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STAGNANT ICE LANDFORMS OF THE CHIPPEWA MORAINE TAYLOR COUNTY, WISCONSIN

BY

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Introduction

Largely of ice stagnation origin (fig 2), the late Wisconsin terminal moraine of Taylor County contains a great variety of stagnant ice landforms and features The focus of this study is an analysis of those landforms, particularly ice walled lake plains and hummocky stagnation moraine The part of the terminal moraine examined here was formed primarily by the Chippewa lobe, with the section in the easternmost part of the county formed by the Wisconsin valley lobe The interlobate moraine separating the two lobes extends northward from northeastern Taylor County into Price County (fig 1).

History of Investigations

No detailed landform studies have been published on the terminal moraine in Taylor County, herein termed the Chippewa moraine Previous investigations and the present state of knowledge are discussed by Attig (in prep) There have been many studies that make brief reference to the moraine, but only three (Attig, in prep.; Cahow, 1976; Weidman, 1907) discuss the terminal moraine of Taylor County in any detail

Some of the more frequently cited studies dealing with ice stagnation features include Mannerfelt (1945) and Hoppe (1952) in Scandinavia; Niewiarowski (1963) in Poland; Flint (1930) in Ireland; Flint (1928 and 1929), Hartshorn (1958), Kaye (1960), and Koteff and Pessl (1981) in New England; Gravenor and Kupsch (1959), Stalker (1960), and Parizek (1969) in the Canadian Great Plains; Florin and Wright (1969) in Minnesota; and numerous studies in North Dakota, largely summarized by Clayton and Freers (1967)

General Description of the Moraine

The topographically prominent Chippewa moraine varies between 7 to 10 km in width The till of the moraine is reddish brown in color and sandy loam in texture, and similar to that of the ground moraine area north of it Drift thickness commonly ranges between 20 to 50 m, reaching a maximum of about 100 m near Perkinstown The bedrock is Precambrian in age No rock outcrops are present within the moraine, and the bedrock topography appears to have had no significant influence on the surface topography Local relief varies from 6 to 20 m in the less hilly parts, typified by the Lublin area, to 25 to 30 m in the more hilly parts, such as around Perkinstown

Stagnant Ice Landform Types

The stagnant ice landforms of Taylor County comprise an orderly landform assemblage or suite, with each landform type occupying a characteristic location relative to the other types. On the basis of (1) morphology, (2) lithology and internal structure, and (3) apparent mode of formation (genesis or origin), about fifteen different types of stagnant ice landforms were identified. They are not, however, all distinctly different from each other. Rather, the various types comprise several gradational series, and the series, in turn, may comprise a continuum. Some landforms consist of only one type of sediment, deposited by a single depositional process, while others are more complex.

Because the emphasis in this study is upon ice walled lake plains, only a few examples of the smaller landform types were mapped. Recognition of them on topographic maps is usually difficult due to their low local relief, and, often, less than ideal form.

The landform assemblage associated with a moraine of stagnant ice origin consists of a variety of ice contact features, interspersed with hummocky stagnation moraine--the latter by far the most widespread landform type (fig. 3). In addition to hummocky stagnation moraine, the more common landform types within the moraine, in approximate descending order of frequency, are: (1) ice walled lake plains of several types, (2) stagnant ice terraces, (3) semicircular disintegration ridges, and (4) circular disintegration ridges. The remaining landform types--all of which are described below--are relatively uncommon.

Hummocky Stagnation Moraine

Hummocky stagnation moraine (Winters, 1963) is the most representative and extensive landform type in the Chippewa moraine, and may account for 75 percent or more of the morainic topography. Gravenor and Kupsch (1959) have characterized this type of topography as consisting of "a non-descript jumble of knolls and mounds of glacial debris, separated by irregular depressions.

The knolls do not align into ridges and no dominant trends are discernible." They further note that topography of this type (fig. 3) is diagnostic of stagnant ice origin.

The ridges and mounds in hummocky stagnation moraine are predominantly composed of collapsed supraglacial till deposited during disintegration of stagnant ice (Attig and Clayton, 1987), and the local relief and slope angles of the knobs reflect the relative instability of the supraglacial environment. According to Attig and Clayton (in press), the supraglacial drift reached the ground primarily by gravitative transfer of various types during disintegration of the stagnant ice (fig. 5).

The ridges and depressions of hummocky stagnation moraine, although varying greatly in size, are commonly closely spaced, averaging about 200 m in diameter (fig. 3). The ridges function as partitions that divide the topography into numerous distinct, frequently closed depressions. As a result, the surface drainage for a large part of the moraine is nonintegrated The ridges, composed mainly of till, are sometimes capped by variably sorted sand and gravel, and occasionally contain pockets or lenses of sand and gravel Hummocky topography extends more or less continuously across the full width of the moraine (fig. 3).

Considerable regional variation exists within the areas of hummocky stagnation moraine with respect to local relief and slope angles For example, low relief hummocky stagnation moraine, with slopes of gentle to moderate inclination, is characteristic of the Lublin district, indicating that in this area the supraglacial till was relatively thin and the supraglacial environment was unstable during disintegration.

In the Perkinstown area, where the hummocky topography is best developed, the local relief usually ranges between 10 to 25 m Outside that area hummocky topography of moderate relief--that is, commonly ranging between 8 to 20 m--is found, except in the western part of the county and between Medford and the moraine, where subdued hummocky moraine topography, typically ranging between 2 to 10 m of local relief, is found.

Many of the hummocks in the part of the moraine shown on the Huron quadrangle (western part of county) do not look like typical hummocks in that they have ice contact slopes and flattened or concave tops and resemble features such as ice walled lake plains, circular disintegration ridges, semicircular disintegration ridges, and grooved top ridges, whose development was arrested before they achieved the ideal forms of those features

Stagnant Ice Hollow

The often deep, closed depressions, so characteristic of hummocky stagnation moraine, have been give various names Hoppe (1952) preferred the designation "dead ice hollow" and Black (1974) referred to them as "swales " The depressions in stagnant ice moraine represent places where the last remnants of the ice melted I prefer the term "stagnant ice hollow" which is both more consistent with the names of the other stagnant ice landform types and preferable (when discussing genesis) to the often used term "kettle" which does not indicate origin

Depressions of this type vary from a few to 30 m or more in depth They are best developed in the Perkinstown area, where they typically exhibit local reliefs of 10 to 15 m, but with some exceeding 30 m The diameter of stagnant ice hollows may vary from as low as a few m to more than a km The great majority, however, have diameters of less than one-half km Their shapes also vary considerably. Most are slightly elongated but display irregular outlines There is no discernible preferred orientation

The bottoms of stagnant ice hollows are typically poorly drained, especially the deeper ones, which results in a profusion of small ponds and wetlands within the moraine Stagnant ice hollows, though common, are an integral part of hummocky stagnation moraine and show the same geographic patterns as that of hummocky stagnation moraine, described previously Their distribution, therefore, will not be discussed separately.

Ice Contact Slope

The typical ice contact slope consists of a steep slope that represents the surface of a mass of sediment deposited on a firm ground surface, but against a steep supporting wall of glacier ice When the ice melted, the drift banked against it slumped. Consequently, the sediments making up such slopes typically stand near the angle of repose Collapse structures commonly observed in the associated stratified sediments provide evidence that slumping took place during the formation of ice contact slopes.

Ice contact slopes are often conspicuous and useful in the interpretation of other stagnant ice landforms For example, many of the landforms shown on figure 4 were first identified by their ice contact slopes

Ice Walled Lake Plain (perched type lake plain)

An ice walled lake plain (Clayton, 1967) is an elevated area of smooth and nearly flat topography underlain (in the ideal case) by horizontally bedded clays, silts, sands, and gravels (and, in some cases, till or flowtills intercalated with water deposited sediments near the margin) that were deposited in a glacial lake that was restricted at least in part by stagnant ice (fig 6) Sediment grain size typically decreases from the margin (usually sand and gravel) to the center (usually clay or silt) of lake plains Ice walled lake plains (perched lake plains) are some of the most characteristic features of the Chippewa moraine, as well as of glacial stagnation in general. About 240 lake plains of all types were mapped in Taylor County.

