Geomorphology of the Southwest Coast of County Cork, Ireland: A Look into the Rocks, Folds, and Joint Systems

Shelby Bowden, Rachel Wireman, Dr. Leslie Sautter, and Dr. Erin Beutel
College of Charleston Department of Geology and Environmental Geosciences

INFOMAR Integrated Mapping for the Sustainable Development of Ireland's Marine Resource

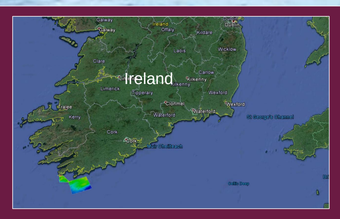
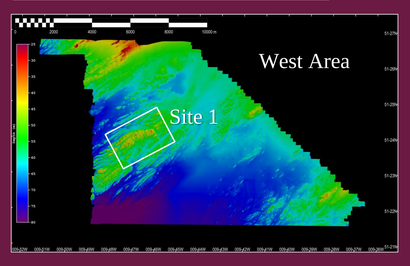
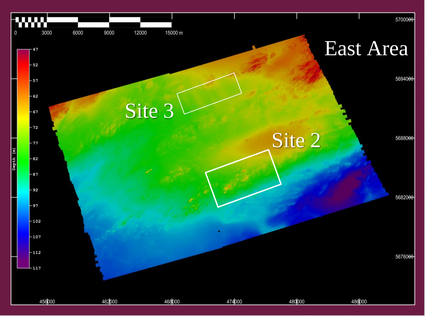


Figure 1: Google Earth image (left) showing location of two adjacent study areas (West and East) off the southwestern coast of Ireland.
1m CUBE BASE surfaces (below) of the two adjacent study areas (West and East), showing Sites 1, 2 and 3.





Abstract

Bathymetric data were collected off the southwest coast of County Cork, Ireland by the Marine Institute of Ireland's INFOMAR project. Data were collected using a Kongsberg EM2040 multibeam sonar on the R/V *Celtic Voyager*, in August and September 2014, and were post-processed with CARIS HIPS and SIPS 8.1 and 9.0 software to create 2D and 3D bathymetric surfaces. From the computer generated images, some of the lithologic formations were relatively aged and observed. The studied regions range in depth from 20 to 118 m, with shallower areas to the northeast. Several large rock outcrops occur, the larger of which shows a vertical rise of nearly 20 m. These outcrops are oriented in a northeast-southwest direction, and exhibit significant bed folding, regional folding, tilted beds, and cross joints. The folds studied are plunging chevron folds. These folds have a northeast-southwest fold axis orthogonal to the cross joints and are older relative to the jointing systems. The NE-SW joints are older than the NW-SE joints due to their correlation with drainage and erosion patterns. Regional folding is the youngest feature due to its superposition on the chevron folding and jointing systems. The interaction of cross jointing and folding is consistent with the geologic history of the area, and creates a unique bathymetry worthy of further study.

Methods

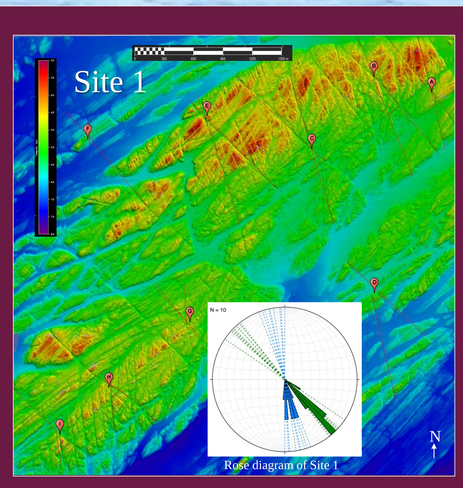
- Data for this research were collected using a Kongsberg EM2040 multibeam sonar aboard the R/V *Celtic Voyager*, from 08/30/14 to 09/18/14.
- The raw sonar soundings were processed and analyzed using CARIS HIPS and SIPS 8.1 and 9.0 software.
- Two 1m resolution CUBE BASE surfaces and profiles of the major vertical changes were made of the entire project and the main data collection sites in order to analyze the geomorphological aspects of the area.
- Backscatter mosaics of targeted study areas were made to analyze drainage patterns and hardness of sediment.
- Structural joints, tilted beds, and folding consistent with this region's geologic past were observed using the tools in HIPS and SIPS 8.1 and 9.0.
- Google Earth was used to measure, orient, and compare lithographic features on the base surfaces.
- Stereonet was used to create the rose diagrams.

