
STRATIGRAPHY AND POLLEN ANALYSIS OF
YARMOUTHIAN INTERGLACIAL DEPOSITS IN
SOUTHEASTERN INDIANA¹

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ABSTRACT

Additional stratigraphic study and pollen analysis of organic units of pre-Illinoian drift in the Handley and Townsend Farms Pleistocene sections in southeastern Indiana have provided new data that change previous interpretations and add details to the history recorded in these sections. Of particular importance is the discovery in the Handley Farm section of pollen of deciduous trees in lake clays beneath Yarmouthian colluvium, indicating that the lake clay unit is also Yarmouthian. The pollen diagram spans a substantial part of Yarmouthian interglacial time, with evidence of early temperate and late temperate vegetational phases. It is the only modern pollen record in North America for this interglacial age. The pollen sequence is characterized by extraordinarily high percentages of *Ostrya-Carpinus* pollen, along with *Quercus*, *Pinus*, and *Corylus* at the beginning of the record; this is followed by higher proportions of *Fagus*, *Carya*, and *Ulmus* pollen. The sequence, while distinctive from other North American pollen records, bears recognizable similarities to Sangamonian interglacial and postglacial pollen diagrams in the southern Great Lakes region.

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The Kansan glaciation in southeastern Indiana as discussed by Gooding (1966) was based on interpretations of stratigraphy in three exposures of pre-Illinoian drift (Osgood, Handley, and Townsend sections; fig. 1). The Osgood section, a road-cut exposure, has been covered with sod since 1966 and has been unavailable for further study. The Handley and Townsend sections are stream bank exposures

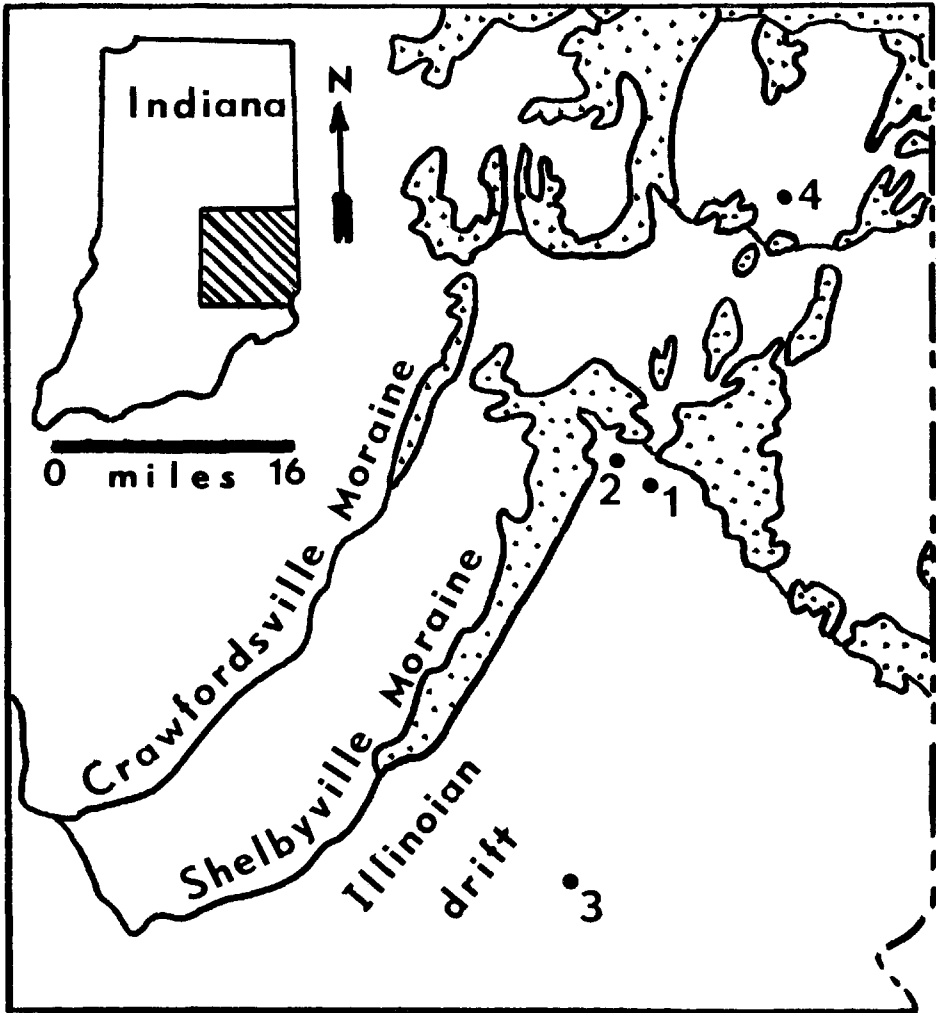


FIGURE 1. Glacial map of southeastern Indiana (from Indiana Geological Survey Regional Geologic Map No. 7, Cincinnati Sheet, Part B) showing locations of Handley section (1), Townsend section (2), Osgood section (3), and Smith and Darrah Farms sections (4).

subject to change through slumping and erosion, and have been examined periodically since 1966. An additional pre-Illinoian stratigraphic unit has been exposed by erosion since 1966 at Handley farm, and new information has been obtained by augering at the base of this exposure. Also, studies of pollen in organic sediments at both Handley and Townsend farm sites have resulted in important data concerning the Yarmouthian interglacial time, and have prompted a re-interpretation of the history of certain stratigraphic units.

