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Authors: McDowell, Lyn, Knight, Jasper, and Quinn, Rory

Source: Journal of Coastal Research, 36(sp1) : 483-486

Published By: Coastal Education and Research Foundation

URL: https://doi.org/10.2112/1551-5036-36.sp1.483

Journal of Coastal Research	SI 36	483-486	(ICS 2002 Proceedings)	Northern Ireland	ISSN 0749-0208

High-resolution geophysical investigations of estuarine and nearshore sediment dynamics, River Bann estuary, Northern Ireland coast.

Lyn McDowell, Jasper Knight, Rory Quinn

Coastal Research Group, School of Environmental Studies,
University of Ulster, Coleraine, Co. Londonderry, Northern Ireland, BT52 1SA, UK, jl.mcdowell@ulst.ac.uk

ABSTRACT

The River Bann, Northern Ireland, discharges onto the high-wave energy, swell-dominated North Atlantic coast. The funnel-shaped estuary, buttressed by Tertiary basalt outcrops, is partially barred by dunes developed on a mid-Holocene gravel barrier. The meso-scale evolution of the estuary and nearshore zone therefore demonstrates the interaction of fluvial, marine and coastal processes. Echo sounder, side-scan sonar and Chirp sub-bottom profiler were used to map bathymetry, surficial sediments and sediment stratigraphy respectively. Side-scan sonar data, ground-truthed by surficial sediment sampling, yielded 3 distinct acoustic facies, interpreted as sand (90% of study area) bedrock (9%) and gravel (1%). Oblique nearshore sandwaves, (wavelength 20 - 60m, height 0.8 - 2.4m) are replaced 1.5km offshore by planar sands (20m water depth). Adjacent to the bedrock headland of Portstewart Point lies a relict shore platform (at –30m OD Belfast), likely formed during a late-Pleistocene lowstand. Individual boulders up to 1m diameter are imaged on the bedrock surface. The surface is partially overlain by active, shore parallel gravel wedges surfaced by ripple beds (wavelength 1.5m, height 1.0m) which are partially overlapped by planar sand. Repeat seasonal surveys show general onshore surface bedform migration during winter and offshore re-distribution of sediment in summer. These changes suggest that west to east tidal currents re-circulating sediment between the offshore and nearshore zones are modified seasonally by changes in wave regime and river discharge. Chirp surveys revealed two main seismic stratigraphic units, termed inshore and offshore, overlying the acoustic basement, the inshore unit being more internally complex. Four major controls on Holocene nearshore sedimentation on the north coast of Northern Ireland are suggested: (1) antecedent geological constraints, (2) sediment supply, (3) wave climate and (4) tidal current regime. Apart from antecedent geology, these controls have been, and continue to be, modified by RSL fluctuations and storm events.

ADDITIONALINDEXWORDS: *RSL, Side-scan sonar, chirp, estuary.*

INTRODUCTION

The north coast of Ireland is a glaciated shelf environment which has been subject to significant RSL fluctuations during the inter-glacial and Holocene (CARTER, 1982; WILSON and MCKENNA, 1996). Consequently, coastal and nearshore geomorphology, sediment supply and shoreline position have undergone relatively rapid changes during these periods. Reconstruction of the development of such shelf environments requires high quality, reliable data on surficial geology, stratigraphy and energy vectors along with reliably dated index points to constrain RSL change. However, little detailed mapping or investigation of the shelf environment of Northern Ireland has been done and questions remain. Of these, two questions are of interest here. Firstly, what is the fate of debris produced during the cutting of shore platforms in the late Pleistocene/early Holocene (WILSON and MCKENNA, 1996). Secondly, is there any surviving seabed and sub-bottom evidence – such as paleo-shorelines - for RSL lowstand, highstand and transgressive RSL phases. Mapping to answer these questions requires the use of high-resolution marine acoustic data.

The estuary of the River Bann, Northern Ireland's longest river, shows good geomorphic, stratigraphic and dating evidence for changes in RSL and sediment supply during the late Pleistocene and early Holocene (CARTER and WILSON, 1990; WILSON and MCKENNA, 1996). At present the river discharges to the sea at the western side of the estuary via a pair of jetties, 150 m apart, built in the 1870s and modified to their present form in the 1890s (Figure 1). The eastern three-quarters of the re-entrant is separated from the sea by a mid-Holocene gravel barrier (CARTER and WILSON, 1993) on which is anchored the

