Geomorphological Analysis and Characterization of Labadie Bank in the Celtic Sea

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R/V Celtic Explorer

ABSTRACT

As part of the INFOMAR program, the Marine Institute of Ireland and the Geological Survey of Ireland plan to have mapped the entire continental shelf surrounding Ireland using high resolution multibeam by 2020. One of the recent surveys was conducted aboard the R/V *Celtic Explorer* from July 22 to August 6, 2017. The study area was located off Ireland's southeastern coast. Sonar data were post-processed to generate bathymetric and backscatter intensity surfaces. Much of the study area is comprised of a large sand bar called Labadie Bank, where depths fluctuate between 63 m at the bank crest to approximately 135 m in surrounding basin. Labadie Bank has an elongate elliptical shape along with several geomorphological features, including four different types of large scours. These geomorphological features are clumped in study sites on different locations on Labadie Bank. The purpose of this study is to interpret the geomorphological features of the Labadie Bank region and to create a classification system for the four different scour types observable.

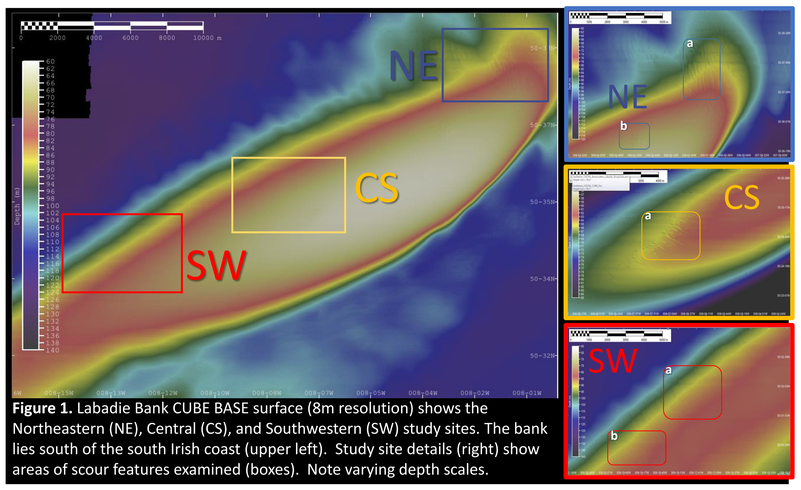


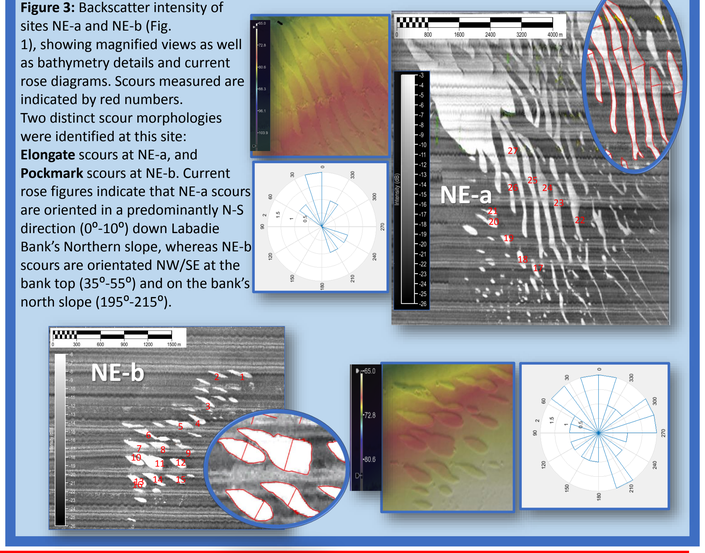
Figure 1. Labadie Bank CUBE BASE surface (8m resolution) shows the Northeastern (NE), Central (CS), and Southwestern (SW) study sites. The bank lies south of the south Irish coast (upper left). Study site details (right) show areas of scour features examined (boxes). Note varying depth scales.

