SEDIMENTOLOGY AND HISTORY OF LATE WISCONSIN ALLUVIATION OF THE WABASH VALLEY

Special Report 56

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Sedimentology and History of Late Wisconsin Alluviation of the Wabash Valley

By Gordon S. Fraser

INDIANA UNIVERSITY
INDIANA GEOLOGICAL SURVEY SPECIAL REPORT 56

BLOOMINGTON, INDIANA: 1993

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On the cover:

Giant foresets exposed in a gravel pit on the east side of the Wabash Valley just south of Attica, Indiana. The foresets were deposited by a very large sandwave that grew and migrated down the Wabash during a catastrophic flood. The flood was the result of an outbreak of subglacial and intraglacial meltwater that entered the Wabash Valley in the vicinity of Delphi, Indiana.

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ABSTRACT

The late Wisconsin sediments in and adjacent to the Middle Wabash Valley were deposited during a period when multiple advances from two ice lobes affected the drainage basin. Meltwater and sediment were supplied directly to the river in the form of outwash fans and debris flow lobes, and indirectly through tributaries that were in contact with the ice.

The primary depositional elements in the basin consisted of 1) gravel-rich longitudinal bars and sheets, and finer-grained deposits of sandwaves and two-dimensional dunes, 2) sand-rich bar-top and interbar channels, 3) topset, foreset and bottomset beds of lacustrine deltas, and 4) debris flow lobes. These depositional elements were active in 1) braided stream channels, 2) lakes that developed both in contact with glacial ice and in unglaciated parts of the drainage basin, 3) outwash fans, 4) ice-walled channels and their associated interfluves.

The earliest Wisconsin deposits in the Wabash Valley accumulated when meltwater and debris entered the trunk stream from those tributaries whose headwaters came into contact with advancing glaciers. The channel of the Wabash began to aggrade rapidly in response to the increased load, and mouths of tributaries not yet in contact with advancing ice were blocked as the main channel filled. Lacustrine sediments accumulated in these blocked tributaries. Eventually, sand and gravel outwash was deposited over the lacustrine muds in those tributaries whose headwaters came into contact with glacial ice as the ice advanced farther into the basin.

Outwash fans prograded into the trunk stream from ice margins adjacent to the valley, and debris flow lobes added unsorted sediment directly from the ice. Tributaries that originated as supraglacial streams evolved into ice-walled channels that filled with an assemblage of lacustrine sediments, fluvial outwash, and debris flow deposits. Subglacial till, ablation debris, and minor amounts of outwash and lacustrine deposits accumulated in the interfluves between these channels.

Two floods of extreme magnitude occurred during the late Wisconsin alluviation of the valley. The first carried gravel-rich sediments that moved through the valley in giant dunes. The second deposited cobble and boulder-rich gravels in places, but it was mainly an erosional event.

INTRODUCTION

PURPOSE

The Wabash River is the trunk stream in a drainage basin that was affected by multiple glacial advances from two ice lobes during the late Wisconsin (Bleuer, unpub. data). During these events, eastern-source ice apparently advanced rapidly to a terminal position and then stagnated, whereas northern-source ice advanced to terminal positions and then began a process of active backwasting (Bleuer, unpub. data). During initial stages of stagnation and backwasting, sediment was supplied directly to the river at points where the ice intersected the valley and down tributaries that were in contact with the ice. As these processes progressed, however, the glacier supplied sediment from the interior of the lobe through drainage systems that developed in the melting ice. These changes in sediment delivery to the valley, the effect of multiple sources of sediment to the river, and the impact of multiple glaciations produced the complex architecture of the glacial alluvium filling the valley.

Sediment supplied directly to the Wabash via ice-marginal outwash fans and debris flows apparently was little changed as it entered the valley. On the other hand, sediment supplied indirectly to the Wabash through tributary streams was altered by various processes of hydraulic fractionation and preferential storage of coarse material. The size of the drainage basins and the large numbers of tributary streams also buffered the extreme flow fluctuations that are characteristic of streams draining glaciers.

This is an attempt to relate the glacially derived sediments in the valley, in its tributary sources, and in the uplands adjacent to the valley to the glacial history of the area. This paper describes the glacigenic sediments in and adjacent to the Wabash Valley, interprets the depositional processes that affected accumulation, and suggests how these processes interacted during multiple glacial advances to produce the complex suite of deposits that are present in the valley. The sediment body consisting of these deposits will be treated as a lithosome with a complex depositional history that was affected by a series of events.

PREVIOUS INVESTIGATIONS

The glacial sediments in and adjacent to the Wabash Valley have been studied for nearly 100 years. The most recent of these have focused on till stratigraphy and geomorphic evolution of the area (Wayne and Thornbury, 1951; Thornbury, 1958; Schneider and Wayne, 1968; Johnson and Bleuer, 1980; Bleuer, Melhorn, and Fraser, 1982; and Bleuer, unpub. data), on the economic potential of the alluvium in the valley (Patton, 1953; Fraser, 1983a), and on the environmental significance of the deposits (Hartke, Hailer, and Fraser, 1983).

In addition to these, there have been a number of sedimentologically oriented studies. McCammon (1961) studied variations in pebble composition of outwash sediments in the valley and concluded that downstream variations in pebble composition could be related to the influx of rock fragments from local bedrock sources. The characteristics of sediments in the valley and the processes that acted during their deposition have been

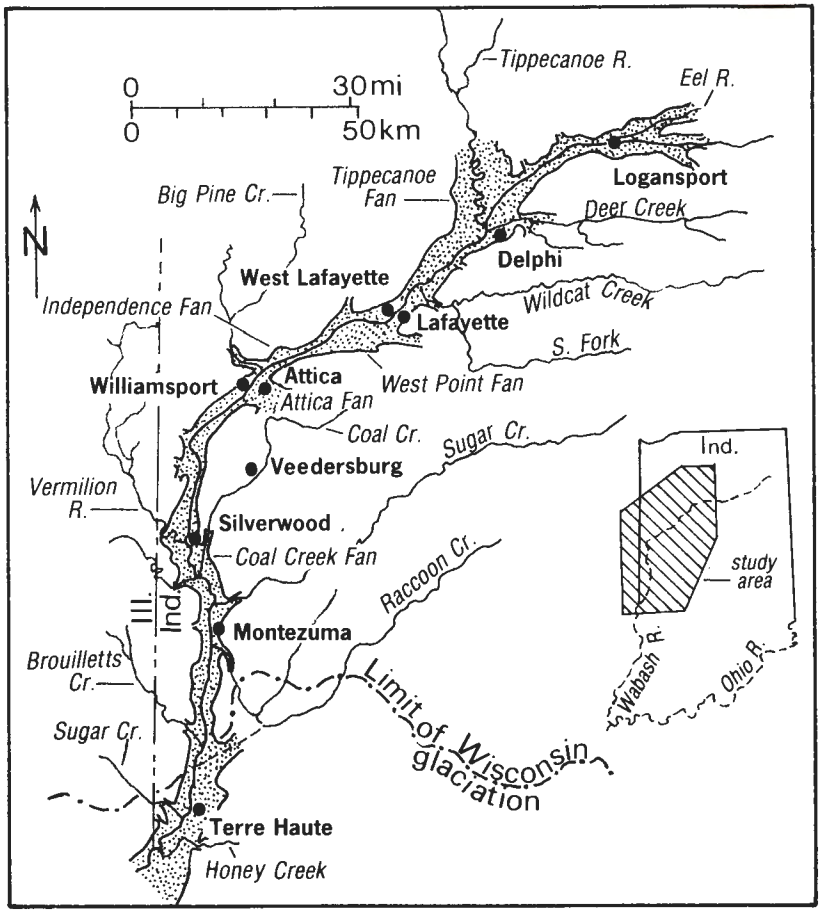

Figure 1. Map showing the location of the study area and the principal points where sediment entered the Wabash Valley during the late Wisconsin.

described by Fraser and Fishbaugh (1980) and by Fraser, Bleuer, and Smith (1983). Fraser and Fishbaugh (1985), Fraser (1982), and Carter (1987) studied the sedimentation in several of the tributary sources to the valley, and Vaughn (1984) and Fraser and Bleuer (1988) described the effects of late Wisconsin catastrophic floods.

SETTING

The Middle Wabash Valley extending from Logansport, at the confluence of the Wabash and Eel Rivers, downstream to Terre Haute, follows essentially the same course it did during the late Wisconsin (Fraser and others, 1983). It has a northeast-southwest trending reach between Logansport and Attica, a north-south trending reach between the confluence of the Wabash with the Vermilion River and Terre Haute, and a broadly curving reach, called the "Great Bend" in the intervening interval (fig. 1).

During the late Wisconsin, ice of the Lake Michigan lobe advanced from the north into Indiana and ice of the Huron-Erie lobe advanced from the east. Their line of contact was nearly coincident with the valley of the Middle Wabash River. The Lake Michigan lobe advanced two and possibly three times into the area, and the Huron-Erie lobe advanced as many as four times (Bleuer, unpub. data).

Lake Michigan lobe ice deposited the Wedron Formation in the area mostly to the north and west of the Wabash Valley. It consists of, from the base upward, the Fairgrange, Batestown, and Snider Members. Huron-Erie lobe ice deposited the Trafalgar Formation mostly to the east and south of the valley (fig. 2). The grain of the topography resulting from differences in the direction of ice advance suggests that the Trafalgar Formation may be the product of as many as four separate advances. However, the unit cannot be readily differentiated into members on the basis of texture, color, or mineralogy.

The stratigraphic relationship between members of the two units is not clear. The two lobes apparently avoided contact with each other except to the northeast in Cass County where the Snider Member occurs between the upper and lower tongues of the Trafalgar, and where the upper tongue of the Trafalgar overlaps the Snider as far west as Illinois (Bleuer, Melhorn, and Fraser, 1982). This is not to say that ice of the two lobes occupied the area simultaneously. Rather, based on the evidence of the stratigraphic relationships between till and outwash along the valley sides, the Wabash basin apparently experienced a

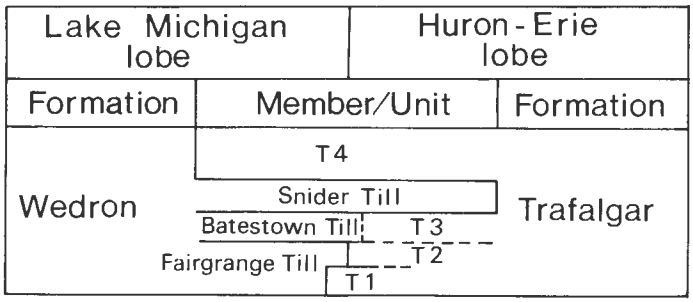

Figure 2. Late Wisconsin stratigraphy in the Wabash Valley and adjacent areas (modified from Bleuer, unpub. data).

"staggered" occupation of its drainage by ice of the Lake Michigan lobe and the Huron-Erie lobe (Bleuer, Melhorn, and Fraser, 1982; Bleuer, unpub. data).

DEPOSITIONAL SYSTEMS

A variety of depositional systems, including deep braided channels, shallow braided channels, braided outwash fans, ice-contact and non-contact lakes, intraice channels, stagnant ice fields, and ice-marginal settings were present in and adjacent to the Wabash Valley and its tributaries. All of these systems were affected by the presence of glacial ice in the drainage basin of the Wabash River. However, the impact glacially-forced processes had on sedimentation and the ability of depositional processes to respond to ice events depended primarily on the proximity of these environments to the ice. The size of the systems was also a factor because it controlled their inertia with respect to changes in the intensity of glacial processes.

