The Erie Lobe Margin in East-Central Indiana During the Wisconsin Glaciation[1]

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Abstract

The ice sheet that deposited the Trafalgar Formation during the Tazewell Subage became inactive east of White River after building the Knightstown Moraine and disappeared by downwasting. Patches of low-relief ice-disintegration hummocks cover much of the Tipton Till Plain in east-central Indiana south of the Union City Moraine, where kames, eskers, and ice-walled disintegration channels are the dominant geomorphic features of the landscape. The low Union City Moraine marks the margin in east-central Indiana of the Lagro Formation, a till sheet deposited by the Erie Lobe during the Cary Subage of the Wisconsin (glacial) Age. The moraine disappears as a recognizable topographic feature across Delaware County because in that region the Erie Lobe ice rode over the thin sheet of stagnant ice that still remained from the earlier advance that deposited the Trafalgar Formation.

Introduction

The topographic features produced by melting ice in east-central Indiana—particularly in and around Muncie—have intrigued geologists for nearly a century. Phinney described them in two reports published in the 1880's, in which he recognized the esker system at Muncie and described but did not name the moraines of that area (12, 13). He regarded the eskers and troughs to have been formed by feeder channels for the flood of "Collett's Glacial River" farther south.

Leverett, who devoted nearly his lifetime to study of the glacial deposits of the central United States, mapped and named a narrow ridge across Randolph County, the Union Moraine (9, pp. 475-494, pl. 11). He was not willing to call the feeble development of a ridge northwest of Muncie a moraine, and his 1902 map showed a moraine only east of that city. He did indicate, though, that he thought it represented an ice-marginal position for a brief time. Later (10, pl. 6) he corrected the name to Union City Moraine and mapped the position across the state as a narrow moraine, but he evidently regarded it to be an insignificant strip of undulating drift that was part of the "Bloomington Morainic System" of Leverett (8, p. 113).

Malott (11, p. 151) believed that the weakly developed rise called the Union City Moraine was related to the other larger Erie Lobe moraines to the east and called the Union City the edge of the "late Wisconsin differentiated lobes" (11, pl. 3). His interpretation was based principally on the parallel and concentric orientation of the group of moraines.

Buckhannon and others (1) recognized a distinction in the texture and composition of the soils of northern and southern Randolph County. They drew their boundary along the south edge of the Union City

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Moraine. Farther east, in Ohio, the south edge of the Union City Moraine is mapped as representing a significant ice border position (4), and Ohio glacial geologists find the surface till to be more clayey to the north of that line.

Wayne and Thornbury (22, p. 14, 18) were unable to recognize the more clay-rich till of the Erie Lobe west of the Mississinewa Moraine in Wabash County, and they found a notable difference in depth of leaching of carbonates on either side of that boundary, so they regarded the Mississinewa Moraine to be the limit reached by the Erie Lobe during the Cary Subage. Thornbury and Deane (17, p. 24, 38) evidently found no evidence in Miami County to cause them to dispute this interpretation.

Thornbury (16, p. 457) later thought it more likely that the Union City Moraine marked the margin of the Cary drift, thus reasserting Malott's interpretation. My 1958 map (18) showed a "significant ice-marginal position" along the Union City Moraine, but I remained unconvinced that Erie Lobe till lithologies could be traced southwest of the Mississinewa Moraine except near the eastern edge of the State. I mapped the overlap of the Lagro Formation only as far as that boundary (19, p. 43-44, fig. 5). Wayne and Zumberge (24, p. 71) suggested, however, that the Union City Moraine probably was part of the same sequence that included the Mississinewa and younger moraines.

During the summer of 1966, new field work was undertaken in west-central Indiana in preparation of more accurate maps to be used in compilation of the glacial geology part of the Muncie Regional Geologic Map. Many new exposures, a careful reexamination of older exposures in critical places, and the availability of modern topographic maps coupled with stereoscopic examination of aerial photographs and the use of a soil auger to check lithologies between exposures has permitted me to gain enough new data to justify a reinterpretation of the significance of the Union City Moraine and related deposits. During the summers of 1966 and 1967, I was capably assisted in both airphoto study and soil auger manipulation by Mr. Robert Nicoll.

