Analysis of Structural Geomorphology in Ballycotton Bay Bedrock on the South Irish Coast

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INFOMAR; Marine Institute Foras na Mara; Geological Survey Suirbhéireacht Gheolaíochta Ireland | Éireann

BACKGROUND

Ballycotton Bay is located in Cork County, Ireland, approximately 18 km northeast of Cork Harbor. The Variscan (or Hercynian) Orogeny (~286 MA) was a Late Paleozoic collisional episode which caused folding and fracturing of the bedrock in the region (MacCarthy and Meere, 2004). Cooper and Trayner (1984) observed that the Variscan Orogeny deformed a sequence of Upper Devonian and Carboniferous sedimentary rocks and generated large upright eastward-plunging folds trending east-west. Additionally, the Cloyne Syncline arcs along the length of Ballycotton Bay, the result of the same deformational event.

Long term coastal erosion of Ballycotton Bay has occurred due to its location at the eastern end of the Cloyne Syncline (National Parks & Wildlife Service, 2014). Carboniferous limestone is found within the apex of the syncline, while the Red Devonian Sandstone, also known as the "Old Red Sandstone," is found on the syncline's limbs and along the apex of many of the regional anticlines (Davies and Whittow, 1975). The purpose of this study is to directly correlate the outcrop geomorphology of Ballycotton Bay to the known regional terrestrial bedrock outcrops in order to potentially identify the seabed rock formations. Classification of bedrock is possible by observing the relationship between patterns in fracturing and folding and character of the bedrock.

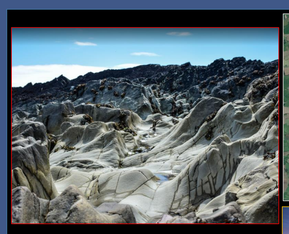


Figure 2. Images of Ballycotton Bay coastal geology depicting limestone in the inner bay with expected jointing (above) and Old Red sandstone (right) looking out to the Ballycotton lighthouse.

(Images from Google Photos)

RESULTS

Figures 4-5.

Site A:

- Multiple fractures are evident in the bathymetry, with a higher density occurring in the western region of study area A. These fractures reveal a consistent set of joints oriented at an angle of 41°.
- Within the eastern region, a higher occurrence of folding is observed, with the majority of these folds being smaller than those seen in site B (Table 1). Profiles do not reveal discernable patterns of fracturing.
- Classified backscatter indicates higher intensity sedimentary rock is present within the study site. Site A is within the southern limb of an arced pattern of higher intensity sedimentation, interpreted to be Old Red Devonian sandstone.

Site B:

- Compared to Site A, structural geologic features in this region occur in greater dimensions with the large upright plunging folds stretching an average of ~590m.
- The angles of the two large fractures (i.e., joints) occur at approximately 77° to one another. Profiles across and along the fold do not indicate significant fracture patterns.
- Lower backscatter intensity was observed for this portion of the seabed indicating less reflective substrate, which in this region would likely be limestone.

Site C:

- Blocky fracturing of the bedrock was observed to occur most frequently in this study site. The folds which persisted within study sites A and B were absent within Site C.
- Profiles revealed terracing in addition the jointing visible on the surface.
- Sedimentary rocks of the area show lower intensity values in backscatter intensity, suggesting the occurrence of carboniferous limestone.

ACKNOWLEDGEMENTS

This research would not have been possible without our academic partnership with CARIS. We are very grateful to our Irish colleagues of the Geologic Survey of Ireland, the Marine Institute of Ireland, and the crew of the R/V *Celtic Voyager* who collected the raw data utilized in this study.

caris

ABSTRACT

During April-May 2013, The Geologic Survey of Ireland, as a part of the INFOMAR project, conducted bathymetric surveys aboard the R/V *Celtic Voyager* on the southern coast of Ireland, northeast of Cork. Ballycotton Bay was surveyed using a Kongsberg EM3002 multibeam echosounder. Data collected were post processed using CARIS HIPS & SIPS 10.4 to create surfaces depicting bathymetry and backscatter intensity. The purpose of this study is to directly correlate the structural geomorphology of Ballycotton Bay to the known regional terrestrial bedrock outcrops in order to potentially identify the seabed rock formations. Observations of the seabed geomorphology were made using the bathymetric surface, revealing variances in structural geology in different regions of the bay. Potential transitions between the Cloyne Syncline and its adjacent Ballycotton Anticline were detected and correlated with terrestrial geology maps.