DEEP BRAIDED CHANNELS

A relatively deep multi-channel stream occupied the Wabash Valley during the early part of the late Wisconsin. Bedload was transported as macroforms that deposited amalgamated sets of planar crossbeds as much as 2 meters thick (fig. 3). Set thickness decreases upward, although grain size does not. The planar sets are capped by sequences of alternating plane beds and low-angle crossbeds. The change upward from lower flow regime structures (planar crossbeds) to transitional and upper regime ones (plane beds and low-angle crossbeds) was probably in response to decreasing flow depth rather than increasing flow velocity. It is likely that these macroforms are analogous to the aggrading unit bars and sand flats described by Cant and Walker (1978) from the present-day Saskatchewan River.

SHALLOW BRAIDED CHANNELS

Once glacially derived sediments entered the Wabash Valley and its tributaries, they generally took on the characteristics of sediments deposited by shallow braided outwash streams (see Smith, 1985 for a review of the literature on the characteristics of fluvioglacial sediments). Deposits of longitudinal bars and sheet floods, sand waves and two-dimensional (2-D) dunes, and three-dimensional (3-D) dunes in interbar channels dominate sedimentary sequences in these valleys.

Deposits of longitudinal bars and sheet floods occur as beds of coarse pebble and cobble gravels as much as 1 meter thick (fig. 4). The coarser-grained of these beds are massive or crudely stratified, whereas the finer-grained ones may display well-developed bedding defined by size-graded stratification. In some cases, low-angle cross-stratification occurs at the downstream ends of bar deposits. These gravel beds probably formed during flood periods under conditions of high bed shear stress.

Deposits of sandwaves and 2-D dunes in the Wabash Valley consist of sets of planar crossbedded sand and gravel as much as 1.5 meters thick that locally extend for tens of meters in longitudinal exposure (fig. 5). Crossbeds dip at angles that normally range from 10° to 20° and may have either tangential or angular basal contacts. Reactivation surfaces within sets of crossbeds suggest that deposits of sandwaves and 2-D dunes accumulated during periods of substantial change in flow velocity and water depth.

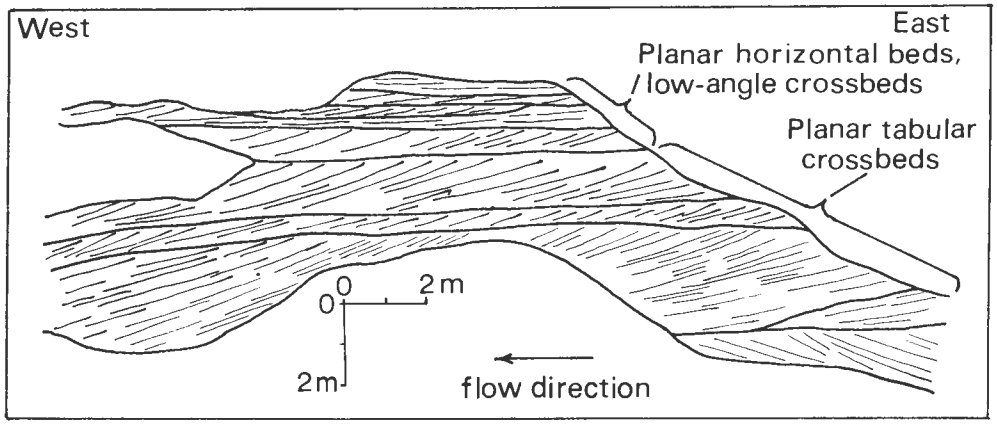

Figure 3. Tracing from a photomosaic showing basal Wisconsin alluvium in the Wabash Valley at Lafayette, Indiana. These sands were probably deposited in a relatively deep braided stream before glacial ice shed sediments directly into the Wabash Valley.

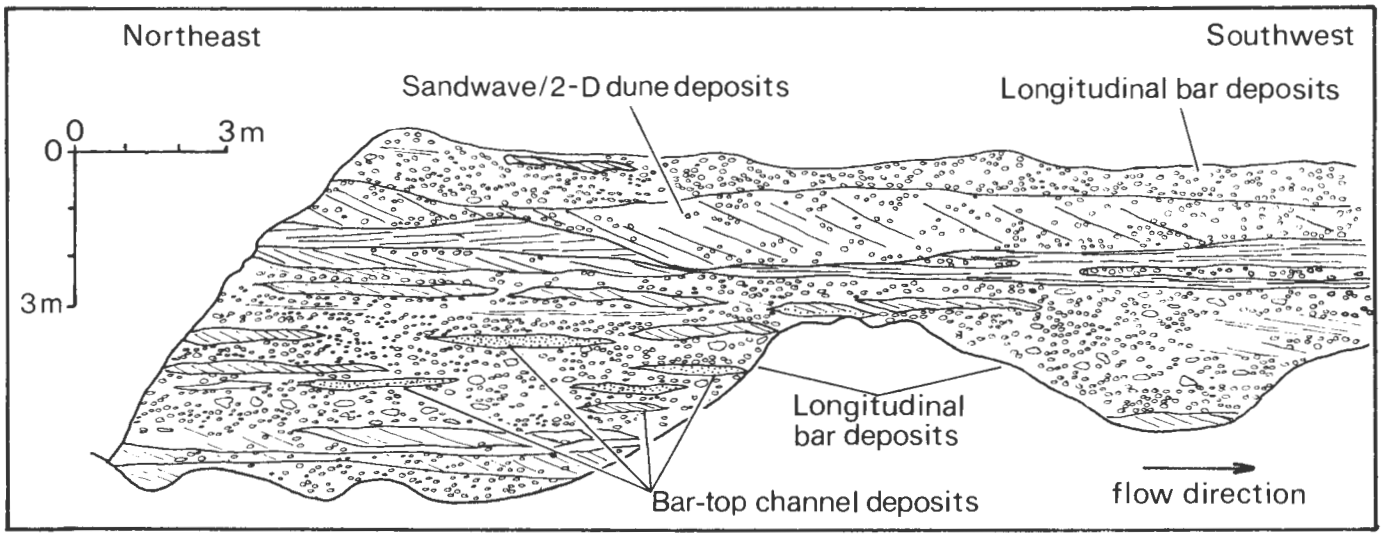

Figure 4. Tracing from a photomosaic showing longitudinal bar and sandwave deposits, and bar-top channel deposits in the shallow braided stream alluvium of the Wabash Valley just south of Attica, Indiana.

Channel deposits in the Wabash Valley system occur in a variety of sizes. All of the deposits, however, are characterized by sediments that are relatively finer grained than the adjacent bar deposits, and all the deposits are crossbedded at various scales. Many channel fill deposits also rest on lag gravels overlying scoured surfaces.

Thin, discontinuous beds of crossbedded sand occur in shallow depressions on surfaces of bar deposits (figs. 4 and 5). These beds probably formed during the waning stages of floods as bars emerged and flow was confined to low areas on irregular bar surfaces. Such deposits probably formed in response to changes in the meltwater regime or to weather-induced changes in insolation or rainfall. They ordinarily do not exceed a few tens of centimeters in thickness and 3 meters in width, and they

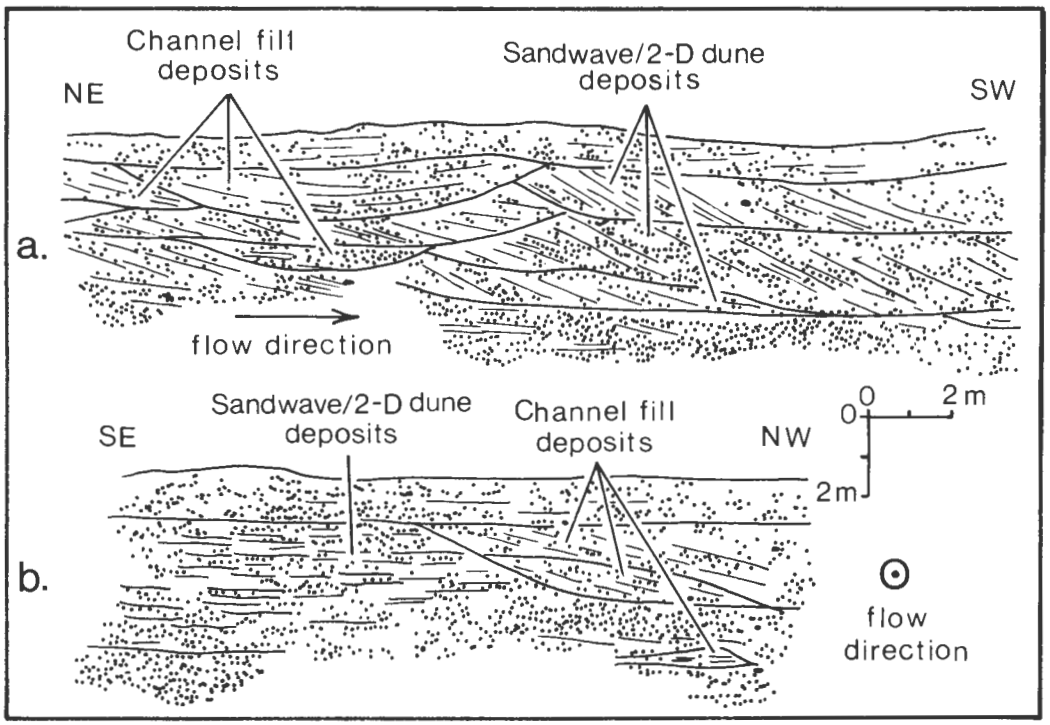

Figure 5. Tracings from photomosaics showing sandwave deposits cut by channels filled with trough-crossbedded sand and gravel just west of West Lafayette, Indiana: (a) section parallel to dominant flood flow direction; (b) section perpendicular to dominant flood flow.

are filled with small- to medium-scale trough cross-sets, ripple-bedded silt, or laminated mud.

Larger interbar channels may cut through one or more sets of bar deposits and, in some instances, may interfinger with bar deposits (fig. 5). Channels are generally filled with stacked sets of large-scale trough crossbeds whose trough axis orientations may deviate greatly from the dominant flood flow direction.

Another type of crossbedded channel deposit onlaps margins of bar deposits. Such beds commonly dip at high angles to mean stream flow away from bar deposits and into adjacent channels. Similar deposits form on modern braided streams where flow across bar surfaces during waning stage builds delta-like accretionary wedges against bar margins (Smith, 1985).

OUTWASH FANS

Braided outwash fans were deposited in the Wabash Valley when glacial ice advanced to the margins of the valley. Glaciers supplied outwash to fans through ice-walled channels. Because they were fed directly by the ice, outwash fans strongly reflect patterns of glacial meltwater flow. Outwash fans prograded away from ice margins into the accomodation space represented by the Wabash Valley. They commonly can be divided into proximal, medial, and distal segments based on associations of sediment size, composition, and primary sedimentary structures (Boothroyd and Ashley, 1975). Sediments deposited in proximal and medial positions on these fans are preserved on the margins of the valley, but distal sediments were most likely deposited nearer the axis of the valley where they were subsequently eroded or reworked by down-valley flow. They are, therefore, not preserved in valley fill sequences.

