Ice-shoved hills and related glaciotectonic features in the Glacial Lake Proven Basin, Riding Mountain uplands, Manitoba

R.A. McGinn
Brandon University

Abstract: Five to six ice-shoved hills and a small composite linear ridge represent the suite of glaciotectonic features mapped in the Glacial Lake Proven basin. The ice-shoved hills appear to be associated with small depression lakes located approximately 2.0 - 4.0 km upstream of a N or NE ice flow (5°-50°). The Odanah Shale member of the Pierre formation forms the core of each ice-shoved hill and approximately 1.0 m of Zelena till overlies the shale core. Pebble clast fabric analysis from the till supports the hill-hole hypothesis.

The small composite linear ridge is described as a broken series of hills 8 km long, 2 km wide and 15-30 m high. The ridge is relatively straight and has a NNW-SSE orientation (335°). The gaps appear to be generated by a combination of ice stagnation drainage and Holocene fluvial erosion. About 2.0 m of till overlies a deformation diamict or distorted sands and gravels. The fluvial facies contains dragfolds, overfolds and small thrust faults. Pebble clast fabric analysis from the upper till suggests a northern ice flow vector (5° azimuth). A secondary vector (40° azimuth), however, supports a northeastern ice flow theory. Glacial Lake Proven sediments surround the constructional glaciotectonic landforms suggesting that they were formed during the Falconer Advance of the Lostwood Glaciation.

Introduction

Constructional glaciotectonic landforms include a variety of hills, ridges and plains which are composed wholly or partly of soft bedrock or drift masses that were deformed or dislocated by glacier-ice movement. (Aber 1985).

The INQUA Commission on the Formation and Properties of Glacial Deposits, formed a Work Group on Glacial Tectonics (WGGT) in 1987. Dr. J. Aber served as the overall coordinator for North America. By 1993 Aber had compiled an extensive bibliography consisting of 575 entries (Aber 1993). In addition, a North American continental wide data base of geographic and glaciotectonic features had been constructed using the ARC/INFO system at the University of Regina. The WGGT (Aber et al. 1993) has classified glaciotectonics into four mappable categories: basement faults, concealed structures, ice-shoved hills and source basins, the later two categories are referred to as “constructional glaciotectonic landforms.”

Aber (1989), classified constructional glaciotectonic landforms into five types: hill-hole pairs, large composite ridges, small composite ridges, cupola-hills and flat lying mega blocks. These classes represent the ideal generic types within a continuum of glaciotectonic landforms. Intermediate, transitional and mixed features also can be described (Aber 1989).

Benn and Evans employ Aber’s 1989 classification in their text and include descriptive examples of each constructional glaciotectonic landform (Benn et al. 1998). The hill-hole pair is described as a discrete hill of ice thrust material situated a short distance down-glacier from a depression of similar size and shape (Bluemle et al. 1984). Aber et al. (1993) illustrate an example of multiple hill-hole pairs from the Devils Lake area in North Dakota.

Composite ridges are composed of multiple slices of upthrust and contorted bedrock and or unconsolidated sediments which are often interlayered and overlain with glaciogenic material (Benn et al. 1998). Aber (1989) subdivides these constructional glaciotectonic landforms into small composite ridges (< 100 m relative relief) and large composite ridges (> 100 m relative relief and arcuate in form). Large composite thrust ridges in North Dakota are described by Moran et al. (1980). The Brandon Hills in southwestern Manitoba are an example of a small composite linear ridge (Welsted et al. 1980: Aber 1989).