Background

The southeastern coast of Ireland off of County Cork has experienced many different deformational events that have caused folding and fracturing of a variety of ages. Known deformational events include Variscan Orogeny around 286 MA, which resulted in up to 50% shortening (Cooper et al., 1985) and northeast trending fold belts of siliciclastic sedimentary rocks.

Observed in our study area is a series of joints superimposed on the folds and tilted beds similar to those observed onshore by Bai et al. (2000), who showed that the NW trending set of joints was formed during the Variscan but post-folding. Nenna and Atilla (2011) showed that NNE trending joints are perpendicular to the fold axes and formed as a result of regional stresses imposed on the area in more recent local folding events. The offshore relationship among the tilted beds, folding, fracturing, and drainage patterns has not been previously investigated.

Figure 2: Joint Structures at Sites 1 and 2. Measurement paths of joint heading and joint angle to bedding for Sites 1 and 2 were created in Google Earth. Rose diagrams displaying the joint headings for each site (Tables 1 and 2) are shown as insets. Blue bars are NE-SW joint and green bars are NW-SE joints.



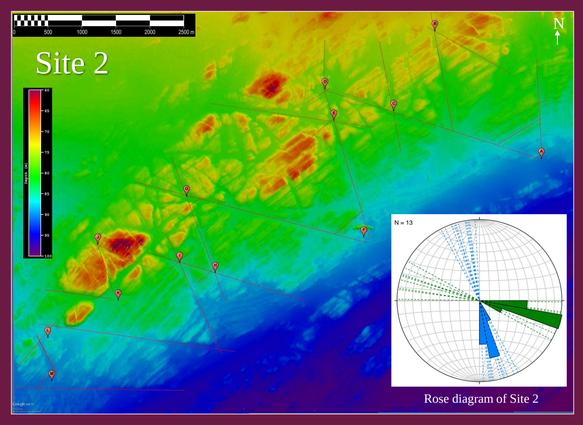
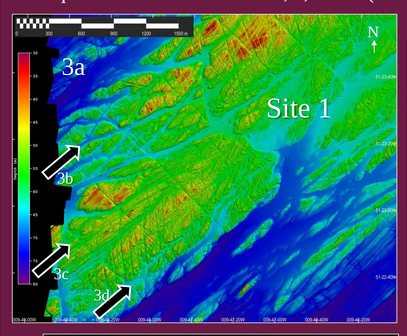
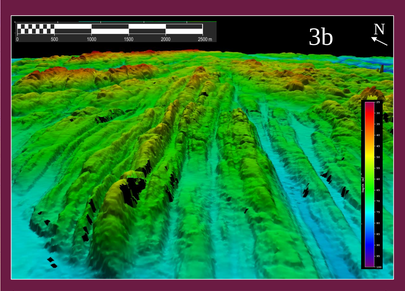
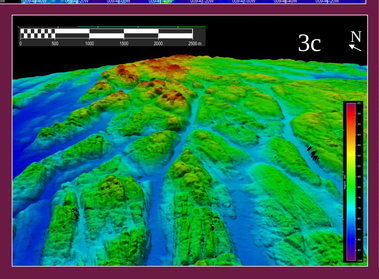


Figure 3: a) Aerial view 3D image (VE: 2.7x) of Site 1 on West Base showing the jointed and plunging folded beds. Black arrows indicate locations of accompanying oblique 3D views shown in 3b, c, and d (VE=2.7x).







