success. Or the sketch might be a commentary
merican playwriting on the uneasy situation
r generation of recently-famous or would-be-
se Shine isn't so sure that he wants to shine
en he is seen only as a celebrity, he is also
recognized for the smiling public man he has
is what it is expected to be. An old Bronx
ember has made it big in shoulder pads, meets
, and doesn't recognize this sneaker-shod drinker
play he will see that night; no one meets him
irport, where a sinister looking inspector general
whereabouts of Glenda Jackson; a would-be
is out to be an admiring high school teacher
ons of a Rolls Royce to meet him turn into
ious Italian director wants to cast a deformed
jockey from St. Louis, armed with a Ph.D.
ure from a California university, in the lead
oman in the film adaptation of his new play.
Shine slowly learns the game. He adopts an
personality as a protection screen for his one
public help him cope with the disease called

theater has long been preoccupied with the
and the price we pay for trying to live up to
place in Miller's continuing dialogue on this
om two short stories he wrote long ago, *Fame*
ssive in that it dignifies the national network
it gives Miller an enormous first-night forum
uestion," writes Miller, "is whether the play-
rtistry broad and deep enough to engage the
humanity of so immense an audience." High-
oubt debunk Miller for his concessions to the
should keep in mind that a world premiere
by a major figure is by no means the usual
ght hook-up. *Fame* may be a slight piece, but
e on N.B.C. is rife with implications for the
drama might become on T.V. in America.

Enoch Brater
The University of Michigan

In southeast Michigan

Ice Stagnation and Paleodrainage In and Near an Interlobate Area

RICHARD L. RIECK
Western Illinois University

The Kalamazoo moraine of the Saginaw lobe extends approximately east-west across southeast Michigan and a related Huron-Erie lobe moraine, which Leverett (Leverett and Taylor, 1915) identified as the Mississinewa, trends about north-south (Figure 1). These two moraines formed about 14,800 years ago (Farrand and Eschman, 1974, p. 38) and merge in eastern Jackson and western Washtenaw Counties to form a northeast-trending interlobate tract. The Grass Lake Plain, an extensive area of glacial outwash, is located in the reentrant between the two moraines. A number of distinctive landforms indicative of glacial stagnation are located throughout the area. It is also obvious that the nature of the interlobate contact had a major effect upon drainage development during deglaciation that is still evident in the landscape today.

Kalamazoo Moraine

East of Jackson the Kalamazoo moraine averages 5 to 7 km in width and displays hummocky topography. Relief is as much as 70 m per survey section. Large amounts of glaciofluvial sediments are distributed throughout the moraine and flow till is common. Ice contact slopes, closed depressions, and stagnation landforms are widespread. Rieck (1976) has shown that this portion of the moraine was formed in contact with stagnant, rather than active, ice.

An apron-like surface as much as 1 km wide and underlain by sand and gravel slopes to the south from the moraine and merges with the Grass Lake Plain (Figure 2A). Both the sedimentary characteristics and topography indicate that this surface is an outwash apron. The apron is bounded on the north by a very steep, east-west–trending ice-contact slope that may exceed 30 m in height. These relationships show that the ice-contact slope marks the approximate location where glaciofluvial sediments were deposited against the stagnant margin of the Saginaw lobe.

A number of gravelly knobs, such as Sackrider Hill, are located on the crest of the outwash apron and form the highest points in the area (Figure 2B). These features, asymmetric and cone-shaped,

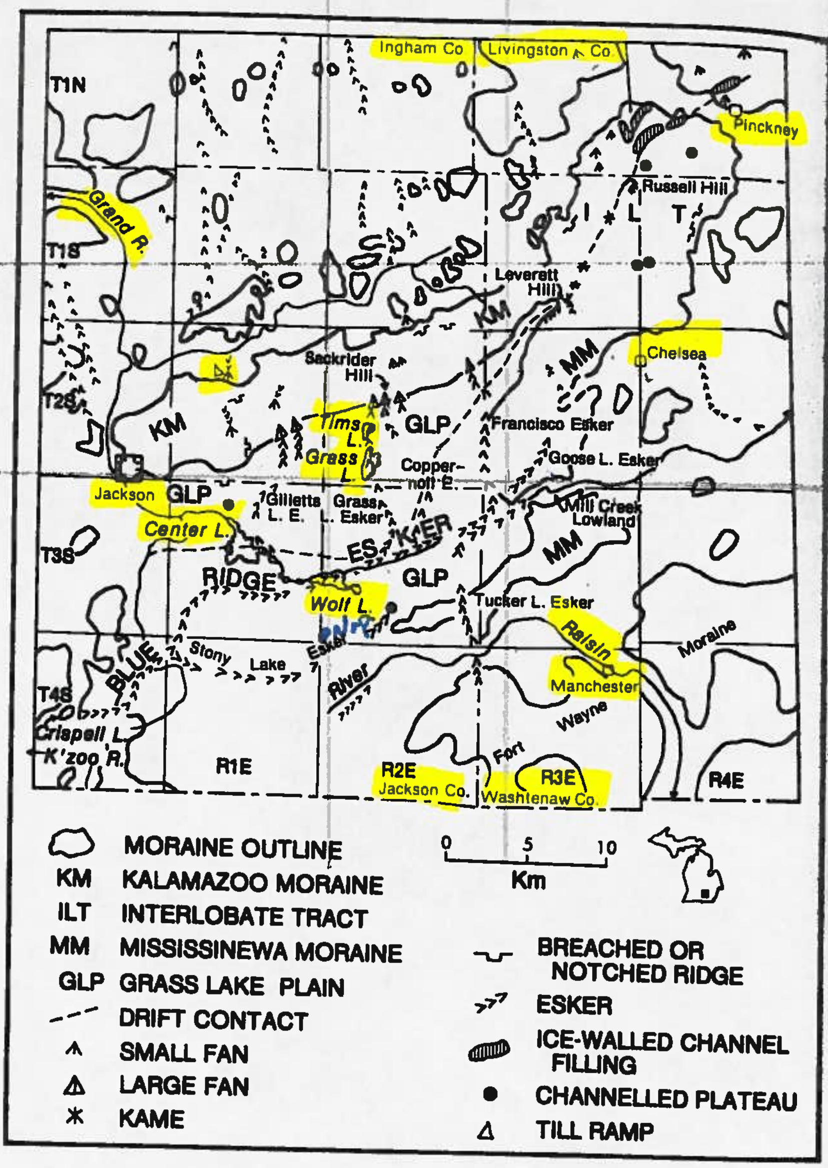

FIG. 1. Landforms of the area.