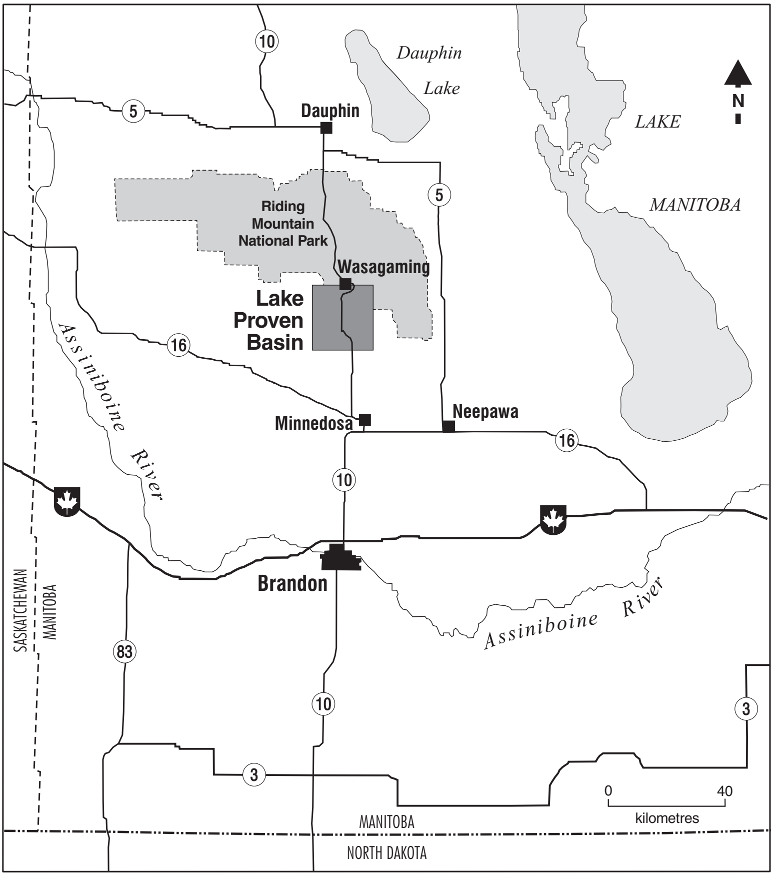

Figure 1: *Location of the Lake Proven Basin in southwestern Manitoba.*

Benn et al. (1998) describe cupola-hills as glaciotectonic hills lacking a hill- hole relationship and or transverse ridge morphology. Cupola-hills have a dome-like morphology, circular to oval to elongated oval shape and are composed of deformed floes of Quaternary sediments of older bedrock overlain by a thin carapace of till (Bluemle et al. 1984).

Megablocks or rafts are dislocated slabs of rock and unconsolidated material transported from their original position by glacial action (Benn et al. 1998). The Qu'appelle Valley megablock located near Esterhazy, Saskatchewan (Christianson 1971) is a local example and demonstrates the susceptibility of the Cretaceous Pierre Shale Formation to glaciotectonism.

Two, perhaps three, of these types of constructional glaciotectonic landforms have been found in the Glacial Lake Proven Basin, Riding Mountain Uplands, Manitoba. Other concealed structures including bedrock folds, faults and contortions have been recognized in Cretaceous exposures along the Manitoba Escarpment.

The Glacial Lake Proven Basin

The Proven Lake area is located on the Riding Mountain Uplands south of Riding Mountain National Park, 80 km north of Brandon, Manitoba (Figure 1). The Glacial Lake Proven basin is generally less than 625 m in elevation and includes present day Clear Lake, Bottle Lake, Proven Lake, Jackfish Lake and Otter Lake covering an area of approximately 340 km^2 (Figure 2). Higher elevations, in excess of 670 m, are located to the north and east of the Lake Proven Basin. The Whirlpool and Rolling Rivers drain the southern portion of the basin towards the south; the northern portion drains to the west by way of Clear Creek (Figure 2). Both drainage routes join the Little Saskatchewan River, (Klassen's ancestral Minnedosa River) and eventually drain into the Assiniboine River to the south.

Detailed surficial mapping (Klassen 1966, 1979; McGinn 1991, 1997) have determined that early Glacial Lake Proven deposits occur at elevations above 625 m in the region to the west and southwest of the topographic basin (Figure 3). These rhythmite deposits represent a supraglacial thermokarst lacustrine facies. The deposits of the later phase of Glacial Lake Proven are believed to represent a topographically controlled terminoglacial lacustrine facies, perhaps supraglacial, but with only a thin ice base. To the west are the deposits of the eastern ridge of the Horod Moraine, an ice marginal ridge associated with the general stagnation of Wisconsinan Ice on the Eastern Uplands (McGinn 1997). This

