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High-resolution onshore–offshore morpho-bathymetric records of modern chalk and granitic shore platforms in NW France☆

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ABSTRACT

Modern shore platforms developed on rocky coasts are key areas for understanding coastal erosion processes during the Holocene. This contribution offers a detailed picture of two contrasted shore-platform systems, based on new high-resolution shallow-water bathymetry, further coupled with aerial LiDAR topography. Merged land-sea digital elevation models were achieved on two distinct types of rocky coasts along the eastern English Channel in France (Picardy and Upper-Normandy: PUN) and in a NE Atlantic area (SW Brittany: SWB) in NW France. About the PUN case, submarine steps, identified as paleo-shorelines, parallel the actual coastline. Coastal erosive processes appear to be continuous and regular through time, since mid-Holocene at least. In SWB, there is a discrepancy between contemporary coastline orientation and a continuous step extending from inland to offshore, identified as a paleo-shoreline. This illustrates a polyphased and inherited shore platform edification, mainly controlled by tectonic processes.

1. Introduction

Understanding how rocky coasts evolve through time needs to better study cliff recession and associated shore platform evolution. It is generally assumed that retreat rates of rocky coast cliffs and downwearing rates of shore platforms are dynamically linked (e.g., Moses and Robinson, 2011; Stephenson, 2000, 2008; Sunamura, 1992; Trenhaile, 2000, 2002; Walkden and Dickson, 2008).

Short-term rock cliff recession may be measured on multi-decadal timescales using aerial photographs, photogrammetry, airborne LiDAR or laser scanning comparisons, where mean erosion rates may be detected. Along the eastern English Channel, average erosion rates of chalk cliffs are of the order of several dm/year (e.g., Costa et al., 2004, Dornbusch et al., 2006; Moses and Robinson, 2011). At this timescale, the rate of surface lowering of shore platforms can be measured using micro-erosion meters (MEM) or traversing micro-erosion meter (TMEM) (e.g., Stephenson et al., 2010). In the eastern English Channel,

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shore platform downwearing and step backwearing erosion rates are of the order of a few mm/year (e.g., Moses and Robinson, 2011). Though direct measurements of erosion cannot be performed on multi-millennial timescales, cosmogenic radionucleides (Be^{10}) have been used successfully in Normandy to date potential paleo-coastline location and to model cliff recession (Regard et al., 2012).

Estimating erosion rates of crystalline rocky coasts is more problematical at multi-decadal timescales due to very low erosion rates (Kennedy et al., 2014). In these cases, coastline evolution needs thus to be documented on time-periods larger than decades (i.e. centuries, Holocene and Neogene scale).

In passive margin contexts, paleo-coastline morphologies may be preserved in the subtidal part of the shore platforms, providing evidence of multiple sea-level fluctuations, tectonic adjustments, isostatic changes and rock resistance to weathering and marine processes. As a first step, paleo-coastlines need to be precisely defined and analyzed using high-precision morpho-bathymetry with regard to the geological context. A second step involves dating of the rock-denudation process in order to quantify coastline evolution during the Holocene and the Neogene. Taking into account the fact that long-term cliff recession is not systematically equivalent to the width of the shore platform (e.g., Moses, 2014; Stephenson, 2008), detailed studies on global environmental conditions (tectonic control, eustatic and isostatic changes) and local marine and weathering conditions need to be conducted on each studied site.

The aim of the paper is to provide an original morphostructural picture of the land-sea transition of rocky shores, including onshore coastal cliffs, beaches, intertidal and subtidal parts of shore platforms. A comparative analysis of two contrasted French coastal sites with rocky shore platforms is proposed. We present new high-precision merged land-sea digital elevation models (DEM) of two distinct types of rocky coasts along the eastern English Channel (Picardy and Upper Normandy: PUN) and in a NE Atlantic area (SW Brittany: SWB) in NW France. The PUN linear coast exhibits 40–90-m-high and poorly fractured vertical chalk (soft rocks) cliffs (Mesnil-Val), whilst the SWB low-elevation coast consists of highly fractured basement granite (Penmarc'h) (Fig. 1). The onshore–offshore coastal DEMs reveal specific multi-scale morpho-bathymetric structures interpreted as paleo-coastlines. The combined analysis of onshore and offshore paleo-coastline markers represents a first step to evaluate modalities of long-term rocky coastline evolution during Holocene and Neogene, in close relation with shore platform morphology, lithology, and the geological context.

Fig. 1. (Color online.) A. Mesnil-Val coastal site (PUN coast), view to the south, with vertical chalk cliffs, up to ~90 m high, and its shore platform (Murons rocks, in the foreground). B. Loctudy site (SWB coast), view to the east, low-elevation granitic coast and its shore platform.

2. Data and methods

2.1. Airborne LiDAR data

PUN and SWB coasts were surveyed using airborne topographic LiDAR (RGEAlti®, IGN in 2011 and Litto3D® IGN/SHOM in 2012 respectively). We selected RGEAlti® LiDAR data south of Le Treport on a coastal surface 4 km long and 1.5 km wide (PUN coast), and Litto3D® LiDAR data along the southern coast of the Pays Bigouden peninsula (SWB coast), on a surface of about 130 km^2, with a length of 25 km from Penmarc'h headland (west) to Bénodet (east) and a width of about 5 km inland. DEMs built inland present a vertical accuracy of 20 cm and a 1-m spatial resolution (Fig. 2).

Along the SWB coast, a subtidal coastal bathymetry was partly acquired in 2012 using bathymetric airborne LiDAR (performed by IFREMER) in water depths varying from 0 m to 10–20 m, on a surface of about 80 km^2 covering the subtidal part of Penmarc'h platform (from Saint-Guénolé to Loctudy) and the Bay of Bénodet (from Loctudy to Bénodet). Submarine LiDAR DEM presents a vertical accuracy of 50 cm and a spatial resolution of 2 m.

2.2. GeoSwath Haliotis

In order to accurately image the subtidal part of the studied shore platforms, high-resolution shallow-water bathymetric data have been acquired using the R/V Haliotis (IFREMER) during the CROCOLIT 1, 2 and 3 surveys in 2013. We used GeoSwath interferometric sonar (from GeoAcoustics), which allows the acquisition of bathymetric data in very shallow water depths ranging from 5 m to about 100 m, with high vertical resolution varying from 20 cm for very shallow water depths to about 1 m for deeper water depths. Vessel navigation was achieved by RTK GPS (Real Time Kinematic Global Positioning System) using a reference station located at a distance less of 10 km on the coast, providing a positioning accuracy of a few centimeters. Sound velocity profiles were repeated daily in the vicinity to correct refraction errors. GeoSwath soundings were treated using CARAIBES software (©IFREMER) to clean and correct data from tide variations using correlations between SHOM hydrographic bathymetric reference,

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