Study of the postglacial marine limit between Wager Bay and Chesterfield Inlet, western Hudson Bay, Nunavut

I. Randour1, I. McMartin2 and M. Roy3

1Département des sciences de la Terre et de l’atmosphère, Université du Québec à Montréal, Montréal, Québec, randour.iyse@courrier.uqam.ca
2Natural Resources Canada, Geological Survey of Canada, Ottawa, Ontario
3Département des sciences de la Terre et de l’atmosphère, Université du Québec à Montréal, Montréal, Québec

This work is part of the Tehery-Wager geoscience mapping activity of Natural Resources Canada’s (NRCan) Geo-mapping for Energy and Minerals (GEM) program Rae project, a multidisciplinary and collaborative effort being led by the Geological Survey of Canada and the Canada-Nunavut Geoscience Office (CNGO), with participants from Canadian universities (Dalhousie University, Université du Québec à Montréal, Université Laval and University of New Brunswick). The focus is on targeted bedrock and surficial geology mapping, streamwater and stream-sediment sampling, and other thematic studies, which collectively will increase the level of geological knowledge in this frontier area and allow evaluation of the potential for a variety of commodities, including diamonds and other gemstones, base and precious metals, industrial minerals, carving stone and aggregates. This activity also aims to assist northerners by providing geoscience training to college students, and by ensuring that the new geoscience information is accessible for making land-use decisions in the future.


Abstract

This paper presents preliminary results of a thematic study on the postglacial marine limit between Wager Bay and Chesterfield Inlet, mainland Nunavut (parts of NTS 46 and 56). The study is part of the surficial geology component of the Tehery-Wager geoscience mapping activity for the Geo-mapping for Energy and Minerals (GEM-2) Rae project area led by the Geological Survey of Canada and the Canada-Nunavut Geoscience Office. The results presented here are compiled from field observations collected in 2015 and 2016.

The geomorphic features used to delineate the postglacial marine limit are derived from distinct raised marine deposits and trimline settings, including boulder beaches, marine terraces, glaciomarine deltas, wave-cut notches in till uplands and wave-washed till surfaces exposing bedrock below. Preliminary mapping and detailed measurement of the maximum marine stand indicate that the limit increases southeastward from 113 to 127 m halfway along Wager Bay (NTS 56H), to 140 m west of Roes Welcome Sound (NTS 46E and 56A) and stays relatively constant at 139–152 m inland toward Tehery Lake (NTS 56B and 56C). Marine shells suitable for radiocarbon (14C) dating are relatively rare in the study area; therefore, bedrock was sampled from wave-washed rock surfaces for cosmogenic nuclide exposure dating at targeted sites along the marine limit to constrain the timing of marine invasion south of Wager Bay.

Résumé


Les éléments géomorphologiques délimitant l’invasion marine postglaciaire sont représentés par des dépôts marins perchés et des signes d’épaulements, tels que les plages de blocs, les terrasses marines, les deltas glaciomarins, les surcreusements par l’action des vagues dans les buttes de till et les surfaces de roc lessivées. La cartographie préliminaire et les mesures détaillées indiquent que la position maximale occupée par la mer augmente de 113 à 127 m au milieu de la baie Wager (56H) jusqu’à 140 m à l’ouest du détroit de Roes Welcome (46E et 56A du SNRC). Dans l’arrière-pays, la limite marine reste

This publication is also available, free of charge, as colour digital files in Adobe Acrobat® PDF format from the Canada-Nunavut Geoscience Office website: http://cngo.ca/summary-of-activities/2016/.

Summary of Activities 2016
relativement constante, variant entre 139 et 152 m en direction du lac Tehery (56B et 56C du SNRC). Afin de déterminer aussi précisément que possible le moment auquel eu lieu l’invasion marine dans la région au sud de la baie Wager, des échantillons ont été recueillis à la limite marine. Les coquillages marins pouvant servir à la datation $^{14}$C sont relativement rares dans la zone d’étude. Par conséquent, des échantillons de socle prélevés de surfaces rocheuses délavées par l’action des vagues seront analysés au moyen de la méthode de datation par durée d’exposition utilisant des nucléides cosmogéniques.