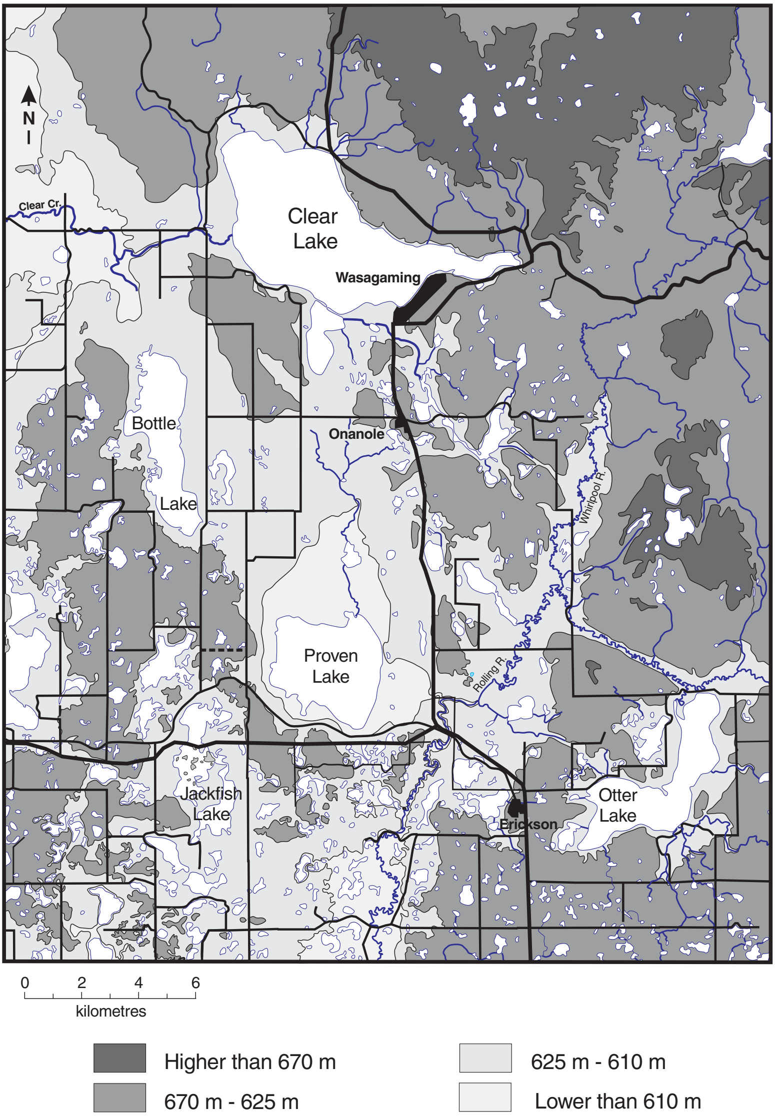

Figure 2: Topography of the Lake Proven Basin.

