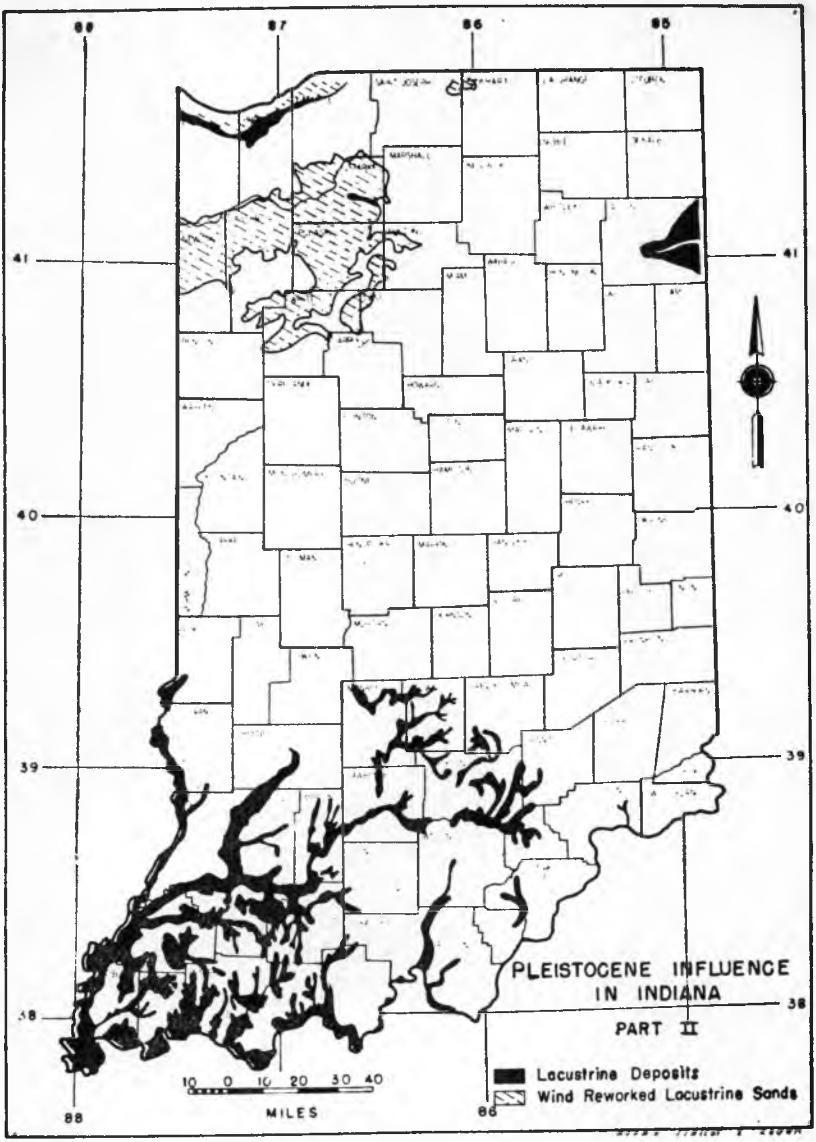


Fig. 24. Pleistocene Influence in Indiana. Part II.

sources of water supply. These valleys are a result of the long period of erosion which followed the Pennsylvanian period previously described. Figure 23 shows the location of the major buried valleys in Indiana.

Drainage ways which were not buried were often dammed, producing lakes and characteristic lacustrine deposits of silt and clay. There are extensive lake deposits throughout the southwestern part of the