see Randy's maps

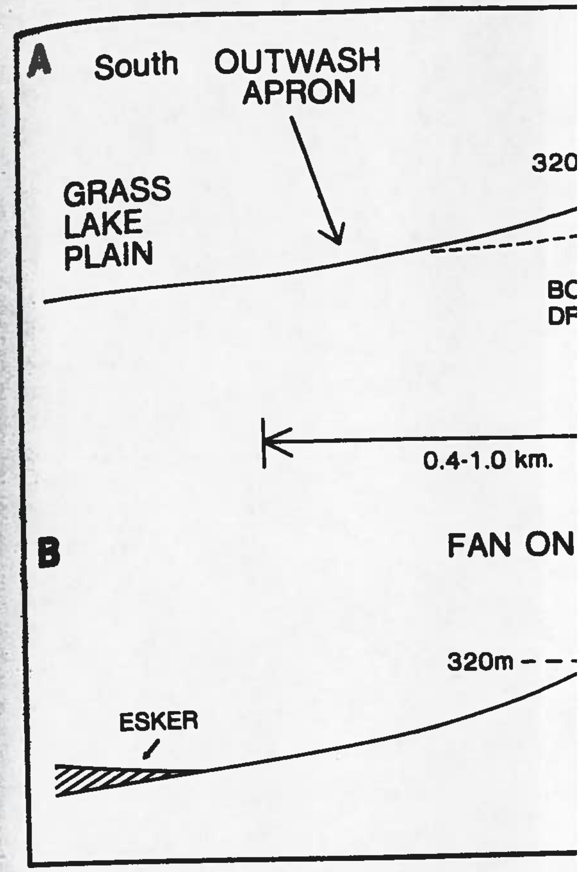

FIG. 2. Schematic profiles of the Kalamazoo mor
Outwash apron and dry channel. (B) Outwash
apron.

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sand and gravel at the ice margin to form
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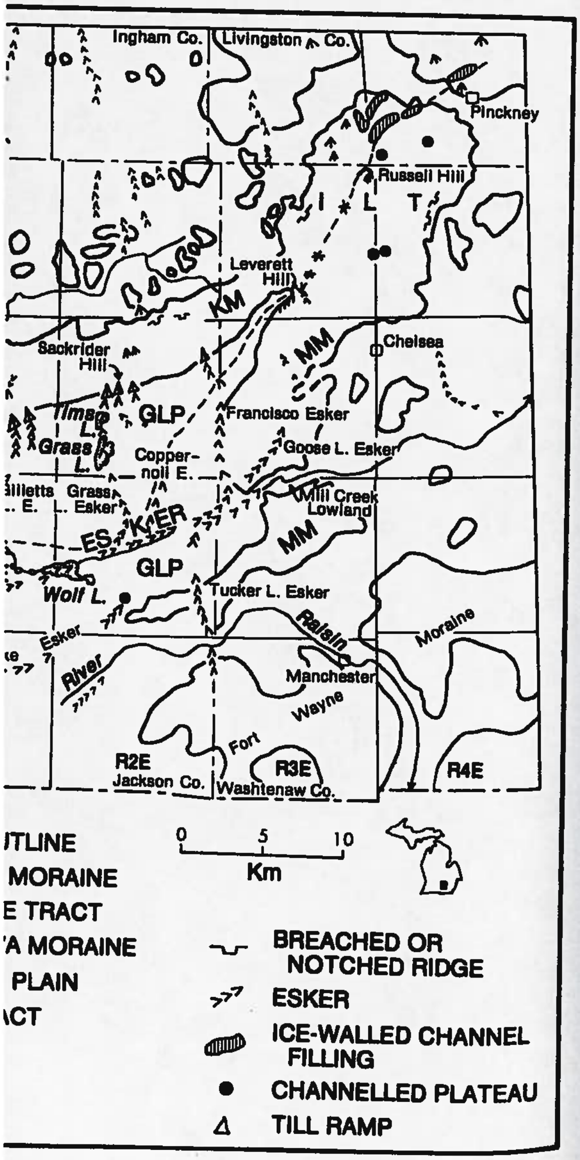

G. 1. Landforms of the area.

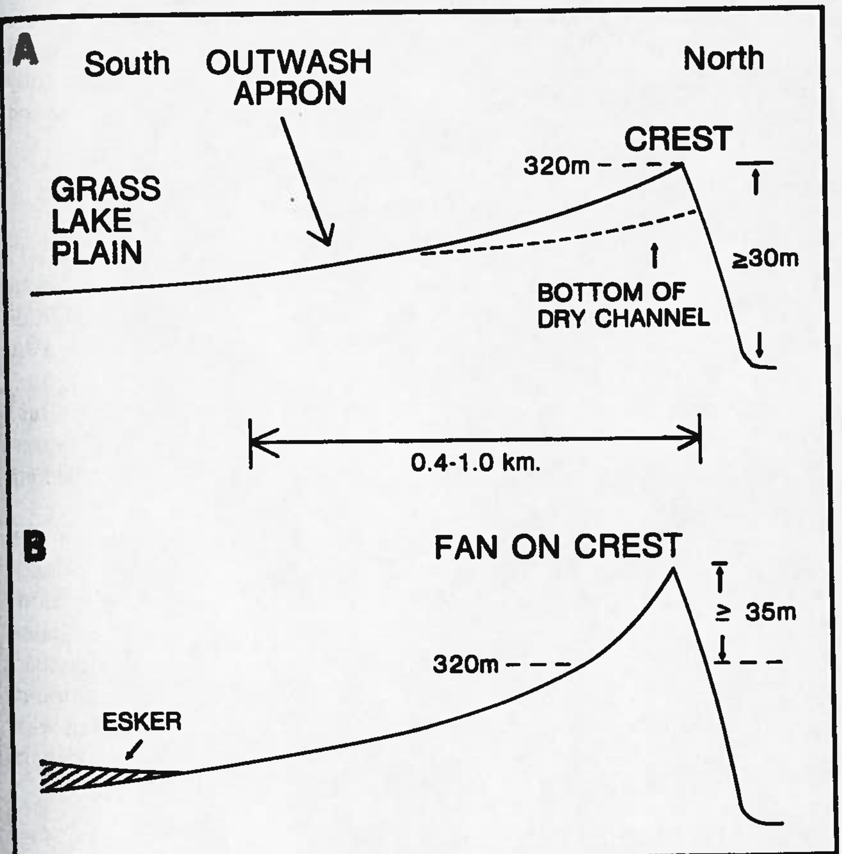

FIG. 2. Schematic profiles of the Kalamazoo moraine outwash apron. (A) Outwash apron and dry channel. (B) Outwash fan on crest of outwash apron.

appear to mark the sites where comparatively large streams deposited sand and gravel at the ice margin to form outwash fans as much as 35 m above the broader and lower surface of the outwash apron. Like the outwash apron these outwash fans have steep ice-contact northern slopes. A number of eskers that trend south across the Grass Lake Plain are clearly associated with the high outwash fans (Figure 2B).

Several streamless channels, as much as 12 m deep, originate at the ice-contact slope marking the distal flank of the moraine and trend south down the surface of the apron (Figure 2A). The channel bottoms are 13 m or more above the base of the ice-contact slope and resemble hanging valleys. This indicates that the channels were eroded after the apron was formed but before the adjacent stagnant ice had completely melted. Furthermore, the dry channels are fully developed at their upstream ends indicating that they formerly extended northward some distance onto the ice of the glacier margin.

Mississinewa Moraine

The portion of the Mississinewa moraine in the area is about 17 km long, trends nearly north-south, and varies in width from about 0.5 km to 6.5 km. Local relief exceeds 50 m. Glaciofluvial materials and flow till are present in considerable quantities. This Huron-Erie lobe moraine was also formed, at least in part, in contact with stagnant ice and it too has an outwash apron which merges with the Grass Lake Plain. The proximal, or eastern, edge of the outwash apron is marked by an irregular ice-contact slope. Shallow dry channels are present on the outwash apron.