Sediments of the proximal parts of fans consist of clasts up to cobble size. They occur in bedding units that are discontinuous laterally and vertically because they were deposited in channels, underwent syndepositional erosion, or were deposited in complex interfingering relationships (fig. 6). Units consisting predominantly of cobbles and coarse pebbles invariably display crude horizontal bedding defined by layering of coarser and finer clasts and parallel horizontal layering of elongate and tabular clasts (figs. 6a and 6b). These cobble gravel beds are similar in form and stratification to longitudinal bar and sheet flood

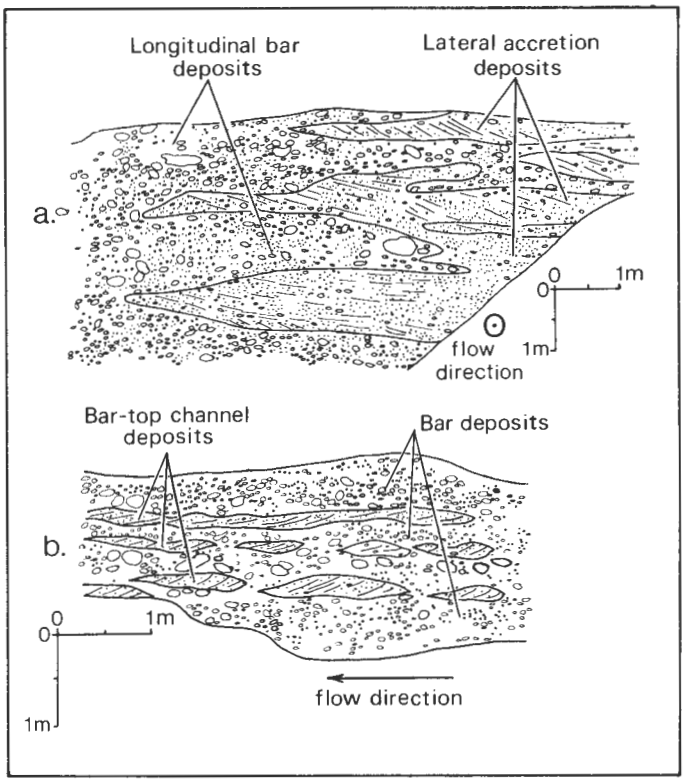

Figure 6. Tracings from photomosaics showing details of proximal outwash fan sediments of the Coal Creek fan at the mouth of Coal Creek: (a) interfingering longitudinal bar and lateral accretionary deposits; (b) interbedded longitudinal bar and bar-top channel deposits.

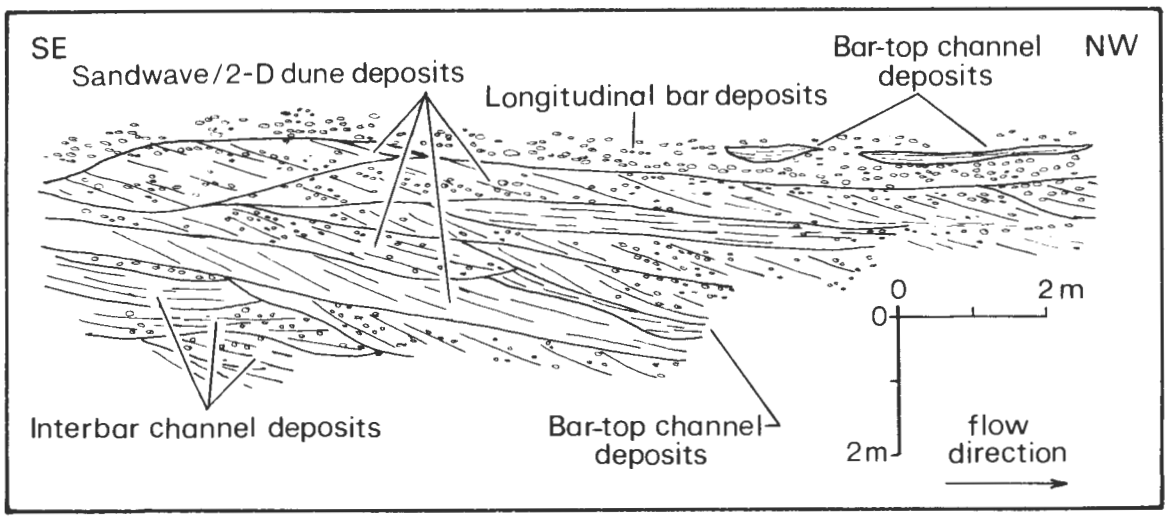

Figure 7. Tracing from a photomosaic showing deposits in the medial part of the Independence outwash fan exposed along Kickapoo Creek near Independence, Indiana. Sediments consist mainly of sandwave deposits and trough crossbedded channel deposits.

deposits formed under conditions of very high bed shear stress during peak flood periods.

Bedding units consisting of sand and fine gravel generally show planar tabular cross-stratification defined by alternating bands of sand, granules, and fine pebbles. Commonly, a concave-upward erosional basal contact marked by a basal lag of coarse pebbles and cobbles is evident. These apparently were deposited as sandwaves and 2-D dunes similar to those that form in braided channels that occur in more distal fan settings under conditions of lower bed shear than longitudinal bars (Smith, 1985). However, deposits of sandwaves and 2-D dunes occur in channels bounded by longitudinal bar deposits and marked by basal lags of coarse pebbles and cobbles. They probably formed in proximal fan channels during low flow conditions of relatively long duration similar to those described by Church and Gilbert (1975) and Hein and Walker (1977).

Bar-top channels filled with crossbedded sand (fig. 6b) are associated with both types of bar deposits and are evidence of short-term fluctuations in discharge. Lateral accretionary beds, on the other hand, evidently are associated only with longitudinal bar deposits. In one exposure (fig. 6a), the interdigitation of bar and lateral accretionary deposits persists vertically for several meters. Such vertical continuity of facies boundaries in an environment normally characterized by abrupt lateral facies shifts indicates a rapid rate of vertical accretion.

The medial parts of fans consist predominantly of sand and gravel up to coarse pebble size in planar tabular crossbeds as much as 1 meter thick (fig. 7). These also were probably deposited as sandwaves and 2-D dunes. Intervening beds of trough crossbedded sand were probably deposited in interbar channels; sand in small-scale trough crossbeds was deposited in shallow scours on bar tops during waning flow stages. Beds of mud of varying thickness and lateral extent also appear in this part of the fan. Larger, thicker mud units were deposited in abandoned interbar channels, whereas thinner ones appear to fill bar-top channels.

LAKES

Ice-contact and non-contact lakes of varying size were present in some tributaries to the Wabash Valley during the period of late Wisconsin glaciation. Non-contact lakes occupied tributaries along the main valley. Although these lakes were not in contact with glacial ice, their occurrence was a direct consequence of glaciation of the drainage basin. Other lakes formed in contact with glacial ice. The deposits of these lakes reflect depositional processes largely controlled by glacial meltwater regimes (see Smith and Ashley, 1985, and Drewry, 1986, for a description of the processes and deposits in ice-contact and non-contact lakes).

Non-contact lakes formed in tributary valleys when the floor of the Wabash Valley aggraded rapidly and blocked the mouths of tributaries in response to the increased sediment yield from melting glaciers in the drainage basin. Much of the sediment in these non-contact lakes came from the Wabash River so that

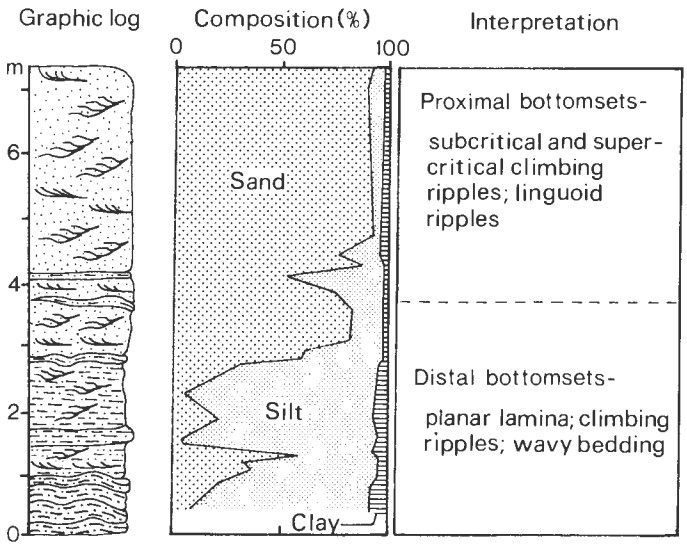

Figure 8. Log of a section through the bottomset deposits of the lacustrine sediments filling the valley of Deer Creek near Delphi, Indiana. Proximal bottomsets consist of ripple-bedded fine sand; distal bottomsets consist of plane-bedded and ripple-bedded silt with mud drapes (modified from Carter, 1987).

coarse-grained deltas formed at tributary mouths, and finely laminated lacustrine muds were deposited in reaches farther upstream. Locally derived material also entered these lakes as fluviodeltaic deposits in the headwaters of the tributaries. Lacustrine sedimentation apparently began as soon as tributaries were dammed (Hartke and others, 1983). As the trunk valley filled, the lakes expanded; therefore, the pattern of sedimentation at tributary mouths was one of deltaic retrogradation even as the deltas aggraded.

Ice-contact lakes formed where glacial ice blocked drainage in the Wabash Valley and its tributaries, or where the floor of the Wabash Valley aggraded rapidly enough to block drainage from ice-walled channels that entered the valley from adjacent glaciers. A complete sequence of bottomset, foreset, and topset beds was observed in the deposits of one of these lakes.

Bottomset deposits of the delta consist of ripple-bedded and plane-bedded silt and sand with minor amounts of clay (fig. 8). Proximal bottomsets consist mainly of climbing and non-climbing ripples in sets that commonly are separated by clay-rich drapes. Distal bottomsets consist mostly of plane-bedded silts in alternating layers of light-colored silt and darker-colored, clay-rich silt of uniform thickness.

Both bedding types formed under conditions of episodic sedimentation during which traction transport events driven by quasi-continuous underflows alternated with deposition from suspension. Such periodicity could be produced in hydraulic regimes dominated by glaciers in response to diurnal or seasonal meltwater flow, or in response to short-term, irregularly-spaced fluctuations in precipitation. The regularity of bed thickness in these deposits suggests that a cyclic process was the forcing factor; the lack of a well-developed clay layer suggests that the cycle was not long enough for clays to settle out. These factors

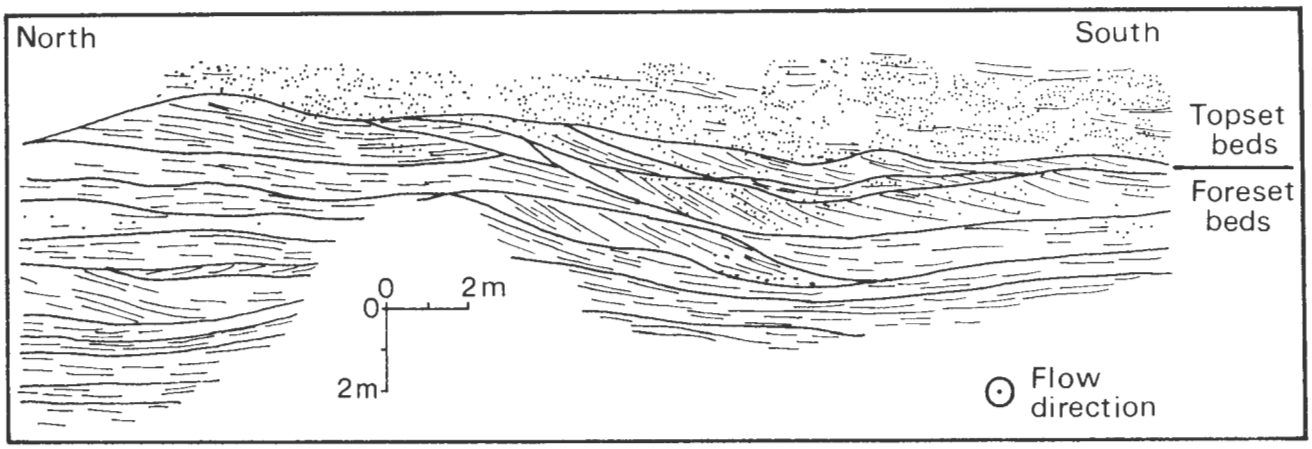

Figure 9. Tracing from a photomosaic of a tranverse (N-S) section through foreset and topset beds of the lacustrine delta in Deer Creek near Delphi, Indiana. The foresets, which dip to the west, consist of sand filling broad, trough-shaped scours in a coarsening-upward sequence. The foresets are overlain by an erosional contact by the topsets consisting of crudely bedded sand and gravel.

indicate that the couplets were formed by diurnal changes in meltwater flow.