Marked variations exist among the ice-walled lake plains of Taylor County They do, however, share several common characteristics. They usually are (1) subcircular, (2) concave upward in profile, (3) mesa- or plateau-like in form, (4) bounded by ice contact slopes, (5) rimmed by low ridges, and (6) topographically higher than the intervening areas of hummocky stagnation moraine. Figures 3 and 6 demonstrate these aspects

A small number of lake plains display forms suggesting two or more stages in their development For example, several lake plains display conspicuous marginal terraces, situated as much as several tens of feet below the summit plain. These terraces are a variety of kame terrace, and probably consist of sediments deposited in a moat separating the receding ice wall from the highest part of the perched plain. Many of the ice walled lake plains are incised by small "dry" valleys, 2 to 6 m in depth, that were formed by streams flowing across them immediately after they had been drained but before the enclosing ice had melted below the surface of the plains; the streams cutting these valleys became extinct when the ice surrounding the lake plains disintegrated more rapidly than the streams could deepen their valleys

There are, however, numerous examples of modern streams that flow across lake plains and incise their surfaces. In at least fourteen places, throughout the moraine, such a condition exists These streams all originate in areas of hummocky stagnation moraine, flow across lake plains, and drain into hummocky stagnation moraine on the opposite side of their respective lake plains from where they enter them. These streams were superposed on their respective lake plains, and provide a significant line of evidence used in reconstructing the late glacial history of the area.

Ice walled lake plains are second only to hummocky stagnation moraine in extent and account for some of the highest features with the Chippewa moraine. They are usually located well back from the margins of the moraine. In the final stage of ice wastage disintegration of the debris-mantled ice that enclosed the ice walled lakes produced the hummocky stagnation moraine that characteristically surrounds perched lake plains (figs. 2 and 3). In terms of relative age, therefore, the ice walled lake plains were formed prior to the intervening areas of hummocky stagnation moraine.

Perched lake plains, although scattered widely throughout the moraine, do not exhibit a homogeneous distribution. They are common and well developed in areas of conspicuous hummocky stagnation moraine but, conversely, are scarce and poorly defined in those areas of hummocky topography that are indistinctly expressed or of limited extent.
Lake plains that formed where the supraglacial drift and associated buried ice were thick are perched well above the surrounding hummocky stagnation moraine, whereas the lake plains that formed in areas of thin superglacial drift (and correspondingly thin buried ice) are commonly lower (fig. 6).

Not uncommonly, the individual lake plains are separated from the surrounding hummocky stagnation moraine by distinct moat-like depressions which formed at places where most of the drift on the ice surface immediately adjoining the lake had creeped, flowed, or been washed into the lake. Thus, when the ice enclosing the lake melted, the thinner-than-average drift cover on the ice nearest the lake plain led to the formation of a depression or moat at the foot of the lake plain rim. Depressions of this type are common in parts of the moraine, and one of the most distinctive characteristics of lake plains is the ring of lakes, ponds, and swamps which encircle them. The lakes encircling the lake plain on which the village of Rib Lake is located illustrates this relationship (see fig. 4 and the Rib Lake 7.5 minute quadrangle).

There are three areas of high local relief hummocky stagnation moraine where the frequency of lake plains is distinctly below average, at least those lake plain types identifiable on topographic maps. Two of these areas are the rough hummocky topography immediately west of Westboro, and that immediately east of Chequamegon Waters Flowage in the western part of the county; the third area is the hilly interlobate area which extends northward into Price County (fig. 4). A possible explanation for this situation may be that because of the thick supraglacial till cover in these areas the ice walled lakes were of the deep, stable type and of relatively small diameter. When the enclosing ice melted the lake plain sediments collapsed resulting in rounded hills rather than flat perched plains. Because the hills of the three areas were not individually examined in the field to determine whether or not they contained lake plain sediments, this explanation is speculative.

The largest lake plains are found in the western part of the county, an area where lake plains are exceptionally abundant. Apparently the ice thickness of the ice cored moraine was ideal for the formation of ice walled lakes in that area

Small tracts of hummocky stagnation moraine are enclosed by and rise above the surface of some ice walled lake plains, suggesting that in the subsurface features of this type are underlain by hummocky stagnation moraine. A major part of the fine grained sediment within the lake plains probably represents reworked loess which originally covered the ice cored moraine; loess is scarce within the moraine but is present on the adjoining lands.

One problem in mapping lake plains is that many do not have a distinct ice contact slope for their entire perimeter. Furthermore, the local relief of some is so small that they are not easily identified on topographic maps. Some of the lake plains shown on figure 4 were not examined in the field, therefore, only those parts of their margins identifiable on maps or photos by form alone are shown on figure 4.

There are many plateau-like features within the moraine that were not mapped that morphologically resemble lake plains but lack their characteristic smooth surface and lacustrine sediment. These features apparently formed in an ice walled environment (that is an ice enclosed depression), but consist primarily of till and/or fluvial sediment. They were mapped as hummocky stagnation moraine.

Ice walled lake plains have been observed throughout the St. Croix and Chippewa moraines of Wisconsin by the author. Furthermore, they are described in Barron County, Wisconsin, by Johnson (1984); in the moraine of the Langlade lobe of Wisconsin by Nelson and Mickelson (1974); by Clayton (1986) in Portage County, Wisconsin, who indicates that lake plains have been observed as far south in Wisconsin as that county; by Attig and Muldoon (1989) in Marathon County, Wisconsin; and by Johnson (in prep.) in Polk County, Wisconsin.

Incipient Ice Walled Lake Plain

Features of this type (fig. 3) resemble perched lake plains in many ways, with a number of significant exceptions. Their overall shapes, rather than being flat or dished, might be more aptly described as resembling rimmed, semicircular ramps, with their rim ridges breached on one side. These breaches are not the result of stream erosion, but gaps of nondeposition. The floor of the central depression, the latter deeper than in normal ice walled lake plains, slopes toward this gap, as shown in figure 3, and, in some cases, gently merges into the land surface lying outside the gap. Fine grained, water laid sediments are typically found beneath their centers, but are thinner than those of normal (relatively flat-topped or completely rimmed) lake plains. Features of this type appear to consist of chiefly coarse and/or unsorted deposits.

The term "incipient" lake plain is considered appropriate for features of this type, because they represent lake plain features whose development was terminated before they had attained the characteristics of normal lake plains, or they may represent lake plains which formed under less than ideal conditions. For example, where the ice on one side of an ice walled lake plain was very thin, the ice surface at that point may not have been high enough to supply sediments to the lake; therefore, no rim developed at that point.

Incipient ice walled lake plains differ markedly from perched lake plains morphologically. Lake plains of the incipient type tend to have asymmetrical longitudinal profiles (fig. 3), and appear to have formed near the margins of stagnant ice masses or where the surface of the stagnant ice sloped markedly in one direction. Under these conditions high rims developed along that part of the lake margin bounded by thicker ice, but little or no rim developed on the side bordered by thinner ice. Disintegration of the enclosing ice produced a lake plain that, though surrounded by hummocky stagnation moraine, is characterized by a surface that slopes conspicuously toward the moraine margin nearby

Ice walled lake plains of the incipient type are common in the Chippewa moraine. Based on this fact and the foregoing interpretations, it seems reasonable to assume that the ice surface in the ice cored Chippewa moraine must have sloped steeply away from the moraine's axis toward its margins

Branching Ice Walled Alluvial-Lacustrine Plain

Branching ice walled alluvial-lacustrine plains are found principally in the Lublin area of the moraine (fig. 4). Linear branching plains of this type are underlain by alluvial (including both glacial and nonglacial stream sediments) and/or lacustrine sediments and possess asymmetrical rims composed of till or stratified sediments, bearing steep, ice contact slopes on their outer sides. Ideally, they are bordered by hummocky stagnation moraine on all sides, except for those places where streams drained from them during their formation. Some of these lowlands are occupied by modern streams.

The ice underlying these lowlands melted earlier than in adjoining areas, probably because the supraglacial streams following these routes had removed much of the insulative supraglacial drift. When the lowlands became ice free, they were occupied by streams, or by lakes connected by streams. Sediments were then deposited in them, derived from the adjoining drift-mantled stagnant ice. Lacustrine sediments were deposited where the lowlands held ponded water; elsewhere, "alluvium" was deposited, except at some places in the rims where till was deposited by mass wastage.