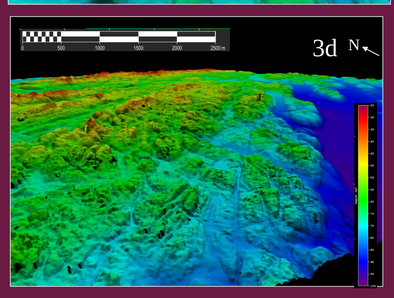


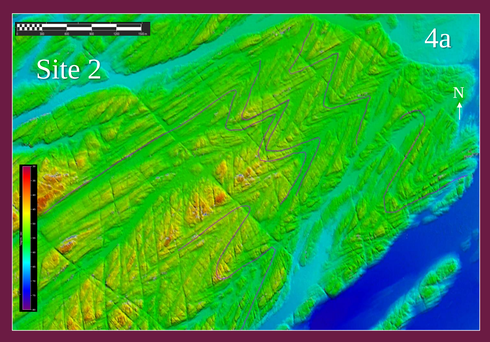
Table 1: West Base NE-SW and NW-SE joint headings and angles between the joints and bedding (Site 1)

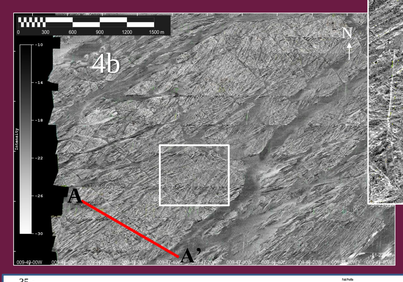
	A	B	C	D	E	F	G	H	I
NE-SW Joint (°)	167	159	164	168	162	176	180	177	171
∠ b/w bedding and joint (°)	67	75	73	77	71	61	61	51	60
NW-SE Joint (°)	142	141	133	134	135	138	138	124	132
∠ b/w bedding and joint (°)	92	93	103	111	97	98	103	104	99

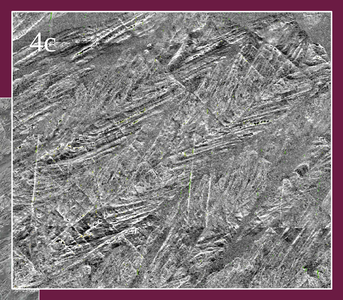
Table 2: East Base NE-SW and NW-SE joint headings and angles between the joints and bedding (Site 2)

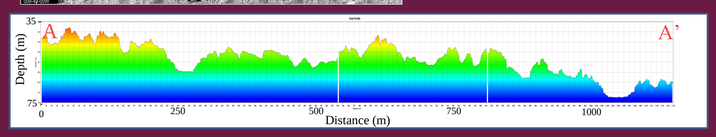
	A	B	C	D	E	F	G	H	I
NE-SW Joint (°)	177	170	170	163	163	163	160	160	155
∠ b/w bedding and joint (°)	62	65	60	74	66	67	71	69	73
NW-SE Joint (°)	108	119	109	109	99	105	105	107	107
∠ b/w bedding and joint (°)	131	116	121	128	131	125	124	122	122

Figure 4: a) 2D image of Site 2 showing the plunging chevron folds. b) 2D backscatter image (with detail inset 4c) of West Base showing location of profile A-A' (below). The profile shows the vertical relief across the folds and joints.









Results

- Plunging chevron folds are visible on the western edge of West Base surface at Site 1 and range from 40 to 60 m in depth (Fig. 3).
- Joints with interlocking sets in the East Base exhibit an average interlimb angle of ~60° while joints on the West Base exhibit an average interlimb angle of ~30°, as shown on the rose diagrams in Figure 2.
- The angle between joints across each base remains relatively constant throughout the regional folding as does the angle between the joints sets and the bedding (Tables 1 and 2)
- Drainage patterns visible on backscatter images (Fig. 5) correspond with NE-SW joint headings (Table 3).

