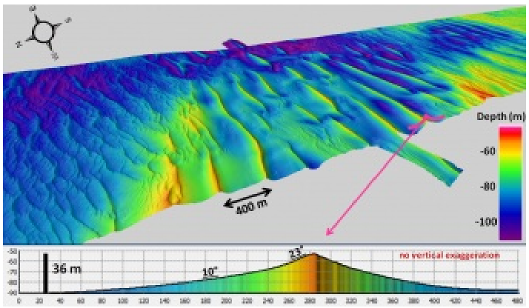
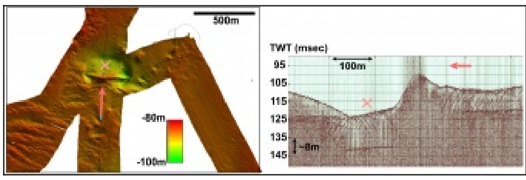
UNDERSTANDING BIG SAND WAVE BEHAVIOUR

Amplified Sediment Waves in the Irish Sea (AmSedIS)





Large sediment waves are striking yet poorly understood seabed features in many shelf seas. Very large sediment waves (3–18m in height) have been documented to migrate up to 70m per year in the Irish Sea and some sand waves reach heights of up to 36m (Figure 1). Such transport of enormous sediment volumes can endanger the stability of submarine pylons, cables and pipes and they cause a highly mobile benthic habitat.

To understand the dynamics of these sediment waves, we identified that we need to focus our investigation on the effects of sediment grain size variability, the availability of mobile sediment and gas seepage.

Amplified Sediment Waves in the Irish Sea (AmSedIS)

As part of the AmSedIS project, a team of marine geoscientists, geochemists and numerical modellers from the UK, Italy, Switzerland and Ireland embarked on an 11-day survey on the RV Celtic Voyager in April 2012 to survey various sites in the Irish Sea.

We set out to

1. Investigate the role of sediment grain size distribution and sediment availability on both ‘extreme’ and ‘normal’ sediment wave development and
2. Investigate the potential association of methane derived carbonate formation with extreme sediment wave growth.

The dataset collected includes swath bathymetry data, boomer and sparker seismic profiles, CTD transects, water sampling and Shipek grab sampling in transects over the sediment waves.

The Survey and the Equipment

The RV *Celtic Voyager* is a 31.4m multi-purpose research vessel. The vessel's wet, dry and chemical laboratories were used extensively by the 7 to 8 scientists on board. The horizontal accuracy of the swath bathymetry data is mostly defined by the vessel’s positioning system. The *Celtic Voyager*'s position is monitored with a Trimble NT Differential GPS and Kongsberg Simrad Seapath 200 motion reference unit (IMU). The dGPS gives a positional accuracy of less than 1m and data for attitude (pitch, roll and heave) via the IMU have accuracies of 0.03% or 5cm, whichever is greater. The combined horizontal error will therefore be 1.1m at its absolute maximum, which is satisfactory for our indicative measurements in this study.

The Multibeam Echo sounder is a Kongsberg Simrad EM1002. During the survey the frequency was 95kHz, with a ping rate of ~208Hz and a beam angle of 65° on both port and starboard side, giving a seabed footprint of maximum about 4.3 times the water depth. Acquisition was done via Kongsberg's Seafloor Information System (SIS) version 3.8.3.

Overall the EM1002 and SIS performed well. The SIS PC crashed on 3 to 4 occasions, the EM1002 once. The DB error bug occurred once and the READ ME file on the desktop resolved this error. These crashes often occur when plugging in a USB storage device whilst pinging and logging.

Water depths in this study have been reduced to lowest astronomical tide (LAT). Tidal information was provided by tidal model runs from the National Oceanography Centre, Liverpool (previously Proudman Oceanographic Laboratory) for the various survey sites, using licensed POLPRED software.

Also, a Kongsberg Simrad EA400 Single beam hydrographic echo sounder (SBES) was used, with transducers at frequencies of 38kHz and 200kHz. The system performed well, used and logged in tandem with the EM1002 at both frequencies.

An IKB-SEISTEC™ boomer seismic profiler was provided by Bangor University, with a Delph seismic acquisition system (Figure 3). The general towing speed was 3 knots; it was towed 5m aft of starboard quarter. Shots of 175J were repeated with 4Hz, at a sampling frequency of 24kHz. The system performed well.

