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Introduction

Quaternary glaciations and sea level change in the Canadian Arctic: special theme in honour of the career of Professor John England

John England and one of his many Arctic friends, Cambridge Bay, summer 2012, after the epic deliverance from southern Banks Island. Another season, another fine story.

During the summer of 2012 John England conducted his last official arctic field season on southwest Banks Island, bringing to a close 47 years of field research in the Canadian Arctic. Over his career John traversed some of the most remote and spectacular terrain in the world, taking an impressive number of undergraduate and graduate students, collaborators, and colleagues along for a ride none will forget. This research has culminated in the production of 17 PhD theses, 13 MSc theses and more than 100 peer-reviewed papers authored by John and various combinations of his extended research family, dealing with site-specific Quaternary glacial and sea level reconstructions as well as conceptual themes ranging from glacial sedimentology to the refinement of geochronological methods. As John generously allowed his students to publish sole-authored papers from their theses (e.g. Bednarski, 1986, 1988; Stewart, 1991; Evans, 1989a,b,c, 1990a,b; Lemmen, 1989; Bell, 1996; Ó Cofaigh, 1998, 1999; Smith, 1999; Atkinson, 2003), statistics on publication output will always under-represent his true productivity. Indeed, it is impossible to quantify the knowledge and wisdom generated over many hundreds of days of traversing a region as large as Europe but without roads, operating out of small tents often in hostile weather conditions, and shouldering the logistical burden of getting graduate student parties, as well as his own, into the field and back home safely. In a golden age of Arctic science, during which the Polar Continental Shelf Project made it possible for Canadian researchers to systematically explore the northern limits of their vast nation, John England has been the right person in the right place at the right time.

John England began his arctic research journey as a field assistant on Baffin Island in 1965, discovering glacial geomorphology and relative sea level change when working with Olav Løken of the Canadian government's Geographical Branch. The next year he was a field assistant for John Andrews, his first for the INSTAAR, Colorado-based arctic research team that would be the start of his own research career and base for his PhD studies (Fig. 1; Andrews et al., 1970; England and Andrews, 1973). From there, while at the University of Alberta, John started a career-defining investigation into the late Quaternary palaeoenvironments of northernmost Canada (Fig. 2), concentrating first on northern Ellesmere Island (e.g. England, 1976, 1983, 1996, 1997, 1998, 1999; England and Bradley, 1978; England et al., 1978, 1981; Evans and England, 1991, 1992; Lemmen and England, 1992). His journey took John across Nares Strait to Greenland (England, 1985), and then south and westwards to cover southern Ellesmere Island (e.g. England, 1990; England et al., 2000, 2004; Ó Cofaigh, 1999, 2000), Axel Heiberg and other northern islands of the Canadian Arctic Archipelago (Ó Cofaigh et al. 1999; Lamoureux and England, 2000; Atkinson and England, 2004; England et al., 2006) to Melville Island and finally to Banks Island (England and Furze, 2008; England et al., 2009) at the southwest edge of the archipelago. Along the way, John also co-supervised with Art Dyke graduate student projects in the central Canadian Arctic Archipelago (e.g. Dyke and Morris, 1988; Dyke et al., 1992).

Over the past five decades John not only completed significant research on Quaternary themes, but also made access possible to one of the world's most beautiful regions for his extended family of graduate students, undergraduate field assistants, colleagues and post-doctoral fellows (Fig. 3). Indeed John's stories never focus on the places, they always focus on the people – far too numerous to mention here. A passionate advocate for the importance of the Arctic for all Canadians, John has lobbied both patiently and vociferously, but always persistently, for greater public and political awareness of and support for the Canadian Arctic and its scientific legacy, as illustrated by his 2010 editorial in Nature (England, 2010) concerning Canadian polar policy (see also England et al., 1998; England, 2000). Science, scientists and the lay public owe a great deal to the efforts of John England, and this special theme is designed to pay due tribute to the numerous contributions of John and his research family. The papers within this special theme cover a wide range of Quaternary

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Fig. 1. John England (right) and John Andrews at Cape Hooper, Baffin Island in 1966 conducting field research on glaciation and sea level history.