The foreset deposits of the delta are as much as 10 meters thick. They consist of sand in planar crossbedded sets 0.3 to 1.0 meters thick dipping 10° to 15° downstream. In sections perpendicular to the flow, these sets are shown to fill broad troughs, as much as 10 meters across, that are arranged in a festoon-like pattern (fig. 9). Individual troughs may be separated by pebble lags or by thin mud drapes. Sets of troughs are locally separated by 10- to 20-cm-thick beds of parallel-laminated or ripple-bedded silt and clay-rich silt. Beds laterally equivalent to the stacked troughs consist of alternating layers of parallel-laminated or ripple-bedded silt and fine sand.

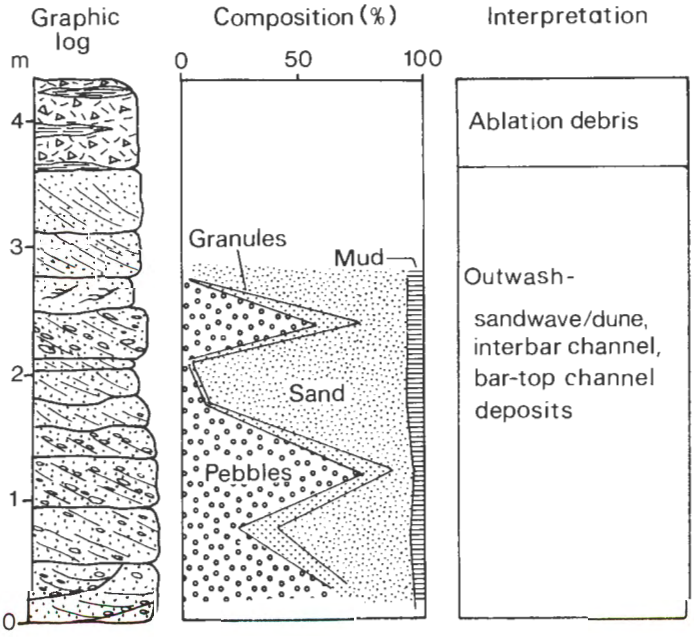

Figure 10. Log of a section through topset deposits of the lacustrine sequence filling the valley of Deer Creek near Delphi, Indiana (modified from Carter, 1987).

Foreset beds were probably deposited by underflows that lasted more or less continuously for relatively long periods of time, whereas mud drapes were deposited during short periods of reduced flow or when flows were inactive. Thicker beds of silt and clayey silt were deposited during extended periods of reduced flow, and laterally equivalent beds of silt and fine sand probably formed as levees flanking the underflow channel.

Foresets may grade downdip into the bottomset beds, or they may have a sharp basal contact that is commonly marked by a pebble lag formed during particularly strong flows. In most places, the foresets grade updip into topset deposits of coarse sand and gravel in trough crossbeds formed in interbar channels and in tabular crossbeds formed by sandwaves and 2-D dunes (fig. 10). Dip directions on the crossbeds of the topsets indicate both longitudinal transport down the trough and lateral input into the trough.

INTRAICE CHANNELS

Intraice channels formed in crevasses in downwasting ice along the margin of the Wabash Valley. Fluvial sediments form the bulk of the deposits that filled these crevasses, but debris flow deposits, reflecting the proximity of ice to these channels, are also abundant (Fraser, 1983b; Carter, 1987). These streams altered the quantity and caliber of the sediment load available to the Wabash Valley by preferentially storing coarse bedload.

Fluvial sediments in intraice channels occur in upward-fining sequences (fig. 11). Gravel-rich beds, deposited as longitudinal bars and by sheet floods, are concentrated at the base of the sequences. The relative proximity of glacial ice to the channels during this early stage of their alluviation is suggested by the common occurrence of small lenses of clay-rich diamicton that were probably deposited as flows of supraglacial and englacial debris. Crossbedded sand and gravel dominate the upper parts of fluvial sequences (fig. 11). Planar tabular crossbeds are

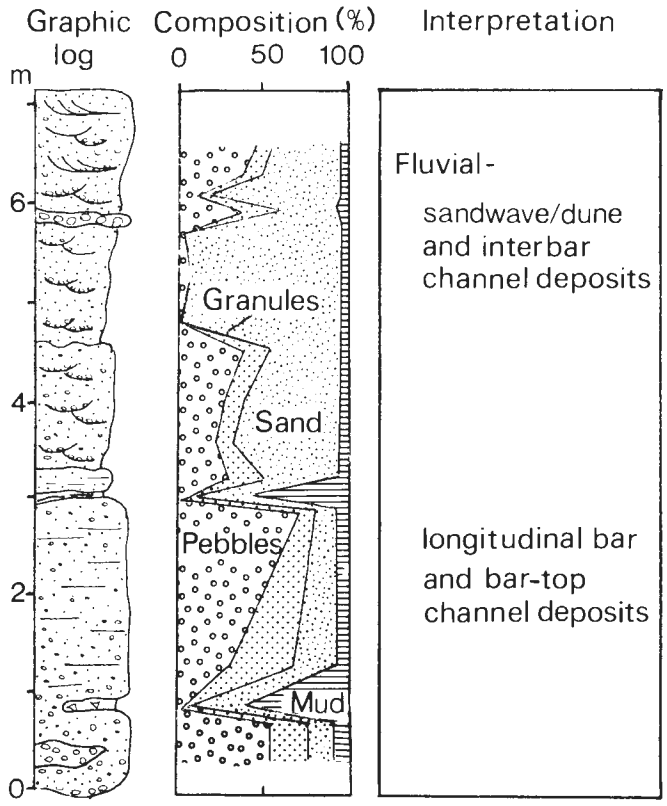

Figure 11. Log of a sequence of fluvial sediments deposited in the valley of Deer Creek near Delphi, Indiana. The sequence fines upward from gravel-rich longitudinal bar deposits in the lower part to crossbedded sandwave and channel deposits in the upper part (modified from Carter, 1987).

probably deposits of sandwaves and 2-D dunes. Amalgamated sets of trough crossbedded sand and gravel, separated by clast-thick lag gravels, were probably deposited by 3-D bedforms migrating in interbar channels during low flow stage.

Stagnant-ice deposits consist of a heterogeneous assemblage of till, lacustrine muds, fluvial sand and gravel, and muddy debris flow deposits in the interfluves of the drainage basin and along the margins of channels where it is interbedded with other facies assemblages.

Till occurs in interfluves in thick, uniform units separated by thinner beds of sand and gravel (fig. 12). Near channels, however, the till units, some of which are probably of debris flow origin, are thinner and they are interbedded with thicker sand and gravel beds, as well as with a variety of ablation facies. Thin beds of sand and gravel in the interfluves may have formed as intertills (Shaw, 1985; Eyles and Menzies, 1983). Thicker beds of sand and gravel interbedded with till near channel margins were deposited during periods of open channel flow in ice-walled meltwater streams.

Ablation debris forms a veneer over basal till in the interfluves and over glaciofluvial and glaciolacustrine facies in the channels (fig. 12). The debris consists of silt-clay mixtures, clay-rich diamicts, and sand and gravel in vertically and laterally complex juxtaposition. Clay-rich diamictons show evidence of deformation by load, deformation caused by basal shear during flow, and the incorporation of underlying material during flow. They are commonly intimately associated with beds of sand and gravel and probably were deposited as debris flows. Silt-clay mixtures are ubiquitous in the interfluves and probably formed in small supraglacial lakes. Sand and gravel beds associated with these other materials are probably deposits of small, ephemeral supraglacial meltwater streams. Post-depositional mass movement is evident in all of these facies.

ICE MARGIN

Ice-marginal processes added sediment, mostly in the form of debris flows, directly to the valley from the margins of disintegrating ice. The internal structures of debris flow deposits reflect the relative resistance of the materials comprising the flows to shear. Frontal margins of highly viscous flows are lobate in cross section, and faces commonly stand at high angles (fig. 13a). Basal contacts are sharp, and relatively little of the underlying material is incorporated into the flow. Evidence of internal flow is rare. Internal flow structures abound in more fluid debris flow

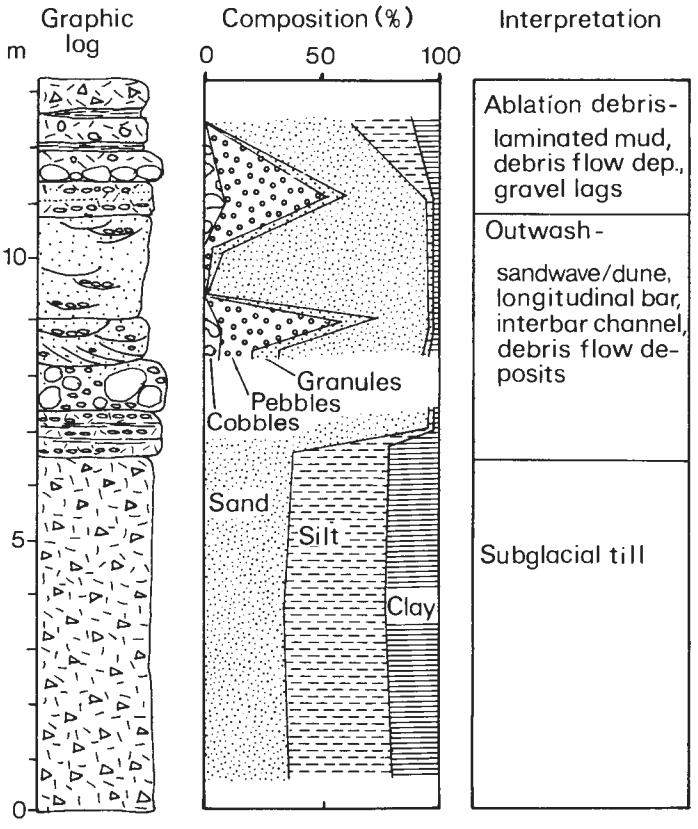

Figure 12. Log of a section through stagnant ice deposits adjacent to the valley of Deer Creek near Delphi, Indiana. The sediments include subglacial till, ablation debris (including sediments of probable debris flow origin), gravel-rich fluvial deposits, and laminated muds of probable lacustrine origin (modified from Carter, 1987).