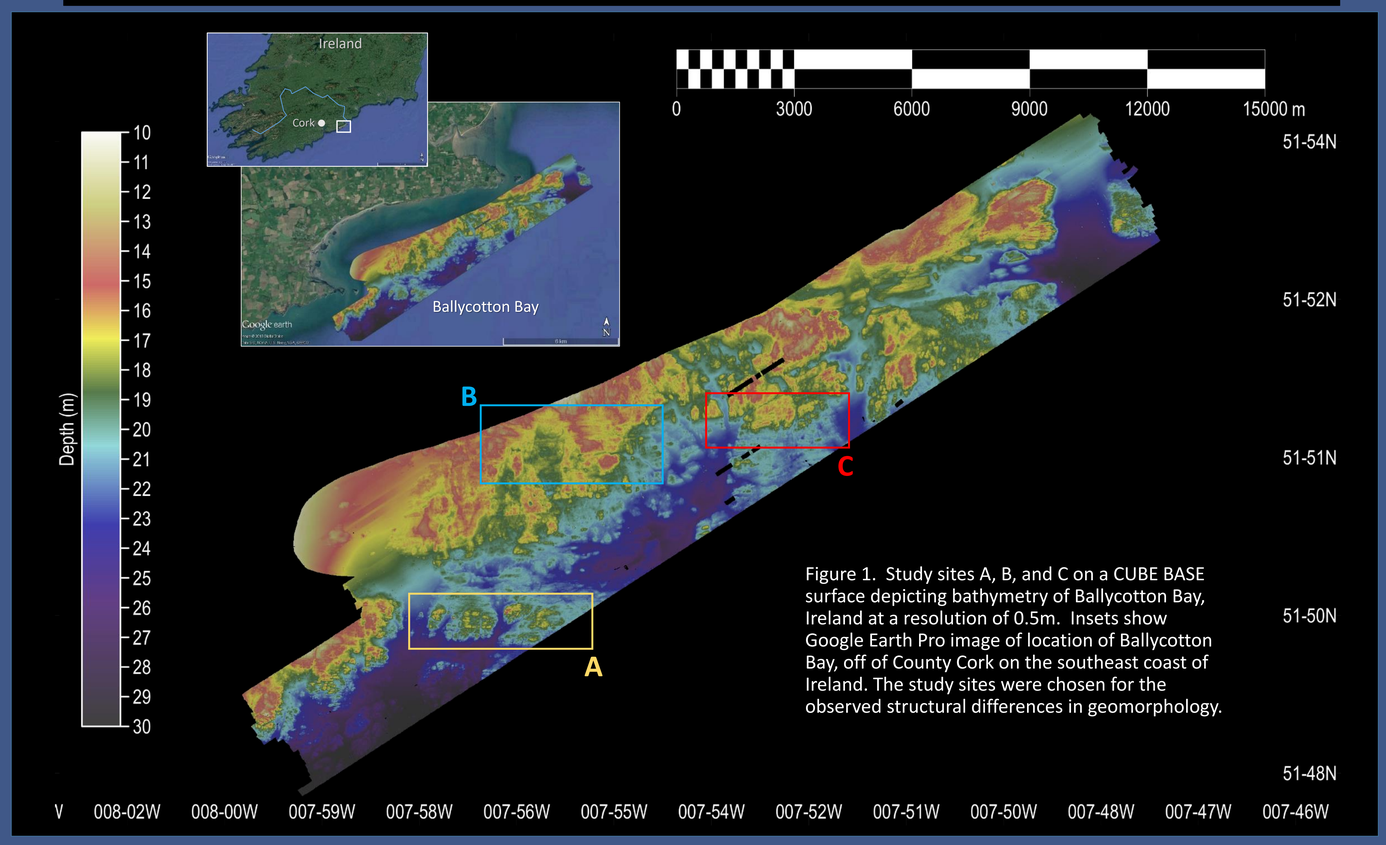


Figure 1. Study sites A, B, and C on a CUBE BASE surface depicting bathymetry of Ballycotton Bay, Ireland at a resolution of 0.5m. Insets show Google Earth Pro image of location of Ballycotton Bay, off of County Cork on the southeast coast of Ireland. The study sites were chosen for the observed structural differences in geomorphology.

METHODS

- Data were collected as part of Ireland's INFOMAR program using a Kongsberg EM3002 multibeam sonar echosounder aboard the R/V *Celtic Voyager*. The survey took place from 04/22/13 to 05/31/13 and was led by the Geological Survey of Ireland (GSI).
- Raw sonar data were post-processed and analyzed utilizing the CAIRIS HIPS and SIPS 10.4 software, generating a 0.5m resolution CUBE surface, 3D renderings, and bathymetric profiles.
- A 2m GeoCoder backscatter intensity mosaic was generated to classify the bedrock substrate character.
- The regional structural geology of the bay was examined through comparison between the bathymetric surface and the terrestrial geologic maps created by the Geological Survey of Ireland (Geologic Survey of Ireland, 2017).
- Google Earth Pro was used to measure the orientation of structural features on the bathymetric surface.

