Geomorphology 203 (2013) 66–78

Contents lists available at ScienceDirect

Geomorphology

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

Modelling the development of rocky shoreline profiles along the northern coast of Ireland

Benjamin Thébaudeau [a], Alan S. Trenhaile [b], Robin J. Edwards [a,*]

[a] School of Natural Sciences, Museum Building, Trinity College Dublin, Dublin 2, Ireland
[b] Department of Earth Sciences, University of Windsor, Ontario N9B 3P4, Canada

ARTICLE INFO

Article history:
Accepted 29 March 2013
Available online 4 April 2013

Keywords:
Wave erosion
Model
Relative sea level
Rock coast
Shore platforms
Marine terraces

ABSTRACT

A mathematical wave-erosion model is used to simulate postglacial shoreline profiles along the rocky, high energy coast of the north of Ireland. The wave erosion model is driven by a suite of relative sea-level (RSL) curves for the last 16,000 years produced from four glacial rebound models. Multiple runs are performed with different initial shore profiles and rock resistances to investigate shoreline evolution and the significance of inherited morphology on the resultant profile shape. The simulated profiles are then compared with mapped profiles from three areas of the north of Ireland with different lithological and hydrographic properties.

Modelled profiles generally replicate the overall mean shoreline gradients observed across the region when rock resistance is relatively high and erosion rates correspondingly low. In these profiles, breaks in mean slope are observed at depths comparable to the RSL minima in several of the RSL scenarios (at c. −10 m, −15 m and −20 m for North Antrim, Derry and Donegal respectively). At Portrush and Portballintrae (Derry), profiles may be influenced by structural controls relating to the underlying basalt surface and the removal of overlying glaciogenic sediments.

All RSL scenarios replicate the observed eastward increase in cliff–platform junction height, reflecting the differential glacioisostatic rebound experienced along the coast. However, the precise elevation at which the simulated cliff base occurs is sensitive to the choice of RSL scenario, suggesting that this parameter may prove useful in evaluating glacial rebound model performance. Several of the RSL scenarios generate raised shore platforms or terraces in North Antrim and Derry at heights comparable to raised shoreline features reported in the literature. However, no single curve or combination of parameters is capable of generating the range of platform and terrace features observed in the bathymetric and topographic data. These misfits are consistent with the idea that many rock platform or terrace features are inherited from an earlier phase or phases of RSL.

1. Introduction

The high energy, wave dominated coastline of the north of Ireland comprises rocky cliffs and shore platforms, commonly associated with gravel ridges, beach sand and eolian dune deposits. In places, this rugged coastline is punctuated by more sheltered sea loughs (estuaries of glacial inheritance) and embayments which permit the accumulation of lower-energy, finer grained estuarine sediment. Whilst rocky coasts are traditionally regarded as being less vulnerable to the effects of climate and sea-level change than their lower-energy sedimentary counterparts (e.g. Nicholls et al., 2007), their actual resilience is poorly quantified and a better understanding of long-term rocky coast evolution is required (Naylor et al., 2010). This issue has particular significance along the rocky coast of the north of Ireland, not least because of the presence of the Giant's Causeway World Heritage Site and associated concerns regarding climate-related increases in erosion and inundation (Orford et al., 2007).

In addition to its actively forming features, relict coastal landforms and facies are exposed along the northern coast of Ireland at a range of elevations above their contemporary counterparts (e.g. Praeger, 1897; Coffey and Praeger, 1904; Movius, 1953; Stephens, 1963; Prior, 1965; Orme, 1966; Synge and Stephens, 1966; Carter, 1982). This varied association of ‘raised shorelines’, which consists of erosional features such as rock platforms, notches, terraces and ‘washing limits’, and depositional features such as gravel ridges, or marine deltas, has been cited as evidence of higher than present relative sea-level (RSL) resulting from glacioisostatic rebound of this formerly glaciated region (Devoy, 1983, 1995; McCabe et al., 2007). Similarly, investigation of the inner shelf has identified potential beach deposits

Abbreviations: RSL, Relative Sea Level; JIBS, Joint Irish Bathymetric Survey; DEM, Digital Elevation Model; MHWS, mean high water spring tide; MHWN, mean high water neap tide; MT, mid-tide; MLWN, mean low water neap tide; MLWS, mean low water spring tide; OD, Ordnance Datum Malin Head.

* Corresponding author. Tel.: +353 1 896 1713; fax: +353 1 671 3397.
E-mail address: Robin.Edwards@tcd.ie (R.J. Edwards).

0169-555X/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.geomorph.2013.03.027

