Barachois Evolution in the Bras d'Or Lakes Under Past, Present and Future Sea-Level Rise: Progress to Date

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Introduction

Barrier beaches enclosing small ponds and lagoons (known in Atlantic Canada as 'barachois') constitute ~12% of the Bras d'Or Lakes (BDL) shoreline in Cape Breton, Nova Scotia (Taylor and Shaw, 2002). Many of these barriers have been developed into harbours, roads and recreational areas. Well preserved, drowned (≤ 25 m below mean sea level) early/mid Holocene coastal landforms in the BDL, including spits, tombolos and barrier islands (Shaw *et al.,* 2006), may be an indication of things to come for the modern barriers, especially given the projected relative sea-level (RSL) rise for this region over the next 100 years (~62–140 cm by 2100[1] at Baddeck, N.S., relative to 1986-2005; James *et al*., 2014). Furthermore, any increase in storm frequency and/or intensity (uncertain according to the latest Intergovernmental Panel on Climate Change projections; Stocker *et al*., 2014) combined with the ongoing decrease in sea ice (Senneville *et al*., 2013) will accelerate coastal erosion processes. Likewise, if shoreline development that results in hardening or removal of sediment persists, sediment supply to coastal barriers may be cut off in some areas, increasing the likelihood of barrier erosion and drowning.

The barrier beaches also serve as protection for the ponds themselves, whose ecosystems will be altered as the barriers become submerged and/or migrate landward. Erosion of the backshore of the barachois, where most of the BDL residential infrastructure (e.g. houses, wells, and septic systems) is located, is also expected with continued sea-level rise. A basic understanding of the age of the barachois, including the nature of the sediments underlying them and the morphodynamics of their barriers (i.e. how quickly they evolve from growing or stable phases to landward-migrating or submerging phases), is required to provide baseline data with which modern and future coastal dynamics may be compared. This paper outlines the approach to this study and progress made so far. For additional background information on this project and on the three study sites in the Bras d'Or Lakes (Irish Vale, Amaguadees and Campbell ponds), please see Nixon (2014).

Methods

Aerial photography analysis and interviews with local, long-term residents and elders will allow for the documentation of major morphological changes in the barriers of the three barachois study sites (Irish Vale, Amaguadees and Campbell ponds; Fig. 1). Such historical research will establish some of the permanent to semi-permanent changes in barrier dynamics that have occurred over the past ~50–80 years; these changes will be compared with evidence for past barrier dynamics recorded in the geological record.

Geological proxy data collected for this study include shallow seismic and sidescan sonar data (previously collected in 2013; Nixon, 2014), as well as sediment cores from each of the three barachois. Cores were obtained in March 2014 through the sea ice using an ice auger, portable

[1]This range was calculated by James *et al*. (2014) using the median projections of four Representative Concentration Pathway (RCP) scenarios of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5): RCP2.6, RCP4.5, RCP6.0 and RCP8.5. The various scenarios are greenhouse gas concentration trajectories adopted by the IPCC AR5, describing four possible climate futures, all of which are considered possible depending on how much greenhouse gases are emitted in the years to come. Note also that the Bras d'Or Lakes have the highest projected RSL rise for 2100 in all of Canada (James *et al*., 2014).

