GUIDE LEAFLET GЕОLOGICAL SCIENCE FIELD TRIP

ROBINSON AREA
Crawford & Jasper Counties
Annapolis, Birds, Hardinville, and Hutsonville 15-Minute Quadrangles

Host—Robinson High School
Sponsored by the
ILLINOIS STATE GEOLOGICAL SURVEY

October 20, 1973
Urbana 61801
TO THE PARTICIPANTS:

The Geological Science Field Trip program is designed to acquaint Illinois residents with the landscape, the rock and mineral resources, and the geological processes that have led to their origin. With this program, we hope to stimulate a general interest in the geology of Illinois and a greater appreciation of the state's vast mineral resources and their importance to the over-all economy.

We encourage you to ask the tour leaders any questions that may occur to you during the trip. Discussion often clarifies points that otherwise would remain confused to many of the participants. We also invite your written comments upon the conduct of the trips so that we might improve them as much as possible.

Additional copies of this guide leaflet, as well as itineraries for field trips that have been held in the past, may be obtained free of charge by writing to the Illinois State Geological Survey. The itinerary maps for each field trip can be purchased for 10 cents each.

Several of the stops along this itinerary are located on private property whose owners have graciously given us permission to visit their lands. Please obey the instructions of your trip leaders and conduct yourselves in a manner that will show respect for the property owners' cooperation. Please do not litter, or climb on fences, and leave all gates as found, so that we may be welcome to return on future field trips. These simple rules of courtesy also apply to public property as well. For the convenience of those persons who may use this itinerary at some future time, the names and addresses of every private property owner are listed for the respective stops on a page at the back of this guide leaflet. Whenever possible, always attempt to obtain permission when visiting private property.

We hope that you enjoy today's field trip and will attend others in the future.
INTRODUCTION

Deposits of earth materials from two different geologic ages can be seen at the surface in the Robinson field trip area. Deposits of loose earth materials (clay, silt, gravel, etc.) cover the whole area. This glacial "drift" was left by glaciers which repeatedly advanced into Illinois during the Pleistocene Epoch, the last 1,200,000 years. Several glaciers flowed across the field trip area, and layers of sandy, pebbly clay called "till" were deposited by them. Meltwater from glaciers filled river valleys with sand and gravel "outwash"--the valley filling being a "valley train." During the gliations, winds blowing "silt" (powder-sized rock particles) off the outwash blanketed the area with "loess" (say "luhs"), which is preserved on the uplands. The modern soils are developed on the loess. Silty, very flat-surfaced lake-bottom deposits accumulated in the streams that were dammed by the valley train filling the Wabash Valley.

Layers (or "beds") of sandstone, shale, and coal underlie the field trip area and stick up through the drift here and there. These sedimentary rocks accumulated in a shallow sea and in bordering deltas and swampy lowlands during the later part of the Pennsylvanian Period, which began about 310 million years ago and lasted about 40 million years. Plate 1 illustrates the attitudes and thicknesses of these beds in the Robinson area. (A more general discussion of Pleistocene and Pennsylvanian geology in Illinois can be found in two articles in the appendix of this leaflet.)

The Route Map shows that the surface of the Robinson area is composed of three major landforms aligned side by side. Along the west side are the valleys of the southeast- and south-flowing Embarras River and its North Fork; on the east side is the valley of the south-flowing Wabash River; between them is a wide, low upland. The total relief, or difference in surface elevations, is low, only about 200 feet between the highest and lowest places. The river valleys and the upland reflect the features of the buried bedrock surface: the valleys and upland were cut into bedrock during the early glaciation; during the later glaciations these bedrock valleys were half-filled and the upland thinly covered with drift. The present-day streams have only begun to wash away the drift and uncover the buried bedrock surface.

The mineral and rock commodities now produced in the Robinson area are sand, gravel, and water from the glacial deposits and oil from Mississippian and Pennsylvanian sandstones and limestones. Sandstone was quarried near Robinson for building stone during the settlement period. Small mines have produced coal for local use from the time of settlement until recently.

GEOLOGY

Pleistocene Deposits - During the first glaciations, meltwater from glaciers entering this side of the state drained southward across the Robinson area and cut the deep bedrock valleys which now contain the modern rivers. The first glaciers known to have reached this area belong to the Kansan (second) glaciation. Although no definitely Kansan deposits have been identified here, such are found not far away to the north and west. In addition, some water wells drilled in the Big Creek and Embarras River Valleys penetrated an older till beneath Illinoian till.
The first and second advances of the Illinoian (third) glaciation covered the area. Illinoian till blankets the upland and is often exposed in ditches and stream cuts. The last Illinoian glacier to advance across the area stagnated—that is, it stopped moving and melted away without moving again. Evidences of stagnation are (1) the extreme flatness of the till plain the ice laid down and (2) the presence of such features as the Mound Church kame at Stop 4.

A warmer interglacial stage followed each glaciation, with the consequence that weather and living things transformed the uppermost layer of a newly exposed drift sheet into soil. In the Robinson area (and many other places in Illinois), a soil can be recognized at the top of the Illinoian drift that formed during the Sangamonian interglacial stage, which followed the Illinoian glaciation. Here the Sangamon Soil is often a vivid rust-red zone at the top of the Illinoian till and is usually covered by Wisconsinan loess or recent slope-wash.

The Wisconsinan glaciation was the fourth and last. The front of the southernmost ice advance stopped about 30 miles north of here, but Wisconsinan meltwater and outwash moved through the Embarras and Wabash Valleys most of the time. At the onset of glaciation, meltwater washed out of the valleys most of the drift left by the earlier glaciations. However, as the glaciers moved south toward this area, their meltwaters were able to move outwash farther southward and outwash began to fill the valleys. When the Wabash Valley was filled high enough that the Embarras River, Lamotte Creek, and other streams could no longer flow into it, these and the other tributaries down the length of the Wabash backed up behind the outwash "dams" blocking their mouths and became lakes (see plate 2). The lakes persisted for some thousands of years during the Woodfordian Substage of the Wisconsinan, a time interval lasting from about 22,000 years ago to about 12,500 years ago. Fine sediments accumulated in the bottoms of the lakes, creating the wide, flat lake plains present in many of the tributary valleys now.

While outwash was filling the Wabash Valley, loess was deposited on uplands beside and downwind from the valley. In the seasons when the outwash plains were dry, winds blew dust off the exposed outwash. Deposits of loess thin away from their source valley; thus, while deposits on the upland beside the Wabash Valley may be as much as 12 feet thick in this area, to the west away from the valley the loess deposits thin rapidly to as little as 2 feet.

As the Wisconsinan glaciation waned and the ice front melted back toward the Great Lakes, less and less outwash reached this part of the Wabash Valley and the meltwaters probably began to remove sediment from the valley instead of depositing it. When the glacial ancestor of Lake Erie overtopped the moraine damming it at Fort Wayne, Indiana, a flood of water—the Maumee Flood—was released. The Maumee Flood cut the valley floor near Palestine down to a level of about 450 feet, 20 feet below the highest level of outwash filling, which was the Shelbyville outwash surface at 470 feet. After the Maumee Flood, the modern Wabash River lowered the valley floor to a lower floodplain level, which is about 430 feet at Palestine. Plate 2 provides a map view of the different valley surfaces. (The history of the Wabash Valley is more thoroughly discussed in the last part of the guide leaflet.)

Paleozoic Deposits - The drift is underlain by layers of sedimentary rock—chiefly beds of limestone, dolomite, shale, and sandstone—having a total thickness of 8000 to 9000 feet. The sediments which made these beds accumulated
Plate 1 - A block diagram showing the generalized structure and thicknesses of the Paleozoic rock layers in the region around the field trip area. The outlines of the old southeastern Illinois oil fields are shown by hatching on the surface of the block. The approximate locations of the oil-producing rock layers, or pay zones, are shown by named, black lenses along the side of the block. From ISGS Circular 110 (1944, out of print).
EXPLANATION

- Present floodplain
- Maumee erosional terrace relict
- Shelbyville alluvial terrace relict
- Lake site
- High level valley braid
- Valley braid core
- Upland and island hills

SCALE

Plate 2 - Landforms associated with the Wabash Valley Drainage System through the Robinson area. This figure reproduces part of Plate 1 in Physiography of the Lower Wabash Valley by M.M. Fidlar (Indiana Department of Natural Resources, Geological Survey, Bulletin 2, 1948).
during the Paleozoic Era, the interval of geologic time that began about 550 million years ago and ended about 270 million years ago. The Paleozoic layers rest on Precambrian granites that are 1.2 to 1.5 billion years old.

Figure 1 is a geologic cross section along a line across a four-state region between southeastern Missouri and Cincinnati, Ohio. It shows the thickness and the general (but exaggerated) attitudes of the Paleozoic layers. It also shows the structures that contain them: the Ozark Dome, the Illinois Basin, and the Cincinnati Arch. (The line of section crosses the Illinois-Indiana line about 40 miles south of Robinson.) Figure 2 is a map of the Illinois region showing the location of the same structures.

For a long time before the Paleozoic, the Precambrian granites were exposed above sea level, but at the beginning of the Paleozoic the Earth's crust under Illinois gradually sagged until shallow seas covered the whole region shown by the cross section. Throughout the Paleozoic—intermittently, slowly, and at different rates—the Illinois Basin sagged and thick layers of sediments accumulated in it. Generally speaking, mud and sand washed from the land into the nearshore parts of seas to make layers of shale and sandstone. Lime sediments largely derived from the shells and skeletons of sea animals accumulated offshore to make limestones. The Ozark Dome and the Cincinnati Arch also were usually covered by seas. However, these areas sank more slowly than the basin and at times were even gently warped up; therefore, the Paleozoic strata generally thin toward and over these structures.

In the Robinson area the Paleozoic beds dip gently southwestward toward the center of the basin. From Lawrence County northward, this dip is interrupted by the La Salle Anticinal Belt (figure 2 and the left end of the block in Plate 1). The Belt is a fold on the east side of the Illinois Basin (along the line shown in figure 2) and has a steeply dipping west flank. Along its crest are numerous domes.