GEOLOGY OF THE HANDLEY FARM SECTION

Stratigraphy. The Handley Farm section (fig. 1) is located about 1 1/3 miles south of the Wisconsin border on the south bank of the North Branch of Garrison Creek in Fayette County, Indiana, in the northwest corner of SW 1/4, Sec. 28, T. 13 N., R. 12 E., on the Alpine, Indiana, quadrangle. Restudy of this section has revealed some additional stratigraphic units not observed earlier (Gooding, 1966). Figure 2 compares the previously published description and classification of units in the Handley section (Gooding, 1966, pp. 427-28) with the present modified description and classification. The change from 1966 to the present in

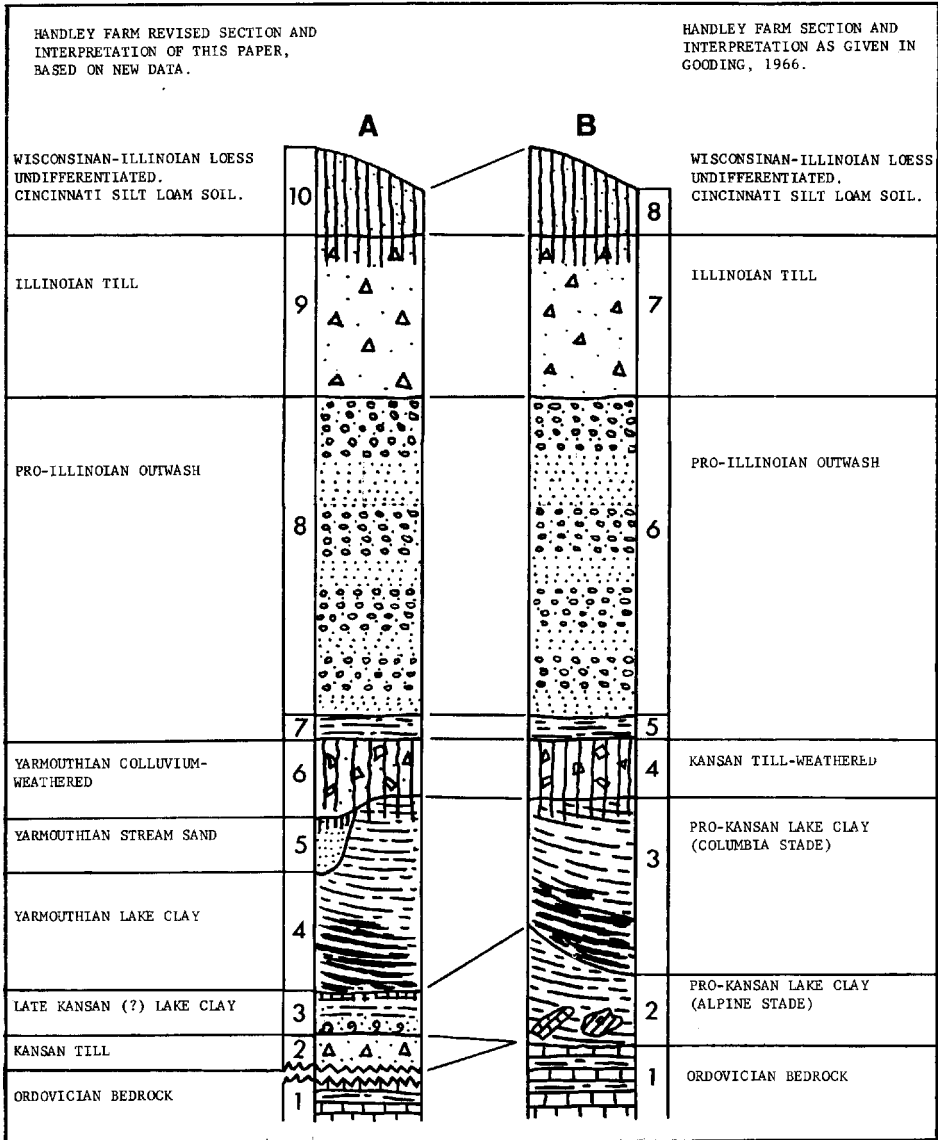


FIGURE 2. The Handley Farm section. Comparison of description and interpretation given in this paper (column A) with that published previously (Gooding, 1966) (column B).

the classification of stratigraphic units as shown in figure 2 is based on a re-interpretation of the origin and age of certain units in the light of pollen data to be discussed in this paper. The stratigraphic relationships and lateral occurrence of units in the Handley sections are shown in figure 3.

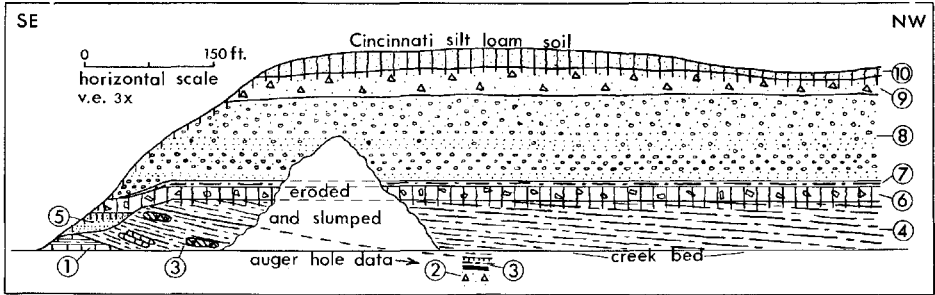


FIGURE 3. Field sketch of Handley Farm exposure, showing relationships of stratigraphic units described in this paper. Units 2 and 3 from auger hole data and unit 5 at the southeast end of the cut are additions to the section description previously given by Gooding (1966).

The revised description and classification of the Handley Farm section is as follows:

Unit	Thickness Meters	Description
Top of section is on an eroded ridge with Cincinnati silt loam soil.		
Wisconsinan-Illinoian loess undifferentiated, and Illinoian drift.		
10	1.2-2.4	Clayey silt, reddish-brown, noncalcareous; Wisconsinan-Illinoian loess undifferentiated.
9	4.6	Till, reddish-brown, noncalcareous in the top 1-4 ft (0.3-1.22 m). The rest of the unit is calcareous and buff (oxidized), except for the bottom 2-3 ft (0.61-0.92 m), which are gray (unoxidized) in places.
8	9.2	Gravel and sand, stratified, calcareous. The upper 5-10 ft (1.5-3.0 m) are firmly cemented into a conglomerate which stands out as a ledge on the slope.
7	0.6	Clay, calcareous, finely laminated.
Yarmouthian deposits and paleosol.		
6	0.9-1.5	Colluvium, brown to reddish-brown, very clayey, thoroughly weathered, noncalcareous. Chert residuum from local Silurian limestone extremely abundant in weathered clay matrix.
5	2.4	Sand, yellow, stratified, at east end of exposure. Top 2.0-2.5 ft (0.61-0.76 m) weathered and leached.
4	9.0	Clay, lacustrine, finely laminated; upper 1-2 ft (0.3-0.61 m) are leached base of Yarmouthian paleosol where directly overlain by weathered colluvial unit 6; remainder calcareous, gray to buff, massive, well jointed. Along joints, cementation by calcium carbonate, iron oxide, and manganese oxide has formed hard wedges. The face of the clay exposure shows good conchoidal fractures. Bottom 6 ft (1.83 m) of unit is black due to finely divided organic matter. At some horizons ostracods are abundant and small gastropods are common. Small fish scales and bones are also present. Pollen of deciduous trees occur throughout the unit.
Kansan drift (?)		
3	1.0-3.0	Clay, lacustrine, calcareous. Where 10 ft (3.0 m) of unit are exposed at southeast end of cut, unit seems to be separated from the overlying lacustrine clay unit 4 by a westward-sloping erosional surface, above and below which are many circular to elliptical finely ringed iron oxide

