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Glacially-megalineated limestone terrain of Anticosti Island, Gulf of St. Lawrence, Canada; onset zone of the Laurentian Channel Ice Stream

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ABSTRACT

Anticosti is a large elongate island (240 km long, 60 km wide) in eastern Canada within the northern part of a deep water trough (Gulf of St. Lawrence) that terminates at the Atlantic continental shelf edge. The island's Pleistocene glaciological significance is that its long axis lay transverse to ice from the Quebec and Labrador sectors of the Laurentide Ice Sheet moving south from the relatively high-standing Canadian Shield. Recent glaciological reconstructions place a fast-flowing ice stream along the axis of the Gulf of St. Lawrence but supporting geologic evidence in terms of recognizing its hard-bedded onset zone and downstream streamlined soft bed is limited. Anticosti Island consists of gently southward-dipping limestone plains composed of Ordovician and Silurian limestones (Vaureal, Becscie and Jupiter formations) with north-facing escarpments transverse to regional ice flow. Glacial deposits are largely absent and limestone plains in the higher central plateau of the island retain a relict apparently 'preglacial' drainage system consisting of deeply-incised dendritic bedrock valleys. In contrast, the bedrock geomorphology of the lower lying western and eastern limestone plains of the island is strikingly different having been extensively modified by glacial erosion. Escarpments are glacially megalineated with a distinct 'zig-zag' planform reflecting northward-projecting bullet-shaped 'noses' (identified as rock drumlins) up to 2 km wide at their base and 4 km in length with rare megagrooved upper surfaces. Drumlins are separated by southward-closing, funnel-shaped 'through valleys' where former dendritic valleys have been extensively altered by the streaming of basal ice through gaps in the escarpments. Glacially-megalineated bedrock terrain such as on the western and eastern flanks of Anticosti Island is elsewhere associated with the hard-bedded onset zones of fast flowing ice streams and provides important ground truth for the postulated Laurentian Channel Ice Stream (LCIS) within the Gulf of St. Lawrence sector of the Laurentide Ice Sheet.

1. Introduction

A new paradigm for modeling paleo-ice sheets has emerged as a result of the integration of the results of glaciological studies at modern ice masses with geomorphological mapping of the exposed beds of paleo-ice sheets (e.g., Hulbe and MacAyeal, 1999; Winsborrow et al., 2004; Benn and Evans, 2010). Large Pleistocene and pre-Pleistocene ice sheets were once viewed as domes having a simple concentric zonation of thermal regime and ice velocity but are now considered as much more dynamic features having low profile streams of fast flowing ice ($\sim$1 km/yr^{-1}) separated by interfluve areas of more sluggish movement. Ice streams are essentially the 'arteries' of ice sheets (Bennett, 2003) discharging large volumes of ice, water and sediment to the ice margin and quickly reacting to changes in climate and fluctuations in water depths and sea level around the ice sheet's periphery. The mapping of glacially-megalineated terrains on bedrock or sediment provides fundamental information regarding the structure and dynamics of paleo-ice sheets (e.g., Jansson et al., 2003; Winsborrow et al., 2004, 2010; Jansson and Glasser, 2005; Roberts and Long, 2005; De Angelis and Kleman, 2008; Stokes and Tarasov, 2010; Ross et al., 2011). The outermost beds of ancient ice streams where they rested on sediment are recorded by large swaths of fluted and drumlinized terrains recording fast-flowing wet-based ice resting on deformable beds (Stokes and Clark, 2003a,b; Moreau et al., 2005). Recent work has also identified their upstream 'hard-bedded' counterparts on bedrock surfaces where rock drumlins and megagrooves define the onset zone of the ice stream (Bradwell et al., 2008; Eyles, 2012; Bradwell, 2013). It is in this latter context that we describe newly recognized megalineated bedrock

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surfaces from Anticosti Island in eastern Canada and relate this to the larger glaciological reconstruction of the eastern sector of the Laurentide Ice Sheet during the maximum of the last (Wisconsin) glaciation (Fig. 1).

The preservation of a distinctive glacially-cut bedrock terrain on Anticosti reflects the widespread presence of relatively soft Paleozoic carbonate strata adjacent to the Canadian Shield which was the major source area for ice that crossed the island on its way to the eastern Canadian continental shelf edge. The abrupt juxtaposition of resistant Archean and Proterozoic crystalline rocks of the Shield with softer offlapping Lower Paleozoic carbonates occurs around much of the periphery of the Shield in North America; low relief 'platforms' underlain by gently dipping limestones and dolostones can be traced as a wide belt through Arctic, northwestern, central and eastern Canada and into the northern USA. This paper is part of a much wider transcontinental project aimed at mapping glaciated limestone plains within this belt using satellite and other digital elevation data to capture the geomorphological record of former ice streams flowing radially off the Shield.