Geomorphic Development of the Tipton Till Plain

Central Indiana was covered during the most extensive glaciation of the Wisconsin Age by ice of the East White Sublobe of the coalesced Ontario-Erie and Huron-Saginaw Lobes. High bedrock along both the eastern and western sides of the state caused interlobate reentrants to form there, thus separating the East White Sublobe from the Miami Sublobe in Ohio and from the Lake Michigan Lobe in Illinois. Although gross aspects of the glacial history are similar from lobe to lobe, details as interpreted from stratigraphic and physiographic evidence differ.

Active ice and the older moraines. The advance of the glacier to its maximum position has been dated by radiocarbon analyses of wood from beneath the till it deposited at about 21,000 years B.P. (before the present, or more specifically, before 1950). Almost immediately the ice margin melted from this position of greatest advance and a pioneer community of vegetation, most likely subarctic and northern open-land

grasses and small shrubby plants, began to grow in favorable spots on the newly emergent land surface (21). When the glacier margin readvanced again, large quantities of outwash sand and gravel were deposited as broad plains and valley trains on the recently deglaciated till surface, particularly near the Wabash and White River valleys. Loess blown from these sediments accumulated on nearby areas along with some of the plants and snails that lived there. This veneer of silt with its incorporated fossils was buried beneath the ice during its readvance, as were the outwash deposits from which the silt was blown. Wood fragments from the silt, called by Wayne (19) the *Vertigo alpestris oughtoni* bed and regarded by Gooding (5) to represent an interstadial phase of the Wisconsin glaciation that he named the Connersville Interstade, have been dated by their radiocarbon content at 20,000 years B.P.

The Shelbyville Moraine, across much of Indiana a weakly developed end moraine that exhibits minor kame and kettle topography in some places, marks the earlier and more extensive of these two ice advances both of which fall within the limits of the Tazewell Subage. A more massive morainal system was built during the advance of the glacier that buried the *Vertigo alpestris oughtoni* bed. Although it had for half a century been correlated with the Champaign and Bloomington Moraines of Illinois, physiographic and stratigraphic evidence show that this morainal complex truncates the Champaign, Bloomington, and Normal ridges of the Lake Michigan Lobe and may be correlative with the younger Chatsworth Moraine (20). The outer morainal belt was renamed the Crawfordsville Moraine, and a younger belt northeast of the great outwash plains along the East Fork of White River was called the Knightstown Moraine. The Knightstown Moraine may represent one or as many as three recognized ice-marginal positions northwest of the East Fork of White River (fig. 1).

The direction of ice motion of the East White Sublobe was recorded by two sets of lineal features that cross the nearly flat till plain (15). One group of lineations, shallow flutes with intervening broad ridges that resemble very long and low drumlinoid features, are readily evident on topographic and soils maps of Cass, Carroll, and Howard Counties but are barely perceptible from a ground examination. These features were produced by an active glacier, as were the moraines and outwash plains. The low drumlinoid ridges have been recognized only in the area between the Wabash River and White River. The other set of lineal landforms is a group of eskers and esker troughs that fan out through the Crawfordsville Moraine. Even though eskers are the remains of subglacial streams and are normally preserved only by stagnant ice, they undoubtedly came into existence while the ice was still active and their trends thus parallel reasonably well the direction of ice motion.

The remarkable flatness of the till plain surface is largely a result of mass wasting that took place after the glacier melted and before the new land surface had been blanketed by a full vegetation cover. Cross-sections through the areas of light and dark mottling of the present