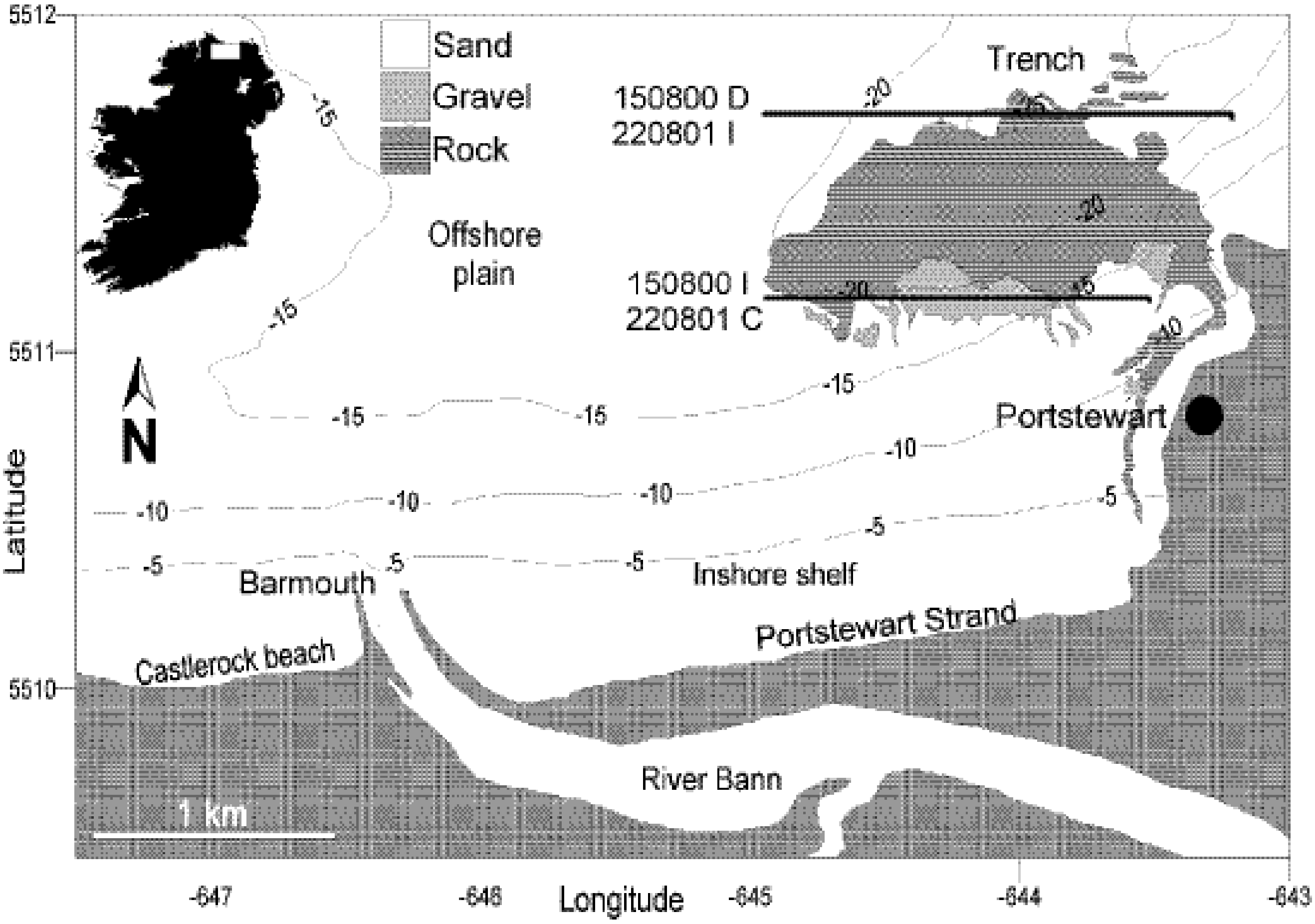

Figure 1. Study area showing surveyed bathymetry; distribution of surface sedimentary facies, as interpreted from acoustic data ground-truthed by sediment sampling; and sites mentioned in text.

Portstewart Strand/dune complex (2.7 km long). The dune and beach system on the western side of the river mouth has prograded significantly since the construction of the jetties, reflecting west to east longshore drift. Both beaches feature wide, dissipative profiles.