In the north a southwest-trending subglacial drainageway terminates in the proximal portion of the moraine. The Mill Creek Lowland, a second drainageway, breaches the moraine in an east-west direction. Several km to the south a wide portion of the moraine contains well-developed stagnation landforms with impressive ice-contact slopes. Farther south this segment of the Mississinewa moraine terminates abruptly in an outwash surface. Eskers are associated with all of these morainic features and, in conjunction with the eskers near the Kalamazoo moraine, form an extensive esker system.

Interlobate Tract and Drift Contact

The Interlobate Tract is a rectangular-shaped area about 8 km wide and 15 km long which trends northeast from the junction of the Kalamazoo and Mississinewa moraines to Pinckney (Figure 1). Maximum local relief in the tract is 55 m per survey section. Associated with a mean local relief of about 35 m are numerous ice-contact slopes. Sand and gravel are the most common surficial sediments in the tract, but considerable flow till is present, and ice-contact glaciolacustrine silts and muds are not unknown. Landforms indicative of glacial stagnation are widespread.

Leverett Hill[1] is situated at the junction of the two moraines, the Grass Lake Plain, and the Interlobate Tract (Figures 1 and 3A). This

[1] An informal designation given to an unnamed landform on the Stockbridge 15′ quadrangle located in portions of secs. 28, 32, and 33, T. 1 S., R. 3 E. and sec. 5, T. 2 S., R. 3 E. This feature physically connects the Kalamazoo and Mississinewa moraines.

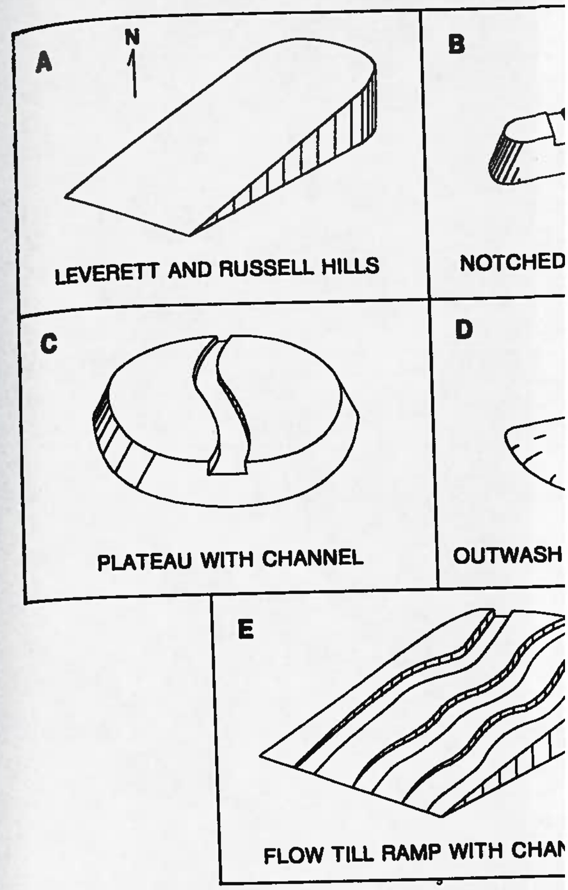

FIG. 3. Selected landforms associated wi

relatively flat-topped feature slopes to the
in height, and consists primarily of sand
wide and 4 km in length its long axis trends no
Tract. Ice-contact slopes mark its northwest
flanks. The shape, southwest slope, ice-con
type all indicate the hill is a large ice-con
by sediment-laden meltwater flowing south

The ice-contact slopes on the outwash
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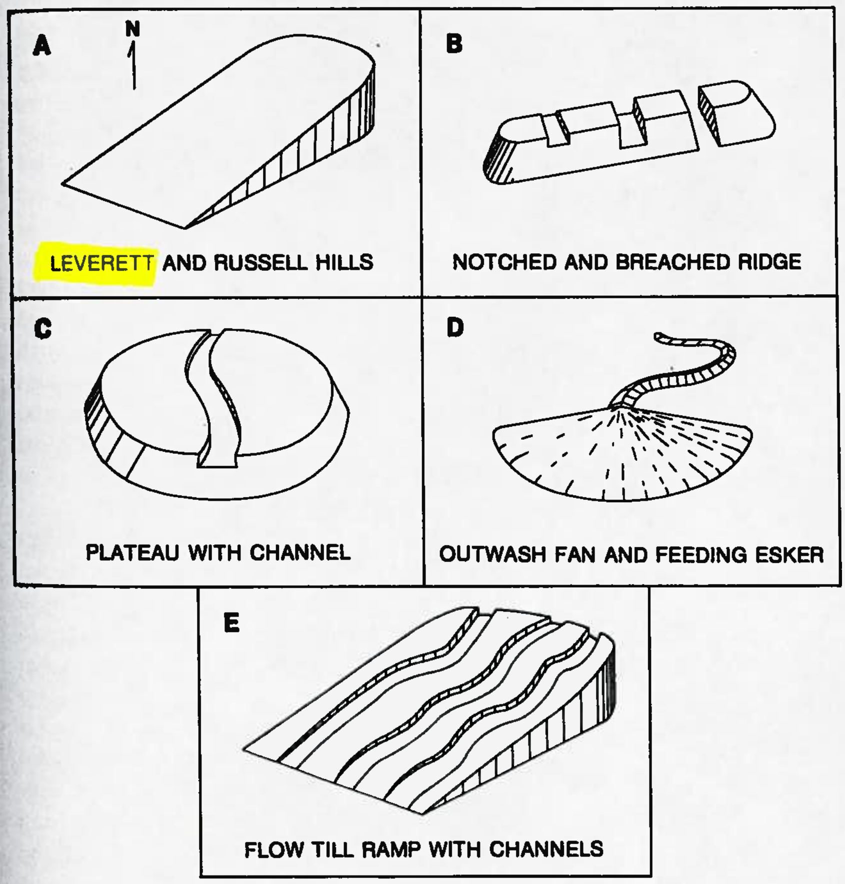

FIG. 3. Selected landforms associated with glacial stagnation.

relatively flat-topped feature slopes to the southwest, exceeds 30 m in height, and consists primarily of sand and gravel. About 1 km wide and 4 km in length its long axis trends northeast into the Interlobate Tract. Ice-contact slopes mark its northwest, northeast, and southeast flanks. The shape, southwest slope, ice-contact flanks, and sediment type all indicate the hill is a large ice-contact outwash fan formed by sediment-laden meltwater flowing southwest.

The ice-contact slopes on the outwash aprons of both moraines can be traced directly to the ice-contact flanks of Leverett Hill. This continuous ice-contact slope connecting the three features proves the distal portion of the Kalamazoo and Mississinewa moraines are exactly time-correlative and formed simultaneously with Leverett Hill.

