Structural Mapping and Geomorphology of Ireland’s Southwest Continental Shelf Using High Resolution Sonar

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ABSTRACT

Bathymetric surveys were conducted on the continental shelf off the southwest coast of County Cork, Ireland by the Marine Institute of Ireland, the Geological Survey of Ireland, and the INFOMAR project. Data were collected from July 2006 through September 2014 using a Kongsberg EM2040 multibeam echosounder aboard the RVs Celtic Voyager and Keary, and a Kongsberg EM1002 on the RV/Celtic Explorer. Sonar data were post-processed with CARIS HIPS and SIPS 9.0 to create 2D and 3D bathymetric and backscatter classification surfaces. The offshore study site is part of the 286 Ma western Variscan orogen front and has several massive outcrops. These outcrops were structurally mapped and relatively aged, and exhibit significant deformation and fracturing. Google Earth, ArcGIS, and previous terrestrial studies were used to further analyze how geomorphology is controlled by seafloor composition and structural features. Rock type and age were interpreted by comparing fracture analysis and backscatter classification of the joints and folds to similar onshore outcrops, to determine an age of 416-299 Ma for the shelf’s outcropping strata and associated structural features. The oldest features observed are 1st order anticlines and synclines containing Upper Devonian and Lower Carboniferous beds. Within the Devonian layers are NE-SW plunging 2nd and 3rd order folds. Jointing is observed in all layers and is superimposed on folding, with some joints appearing to be pre-Variscan. Rotation of the regional folds is the youngest structural feature, as both the 2nd and 3rd order folds and rock fractures are warped. Our study shows that high resolution sonar is an effective tool for offshore structural mapping and provides an important resource for understanding the geomorphology and geologic history of submersed outcrops on continental shelf systems.

BACKGROUND

County Cork is a geologically complex area that has experienced varying tectonic regimes since the Devonian. Following the Ordovician Caledonian Orogeny, north-south extension in the Middle and Late Devonian (387 mya) formed the Bantry and Kinsale Sub-Basins (Fig. 2a) (MacCarthy, 2007). Subsidence of the region and continued extension is displayed in a fining upward marine transgression in the stratigraphic sequence (Fig. 2b) (Higgs, 2000). In the Late Carboniferous, the Munster Basin experienced extensive N-S compression during the Variscan Orogeny which formed regional anticlines and synclines, and a complex system of rock fractures (Fig. 2c) (Naylor, 1978). Erosion from post-Variscan weathering and two glaciation events has exposed joint sets and deposited quaternary sediments in topographically low areas.

METHODS

- Bathymetric surveys were conducted by the Marine Institute of Ireland, the Geological Survey of Ireland, and the INFOMAR project from July 2006 - September 2014.
- A Kongsberg EM2040 multibeam echosounder aboard the RVs Celtic Voyager and Keary, and a Kongsberg EM1002 on the RV/Celtic Explorer were used to collect bathymetry and backscatter data.
- The sonar soundings were processed to create 2D and 3D bathymetric and backscatter classification surfaces using CARIS HIPS and SIPS 9.0 software.
- Onshore and offshore joint, fault, and fold data were collected using ArcGIS 10.3 using the ESRI World Imagery Basemap and the Geologic Survey of Ireland 1:100k Geologic Basement shapfile.
- Joint data were plotted in rose diagrams using Steinmetz 9 software.
- A proposed offshore map showing first order folds, faults, and basement rock type was created in ArcGIS 10.3 based on merged data from the study.

RESULTS

- First, second, and third order folds and faults are measurable on the bathymetric surfaces (Fig. 3 A-E).
- Angle between different joint sets and bedding ranged from ~90° to ~80° (Fig. 4).
- Offshore joints were visible in the bathymetry and were significantly longer than onshore joints (Figs. 6, 7 A, F, & 9 J).
- Shallower outcrops with the highest intensity backscatter return displayed visible structural features, while deeper surrounding areas with a lower return had a homogenous surface (Fig. 8 A-D).
- Relationships were found between onshore and offshore basement rock type, joint heading, and preservation level (Figs. 5 & 9 A-L).

DISCUSSION

Geologic maps are a useful tool for understanding a region’s climatic and geologic past; however, offshore structural analysis has previously been nearly impossible due to bedrock inaccessibility. Study results indicate that bathymetric surveys using high resolution sonar provide sufficient data for offshore structural analysis through rock type identification and feature correlation. Where quaternary sediment has not been deposited, offshore rock fractures were better preserved than onshore equivalents, making them easier to identify (Fig. 9 J-L). Patterns between joint heading, bedrock preservation extent, and folds offshore can be correlated with offshore features to identify rock layering and propagation consistent with the region’s geologic past (Breese M, Sautter L, 1999, Fig. 9 A-L). Relative age of structural features can also be determined in bathymetry using the Law of Cross-Cutting Relationships (Fig. 4). Coring and further research from future surveys would ground truth and accurately the accuracy of bathymetric structural analysis.

REFERENCES