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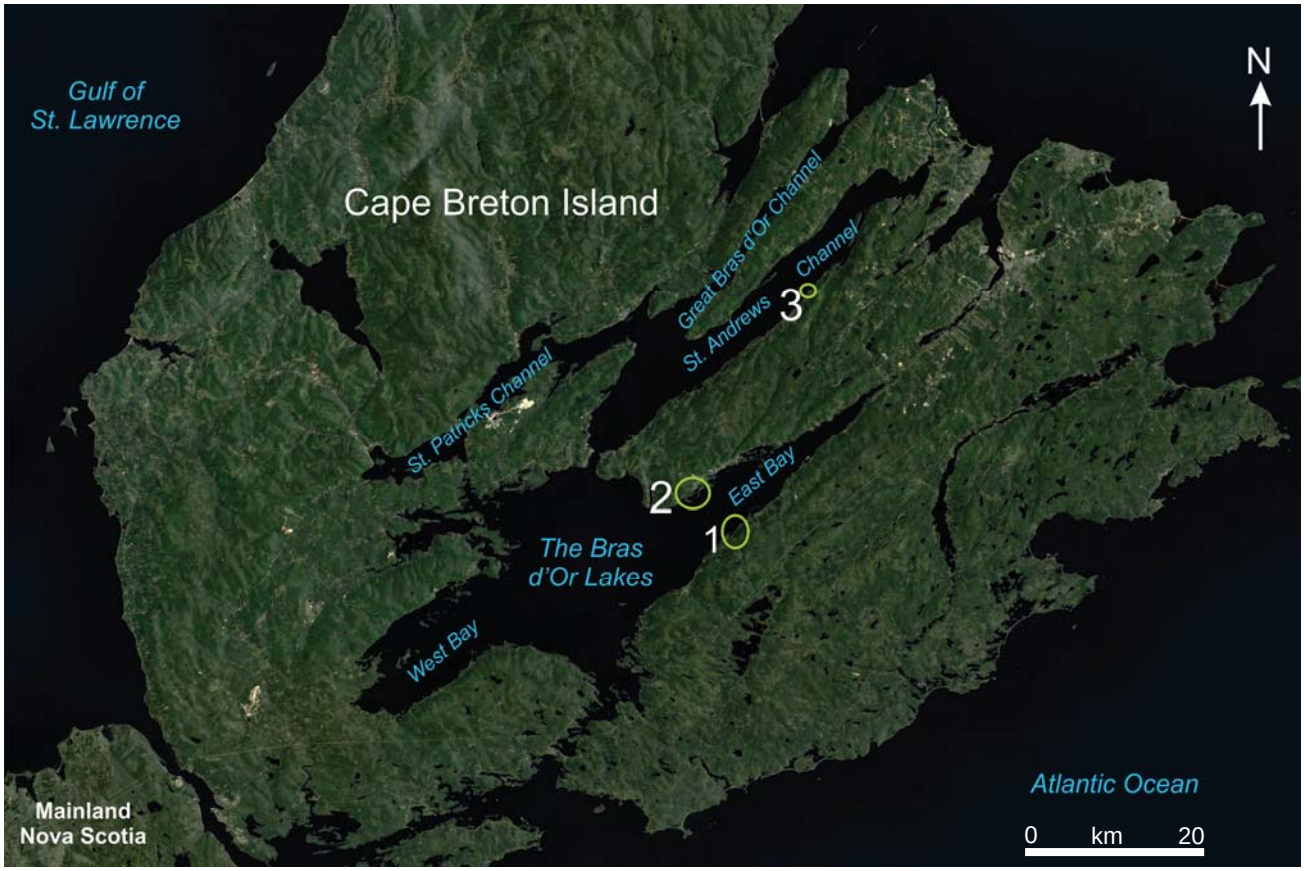

Figure 1. Location of Bras d'Or Lakes, Cape Breton Island, Nova Scotia, and barachois study sites: 1. Irish Vale Pond; 2. Amaguadees Pond; 3. Campbells Pond.

percussion coring system, and 3-inch diameter polyvinyl chloride core tubes (Gilbert and Glew, 1985; Reasoner, 1993). Once collected they were placed in cold storage (4°C) at Dalhousie University (Department of Earth Sciences). Following splitting and logging, the cores were subsampled for sedimentological, microfossil and geochemical analyses with the aim of documenting paleoenvironmental change from the pond sediments (e.g. initial barrier development, barrier breaching during large storms and break-down of the barrier).

Sedimentological analyses will be based on stratigraphic logging of the cores, particle-size analysis (to be done at the Bedford Institute of Oceanography) and organic matter content (loss on ignition). Micropaleontological analysis will include washing each sample through a stack of three sieves to sort the sediment into the following grain size categories: >45 µm, >63 µm, and >1.00 mm. Micropaleontological samples will then be examined wet under a binocular microscope to facilitate the identification and counting of agglutinated foraminifera and thecamoebians (which can disintegrate if dried). Foraminifera occupy marine environments, but some species tolerate brackish conditions. Thecamoebians are testate amoebae that occupy freshwater environments, although a few species will tolerate slightly brackish conditions. The ecological information provided by the species and proportions of foraminifera and thecamoebians will thus provide paleosalinity levels in the barachois and, by extension, the integrity of the barrier (i.e. whether it was fully closed or open to the BDL).