BACKGROUND

Labadie Bank is an **IN**tegrated Mapping **FO**r the Sustainable Development of Ireland's **MA**rine **R**esource (INFOMAR) priority mapping area due to its impact on navigation and the regional fishing economy. The dynamic shape and size of this bank provide optimal conditions for fish habitat, while posing a possible navigation risk. With water depths ranging 63 to 137 m and an approximate length of 70km, this geographical feature interacts with currents and possibly storm wave bases. The interaction of this oblong, mounded bank with bottom currents was studied aboard the R/V *Celtic Explorer* (cruise CV1701) during a seabed mapping survey in summer 2017. Areas with relief in topography like Labadie Bank or Jones Bank are found to generate 'internal wave packets' as the topography interacts with seasonal stratified flows to result in mixing of the water column. This turbulence may lead to pockets of high productivity (Palmer et al. 2013). This mapping survey also revealed unique scour-like features along the flanks of the bank. These features were found on the northern half of Labadie Bank, and vary in size, orientation, and shape. The purpose of this study is to create a technique for the classification of these features and attempt to determine the factors responsible for the variations in shape and orientation.

North Eastern Study Site (NE)

Figure 3: Backscatter intensity of sites NE-a and NE-b (Fig. 1), showing magnified views as well as bathymetry details and current rose diagrams. Scours measured are indicated by red numbers. Two distinct scour morphologies were identified at this site: **Elongate** scours at NE-a, and **Pockmark** scours at NE-b. Current rose figures indicate that NE-a scours are oriented in a predominantly N-S direction (0°-10°) down Labadie Bank's Northern slope, whereas NE-b scours are orientated NW/SE at the bank top (35°-55°) and on the bank's north slope (195°-215°).



METHODS

- Kevin Sheehan was the chief scientist aboard the R/V *Celtic Explorer* for expedition CV1701 from July 22 to August 6, 2017 Multibeam sonar bathymetric and backscatter intensity data were collected using a Kongsberg EM2040 transducer.
- Post-processing was performed with CARIS HIPS 10.2 and 10.4 to create 3D images as well as an 8m CUBE BASE surface, profiles, and backscatter intensity surfaces (Fig. 3-5).
- Quantitative data were collected using Google Earth Pro and CARIS Hips and Sips 10.2.
- Scours were outlined, and numbered. A method of classification/measuring was created to record the features' geomorphologic data (Fig. 2).
- Statistical analyses were used to compare the geomorphic data (Fig. 7).

Measurement System

Along Axis Length (green) - length along the feature's (valley) axis
Crow Flies Length (red) - length from head to tail
Width (dashed white) - at the widest point, perpendicular to the 'Length'
Head Length (black arrow) - length from head to the 'width' line
Tail Length (black arrow dashed) - length from 'width' line to end of tail
Tail Angle - angle at which the tail 'opens'
Heading - orientation
Area - area covered by feature (m2)
Tail Width (white solid) - width of the tail halfway between the 'Width ' marker and the end of the tail
Sinuosity - along axis length/crow flies length

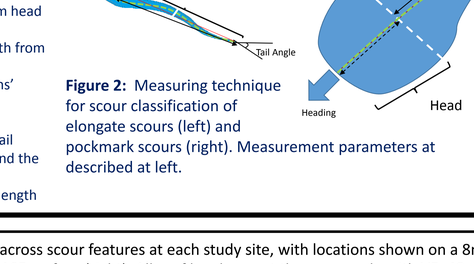
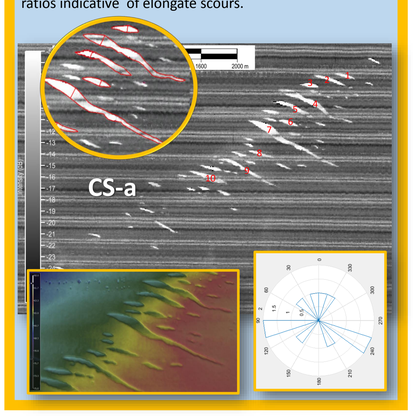


Figure 2: Measuring technique for scour classification of elongate scours (left) and pockmark scours (right). Measurement parameters at described at left.

