Surficial Geology Mapping in the Metropolitan Area of Halifax Regional Municipality: New Discoveries

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Introduction

In 2007, in response to flooding following Hurricane Juan, a LiDAR (Light Detection And Ranging) digital elevation model (DEM) was collected to predict flood levels for the metropolitan area of Halifax Regional Municipality (Fig. 1). Additionally, the LiDAR Survey gives 'bare-earth' hillshade model that proves excellent for mapping surface features and provides the basis for a new series of detailed surficial geology maps. The LiDAR data were also used to identify abandoned mine openings and karst sinkholes. New interpretations of the surficial geology provide insights regarding the glacial history and pre-glacial topography of the Halifax Regional Municipality. This report summarizes some of the key new findings.

LiDAR is a relatively new remote sensing technique that transmits light pulses from an airborne (plane or helicopter) unit. The pulses reflect off surfaces (trees, houses, buildings, ground), and the time delay from transmission to the reflected return gives a precise measurement (within centimetres) of the distance between the airborne unit and that surface. Since the location and orientation of the airborne unit is known, a precise digital elevation model of the surface elevation can be calculated.

One of the most useful geological applications of this type of survey is the production of the 'bare earth' model, which shows the topography of the earth's surface without vegetation. This is possible because pulses are partially reflected off some surfaces, but continue to penetrate through others (such as the tree canopy). This allows the data to be processed to the lowest surface elevation, which is the ground. Application of the bare earth model to geology improves the precision of mapping surficial materials and bedrock structures.

New Surficial Geology Maps

In 2011, the Nova Scotia Department of Natural Resources will release new surficial geology maps based on interpretation of the LiDAR data. These maps, released at 1:25 000 scale, are based on mapping at a scale of 1:10 000, and provide the first improvement on surficial geology mapping for the area since 1:100 000 scale maps released in the early 1980s (Finck et al., 1992; Stea and Fowler, 1979; Stea and Fowler, 1981).

These new maps identify areas of exposed bedrock, glacial and post-glacial deposits. Drumlins are the most predominant glacial landform in the area. A number of these have had historical significance, such as the drumlins forming Citadel Hill, Fort Needham and Georges Island, as well as the drumlin first farmed by Captain Spry because of its superior quality of soil to the surrounding Beaver River Till. These features notwithstanding, the majority of drumlins are located in topographic lows that are thought to be deeper pre-glacial valleys (see section on paleo-valley identification). No obvious trend of the thinner till units (veneers and blankets) is evident.

Subdivisions of Beaver River Till into lithologic categories (e.g. granite, slate and greywacke facies) was not done in this series of maps; to map these at the appropriate scale would require extensive till sampling, much of it taking place on private property. Three different geomorphic expressions of Beaver River Till were mapped, however: till veneer, till blanket and hummocky till. Till veneer