Geochemical analysis of core sediments will be conducted using the Department of Natural Resource (DNR) portable x-ray fluorescence spectrometer (XRF) to characterize elemental variability in the pond sediments through time, which, depending on the elements present and their concentration trends down core, may be used as a

proxy for paleoclimate. Historical anthropogenic activities may also be evident in the XRF data and could potentially be used as age markers in the cores. Radiocarbon dating of organic matter will allow a temporal framework for the documented paleoenvironmental change to be established.

2014 Work Program and Results to Date

Approximately 25 line-kilometres of sidescan and high-resolution (low penetration) echosounder profiler data were collected across Irish Vale, Amaguadees and Campbells ponds in October, 2013 (see Nixon, 2014). The acoustic data were used to develop 3-D bathymetric models of Irish Vale and Amaguadees ponds (Figs. 2, 3); the seismic data from Campbells Pond was not of high enough quality to produce a 3-D bathymetric model. The acoustic data were also used to determine the best sites for sediment coring, specifically sites where several metres of stratified sediment have accumulated. Six cores in total were collected from the Bras d'Or Lakes between the 4th and 9th of March 2014 (Fig. 4): two from Amaguadees Pond (220 and 309 cm long), two from Irish Vale (107 and 66 cm long; Fig. 5) and two from Campbells Pond (72 and 94 cm long).

From May to July 2014, the cores were split, photographed, logged and sub-sampled for XRF, microfossil and particle size analyses. Results from all core analyses are expected to be complete by December 2015. An example of results obtained so far on a core from Irish Vale (IV-01) is provided below; however, particle size and XRF analyses are currently in progress, and thus these results are not available for this report.

Irish Vale Core IV-01

Irish Vale core IV-01, 107 cm in length (Fig. 5), was collected from the north end of Irish Vale pond on 8th March 2014 (Fig. 1). Several samples of shells and plant material in this core have been extracted and prepared for radiocarbon dating and will be sent to a commercial lab in February 2015. Results are expected by late March 2015.

Stratigraphy

Medium-brown, organic-rich, massive silty clay constitutes the uppermost 31 cm of core IV-01 (Unit 1, Fig. 5). Between 4 and 31 cm, medium-brown silty clay is discontinuously mottled with dark brown silty clay. A sharp contact at 31 cm marks the transition to Unit 2, an olive-grey silty clay with rare shell fragments (31-68 cm). Below 68 cm, sediments are sorted into beds of grey-brown silty clay that transitions upwards into darker grey-brown silty clay (Unit 3; Fig. 5). These beds vary in thickness from ~2–5 cm. A sharp contact at 92 cm marks an abrupt transition to Unit 4, a clast-supported, dark brown, organic-rich diamict with a silty-clay to coarse-sand matrix. Clasts in Unit 4 range in size from granule to gravel (~1 cm) and include wood and other plant fragments. At 99 cm there is an unconformable contact with Unit 5, the basal unit, which comprises a light-grey, clay-rich, matrix-supported diamict. Clast sizes range from granule to gravel (3-4 cm). Organic matter was not observed in Unit 5. Lithology of the gravel clasts for units 4 and 5 is currently being assessed.

Microfossil Results

Four samples from IV-01 were selected for initial microfossil analysis; additional samples will be processed depending on initial results. The four samples are (core depths in parentheses following sample name) IV-01-01 (10–12 cm), IV-01-03 (30–32 cm), IV-01-07 (70–72 cm) and IV-01-09 (90–92 cm). For all of the IV-01 samples, the >1.00 mm fraction consisted of rare fragments of grasses, wood and other plant material that decreased in abundance down core. The >1.00 mm fraction of sample IV-01-01 included one small shell fragment (~2 mm). Small (1.5–3 mm) gravel chips caught on the 1.00 mm mesh increased in abundance down core, but were rare in general.

Species identifications of the foraminifera, thecamoebians, and other microflora and microfauna observed to date require confirmation for accuracy, and additional counting is necessary for statistical analyses. However, preliminary qualitative results described below provide an early assessment of paleoenvironmental conditions of the barachois at Irish Vale.