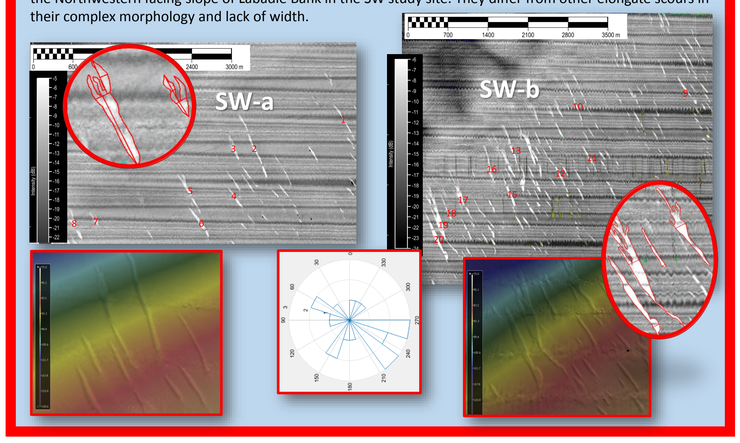
Central Study Site (CS)

Figure 4: Backscatter intensity of site CS-a (Fig. 1) with 3D bathymetry and a current rose diagram and magnified view depicts a third type of scour morphology. These scours are also **elongate** with headings in a predominant SE direction (235°-255°) near the central section of the bank top. They differ from elongate NE-a scours in sinuosity as well as overall size; and from NE-b scours due to length vs width ratios indicative of elongate scours.



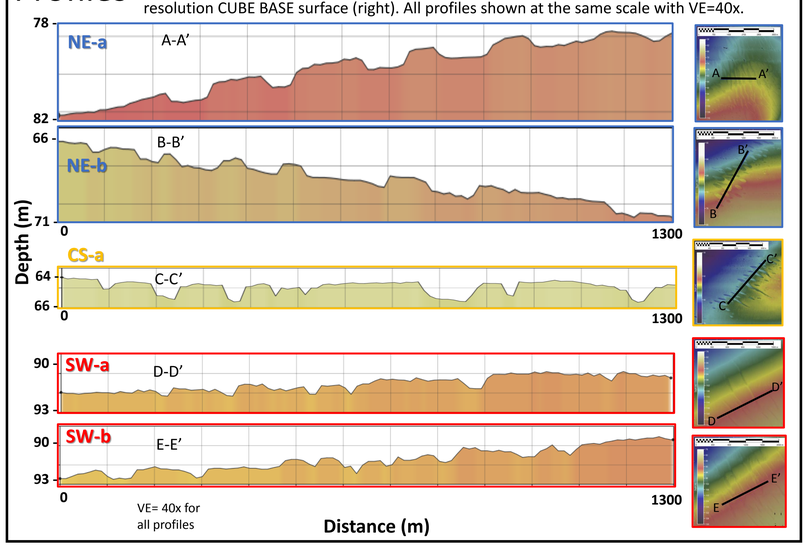
South Western Study Site (SW)

Figure 5: Backscatter intensities for SW-a and SW-b sites (Fig.1), showing 3D bathymetry and current rose diagrams as well as magnified views of the scours within the site. These scours are classified as **elongate** scours despite their complex morphology, which is similar regardless of the spread-out nature of the scour features. These elongate scours have headings in a predominantly SE direction (215°-235° or 250-270°) down the Northwestern facing slope of Labadie Bank in the SW study site. They differ from other elongate scours in their complex morphology and lack of width.



Profiles

Figure 6: Profiles across scour features at each study site, with locations shown on a 8m resolution CUBE BASE surface (right). All profiles shown at the same scale with VE=40x.