The streams occupying the trunk lowlands apparently had tributaries, and ice walled tributary lowlands were melted out along them; within the latter waterlaid sediments were also deposited. In places, the lowlands were underlain by thin stagnant ice, until after active sedimentation had ceased. As a result, the floors of the ice walled alluvial-lacustrine lowlands are sometimes pitted. Due to the complex character of these lowlands and their surroundings, it is in most cases impossible to reconstruct the drainage conditions associated with them at the time of their formation.

Branching ice walled alluvial-lacustrine plains are uncommon and found principally in the Lublin area, where three such features exist (fig. 4). Although few in number, they are exceptionally large features. The two largest are seven and five miles in length (fig. 4)

Stagnant Ice Terrace

A stagnant ice terrace is simply a terrace in an area of stagnant ice moraine, which is bounded by an ice contact slope on one side and higher ground on the other. In effect, it is a shelf-like feature that interrupts an otherwise steeper slope. Stagnant ice terraces may consist of till, lacustrine deposits,glaciofluvial sediments, colluvium, or a combination of these. They contain material which collected in a depression separating a buried stagnant ice mass from a nearby hill or valley wall.

The sediments comprising a given stagnant ice terrace may have flowed, slid, or been washed into a depression either from the adjoining ice on one side or the ice-free area on its other. When the ice melted, the materials were left standing above the depression formerly occupied by the ice mass against which they had rested.

Stagnant ice terraces are common features within areas of hummocky stagnation moraine. Features of this type are highly variable in their size, morphology, and relative location. They are not necessarily linear features and may be found at any height, from near the bottoms of valleys to near the tops of hills or upland features.

Stagnant ice terraces tend to be more conspicuous, and may actually be more abundant, in areas where hummocky stagnation moraine is poorly developed, such as in the Lublin area. In the Perkinstown and other high relief areas they are found around the flanks and bases of up

Circular Disintegration Ridge

The circular disintegration ridges of the Chippewa moraine form nearly circular, mesa-like hills, with a central depression that may vary in size. The outward-facing surfaces of the circular ridges are steep and appear to be ice contact slopes, but they possess gently- to moderately-inclined inner slopes that grade into the floors of the central depressions (fig. 7). The altitude of these central depressions is distinctly higher than the ground surface in the stagnant ice hollows adjacent to the circular disintegration ridges.

Gravenor (1955) was one of the first to describe the features herein designated circular disintegration ridges, although he termed them "closed disintegration ridges." Clayton (1967), employing many of Gravenor's ideas, described the steps in the formation of these features as follows:

> Circular disintegration ridges formed by (a) sliding or flowing of supraglacial till into a sinkhole in the stagnant ice, (b) inversion of topography as a result of the insulating effect of the drift in the bottom of the sinkhole, followed by mass movement of this drift away from the center and down the sides of the buried ice core, and (c) melting of the ice core, forming a circular ridge.

Because their central depressions occasionally contain more waterlaid sediments than might reasonably be expected to have been derived from the inner slopes of the circular disintegration ridges in postglacial time and because the steep outer slopes of the circular disintegration ridges of the Chippewa moraine seem to be ice contact slopes, the author proposes an alternate hypothesis for he formation of these features to account for the above-cited anomalies to Gravenor's model Step one would be similar to that described by Clayton (1967), except that the sinkhole would not be underlain by ice In step two the ice melts, leaving the material previously banked against the sinkhole wall as a steep ice contact slope (fig 7).

The circular disintegration ridges of the area are, in the majority, located within areas of hummocky stagnation moraine (fig 4), and appear to have formed after the ice walled lake plains that have a higher altitude Furthermore, they seem to be most common near the lake plains and may, collectively, completely encircle them, as is the case in the area immediately northeast of Lublin on figure 4

Circular disintegration ridges are best developed in low and moderate relief hummocky stagnation moraine, such as the Lublin area, but uncommon in high relief hummocky stagnation moraine, as around Perkinstown The smallest features shown on figure 4 are usually circular or semicircular disintegration ridges

Circular disintegration ridges sometimes exist in an aligned series, in which the rims of the individual circular disintegration ridges are interrupted at those places where the centerline of the series passes through them Clayton (1967) attributes these breaches to the melting of an ice-cored crevasse filling that underlay the series If this interpretation is correct, the circular disintegration ridges of such an aligned series apparently all developed along the same or at least closely spaced crevasses

Semicircular Disintegration Ridge

Features of this type resemble coastal blow-out dunes in several respects: they are parabolic in plan view and asymmetrical in side view (fig 3 and 8), as well as highest on their convex ends and lowest on their concave ends The central depression of a semicircular disintegration ridge is always higher than the altitude of the stagnant ice depression enclosing the convex side of the feature, and it slopes toward the open end of the ridge, as do the terminal parts of the ridge The ridge has a steep ice contact slope on its convex side but slopes with a moderate inclination toward the central depression.

Semicircular disintegration ridges appear to have formed in melt-embayments in the sloping margins of debris-mantled stagnant ice masses They are believed to usually consist of till transported into these melt-embayments by mass wastage; the concave side of a given ridge originally faced toward the adjoining ice free area Figure 8 illustrates the general morphology of semicircular disintegration ridges.

Semicircular disintegration ridges may exist anywhere within the moraine, as shown on figure 4, but seem to be more common along the margins of the moraine, where the ice was thinner Furthermore, they are abundant in the relatively-low relief Lublin, Rib Lake, and Medford-Whittlesey areas This probably indicates that thinner ice also existed in these areas, which was more favorable for the formation of features of this type Often two or more of them may be found in the same locality and at several places within the moraine there exist an aligned series of semicircular disintegration ridges The ridges of a given series collectively appear to mark progressive elongation of their respective melt-embayments

Linear Disintegration Ridge

A linear disintegration ridge is a narrow, commonly steep-sided, generally non-sinuous, distinctly linear ridge, usually less than 2 km in length and consisting of till, sorted drift, or a combination of both types; eskers are not included As proposed by Gravenor and Kupsch (1959), ridges of this type are composed of material that was deposited during the disintegration of stagnant or near-stagnant glacier ice Clayton (1967) described several ways by which linear disintegration ridges may be formed

The linear disintegration ridges of the Chippewa moraine are clearly members of a gradational series. They show similarities to, and may grade into, almost any of the other disintegration features, except perhaps some of the larger non-linear features, such as ice walled lake plains

The linear disintegration ridges are located within the areas of hummocky stagnation moraine and show no preferred orientation. They appear to be more in the nature of random ice-fracture fillings described by Kaye (1960), and probably represent "uncontrolled disintegration" of the ice, as defined by Gravenor and Kupsch (1959) Linear disintegration ridges, though not abundant, exist at a number of places (fig. 4).

A variation in the basic form of linear disintegration ridges is a feature termed here a "grooved top ridge " Rather than having a single crest, as is typical of linear disintegration ridges, a grooved top ridge has two linear crests separated by a trough-like depression (fig. 9). A feature of this type is made of sediment that accumulated in a relatively wide, trench-like depression in the disintegrating, debris-covered stagnant ice While the ice still existed, the trench filling was of greater height near the ice walls than near the center of the trench When the ice melted, the trench filling was of sufficient width that collapse of the sediments banked against the ice walls did not destroy the central trough of the trench filling The result was formation of a grooved top ridge.

Two locations where grooved top ridges are found are the east side of Mud Lake in section 28, in the west central part of the Bellinger quad (southwestern Taylor County), and the southeastern corner of section 28, in the west central part of the Westboro quad (northern part of the county).

Stagnant Ice Margin Linear Ramp

Features of this type, although constituting some of the larger, more prominent landforms of the moraine, are not as numerous as most of the other types. A stagnant ice margin linear ramp consists of material deposited at the margin of a stagnant ice mass whose border was relatively straight. Ramps of this type are asymmetrical in cross section and in overall form resemble small homoclinal ridges or cuestas (fig. 3). Their steep sides are ice contact slopes and may be irregular, but their distal slopes are usually smooth and of gentle to moderate inclination.

