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Reconstruction of glacial Lake Hind in southwestern Manitoba, Canada *

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Abstract

Glacial Lake Hind was a 4000 km^2 ice-marginal lake which formed in southwestern Manitoba during the last deglaciation. It received meltwater from western Manitoba, Saskatchewan, and North Dakota via at least 10 channels, and discharged into glacial Lake Agassiz through the Pembina Spillway. During the early stage of deglaciation in southwestern Manitoba, part of the glacial Lake Hind basin was occupied by glacial Lake Souris which extended into the area from North Dakota.

Sediments in the Lake Hind basin consist of deltaic gravels, lacustrine sand, and clayey silt. Much of the uppermost lacustrine sand in the central part of the basin has been reworked into aeolian dunes. No beaches have been recognized in the basin. Around the margins, clayey silt occurs up to a modern elevation of 457 m, and fluvio-deltaic gravels occur at 434–462 m. There are a total of 12 deltas, which can be divided into 3 groups based on elevation of their surfaces: (1) above 450 m along the eastern edge of the basin and in the narrow southern end; (2) between 450 and 442 m at the western edge of the basin; and (3) below 442 m.

The earliest stage of glacial Lake Hind began shortly after 12 ka, as a small lake formed between the Souris and Red River lobes in southwestern Manitoba. Two deltas at an elevation of 450 were formed in this lake. At the same time, the Souris Lobe retreated far enough to allow glacial Lake Souris to expand farther north along the western side of the basin from North Dakota into what was to become glacial Lake Hind. Three deltas were built at an elevation above 460 m in the Canadian part of this proglacial lake. Continued ice retreat allowed the merger of glacial Lake Souris with the interlobate glacial Lake Hind to the east. Subsequent erosion of the outlet to the Pembina Spillway allowed waters in the glacial Lake Hind basin to become isolated from glacial Lake Souris, and a new level of glacial Lake Hind was established at 442 m, with 5 deltas built at this level by meltwater runoff from the west. Next, a catastrophic flood from the Moose Mountain uplands in southeastern Saskatchewan flowed through the Souris River valley to glacial Lake Souris, spilling into Lake Hind and depositing another delta. This resulted in further incision of the outlet (Pembina Spillway). A second flood through the Souris Spillway from glacial Lake Regina further eroded the outlet; most of glacial Lake Hind was drained at this time except for the deeper northern part. Coarse gravel was deposited by this flood, which differs from previous flood gravel because it is massive and contains less shale.

Introduction

The glacial Lake Hind basin is located in the southwestern corner of Manitoba, Canada (lat. 49 °–50 °N., long. 100 °–101 °W) (Figure 1). It lies in a topographic basin north of the Turtle Mountain upland and east of the Moose Mountain upland; it is linked to the glacial Lake Souris basin in North Dakota by a 10 to 30-km-wide corridor (Figure 1). During the late Wisconsinan, glacial Lake Hind was a 4000 km^2 ice-marginal lake impounded by ice lobes to the east

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Contribution to the Southern Prairies NATMAP project of the Geological Survey of Canada.

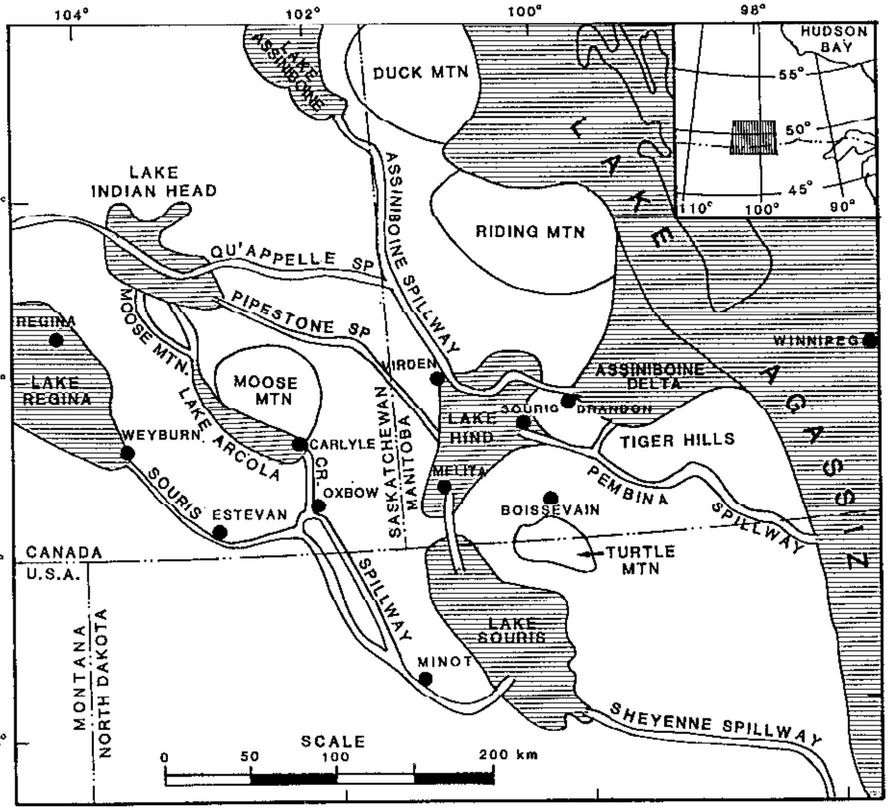

Figure 1. Location map and physiographic division of southwestern Manitoba, southeastern Saskatchewan, and northern North Dakota, showing glacial lakes, meltwater spillways, and uplands (Modified from Kehew & Teller, 1994; Klassen, 1979).

and north (Elson, 1956). It received meltwater from Saskatchewan, North Dakota, and western Manitoba via the Souris River valley (Kehew, 1982; Kehew & Clayton, 1983; Kehew & Lord, 1986; Kehew & Teller, 1994), Pipestone Creek, and a dozen smaller rivers. It drained east to Lake Agassiz through the Pembina Spillway (Elson, 1956, 1967). Because of the tight linkage between glacial Lake Hind, Lake Agassiz, and meltwater channels from Saskatchewan and North Dakota, the deglaciation history of the glacial Lake Hind area has been reconstructed within the framework of the deglacial chronology in the glacial Lake Agassiz basin (Teller, 1985, 1987; Fenton et al., 1983; Clayton & Moran, 1982), and in the region to the west in Saskatchewan which supplied most of the runoff to the Lake Hind Basin (Christiansen, 1979; Klassen, 1975, 1983, 1989; Kehew & Teller, 1994).

The purpose of this paper is to describe the development of glacial Lake Hind, and the chronology of major meltwater flows (including floods) into and out of glacial Lake Hind, and to reconstruct the deglaciation history of the glacial Lake Hind area. This will be done by examining the distribution and elevation of deltaic and lacustrine sediments in the Lake Hind basin.

Geological settings

Physiography and modern drainage systems

The Lake Hind basin lies north and west of the Turtle Mountain upland and the rolling plains along its base (Figure 1). To the west, the surface rises continuously and uniformly toward the Moose Mountain Upland. The northern side of the Lake Hind basin lies close to the modern Assiniboine River valley, which is bounded to its north by another distinct upland, the Riding Mountain Upland.

