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Tunnel channel character and evolution in central southern Ontario

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6.1 Introduction

Valleys that truncate subglacial bedforms, contain eskers and follow upslope paths are the geomorphological expression of large subglacial channels—tunnel channels or valleys—that efficiently evacuated meltwater from beneath past ice sheets. In recent years there has been considerable debate as to the mechanism by which such large meltwater channels formed (e.g. Ó Cofaigh, 1996). Such debate is important as interpretations have a direct bearing on reconstructions of Late Wisconsinan ice-sheet dynamics and hydrology. Tunnel valleys may have formed at below bankfull conditions in a headward progression as saturated substrate dewatered and formed pipes at the ice margin or may have formed at bankfull conditions and filled rapidly over the course of a megaflood or jökulhlaup, draining a subglacial or supraglacial meltwater reservoir.

6.2 Background and methods

Central southern Ontario, Canada, exhibits a regional Late Wisconsinan unconformity that truncates Palaeozoic bedrock and a thick Quaternary sediment cover (e.g. Sharpe *et al.*, 2004; Fig. 6.1). This unconformity is composed of drumlins, s-forms and valleys (Fig. 6.2). Valleys were mapped and characterized using remote sensing, digital elevation models (DEMs) and field surveys (e.g. Brennand & Shaw, 1994; Russell *et al.*, 2003). Buried valleys were discovered and their geometry and sediment fill characterized by seismic reflection profiling and outcrop and drillcore sedimentology (e.g. Russell *et al.*, 2002).

6.3 Tunnel channel character

The valleys are assigned to five main classes based on their geomorphology, likelihood of breaching a regional till sheet (Newmarket Till), and probable depth of erosion (Figs 6.1 & 6.2). Structurally controlled, mainly bedrock valleys (class R) are steep-sided and form an anabranched NE–SW orientated system headward (north and east) of sediment-walled valleys. Bedrock valley walls are ornamented by s-forms (Shaw, 1988). Sediment-walled valleys continue the anabranched network and dissect a drumlinized terrain (Fig. 6.2). The largest sediment-walled valleys (class 1) trend NE–SW, are up to 40 km long and <7 km wide, have up to 50 m of topographic relief, and extend to bedrock at depths of >170 m. Between these large valleys are two systems of smaller, shallower (<20 km long, <2 km wide, <100 m deep), nested valleys. Deep channels (class 2) completely dissect the regionally

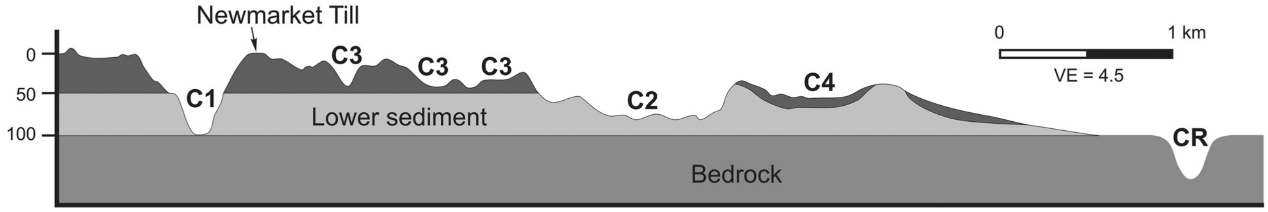

Figure 6.1 Simplified stratigraphy of central southern Ontario showing the relative depths of incision of five tunnel channel classes (C1, C2, C3, C4 and CR).