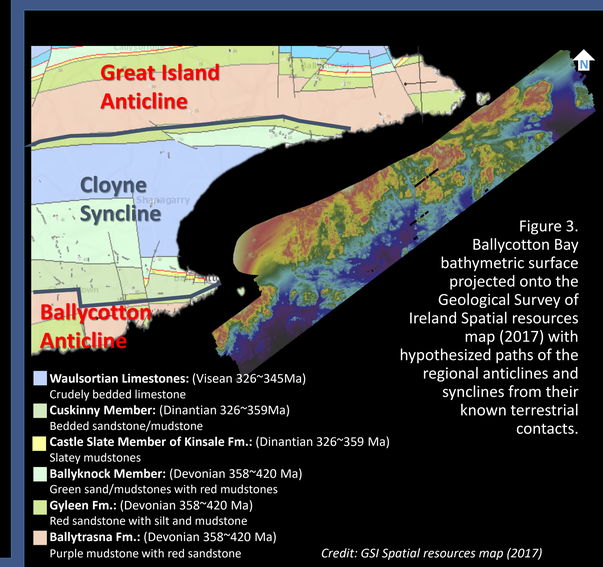
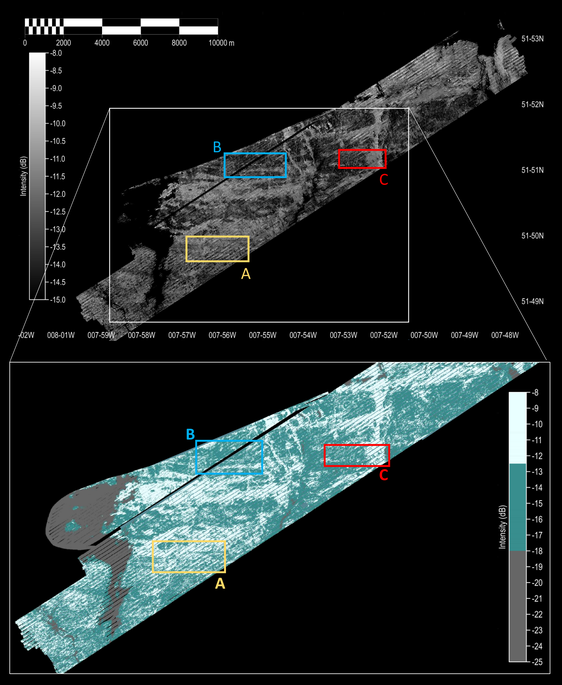


Figure 3. Ballycotton Bay bathymetric surface projected onto the Geological Survey of Ireland Spatial resources map (2017) with hypothesized paths of the regional anticlines and synclines from their known terrestrial contacts.

Figure 4A (below, top). Study Sites A-C are shown on a Geocoder Backscatter surface illustrating intensity of seabed substrate at 2.0m resolution.
Figure 4B (below, bottom). Geocoder backscatter classified to depict locations of highest intensity substrates. Higher intensity (white areas) is indicative of harder substrate, which, regionally, would be Devonian Old Red Sandstone. Lowest intensities (gray areas), are indicative of unconsolidated sediment.



Site	Avg. Fold Length (m)	Avg. Fracture Angle (°)
A	141.03	41.41
B	589.89	76.75
C	N/A	82.72

Table 1. Average measurements of folds and fractures from each site were recorded for comparison of the structural features. Within the sites, radii of the folds produced similar values, Site B trending averaging larger folds. Fracture angles which were trending northeast-southwest were measured, angles increasing in an easterly direction.

REFERENCES

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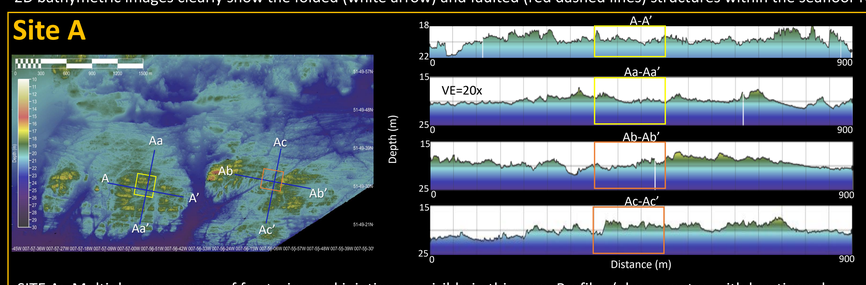
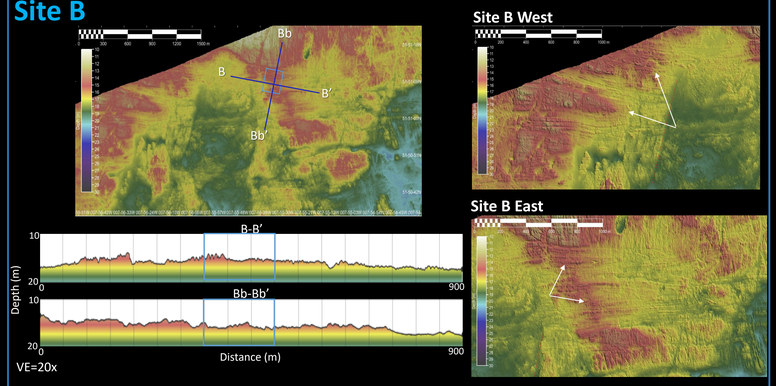
Figure 5. Cross-sectional profiles were made for each study area and a subset was highlighted from 350m-500m. The profile and subset locations are shown on the 2D surfaces. Enhanced 2D bathymetric images clearly show the folded (white arrow) and faulted (red dashed lines) structures within the seafloor rocks each at VE=4x.