Two major and several smaller drainage systems drain through and into the basin of former glacial Lake Hind. The Souris River, which enters the basin from the south, flows in a shallow channel which follows the southern margin of the old basin. The Assiniboine Riv-

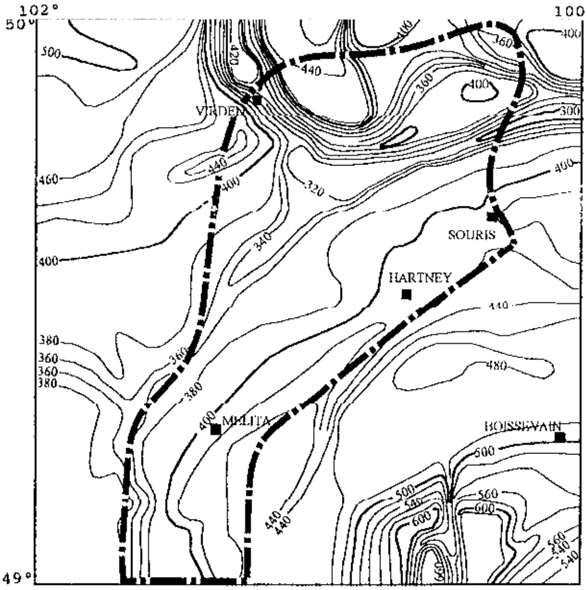

Figure 2. Elevation (meters above M.S.L) of bedrock subsurface in glacial the Lake Hind area, southwestern Manitoba (After Betcher, 1983). Outline of glacial Lake Hind is shown by Dashed-dot lines.

er, which enters the northwestern corner of the basin, cuts across the northern part of the basin roughly coinciding with a deep buried channel of that river. West of the glacial Lake Hind basin, a dozen roughly parallel rivers and creeks head in the Moose Mountain Upland and flow southeastward to the western Lake Hind Basin.

Bedrock geology and topography

Bedrock in the Lake Hind basin consists exclusively of Cretaceous shale of the Pierre Formation (McNeil & Caldwell, 1981; Betcher, 1983). The top of the shale is more than 40 m below the ground surface in the central Lake Hind area (Klassen et al., 1970; Teller et al., 1976; Betcher, 1983), but is very close to the surface where the Assiniboine and Souris River valleys have cut through the lacustrine sediments. Figure 2 shows the elevation of the bedrock surface in the region based on 216 boreholes studied by Betcher (1983). Note how the area occupied by glacial Lake Hind roughly coincides with the topographically low area in the Cretaceous bedrock surface.

Quaternary deposits

Most Quaternary deposits in southwestern Manitoba were deposited as a direct result of Pleistocene glaciations. Only a small portion of them – including eolian dunes, alluvium, and organic rich sediments – were deposited during the Holocene or other interglacials. In the glacial Lake Hind basin, till, fluvio-deltaic gravels, and lacustrine sand and clayey silt are dominant. Sand covers the surface in the central part of the basin, while clayey silt and deltaic gravels are exposed at the surface around the margin of the basin (Figure 3). In general, the lacustrine sand is underlain by up to 25 m of clayey silt and has been partly reworked into Holocene aeolian dunes in many areas; the fluvio-deltaic gravels are underlain by either till or clayey silt (Figure 5).

Geology and geomorphology of surficial sediments

Glacial Lake Hind boundaries

A scarp observed in the field and identified on aerial photographs marks the southern edge of glacial Lake Hind (Figure 3). The scarp has a relief of 15 to 20 m. Cretaceous shale is only one to a few meters below the surface of the scarp, but to the north in the glacial Lake Hind basin, shale is buried by more than ten meters of till and lacustrine sand and clayey silt. The western margin of glacial Lake Hind is outlined by a chain of deltas along a gently rising surface of till; the eastern margin is marked by a till ridge (Figure 3; Sun, 1993). The northern boundary is not distinct, as glacial Lake Hind clayey silt grades into superglacial lacustrine clayey silt at a higher elevation to the north.

Deltas and deltaic gravels

There are 12 deltas along the margin of the glacial Lake Hind basin (Figure 3); they are composed mainly of gravels and gravelly sand. The sediment grain size and structure of these deltas are similar to that of braid deltas described by McPherson et al. (1987), where gravel and coarse grained sand are deposited into a standing body of water by progradation of a braided fluvial system. Of the 12 deltas, 9 form an irregular and nearly continuous fringe of coarse sediment between the higher elevation till to the west and the finer lacustrine sediments in the lake basin to the east. Based on lithology, deltaic gravels in the glacial Lake Hind basin can be divided into two groups: shale-rich