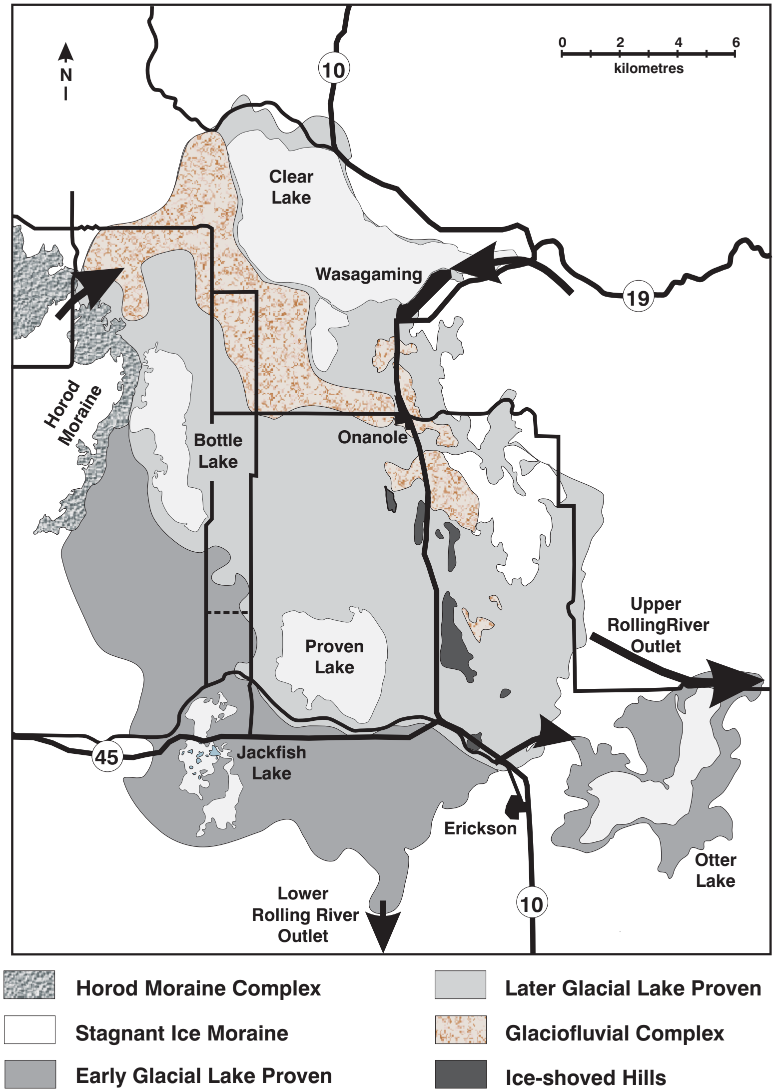

Figure 3: *Surficial deposits in the Glacial Lake Proven Basin.*

landform delimits part of the western shoreline of early Glacial Lake Proven (Figure 3).

To the north, a glaciofluvial facies (proglacial outwash) merges with constructional glaciotectonic features in the east. It is these constructional glaciotectonic landforms that are the topic of this paper. The suite of landforms include: two small oval shaped hills in the south (OH), a large elongate oval ridge (EOR), three other smaller elongate oval shaped hills (EOH) and an 8 km long segmented ridge centred on the town of Onanole (Figure 4).

Ice- Shoved Hills

The two southern ice-shoved hills (OH) are oval in form, approximately 0.75 km in diameter and 10 m - 15 m high. The northern ice shoved hills (EOH) are elongated but do not display arcuate form. These hills are generally larger, 2.0 km - 3.5 km in length, 0.25 km -1.0 km wide, display 10 m -15 m relative relief and are aligned along a north-south vector (350° azimuth).

A large elongated oval ridge (EOR) is situated north of Erickson, east of Provincial Highway 10 and approximately half way between the southern ice-shoved oval hills and the more northern elongated oval hills (Figure 4). This ice-shoved elongated oval ridge is 7.0 km long and 2.3 km wide. The feature is approximately 15 m in relative relief except for a prominent dome shaped hill located near the southern end, which stands 45 m above the Glacial Lake Proven plain.

The two oval shaped hills and the large elongated oval ridge (EOR) north of Erickson appear to be associated with small depression lakes located approximately 2.0 km upstream of ice flow directions (40°-50° azimuth) (Figure 5). The other three elongated oval hills may be related to depression lakes 4.0 km upstream (azimuth 0°-20°) (Figure 5).

The hill-hole pairs (Figures 4 and 5) are composed of the Odanah Shale member of the Pierre formation. Odanah Shale is described as hard olive-grey siliceous shale with soft interbeds of darker olive-grey shale. The shales are composed of clay sized siliceous particles which show no sign of biogenic origin (McNeil et al. 1981). The