In this part of the state, interest has focused on the upper part of the Paleozoic rocks because they were found to contain oil at shallow depths accessible to the pioneer drillers. The Pennsylvanian System may be from about 1000 to 1500 feet thick in Crawford County (refer to plate 1). The System is made up largely of alternating thick beds of sandstone and shale which sometimes have thin limestone beds and often coal beds between them. A few thicker coal beds are little more than 3 feet thick; commonly the coals are 2 feet thick or less. Several
thick sandstone pay zones in the lower half of the system—the Robinson sand, the Bellaire sand, etc.—are the important oil-producing layers in Clark, Crawford, and Lawrence Counties.

The Chesterian Series of the Mississippian System is generally about 200 feet thick hereabouts but thickens southwestward to as much as 600 feet in Crawford County. The Chesterian Series is composed of alternating beds of sandstone, limestone, and shale, and several of its porous and permeable units produce oil.

PHYSIOGRAPHY

The map "Physiographic Divisions of Illinois" in the appendix shows the state divided into districts, each district containing landforms having the same shape and origin. The boundary between the Springfield Plain and the Mt. Vernon Hill Country passes through Crawford County, and as might be expected, the land surface of this area is transitional between these two districts. Both divisions were glaciated, but in the Springfield Plain the drift is thick enough to smooth off all but the largest of the underlying bedrock features and form a flat till plain. North of Robinson and Route 33, only the broad, flat uplands between the creeks have the character of the Illinoian till plain surface so striking north and west of here. The Mt. Vernon Hill Country is a bedrock surface of low hills and wide valleys smoothed only a little by a thin drift cover, and the land surface south of Robinson has this character.

The field trip area has little relief. The difference between the highest and lowest elevation along Route 33 from the west edge of the Route Map to the present Wabash floodplain east of Palestine is only about 110 feet. In contrast, the relief on the bedrock surface in the same traverse is about 200 feet—so much has the valley filling reduced the relief. It is difficult to see the ridge that passes through Robinson and divides the area north-south, yet elevations on this ridge are the highest in the area, attaining 600 feet and more. The ridge is the area's major drainage divide and is a bedrock upland covered by less than 50 feet of drift. A short bedrock ridge and divide extends south from Palestine. Many of the rock outcrops in the area occur on the flanks of these ridges.

The Wabash River is a meandering stream. Its course loops back and forth on a floodplain that falls less than 10 feet in the length shown on the Route Map.

MINERAL PRODUCTION *

The statewide value of minerals produced in 1970 was $716,300,000. In 1970 Crawford County ranked 25th among the counties in mineral production. The total value of minerals produced there in 1970 was reported to be $11,565,053.

* Information reported in ISGS Illinois Mineral Note 48 and Circular 469.
Of this amount, over half—$6,532,500—was the value reported for the 2,010,000 barrels of crude oil produced. The remaining amount represents the combined value of the other mineral productions reported that year: clay products, gravel, sand, and gas. (Clay is not from local deposits.)

Crawford County ranked 7th among oil-producing counties in 1970, producing 4.59% of the total for Illinois. Total oil production for the county from the first year of production through 1970 is 220,296,000 barrels.

The production figures available show that 45,400 tons of coal were produced in the county in 16 years out of the period between 1882 and 1961. No coal production is now listed. No value or quantities are reported for ground water, but the supplies in the Wabash Valley train deposits are adequate for heavy industrial and domestic use.

Of the petroleum produced in Illinois during 1970, secondary recovery methods accounted for more than 71 percent. Oil produced from waterflooding amounted to more than 30.8 million barrels or a little less than 71 percent of the total produced. Pressure maintenance operations yielded 297,700 barrels, or a little more than 1/2 percent of the total production. There were 855 active and 448 abandoned waterfloods in Illinois through 1970, with waterflood acreage accounting for slightly less than 50 percent of the state's total pay acreage.

Crawford County had 68 active waterfloods and 47 abandoned ones through 1970, with 1,818 active water input wells and 1,998 producers. Jasper County had 14 active and 12 abandoned waterfloods through 1970, with 133 water input and 250 producing wells.

Approximately 64,204 oil wells have been drilled in Illinois with 26,169 listed as producing wells through 1970. Several thousand wells have been drilled in Crawford and Jasper Counties, and a few thousand were still producing oil at the end of 1970, with by far the largest number in Crawford.

**ITINERARY**

Assemble on west side of high school on west limb of U-shaped drive. Prepare to turn right (northwest).

0.0 0.0 STOP. TURN RIGHT (northwest) on West Highland Avenue.

0.45 0.45 T-road intersection with Allen Street. TURN RIGHT (north) on Allen.

0.15 0.6 Curve left and proceed northwest out of town on road along old Indian Boundary.

0.5 1.1 Note the comparatively flat interstream areas of the Illinoian till plain on either side of the road.

0.95 2.05 Curve right.

0.05 2.1 T-road from left. TURN LEFT (west).

0.15 2.25 Crossroad. Continue straight.

0.2 2.45 Oil tank battery to left. Continue ahead.
0.2 2.65 CAUTION. Narrow one lane bridge. Seventy-five feet to the right of
the bridge on the west side of the stream, is an Illinoian till ex­
posure (SW\(^\circ\), SW\(^\circ\), SE\(^\circ\), Sec. 19, T. 7 N., R. 12 W.).

About 90% of Illinois is covered by glacial drift, and drift is probably
the earth material most heavily and variously used in our state. It supports our
constructions and supplies much of our water and sand and gravel, it is the growing
medium for crops, it is the container for most of our solid-waste materials. As
time passes more and more people seek to use it, and the question of its capacity
to sustain our use (and abuse) requires specific answers. A good deal of work is
being done at the Illinois State Geological Survey to define the boundaries, deter­
mine the qualities, and discover the resources of the drift deposits.

The till exposed here is 3\(\frac{1}{2}\) miles northeast of the till exposure near
Stoy at Stop 6. To illustrate how drift layers may be identified and traced from
one place to another and to show what some of the material is, a sample of this till
was taken so that grain-size and X-ray diffraction analyses could be made and com­
pared to the till at Stoy. About a cupful of till was scraped off the gray zone at
the bottom of this exposure--anticipating that the gray till would be "fresh," that
little if any of the minerals in it would be lost or altered because of exposure to
weather. This table summarizes the analysis. Compare it to the analysis of the
grayish brown zone in the Stoy section. Would you say that the tills are similar
or not?

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I - % of gravel in total sample
II - % of sand, silt, and clay in less-than-2-mm fraction of sample (totals 100%)

A grain-size analysis (columns I and II on the table) is performed by
sieve analysis and measuring the relative quantities of gravel, sand, silt,
and clay in it. The silt and clay separation is determined by hydrometer analysis.
An X-ray diffraction analysis (columns III and IV), which determines the relative
amounts of clay and carbonate minerals in a sample, is made by rotating a sample in
an X-ray beam and recording the various intensities of radiation reflected by the
sample during its rotation. The results of these analyses can be used to identify
the layers of drift deposited by different glaciers if the deposits of each glacier
prove to have a regionally distinctive, recognizable grain-size and mineral composi­
tion. Such is often the case, because each flowing glacier ground the rock and
earth it picked up into a very homogeneous mixture and because the glaciers that
flowed into the state came from several different directions and moved over different
materials. Therefore, in small, several-county-sized regions one can expect
that the grain size and mineral composition of a particular till will be consistent.

0.55 3.2 To the right is an oil well in the field that is pumping from a basal
Pennsylvanian sandstone lens.
This stop is to acquaint you with some of the early equipment used in recovering oil that is still operable in the Robinson area. During the first decade of this century, there were few if any legal limitations on spacing and drilling procedures for oil wells and, because of the absence of electricity for powering individual pump jacks, many holes were drilled close together so that a number of oil wells could be operated from a single power source (pl. 3, fig. A). Although as many as 40 wells could be operated from one power house through a connecting system of steel rods or wire cables, the usual number was 25 to 30 (pl. 3, figs. A and C). The power house contained a natural gas-powered engine connected by a large, long belt to a revolving pull-wheel (pl. 3, fig. B) which provided horizontal movement to the steel pull-rods radiating to the various well sites. The gas for the engine came from the wells on the lease or was purchased from a neighboring lease or a nearby pipe line. The rods are pulled toward the power house by the pull-wheel, but the return movement of the rods is at least partially due to gravitational pull on the weight of the sucker rod that extends down into the well. The pumping jacks were constructed either of wood or steel or a combination of the two (pl. 3, figs. A, C, E). In addition to the steel jacks, a few combination wood/steel jacks can still be found in the area.

Although about 15 wells were serviced, starting in late 1907, by this power house, now only five wells are pumped here. Two of these wells have sufficient oil to permit straight or continuous pumping while the other three have only enough oil to permit pumping for part of each day. Fluid produced from the wells is piped to a series of wooden storage tanks protected by a board shed (pl. 3, fig. C), where the oil and water are separated, about 200 feet northwest of the power house. Periodically, the stored oil is metered into Marathon Oil Company's nearby pipeline. The installation is checked several times each day in order to service the engine, check the pull-rods and change them from one well to another, and to check the level of oil in the storage tanks.

Together, the five producing wells here have an average yield of about seven barrels of oil per day from the Robinson sand. (Note: an "oil field" barrel = 42 standard gallons.) This pay zone comprises three nonmarine sandstones that occur in the early Pennsylvanian aged rock sequence, the lowermost sandstone occurring close to the base of the Pennsylvanian. These sandstones, which were deposited by streams between 310 million and 300 million years ago, are lenticular and discontinuous throughout the region. Not all holes drilled on this lease, approximately 20, encountered all three units. The upper sandstone appears to be absent in several of these holes, while the middle zone, at a depth averaging 970-990 feet, is the main producer on this lease.

0.0 4.6 Leave Stop 1. TURN AROUND and retrace itinerary north.

1.3 5.9 T-road from left. TURN LEFT (west).

0.5 6.4 Between the streams note the even upland developed on the Illinoian till plain.

0.5 6.9 CAUTION. End of pavement. Continue west.
CAUTION. Narrow bridge.

CAUTION. Narrow bridge.

CAUTION. Narrow bridge.

T-road from right. TURN RIGHT (north) toward Prairie United Methodist Church.

Stop 2. View to west of tanks and pump jacks of Marathon Oil Company's Maraflood Project (SE cor. SW¼ NW¼, Sec. 22, T. 7 N., R. 13 W., Anna­polis 15' Quadrangle, Crawford County).