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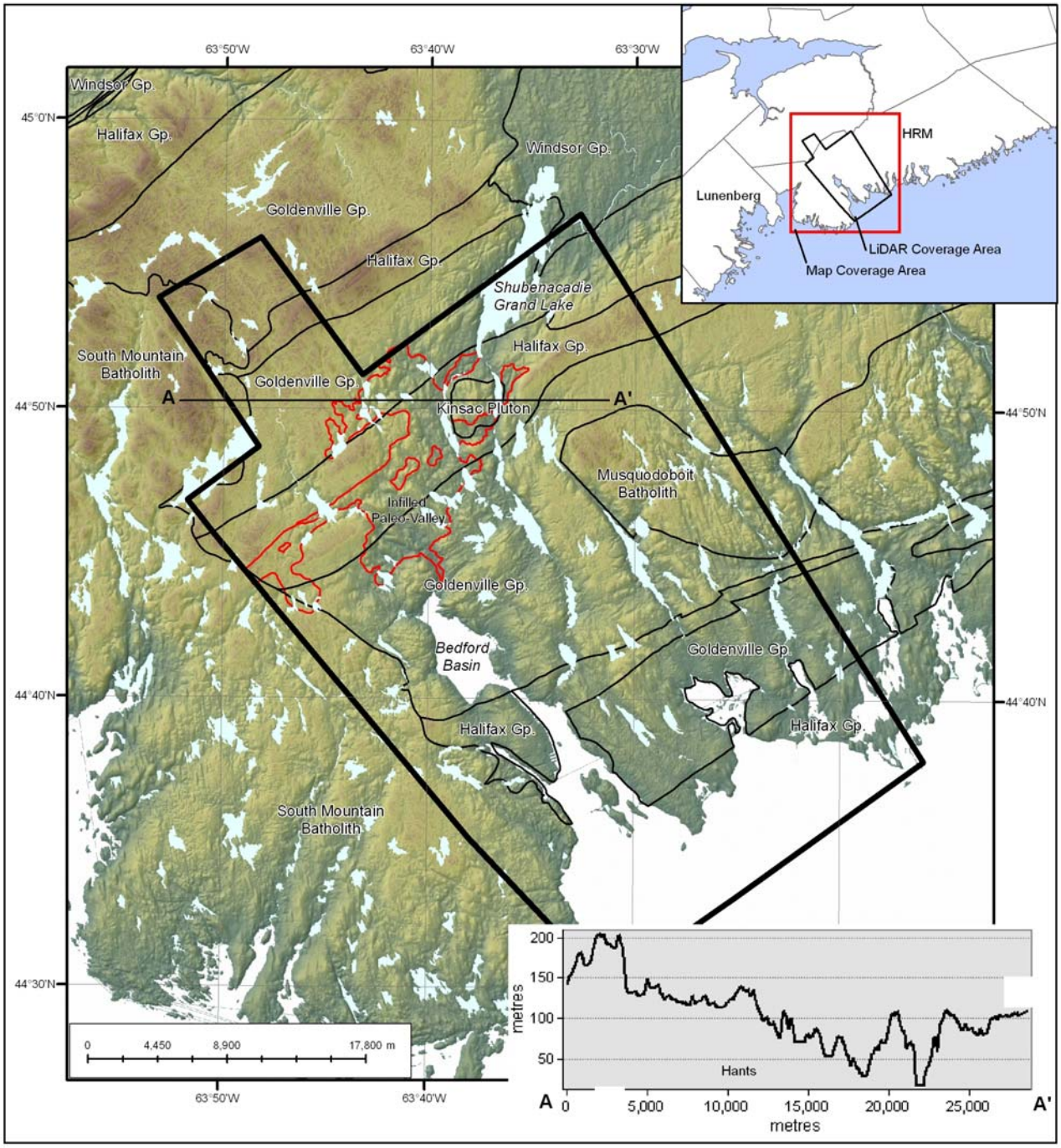

Figure 1. Study area, with LiDAR coverage shown. Bedrock geology modified from Keppie (2000). Topographic profile A-A' is perpendicular to a trough cutting the paleo-surface between Shubenacadie Grand Lake and Bedford Basin. The area of a potential paleo-valley is indicated, a location typified by continuous surficial material cover, predominantly drumlins. Modified after Utting (2009).

and blanket are similar deposits types, but vary in thickness. Till veneer is the predominant unit, and has a thickness of 0.5 – 5 m. Till blanket is less extensive, and is greater than 5 m thick. Hummocky till deposits are thought to relate to; areas where stagnant blocks of ice melted; these areas have generally sandier till and larger boulders at the surface (Fig. 2). Such deposits might indicate the position of a glacial margin in the Lake Charles area.