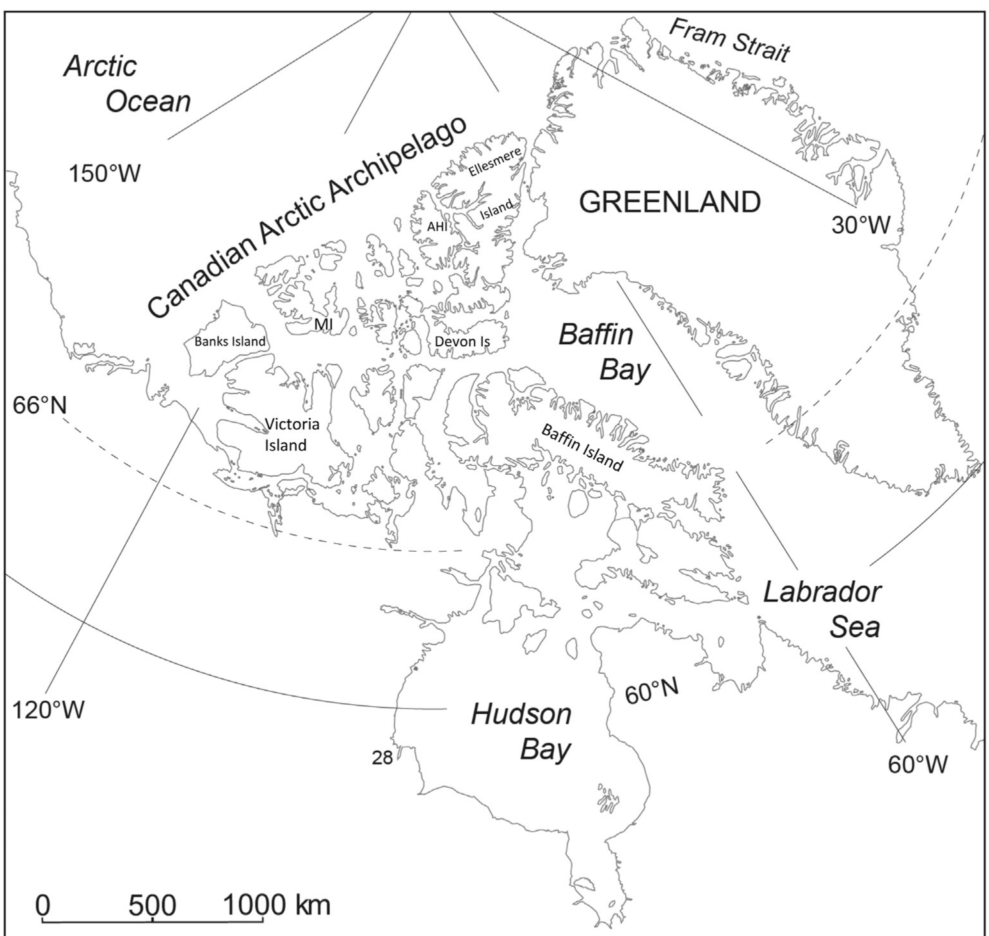

Fig. 2. Map of John England's research arena, the Canadian Arctic. AHI = Axel Heiberg Island; MI = Melville Island.

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Fig. 3. John England and most of his former and present graduate students at the CANQUA/CGRG biennial meeting, Edmonton 2013, where John was awarded the W.A. Johnston Medal for professional excellence in Quaternary Science, and a special session entitled "A passion for the Arctic: recent and ancient environmental change" was held in his honour. From left to right: Tom Lakeman, Michelle Trommelen, Michelle Hanson, Jess Vaughan, Roy Coulthard, Mark Furze, Anna Pienkowski, Chantel Nixon, Nigel Atkinson, John England, Scott Lamoureux, Rod Smith, Trevor Bell, David Evans, Don Lemmen, Tom Stewart, Jan Bednarski.

glacial and sea level research from around the Canadian Arctic Archipelago and Greenland. They include reports on some of the most recent research emerging from John's programme, featuring as co-authors his latest graduate students and clearly illustrating how current John's research has remained right up to his retirement year and beyond.