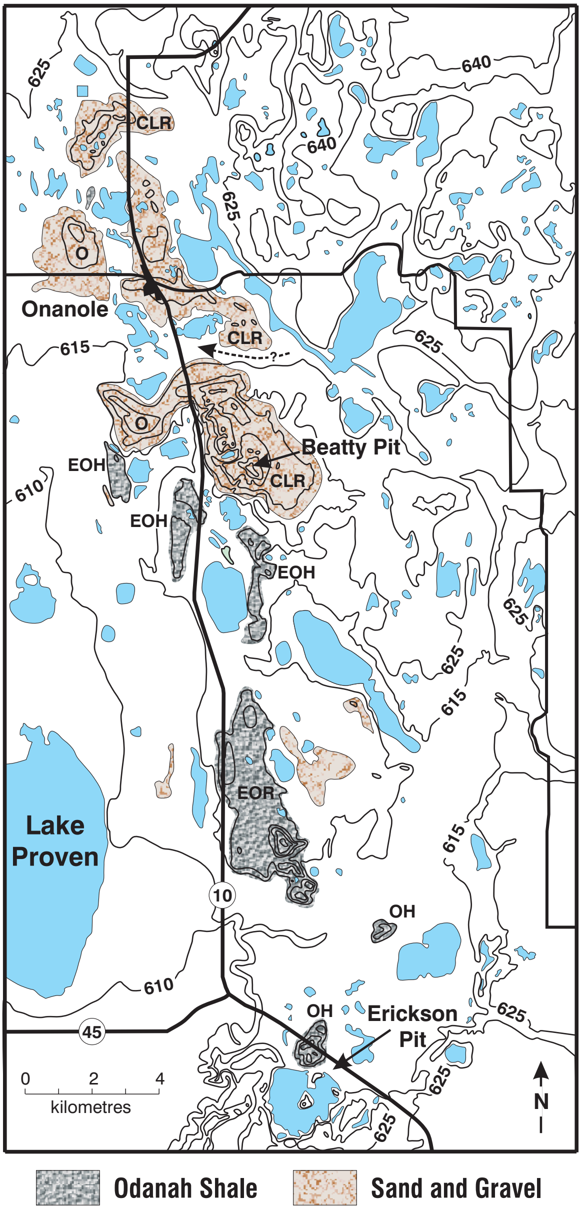

Figure 4: *Topography of constructional glaciotectonic landforms in the Glacial Lake Proven Basin.*