Introduction

Surficial geology studies and targeted surface sediment sampling were initiated in 2015 south of Wager Bay (Figure 1) as part of a geoscience mapping activity led by the Geological Survey of Canada (GSC) and the Canada-Nunavut Geoscience Office (CNGO) under the GEM-2 Program (see McMartin et al., 2015a, 2016a, b). One of the objectives of the surficial component is to provide a glacial and postglacial history framework required for interpreting the nature and transport history of surficial sediments. Together with bedrock studies (Steenkamp et al., 2015, 2016; Tschirhart et al., 2016; Wodicka et al., 2015, 2016), the work will increase the level of geoscience knowledge, which is needed to help northern communities make informed decisions about their lands, the economy and society.

One of the striking features of the Quaternary geology in the study area is the postglacial marine inundation by the Tyrrell Sea, as shown on the Glacial Map of Canada (1:5 000 000; Prest et al., 1968). At present, the maximum extent of the marine invasion is largely based on reconnaissance-scale mapping with limited ground observations in the study area. Determining more precisely the maximum limit and timing of marine inundation is important for reconstruction of postglacial rebound and crustal deformation, glacial retreat patterns and chronology, and to evaluate the effects of marine processes on sediment composition and redistribution for surface exploration using glacial sediments. Recent mapping south of Brown Lake in NTS 56G (Dredge and McMartin, 2005a, b, 2007), and GEM-1 preliminary mapping initiatives along Roes Welcome Sound in NTS 46D and 56A (Dredge et al., 2013a–c), provided the framework to reconstruct the marine limit for the entire area south of Wager Bay. For this study, detailed field observations and elevation measurements of the marine limit were collected along the southern shores of Wager Bay in NTS 56H, and remapping of the marine limit was completed using all recent and previous maps, as well as new targeted data over the entire region.

To constrain the timing of marine invasion along the northwestern coast of Hudson Bay and to obtain minimum deglaciation ages for the outer part of Chesterfield Inlet and Wager Bay, geochronological samples were collected in the study area. Two marine shell samples collected in NTS 56B were submitted for radiocarbon ($^{14}$C) dating and six bed-

rock samples from wave-washed surfaces immediately below the marine limit were collected for cosmogenic nuclide surface exposure dating. Presumably, this latter method has never been used to date a marine limit and this approach may help avoid inaccuracies related to the marine reservoir effects, which can skew $^{14}$C dating of shell samples (i.e., McNeely et al., 2006; Ascough et al., 2009). In addition, till samples were collected from frost boils above and below the marine limit as part of a detailed study to document the effects of marine reworking and winnowing on the geochemical composition of till in periglacial environments. This paper provides a summary of the postglacial marine limit mapping, and elevation, chronological and compositional datasets collected during the 2015 and 2016 field seasons.

Location and physiography

The study area lies south of Wager Bay and north of Chesterfield Inlet, in central mainland Nunavut, between latitudes 64–66°N and longitudes 87–93°W (Figures 1, 2) It covers two complete 1:250 000 NTS map areas (56A, 56B) and parts of four more (46E, 46D, 56C, 56H).

Figure 1: Location of the Tehery-Wager geoscience mapping activity study area (outlined in red) on the western side of Hudson Bay, Nunavut.
Elevations within the area vary from sea level up to 610 m. The area consists of a mixture of coastal lowlands and dissected plateaus. Steep rocky hills rise abruptly from the southern shore of Wager Bay. Two hydrographic basins drain the area toward Hudson Bay: the Wager Bay basin in the extreme north and the Lorillard River basin, which is the dominant drainage basin of the area.

**Surficial geological setting and previous work**

The study area was covered by Keewatin Sector ice of the Laurentide Ice Sheet during the Late Wisconsinan glaciation (e.g., Dyke and Prest, 1987a). Ice flowed radially from the Keewatin Ice Divide positioned in the uplands, south of Wager Bay, during the last glaciation (i.e., Aylsworth and Shilts, 1989a, b; McMartin and Dredge, 2005).

