Quaternary Science Reviews 47 (2012) 82–100

Contents lists available at SciVerse ScienceDirect

Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

Paleoglaciological insights from the age and morphology of the Jesse moraine belt, western Canadian Arctic

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ARTICLE INFO

Article history:
Received 19 December 2011
Received in revised form
21 April 2012
Accepted 24 April 2012
Available online 21 June 2012

Keywords:
Laurentide Ice Sheet
Last Glacial Maximum
Bølling–Allerød
Canadian Arctic Archipelago
Ice sheet dynamics
Controlled moraines
Paleo-ice streams
Paleoglaciology
Glacial geomorphology
Paleoclimate

ABSTRACT

The Jesse moraine belt (350 km-long) was deposited by the northwest Laurentide Ice Sheet on Banks and Victoria islands in the western Canadian Arctic Archipelago during the last deglaciation. The moraine belt is composed of (ice-cored) controlled moraines that contrast markedly with adjacent glacial sediments deposited during preceding ice sheet retreat. More than 80 radiocarbon ages from fossil molluscs illustrate that deposition of the moraine belt was brief, occurring between 13.75 and 12.75 cal ka BP. The chronology demonstrates that moraine deposition was coeval with ice sheet drawdown and ice streaming on adjacent Victoria Island. Detailed geomorphic mapping demonstrates that the moraine belt is the product of a regional change in ice-marginal processes. This involved a predominantly cold-based ice margin giving way to polythermal bed conditions, which were conducive to widespread deposition of controlled moraines and ice stream bedforms. The expansion of warm-based thermal regimes in the northwest Laurentide Ice Sheet followed widespread ice sheet withdrawal from M'Clure Strait and western Amundsen Gulf. This suggests a re-equilibration of regional ice divides in response to rapidly changing ice sheet margins and surface gradients. The reconstructed dynamical behavior of the northwest Laurentide Ice Sheet provides new insights regarding ice sheet responses to late-glacial climate and relative sea level change, among other variables.

1. Introduction

Late Wisconsinan deglaciation of the Canadian Arctic Archipelago (CAA) involved ice sheet withdrawal along predominantly cold-based, terrestrial margins and faster-flowing, marine-based margins in the interisland channels, where multiple, former ice streams are hypothesized (Dyke and Prest, 1987; Hodgson, 1994; Dyke, 1999, 2004; Dyke et al., 2002; Atkinson, 2003; De Angelis and Kleman, 2005; Stokes et al., 2005, 2006, 2009; England et al., 2006, 2009; De Angelis and Kleman, 2007). Importantly, ice sheet mass loss during deglaciation was dominated by calving along tidewater margins, a configuration very similar to that of the present West Antarctic Ice Sheet, which has long been recognized as potentially unstable (Weertman, 1974; Mercer, 1978). In this respect, inferences of former terrestrial, ice-marginal processes in the CAA, as well as the timing and nature of adjacent marine-based ice sheet retreat, constitute important constraints on our understanding of the dynamical response of high latitude ice sheets to such variables as paleoclimate and sea level change. Furthermore, the Late Wisconsinan history of ice dynamics and ice-marginal processes in the CAA comprises a valuable analogue for models addressing future ice sheet stability (i.e. Bentley, 2010).

Banks Island (70,028 km^2) is situated in the western CAA (Fig. 1) and has a long history of geomorphological investigations aimed at characterizing the history of Quaternary glaciation (Hobbs, 1945; Jenness, 1952; Wilson et al., 1958; Fyles, 1962; Prest, 1969; Vincent, 1982, 1983; Dyke, 1987). Until recently, much of the island was regarded as an ice-free refugium during the last glaciation, and eleven till sheets purported to be of different geomorphic or lithologic character, lying beyond the inferred Late Wisconsinan ice limit (Fig. 2), were ascribed to three to four glaciations of vastly different ages (Fyles, 1962; Prest, 1969; Vincent, 1982, 1983; Dyke, 1987, 2004; Dyke and Prest, 1987; Dyke et al., 2002). A new, robust chronology presented in Lakeman and England (submitted for publication) and in England et al. (2009) demonstrates that the northwest Laurentide Ice Sheet (LIS) inundated Banks Island during the Last Glacial Maximum (LGM), terminating on the Beaufort Sea shelf. As a result, the purported till sheets that span the island are now considered to be part of a single depositional sequence of Late Wisconsinan age that left the bedrock