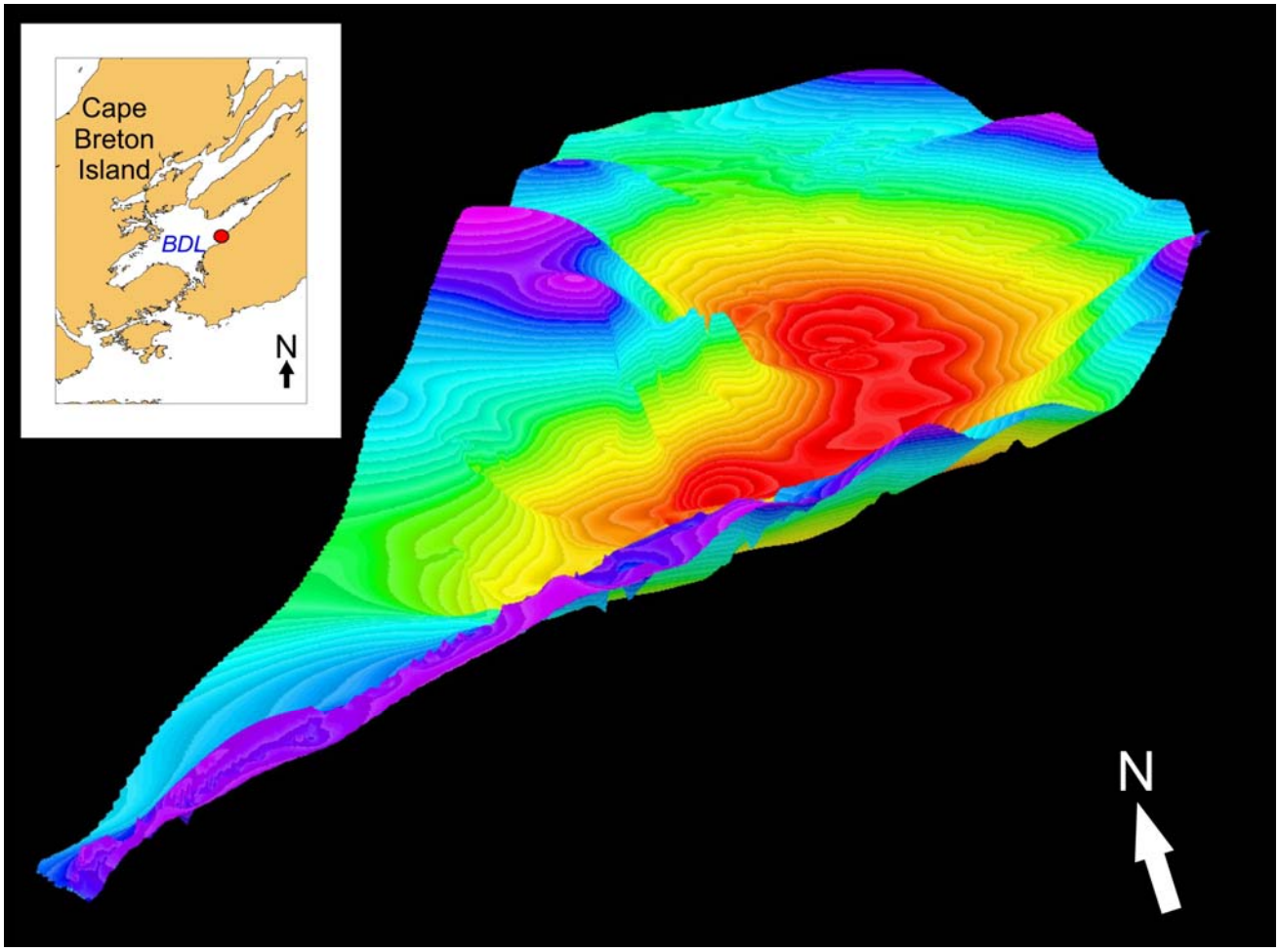

Figure 2. Three-dimensional model of modern bathymetry of Irish Vale Pond created using acoustic data collected in October 2013. The approximate dimensions of Irish Vale Pond are 490 m (maximum length) by 140 m (maximum width) by 7 m (maximum depth; in red).