"Hiesegang" features that probably developed around former root tubes. This unit also contains several lenticular noncalcareous red clay masses full of chert fragments, and some slabs of local Ordovician limestone, completely surrounded by the lacustrine clay. These inclusions must have been rafted by ice from the shore zone and dropped in the lake. In places the lacustrine clay contains finely divided organic matter and abundant small snails and clams.

About midway along the exposure where the overlying unit 4 occurs at creek level, augering below creek level revealed 2.5 ft (0.76 m) more of dark, organic-rich unit 4 and 3.2 ft (0.99 m) of unit 3. In the core the upper 7 inches (0.18 m) of unit 3 is a pure weakly calcareous, very light gray clay. The remaining 2.6 ft (0.79 m) of unit 3 is calcareous and has several thin silt, sand, and pebble layers (the latter being mostly local Ordovician limestone pebbles). Mollusks and coniferous pollen are abundant in a silt layer near the bottom.

Kansan till		
2	0.16+	Till, gray calcareous; penetrated in auger hole.
Ordovician limestone		
1	2.1+	Limestone, bedrock, exposed at southeast end of exposure.

DISCUSSION

Weathered unit 6, which contains a few erratic quartzite pebbles and abundant locally derived chert, resembles weathered Kansan till at other localities in the area. Thus, unit 6 was interpreted as Kansan till weathered during Yarmouthian time (Gooding, 1966). The underlying lacustrine clay units 3 and 4, separated from each other by an erosional unconformity, were therefore interpreted as pro-Kansan in age, probably having formed by ice or valley-train damming of a valley by different Kansan ice advances recorded by two Kansan tills (units 1 and 3) in the nearby Townsend Farm section.

The Handley Farm section was one of the stops on the Great Lakes field excursion of the 1965 International Quaternary Association (INQUA). Dr. H. J. Beug, University of Göttingen, collected a "grab" sample of the lacustrine clay unit 4 and later, on his return to his laboratory, found it to contain pollen of deciduous trees. This prompted us to examine in detail the pollen in the lake clays (unit 3 and 4).

The Handley Farm section is exposed in a NW-SE-trending stream-bank exposure nearly 1200 ft long (fig. 3). At the southeast end of the cut, 10 ft (3.0 m) of lacustrine clay unit 3 lies directly on exposed Ordovician limestone. The contact between lacustrine clay units 3 and 4 slopes downward to the northwest (upstream) and goes below the stream bed about one-third of the distance along the exposure. Westward from this point, only lacustrine clay unit 4, whose laminae dip gently westward, is exposed at creek level. This succession of units was given in the earlier Handley Farm stratigraphic description (Gooding, 1966, p. 427-428 and fig. 3).

Samples of the lacustrine clays, to be used for pollen analysis, were taken at 2 in (.05 m) intervals at the northwest end of the cut from the weathered unit 6 downward through unit 4 to creek level, thence at lower levels downstream, and finally by augering at a point midway along the exposure (fig. 3). At the auger site, unit 3 was penetrated, but its thickness here beneath the erosional unconformity is reduced to 3.2 ft (0.97 m) and the top 7 in (0.18 m) are only weakly calcareous. Till unit 2 was encountered at the bottom of the auger hole.

The analysis of fossil pollen in the lacustrine clays of unit 4 in the Handley Farm section has yielded a pollen diagram (fig. 4) which reflects the vegetation of an interglacial age and permits a characterization of the vegetation of the depositional interval. Pollen analysis thus shows conclusively that lacustrine clay unit 4 is not proglacial in origin as originally interpreted (Gooding, 1966), but was deposited over a long time span during the Yarmouthian interglacial age. During the period of deposition, the temperature was equivalent to or warmer than the Sangamon interglacial age and postglacial time in the area.

A mollusk-rich layer near the bottom of unit 3 at the auger-hole site contains conifer pollen, recording evidence of a glacial climate at the time lacustrine clay unit 3 began to be deposited. Unfortunately, when pollen sampling for this study was done, the 10 ft (3.0 m) of unit 3 at the southeast end of the cut was badly slumped and could not be sampled. It is possible that the 10 ft (3.0 m) of unit 3 may contain a pollen spectrum showing the vegetational and climatic transition from late Kansan glacial to Yarmouthian interglacial time.