Numerous streamlined landforms and glacial striations indicate a predominant ice-flow direction toward the southeast and southeast from the ice divide. However, the pattern of glacial retreat is more complex, as shown by relationships between streamlined forms, striations, eskers, subglacial meltwater corridors and proglacial meltwater channels (see McMartin et al., 2015a, 2016b). According to Dyke (2004), deglaciation of the area occurred between 7700 and 6000 \(^{14}C\) yr BP. During the last glaciation, the weight of the ice sheet depressed the terrestrial crust with respect to today’s topographic configuration. Throughout deglaciation, the massive release of meltwater associated with the melting of the ice mass caused a significant rise in sea level, which occurred more rapidly than the glacial isostatic adjustment of the land (postglacial rebound). Consequently, as the ice margin retreated inland toward the northwest, the marine waters inundated the isostatically depressed coast of Hudson Bay. The marine limit is the highest elevation reached by the postglacial sea and thus marks the frontier between submerged lands and those that were never inundated.
The timing of the marine invasion is poorly understood in the study area. Prior to this study, only one $^{14}$C date of $\sim$6600 $^{14}$C yr. BP on marine shells from a site at an elevation of 126 m was available between Wager Bay and Chesterfield Inlet (GSC-289: corrected age of 6600 ±170 $^{14}$C yr. BP; Craig, 1965). Marine shells were found north of Wager Bay (Figure 2) at two sites, in small deltas standing at an elevation of approximately 60 m, well below the postglacial marine limit (Dredge and McMartin, 2005b). The corrected ages for these marine fossils range between 5540 ±60 $^{14}$C yr. BP (GSC-6839) and 5690 ±80 $^{14}$C yr. BP (GSC-6841). McMartin et al. (2015b) suggested that, northeast of Wager Bay, along the shores of Roes Welcome Sound, the ice had disappeared from Aiviliuq tarinuga (formerly Repulse Bay) and the northern part of Roes Welcome Sound by $\sim$7000 $^{14}$C yr. BP.

**Methodology**

**Marine limit mapping**

The marine limit was compiled using a combination of different features from existing surficial geology maps (Aylsworth, 1990a–b; Aylsworth et al., 1990; Dredge et al., 2013a–c) and detailed mapping in progress within NTS 56H south and 46E south. Where the marine limit was not developed and/or identified in previous map areas, elevation measurements from the mapped trimlines were extrapolated from 1:50 000 topographic contour maps (±10 m) and/or directly measured in the field (NTS 56B and 56C). In NTS 56H south, the marine limit was mapped using aerial photographs, a digital elevation model (derived from Canadian digital elevation data based on 1:50 000 National Topographic Data Base digital files), topographic contours (1:50 000) and satellite imagery (SPOT 4 and 5, and Landsat 7 composite, bands 742). In NTS 46E south, mapping in progress was completed using aerial photographs and topographic contours (1:50 000). The marine limit was then approximately traced using these elevation measurements and interpreted positions.

Different types of geomorphic evidence exist for identifying the maximum extent of the marine invasion. The most common features include boulder beaches, perched marine deltas, wave-cut notches in till, wave-washed rock surfaces, raised marine terraces and till remnants on small top-

---

**Figure 3:** Different features that mark the marine limit (shown with dashed white line) in the Wager Bay–Chesterfield Inlet study area: a) perched boulder beaches along Wager Bay in NTS 56H; b) wave-cut notch in till veneer and wave-washed, exposed bedrock along Wager Bay; bedrock sample collected in 2015 field season for surface exposure dating using cosmogenic nuclides is shown at the front of the photograph; c) perched boulder beaches and wave-washed bedrock surfaces along Wager Bay in NTS 56H; d) limit between boulder beaches and unmodified till veneer.
ographic highs with nearshore-sediment assemblages below and intact till above (Figure 3a–d). In NTS 56H, mainly raised boulder beaches and perched deltas were observed: they show a typical pale grey colour on the airphoto and a less well defined texture than bedrock (Figure 4a–d). Marine limit features represent a time when the marine level was relatively stable for a given period of time.

Elevation measurements

During the 2016 field season, several sites were visited along the coast of Wager Bay to record detailed postglacial marine-limit measurements. These sites were selected based on aerial photographs, satellite imagery (SPOT 4 and 5) and the central location of a nearby National Topographic Data Base bench mark. Six sites were measured at the highest points of selected marine features, mainly boulder beaches.

In order to obtain the highest precision for the detailed measurements, a combination of stationary and mobile devices was used (see Roy et al., 2015). A Track-It™ barometric data logger was placed for the day on a geodesic survey marker (bench mark) with a known elevation near the coast (stationary unit). Several other mobile devices were used at ground-truthing points and calibrated two times a day with the stationary bench mark point. To improve the measures used for calibration, all the instruments, including the data logger, were set relatively close to each other, within a maximum distance of 20 km, and a day with stable (high-pressure) weather was preferentially chosen for the measurements.