Stagnant ice margin linear ramps, although usually consisting of till, may also contain, or consist entirely of, stratified sediments. Genetically, they are a variety of linear disintegration ridge. The dominant depositional process in their formation was apparently flowage of saturated supraglacial till off a stagnant ice mass into the adjacent ice free area. In some cases supraglacial material was washed off the ice and deposited as stratified drift; lacustrine sediments were also deposited in the ramps where the ice was bordered by a lake.

Where largely composed of till, their smooth distal slopes were presumably graded by mass wasting and running water before the adjacent stagnant ice had melted; when the latter event occurred, the watersheds for their distal slopes were largely destroyed, thus these slopes show only minor postglacial modification by running water.

Stagnant ice margin linear ramps did not form continuously along the margins of the ice cored moraine (fig. 4). Their discontinuous nature may reflect to some extent local variations in the amount of water that drained from the ice margins: where excessive, linear ramp development may have been inhibited. For example, in some cases linear ramps have conspicuous notches cut by supraglacial streams that drained across the ramps into the adjoining ice free area. In other places, ice margin linear ramps may not have formed (or be present) because (1) the slope of the stagnant ice surface was not favorable for flowage of the supraglacial till; (2) the ice margin was highly embayed, irregular, or rapidly receding; (3) the amount of supraglacial till may not have been adequate to construct an ice margin ramp of any consequence; or (4) they may have formed in places, but were later buried by fluvial sediment washed from the ice cored moraine.

Stagnant ice margin linear ramps usually trend parallel to and typically mark the edges of tracts or belts of hummocky topography; in this respect they may be found on either the proximal or distal sides of the moraine. However, they did not form continuously along the margin of the ice cored moraine. Furthermore, in some instances they were apparently formed at the margins of isolated ice masses and show no distinctive trends.

Stagnant ice margin linear ramps tend to be bordered on their ice contact sides by hummocky stagnation moraine and on their distal sides by ground moraine, outwash, or ice walled lake sediments (fig. 3). One of the best defined linear ramps is that bordering the moraine at Esadore Lake, about five miles northwest of Medford (fig. 4 and Medford NW 7.5-minute quadrangle). That particular ramp is bordered by a flat outwash plain on its south and hummocky stagnation moraine on its north. Similar features are found at scattered locations on both the distal and proximal moraine margins.

Stagnant Ice Margin Semicircular Ramp

Features of this type resemble stagnant ice margin linear ramps in several aspects of their morphology and genesis; however, instead of forming at the edge of stagnant ice masses whose margins were straight, they formed in arcuate-shaped melt bays in the margins of the stagnant ice (fig. 8).

Stagnant ice margin semicircular ramps are asymmetrical when viewed from the side (fig. 8), show a convex-outward form on their ice contact slopes and gently to moderately sloping, flat surfaces on their distal sides; the latter merge with no apparent break into the typically low relief topography that adjoins their distal sides. They may consist of till, stratified sediments, or a combination of both types.

Stagnant ice margin semicircular ramps exhibit the same relative location as do linear ramps. They differ from them in form only. The most favorable environment for the formation of semicircular ramps seems to have been where the margin of the stagnant ice was relatively thin, for they are far more common in the western part of the county. As is true of linear ramps, their ice contact slopes commonly face toward hummocky stagnation moraine.

Ice Walled Outwash Plain

Ice walled outwash plains are similar to ordinary outwash plains but are more than half surrounded by an outward-facing ice contact slope. Features of this type consist of outwash that was deposited in large indentations in the ice margin, and in some cases display rimmed margins. They are not common in Taylor County.

Ice walled outwash plains consist of outwash that was deposited in large indentations in the margin of the stagnant ice that formerly cored the moraine. Their surfaces slope toward and merge into the larger proglacial outwash plains bordering the moraine. Because of these relationships, ice walled outwash plains may be bounded on three sides by hummocky stagnation moraine. In effect, then, ice walled outwash plains represent lobate- or irregularly-shaped extensions of proglacial outwash plains into the moraine itself.

In the area along Highway 13 and the headwaters of the Black River, between Medford and Westboro, the moraine is traversed by a large, linear depression, which does not serve as a routeway for a modern stream crossing the moraine nor does it display the typical morphology of a major glacial spillway. Nevertheless, meltwater appears to have played a major role in its formation.

This large, linear, transmorainal depression is floored with an ice walled outwash plain for most of its length (fig. 4). Excluding the ice-block basins which pit its floor, this gap in the moraine is believed to represent a place where meltwater, draining across the ice cored moraine from the active glacier situated on its proximal side, removed much or all of the supraglacial debris. At the time it was active, the floor of this spillway presumably stood somewhat higher than the present altitude of the same locality. Eventual disintegration of the underlying ice lead to the destruction of the original form of the supraglacial spillway, as a discrete morphologic feature, but its former existence is still vaguely apparent.

Transmorainal meltwater depressions are rare and are not a part of the basic assemblage of stagnant ice landforms. However, where found they are important because they represent gaps in the moraine. In other words, they interrupt the moraine and divide it into segments. They are, of course, bordered by hummocky stagnation moraine.

Eskers

At least four eskers were identified in the terminal moraine of Taylor county, and are shown on figure 4. Most of the eskers of the county are associated with the ground moraine area, located on the proximal side of the moraine, and are commonly situated in the floors of valleys which lay parallel to the direction of ice flow. They tend, therefore, to be oriented perpendicular to the trend of the moraine. Those eskers situated within the moraine are in some cases almost impossible to identify because of the hilly topography of these areas, or because portions of them are completely obscured by a thick covering of collapsed supraglacial till.

The Mondeaux esker, which borders the Mondeaux Flowage in the north central part of the county, is perhaps the most interesting esker of the area. Mondeaux Flowage occupies what appears to be a subglacially-stream-eroded tunnel channel, and the Mondeaux esker is located within this channel. During wastage of the glacier an isolated mass of stagnant ice occupied this depression, and a large linear ice margin ramp formed along its western side; this ice margin ramp today is located on the western side of the flowage, just west of the esker

Kames

The Taylor County moraine contains few kames that fit Holmes' (1947) ideal type, that is, "an isolated symmetrical hill, consisting chiefly of gravel and sand." Instead, most of its kame-like features are variants of such stagnant ice landforms as ice margin gravel ramps, crevasse fillings, and stagnant ice "sinkhole fillings." They were, therefore, not classified as kames but, instead, assigned to the landform type they individually bear greatest resemblance to

Postglacial Modification of the Stagnant-Ice Landforms

The great majority of the stagnant-ice landforms are remarkably well preserved. Numerous rather fragile forms exist, which certainly could not be preserved had there been significant postglacial morphological modification of the stagnant-ice landforms.

The largest modifications have taken place along drainageways. Despite the incisement of the surfaces of some of the larger perched-type ice-walled lake plains by postglacial ravines, their rims are strikingly well preserved. By comparison, the lowland-type ice-walled lake plains have experienced greater postglacial modification because they are traversed by more numerous and larger drainageways. Several of them contain entrenched streams, which are descendants of streams whose courses were in part supraglacial at the time entrenchment was initiated

Perhaps the most obvious evidence of postglacial modification of the landscape may be found along streams that drain through rough morainic topography, but these are not abundant. The valleys of these streams are segmented, alternating between narrow erosional segments and wide depositional segments. Where a stream initially crossed morainic ridges, it has cut notches into them; the floors of the intervening stagnant ice hollows or basins are commonly poorly drained and underlain by fluvial or lacustrine sediments, or both. This kind of modification of the glacial topography is especially conspicuous where the drainage is still largely nonintegrated

Although postglacial modification of the glacial landforms is very apparent along streams, postglacial filling of depressions in the glacial topography has not been restricted to basins of this type. Probably the most frequent and widespread type of postglacial modification is represented by the many small ice-block basins, scattered throughout the moraine, that have been partially or completely filled with organic and inorganic sediments. Very likely, ponds were more numerous at the close of the glacial epoch, but most have since been filled

FIGURE CAPTIONS

Figure 1. Boundaries of the Chippewa moraine, Taylor County

Figure 2. Possible manner of formation of Chippewa moraine. All drawings represent cross sections of the glacier margin and related moraine.

Figure 3. Assemblage of landforms associated with a stagnant-ice moraine. Hummocky stagnation moraine, shown in the foreground and background, also occupies the blank areas separating the other landform types within the moraine.