IV-01-01 (10–12 cm; >63 µm fraction)
Agglutinated and calcareous foraminifera (several *Elphidium* species and *Miliammina fusca*) and rare thecamoebians (1 or 2 species) are present in low abundances. Many of the calcareous foraminiferal tests are etched, possibly indicating partial dissolution due to acidic conditions or to mechanical abrasion indicating higher energy conditions (i.e. transportation and deposition during a storm). Very fine quartz sand was noted as visually abundant in this interval.

IV-01-03 (30–32 cm; >63 µm fraction)
Foraminifera are absent and thecamoebians rare in this interval of core IV-01. Diatoms (several unknown species) are abundant, as are pine pollen and an unknown species of freshwater mites (order Hydracarina; Andrew Hebda, pers. comm., December 2014). Very fine quartz sand is common.

IV-01-07 (70–72 cm; >63 µm fraction)
Agglutinated foraminifera and thecamoebians are present in this sample, but in low abundance. Foraminiferal test linings are relatively abundant, and very fine quartz sand is also abundant (more so than any other sample from this core). A few scolecodonts (the jaw from polychaete annelids, i.e. marine worms) were also observed in this sample.

IV-01-09 (90–92 cm; >63 µm fraction) A few species of agglutinated foraminifera and at least two species of thecamoebians were observed in