For about the past 10 years, Marathon Oil Company has been field testing its patented, commercially available, Maraflood oil recovery process in Illinois at eight locations, six of which are in the Pennsylvanian aged Robinson sand of Crawford County. In this process, micellar solutions are injected into the reservoir in order to release oil from void spaces and grain surfaces and move it toward producing wells. A micellar solution can be generally defined as a special detergent that is dissolved in water and emulsified with oil and that has the unique capability of dissolving either water or oil, or both, with which it comes into contact.

The initial test of this process was made on a 2.5-acre area (330' x 330') that had been drilled in the early 1900's and in which no secondary recovery methods, such as waterflooding, had been attempted. A five-spot drilling pattern was used, with four injection wells, one at each corner, and a center producing well. In addition, four off-pattern producing wells surround the area. Oil saturation in the reservoir was approximately 50 percent when the test began. Within the area affected by the micellar solutions, recovery amounted to 440 barrels of oil per acre per foot of thickness (440 bbl/acre-ft) whereas the usual waterflood recovery from the Robinson sand is about 200 bbl/acre-ft. It was concluded, on the basis of the data received, that the test was successful.

When the first test was completed, it was decided to try this process on areas that had been subjected to secondary waterflood recovery methods. The Henry reservoir, which is tapped by the wells to the north and northwest of this location, was selected as one of the sites for testing. This reservoir had an estimated oil saturation of about 40 percent after waterflooding. A portion of the reservoir was first tested from late 1965 until mid 1967.

Another project, visible to the west and northwest from this locality, is the 119-R test, which began in September 1968 on 40 acres. It has three north­west-trending rows of oil producers separated by two rows of injector wells (those having wooden boxes over them). The rows are 467 feet apart and each has nine wells, 116 feet apart. Here, for the first time, crude oil from the lease was used as the hydrocarbon in the micellar solutions. Since the test began, more than 100,000 barrels of oil have been produced from the estimated 600,000 barrels of oil in place within the 40-acre test pattern. The Robinson sand averages about 25 feet thick in the test area and is about 1000 feet deep.

Leave Stop 2 and continue ahead (north).

To the left is another string of producing oil wells and to the west of them is a series of wooden boxes covering water injection wells that are part of the 119-R test site.
Plate 3 - Pioneer Equipment in the Crawford County Oil Field.

A. Power house with pull-rods running on guide posts to the pump jacks. Firebaugh Lease, NE\(\frac{1}{4}\) SE\(\frac{1}{4}\) NE\(\frac{1}{4}\), Sec. 36, T. 7 N., R. 13 W.

B. Inside a power house. Belt from natural gas-powered engine turns wooden pull-wheel; oscillating pull-rods connected to eccentric hub. SE\(\frac{1}{4}\) SW\(\frac{1}{4}\) SW\(\frac{1}{4}\), Sec. 30, T. 7 N., R. 12 W.

C. Board shed housing wooden storage tanks receiving oil from pumped wells. Firebaugh Lease.

D. A horse-drawn wooden tank for transporting oil. Near power house in Sec. 30.

E. The J. Shire No. 1 discovery well. Home-made wooden pump jack (pull-rod to left) and pole for servicing well. NW\(\frac{1}{4}\) NE\(\frac{1}{4}\) NE\(\frac{1}{4}\), Sec. 15, T. 6 N., R. 13 W.
CAUTION. Crossroads. TURN LEFT (west) on blacktop. Immediately after making the turn, note to the right the old rod pump jack in the brush in the field.

To the right is another rod-driven well. The building 1/4 mile to the north with the rusty tin roof is the power house for driving the rods of these wells.

Crossroad. Continue ahead straight.

Note the flat Illinoian till plain across this interstream area.

Note the old wood covered oil tank to the right.

T-road from left. Continue ahead (straight).

STOP. T-road from right. TURN RIGHT (north) toward Dogwood. Marathon Oil Company supply yard is to the left (south) before the turn.

Marathon Oil Company - J. H. Wilkin Water Treating Plant is to the left.

Crossroad. TURN LEFT (west) on the gravel road.

Stop 3. View of Marathon Oil Company’s LACT Unit and aeration pond and discussion of the Wilkin Maraflood test (NE 1/4 NE 1/4 NE 1/4, Sec. 18, T. 7 N., R. 13 W., Annapolis 15’ Quadrangle, Crawford County).

On the basis of the successful results of its initial Maraflood project, Marathon Oil Company decided to test its new process on an area that had already been subjected to secondary waterflooding recovery procedures. Testing of the Wilkin waterflood, which operated in the Robinson sand, began in early 1964. The sand here consists of two zones, together ranging from 16 to 42 feet thick, that are at least partially interconnected but that have different reservoir characteristics. Neither zone was uniformly thick across the test site, in which the same spacing and pattern of wells as used on the first test were used, that is, four injection wells delimiting an area of 2.5 acres with a central producing well.

Cores of the reservoir rock were recovered by drilling, and these were subjected to a number of exhaustive tests in order to determine such factors as available porosity, amount of permeability, percent of oil saturation, viscosity of oil in place, chloride content of reservoir water, etc. The results of these investigations, then, helped the petroleum engineer and chemist determine the types and proportions of the various constituents of the micellar solutions that might be needed for this particular project.

Although oil was successfully displaced in this waterflooded reservoir by micellar solutions, the amount of oil recovered was disappointingly small, apparently because the injected water channeled the sand and bypassed much of the displaced oil. However, test results from this site later contributed to the successful displacement and recovery of significant quantities of oil in different waterflood projects.

At present, recovered formation water is separated from the oil and then is aerated in the lagoon east of the tank battery. From the lagoon, the water is
transferred to the water-treating plant to the southeast, where it is filtered, purified, and chemically treated before being returned to the reservoir strata.

The tanks at this site collect oil from producing wells in this vicinity. The oil collection system is controlled by a LACT Unit (Lease Automatic Custody Transfer).

Whereas the normal procedure is to manually gauge the oil that a tank holds before it is transferred from the producing company to the pipeline purchasing company, the LACT Unit permits the transfer to be made automatically. When the storage tank is full, an electric signal is given to the LACT Unit. Valves then open from the tank to the pipeline gathering system, and the pump, which is needed to move oil into the pipeline, starts. A meter measures the oil as it passes through the system, and monitoring equipment determines the amount of impurities contained in the oil. After the oil in the tank reaches a pre-determined low level, the system shuts down and a meter ticket is punched out telling everything that took place during the period of oil transfer. Built-in safety controls in the system prevent spills or accidents. (See Figure 3 for diagram of typical production unit.)

0.0 13.1 Leave Stop 3. Continue ahead (east).
0.4 13.5 CAUTION. Narrow bridge.
0.55 14.05 STOP. Crossroad. TURN LEFT (south).
0.5 14.55 T-road from left. Continue ahead (south) on the blacktop.
0.2 14.75 T-road from right. TURN RIGHT (west) on gravel.
0.5 15.25 T-road. TURN RIGHT (north).
0.1 15.35 T-road from left. TURN LEFT (west) and later curve north.
0.65 16.0 T-road from left. TURN LEFT (west).
0.25 16.25 T-road. TURN RIGHT (north).
0.25 16.5 Cross Willow Creek. Continue ahead (west).
1.4 17.9 Cross North Fork Embarras River. Continue ahead (west).
0.45 18.35 Small knoll to the right may be a kame (note discussion and diagrams in the attached Pleistocene Appendix).
0.5 18.85 CAUTION. Narrow bridge with unmarked sides.
0.1 18.95 To the left is another small knoll that also may be a kame.
0.25 19.2 T-road intersection. TURN LEFT (south).
0.45 19.65 About 11 o'clock toward the southeast there is a good view of the kame at Stop 4. Note how abruptly it rises from the adjacent Illinoisan till plain.
1.3 20.95 T-road from left. TURN LEFT (east) on gravel. Excellent view of the mound to the east.
1. Oil and salt water flow into the well chamber through fractures, cavities, and spaces between the grains of the rock bed that is the PRODUCING LAYER (the "oil sand" or "pay zone").

2. Motor- or engine-driven PUMP lifts the fluid out of the producing layer and pushes it through the system.

3. Gravity and heat in an oil-fired HEATER TREATER separate the oil from the salt water. Oil flows out of the top and water out the bottom.

4. Cleaned oil is held in the STOCK TANK until it is purchased.

5. Salt water flows into a pit to evaporate, into a disposal well, or through a treatment plant into a waterflood well.

Fig. 3 - Schematic diagram of a common type of oil production unit in Illinois.
Stop 4. Park along south side of road. Discussion of glacial landforms and view across the Illinoian till plain (NW¼ NW¼ NE¼, Sec. 28, T. 7 N., R. 14 W., Annapolis 15' Quadrangle, Jasper County).

The Illinoian glacier moved across this region, generally from north to south, during the Liman, the oldest, and Monican ice advances, which occurred from about 300,000 up to perhaps 205,000 years ago. The third Illinoian glacial advance, the Jubileean, came to within about 40 miles to the north of this stop. Near the end of the Monican glaciation, the glacier stagnated as temperatures warmed. No new ice nor drift was brought into the area and the ice melted away. Meltwater flowing across the ice surface dumped its load into cracks and crevasses in the ice, and at the ice front it formed fan-shaped deltas that were in contact with the ice. When the ice melted, these deposits of sand and gravel collapsed to form roughly conical hills called "kames." The flat upland till plain formed in part when the glacier's load was dropped in place when the ice melted (note additional material relative to glaciers and their deposits in the Pleistocene Appendix).

There are several facts about this mound that indicate that it is a kame. Deep sand containing a small amount of clay and some pea gravel is found along the roadcuts across the mound and in the graves in the cemetery. In the farm water well drilled near the apex of the mound, casing had to be installed as the well was being drilled, because the unconsolidated materials continually collapsed into the hole. The casing extends below the base of the mound. No bedrock has been found either on the mound or adjacent to it. If this is a kame, one might reasonably expect that the side that was in contact with the ice would be somewhat steeper than the other sides. A visual examination of the mound and a look at the topographic-based Route Map confirm that the mound is steepest on the west-northwest side.