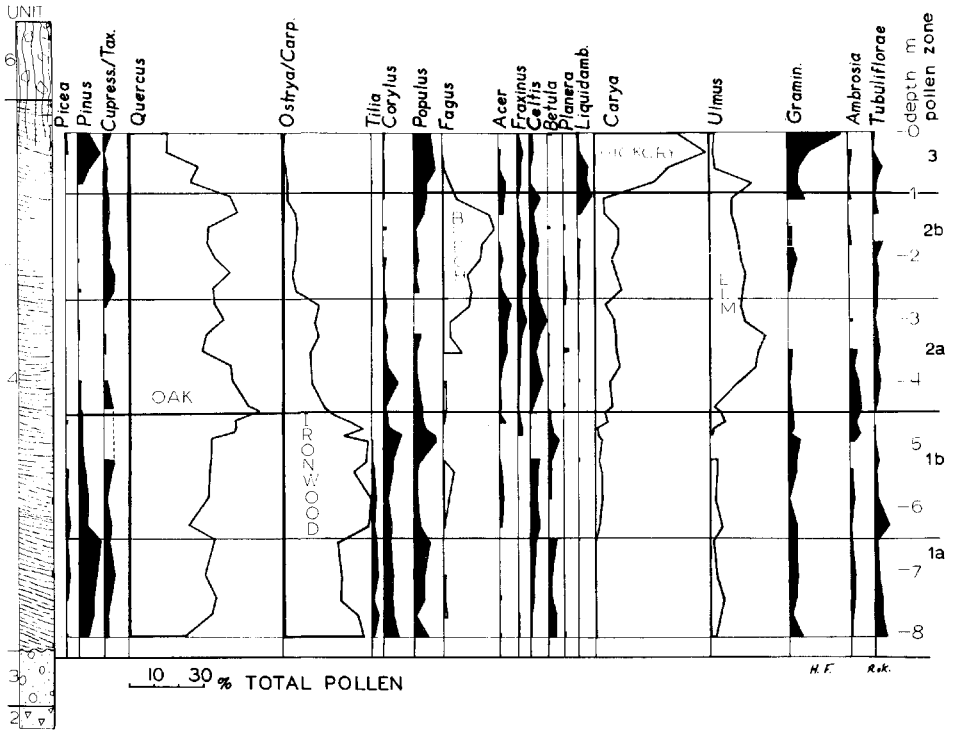


FIGURE 4. Pollen diagram through lacustrine clay unit 4, Handley Farm section.

The earlier interpretation of the till-like unit 6 as weathered Kansan till is obviously untenable, because the underlying lake clay unit 4 has been demonstrated by pollen analysis to be Yarmouthian in age. Unit 6 must be bedrock and/or Kansan till-derived colluvium that washed down from an adjacent slope onto lake-clay unit 4 during Yarmouthian time. Because weathering extends downward through colluvial unit 6 into the underlying Yarmouthian lake-clay unit 4, the weathering would have occurred during late Yarmouthian time. Thus, although lake clay unit 4 and the pollen spectrum derived therefrom are believed to represent a substantial part of Yarmouthian time, they do not represent the entire interglacial episode. Other Yarmouthian events were erosion of the lake clays, and deposition and partial weathering of alluvial sand unit 5, prior to covering by colluvial unit 6 (fig. 3).

HANDLEY FARM POLLEN DIAGRAM

Procedures. Samples of freshly exposed sediments were collected for pollen analysis at 5 cm intervals from the surface of the exposure near the northwest end

of the cut. Additional samples were retrieved through augering and from stratigraphically-lower units subsequently discovered downstream.

All samples were macerated mechanically and treated with 6% HCl followed by concentrated HF. Standard acetolysis treatment was used and the residue suspended in glycerine jelly. All samples were calcareous, showing a vigorous reaction with dilute HCl.

Pollen samples were counted under oil immersion (950X) along traverses so spaced that an entire slide was covered while identifying a minimum of 200 grains per sample. Percentages of each pollen type were calculated; the numerical basis for the pollen sum was all tree, shrub and herbaceous pollen, excluding aquatic pollen types. A table recording the count tally from each stratigraphic level is available from the authors. The percentage pollen spectra from each of the levels have been plotted in a pollen diagram (fig. 4); palynological data from certain noncontiguous levels are not presented in the diagram.

Results. The Yarmouthian interglacial pollen diagram (fig. 4) may be divided into three major pollen zones and additional subzones. However, certain pollen types transcend these zones. With the exception of the uppermost samples, *Quercus* (oak) pollen is present in rather uniform percentages (25%) throughout the diagram. Pollen of aquatic plants (*Potamogeton*, *Typha*, *Sparganium*, *Myriophyllum*) and *Equisetum* spores are found in low proportion (2-7%) in all zones, except these types are at low levels (0-1%) at the boundary of subzones 1a/1b (2-3M).

Remains of the colonial green alga, *Pediastrum*, were present throughout the section; at least two species appeared to be present. One type, with a single, long protuberance on the marginal cells, was very abundant in the lower sediments; a second type, the margin cells bearing two low protuberances, is present in small numbers throughout most of the section and increases to dominance in certain of the top samples.

Pollen Zone 1. The lower sediments of stratigraphic unit 4 are characterized by very high percentages of *Ostrya-Carpinus* (ironwood) pollen (20-35%), consistent representation of *Tilia* (basswood), and prominence of *Corylus* (hazel), *Populus* (aspen, cottonwood), *Betula* (birch) and *Pinus* (pine) pollen. *Ulmus* (elm), *Fagus* (beech), *Carya* (hickory), and *Fraxinus* (ash) pollen is poorly represented or absent.

The lowermost samples are designated pollen subzone 1a and are characterized by the virtual absence of *Carya* and *Acer* (maple) pollen and higher percentages of *Pinus* than the subzone above. *Ostrya-Carpinus* is somewhat less abundant than in 1b. NAP (non-arboreal pollen), dominated by composites, averages 10%.

Subzone 1b has less *Pinus* pollen, declining proportions of *Tilia*, the last significant representation of *Picea* (spruce) and *Betula*, and the first evidence of *Carya* pollen. *Ostrya-Carpinus* pollen is consistently above 25% and reaches a maximum of 36%.

Pollen Zone 2. *Ostrya-Carpinus* pollen declines, initially to about 15% in subzone 2a then to about 5%. This change is accompanied by increases in *Ulmus*, *Carya*, *Fraxinus*, *Acer*, *Celtis*, and, especially in subzone 2b, *Fagus* pollen. *Pinus* pollen is nearly absent and NAP pollen types reach minimum levels (5-6%); grasses and other open-vegetation types are notably sparse. Although present in low frequency, the regular representation of *Planera* (water elm) and *Liquidambar* (sweet gum) is significant in that it marks the migration of these southern deciduous species into the locale.

Pollen Zone 3. This pollen zone is nearly coincident with the zone of soil weathering (the uppermost part of unit 4) and in many samples the pollen grains are partially degraded. Evidence of differential degradation among the pollen types was sought during the counting process; while differential loss cannot be discounted as an influence on the upper pollen spectra, we have no evidence that

it has a significant or predictable influence on these data. The diversity of the pollen spectra and persistence of thin-walled, fragile types (such as *Populus* and *Cupressaceae*) further suggests that weathering and degradation has not been so severe as to nullify the significance of the differences noted between zones II and III.