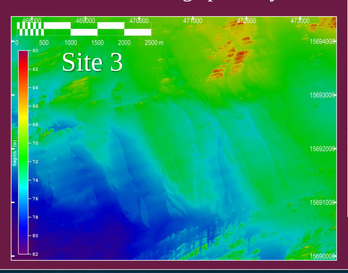
Table 3: NE-SW joint and drainage headings.

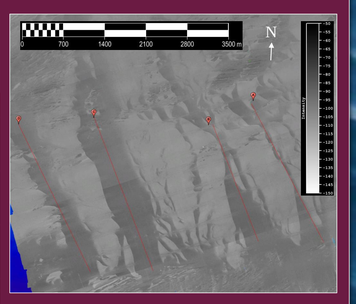
NE-SW Joint	Joint Heading (degrees)	Line	Drainage Heading (degrees)
H	159.6	A	156.17
I	155.34	B	155.81
J	162.23	C	159.66
K	162.75	D	154.86

Discussion

From the results of the study, the relative ages and formational processes of the southwest coast of County Cork, Ireland were observed. The oldest feature studied was a series of highly deformed chevron folds located in the shallower (40-60 m depth) areas of the West Base surface, likely to have formed from southeast to northwest compression (Bresser and Walter, 1999). These folds were seen to be plunging and tilted with a fold axis in the northeast to southwest direction (Fig. 4a). The relative ages of the folds were determined by cross cutting relationships of other features studied (Fig. 2). The second oldest feature was the cross jointing sets seen throughout the study area. The older set is oriented in a northeast to southwest direction, while the younger set is northwest to southeast (Fig. 2). The older age of the northeast to southwest set was determined by its correlated headings with drainage runoff which follows the joint sets as opposed to preexisting beds. Additionally, these joints have greater relief, which indicates more erosion due to earlier formation (Table 3). Although the angle between the two joint sets in the East Base (~60°) is greater than in the West Base (~30°), the angle remains relatively stable throughout each respective study area, while the joint set headings change. Likewise, the heading of the bedding orthogonal to the joint sets changes while the angle between the bedding and the joints remains stable (Tables 1 and 2). The stable angle indicates that the joint sets and bedding rotate across the study areas as a unit, and that regional folding occurred after jointing. Beginning during the Variscan Orogeny 286 Ma, southeast to northwest compression formed chevron folds, which were plunged and tilted. Stretching formed two sets of joints that crossed each other at angles consistent with their sediment composition. Finally, compressional forces caused regional folding that affected the folds and joints.

Figure 5: Site 3's bathymetry (below) shows large, low relief sand bodies. The backscatter (right) image indicates that the low areas are drainage pathways. Headings (red lines)shown on the backscatter image correspond to regional NE-SW joint systems (Table 3).





Rachel Wireman
Shelby Bowden

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References

Bai, T., Maerten, L., Gross, M., and Aydin, A., 2000, Orthogonal cross joins: do they imply a regional stress rotation?: Journal of Structural Geology, v. 24, p. 77-88.

Bresser, G., and Walter, R., 1999, A new structural model for the SW Irish Variscides: The Variscan front of the NW European Rhenohercynian: Tectonophysics, v. 309, p. 197-209.

Cooper, M., Collins, D., Ford, M., Murphy, F., Trayner, P., and O'sullivan, M., 1986, Structural evolution of the Irish Variscides: Journal of the Geological Society, p. 53-61.

Nenna, F., and Aydin Atilla., 2011, The role of pressure solution seam and joint assemblages in the formation of strike-slip and thrust faults in a compressive tectonic setting; The Variscan of south-western Ireland: Journal of Structural Geology, p. 1595-1610.