The 50 to 60 foot height of the mound affords an excellent view out across the southern limit of the Springfield Plain (see attached Physiographic Map), which was deposited by the early Illinoian glaciers. There the topography is relatively flat, with large areas that are not dissected by streams. Bedrock exposures are sparse in the area. A few miles to the south, however, the landscape changes noticeably because the bedrock surface is only thinly mantled with Illinoian drift in the Mt. Vernon Hill Country. There the topography is much more coarse and stream dissection is more advanced, with few large, flat undissected interstream areas.
0.1 26.9  **Stop 5.** LUNCH and visit to the Oil Field Museum, which is located to the west of the pavilion along the southwest side of Oblong Lake (N² NE¹ SW¹, Sec. 31, T. 7 N., R. 13 W., Annapolis 15' Quadrangle, Crawford County).

In addition to the old oil field equipment located along the shore of the lake, there are models, displays, and smaller pieces of oil field equipment inside the building on the west side of the park drive.

0.0 26.9 Leave Stop 5. Continue around drive to the left and then right. Retrace route (south) via Legion Parkway to Route 33.

0.2 27.1 **STOP.** Illinois Route 33. TURN LEFT (east).

3.5 30.6 Prepare to turn right.

0.15 30.75 TURN RIGHT (south) on Stoy Road.

0.3 31.05 Enter village of Stoy. **CAUTION.**

0.2 31.25 **CAUTION.** Railroad crossing. Continue ahead (south). Do not block the railroad crossing.

0.15 31.4 **Stop 6.** Do NOT park on bridge or railroad crossing. Illinoian till section (SE² NE¹ NE¹, Sec. 3, T. 6 N., R. 13 W., Hardinville 15' Quadrangle, Crawford County).

About 25 feet of drift are exposed in the creek bank. The till was deposited by an Illinoian glacier. The silt layer that covers it may be a mixture of loess deposited during the Wisconsinan and gravel and sand washed off the till surface and mixed with the loess while the loess was being deposited. Figure 4 displays the results of the laboratory analyses that were made of the material and summarizes the physical properties that can be seen at the exposure. Let us consider this information, using the topics of grain size, color, and mineral content to organize our review—with regard in each case, first, to what can be seen with the material in hand and then to the laboratory data.

**Grain size** - The silt deposit is finer grained than the till. This fact is evident when one looks at the materials and rubs and molds them between thumb and finger. The grain-size analysis shows that 80% of the particles in the top sample of the silt are of silt size (1/256 to 1/16 mm) or of clay size (less than 1/256 mm). The till samples are coarser grained, containing about 50% sand and conspicuous amounts of gravel.

**Till** is characteristically a poorly sorted material. A glacier picks up and carries grains of all sizes from boulders to clay particles, and the grains are of different kinds of rock. Loess is a well-sorted, fine-grained deposit. Unlike glaciers, winds winnow and sort material quite well, carrying only the finest sizes aloft. The silt here could be a mixture of loess and coarser material eroded by slopewash from the surface of the till.

**Color** - A hue of gray is the "fresh" color of newly deposited till. The color of the brownish gray zone at the base of the exposure indicates that the till in that zone is "fresh," perhaps only a little weathered. The color of a till layer can often be used to distinguish it from other till deposits, but this
**Fig. 4 - Till section in cutbank on south side of Bennett Creek, just west of road (Sec. 3, T. 6 N., R. 13 W., Crawford County).**
criterion like others must be used cautiously. Above the gray zone the till color changes. The weathering of the till layer has created horizontal bands of brown and yellowish brown across the exposure. The term "weathering" includes all influences of climate and activities of organisms that cause physical and chemical changes in earth materials. In a newly deposited till layer, weathering begins at the exposed surface and progresses downward as air and water seep down and as organisms begin to inhabit the surface zone. Color changes caused by weathering are often conspicuous, because earthy yellow, brown, and red hues are produced by the oxidation ("rusting") of iron-bearing minerals.

Mineral content - The pebbles in the till came from rock exposures that the glaciers moved across as they flowed from Canada and consequently are a mixture of rock types native to this area and to the region generally north and northeast of here into Canada.

Tills in Illinois contain large quantities of the minerals calcite and dolomite picked up by the glaciers when they eroded wide belts of exposed limestones and dolomites which are composed largely of these minerals. Dilute (10%) hydrochloric acid dripped down the face of a till exposure fizzes and froths wherever it touches these minerals. If the acid causes no reaction, calcite and dolomite have been leached out of the till by ground water. Both the acid test and the X-ray diffraction analysis indicate that the upper 5 feet of the till at this stop is leached. The loss of calcite and dolomite from a till alters the look and feel of the material.

The X-ray diffraction analyses reveal some other changes. Compare the clay-mineral analysis of the bottom sample in the grayish brown till with the other samples. Several changes in what was deposited as a very homogeneous layer of till are evident:

1. The kaolinite plus chlorite (the K+C column) percentages decrease upward. The sharpest reduction is between the bottom sample (22%) and the next higher (14%). The mineral chlorite is rapidly oxidized and lost.

2. The percentage of expandable clay minerals (the EX column) increases upward, because, generally speaking, the other clay minerals alter to expandable clay minerals as they weather. The largest increase in expandable clays takes place in the leached till layer, which, being close to the surface, has been more intensely weathered than the lower zones.

0.0 31.4 Leave Stop 6. Continue ahead (south).
1.6 33.0 In the area south of Stoy, the Illinoian till plain is considerably more dissected than it is north of Route 33. The upland flats are not nearly as extensive as they are north of Highway 33.
0.2 33.2 Crossroad. TURN RIGHT (west). This is the site of the old village of Oil Center.
0.2 33.4 CAUTION. Narrow bridge.
0.05 33.45 Stop 7. J. W. Shire oil well to left in field (NW¼ NE¼ NE¼, Sec. 15, T. 6 N., R. 13 W., Hardinville 15' Quadrangle, Crawford County).
The first wildcatting for oil and gas in Illinois took place in 1865 about 30 miles north-northwest of this stop, near Casey. Only a small amount of oil was found and the area was abandoned. Sporadic prospecting took place around the state after that early venture.

From 1900 to 1904, a number of holes were drilled in the area near Robinson in search of fuel supplies, particularly coal for the local power plant, which failed frequently, largely because of a shortage of coal. A national coal famine that developed in 1903 sparked increased local interest in finding coal in the area. Gas was frequently encountered in some of these early drillings for coal east and north of Robinson and south of Palestine. During 1903 attempts were made to exploit any gas encountered in drilling so that it could be used locally. Up to 11 coal "veins" were reported from drillings about 8 miles northeast of this stop, and small amounts of gas and oil were also produced. However, the holes usually were ruined by salt water in attempts to drill them deeper.

During 1905 enough gas was produced in the area near Robinson for many people there to use it for heat and light. Some individuals were even replacing their electric lights with gas because the gas was a more dependable source of light.

In early February 1906, D. T. Finley of Pittsburgh drilled the well located here, which in addition to gas, yielded a steady flow of oil from a depth of 890 feet. According to local reports, Finley selected the drilling site by throwing an empty whiskey bottle from the bridge and telling the driller to drill wherever the bottle landed. The well came in as a gusher with initial oil production of 250 barrels per day. This well has been credited with opening up the Robinson pool. Plate 3, figure E is a photograph of this well shortly after it was completed.

According to an unpublished University of Illinois master's thesis by Martha Ellen Firebaugh, the Shire well was flowing an average of one barrel per hour by the middle of February 1906. Interest became so intense in the area that the owner of a 140-acre farm in the Shire district received $5000 plus a share of the oil produced in return for a lease on his property. Two tank cars, each containing 300 barrels of oil, were shipped from Stoy Station on May 23, 1906—the first oil shipped from Crawford County. Sixty cars had been shipped by June 6. The Robinson Argus reported that by July 4, 10,000 barrels of oil per day were being produced from the Shire field but that only about half was being shipped, because transportation facilities were inadequate. At that time, Illinois crude was selling for $0.86 per barrel, and John Shire received $789.00 for 15 days production in July. During July, 435 wells were completed and only 69 of them were dry holes. In mid August one well came in at 1100 barrels for the first 24 hours. It was reported that by the end of 1906 at least 3000 producing wells had been drilled in this southeastern Illinois oil field. At that time, the Robinson pool, which contained about 110 square miles of productive territory, was the largest pool in the oil area. By 1908 production was declining, and by 1910 the wildcat days were over. At that time the major companies were consolidating their holdings and acquiring various independents.

0.0 33.45 Leave Stop 7. Retrace itinerary to Oil Center.
0.25 33.7 STOP. Crossroad. TURN RIGHT (south).
1.0 34.7 STOP. T-road intersection. TURN RIGHT (west).
In a continuing program of attempting to recover additional oil from a reservoir, Marathon Oil Company searched for an area in which to conduct an in situ (in place in the reservoir) combustion test. The Fry waterflood unit was selected as being most desirable for this type of research project.

The Fry unit, as originally set up, consisted of 11 leases comprising 337 acres. Although oil production had been high in the early years of its development, oil recovery had declined over the years as the pressure/energy relationships dissipated. Air and gas repressuring of the reservoir preceded waterflooding. The latter began in 1952, but by 1960 it was apparent that in this unit, waterflooding was no longer successful.

The Robinson sands were the reservoir strata in which this test was conducted. Here the sandstones occur in a stream-deposited (fluvial), lenticular body about 12,000 feet long from northeast to southwest and 3500 feet wide. Three sandstones, each with distinct reservoir properties, vary from 0 to 55 feet thick and occur at depths between 880 and 936 feet.

The Fry in situ combustion project was a pilot-scale test on a 3.3-acre plot with an inverted 5-spot pattern, in which the plot was delimited by four producing wells, one at each corner, and a central injection well. An air compressor plant using a high-speed 500 hp diesel engine was constructed at the site in 1961 so that air injection tests and other engineering studies could be conducted. When these tests were completed, a 40 kw electrical igniter was lowered into the central injection well and was partially energized on October 9, 1961. By increasing the operating time of the element and pumping in air at the rate of 100,000 scf/D (standard cubic feet per day), initial ignition was accomplished on October 31, 1961, as determined by a temperature survey of an observation well located 100 feet west of the injection well.

Liquids and gases were collected in separate gathering lines and transported to the tank battery, where provisions had been made for isolating the production from an individual well for test purposes. It was found that the wells produced normally until the combustion front approached them. Emulsion and corrosion problems were encountered only when the well-bore temperature exceeded 150° F. Although toxic gases, explosive gases, and high-pressure air lines are potential dangers at this site, awareness of the problems with them can reduce or eliminate the risk of accident.