Figure 4. Stagnant ice landforms of Taylor County. (large folded map)

Figure 5. Diagram showing sequence of events resulting in formation of hummocky stagnation moraine. Ice (no pattern) melts most rapidly where the debris cover (stippled pattern) is thin (A,B) resulting in redistribution of debris (C). The process repeats itself until all of the ice has melted (D,E,F). Source: Attig and Clayton, in press

Figure 6. Formation and characteristics of ice-walled lake plains. A and B show lake plains formed in unstable depositional environments. C and D show lake plains formed in stable depositional environments. Source: Clayton (1967, Figure B-9)

Figure 7. Msanner of formation of circular disintegration ridges. Squence A: formation according to Clayton (1967, figure A-z). Sequence B: alternate mode of formation proposed by author.

Figure 8. (see accompanying figure 8 diagram for caption).

Figure 9. Grooved top ridge. Cross sections at top show the ridge's formation along line A-B.

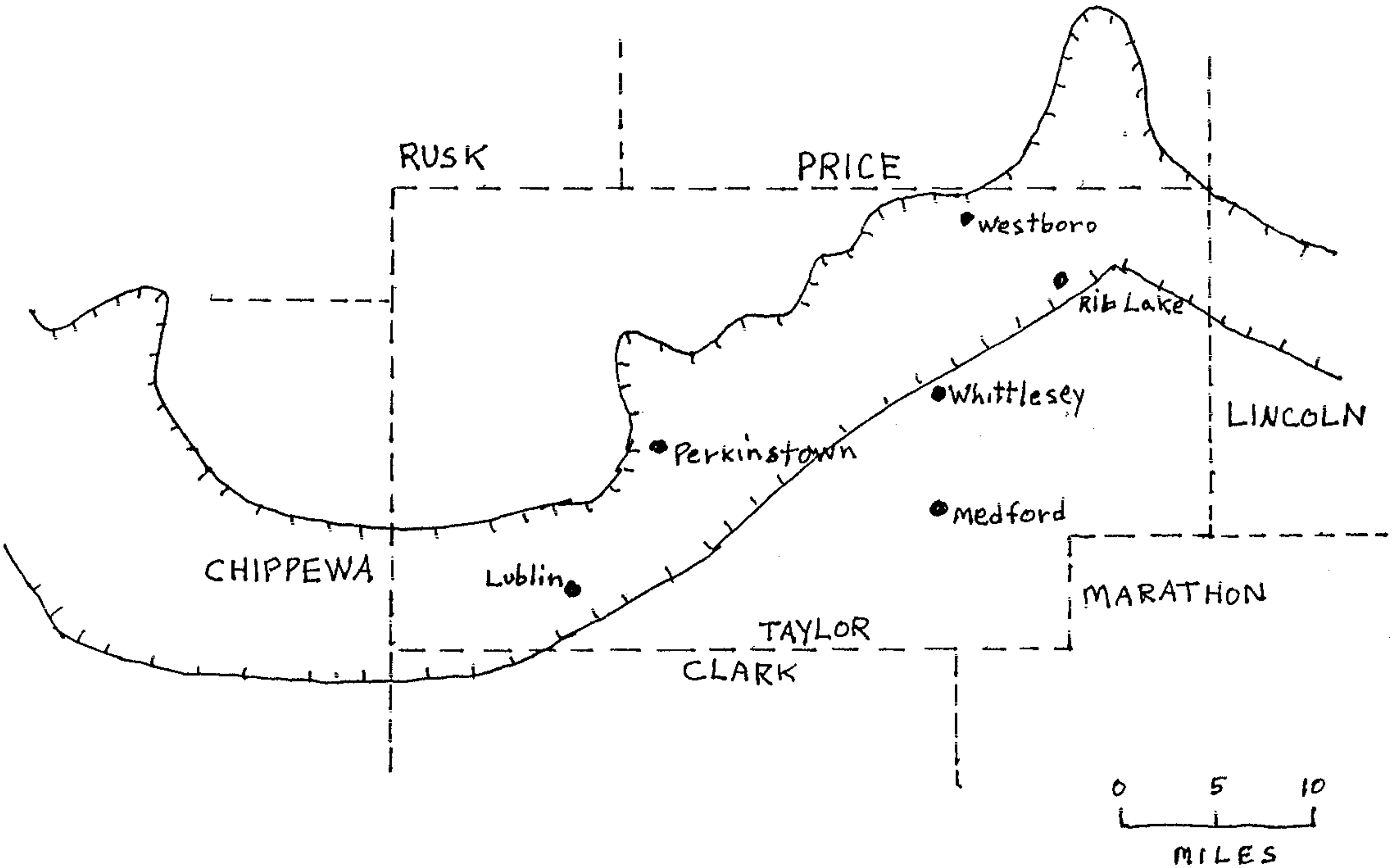
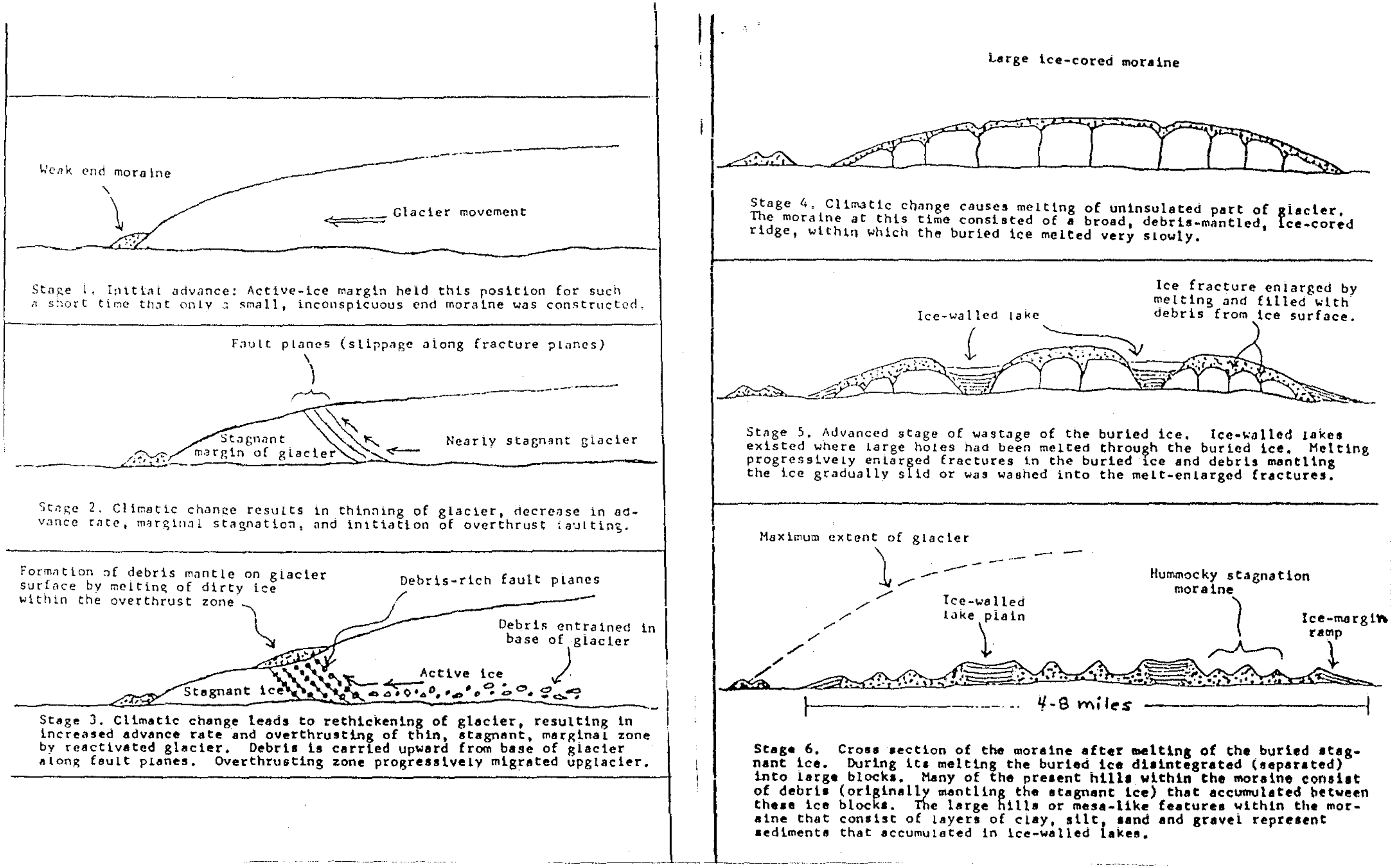


Figure 1. Boundaries of the Chippewa moraine, Taylor County.