A linear series of large kames trends northeast from Leverett Hill into the Interlobate Tract (Figure 1). On the basis of morphology, and also sedimentary evidence to be presented later, these kames appear to be located at, or very near, the interlobate contact. When the trend of this series of kames is extended northeast it encounters Russell Hill,[2] a flat-topped feature which is slightly less than 1 km wide and nearly 2 km long (Figure 3A). The hill, as much as 35 m high, slopes to the southwest. Composed primarily of sand and gravel its northwest, northeast, and southeast flanks are ice-contact slopes. When the proximal edge of the Kalamazoo moraine is extended east and the crest of the Mississinewa moraine is extended north into the Interlobate Tract, they meet at Russell Hill. The similarities between Russell and Leverett Hills such as slope, trend, sediments, ice-contact flanks, and regional relationships are striking and suggest both are interlobate features that were formed in reentrants between the stagnant Saginaw and Huron-Erie lobe margins.

As mentioned previously Leverett Hill has a number of kames located to the northeast. Northeast of Russell Hill lie several linear, flat-topped, glaciofluvial features flanked by ice-contact slopes. These large forms are as much as 35 m high, 2 km long, and slope to the southwest just as do Leverett and Russell Hills. The glaciofluvial sediments, ice-contact flanks, linear nature, and regional slope suggest they are large ice-walled channel fillings formed by a superglacial stream flowing southwest. A profile (not shown here) drawn along the channel fillings indicates they are probably graded to Russell Hill.

It has been shown that the clay mineralogies of Saginaw and Huron-Erie lobe drifts are distinctively different in this part of the state (Rieck, 1976, and Rieck, et al., in press). X-ray diffraction analysis of clays from numerous samples in the moraines clearly distinguishes the tills of the two lobes because Saginaw lobe tills have 7 Å/10 Å peak height ratios of 0.91 or more and Huron-Erie lobe tills ratios of 0.90 or less. X-ray diffraction analysis of several drift samples from the Interlobate Tract indicates the samples from the northwest portion have a Saginaw lobe provenance and those from the southeast were deposited by Huron-Erie ice. In fact, a line marking the surficial drift contact indicated by this clay mineralogy is nearly coincident with the linear sequence of landforms including Leverett Hill and associated kames and Russell Hill and its ice-walled channel fillings

[2] An informal designation given to an unnamed landform on the Stockbridge 15′ quadrangle located in sec. 1, T. 1 S., R. 3 E. I. C. Russell collaborated with Frank Leverett on the Ann Arbor geologic folio in 1908.

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Other Stagnation Landfor

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a notch was eroded.

A related landform type, which may have
circular to irregular, is a high, relatively flat
with steep flanks (Figures 1 and 3C). One
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(Figure 1). In addition, it was shown earlier that Leverett and Russell Hills formed in reentrants between the stagnant Huron-Erie and Saginaw lobe margins. Thus it appears likely that Leverett Hill was deposited as an interlobate ice-contact outwash fan by a superglacial meltwater stream flowing at, or very near, the contact of the two lobes. The kames northeast of Leverett Hill were probably deposited by the stream at about the same time in perforations in the stagnant ice. Somewhat later the same superglacial interlobate stream probably formed Russell Hill in a manner similar to Leverett Hill. The ice-walled channel fillings were also deposited at this time for they seem to be graded to Russell Hill. Two additional ice-walled channel fillings to the north appear to mark the location of streams from the Saginaw lobe which were tributary to the main interlobate stream (Figure 1).

Other Stagnation Landforms

Although the Kalamazoo moraine outwash apron and the Leverett and Russell Hill assemblages may be unusual they are certainly not the only interesting features located in the area. For example, another type of landform is a linear sand-and-gravel feature, often flat-topped, with steep flanks and a dry channel or notch perpendicular to the long axis (Figures 1 and 3B). Some of these ridges have been breached completely; others have not. They bear a strong resemblance to wind and water gaps which are found in bedrock ridges. On the basis of their sediments and steep flanks, it is postulated that the breached and notched ridges represent crevasse or channel fillings with post-depositional glaciofluvial erosion. After the ridge sediments were deposited and a portion of the adjacent stagnant ice had melted, superglacial streams probably flowed across the features, eroding some of the sediments. The depth of the eroded channels was determined by the length of time that the streams flowed in those locations. If the superglacial environment was relatively stable, the streams may have flowed long enough to completely breach the ridge; if not, only a notch was eroded.

A related landform type, which may have any shape from almost circular to irregular, is a high, relatively flat, sand-and-gravel feature with steep flanks (Figures 1 and 3C). One or more dry channels may trend across such plateaus from one side to the other. The channels head and end abruptly at ice-contact slopes and are not graded to the surrounding lowland. A variation includes high, flat features with a dry depression on top and an associated dry channel which trends across the upper surface toward lower ground. Genesis of the flat-topped features and their channels is probably similar to that of the breached and notched ridges except that deposition evidently took place in some sort of perforation in the ice rather than in a crevasse. The origin of the channels associated with the depressions is not as obvious.

There are also a number of asymmetric fan-shaped landforms with ice-contact proximal flanks as much as 20 m high. They are composed primarily of sand and gravel and resemble the high, fan-shaped knobs along the crest of the Kalamazoo moraine outwash apron but are smaller and located at lower elevations in morainic areas (Figures 1 and 3D). The forms and sediments suggest the features are ice-contact outwash fans formed by meltwater streams and deposited against stagnant ice. Narrow sinuous ridges of sand and gravel trend into the steep proximal slopes of 3 of the fans. These particular features seem to be ice-contact fans with associated feeding eskers. It is interesting to note that of the 14 fans identified, both with and without eskers, 13 are associated with the Saginaw lobe.

An individual feature of interest is about 10 m high, 0.75 km long, and located just north of the Kalamazoo moraine. It is underlain by till and resembles a ramp (Figures 1 and 3E). Three channels, up to 4 m deep, trend down its sloping surface, and ground silos in the feature expose large amounts of flow till. Steep marginal slopes on the south indicate an ice-contact origin, and the morphology suggests that it is a deposit of flow till which moved downslope off a nearby block of stagnant ice. The three channels head at an ice-contact slope and appear to "hang." This suggests that after deposition meltwater from nearby stagnant ice flowed over the till ramp and eroded the channels.

Grass Lake Plain

Local relief on the Grass Lake Plain is generally less than 15 m, but near the Center Lake-Wolf Lake chain of lakes it is somewhat greater, partially due to the depth of the lakes. A series of profiles (not shown here) constructed across the Grass Lake Plain and orthogonal to the moraines shows that the tops of hills mark the remnants of a surface which slopes gently from the moraines. The contact between the remnants of the sloping outwash surfaces from the two lobes is interpreted to mark the boundary between surficial drift of the two lobes. Near the moraines the surface sediments of the Grass Lake Plain are rather coarse with considerable amounts of gravel and large cobbles. However, with increasing distance from the moraines the surface sediments become finer until little gravel is present. X-ray diffraction analysis of clays from the few till exposures on the Grass

Lake Plain yields results very similar to the pr
topographic and mineralogic lines of evidence thus
of the surficial drift contact (Figure 1).

Blue Ridge Esker System

Trending across the Grass Lake Plain, and very
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Wisconsin, respectively, but reported none whi
from both lobes merging with the trunk, int
Blue Ridge seems to be rather unusual beca
close proximity to a significant interlobate con
tributary eskers associated with both lobes.