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0277-3791/$ – see front matter
doi:10.1016/j.quascirev.2012.04.018

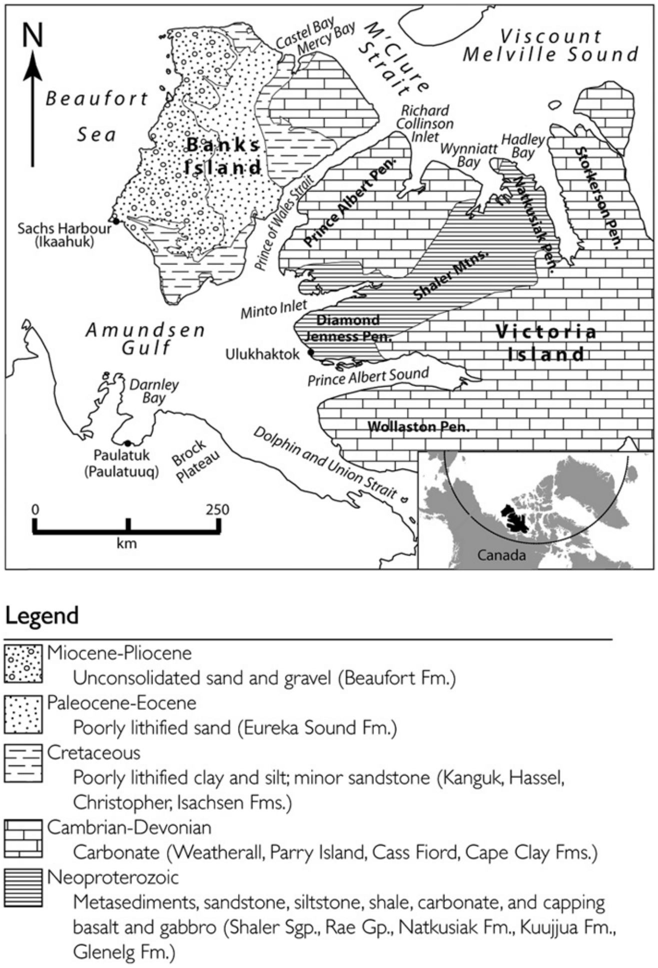

Fig. 1. Place names and generalized bedrock geology of Banks Island and Victoria Island, western Canadian Arctic Archipelago.

predominantly unobscured (England et al., 2009; Fig. 2). Hence, Vincent's (1982, 1983) formal recognition of discrete till sheets of climatostratigraphic importance (Fig. 2, inset) has been abandoned. Here we elaborate on the nature of Late Wisconsinan glaciation on Banks Island, using the glacial geomorphology to reconstruct past ice sheet dynamics of the northwest LIS.