Stage 1. Initial advance: Active-ice margin held this position for such a short time that only a small, inconspicuous end moraine was constructed.

Stage 2. Climatic change results in thinning of glacier, decrease in advance rate, marginal stagnation, and initiation of overthrust faulting.

Stage 3. Climatic change leads to rethickening of glacier, resulting in increased advance rate and overthrusting of thin, stagnant, marginal zone by reactivated glacier. Debris is carried upward from base of glacier along fault planes. Overthrusting zone progressively migrated upglacier.

Stage 4. Climatic change causes melting of uninsulated part of glacier. The moraine at this time consisted of a broad, debris-mantled, ice-cored ridge, within which the buried ice melted very slowly.

Stage 5. Advanced stage of wastage of the buried ice. Ice-walled lakes existed where large holes had been melted through the buried ice. Melting progressively enlarged fractures in the buried ice and debris mantling the ice gradually slid or was washed into the melt-enlarged fractures.

Stage 6. Cross section of the moraine after melting of the buried stagnant ice. During its melting the buried ice disintegrated (separated) into large blocks. Many of the present hills within the moraine consist of debris (originally mantling the stagnant ice) that accumulated between these ice blocks. The large hills or mesa-like features within the moraine that consist of layers of clay, silt, sand and gravel represent sediments that accumulated in ice-walled lakes.

Figure 2. Possible manner of formation of Chippewa moraine. All drawings represent cross sections of the glacier margin and related moraine.

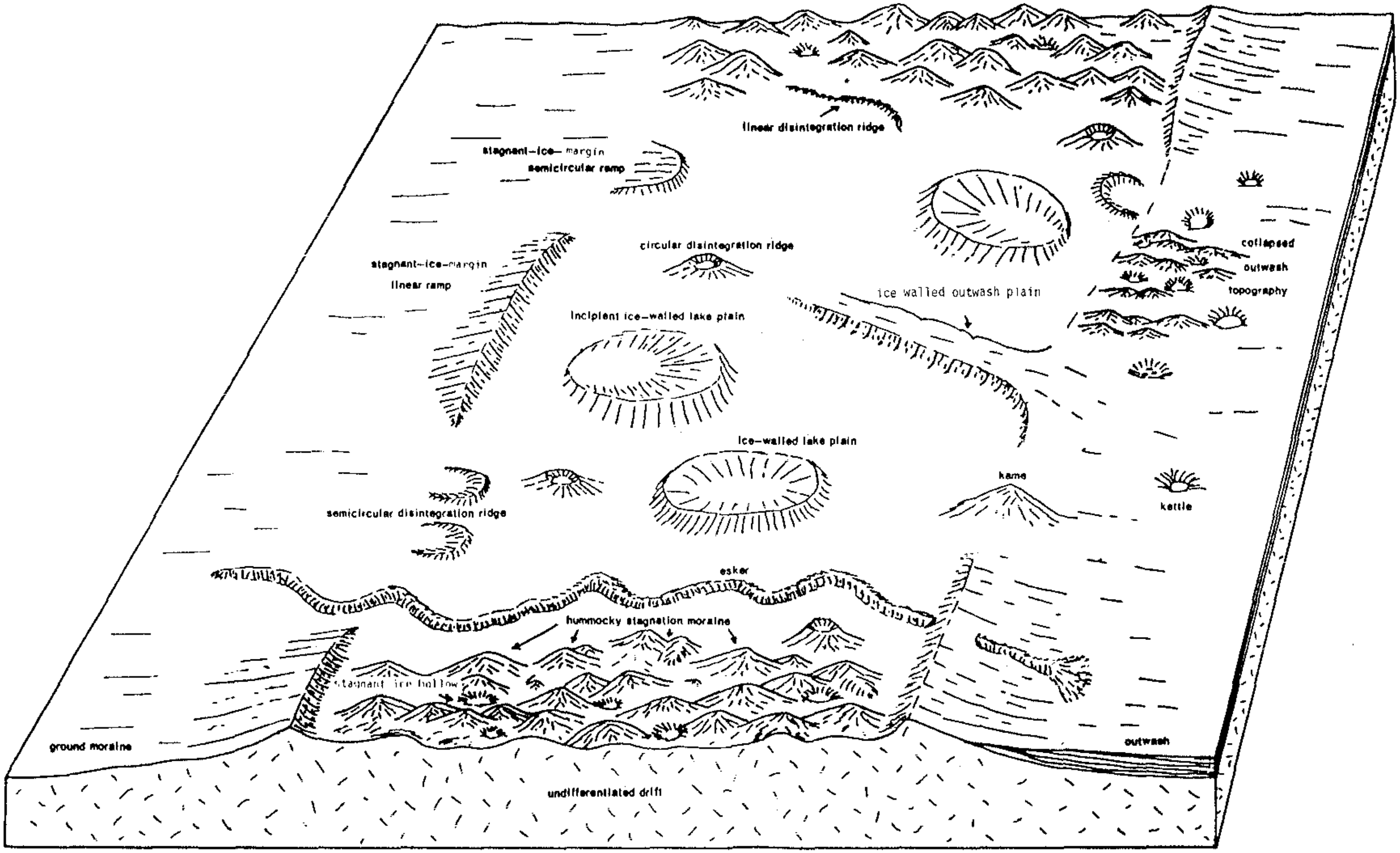
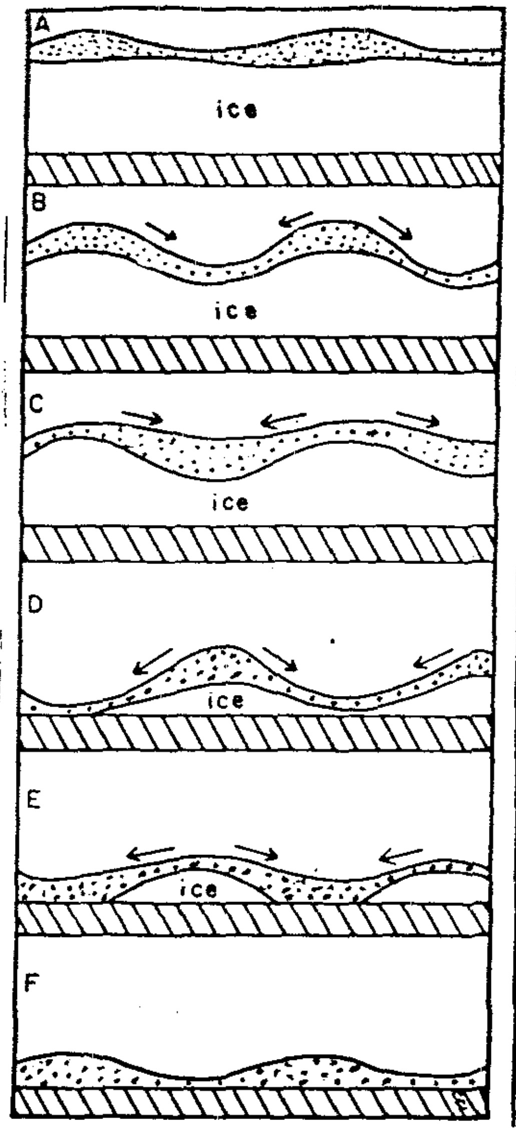


Figure 3. Assemblage of landforms associated with a stagnant-ice moraine. Hummocky stagnation moraine, shown in the foreground and background, also occupies the blank areas separating the other landform types within the moraine.

Figure 4 Stagnant ice landforms of Taylor County.

The Survey does not have a reproducible of Figure 4. Original author copy may be examined at the Survey during normal working hours.