The Tributary Eskers

As is common with most eskers, none of
Blue Ridge system are continuous for their en
from ridge segments only a few meters high
close stereoscopic inspection of air photos to
visible in the field at a distance of several
that all the tributary eskers are situated in troug
even though they are located on an outwas
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Blue Ridge Esker System

Trending across the Grass Lake Plain, and very near the drift contact, is a landform that Leverett (Leverett and Taylor, 1915, p. 203) first identified as the Ackerson esker, describing it as a single ridge about 11 km long and 12 m high. Modern topographic maps label the feature as "Blue Ridge." More recent workers (Rieck, 1972, Keifenheim, 1974, and Rieck, 1976) have shown, however, that it is at least 30 km long, as much as 24 m high, and merely the central ridge of one of the best-developed esker systems in the state.

The esker system in which Blue Ridge is the trunk feature forms a dendritic pattern with four tributary eskers on the Kalamazoo moraine or Saginaw lobe flank and three on the Mississinewa moraine or Huron-Erie lobe flank. There are numerous reports from Finland of "interlobate eskers" including those by Repo (1960), Okko (1962), and Aartolahti (1972). The lobes between which these Finnish eskers formed were generally small, however, often only 15 to 25 km wide or less and protruded just a short distance from the margin of the Scandinavian ice sheet. Buddington and Leonard (1962, p. 15) mapped an esker in the Adirondacks which was deposited between somewhat larger lobes. Wilson (1939, p. 124) and Stoelting (1970) described interlobate eskers which formed between major lobes in Canada and Wisconsin, respectively, but reported none which had tributary eskers from both lobes merging with the trunk, interlobate, esker. Thus, Blue Ridge seems to be rather unusual because it was formed in close proximity to a significant interlobate contact and has connecting tributary eskers associated with both lobes.

The Tributary Eskers

As is common with most eskers, none of the tributaries in the Blue Ridge system are continuous for their entire length. They range from ridge segments only a few meters high and visible only with close stereoscopic inspection of air photos to ridges 20 m high easily visible in the field at a distance of several km. A striking fact is that all the tributary eskers are situated in trough-like linear depressions even though they are located on an outwash plain. Such flanking depressions might possibly result from the ablation of ice blocks buried during genesis of the plain. There is no obvious explanation, however, for the formation of the required narrow ice masses as much as

5 km long nor for their presence only near the eskers. Similar trough-like features are often associated with eskers and are generally attributed to subglacial erosion by the esker stream. It seems apparent that the depressions were probably not formed prior to the outwash plain because they would then have subsequently filled with the younger outwash and would no longer be visible.

Total ridge length of the four Saginaw lobe tributary eskers is about 24 km; if the gaps are included, esker length is more than 40 km (Table I). From west to east I have labelled them the Gilletts Lake, Grass Lake, Coppernoll, and Francisco eskers.

The westernmost tributary ridge is the Gilletts Lake esker. It trends south from one of the high, gravelly knobs on the outwash apron of the Kalamazoo moraine. Eight kilometers to the south it is lost to view as a peninsula at the southeast end of Center Lake, about 2 km from Blue Ridge. It is ordinarily less than 8 m in height and one of the smaller tributary eskers.

A high, gravelly knob just west of Sackrider Hill is the upstream terminus of the Grass Lake esker. The northern portion of this ridge consists of a number of segments—several of which are clearly visible on air photos and on hydrographic maps showing the underwater

TABLE I
BLUE RIDGE AND TRIBUTARY ESKER LENGTHS

	Segments Only (km)	Segments and Associated Gaps (km)
Saginaw Lobe Tributaries		
Gilletts Lake	5	10
Grass Lake	8	11
Coppernoll	5	11
Francisco	6	10
	24	42
Huron-Erie Lobe Tributaries		
Goose Lake	3	6
Tucker Lake	5	10
Stony Lake	8	14
	16	30
Interlobate Trunk		
Blue Ridge	30	37
Total	70	109

topography of Tims and Grass Lakes. Leverett p. 63), who identified the feature only as a "n located an exposure which showed its parent north to south. South of Grass Lake the esker more than 5 m high, and connects with Blue Ri Lake. The Grass Lake esker has more total rid any other Saginaw lobe tributary.

A continuous ridge almost 2 km long trends s of Sackrider Hill. Locally it is nearly 15 m hi Dorr and Eschman (1971, p. 156). Four kilom the Coppernoll esker which closely approaches, with, Blue Ridge. There is a strong possibilit the moraine and the Coppernoll esker were bot stream even though a gap of 5 km separates th

The Francisco esker, which averages about at a high, gravelly knob on the crest of the Kalam apron, very near the Washtenaw-Jackson Coun south along the distal edge of the Mississine marked by an ice-contact slope and closed depr lobe tributary esker runs parallel to Blue Ri 1 km before connecting with it just west of the

The Huron-Erie lobe tributary eskers displ length of about 16 km; about 30 km if gaps ridges have somewhat variable relations with the I have labelled two of them the Goose Lake an A third ridge, Stony Lake esker, was recognized

Located entirely in the Mississinewa mora Huron-Erie esker is only about 3 km long, an average height of about 10 m. This is th Beginning and ending abruptly, it trends southw of the subglacial drainageway which termina does not seem to be physically connected wi lobe Francisco esker nor with Blue Ridge.

Beginning on the south side of River Raisin trends completely through a wide portion of the in an area where ice-contact stagnation lanc pits and ridges, are well expressed. Locally m high. A gap in the ridge about 1 km long Raisin valley and is probably due to late- Although the Goose Lake and Tucker Lake with Blue Ridge it seems clear from the trenc of the system that the streams which formed t and sediments to the trunk stream.

r presence only near the eskers. Similar trough-like
sociated with eskers and are generally attributed
a by the esker stream. It seems apparent that
probably not formed prior to the outwash plain
then have subsequently filled with the younger
no longer be visible.

of the four Saginaw lobe tributary eskers is about
are included, esker length is more than 40 km
t to east I have labelled them the Gilletts Lake,
noll, and Francisco eskers.

ributary ridge is the Gilletts Lake esker. It trends
the high, gravelly knobs on the outwash apron
moraine. Eight kilometers to the south it is lost
ula at the southeast end of Center Lake, about
lge. It is ordinarily less than 8 m in height and
ibutary eskers.

nob just west of Sackrider Hill is the upstream
s Lake esker. The northern portion of this ridge
of segments—several of which are clearly visible
on hydrographic maps showing the underwater

TABLE I
AND TRIBUTARY ESKER LENGTHS

	Segments Only (km)	Segments and Associated Gaps (km)
aries		
	5	10
	8	11
	5	11
	6	10
	24	42
butaries		
	3	6
	5	10
	8	14
	16	30
	30	37
Total	70	109

topography of Tims and Grass Lakes. Leverett (field notebook 166, p. 63), who identified the feature only as a "narrow gravel ridge," located an exposure which showed its parent stream flowed from north to south. South of Grass Lake the esker is nearly continuous, more than 5 m high, and connects with Blue Ridge just east of Wolf Lake. The Grass Lake esker has more total ridge length, 8 km, than any other Saginaw lobe tributary.