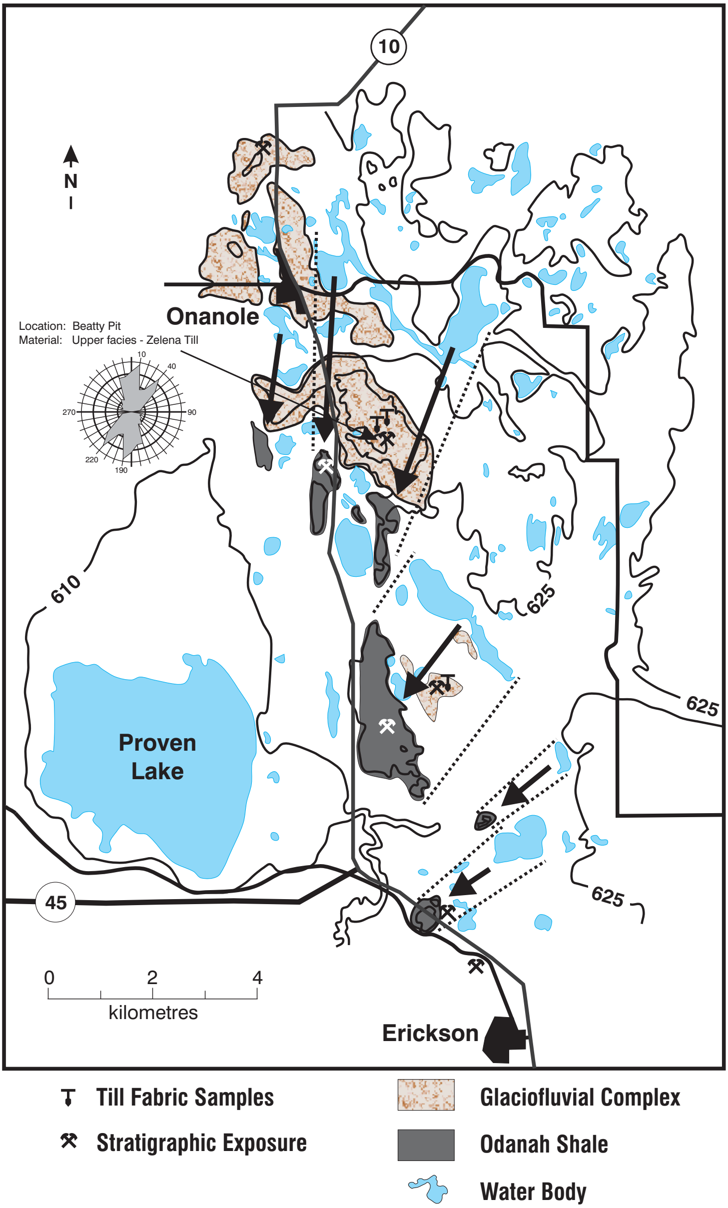

Figure 5: *Glacial Lake Proven Basin hill-hole pairs.*

mineralogy is described as amorphous silica and illite with traces of quartz and organic carbon (Bannatyne 1959). Roadcut exposures in the small oval hill just north of Erickson indicate that the strike is generally as expected, however, dips appear to be disrupted and plunge opposite the acknowledged trend.

Approximately 1.0 m of Zelena till overlies the shale core. The Zelena formation, on average, is 3.0 m - 5.0 m thick in the region and represents the uppermost tills and intertill sediments on the Riding Mountain Uplands. Klassen (1979) suggests that the Zelena formation was deposited during the final stages of glacial stagnation during the Late Wisconsinan. Oxidized Zelena till is usually yellowish brown or very dark grey brown in colour. Fresh (unoxidized) exposures are dark olive grey or very dark grey (Klassen 1979). The till is shale rich but since Pierre Shale clasts tend to disintegrate when removed from the matrix, it is difficult to determine a percentage composition. Carbonates constitute approximately 26% - 36% of the clasts (Klassen 1979).

Stratigraphic exposures in the Erickson Pit (Figure 5) located adjacent to the southernmost hill-hole pair reveal two tills overlying deformed sands and gravel. The upper diamict, described as a supraglacial meltout complex (Brodzikowski and van Loon, 1991), overlies a slightly more compact supraglacial ablation till. The meltout complex is usually a typical diamict, massive in appearance but with occasional concentrations of relatively coarse or fine material forming vague lenses. The ablation till is massive, and slightly more compact. The prominent clasts are typically Interlake carbonates as the local Odanah Shale clasts quickly achieve terminal grade. Larger shale clasts are evident but difficult to remove without fracture. The underlying fluvial facies (proglacial outwash) contains shearing flexures and small thrust faults, which supports a glaciotectonic modification. Unfortunately, the Erickson Pit was reclaimed before pebble clast fabric analysis was undertaken. Pebble clast fabric analysis from the till exposures towards the north, however, support the hill-hole hypothesis illustrated in Figure 5.

Small Composite Linear Ridge

Associated with the ice shoved hill-hole pairs is a low relief ridge, centred on Onanole, Manitoba (Figure 4). This small composite linear ridge is described as a broken series of hills 8.0 km long, 2.0 km wide and 15 m -30 m high. The gaps appear to be generated by a combination of ice stagnation drainage and Holocene fluvial erosion.

The ridge may be divided into a NNW-SSE orientation (335°) tri-sectional ridge (CLR) and two distal outlier hills (O) (Figure 4). The tri-sectional ridge is slightly arcuate, suggesting an ice advance from the northeast.

An alternate interpretation employs a natural drainage channel to divide the landform into a northern suite (two sections of the ridge and a northern outlier) and a southern unit composed of a contiguous ridge section and outlier (Figure 4). The northern hills typically exhibit 15 m - 20 m relative relief. The southern unit is higher and broader.

Ice proximal sections in the Beatty Pit (Figure 4) expose about 2.0 m of till overlying a deformation diamict and/or distorted sands and gravels. The fluvial facies contains dragfolds, overfolds and small thrust faults. The deformation diamict, in places, is predominantly reworked coarse glaciofluvial material. When this is the case, dragfolds, overfolds and crenulations are common. When the deformation diamict is reworked till, shear flexures and small thrust faults occur. Pebble clast fabric analysis (Figure 5) from the upper till suggests a northern ice flow vector (5^{o} azimuth). A secondary vector (40^{o} azimuth), however, supports the northeastern ice flow theory.