Oil that was produced from this test was not substantially different from that produced normally. Oil characteristics changed only when the temperature increased at a producing well as a result of the approach of the combustion front. Most changes were very slight, but the odor of the oil did change noticeably, from the sweet odor of crude to the odor of varnish and later to that of used crankcase oil—all typical changes of oil subjected to high temperature. The specific gravity decreased slightly, but the viscosity decreased considerably with the result that the oil became more fluid and moved more readily toward producing wells.
The tank battery collected fluids from eight wells beyond the test pattern, but from a close monitoring of each well, accurate production statistics were available. The wells that were stimulated by the combustion project produced a total of 123,090 barrels of oil. A study of the production history of this site indicates that an estimated 100,586 barrels of the recovered oil were a direct result of the Fry combustion test.

Although it is technically feasible to recover oil by in situ combustion techniques, the method is not economically practical now.

0.0 39.8 Leave Stop 8. Continue ahead (east).
0.05 39.85 CAUTION. Narrow culvert, sides hidden.
0.2 40.05 STOP. Use extreme caution as sign may be knocked down! Continue ahead (east).
0.5 40.55 T-road intersection. TURN LEFT (north) at Zion Church.
0.4 40.95 T-road from right. TURN RIGHT (east).
0.45 41.4 CAUTION. Narrow culvert. TURN LEFT beyond culvert.
0.15 41.55 TURN RIGHT (east). About 150 feet northwest from this corner, 15 feet or so of Illinoian till is exposed in the west creek bank.
0.5 42.05 STOP. Crossroad. TURN LEFT (north).
1.05 43.1 STOP. Crossroad. Use extreme caution - visibility is poor toward the west. TURN RIGHT (east).
1.1 44.2 Pleistocene materials exposed in roadcut; somewhat slumped.
1.25 45.45 STOP. Crossroad at north side of hamlet of New Hebron. TURN LEFT (north) on blacktop.
2.3 47.75 T-road from right. TURN RIGHT (east).
0.5 48.25 T-road from left. TURN LEFT (north).
0.2 48.45 To the right about 1/2 mile is a Union Carbide carbon coke plant with large coke piles nearby.
0.35 48.8 Crossroad. Continue ahead (north) and enter Robinson.
0.15 48.95 TURN RIGHT and enter parking lot.
0.15 49.1 Stop 9. View of Marathon Oil Company's Robinson Refinery (SE 1/4 NW 1/4, Sec. 3, T. 6 N., R. 12 W., Birds 15' Quadrangle, Crawford County).

The Refinery - In 1924, the Ohio Oil Company, which later became Marathon Oil Company, purchased the Lincoln Oil Company's refinery at this location. There was at least one predecessor to the Lincoln Oil Company's facility, a small refinery operated by the Robinson Oil Company, which went out of business in 1908. The
Present refinery installation was completed in 1970 and is the result of the fifth modernization and expansion program undertaken by Marathon since purchasing the facility.

The refinery is supplied with raw material by the Platte Pipeline, which runs westward through northern Missouri, and by the Capline, a 40-inch diameter pipeline which brings crude oil from the Gulf Coast. In 1970, the crude oil distillation unit was reported to be running at a rate of 110,000 barrels of crude oil per day.

The refinery produces fuel gas and LPG, regular and premium gasolines, kerosene, Nos. 1, 2, and 6 fuel oils, sulfur, and coke. About half of the refinery's production—batches of gasoline, diesel fuel, and home-heating oils—moves through the Wabash Products Pipeline, which goes through Champaign to Chicago. The Marathon Products Pipeline carries fluids through Indianapolis to Lima, Ohio.

It is reported that the plant requires only 38 gallons of water to process each barrel of crude oil—the national average in 1970 being 204 gallons per barrel. The Robinson Refinery has effected water economy partly by reuse of water and by air cooling some installations. The refinery draws 3.5 million gallons of water per day from ponds near Palestine that are dug into the outwash gravels filling the Wabash Valley. It discharges about 2.5 million gallons of water each day after treating the waste water to remove pollutants.

The spectacular vapor plumes and flares that the refinery emits day and night are steam and wholly burned wastes from the process vessels.

Plant Tours and Other Information—The Marathon Oil Company extends its hospitality to groups who wish to visit the refinery. The person responsible for this activity tells us that:

1. Plant tours should be arranged well in advance of the desired date. Contact Employee Relations Supervisor
   Marathon Oil Company
   Marathon Avenue
   Robinson, IL 62454 Telephone: 618-544-2121

2. Tour participants must be of junior high age or older.

3. Parking for the cars of individuals and groups of fewer than 15 people can be arranged, but larger groups should come by bus. Brochures describing the operation of the refinery and related matter, if available, may be obtained from the same office.

0.0 49.1 Leave Stop 9. TURN RIGHT (north) on South Eaton Street.

0.1 49.2 Curve left and then right.

0.15 49.35 CAUTION. TURN RIGHT (east) and cross two sets of unguarded railroad tracks and immediately TURN LEFT (north).

0.15 49.5 CAUTION. Unguarded railroad crossing. Continue ahead (north).

0.05 49.55 Entrance to Marathon Oil Company Office to right. Continue ahead.
20

0.2 49.75 STOP. Intersection with East Main Street (Illinois Route 33). TURN RIGHT (east).

2.45 52.2 STOP. Junction with Illinois Route 1. Continue ahead (east) on Illinois 33.

0.25 52.45 To the north-northeast is the town of Merom, Indiana, situated on the top of a 110-120 foot high Pennsylvanian sandstone bluff on the east bank of the Wabash River.

0.55 53.0 To the right the green metal shed houses one of Robinson’s city wells. The well is drawing water from a sand and gravel aquifer in the Wabash Valley. This well is located on the Shelbyville outwash surface, the alluvial terrace relict shown on Plate 2. As the itinerary continues eastward down slope, it descends to the Maumee terrace level. Plate 2 and figure 5 illustrate the valley features that will be traversed on the rest of the itinerary.

0.55 53.55 Descend to a slightly lower portion of the Maumee terrace, upon which the Robinson airport is located to the left.

0.6 54.15 The hill to the right is a bedrock highland that became mantled with sand that was blown from the terrace as the lake that covered the area receded.

0.35 54.5 CAUTION. Prepare to turn right.

0.1 54.6 USE EXTREME CAUTION. TURN RIGHT (south) at crossroad on the east side of the airport and rise abruptly to the unguarded Illinois Central Gulf Railroad crossing.

0.9 55.5 T-road intersection. TURN HARD LEFT (northeast) on blacktop road.

0.15 55.65 The flat, low area to the north for a short distance and to the south is the lake plain (the dry bottom) formed by glacial Lake Palestine. The first ridge to the south is a shoreline of the lake and is covered with sandy beach and dune deposits.

0.7 56.35 STOP. T-road. TURN RIGHT (south).

0.4 56.75 The itinerary crosses the lake plain formed on the bottom of glacial Lake Palestine. Note how level the terrain is.

0.65 57.4 Crossroad. Continue ahead straight. The itinerary ascends the beach ridge noted from the other side of the lake plain. Note how sandy the roadcut is. Lamotte Creek is ahead. Its valley contained another arm of glacial Lake Palestine.

0.4 57.8 Laminated (very thin layered) silts are exposed in the bottom of the ditch on the west side, near to and north of the creek. Such fine-grained, thin layers are characteristic of lake bottom deposits and indicate quiet water at depths unaffected by waves.

0.15 57.95 On the south side of the valley is a better exposure of lake silts overlain by silty and sandy slopewash materials, which in turn are
overlain by sand that must have been piled up onshore as beach and dune features.

0.5  58.45  Lamotte Township Sanitary Landfill entrance to left.

1.45  59.9.  The itinerary descends the low north side of a peculiarly straight, wide, flat-floored valley. It is a trough crossing a ridge that extends from Robinson through Morea. The valley floor is the lowest elevation on the ridge, about 510 feet. Small creeks like the ones running into it from its ends would ordinarily cut narrow, V-shaped valleys into an upland--as such small creeks are doing elsewhere on the ridge. The creeks in this valley don't "fit" it.

It seems likely that the valley was cut by meltwaters running off an Illinoian glacier front standing along a line between Robinson and Palestine and impounding water between itself and the ridge. Meltwater spilling over the ridge at a low spot would create a valley like this one, a sluiceway. The 510 foot elevation on the valley floor is about 40 feet above both the Shelbyville (Wisconsinan) outwash surface and the floor of a sluiceway southeast of Palestine (mileage 71.2) that carried Wisconsinan meltwater. On the ridge here down-cutting could have started at about 540 feet (the sluiceway sides being outlined by the 540 foot contour). The 540 foot elevation is much higher than other estimates of Wisconsinan meltwater levels; therefore it seems likely that this sluiceway was cut by Illinoian meltwater.

0.85  60.75  The recently scraped ditch on the left side of the road shows an excellent exposure of rust-red Sangamon Soil developed on Illinoian till and covered by brown and tan Wisconsinan loess. The soil zone developed on the surface of the till during Sangamonian interglacial time. When the Wisconsinan glaciations brought outwash into the Wabash Valley in this region, loess was blown off the outwash and carried here where it buried the interglacial soil and land surface that had developed on the till.

0.1  60.85  To the right (south-southwest) is another view of the sluiceway.

0.15  61.0  T-road from right. Continue ahead (south).

0.5  61.5  T-road from left. TURN LEFT (east) in the hamlet of Morea.

0.25  61.75  The field on the left has been contour plowed to reduce erosion.

0.25  62.0  To the left, on the north side of the road and east of the cemetery, is a gob pile beside the shaft of an old, abandoned coal mine. Continue ahead (east).

0.7  62.7  Curve right (south) and then left (east) on the blacktop.

1.3  64.0  STOP. Junction with Lincoln National Memorial Highway. Continue ahead (east). CAUTION. Fast traffic from the left (north).

0.75  64.75  T-road intersection. TURN RIGHT (south).

0.1  64.85  T-road intersection. TURN LEFT (east).
The area to the right (south and southeast) toward the creek is part of one of the glacial lake bottoms.

T-road intersection. TURN RIGHT (south).

T-road from left. TURN LEFT (east).

The high land through this area was an upland peninsula jutting out into the glacial lake to the south.

T-road from left. TURN LEFT (north). Just east of the intersection, about 0.1 mile, the hill is mantled with sand that was probably wind-blown from the adjacent beaches of the glacial lake.