The sharp increase in pollen of *Carya*, *Populus*, *Pinus* and Gramineae (grass) is accompanied by reciprocal decreases in *Ostrya-Carpinus*, *Fagus*, *Ulmus* and *Quercus*. NAP increases from about 5% at the base of the zone to 25% in the uppermost sample. *Picea* (spruce) pollen re-enters the record and individual grains of *Tsuga* (hemlock), *Larix* (tamarack), and *Ilex* (holly) were identified. *Pediastrum* is abundant in the uppermost samples.

Other pollen data. Dr. Hans J. Beug (*in Litt.* November 19, 1965), of the Systematisch-Geobotanisches Institut of the University of Göttingen, Germany, reported pollen counts from a sample taken 11 October 1965 on INQUA Field Trip G at the Handley Farm Section. The counts submitted were calculated on the same basis as the pollen diagram (fig. 4) and are as follows:

	Pollen %
<i>Quercus</i>	30.2
<i>Corylus</i>	23.6
<i>Carpinus-Ostrya</i>	14.7
<i>Betula</i>	6.7
<i>Pinus</i>	4.3
<i>Alnus</i>	3.5
<i>Ulmus</i>	3.7
<i>Carya</i>	2.9
<i>Celtis</i>	1.6
<i>Picea</i>	1.2
Cupressaceae-Taxaceae	1.2
<i>Fagus</i>	1.0
<i>Fraxinus</i>	0.4
<i>Tilia</i>	0.4
<i>Salix</i>	0.4
Moraceae	0.2
<i>Platanus</i>	0.2
Gramineae	0.2
Cyperaceae	1.6
<i>Artemisia</i>	1.0
Other compositae	0.6
Unbelliferae	0.2

The following aquatic types were also counted: *Potamogeton* (0.8%) and *Nymphaea* (0.2%). *Acer* and *Larix* were observed, but were outside the count. The sample examined by Dr. Beug corresponds well to pollen zone 1, although the proportions of *Corylus* and *Ostrya-Carpinus* are not identical.

Samples analyzed from the uppermost weathered portions of unit 4 yielded quantities of pollen which were too small for reliable percentage counts or inclusion in the pollen diagram. The fragmentary data verify that the pollen zone 3 assemblage (*Carya*, *Ulmus*, *Pinus*, *Planera*, Gramineae, etc.) and lake conditions (e. g., with *Pediastrum*) extend to the top of stratigraphic unit 4.

Samples retrieved by augering below the level of the pollen diagram indicate that the deciduous assemblage (pollen zone 1a) continues downward to the base of unit 4. Gray clay samples from the Kansan drift (?), unit 3, were devoid of pollen, while a sample of silty gray clay near the bottom of unit 3 contained sparse, poorly preserved coniferous pollen (*Picea* predominant, with *Pinus* and *Larix*), occasional, unidentified Paleozoic(?) spores and some *Pediastrum*. This is doubtless a fragmentary record of a Kansan interstadial or late-glacial period.

Correlation with Interglacial Phases and Other Sites. Since no other Yarmouthian pollen records exist in North America, comparisons with correlative interglacial sequences are impossible. Studies of the equivalent interglacial age

(penultimate) in Britain (Hoxnian) and Northern Europe (Holsteinian or Needian) are only generally instructive. By this mid-Pleistocene interglacial age warm-temperate European tertiary relicts such as *Carya*, *Pterocarya* and *Tsuga* are no longer found in North European interglacial pollen records (Zagwijn and Zonneveld, 1956; Zagwijn, 1963).

West (1956; 1958; 1961; West and McBurney, 1954) has completed pollen analysis on Hoxnian interglacial deposits in England and describes four major vegetational phases: I. Late glacial (open vegetation, high NAP, scattered *Betula*), II. Early temperate (mixed oak forest of *Quercus*, *Alnus*, *Ulmus* and *Tilia*, accompanied by *Corylus*, with *Pinus* and *Betula* well-represented only at the beginning of the stage), III. Late temperate (mixed oak forest replaced by *Carpinus* and conifers), and IV. Early glacial (park-tundra with scattered forest, including dwarf willows and birch). The Hoxnian interglacial, at its climatic optimum in stage II and in the beginning of stage III, was characterized by an oceanic climate which was much more moderate than at present. The occurrence together of pollen of such evergreen genera as *Taxus*, *Abies* and *Ilex* appears to be characteristic of this interglacial and indicates that oceanic conditions extended from the British Isles into Northern and Central Europe as far east as Poland (West, 1962).

Turner and West (1968) proposed the following generalized four-phased vegetational sequence as typical of interglacial ages in England: phase I, a pre-temperate phase, marks the late glacial; phase II, the early temperate, and phase III, the late temperate, represent the interglacial proper; and phase IV, the post-temperate, records the onset of the next glacial age. Wright (1972) discussed the applications of this generalized sequence to Sangamonian interglacial and Holocene records from North America.

Comparisons may be made between the Handley Farm Yarmouthian interglacial pollen diagram and the pollen records of the (later) Sangamonian interglacial and the postglacial (Holocene) from the Southern Great Lakes region. Table 1 assigns the pollen zones of these records to the major interglacial phases or to full-glacial stages.

The nearby Smith and Darrah Farms sections (fig. 1) have yielded pollen diagrams of Sangamonian interglacial age (Kapp and Gooding, 1964). At these sites the records begin with a post-Illinoian pre-temperate phase (I) characterized by prominence of conifers (*Pinus* and *Picea*), and absence of all deciduous species except *Betula*. The early temperature phase (II) is dominated by *Carya*, *Quercus*, *Betula*, *Alnus* and *Corylus*. *Fagus*, *Liquidambar*, *Liriodendron* (tulip-poplar), *Juglans* (walnut) developed prominently in the late temperate phase (III). The Sangamon record is interrupted at the climatic optimum by a major hiatus; the latest sediments record the return to full-glacial (Wisconsinian) climate and vegetation (*Picea*, *Abies*, *Pinus*).