The focus of this study is the 350 km-long Jesse moraine belt, which includes the formerly recognized Jesse till on eastern Banks Island and an unnamed, correlative deposit on adjacent Prince Albert Peninsula, Victoria Island (Fig. 2). Originally identified by Fyles (1962), the thickness, continuity, and geomorphology of the Jesse till make it unique among the eleven formerly recognized till sheets on Banks Island (Vincent, 1982, 1983). Consequently, the study aims to characterize the age and significance of the Jesse moraine belt (Fig. 2) in relation to distal glaciogenic landforms and sediments, deposited during preceding ice sheet retreat (Fig. 2). The objectives are to: i) describe the geomorphology and sedimentology of the Jesse till in relation to distal glaciogenic deposits in order to characterize former ice-marginal processes, ii) evaluate spatial and temporal variations in ice-marginal depositional environments to inform estimates of past ice sheet dynamics, and iii) consider potential causal linkages between former ice sheet dynamics and past fluctuations in climate, sea level, and the timing and pattern of regional deglaciation. To address these objectives a robust radiocarbon chronology is combined with detailed glacial geomorphological observations. The resulting, conceptual model of deglaciation documents the nature of the final phase of ice sheet retreat from Banks Island and northwest Victoria Island. The timing and pattern of penecontemporaneous deglaciation in M'Clure Strait and elsewhere are summarized and their impacts on ice-marginal processes on Banks Island and Victoria Island are considered. Similarly, the importance of late-glacial relative sea level changes and climatic perturbations of varying magnitude and regional significance, such as those during the Bølling–Allerød and Younger Dryas chronozones (Rasmussen et al., 2006), are scrutinized. This new reconstruction of the deglacial environments of eastern Banks Island and northwestern Victoria Island improves our understanding of the last glacial–interglacial transition in Arctic Canada and serves as a proxy for Late Pleistocene environmental change.

2. Methods

Glacial and marine landforms and sediments on north-central and eastern Banks Island were mapped over the course of widespread field surveys spanning two summers, using available aerial photography and satellite imagery. The extent and pattern of retreat for the LIS was determined using cross-cutting relationships among mapped glacial landforms. Observations from Banks Island were collated with those from Prince Albert Peninsula, Victoria Island, which are available in Fyles (1962, 1963), Stokes et al. (2005), and Storrar and Stokes (2007). The chronology of Late Wisconsinan ice sheet retreat was established using radiocarbon ages of fossil marine molluscs collected from glacial and marine sediments along more than ~900 km of coastline. This suite of ages, consisting of 50 from Banks Island, 33 from western Victoria Island, and 3 from the Canadian Arctic Mainland, is summarized in Table 1. The total from Banks Island includes 34 new Accelerator Mass Spectrometry (AMS) radiocarbon ages that were obtained from the W. M. Keck Carbon Cycle Accelerator Mass Spectrometry Laboratory, University of California (Irvine). All radiocarbon ages were calibrated using a ΔR value of 335 ± 85 years (Coulthard et al., 2010) in Calib v.6.0, which uses the Marine09 calibration curve (Reimer et al., 2009).

3. Geomorphic observations

The study area includes many of Vincent's (1982, 1983) proposed till sheets that were partly based on early physiographic divisions by Fyles (1962; Fig. 2). The oldest till sheets recognized by Vincent (1982, 1983) were the Bernard, Plateau, and Durham Heights tills (Fig. 2), which Vincent (1982, 1983) and Vincent et al. (1984) surmised were correlative and deposited during the Banks Glaciation, more than 780,000 years ago (i.e. during the Matuyama Chron). However, their lithologies essentially mimic the underlying bedrock, thereby precluding their utility (Figs. 1 and 2). Furthermore, recent mapping has demonstrated that these surfaces contain only sparse igneous and metamorphic erratics, and are dissected by a complex pattern of glacial meltwater channels. Till flanking the Thomsen River valley was termed the Baker till by Vincent (1982, 1983; Figs. 2 and 3) and postulated to be younger than the Bernard and Plateau tills but nonetheless deposited during a pre-Wisconsinan glaciation. Baker till is predominantly a mixture of sand, silt, and clay derived from the underlying Cretaceous bedrock with a low concentration of erratic clasts of primarily quartzite, granite and limestone that range in size from pebbles to small cobbles with rare boulders. Finally, Vincent (1982, 1983) proposed that the northern limit of the Baker till was cross-cut by the Mercy till, however this proposal was dismissed by England et al. (2009). As stated, the purported till sheets of Vincent (1982, 1983) are now considered to be part of a discontinuous deposit of Late Wisconsinan age (England et al.,