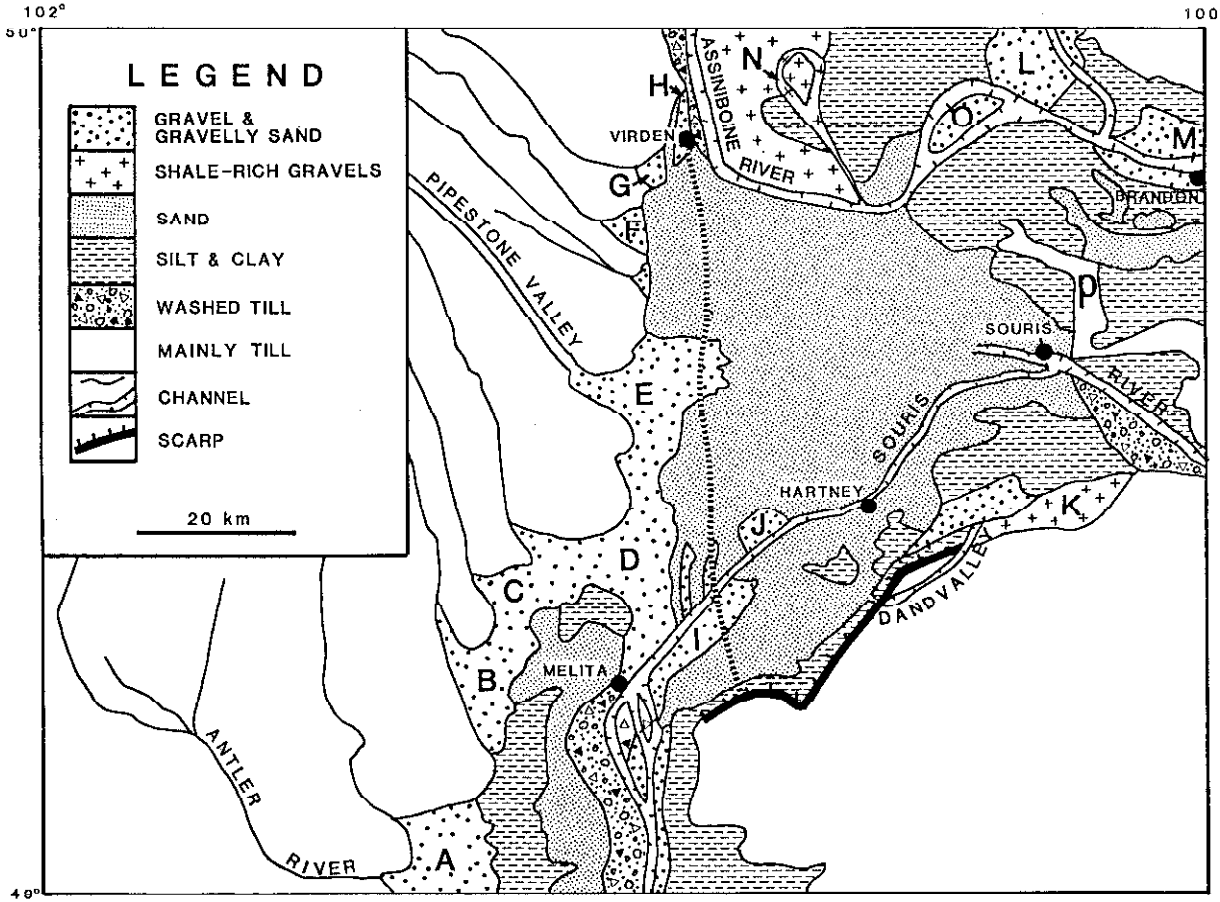

Figure 3. Surficial geology and topography of the glacial Lake Hind basin (After Sun & Fulton, 1995a, 1995b). Letters identify location of deltas (A–L), a gravel bar in the Assiniboine Flat (M), Arrow Hill esker (N), and the Alexander moraine (P) mentioned in the paper. The dotted line shows the location of Figure 5.

and low-shale gravels. Shale-enriched gravels mainly occur in the Melita and Dand deltas (K and I, Figure 3). In these two deltas, sediments consist of up to 90% shale fragments in their proximal areas, and 20% to 50% shale fragments in the distal areas. The rest of the deltaic gravels in the Lake Hind basin include little shale, and mainly consist of carbonate and granitic, metamorphic, and basaltic pebbles.

In order to reconstruct the relative elevation of the surface of these deltas at the time of deposition, the isostatic rebound isobases of Teller and Thorleifson (1983, Figures 2 & 3) were used to 'reconfigure' their surfaces. Modern surface elevations were corrected by subtracting the differential rebound of the surface across the Lake Hind basin. Thus greater numbers were subtracted from more northerly deltas because rebound was greater there than in the south. Figure 4 shows the elevation of the 12 modern delta surfaces and their relative elevation during the late glacial.

As can be seen in Figure 4, late glacial delta elevations vary considerably in the basin, indicating that the level of Lake Hind varied during the time that these deltas were formed. In general, deltas to the north lie at lower elevations. Based on the *corrected* late glacial elevation of deltas, the 12 deltas can be divided into 3 groups. In all but the Little Saskatchewan and Virden deltas, these values are in the same *relative* positions as the *un*corrected (modern) elevations that are used in this paper; equivalent 'rebound adjusted' values are shown in Figure 4. The 3 groups of deltas, reflecting 3 different lake phases, are: (1) above 450 m; (2) 450–442 m, and (3) below 442 m.

Deltas with surface elevations above 450 m are: Antler, Graham, and Jackson deltas in the narrow southwestern end of the basin, the Little Saskatchewan

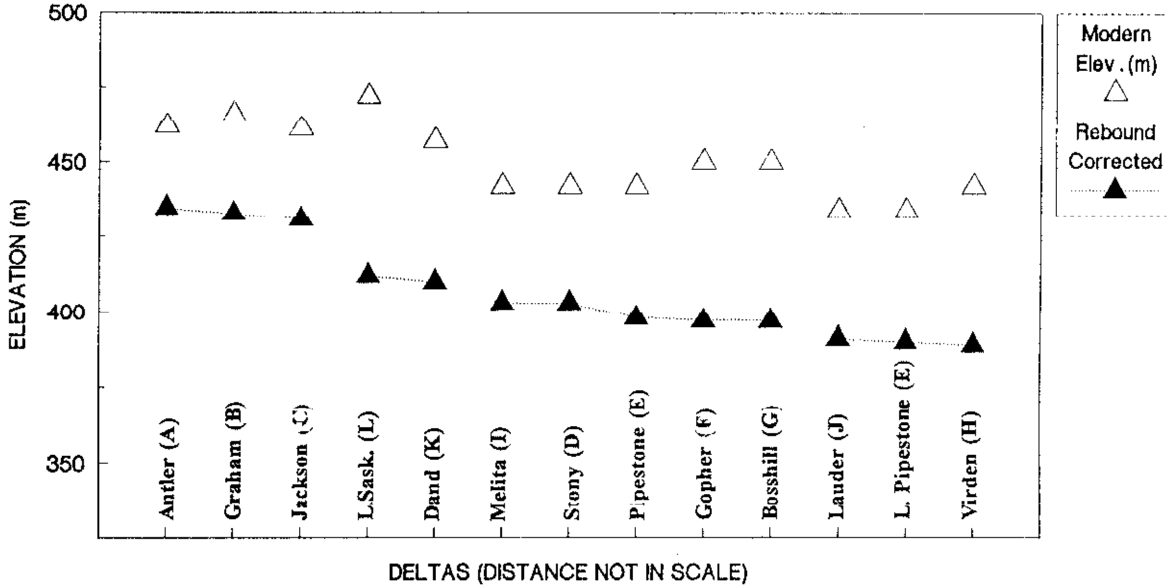

Figure 4. Modern elevation and the corrected late glacial elevation of the delta surfaces.

delta in the northeastern corner, and Dand delta in the southeastern part of the basin (Figure 3, A, B, C, L, K). These deltas are typically 3 to 5 m thick and consist of massive gravels of pebble to boulder size. Paleozoic carbonate and Precambrian crystalline rocks dominate in all but the Dand delta, where shale is the most abundant lithologic type.

The Dand delta (Figure 3, K) is a long and narrow delta and is oriented parallel with the southeastern edge of the basin. The modern surface of the delta slopes northwest, from an elevation of 457 m in the east to 450 m in the northwest (Figure 6), and correction of isostatic rebound will not change the westerly slope of the delta surface. The eastern part of the delta consists of a 3+ m-thick planar cross bedded sandy gravel that is overlain by a 2 m-thick stratified coarse gravel; shale fragments are the dominant lithology. The surface of the cross beds dip northeastward. In contrast, the western part consists of massive coarse gravels, overlain by massive to faintly flat-bedded medium to coarse grained sand, both deficient in shale fragments. The channel that leads to the delta is only 20 km long. It starts at the southern edge of the Lake Hind basin, cuts across a ridged till plain, and enters the same basin from the southwest with three branches (Figure 7). The western branch is at a lower elevation than the eastern two.