METHODOLOGY

A range of marine acoustic methods were used to map bathymetry, surficial sediments and stratigraphy. These were:

1. A *Nautech* ST50 single beam echo-sounder, used to map bathymetry at a sampling interval of approximately 6 m horizontal spacing of individual readings.
2. A side-scan sonar equipment suite, comprising an *Edgetech* 272-TD towfish and *Edgetech* 260-TH data logger/printer, to map surficial geology. Three surveys were conducted between August 2000 and August 2001, the first yielding complete coverage of the area followed by two specifically targeted surveys, totaling 170 km of survey lines. Survey parameters were in the ranges: 100 – 500 kHz frequency, 150 - 250 m line spacing and 200 – 300 m total swath width. Side scan sonar evidence was ground-truthed by bucket dredge sediment sampling.
3. An *Edgetech* X-Star SB 216-S towfish, allied with an *Edgetech* Midas processor and recorder were used to image sub-surface stratigraphy. The towfish was deployed at a 3 m water depth using a 2 –10 kHz pulse rate – chosen for its higher resolution.
4. All marine positional data were acquired with a *Litton Marine* LMX 400 dGPS with a horizontal accuracy of ± 5 m.
5. A further program of diver sampling is planned for spring 2002. Tide gauges and wave recorders will also be deployed at that time.

RESULTS

Echo-sounding revealed three main bathymetric features (Figure 1):

1. An inshore shelf, present just seaward of the surf zone in 5 -10 m water depths.
2. A break of slope, marking the edge of the inshore shelf, shelves down to a largely featureless offshore plain in 14 -15 m water depths.
3. A north-east trending, flat-floored trench which is cut into the plain.

Side scan sonar results from the first two surveys were compiled to produce the simplified facies map in Figure 1 which depicts the main sedimentary facies boundaries. Three distinct acoustic facies were identified and sediment sampling confirmed these to be sand, gravel and rock. These can be considered the end members of a continuum within which each facies is likely to contain components of all three types. Figure 2 is sonograph of an east-west transect across the southern margin of the bathymetric trench (location in Figure 1), and shows each of the facies and their typical spatial relationships to one another.

Overall, the area is dominated by sand, except for the floor and eastern flank of the bathymetric trench and the bedrock shelf paralleling the hard coast. The geological constraints imposed by the hard coast are likely to control tidal current vectors, and thus sediment transport, in this area. Tidal scouring has exposed, or maintained the exposure of, a bedrock surface. Individual boulders up to 1 m diameter, which may be glacial erratics, winnowed glacial till or inter-tidal shore platform debris are imaged on the bedrock surface. The surface is overlain by rippled gravel beds at its southern margin and both bedrock and gravel are overlain by generally planar sands. The gravel ripples are well defined, with typical amplitudes and wavelengths of 1.0 m and 1.5 m respectively. They are generally characterised by west to east trending, sub-parallel ripple crests but their bifurcation ratio increases eastwards while amplitude and wavelength both reduce eastwards. The sand facies features a series of narrow, north-south trending channels, floored by the rippled gravel. These may be the product of tidal scouring or of north-south trending bathymetric highs, albeit of low relief, in the gravel bed onlapped from east and west by the sand facies. Repeat side-scan sonar surveys suggest the channels to be seasonally mobile.

Results from a 1998 Chirp sub-bottom profiler survey (COOPER *et al*, 2002) were made available and complemented by the 2001 survey. Profile 230801 C-D, oriented north-south along a line 150 m east of the Barmouth, has two main seismic stratigraphic units, termed offshore and inshore units, overlying the acoustic basement:

1. An offshore unit. Internally this comprises a low-reflectivity matrix, which constitutes the bulk of the unit. Within this are a single near-surface, and surface parallel, high intensity reflector and a second, diffuse reflector, of moderate intensity, which is sub-parallel with the surface of the unit at 5–7 m depth in the sediment pile.
2. The offshore unit is overlain from inshore by a second unit of greater internal complexity containing 9 internal reflectors in the uppermost 3–5 m. These are parallel with the uppermost surface and generally laterally continuous in the seismic profile, although there are some breaks.

A second profile (Figure 3) through the bathymetric trench, includes a bedrock and gravel surface exposure (3) corresponding to the inshore margin of the trench which is onlapped from the north by an offshore unit of sands (1) containing a diffuse internal reflector, probably re-worked glacial debris. The unit is also downlapped from the south by an inshore sand wedge (2) which is internally more complex, featuring one continuous, parallel, near-surface reflector and a sequence of up to six sub-parallel, but less