Y-road intersection. BEAR RIGHT (north) and descend hill.

Cross culvert. Note glacial till and loess exposed in stream bank to the right.

T-road from right. TURN RIGHT (north).

CAUTION. Narrow bridge.

Stop 10. Pennsylvanian bedrock exposure in east bank of No Business Creek. (NW¼ SE¼ SW¼ parcel Sec. 20, T. 6 N., R. 10 W., Birds 15' Quadrangle, Crawford County).

Strata exposed here are (from top downward):

<table>
<thead>
<tr>
<th>Strata</th>
<th>Thicknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shale - light to medium gray, fairly well laminated, weak; weathered, with considerable iron staining along fracture and bedding surfaces, especially near the top; grades downward into:</td>
<td>6'+</td>
</tr>
<tr>
<td>Shale - dark gray, fairly well laminated</td>
<td>4&quot;-10&quot;</td>
</tr>
<tr>
<td>Flat Creek Coal Member</td>
<td>2'+</td>
</tr>
<tr>
<td>Coal - somewhat weathered, tends to be blocky</td>
<td>2&quot;</td>
</tr>
<tr>
<td>Clay - light gray, soft</td>
<td>1/8&quot;-1/4&quot;</td>
</tr>
<tr>
<td>Coal - blocky, hard; contains pyritized plant remains</td>
<td>7&quot;+</td>
</tr>
<tr>
<td>Coal - top 3/4&quot; very bony, underlain by 1 1/2&quot; hard, massive, canneloid-appearing coal; remainder of coal is bright banded, hard, and blocky</td>
<td>7 1/4&quot;</td>
</tr>
<tr>
<td>Coal - bright banded, hard; bony in part; canneloid (?) in bottom 1/2&quot;</td>
<td>7&quot;</td>
</tr>
<tr>
<td>Underclay - medium gray; starchy fracture; contains root traces; base concealed</td>
<td>2'+</td>
</tr>
</tbody>
</table>

Creek level
A study of the plant spore assemblage isolated by macerating samples of this coal shows that the coal is in the Bond Formation of the McLeansboro Group (upper part of Pennsylvanian). The coal appears to correlate most closely with the Flat Creek Coal Member of Bond County in southwestern Illinois. However, it might possibly correlate with the Flannigan Coal Member of Hamilton County some 75 miles south-southwest of this stop. These two mentioned coal members are almost correlatives.

This coal was mined nearby for local use in years past. The mines to the north near Palestine also worked this coal along the west valley wall of the Wabash River.

0.0 68.6 Coal exposure. Leave stop 10 and continue ahead.

0.7 69.3 T-road from left. Continue ahead straight.

1.65 70.95 View to the left is across a sluiceway through which Wisconsinan meltwater drained toward the south, leaving this upland area as an island.

0.15 71.1 The Wabash River Valley is to the right.

0.1 71.2 Descend valley wall into the sluiceway.

0.05 71.25 Sandstone bedrock crops out on both sides of the roadcut. Continue ahead.

0.1 71.35 The fenced area to the left of the road is an old abandoned mine shaft that has collapsed. On the left for the next quarter of a mile are a number of gob piles from old shaft mines into the Flat Creek Coal Member.

0.6 71.95 T-road from left. Continue ahead straight on blacktop.

1.2 73.15 Note limestone (Millersville Limestone Member?) exposed in cut just behind the new house on the left.

0.4 73.55 Palestine village park on right.

0.2 73.75 T-road from left. Continue ahead (north).

0.3 74.05 Curve left (west) and enter Palestine.

0.2 74.25 STOP. Continue ahead (west).

0.45 74.7 STOP. Intersection with Illinois 33. TURN RIGHT (north) on Jackson Street.

0.15 74.85 TURN LEFT (west) on Route 33.

0.1 74.95 TURN RIGHT (north) on Main Street.

0.05 75.0 CAUTION. Two railroad tracks. Continue ahead (north).

0.1 75.1 Curve right and then bear left (north) on Lincoln Heritage Highway.
0.1 75.2 Cross bridge. To the southwest two aqua-colored sheds near the railroad track house two more water wells for Robinson.

0.7 75.9 The itinerary crosses the Maumee erosional surface, or terrace level. Many of the minor imperfections and higher points on the otherwise flat Maumee erosional surface are sand dunes and beach bars and features of that sort.

1.55 77.45 Top of the Maumee Terrace. The view to the right is down across the present floodplain to the Wabash Valley. In the distance is Merom, Indiana. Continue ahead (north).

0.25 77.7 T-road intersection. Continue ahead; curve to the right (north).

1.05 78.75 T-road from left. Continue ahead (north) on blacktop. The low area to the right is the present floodplain, which floods very readily. To the left is a gravel pit of the Crawford Sand and Gravel Company.

1.2 79.95 T-road from left. Continue ahead (north). Note gravel pit to the left.

1.0 80.95 Crossroad. TURN RIGHT (east) on gravel road.

0.05 81.0 Stop II. Stockpiles at a pit of the Crawford Sand and Gravel Company (SW\(\frac{1}{4}\), SW\(\frac{3}{4}\), SW\(\frac{1}{4}\), Sec. 34, T. 8 N., R. 11 W., Hutsonville 15' Quadrangle, Crawford County).

PLEASE do not enter this property without the permission of the owner, Mr. Dick Gray (Crawford Sand and Gravel Company, Box 284, Hutsonville, IL 62433).

An illustration of the thickness of the Wisconsinan outwash filling was provided by Mr. Gray. He told us that a hole drilled at the road intersection here penetrated about 129 feet of outwash before encountering sandstone bedrock.

Explanation of Figure 5 - The figure is a cross section of the Wabash Valley that shows (1) the relation of the buried bedrock surface to the present land surface and (2) the landforms expressed on the land surface. The line that cross section A - A' follows is shown on the Route Map.

Consider the features illustrated on the cross section as you read the following summary narrative of the events that created the present Wabash Valley.

1. The bedrock valley surface, in places a hundred feet beneath the present valley floor, was cut by early glacier-fed rivers.

2. Of the first three glaciations, at least the Kansan and Illinoian (the second and third) covered the area, leaving till deposits on the uplands and in the valleys and outwash deposits in the drainageways.

3. Most of this glacial drift was washed out of the valley before and during the onset of the Wisconsinan (the fourth) glaciation.

4. As the Wisconsinan glaciers advanced, their meltwaters began refilling the bedrock valley with outwash deposits, largely the valley train of the Woodfordian glacier. Outwash from the Woodfordian glacier, which reached its southern limit
about 20,000 years ago, filled the valley to a level of about 470 feet, creating the Shelbyville outwash surface.

5. The outwash deposits gradually blocked the mouths of streams flowing into the Wabash Valley. The streams backed up and became lakes, their beds being filled in to a level of about 460 feet in this area.

6. About 14,000 years ago, the meltwater-swollen, higher level ancestor of Lake Erie overtopped its moraine dam at Fort Wayne, Indiana, and drained down the Wabash River. This drainage, called the Maumee Flood, eroded most of the Shelbyville outwash surface and created a new, lower valley floor--the Maumee erosional surface--at about 450 feet in this area.

7. As the last glaciation waned, the modern Wabash River entrenched itself into the valley fill. Later it built up the present floodplain to about 430 feet.

END OF TRIP.
REFERENCES NOT CITED IN THE TEXT:


PROPERTY OWNERS:

Stops 1 & 7. Mr. Harold Funcannon, Star Route, Robinson, Illinois 62454, and Mr. Ray Hall, Box 69, Albion, Illinois 62806.

Stops 2, 3, and 8. The Marathon Oil Company, Robinson Production Office, Bridgeport, Illinois 62417.

Stop 6. Mr. William Collins, 4776 Delaware Street, Gary, Indiana 46409.


PLEISTOCENE GLACIATIONS IN ILLINOIS

Origin of the Glaciers

During the past million years or so, the period of time called the Pleistocene Epoch, most of the northern hemisphere above the 50th parallel has been repeatedly covered by glacial ice. Ice sheets formed in sub-arctic regions four different times and spread outward until they covered the northern parts of Europe and North America. In North America the four glaciations, in order of occurrence from the oldest to the youngest, are called the Nebraskan, Kansan, Illinoian, and Wisconsinan Stages of the Pleistocene Epoch. The limits and times of the ice movement in Illinois are illustrated in the following pages by several figures.

The North American ice sheets developed during periods when the mean annual temperature was perhaps 4° to 7° C (7° to 13° F) cooler than it is now and winter snows did not completely melt during the summers. Because the cooler periods lasted tens of thousands of years, thick masses of snow and ice accumulated to form glaciers. As the ice thickened, the great weight of the ice and snow caused them to flow outward at their margins, often for hundreds of miles. As the ice sheets expanded, the areas in which snow accumulated probably also increased in extent.

Tongues of ice, called lobes, flowed southward from the Canadian centers near Hudson Bay and converged in the central lowland between the Appalachian and Rocky Mountains. There the glaciers made their farthest advances to the south. The sketch below shows several centers of flow, the general directions of flow from the centers, and the southern extent of glaciation. Because Illinois lies entirely in the central lowland, it has been invaded by glaciers from every center.

Effects of Glaciation

Pleistocene glaciers and the waters melting from them changed the landscapes they covered. The glaciers scraped and smeared the landforms they overrode, leveling and filling many of the minor valleys and even some of the larger ones. Moving ice carried colossal amounts of rock and earth, for much of what the glaciers wore off the ground was kneaded into the moving ice and carried along, often for hundreds of miles.

The continual floods released by melting ice entrenched new drainageways, deepened old ones, and then partly refilled both with sediments as great quantities of rock and earth were carried beyond the glacier fronts. According to some estimates, the amount of water drawn from the sea and changed into ice during a glaciation was probably enough to lower sea level more than 300 feet below present level. Consequently, the melting of a continental ice sheet provided a tremendous volume of water that eroded and transported sediments.
In most of Illinois, then, glacial and meltwater deposits buried the old rock-ribbed, low, hill-and-valley terrain and created the flatter landforms of our prairies. The mantle of soil material and the deposits of gravel, sand, and clay left by the glaciers over about 90 percent of the state have been of incalculable value to Illinois residents.

Glacial Deposits

The deposits of earth and rock materials moved by a glacier and deposited in the area once covered by the glacier are collectively called drift. Drift that is ice-laid is called till. Water-laid drift is called outwash.