Along the western side of the basin from Melita to Virden, 4 deltas occur at an elevation between 450 and 442 m. From south to north they are Melita, Stony Creek, Pipestone, Gopher, and Bosshill deltas (Figure 3, I, D, E, F, G). All these deltas, with the exception of the Melita delta, consist of pebble to cobble-sized gravels that are massive and non-stratified and composed mainly of Paleozoic carbonate and Precambrian crystalline rocks. These deltas have relatively flat delta plains and relatively steep delta fronts. Among these deltas, Pipestone delta is the largest with the thickest deltaic sediment sequence, with up to 17 m of gravels (Figure 5); it is underlain by lacustrine silt and clay. In comparison, other deltas are normally less than 5 m thick (Groom, 1988), and also are underlain by thick lacustrine silt and clay.

The Lauder and Virden deltas are the two lowest deltas (Figure 4; Figure 3, J and H). The Lauder delta is located on the north side of the Souris River, and consists of 6 m of massive, non-stratified, and clast supported cobbles, underlain by till and areas of well laminated clayey silt. This delta differs from the Melita delta by having much coarser gravels that are deficient in shale fragments, and by a lack of stratification.

Fine lacustrine deposits

Fine lacustrine deposits include silt, clay, and sandy silt. The distribution of these sediments on the surface follows a geographic pattern. In the narrow southwestern end near the International Border, silt and clay

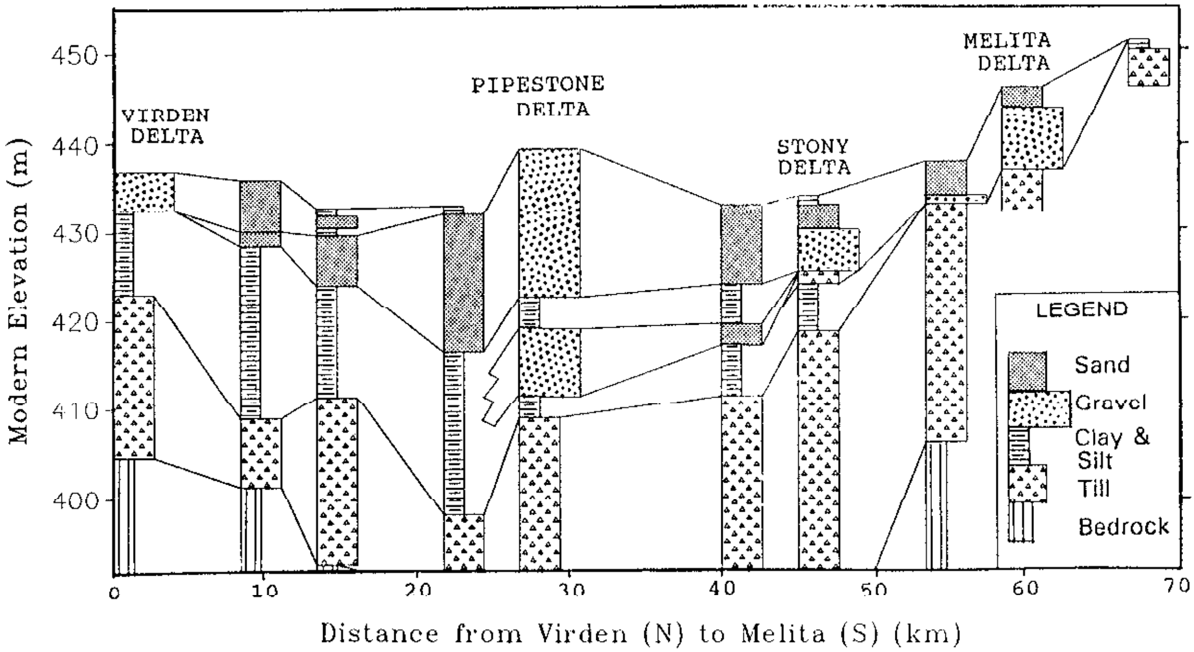

Figure 5. Section across the western glacial Lake Hind basin from north to south. Location is shown as a dotted line in Figure 3.

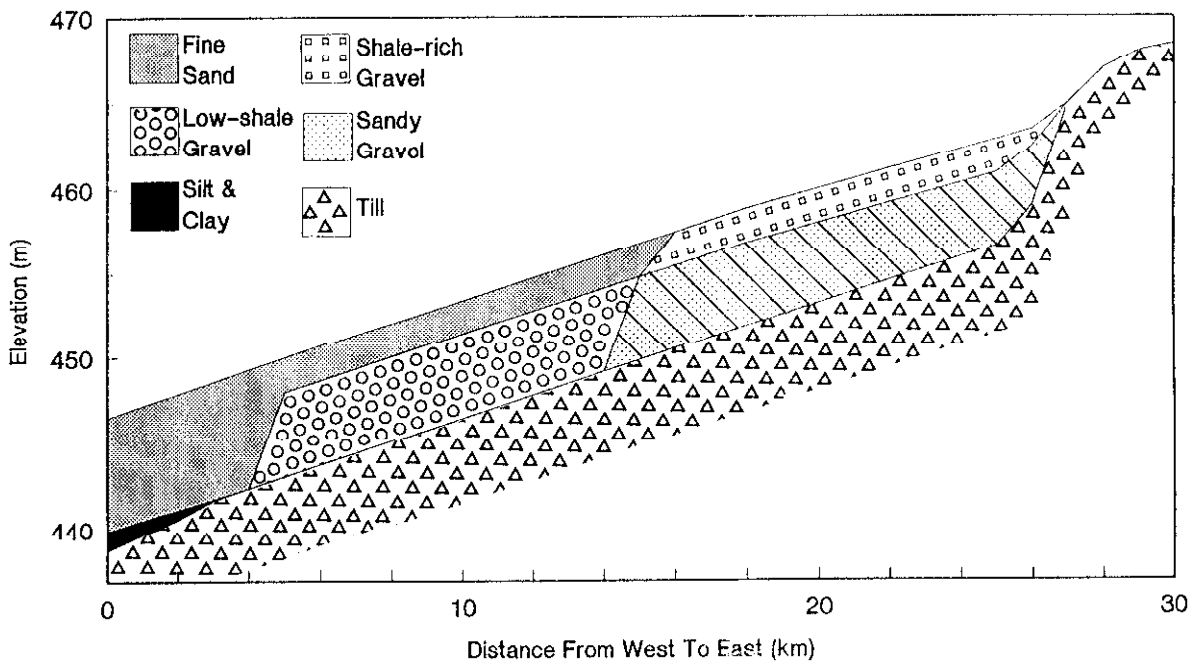

Figure 6. A west-east section across the Dand delta. Notice the westward slope of the delta surface. See Figure 7 for location of cross section.

occur at a modern elevation of up to 453 m. Northward along the southern edge of the basin, they are exposed at gradually lower elevations between 443 and 434 m. On the eastern side of the basin, silt and clay on the surface is everywhere below 434 m. In the north end of the basin, fine lacustrine sediments occur between 426 and 442 m. In the western basin, there are no fine lacustrine sediments above 434 m.