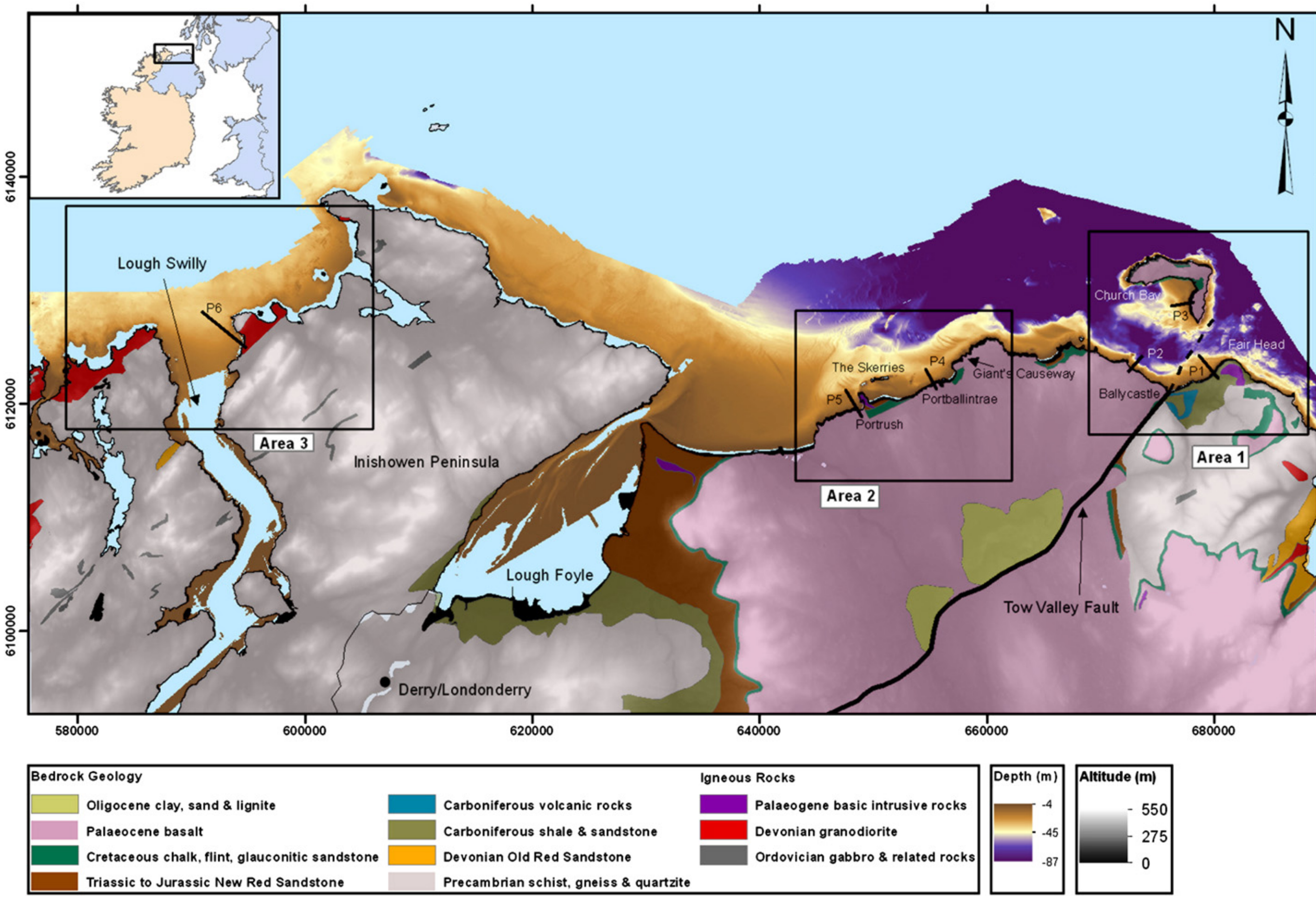

Fig. 1. Map displaying the study area and location of the shoreline profiles plotted against the Joint Irish Bathymetric Survey (JIBS) swath bathymetry dataset (offshore) and the bedrock geology (onshore).

and erosional notches now submerged by several tens of metres of water, suggestive of periods during which RSL was below present (Cooper et al., 2002; Kelley et al., 2006).

However, despite more than a century of work, the RSL history of the north of Ireland remains poorly resolved and the subject of ongoing debate (Carter, 1982; Lambeck, 1995; Lambeck and Purcell, 2001; Peltier et al., 2002; Shennan et al., 2006; McCabe et al., 2007; Brooks et al., 2008; Edwards et al., 2008; McCabe, 2008). Difficulties in reliably delimiting the vertical relationships of inferred shorelines to the sea level at the time of their formation, coupled with uncertainties in constraining their age, have contributed to this lack of consensus. This situation is exemplified by the use of rocky shore morphology, such as shore platforms and notches, which have featured prominently in previous work.

Shore-platforms develop in the intertidal zone where erosional processes, such as hydraulic quarrying, operate at or near to the water surface (Trenhaile, 1997, 2000, 2012). Whilst they are clearly linked to RSL and tidal range, mean platform elevation and the height of the junction between the cliff and the seaward shore platform (the cliff–platform junction) varies within the intertidal zone according to wave exposure, weathering intensity and the resistance of the rock (Trenhaile and Byrne, 1986; Trenhaile, 2002). Consequently, these features can constrain the height of RSL but with vertical uncertainties of several metres (Carter, 1983).

With a change in RSL, shore platforms may be converted into subaerial or submarine terraces, or sloping erosional continental and island shelves. Since they can rarely be dated directly, these erosional features

Table 1
Summary wave data derived from the Irish Department of Transport buoy M4 (Station 62093), Donegal Bay (water depth = 72 m). H_0 = binned significant wave height (metres); F = proportion of the total record in each bin; T = average wave period within each bin (seconds).

H_0 (m)	F (%)	T (s)
<1	5.6	5.1
1–2	31.0	5.7
2–3	28.2	6.7
3–5	26.0	7.8
5–7	7.1	9.2
7–9	2.1	10.3

Table 2
Summary tidal data for the three study areas (m OD Malin Head). MHWST = Mean high water of spring tides; MHWNT = mean high water of neap tides; MLWNT = Mean low water of neap tides; MLWST = mean low water of spring tides.

Tidal Station	Tidal Data (m OD Malin Head)			
	MHWST	MHWNT	MLWNT	MLWST
Ballycastle (Area 1)	+0.5	+0.2	−0.1	−0.4
Portrush (Area 2)	+0.7	+0.6	−0.3	−0.8
Fanad Head (Area 3)	+1.3	+0.3	−1.2	−2.2

Source: British Admiralty Tide Tables (2011).