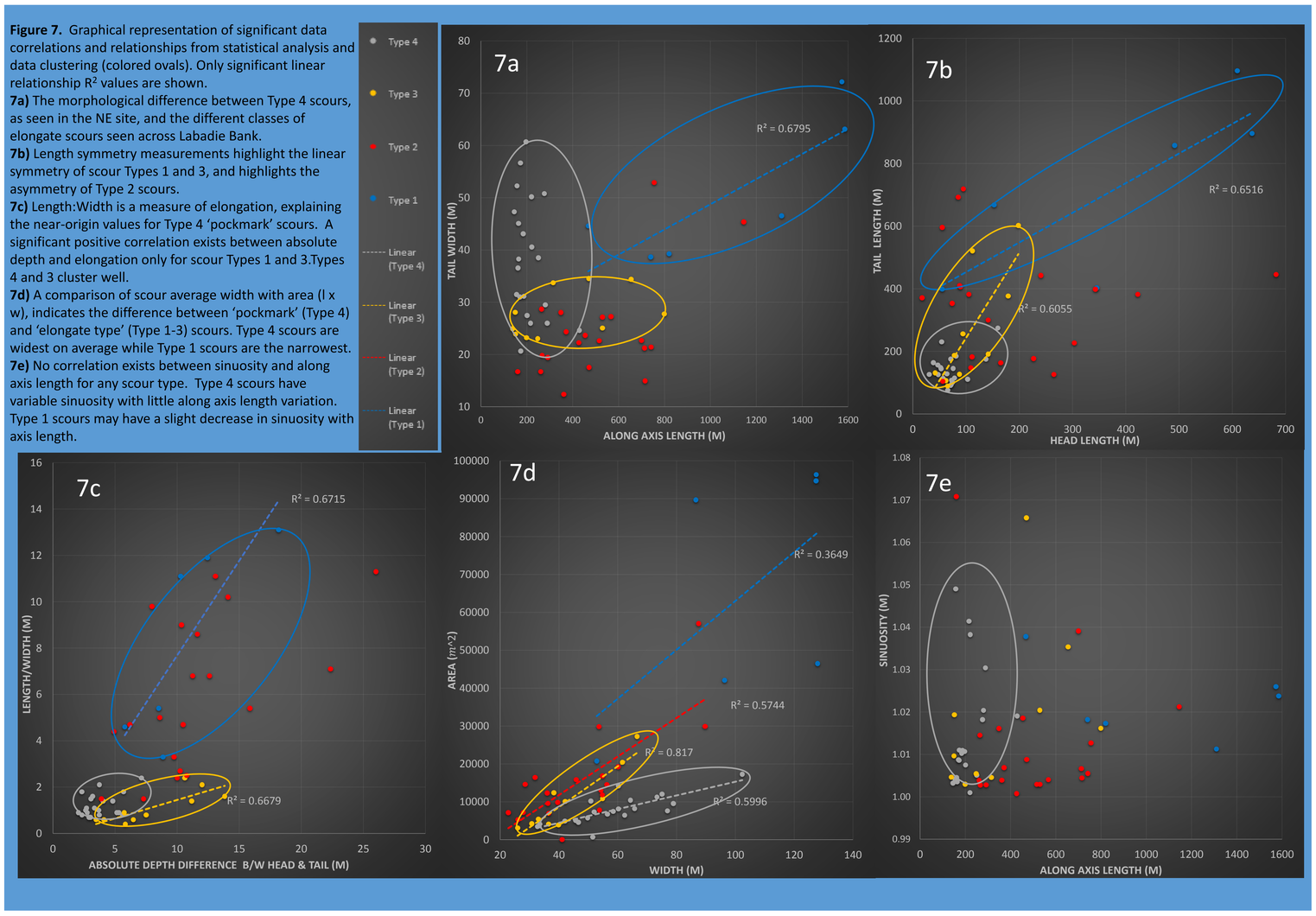


DISCUSSION

The purpose of this study was to analyze and characterize the erosional scour features found on Labadie Bank using their geomorphological characteristics (Figure 1). The scours were visually and quantitatively separated into either a 'pockmark' or an 'elongate' scour class, based on comparing numerous measured variables, some of which showed significant correlation (Figures 7a-d). For each of the variable comparisons, several of the scour types showed a clustering of data points, indicating distinct morphologic differences. Type 4 scours are teardrop or elliptically shaped, and are only present in the Northeastern study site, NE-b. The aesthetic 'greatest average width' attribute, is a major factor in 'pockmark' classification (Figures 5, 7 a/d, 8). The uniqueness of Type 4 scours is also seen in the fact that the profiles of the Type 4 scours show shallow, flat, scours similar to those of Type 1, though the relative lengths of these two different scour types are vastly different (Figure 6). Type 4 and Type 1 scours differ in length symmetry and sinuosity despite having similar profile shapes (Figures 6, 7 b/e). Type 1 scours are the outlier group of the elongate scours (Figures 7, 8), whereas Type 2 scours are extremely variable in most circumstances excluding their elongate shape (Figure 7d, 8). Length symmetry and area comparisons show Type 3 scours are the 'elongate scours' most similar to the 'pockmark' scour class (Figure 7b/c, 8). The similarity between Type 1 and 2 scours is observable as both are more elongate than Type 3 scours (Figure 8). Type 1-3 scours are morphologically unique from each other despite both being elongate class scours.