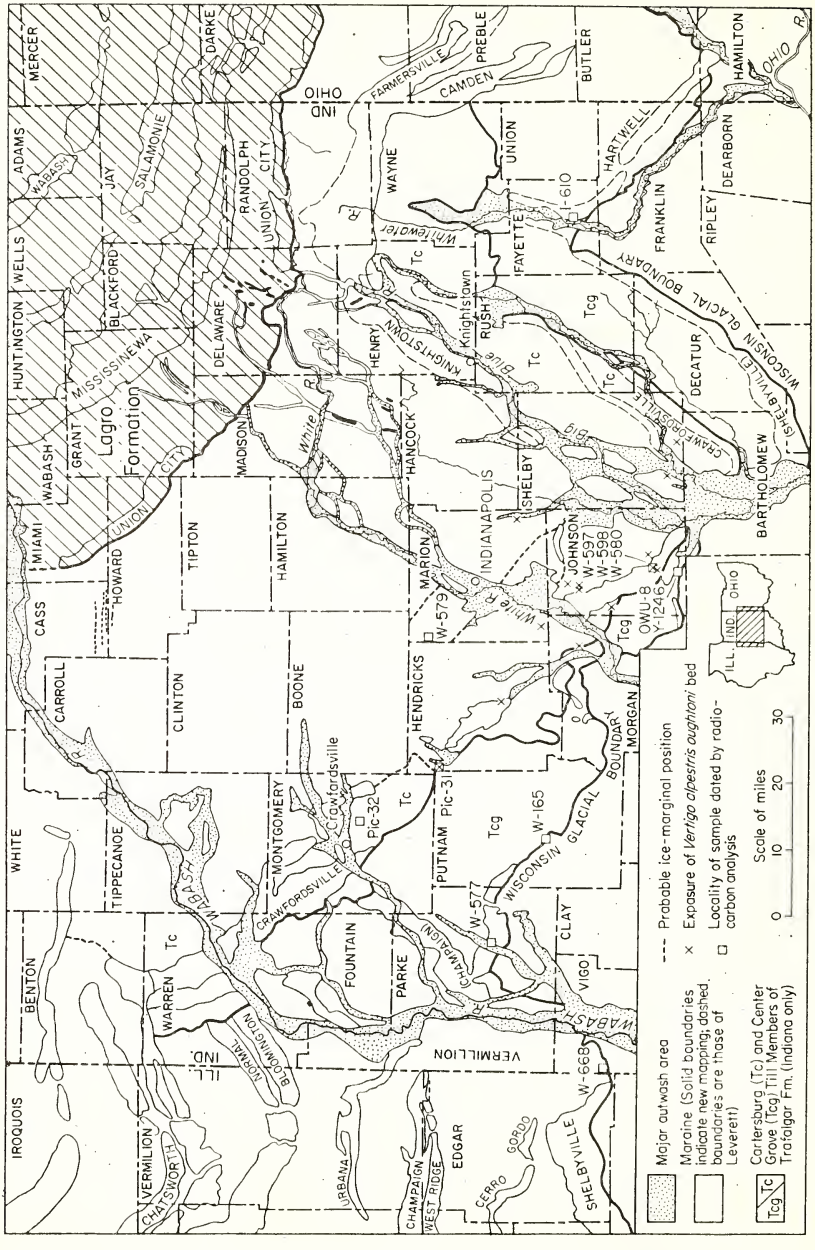

Figure 1. Glacial geomorphology and Pleistocene stratigraphy of central Indiana. Heavy lines indicate limits of the members of the Trafalgar Formation and of the Lagro Formation. Eskers in Delaware, Madison and northern Henry counties shown in solid black. Modified from Wayne, 1965, fig. 2.

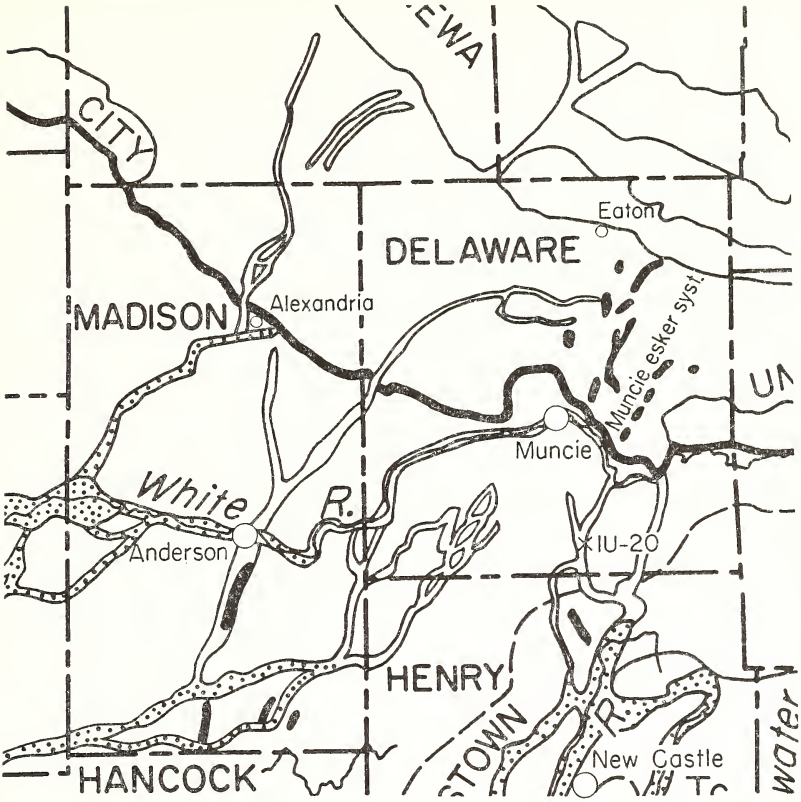

Figure 2. Major geomorphic elements of Delaware and Madison County area (enlargement of part of figure 1; for explanation see figure 1).

surface show that relief was considerably greater when the ice disappeared than it is now. Early in the postglacial history of the till plain solifluction undoubtedly was the dominant process; thus the low areas on the till surface were filled and a surface of almost no relief came into existence soon after the land became free of ice.