Following deglaciation there has been a nearly continuous transgression (landward migration of the shoreline) due to rising sea levels (Shaw et al., 2002). The effect of this transgression includes the transformation of Bedford Basin from a separate lake (Fader and Miller, 2008), and formation of saltmarshes in Eel River and Cole Harbour. Saltmarshes and tidal flats were grouped into one unit, called marine intertidal flats, and occur primarily in Eel River and Cole Harbour. The coastline was separated into a separate marine littoral unit, if it was considered large enough to be depicted by an individual polygon. Other coastal deposits, such as dunes, were also included in this map unit (Conrads and Lawrencetown beaches, for example).

Glaciation left expansive areas covered with poorly drained till, resulting in numerous small lakes and ponds. The tills and organic material deposited in these water bodies are mapped as lacustrine. Many of these areas now contain wetlands.

Figure 2. Photograph of an area of hummocky till. Note the sandy matrix with boulders at surface. Location of photograph near Herring Cove.

Some areas that were disrupted or redistributed by human activity were mapped as anthropogenic material. In a number of areas, especially residential communities, the nature of the modification is localized and shallow, so these were not delineated as separate polygons.

Re-interpretation of a Classic Geological Section

Re-interpretation of the glacial history of the area was presented in Utting (2009), based on using the LiDAR hillshade image to map the orientation of drumlins in the area (Fig. 3). A drumin exposed at West Lawrencetown, which is the basis for much of the regional stratigraphy, was re-examined. It was thought previously that the last ice flow direction had only minimal effect on the surface morphology of the drumlins, and that the surface morphology reflected both the penultimate and earlier till fabric (i.e. ice flow) direction (Stea and Brown, 1989). Based on the LiDAR hillshade image it is likely, however, that the last ice flow direction was the primary event controlling surface morphology, and that this corresponds with the till fabric in the uppermost till unit. A conclusion of this study is that the drumlin-forming event might be later in the glacial history than previously thought.

Paleo-valley Identification

In the preliminary stages of map production, once the polygon mapping had been completed, it became apparent that there is an extensive area (Fig. 1) of continuous surficial coverage. With the LiDAR hillshade it is usually possible to identify exposed bedrock between drumlins, but in this area there is continuous till or alluvium cover. This area is generally a topographic low.

Well logs (Kennedy *et al.*, 2009) from a number of water wells in this area suggest that the thickness of the surficial cover exceeds the surface relief of the drumlins (for example a drumlin in this area with 30 m in surface height might have a water well drilled to 60 m depth to bedrock). One of these water wells encountered Cretaceous sand between the overlying till and underlying bedrock (Piper,

unpublished report, 2004). This, and the fact that a number of the water well logs reported sand or gravel at this same contact, suggest the potential for a more extensive aquifer, leading this to be investigated more extensively (Kennedy and Utting, this volume, 2011).

Identification of Abandoned Mine Openings

An investigation on the utility of identifying abandoned mine openings in the Montague area was presented by Utting *et al*. (2010). This study used the bare-earth hillshade model to identify a number of previously unknown openings, and potentially identify a subsidence feature (caving of an in-filled mine shaft). Locations of abandoned mine openings are reported in Fisher and Hennick (2009).

Karst Sinkholes

Karst-related sinkholes are located in the area underlain by the Windsor Group (Fig. 4). LiDAR has been shown as an excellent tool to identify karst topography using the bare-earth image in Antigonish (DeMont et al., 2010). Sinkholes in Halifax Regional Municipality appear to be of limited aerial extent, in an area currently with little development.

Summary

LiDAR coverage in the metropolitan Halifax area has provided for a number of revisions to the surficial geology of the area. New surficial geology maps are being released in 2011 based on interpretation of the bare-earth hillshade images.

