Glacigenic Undulating Terrain on the Southeastern Plains of Canada: Evidence of Glaciotectonism or Subglacial Meltwater Erosion?

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Introduction

The legacy of glaciation in Canada is evidenced in the diversity of landforms dotting the landscape. Traditional subglacial features such as drumlins, eskers and flutes are found in numerous locations. On the Southeastern Plains large tracts of undulating terrain, a previously unidentified landform, can be recognized on satellite imagery and digital elevation models of southern Manitoba and southeastern Saskatchewan. Undulating terrain consists of sets of broad, sub-parallel ridges that are separated by depressions. Individual ridges can be upwards of 5 metres high and several kilometres in length. By addressing the formative processes of this landform this research advances our knowledge of Laurentide Ice Sheet processes on the Southeastern Plains.

Objectives of the Research

❶To determine the sedimentary composition of a variety of undulating terrain fields.
❷Investigate the spatial distribution of undulating terrain and other glacial features such as spillway channels, eskers and flutes.
❸To infer the process(es) responsible for the formation of undulating terrain and its wider implications for Laurentide Ice Sheet behaviour.

Methodology

Undulating terrain was mapped using aerial photography, Landsat imagery, and digital elevation model interpretation. Sedimentological exposures were described and the data integrated into a GIS package.

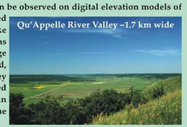
Study Area

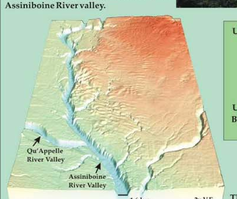
The sets of undulating terrain are located across a large area straddling the Saskatchewan/Manitoba border in west central Canada. This region is underlain by a variety of Cretaceous shales which are part of the Western Canada Sedimentary Basin. The study area is separated from the flat glacial Lake Aggassiz plain by the Manitoba Escarpment. West of the escarpment the topography is punctuated by various uplands, and dissected by large valleys.

In the early Wisconsinan the Laurentide Ice Sheet began growing and expanding from the Hudson Bay area of Central Canada. Approximately 18-20 ^{14}C ka BP the ice sheet reached its maximum size and extended well south of the study area. From its furthest extent the ice sheet retreated until the study area was ice free at roughly 11 ^{14}C ka BP (Dyke *et al.*, 2002).

Undulating Terrain on the Southeastern Plains

Five swaths of undulating terrain can be observed on digital elevation models of the Southeastern Plains. Four are located abutting, or spanning deep trench like valleys which have been interpreted as spillways carved by catastrophic drainage of proglacial lakes (e.g Kehew and Lord, 1986). This association of spillway valley and undulating terrain is clearly observed in the Assiniboine undulating terrain field located on the northeast side of the Assiniboine River valley.





Undulating Terrain Associated With Spillways
1. Assiniboine
2. Pembina
3. Qu'Appelle
4. Swan

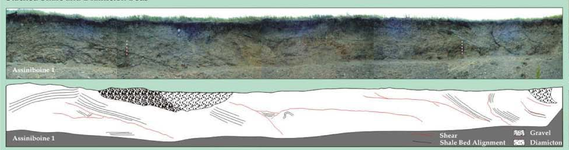
Undulating Terrain Between High Points
5. Convergent

The fifth site is located in a broad swath between subtle highs. All of the undulating terrain sites are located either on a slope, or on a high. Individual ridges range in relief from 2 to 10 m with an intracrest spacing of typically greater than 1 km. Field observations were concentrated in the Assiniboine and Pembina undulating terrain swaths.

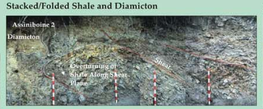
Summary of Site Observations

1. Sedimentary exposures in undulating terrain reveal highly variable compositions within and between swaths of undulating terrain.