Disappearance of the ice lobe. Southeast of White River the Tipton Till Plain is characterized by a large number of shallow anastomosing channels, some of which now are the courses of modern streams and some of which carry no surface drainage. Eskers are present in or along some of the channels and are particularly notable in parts of Madison, Hamilton, Hancock, Henry, and Delaware Counties (fig. 1, 2).

Some of the streamless troughs that anastamose across the Tipton Till Plain are clearly part of a system of sluiceways that carried meltwater from the glacier; they connect with larger sluiceways and are floored with outwash sand and gravel, although they may have a veneer of alluvium or muck. Others have irregular courses that can be followed short distances but end without seeming to join another watercourse.

Most of the channels of this kind are partly filled with organic sediments, silt, or clay, which may with equal frequency be found to overlie till or gravel and sand. Channels of this kind are more or less parallel, although some are connected angularly by minor intersecting channels.

Broad open troughs such as these were described by Gravenor and Kupsch (6, p. 55), who regarded the ones they studied in Saskatchewan to be erosional features formed by meltwater during the decay of a mass of stagnant ice. Most of the ice-walled channels that cross the till plain in east-central Indiana probably formed first in tunnels through and under dead ice but became open ice-walled valleys in the last phases of their existence. The valleys now followed by Big Blue River and Flatrock Creek probably owe their positions and present form to former ice marginal streams, but may have originated under ice (14, p. 11-14, 34). The Buck Creek-Big Blue River trench retains its ice-walled valley morphology to a point well south of the divide. Some, such as the trenches near Springport in northern Henry County, rise into some scattered kamelike gravel mounds at their southern ends and may have formed entirely in closed tunnels.

The divide between southward-flowing Big Blue River and northward-flowing Buck Creek is in the middle of a flat-bottomed trench more than a half mile wide that passes through the Knightstown Moraine in the north edge of Henry County. From the divide southward the valley of Big Blue River takes on increasingly the shape of a glacial sluiceway. North of the divide the trench of Buck Creek is one of several similar valleys cut by southward flowing streams of glacial meltwater that undoubtedly flowed through subglacial tunnels.

The trench floor now has a northward gradient that originated by subglacial erosion but has been smoothed by postglacial deposition on the originally uneven floor of the trench. Excavations, ditch bank exposures, and auger borings along Buck Creek show that in some places a thin cover of muck and alluvial sand and silt lies directly over till or outwash; elsewhere lenses of marl and peat exceed 10 feet in thickness.

Studies of the snails in a bed of late glacial alluvial sand and silt exposed along the bank of Buck Creek one mile north of the Delaware-Henry county line suggest that Buck Creek and other similar trenches remained a series of sloughs and ponds for several thousand years after active ice had disappeared from the area. A radiocarbon date from a piece of coniferous wood collected from the base of the 90 cm. thick bed of late-glacial fossiliferous silt along Buck Creek gave a 10,150 $\pm$ 250-year B.P. age (IU-20).

Stereoscopic study of airphotos has shown that the surface of the till plain in east-central Indiana is covered in many places with patches of low hummocky microtopography that is almost undetectable on the ground. The soil pattern in these patches resembles the pattern of knob and kettle topography in contrast to the broad light and dark mottling characteristic of most of the till plain. The areas that exhibit the hummocky pattern seem to follow no definite trend, and the margins of many of them grade imperceptably into non-hummocky till plain. Excavations and hand-auger cuttings show that the surface ma-

terials in the hummocky patches consist of loose till mixed with thin layers of crudely water-washed sediments, a composition that readily fits the standard concept of ablation till (3, p. 120-122).