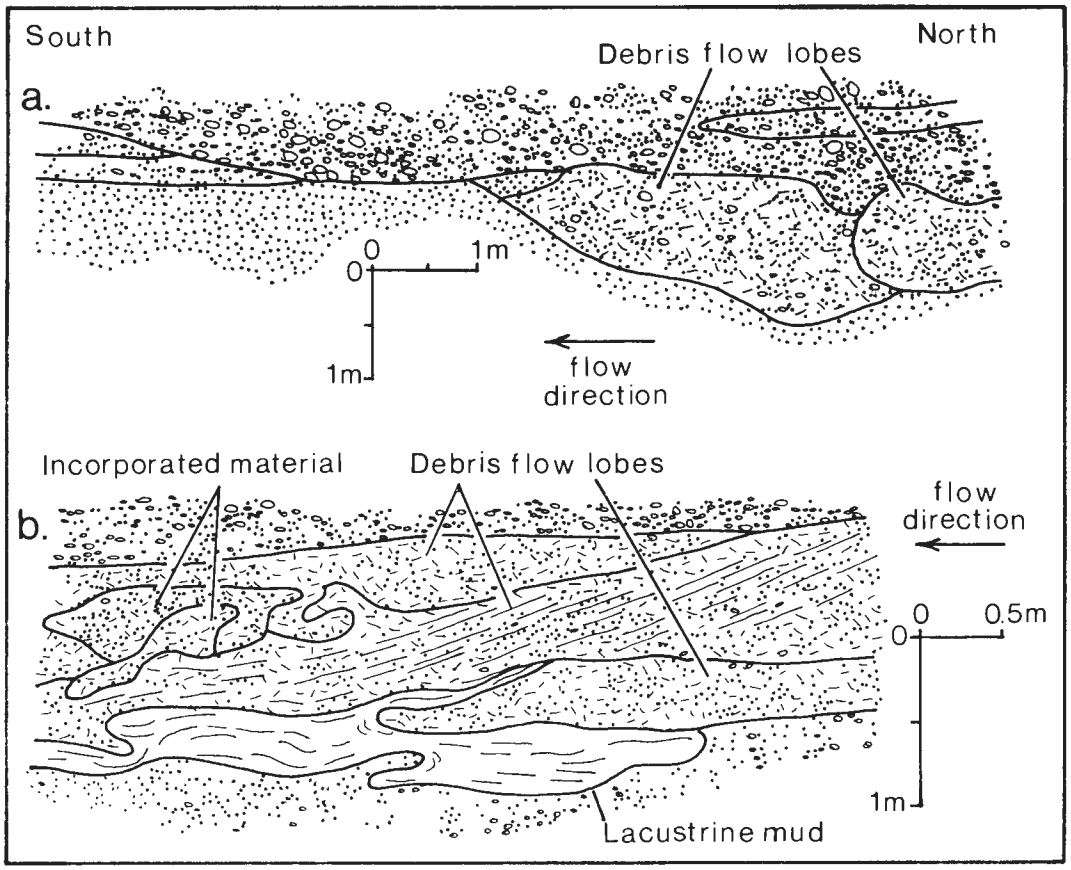

Figure 13. Tracings from photomosaics showing debris flow deposits in the glaciofluvial deposits of the Wabash Valley at West Lafayette, Indiana: (a) highly viscous debris flow filling a channel in outwash; (b) more fluid flow showing a high degree of deformation and closely spaced shear planes.

deposits, and upper surfaces are commonly highly deformed as a result of loading by the overlying material (fig. 13b). Large amounts of the underlying glacigenic materials have been incorporated into the deposits of these flows.

HISTORY OF WISCONSIN ALLUVIATION

Glacially derived fluvial sediments of late Wisconsin age probably entered the Wabash Valley at about 25 ka when the Lake Michigan lobe over-rode the drainage basins of several of its larger tributaries and deposited the Fairgrange Member of the Wedron Formation (Bleuer, unpub. data) (fig. 14). Most of the sediments of this phase of alluviation are either covered by subsequent deposits or eroded by subsequent flows, but two exposures that have been examined show evidence of the nature of the fluvial processes that acted at that time. One exposure is near Lafayette where the sediments are overlain by basal till of the Wedron Formation and underlain by a gravel lag developed on Illinoian till. The lower part of the sequence consists of sand and fine gravel in large-scale planar tabular crossbeds that decrease in set thickness upward (fig. 15). The sequence is capped by a meter of sand with granules and fine pebbles in 10- to 20-cm-thick beds of low-angle crossbeds intercalated with plane beds. The thick sets of planar crossbeds formed on large-scale sand waves in a river of moderate depth, but the upward change in bed thickness and bedding type suggests that the upper part of the sequence formed in much shallower flows, probably as a result of aggradation of the channel floor.

Similar sequences formed in Coal Creek when Huron-Erie lobe ice entered the southeastern part of the drainage basin. In both cases, alluviation occurred in response to increased discharge and sediment load imposed by the glaciers as they entered the outer margins of the Wabash drainage basin. The response of these rivers to glacial events, however, was muted by the relatively large distance over which flow occurred and also by the inflow of tributaries that were not directly affected by glacial processes at that time.

Sediment yield to the Wabash increased significantly when the Lake Michigan lobe reached the Great Bend area near Williamsport sometime before 20 ka (Bleuer, unpub. data) (fig. 14). Meltwater and sediment were supplied directly to the river along a broad front that nearly paralleled the valley above the Great Bend, and indirectly through several tributaries downstream from the Great Bend. The valley floor aggraded rapidly in response to this increased sediment flux, and lakes formed where mouths of tributary valleys were blocked by the fill in the trunk stream (fig. 16).

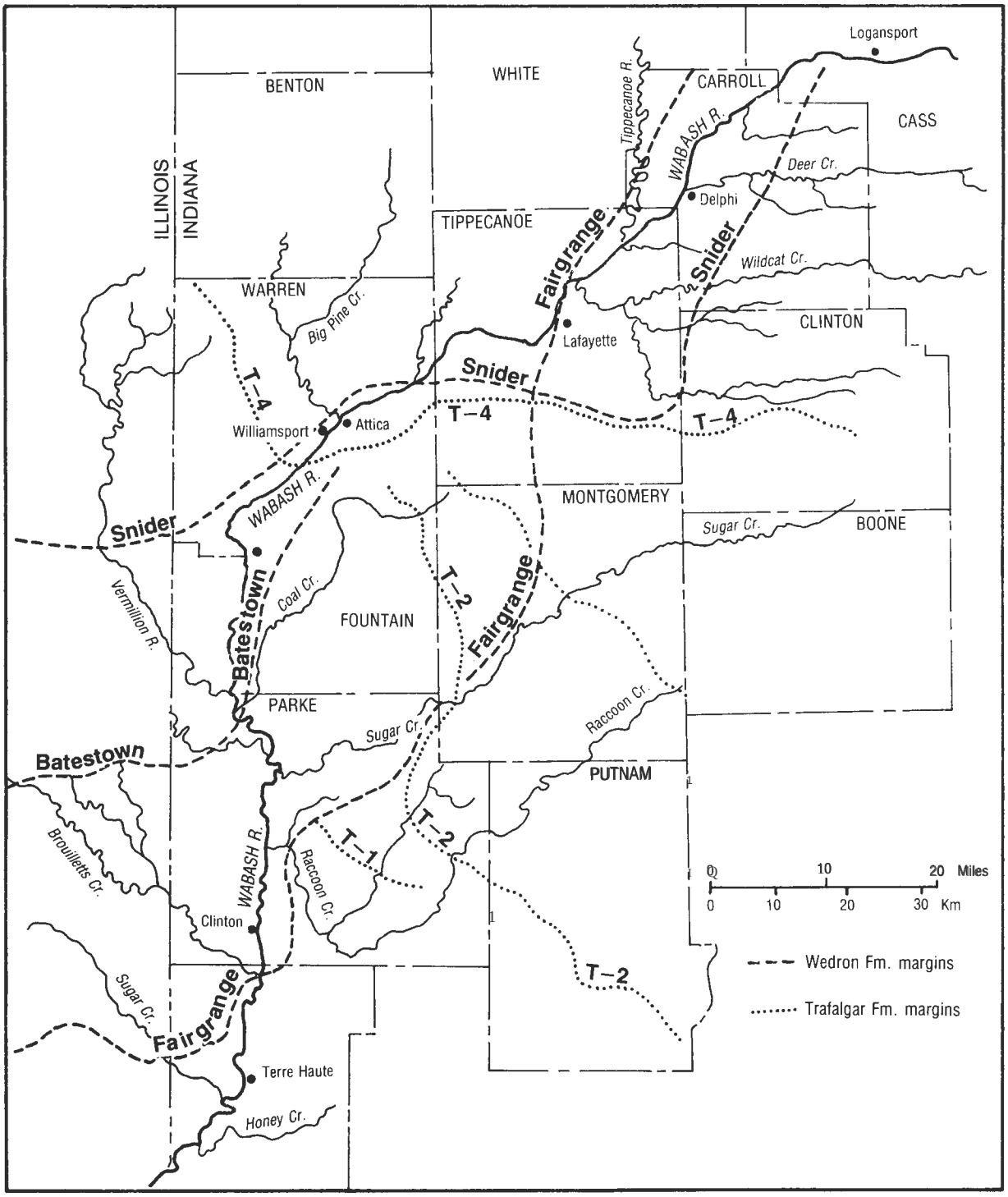

Figure 14. Map of the Middle Wabash River showing the relationships of the various ice advances to the Wabash Valley and its tributaries (modified from Bleuer, unpub. data). The margins of the Lake Michigan lobe are shown with a dashed line; margins of the Huron-Erie lobe are shown with a dotted line.

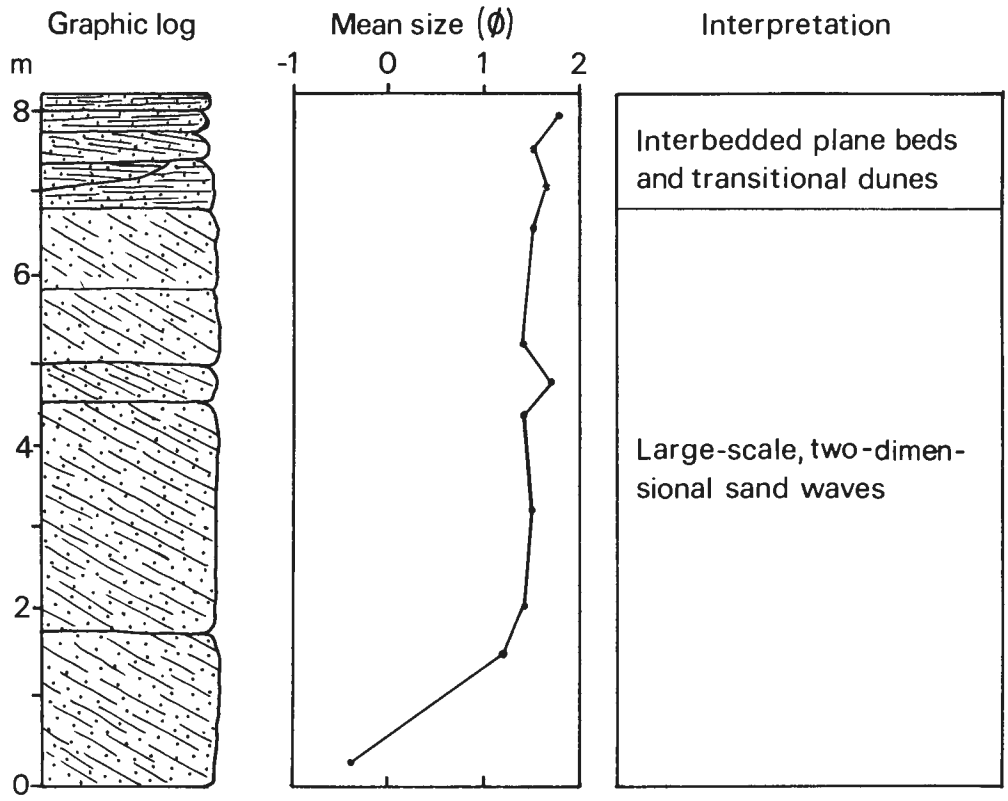

Figure 15. Log of a section through basal Wisconsin deposits just east of Lafayette, Indiana. The section consists of planar crossbeds deposited on large-scale sand waves in a relatively deep channel. These beds are capped by thinner beds of low-angle crossbeds and planar beds deposited in shallower water flows.