A continuous ridge almost 2 km long trends south from the vicinity of Sackrider Hill. Locally it is nearly 15 m high and is pictured by Dorr and Eschman (1971, p. 156). Four kilometers to the south is the Coppernoll esker which closely approaches, and probably merges with, Blue Ridge. There is a strong possibility that the ridge near the moraine and the Coppernoll esker were both formed by the same stream even though a gap of 5 km separates the segments.

The Francisco esker, which averages about 10 m in height, heads at a high, gravelly knob on the crest of the Kalamazoo moraine outwash apron, very near the Washtenaw-Jackson County boundary. It trends south along the distal edge of the Mississinewa moraine which is marked by an ice-contact slope and closed depressions. This Saginaw lobe tributary esker runs parallel to Blue Ridge for a distance of 1 km before connecting with it just west of the Mill Creek Lowland.

The Huron-Erie lobe tributary eskers display an aggregate ridge length of about 16 km; about 30 km if gaps are included. These ridges have somewhat variable relations with the Mississinewa moraine. I have labelled two of them the Goose Lake and Tucker Lake eskers. A third ridge, Stony Lake esker, was recognized and named previously.

Located entirely in the Mississinewa moraine the northernmost Huron-Erie esker is only about 3 km long, although it does have an average height of about 10 m. This is the Goose Lake esker. Beginning and ending abruptly, it trends southwest along the extension of the subglacial drainageway which terminates in the moraine. It does not seem to be physically connected with the nearby Saginaw lobe Francisco esker nor with Blue Ridge.

Beginning on the south side of River Raisin the Tucker Lake esker trends completely through a wide portion of the Mississinewa moraine in an area where ice-contact stagnation landforms, such as linear pits and ridges, are well expressed. Locally the esker is nearly 20 m high. A gap in the ridge about 1 km long is located in the River Raisin valley and is probably due to late-glacial fluvial erosion. Although the Goose Lake and Tucker Lake eskers do not connect with Blue Ridge it seems clear from the trends and dendritic pattern of the system that the streams which formed them supplied meltwater and sediments to the trunk stream.

Near the abrupt southeast termination of this portion of the Mississinewa moraine is one of the large plateau-like features with a depression on top. More than 15 m high, it marks the upstream end and probable source of the third Huron-Erie lobe tributary, the Stony Lake esker. The landform was named by Keifenheim (1974), who described it as a series of ridge segments totaling about 2.5 km in length with an eastern terminus at the longitude of Center Lake. It is here recognized as continuing for a much longer distance to the east. The total segment length of 8 km makes it the longest Huron-Erie lobe ridge and about equal in ridge length to the Grass Lake esker. Locally it is as much as 13 m high and exposures indicate meltwater flow was from east to west. The Stony Lake esker is physically connected with the Blue Ridge esker.

A comparison of tributary eskers from the two lobes reveals the following relationships: (1) Three, and probably all four, Saginaw lobe tributaries are associated with, and begin at, the high, gravelly knobs on the crest of the Kalamazoo moraine outwash apron. Huron-Erie lobe eskers are found in conjunction with both depositional and erosional meltwater features in and near the Mississinewa moraine. (2) All the Saginaw lobe eskers were formed by streams flowing north to south, but the Huron-Erie lobe ridges are associated with former stream flows of northeast-to-southwest, southeast-to-northwest, and east-to-west. (3) Four of the seven tributary eskers are physically connected with Blue Ridge, and the remaining three have configurations suggesting that the streams which formed them were also confluent with the Blue Ridge stream. This indicates the entire system was probably formed at the same time. (4) All of the eskers are located in troughs. This fact must be considered when proposing an explanation for the genesis of the system.

Blue Ridge Esker

The trunk esker of the system, Blue Ridge, consists of a number of segments with a total length of 30 km. This feature was formed by meltwater flowing from northeast to southwest as is shown by cross-bedding exposed at several locations. Morphologic evidence provides a similar interpretation because of the tributary esker trends and the dendritic pattern they display. It has already been established that the Blue Ridge esker formed at, or near, the Saginaw/Huron-Erie interlobate contact and thus is associated with interlobate drainage.

Blue Ridge originates in the Mill Creek Lowland which breaches the Mississinewa moraine in an east-west direction. Here, at its

upstream terminus, the esker consists of a seri
separated by gaps of 300 m or more. The seg
5 m high or less and no more than 30 or 35 m
of contact with Coppernoll esker the segments
and higher, may be nearly 1 km long, and ar
shorter gaps. Even here near its source, the
feature. The Wolf Lake hydrographic map sho
and esker segments on the bottom of the la
of the lake a ridge segment is flat-topped anc
Center Lake for a distance of about 1 km
topographic expression and is apparent only
the presence of gravel pits. From this area it
a conspicuous, nearly continuous, steep-side
m high. Near its confluence with the Stony L
is flat-topped reaching its maximum width of
a maximum height of 24 m. Several km to
downstream terminus Blue Ridge merges with
and ridges near Crispell Lake at the headwa
River North Branch. Meltwater from the esker
down the river.

Crest form of the esker varies from quit
to flat where its width is maximum to some
downstream terminus. This is undoubtedly
the tunnel in which it was formed and slun
with melting of the ice. A longitudinal profil
of Blue Ridge (not shown here) indicates a
m above sea level near the Mill Creek Low
much as 329 m at its southwest end suggesting
was probably subglacial and flowing under h

Genesis of the Syster

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Blue Ridge esker system. All the eskers in t
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plain because deposition of related sedimen
troughs. The Grass Lake Plain is geneticall
not only on the basis of topography but al
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upstream terminus, the esker consists of a series of short segments separated by gaps of 300 m or more. The segments are only about 5 m high or less and no more than 30 or 35 m wide. Near the point of contact with Coppernoll esker the segments are somewhat wider and higher, may be nearly 1 km long, and are separated by much shorter gaps. Even here near its source, the ridge is an impressive feature. The Wolf Lake hydrographic map shows ice-contact slopes and esker segments on the bottom of the lake. Immediately west of the lake a ridge segment is flat-topped and 20 m high. South of Center Lake for a distance of about 1 km Blue Ridge has little topographic expression and is apparent only on soil maps and by the presence of gravel pits. From this area it extends southwest as a conspicuous, nearly continuous, steep-sided ridge more than 15 m high. Near its confluence with the Stony Lake esker, Blue Ridge is flat-topped reaching its maximum width of more than 200 m and a maximum height of 24 m. Several km to the southwest at its downstream terminus Blue Ridge merges with a complex area of pits and ridges near Crispell Lake at the headwaters of the Kalamazoo River North Branch. Meltwater from the esker stream may have flowed down the river.

Crest form of the esker varies from quite sharp near its origin to flat where its width is maximum to somewhat rounded near the downstream terminus. This is undoubtedly related to the width of the tunnel in which it was formed and slumping which took place with melting of the ice. A longitudinal profile drawn along the crest of Blue Ridge (not shown here) indicates an altitude of about 310 m above sea level near the Mill Creek Lowland, but it rises to as much as 329 m at its southwest end suggesting that the related drainage was probably subglacial and flowing under hydrostatic pressure.