The stationary unit data were used to correct the pressure’s daily changes, which are related to the elevation as expressed by the ideal gas law. These changes can be large enough to make important differences in the elevation measurements. Data were remotely collected in terms of pressure and temperature and recorded at fixed intervals of 30 seconds during the entire day.

The mobile units included two GPS devices (Garmin GPS-12™ and Oregon® 650t) and one altimeter barometer (Suunto model Escape 203). Elevation data at the selected marine-limit sites were recorded from each mobile unit at intervals of 1 minute during a period of 5 minutes. An average of the three device readings was first done for each minute. The five averages were then corrected if necessary us-
ing the stationary unit records. This adjustment was done by adding or subtracting the difference recorded on the stationary unit from the averages at each recorded time. The corrected data were then averaged to obtain the final elevation at each site. Elevations were recorded to a precision of ~1 m. Moving inland, more than 15 measurements were collected in both NTS 56B and 56C. Due to time constraints associated with field logistics, these measurements were collected using the Garmin GPS-12™ and are considered to be accurate to within ±5 m.

**Geochronology**

Marine shells were collected at two sites in 2015 near the Connerly River northeast of Chesterfield Inlet (McMartin et al., 2015a). The shells were sampled from the surface of frost boils developed in till mixed with marine sediments at 120 and 80 m above sea level. Single shells of *Hiatella arctica* from each of the two sites were analyzed for $^{14}$C age determinations at the André E. Lalonde Accelerator Mass Spectrometry Laboratory at the University of Ottawa. Marine shells were not found during the 2016 field season.

In 2015, bedrock from wave-washed surfaces defining trimlines with unmodified till at the marine limit was sampled (McMartin et al., 2015a) for surface exposure dating using cosmogenic nuclides (Dunai and Lifton, 2014; Ivy-Ochs and Briner, 2014). The rock samples were collected using a gas-powered rock saw and a chisel. The $^{10}$Be ages will be obtained from quartz grains using standard procedures. Accordingly, bedrock types sampled for this study were rich in quartz, coming from the Hudson suite granite, tonalite to granodiorite orthogneiss and pegmatite intrusions. Two samples were taken directly along Wager Bay, in NTS 56H, and four others were taken further inland, in NTS 56B (Figure 2).

**Frost boil sampling**

In order to assess the influence of marine processes on till composition, two sites were selected along the marine limit in 2016, one in NTS 56B and one in NTS 56C (Figure 2). The sampling sites were chosen for their well-defined marine limit as identified on airphotos, the presence of thick till above and below the trimline and continuous bedrock
At each site, the vertical profiles of paired frost boils were sampled at 10–15 cm intervals down to 95 cm maximum depth; one site was located immediately below the marine limit and the other directly above (Figure 5c–e). An additional large till sample was collected at depth from each hole for precious-metal–grains and indicator-mineral analyses. Five small field duplicate samples were also collected near each frost boil at approximately 40 cm depth to measure the local variability. Geochemical and textural analyses will be performed on the samples to assess how the texture and geochemical composition vary with depth and between sites above and below the marine limit. Till geochemical analytical procedures will follow the protocols used at the Geological Survey of Canada (see Spirito et al., 2011; McMartin et al., 2016b).

**Preliminary results**

The postglacial limit of marine inundation was mapped, characterized and measured across the study area (Figure 2). Detailed elevation measurements on the highest boulder beaches about halfway along the southern shores of Wager Bay vary from 113 to 127 m asl. The observed marine limit lies at 95 m west of Brown Lake and at 110 m in the inner part of Wager Bay (Dredge and McMartin, 2005b). In the outer, eastern part of the bay within NTS 46E, the elevation of the interpreted marine limit ranges between 120 and 140 m (estimated from 10 m contours). Regionally, the new compilation indicates that the marine limit decreases inland along both shores of Wager Bay (this study; McMartin et al. 2015b). The general inland decrease in the marine-limit elevation suggests that the outer (eastern) part of Wager Bay was deglaciated earlier than the inner (western) part of the Bay. Marine water was prevented from inundating lower lands around Wager Bay by the presence of glacial ice remnants inland and over the western part of the bay.