Harrison (8) recognized similar landforms in Marion County and compared them with some of the geomorphic elements produced by stagnant ice described by Gravenor and Kupsch (6) from Sasketchewan. Although their relief is slight, the features of the till plain in east-central Indiana resemble those of an uncontrolled hummocky disintegration moraine of low relief. Such disintegration features are formed as a result of the decay of masses of stagnant ice. A hummocky pattern resulted from local washing and sloughing that took place when buried ice supporting englacial and superglacial debris melted.

In contrast to the interpretation offered for higher relief dead ice moraines of the Missouri Coteau, which are thought to represent the collapse of thick superglacial till (2), the extremely low relief (less than 10 feet) of the disintegration moraine of the east-central Indiana till plain probably resulted from the decay of ice that carried a large basal load but had little surface debris.

Along the Missouri Coteau, active ice is thought to have continued to bring large amounts of subglacial drift-filled ice to the top of the glacier along thrust planes where it provided a thick, insulating blanket of superglacial drift that eventually collapsed when the buried dead ice melted, whereas in central Indiana the entire lobe became stagnant and melted in place. Low relief disintegration features in Indiana began to come into existence after the clean ice in the upper part of the glacier had melted and only the relatively thin debris-charged basal zone remained to ablate.

The Erie Lobe Drift

Moraines of the Erie Lobe form an arcuate series of concentric ridges that mark the positions of the ice margin at successively younger stands. The moraines in this series are the Union City, Mississinewa, Salamonie, Wabash, and Fort Wayne in Indiana and the Defiance in Ohio.

The Union City Moraine. The outermost moraine of this group, the Union City Moraine, is an insignificant looking feature, but it represents a major re-expansion of glacial ice into east-central Indiana. The distal margin of the moraine marks the limit of overlap of a clay-rich till sheet, the New Holland Till Member of the Lagro Formation, onto the older Trafalgar Formation, a much sandier and stonier silty till. Named from Union City on the Indiana-Ohio state line, where it stands as a distinct though narrow ridge, the moraine becomes almost unrecognizable across Delaware County and forms only a slight rise in Madison County northwest of Alexandria, but the thin till sheet it bounds is present as a distinctive and mappable stratigraphic unit.

Its clay-rich lithology contrasts greatly with the underlying sandy and silty till. Reexamination of western Wabash County road cuts indicates that the clayey till is present there, but is generally less than 3 feet thick, thus within the leached portion of the soil profile. The

stagnant ice features on the surface of the Trafalgar Formation in east-central Indiana take on a different appearance north of the boundary of the Lagro Formation. Patches of low relief disintegration hummocks that characterize the surface of the Trafalgar Formation are drained internally; in contrast similar features that have been recognized on the Lagro are part of an embryonic surface drainage system. The differences in lithology clearly correlate with differences in permeability, thus differences show up in the landforms and their appearance on airphotos. In addition to a few long, narrow, shallow, generally till-floored channels that cross the till plain between the Union City and Mississinewa Moraines and several large shallow boggy areas, two other groups of geomorphic features ascribable to glacier stagnation are present in that area. These are the Muncie esker system and a pair of ice-walled troughs in southern Grant County.

The Muncie esker system. The esker system east and north of Muncie is a series of disconnected ridges and hills of gravel that extends from the south edge of the Mississinewa Moraine southward to White River east of Muncie, where it runs into a complex group of disintegration channels and small esker fragments that lead southward to the broad valley train of Big Blue River (fig. 2). The parts of the Muncie esker system meander somewhat, but the main trend is S 10° W from its beginning east of Eaton to its diffuse terminus east of Muncie. Along this course it is joined by segments of several small eskerine tributaries. The main trend of the esker system is parallel to the dominant trend of the ice-walled disintegration channels south of the margin of the Lagro Formation between Muncie and Newcastle and to the trend of the large esker just south of Anderson (fig. 2).

Most of the segments of the esker system near Muncie have a cover of 4 to 15 feet of clayey till lithologically similar to that of the Lagro Formation. Although patches of till are reasonably common on eskers, this particular till cover is unusual enough to warrant further study of the conditions of deposition.

The Erie Lobe evidently carried little coarse material in its advance that deposited the Lagro Formation in eastern Indiana. As a result, few extensive outwash deposits or kames and eskers are associated with the till of the Lagro Formation. Both eskers and large amounts of coarse outwash sediments are commonly found with the till of the Trafalgar Formation, however.