Genesis of the System

The exact mechanisms of esker formation are still a matter of some debate, and it is especially difficult to interpret the genesis of the Blue Ridge esker system. All the eskers in the system have adjacent troughs indicating that they cannot have formed prior to the outwash plain because deposition of related sediments would have filled the troughs. The Grass Lake Plain is genetically related to the moraines not only on the basis of topography but also by areal variations in grain size. In addition, all the eskers are directly associated with features in the moraines. These multiple relationships indicate that the Grass Lake Plain, the Kalamazoo and Mississinewa moraines, and Blue Ridge esker system all formed contemporaneously or pene-contemporaneously.

A mechanism which explains most features requires the area distal to the moraines to be occupied by a thin sheet of stagnant ice from both lobes. Evidence that masses of stagnant ice existed in the Grass Lake Plain area at the time the sediments were deposited is widespread. Numerous depressions and ice-contact features, such as the breached and notched ridges and channeled plateaus, exist within the plain. "Perched" dry channels on either side of ice-contact depressions are also present. Shallow depressions that are linear and parallel exist even on the flattest portions of the plain and indicate that sand and gravel was deposited in contact with stagnant ice. The presence of the esker system is also highly suggestive of stagnant ice (Embleton and King, 1968, p. 389).

It is proposed that sediment-laden meltwater from the two ice margins was sluiced onto the stagnant ice distal to the moraines and formed a superglacial outwash plain (Figure 4A). Concurrently, several large superglacial meltwater streams formed the gravelly knobs which are built above the general level of the Kalamazoo moraine outwash apron. These larger streams continued to drain southward within and beneath the stagnant ice and formed the Saginaw lobe tributaries to Blue Ridge. Streams also flowed from the stagnant ice associated with the Mississinewa moraine and formed the Huron-Erie lobe tributary eskers. As all the subglacial and englacial streams flowed outward toward the margins of the lobes, meltwater and sediments accumulated along the interlobate contact forming the Blue Ridge esker.

Later ablation of the ice supporting the plain superimposed the superglacial sediments onto the underlying material and eskers, preserving the subglacial forms and troughs even though covering them with a veneer of sediments (Figure 4B). Considering the plain, Leverett (Leverett and Taylor, 1915, p. 197) also concluded that "only a small portion of its surface is up to the plane of deposition." The melting of the ice and lowering of the glaciofluvial sediments completed formation of the Grass Lake Plain, which is probably best described as a collapsed outwash plain.

If the Grass Lake Plain formed as proposed, the stratification in the sediments would have been highly deformed or destroyed during superimposition. Unfortunately, exposures are nearly nonexistent in the area and with this lack of supporting field evidence the hypothesis remains somewhat speculative.

Howarth (1971) has studied in detail a Holocene esker in Iceland which was being exposed by ablation of the ice beneath a superglacial sandur. The melting process resulted in an esker trending across a rather low relief outwash plain. Although Howarth made no mention of an esker trough the similarities between the Icelandic ridge and

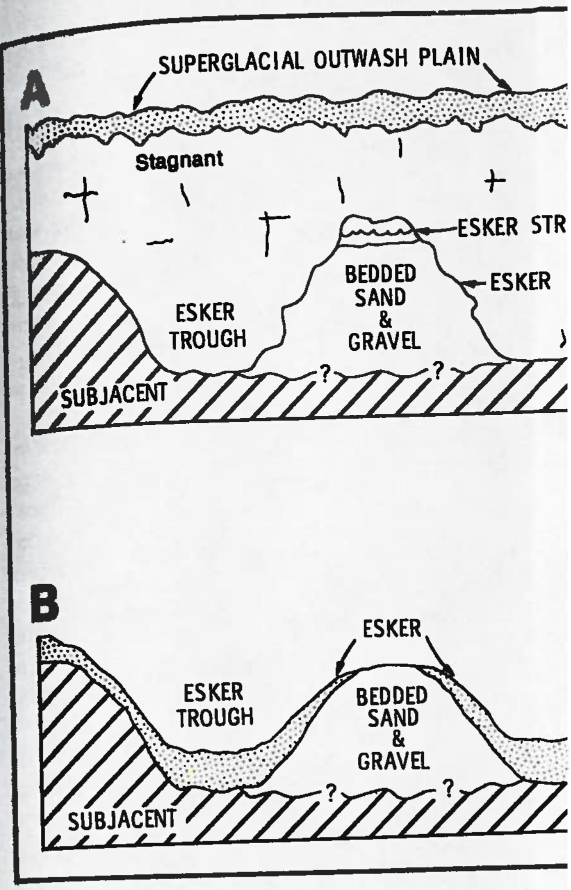

FIG. 4. Possible genesis of the Grass Lake Plain and formation of superglacial outwash plain and eske

the eskers in the Blue Ridge system are, no suggest the possibility of a similar origin.

Conclusions

Although most Pleistocene moraines may active ice the portions of the two moraine associated interlobate area were formed prim conditions by large amounts of glaciofluvial, flow till deposition. A considerable number including the outwash aprons and fans, breac explains most features requires the area distal occupied by a thin sheet of stagnant ice from hat masses of stagnant ice existed in the Grass me the sediments were deposited is widespread. and ice-contact features, such as the breached .d channeled plateaus, exist within the plain. els on either side of ice-contact depressions ›w depressions that are linear and parallel exist ›rtions of the plain and indicate that sand and in contact with stagnant ice. The presence of ›o highly suggestive of stagnant ice (Embleton).

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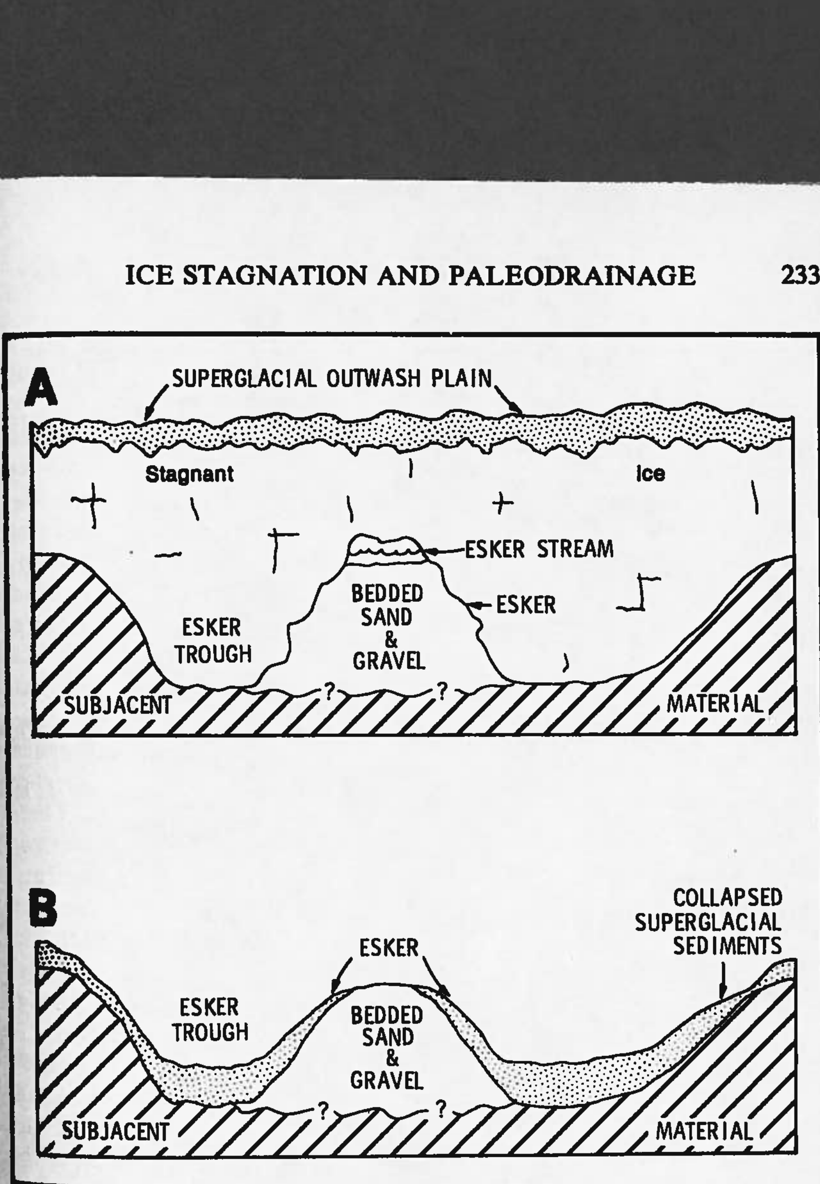