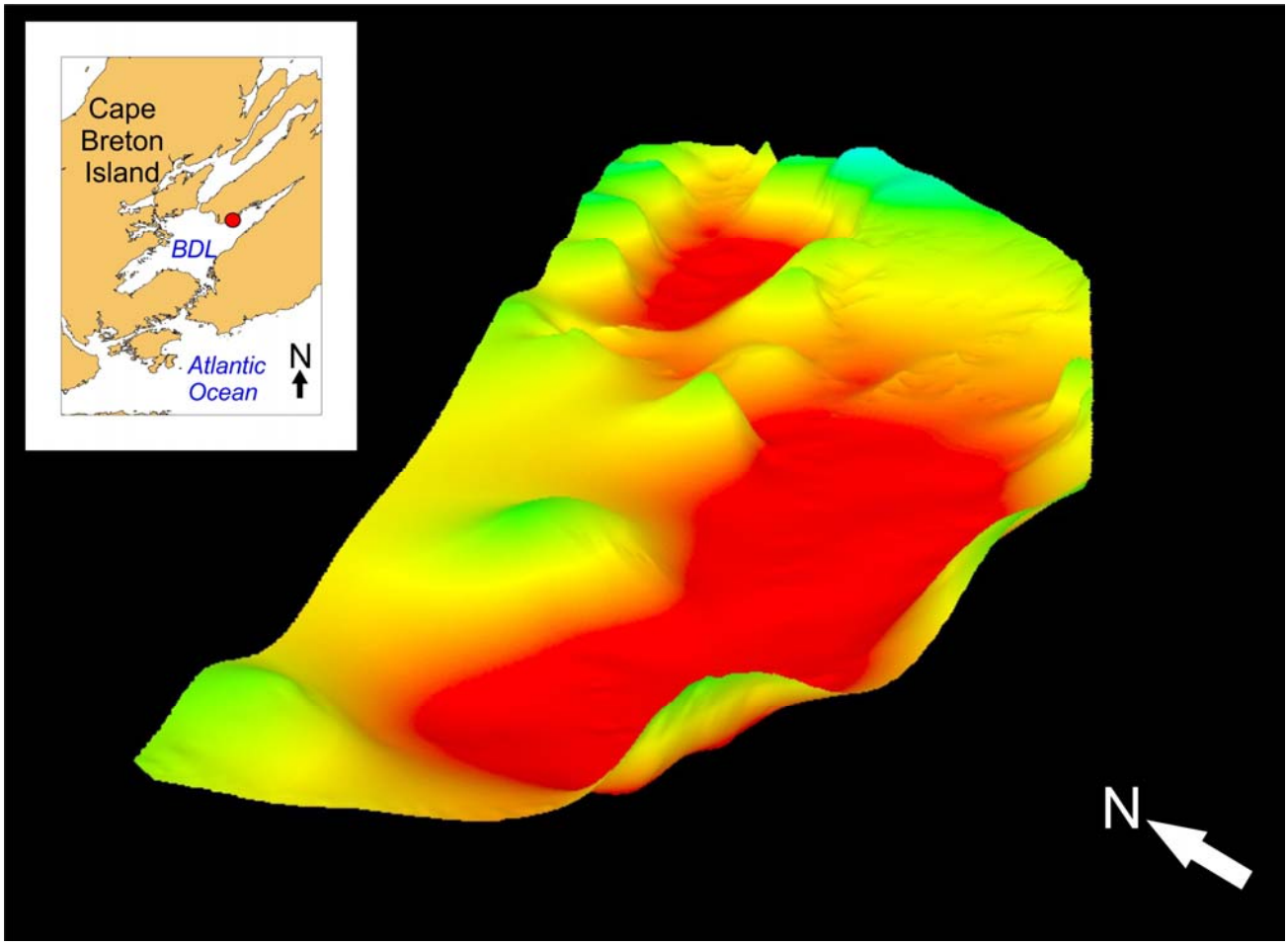

Figure 3. Three-dimensional model of modern bathymetry of Amaguadees Pond created using acoustic data collected in October 2013. The approximate dimensions of Amaguadees Pond are 2100 m (maximum length) by 770 m (maximum width) by 12.5 m (maximum depth; in red).

IV-01-09. Very fine quartz sand was observed to be rare. Diatoms and scolecodonts are also present in this core interval in low abundance.

Future Work

Analytical work on the six BDL sediment cores is expected to be completed in 2015. Interpretation and discussion of the results described above and those remaining will be published in a separate DNR Open File Report. It is hoped that the results of this study will elucidate the long-term stability of the barriers in the Bras d'Or Lakes and their future under projected RSL rise over the next 80 to 100 years. The expected future state of the barriers and barachois have important implications for the residents of the Bras d'Or Lakes and industries, in particular, aquaculture and tourism.

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Figure 4. Percussion coring through the ice at Campbells Pond in March, 2014.

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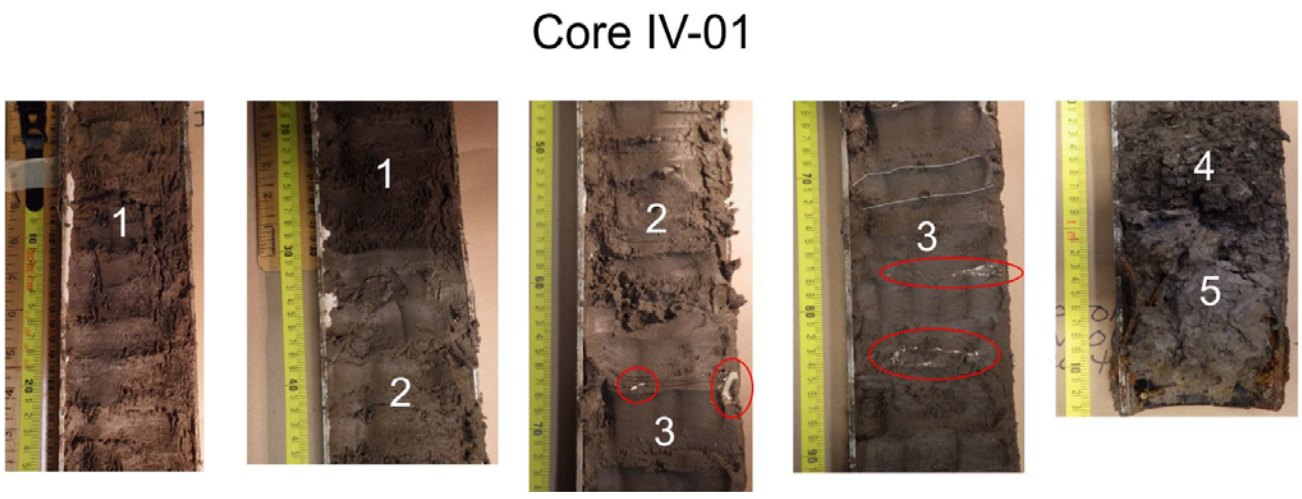

Figure 5. Core IV-01 showing the five stratigraphic units described in the text. Shells are circled in red. Note that the core starts 6 cm below the top of the tape measure.

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