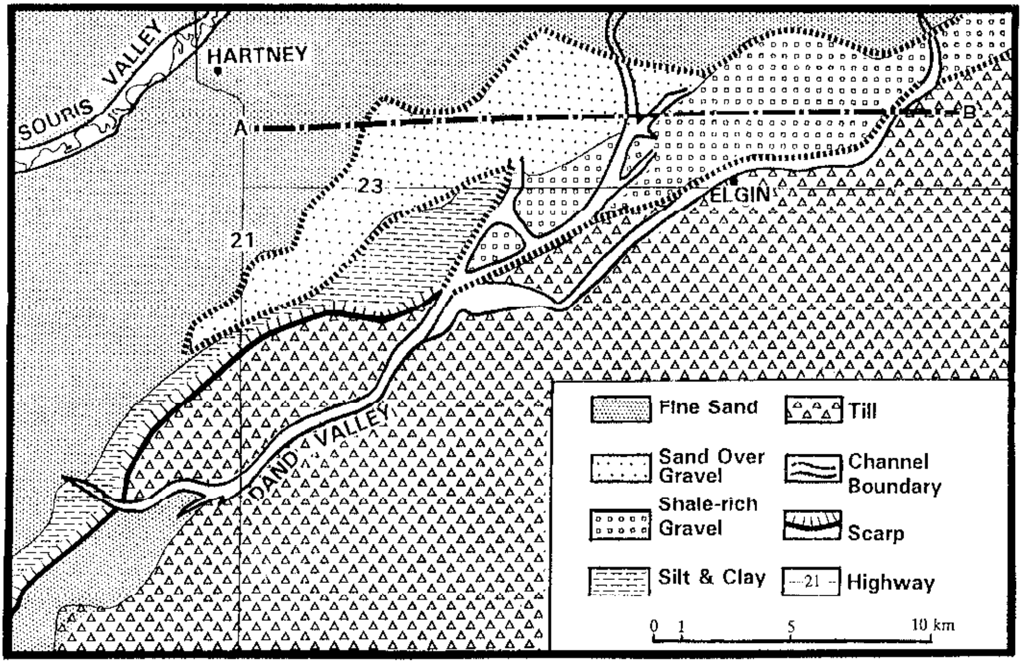

Figure 7. Surficial geology of the Dand delta region. Outline of the delta is shown by dotted lines. Dashed-dot line is location of cross-section in Figure 6.

In exposures, this silt and clay is commonly massive and structureless, only occasionally being laminated. It lies over till, and underlies lacustrine sand and gravel (Figure 5). The thickness of the clayey silt unit ranges from a few meters to 25 m. It is thickest in the northern end of the basin and thinnest near the Pipestone delta.

Lacustrine sand

This unit differs from the deltaic gravelly sand by having a fine grain size and less than 1 percent pebble sizes. It consists of sand and silty sand that is well to moderately well sorted, massive to laminated, and up to 20 m thick. It occurs mainly in the central part of the Lake Hind basin with a sharp contact to the underlying lacustrine clay and silt. The surface of the sand is generally flat, but in some areas sand has been reworked by wind into dunes up to 5 m high that are oriented northwest-southeast. The surface of the lacustrine sand has broad water scoured channels in the northern basin, which start from the Assiniboine River near Virden and extend SE toward the Pembina Spillway.

Late glacial history

During the late Wisconsinan, there were two ice lobes in the Lake Hind region: the Red River Lobe and the Souris Lobe (Elson, 1956). Ice of the Red River Lobe, which was named the Sub-Assiniboine Ice Lobe by Klassen (1975, 1983), flowed from the northeast. It built the Darlingford Moraine (Elson, 1956, 1967; Conley, 1986) and its northwestern extension, the Alexander Moraine (Figure 3; Sun, 1993). The Souris Lobe, which was refereed to as the Assiniboine Lobe by Klassen (1975, 1983), flowed from the north or northwest and met the Red River Lobe in the eastern glacial Lake Hind basin (Elson, 1956; Sun, 1993).

Based on the approximate locations and ages of the ice marginal boundaries by Clayton & Moran (1982), deglaciation of the glacial Lake Hind basin began after 12 ka and ended before 11 ka. This ice retreat can be divided into 4 phases based on the sedimentary and geomorphic record in the Lake Hind basin and of the major meltwater channels leading to this basin.

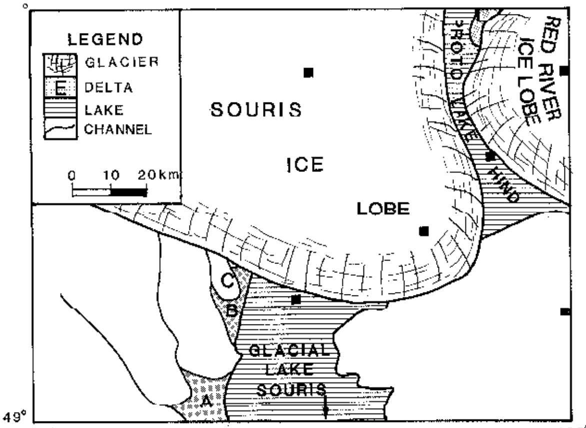

Figure 8. Phase 1A of glacial Lake Hind, Diagram showing the locations of the two ice lobes, glacial Lake Souris, and proto glacial Lake Hind.

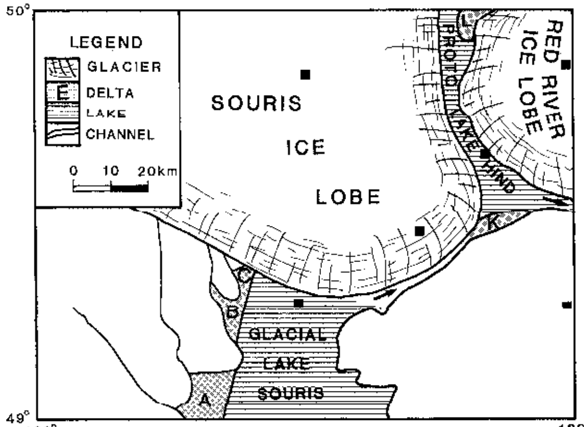

Figure 9. Phase 1B of glacial Lake Hind, Waters from glacial Lake Souris overflow into proto glacial Lake Hind and deposited Dand delta at a modern elevation about 457 m.

Phase 1, glacial Lake Souris and proto glacial Lake Hind

Initially, the Souris Lobe occupied the entire glacial Lake Hind basin (Elson, 1956). During the retreat of this lobe, the Red River Lobe advanced into the eastern region. Shortly after 12 ka, as the southern margin of the Souris Lobe retreated northward, glacial Lake Souris extended an 'arm' northward into the narrow southern end of the Lake Hind basin (Figures 1 and 8). The lake level was probably at an elevation between 433 and 435 m, which is equivalent to a modern elevation of 462 to 466 m, as indicated by the reconstructed elevations of three deltas on the western side of the basin (Antler, Jackson, and Graham deltas, A, B, and C of Figures 3 and 8; Figure 4) and the fine lacustrine deposits at the same elevation along the eastern side (Figure 3).

Meanwile, as the eastern margin of the Souris Lobe wasted back, a long and narrow interlobate lake (proto glacial Lake Hind), was formed between the Red River and Souris Lobes in the eastern part of the basin (Figure 8). The level of this lake, which drained eastward along the ice margin to the Pembina Spillway (Figure 1), was at about 457 m, as evidenced by the elevation of the Little Saskatchewan River delta (L of Figures 3 and 4). The central glacial Lake Hind basin was still occupied by the Souris Lobe, which separated proto glacial Lake Hind to the east from glacial Lake Souris to the southwest.