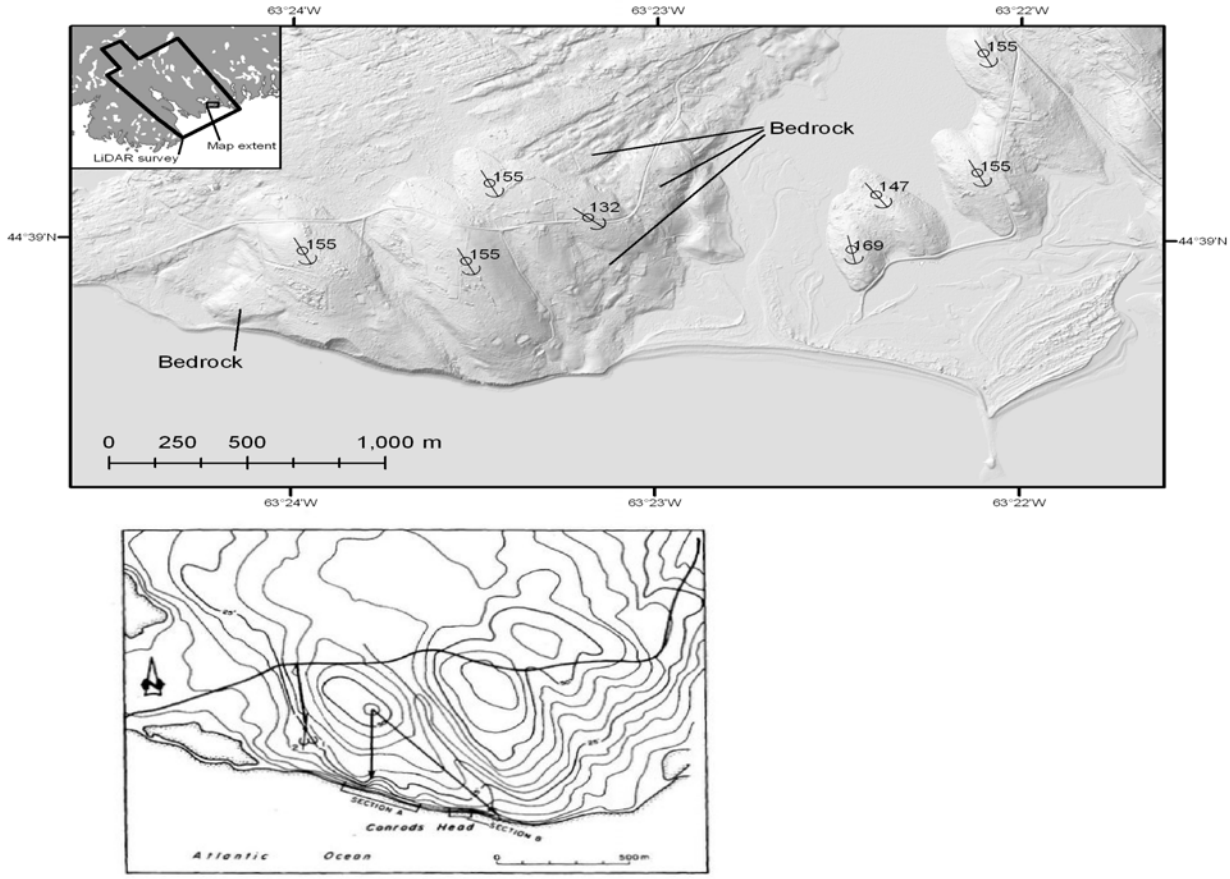

Figure 3. Close-up view of the bare-earth hillshade model of a drumlin at West Lawrencetown. Note the 'fresh' trend of drumlin is toward the southeast. Previous interpretation of the palimpsest origin of the drumlins was based on less accurate topographic maps (lower illustration, modified after Stea and Brown, 1989). Thick till at the section, derived from southward ice flow, may be due to preservation in the lee of a bedrock ridge. Modified after Utting (2009).