The limit of the maximum marine stand stays relatively constant at 139–152 m between Roes Welcome Sound (NTS 46E and 56A) and the Armit and Tehery lakes areas (NTS 56B and 56C). The newly defined marine limit is relatively similar to the one presented on the Glacial Map of Canada (Prest et al., 1968). Within the centre of Wager Bay, the elevation remains similar; however, near the boundary between NTS 56H and 46E, the Glacial Map indicates an elevation of 300 feet (92 m), much lower than the new measurement of 114 m. On the western side of NTS 46D, the Glacial Map shows an elevation at 490 feet (149 m), whereas Dredge et al. (2013a) mapped the extent of the marine inundation at a maximum of 140 m.

The location of the marine limit shows that the Tyrrell Sea once occupied a vast area along Hudson Bay, particularly over the coastal lowlands north of Chesterfield Inlet and along Roes Welcome Sound, and a restricted fringe area along the southern abrupt shores of Wager Bay. The character of the marine deposits varies from mainly erosive facies (wave-washed bedrock surfaces and wave-cut notches) along Wager Bay to reworked/depositional facies in the lowlands. Reworked and mixed till with marine sediments are present in areas where the topography is smoother and of lower relief, and where there is greater abundance of glacial/glacioluvial sediment cover.

The chronology of the local ice retreat remains poorly known in the study area, in part due to the lack of marine shells available for $^{14}$C dating. Radiocarbon analysis of the two marine shell samples collected in 2015 provided corrected ages of $6252 \pm 47$ (BP (UOC-1674) and 6373 ±43 $^{14}$C yr. BP (UOC-1675), using the marine-reservoir correction of 630 years suggested for this area of Hudson Bay (zone 6: Foxe Basin; see McNeely et al., 2006). However, the marine-reservoir effect is poorly defined in the study area with the closest site with pre-bomb marine material available for testing located at Naujaat (formerly Repulse Bay), 250 km to the northeast (i.e., McNeely et al., 2006). Surface exposure dating of wave-washed bedrock surfaces offers a promising avenue. Five samples were selected for cosmogenic nuclide surface exposure dating and results will help constrain the timing of deglaciation and marine inundation. Variations in the elevation of the marine limit will be studied further with respect to local deglacial patterns and the new chronological constraints.

**Economic considerations**

The determination of the marine limit will help separate first order glacial sediments, which are deposited directly by glacial ice, from second order sediments, which are reworked, in this case by marine processes. First order sediments, such as till, are commonly used in drift prospecting surveys, whereas the complex transport history of the second order sediments makes them more difficult to use for interpreting provenance and mineralized bedrock sources (i.e., McMartin and Campbell, 2009).

The detailed profile sampling in frost boils above and below the marine limit will help assess the impact of marine invasion on till composition in soils affected by cryoturbation. Texture and geochemical composition may be affected by the winnowing and reworking effects of marine waves and currents, and/or diluted by the incorporation of fine-grained marine sediments. The vertical profile sampling at detailed intervals will help measure the variations as a function of depth, an important factor to consider in surface mineral exploration in northern Canada, where systematic till sampling in frost boils is an exploration technique commonly used to find many commodities of economic value.
Acknowledgments

This study is part of a M.Sc. thesis by I. Randour at the Université du Québec à Montréal under the co-supervision of M. Roy and I. McMartin. Funding is provided by grants from the National Sciences and Engineering Research Council and the Quebec Fond de recherche–Nature et technologies to I. Randour, as well as by Natural Resources of Canada through the Research Affiliate Program and the Geo-mapping for Energy and Minerals program, Phase 2 (GEM-2). All the field support and logistics were provided by the Tehery-Wager geoscience mapping activity of the GEM-2 Rae Project led by the Geological Survey of Canada and the Canada-Nunavut Geoscience Office. Special thanks to N. Wodicka and H. Steenkamp for their continued support and for project management. The authors would like to thank E. Girard for GIS support during the field season and D. Guilfoyle for her gorgeous meals at camp. Thanks to J. Campbell for providing a review of the manuscript.

Natural Resources Canada, Earth Sciences Sector contribution number 20160215

References


Prest, V.K., Grant, D.R. and Rampton, V.N. 1968: Glacial map of Canada; Geological Survey of Canada, A Series Map 1 2 5 3 A , 1 : 5 0 0 0 0 0 0 s c a l e , U R L < h t t p : / / geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/fullf.web&search1=R=108979> [September 2016], doi:10.4095/108979