Continuous retreat of the Souris Lobe permitted ice marginal drainage to cut the Dand valley (Figures 3 and 9). Meltwater from Lake Souris eroded the Dand valley into shale bedrock and deposited the shale-rich eastern half of the Dand delta into the southern end of the proto glacial Lake Hind. With opening of this lower outlet, glacial Lake Souris began to shrink and its Sheyenne River outlet to the south (Figure 1) was abandoned. Meanwhile, as the Souris Lobe retreated farther into the glacial Lake Hind basin, meltwater abandoned the Dand valley and flooded through a lower channel between the ice margin to the north and the southern scarp, and deposited the western Dand delta that is deficient in shale fragments. With further ice retreat, glacial Lake Hind came into existence by joining proto glacial Lake Hind with the newly isolated northern 'arm' of glacial Lake Souris in the narrow southern end of glacial Lake Hind basin (Figure 10). The water level dropped to 450 m with cutting of the deeper eastern outlets to the Pembina Spillway. The newly formed glacial Lake Hind was now separated from glacial Lake Souris by newly exposed high ground near the International Border, linked only by a meltwater channel (Figure 1).

Phase 2, the Moose Mountain valley flood from glacial Lake Indian Head

During Phase 2, the Souris Lobe retreated across the lake basin. Glacial Lake Hind expanded northward while lake level dropped from 450 m to 442 m, presumably because the outlet to the Pembina valley was being eroded. Lake Hind must have remained at this level for a relatively long period, because 25 m of clay

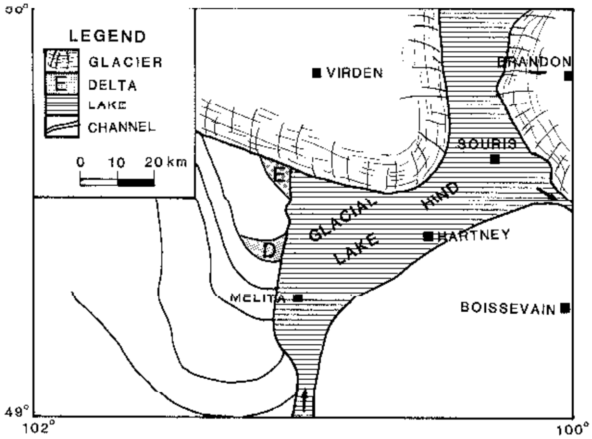

Figure 10. Phase 2 of glacial Lake Hind: early stage of the Pipestone valley and Pipestone delta.

and silt clay were deposited in the Lake Hind basin (Figure 5). During this period, four ice contact deltas were deposited into the western lake basin by meltwater from the Stony, Pipestone, Gopher, and Bosshill creeks (D, E, F, G of Figures 3 and 11), which may have had an ice marginal or subglacial origin (Fulton et al., 1994). Meanwhile, the Arrow Hills Esker (Figure 3) and associated low linear ridges were deposited north of the Lake Hind basin by subglacial meltwater flows.

The Melita delta (I in Figure 11) is different from other deltas because it was not deposited by normal meltwater flows, but by a catastrophic flood that eroded the Souris valley into till and shale bedrock. The source water for this flood may have been from glacial Lake Indian Head or glacial Lake Regina (Figure 1). Previous research by Kehew (1982), Kehew & Clayton (1983), Kehew & Lord (1986), and Kehew & Teller (1994) indicate that a single catastrophic flood from Lake Regina eroded the Souris valley, and in a 'domino' fashion, resulted in the drainage of Lake Souris into Lake Hind, the next basin downstream; in turn, Lake Hind abruptly overflowed into Lake Agassiz through the Souris-Pembina Spillway system (Figure 1). However, the occurrence of two separate and distinct deltas, the Melita and Lauder deltas, at the mouth of the Souris River in glacial Lake Hind (I and J of Figure 3) suggests that there were two flood events, not just one. Is it possible that there was an earlier catastrophic flood from Lake Regina? Based on previous research, there appears to be no evidence for this and, in fact, the very nature of the outburst from this lake seems to preclude this (e.g. Kehew & Lord, 1986, 1987). Recent research, however, suggests that there may have been a second flood through the lower part of the Souris River valley, downstream from where Moose Mountain valley joins with it near the town of Oxbow which is 350 km upstream from Lake Hind (Figure 1). This channel is wide and deep between glacial Lake Indian Head and glacial Lake Arcola, and between glacial Lake Arcola and the Souris River valley (Figure 1), and contains massive, very poorly sorted, sandy coarse gravels in several locations. The massive sandy coarse gravels in the northern end of glacial Lake Arcola and near the Souris junction suggest a major outflow of meltwater from glacial Lake Indian Head and glacial Lake Arcola. Furthermore, Moose Mountain valley is very small and shallow within glacial Lake Arcola (Christiansen, 1958), exactly what is characteristic of a lake that drains when a catastrophic flood causes its overflow outlet to be rapidly deepened (Kehew & Lord, 1987). Thus, an outburst of water from glacial Lake Indian Head may have incised the Moose Mountain channel and the Souris River valley between the town of Oxbow and glacial Lake Souris. In turn, this flood deepened the spillway from glacial Lake Souris to glacial Lake Hind. This resulted in deposition of the Melita delta (I of Figure 11) in the glacial Lake Hind basin. Shortly after the flood through Moose Mountain valley, a catastrophic flood from glacial Lake Regina (discussed in phase 4) further enlarged and deepened the Souris valley. The magnitude of the flood from Lake Regina may have been much larger than the flood from the glacial Lake Indian Head, because (1) the Souris valley is about 50% wider than Moose Mountain valley near Oxbow, and (2) glacial Lake Regina was at least triple the size of glacial Lake Indian Head and glacial Lake Arcola.

Evidence that the first flood came from Moose Mountain, and the second flood from glacial Lake Regina, is based on the extension of scoured subupland valleys. The broad and scoured subupland area adjacent to the main deeply incised spillway was described by Kehew (1982) as one of the three main characteristics for identifying the occurrence of a catastrophic flood. This scoured subupland zone is present along the Souris valley from its outlets at glacial Lake Regina downstream to Oxbow (Kehew & Clayton, 1983, Figure 1). This suggests that the flood water from glacial Lake Regina eroded the upper reach of the Souris valley from Weyburn to Oxbow (Figures 12, 13A-A'). But the absence of this scoured subupland downstream from Oxbow (Figure 12) suggests that (1) the flood water from glacial Lake Regina, which was probably

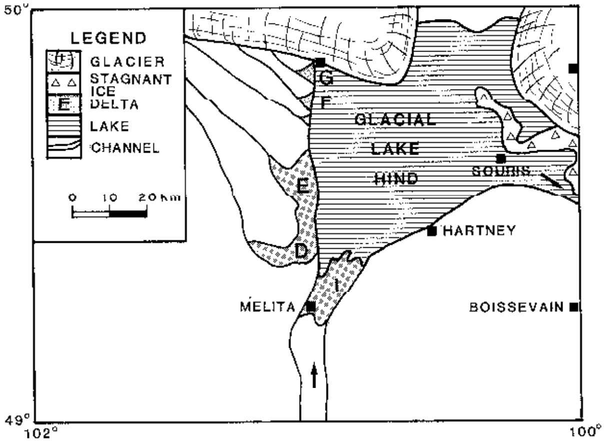

Figure 11. Phase 2 of glacial Lake Hind; Lake Hind was at an elevation about 397 m and was in its maximum areal extension.