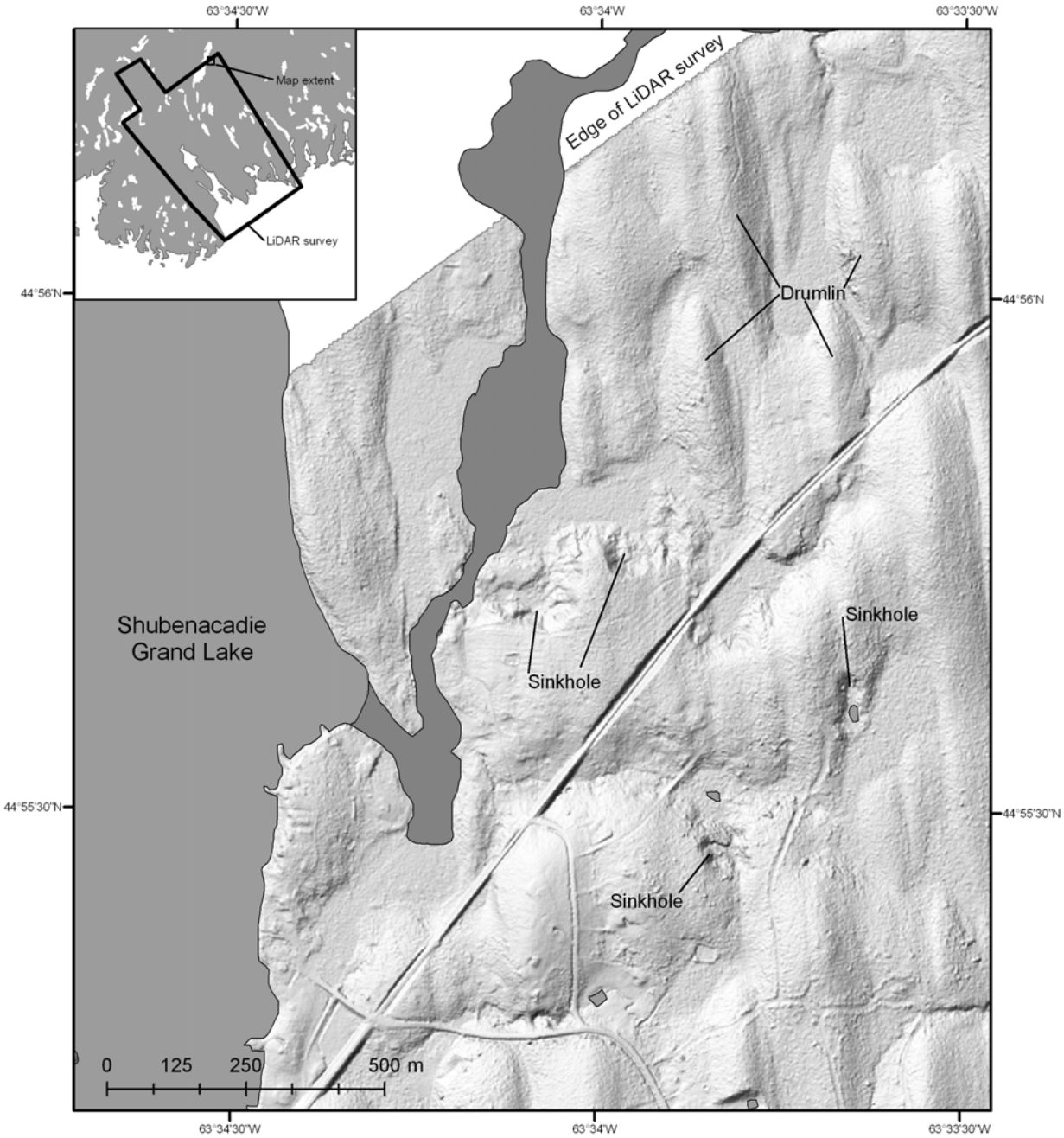

Figure 4. Bare-earth LiDAR image, showing drumlins and karst sinkholes. The karst has likely formed in Windsor Group gypsum, and has a similar geomorphic expression as karst in the Bridgeville Formation in Antigonish (DeMont *et al.,* 2010).

Other new discoveries include re-interpretation of the glacial history of the area, identification of a potential paleo-valley, and better mapping of abandoned mine openings and karst sinkholes.

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