North of Onanole discordant shale bedrock is exposed in a small borrow pit on the proximal side of the ridge. At this site the strike appears to be as expected, apparent dips seem to be disrupted, plunging opposite the acknowledged trend.

Conclusions

One might suggest that these hypothesized ice shoved hills are in fact shale bedrock subcrops. Perhaps subsurface drilling could resolve the conflict, but that is unlikely to occur. The stratigraphic evidence (tills over deformed glaciofluvial material) in both the surrounding ice stagnation plain and the Small Composite Linear Ridge support the conclusion that these features are Cupola-Hills and perhaps Hill-Hole Pairs.

All appear to have formed during the Falconer Advance of the Lostwood Glaciation and are surrounded by Glacial Lake Proven sediments. The fluvial facies appears to be outwash suggesting the glacier advanced over its outwash plain. Subglacial shear and folding were probably aided by porewater pressure and frictional drag.

References:

ABER, J. 1985 "The character of glaciotectonism" *Geologie en Mijnbouw* 64: 389-395

ABER, J. 1988 "Ice-shoved hills of Saskatchewan compared with Mississippi Delta mudlumps – Implications for glaciotectonic models" Croot, D. (ed) *Glaciotectonics Forms and Processes* Rotterdam: Balkama 1-9

ABER, J. 1989 "Spectrum of constructional glaciotectonic landforms" Goldthwait, R. and Matsch, C. (eds) *Genetic Classification of Glacigenic Deposits* Rotterdam: Balkema 281-292

ABER, J. 1993 "Expanded Bibliography of Glaciotectonic References" Aber, J. (ed) *Glaciotectonics and Mapping Glacial Deposits* Regina: Canadian Plains Research Center 99-137

ABER, J., BLUEMLE, J., DREDGE, L., SAUCHYN, D. and ACKERMAN, D. 1993 "Glaciotectonic Data Base and Mapping of North America" Aber, J. (ed) *Glaciotectonics and Mapping Glacial Deposits* Regina: Canadian Plains Research Center 177-200

BANNATYNE, B. 1970 "The clays and shales of Manitoba" *Manitoba Department of Mines and Natural Resources, Mines Branch, Publication* 67(1): 1-104

BENN, D. and EVANS, D. 1998 *Glaciers and Glaciation* London: Arnold Bluemle, J. and Clayton, L. 1984 "Large scale glacial thrusting and related processes in North Dakota" *Boreas* 13: 279-299

CHRISTIANSON, E. 1971 "Geology and groundwater resources of the Melville Area (62 k, l) Saskatchewan" *Saskatchewan Research Council, Geology Division, Map* 12

KLASSEN, R. 1966 "Surficial geology of the Riding Mountain area, Manitoba-Saskatchewan" *Unpublished Ph.D. Thesis* Saskatoon: University of Saskatchewan

KLASSEN, R. 1979 "Pleistocene Geology and Geomorphology of the Riding Mountain and Duck Mountain areas, Manitoba-Saskatchewan" *Geological Survey of Canada Memoir* 396: 1-52

McGINN, R. 1991 "The formation and draining of late Wisconsinan superglacial lakes on the Riding Mountain Uplands, Manitoba" *Atlantic Geology* 27: 221-227

McGINN, R. 1997 "The Horod Moraine: The facies and deposits of a supra-terminoglacial subenvironment" Thraves, B., Paul A. and Widdis, R. (eds) *The Estevan Papers. Regina Geographical Studies, 6.* Regina: 100-112

MORAN, S., CLAYTON, L., HOOKE, R., FENTON. M. and ANDRIASHEK, L. 1980 "Glacier-bed landforms of the Prairie Region of North America" *Journal of Glaciology* 25(93): 457-476

McNEIL, D. and CALDWELL, W. 1981 "Cretaceous rocks and their foramifera in the Manitoba Escarpment" *Geological Association of Canada Special Paper* 21: 1-439

WELSTED, J. and YOUNG, H. 1980 "Geology and origin of the Brandon Hills, southwest Manitoba" *Canadian Journal of Earth Sciences* 17: 942-951