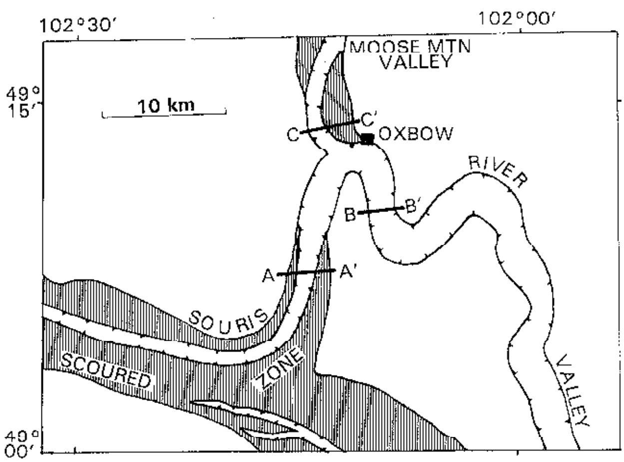

Figure 12. Map of the Souris River valley near the Moose Mountain junction. Shaded areas are the scoured zones discussed in the text. Topographic cross sections at indicated locations shown in Figure 13.

much larger in magnitude than the Moose Mountain flood, utilized and enlarged the Moose Mountain valley from Oxbow to glacial Lake Souris, and (2) previously scoured upland zones by the Moose Mountain flood were destroyed by the later flood (Figure 13B-B', C-C').

Elsewhere to the west of glacial Lake Hind, meltwater eroded one after another subparallel meltwater channels as the ice retreated. These channels probably started as subglacial channels that were oriented northwest-southeast, oblique to the ice margin (Figure 10). The orientation of these channels was probably the result of the eastward slope-gradient from Moose Mountain upland to the Lake Hind basin combined with the tendency for meltwater to flow toward the ice margin to the south. Among these channels, the Pipestone Channel was the longest and deepest, and supplied the most sediment to glacial Lake Hind. In contrast, coarse sediment- supply from Gopher, and Bosshill creeks (F and G of Figure 11) was not significant. The Pipestone delta is the largest one in the basin, with sediment at least twice as thick as other deltas.

Phase 3, glacial Lake Hind and Lake Brandon

Because of the erosion of the outlet to the Pembina Spillway, the level of the lake dropped; the region east of the Alexander moraine became separated from Lake Hind, forming a glacial lake, referred to as Lake Brandon by Elson (1956) (Figure 14). This lake overflowed westward across the moraine through the Alexander Channel and possibly through the Assiniboine Channel into Lake Hind; these two lakes probably were at about the same elevation.

In the western Lake Hind basin, meltwater from the Pipestone valley, whose headwaters were in glacial Lake Indian Head (Figure 1), eroded a wide channel across the early delta and deposited a lower delta into Lake Hind at about 434 m (Figure 4). Strong wave action in the shallowing Lake Hind basin carried sand from the deltas into the central lake and transported the silty and clayey portion to the next like downstream, Lake Agassiz.

Phase 4, the Souris flood from glacial Lake Regina

Farther east, retreat of the Red River Lobe allowed glacial Lake Brandon to overflow east into Lake Agassiz through a series of shallow channels south of the city of Brandon. This resulted in a reversal of outflow across the Alexander Moraine, and glacial Lake Hind probably overflowed eastward for a short time both across the former glacial Lake Brandon basin and through the long-standing outlet from the southeastern corner into the Pembina valley (Figure 15). Eventually Lake Hind drained, as the Assiniboine River channel was established across the northern side of the basin and the Souris River valley was established across the south side.

It is possible that the southern route of the Souris River across the basin floor came about as a result of a second catastrophic flood, described by Kehew (1982), Kehew & Clayton (1983), Kehew & Lord (1986, 1987) and others. This flood resulted from the abrupt draining of glacial Lake Regina in Saskatchewan (Figure 1), and eroded the upper Souris River valley (west of Oxbow,

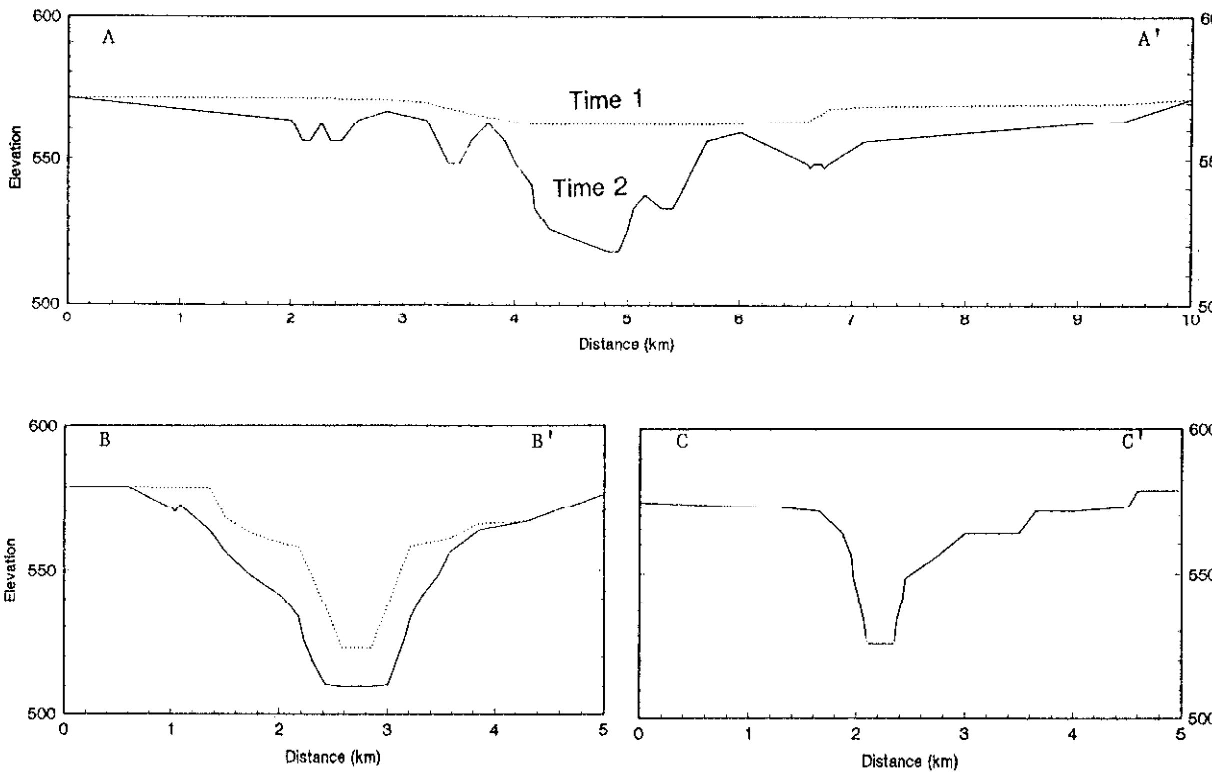

Figure 13. Cross sections of the Souris River valley. Time 1 represents the cross section after the Moose Mountain valley flood and before the Glacial Lake Regina flood; Time 2 stands for modem cross section (after the glacial Lake Regina flood). Section A-A' is 8 km upstream from the town of Oxbow, Saskatchewan; B-B' is 6 km downstream from Oxbow; and C-C' is Moose Mountain valley near the junction (Figure 12).