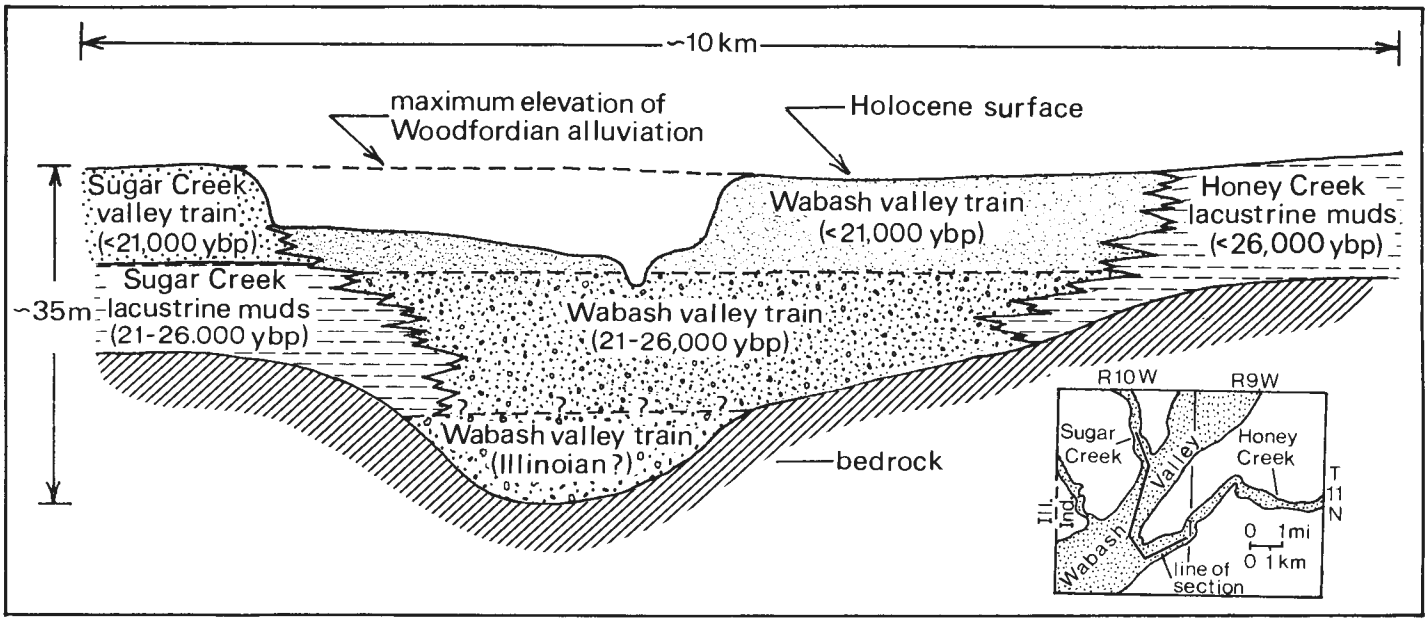

Figure 16. Transverse cross-section, based on auger borings, across the Wabash Valley and up the tributary valleys of Sugar Creek and Honey Creek at Terre Haute, Indiana. The valley of Honey Creek was filled with lacustrine muds that were deposited as the Wabash Valley aggraded and damned the mouth of the creek. The valley of Sugar Creek also contains lacustrine muds, but these are overlain by a thick sequence of outwash sand and gravel that was deposited when Lake Michigan lobe ice intersected its drainage basin.

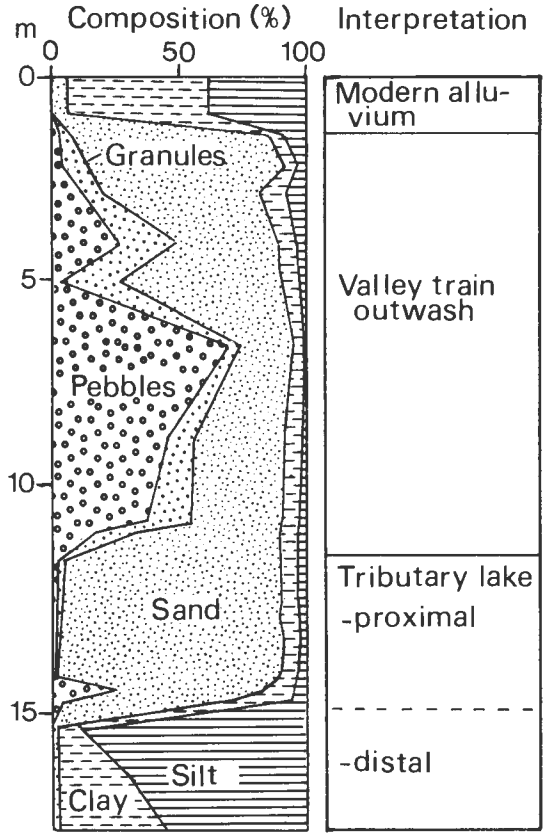

Figure 17. Log of a section penetrated by auger borings showing valley train outwash sediments overlying lacustrine basinal and deltaic deposits in Sugar Creek southwest of Terre Haute, Indiana. The lacustrine sediments accumulated during the early stages of ice advance into the Wabash drainage basin; the outwash sediments were deposited when the Lake Michigan lobe reached its terminal position at the Fairgrange margin (see fig. 14).

The situation remained static until about 21 ka when the advancing Huron-Erie lobe reached the T-1 margin just east of the valley (fig. 14). Most of the drainage from this ice bypassed the river, but coarse-grained outwash entered the lower reaches of the Middle Wabash along Raccoon and Sugar Creeks to the east. Soon afterward, the Lake Michigan lobe resumed its advance to the south and east. It finally reached the Fairgrange margin where the ice crossed the valley, blocking it between Lafayette and Terre Haute. Drainage from the margin of this ice sheet entered the Wabash Valley through Sugar Creek to the west, depositing outwash over lacustrine muds (fig. 17), and through Racoon Creek to the east where additional coarse outwash was added to that supplied previously by the Huron-Erie lobe (fig. 18). The Huron-Erie lobe readvanced to its T-2 terminus at the eastern margin of the Lake Michigan lobe and added finer-grained outwash to Sugar and Raccoon creeks to the east.

The timing of these earlier advances is fairly well established, but the chronology of later events is uncertain because of the apparent lack of datable organic material. However, relative chronology indicates that sometime after 20 ka, the Lake Michigan lobe readvanced to its Batestown margin which crosses the Wabash Valley just north of its confluence with Coal Creek. Marginal drainage west of the valley was directed into the river by Brouilletts Creek, and on the east the ice drained laterally into Coal Creek.

Meltwater also entered the Wabash directly from the ice just north of Coal Creek and built an elongate outwash fan in a downvalley direction (Fraser and Fishbaugh, 1985). Sediments deposited in the proximal part of this fan show evidence of very rapid aggradation and a strong response to glacial meltwater events. In some places, stacked deposits of longitudinal unit bars are separated only by thin trough crossbedded bar-top channel deposits, and are intercalated on their lateral margins with lateral accretionary wedges (fig. 19). In other areas, longitudinal bar deposits alternate with deposits of 2-D dunes and sandwaves that probably formed in channels during waning-stage flow.

The Huron-Erie lobe advanced a third time into the area from the northeast. Like the second advance of eastern-source ice, the northern lateral margin of the lobe to the northwest coincided with the south margin of the valley between Logansport and Attica, but the ice did not advance as far to the southwest (fig. 14). This lobe supplied sediment directly to the river from its northwest margin at Attica where an extensive outwash fan was built. Sand and gravel up to coarse pebble size was deposited primarily by sandwaves and 2-D dunes on the medial part of this fan. Trough crossbedded sand occurs in the sequence filling small channels on the tops of sandwaves and dunes and in large channels lateral to sandwave and dune deposits (fig. 20).

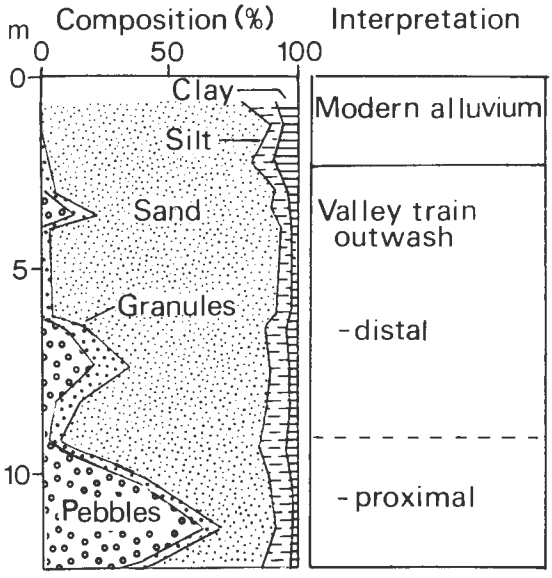

Figure 18. Log of a section penetrated by auger borings showing valley train outwash sediments in the valley of Raccoon Creek. The coarser, more proximal sediments were deposited when the Huron-Erie lobe reached its terminal position at the T-1 margin; the finer-grained, more distal sediments were deposited when the ice downwasted and then readvanced to the T-2 position (see fig. 14).

Laminated and ripple-bedded muddy sediments also were deposited in such channels during waning flow or upon channel abandonment.

Southwest-flowing tributaries of the Wabash, principally Coal Creek and Sugar Creek, drained the terminus of this glacier adding outwash indirectly to the Wabash. The sand and fine gravel in these valleys tends to be finer grained than the sediments in the trunk stream, and it is organized almost entirely into deposits of sandwaves and associated channels (fig. 21). The upcurrent parts of the sandwave deposits contain planar tabular crossbeds with angular basal contacts, whereas downcurrent ends consist of low-angle crossbeds with tangential basal contacts (fig. 21a). Such a downcurrent change in bedding style suggests that sandwaves evolved from relatively straight-crested 2-D forms to more complex 3-D forms, possibly in response to rising flow stage during flood events. Such a response is indicative of the immediate impact of glacial meltwater events on sedimentation in these tributary streams.

Small channels occur on upper surfaces of sandwave deposits, and thicker and more extensive channel deposits, filled dominantly with trough crossbedded sand and granules, form their lateral margins. In places, channel deposits interfinger with sandwave deposits, reflecting relative stability of channel and barform positions through several growth stages (fig. 21b). Such a pattern, in an environment more noted for the short-term instability of its depositional components, suggests that these stream valleys aggraded very rapidly.

The Huron-Erie lobe advanced a final time westward through the Great Bend area to its T-4 margin (fig. 14). This advance substantially altered the pattern of alluviation in the Wabash Valley and several of its tributaries. The southern lateral margin was well north of previous margins, passing just south of Lafayette, and it extended much farther to the west. It crossed the valley at Attica marking the only time that the Huron-Erie lobe crossed the Wabash River.

This fourth advance of the Huron-Erie lobe probably deposited most of the sequences exposed in gravel pits and outcrops in the terraces lining the margins of the Wabash Valley. Sediments in the valley were deposited in a shallow braided stream where abrupt lateral and vertical changes in sediment size and bedding characteristics occurred in response to changes in flow conditions, the relative proximity of tributary sources, and valley width and local gradient. Although most of the braided stream alluvium in the Wabash Valley presents a complex pattern of erosional remnants of bar and channel deposits, more or less complete sequences occur occasionally that document the dominance of flood episodes during alluviation of the valley.