2. Physical setting and geologic history of Anticosti Island

Anticosti (8000 km^2 in area; 240 km long, 60 km wide) is underlain entirely by Ordovician–Silurian carbonate rocks directly in the pathway of a postulated fast flowing ice stream along the axis of the glacially-overdeepened Gulf of St. Lawrence c. 18,000 years before present (ybp) (Fig. 1). The Laurentian Channel Ice Stream (LCIS) was named by Shaw et al. (2006) and though its existence is acknowledged by later work (see Stokes and Tarasov, 2010; Piper et al., 2012) direct geologic evidence identifying the existence of an ice stream landsystem has not so far been forthcoming. Offshore and onshore data have revealed the presence of classic drumlin fields associated with fine-grained tills that likely formed part of the ice stream's soft bed but such data have not yet been expressly related to the presence of a major ice stream along the axis of the Gulf of St. Lawrence (see Stea and Finck, 2001; Stea, 2004; St. Onge et al., 2008, and refs therein).

Anticosti Island is the exposed top of a large submarine bank surrounded by relatively deep waters of the Anticosti Channel,

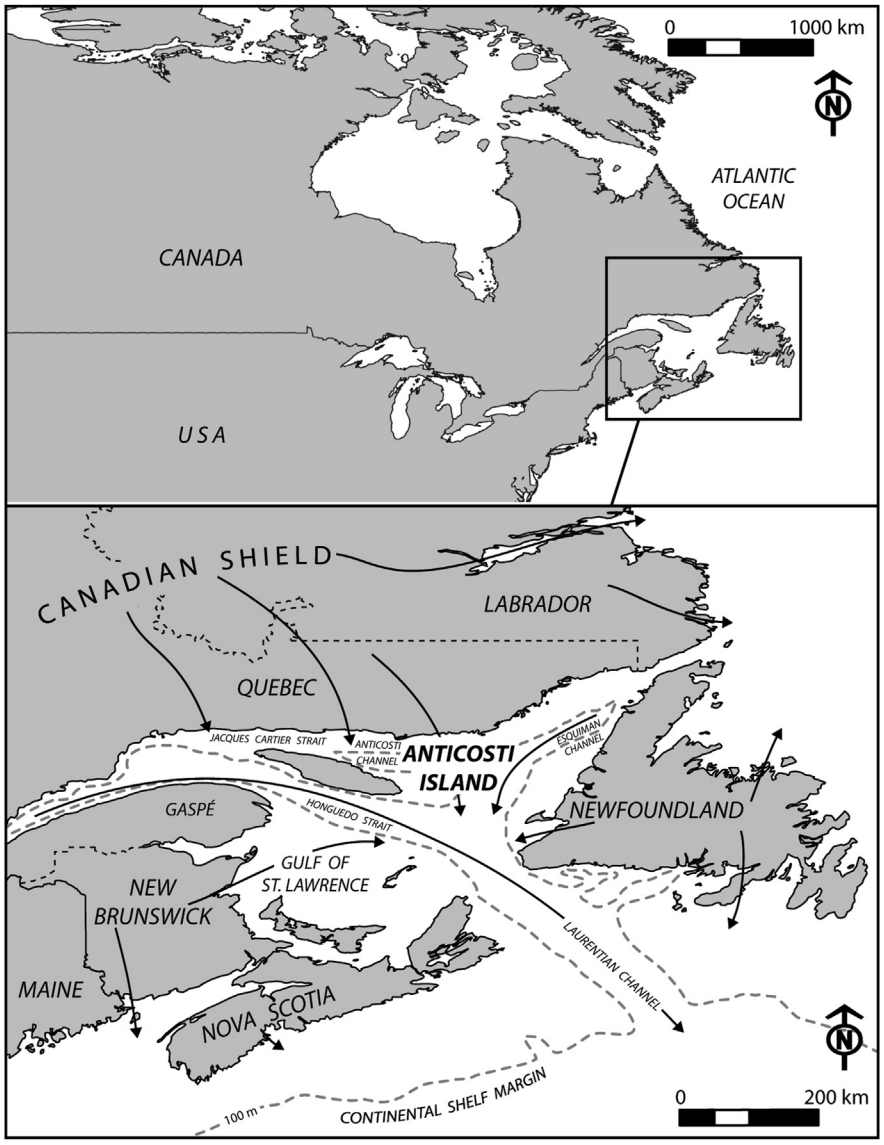

Fig. 1. Location of Anticosti Island in the Gulf of St. Lawrence of eastern Canada with generalized ice flow directions associated with a postulated Laurentian Channel Ice Stream. Data from Anticosti Island indicate broadly southward flow across Anticosti Island but with local variation (Fig. 10).