Till is deposited when a glacier melts and the rock material it carries is dropped. Because this sediment is not moved much by water, a till is unsorted, containing particles of different sizes and compositions. It is also unstratified (unlayered). A till may contain materials ranging in size from microscopic clay particles to large boulders. Most tills in Illinois are pebbly clays with only a few boulders.

Tills may be deposited as end moraines, the arc-shaped ridges that pile up along the glacier edges where the flowing ice is melting as fast as it moves forward. Till also may be deposited as ground moraines, or till plains, which are gently undulating sheets deposited when the ice front melts back, or retreats. Deposits of till identify areas once covered by glaciers. Northeastern Illinois has many alternating ridges and plains, which are the succession of end moraines and till plains deposited by the Wisconsinan glacier.

Sorted and stratified sediment deposited by water melting from the glacier is called outwash. Outwash is bedded, or layered, because the flow of water that deposited it varied in gradient, volume, velocity, and direction. As a meltwater stream washes the rock materials along, it sorts them by size—the fine sands, silts, and clays are carried farther downstream than the coarser gravels and cobbles. Typical Pleistocene outwash in Illinois is in multilayered beds of clays, silts, sands, and gravels that look much like modern stream deposits.

Outwash deposits are found not only in the area covered by the ice field but sometimes far beyond it. Meltwater streams ran off the top of the glacier, in crevices in the ice, and under the ice. In some places, the cobble-gravel-sand filling of the bed of a stream that flowed in the ice is preserved as a sinuous ridge called an esker. Cone-shaped mounds of coarse outwash, called kames, were formed where meltwater plunged through crevasses in the ice or into ponds along the edge of the glacier.

The finest outwash sediments, the clays and silts, formed bedded deposits in the ponds and lakes that filled glacier-dammed stream valleys, the sags of the till plains, and some low, moraine-diked till plains. Meltwater streams that entered a lake quickly lost speed and almost immediately dropped the sands and gravels they carried, forming deltas at the edge of the lake. Very fine sand and silts were moved across the lake bottom by wind-generated
currents, and the clays, which stayed in suspension longest, slowly settled out and accumulated with them.

Along the ice front, meltwater ran off in innumerable shifting and short-lived streams that laid down a broad, flat blanket of outwash that formed an outwash plain. Outwash was also carried away from the glacier in valleys cut by floods of meltwater. The Mississippi, Illinois, and Ohio Rivers occupy valleys that were major channels for meltwaters and were greatly widened and deepened during times of the greatest meltwater floods. When the floods waned, these valleys were partly filled with outwash far beyond the ice margins. Such outwash deposits, largely sand and gravel, are known as valley trains. Valley trains may be both extensive and thick deposits. For instance, the long valley train of the Mississippi Valley is locally as much as 200 feet thick.

Loess and Soils

One of the most widespread sediments resulting from glaciation was carried not by ice or water but by wind. Loess is the name given to such deposits of windblown silt and clay. The silt was blown from the valley trains on the floodplains. Most loess deposition occurred in the fall and winter seasons when low temperatures caused meltwater floods to abate, exposing the surfaces of the valley trains and permitting them to dry out. During Pleistocene time, as now, west winds prevailed, and the loess deposits are thickest on the east sides of the source valleys. The loess thins rapidly away from the valleys but extends over almost all the state.

Each Pleistocene glaciation was followed by an interglacial stage that began when the climate warmed enough to melt the glaciers and their snowfields. During these warmer intervals, when the climate was similar to that of today, drift and loess surfaces were exposed to weather and the activities of living things. Consequently, over most of the glaciated terrain, soils developed on the Pleistocene deposits and altered their composition, color, and texture. Such soils were generally destroyed by later glacial advances, but those that survive serve as keys to the identity of the beds and are evidence of the passage of a long interval of time.

Glaciation in a Small Illinois Region

The following diagrams show how a continental ice sheet might have looked as it moved across a small region in Illinois. They illustrate how it could change the old terrain and create a landscape like the one we live on. To visualize how these glaciers looked, geologists study the landforms and materials left in the glaciated regions and also the present-day mountain glaciers and polar ice caps.

The block of land in the diagrams is several miles wide and about 10 miles long. The vertical scale is exaggerated—layers of material are drawn thicker and landforms higher than they ought to be so that they can be easily seen.
1. **The Region Before Glaciation** - Like most of Illinois, the region illustrated is underlain by almost flat-lying beds of sedimentary rocks—layers of sandstone (\(\text{\textcolor{red}{\text{\textbf{BR}}}}\)), limestone (\(\text{\textcolor{blue}{\text{\textbf{BR}}}}\)), and shale (\(\text{\textcolor{green}{\text{\textbf{BR}}}}\)). Millions of years of erosion have planed down the bedrock (BR), creating a terrain of low uplands and shallow valleys. A residual soil weathered from local rock debris covers the area but is too thin to be shown in the drawing. The streams illustrated here flow westward and the one on the right flows into the other at a point beyond the diagram.

2. **The Glacier Advances Southward** - As the glacier (G) spreads out from its snowfield, it scours (SC) the soil and rock surface and quarries (Q)—pushes and plucks up—chunks of bedrock. These materials are mixed into the ice and make up the glacier's "load." Where roughnesses in the terrain slow or stop flow (F), the ice "current" slides up over the blocked ice on innumerable shear planes (S). Shearing mixes the load very thoroughly. As the glacier spreads, long cracks called "crevasses" (C) open parallel to the direction of ice flow. The glacier melts as it flows forward, and its meltwater erodes the terrain in front of the ice, deepening (D) some old valleys before the ice covers them. Meltwater washes away some of the load freed by melting and deposits it on the outwash plain (OP). The advancing glacier overrides its outwash and in places scours much of it up again. The glacier may be 5000 or so feet thick, except near its margin. Its ice front advances perhaps as much as a third of a mile per year.
3. The Glacier Deposits an End Moraine - After the glacier advanced across the area, the climate warmed and the ice began to melt as fast as it advanced. The ice front (IF) is now stationary, or fluctuating in a narrow area, and the glacier is depositing an end moraine.

As the top of the glacier melts, some of the sediment that was mixed in the ice accumulates on top of the glacier. Some is carried by meltwater onto the sloping ice front (IF) and out onto the plain beyond. Some of the debris slips down the ice front in a mudflow (FL). Meltwater runs through the ice in a crevasse (C). A superglacial stream (SS) drains the top of the ice, forming an outwash fan (OP). Moving ice has overridden an immobile part of the front on a shear plane (S). All but the top of a block of ice (B) is buried by outwash (O).

Sediment from the melted ice of the previous advance (figure 2) was left as a till layer (T), part of which forms the till plain (TP). A shallow, marshy lake (L) fills a low place in the plain. Although largely filled with drift, the valley (V) remained a low spot in the terrain. As soon as its ice cover melted, meltwater drained down the valley, cutting it deeper. Later, outwash partly refilled the valley—the outwash deposit is called a valley train (VT). Wind blows dust (DT) off the dry floodplain. The dust will form a loess deposit when it settles.

4. The Region after Glaciation - The climate has warmed even more, the whole ice sheet has melted, and the glaciation has ended. The end moraine (EM) is a low, broad ridge between the outwash plain (OP) and till plains (TP). Run-off from rains cuts stream valleys into its slopes. A stream goes through the end moraine along the channel cut by the meltwater that ran out of the crevasse in the glacier.

Slopestreash and vegetation are filling the shallow lake. The collapse of outwash into the cavity left by the ice block’s melting has made a kettle (K). The outwash that filled a tunnel draining under the glacier is preserved in an esker (E). The hill of outwash left where meltwater dumped sand and gravel into a crevasse or other depression in the glacier or at its edge is a kame (KM). A few feet of loess covers the entire area but cannot be shown at this scale.
<table>
<thead>
<tr>
<th>STAGE</th>
<th>SUBSTAGE</th>
<th>NATURE OF DEPOSITS</th>
<th>SPECIAL FEATURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOLOCENE</td>
<td>Years Before Present</td>
<td>Soil, youthful profile of weathering, lake and river deposits, dunes, peat</td>
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<td></td>
<td>7,000</td>
<td>Valderan</td>
<td>Outwash along Mississippi Valley</td>
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<td>11,000</td>
<td>Twocreekan</td>
<td>Ice withdrawal, erosion</td>
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<td>WISCONSINAN</td>
<td>12,500</td>
<td>Woodfordian</td>
<td>Glaciation; building of many moraines as far south as Shelbyville; extensive valley trains, outwash plains, and lakes</td>
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<tr>
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<td>22,000</td>
<td>Farmdalian</td>
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<td></td>
<td>28,000</td>
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<td>Glaciation in northern Illinois, valley trains along major rivers</td>
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<td>Jubileean</td>
<td>Glaciers from northeast at maximum reached Mississippi River and nearly to southern tip of Illinois</td>
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<td>Monican</td>
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<td>Glaciers from northwest invaded western Illinois</td>
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<tr>
<td>(1st glacial)</td>
<td>1,200,000 or more</td>
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(Ilinois State Geological Survey, 1973)
SEQUENCE OF GLACIATIONS AND INTERGLACIAL DRAINAGE IN ILLINOIS

1. NEBRASKAN inferred glacial limit
2. AFTONIAN major drainage
3. KANSAN inferred glacial limits
4. YARMOUTHIAN major drainage
5. LIMAN glacial advance
6. MONICAN glacial advance
7. JUBILEEAN glacial advance
8. SANGAMONIAN major drainage
9. ALTONIAN glacial advance
10. WOODFORDIAN glacial advance
11. WOODFORDIAN Valparaiso ice and Kankakee Flood
12. VALDERAN drainage

(From Willman and Frye, "Pleistocene Stratigraphy of Illinois," ISGS Bull. 94, fig. 5, 1970.)
GLACIAL MAP OF ILLINOIS

H.B. WILLMAN and JOHN C. FRYE

1970

EXPLANATION

HOLOCENE AND WISCONSINIAN
- Alluvium, sand dunes, and gravel terraces

WISCONSINIAN
- Lake deposits

WOODFORDIAN
- Moraine
- Front of morainic system
- Groundmoraine

ALTONIAN
- Till plain

ILLINOIAN
- Moraine and ridged drift
- Groundmoraine

KANSAN
- Till plain

DRIFTLESS

Modified from Bull. 94.—pl. 2
GLACIAL MAP OF NORTHEASTERN ILLINOIS

George Ekblaw
Revised 1960
At the close of the Mississippian Period, about 310 million years ago, the Mississippian sea withdrew from the Midcontinent region. A long interval of erosion took place early in Pennsylvanian time and removed hundreds of feet of the pre-Pennsylvanian strata, completely stripping them away and cutting into older rocks over large areas of the Midwest. An ancient river system cut deep channels into the bedrock surface. Erosion was interrupted by the invasion of the Morrowan (early Pennsylvanian) sea.