Initially, this ice blocked the Wabash Valley as far downstream as Attica, but eventually through-flowing drainage was reestablished in the valley, and meltwater and sediment entered it directly down outwash fans. The large fan at West Point and the smaller fan at Independence were deposited, and the fan at Attica was reoccupied at this time (fig. 22). During this second phase of fan growth, sediment was supplied to the Attica fan through a series of north-south oriented crevasses that were filled and presently exist as kames.

Meltwater and debris flowed to the south out of these troughs but were then redirected to the west down the fan. Sediments in these kames consist of a heterogeneous assemblage of poorly sorted sediment in discontinuous, massive, and commonly

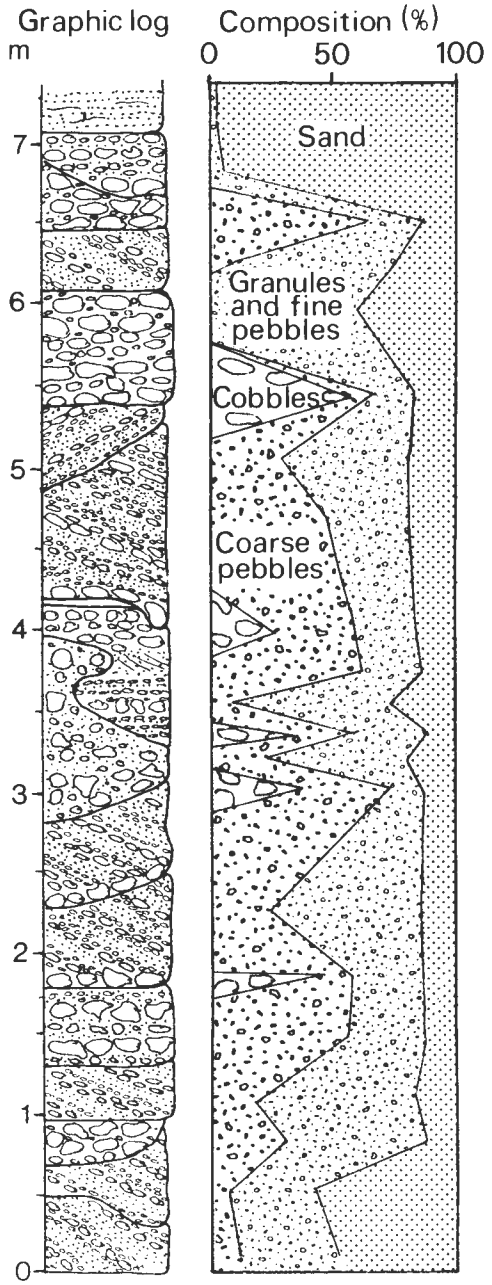

Figure 19. Log of a section in the proximal part of the Coal Creek fan exposed in a gravel pit near Silverwood, Indiana. The fan was deposited when the Lake Michigan lobe advanced to its terminal position at the Batestown margin. The sediments consist mainly of cobble-rich longitudinal bar deposits interbedded with finer-grained crossbedded deposits of sand waves and lateral accretionary prisms overlying gravel lags in interbar channels.

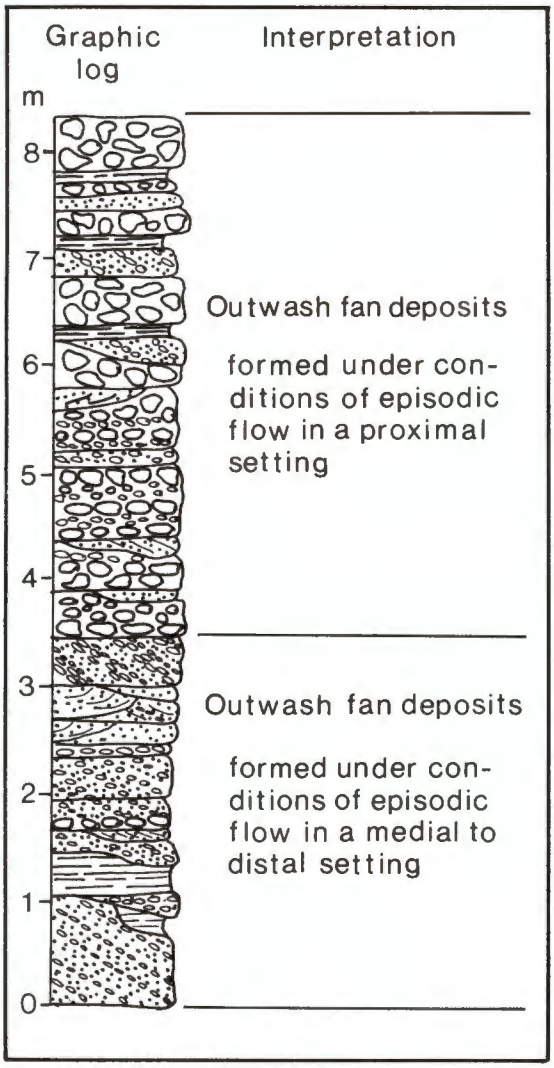

Figure 20. Log of a section in the Attica fan exposed in a gravel pit southwest of Attica, Indiana. Relatively fine-grained sediments in the lower part of the sequence were deposited during the first stage of fan sedimentation; the upper, more coarse-grained sediments were deposited during a second phase.

deformed beds. Cobbles are abundant, boulders are common, and the sediments in the fan are commensurately coarse. Longitudinal bar and sheet flood deposits are the dominant fan sediments, but bar-top channel deposits of crossbedded sand and fine gravel or laminated mud are also present (fig. 20).

Sediment also entered the Wabash Valley indirectly through a number of tributary streams. Because of the facies relationships between glaciofluvial sediments and till of debris flow origin at the margins of these valleys, many of the tributaries probably originated as intraice drainageways. Deer Creek, the three branches of Wildcat Creek, and their tributaries all occupy east-west valleys that probably originated in crevasses formed during the rapid extension of ice into the area (fig. 22).

Three facies assemblages have been defined in the drainage basin of Deer Creek (Carter, 1987). The ice-contact assemblage is dominant in the interfluves of the basin, and it also occurs along the margins of the channels where it is interbedded with other facies assemblages (fig. 23a). The assemblage includes subglacially deposited sandy loam till, and ablation debris consisting of a variety of sediment types including debris flow deposits, muds deposited in supraglacial ponds, and sand and gravel deposited in small, ephemeral streams.

A deltaic facies assemblage was deposited in a bedrock low at the confluence of Deer Creek and Batchelor Run, its principal tributary (Fraser and Bleuer, 1986; Carter, 1987). It accumulated at a time when ice or outwash sand and gravel, filling the channel of the Wabash, dammed Deer Creek at its outlet. The assemblage includes bottomset beds consisting of ripple-bedded sand and plane-bedded silt with minor amounts of clay and fine sand, and foreset deposits consisting of planar crossbedded sets of sand and fine gravel filling broad, trough-shaped scours (fig. 23b). The foresets grade downdip into bottomset beds and laterally into levee-like beds that were deposited by overflows from the main channel. They grade updip into topset beds consisting of sand and gravel deposited on sandwaves and 2-D dunes and in interbar channels.

Sediments of the fluvial assemblage of intraice channels typically occur in upward-fining sequences that were deposited in response to a decline in grain sizes being supplied to the channel and by a gradually diminishing flow in the channel (fig. 23c). Gravel-rich beds deposited on longitudinal bars and sheet floods dominate the lower parts of these sequences, and with the occasional intercalated debris flow deposits, they indicate the relative proximity of glacial ice to the channels during early stages of alluviation. Sand and relatively fine-grained gravel accumulated on sandwaves and 2-D dunes and in interbar channels during deposition of the upper parts of fluvial assemblages in the troughs. The change in grain size and bedding characteristics signals a reduction in the caliber of the sediment being supplied to the trough and a decline in flow. Such a change might have resulted from areal downwasting of the ice lobe when the ice margins receded from the channels and as the ice mass diminished and became insulated by ablation debris.

A catastrophic flow of meltwater entered the Wabash Valley from water-saturated disintegrating ice to the north of the valley (Fraser and Bleuer, 1988). This marked the final stage of outwash sedimentation in the Middle Wabash Valley that is attributable to the T-4 advance of the Huron-Erie lobe. The flow was initially erosive, but as flow waned it deposited the Tippecanoe Fan near Delphi (see fig. 1 for location) where it entered the valley. It also laid down sequences of megascale crossbeds over very coarse lag gravels in the valley itself. The flow must have been sufficiently deep to deposit gravel trough sets as much as 5 meters thick. It peaked rather quickly and then declined, probably over a span of days rather than weeks.

The last glacigenic event in the valley was a second catastrophic downvalley flood (Fraser and Bleuer, 1988). A series of advances and retreats of the Huron-Erie lobe occurred around

14 ka and left a series of recessional moraines in the northeastern part of Indiana (Wayne and Zumberge, 1965; Wayne, 1968). Meltwaters of the Huron-Erie lobe impounded behind the easternmost of these moraines in the state broke through the moraine at Fort Wayne. This flood was mainly erosional in the upper and middle Wabash Valley. It scoured a deep trough through the previously deposited alluvium in the valley, sculpting bedrock outcroppings in the valley floor, and even cutting shallow troughs in the adjacent till upland where the flood topped the valley wall. In places, however, it deposited features such as lee-eddy bars, pendant bars, expansion bars, and trains of megaripples that are analogous to features deposited by the Lake Missoula flooding in the Channeled Scablands described by Baker (1973) (Fraser and Bleuer, 1988).

SUMMARY

The late Wisconsin alluvium in the Wabash Valley and its tributaries, and the till in the uplands adjacent to the valley and its tributaries, were deposited when multiple advances of the Lake Michigan and Huron-Erie lobes occupied the drainage basin of the river. The bulk of the sediments in the main valley consist of gravel-rich alluvial deposits of sheet floods and longitudinal bars juxtaposed laterally and vertically with finer-grained deposits of sandwaves and 2-D dunes. Lateral margins of the bar deposits are commonly truncated by large channels filled with sand and fine gravel in large-scale troughsets deposited by 3-D dunes and planar crossbedded lateral accretionary deposits.

Debris flow deposits occur in the glaciofluvial deposits of the Wabash Valley, but outwash fans were the main repository of sediment that was supplied directly to the valley from the ice. Outwash fans contain the coarsest-grained sediment in the lithosome and were probably the primary source of coarse gravel to the Wabash Valley. Deposits of sheet floods, channels, and longitudinal bars, and sandwaves and 2-D dunes dominate outwash fan sequences; however, debris flow deposits occur at fan heads, and lenses of mud are common in bar-top channels and interbar channels. The relative abundance of mud, probably deposited in slackwater ponds on outwash fan surfaces, suggests that aggradation was so rapid that such deposits could be preserved during subsequent flood events. It also suggests that flow fluctuations over the fans more fully reflected the hydrologic cycle of the glaciers than did the flow in the main channel.