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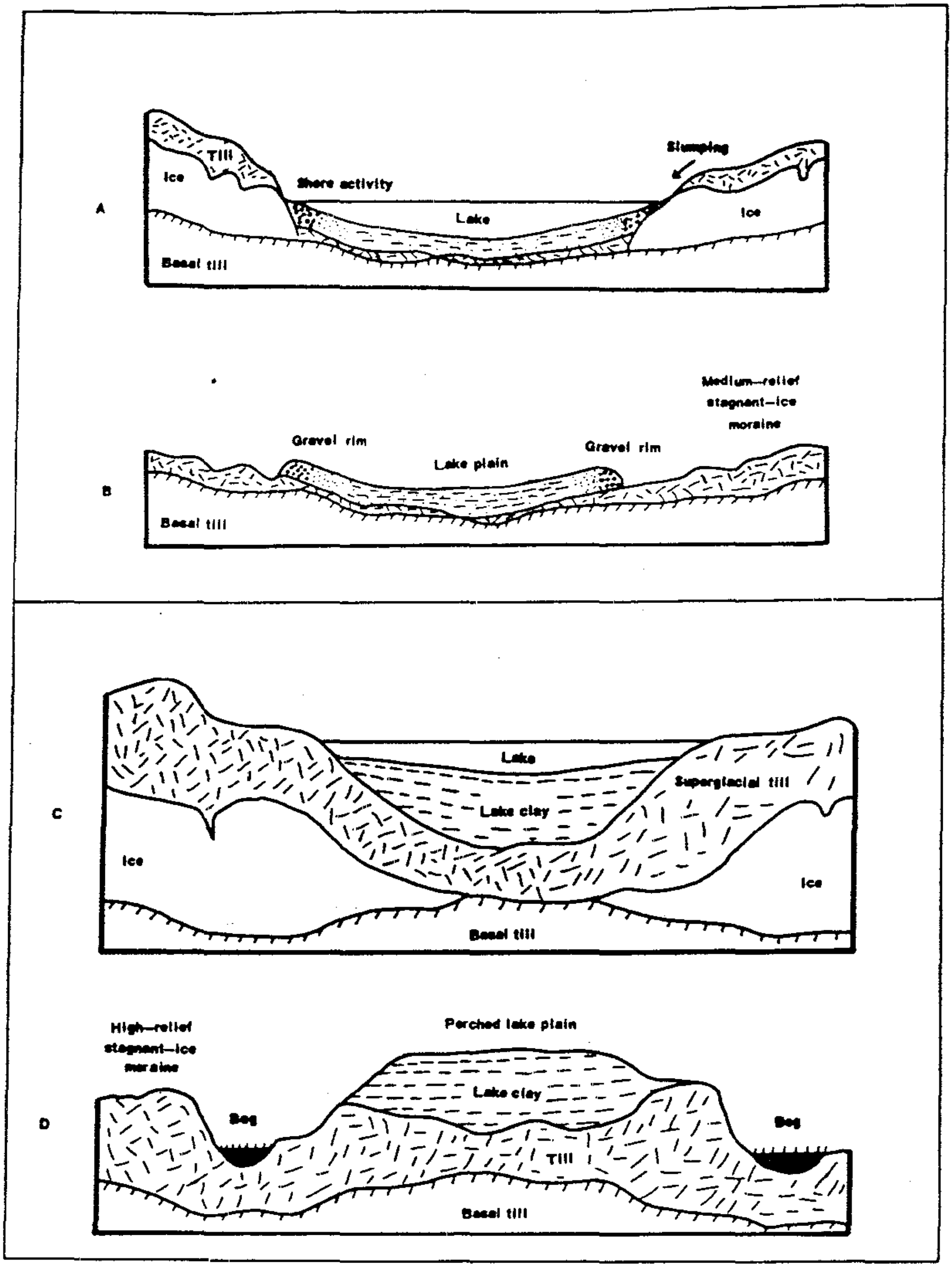

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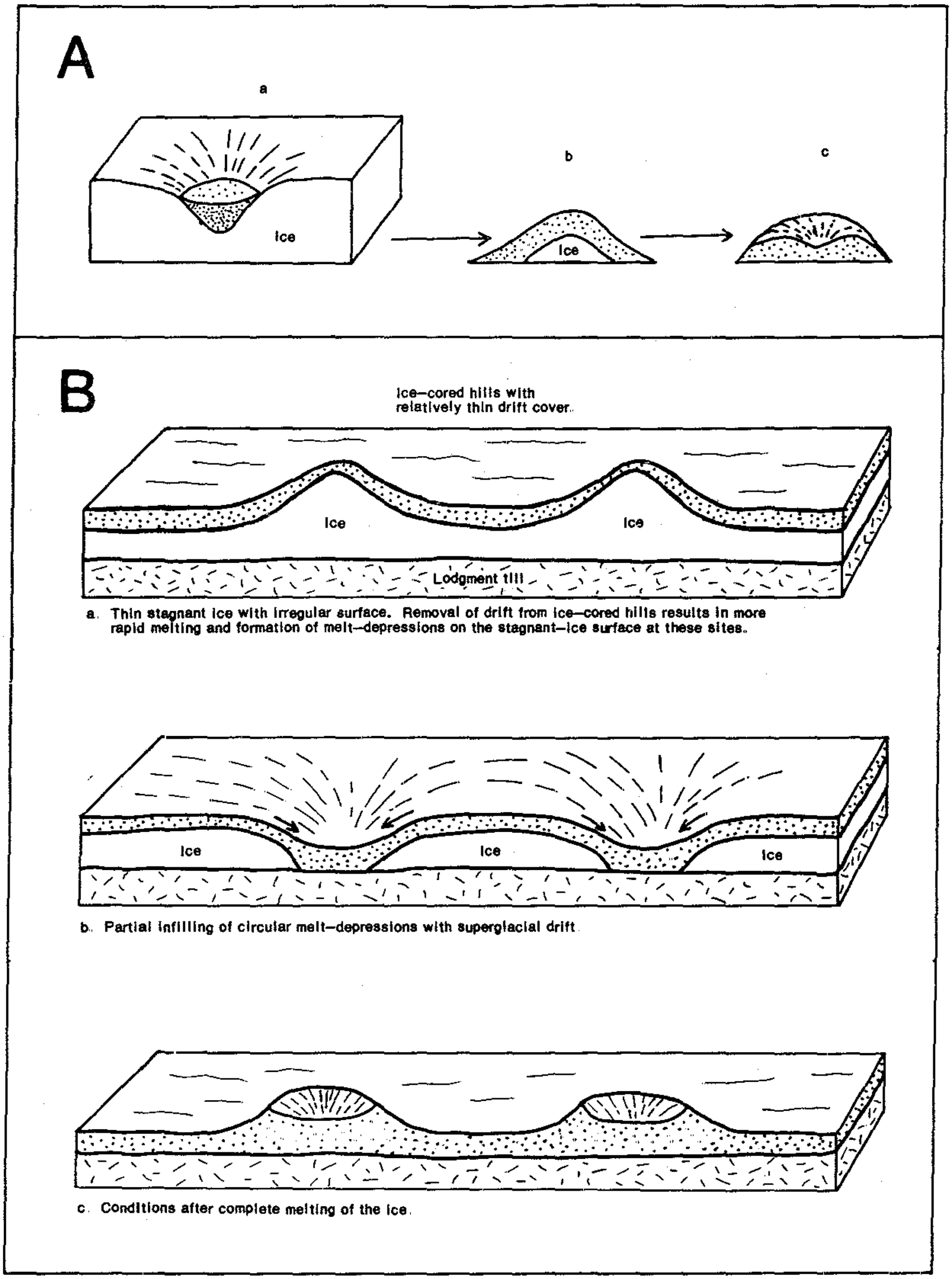


Figure 7. Manner of formation of circular disintegration ridges. Sequence A: formation according to Clayton (1967, Figure A-2). Sequence B: alternate mode of formation proposed by author.