A pollen record from southern Illinois, which apparently extends from the Illinoian late-glacial to the present, also provides another example (table 1) of the interglacial vegetational sequence from the Ohio River region (Grüger, 1970; 1972). The pre-temperate interglacial phase (I) is dominated by *Picea* and *Pinus*, accompanied by *Artemisia*. It is replaced by the early temperate phase (II) (*Quercus*, 20–40%; *Ostrya-Carpinus*, up to 23%; *Carya* and *Ulmus* at 5–10%, and *Taxodium*, to 30%). The interglacial maximum (late temperate phase) is marked by decrease in *Taxodium* and increase in *Ambrosia*, probably the result of lowering of the ground water table. *Taxodium*, *Liquidambar*, *Fagus*, *Ostrya-Carpinus* and *Ulmus* increase late in phase III, and in post-temperate phase IV. Hardwood pollen decreases, while *Pinus*, *Picea* and NAP increase during the Wisconsinian full-glacial stage.

The Sangamonian interglacial record from the Don Beds, Toronto, Ontario (Terasmae, 1960) appears to begin during the interglacial maximum and records

the decline of interglacial vegetation (late temperate phase III) and return of glacial conditions. At the Don Beds, as in each of the Sangamonian interglacial pollen records published from this region of North America, conditions at the climatic optimum permitted southern species to migrate farther north than during the Holocene.

Other reputed Yarmouthian and Sangamonian pollen records have not been included in this synopsis. Some such deposits are now known to be of interstadial age (Sangamon deposits of Voss, 1939; Leighton, in Litt., 1960; Smith and Kapp, 1964). Others, such as the Quincy deposit of Adams County, Illinois, may be Yarmouthian but the pollen record is exclusively *Picea*, *Abies* and *Pinus* (Voss, 1939). Lane's report (1941) on the interglacial peats of Iowa, includes pollen analysis of Aftonian (oldest interglacial) deposits; these sequences seem to reflect a shift from a pre-temperate conifer-dominated phase to grassland at the glacial maximum. Glacial and interglacial sequences from the late Pleistocene of the southern High Plains record the advance of forests into the grasslands during the Illinoian glacial and subsequent retreat during the Sangamonian (Kapp, 1965; 1970).

Postglacial sequences in the Southern Great Lakes region show similar phases (table 1); in fact Wright (1972) postulates that we may be near the end of the present interglacial. The Wisconsinan full glacial is well represented at Bacon's Swamp in Central Indiana (Engelhardt, 1960; 1965). The Holocene pre-temperate phase is dominated by conifers in this region (Lat. 39° 30'–40° 30' N, Long. 83° 30'–

TABLE 1

Glacial and interglacial vegetational phases represented in pollen zones of late Pleistocene records from the southern Great Lakes Region, U.S.A. (References include: Bacon's Swamp, Engelhardt, 1960; Silver Lake, Ogden, 1966; Pittsburg Basin, Gröger, 1972; Smith Farm, Kapp and Gooding, 1964; Don Beds, Terasmae, 1960.)

Glacial/Interglacial Phase	Pollen Zone Characterization ¹					
	Holocene		Sangamonian		Yarmouthian	
	Bacon's Swamp (Indiana)	Silver Lake (Ohio)	Pittsburg Basin (Illinois)	Smith Farm (Indiana)	Don Beds (Ontario)	Handley Farm (Indiana)
Full glacial	—	—	(3,4) <i>Pinus</i> , <i>Betula</i> , <i>Alnus</i>	(5,6) <i>Abies</i> , <i>Picea</i> , <i>Pinus</i>	<i>Picea</i> , <i>Pinus</i> , <i>Abies</i> , <i>Betula</i> , <i>Alnus</i>	absent
IV. Post-temperate	—	—	(2c,3a) cf. <i>Taxodium</i> , <i>Quercus</i> , <i>Ulmus</i>	absent	<i>Picea</i> , <i>Pinus</i> , <i>Abies</i> , <i>Larix</i> , <i>Salix</i>	absent
III. Late temperate	<i>Quercus</i> , <i>Carya</i> , <i>Acer</i> , <i>Fagus</i> , <i>Juglans</i>	(3) <i>Quercus</i> , <i>Carya</i> , <i>Fagus</i> , <i>Acer</i> , <i>Ulmus</i> , <i>Juglans</i>	(2b) <i>Quercus</i> , <i>Ambrosia</i> , Gramineae	(4) <i>Quercus</i> , <i>Fagus</i> , <i>Juglans</i> , (truncated)	<i>Quercus</i> , <i>Fagus</i> , <i>Carya</i> , <i>Ulmus</i> , <i>Acer</i> , <i>Tilia</i> , <i>Liquidambar</i>	(2a, 2b) <i>Quercus</i> , <i>Fagus</i> , <i>Ulmus</i> , <i>Carya</i> , (truncated)
II. Early temperate	<i>Quercus</i> , <i>Pinus</i> , <i>Ostrya-Carpinus</i> , <i>Fraxinus</i> , <i>Betula</i> , <i>Corylus</i>	(2) <i>Pinus</i> , <i>Quercus</i> , <i>Betula</i> , <i>Fraxinus</i>	(2a) <i>Quercus</i> , <i>Ostrya-Carpinus</i> , <i>Frax. nigra</i> , <i>Ulmus</i> , <i>Taxodium</i>	(3) <i>Quercus</i> , <i>Carya</i> , <i>Betula</i>	absent	(1a, 1b) <i>Quercus</i> , <i>Ostrya-Carpinus</i> , <i>Corylus</i> , <i>Pinus</i>
I. Pre-temperate	<i>Picea</i> , <i>Pinus</i>	(1) <i>Picea</i> , <i>Pinus</i> , <i>Abies</i>	(1) <i>Picea</i> , <i>Pinus</i> , <i>Artemisia</i>	(1, 2) <i>Picea</i> , <i>Pinus</i>	absent	trace
Full glacial	<i>Picea</i> , <i>Abies</i>	absent (?)	absent	absent	absent	absent

¹Pollen zone numbers are from the original diagrams of the authors cited.

86° 30'). *Ostrya-Carpinus*, and usually *Betula* and *Fraxinus* are prominent in the early temperature phase II of both Bacon's Swamp and Silver Lake, Ohio (Ogden, 1966). These components decline as *Ulmus*, *Carya* and *Fagus*, *Juglans*, and *Liquidambar* increase in late temperate phase III.