Facies in the tributary valleys vary with respect to the relationship of the tributary to the ice sheets. Those tributaries that were never glaciated are filled with lacustrine sand and mud deposited when the tributaries were dammed at their mouths by the aggrading channel floor of the main valley. Tributaries whose headwaters were glaciated are of two types: those that carried meltwater flow before the trunk stream did, and those that did not. Outwash only occurs in tributaries, such as Big Pine Creek, where meltwater flow was established prior to the initiation of such flow in the Wabash. In cases where the glaciers did not reach such tributaries as Racoon Creek and Brouilletts Creek until after meltwater had entered the main valley, outwash is underlain by lacustrine sediments. Deposits of sandwaves and 2-D dunes, and associated channel deposits dominate most

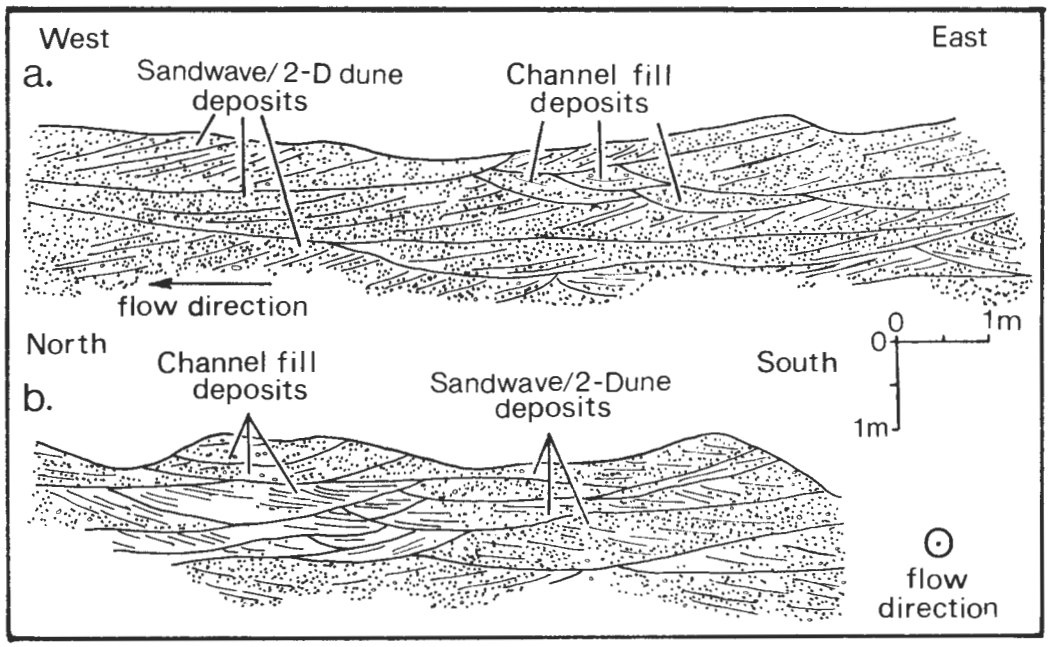

Figure 21. Tracings from photomosaics showing bedding characteristics in sediments filling the valley of Coal Creek, an outwash tributary of the Wabash Valley near Veedersburg, Indiana. Sediments consist of sandwave and channel deposits and are shown in section parallel to dominant flood flow (a), and transverse to dominant flood flow (b).

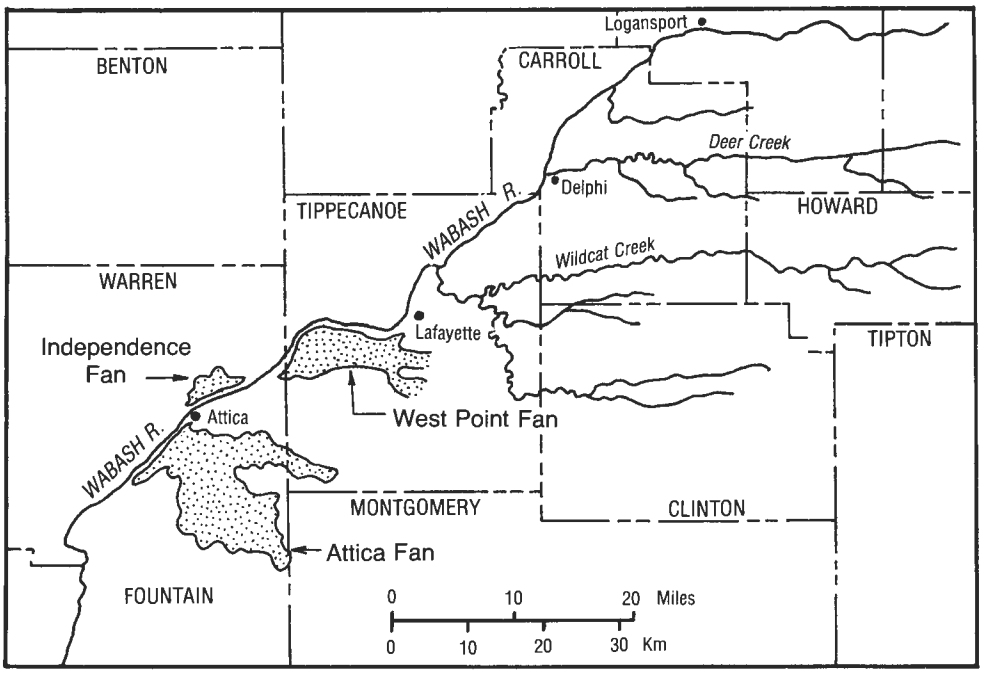

Figure 22. Map of the Great Bend area of the Wabash River showing the distribution of outwash fans, and the orientation of tributaries that formed during the period of downwasting that followed the advance of the Huron-Erie lobe to its T-4 margin.

successions, and evidence that channel floors aggraded rapidly is abundant.

Tributaries that originated as ice-walled channels in downwasting ice sheets contain a markedly heterogeneous assemblage of sediment facies. Fluvial deposits consist of sand and gravel in upward-fining sequences deposited in response to waning flow from the downwasting glacier. Gravel-rich beds at the base were deposited in sheets or on longitudinal bars during flood stage, and finer-grained sand and gravel higher in the sequences were deposited on sandwaves and in channels. Debris flow deposits and deformed lenses of lacustrine mud occur in fluvial sediments near channel margins and probably represent water-saturated supraglacial material that slumped into the channel. Other ice-walled channels accumulated thick lacustrine sequences.

Minor facies in the alluvium of the Wabash Valley include lenses of ripple-bedded sand and silt and plane-bedded mud. These were deposited during low flow conditions, but the relative scarcity of sediments in the valley that were deposited from suspension during still water conditions suggests that at least some flow was maintained in the channels most of the time. Apparently, the extreme flow fluctuations characteristic of glacial meltwater regimes (Smith, 1985) were buffered to some extent by the large size of the drainage basin, and by the variety of sources of the water. Like sequences in the main valley, there are relatively few beds of ripple-bedded silt and plane-bedded mud in sequences deposited in tributary drainageways. It seems even these smaller valleys were too large to respond rapidly to short-term flow fluctuations. However, outwash fans and tributaries that originated as ice-walled channels contain abundant lenses of mud and sand deposited on bar-top channels, in slackwater ponds, and in abandoned anabranches on braid plains. These depositional systems were connected very closely to their glacial sources and thus were able to respond rapidly and completely to the hydrologic regime of the melting ice.

Extreme events that occurred during the latter part of the late Wisconsin happened very rapidly, but profoundly affected the geomorphology and pattern of sedimentation in the valley. The first of the floods deposited the Tippecanoe fan at Delphi and a gravel-rich sequence of large-scale cross-sets as much as 10 meters thick in the middle part of the valley. The second flood scoured a channel through previously deposited outwash in the upper and middle parts of the valley, and eroded valley margins and upland surfaces where the flow topped the valley wall. It also deposited cobble-rich gravels at points of flow expansion and behind flow obstructions in the valley.

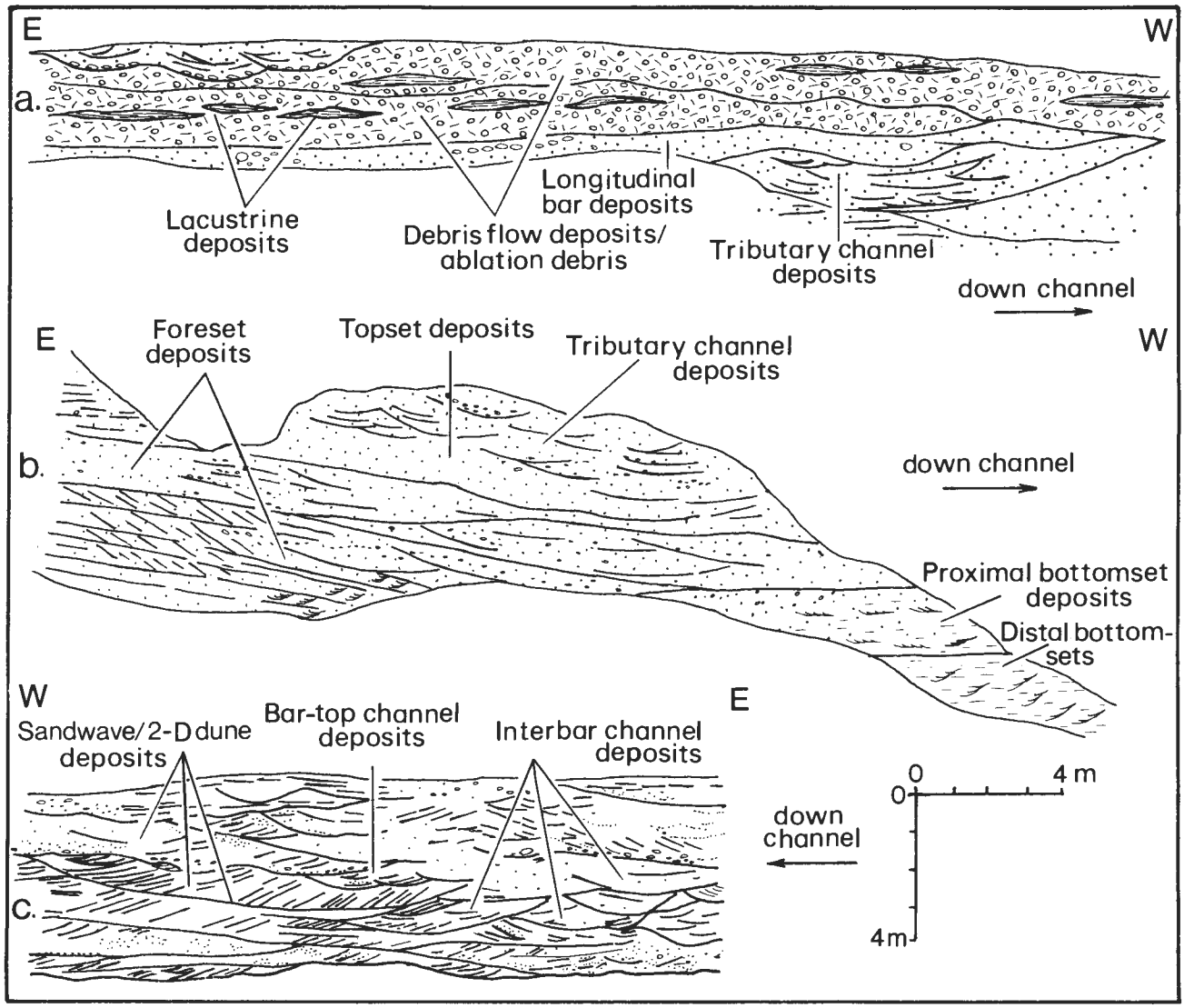

Figure 23. Tracings from photomosaics showing characteristics of the facies assemblages in the ice-walled channel deposits in and adjacent to Deer Creek near Delphi, Indiana: 1) sediments of the stagnant ice assemblage overlying sediments of the fluvial assemblage; 2) topset, foreset, and bottomset deposits of the deltaic assemblage; and c) bar and channel deposits of the fluvial assemblage (modified from Carter, 1987).

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