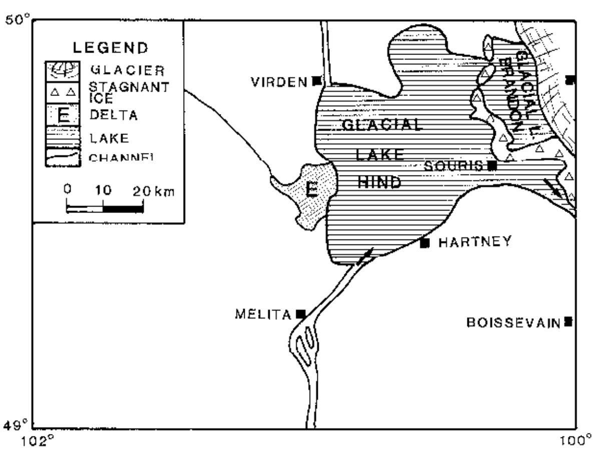

Figure 14. Phases 3 of glacial Lake Hind showing formation of Lake Brandon after the first flood from the Souris Spillway.

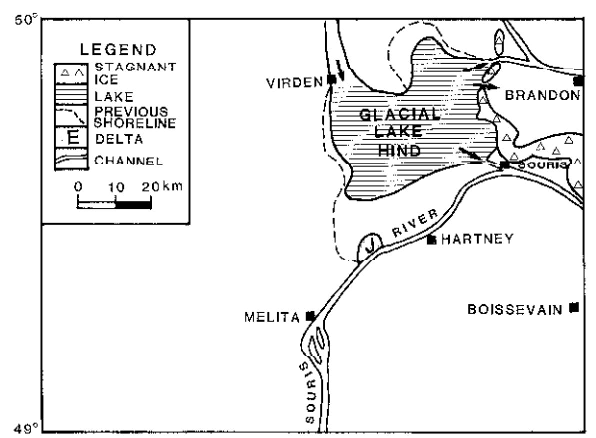

Figure 15. Phase 4 of glacial Lake Hind after the second flood from the Souris valley and before the flood from the Assiniboine valley. Arrows show possible contemporaneous routing of water across the Lake Hind basin to two different routes to Lake Agassiz.

Figures 1 and 12), depositing most eroded material in glacial Lake Souris. When these waters reached glacial Lake Hind, they eroded a shallow channel in the southern end of the basin, and deposited the Lauders delta (J of Figures 3 and 15) at an elevation of 434 m. The shallow channel was subsequently occupied by the Souris River when glacial Lake Hind drained. Because this second flood was largely confined within a previously existing channel (the one that was cut by the Moose Mountain flood), the Lauder delta is small, and contains less shale fragments than the delta deposited by the previous Moose Mountain flood.

Phase 5, the Qu'Appelle-Assiniboine flood

As ice retreated northeastward, a flood entered the lake basin from the north, this time via the Qu'Appelle-Assiniboine Spillway system (Kehew & Teller, 1994). The flood originated in the upper reaches of the Qu'Appelle basin and passed through glacial Lake Indian Head. In glacial Lake Hind, the incoming flood became a sheet-flow, which eroded many shallow sub-parallel grooves and deposited sand-sized material onto the Virden delta (H of Figure 3) and the lake floor. Lack of fine lacustrine sediments in the central part of the lake basin suggest the basin was not a very effective sediment trap. Sand was deposited in shallow water and was probably reworked by waves and moved into the central part of the basin as the lake level fell even further; finer sediment remained in suspension and was carried out of the basin into glacial Lake Agassiz through the Pembina Spillway, Alexander Channel, and the Assiniboine Channel. This flood probably caused complete drainage of the glacial lake, and incised the Assiniboine channel across the northern side of the basin. Subsequently, there were several floods from the Qu'Appelle-Assiniboine valley that reached Lake Agassiz (Kehew & Teller, 1994) through the newly incised Assiniboine channel; Sun (1993) suggested that at least three floods from the Assiniboine Spillway poured into Lake Agassiz and deposited coarse sediments in the Assiniboine delta. Lack of evidence for multiple floods in the Virden delta and glacial Lake Hind suggests that these floods were probably confined within the channel, enlarging the channel into bedrock which became the modern route of the Assiniboine River.

Conclusion

Most of the 12 deltas, except the Melita, Lauder, and Virden deltas, started as ice contact deltas deposited by ice marginal flows into the lake basin. The surface elevations of deltas in the western lake basin, after correcting for isostatic tilting, suggest an episodic falling of water level from south to north due to the incision of the outlet by floods.

During initial deglaciation, proto glacial Lake Hind formed as an interlobate lake in the eastern part of the basin, which overflowed east to glacial Lake Agassiz through the Pembina Spillway. In the southern part of the basin, waters of glacial Lake Souris expanded northward from North Dakota; several deltas were deposited into this lake at an elevation of 457 m by meltwater from the west; this lake overflowed south into glacial Lake Agassiz through the Sheyenne Spillway in North Dakota. When the retreat of ice opened a lower northeastern outlet in Manitoba, waters of the northern end of glacial Lake Souris, which had expanded into the southern end of the glacial Lake Hind basin, began to overflow into proto glacial Lake Hind via the Dand valley. Continued ice retreat allowed these bodies of water to amalgamate into one lake, glacial Lake Hind, and to drain east through the Pembina River valley.

Two catastrophic floods in the Souris River valley impacted on the history of Lake Hind. One flood came from glacial Lake Indian Head, via the Moose Mountain valley and glacial Lake Souris, and deposited the Melita delta in Manitoba. The other flood came from glacial Lake Regina, which resulted in the complete drainage of glacial Lake Souris, and deposition of the Lauder delta in glacial Lake Hind basin.

An early flood from the Assiniboine River valley deposited sand sized materials onto the Virden delta and the lake floor, probably entering glacial Lake Agassiz via the Pembina Spillway, Alexander channel, and the Assiniboine channel, and causing the complete drainage of glacial Lake Hind. Subsequent floods from the Assiniboine River valley enlarged the valley, and deposited the Assiniboine Delta into Lake Agassiz, but these floods left no records in the Lake Hind sediments.

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