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Drumlinized tunnel valleys in south-central Ontario

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A B S T R A C T

A network of Late Wisconsin valleys deeply incise thick successions (up to 200 m) of Quaternary sediment and Paleozoic bedrock across south-central Ontario. The valleys have previously been interpreted as an integrated network of tunnel channels recording catastrophic releases of subglacial meltwater across the bed of the Laurentide Ice Sheet (LIS). Recent geologic investigations in the western part of the valley network integrate information gained from surficial sediment and landform mapping, continuously-cored boreholes that penetrate the entire Quaternary sediment succession in valleys as well as intervening uplands, and both water-borne and land-based geophysical surveys. Together, these data provide new insights and a refined interpretation of the genesis, timing and paleoglaciological significance of these valleys.

Valleys within the study area are some of the largest observed within the regional network – up to 30 km long, 7 km wide and >175 m deep. They are oriented both north-south and in a radial pattern, varying from NE-SW in the southern part of the study area, to ESE-WNW in the north. An undulating Late Wisconsin till sheet (Newmarket Till) caps the regional uplands and is commonly observed along the flanks and floors of the valleys – all of which show evidence of a drumlinization phase that postdates excavation of most of the valleys. At least two generations of valleys are interpreted from cross-cutting relationships, with abrupt heads and locally perched downflow ends of some valley forms. Radiocarbon age determinations of organic material from both below and above the Newmarket Till constrain the timing of valley excavation to between 28.05 and 12.81 ^{14}C kyr BP. Borehole and outcrop data within the valleys reveal four stratigraphic units (SU1-SU4) that form the floor and sediment infill of the valleys. The Newmarket Till (SU1) is commonly underlain by deformed substrates. The till is absent in parts of some valleys and the lowermost parts of the valley fill commonly consist of coarse-grained gravels (SU2) that pass upwards into sands (SU3). The bulk of the sediment infill consists of glaciolacustrine silt-clay rhythmites (SU4) that pass upwards into organic- and mollusk-bearing nearshore and fluviodeltaic deposits that record drainage of proglacial lakes from the study area during deglaciation.

It is proposed that these features are a previously unrecognized type of tunnel valley that developed subglacially during Late Wisconsin ice cover. Meltwater surpluses would be generated at the ice-bed interface due to the low-transmissivity substrate in the study area with flow preferentially routed into lows on the bed. Downward incision into confined and pressurized aquifers likely facilitated rapid headward erosion of the valleys enhanced by piping. Waning meltwater flow velocities/discharges allowed ice creep to re-occupy newly-formed valleys permitting renewed till deposition and subsequent drumlinization of the valleys. The valleys also provided efficient routing for meltwater draining the retreating ice marginal zone during deglaciation and allowed localised sand and gravel deposition as eskers and ice-proximal subaqueous fans in the Oak Ridges Moraine and within proglacial lakes that developed during ice retreat. However, there is no evidence for regional-scale catastrophic release of subglacial meltwater in the valley infills. This integrated dataset represents one of the most complete characterizations of subglacial valleys in a terrestrial setting in North America.

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1. Introduction

Glacial sediments are found across the globe and host or form a variety of important resources, ranging from groundwater to hydrocarbons, aggregates and industrial minerals (Huuse et al., 2012). Developing improved models of glacial erosion, transport, deposition and associated sediment facies architecture is an essential prerequisite for reliably discovering and characterizing, as well as efficiently and safely managing these resources. In southern Ontario, thick successions (>200 m) of glacial sediments host regional and local aquifers that supply drinking water to millions of residents, assist in maintaining ecologically sensitive habitats, and form aggregate resources essential for infrastructure development (Barnett, 1992a; Sharpe et al., 2013).

Demand for improved geologic information in support of groundwater studies across southern Ontario has led to the collection of a wealth of high quality geologic data over the last 25 years (Barnett et al., 1998; Sharpe et al., 2002; Burt and Dodge, 2011). These data have shed light on and highlighted the importance of large surficial and buried Quaternary-aged valleys in regional groundwater systems (Desbarats et al., 2001; Sharpe et al., 2013). Recent investigations in Simcoe County, Ontario (Fig. 1) have integrated detailed surficial mapping with extensive, high quality, continuous sediment coring and regional geophysical surveys (Bajc and Rainsford, 2010, 2011; Mulligan, 2011, 2013; 2014, 2015; 2016, 2017a; b; c; Bajc et al., 2012, 2014; 2015; Mulligan and Bajc, 2012) to provide new insights into the properties and sedimentary architecture of regionally identified stratigraphic units in the area (Mulligan and Bajc, 2018; Mulligan et al., 2018).