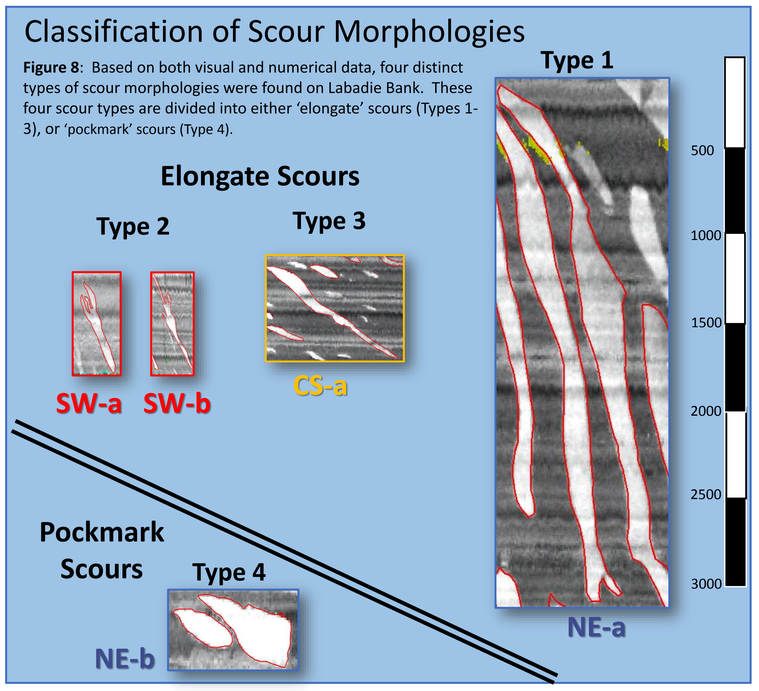
The size and similar orientations of the 4 different scour types suggests that these are erosional features associated with currents of a turbulent, seasonal or tidal nature (Figures 3-5). Werner and Newton (1975) suggested that an increase in water turbulence from current-shoal interactions can facilitate erosion and create scour marks. The USGS carried out studies on similar features discovered proximal to sand banks off Rhode Island's coast and found that the scours were likely to have been initiated by tidal currents ripping through the relatively shallow continental shelf waters, having been channeled by sand banks (Lawrence et al., 2016). Each scour type has a different predominant heading, as shown in the rose diagrams (Figures 3-5). These headings can be used to represent direction of ongoing erosion, and continued current interaction (Lawrence et al., 2016). The similarity of orientations at each site suggests that the different scours types may have been generated by currents specific to each study site (Figures 3-5 [rose diagrams], 8). The propagation of these scour marks can lead to scour features combining together, and perhaps different scour types may represent different stages in the evolution of larger-scale erosional features (Lawrence et al., 2016). The evolution of these scour features can be studied through the analysis and characterization of similar, proximal, scours. Further studies of interactions between scour types and scour propagation, could yield data crucial to understanding the directions and velocities of currents in this area, as well as the impact of current-bank interactions and their effects on the local biosphere.

Figure 7. Graphical representation of significant data correlations and relationships from statistical analysis and data clustering (colored ovals). Only significant linear relationship R^2 values are shown.
7a) The morphological difference between Type 4 scours, as seen in the NE site, and the different classes of elongate scours seen across Labadie Bank.
7b) Length symmetry measurements highlight the linear symmetry of scour Types 1 and 3, and highlights the asymmetry of Type 2 scours.
7c) Length:Width is a measure of elongation, explaining the near-origin values for Type 4 'pockmark' scours. A significant positive correlation exists between absolute depth and elongation only for scour Types 1 and 3.Types 4 and 3 cluster well.
7d) A comparison of scour average width with area (l x w), indicates the difference between 'pockmark' (Type 4) and 'elongate type' (Type 1-3) scours. Type 4 scours are widest on average while Type 1 scours are the narrowest.
7e) No correlation exists between sinuosity and along axis length for any scour type. Type 4 scours have variable sinuosity with little along axis length variation. Type 1 scours may have a slight decrease in sinuosity with axis length.



Classification of Scour Morphologies

Figure 8: Based on both visual and numerical data, four distinct types of scour morphologies were found on Labadie Bank. These four scour types are divided into either 'elongate' scours (Types 1-3), or 'pockmark' scours (Type 4).



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