Site A



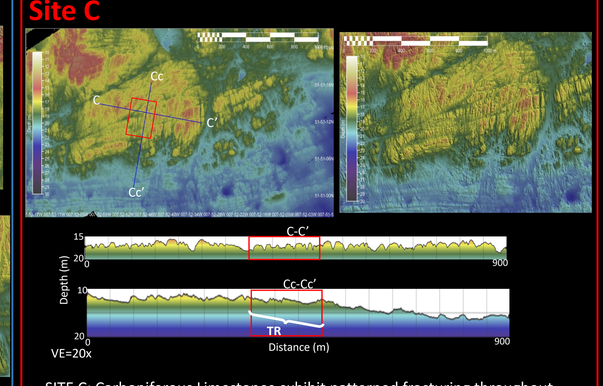
SITE A: Multiple occurrences of fracturing and jointing are visible in this area. Profiles (above center, with locations shown at left) do not show patterns in fractures. 2D images of the bathymetric surface show the folded features on the southern region of Ballycotton Bay. The western area of the study site reveals multiple incidences of consecutive fractures while folds occur more frequently in the eastern zone. Additionally, two large fractures are observed within the eastern zone.

Site B



SITE B: Differing from the folds observed in Site A, these large upright plunging folds stretch across joints which fractured at a high angle. The eastern region in this study site presents longer, undulating folds. Consecutive fractures found in Site A are absent at this location. Profiles (bottom-left) do not show significant patterns in fractures.

Site C



SITE C: Carboniferous Limestones exhibit patterned fracturing throughout the central region of the bay. The semi-linear blocky joints are reflected in the profiles (bottom) as well as terracing (TR). Folded beds are absent within the area.

DISCUSSION and CONCLUSIONS

Through correlation of the terrestrial geology documented by the Geological Survey of Ireland with the bathymetry and backscatter intensity, a hypothesis of the location of the marine extension of local anticlines and synclines can be created (Fig. 6). Areas of Ballycotton Bay exhibiting lower intensity backscatter, along with the blocked fracturing patterns are consistent with limestone. Zones of higher intensity, where profiles reveal little correlation in the fractures are hypothesized to be Old Red Devonian sandstone. This formation is the oldest regional sedimentary rock, known to be highly resistant to erosion, and thus, is likely to be the most reflective lithology. Ballycotton Bay's persisting erosion of its interior, found in this study to be limestone, substantiates the belief that the regional geology is shaping the bay's shape. Reflective of extant structural literature on anticlines, Ballycotton Bay's bedrock progression transitions from older substrate, along the high intensity arc outlined in Table 1 to the lower intensity, younger, substrate.

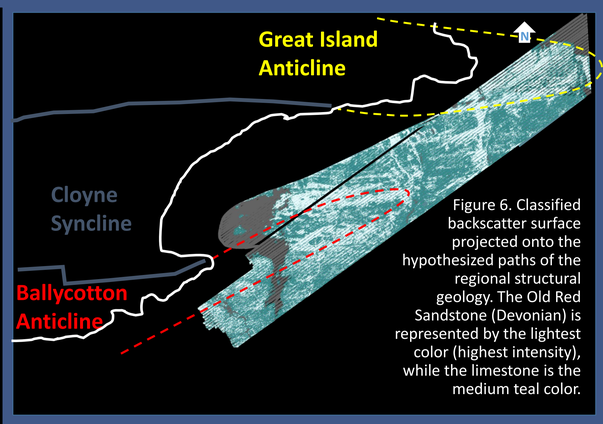


Figure 6. Classified backscatter surface projected onto the hypothesized paths of the regional structural geology. The Old Red Sandstone (Devonian) is represented by the lightest color (highest intensity), while the limestone is the medium teal color.