The Muncie esker system as well as the pair of disintegration trenches in Grant County are aligned with eskers and disintegration channels south of the Union City Moraine. In contrast, the very shallow and narrow channels of the rest of the outer part of the Erie Lobe tills seem to be part of a system that crosses this alignment in many places and only locally coincides with it. To consider the Delaware County esker system and the Grant County trenches as geomorphic elements of the earlier ice advance that left the Trafalgar tills would seem a reasonable hypothesis, but if these features existed at the time the Erie Lobe ice expanded to the Union City Moraine, the overriding ice sheet should have extensively modified or destroyed them. Neither has taken place.

The Erie Lobe tills have long been regarded as considerably younger than the Wisconsin tills south of their overlap. The principal argument for this age differentiation has been based on the nearly perfect elliptical boundary of the lobe and the series of moraines that mark its successive positions. To have produced such a smooth boundary probably would have required the earlier ice to have melted and the readvance to have begun well within the area of the present Lake Erie basin. The length of time for this to take place was variously estimated in the range of several thousand years prior to the use of radiocarbon to date the bulk of Wisconsin deposits, but the total time available for the many fluctuations of the Wisconsin glacier across the Indiana landscape has been compressed into a brief 6,000 years. Ice began to build the Crawfordsville Moraine 20,000 years ago, and by 14,000 years ago the active margin of the glacier had melted to some point east of the Wabash Moraine. Such a short time helps explain the absence of either a weathering profile or remains of vegetation along the contact between the Trafalgar and Lagro Formations.

Geomorphic evidence seems to indicate that the ice that deposited the younger tills of the Trafalgar Formation disappeared by stagnation. Even though active ice began to readvance through the Lake Erie basin, it probably required several hundred years or longer to reach its maximum extent. During this time little soil formation would have taken place in the area into which the Erie Lobe expanded because it still lay beneath the decaying remains of the earlier ice lobe.

Stagnant Ice and the Erie Lobe Margin

Geomorphic features along the margin of the till sheet indicate that little remained of the Tazewell dead ice mass between the Wabash River and Alexandria in northern Madison County by the time the Erie Lobe glacier built the weak Union City Moraine, which probably marks the maximum extent of ice into east-central Indiana during the Cary Subage. Lack of any evidence of weathering or the remains of vegetation along the contact between Lagro and Trafalgar tills suggests that the ice had not been gone long. In northern Delaware and southern Grant Counties, though, the greatly thinned and heavily drift-charged remains of the earlier glacier probably still remained. I believe that the esker system near Muncie existed as gravel fill in an open ice-walled channel through which meltwater and rainfall drained from the stagnant ice. The double trench in southern Grant County probably was the site of a subglacial tunnel.

The stream that flowed through the ice-walled channel in which the Muncie eskers and kames formed may have trenched its course far enough below the original upper level of esker fill that soil development had begun on the sandy sediment at the top of the esker. In two places a thin brown noncalcareous zone that resembles a profile of weathering has been discovered on sand that lies beneath 8 to 10 feet of calcareous Lagro Formation till (23, p. 22). In one of the thin embryonic paleosols, exposed in 1951 in the upper part of an elongate kame 2 miles southeast of Eaton, a tubular inclusion in the sand filled with poorly stratified clayey till was buried beneath 8 feet of clayey

Lagro till (fig. 3). The most likely explanation for the tubular inclusion is to consider it a former animal burrow. The development of weathering features like these and the excavation of the burrow probably took place after the esker tunnel became unroofed, and they were preserved because the ice walls of the disintegration channel still remained to form a ramp across which the active Erie Lobe ice moved. The dead ice need not have been more than 60 to 70 feet thick at that time. The thinness of the Lagro till sheet (generally no greater than 10 feet under the till plain between the Union City and Mississinewa Moraines and less than 5 feet over much of western Wabash County) strongly suggests that the depositing ice sheet could not have been thick (7). Relatively thin and highly mobile ice carrying a debris load that was dominantly clay and silt could have spread across a thin mass of dead ice highly charged with stony and sandy drift without causing the stagnant ice to become active again. Reactivation of the ice would have destroyed the esker rather than allow it to remain and become blanketed with the younger till.