The study area comprises parts of two 3D mapping areas in Simcoe County, where a number of deeply incised valleys truncate late Pleistocene glacial units, locally extending into underlying Paleozoic bedrock (Figs. 1 and 2). The valleys are only partially infilled, giving the present landscape a characteristic upland-lowland configuration (Chapman and Putnam, 1984). They have previously been interpreted to form part of a broad, integrated tunnel channel network that spans much of south-central Ontario (Brennand and Shaw, 1994; Sharpe et al., 2004, Fig. 1). Their presence has been known for decades (Straw, 1968; Barnett, 1990; Sharpe et al., 2004; Sookhan et al., 2018), but consensus on the underlying processes responsible for their formation has not been reached. This paper provides new insights on the geomorphic relationships between uplands and valleys and describes the character and architecture of major sediment units comprising the valley infill, as well as the underlying regional strata. An emphasis is also placed on the implications of these observations for understanding valley genesis and their relationship with changing subglacial conditions beneath the Laurentide Ice Sheet (LIS).

2. Regional geologic setting

The study area is bordered by Georgian Bay in the northwest, the Precambrian Shield peneplain to the northeast, Lake Simcoe and the till plain of the Peterborough drumlin field (PDF) to the east and southeast, high hummocky topography of the Oak Ridges Moraine (ORM) to the south, and the Niagara Escarpment to the west (Fig. 1). Within southern Simcoe County, predominantly drumlinized upland terrain (the western extension of the PDF) is underlain by thick successions (up to 200 m) of Quaternary sediment. The uplands are truncated by a series of valleys in-filled by up to 120 m of deglacial sediments and are presently occupied by underfit streams and rivers, extensive wetlands, and elongated bays in Lake Simcoe (Figs. 1 and 2).

2.1. Bedrock geology

Beneath the study area, gently-dipping strata of Paleozoic limestone and shale onlap the buried Precambrian shield which outcrops approximately 45 km to the north (Fig. 2a), although an increasing number of possible inliers of Precambrian basement rocks have been intersected during recent drilling investigations immediately north of the study area (Mulligan, 2016, 2017c). Paleozoic strata dip gently to the southwest and are deeply eroded within a broad valley/trough extending from Georgian Bay to Lake Ontario (Fig. 2b; Gao et al., 2006). The trend and location of the valley are generally thought to be inherited from underlying structural features in Precambrian basement rocks (Eyles et al., 1997) and it may mark the possible location of a preglacial fluvial system (Laurentian Valley; Spencer, 1890) draining the upper Great Lakes. Recent papers have advocated a polygenetic origin for the trough invoking various degrees of glacial/glacial meltwater modification of the preglacial landscape throughout the Quaternary (Gao, 2011; Mulligan and Bajc, 2018; Sharpe et al., 2018). The Laurentian trough is bounded to the west by the Niagara Escarpment, a prominent (>300 m) bedrock scarp interrupted by a series of near-parallel re-entrant valleys (Figs. 1 and 2; Straw, 1968; Eyles et al., 1997). The eastern and northern extents of the Laurentian Valley, as well as details on potential tributaries and discrete channel features within the main valley/trough, remain poorly-defined (Sharpe et al., 2018; Mulligan, 2017c), largely due to the lack of deep subsurface information constraining the geometry of the bedrock surface (Fig. 2c).

2.2. Quaternary geology

Sediments infilling the Laurentian valley/trough in the study area are attributed to at least the last two glacial-interglacial episodes (Karrow, 1967; Bajc et al., 2014; Mulligan, 2016, 2017c; Mulligan and Bajc, 2018). The succession consists of a lower (Illinoian and/or older) glacial package (tills and interbedded glaciolacustrine deposits) overlying Paleozoic bedrock (Fig. 2c), with a regionally identified subaerial unconformity on its upper surface. Thin, non-glacial, alluvial, lacustrine, and peat deposits that span Sangamon (last interglacial) through to Middle Wisconsin time overlie the unconformity (Mulligan and Bajc, 2018; Mulligan, 2017c, Fig. 2c). The regional unconformity and its associated deposits are buried by thick successions of glaciolacustrine rhythmites, the earliest deposits of which lack evidence of proximal ice. Glacially influenced rhythmites higher in the succession are interbedded with sand bodies often containing detrital organic accumulations. Together, these lake deposits record a flooding event resulting from ice advance into the St. Lawrence valley beginning in the Early Wisconsin that prevented eastward drainage of the Lower Great Lakes (Figs. 2c and 3a; Eyles et al., 1985). Within the study area, the sand interbeds within the glaciolacustrine succession both thin and fine towards the south (Mulligan and Bajc, 2018). However, units to the north and south of the study area, containing significant thicknesses of sand and locally, gravel, have been identified at the same stratigraphic position (Sharpe et al., 2002; Burt and Dodge, 2011; Mulligan, 2016, 2017c; Gerber et al., 2018).

Capping the glaciolacustrine sequence is the Newmarket Till, recording Late Wisconsin ice advance into the study area and southward into the northern United States (Figs. 2c and 3b; Gwyn and Dilabio, 1973; Sharpe et al., 1994; Bajc and Rainsford, 2010). The surface of the Newmarket Till is highly undulating, drumlinized, and well-exposed across the majority of upland areas throughout the region, but its full topographic expression is less well understood beneath modern lakes and under extensive ice-marginal and postglacial glaciolacustrine deposits within the