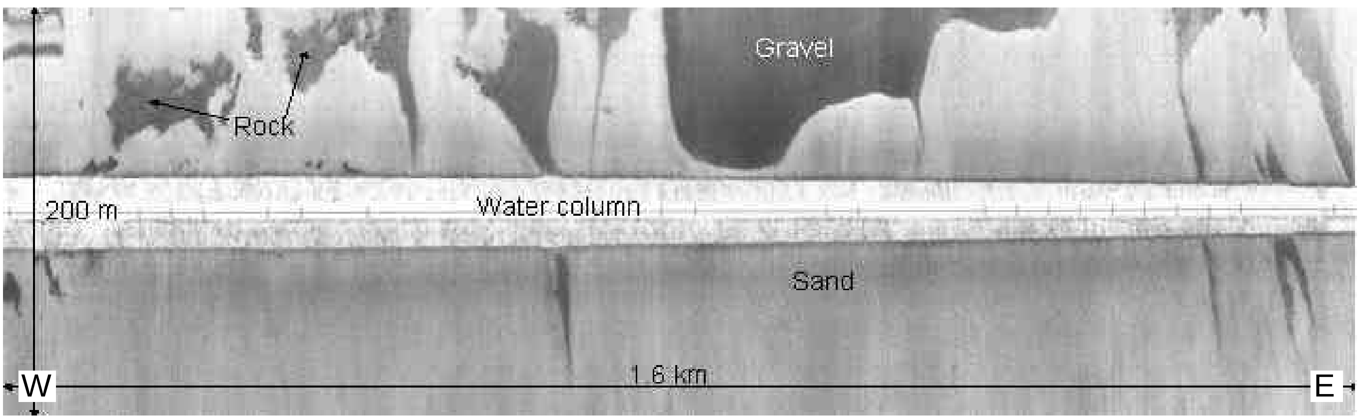

Figure 2. East-west sonograph (220801 C) across bathymetric trench showing examples of all three facies, (a) sand, (b) gravel, (c) rock, and their relationships to one another.

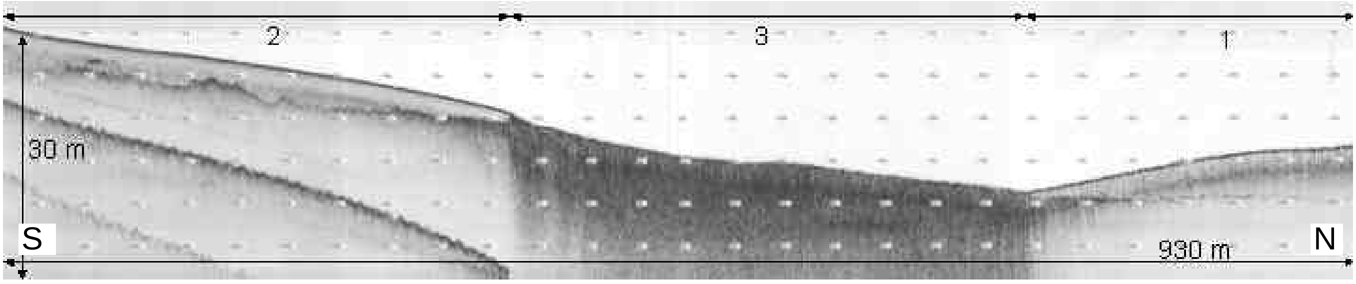

Figure 3. Chirp sub-bottom profile 230801 A-B oriented north-south through inshore wedge (2), bathymetric trench (3) and offshore plain (1). The profile is compensated for vessel heave and vertical exaggeration is ~ 4.5

continuous, reflectors in the nearshore zone. The same diffuse reflector that is present in the offshore unit is evident also in the inshore wedge but is neither as extensive nor as well defined.

INTERPRETATION

Results from the north coast inner shelf demonstrate three major controls on Holocene nearshore sedimentation along Northern Ireland's north coast: (1) sediment supply; (2) the configuration of basement geology operating as a constraint on tidal current vectors, and (3) the effect of wave climate.

Late-Pleistocene glaciation deposited large quantities of debris further out on the shelf (CARTER, 1982; WILSON and MCKENNA, 1996) and it is this material that has been the major source of sediment for the construction of the soft coast features described above (WILSON and MCKENNA, 1996). However, prolonged re-working onshore of the contents of this finite store means that net supplies to the present day coast are now dwindling (CARTER, 1982; WILSON and MCKENNA, 1996), although they are augmented to some degree by west to east longshore drift from the Tunns Bank - a component of Magilligan Foreland, Irelands' largest and most actively prograding coastal foredune.

The morphologic constraint imposed on the River Bann estuary and the nearshore zone by basement geology (in the form of the Tertiary basalt outcrops that delimit the coastal re-entrant occupied by the estuary) also constrains the dynamic interaction of fluvial and marine processes. The eastern outcrop is interpreted as a significant control on the role of tidal currents in the down-cutting of the bathymetric trench due to its interference with dominant west to east longshore drift and thus in the localised orientation and operation of those currents.

RSL fluctuations have also been an important control on the timing, location and elevation of effective wave attack. Superimposed on the basic wave climate are frequent storm events which have had, and continue to have, significant effects on the soft coast geomorphology of Northern Ireland's exposed coast (WILSON and MCKENNA, 1996; COOPER *et al*; 2002).

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