The Handley Farm pollen diagram is clearly an incomplete record of the Yarmouthian interglacial. The Kansan late-glacial (pre-temperate phase) is absent or represented only in its declining phases in pollen zone 1a (table 1). The development of the deciduous forest maximum (phase II and III) and the sequence of establishment of the major forest components is well documented in the Handley Farm lacustrine clays. This establishment sequence for major tree pollen components at Handley Farm is: *Pinus-Quercus-Ostrya*→*Quercus-Ulmus-Fagus*→*Carya*. The late maximum for *Carya* may be a local successional phenomenon or could be distinctive for the Yarmouthian interglacial vegetational records for the region.

Paleoecological Implications. The Handley Farm sequence bears similarity to the Sangamonian sequence from Illinois and to postglacial records from Bacon's Swamp, Silver Lake, and the prairie border of Minnesota (McAndrews, 1966). In these records, however, *Ulmus* and, except in Minnesota, *Carya*, enter more prominently in the pollen record in the *Ostrya-Carpinus* zone. Ogden (1966, p. 395) interprets the initial maximum of elm and *Ostrya-Carpinus* with the rising oak curve to be an indicator of a moist and warming climate.

It is likely that the climate became still warmer during the period of deposition of pollen zone II at Handley Farm causing the displacement of *Ostrya* and *Corylus* by *Fagus* and *Acer* in the uplands and *Populus* by *Ulmus* in the lake basin. Progressive leaching of the glacial tills and soil maturation would have permitted migration of *Liquidambar* (sweet gum) onto the Kansan drift. At least one southern species (*Planera aquatica*, the water elm) extended its range north beyond its present limits during the Yarmouthian late temperate phase.

Pollen zone 3, with sharp increases in *Carya* and grass pollen, reflects a drier climate with concomitant opening of the forest canopy. Except for the decrease in *Quercus* percentages at Handley Farm, this phase is reminiscent of the Xerothermic maximum (decreased *Ulmus* and *Fagus*, increased *Carya* and *Quercus*) in the postglacial record at Silver Lake. This zone may record a local lowering of the ground water table similar to that postulated for mid-Sangamonian time in southern Illinois by Gröger (1972).

TOWNSEND FARM SECTION

Stratigraphy. The Townsend Farm section (fig. 1) is located three quarters of a mile outside the Wisconsinan boundary in a stream bank on the south side of the North Branch of Garrison Creek in Fayette County, Indiana, in the northwest corner of Sec. 20, T. 13 N., R. 12 E., Alpine, Indiana, Quadrangle. No new stratigraphic units have been discovered at this section since 1966, but pollen data reported in this paper have prompted a change in classification of unit 4 from Yarmouthian to early Illinoian.

Thickness		Description
Unit	Meters	
Illinoian stage and post-Illinoian soil		Top of section on eroded slope 100 feet below the upland.
6	6.1+	Till, upper 15.0 ft (4.5 m) determined by several auger holes up slope from top of exposure. Top 6.5 ft (1.98 m) is noncalcareous, eroded, post-Illinoian soil. Lower 13.5 feet (4.1 m) calcareous, buff (oxidized) till.
5	0.2	Clay, buff (oxidized) to gray (un-oxidized), calcareous; with white streaks of secondary calcium carbonate in places and with blocky structure.
4	0.3-0.6	Silt, black, noncalcareous; organic-rich, containing badly damaged conifer pollen.
Kansan stage and Yarmouthian soil		
3	6.4	Till, upper 6-7 ft (1.83-2.14 m) noncalcareous, very clayey, grayish

- brown, containing many chert pebbles and cobbles and limonite concretions, with a 4-in (0.10 m) reddish brown limonite-cemented layer at bottom. The soil is a humic-gley formed during Yarmouthian time. Lower 16 ft (4.83 m) of till is calcareous, gray (unoxidized), containing abundant chert cobbles. Wood occurs in lower part.
- 2 0.2-0.6 *Sand*, buff (oxidized), calcareous. In places a 2 to 4-in (.05-10 m) calcareous gray-to-black silt, containing abundant finely divided plant remains and twigs, occurs at top; no mollusks found.
- 1 5.5+ *Till*, gray (unoxidized), calcareous; containing abundant chert cobbles. In basal 10 ft (3.0 m) occur sand and gravel pockets and large inclusions of chert pebbles in noncalcareous bright red clay matrix, probably from a local residual pre-Kansan limestone soil. Wood occurs throughout till Creek bed.

Pollen Analysis and Discussion. Careful field examination of the zone of weathering (units 3 and 4) along 20 ft (6.0 m) of exposure revealed no evidence of an unconformity between the black humic unit 4 and the weathered till of unit 3. For this reason, Gooding (1966) concluded that the humic zone and underlying weathered till must represent a complete Yarmouthian humic-gley soil leached between 7 and 9 ft (2.1-2.75 m). It was hoped, therefore, that the humic unit 4 would contain a pollen record of the Yarmouthian interglacial age.

Samples for pollen analysis were collected at one-inch (.025 m) intervals from the top of unit 5, down through unit 4, and into unit 3 of the soil profile. Pollen analysis showed only badly damaged coniferous pollen, too sparse for a meaningful spectrum. Thus, the pollen data seem to indicate that humic unit 4 represents a cold period either at the beginning or at the end of the ice-free interval. Because humic unit 4 has a twig litter at the top in places, indicating that organic matter was accumulating just before Illinoian ice covered the site, the latter would seem most likely. Apparently accretion of organic debris unit 4 resulted from a decreasing rate of decomposition of plant material, and possibly wetter conditions, as the climate deteriorated with the advance of Illinoian ice into the area.

In light of the above pollen data and discussion, and the presence of the more complete Yarmouthian pollen spectrum from the nearby Handley Farm section, humic unit 4 in the Townsend Farm section is now classified as early Illinoian, rather than Yarmouthian, as originally interpreted by Gooding (1966). The pollen spectrum probably spans a substantial period of interglacial time, and provides one of the most complete pollen records in North America for the Yarmouthian interglacial age. Extraordinarily high percentages of *Ostrya-Carpinus* and *Corylus* pollen appear to be distinctive among North American pollen records and may characterize Yarmouthian interglacial sediments in this region. The new stratigraphic and pollen data do not change the Kansan geologic-climate classification for southeastern Indiana proposed by Gooding (1966), which is based on the Kansan stratigraphy at the Townsend Farm site.