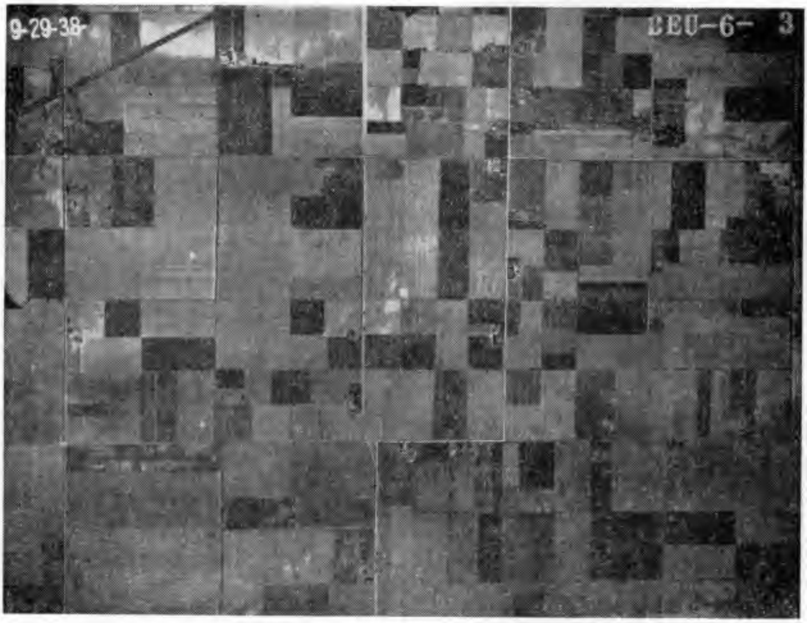


Fig. 25. Airphoto of lakebed area in Allen County, Indiana.

Fig. 26. Groundview of dune sand in Newton County, Indiana.

state as seen in Figure 24. The sandy Kankakee basin in Newton, Jasper, Stark and Pulaski counties is believed associated with the loosening of one such natural dam which was located in what is now Illinois. The Great Lakes also were formed and for a time stood higher than at present. This produced lacustrine deposits in northwestern Indiana

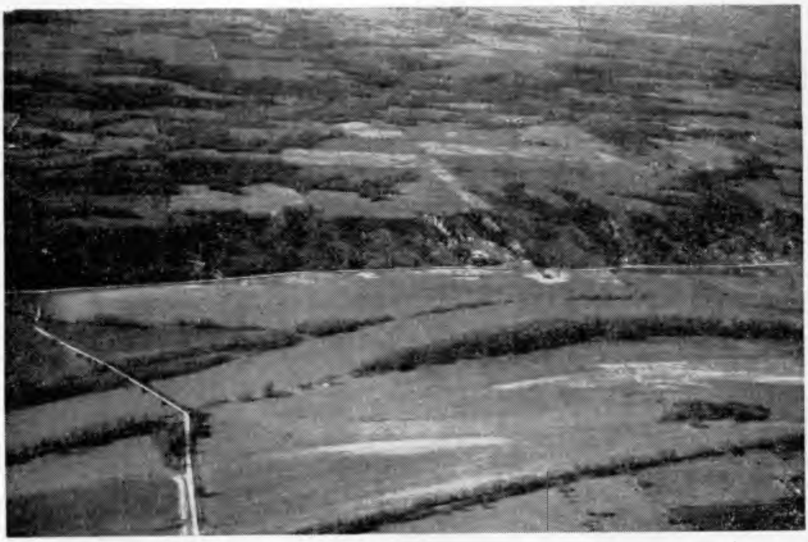


Fig. 27. Flooded Wabash Valley at Granville Bridge below Lafayette, Indiana.

and to the east and northeast of Fort Wayne. Figure 25 illustrates a typical lacustrine plain in Allen County. Note the flat featureless character of the land. Location problems are at a minimum but lacustrine clays produce many foundation problems.

The problem of the Kankakee Basin is a peculiar one and not completely understood as yet. Essentially it represents an outwash area marginal to the moraine systems. Its drainage was probably blocked for sometime, forming a shallow inland lake. With the release of the natural dam, the course materials were left behind. These have been reworked into many inland sand dunes. A typical example is shown in Figure 26.

Since the disappearance of the glaciers, periodic floods have widened river bottoms and established flood plains particularly along the White, Wabash and Ohio Rivers. Although fertile in character, these flood plains produce problems in bridging and foundations. Figure 27 shows the Wabash River in flood stage at the Granville Bridge south of Lafayette.

Only the broad aspects of Indiana geology and only a few of the many engineering problems have been described here. But perhaps this discussion will serve to show that the form of the land and the associated problems stem from the accumulated results of earth's long and continual process of constant change. To understand and predict engineering problems with intelligence, a knowledge of earth history is essential.