Depositional conditions in the Illinois Basin during the Pennsylvanian Period were somewhat similar to those that existed during Chesterian (late Mississippian) time. A river system flowed southwestward across a swampy lowland, carrying mud and sand from highlands in the northeast. A great delta was built out into the shallow sea (see paleogeography map on next page). As the lowland stood only a few feet above sea level, only slight changes in relative sea level caused great shifts in the position of the shoreline.

Throughout Pennsylvanian time the Illinois Basin continued to subside while the delta front shifted owing to worldwide sea level changes, intermittent subsidence of the basin, and variations in the amounts of sediment carried seaward from the land. These alternations between marine and nonmarine conditions were more frequent than those during pre-Pennsylvanian time, and they produced striking lithologic variations in the Pennsylvanian rocks.

Conditions at various places on the shallow sea floor favored the deposition of sandstone, limestone, or shale. Sandstone was deposited near the mouths of distributary channels. These sands were reworked by waves and spread as thin sheets near the shore. The shales were deposited in quiet-water areas—in delta bays between distributaries, in lagoons behind barrier bars, and in deeper water beyond the nearshore zone of sand deposition. Most sediments now recognized as limestones, which are formed from the accumulation of limey parts of plants and animals, were laid down in areas where only minor amounts of sand and mud were being deposited. Therefore, the areas of sandstone, shale, and limestone deposition continually changed as the position of the shoreline changed and as the delta distributaries extended seaward or shifted their positions laterally along the shore.

Nonmarine sandstones, shales, and limestones were deposited on the deltaic lowland bordering the sea. The nonmarine sandstones were deposited in distributary channels, in river channels, and on the broad floodplains of the rivers. Some sand bodies, 100 or more feet thick, were deposited in channels that cut through many of the underlying rock units. The shales were deposited mainly on floodplains. Freshwater limestones and some shales were deposited locally in freshwater lakes and swamps. The coals were formed by the accumulation of plant material, usually where it grew, beneath the quiet waters of extensive swamps that prevailed for long intervals on the emergent delta lowland. Lush forest vegetation, which thrived in the warm, moist Pennsylvanian climate, covered the region. The origin of the underclays beneath the coals is not precisely known, but they were probably deposited in the swamps as slackwater muds before the formation of the coals. Many underclays contain plant roots and rootlets that appear to be in their original places. The formation of coal marked the end of the nonmarine portion of the depositional cycle, for resubmergence of the borderlands by the sea interrupted nonmarine deposition, and marine sediments were then laid down over the coal.
Paleogeography of Illinois-Indiana region during Pennsylvanian time. The diagram shows the Pennsylvanian river delta and the position of the shoreline and the sea at an instant of time during the Pennsylvanian Period.

Pennsylvanian Cyclothsms

Because of the extremely varied environmental conditions under which they formed, the Pennsylvanian strata exhibit extraordinary variations in thickness and composition, both laterally and vertically. Individual sedimentary units are often only a few inches thick and rarely exceed 30 feet thick. Sandstones and shales commonly grade laterally into each other, and shales sometimes interfinger and grade into limestones and coals. The underclays, coals, black shales, and
limestones, however, display remarkable lateral continuity for such thin units (usually only a few feet thick). Coal seams have been traced in mines, outcrops, and subsurface drill records over areas comprising several states.

The rapid and frequent changes in depositional environments during Pennsylvanian time produced regular or cyclical alternations of sandstone, shale, limestone, and coal in response to the shifting front of the delta lowland. Each series of alternations, called a cyclothem, consists of several marine and non-marine rock units that record a complete cycle of marine invasion and retreat. Geologists have determined, after extensive studies of the Pennsylvanian strata in the Midwest, that an ideally complete cyclothem consists of 10 sedimentary units. The chart on the next page shows the arrangement. Approximately 50 cyclothems have been described in the Illinois Basin, but only a few contain all 10 units. Usually one or more are missing because conditions of deposition were more varied than indicated by the ideal cyclothem. However, the order of units in each cyclothem is almost always the same. A typical cyclothem includes a basal sandstone overlain by an underclay, coal, black sheety shale, marine limestone, and gray marine shale. In general, the sandstone-underclay-coal portion (the lower 5 units) of each cyclothem is nonmarine and was deposited on the coastal lowlands from which the sea had withdrawn. However, some of the sandstones are entirely or partly marine. The units above the coal are marine sediments and were deposited when the sea advanced over the delta lowland.

Origin of Coal

It is generally accepted that the Pennsylvanian coals originated by the accumulation of vegetable matter, usually in place, beneath the waters of extensive, shallow, fresh-to-brackish swamps. They represent the last-formed deposits of the nonmarine portions of the cyclothems. The swamps occupied vast areas of the deltaic coastal lowland, which bordered the shallow Pennsylvanian sea. A luxuriant growth of forest plants, many quite different from the plants of today, flourished in the warm Pennsylvanian climate. Today's common deciduous trees were not present, and the flowering plants had not yet evolved. Instead, the jungle-like forests were dominated by giant ancestors of present-day club mosses, horsetails, ferns, conifers, and cycads. The undergrowth also was well developed, consisting of many ferns, fernlike plants, and small club mosses. Most of the plant fossils found in the coals and associated sedimentary rocks show no annual growth rings, suggesting rapid growth rates and lack of seasonal variations in the climate. Many of the Pennsylvanian plants, such as the seed ferns, eventually became extinct.

Plant debris from the rapidly growing swamp forests—leaves, twigs, branches, and logs—accumulated as thick mats of peat on the floors of the swamps. Normally, vegetable matter rapidly decays by oxidation, forming water, nitrogen, and carbon dioxide. However, the cover of swamp water, which was probably stagnant and low in oxygen, prevented the complete oxidation and decay of the peat deposits.

The periodic invasions of the Pennsylvanian sea across the coastal swamps killed the Pennsylvanian forests and initiated marine conditions of deposition. The peat deposits were buried by marine sediments. Following burial, the peat deposits were gradually transformed into coal by slow chemical and physical changes in which pressure (compaction by the enormous weight of overlying sedimentary layers), heat (also due to deep burial), and time were the most important factors. Water and volatile substances (nitrogen, hydrogen, and oxygen) were slowly driven off during the coalification process, and the peat deposits were changed into coal.
Coals have been classified by ranks that are based on the degree of coalification. The commonly recognized coals, in order of increasing rank, are (1) brown coal or lignite, (2) sub-bituminous, (3) bituminous, (4) semibituminous, (5) semianthracite, and (6) anthracite. Each increase in rank is characterized by larger amounts of fixed carbon and smaller amounts of oxygen and other volatiles. Hardness of coal also increases with increasing rank. All Illinois coals are classified as bituminous.

Underclays occur beneath most of the coals in Illinois. Because underclays are generally unstratified (unlayered), are leached to a bleached appearance, and generally contain plant roots, many geologists consider that they represent the ancient soils on which the coal-forming plants grew.

The exact origin of the carbonaceous black shales that occur above many coals is uncertain. The black shales probably are deposits formed under restricted marine (lagoonal) conditions during the initial part of the invasion cycle, when the region was partially closed off from the open sea. In any case, they were deposited in quiet-water areas where very fine, iron-rich muds and finely divided plant debris were washed in from the land. The high organic content of the black shales is also in part due to the carbonaceous remains of plants and animals that lived in the lagoons. Most of the fossils represent planktonic (floating) and nektonic (swimming) forms—not benthonic (bottom dwelling) forms. The depauperate (dwarf) fossil forms sometimes found in black shales formerly were thought to have been forms that were stunted by toxic conditions in the sulfide-rich, oxygen-deficient waters of the lagoons. However, study has shown that the "depauperate" fauna consists mostly of normal-size individuals of species that never grew any larger.
Shale, gray, sandy at top; contains marine fossils and ironstone concretions, especially in lower part.

Limestone; contains marine fossils.

Shale, black, hard, laminated; contains large spheroidal concretions and marine fossils.

Limestone; contains marine fossils.

Shale, gray; pyritic nodules and ironstone concretions common at base; plant fossils locally common at base; marine fossils rare.

Coal; locally contains clay or shale partings.

Underclay, mostly medium to light gray but dark gray at top; upper part noncalcareous, lower part calcareous.

Limestone, argillaceous; occurs in nodules or discontinuous beds; usually nonfossiliferous.

Shale, gray, sandy.

Sandstone, fine grained, micaceous, and siltstone, argillaceous; varies from massive to thin bedded; usually has an uneven lower surface.

AN IDEALLY COMPLETE CYCLOTHEM
(Reprinted from Fig. 42, Bulletin No. 66, Geology and Mineral Resources of the Marseilles, Ottawa, and Streator Quadrangles, by H. B. Willman and J. Norman Payne)
PHYSIOGRAPHIC DIVISIONS OF ILLINOIS

Reprinted 1970

[Map of Illinois showing physiographic divisions with labels for each province and sections.]
GEOLOGIC MAP OF ILLINOIS
showing
BEDROCK BELOW
THE GLACIAL DRIFT
1970
(From Willman and Frye, 1970.)

Pleistocene and
Pliocene not shown

TERTIARY

CRETACEOUS

PENNNSYLVANIAN

Bond and Mattoon Formations
Includes narrow belts of older formations along
La Salle Anticline

PENNNSYLVANIAN

Carbon and Modesto Formations

PENNNSYLVANIAN

Caseyville, Abbott, and Spoon
Formations

MISSISSIPPNIAN

Includes Devonian in Hardin County

DEVONIAN

Includes Silurian in Douglas, Champaign, and western
Rock Island Counties

SILURIAN

Includes Ordovician and Devonian in Calhoun, Greene, and Jersey Counties

ORDOVICIAN

CAMBRIAN

Des Plaines Complex - Ordovician to Pennsylvanian
Fault