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LITERATURE CITED

- Beug, H. J. In litt. (to R. P. Goldthwait), Nov. 19, 1965.
- Engelhardt, D. W. 1960. A comparative pollen study of two early Wisconsin bogs in Indiana. Proc. Indiana Acad. Sci. 69: 110-118.
- 1965. A late-glacial—postglacial pollen chronology for Indiana. Amer. Jour. Sci. 263: 410-415.
- Gooding, Ansel M. 1966. The Kansan glaciation in southeastern Indiana. Ohio J. Sci. 4: 426-433.
- Grüger, E. 1970. The development of the vegetation of Southern Illinois since late Illinoian time (preliminary report). Revue de Géographie Physique et de Géologie Dynamique 12: 143-148.
- 1972. Late quaternary vegetation development in south-central Illinois. Quaternary Research 2: 217-231.

- Kapp, R. O.** 1965. Illinoian and Sangamon vegetation in Southwestern Kansas and adjacent Oklahoma. *Contrib. Mus. Paleontol., Univ. Michigan* 19: 167-255.
- 1970. Pollen analysis of Pre-Wisconsin sediments from the Great Plains. Pp. 143-155 In: Dort, W. and J. K. Jones, Pleistocene and Recent Environments of the Central Great Plains. Univ. Kansas Press, Lawrence. 433 pp.
- and **A. M. Gooding.** 1964. Pleistocene vegetational studies in the Whitewater Basin, Southeastern Indiana. *Jour. Geol.* 72: 308-326.
- Lane, G. H.** 1941. Pollen analysis of interglacial peats of Iowa. *Iowa Geol. Survey, Ann. Reports* 37: 231-262.
- Leighton, M. M.** In litt. (to R. O. Kapp), April 7, 1960.
- McAndrews, J. H.** 1966. Postglacial history of prairie, savanna, and forest in northwestern Minnesota. *Mem. Torrey Bot. Club* 22: 1-72 plus plates.
- Ogden, J. G. III.** 1966. Forest history of Ohio I. Radiocarbon dates and pollen stratigraphy of Silver Lake, Logan County, Ohio. *Ohio Jour. Sci.* 66: 387-400, plus plates.
- Smith, J. R. and R. O. Kapp.** 1964. Pollen analysis of some Pleistocene sediments from Illinois. *Trans. Illinois State Acad. Science* 57: 158-162.
- Terasmae, J.** 1960. A palynological study of Pleistocene interglacial beds at Toronto, Ontario. *Geol. Survey Canada, Bull.* 56: 23-41.
- Turner, C. and R. West.** 1968. The subdivision and zonation of interglacial periods. *Eiszeitalter und Gegenwart* 19: 93-101.
- Voss, J.** 1939. Forests of the Yarmouth and Sangamon interglacial periods in Illinois. *Ecology* 20: 517-528.
- West, R. G.** 1956. The Quaternary deposits at Hoxne, Suffolk. *Phil. Trans. Royal Society London* 239: 265-356.
- 1958. The Pleistocene epoch in East Anglia. *Jour. Glaciology* 3: 211-216.
- 1961. The glacial and interglacial deposits of Norfolk. *Trans. Norfolk and Norwich Naturalist's Soc.* 19: 365-375.
- 1962. A note on *Taxus* pollen in the Hoxnian interglacial. *New Phytologist* 61: 189-190.
- and **C. M. B. McBurney.** 1954. The Quaternary deposits of Hoxne, Suffolk, and their archeology. *Proc. Prehistoric Soc.* 20: 131-154.
- Wright, H. E.** 1972. Interglacial and postglacial climates: the pollen record. *Quaternary Res.* 2: 274-282.
- Zagwijn, W. H.** 1963. Pleistocene stratigraphy in the Netherlands, based on changes in vegetation and climate. *Verhandelingen Koninklijk Nederlands Geolog. Mijnbouwkundig Genootschap, Geol. Serie* 2: 173-196.
- and **J. I. S. Zonneveld.** 1956. The interglacial in Westerhoven. *Geologie en Mijnbouw, N. S.* 2: 37-46.

Chemical Mutagenesis in Mammals and Man. *Friedrich Vogel and Gunter Roehrborn, editors.* Springer-verlag, New York, Berlin, Heidelberg. 1970. xiv+520 p. \$34.10.

This volume contains the papers presented at a Symposium held 7 October 1969 at Mainz, Germany. In addition, there are several chapters representing texts not presented at the Symposium. Much of the content is devoted to cytology, biochemistry, genetics (including cytogenetics), statistical analysis, hemocytology, tissue-culture studies, etc. Although 17 of the authors of the articles are German, the text is entirely in English. Of the other seven authors, six are from the United States and one is from India. Six authors (including the two editors) are from the University of Heidelberg.

The practical importance of the contents of this volume is immense, since many of the chemical substances consumed by human beings in our modern age are shown to be mutation-producing, demonstrable in experiments with lower animals. The 30 chapters (representing 30 articles) are devoted to the important effort of determining if mutations actually occur, and if they do, under what conditions, and if they can be considered of any danger to human beings. The text is divided into four primary sections: (1) problem definition; (2) research methods developed, involving suitable mammalian test systems; (3) findings and applications; and (4) an appendix, which discusses statistical methods as applied specifically to mutation research.

Of practical interest is part (3), since it deals with matters of life and death important to all of us. Three different groups or substances are considered: (1) the cytostatics, agents which stop cell growth and subdivision (such as the antimetabolites); (2) the acridines, such as tryptamine and proflavine; and (3) caffeine, popularly consumed in such beverages as tea, coffee, and many soft drinks. Two chapters are devoted to caffeine mutagenicity. Studies with caffeine were made on bacteria, plants, the fly *Drosophila*, human cells *in vitro* (HeLa cells, leucocyte cultures), and mammals *in vivo*. The conclusion of both chapters is that there is as yet no sufficient proof of the mutagenic nature of caffeine in humans even though in some lower organisms this process can be demonstrated.

The book is well bound, with clear text and figure reproduction, bibliographies following each chapter, and a comprehensive terminal subject index. There is no author index.

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