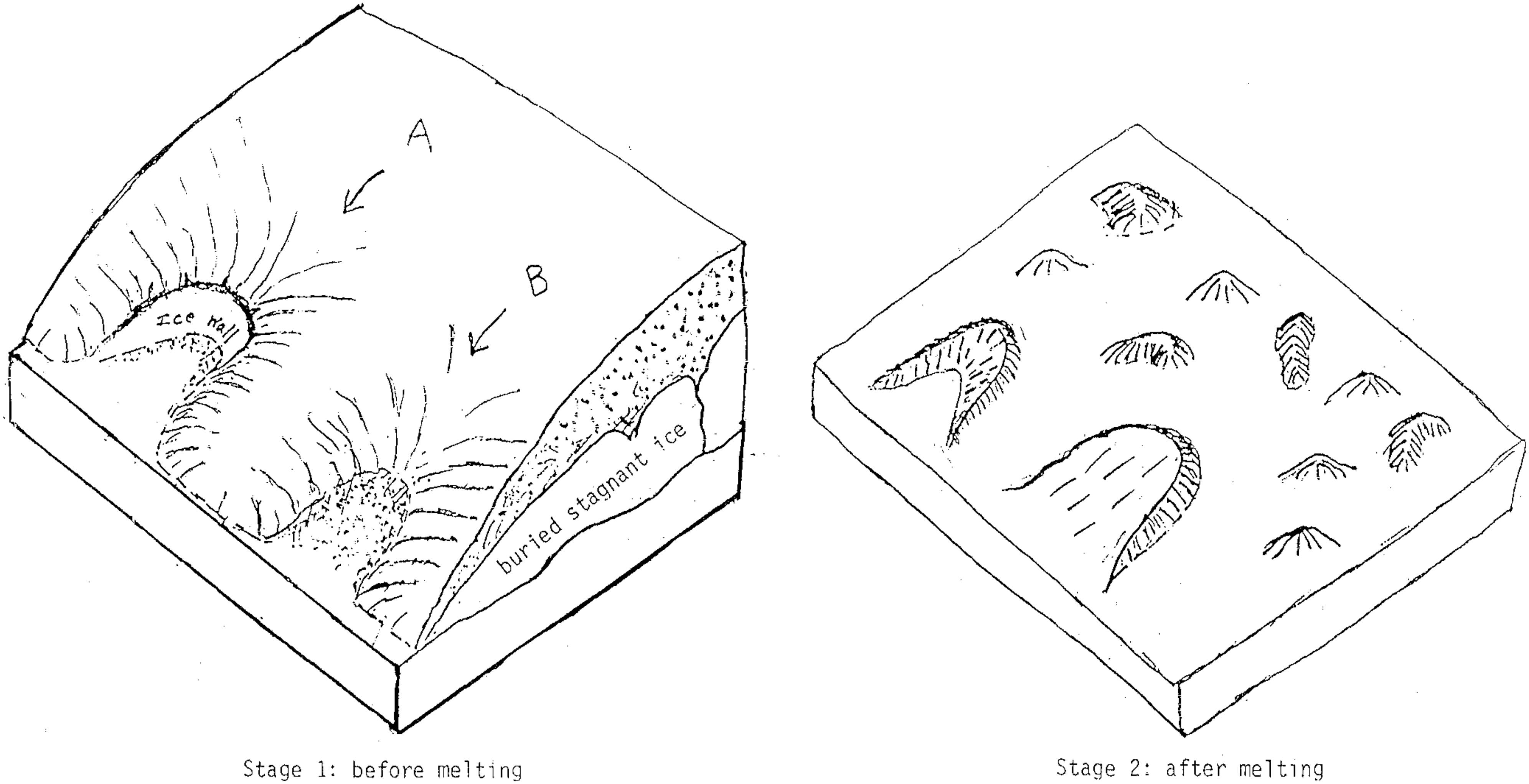
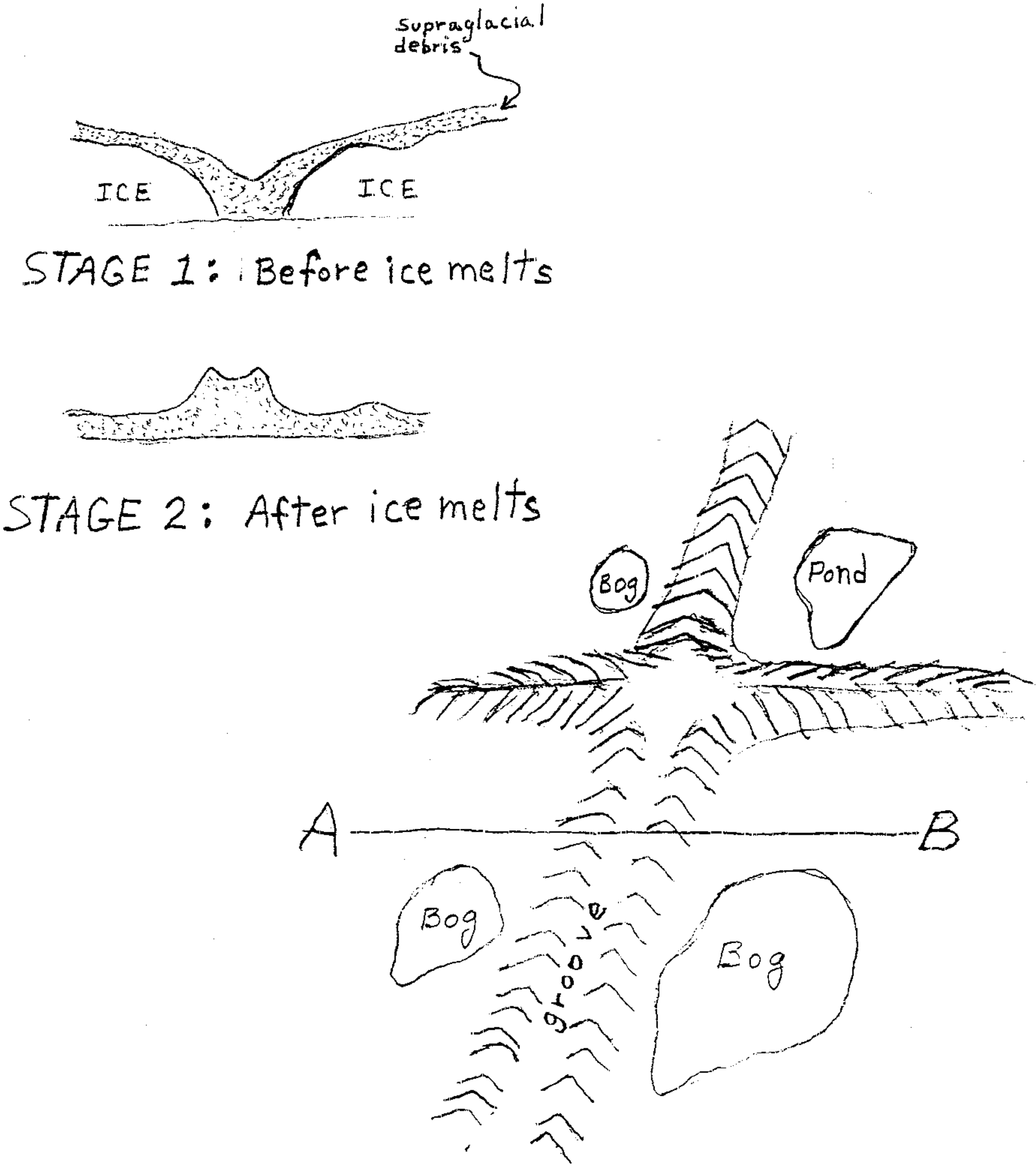


Figure 8. Manner of formation of semicircular disintegration ridge (A) and stagnant ice margin semicircular ramp (B). In Stage 1 sediment is moved from the ice surface into embayments (bay-like indentations) in the ice margin. The ice wall has its greatest height at the head of the melt bays. Sediment therefore collects to a greater height at the head of the melt bays than near their mouths. Debris accumulates against the ice in embayment A but not at its center. Supraglacial debris is also washed or slides into embayment B, nearly filling it. However, this sediment surface is flat and gently sloping. Stage 2 drawing shows the same area as in Stage 1 but after melting of the buried ice. The sediment deposited in embayment A in Stage 1 has become a <u>semicircular disintegration ridge</u> (a horseshoe-shaped asymmetrical ridge), while that in embayment B has become a <u>stagnant ice margin semicircular ramp</u> with a flat sloping surface. Both features have steep ice-contact slopes on their convex sides. The smaller hills are hummocky stagnation moraine and represent debris formerly covering the stagnant ice.



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