Two of the papers in this special theme issue report on work undertaken on Banks Island, the final destination on John England's pan-Canadian Arctic journey. Previous studies of the Quaternary history of Banks Island produced a complex and long stratigraphic record with significant implications for longer timescale reconstructions of palaeoenvironmental change over the Arctic region as a whole (Barendregt and Vincent, 1990; Barendregt et al., 1998; Clark et al., 1984; Vincent, 1982, 1983, 1990; Vincent et al., 1983, 1984). Work on the terrestrial record by John and his colleagues re-evaluated this model, identifying a less complex history of glacial and interglacial events and evidence of extensive Late Wisconsinan glaciation in the western Canadian Arctic (England et al., 2009; Lakeman and England, 2012, 2013, 2014). This has involved site-specific scrutiny of the stratigraphy and sedimentology of the Quaternary geology of Banks Island, specifically at Worth Point (Vaughan et al., 2014) and at Duck Hawk Bluffs (Evans et al., 2014). Both papers emphasize the importance of glacitectonic deformation in the construction of glacial landforms and the creation of the complex Quaternary stratigraphic architecture on Banks Island. The stratigraphic relationships and tectonic signatures within the Worth Point cliffs documented by Vaughan et al. (2014) show that the stratigraphy previously interpreted as multiple conformable units by Vincent (1982, 1983) has in fact been heavily compressed and disrupted by ice advance. A similar interpretation is proposed for the Duck Hawk Bluffs by Evans et al. (2014), a site previously regarded as critical to the longer timescale Quaternary glacial and interglacial record around the Arctic Ocean basin (Vincent et al., 1983). Evans et al. (2014) interpret the larger scale architecture of the Duck Hawk Bluffs as being a thrust block moraine constructed from deposits recording three phases of glacigenic sedimentation. Evans et al. (2014) further propose a predominantly glacigenic depositional sequence at this site with evidence for only one in situ interglacial.

The former glaciation of the western Canadian Arctic Archipelago is the subject also of papers by Nixon and England (2014) and Nixon et al. (2014), which report on the hitherto sparsely studied glacial landforms, sea level history and Late Wisconsinan morphochronology of Melville and Eglinton islands. Nixon and England (2014) document the advance of the northwestern margin of the Laurentide Ice Sheet onto Eglinton Island based on evidence of tills with Canadian Shield erratics and patterns of meltwater channel incision that are compatible with ice retreat offshore into M'Clure Strait. The dating of raised marine deposits provides a deglacial chronology for the Melville Island ice cap that features ice recession after 13.0 cal ka BP. Earlier deglaciation of southern Eglinton Island at around 13.6 cal ka BP is indicated by higher shorelines in the area and indicates ice sheet margin recession that is synchronous with other areas affected by the northwestern Laurentide Ice Sheet to the south. The early and rapid nature of this regional deglaciation at around 14.2–13.6 cal ka BP is proposed to be a significant contributor to meltwater pulse 1A. The details and implications of this sea level history for Melville and Eglinton islands are investigated by Nixon et al. (2014), who use more than 200 new radiocarbon dates from raised marine sediments to produce eight relative sea-level curves and an isobase map for the 9.5 cal ka BP shoreline for a large area of the western Canadian Arctic. The sea level curves are used to reconstruct the asynchronous retreat of the Laurentide and Innuitian Ice Sheets, whose coalescence zone lay over the area during the last glaciation. Flat-topped relative sea level curves (cf. England, 1983) are identified in this study, a characteristic that reflects locations within the peripheral depression of the stable Innuitian Ice Sheet after the relatively earlier deglaciation of the Laurentide Ice Sheet.

The reconciliation of such terrestrial records as those exemplified above with an increasingly more detailed selection of offshore stratigraphies has been an area of significant development within Quaternary science over the period of John England's career. This is reflected in the work of his own students in the Canadian Arctic Archipelago (Pienkowski et al., 2014) as well as palaeoceanographic studies on the wider Arctic region (Andrews et al., 2014). Work by Pienkowski et al. (2014) on a marine sediment core from the east-central Canadian Arctic Archipelago provides detailed multiproxy evidence of changing oceanographic conditions since deglaciation. They identify six palaeoenvironmental zones, the oldest of which (Zone I, waterlain diamicton) records initial deglaciation at 11.54 cal ka BP. Subsequent changes in the marine environment are then clarified using lithostratigraphy, biogeochemistry and micropalaeontology.