A Geo-Source 400 1.5kJ FW sparker seismic profiler was provided by Geo Marine survey systems, with a Mini-Trace 2 duo-channel 24-bit GeoSuite seismic acquisition system. A 1.5kJ Geo-Pulse power supply fed a 200 tips -Geo-Spark pulse source and an 8 elements mini-streamer towed behind the vessel receives the signal. The towing configuration was a source 5m aft of centre, and a receiver 10m aft of starboard quarter. The shot repetition rate was 1Hz with a Sampling frequency of 10kHz. The system performed well, even in very poor weather.

In addition, a CTD profiler with O_2 sensor and rosette water sampler with 12 Niskin bottles was used (Figure 4).The CTD was used for vertical and horizontal profiling, performing well. The files were processed to include as many output variables as possible: water depth, density, pressure, salinity, temperature, position, O_2 concentration and saturation, transmission, fluorescence, sound velocity, conductivity, plume anomaly, specific volume anomaly, and thermosteric anomaly.

A Duncan & Associates Shipek sampler was used to sample seafloor sediments. The sampler scoops a sediment sample from the top 10cm of the seabed. Live clams sitting on the surface of a sample acknowledged the undisturbed nature of the sample with preservation of original seabed layering. The Shipek grab was deployed on the starboard winch mid-ship and performed very well.

Preliminary Results

1. The crests of unusually high and trochoidal sediment waves still migrate over several metres per year. Repeated swath bathymetry data permits sediment wave sizes and migration rates to be documented. Sediment waves of all sizes typically migrated a few metres per year, locally amplified where currents are deflected around regional bathymetric changes. In the deep central Irish Sea, the largest of Irish Sea sediment waves (25–36m high - Figure 1) are still mobile. The migration of the lateral sediment wave edges is usually significantly higher than the migration of the highest part - the middle part- of the sediment wave. These lateral edges thus seem important in the overall sediment transport mechanism from one bedform to another.
2. Unusually high and trochoidal sediment waves consist of coarser, more poorly sorted sediments in comparison to the ‘normal’ sediment waves. From 22 sediment waves in various places of the Irish Sea, sediment grabs were collected in transect and analysed for variations in grain size distribution. The coarsest sediments -coarse sands to fine gravels- are found in the central Irish Sea, where also the largest bedforms occur (Figure 1). Particle size distributions of sediments of the trochoidal sediment waves are multi-modal, while the neighbouring ‘normal’ sediment waves are mostly composed of uni-modal sediments. With likely stronger currents in the past, perhaps the initially poorly sorted sediments would have strengthened sediment wave growth due to the hiding-exposure effect. This effect occurs where larger grains ‘stick out’ in a mixture of sediments and as they are more exposed, they are more easily picked up (‘entrained’) by the flow. The smaller grains in between the larger grains are relatively hidden and are not entrained as easily as you would expect. This hiding-exposure effect alters the threshold of entrainment of differently sized sediment and favours the mobility of the coarser sediment fraction.
3. Methane seepage may not be a factor in extreme sediment wave development. Some bad luck stood in the way of collecting vibrocores, which would have provided more conclusive data. However, the surficial sediments from the unusually high sediment waves in the Irish Sea did not contain methane-derived authigenic carbonates (MDACs). Neither the sediments nor the water column showed any increase in methane concentrations compared to background values. In the Croker MDAC slabs (Special Area of Conservation in the central Irish Sea), shallow gas was clearly observed underneath sediment waves (Fig. 5). High concentrations of methane were found near sediment waves, but no increase in methane values were found in the actual sediments that make up the unusually high sediment waves.
4. The excess of mobile sediment supply seems to allow for ‘extreme’ sediment wave growth, and is linked to palaeo-tunnel valleys and the finer sediments that fill them or with converging sediment transport pathways. The spatial relationship of tunnel valleys (as delineated by the British Geological Survey) and unusually high sediment waves suggests that the infill of flooded landscapes scoured by glacial processes in the Irish Sea increases the amount of mobile sediment available for sediment wave formation.
5. The variation in sediment from sediment wave trough to crest to trough will form the basis for more advanced numerical modelling. Our dataset is envisaged to allow for more advanced numerical modelling of sediment wave development in these particular circumstances (bi-directional rectilinear tides and multi-modal sediment mixtures). This is on-going work with colleagues at the Universities of Ghent and Genoa.

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More Information

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After a degree in Marine Geology at Ghent University, Belgium, **Katrien van Landeghem** started studying and mapping the seafloor of the Irish Sea during her PhD at University College Cork (Ireland) and Cardiff University (UK). She continued to study changing seafloor morphology during a research fellowship at the University of Liverpool and was appointed lecturer in Marine Geology and Geophysics in Bangor University in 2012, benefitting from the marine geophysical equipment on the university’s own research vessels and a bridge of expertise across the various oceanographic, geological and biological disciplines in the School of Ocean Sciences.