FIG. 4. Possible genesis of the Grass Lake Plain and eskers. (A) Simultaneous formation of superglacial outwash plain and esker. (B) After deglaciation.

the eskers in the Blue Ridge system are, nonetheless, striking and suggest the possibility of a similar origin.

Conclusions

Although most Pleistocene moraines may have been created by active ice the portions of the two moraines considered and their associated interlobate area were formed primarily under stagnant ice conditions by large amounts of glaciofluvial, and to a lesser extent, flow till deposition. A considerable number of unusual landforms, including the outwash aprons and fans, breached and notched ridges, and notched plateaus[3] are also indicative of stagnation and testify to the impact of this particular mode of deglaciation in and near the moraines.

In the Interlobate Tract Leverett and Russell Hills, their associated kames and channel fillings all seem to be associated with two successive episodes of deposition by superglacial drainage at the stagnant interlobate contact. Farther to the southwest the Grass Lake Plain was deposited by superglacial streams on stagnant ice. Contemporaneously tributary eskers were formed beneath the stagnant ice and subglacial meltwater was coursing along a central interlobate tunnel to form the Blue Ridge esker system.

Blue Ridge and its associated tributaries form the largest and most complete esker system identified so far in the state. While forming, the system had a drainage area that was, at an absolute minimum, 200 km^2. Total length of the ridges is at least 70 km and if the gaps between segments are included the figure is nearly 110 km. Three additional facts stand out: (1) The Blue Ridge esker system formed in a significant interlobate zone. (2) For much of its length the trunk feature, Blue Ridge, trends along, or near, the interlobate contact. (3) Tributary eskers of the system are associated with both the Huron-Erie and Saginaw lobes. These points indicate that the system is very unusual and perhaps unique, for it appears that no similar interlobate feature has been reported anywhere else in the world.

On the basis of this evidence the interlobate contact seems to have exerted a great degree of control on both superglacial and subglacial drainage during the events of deglaciation at the junction of the Kalamazoo and Mississinewa moraines. The stagnant ice of both the Saginaw and Huron-Erie lobes and the associated meltwater were thus responsible for the remarkable drainage patterns preserved today in individual landforms, landform assemblages, and the integrated esker system that are all located at or near the interlobate contact.

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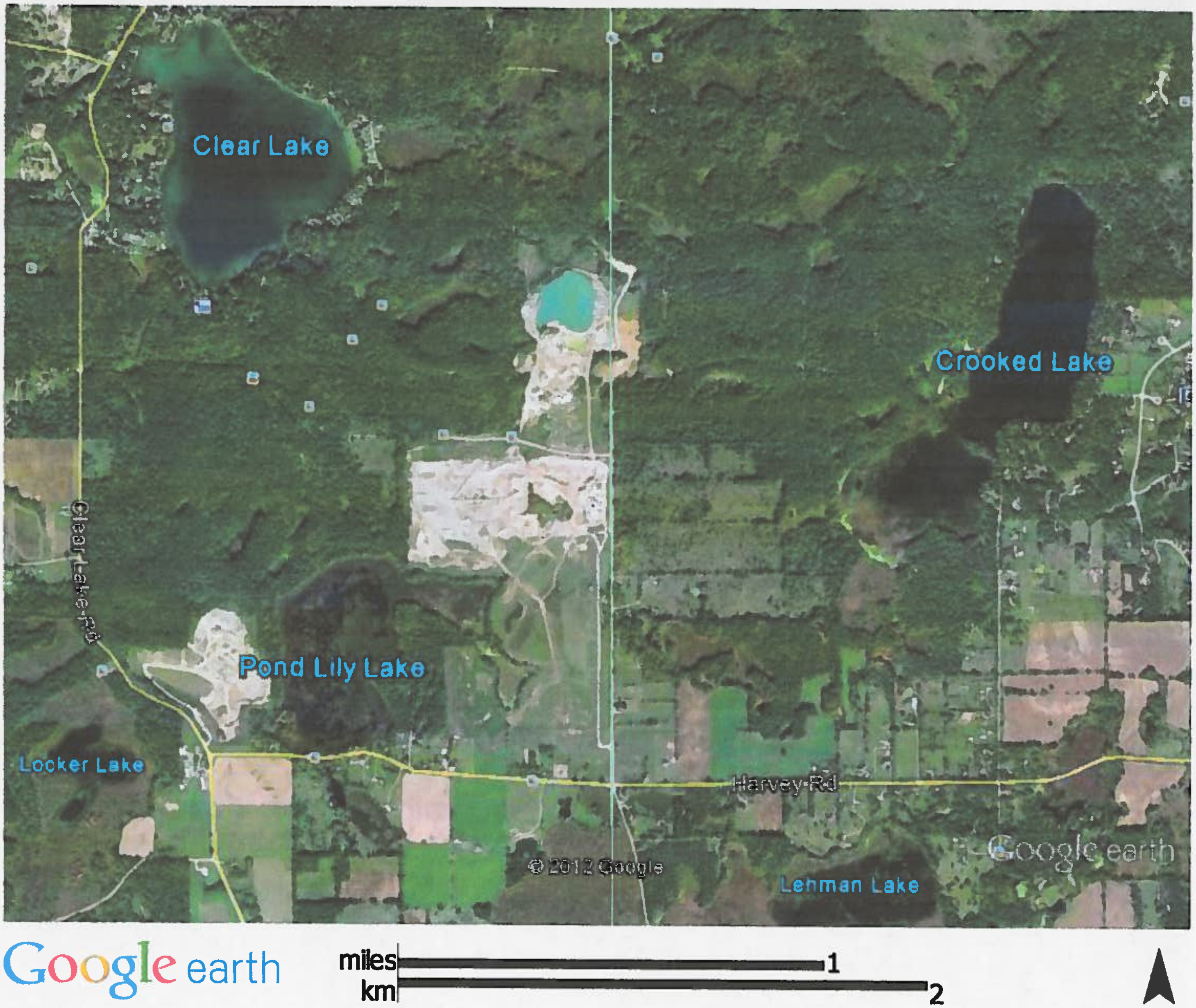

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