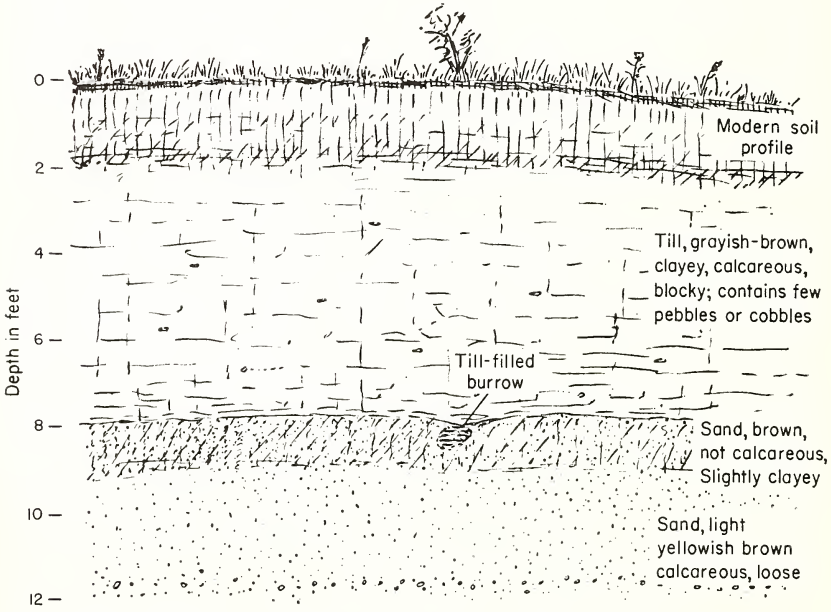

Figure 3. Lagro Formation clayey till over weathered sand with a till-filled tubular inclusion (burrow?); overburden at gravel pit in segment of Muncie esker system 2 miles southeast of Eaton (sketched from photographs taken in September 1951).

Irregularities on the surface of the stagnant ice probably were planed off or obscured by the base of the overriding ice sheet. The Union City Moraine represents only a slight thickening of Erie Lobe till, thus it shows up as a very low rise on the level till plain in Madison, Grant, and Howard Counties. The rise is almost completely obscured

across Delaware County where the Erie Lobe crossed dead ice. The irregularity of topography produced by the melting of the underlying ice masked the low, smooth rise of the Union City Moraine. The small amount of till left by the Erie Lobe on top of the thin debris-laden dead ice that it overrode was inadequate to produce the effect of collapsed sediments that seem to be so abundant in North Dakota, although some minor stagnation landforms were produced in the overlap area when thin ice melted.

Summary

The Union City Moraine is an insignificant-looking low rise that marks the boundary of a major reexpansion of Erie Lobe glacial ice into east-central Indiana during the Wisconsin glaciation. It marks the limit of overlap of a clay-rich till sheet, the New Holland Till Member of the Lagro Formation, onto the slightly older stony and sandy till of the Trafalgar Formation. The surface of the Trafalgar Formation in east-central Indiana is covered with very low relief ice-disintegration ridges and hummocks discernable in airphoto study and is crossed by many shallow to deep ice-walled channels and eskers that give the topography of southern Delaware County a rugged aspect. Most of the ice-walled channels end at the proximal edge of the Knightstown Moraine. The pattern of these linear features outlines well the orientation of the ice lobe before it became stagnant. Two major esker systems, one at Anderson and the other at Muncie, are part of this pattern, as is the set of till-, sand- and gravel-lined troughs that leads through the Knightstown Moraine into Big Blue River Sluiceway.

North of the edge of overlap by the Lagro Formation, ice-disintegration ridges change character because of the changes in till lithology, and long, narrow, shallow ice-walled channels extend across the till plain. These channels are floored with Lagro till, although in many gravel lies below the till, and some segments of the Muncie esker system are capped with the same till. Northwest of Alexandria the edge of the Lagro till is distinct and readily mapped along the low Union City Moraine but from Alexandria to eastern Delaware County the moraine ceases to look like an active ice feature and seems to merge with the dead ice topography of that region.

In its advance to the Union City Moraine, the glacier crossed terrain free of ice except for a few scattered blocks northwest of Alexandria, but from Alexandria to eastern Delaware County it probably overrode thin debris-charged stagnant ice. Gravel-filled channels in the dead ice mass were not destroyed by the overriding glacier, but a veneer of clayey till was spread over them as well as over the supporting stagnant ice. A thin and highly mobile ice lobe carrying a small debris load of silt and clay could have spread across thin dead ice heavily loaded with sandy and stony till without causing it to become active again. Such a history would account for the loss of active ice features along the Union City Moraine in Delaware County and the presence of Lagro till on most of the segments of the Muncie esker system.

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