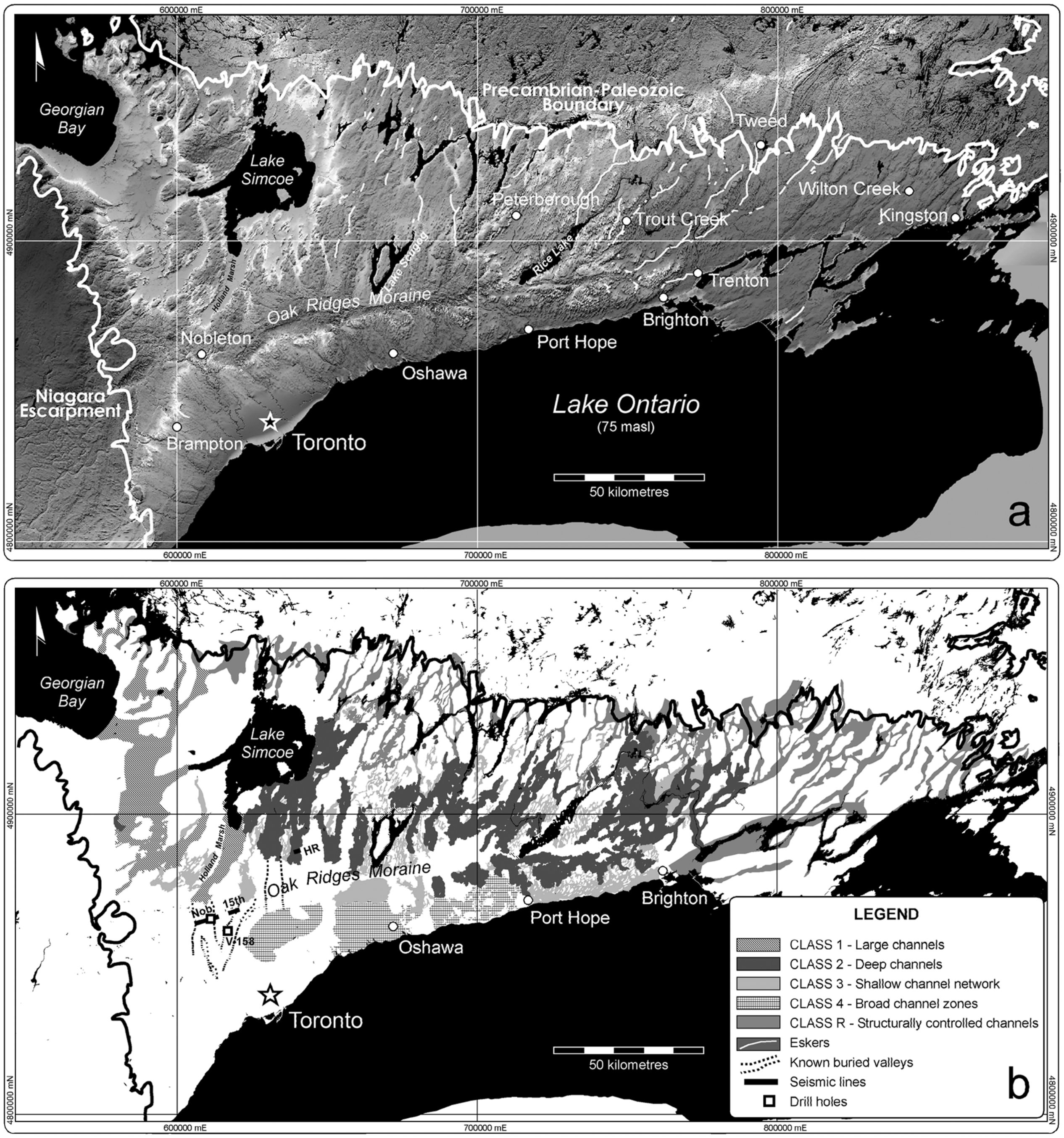

Figure 6.2 (a) Hillshaded digital elevation model (DEM) of central southern Ontario showing dissected drumlinized terrain, the Oak Ridges Moraine, escarpments and eskers. (b) Distribution of five tunnel channel classes, buried valleys, seismic lines and drill holes between the Precambrian–Palaeozoic boundary and the Niagara escarpment.

extensive Newmarket Till, whereas shallow channels (class 3) have a Newmarket Till substrate (Fig. 6.1). South of the Oak Ridges Moraine, broad, shallow erosional corridors (class 4) extend into Lake Ontario (Fig. 6.2).