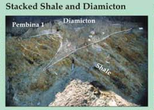
Stacked Shale and Diamicton Beds



Stacked/Folded Shale and Diamicton



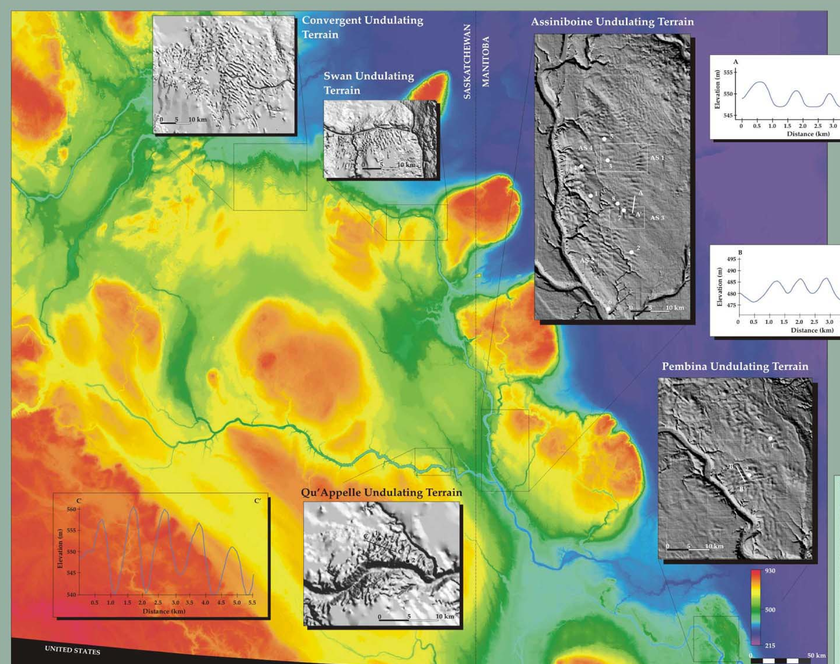
Stacked Shale and Diamicton



Deformed Sand and Gravel

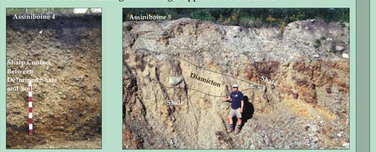
Diamicton

Fractured Shale

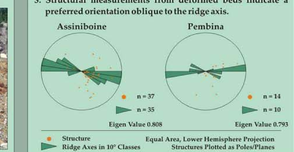


100-metre Resolution Digital Elevation Model of the Southeastern Plains, Canada with elevation colour classes. Hillshade images highlight areas of undulating terrain. Each hillshade has a unique sun angle to better emphasize undulating terrain. Topographic profiles extracted from the DEM show the general relief of undulating terrain. Numbers on the hillshade correspond with the location label found on photographs.

2. Material in the undulating terrain ridges appear to be truncated.

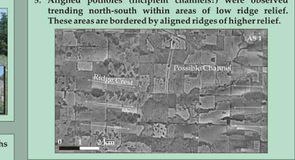


3. Structural measurements from deformed beds indicate a preferred orientation oblique to the ridge axis.

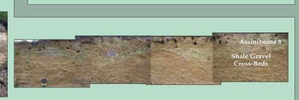


4. Boulder lags and imbricate boulders are present above the spillways.

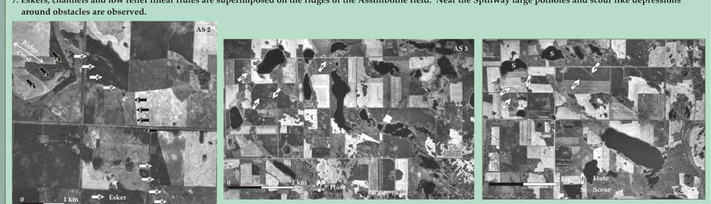
5. Aligned potholes (incipient channels?) were observed trending north-south within areas of low ridge relief. These areas are bordered by aligned ridges of higher relief.



6. Within the Assiniboine undulating terrain fluvial deposits are found in troughs and on the back of ridges.



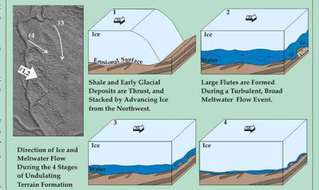
7. Eskers, channels and low relief linear flutes are superimposed on the ridges of the Assiniboine field. Near the Spillway large potholes and scour like depressions around obstacles are observed.



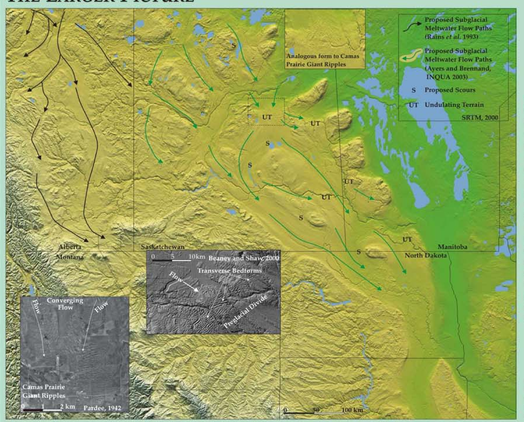
Summary of Interpretations

1. Although there is evidence for substrate deformation a solely glaciotectonic origin for undulating terrain is discounted. Structural elements indicate a deforming force acting at an oblique angle to the ridge axes. The nascent glaciotectonic and bedrock structures may have provided favourable conditions for the development of undulating terrain.
2. Truncation of material within ridges and compositional differences between tracts of undulating terrain suggest an erosional origin.
3. Ice is not likely the eroding agent as flow structures within the ice could not account for the erosion of ridges into more or less, undeformed shale in the Pembina area.
4. Erosion of the ridges likely occurred subglacially. The Assiniboine undulating terrain is superimposed on large flutings. Flutings elsewhere have been interpreted as having been formed by subglacial meltwater erosion (Shaw *et al.*, 2000). Furthermore, subglacial features such as eskers, flutes, and channels are superimposed on, or cut through the ridges.
5. Evidence of water overtopping spillways, potholes, incipient channels, flutings and fluvial deposits suggest a dynamic subglacial hydrological system.
6. As the meltwater flow became unstable, erosion became concentrated in broad swaths resulting in areas with low relief and an absence of ridges. Higher relief aligned ridges border these areas.

Hypothetical Sequence of Events in the Formation of Assiniboine Undulating Terrain



The Larger Picture



Form analogous transverse ridges in Montana and southeastern Alberta further support the proposed meltwater erosion hypothesis. Using the proposed hypothesis for undulating terrain formation, the location of undulating terrain, flutings and scours, enabled identification of several proposed subglacial meltwater flow paths. Similar flow paths have been outlined for Alberta (Rains *et al.* 1993).

Conclusions

Compositional differences between tracts of undulating terrain suggest an erosional origin for this landform. It is proposed that following glaciotectonism, undulating terrain was sculpted by subglacial meltwater erosion. Topographic images of the Canadian Plains show broad, fluted swaths, scours around obstacles, and undulating terrain along deep trench-like valleys. It is hypothesized here that undulating terrain on the Southeastern Plains is part of a larger more integrated subglacial drainage system.

Acknowledgments

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