Further afield, Andrews et al. (2014) combine proxy data with numerical modelling to examine the patterns of changing ice-rafted sediment sources in the Iceland/East Greenland offshore region. They report that the "far-travelled" sediments in the Denmark Strait area are overwhelmingly of local provenance, originating from mid-East Greenland. This indicates a significant cross-channel travel component. Additionally, they propose that three phases of iceberg sediment transport can be recognized in the Holocene, conforming to the tripartite division of the epoch suggested by Walker et al. (2012). The most notable trend is the increase in iceberg rafting starting at ca 4000 cal yr BP, likely driven by Neoglacial readvance of glaciers on the Geikie Plateau and their change from terrestrial- to marine-terminating.

The development of geochronology to constrain glacial and sea level events in the Canadian Arctic has been central to the research output of John England and colleagues since the 1970s. This has predominantly centred on the refinement of the radiocarbon chronology for marine shells, especially in the dating of raised marine sediments associated with former glacier margins (e.g. England and Furze, 2008; Coulthard et al., 2010; England et al., 2013), but has also increasingly involved the dating of marine mammals to contribute to relative sea level histories and determine changing sea ice and ice shelf conditions throughout the Holocene (e.g. Stewart and England, 1983; Evans, 1989a; Dyke et al., 1997; Dyke and England, 2003; Bradley and England, 2008; England et al., 2008). Furze et al., 2014 address the problems associated with marine reservoir corrections in the reconstruction of Holocene sea-ice histories. They provide new, statistically-derived δ^{13}C and ΔR values for previously published marine mammal radiocarbon dates from the Canadian Arctic Archipelago. Their findings indicate average δ^{13}C values of $-16.1 \pm 1.1‰$ on bone collagen for bowhead whales, $-14.4 \pm 0.5‰$ on dentine) for beluga whales, and $-14.8 \pm 1.9‰$ on teeth and tusks and $-18.0 \pm 4.7‰$ on bone collagen for walrus. The calculated ΔR values are 170 ± 95 ^{14}C years for bowhead whales and 240 ± 60 ^{14}C years for beluga whales. The new ΔR values allow the authors to compile a revised database of 651 calibrated bowhead dates, which reveals pronounced spatio-temporal fluctuations in bone abundance. Additionally, the database facilitates a refinement of earlier reconstructions of whale frequency during the Holocene, revealing that the early- and mid-Holocene increases in whale abundance were of longer duration and lower amplitude than hitherto thought. Also evident is a more even and persistent spread of infrequent low-abundance remains during what were previously regarded as "whale free" intervals. The authors conclude that the widely acknowledged relationships between bowhead whale frequencies, population densities, and sea-ice thickness and distribution appear to be highly complex. Indeed, the correlation of whale bone abundance to sea-ice histories is complicated by factors like broad sea-ice preferences, variable mortality rates and causes, long distance carcass transport, variable coastline and basin/channel geometries, and changing emergence rates.

The impacts of Holocene climate change are the subject also of the paper by Margreth et al. (2014), who report on the dating of Neoglacial ice expansion episodes in the eastern Canadian Arctic based upon the dating of fossil flora and fauna emerging from receding ice cap margins. This is a research area in which John England has previously collaborated with one of the authors of this paper, Art Dyke (cf. Wolken et al., 2005, 2008a,b), and with botanists on the potential bryophyte survival of little Ice Age glacier overriding (La Farge et al., 2013). Radiocarbon dating of the fossil flora and fauna emerging from polythermal glaciers on Cumberland Peninsula by Margreth et al. (2014) demonstrate that the onset of Neoglaciation shortly after 5 ka was concomitant with increased sea ice cover, that the intensification of ice expansion occurred at 1.9–1.1 ka and was followed by a halt in ice growth or ice recession during the Medieval Warm Period, and that renewed ice expansion occurred after 0.8 ka as a response to cooling driven by large volcanic eruptions and low solar activity. These findings indicate that glacial response to regional climate was almost instantaneous and that responses were synchronous throughout the eastern Canadian Arctic and potentially also eastern Greenland.

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