Valley fills are up to ca. 150 m thick and include tunnel channel fills (20–60 m thick) in places overlain by ridge-building sediments of the Oak Ridges Moraine (<50 m thick), Halton Till (<30 m thick), deglacial lake sediments (<2 m thick) and/or Holocene fluvial and wetland sediments (<2 m thick). Tunnel channel fills often fine upward from gravel sheets, mesoforms (dunes) and eskers to beds of massive, graded and/or rippled sand to silt–clay rhythmites (e.g. Russell *et al.*, 2002).

6.4 Tunnel channel origin

This integrated, anabranched valley network is inferred to record a tunnel channel system that was produced and/or re-utilized by turbulent, subglacial meltwater flow released during outburst floods in the Late Wisconsinan, because valleys: (i) are incised into Late Wisconsinan, drumlinized till (Newmarket Till), are locally buried by Oak Ridges Moraine sediment and contain deglacial lake sediment; (ii) have undulating floors and upslope paths; (iii) locally contain eskers and are filled by sediments indicative of rapid sedimentation (e.g., sandy hyperconcentrated flow deposits); (iv) exhibit no evidence of convergent sediment deformation along their margins; (v) are cut to elevations below Lake Ontario base level and fail to terminate in deltas or fans at proglacial or modern shorelines; and (vi) contain modern underfit streams up to an order of magnitude narrower than the valleys (e.g. Brennand & Shaw, 1994; Russell *et al.*, 2002).

6.5 Tunnel channel evolution

The spatial variation in valley character records the temporal evolution of a jökulhlaup from a regional shallow channel network (class 3) to progressively fewer, larger channels (class 2 then 1) as flow concentrated and waned; the bedrock channels (class R) were probably antecedent and re-utilized. Bedrock structure, ice-bed gap width (Brennand & Shaw, 1994) and enhanced scour at thread confluences and hydraulic jumps (Russell *et al.*, 2002) controlled tunnel channel location. Erosion of sediment-walled channels was probably enhanced by groundwater flow and piping at depth (through sandy beds of the lower sediment, Fig. 6.1; Russell *et al.*, 2002). Channel fills record rapid and voluminous sedimentation during waning jökulhlaup flow (both fluidal and hyperconcentrated) followed by subglacially ponded sedimentation (e.g. Brennand & Shaw, 1994; Russell *et al.*, 2002).

This interpretation of central southern Ontario tunnel channels is consistent with the view that the subglacial landsystem (drumlins, valleys and s-forms) was eroded by a regional meltwater underburst—the Algonquin event—that unsteadily evolved from sheet to channelized flow (e.g. Shaw & Gilbert, 1990). As fan deposits are not observed at the southern ends of channels it is likely that channel formation was contemporaneous with an underburst event that eroded drumlins in Lake Ontario and swept away most sediment derived from channel erosion. Ice sheet thinning and flattening associated with underbursts facilitated deglaciation by regional downwasting and stagnation.

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Glacial bedforms and the role of subglacial meltwater: Annandale, southern Scotland

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Since the advent of satellite imagery, geomorphologists have used remotely sensed images to gain a better understanding of large-scale landform assemblages. The main benefits of using satellite imagery are clear: the large field of view and the range of display scales, both allowing a higher speed of coverage. Many features undetectable on aerial photographs at large scales become readily apparent on LANDSAT images when viewed at a scale of 1:100,000 or more. Unfortunately, few studies use both types of imagery in tandem. This study shows the advantages of combining modern satellite images with aerial photographs and traditional field survey techniques to address problems across a wide range of scales.

The geomorphology of Lower Annandale, between Lockerbie and Moffat, is very intriguing. When viewed from the ground or low-flying aeroplane the ground looks unremarkable—rolling farmland punctuated by occasional streams, typical of much of